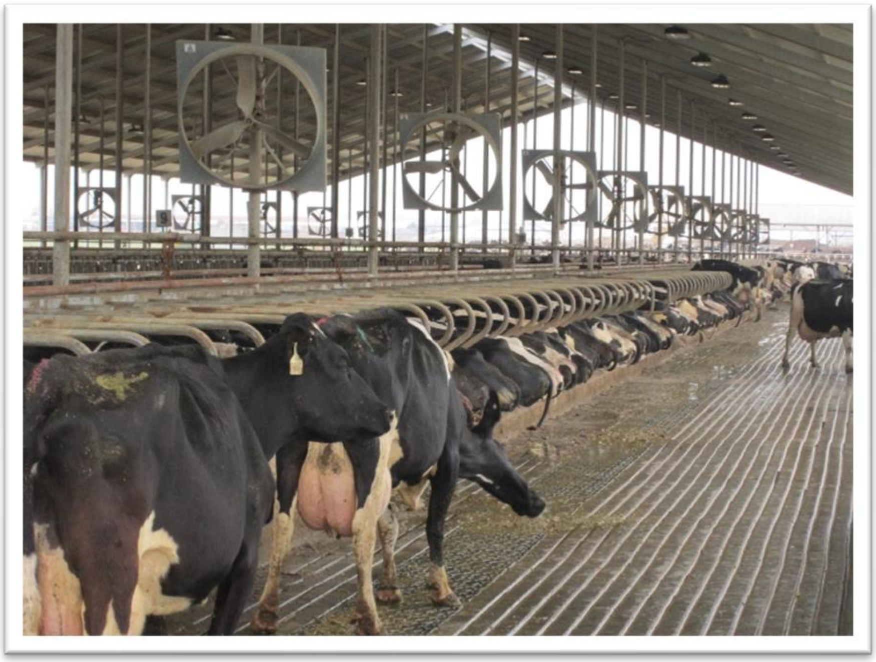
Emerging Technologies

Dairy Cooling Fan Controller Project

ET18SCE1110



Prepared by:

Emerging Products & Technologies
Customer Programs & Services
Southern California Edison

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SOUTHERN CALIFORNIA EDISON
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Acknowledgements

Southern California Edison's (SCE) Emerging Products (EP) group is responsible for this project. It was developed as part of SCE's Emerging Technologies Program, under internal project number ET18SCE1110. Both RMS Energy Consulting, LLC and MWE2, LLC conducted this technology evaluation, with overall guidance and management from Paul Delaney. Applied Quantum Technologies, LLC, and the Dairy Cooling Fan Controller (DCFC) manufacturer also contributed to the project. For more information on this project, contact paul.delaney@sce.com.

EXECUTIVE SUMMARY

The purpose of this DCFC Field Monitoring Assessment is to confirm the annual energy use and savings resulting from the DCFC technology assessed in Tulare County, California. The results of the study will help inform SCE Energy Efficiency (EE), Demand Response (DR), and Self-Generation (SG) program offerings.

Alignment with Statewide Goals
This field assessment aligns with several statewide goals and regulatory and policy compliance mandates, including AB 32, AB 793, and AB 802. The DCFC technology solar component enables using clean, renewable energy instead of grid power during daylight hours. The technology can also achieve energy savings during evening hours, as each dairy pen fan is controlled individually. Control strategies are based on a Temperature Humidity Index (THI) sensor and Variable-Frequency Drive (VFD) controls. These control strategies allow energy savings over existing baseline conditions. Lastly, the project aligns with AB 793, because AB 793 is focused on an energy management tool that helps customers better understand and use their energy.

Project Goal
The goal of this project was to conduct a field assessment of a new DCFC paired with solar panels. The project aimed to 1) document upstream and downstream electric system impacts from the point of technology adoption, and 2) enabling a holistic understanding of how the technology solution proposed to drive customer actions that affected SCE’s electric system.

Field Assessment Scope and Technology Description
The project assessed the effectiveness and efficiency of the DCFC technology in reducing energy consumption in kilowatt-hours (kWh), peak demand in kilowatts (kW), inrush current, and costs for California dairy farms. This field assessment aligns with SCE's electrification corporate goals because the technology is a load shifting VFD technology using solar renewable power during daylight hours, and blends and controls Air-Conditioning (A/C) motor loads (the cooling fan) during non-daylight hours. The proposed DCFC technology has the potential to increase EE and provide an opportunity for peak demand reduction and load-shifting control through DR signals.

Expected Outcomes
This report documents and summarizes findings from the site field demonstration. This includes documenting the electric system impact, both upstream and downstream, of the point of technology adoption, and enabling a holistic understanding of how customer actions affect SCE’s electric system.

Additionally, this report captured overall benefits and avoided impacts, including (but not limited to) 1) Greenhouse Gas (GHG) emission reductions, 2) EE peak demand reductions, and 3) the solar Photovoltaic (PV) resource’s localized generation. These benefits demonstrated the customer and utility achieved energy and peak demand reduction savings, as well as economic impacts, during SCE’s new Time-of-Use (TOU) periods.

Project Findings

Based on preliminary estimates, there are approximately 15,000 fans on dairy farms within SCE's service territory, amounting to 38.8 gigawatt-hours (GWh) of energy use and 18 megawatts (MW) of peak demand. If the DCFC technology successfully replaced all 15,000 fans, the gross estimated annual electric savings would amount to over 9.5 million kWh (9,510 MWh) in annual energy savings, with no peak demand savings. SCE's 2019 Sustainability Report estimates approximately 534 pounds of carbon dioxide (CO_2) is emitted for every MWh of electricity delivered through SCE's generation mix. If all 15,000 baseline fans were replaced with DCFC fans, this would avoid 5.08 million pounds of GHG emission, or 2,304 metric tons of CO_2 equivalent (CO_2e).

TABLE-ES 1. SUMMARY OF ENERGY SAVINGS AND DEMAND REDUCTION

	Annual Energy Consumption (kWh/yr.)	Annual Energy Savings (kWh/yr.)	Peak Demand (kW)	Peak Demand Reduction (kW)
Baseline	2,610	-	0.194	-
New Technology	1,976	634	0.215	(0.021)

ABBREVIATIONS AND ACRONYMS

Abbreviation	Full Description
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
AB 32	Assembly Bill 32
AB 802	Assembly Bill 802
A/C	Air-Conditioning
CEC	California Energy Commission
CET	Cost Effectiveness Tool
CEUS	Commercial End Use Survey
CLTEESP	California Long Term Energy Efficiency Strategic Plan
CO_2	Carbon Dioxide
CO_2e	CO_2 Equivalent
CPUC	California Public Utilities Commission
CT	Current Transducers
CVRMSE	Coefficient of Variance Root Mean Squared Error
DAS	Data Acquisition System
DCFC	Dairy Cooling Fan Controller
DEER	Database for Energy-Efficiency Resources
DG	Distributed Generation
DR	Demand Response

Abbreviation	Full Description
ECM	Energy Conservation Measure
EE	Energy Efficiency
EP&T	Emerging Products & Technologies
ET	Emerging Technologies
FRD	Facility-Related Demand
GHG	Greenhouse Gas
GW	Gigawatt
GWh	Gigawatt-Hour
HP	Horsepower
HTR	Hard to Reach
IDSM	Integrated Demand-Side Management
IPMVP	International Performance Measurement and Verification Protocol
kW	Kilowatt
kWh	Kilowatt-Hour
M&V	Measurement and Verification
MPPT	Maximum Power Point Tracking
MW	Megawatt
MWh	Megawatt-Hour
O&M	Operations and Maintenance
OAT	Outside Air Temperature

Abbreviation	Full Description
PA	Program Administrator
PF	Power Factor
PV	Photovoltaic
QA	Quality Assurance
RH	Relative Humidity
ROI	Return on Investment
SCE	Southern California Edison
SG	Self-Generation
THI	Temperature-Humidity Index
TOU	Time-of-Use
TRC	Total Resource Cost
VFD	Variable-Frequency Drive
ZNE	Zero Net Energy

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INTRODUCTION

Background

Dairy farms are an important part of California's economy. The dairy industry pushed the state to rank as the largest milk-producing state in the U.S., with more than 1,400 licensed dairies milking a total population of 1,700,000 cows. Within SCE's service area, Tulare County contributes over 25% of California's milk production. Milk is the leading agricultural commodity in Tulare County, worth $1.6 billion according to a 2016 CDFA report.

Crop	Year	No. of Head	Total Liveweight	Unit	Value Per Unit	Total
Cattle & Calves	2016	635,000	X	Head	1,040.00	660,400,000
	2015	636,000	X	Head	1,480.00	941,280,000
Sheep & Lambs	2016	21,900	2,179,000	Pound	1.59	3,465,000
	2015	21,600	2,145,000	Pound	1.44	3,089,000
Poultry [a]	2016	13,475,000	84,649,000	Pound	0.79	66,873,000
	2015	14,709,000	78,833,000	Pound	0.83	65,431,000
Miscellaneous [b]	2016	X	X	X	X	11,322,000
	2015	X	X	X	X	12,820,000
TOTAL	2016					742,060,000
	2015					1,022,620,000

[a] Includes Chicken Fryers, Ducks, Fryer Chicks, Game Birds, Pullet Chicks, and Turkeys.

[b] Includes Aquaculture, Beneficial Organisms, Goats, Mutton, and Hogs.

Livestock production in Tulare County decreased by 27.4% in overall value. This was attributed to low cattle prices and fewer birds produced.

FIGURE 1: LIVESTOCK PRODUCTION IN TULARE COUNTY

Crop	Year	Production Total	Unit	Value Per Unit	Total
Manure [a]	2016	2,612,000	Ton	4.19	10,944,000
	2015	2,679,000	Ton	5.01	13,422,000
Milk - Market	2016	110,157,000	Cwt.	14.90	1,641,339,000
	2015	111,962,000	Cwt.	15.30	1,713,019,000
- Manufacturing	2016	255,000	Cwt.	16.60	4,233,000
	2015	288,000	Cwt.	17.30	4,982,000
Miscellaneous [b]	2016	X	X	X	1,588,000
	2015	X	X	X	1,610,000
TOTAL	2016				$1,658,104,000
	2015				$1,733,033,000

[a] Includes Dairy and Poultry Manure

[b] Includes Turkey Hatching Eggs, Chicken Eggs (Market & Hatching), Goat Milk, and Wool

FIGURE 2: 2016 REVENUE FROM LIVESTOCK AND POULTRY PRODUCTS

Situational Analysis

California dairy electricity usage increases significantly during the summer months, when fans are required to mitigate the effects of heat stress on cows. Summer electricity usage and costs can triple compared to winter usage and costs. Operating fans in dairy barns during the summer months presents huge energy costs for California dairies, as well as an ongoing concern about utility company grid reliability.

California dairies are mandated to run fans to keep dairy cows cool in their barns, and healthy during the summer months. Cooling and ventilation accounts for 24% of dairy farm electricity usage. Fans consume an enormous amount of energy and also have significant peak demand requirements, which may destabilize power grid operation. Based on preliminary estimates, there are approximately 15,000 fans on dairy farms in SCE's service territory, totaling 38.8 GWh of energy use and 18 MW of peak demand.

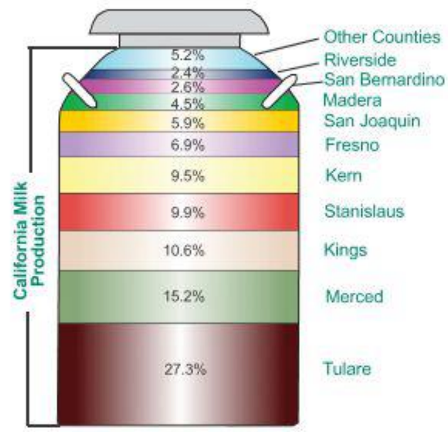


FIGURE 3: CALIFORNIA MILK PRODUCTION BY COUNTY

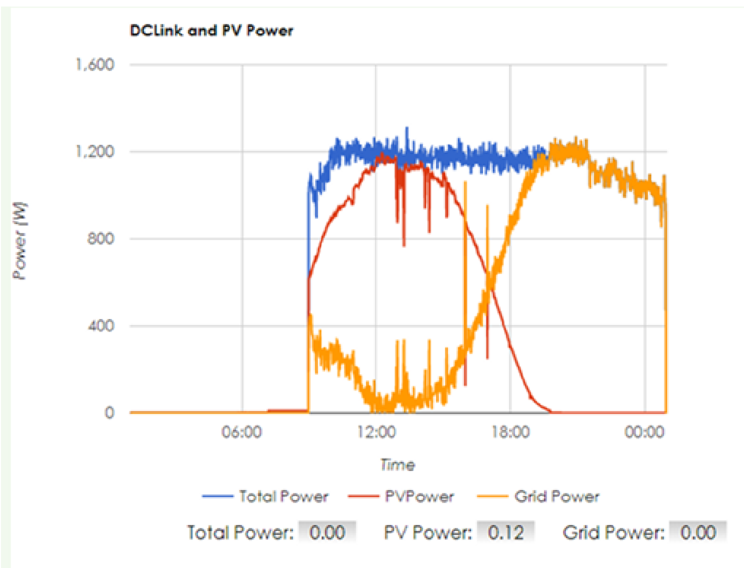
Project Purpose

It is estimated that the 269 dairies within Kern and Tulare counties have approximately 629,000 cows and more than 10,000 installed holding pen fans to operate during the summer peak period.

Value Proposition 1: Individual Fan Control Allows for Electric Reliability

DCFC technology provides controls to manage electricity usage by each individual fan, allowing for increased electric reliability and grid resiliency, since not all fans require simultaneous operation. The technology also provides energy savings by using variable-speed capable controls at each fan, where fan usage depends on ambient outside air conditions. More specifically, the technology contributes to grid stability and resiliency by providing the ability to respond to utility signals for solar curtailment or direct VFD fan control, if needed to reduce demand when ambient conditions do not require 100% fan speed during "shoulder" periods, and when the system is not using locally-generated electricity. Shoulder periods occur during the early fall and late spring months of the year, when outside temperatures range between 45°F and 65°F. This is important, because the air outside air temperature is cool enough that mechanical cooling is typically not needed.[1]

DCFC technology also saves energy by controlling fan speeds based on existing climate conditions and actual airflow requirements. Baseline fans without DCFC technology generally run at full load during summer peak and off-peak periods. However, fans with DCFC technology use a blend of local solar generation and VFD controls. During the first half of the new peak hours (4 p.m. to approximately 6:30 p.m.) the DCFC fans run primarily on available locally-generated solar power. If ambient conditions during the second half of the new peak hours (approximately 6:30 p.m. to 9 p.m.) require the fans to continue running, the fans will transition to drawing power from the grid. However, due to milder weather conditions, fans are not required to run at maximum capacity. Thus, VFD capability reduces fan motor speeds. Fan power consumption drops from 1,200W to approximately 720W, reducing peak-demand load on the grid.



- Fans Turn On: 10:58
- Sunset: 19:12
- No Solar Input: 19:26
- Fans Turn Off: 19:26
- Total Time On: 8.5 Hours
- Time With Solar: 8.5 hours
- Time On Grid Only: 0 hours
- VFD Ramp Up: 4 hours
- VFD Ramp Down: 3 hours
- VFD Range: 300W

FIGURE 4: SOLAR AND GRID USE FOR SAMPLE DAY IN AUGUST

Value Proposition 2: Individual Fan Control Allows for DR Opportunities

Dairy barns are typically very long, and have many fans installed in them. The fans are wired in multiple circuits, each controlled by its own thermostat setpoint. The problem with this conventional installation scheme is that once the ambient temperature reaches a circuit's thermostat set point, all fans in the barn that are wired on that circuit are turned on, whether or not the entire barn needs cooling. Because each DCFC fan is independently temperature controlled, there is a DR opportunity to shed load to off-peak periods by controlling fans individually, instead of by group or circuit.

[1] Aquicore.com

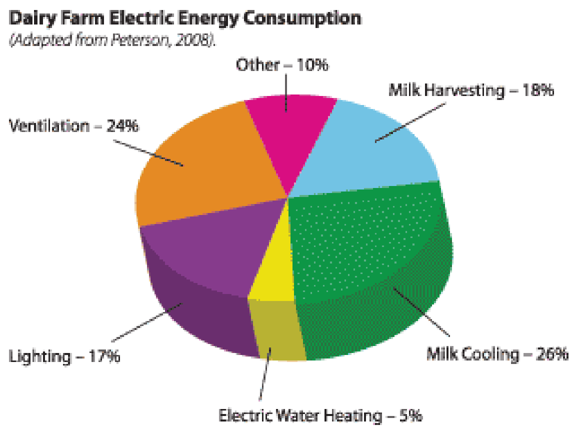


FIGURE 5: ENERGY USAGE ON A COMMERCIAL DAIRY FARM

During summer months, heat stress and increased heat load leads to decreased milk production, loss of reproductive efficiency, and other physiological and behavioral changes to lactating cattle, including increased mortality rates. Effective, efficient cooling systems are needed, to offset the effects of heat stress at a reasonable cost that maintains profit margins. Current heat abatement methods commonly used on California dairy farms include fans and feed lane water soaking systems.

In California, evaporative cooling is the typical method of cooling dairy cows, combining airflow from large, high-speed, low-volume panel fans and water from soaker lines installed along feed lanes. California dairy electricity usage increases significantly during the summer, when fans run to reduce heat stress on cows. Summer electricity usage and costs can be triple that of winter usage and costs.

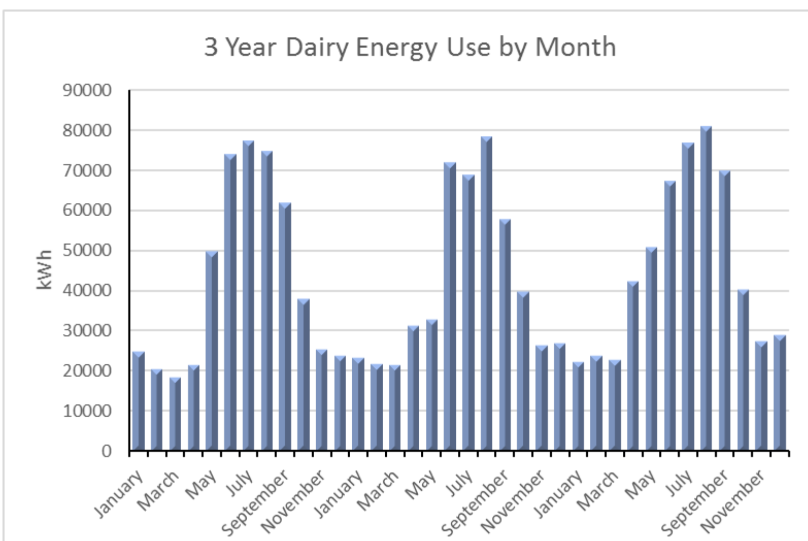


FIGURE 6: TYPICAL DAIRY FARM ELECTRICITY USAGE (KWH) 2010 - 2012

Target Sector and Market Segments

Dairy farms and livestock barns are Agricultural sector market segments. Many ventilation fans are installed in these barns to provide livestock cooling. Livestock barns are typically long in length, so as the sun moves across the sky throughout the day, temperature and humidity conditions can vary widely from one end of the barn to the other. This often results in unnecessary fan operation because portions of the barn are not affected by the sun's temperature while the sun's trajectory shifts position throughout the day.

Fans are wired in multiple circuits, each controlled by its own thermostat. This allows the dairy farm to set a bank of fans on one circuit at one temperature setpoint, and another at a different setpoint. In long livestock barns, fans are generally set in long rows, and two circuits are created with every other fan in a row grouped into the same circuit. Each fan is separated by approximately 40 feet. Once the ambient temperature reaches a circuit's thermostat set point, all barn fans on that circuit are turned on, regardless of whether ventilation is needed at each fan location. DCFC technology reduces energy use by controlling fans individually, rather than controlling a bank of fans as a group.

The technology has built-in VFD capability to control fan motor speeds, depending on actual airflow requirements. This feature consumes less energy when the fans are blended back to the grid during nighttime hours. When the sun goes down during the night or in the early morning before the sun comes out, the temperature may be warm enough to require ventilation, but not enough to require maximum airflow. This presents an opportunity for dairy farmers to maximize energy and cost savings by reducing fan speeds as needed.

BACKGROUND

ASSEMBLY BILL 802 AND STRANDED ENERGY SAVINGS

Assembly Bill 802 (AB 802) requires the CPUC to authorize Program Administrator (PA) energy utilities to count all energy savings achieved through eligible EE programs toward overall EE goals[2]. This field assessment aligns with statewide goals, including:

- AB 32: Intended to reduce GHG emissions,
- AB 802: Intended to reduce energy usage from existing conditions, and
- AB 793: Provides an energy management tool that helps customers understand their energy use.

Solar usage will have significant reductions on GHG impacts. Reliance on solar renewable technology throughout the day will result in less reliance on other generation sources and lower GHG emissions.

EMERGING TECHNOLOGY/PRODUCT

The DCFC is a device that seamlessly blends input energy from solar arrays and the power grid. It is ideally suited for applications that require 24/7 (or some nighttime) operation, particularly in areas with high power costs. This unique solution represents a cost-effective way to intelligently supplement solar power with controllable nighttime operation, without the expense of adding a battery bank.

During times of full solar irradiance, the DCFC draws all power from the PV array. When cloud cover or darkness reduces the level of solar irradiance, the system automatically draws power from the grid, to make up the difference. As dusk approaches and turns to night, the system draws all of its power from the grid. This allows for consistent power delivery during the day, and full nighttime operation, while consuming as little grid power as possible. Most daytime operation is effectively offloaded from the grid, which is particularly useful in areas with high demand charges or TOU pricing.

The DCFC is a fully-integrated unit, with a solar inverter, a Maximum Power Point Tracking (MPPT) controller, a voltage booster, and a phase initiator for three-phase motors. The unit is approximately the size of a common tissue box. Instead of constructing a mechanical-electrical configuration, the technology uses adaptive firmware to achieve a simplified controller solution. Figure 7 illustrates the DCFC's circuitry, while Figure 8 exhibits the DCFC's system setup.

[2] Assembly Bill 802

FIGURE 7: DCFC CIRCUITRY

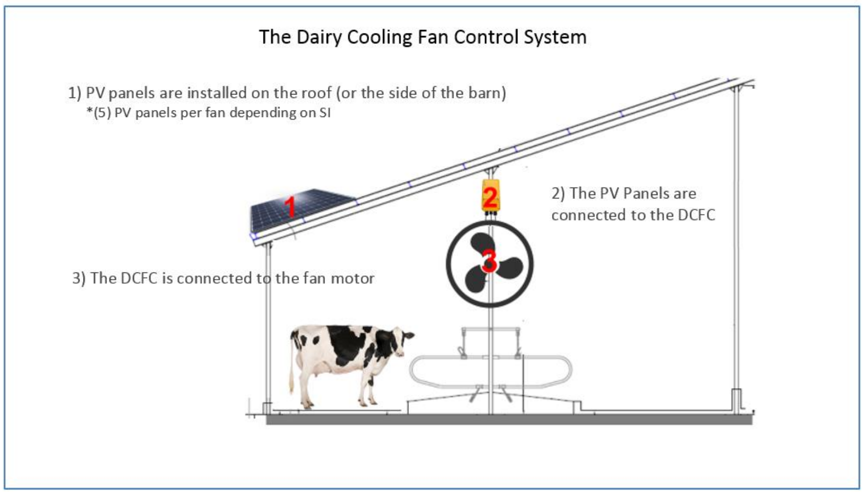


FIGURE 8: DCFC SYSTEM SETUP

PHYSICS BEHIND THE TECHNOLOGY

The DCFC automatically operates AC motors on solar energy during the day, and on grid power during the night. The technology also blends power between solar and grid power, as appropriate throughout the day. During the daytime hours, the technology draws all of its power from the solar PV array, which shifts all fan usage entirely off the grid. One of the benefits of this approach is to avoid or reduce high peak demand charges. In overcast conditions, the controller blends power from the solar PV and the grid, to ensure uninterrupted ventilation and satisfy dairy pen temperature conditions. Each controller has its own THI sensor. DCFC features include:

- Die cast aluminum housing (8in X 4 ½ in X 3-in)
- Rated NEMA 4/IP66
- Tested to be fully operational between -40C to 65C
- Passive cooling (no fan)

The DCFC has a built-in VFD capability, to control fan motor speeds based on actual airflow requirements. This feature consumes less energy when the fans are blended back to the power grid during the night. The DCFC VFD feature also provides fan soft start capability, eliminating voltage drops on the power grid.

The DCFC is coupled with PV panels, which are installed on the roof or the side of the barn. Typically, there are approximately five PV panels per fan. The PV panels are connected to the DCFC, which is then connected to the fan motor. A side-mount rack system may be designed to mount the solar PV panels on the side of the barn, if there are roof oxidation problems due to ammonia emitted from the manure in the dairy pen.

ADVANTAGES OVER INCUMBENT TECHNOLOGIES

Each DCFC has its own THI sensor. Fans are typically wired in multiple circuits, each controlled by its own thermostat. For example, Circuit #1 (which is typically every other fan) may be set at 72°F. Circuit #2 (the rest of the fans) may be set at 75°F.

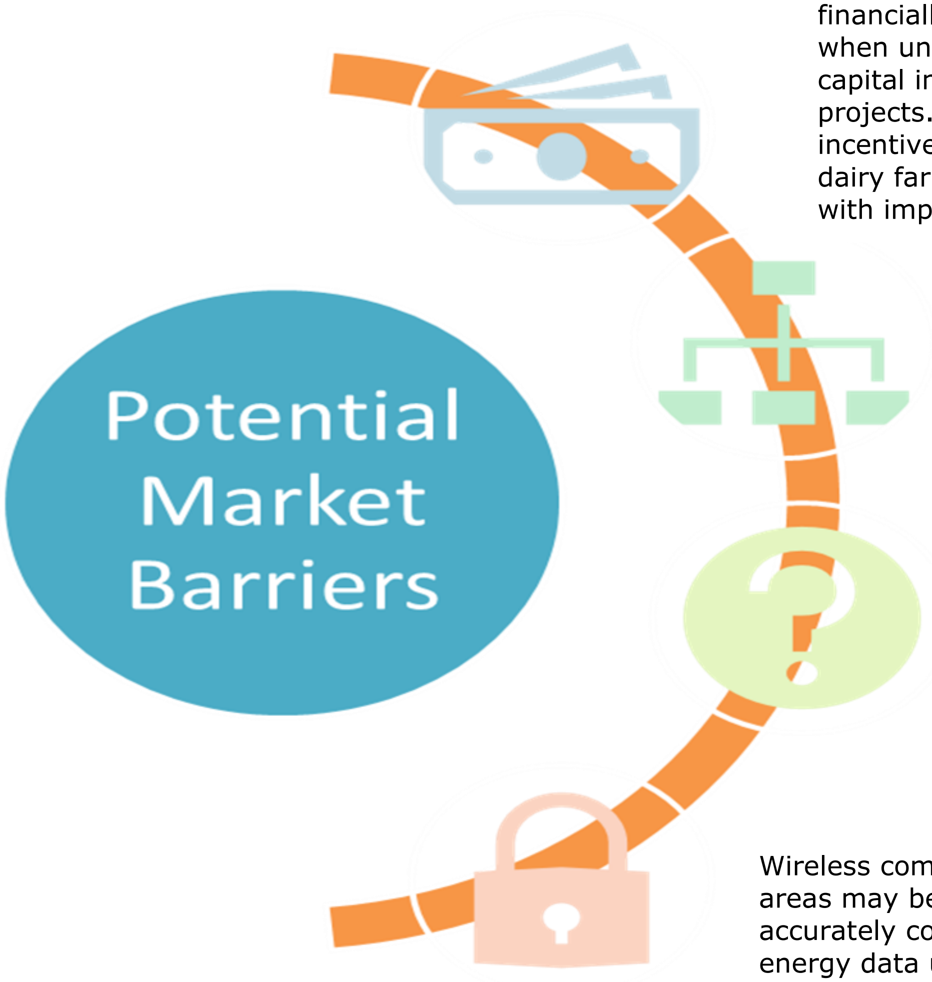
Once the ambient temperature reaches a circuit's thermostat setpoint, all fans wired on that circuit are turned on, whether or not the entire barn needs cooling. In a long livestock barn, where fans may be separated by as much as 40 feet, this could cause fans hundreds of feet apart to turn on together. The DCFC reduces energy usage and costs by controlling fans individually, depending on the ambient THI in a fan's particular barn coverage zone. Additional advantages are highlighted in Figure 9.

PRODUCT HIGHLIGHTS

- Run installed or new AC motor/pump/compressor/fan with free solar power
- Intelligently blends energy input from solar PV and power grid
- Maintains full power 24/7 while minimizing power costs
- Simple installation, weather proof, durable, and automatic
- Universal compatibility – use single or three phase, 50 or 60Hz, 120Vac or 230Vac
- No circuit panel installation required, plugs in as simple outlet load
- Intelligent design automatically improves operation and life of motor
- Maintains full variable frequency drive (VFD) operation while blending inputs
- Corrects poor quality grid power/voltage
- Patented and Made in the USA

FIGURE 9: DCFC ADVANTAGES AND PRODUCT HIGHLIGHTS

Market Barriers



Many dairy farmers are financially constrained when undertaking new capital improvement projects. Without financial incentives, it is difficult for dairy farmers to proceed with implementation.

Dairy farmers are resource constrained to undertake new efficiency projects.

Uncertainty of harmonic distortion created from the VFDs impacting milk production could result in adoption challenges.

Wireless communication in rural areas may be challenging to accurately collect real-time energy data use. Additionally, the change in TOU peak periods affects the project Return on Investment (ROI).

Figure 10: Potential Market Barriers to DCFC Adoption

Market Barriers Addressed

SCE works closely with its account management team to provide customer rebates and incentives, where possible. This research project allows SCE to consider solutions beyond EE, because it quantified grid savings, which can be counted in future pilot programs. SCE is also working with its account management team to assist dairy farmers with new tools to make it easier to apply for incentives.

Additionally, SCE provides grid services related to transmission and distribution issues, including total harmonic distortion challenges experienced on dairy farms. This project helps inform how SCE can enhance its relationship with dairy farm customers by providing grid-related services that routinely identify harmonic issues when undertaking efficiency projects. SCE continues to employ educational awareness and outreach efforts, to ensure dairy farm customers easily understand the rate changes that occur in TOU peak periods.

ASSESSMENT OBJECTIVES

The goal of the project was to document and summarize site field demonstration findings, including the electric system impact, both upstream and downstream of the point of technology adoption, enabling a holistic understanding of how customer actions affect SCE's electric system.

Additionally, this report captured the overall benefits and avoided impacts, such as (but not limited to) 1) GHG emission reductions; 2) EE peak demand reductions; and 3) the solar PV resource localized generation. These benefits demonstrated the customer and utility achieved energy and peak demand reduction savings and economic impacts during SCE's new TOU periods. The method used for this pilot was a one-part study. Energy submetering was conducted on components directly or indirectly affecting DCFC and baseline system performance. The objectives of this ET field monitoring assessment include:

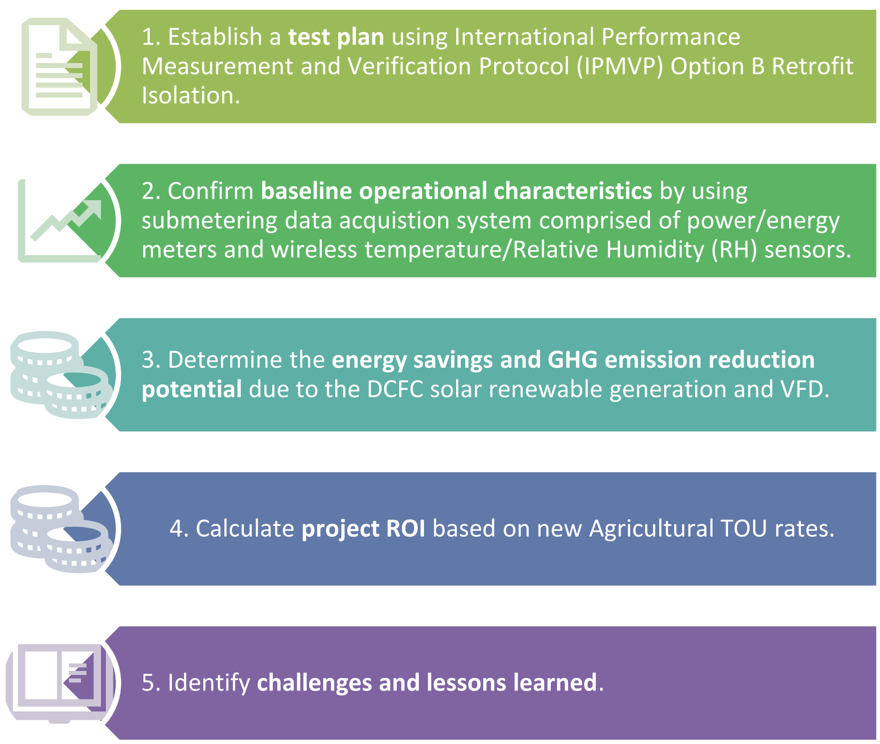


FIGURE 11: ET FIELD MONITORING ASSESSMENT PROJECT OBJECTIVES

TECHNICAL APPROACH/TEST METHODOLOGY

IPMVP

IPMVP is a guidance document describing common practices in measuring, computing, and reporting savings achieved by energy- or water-efficiency projects at end-user facilities. It provides standardized protocols, methods, and tools to quantify and manage the performance risks and benefits associated with end-use EE, renewable energy, and water-efficiency business transactions. IPMVP presents a framework and four Measurement and Verification (M&V) options for transparently, reliably, and consistently reporting project savings.

IPMVP OPTION B RETROFIT ISOLATION

IPMVP Option B describes a Retrofit Isolation scenario, which involves monitoring independent variables and static factors when retrofits affect only a portion of the facility. The results of retrofit isolation techniques cannot be correlated to the facility's total energy use shown on utility bills, because measurements are taken at the system level rather than at the whole building level. Any facility changes unrelated to the Energy Conservation Measure (ECM) will not be reported by retrofit isolation technique but are included in the utility's metered consumption or demand. Measurements of baseline and post-installation energy are required. The duration of the measurements must be sufficient to capture the full range of operating conditions. Option B is best applied where:

- Meters are used to isolate end-use systems of interest.
- There is a desire to measure all applicable variables that provide energy savings estimates within the measurement boundary.

IPMVP OPTION B CHALLENGES

IPMVP Option B generally requires accurate meters for short-term and long-term monitoring. Measuring electrical energy data may involve revenue-grade meters for certain projects, which increases data acquisition costs. Additionally, quantifying electric peak demand may vary from one utility company to the next. For instance, some utilities may measure peak demand between 4 p.m. and 9 p.m., while other utilities may measure peak demand between 2 p.m. and 5 p.m. However, some jurisdictions may use a different peak period to quantify peak demand based its policy framework, which may not exactly align with the measured peak period.

TECHNOLOGY FIELD TESTING

FIELD ASSESSMENT SITE CONDITIONS

This field assessment was conducted at a dairy farm located in Climate Zone 13 (CTZ 13). CTZ 13 is located in the San Joaquin Valley of Central California. The San Joaquin Valley, along with all counties where dairy farms are generally located, receives a higher-than-average level of solar irradiance compared to the rest of California. The site was primarily selected because it is typical of an open dairy farm, with ventilation fans installed approximately 40 feet apart in its free-stall barn, or dairy pens, as shown in Figure 12.

FIGURE 12: FREE STALL BARN WITH VENTILATION FANS

CTZ 13 has very warm and humid temperatures during the summer, when ventilation is required to ensure the cows' safety and wellness. Thus, additional ventilation is needed to satisfy cow heat stress comfort requirements.

FIGURE 13: DAIRY PEN BIRD'S EYE VIEW

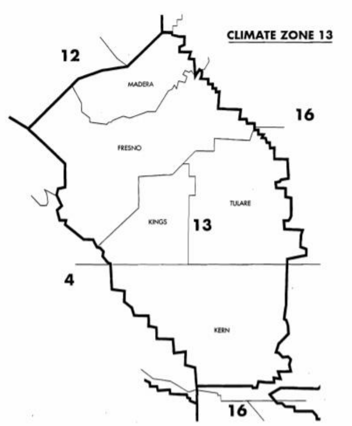


FIGURE 14: CEC CLIMATE ZONE 13 MAP

DATA COLLECTION REQUIREMENTS

Two of the ET field assessment objectives outlined that the project 1) establish total annual energy consumption; and 2) determine energy savings potential due to the DCFC's actual performance with and without the PV. To achieve these project objectives, circuit-level electrical data and external weather temperature and humidity data were needed to ensure the data was normalized for non-routine adjustments (non-routine adjustment factors are those not expected to change, but that affect building energy use). This change in energy use is not a result of the ECMs installed as part of the retrofit.

Additionally, to minimize the costs of monthly physical site visits, we used a Data Acquisition System (DAS) to collect 15-minute interval data for individual loads, including the solar PV and temperature sensor data, which could be remotely accessed. Given these data collection requirements, the goal was to select a DAS that could collect the needed data points to establish both energy consumption and energy savings using a web-based metering and monitoring system.

M&V PLAN

The project-specific M&V plan included project-wide items and details, including:

- Baseline conditions and collected data
- Documentation of all assumptions and data sources
- Items to be verified, and associated timeline
- Resources needed to conduct M&V activities
- Schedule for all M&V activities
- Discussion on risk and savings uncertainty
- Engineering analysis performed
- Information on how energy and cost savings were calculated
- Energy rate structures and escalation rates (if applicable)
- Operations and Maintenance (O&M) cost savings claimed, and reporting responsibilities (if applicable)
- Agreement on how and why the baseline (and therefore justification for savings) may be adjusted

METERING

Manufacturer metering equipment was installed to monitor applicable electrical loads. The manufacturer's DCFC and storage meters measured relevant power data, including system kW, kWh, Power Factor (PF), current, and voltage. DCFC meter accuracy was checked by using redundant submetering equipment manufactured by Powerwise, which consisted of:

- **Powerwise InGate:** A commercial-grade ethernet gateway designed for monitoring and controlling building systems with remote access capability.

- **Powerwise InPower:** a kWh energy and power meter with ANSI C12.1 and ANSI C12.20 class 0.5 accuracy, with communications via Modbus RTU. This meter can measure up to three phases, in delta or wye services, from 120 to 600 Vac. Using split-core current transformers, it can measure five to 6,000 amps. It is packaged in a compact, DIN-rail mount enclosure. Collected power data collected:

    - Power (Real, Apparent, & Reactive)
    - Energy (Real, Apparent, & Reactive)
    - PF

- Voltage (phase-neutral, phase-phase)
- Line Frequency
- Current

- **Powerwise DTS DC Energy Submeter with Remote Communications:** DC power/energy submeter provides voltage, current, power, and energy measurements.

- **Vaisala Humidity and Temperature Probe:** Measurement range: 0 to 100 % RH and temperature measurements ranging from -40°C to 60 °C.

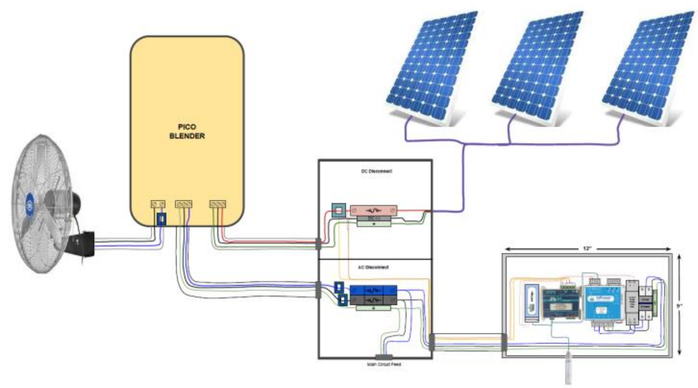


FIGURE 15: DCFC MONITORING AND POWERWISE SUBMETERING INSTRUMENTATION SETUP

Figure 16 depicts the test setup for the baseline control fans and DCFC test fans.

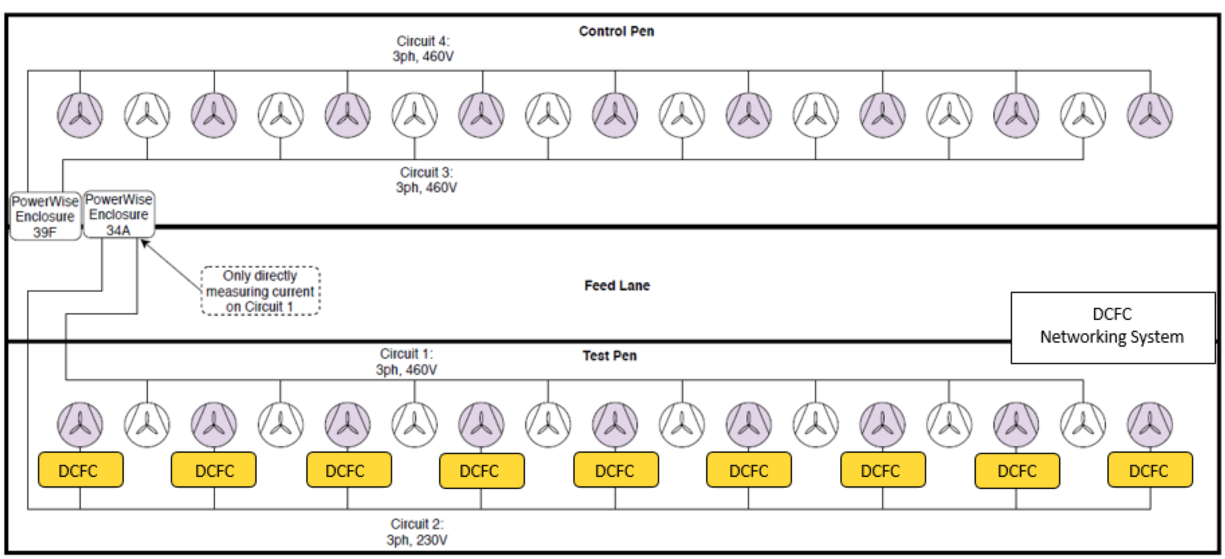


FIGURE 16: CONTROL AND TEST FAN CONFIGURATIONS

DATA GATHERING

The recorded kW and temperature data were checked weekly. Data anomalies were investigated immediately, and data reporting problems were corrected as soon as possible.

The RMS team pre-screened the monitoring data, to confirm all required data was available and identify any anomalous data points which may have biased the analysis.

REPORTING PERIOD

Four (4) months of hourly measurement data was obtained, to determine the system energy savings and peak demand reduction resulting from installing the DCFC and the inrush current savings due to the DCFC's soft-start capabilities.

ANALYSIS PROCEDURE

Site Walkthrough: RMS staff conducted a site walkthrough, to familiarize themselves with the site, obtain a better understanding of the system, and identify optimal locations and selections for data monitoring equipment.

Finalize M&V Plan: All information gathered at the site walkthrough was used to revise and finalize the M&V plan, to ensure all expected results could be achieved.

Implement M&V Plan: Relevant electrical data was collected weekly for four months, using the DCFC monitoring system and the Powerwise redundant submetering system.

FIELD TESTING OF TECHNOLOGY

This field assessment concerns a single technology at a dairy farm in California's Central Valley. Dairy farm pen roofs were structurally sound, to support solar panel installation. Baseline (controlled) and test fans were simultaneously tested, to capture the same testing period conditions.

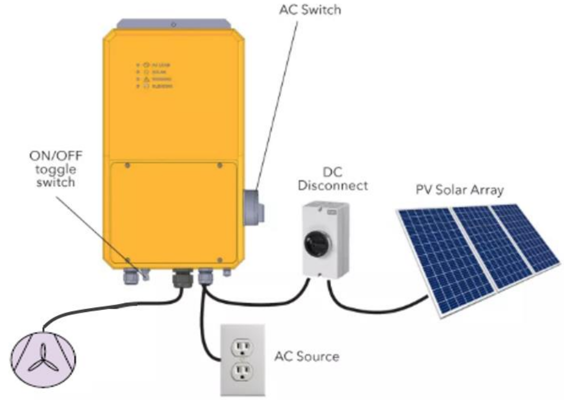


FIGURE 17: DCFC EQUIPMENT COMPONENTS AND ELECTRICAL SETUP

Existing Baseline Systems

Baseline Conditions

The baseline system consisted of one-horsepower (hp) fans installed over the free-stall beds at every 40 feet, powered entirely by the grid during day and night hours. This configuration is common among free-stall barns in SCE's service territory that cool dairy cows. The first stage of the test dairy fan system turned on 50% of the fans via a circuit thermostat set at 70°F. The second stage (the rest of the fans) turned on via a circuit thermostat set at 75°F.

Figure 18: One-HP Fans Installed at Test Dairy

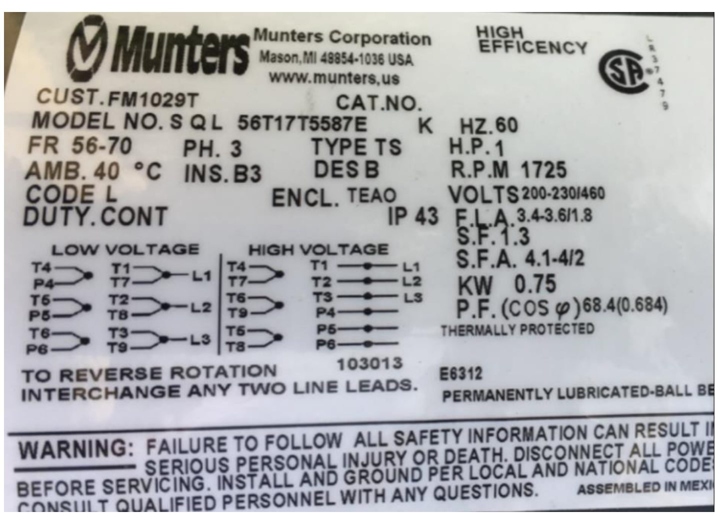


Figure 19: Dairy Ventilation Fan Motor Nameplate

DCFC

The DCFC technology can be controlled by THI or temperature alone. The technology can also be controlled based on solar, grid power, or a mix of both. The system is designed to turn on at 65°F, as long as power is supplied completely from solar. After 74°F, the DCFC blends grid and solar power as needed to run fans at full capacity, relying primarily on solar and supplemental grid power, as necessary. The DCFC is programmed to operate fans between 0.3 kW to 1.2 kW, depending on THI requirements.

Scenario 1 Baseline versus Solar-Controlled Fans

Scenario 1 occurred between June 1 and July 31, for a total of 60 testing days. Nine baseline-controlled fans were monitored simultaneously against nine DCFC test fans, and were controlled with a manually-switched thermostat set at 74°F. The nine test fans had the DCFC's controller set to temperature sensing only at 74°F, to isolate an equivalent comparison against the baseline. In this scenario, the DCFC fans ran on a blend of local solar-generated power or utility grid power, and THI, VFD, and soft-start capability were not considered. Only solar usage and ambient outside temperature were compared.

Scenario 2 Baseline versus Solar-Controlled Fans with VFD

Scenario 2 occurred between August 1 and August 29, for a total of 30 days. The baseline fans were compared against the DCFC test fans with solar and VFD capabilities. Additionally, because THI was not included in the testing scenario, the baseline and test fan thermostat setpoints were changed to 72°F, to prioritize effective cooling and ventilation for the cows' well-being.

Scenario 3 Baseline versus Solar-Controlled Fans with VFD and THI

Scenario 3 occurred between August 30 and September 30, for a total of 31 days. The baseline fans were compared against the DCFC test fans with solar, VFD, THI, and precooling capabilities. DCFC fans were controlled based on THI settings, and not a fixed temperature setting. THI is described in further details below.

THI

The concept behind THI for lactating cows illustrates the stress thresholds for different temperatures. The DCFC technology is programmed to account for THI, which is a key concern for dairy farmers because higher milk production is a function of a cow's respiration rates and rectal temperature.

Temperature Humidity Index For Lactating Dairy Cows

Themperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95	96	98
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
105	40.5	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	103	105
106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103	104	106
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104	106	107
108	42.0	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
109	43.0	81	82	84	85	87	89	89	91	92	94	95	96	98	99	101	102	103	105	106	108	109
110	43.5	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110
111	44.0	82	83	85	86	88	90	91	92	94	95	96	98	99	101	102	104	105	107	108	110	111
112	44.5	82	84	85	87	88	90	91	93	94	96	97	99	100	102	103	105	106	108	109	111	112
113	45.0	83	84	86	87	89	91	92	93	95	96	98	99	101	102	104	105	107	108	110	111	113
114	45.5	83	85	86	88	89	92	92	94	96	97	99	100	102	103	105	106	108	109	111	112	114
115	46.0	84	85	87	88	90	92	93	95	96	98	99	101	102	104	106	107	109	110	112	113	115
116	46.5	84	86	87	89	90	93	94	95	97	98	100	102	103	105	106	108	110	111	113	114	116
117	47.0	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	48.0	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	48.5	85	87	89	90	92	94	96	87	99	101	102	104	106	107	109	111	112	114	116	117	119
120	49.0	86	88	89	91	93	95	96	98	100	101	103	105	106	108	110	111	113	115	117	118	120

Stress Threshold Respiration rate exceeds 60 BPM. Milk yield losses begin. Repro losses detectable. Rectal Temperature exceeds 38.5°C (101.3°F)

Mild-Moderate Stress Respiration Rate Exceeds 75 BPM. Rectal Temperature exceeds 39°C (102.2°F)

Moderate-Severe Stress Respiration Rate Exceeds 85 BPM Rectal Temperature exceeds 40 °C (104°F)

Severe Stress. Respiration Rate 120-140 BPM. Rectal Temperature exceeds 41 °C (106°F)

FIGURE 20: THI FOR LACTATING DAIRY COWS

SCENARIO 4 TESTING DCFC SOFT-START CAPABILITIES

Scenario 4 occurred on October 18. The purpose of Scenario 4 was to measure the impact of the DCFC's soft-start capabilities on inrush current. This was accomplished by turning the fans on and off multiple times in a 15-minute period with the soft-start code disabled. This was also repeated multiple times with the code enabled. More information is described in the Results section of this report.

INSTRUMENTATION PLAN

POWERWISE INTELLERGY ENERGY MANAGEMENT AND DAS AND SPECIFICATIONS

Powerwise manufactures an energy management DAS called Intellergy, which has the capability of circuit-level monitoring for three-phase electricity. The Intellergy DAS provides minute-by-minute electricity, temperature, and humidity data. The Powerwise Intellergy DAS requires a licensed electrician to install the InGate Zigbee 1.0 commercial-grade ethernet Gateway (InGate) and the InPower 3-Phase Modulus electricity monitoring meter (InPower).

The Powerwise InGate is designed for data monitoring and building system control. The device integrates with the InSense Wireless Sensor, electricity meters, water flow and BTU meters, data acquisition devices, controllers, wireless bridges, thermostat, and select Zigbee sensors. The InGate communicates performance and control data with the Powerwise InView application, where advanced analytics are accessed remotely from any web-based device. The InGate offers plug-and-play functionality and supports Modbus RTU and Zigbee 3.0. The InBridge can help with communications from Modbus RTU devices to the InGate.

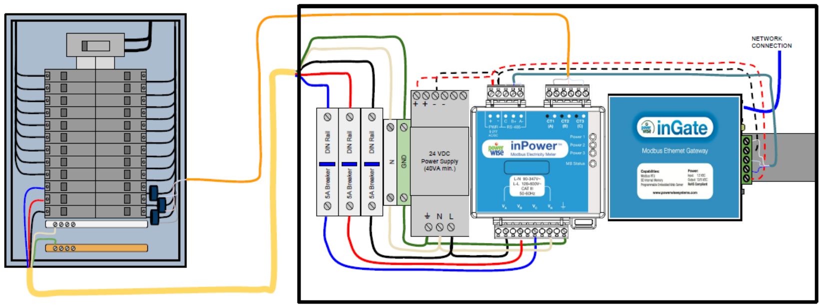


FIGURE 21: POWERWISE INTELLERGY INGATE AND INPOWER ELECTRICAL DIAGRAM

FIGURE 22: POWERWISE INTELLERGY INGATE AND INPOWER SUBMETERING SYSTEM

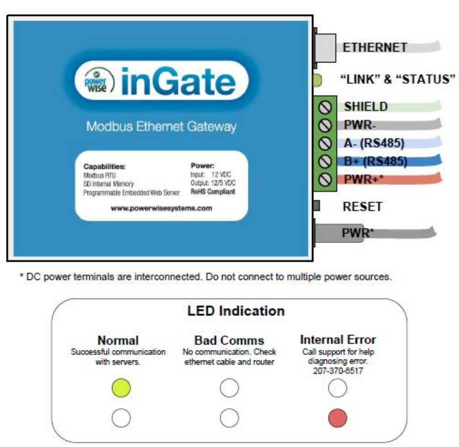


FIGURE 23: POWERWISE INGATE SCHEMATIC

RESULTS

Estimates of energy consumption, energy savings, and peak demand reduction for energy conservation and DR potential measures were obtained based on the Intellergy energy management DAS. Applicable electrical and temperature hardware equipment enabled us to collect desired data points and operating schedules. Once relevant data was collected at regular interval levels, data was aggregated and estimated at hourly interval levels, to reduce the number of data points. The data analysis entailed meeting the following Quality Assurance (QA) objectives:

- Verifying that actual submetering hourly measurement field data is within acceptable accuracy and precision levels, including normalization due to weather, and other relevant non-routine variables
- Performing error and uncertainty statistical analyses of the final results; and
- Deriving the final results in estimating energy savings.

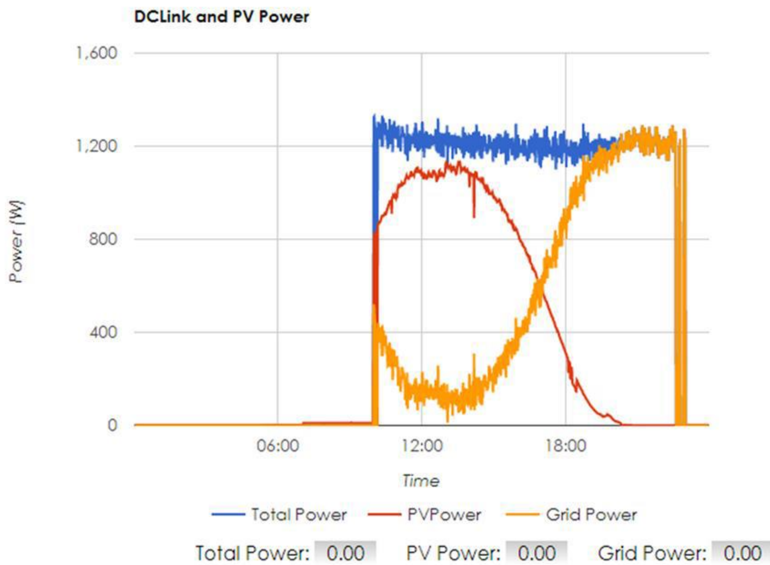
VERIFYING ACTUAL SUBMETERING HOURLY MEASUREMENT FIELD DATA

To confirm the DCFC system's operational characteristics, the monitoring plan required collecting sufficient hourly measurement data through a DAS submetering system on the dairy pen's electrical loads and outdoor weather temperature. The hourly sub-metered field data was compared to redundant submetering equipment, to ensure data accuracy and minimize uncertainty and error.

ASHRAE 14-2014 describes a Retrofit Isolation Approach, which involves measuring the energy use and relevant independent variables (outdoor air temperature, desired thermostat temperature) of the individual systems and equipment (VFD) affected by the retrofit. Baseline and post-installation energy measurements were required. The duration of the measurements was sufficient to capture the full range of operating conditions. The following figures and tables show adherence to ASHRAE 14-2014 guidelines.

SCENARIO 1 RESULTS

Scenario 1 occurred between June 1 and July 31, for a total of 60 days. The baseline control fans operated as normal using the manual thermostat set at 74°F. The DCFC fans operated with a blend of local solar generation and utility grid power, also at a temperature setpoint of 74°F. The purpose of this scenario was to isolate the effects of the DCFC's solar generation savings from VFD savings at the same temperature setpoints. Figure 24 illustrates a daily DCFC load profile in Scenario 1.



- Fans Turn On: 10:01
- Sunset: 20:19
- No Solar Input: 20:45
- Fans Turn Off: 22:57
- Total Time On: 13 hours
- Time with Solar: 11 hours
- Time on Grid Only: 2 hours

FIGURE 24: DCFC DASHBOARD IN SCENARIO 1

Figure 25 indicates that savings due to solar generation occurred between 8:00 to 17:00. During the 0:00 to 8:00 and 17:00 to 24:00 periods, the DCFC fans used more energy. This was because the DCFC fans drew a peak load of approximately 1.3 kW, while the control fans drew a peak load of approximately 1.05 kW. Outside of 8:00 to 17:00, when there was insufficient solar input, the DCFC fans drew power from the grid and used more energy than the baseline control fans did during the same period.

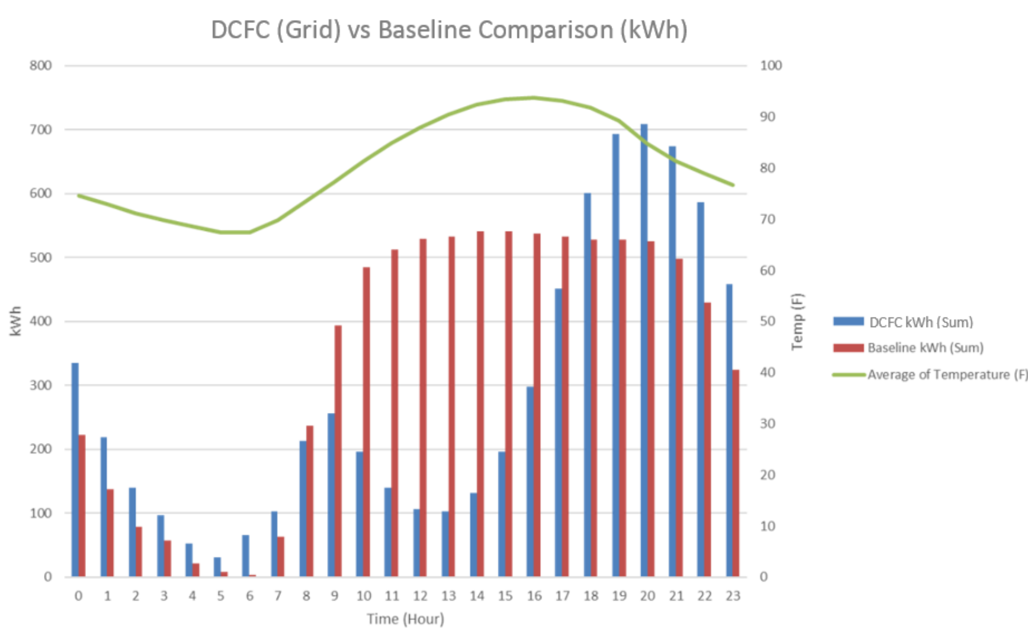


FIGURE 25: SCENARIO 1 BASELINE AND DCFC DAILY LOAD PROFILE COMPARISON

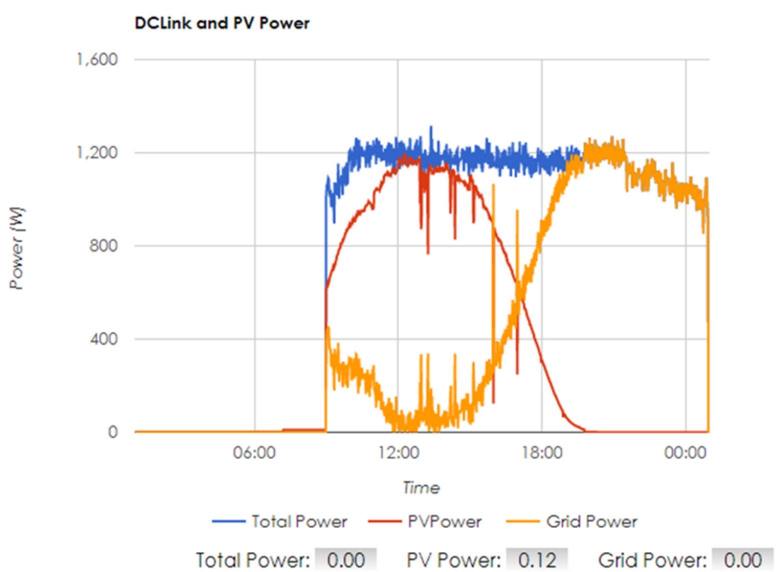
The raw data results for Scenario 1, before weather normalization, are shown in Table 1. Overall savings across all nine fans for Scenario 1 was 17% over baseline conditions. The savings during the former Database for Energy-Efficiency Resources (DEER) 2 p.m. to 5 p.m. peak period illustrated 61% savings, primarily due to using solar power instead of grid power. However, during the new 4 p.m. to 9 p.m. peak period when solar was less available, the DCFC used 4% more energy compared to the baseline control fans due to the increased peak power draw.

TABLE 1: SCENARIO 1 RAW DATA GRID POWER ENERGY SAVINGS BY TIME PERIOD

TIME PERIOD	BASELINE KWH	DCFC KWH	% SAVINGS
All Day	8,266	6,852	17%
2-5 p.m.	1,619	625	61%
4-9 p.m.	2,651	2,751	-4%

SCENARIO 2 RESULTS

Scenario 2 occurred between August 1 and August 31. During this test scenario, the DCFC enabled both solar generation and VFD functions to isolate VFD savings from solar generation savings attributed to the DCFC technology. Figure 26 shows a DCFC daily load profile in Scenario 2. As outside air temperature and humidity were increased during this period when compared to Scenario 1, the temperature setpoint for the baseline control fans and DCFC test fans were changed from 74°F down to 72°F. This was done to prevent the cows from experiencing heat exhaustion. DCFC fans used the VFD capability between 72°F and 74°F, to satisfy temperature setpoint conditions when solar generation was unavailable. This VFD mode can be seen in Figure 26, with power ramping up when the fans turned on at 9:00 and when they slowed down at around 20:00.



- Fans Turn On: 9:04
- Sunset: 19:50
- No Solar Input: 20:10
- Fans Turn Off: 1:10
- Total Time On: 16 hours
- Time with Solar: 11 hours
- Time on Grid only: 5 hours
- VFD Ramp Up: 1.5 hours
- VFD Ramp Down: 4 hours
- VFD Range: 300W

FIGURE 26: DCFC DASHBOARD IN SCENARIO 2

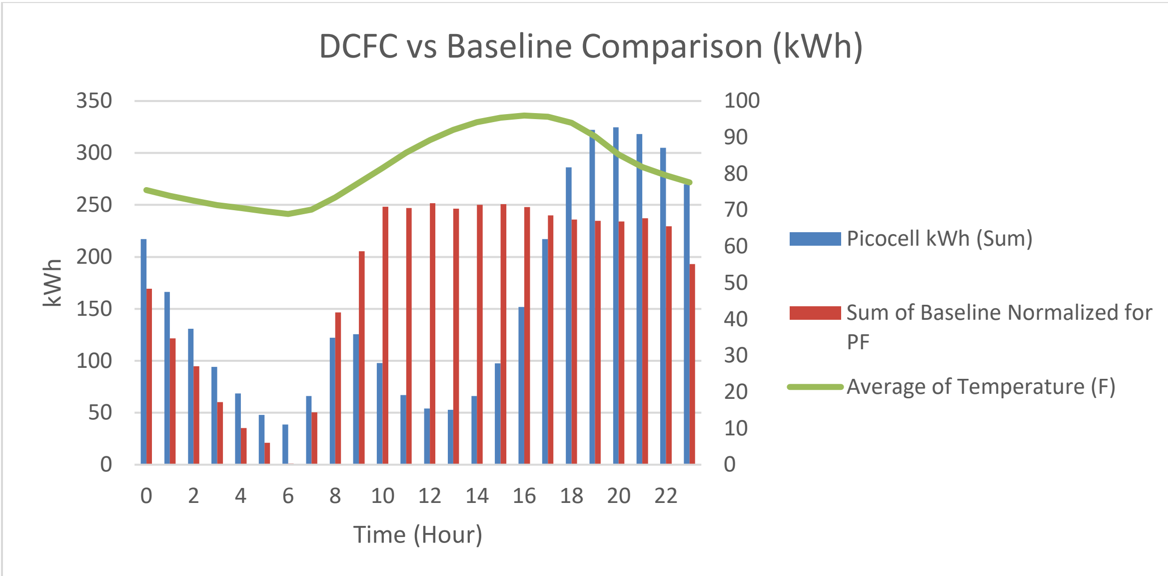


FIGURE 27: SCENARIO 2 BASELINE AND DCFC DAILY LOAD PROFILE COMPARISON

Raw data results for Scenario 2, before weather normalization, are shown in Table 2. The overall savings across all nine fans for Scenario 2 was 13% over baseline conditions. The savings during the former DEER 2 p.m. to 5 p.m. peak period illustrated 58% savings, primarily due to using solar power instead of grid power. However, during the new 4 p.m. to 9 p.m. peak period when solar was less available, the DCFC used 9% more energy compared to the baseline control fans, due to the increased peak power draw.

From Scenario 1 to Scenario 2, there was more energy usage throughout the entire day, as well as during the new 4 p.m. to 9 p.m. peak period. The average high temperature in June was 92°F. However, the average high temperature in August was 96°F. This meant the fans in Scenario 2 turned on earlier and stayed on well after the sun had set, leading to longer overall fan runtime. Additionally, the sun set 30 minutes earlier in August compared to June. Thus, there was a longer duration during the peak period when the test fans ran on grid power only, leading to increased energy usage by the DCFC fans over the baseline fans due to their higher peak power draw. While there were some savings from the solar and VFD functions being enabled, overall savings dropped from Scenario 1.

TABLE 2: SCENARIO 2 RAW DATA GRID POWER ENERGY SAVINGS BY TIME PERIOD

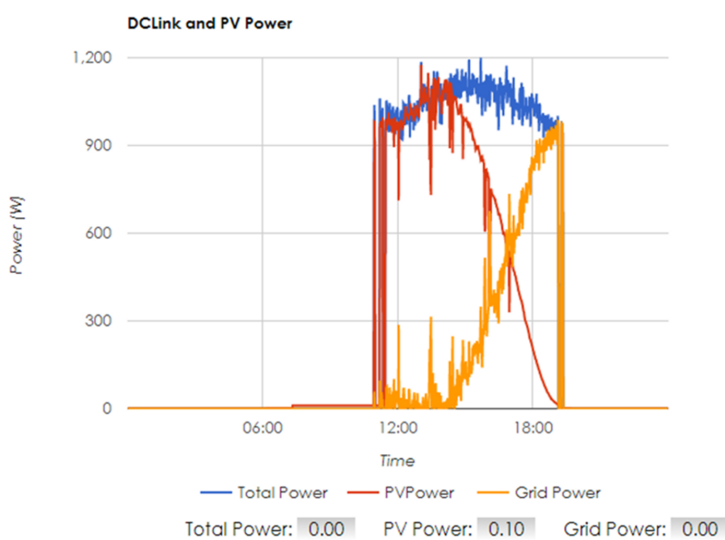
TIME PERIOD	BASELINE KWH	DCFC KWH	% SAVINGS
All Day	4,251	3,707	13%
2-5 p.m.	748	315	58%
4-9 p.m.	1,192	1,301	-9%

SCENARIO 3 RESULTS

Scenario 3 occurred at the end of the summer period between August 30 and September 30. In this scenario, the DCFC technology's algorithms were modified to demonstrate the full capabilities and benefits of running the fans, to:

1) use solar generation and blending when available,
2) account for THI,
3) leverage the VFD capabilities when appropriate; and
4) pre-cool the dairy pen early in the morning before the summer heat occurred at midday.

In addition to the THI function, the DCFC technology had the ability to pre-cool the dairy pen before the outside air temperature and humidity became unsafe for the cows. As shown in Figure 28, the concept behind the precooling function was to ensure the fans turned on and operated on solar power only, before they were needed. Without solar input, the fans operated according to THI, along with the VFD capabilities.



- Fans Turn On: 10:58
- Sunset: 19:12
- No Solar Input: 19:26
- Fans Turn Off: 19:26
- Total Time On: 8.5 Hours
- Time With Solar: 8.5 hours
- Time On Grid Only: 0 hours
- VFD Ramp Up: 4 hours
- VFD Ramp Down: 3 hours
- VFD Range: 300W

FIGURE 28: DCFC DASHBOARD IN SCENARIO 3

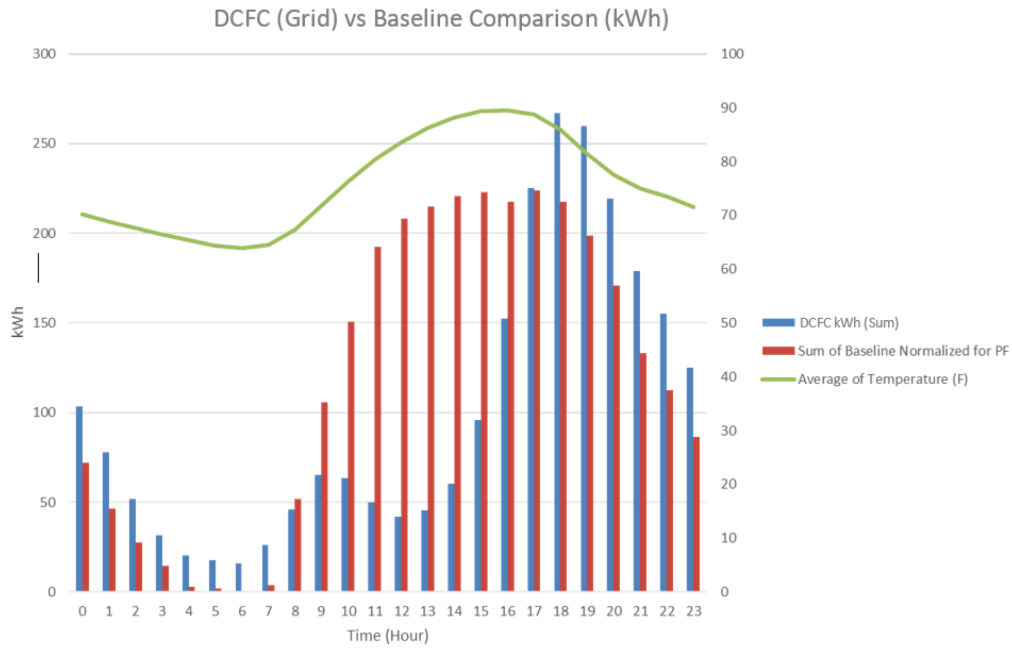


FIGURE 29: SCENARIO 3 BASELINE AND DCFC LOAD PROFILE COMPARISON

Raw data results for Scenario 3, before weather normalization, are shown in Table 3. The overall raw data savings across all nine fans for Scenario 3 was -5% over baseline conditions. The raw data savings during the former DEER 2 p.m. to 5 p.m. peak period illustrated 41% savings, primarily due to using solar power instead of grid power. However, during the new 4 p.m. to 9 p.m. peak period, when solar was less available, the DCFC used 38% more energy compared to the baseline control fans.

From Scenario 2 to Scenario 3, savings decreased throughout the entire day, as well as in the new 4 p.m. to 9 p.m. peak period. The average high temperature in August was 96°F. However, the average high temperature in for Scenario 3 in September was 89°F. This meant the fans in Scenario 3 turned off more often, resulting in lower consumption for the baseline control fans and DCFC test fans. However, the sun set 45 minutes earlier in September compared to August and overall, there was less solar energy available throughout the day. Thus, there was a longer duration during the peak period when both sets of fans were running on grid power only. This led to increased DCFC fan energy usage over the baseline fans, due to their higher peak power draw.

TABLE 3: SCENARIO 3 RAW DATA GRID POWER ENERGY SAVINGS BY TIME PERIOD

TIME PERIOD	BASELINE KWH	DCFC KWH	% SAVINGS
All Day	2,279	2,397	-5%
2-5 p.m.	519	309	41%
4-9 p.m.	812	1,124	-38%

SCENARIO 4 SOFT-START CAPABILITIES

Scenario 4 occurred on October 18. The purpose of Scenario 4 was to measure the impact of the DCFC's soft-start capabilities on inrush current. The DCFC manufacturer remotely turned DCFC Fan #9 on and off while the soft-start feature was disabled. Figure 30 illustrates the measured power without the soft-start feature. The inrush current is shown by the thin spikes, which represent a large initial current draw as the fan is started.

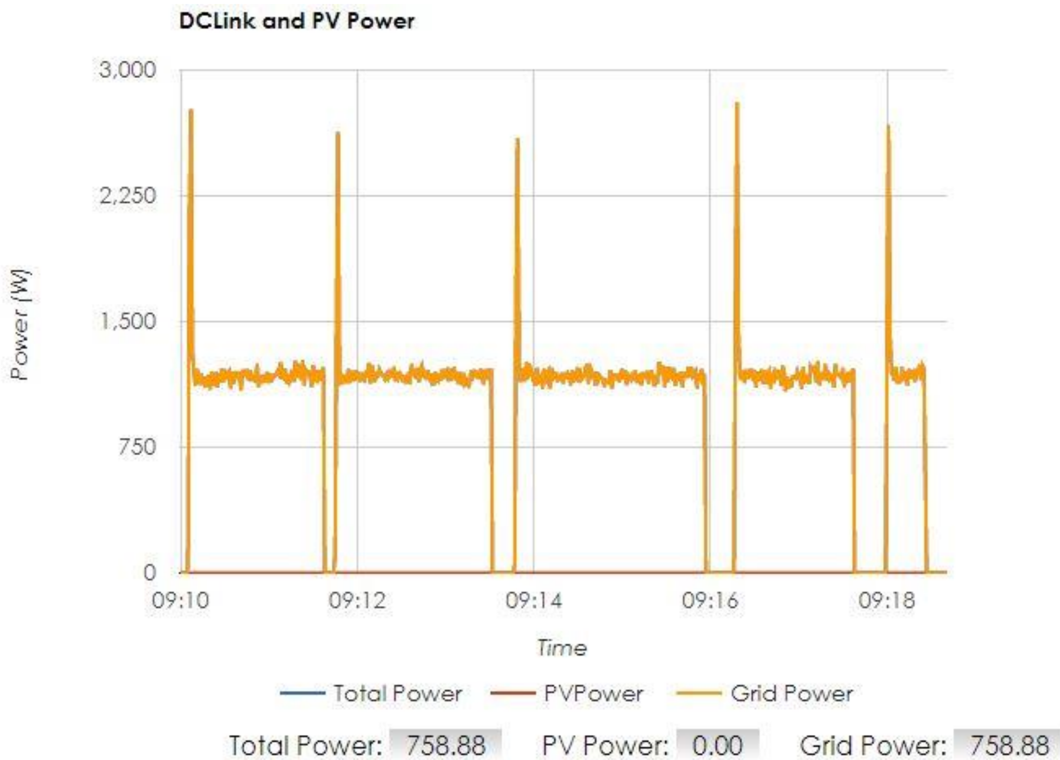


FIGURE 30: DCFC WITHOUT ENABLING SOFT-START FEATURE

The DCFC then manufacturer enabled the soft-start feature, and remotely turned DCFC Fan #9 on and off. Figure 31 illustrates the measured power with the soft-start feature.

FIGURE 31: DCFC SOFT START ENABLED

Comparing Figures 30 and 31 and taking power draw to be proportional to current draw illustrates that the DCFC's soft-start feature gradually ramps up the fan's current draw, eliminating the large peak current draw typically seen at fan startup. This minimizes the impact of large, instantaneous current draws on electrical infrastructure.

Facility-Related Demand (FRD) charges and TOU peak demand charges are quantified differently on energy bills. FRD charges are billed on a per-kW basis and are applied to the maximum peak demand registered in each billing period. TOU peak demand charges are applied only during the summer peak periods (typically June 1 through October 1) and are in addition to and separate from FRD charges. TOU demand charges are on a per-kW basis and are applied to the greatest amount of registered demand in the on-peak summer season billing period.

DISCUSSION

BASELINE FAN PF NON-ROUTINE EVENT

Scenario 2 showed the baseline control fans were using less energy and peak demand power when compared to the DCFC test fans. The primary reason for this large difference was attributed to the baseline control fans' PF, which Figure 32 illustrates steadily hovered at 0.70 until halfway through testing, in mid-August 2019, as measured by the Powerwise DAS. The baseline control fans' PF dropped from 0.70 to approximately 0.6 during Scenario 2, and again to approximately 0.55 in September 2019. On the other hand, during the same test period, the DCFC fans maintained a PF at or near 1.0.

To confirm whether the issue was a result of faulty instrumentation, the project team used a three-phase power meter to spot measure the PF on September 25, 2019. This confirmed the baseline control fans' PF was 0.55, meaning the Powerwise DAS measured accurately, and the PF issue was a result of some other non-routine event that could not be explained.

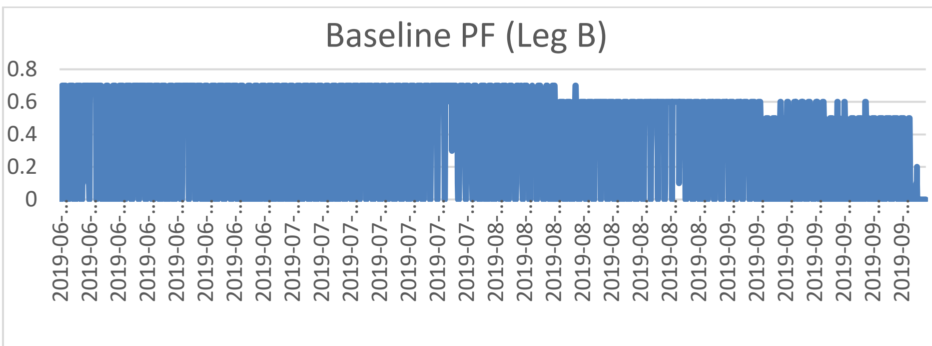


FIGURE 32: PF COMPARISON FOR BASELINE FANS

The project team speculated several causes for the low PF. One suggestion was that the voltage legs were out of balance. However, after reviewing the data, the project team confirmed the voltage for all three legs of the baseline control fans were normal, as shown in Figure 33.

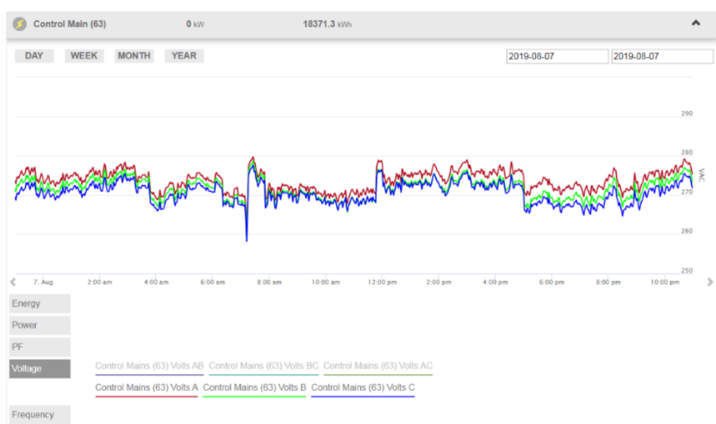


FIGURE 33: BASELINE CONTROL FAN VOLTAGE LEG ANALYSIS

Sub-metered Data Collection Timing

Another source of confusion occurred for the same data periods, as the DCFC manufacturer's sub-metered data did not show as high DCFC fan peak demand use as the Powerwise sub-metered data. Both the DCFC manufacturer's and Powerwise sub-metered data showed an average peak usage of 1.1 kW per fan. However, evidence showed the DCFC manufacturer's sub-metered data read zero W when all nine fans were off, while the Powerwise sub-metered data showed a low-level reading of 30 W for all nine fans when they were off during the same period.

The project team confirmed with the manufacturer that the difference in power draw was likely attributed either to the fans being operated based on the DCFC thermostats and logic boxes, or the DCFC electronics that required powering even when the fans were off. The project team verified the Powerwise submetering data in as many manners as possible, including taking live spot readings and comparing it to the sub-metered data. The project team believed both the DCFC manufacturer's and Powerwise's submetering data was being read at different points in the circuit. Despite these differences, the project team felt it was necessary to use Powerwise submetering data for the DCFC fan use, to ensure a consistent and fair comparison between the data sets.

Scenario 3 Pre-Cooling

One of the primary proposed benefits of the DCFC technology was the ability to pre-cool the dairy pen before the midday summer heat, given two conditions:

1. When THI was greater than 65°F, but less than 72°F; and
2. When the DCFC operated only on solar power.

Without solar power, the fans were programmed to operate according to THI desired settings (> 65°F) using grid power with the VFD capabilities to satisfy dairy pen cooling requirements.

Scenario 3 occurred between August 30 and September 30. Despite THI conditions (> 65°F) being satisfied, solar hours decreased in August and September as compared to June and July. Consequently, the pre-cooling function was not realized, because the upper limit of the THI conditions was reached before full solar power was available to power the fans. Accordingly, the energy savings potential from pre-cooling was not achieved since the pre-cooling conditions did not occur during the testing period.

Table 4: Monthly Solar Hours and Average Monthly Temperature

Month	Monthly Solar Hours	Average Monthly Temperature (°F)
June	437.25	92.37
July	444.28	95.36
August	418.07	95.95

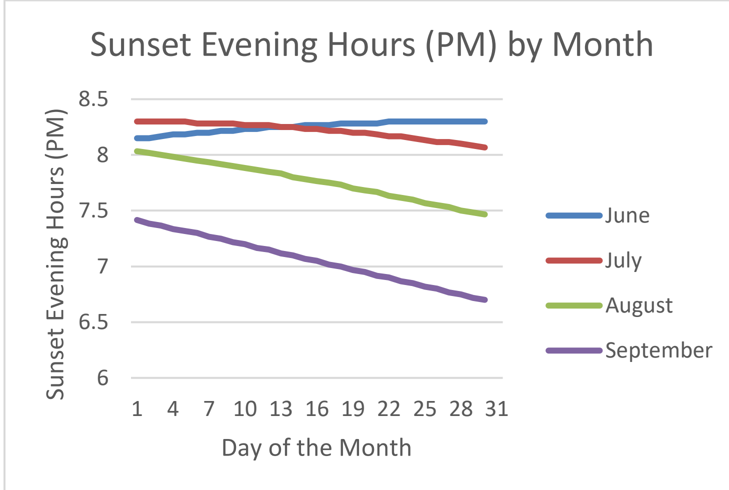


FIGURE 34: SUNSET EVENING HOURS (P.M.) BY MONTH

NORMALIZING ENERGY DATA WITH OUTSIDE WEATHER TEMPERATURES

During analysis, control fan PF dropped over the course of the study. The root cause of this non-routine event could not be determined. Thus, the baseline data was normalized to use a PF of 0.70, because this was consistently seen throughout Scenarios 1 and 2 from June through August.

To estimate energy savings using IPMVP Option B Retrofit Isolation protocols, the raw baseline fan data was normalized to outside air temperature in CTZ 13, to account for both routine and non-routine events. A breakdown of the normalized baseline annual energy usage (kWh) is shown in Table 5. Sub-metered data collection commenced in June and concluded in July of 2019. Normalized baseline annual energy usage (kWh) amounted to 23,595 kWh for all nine baseline fans, or 2,621 kWh per fan.

TABLE 5: NINE (9) BASELINE CONTROL FANS

OAT	Days	kWh	Normalized %	Annual Energy Consumption (kWh)
106	10	195	100%	1958
101	33	173	100%	5718
96	47	150	100%	7083
91	23	128	100%	2946
86	27	105	100%	2849
81	17	82	100%	1409
76	27	60	100%	1629
71	23	37	100%	1958
66	23	15	100%	5718
Normalized Baseline (kWh) for Nine Baseline Fans				**23,595**
Normalized Baseline (kWh) per Fan				**2,621**

To estimate energy savings using IPMVP Option B Retrofit Isolation protocols, the raw DCFC fan data was also normalized to outside air temperature in CTZ 13, to account for both routine and non-routine events. A breakdown of the normalized DCFC test fan annual energy usage (kWh) is shown in Table 6. Sub-metered data collection commenced and ended in July of 2019. Normalized DCFC test fan annual energy usage (kWh) amounted to 17,782 kWh for all nine DCFC test fans, or 1,976 kWh per fan.

TABLE 6: NINE (9) DCFC TEST FANS

OAT	DAYS	KWH	NORMALIZED %	ANNUAL ENERGY CONSUMPTION (KWH)
111	3	156	100%	468
106	17	139	100%	2,366
101	41	122	100%	5,016
96	43	105	100%	4,534
91	19	88	100%	1,683
86	24	71	100%	1,721
81	17	54	100%	932
76	28	38	100%	1,062
Normalized Annual (kWh) for Nine DCFC Test Fans				**17,782**
Normalized Annual (kWh) per DCFC Test Fan				**1,976**

After normalizing both baseline control and DCFC test fans to CTZ 13 outside air weather temperatures, the energy savings was 634 kWh per fan. However, the peak demand use was 21 watts, or 0.021 kW higher during the new 4 p.m. to 9 p.m. peak period. The values were inserted into the CPUC Cost-Effectiveness Tool (CET), as shown in Table 7, illustrating the total savings per fan attributed to both solar blending and VFD.

TABLE 7: SUMMARY OF SOLAR AND VFD TOTAL RESOURCE COST (TRC) BENEFIT RATIO

	ANNUAL ENERGY SAVINGS (KWH/YR)	PEAK DEMAND (KW)	TOTAL RESOURCE COST (TRC) COST BENEFIT RATIO
Post Install w/Solar & VFD Savings	634	(0.021)	0.04

EE AND INTEGRATED DEMAND-SIDE MANAGEMENT (IDSM) POLICY BACKGROUND

California's future clearly encompasses IDSM solutions to include EE, DR, DG, and battery storage. However, the CPUC's EE Policy Manual (Version 5) specifically outlines that ratepayer-funded EE activities must focus on EE efforts, to keep the cost of EE as an energy resource as low as possible.

Although the other IDSM activities are important to California's future electrification goals, to keep EE programs cost-effective, those activities are restricted from EE funding, because those activities have their own separate funding. Moreover, when determining cost-effectiveness, only the EE portion can be counted, since EE funding is granted for the sole purpose of supporting EE activities. This is done to ensure a fair and equitable way to evaluate and distribute program benefits over program costs.

Therefore, this is an important consideration when assessing a technology that provides multiple benefits including EE, onsite generation, and the capability to include both DR and battery storage, because only the EE savings can be counted to comply with the CPUC EE Policy Manual.

Isolating VFD EE Savings from Total Solar Savings

The DCFC technology has a built-in VFD capability to control the fan motor speed, depending on actual airflow requirements. This feature consumes less energy when the fans are blended back to the grid during the night. One of the solar blending technology functions is the ability to seamlessly shift the fans to draw power from the grid when the sun goes down and leverage the VFD capability when possible. The technology provides significant savings by mainly drawing solar PV to run the fans during the day, which reduces dependency on grid power.

However, based on the EE policy manual, VFD savings must be separated from total savings, to ensure EE activities are separately captured from other IDSM activities, including any savings from the solar PV.

Calculating VFD kWh EE Savings

Since there were different scenarios and associated monitoring periods, it was initially thought that a fair comparison would assess the average power of the baseline control fans in Scenario 1 against the average power of the test fans with VFD mode in Scenario 2, because this would isolate the VFD operational conditions with the only variable being the dairy pen's temperature setpoint at 74°F. The theory was that VFD energy savings data would be calculated by taking the difference of power between the baseline fans without VFD and the test fans with VFD, at a fixed thermostat setpoint of 74°F. Thus, it was first assumed that the VFD-enabled mode would have a high overall full-power load, and that difference should be taken out of any savings the VFD mode incurred from 72°F-74°F.

However, after reviewing both the max kW and average kW data, both data points were lower during Scenario 2 than Scenario 1. Therefore, only VFD EE savings were captured when the dairy pen's thermostat setpoint was between 72°F-74°F. The data indicated that for the month of July (Scenario 2) the total energy savings, including the solar PV and VFD EE raw savings, was 544 kWh when comparing the baseline control fans against the test fans. When isolating the VFD EE savings by removing the data that included solar PV savings, the VFD EE savings during Scenario 2 represented from three to nine kWh (1-3% savings) of the total 544 kWh savings during the month of July 2019. After normalizing for weather, the normalized energy savings per fan from the VFD was between 6-20 kWh.

Calculating Peak Demand Reduction with New 4 p.m. to 9 p.m. TOU Period

Prior to 2019, California's peak demand use occurred during the summer months from 12 p.m. to 6 p.m. When the temperature exceeds thermostat setpoints, fans must operate at full speed to provide maximum airflow and avoid heat stress for the cows. However, given the DCFC test fans have more peak usage compared to the baseline control fans, the new TOU calculation is not applicable when considering cost effectiveness. A summary of the TRC values is shown in Table 8 based on the different scenarios, including: 1) preliminary scorecard estimates; 2) solar and VFD savings; and 3) VFD savings only.

TABLE 8: SUMMARY OF ALL TOTAL RESOURCE COST (TRC) BENEFIT RATIO SCENARIOS

	Annual Energy Savings (kWh/yr)	Peak Demand (kW)	Total Resource Cost (TRC) Cost Benefit Ratio
Preliminary Scorecard Estimate	7,985	0.84	0.49
Post Install w/Solar & VFD Savings	634	(0.021)	0.04
Post Install w/VFD Savings Only	20	(0.021)	0.00

Tables 9 and 10 compare the different PA-2 Agricultural and Pumping Demand and Energy Rates between 2018 and 2020. The 2018 values use the old 12 p.m. to 6 p.m. peak demand rates, while the 2020 values use the new 4 p.m. to 9 p.m. peak use rates.

TABLE 9: COMPARISON OF 2018 AND 2020 PA-2 AGRICULTURAL & PUMPING DEMAND RELATED RATES

	Customer Charge	Facility-Related Demand (FRD)	Time Related Demand On-Peak (TRD)	Time Related Demand Mid-Peak (TRD)
2018 TOU-PA-2 B	$43.15/Month	11.47/kW	12.24/kW	$2.21/kW
2020 PA-2/Agricultural & Pumping	$41.40/Month	$7.93/kW	$3.49/kW	-

TABLE 10: COMPARISON OF 2018 AND 2020 PA-2 AGRICULTURAL & PUMPING ENERGY RELATED RATES

	Summer On-Peak (kWh)	Summer Mid-Peak (kWh)	Off-Peak (kWh)	Super Off Peak (kWh)
2018 TOU-PA-2 B	$0.13964	$0.07872	$0.05607	-
2020 PA-2/Agricultural & Pumping	$0.12275	-	-	-

Scenario 1 includes energy savings associated only with solar generation and blending, and indicates the DCFC fans, on average, peak at approximately 1.3 kW, while the baseline control fans, on average, peak at approximately 1.05 kW between June 1 through July 31. Average monthly baseline control energy use amounted to 4,133 kWh, while the average monthly DCFC test fan use was 3,426 kWh. Table 11 illustrates estimated monthly customers' bills, based on both 2018 and 2020 Agricultural and Pumping Rates. The total estimated monthly operational costs savings from installing the DCFC technology compared to baseline control fans amounted to $21.09 per month, based on the 2018 Agricultural and Pumping Rates. Using the 2020 Agricultural and Pumping rates, the total estimated monthly operational costs savings from installing the DCFC technology compared to the baseline control fans amounted to $67.55.

TABLE 11: COMPARISON OF 2018 AND 2020 PA-2 AGRICULTURAL & PUMPING DEMAND AND ENERGY CHARGES SCENARIO 1

	CUSTOMER CHARGE	FACILITY-RELATED DEMAND (FRD)	TIME RELATED DEMAND ON-PEAK (TRD)	TIME RELATED DEMAND MID-PEAK (TRD)	SUMMER ON-PEAK (KWH)	SUMMER MID-PEAK (KWH)	TOTAL ESTIMATED MONTHLY CUSTOMER BILL
2018 TOU-PA-2 B Baseline	$43.15	$108.39	$115.67	$20.88	$185.09	$113.11	$586.29
2018 TOU-PA-2 B DCFC	$43.15	$134.20	$143.21	$25.86	$192.14	$24.64	$565.20
2020 PA-2/Agricultural & Pumping Baseline	$41.40	$74.94	$32.98	-	$162.71	$99.43	$411.46
2020 PA-2/Agricultural & Pumping DCFC	$41.40	$92.78	$40.83	-	$168.90	-	$343.91

Similarly, Scenario 2 includes savings from both solar and VFD savings. Using the 2018 Agricultural and Pumping rates, the total estimated monthly operational costs savings from installing the DCFC technology compared to baseline control fans amounted to $14.07 per month. Using the 2020 Agricultural and Pumping rates, the total estimated monthly operational cost savings from installing the DCFC technology compared to the baseline control fans amounted to $37.97.

TABLE 12: COMPARISON OF 2018 AND 2020 PA-2 AGRICULTURAL & PUMPING DEMAND AND ENERGY CHARGES SCENARIO 2

	CUSTOMER CHARGE	FACILITY-RELATED DEMAND (FRD)	TIME RELATED DEMAND ON-PEAK (TRD)	TIME RELATED DEMAND MID-PEAK (TRD)	SUMMER ON-PEAK (KWH)	SUMMER MID-PEAK (KWH)	TOTAL PROPOSED MONTHLY CUSTOMER BILL
2018 TOU-PA-2 B Baseline	$43.15	$108.39	$115.67	$20.88	$185.09	$113.11	$586.29
2018 TOU-PA-2 B DCFC	$43.15	$134.20	$143.21	$25.86	$181.81	$43.99	$572.22
2020 PA-2/Agricultural & Pumping Baseline	$41.40	$74.94	$32.98	-	$162.71	$99.43	$411.46
2020 PA-2/Agricultural & Pumping DCFC	$41.40	$92.78	$40.83	-	$159.82	$38.66	$373.49

SIMPLE PAYBACK RETURN ON INVESTMENT

The total labor and material costs for the DCFC technology was estimated to be $5,827.74. Using the 2020 Agricultural and Pumping rates, the annual operating cost savings was estimated to be approximately $455.64. Thus, the simple payback without utility EE and SG incentives would take 12.79 years.

CONCLUSIONS

IPMVP Option B was used to isolate savings from the DCFC technology compared to baseline conditions. The monitoring period occurred across most of the summer into the early fall, from June to October of 2019. The DCFC's solar generation and blending feature resulted in a 61% grid savings during the old DEER 2 p.m. to 5 p.m. peak period from baseline conditions alone in Scenario 1 (June 1 to July 31). However, the overall raw data savings only showed a 17% grid savings over baseline conditions during the same period, because the fans ran longer during and beyond the new 4 p.m. to 9 p.m. TOU peak period.

Baseline control fan operational conditions had consistent use patterns during Scenario 1. However, during Scenarios 2 and 3, the PF dropped dramatically, from 0.70 down to between 0.50 to 0.60. This impacted the baseline energy and peak demand use for both periods in comparison to the DCFC test fans. After the project team conducted spot measurements to confirm the PF matched that of the DAS, we concluded it was a non-routine event that could not be explained. To account for this variable in energy savings calculations, the PF was normalized using Scenario 1 baseline energy and peak demand use, as the PF was consistently 0.70.

Based on preliminary estimates, there are approximately 15,000 fans on dairy farms within SCE's service territory, totaling 38.8 GWh of energy use and 18 MW of peak demand. If the DCFC technology successfully replaced all 15,000 fans, the gross estimated annual electric savings would amount to over 9.5 million kWh (9,510 MWh) annual energy savings, with no peak demand savings. SCE's 2019 Sustainability Report estimates approximately 534 pounds of CO_2 is emitted for every MWh of electricity delivered through SCE's generation mix. If all 15,000 baseline fans were replaced with DCFC fans, this would avoid 5.08 million pounds of GHG emission, or 2,304 metric tons of CO_2e.

LESSONS LEARNED

- Solar blending and generation benefits decline as the summer period reaches early fall.
- The DCFC technology uses more energy during the new 4 p.m. to 9 p.m. peak period to satisfy THI thresholds for cow cooling requirements.
- Wiring problems occurred because the diagrams were not followed during installation; close coordination with electricians and data acquisition staff is extremely important.
- Data monitoring required checking all legs of data (power and PF, specifically) to make sure instrumentation was correctly connected.
- The DAS manufacturer's technical support team was located on the East Coast. Thus, local support was not available; selecting a local vendor would have been ideal, to ensure proper inspection to troubleshoot issues.
- Farm electricians are difficult to contact and often do not respond to emails. They need to be contacted via phone, which makes troubleshooting and communication difficult.

RECOMMENDATIONS

Based on the results of our field assessment, the DCFC measure is not cost-effective under the EE policy framework, as the TRC fell below the 1.0 threshold. However, given the grid and environmental benefits of having solar generation and blending as a feature with THI, pre-cooling, and VFD options, the DCFC technology is a viable solution to help meet California's decarbonization and building electrification future goals. Should the metrics change to include and incentivize GHG emission reduction values, the DCFC technology may be a future option for many dairy farmers and utilities to consider.

APPENDIX

PRELIMINARY TOTAL RESOURCE COST (TRC) ANALYSIS

Project Recommendations

The CPUC's EE Policy Manual (Version 5) specifically outlines that ratepayer-funded EE activities must focus on EE efforts, to keep the cost of EE as an energy resource as low as possible. Although the other IDSM activities are important to California's future electrification goals, to keep EE programs cost effective, those activities are restricted from EE funding, because they have their own separate funding. Moreover, when determining cost-effectiveness, only the EE portion can be counted, since EE funding is granted for the sole purpose of supporting EE activities. This is done to ensure a fair and equitable way to evaluate and distribute program benefits over program costs.

EE cost effectiveness is determined using a TRC cost-benefit test. A TRC above 1.0 indicates the proposed measure provides more benefits compared to its costs. A TRC below 1.0 means fewer benefits compared to costs. Table 14 illustrates the TRC cost-benefit ratios prior to the project start, post installation with both solar and VFD EE savings, and VFD EE savings only.

Based on field assessment results, the DCFC measure is not cost-effective under the EE policy framework, because the TRC fell below the 1.0 threshold. But because of the grid and environmental benefits of blending solar generation with THI, pre-cooling, and VFD, it is a potential solution toward meeting California's decarbonization and building electrification goals. If the metrics change to include and incentivize GHG emission reduction values, the technology may be a future option for dairy farmers and utilities.

TABLE 13~~14~~: SUMMARY OF EE TOTAL RESOURCE COST (TRC) BENEFIT RATIO

	ANNUAL ENERGY SAVINGS (KWH/YR)	PEAK DEMAND (KW)	TOTAL RESOURCE COST (TRC) COST BENEFIT RATIO
Preliminary Scorecard Estimate	7,985	0.84	0.49
Post Install w/Solar & VFD Savings	634	(0.021)	0.04
Post Install w/VFD Savings Only	20	(0.021)	0.00

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