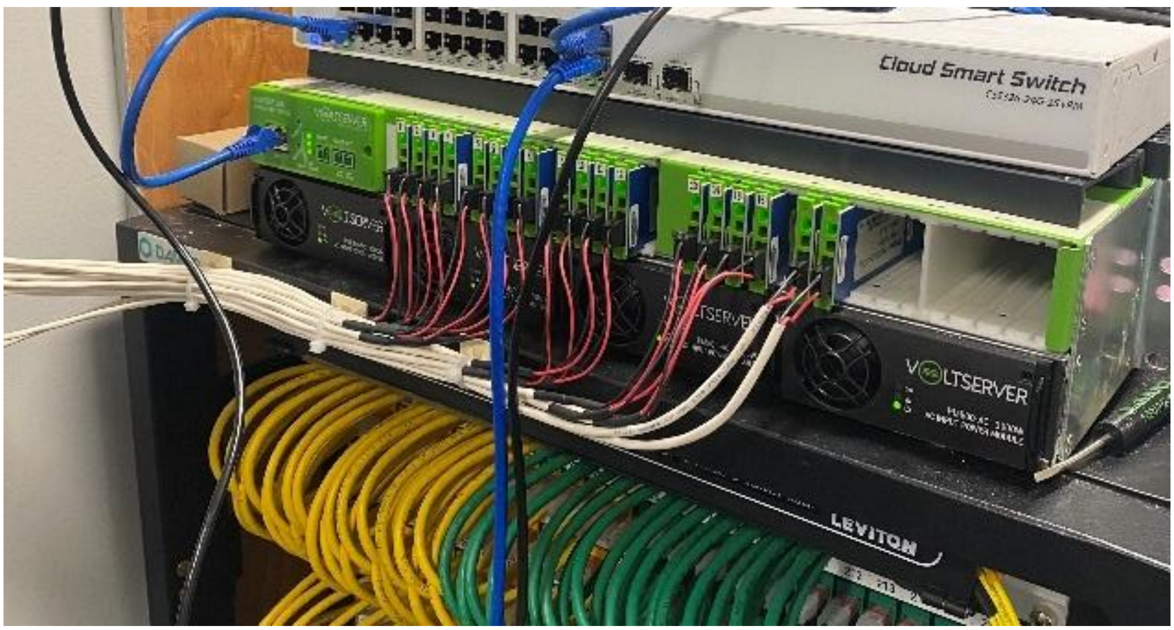
Enabling Non-Residential Electrification and Efficiency with Fault Managed Power Systems (FMPS)

Final Report

ET24SWE0021



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Executive Summary

The Non-Residential Electrification and Efficiency with Fault-Managed Power Systems (FMPS) CalNEXT project explored the market potential and assessed how FMPS can reduce the barriers to electrification efforts by reducing the complexity and cost of electrical infrastructure upgrades across non-residential (commercial, industrial, and agricultural) customer segments. This project characterized associated individual technologies to better understand the landscape and program impacts with an interest in scaling the market for commercial, industrial, and agricultural systems. With the rising need for widespread electrification of buildings in California, innovative solutions are needed to support broad decarbonization efforts.

FMPS technology capitalizes on providing *direct current (DC)* power to DC-powered devices, reducing line losses over long distances via efficient power delivery. This then provides simpler, lower-cost electrical infrastructure that enables the electrification of space heating, water heating, foodservice, and electric vehicle (EV) charging infrastructure. This also provides energy savings through high-efficiency power distribution and flexible demand management. FMPS reduces barriers to installing new electrical distribution by lowering the cost and complexity of installing new power distribution. FMPS uses an entirely separate power distribution pathway (communication cable) to overcome physical space constraints within cities.

The market assessment investigated FMPS adoption, technology penetration, and energy savings potential using literature reviews, surveys, interviews, and site visits. A summary of measure descriptions is provided in the Market Assessment Recommendations section of this Report.

The technology roadmap explored FMPS energy savings potential with one field demonstration at an indoor farm. An overview of the suggested path for measure development is provided in the Conclusions section of this report.

Key findings from each instrument are reported below.

Literature Review

Literature review assessed dozens of case studies, trade journal articles, industry publications, and conference proceedings to understand existing power distribution technologies, off-the-shelf technology currently available, the latest vendor offerings in the market, and insights on FMPS infrastructure and energy savings potential of FMPS for non-residential building systems. Findings include demographics of building owners and managers in California to help the *Investor-Owned Utility (IOU) Energy Efficiency (EE)* Programs understand the commercial, industrial, and agricultural buildings market to gain insights into EE opportunities in these sectors.

- There are 24,000 *commercial buildings* totaling 12 billion square feet across every county in California; these facilities comprise 80 percent of the non-residential buildings in California.
- California Energy Code (Title 24, Part 6) requires electrification of space-conditioning building systems in new and existing buildings which could drive a growing need for high-performance power distribution systems.
- FMPS systems have the potential to reduce electricity consumed by DC-powered building systems by 1 to 5 percent in California commercial buildings.

Surveys

Building owners and facility managers across California shared information about their baseline power distribution systems and level of interest in efficiency and electrification projects. The objective was to understand the California non-residential buildings market's adoption of FMPS systems and barriers to efficiency. Survey respondent facilities ranged from 10,000 square feet to 250,000 square feet, with an average size of 69,169 square feet, and a median size of 42,973 square feet.

FMPS Adoption

- Every survey respondent uses *alternating current (AC)* driven power distribution equipment.
- Most facilities have at least one natural gas-driven heating, ventilation, and air conditioning (HVAC) system or commercial kitchen. FMPS could enable the electrification of these systems if power distribution equipment upgrades are required.

Barriers to Energy Efficiency

- Every survey respondent prioritizes the lowest-cost equipment when selecting new power distribution systems.
- Two- to five-year payback periods are preferred by 66 percent of survey respondents.

Interviews

Industry experts and stakeholders across several key non-residential buildings market segments provided feedback on the level of FMPS adoption across commercial, industrial, and agricultural buildings in California. Feedback provided insights on energy savings potential of FMPS systems and offered context about baselines, industry standard practice, and the status of standards, energy codes, and third-party certification programs affecting non-residential buildings in California.

Electrical Power Distribution

- California electrical system designers have discussed DC power distribution in a few projects but have not reviewed compelling evidence for energy savings.

FMPS technology manufacturers have not quantified the variable energy savings of FMPS and market systems using non-energy benefits.

Electrification Projects

- Facility managers of non-residential buildings are motivated by net zero greenhouse gas (GHG) Emissions goals to plan electrification projects within the next twelve months.
- Decarbonization advocacy groups facilitate working groups focused on issues affecting service-side upgrades such as right-sizing electrical panels and standards for flexible load technology.

Site Visits

Four commercial buildings were visited in 2024 to observe building systems like electrical power distribution, space heating, water heating, and commercial foodservice equipment. Visited facilities ranged from 10,000 square feet to 73,700 square feet, with an average size of 69,169 square feet, and a median size of 42,973 square feet.

Power Distribution

- Half of the sites visited were equipped with high-voltage (480 Volts Alternating Current (VAC)) utility service.
- Facilities with 480 Volts (V) service were equipped with multiple onsite transformers to step down voltages to 208/120 V for plug loads and other end-use equipment, occupying significant space within the facilities' electrical rooms.

Energy Analysis

Electricity data from four commercial buildings in California were analyzed to understand monthly electricity use, peak demand, and electric energy use intensity for January – December 2023.

Energy Efficiency

- Average peak demand across the four buildings analyzed for 2023 was 191 kilowatts (kW).
- Average annual energy usage across the four buildings was 534,140 kWh in 2023.

Technology Roadmap Highlights

Using the recommendations from the market assessment, as well as the results of one field demonstration in a hard-to-reach community in California, the Technology Roadmap identified and detailed low-cost, readily available solutions for adoption — especially those that would be successful in disadvantaged communities.

Field Demonstration

The team installed an FMPS system at one indoor farm in California to evaluate the energy savings potential of FMPS for horticultural lighting process systems and uncover a strategic direction for FMPS program development. These systems observed energy and environmental data for four weeks to confirm lighting system operation during a flowering cannabis growth cycle.

ENERGY SAVINGS POTENTIAL

- Electrical infrastructure with higher power factor has lower potential FMPS energy savings.
- FMPS has the potential to achieve 5 percent electricity savings in indoor agriculture process lighting applications.
- The indoor cannabis industry could save 71 million kWh across 9,500,000 square feet of cultivation facilities.

CUSTOMER INSIGHTS

- FMPS is easier to implement in new construction projects or phased retrofits of large buildings.
- Consider creating new inducement payments for FMPS through new construction programs to encourage new construction projects to adopt Class 4 Power while electrifying other building systems.

Glossary of Terms

Alternating current: A type of electrical current in which the flow of electrons alternates at regular intervals.

Circuit panel: Electrical equipment that distributes electricity from the utility company to a building's circuits in a safe and controlled manner. Also known as distribution panels or panelboards.

Direct current: Type of electrical current that is uni-directional (flow of electrons is the same direction) and eliminates the need for conversion from Alternating Current to Direct Current at the load level.

Energy Star Portfolio Manager: Interactive resource management tool that enables building owners to benchmark the energy use of any type of building.

Fault: an electrical defect in a power system that results in an abnormal and excessive flow of current.

Fault-Managed Power System: A distribution system that can deliver large amounts of power over long distances and provides DC power to devices and eliminates transformers. Also known as Class 4 Power.

Switchgear: The collection of safety and switching devices to control, protect, or cut off circuits in an electrical system.

Switchboard: An electrical infrastructure that routes electrical power and distributes power to various circuits in a building.

Commercial building: A structure dedicated entirely to trade, commerce, and professional activities.

Industrial building: A structure that is primarily for industrial activity, generally not open to the public, including but not limited to warehouses, factories, and storage facilities.

Agricultural building: A structure designed to cultivate agricultural commodities and raise livestock.

Abbreviations and Acronyms

Acronym	Meaning
AC	Alternating Current
AR	Augmented Reality
CEA	Controlled Environment Agriculture
CEC	California Energy Commission
CFM	Cubic Feet per Minute
CZ	Climate Zone
DAC	Disadvantaged Communities
DAS	Distributed Antenna System
DC	Direct Current
DEER	Database of Energy Efficiency Resources
ECM	Electronically Commutated Motor
EE	Energy Efficiency
ESPM	Energy Star Portfolio Manager
ET	Emerging Technology
EUI	Energy Use Intensity
EV	Electric Vehicle
FMPS	Fault-Managed Power Systems
GHG	Greenhouse Gas
HP	Heat Pump
HPWH	Heat Pump Water Heater
HTR	Hard-to-Reach

Acronym	Meaning
HVAC	Heating, Ventilation, and Air Conditioning
IDF	Individual Distribution Frame
IOU	Investor-Owned Utility
IT	Information Technology
kWh	Kilowatt-hour
LED	Light Emitting Diode
MBH	Thousand British Thermal Units per Hour
NEC	National Electrical Code
NFPA	National Fire Protection Association
OASF	Outside Air Supply Fan
PA	Program Administrator
PG&E	Pacific Gas & Electric
PoE	Power-over-Ethernet
Q	Quarter
RMS	Root Mean Squared
RTU	Roof Top Units
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
TPM	Technology Priority Map
UPS	Uninterruptible Power Supply
USDA	United States Department of Agriculture
VAC	Volts Alternating Current

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Introduction

The following sections offer a comprehensive analysis of the 2024 California non-residential building markets, encompassing commercial, industrial, and agricultural sectors.

Notably, the 2023 edition of the CalNEXT Whole Buildings Technology Priority Map (TPM) underscores the critical importance of Electrical Infrastructure, highlighting it as a high-priority area (CalNEXT 2023). Moreover, direct current (DC) Power Systems are identified as a promising avenue for enhancing energy efficiency, bolstering demand flexibility, and advancing decarbonization efforts within the state's non-residential building landscape.

Market Overview

The size and age of California's commercial, industrial, and agricultural building stock are described in the sections below to evaluate the segments of the state's non-residential buildings present the greatest potential applications for Fault Managed Power Systems (FMPS) for energy savings in power distribution applications.

Existing buildings comprise the majority of California's commercial building stock; 93 percent of California buildings were built prior to 2000 (NREL 2021). While there is market potential for new energy recovery technologies installed to serve new construction projects, given the scale of historic California commercial building stock, retrofits of older existing buildings represent a larger market opportunity for the integration of FMPS systems to enhance efficiency and resiliency.

The results of the buildings industry analysis for each of the three sectors are summarized in Table 1. The building area is quantified in millions of square feet. Commercial buildings comprise 80 percent of the total non-residential building area in California. The combined categories of Large and Small Offices make up the largest sector within non-residential buildings (2.09 billion square feet) and present the greatest opportunity for FMPS systems.

Table 1. California Non-Residential Building Area by Sector

Buildings Industry Sector	Building Area (million sq ft)
Commercial	12,000
Industrial	2,640
Agricultural (Indoor Agriculture)	313
Statewide Total	**14,953**

Table Data Source: ERI 2025.

Commercial Buildings

The United States Department of Energy (U.S. DOE) defines commercial buildings as buildings that are not considered a residential building (U.S. DOE n.d.). Energy consumed by commercial buildings generates significant *greenhouse gas (GHG)* emissions, contributing to 16 percent of GHG emissions in the U.S. (Steven Winters Associates 2023). In California, the commercial real estate sector has witnessed substantial growth, with commercial floorspace expanding by 21 percent since 2006; this growth can most likely be attributed to the recovery from the 2007 global financial crisis.

In 2022, the total combined area of commercial spaces in the state was estimated to be over 12 billion square feet, spread across over 24,000 individual facilities according to the California Commercial End-Use Survey (CEUS 2022).

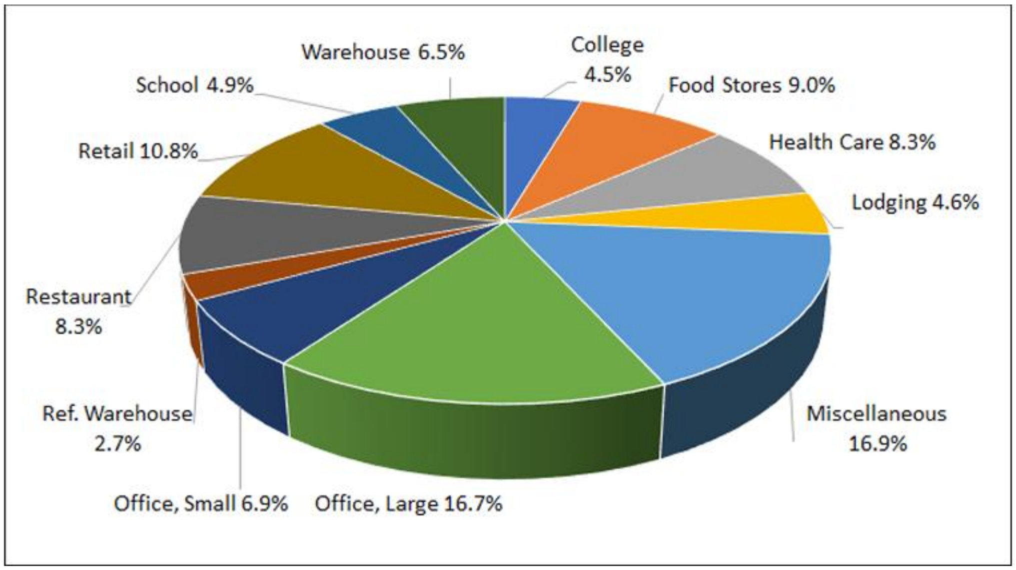

Figure 1: California Statewide Commercial Building Electricity Use by Building Type

Figure Data Source: CEC 2022.

Figure 1 describes the footprint of California commercial buildings in percentage of total statewide commercial building square foot. The data reveals the scale of electricity used across California's commercial building types. The combined categories of Large and Small Office make up the largest area (2.09 billion sq ft).

The largest individual commercial electricity users are miscellaneous commercial buildings (including buildings like auto repair shops, amusement parks, prisons, and dry cleaners). These make up the largest area (1.7 billion sq ft). Other categories with large floor stock include Large Office (1.32 billion sq ft), Warehouse (1.39 billion sq ft), and Retail (1.12 billion sq ft) (Ibid.).

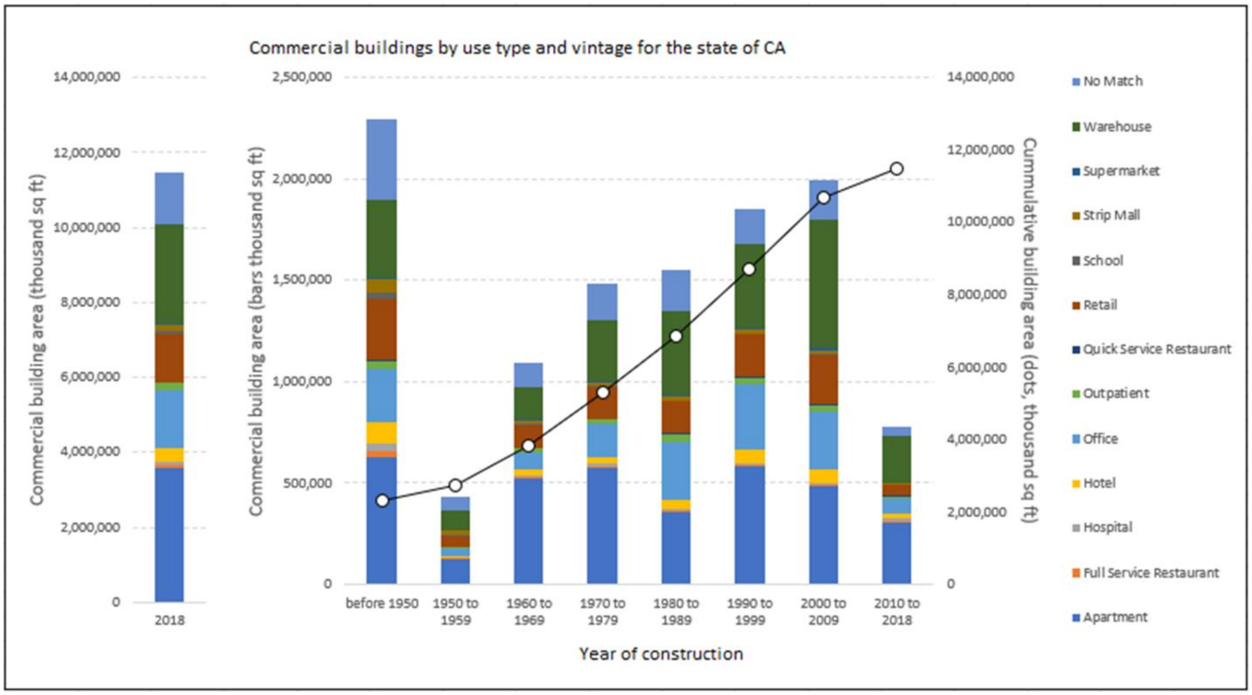

Figure 2: California Commercial Building Square Footage by Year

Figure Data Source: NREL 2021.

Most of California's building stock is existing buildings; only seven percent of California's commercial buildings were built within the past twenty years. California had 11.48 billion square feet of commercial buildings in 2018, shown at left in Figure 2. The largest categories include schools, retail stores, offices, and apartment buildings. At right, Figure 2 shows the distribution of California commercial building stock across year of construction for different decades using data from 2018 (NREL 2021).

Growth in commercial building inventory was slow between 2010 and 2018 and can be attributed to several factors including stringent building codes and zoning regulations, rising construction costs, limited land availability, economic downturns such as the global financial crisis of 2007, and a preference for renovating existing structures. These challenges made new construction projects more time-consuming and expensive, leading to a slower rate of new commercial building development in California.

Industrial Buildings

Coldwell Banker Richard Ellis (CBRE) examined California's *industrial building* stock separated by region in the first quarter of 2025. Industrial markets are typically surveyed by region due to variations in economic conditions, infrastructure, natural resources, and regulatory environments. These nuances impact industrial demand, investment patterns, and logistics, which makes it less relevant to characterize the industrial market of the state of California as a whole. The following section describes the California industrial buildings sector by region using data from three major metropolitan areas: The Bay Area, Central Valley, and Southern California (CBRE 2025). The industrial inventory of California is only analyzed for regions where data is readily available and publicly accessible; it can be assumed that most of the industrial activity in California occurs in these three regional areas.

Across the three major California metropolitan regions sampled, there are 2.64 billion square feet of rentable industrial buildings. Figure 3 shows the distribution of industrial buildings by region. The Southern California region of California has the largest industrial building stock of the three regions, with 1.8 billion square feet of rentable industrial buildings. The Bay Area region has the least industrial building area of the three California metropolitan regions studied with 389 million square feet of rentable industrial building area but has a similar sized industrial building stock to the Central Valley (447 million square feet).

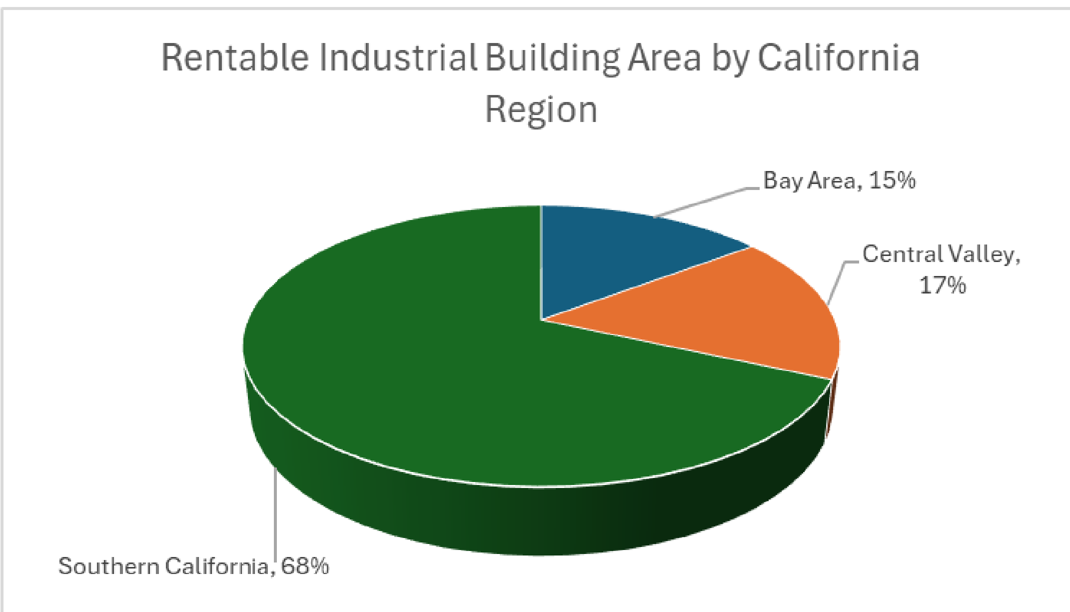

Figure 3: Rentable California Industrial Building Area, Q1 2025

Figure Data Source: CBRE 2025.

The following sections explore these three regions in greater detail and uncover that Oakland, Sacramento, and Los Angeles County are the California metropolitan areas with the largest industrial building stock with potential for WET system applications.

BAY AREA REGION

The California Bay Area region includes six metropolitan areas. Table 2 shows the distribution of the 389 million square feet of rentable industrial building stock across those areas. Oakland is the region with the greatest concentration of industrial buildings. The proportion of warehouse and manufacturing square feet in this region is displayed in Figure 4; this data is not available for the other regions.

Table 2. Bay Area Rentable Industrial Building Area

Bay Area Metropolitan Area	Rentable Industrial Building Area (sq ft)
San Francisco	21,965,419
SF Peninsula	34,231,921
Silicon Valley	110,700,518
Oakland	127,107,625
I-680 Corridor	38,296,020
Napa/Solano	56,359,537
Total Bay Area Rentable Industrial Building Area	**388,661,040**

Table Data Source: Ibid.

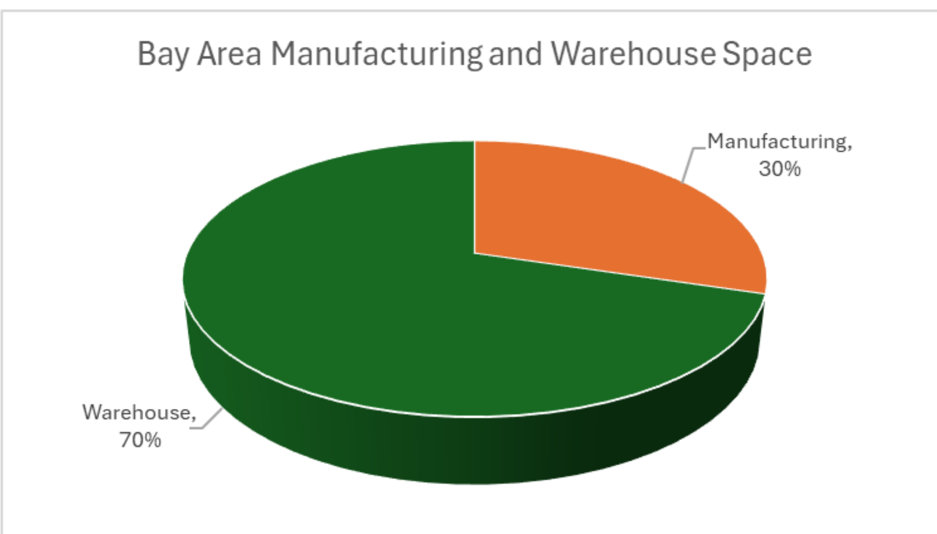

Figure 4: Rentable Bay Area Warehouse and Manufacturing Building Area, Q1 2025

Figure Data Source: Ibid.

CENTRAL VALLEY REGION

The Central Valley region of California is comprised of three market sectors with an industrial building area totaling 447 million square feet of buildings with 10,000 square feet or more. Sacramento is the metropolitan area with the greatest concentration of industrial buildings in the Central Valley region. Table 3 shows the rentable industrial building area in each of the three metropolitan areas in California's Central Valley.

Table 3. Central Valley Rentable Industrial Building Area

Central Valley Metropolitan Area	Rentable Industrial Building Area (sq ft)
South Central Valley	109,959,864
Central Valley	142,527,980
Sacramento	194,771,368
Total Central Valley Rentable Industrial Building Area	**447,259,212**

Table Data Source: Ibid.

SOUTHERN CALIFORNIA REGION

The Southern California region of California is comprised of five metropolitan areas with 1.8 billion square feet of industrial buildings larger than 10,000 square feet. Los Angeles County is the metropolitan area with the greatest concentration of industrial buildings in the Southern California region. Table 4 shows the rentable industrial building area in the Southern California region.

Table 4. Southern California Rentable Industrial Building Area

Southern California Metropolitan Area	Rentable Industrial Building Area (sq ft)
Los Angeles County	882,813,037
Ventura County	67,783,314
Inland Empire West	354,763,781
Inland Empire East	310,185,059
San Diego	188,120,866
Total Southern California Rentable Industrial Building Area	**1,803,666,057**

Table Data Source: Ibid.

Agricultural Buildings

This section summarizes a segment of the agricultural market using enclosed buildings for crop production that could feasibly use FMPS systems: greenhouses and indoor farms.

Greenhouses and indoor farms are a growing segment of the *agricultural buildings* growing crops in closed environments (characterized as controlled environment agriculture (CEA)). The U.S. Department of Agriculture defines CEA as production "under glass or other protection" (U.S. Department of Agriculture 2024), while the California Energy Code categorizes CEA facilities into greenhouses, conditioned greenhouses, and indoor growing spaces (California Energy Code 2022). Greenhouses feature a skylight-roof ratio of 50 percent or more, conditioned greenhouses have heating or cooling systems exceeding specific capacities.

More greenhouses and indoor farms are being built in California to meet the increasing demand for a consistent supply of high-quality horticultural products. In 2017, there were only 2,464 CEA operations active within the state of California (U.S. Department of Agriculture 2019), and in 2024, this number grew to 4,611 CEA operations (U.S. Department of Agriculture 2024).

Figure 5 describes the footprint of the California CEA industry in square feet. There are 313 million square feet of greenhouses and indoor farms in California. 61 percent of every square foot of CEA facility in California is for greenhouse floriculture or nursery crop production.

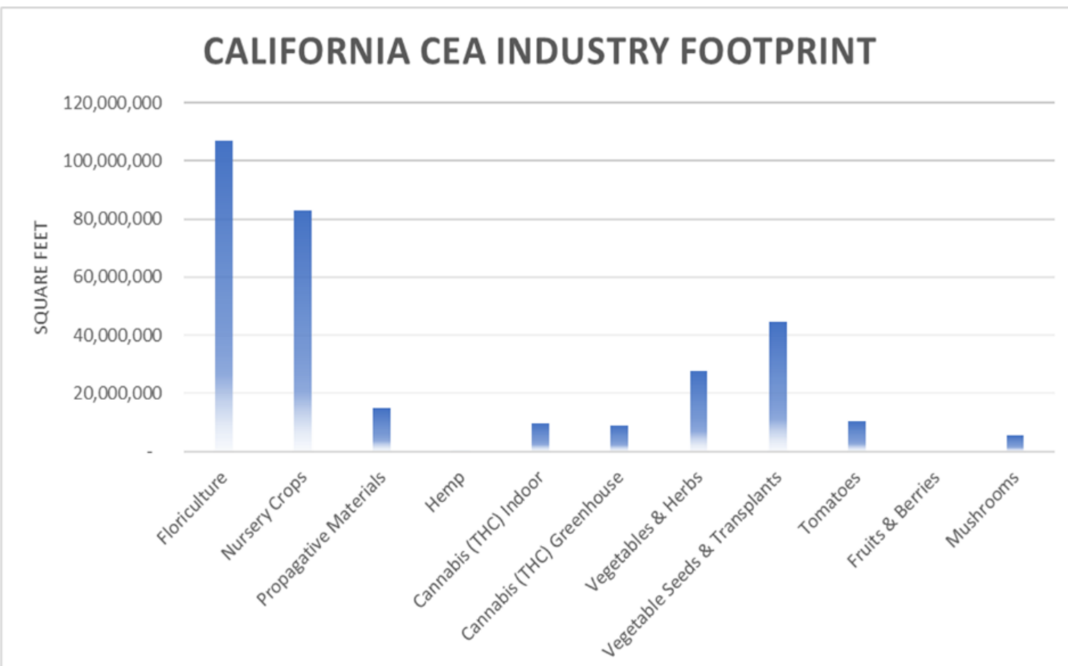

Figure 5: California Greenhouse Square Footage by Crop Type

Figure Data Source: USDA 2024; California DCC 2024.

CEA facilities are potential candidates for FMPS system application as many greenhouses in California have year-round lighting and ventilation loads and could integrate FMPS into power delivery infrastructure for new supplemental lighting or fan systems.

Background

This study focuses on opportunities for efficient power distribution to reduce the energy consumption driven by equipment in commercial, industrial, and agricultural buildings and enable electrification of buildings across the non-residential sector in California.

The following sections describe the energy consumed by commercial, industrial, and agricultural buildings, the components associated with a FMPS and key differences from a traditional power distribution system, and the energy saving potential of FMPS when powering various types of building equipment.

Non-Residential Facility Energy Consumption

Commercial office buildings are the primary consumer of electricity statewide. Understanding the dynamics of energy consumption within these diverse commercial spaces is essential for identifying the opportunities for efficient power distribution with the greatest energy-saving potential. Figure 6 describes statewide commercial building electricity usage by building type (CEC 2022).

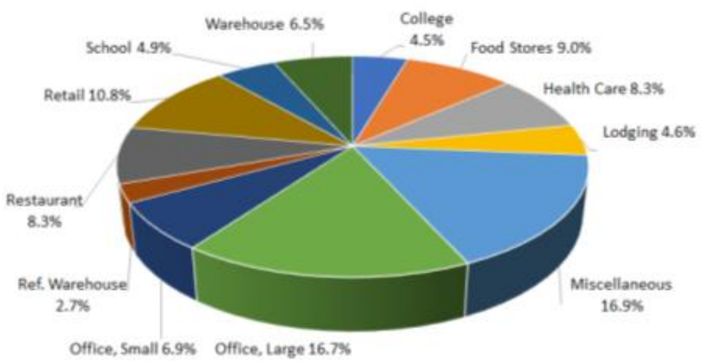

Figure 6: California Commercial Building Electricity Usage by Type

Figure Data Source: CEC 2022.

The greatest market potential for energy savings in commercial buildings is within the Miscellaneous, Large Office, Food Stores, Healthcare, and Restaurants categories. The building type consuming the most electricity in California is categorized as Miscellaneous, which includes various kinds of buildings such as auto repair shops, dry cleaners, and amusement parks. The major systems driving electricity consumption at these types of buildings are lighting, HVAC, and plug loads for specialty business equipment (for example, washers and dryers at laundromats, air compressors and power tools at auto repair shops, and concessions foodservice equipment at amusement parks).

The second-highest commercial consumer of electricity is the Large Office. The major systems driving electricity consumption in these buildings can be lighting, HVAC, plug loads from computers and copiers, breakroom equipment, and potentially electricity to drive elevators, data centers, and commercial kitchens (CEC 2022).

Food Stores, Healthcare facilities, and Restaurants are also categories of commercial buildings driving statewide electricity consumption. Food Stores use electricity for refrigeration, lighting, and HVAC systems as well as commercial kitchens like bakeries and delis. Healthcare electricity consumption is driven by lighting, advanced HVAC systems, plug loads for medical equipment, and data centers for hospitals and larger medical office buildings. Restaurants use electricity predominantly for lighting, refrigeration, commercial kitchen appliances, and HVAC including kitchen exhaust and makeup air systems (Energy Star n.d.).

Decarbonization and Electrification

California's commercial buildings have significantly contributed to the recent 13 percent increase in statewide electric energy consumption from 2006 to 2018 (CEC 2024). This can be, in part, attributed to the accelerated decarbonization of commercial buildings and the associated electrification of building systems (such as space heating, hot water heating, and commercial foodservice equipment) and the increased installation of EV charging infrastructure. Only 1 percent of buildings were electrically heated in the 1950s whereas in 2020, over 40 percent of buildings use electricity for heating and cooling (Steven Winters Associates 2023).

The 2022 version of Title 24, Part 6[1] includes requirements for commercial new construction and major renovation projects to incorporate heat pumps for heating (see summary in Table 5).

Table 5. California Energy Code Requirements Affecting Non-Residential Building Systems

Category	Regulation	Details
HVAC	Title 24, Part 6 (2022)	The 2022 version of Title 24, Part 6 includes requirements for commercial new construction and major renovation projects to incorporate heat pumps for heating. Title 24 mandates the use of heat pumps for single-zone systems with a cooling capacity under 20 tons; the 2022 update also prohibits the use of 100 percent electric resistance heating systems to minimize natural gas consumption.

[1] California's Statewide energy code.

Category	Regulation	Details
	Title 24 Amendments (2025)	Amendments to Title 24 for 2025, to be adopted in August 2024, would introduce prescriptive heat pump standards for nonresidential building types when replacing single-zone rooftop units (RTUs). The current prescriptive heat pump standards will also be updated. These updates include increased efficiency requirements for controlled environment horticulture buildings, introduced prescriptive heat pump standards for select nonresidential building types when replacing single-zone rooftop units less than 65,000 British Thermal Units per hour (BTU/h), and increased space conditioning system efficiency and control standards.
Hot Water Heating	Title 24, Part 6 (2022)	The energy code specifies prescriptive requirements for the incorporation of heat pump water heaters (HPWH) over traditional natural gas water heaters.
	Title 24 Amendments Impacts (2025)	These amendments will motivate and drive more non-residential buildings to electrify their HVAC systems to meet state code requirements, and to accomplish this, more efficient power distribution equipment is required to support these new electric systems.
EV Charging	CalGREEN (Title 24, Part 11)	The California Green Building Standards Code (Title 24, Part 11 is also more commonly known as CalGREEN) specifies requirements for non-residential new construction projects to have 25% of all planned parking spaces to be have Electric Vehicle Service Equipment (EVSE).
	EV Infrastructure Requirements	Non-residential buildings undergoing significant additions or alterations must include provisions for future EV charging. This includes providing electrical panel capacity, installing conduit, and setting up termination boxes to support future EV charging infrastructure.

Table Data Source: kW Engineering. n.d.

MUNICIPAL POLICIES ADDRESSING DECARBONIZATION

Currently, multiple California cities and municipalities have adopted decarbonization policies described by some as climate goals or climate action plans. At the city and county level, these polices require private and/or public commercial buildings to electrify space heating, water heating, and foodservice equipment. Table 6 describes eight city policies for GHG reductions, the year for achieving the climate goal, and reported progress (if available) as of 2024.

These policies are evolving and continue to be impacted by the Ninth Circuit Court's April 2023 decision No. 21-1627 in the case *California Restaurant Association v. City of Berkeley*. The amended opinion preempts "building codes" that "prohibit natural gas piping in new construction buildings from the point of delivery at the gas meter" (Carpenter-Gold 2024).

Table 6. California Municipal Decarbonization Policies, 2024

California City	Commercial Buildings Policy	Municipal Buildings Policy	GHG Reduction Goal	Goal Target Year	Reported Progress
Berkeley	Benchmarking Ordinance: Large commercial buildings over 50,000 sq ft must benchmark their energy use each year and perform a comprehensive energy assessment every five years. Reach Code: 2019 Berkeley Reach Code incorporated into 2022 California Energy Code.	Berkeley plans to implement building permit requirements, adhere to permit fees, and ensure compliance with inspections. Key activities will include upgrading municipal buildings to meet energy efficiency standards, reducing emissions through electrification projects, and integrating renewable energy sources.	Zero net GHG emissions	2045	GHG emissions reduction of 31% since 2000
Carlsbad	Participation in statewide 2022 CEC Benchmarking Program.	Adopted 2022 Building Energy Efficiency Standards.	GHG reduction of 52% reduction over year 2012 baseline	2035	4.8% reduction in GHG emissions since 2012
San Diego	Benchmarking Ordinance: Commercial buildings over 50,000 sq ft are required to submit energy data to City of San Diego in Energy Star Portfolio Manager (ESPM) annually. Reach Code: All-electric building systems standard requirement for new development. EV readiness (electric vehicle supply equipment).	Zero Emissions Municipal Buildings and Operations Policy (ZEMBOP) aims to eliminate 100% of natural gas use in municipal buildings by 2035.	Phase out 90% of natural gas usage from existing buildings by 2035	2035	25% GHG reductions since 2022

California City	Commercial Buildings Policy	Municipal Buildings Policy	GHG Reduction Goal	Goal Target Year	Reported Progress
San Mateo County	The City of Brisbane implemented Brisbane Building Efficiency Program which requires building owners to benchmark energy consumption in Energy Star Portfolio Manager (ESPM) annually.	Electrical panel upgrades must include capacity for future electrification of building systems.	Reduce GHG emissions to 85% below 1990 levels	2045	22% decrease in GHG emissions from 2005 to 2019
Santa Monica	Implementing Building Performance Standards & Benchmarking for existing buildings by end of 2024.	Participation in CalGREEN, requiring a minimum percentage of EV parking spaces in new non-residential projects in 2024.	80% GHG emissions reduction below 1990 levels	2030	10% reduction in emissions since 2019
Solana Beach	Compliance with California Energy Code AB802, currently implementing Energy and Water Building Benchmarking and Performance Standards for existing buildings by 2026.	Photovoltaic system required for all construction projects, all-electric heating and air conditioning, water heating, and clothes drying systems required for construction projects that alter 50% or more building area as of 2021.	50% below 2010 levels	2035	40% GHG emissions reductions below 2021 levels
San Jose	Beyond Benchmarking program requires buildings to either demonstrate satisfactory building energy and water efficiency or undergo actions for efficient improvement.	San Jose requires all new buildings constructed after August 2021 to be all-electric.	Carbon neutrality (net zero GHG emissions)	2030	As of 2021, 36% reduction in total GHG emissions from 2008
San Francisco	Existing Buildings Energy Ordinance requires buildings larger than 10,000 sq ft to benchmark annual energy usage. An energy efficiency audit is also required every five years for commercial buildings.	Municipal code requires large buildings to obtain electricity from renewable sources such as CleanPowerSF or SFPUC Hetch Hetchy Power.	Net zero emissions	2040	41% reductions in GHG emissions from 1990 levels as of 2019

Table Data Source: ERI. 2024b.

Non-Residential Building Power Distribution

Various types of power distribution equipment can serve electrically-driven equipment that contribute to the bulk of the energy consumption of non-residential (commercial, industrial, and agricultural) buildings.

Electricity is delivered to buildings in the form of alternating current (AC) power. Utilities distribute power at a variety of voltages, typically at 480 Volts Alternating Current (VAC) for large commercial customers. VAC is a measure of the electric potential difference in AC power systems. Some very large customers may receive direct access voltages of up to 13.8 kilo-Volts (kV). The specific level of electric service depends on ownership of the transformer and ability to own and maintain the equipment. Large non-residential buildings may purchase power at this voltage and maintain their own step-down transformer to lower voltage to 480/277 V (480V between any two phases of a 3-phase, 4-wire system, and 277V between a phase and the neutral wire). For smaller commercial buildings, utility-owned transformers lower voltage to 120/240 V before feeding electricity to the building's meter (Arch Toolbox 2021). Figure 7 shows a typical electrical power distribution infrastructure for a large building.

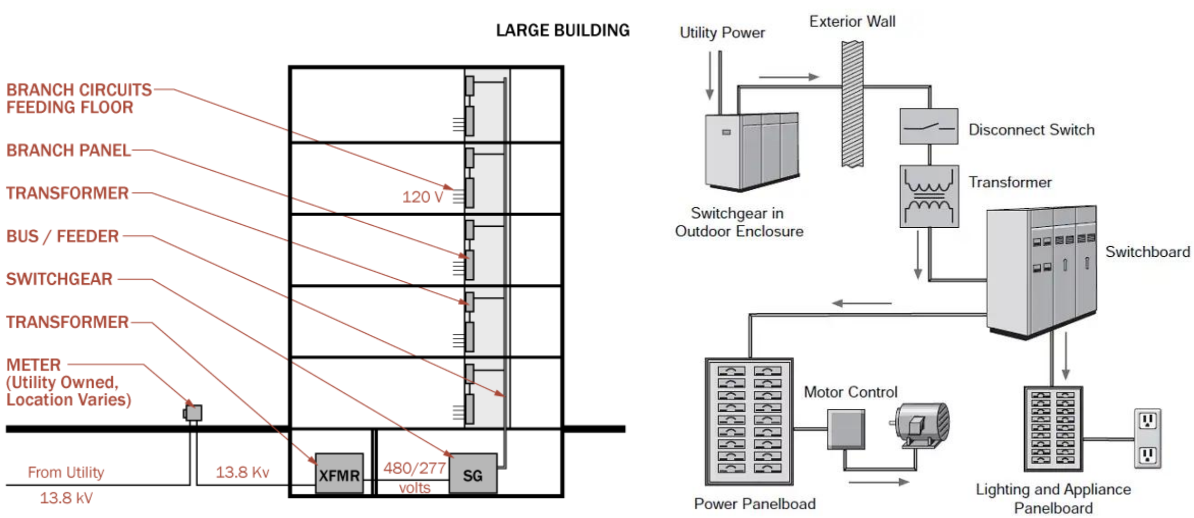

Figure 7: Typical Electrical Infrastructure Network for Large Buildings

Figure Data Source: Arch Toolbox 2021 (left). Electricity Forum 2025 (right).

In a traditional electric power systems, the infrastructure contains *switchgears*, *transformers*, *switchboards,* and *panelboards*. These systems predominantly utilize AC power. AC power is industry standard practice in electrical engineering since AC power is easier to step up and down in voltage compared to DC and can be done more efficiently. However, there are efficiency losses associated with altering electrical service through the use of step-up or step-down transformers.

Switchgears are where utility usage meters are located and serve as the start of the electrical power distribution network, regulating the flow of electricity and isolating faulty circuits. They manage and protect electrical circuits with a combination of switches, fuses, and circuit breakers housed within control panels. Switchboards are power distribution points within the building, where incoming electrical power is routed and distributed to various circuits and loads. These manage power consumption and typically house a series of switches, breakers, and meters. Panelboards, also known as *circuit panels*, distribution panels, or breaker boxes, form the final link in the chain of electrical power distribution. These panels receive power from the switchboards and further distribute it to individual circuits, outlets, and appliances throughout the building. Each circuit is protected by a circuit breaker, which automatically trips in the event of an overload or short circuit, safeguarding both the electrical system and the building occupants from potential hazards (Team Vskills n.d.).

Fault Managed Power Systems (FMPS)

A *FMPS* is an advanced DC power distribution system that continuously detects and mitigates *faults* in power networks. Unlike traditional AC power distribution systems, which often rely on reactive measures to address faults after they occur, FMPS utilizes real-time monitoring, diagnostics, and control mechanisms to detect potential issues and isolate affected areas swiftly. FMPS imposes no limitations on power supply under normal operation but will precisely limit the amount of energy transferred under a fault condition to reduce shock and fire hazard (Bjelkefelt 2023). Since FMPS systems do not transform power from DC to AC, there is a potential for FMPS systems to enhance the efficiency of building systems; this is explored further in the FMPS Energy Savings section of this report. FMPS case studies for four U.S. facilities are included in Appendix A of this report.

FMPS is an emerging commercially available technology that was standardized in 2023 by the U.S. National Electrical Code (NEC); Article 726 of the 2023 edition of the NEC classifies FMPS as “Class 4 Power.” Underwriters Laboratories (UL) introduced UL 1400-1 and UL 1400-2 to describe the requisite criteria for FMPS integration and deployment (Cence Power 2023). These documents are also more commonly known as UL’s “Investigation for Fault-Managed Power Systems.”

There is one predominant supplier of FMPS technology in the United States: VoltServer. A few others with footprint in the U.S. include Cisco Power, Panduit, Cence Power, and EnerSys. Globally, Italian manufacturer Prysmian supplies FMPS technology across Europe, Oceania and most of Asia (Leach 2024).

FMPS is structured around two core components: the Transmitter and the Receiver, as shown in Figure 8. Acting as the power source interface, the Transmitter establishes the Class 4 power circuit and transmits power to the Receiver. Upon receiving the Class 4 power, the Receiver converts power into the necessary form for the load device. Depending on the setup, the Receiver may function autonomously, supplying power to the end device, or it could be seamlessly integrated into the end device itself (VoltServer 2022).

In an FMPS power distribution system, several traditional power distribution components are eliminated, replaced or reconfigured:

- **Transformers:** Eliminated by the FMPS Transmitter which delivers DC power to DC-driven systems in buildings and reduces efficiency losses traditionally associated with step-up and step-down transformers.
- **Switchgear and Switchboards:** Replaced by the FMPS Transmitter which initiates the Class 4 power distribution.
- **Panelboards (Circuit Panels):** Replaced by the FMPS Receiver which receives the Class 4 power and converts it to the required form (DC) for end-use devices.

- **Conventional AC Wiring:** Specialized cables designed for Class 4 power distribution, which allows for more power distribution using a smaller single cable, eliminating the need for multiple cables in parallel or a single cable with a larger gauge.

An FMPS transmitter integrates into existing infrastructure by replacing conventional switchgears in electrical rooms where power is initially received. The transmitter converts incoming electrical power into digital packets, which are transmitted via specialized FMPS cables alongside existing data cables or within the same conduits throughout the building. The "mains" block represents the power source (such as utility grid power routed through switchboards) for the FMPS power transmitter. The FMPS transmitter connects to main switchboards, integrating with the building's existing electrical distribution system. On the receiving end, FMPS receiver units convert Class 4 power back into usable AC or DC power for various devices.

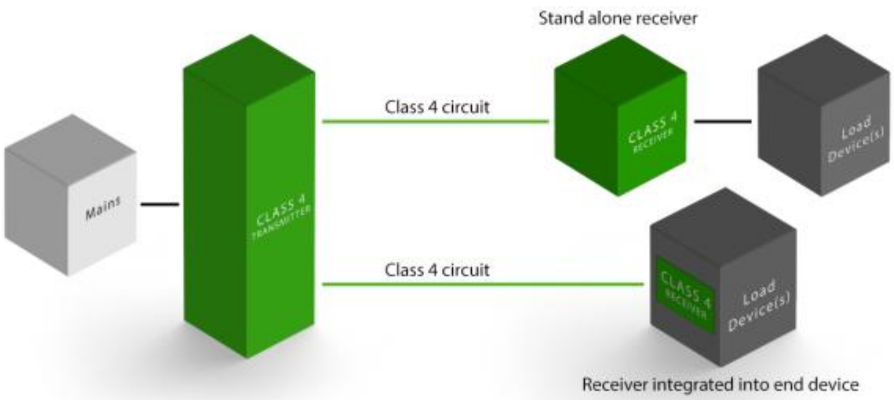

Figure 8: FMPS System Components

Figure Data Source: VoltServer 2022. To monitor for safe power distribution, FMPS technology converts energy into packetized units of power to integrate power delivery and data points. The result is a continuous data stream, monitoring for faults such as improper wiring or short circuits at a rate of hundreds of packets per second. Upon detection, the transmitter swiftly stops packet transmission to mitigate potential hazards. The platform accommodates both AC and DC-driven devices and equipment, ensuring power compatibility by leveling the energy to a DC stream during distribution and subsequently adapting it to meet the specific output requirements at the receiving end (Dagostino Electronic Services n.d.). During transmission, every energy packet transmitted through the structured cable is checked for safe transfer from transmitter to receiver. Figure 9 shows a FMPS system diagram, illustrating the transition from conventional electricity to local loads.

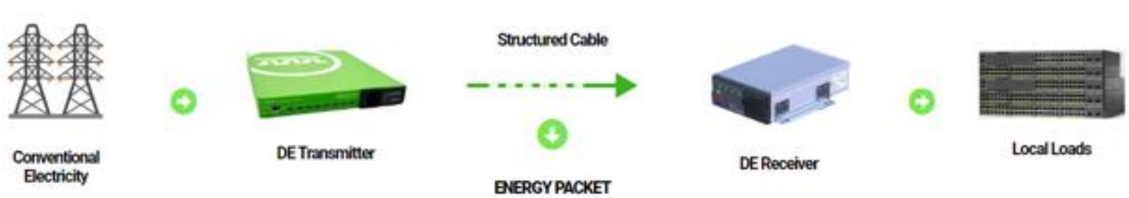

Figure 9: FMPS Power Distribution

Figure Data Source: VoltServer n.d.

FMPS Applications

FMPS power distribution infrastructure can serve any electrical end use in all types of buildings; this study focused on the applications for non-residential buildings.

FMPS has diverse applications across non-residential sectors. Table 7 provides a comprehensive overview of key FMPS use cases across various sectors.

Table 7. Use Cases for Fault Managed Power Systems

Non-Residential Building Use Case for Commercial Buildings	FMPS Power Distribution Application
EV Infrastructure	Level 1 EV Chargers Level 2 EV Chargers DC Fast Charging
Foodservice	Electric Kitchen Appliances (Refrigerators, Freezers, Walk-in Coolers, Ranges, Ovens, Fryers, Broilers, Steamers)
HVAC	Air Conditioners, Boilers, Chillers, Dehumidifiers, Fans, Heat Pumps, Humidifiers, Pumps
Hot Water Heating	Electric Hot Water Heaters, Heat Pump Hot Water Heaters
Lighting	Interior and Exterior Light Fixtures Lighting Accessories (Switches, Occupancy Sensors)
Specialty Business Uses (Miscellaneous Building Types)	Office Plug Loads (Laptops, Desktop PCs, Phones, Printers, Copiers, Scanners) Air Compressors Commercial Clothes Washers & Dryers Horticultural Lighting Security Systems Uninterruptible Power Supply (UPS) systems

Table Data Source: Dagostino Electronic Services n.d.

Each use case highlights specific scenarios where FMPS can play a transformative role in optimizing power distribution, enhancing resilience, and improving overall operational performance. New construction projects can incorporate FMPS power distribution in all-electric building designs to comply with decarbonization policies as more commercial buildings must comply with all-electric energy code requirements (see Table 6 in the Municipal Policies Addressing Decarbonization section of this report). For example, office building designs can specify FMPS to distribute power to electric HVAC and hot water heating equipment. Another example affecting some areas of California are municipal requirements to eliminate gas-fired kitchen equipment; commercial buildings with foodservice equipment can utilize FMPS to serve all-electric kitchens. An example of a specialty business use case for FMPS in new construction is to power energy-intensive horticultural lighting systems for greenhouses and indoor farms.

Electrification retrofits also present a compelling value proposition for FMPS. For example, existing buildings like large offices or hotels can use FMPS to serve new EV charging stations in parking garages or expand power distribution to a new heat pump HVAC system, heat pump hot water heater, or electric foodservice equipment installed to comply with decarbonization policies.

FMPS Benefits

FMPS applications in commercial, industrial, and agricultural buildings can provide diverse non-energy benefits that may drive FMPS adoption faster than energy savings alone. A summary of FMPS non-energy benefits is provided in Table 8.

Table 8. Non-Energy Benefits of Fault Managed Power Systems

Non-Energy Benefit	Details
Monitoring and Control	FMPS wiring supports both power and communication on a single cable, allowing for the operation and power consumption of endpoint load devices to be easily monitored through a centralized energy management system. Simplifies installation and integration of advanced control systems and supports implementation of energy-saving control strategies.
Convenience	Since endpoint use devices can be easily monitored and controlled remotely, troubleshooting and power cycling of malfunctioning devices and systems can be easily done remotely.
Safety	Fault management technologies stop power transmission within milliseconds upon detection of a fault, reducing the risk of fire or electric shock when compared to traditional AC power distribution.
Equipment footprint	FMPS wiring does not require conduits and eliminates the need for floor level voltage transformers in large building power distribution systems. Eliminating this equipment and infrastructure reduces the space required for power distribution equipment in electrical and utility rooms, and allows for more power-intensive electrification projects to be undertaken at existing facilities where space is at a premium.
Installation Cost and Speed	FMPS wiring can be installed by low voltage technicians, using open tray methods similar to ethernet and other low voltage wiring, rather than the conduit required by traditional AC wiring. This reduces material and labor costs associated with an FMPS installation. Additionally, the decreased equipment footprint reduces the likelihood that electrification projects will require major renovation to expand electrical rooms and other utility spaces.
Flexible and Scalable	Due to the modular nature of both FMPS transmitter and receiver units, endpoint use devices can be easily moved, added, or reconfigured, without major changes to the overall power distribution system.

Table Data Source: ERI. 2024b.

FMPS Energy Savings

Since FMPS technology is still in its infancy, the availability of FMPS-compatible technology available is limited. There is also relatively little existing literature and case studies documenting energy efficiency, and most existing case studies focus on the installation cost benefits of FMPS wiring rather than on the energy benefits.

FMPS power distribution technology has the potential to reduce energy consumption through three mechanisms. Figure 10 shows a simplified comparison of traditional AC distribution and FMPS distribution, with loss reduction benefits called out.

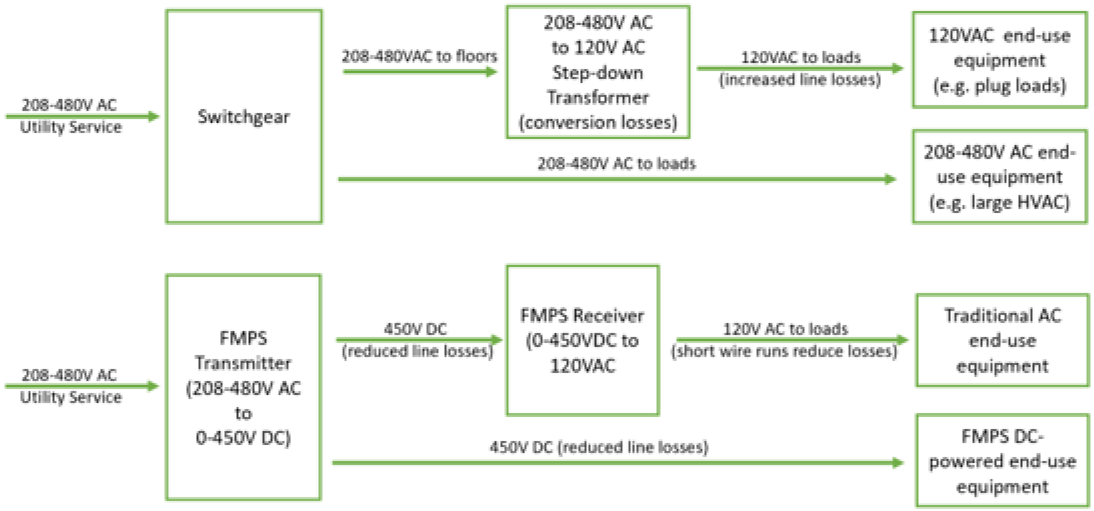

Figure 10: Traditional AC Power Distribution Compared to FMPS Power Distribution

Figure Data Source: ERI 2024c.

The mechanisms for energy efficiency are as follows:

1. The reduction of conversion losses from step-down transformers.
    a. As discussed in the Non-Residential Building Power Distribution section, most medium and large commercial buildings are typically equipped with internal transformers to step down their utility service voltage (typically 480 V, though some large customers may receive up to 13.8 kV) down to voltages that are usable by electric end-use equipment (generally 120 V for plug loads, and 240 V for larger equipment). In large buildings, typically electricity is distributed through the building by a central bus at 480/277 V, and then stepped down by transformers at the floor level at 120 V for distribution to electrical receptacles (wall outlets) and end-use devices. FMPS allows for these step-down transformers to be removed and eliminates their associated efficiency losses.
2. The reduction of line losses within buildings.
    a. FMPS and conventional electricity exhibit distinct characteristics regarding distance and delivered power. In conventional electricity distribution, power transmission over long distances can result in significant energy losses, or line losses, as a function of both resistance (R) in the wires, and the square of current transmitted (I^2). As a result, the further the distance from the power source, and the higher the current, the lower the delivered power at the end of the line. FMPS technology mitigates these losses by transmitting at higher voltages than typical DC systems, up to 450 V, which is enabled through packetized transmission and real-time monitoring, and fault management. As a result, some facilities (larger buildings with longer power distribution cabling) may expect to see a significant reduction in line losses, though this will be highly dependent on each facility's baseline service voltage and transformer/distribution configuration.

3. The elimination of conversion losses from DC-driven end-use devices.
    a. Many electronic end-use devices already are driven by DC power and typically include an internal or external power supply that converts AC power from the wall to DC power for the devices. Often, especially in lower-cost devices, these power supplies will use simple, low-efficiency designs and lower quality components. Leveraging FMPS to provide DC power directly to end-use devices eliminates inefficient AC-DC power conversions.

Several building systems described in Table 5 in the FMPS Applications section of this report can save energy when powered by FMPS via one or more of the mechanisms for energy efficiency.

- **Heating, Ventilation, and Air Conditioning (HVAC) Systems**
  HVAC systems equipped with DC-powered Electrically Commutated Motors (ECMs) are an example of a DC-driven device which has potential for reduced conversion losses when powered by FMPS. HVAC equipment located in large buildings can benefit from reduced line losses.

- **Light Emitting Diode (LED) Lighting**
  Individual LED diodes operate on DC power and have the potential for reduced conversion losses when powered by FMPS. In most LED lamps and fixtures, an internal or external LED driver converts 120 VAC from the wall to a DC voltage usable by the LEDs. In lower-cost devices, these drivers will often use simpler, less efficient designs to keep unit costs down, resulting in excessive efficiency losses. Lighting equipment located in large buildings can benefit from reduced line losses.

- **Specialty Business Use: Office**
  Office equipment like laptops and desktop PCs, tablets, phones, and networking equipment all operate using DC power and have the potential for reduced conversion losses when powered by FMPS. These devices typically include an internal or external power supply that converts AC power from the wall to DC power for use in the devices. Office equipment located in large buildings can benefit from reduced line losses.

- **Specialty Business Use: Data Centers**
  Data centers contain high densities of electrically-powered equipment, all of which use DC power to function. Most data centers are equipped with an *Uninterruptible Power Supply (UPS)* to provide backup power to critical equipment. Because UPS batteries require DC power, a UPS battery charging circuit must convert AC input to DC. The UPS must then convert DC power back to AC to be distributed through the data center[2]. Finally, the AC electricity distributed through the data center is converted once again back to DC by the internal power supplies of the end-use equipment. Leveraging FMPS to charge backup batteries and directly power equipment in data centers would eliminate two separate AC/DC

[2] Many UPSs have a bypass mode that avoids this AC-DC-AC double conversion during normal operation. However, most data center operators do not use bypass modes, due to concerns regarding increased switching time between the bypass mode and battery operation in the event of a utility outage.

conversions, and their associated efficiency losses. Equipment located in large data centers can benefit from reduced line losses.

Other potential end-uses for FMPS, such as hot water heating, commercial kitchen equipment, and EV chargers are less likely to result in substantial energy savings when compared to non-FMPS equivalents. While there may be limited energy benefits for these end-uses, leveraging FMPS equipment for them does provide non-energy benefits that allow for more widespread electrification and decarbonization.

- **Hot Water Heating Systems**
  Hot water heating equipment is currently dominated by natural gas consuming equipment. Electric hot water heating is typically AC-powered, so there is no opportunity for FMPS to save energy by eliminating conversion losses. However, the reduced footprint of FMPS wiring and equipment can allow for higher-capacity hot water heaters to be more easily installed in locations where it would be impractical or prohibitively expensive to install the conduit and higher gauge wiring required by traditional AC distribution.

- **Foodservice Equipment**
  Commercial kitchen equipment is currently overwhelmingly natural-gas fired, and electrification projects therefore increase electrical use, rather than savings, when compared to the existing baseline. Additionally, electric commercial kitchen equipment is typically AC-powered, so there is no opportunity for FMPS to save energy by eliminating conversion losses when considering traditional AC distribution as a baseline. However, the reduced footprint of FMPS wiring and equipment can allow for electric kitchen equipment to be more easily installed in locations where it would be impractical or prohibitively expensive to install the conduit and higher gauge wiring required by traditional AC distribution.

- **EV Charging Stations**
  EV chargers consist of both AC and DC powered devices: EV batteries require an output DC voltage; Most EVs can accept AC power and convert this internally to DC, though chargers that output DC directly to EVs do exist. However, the AC-to-DC conversion performed by existing fast chargers or EV internal charging circuitry has similar efficiency to the AC-to-DC conversion performed by FMPS, and as a result conversion losses are not significantly reduced (Yasa 2023). However, the reduced footprint of FMPS wiring and equipment can allow for EV chargers to be more easily installed in locations where it would be impractical or prohibitively expensive to install the conduit and higher gauge wiring required by traditional AC distribution.

- **Specialty Business Use: Commercial Laundry Equipment**
  Commercial laundry facilities use large quantities of hot water and steam and are frequently located in older buildings where space is at a premium. Installing high-capacity electric water heaters using traditional AC distribution and the associated high gauge wiring and conduit would frequently be prohibitively expensive and require extensive renovations to make space for electrical infrastructure. Leveraging FMPS for power distribution to electrify water heating systems would allow for the electrification of facilities where it would not otherwise be feasible.

Energy savings potential for FMPS in California's non-residential buildings can be estimated using theoretical energy savings calculations. Energy savings potential for facility-level and market-level energy savings are summarized in Table 9 and Table 10.

Energy savings calculations use aggregated energy use breakdown data from the California Commercial End-Use Survey (CEUS) and apply estimated efficiency gains to aggregate floor stock areas and end-use energy intensities in kilowatt-hours per square feet (kWh/sq ft). FMPS savings potential was calculated for three energy end-uses (lighting, HVAC, and IT equipment) across four market sectors (Small Offices, Large Offices, Colleges, and Hotels). Average building size for these sectors were applied: 15,000 square feet for Small Office, 250,000 square feet for Large Office, 1,000,000 square feet for College Campus, and 100,000 square feet for Hotel.

These market sectors were selected as they are likely to face barriers to large-scale electrification, such as available space for electrical distribution infrastructure, that FMPS is specifically intended to address. Energy savings calculations were designed to be easily expandable to include other end-uses and market sectors, and these may be added as the study continues and additional current or future applications for FMPS are identified.

Table 9. Facility-Level FMPS Savings Potential

	Facility-Level FMPS Savings Potential			
FMPS Application	**Small Office Savings (kWh)**	**Large Office Savings (kWh)**	**College Campus Savings (kWh)**	**Hotel Savings (kWh)**
Lighting	1,061	15,309	17,686	13,397
IT Equipment	1,506	33,485	36,144	N/A
HVAC	1,990	N/A	56,409	49,719
Total Building-Level FMPS Energy Savings Potential	**4,557**	**48,794**	**110,240**	**63,116**

Table Data Source: ERI 2024c.

Table 9 illustrates the energy savings that could be expected for a typical facility of each considered market sector. These savings figures illustrate that while FMPS end-uses do provide energy efficiency benefits, these benefits are relatively small compared to the size and total energy use of the facilities. For example, the above detailed total energy savings are approximately 1 percent to 5 percent of total energy use for their respective facilities. Facilities are therefore likely to consider FMPS for non-energy and business benefits, rather than solely for accessing energy-saving benefits.

Table 10 illustrates that while the facility-level savings would likely be relatively low, large statewide aggregate savings could be expected with widespread adoption.

Table 10. Market-Level FMPS Savings Potential

	Market-Level FMPS Savings Potential			
FMPS Application	**Small Office Savings (GWh)**	**Large Office Savings (GWh)**	**College Campus Savings (GWh)**	**Hotel Savings (GWh)**
Lighting	27.2	81.0	27.2	25.2
IT Equipment	60.7	177	13.9	N/A
HVAC	81.8	N/A	21.7	47.0
Total Market-Level FMPS Energy Savings Potential	**169.7**	**258**	**62.8**	**72.2**

Table Data Source: ERI 2024c.

Market Assessment Objectives

This section describes the diverse approaches taken for stakeholder outreach and engagement for this market assessment. The technology assessment portion of this project examines new measures that may remove market barriers and improve market penetration. To characterize the state of the non-residential buildings market in California, surveys, interviews, and site visits were conducted as part of this study to gain insight from various stakeholders across the commercial, industrial, and agricultural industries. A data analysis was performed to determine the energy savings over the incumbent technology.

Customer Surveys

The objective of conducting customer surveys was to collect information about their building system characteristics, installed power distribution systems, and capacity of electrical service to their building. The survey also aimed to collect data regarding type of facility (commercial, industrial, and agricultural), size of facility, and timeline for electrification projects.

Stakeholder Interviews

The objective of conducting stakeholder interviews was to corroborate information gathered from customer surveys and site visits by gathering insights from industry subject matter experts working closely on decarbonization policies in California. Interviews also aimed to collect additional data on the level of FMPS adoption in California, FMPS applications, and recommended measure approach.

Customer Site Visits

The objective of conducting site visits at facilities across California was to corroborate information gathered from customer surveys and interviews by gathering insights from the field and documenting electrical power distribution and building system characteristics. Site visits also aimed to identify energy efficiency opportunities, collect information about the level of adoption of FMPS, and identify specific barriers for non-residential buildings to implement energy efficiency projects. The scope of the site visits for the market study was observation only; FMPS technology was not installed at any site.

Market Assessment Methodology & Approach

This section summarizes the outcomes of stakeholder outreach and engagement activities.

Table 11 summarizes the results of the assessment mechanisms. Target response rates for surveys, interviews, and site visits were exceeded or achieved. ERI surveyed eight building owners/facility managers, interviewed three buildings industry stakeholders, and visited four commercial buildings between April and August 2024.

Table 11. Stakeholder Engagement Summary

Stakeholder Engagement Instrument Outreach Mechanism	Target	Individuals Contacted	Respondents	Target Achieved	Response Rate
Surveys	800 – 1,000	813	8	Achieved	1%
Interviews	6 – 10	12	5	Not met	42%
Site Visits	4	813	4	Achieved	0.5%

Table Data Source: ERI 2024e.

Market Assessment Results

The sections below provide detailed insights from the market assessment's feedback mechanisms: surveys, interviews, and site visits.

Each of the four site visit participants provided energy data for analysis. Insights from this analysis are provided in the Energy Analysis section of this report.

Survey Results

Figures 11 through 16 in this section illustrate collected data for survey respondents (ERI 2024f).

Input from the owners and property managers of eight non-residential buildings shared between April and August 2024 is analyzed below. See Appendix B of this report for the questionnaire provided to survey respondents.

Survey respondents represented non-residential facilities in diverse climates throughout California, including example, example and example. Survey respondents represent 3 out of the 16 California climate zones (CZ), with the following CZ represented: CZ03, CZ04, CZ07. The oldest surveyed facility was built in 1906, though most respondents' facilities are much newer; the median facility age is 37 years, and the newest facility is eight years old.

Survey responses cover a wide range of facility sizes, ranging from 10,000 sq ft to 250,000 sq ft. The average facility size is 69,169 sq ft, while the median facility size is 42,973 sq ft.

Figure 11 describes the buildings operated by survey respondents. 'Services' describes commercial businesses like auto repair shops while 'Public Services' describes municipal buildings like libraries. Office and Public Service buildings are operated by 25 percent of respondents, respectively.

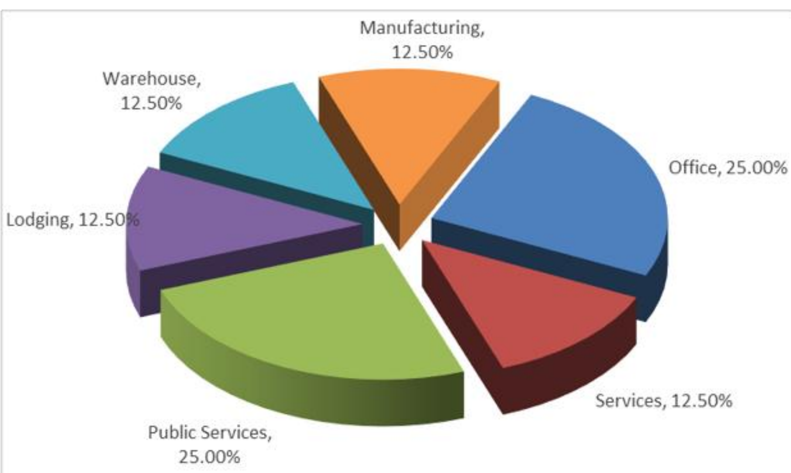

Figure 11: Survey Respondents by Building Type

Figure Data Source: ERI 2024f.

Figure 12 illustrates the breakdown of heating fuels used by surveyed facilities. Natural gas is the sole heating fuel for 50 percent of surveyed facility managers. A combination of natural gas and electric heating systems is used by 25 percent of survey respondents while 12.5 percent use only electric systems and the remaining 12.5 percent had no heating systems. Electrification retrofits for HVAC systems are being planned in the next 12 months by 25 percent of survey respondents.

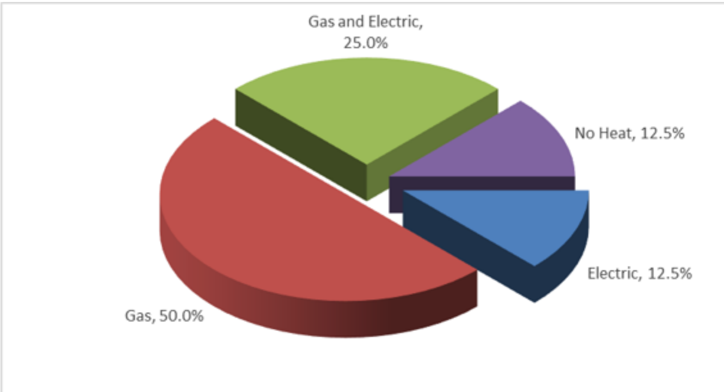

Figure 12: Survey Respondents by Heating Fuel Source

Figure Data Source: Ibid.

Figure 13 illustrates that 25 percent of surveyed facilities were equipped with a commercial kitchen. Of the facilities equipped with a commercial kitchen, half used only natural gas appliances, and half used a combination of gas and electric appliances.

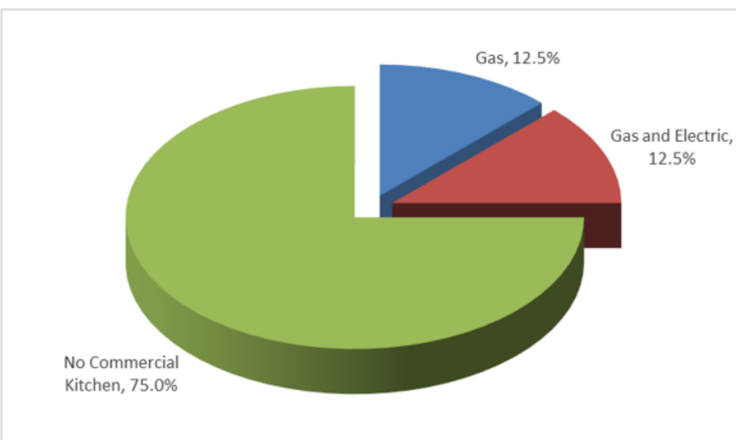

Figure 13: Survey Respondents by Commercial Kitchen Fuel Source

Figure Data Source: Ibid.

Figure 14 shows that most surveyed facilities have no existing EV charging infrastructure. Level 2 (240 VAC) EV chargers are used by 37.5 percent of surveyed facilities while the remaining facilities had no existing EV charging infrastructure.

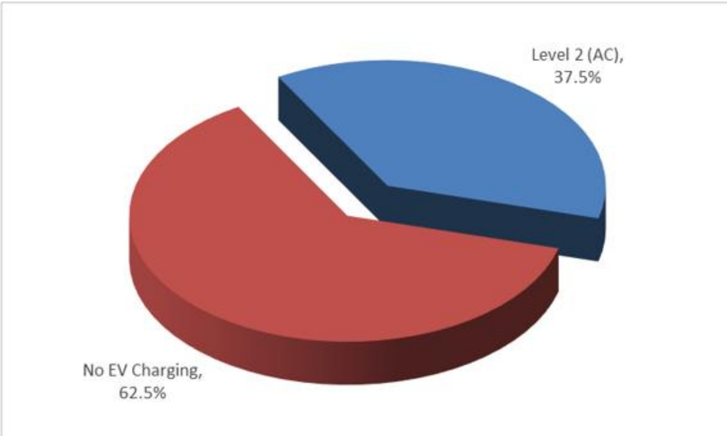

Figure 14: Survey Respondents by EV Charging Infrastructure

Figure Data Source: Ibid.

All survey respondents use AC power distribution and do not use FMPS in their buildings. Most survey respondents operate buildings served by low-voltage (120 VAC switchboards) power distribution equipment while 37.5 percent of respondents use high-voltage (480 VAC) switchgears and 12.5 percent of respondents use medium-voltage (240 VAC) switchgears in their buildings. The average size of electrical service to survey respondents' buildings is 1,000 Amps (A).

Half of survey respondents measure energy consumption at the facility level while the other half do not monitor building energy use.

Survey respondents felt that 23 percent of California building owners and facility managers are planning electrification projects in the next 12 months. Half of the survey respondents indicated that they plan to electrify at least one natural gas system.

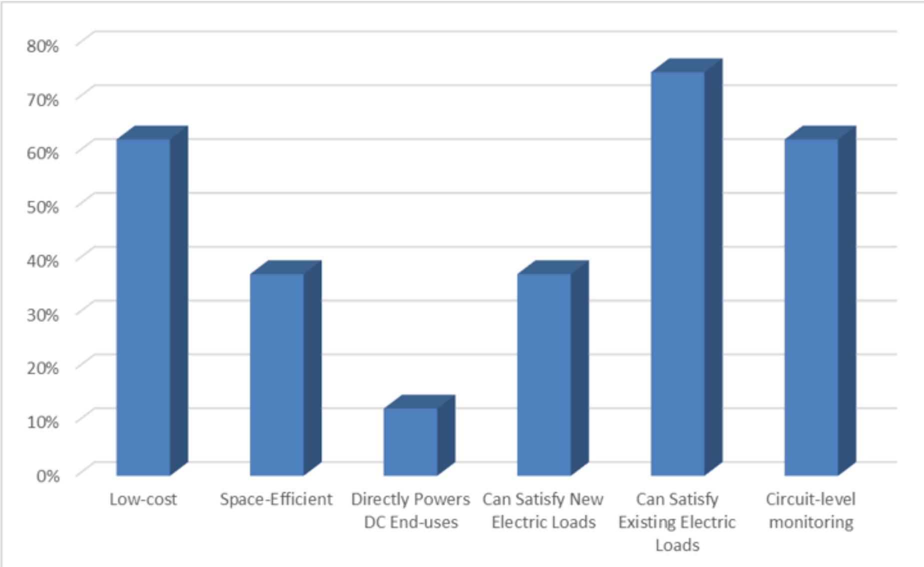

Figure 15: Survey Respondent Power Distribution Priorities

Figure Data Source: Ibid.

Figure 15 demonstrates that the most important feature for selecting new power distribution equipment for most survey respondents is the capability for the infrastructure to satisfy existing electric loads; less respondents need power distribution equipment to satisfy new electric loads. Low cost and circuit-level monitoring are secondary priorities but are much more important than space efficiency or delivery of DC power to DC-driven devices. Also, all of the survey respondents indicated that their electric service level was sufficient to meet their current and anticipated electrification needs. Lastly, upgrading power distribution equipment is also not a priority for most survey respondents; 87.5 percent said that they are satisfied with their facility's power distribution systems.

All three of these findings are indicators that the space-saving benefits of FMPS technology may not be a major consideration for many California non-residential facility owners and property managers. If a facility's existing electrical capacity is sufficient to support proposed electrification projects, then less alteration to the facility's electrical infrastructure will be required, and the space savings of FMPS wiring are less likely to be seen as a major benefit by decision-makers. Also, if a facility needs to upgrade power distribution equipment and is selecting equipment by lowest cost, building owners and managers are unlikely to select FMPS.

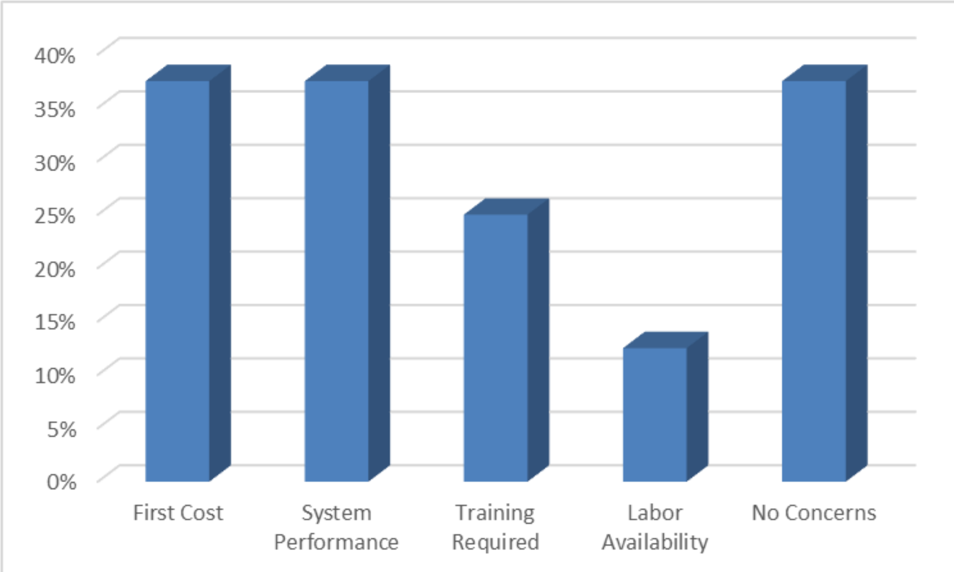

Figure 16: Survey Respondent Energy Efficiency Barriers

Figure Data Source: Ibid.

Figure 16 demonstrates that there are many survey respondents who have no concerns with implementing energy efficiency projects. For those who do have concerns, survey respondents were most concerned with the first cost of energy efficiency projects and system performance.

Payback periods of two to five years are preferred by 66 percent of survey respondents who answered the question.

Interview Findings

Conversations with industry subject matter experts complemented findings from property manager surveys. Findings from interviews align with survey results in some ways but offer additional perspectives from different types of industry stakeholders.

Equipment vendors and industry organizations were interviewed to understand emerging technologies and new products. Some growers were interviewed to gather opinions on the level of adoption of smart CEA environmental controls, qualitative feedback on system performance of smart environmental controls systems, and experience with efficiency program participation.

This section anonymizes interviewee affiliation by using industry segments and a unique letter to identify each subject matter expert as described in Table 12. Input from five interviewees is representative of the key stakeholders transforming the California buildings market.

Table 12. Interview Summary

Stakeholder Type	Location	Number of Stakeholders	Stakeholder IDs
Building Owners / Managers	California	1	California Portfolio Manager A
City Sustainability Officers	California	1	City Sustainability Director A
Equipment Manufacturers	Global with projects in California	1	Manufacturer A
Facility Designers	California	1	Designer A
Energy Policy Expert	California	1	California Energy Policy Expert A

Source: ERI 2024g.

Electrical Power Distribution Commentary

California Portfolio Manager A has been working with an energy consultant to assess more than 60 of their 400-facility portfolio for efficiency and electrification retrofit opportunities. "100 percent of our facility managers are planning electrification projects." Eight buildings were identified as candidates for "high-efficiency transformers."

Designer A has been involved with one or two projects that discussed using DC power distribution. However, Designer A has "never had anyone give me a compelling explanation why DC is more efficient than AC other than many of the end applications these days are DC."

Manufacturer A shared that the energy savings from FMPS systems are extremely case-dependent. For instance, energy savings from line losses may be significant at very large industrial buildings or multi-level parking garages. However, in other cases, FMPS installations may not save energy, or in others may save very little electricity. They have found that non-energy benefits are more important for non-residential customers.

Decarbonization Policy Commentary

City Sustainability Director A shared that their city follows California state energy code and has a benchmarking ordinance for buildings of 50,000 square feet and above. Privately-owned buildings in the city are not required to go all-electric. The city has a draft building performance standard that is not yet required. The Ninth Circuit Court decision in the case *California Restaurant Association v. City of Berkeley* affected their plans for a stretch code.

California Energy Policy Expert A provides electrification education, decarbonization marketing campaigns, and advises states and their utility providers on changes to energy codes. In California, their organization focuses on natural gas transition planning and the impact of the Ninth Circuit Court decision affecting decarbonization policies in California that seek to accelerate retrofits and construction of all-electric buildings.

Electrification Projects Commentary

California Portfolio Manager A has a 2035 goal for Net Zero GHG Emissions and has six strategies for achieving it; one of them is Energy and Decarbonization in the Built Environment. Their primary issue is the first cost of construction projects and training (especially for electrification projects) is their second issue. Labor is their third priority; their facilities team has a significant deferred maintenance backlog.

California Energy Policy Expert A facilitates a Power Working Group focused on right-sizing electrical panels, NEC and NFPA standards for flexible load technology like smart electrical panels and load-switching devices, and load-sharing devices and shared that "service-side upgrades are a part of the electrification discussion."

Site Visit Results

Site visits and discussions with facility managers at non-residential facilities in California complemented findings from customer surveys and industry stakeholder interviews. Equipment and systems serving four facilities were observed in the field in one California CZ (CZ07). The average facility size was 37,875 sq ft and the median size was 33,900 sq ft.

Table 13 describes the four commercial buildings visited in July 2024 and the characteristics of each building and its power distribution infrastructure. Refer to Appendix C of this report for detailed site visit reports for each facility.

Table 13. Site Visit Summary

Facility ID	Climate Zone	Building Type	Facility Square Feet (sq ft)	Utility Electrical Service (Amps)	Utility Service Voltage (VAC)	Transformer Quantity	Candidates for Retrofits
Class A Office	CZ07	Large Office	73,700	800	277/480V	11	- EV Charger Expansion - Electrify WSHP Boiler - Electrify Water Heating
Public Library	CZ07	Assembly	10,000	600	208/120V	0	- Electrify Heating - Electrify Water Heating
Rec Center	CZ07	Assembly	15,000	Unknown	120/240V	Unknown	- Electrify Heating - Electrify Water Heating - Electrify Kitchen
Ops Yard	CZ07	Small Office	52,800	800	480V, 120/240V	2	- Electrify Water Heating - EV Chargers

Source: ERI 2024h.

Site Visit Findings

Based on the findings of the site visits, the level of electrical service and distribution infrastructure varied significantly between facilities of different sizes. The service voltage of the two larger facilities was 480V with onsite transformers to step down voltage to 208/120V. The Class A Office facility was equipped with (11) transformers, with multiple transformers on each floor stepping down voltages to 208/120V between electric panels. Transformers occupied a significant portion of the electrical rooms on each floor. The Ops Yard facility was equipped with (2) transformers with step-down voltages of 208/120V. The Class A office was equipped with a mix of 480V and 208V HVAC equipment, while the Ops Yard was not observed to be equipped with 480V equipment. The two smaller facilities had 208/120V electrical service with no observed onsite transformers.

While organization-level staff indicated intent to electrify all four sites, facility-level staff were not aware of any near-term electrification plans, indicating that electrification may be a longer-term, conceptual goal. Additionally, major loads were already largely electrified at the two largest visited facilities, with both the Class A office and Ops yard using heat pump systems for both heating and cooling. The two smaller facilities do primarily use natural gas for heating, and the Class A office's water-source heat pump system did include natural gas fired boiler; electrifying these loads would offer potential to leverage FMPS for cost and space savings compared to traditional electrical infrastructure.

Only one of the four sites were equipped with EV chargers, which were observed to be primarily used for municipal fleet vehicle charging. Site and organization-level staff both indicated an interest in expanding EV charging capacity to support further fleet electrification. Expansion of EV charging capacity would provide an opportunity to leverage FMPS for cost and space savings, with regards to installing DC fast chargers.

Energy Analysis

Each of the four site visit participants voluntarily provided energy data for analysis.

Table 14 summarizes the facility details for the commercial building and provides the annual electricity usage in kWh as well as the calculated electric *EUI* for the timeframe of January through December 2023.

Table 14. Energy Analysis Summary

Energy Analysis ID	California Climate Zone	Building Type	Facility Size (ft^2)	Annual kWh	Electrical Service Rating (Amps)	Electric EUI, 2023 ($kWh/ft^2/year$)
Class A Office	CZ07	Large Office	73,700	994,085	800	13.49
Public Library	CZ07	Assembly	10,000	78,724	600	7.87
Rec Center	CZ07	Assembly	15,000	104,119	Unknown	6.94
Ops Yard	CZ07	Small Office	52,800	959,633	800	18.17

Table Data Source: ERI 2024i.

The calculated EUI for the visited facilities shows a sharp divide between the larger office facilities and the smaller public-facing facilities. The Public Library and Rec Center have EUIs of 7.87 and 6.94 kWh/ft^2, respectively, while the Class A Office and Ops Yard have EUIs of 13.49 and 18.17 kWh/ft^2. This is likely primarily attributable to the difference in density of human occupancy and IT loads between the sites. The Rec Center is not mechanically cooled, and the main onsite electrical usage consists of lower intensity loads such as LED lighting and fans, which results in a low overall EUI. The library is mechanically cooled; however it supports a relatively low density of human occupancy and IT systems, which results in low cooling load, and subsequently low EUI. The Class A Office and Ops Yard, by comparison, have higher density of IT equipment including dedicated server rooms, as well as higher human occupancy, both of which require more intensive use of mechanical cooling. The combination of cooling load and direct energy usage by IT equipment results in an elevated EUI for both facilities.

The following sections describe each facility's energy analysis including monthly load profiles and peak demand where available.

Class A Office

The Class A Office property is a 73,700 square foot, three-story office building located in San Diego, CA (CZ07). The facility uses a water-source heat pump system for HVAC and there is a medium-sized data center on the first floor of the building. As a result of using electricity for both cooling and heating, as well as a high baseload from the data center, the facility has relatively flat electrical usage and demand throughout the year, as illustrated by Figure 17. The Class A Office has an average monthly electricity consumption of 82,840 kWh, and an average peak demand of 201.66 kW.

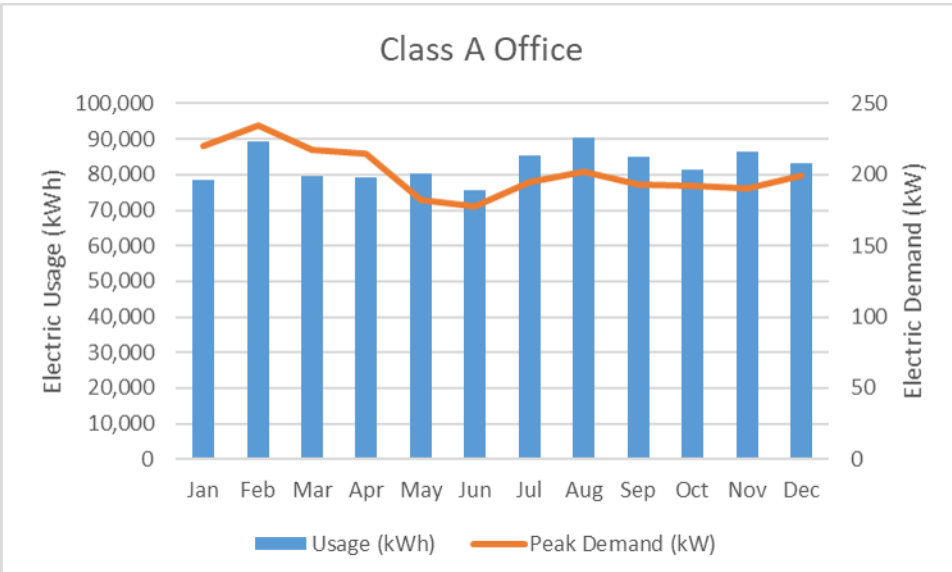

Figure 17: Class A Office Annual Usage and Peak Demand, 2023

Figure Data Source: ERI 2024i.

Public Library

The Public Library is property is a 10,000 square foot building located in San Diego, CA (CZ07). The library has a low density and intensity of IT equipment and is conditioned by packaged air conditioners with natural gas furnaces. The facility has increased electrical usage and demand during July through October when the weather is warmer and air conditioners are in cooling mode, with reduced usage in winter and spring, when there is primarily heating and ventilation demand with less need for cooling. This usage trend is illustrated in Figure 18. The library has an average monthly electricity consumption of 6,560 kWh, and an average peak demand of 37.44 kW.

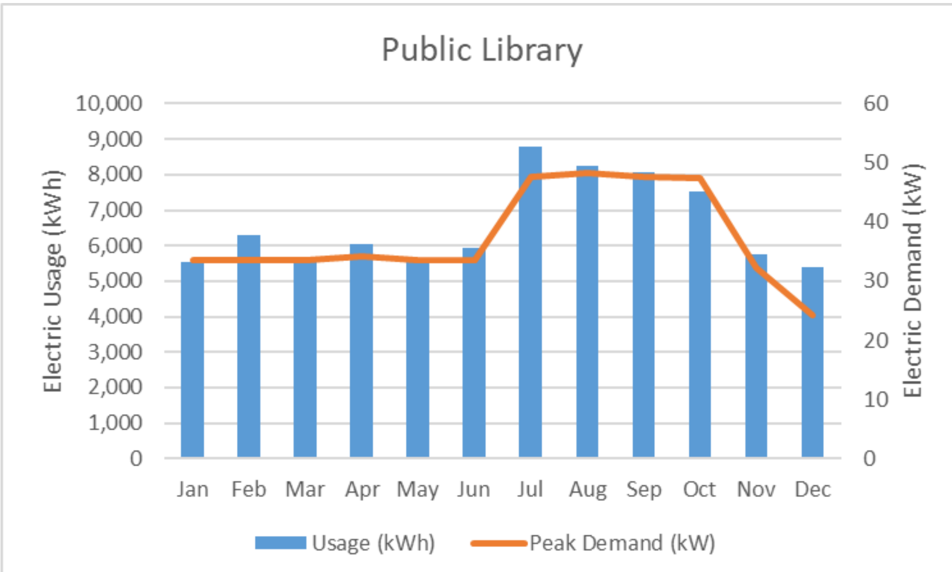

Figure 18: Public Library Annual Usage and Peak Demand, 2023

Figure Data Source: ERI 2024i.

Rec Center

The Rec Center property is a 15,000 square foot facility consisting of (2) single-story buildings, located in San Diego, CA (CZ07). The facility has a gymnasium and a theater/multipurpose space, which both are equipped with natural gas heating equipment, limited IT equipment, and no cooling equipment except for (1) portable air conditioner serving an office. As a result, the facility has overall low electricity usage, with increased usage in the winter compared to the summer, as illustrated by Figure 19. This usage pattern is likely due to the operation of heating fans and extended lighting hours during the winter months. The Rec Center has an average monthly electricity consumption of 8,677 kWh, and an average peak demand of 72.15 kW.

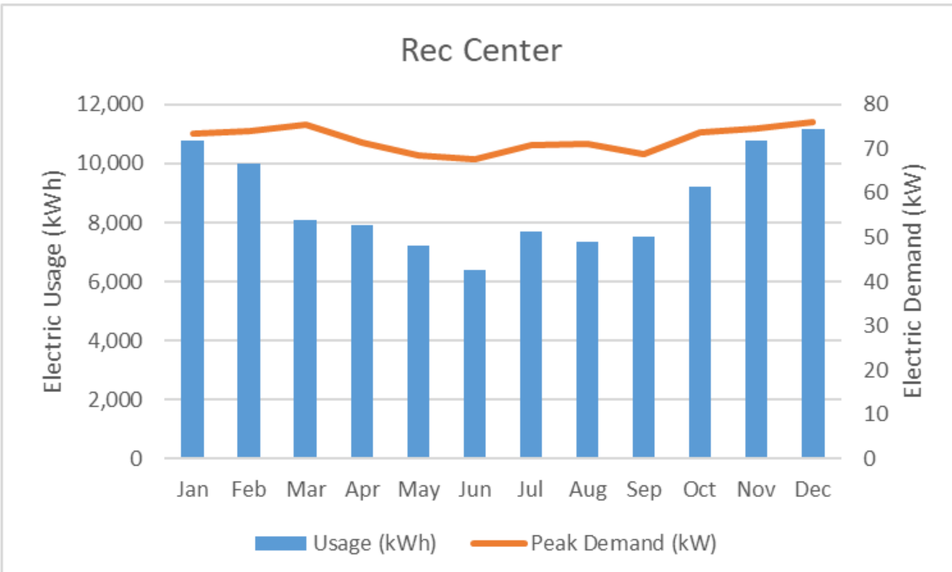

Figure 19: Rec Center Annual Usage and Peak Demand, 2023

Figure Data Source: ERI 2024i.

Ops Yard

The Ops Yard property is a 52,800 square foot facility consisting of a two-story office building and a one-story warehouse, located in San Diego, CA (CZ07). The facility is heated and cooled primarily by split-system heat pumps, with a single packaged air conditioner located on the roof. As a result of using electricity for both heating and cooling, the facility has fairly consistent usage and demand throughout the year, with a slight increase in the summer months, as illustrated by Figure 20. The Ops Yard has an average monthly electricity consumption of 79,969 kWh, and an average peak demand of 452.88 kW.

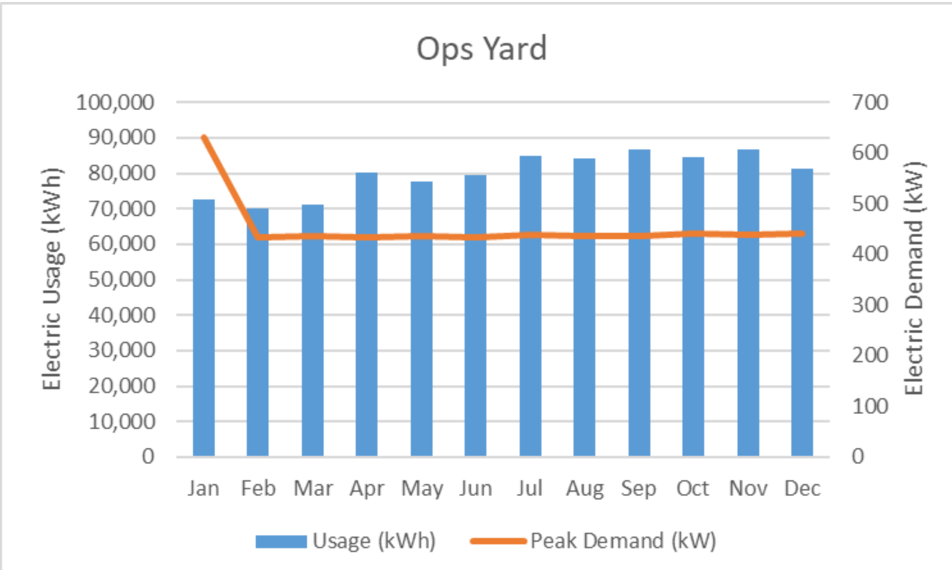

Figure 20: Ops Yard Annual Usage and Peak Demand, 2023

Figure Data Source: ERI 2024i.

Field Demonstration Overview

The sections below provide detailed insights from the field demonstration conducted in one California indoor farm from May 2025 to September 2025. Refer to Appendix D of this report for the detailed scope of the field demonstration and a summary of identified barriers to energy efficiency.

The objectives of the field demonstration were to:

1. Test FMPS and energy monitoring systems in a representative environment in a California commercial, industrial, or agricultural facility.
2. Monitor energy at the circuit level to inform energy savings potential of smart controls measures.
3. Validate energy savings potential of FMPS power distribution equipment.
4. Analyze barriers to adoption, energy savings, and non-energy benefits.

Field Demonstration Methodology

At the field demonstration site, emerging technology controlled two zones at the facility. Both zones implemented FMPS equipment to provide power to horticultural lighting systems. Both zones had energy monitoring.

The team used energy monitoring data from the FMPS power reporting platform to validate energy savings estimates. The research team observed four weeks of a flowering cannabis growth cycle to quantify the impact of FMPS on energy- and non-energy benefits.

The research team and the field demonstration participant had access to data through an online dashboard maintained by the project's technology partner, VoltServer. The VoltServer software provided a graphic user interface that can export real-time power data and environmental data for each flowering room for the field demonstration observation period.

Field Demonstration Results

The field demonstration conducted at an indoor cannabis farm (Indoor Farm A) validated electricity savings for a horticultural process lighting application.

Table 15 describes the field demonstration's climate zone, crop type, size, and target process system for FMPS energy savings.

Table 15. Field Demonstration Summary.

Field Demonstration ID	California Climate Zone (CZ)	Crop Type	Target Process System for FMPS	FMPS Power Distribution Capacity (kW)
Indoor Farm A	CZ02	Cannabis	Horticultural lights	18

Source: ERI. 2025a.

The FMPS system at Indoor Farm A served intracanopy horticultural lights. Table 16 describes the scale of the field demonstration's installation and validated energy savings. Refer to Appendix D to review the scope, business benefits, lessons learned, and barriers to efficiency for the field demonstration in more detail.

Table 16. Site-FMPS Measure Savings Potential.

Application	Light Fixture Quantity	Average Electricity Savings (kWh)	Validated % Savings	Average Demand Reduction (kW)
Process Lighting	156	3,745	5%	0.44

Source: ERI. 2025b.

The following sections describe insights that can be used by California IOU EE programs to develop smart controls EE program offerings.

Energy Monitoring Insights

The field demonstration participant did not collect historical energy consumption data at the system level prior to participating in the study. The following insights relate to process lighting trends observed at the demonstration site.

PROCESS LIGHTING

Intracanopy horticultural lighting systems are systems that complement top lighting systems to increase yield at lower elevations of plants like cannabis and vine crops like cucumbers and tomatoes.

In the field demonstration at Indoor Farm A, the intracanopy lighting system operation was routinely scheduled to coincide with the 12-hour photoperiods of the top canopy lighting system. Room A and Room B had ‘flip flopped’ schedules resulting in consistent lighting demand for every hour of the day.

Market Assessment Recommendations

This section explores the impact of this market assessment results, recommendations for the field evaluation, and the proposed course of action for each controls technology. The inputs from the literature review, surveys, interviews, and site visits were used to create a measure description for FMPS infrastructure that reduces energy use from building systems in non-residential buildings.

Measure Description

This market assessment determined that FMPS has limited energy savings potential. Table 17. FMPS Measure Descriptions demonstrates that California IOUs can uncover small savings claims within electrically driven building systems powered by FMPS.

Table 17. FMPS Measure Descriptions

Measure System	Measure Name	Measure Description	Process Electricity Savings Potential
Power Distribution	FMPS	Class 4 electrical power distribution to DC-powered devices	1 – 5%

Table Data Source: ERI 2024j.

Impact of Market Assessment Findings

The impact of this market assessment's findings on the non-residential buildings market and key industry stakeholders including California IOUs include:

- Within California's over 12 billion square feet of commercial buildings, Large and Small Office buildings present the largest market for FMPS systems.
- Incentive programs for an FMPS measure identified in this market assessment would not be affected by requirements of the 2025 version of California's energy code. The evolving state energy code may drive market adoption of FMPS as it accelerates the electrification of building systems like space heating and water heating and mandates the installation of EV charging infrastructure.
- Some municipal decarbonization policies are encouraging the construction of all-electric buildings but are barred from prohibiting natural gas piping in new construction projects. Buildings in cities with decarbonization policies are more likely to be motivated to implement electrification projects that can be supported by FMPS power distribution.
- High-voltage systems have greater FMPS energy savings potential because the transformers they use for power conversion are a source of power losses. More than ten transformers may be used by a single building; this equipment also uses significant space in electrical rooms.

- The energy savings benefit of FMPS at the building level may be nominal (1 – 5 percent) but the non-energy benefits include capacity to serve electrification projects, access to real-time energy monitoring data, and capability to implement flexible demand management strategies.

Conclusions

These lessons learned from the market assessment and a field demonstration combine to create a technology roadmap, which offers a strategic direction for program development, identifying cost-effective measures, and presenting program offerings—including the need for new or updated measure packages. The findings also support utilities in designing EE measures for power distribution products, with a focus on innovative strategies for deemed or hybrid approaches.

This technology roadmap for FMPS identified and evaluated high-performance power distribution infrastructure's potential for energy savings and demand response, proposing paths to address market barriers and providing intervention strategies for market implementation.

The savings estimates described in this section were generated using a custom energy savings calculator that leverages savings validation from the field demonstration for lighting applications. The team used data from the field demonstration to confirm the energy savings model's baseline controls strategies and calibrate the energy savings estimated from FMPS (ERI 2025b).

We do not recommend a measure for FMPS in this technology roadmap for IOU EE program development.

Program Pathways

The field demonstration confirmed that FMPS has limited energy savings potential. Data from one indoor agriculture application in California does not support FMPS program design. The impact of the field demonstrations' findings on the commercial, industrial, and agricultural buildings market and key industry stakeholders including California IOUs include:

1. **FMPS power distribution does not provide cost-effective energy savings to support measure package development.** There are non-energy benefits from FMPS which can support new construction and electrification programs, but the electrical energy savings at the equipment level does not justify the significant investment. The team recommends continuing to research the development of the Class 4 Power industry in California as more products are introduced to the non-residential buildings market and costs of FMPS may decrease to improve cost-effectiveness.

   This measure would be applicable across other market sectors like offices, college campuses, and hotels. However, the savings potential for these applications is much lower than indoor agriculture because of the much higher lighting demand from horticultural process lighting. See Appendix E: FMPS Savings Calculations for a detailed summary of the savings potential estimated for other building types.

   Table 18 summarizes the savings potential of FMPS for the market sector validated by the field demonstration (indoor cannabis cultivation). For a 10,000 square foot facility, FMPS could save 74,850 kWh annually in a process lighting application.

Table 18. California FMPS measure savings potential.

Application	Baseline Lighting Energy Intensity (kWh/ft^2)	Market Size (ft^2)	Validated % Savings	Market Level Savings Potential (kWh)
Indoor Agricultural Process Lighting (Cannabis)	150	9,500,000	5%	71,107,500

Source: ERI. 2025b.

Appendix A: FMPS Case Studies

Circa Resort & Casino Las Vegas

The Circa Resort & Casino Las Vegas is a 35-floor, 1.2 million sq ft hotel building located in downtown Las Vegas, Nevada. The property features a fifth-floor aqua theater called Stadium Swim, which includes six pools and a 40 ft by 143 ft high-definition screen on the side of the building (see Figure A-1). However, the realization of this resort was not devoid of challenges, particularly for the power team entrusted with designing the resort's electrical infrastructure. Situated amidst the narrow confines of Las Vegas' historic downtown district and surrounded by towering structures, the property's design required meticulous planning to ensure unobstructed views for the screen, a task compounded by stringent COVID-19 health mandates that restricted on-site workforce capacity (Belden 2022).

Figure A-1: Stadium Swim at The Circa Resort & Casino

Figure Data Source: Komenda 2021.

To surmount these challenges, the deployment of FMPS technology emerged as a strategic imperative. Leveraging VoltServer's FMPS infrastructure, the project utilized the expertise of low-voltage technicians, akin to Power-Over-Ethernet (POE) cable installations. This approach allowed for the pre-drywall termination of connections, streamlining installation processes and yielding significant labor savings. Moreover, the phased deployment of the FMPS system afforded workers the flexibility to progress to a considerable extent before vacating the site, thus accommodating concurrent contractors amidst the COVID-19 pandemic backdrop. The successful integration of FMPS technology culminated in the project's completion two months early.

In addition to expediting construction timelines, the adoption of FMPS technology yielded substantial cost savings, a testament to its efficacy over conventional dedicated AC power solutions. DKNQ Inc., the project management firm overseeing the project, estimates cost reductions ranging between $2 million and $3 million from the power distribution approach, underscoring the economic viability of FMPS technology in large-scale commercial construction projects (Belden 2022).

Hard Rock Stadium

Located in Miami Gardens, FL, the Hard Rock Stadium is a 65,000-seat multi-purpose arena, renowned for its expansive structure and modern stadium design. Tasked with providing robust wireless connectivity, the Distributed Antenna System (DAS) encountered significant challenges due to the stadium's large size and intricate architectural layout. The DAS was required to ensure comprehensive coverage of 4G LTE, 5G mmWave, and Wi-Fi networks, further complicated by the integration of interactive augmented reality (AR) devices. Additionally, the power distribution system faced the formidable task of supplying substantial power loads across extensive distances to energize remote radio locations dispersed throughout the venue, a challenge exacerbated by the power drop limitations of traditional dedicated AC systems. Due to the use type of the stadium, project timelines were sensitive as well to not affect gamedays (VoltServer 2021).

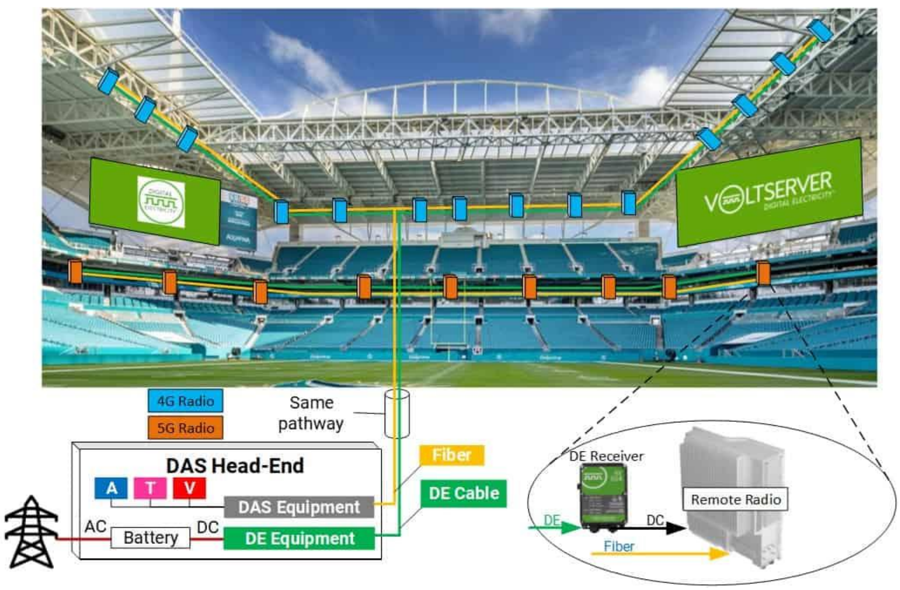

Figure A-2: DAS System Diagram in Hard Rock Stadium

Figure Data Source: VoltServer 2021.

To overcome these challenges, VoltServer FMPS infrastructure supports the Hard Rock Stadium (see Figure A-2). A crucial element of this deployment entailed the integration of over 700,000 ft of cables, customized for the stadium's unique requirements to ensure uninterrupted power distribution across extensive stretches of cable. Leveraging a centralized battery plant situated at the head-end, the DE platform facilitated long-distance and high-power transmission to the stadium's remote radio locations. Throughout the project, alterations and enhancements to the power system design necessitated adjustments to meet changing remote powering demands. However, the inherent flexibility in FMPS technology enabled seamless relocation and reuse without concerns of stranded outlets or unused conduits. This adaptability empowered the power team to effect real-time modifications up to the project's final stages, a departure from conventional stadium construction paradigms reliant on multiple power distribution rooms housing individual power plants, thereby optimizing space utilization (VoltServer 2021).

Beyond the inherent flexibility of the DE platform, the DAS system boasts the capability to deliver uninterrupted power supply to every radio, ensuring continuous connectivity even in the event of an outage from the AC mains. The adoption of FMPS technology yielded substantial cost savings across various fronts, including reductions in battery, labor, and material expenditures, while concurrently enhancing operational efficiencies (VoltServer 2021). Such advantages underscore the impact of FMPS technology in addressing critical power distribution challenges within large-scale venues like the Hard Rock Stadium, heralding a paradigm shift towards more resilient and cost-effective infrastructure solutions in the sector of stadium and venue construction.

Long Island Railroad

The Long Island Railroad Jamaica Station, located in Queens, New York, stands as a pivotal transit terminal boasting a weekday ridership exceeding 200,000 passengers and accommodating over 1,000 trains daily, rendering it the busiest transit hub on Long Island (see Figure A-3). Comprising of six island platforms serving trains, the station began an initiative to enhance its operational infrastructure by offering wireless connectivity for 4G, 5G, and public Wi-Fi within its confines. However, the inherent challenges associated with public transit terminals, including congested urban spaces, concrete infrastructure, and underground platforms, often combine to create wireless dead zones. Complicating these challenges is the station's high pedestrian foot traffic, which necessitates weatherproof, inaccessible, and inconspicuous equipment installations. These challenges are exacerbated by the absence of off-hours conducive to installation activities with limited pedestrian interference, and it demonstrates the necessity for an innovative approach to communication infrastructure deployment within the station (Dextradeur 2022).

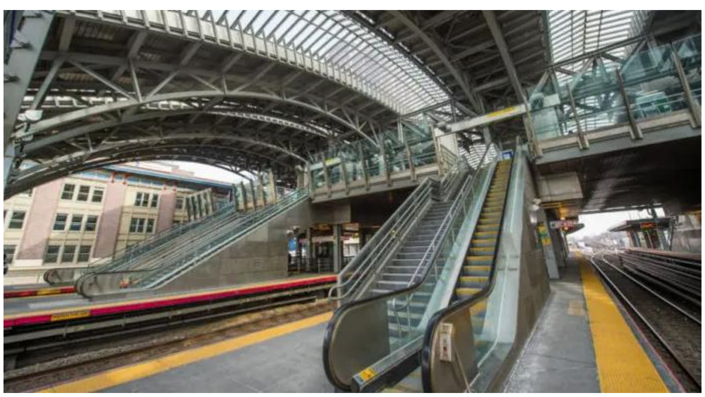

Figure A-3: Long Island Railroad Jamaica Station

Figure Data Source: Dextradeur 2022.

In response to these roadblocks, a strategy known as small cell densification emerged as the preferred solution, entailing the strategic placement of multiple small cell radios throughout the station to minimize coverage areas while obviating the need for signal transmission across barriers and walls. Leveraging Digital Electricity (DE) as the chosen power distribution system, the station circumvented the logistical challenges inherent in traditional AC mains power connections, which would prove prohibitively expensive and time-consuming when interfacing with a diverse array of high-powered radios. The DE platform, characterized by its capacity to consolidate a vast network of energized equipment in a streamlined and secure manner, emerged as an optimal solution. Furthermore, the centralized nature of the DE system facilitated seamless integration of universal battery backup systems, ensuring uninterrupted power supply to the equipment in the event of an outage. VoltServer's DE system now powers Jamaica Station with nearly 60 kW of load capacity distributed across PoE switches, 4G, and 5G radios, underscoring its pivotal role in bolstering the station's operational resilience and connectivity infrastructure (Dextradeur 2022).

Westfield Public Schools

Westfield Public Schools, located in Westfield, New Jersey, heavily leverages PoE devices for various systems, including security cameras, building access control, WiFi access points, lighting, and informational displays (see Figure A-4). Leveraging PoE for these systems allows them to be installed and reconfigured by district IT staff, rather than requiring an outside electrician as would be necessary if they were powered by AC. However, in the event of a power outage, the PoE switch powering these devices would lose power, causing a loss of critical security systems in the time between loss of power and a backup generator coming online.

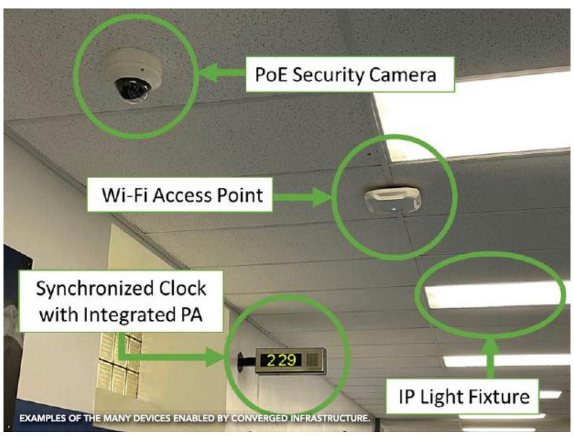

Figure A-4: Power-Over-Ethernet Devices

Figure Data Source: Connected Real Estate 2020.

This can be mitigated by installing an UPS to provide backup power to the PoE switch, however traditional methods would require a UPS to be installed in every IT closet serving PoE devices, approximately 40 in total throughout the district. Aside from the material cost of 40 standalone UPS systems, each UPS would take up valuable rack space in the IT closets and have associated maintenance costs that would exceed the initial project cost within five to seven years. Additionally, the heat load generated by the individual UPSs would either require costly modifications to add cooling systems to IT closets or require the district to accept reduced UPS lifespan. (Connected Real Estate, 2020). Leveraging Voltserver's DE platform allowed the district to provide backup power to all IT closets at a site from a single UPS in a centralized location. The central UPS was able to be placed in a climate-controlled space with sufficient cooling capacity, reducing the capital cost of installation while still maintaining proper UPS lifespan. As with the existing PoE systems, DE infrastructure can be maintained and reconfigured by district IT staff rather than outside electricians. Voltserver systems can additionally integrated with a building management system (BMS) in order to analyze power use and, and prioritize critical loads during an outage (Connected Real Estate, 2020)

Appendix B: Survey Questionnaire

Thank you for taking 5 – 7 minutes to answer a few questions regarding **electric power distribution systems for commercial and industrial buildings in California**. The results from this survey will be used by utilities to develop incentives and programs to improve the adoption of fault-managed power systems.

Please answer the following questions to best of your knowledge:

**Mandatory question*

Building Details

Please tell us about a non-residential building in California that you own/operate and how it is used.

1. *Which of these options best describes the primary building type of your California property?
    a. Agricultural (ex. greenhouse)
    b. Financial (ex. bank branch)
    c. Education (ex. university)
    d. Entertainment/Public Assembly (ex. convention center)
    e. Food Sales & Service (ex. restaurant)
    f. Healthcare (ex. hospital)
    g. Lodging (ex. hotel)
    h. Manufacturing (ex. industrial)
    i. Office
    j. Public Services (ex. library)
    k. Retail (ex. grocery store)
    l. Services (ex. auto repair shop)
    m. Technology/Science (ex. laboratory)
    n. Warehouse (ex. distribution center)
2. *Where is your facility located in California? Enter the nearest city.
    a. __________
3. When was your facility built? If recently retrofitted, use the year of the most recent major renovation or addition.
    a. __________
4. What is the gross square footage of your facility?
    a. __________

Facility Details

Please tell us about your California facility's lighting, HVAC, and irrigation equipment.

5. *Which of these options best describes your facility's primary type of **cooling** equipment? Select all that apply.
    a. Packaged Air Conditioners
    b. Heat Pump System
    c. Gas Chiller
    d. Electric Chiller
    e. Other (please specify)
    f. None of the above (no cooling)

6. *Which of these options best describes your facility's primary type of **space heating** equipment? Select all that apply.
    a. Electric Baseboard Heaters
    b. Heat Pump System
    c. Gas Boiler
    d. Gas Unit Heaters / Furnaces
    e. Gas Infrared Heaters
    f. Other (please specify)
    g. None of the above (no heating)
7. *Which of these options best describes your facility's primary type of **commercial foodservice** equipment? Select all that apply.
    a. Gas Broilers / Stoves / Ovens / Fryers / Steamers / Pizza Ovens
    b. Electric Broilers / Stoves / Ovens / Fryers / Steamers / Pizza Ovens
    c. Other (please describe)
    d. None of the above (no commercial kitchen or foodservice equipment)
8. *Which of these options best describes your facility's **electric vehicle charging** equipment? Select all that apply.
    a. Facility has AC EV charging stations (ex. Level 2)
    b. Facility has DC EV charging stations (ex. Level 3 or 'fast charging')
    c. None of the above (no EV charging)

Electrical System Details

Please tell us about the electrical power distribution systems in use at your California facility. (A power distribution system refers to the hardware delivering electricity to your building's electrically-driven equipment).

9. *Which of these options best describes the components of your facility's electrical power distribution system? Select all that apply.
    a. High-voltage (480V) switchgear(s)
    b. Medium-voltage (240V) switchgear(s)
    c. Low-voltage (120V) switchboard(s)
10. *Please share the capacity of your facility's electrical service (ex. 1,000 AMP):
    a. ________ AMP
    b. I don't know / not sure
11. * Which of these options best describes the capacity of your electric service?
    a. Excess capacity for our needs (we have more amps to power equipment than we need)
    b. Sufficient capacity for our needs (we have enough amps to power equipment)
    c. Insufficient capacity for our needs (we do not have enough amps to run our equipment)
12. *Which of these options best describes your approach to monitoring energy consumption of your building systems?
    a. Do not monitor energy consumption.
    b. Monitor energy consumption at the facility level.
    c. Monitor energy consumption at the system level.
13. *What is your level of overall satisfaction with your facility's power distribution system?
    a. Very Satisfied
    b. Satisfied
    c. Neutral
    d. Dissatisfied
    e. Very Dissatisfied

Electrification Details

Please tell us about your plans for building system electrification at your California facility and whether you plan to incorporate a Fault-Managed Power System. (An FMPS is a power distribution system that safely transfers DC power to DC-driven devices across significant distances, also known as Class 4 Power).

14. *Are you currently using FMPS power distribution infrastructure to provide DC power to DC-driven devices in your facility?
    a. Yes
    b. No
15. If yes, please specify the technology you are using:
    a. ____________________
16. *Does your organization plan to replace natural gas-driven equipment with electrical equipment in the 12 months? This process can be called 'electrification' and can be part of a decarbonization strategy.

    a. Yes
    b. No
17. *If yes, which of these options best describes your plans for building system electrification in the next 12 months? Select all that apply.
    a. Planning to electrify HVAC equipment (ex. install heat pumps)
    b. Planning to electrify foodservice equipment (ex. build out an all-electric kitchen)
    c. Planning to install electric vehicle charging infrastructure (ex. parking lot charging stations)
18. *Which of these options best describes how your building's electrical power infrastructure affects your electrification plans?
    a. My electrification plans are limited by my building's power infrastructure (i.e. planned upgrades will require an electrical service upgrade or installation of additional subpanels)
    b. My building has sufficient power infrastructure to support my electrification plans
19. If you like, please tell us more about your capital plans for the next year. Describe system replacements, equipment upgrades, and new loads being added to the building.
    b. ____
20. *Which of these options best describes the most important features would you prioritize when selecting a new power distribution system for your facility? Select all that apply.
    a. Low cost
    b. Can satisfy limited space constraints for electrical infrastructure
    c. Can provide DC power to DC-driven equipment
    d. Can satisfy new electric building loads (supports electrification of HVAC, foodservice, and EV charging infrastructure)
21. *Are there any specific integration requirements or compatibility considerations you have for power distribution technology in your facility? Select all that apply.
    a. Supplies required electrical power capacity (meets building service needs)
    b. Distributes high power demand across long distances
    c. Operates at buildings with limited cellular coverage
    d. Monitors energy demand and consumption at the circuit level
    e. Other (Please Specify):______________________

Energy Efficiency Details

If you like, please tell us a bit more about your energy goals so that we can ensure efficiency programs are effective at reducing barriers to energy efficiency for growers.

Questions are all optional.

22. What was your facility's electricity usage for the past 12 months?
    c. ______________ kWh
23. What was your facility's natural gas usage for the past 12 months?
    d. ______________ therms
24. What are your primary concerns with implementing energy efficiency upgrades?
    e. First cost of materials and labor for installation
    f. System performance
    g. Training needed for new systems
    h. Labor (availability of resources)

i. Have no concerns about implementing energy efficiency upgrades

25. If an energy efficiency project is proposed which involves retrofitting existing equipment to reduce energy consumption & costs, what is an ideal payback period that you are willing to consider for the project?
    j. <1 year
    k. 1 – 2 years
    l. 2 – 5 years
    m. 5 – 10 years
26. Based on your best estimation, what proportion of building owners and facility managers are planning electrification projects in the next 12 months?
    a. ____________ (value from 0-100)

Appendix C: Site Visit Reports

Site Visit Report #1: Class A Office

Figure C-1. Office Building Exterior.

Figure Source: ERI 2024h.

The Class A Office is a 73,700 sq ft facility in San Diego, California, originally constructed in 1981 that serves the function of an office space (see Figure C-1). The facility is serviced by a 1,600 Amp meter supply (277/480V service), the main disconnects indicate a 3 phase, 4 wire system. The building is occupied from 5:00AM to 5:00PM, Monday through Friday, totaling to approximately 3,120 hours per year, with earlier start times than usual for facilities maintenance to arrive on-site.

Electrical Service Equipment

Electrical service at the facility is rated at 800 Amps. An electrical room located on the exterior of the building houses all electrical infrastructure that serves the building. This room contains the SDG&E electrical meter and main service disconnects that serve the building, as well as 3-phase, 30 kiloVolt-amperes (kVA), 60 Hz power transformers (see Figure C-2 and Figure C-3). There are floor-level electrical rooms that house Individual Distribution Frame (IDF) equipment as well as three to four transformers per electrical room (see Figure C-4). These transformers were observed to be 3-phase, 30 kVA, 60Hz power transformers, similar to the transformers located on the exterior of the building (see Figure C-5).

Figure C-2: Electric Meter and Meter Box

Figure C-3: Main Switchboard Section #2

Figure C-4: Electrical Room, Third Floor

Figure C-5: Transformers, Exterior Room

Figure Source: Ibid.

HVAC Equipment and Controls

Heating and cooling loads are served by water source heat pumps (WSHP), with separate water source/sink loops serving the east and west wings of the building. Ventilation requirements are met by (1) variable-speed 5 horsepower (hp) outside air supply fan (OA SF) serving each wing. Heat is rejected from each water loop by a Thermal Care model FT8280 cooling tower, each rated at 120 tons of heat rejection (see Figure C-8). During cooler weather, heat is added to the water loop by natural gas boilers (manufactured by RayPak Inc and Ajax Boiler Inc) rated at 926,000 BTU/hr and 700,000 BTU/hr (see Figure C-7). A detailed audit of all WSHP units could not be conducted during the audit. However, based on several WSHP units that were visible through exposed ceiling tiles, as well as a replacement unit that was observed in shipping/receiving, the units are estimated to have an average capacity of 30,000 BTU/hr. Total capacity is assumed to be equivalent to the heat rejection of the cooling towers: 240 tons total for both loops.

Figure C-6: Rooftop OA Supply Fan #1

Figure C-7: Boiler Serving Loop #1

Figure C-8: Cooling Tower Serving Loop #1

Figure C-9: BMS Controller

Figure Source: Ibid.

The facility currently does not monitor energy consumption through a Building Management System (BMS), although a Trane Tracer BMS control box was noted by ERI engineers during the site visit (see Figure C-9). Through further discussions with building management, it was learned that onsite personnel do not have access to this Trane BMS, and the system is monitored and controlled remotely by a controls contractor. In addition to the remote BMS control, it was observed that several spaces located throughout the building were controlled by manual thermostats.

During the site visit, facilities maintenance noted no issues or reported problems with the current HVAC system serving the building. The facilities team did not indicate that the HVAC system is going to be electrified in the next one to three years.

Telecommunications Infrastructure

The facility's telecommunications network is served by AT&T T1 Lines that are terminated in an Individual Distribution Frame (IDF) room to serve the building (see Figure C-10). This termination is accomplished using Westell Inc. Digital Termination Telephone lines and panel boxes (see Figure C-11). In telecommunications terminology, "termination" refers to connecting the customer's data or telephone equipment to a network provider's line that comes into a building. Inside IDF rooms are TrippLite UPS systems, each rated at 120V 60 Hz, 1500 volt-amperes (VA), 1350 Watts (W) and 12 amperes (A) output. These UPS systems provide backup power to telecommunication systems and server systems during power outages or fluctuations (see Figure C-12). Network access is distributed within the building using Amphenol Fiber Optic cables connected to a COX communications cable box. There is a main server room located on the ground floor that contains server racks which house telecom equipment for the facility. Each server rack is served by a UPS system rated at 120 V, 60 Hz, 3000 VA, 2250 Watts, 24 A backup power supplies in the event of a power outage.

Figure C-10: Telephone Lines

Figure C-11: Digital Termination Telephone

Figure C-12: IDF Room UPS, Second Floor

Figure Source: Ibid.

EV Charging Infrastructure

The facility has (10) ChargePoint CT4000 EV charging stations located in the front parking lot. During the site visit, it was noted that around half of the EV charging stations are currently being utilized to serve commercial city vehicles (see Figure C-13). These ChargePoint stations have a maximum rated output of 208/240 VAC, 60 Hz, 30 Amp electric service supply.

Figure C-13: EV Chargers

Figure Source: Ibid.

Site Visit Report #2: Public Library

Figure Source: Ibid.

Figure C-14. Public Library Interior.

The public library is a 10,000 sq ft building located in San Diego, California originally constructed in 1987 (see Figure C-15 above). The facility is serviced by a 600 Amp (A) meter supply, 120/208V service, and the main switchboard indicates that the system is 3 phase, 4 wire. The building is occupied from 11:30 am to 8:00 pm on Monday and Tuesday, and 9:30am to 6:00pm on Wednesday through Saturday, and is closed on Sundays (2,652 annual hours of operation).

Electrical Service Equipment

Electrical service at the facility is rated at 600 Amps. An electrical room located on the exterior of the building houses all electrical infrastructure that serves the building. This room contains the SDG&E electrical meter and the main switchboard with tag “MHSB” (see Figure C-15). The nameplate data for switchboard MHSB corresponds to the electrical drawings for the facility (600 Amp, 120/208V with a short circuit current rating of 10 kilo-Amps, kA as built). Inside the library, circuit breaker panels that house the lighting relays were observed, however no nameplate data was available for these panelboards (see Figure C-16).

Figure C-15: Electric Meter and Switchboard

Figure C-16: Panelboards

Figure Source: Ibid.

HVAC Equipment and Controls

The facility is serviced by four Carrier rooftop AC units (see Figure C-19). An equipment summary for this facility can be found in Table C-1. Based on the equipment model numbers, all units are constant-volume, and no field-installed VFDs were observed. The facility currently does not monitor energy consumption through the form of a BMS, and no BMS control boxes were noted on-site by ERI engineers during the site visit. Through further discussions with building management, it was confirmed that the facility does not have a BMS system. It was observed that the HVAC system is controlled by digital thermostats located inside the library. The thermostat is shown in Figure C-20.

Table C-1. Public Library HVAC Equipment Inventory

Unit Designation	Airflow (CFM)	Cooling Capacity (BTU/hr)	Heating Capacity (BTU/hr)	System Amps
AC-1	4,300	139,000	147,600	60.6
AC-2	4,300	139,000	147,600	60.6
AC-3	3,000	90,000	72,900	38.2
AC-4	4,300	139,000	147,600	60.6

Source: ERI. 2024z.

Figure C-17: Rooftop AC Unit

Figure C-18: Digital Thermostat

Figure Source: Ibid.

Telecommunications Infrastructure

The facility's telecommunications network is served by AT&T Broadband Lines that are terminated in the same exterior electrical room where the MHSB and electrical meters are located (see Figure C-19). The broadband is distributed within the library through copper ethernet cables that are housed in a panel box adjacent to the AT&T panel box (see Figure C-20).

Figure C-19: Broadband Panel Box

Figure C-20: Ethernet Cabling Box

Figure Source: Ibid.

EV Charging Infrastructure

The facility currently does not have any on-site EV charging infrastructure. The public library is slated to have EV charging stations installed within the next two years.

Site Visit Report #3: Recreation Center

Figure C-21: Recreation Center Kitchen

Figure Source: Ibid.

The recreation center is a 16,000 sq ft building located in San Diego, California. Originally constructed in 1960, with major renovations in 1998, the building has a commercial kitchen to serve community and club activities (see Figure C-21). The facility is occupied from 10:00am to 8:00pm from Monday through Thursday, from 11:00am to 7:00pm on Fridays, and 9:00am to 3:00pm on weekends (3,120 hours per year).

Electrical Service Equipment

The main switchboard that serves the facility is located on the southern exterior of the recreation center. During the site visit, access to this switchboard was restricted, and on-site management had no access to the switchboard (see Figure C-22). However, circuit breaker panelboards were observed throughout the facility that provide insights into the level of electrical service at the facility. The panelboard serving the gymnasium is rated for 120/240 VAC service and the system is single phase 3-wire with an Amp section rating of 225 A (see Figure C-23). A separate panelboard with tag “Panel A” was observed to be serving most of the facility, including lights inside the gymnasium, exhaust fans, emergency lights, supply fans, parking lot lighting, and commercial kitchen equipment (see Figure C-24). The nameplate on “Panel A” indicates the maximum Amperage is rated at 225 A, with electrical service at 120/240V on a single phase 3-wire system. The panelboard “B” services the remainder of the facility, including bathroom hand dryers, bathroom exhaust fans, unit heaters located throughout the building, and irrigation controls (see Figure C-25). The nameplate data indicates the electrical service from this panelboard is rated at maximum 100 Amps, 120/240V on a single phase 3-wire system.

Figure C-22: Main Switchboard

Figure C-23: Panelboard, Gymnasium

Figure C-24: “Panel A” Panelboard

Figure C-25: “Panel B” Panelboard

Figure Source: Ibid.

HVAC Equipment and Controls

The facility does not have rooftop units or air handling units. A majority of the spaces were not served by any cooling equipment, though one office was observed to be equipped with an individual portable air conditioner unit, and an evaporative cooler serves the commercial kitchen. Heating loads are served by ceiling mounted unit heaters rated at 30,000 BTU/hr for the office spaces and 100,000 BTU/hr for the theatre (see Figures C-26 and C-27). Ceiling-mounted natural gas heaters also serve the gymnasium, though their size or other nameplate data could not be confirmed due to the height of the ceiling. The facility currently does not monitor energy consumption through the form of a BMS, and no BMS control boxes were noted on-site by ERI engineers during the site visit. Through further discussions with building management, it was confirmed that the facility does not have a BMS system.

For controlling HVAC systems, the controls for the portable air conditioners are located on the unit, and it was observed that the unit heaters are controlled by manual thermostats located inside the recreation center. Controls for the kitchen’s evaporative cooler and exhaust fan were not observed but are assumed to be switched on and off manually. The thermostat is shown in Figure C-28.

Figure C-26: Portable Air Conditioners

Figure C-27: Theatre Unit Heaters

Figure C-28: Manual Thermostats

Figure Source: Ibid.

Telecommunications Infrastructure

The facility's telecommunications network is served by AT&T broadband lines that are terminated in a CommScope panel box located in the server room on the facility (see Figure C-29). The internet access is distributed across the recreation center using a wireless fiber (Wi-Fi) signal box from Lokket Inc. located directly adjacent to the CommScope panel box (see Figure C-30).

Figure C-29: Broadband Panel Box

Figure C-30: Wireless Fiber Signal Box

Figure Source: Ibid.

EV Charging Infrastructure

The facility currently does not have any on-site EV charging infrastructure. Facilities management described that there are currently not enough EV chargers in the City of San Diego to support the city's EV fleet, indicating potential and interest from the city in expanding its EV charging network.

Site Visit Report #4: Operations Yard

Figure C-31: Operations Yard Exterior

Figure Source: Ibid.

The Operations Yard is a 14,436 sq ft facility in San Diego, California originally constructed in 1985 that is an office and city sanitation vehicle maintenance facility (see Figure C-31). The facility has a total load of 149.7 Amps, and the 15 kVA main transformers indicate a 480 VAC, 3-phase and 3-wire system as the primary supply, with a secondary supply of 120/240V, 3-phase 4-wire system. The building is typically occupied from 5:30AM to 5:30PM (4,368 hours per year), though occasional occupancy as late as 10:00PM may occur when dealing with special circumstances such as a vehicle breakdown.

Electrical Service Equipment

Electrical service at the facility is rated at 800 Amps. An electrical room located inside the building houses all the electrical infrastructure that serves the building, including a panelboard from General Electric that indicates the level of service is 277/480 VAC, 3-phase 4-wire with a maximum root mean square (RMS) system amperage rating of 2,400 Amps (see Figure C-32). Electrical line diagrams indicate that all transformers are 480 VAC, 3-phase 3-wire primary, and 120/240V, 3-phase 3-wire secondary. There are (5) transformers located on site, and a capacity summary can be found in Table C-2. A panelboard manufactured by Grossmont Electric was observed in the electrical room at the facility, where the panel diagram indicates service for the AC-1 unit, ice machines, lighting, electrical receptacles (outlets), and 208 VAC air compressors (see Figure C-33).

Table C-2. Facility Transformers Inventory

Unit Designation	Transformer Sizes (kVA)
T1	75
T2	75
T3	45
T4	30
T5	30
T6	45

Table Data Source: ERI. 2024x.

Figure C-32: Main Panelboard

Figure C-33: Panelboard Serving Various Equipment

Figure Source: Ibid.

HVAC Equipment and Controls

The facility is serviced by a Trane rooftop AC unit designated as "AC-1", (13) heat pump condensing units located on the ground floor, and (2) Make-Up Air Units for ventilating with outside air (see Figures C-34 and C-35). An equipment summary for this facility can be found in Table C-3. The Supply Fans were not observed to be equipped with variable frequency drives (VFDs).

The facility monitors energy consumption through a BMS. A Tridium Niagara Framework BMS panel box was observed on-site by ERI engineers during the site visit (see Figure C-36). Through further conversations with building management, it was confirmed that there is no front-end for this BMS system and on-site personnel do not have access to the system without the assistance of a contractor.

For controlling HVAC systems, no pneumatic or digital thermostats were observed on-site, suggesting that the HVAC system serving the facility is controlled through the BMS interface.

Table C-3. Facility HVAC Equipment Inventory

Unit Designation	Airflow Rating (CFM)	Cooling Capacity (MBH)	Heating Capacity (MBH)	Electrical Rating
MAU-1	650	-	-	460 V
MAU-2	1540	-	-	460 V
AC-1	800	25.6	-	Rated Load Amps 9.7 A
HP-1	1000	29.4	20.9	Minimum Circuit Amps 7 A
HP-2	800	21.5	17	14 A
HP-3	870	29.2	20.9	7 A
HP-4	1200	35.2	27.4	8 A
HP-5	1400	39	32.1	9 A
HP-6	1750	55	43.6	9 A
HP-7	1000	29.2	20.9	7 A
HP-8	1000	29.2	20.9	7 A
HP-9	800	21.5	17	14 A
HP-10	1600	46.6	34	10 A
HP-11	1300	35.2	27	8 A
HP-12	1600	46.6	34	10 A
HP-13	500	15.7	12.4	11 A

Table Data Source: ERI. 2024x.

Figure C-34: Rooftop AC-1

Figure C-35: Heat Pump Condensing Units

Figure C-36: Tridium BMS Controller

Figure Source: Ibid.

During the site visit, facilities maintenance noted no issues or reported problems with the current HVAC system serving the building.

Telecommunications Infrastructure

The facility's telecommunications network is served by a Valcom signal box that is connected to a Siecor LANscape ethernet box to distribute network access across the facility (see Figure C-37 and C-38). These signal and ethernet boxes were in an information technology (IT) room within the facility, accompanied by TrippLite AC Voltage Regulators and Noise Filters. These filters ensure that the voltage output remains consistent at a predetermined level irrespective of fluctuations that may occur on the input voltage. There are two UPS units located on-site, one in the main IDF room and the other inside an IT closet on the ground floor, rated at 120 VAC, 60 Hz, 8.33 A, 1000 VA, and 800 W (see Figure C-39 below).

Figure C-37: Telecom Signal Box

Figure C-38: Ethernet Panel and AC Voltage Regulator

Figure C-39: UPS in Main IDF Room

Figure Source: Ibid.

EV Charging Infrastructure

The facility currently does not have any on-site EV charging infrastructure. They do not plan to install EV infrastructure as the department elected to not purchase electric garbage trucks.

Appendix D: Field Demonstration Report

Indoor Farm A

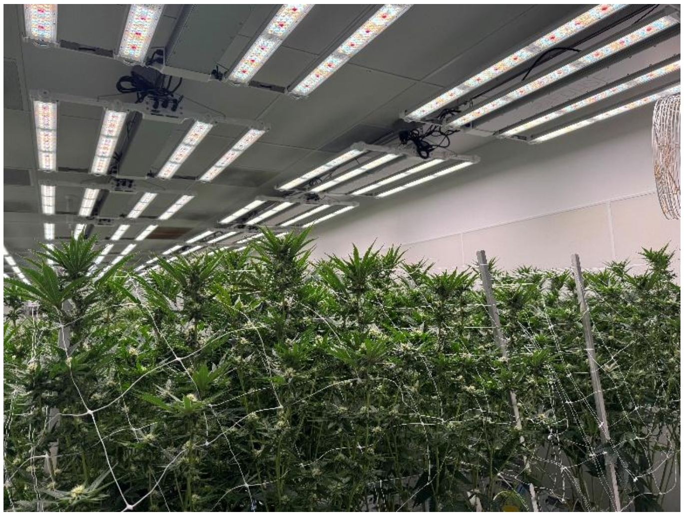

Figure 21: Indoor Farm A.

Source: ERI. 2025a.

This indoor cannabis facility has been operated by the same business since 2019. This site qualifies as HTR, both geographically and because the business leases their space. The facility grows adult-use cannabis for the legal commercial market and retrofitted a room of their existing building in 2025 to install new LED lights served by FMPS power distribution infrastructure. Figure 22 shows a circuit panel directory of the facility.

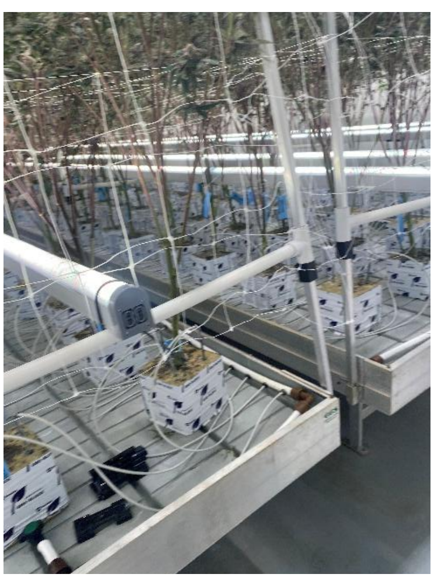

Figure 22: Intracanopy Lighting.

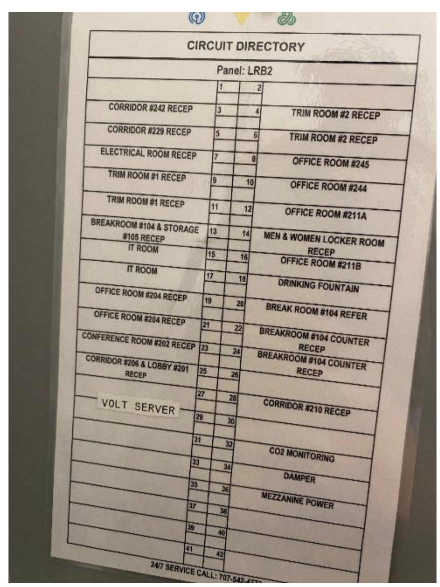

Figure 23: Circuit Powering FMPS.

Field Demonstration Scope

One FMPS system was installed to serve intracanopy lighting equipment to explore the energy savings of Class 4 Power applied to horticultural lighting systems, shown in Figure 22. Within Room A and Room B, FMPS infrastructure was connected to LED light fixtures to validate the energy savings potential of FMPS in process lighting applications.

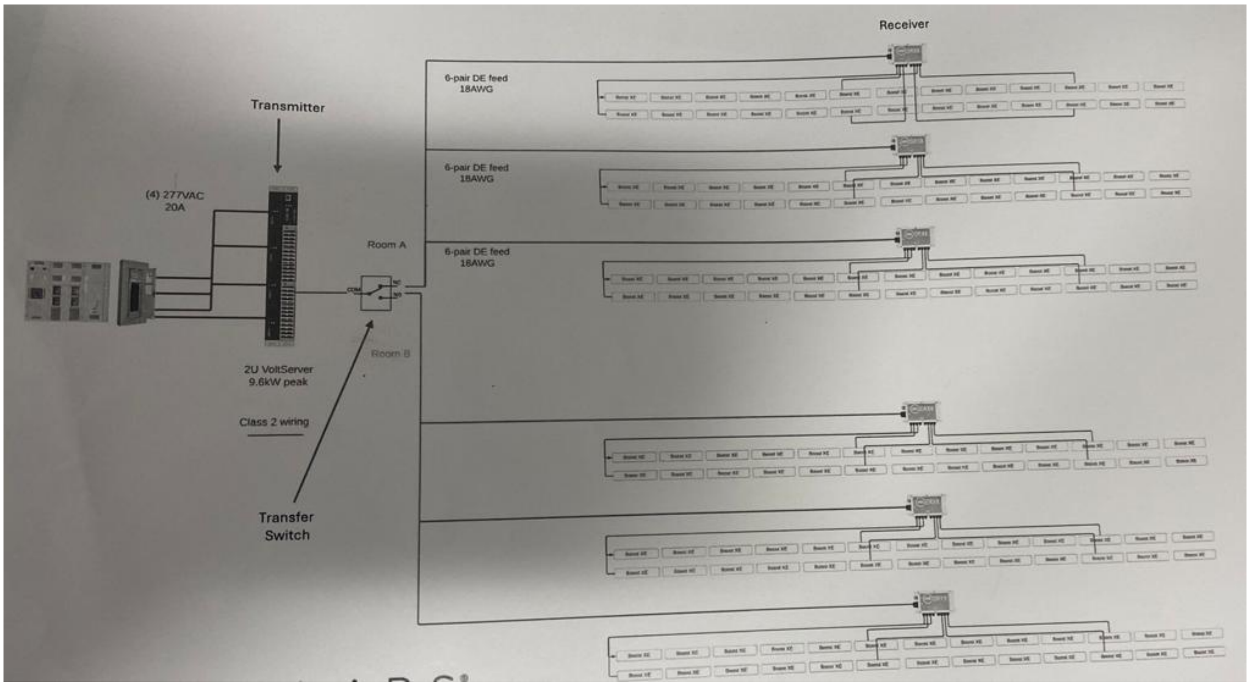

Figure 24: FMPS Power Distribution to Process Lighting Equipment

BUSINESS BENEFITS

The grower was interested in participating in the field demonstration to get support for a high-performance equipment installation and receive third-party evaluation of energy savings benefits.

Indoor Farm A leadership and grower teams expressed interest in understanding the holistic financial impact of installing FMPS.

LESSONS LEARNED

From February to September 2025, the research team documented issues and resolutions to identify field demonstration deficiencies, meeting with the Indoor Farm A teams. The following lessons learned could shape program recommendations:

1. Energy monitoring is not industry standard practice for process lighting applications. The grower's existing lighting systems did not report energy use at the system level.
2. AC power is industry standard practice. The existing lighting systems are served by AC power distribution infrastructure.
3. The California cannabis market continues to be a volatile sector. During the field demonstration, the business announced a divestment plan including a plan to sell their California assets.

BARRIERS TO EFFICIENCY

Accelerating the adoption of FMPS systems with energy monitoring at commercial, industrial, and agricultural facilities may be challenging for EE programs for the following reasons:

- Cannabis growers have high electrical power demand but generally have more critical priorities than managing energy use, like retaining skilled labor, managing labor costs, managing production costs, and maintaining crop quality.
- The business priorities for sustainability and EE projects may ebb and flow.
- Staff resources that can be focused on EE may not exist or likely will not be consistently engaged.
- Remote access was not provided for continuous access to energy monitoring data which made savings validation dependent on third party collaboration.

Appendix E: FMPS Savings Calculations

Figure 25 is a screenshot of the of the study's custom energy savings calculator outputs for market-level savings for five different lighting power distribution applications: small office, large office, college campus, hotel, and indoor agriculture.

Description	Quantity	Units
FMPS+Lighting Energy Savings		
Baseline Losses		
480V Transformer Efficiency	100.0%	
120V Transformer Efficiency	98.5%	
LED AC/DC Efficiency	96.0%	
Stacked Efficiency	94.6%	
FMPS Losses		
FMPS AC/DC Efficiency	95%	
Conversion Loss Reduction	0.4%	
Controls Efficiency Improvement	1.5%	
Validated Lighting Savings	5.0%	
Small Office Savings Potential		
Baseline Lighting EI	3.65	kWh/sqft
Statewide Floor Stock	384,440	sqft*1000
Market Level Potential	69,955,859	kWh
25,000 sqft Office Savings	4,549	kWh
Large Office Savings Potential		
Baseline Lighting EI	3.16	kWh/sqft
Statewide Floor Stock	1,321,787	sqft*1000
Market Level Potential	208,197,117	kWh
250,000 sqft Office Savings	39,378	kWh
College Campus Savings Potential		
Baseline Lighting EI	3.65	kWh/sqft
Statewide Floor Stock	384,440	sqft*1000
Market Level Potential	69,955,859	kWh
1,000,000 sqft Campus Savings	181,968	kWh
Hotel Savings Potential		
Baseline Lighting EI	2.76	kWh/sqft
Statewide Hotel Floor Stock	471,706	sqft*1000
Market Level Potential	65,016,743	kWh
100,000 sqft Hotel Savings	34,458	kWh
Indoor Agr Savings Potential		
Baseline Lighting EI	150	kWh/sqft
Statewide Indoor Ag Floor Stock	9,500	sqft*1000
Market Level Potential	71,107,500	kWh
10,000 Square foot Facilty	74,850	kWh

Figure 25: FMPS Energy Savings for Lighting Applications

Table Data Source: ERI 2025b.

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