CALIFORNIA ENERGY COMMISSION

ENERGY RESEARCH AND DEVELOPMENT DIVISION

## FINAL PROJECT REPORT

# Thermal Energy Storage System for Packaged HVAC Systems

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# PREFACE

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

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

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

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

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

# ABSTRACT

The effects of climate change have worldwide and widespread damaging impacts including increased global average temperatures resulting from increased greenhouse gas emissions which cause harmful environmental and societal consequences. Without proactive intervention and mitigation strategies, erratic weather patterns including excessive drought and heightened risk of wildfires will be a dangerous daily reality. California has undertaken a variety of innovative and ambitious steps to reduce the effects of climate change, including the establishment of greenhouse gas reduction and clean energy goals. Senate Bill 846 (Dodd, Chapter 239, Statutes of 2022) resulted in a load flexibility goal of 7,000 MW by 2030 to help reduce net peak electrical demand in California. Technologies such as thermal energy storage present a viable pathway to address load shifting needs and enable greater load flexibility to help California meet energy targets. The project evaluated the energy performance of Stasis Energy Group's thermal energy storage system, which was installed in the air ducts of 10 commercial building locations with rooftop heating, ventilation, air conditioning units, across several climate zones. This project accomplished several agreement goals, such as an average annual load shift savings of 46 percent, a reduction of 5.13 metric tons of carbon dioxide emissions, and an average of 13 percent energy efficiency savings across all 10 project sites. Based on the results of this project, Stasis Energy Group calculated that installing their thermal energy storage system in as little as 1 percent of the commercial rooftop unit market would result in more than 16.8 million kilowatt-hours of energy efficiency and 59.5 million kilowatt-hours of load shifting annual energy savings. This equates to reducing the greenhouse gas emissions by 3,872 metric tons of carbon dioxide and 13,701 metric tons of carbon dioxide from energy efficiency and load shifting, respectively.

**Keywords**: Load flexibility, load shifting, thermal energy storage system, TESS, phase change material, demand response, DR, energy efficiency, EE, technology transfer, measurement and verification, greenhouse gas, GHG, rooftop units, investor-owned utilities, IOU, heating ventilation and air conditioning, HVAC.

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# Executive Summary

## Background

The effects of climate change have widespread damaging impacts including increased global average temperatures caused by increased greenhouse gas emissions. Without proactive mitigation strategies, erratic weather patterns including excessive drought and heightened risk of wildfires will be a dangerous daily reality. Additionally, excessive heat waves continue to impact electricity grid reliability, necessitating constant air conditioning use during the scorching summer months and risking systemwide electricity rotational outages. For example, in September 2022, California logged record-high temperatures and hit its historically highest peak load at 52,061 MW. This peak load occurred at 4:57 p.m. when renewable solar generation was ending, necessitating the use of fossil fuel energy supply. Peak demand is defined as extremely high energy use between 4:00 p.m. and 9:00 p.m., usually occurring during the summer weekdays.

In 2022, California adopted Senate Bill 846 (Dodd, Chapter 239, Statutes of 2022), which required the California Energy Commission (CEC) to develop a statewide goal for load shifting to reduce net peak electrical demand. In response, the CEC established a load-shift goal of 7,000 MW by 2030. This goal is intended to be met through three broad approaches: load-modifying interventions, including time-of-use rates, dynamic pricing, and load modifying programs, account for 3,000 MW. Resource Planning and Procurement (including various demand response programs) and Incremental and Emergency interventions account for the remaining 4,000 MW.

Cost-effective energy storage technologies are a type of load-modifying intervention that can help California meet its load-shift goal by shifting heating, ventilation, and air conditioning (HVAC) energy use from peak demand hours to off-peak hours. Accordingly, Stasis Energy Group LLC has developed a thermal energy storage system designed to simultaneously achieve energy efficiency savings and shift a significant portion of HVAC energy away from peak energy demand hours to off-peak hours when renewable energy is plentiful.

Packaged HVAC rooftop units comprise a substantial portion of California's commercial floor space and energy use. Reducing commercial HVAC load during summer peak hours would make a significant contribution towards meeting California's energy goals, but few, if any, technologies adequately and economically address this market. Consequently, small commercial buildings considering rooftop unit efficiency upgrades have proven to be a difficult segment to target in California.

## Project Purpose

The purpose of this project was to advance the technology deployment and demonstration of Stasis Energy Group's thermal energy storage system installations in packaged HVAC systems throughout California investor-owned utility territories and demonstrate peak shifting performance across a wide range of rooftop unit types, climate zones, and building types.

Accordingly, the project team aimed to show that thermal energy storage system technology could simultaneously achieve energy efficiency savings, reduce peak demand, and shift electricity use during summer peak periods for non-residential customers with commercial rooftop units. The project research findings are important and timely to California because thermal energy storage systems have significant load shifting and load flexibility capabilities to help support the SB 846 goal.

# Project Approach

This project evaluated the energy performance of 10 commercial rooftop sites both before and after Stasis Energy Group's thermal energy storage system installation. Concurrently, through this grant funding opportunity, the project team created a technology transfer plan in which customers have access to various utility incentive programs as early as 2025 to help bridge the technology transformation gap. This project included a comprehensive measurement & verification (M&V) plan to prove benefits to California utilities and ratepayers and a Technology Transfer Plan to accelerate commercialization of the technology.

## High-Level Project Goals

Listed below are the high-level project goals and associated desired outcomes aimed to achieve project success. The goals were developed by researching relevant and well-established California state policy initiatives, end-use customer feedback on needs and desired outcomes, and input from key technology transfer stakeholders who are intimately involved with investor-owned utility incentive and rebate programs.

- Grid Reliability
    - Simplify the challenge facing grid operators and reduce the risk of energy shortages, public safety power shutoffs, brownouts, and blackouts by shifting the HVAC peak load to non-peak periods by at least 40 percent compared to baseline conditions.
- Technological Advancement and Breakthroughs
    - Target underserved small commercial buildings across several climate zones, including disadvantaged communities, where research participants could experience annual energy efficiency savings, peak kilowatt demand reduction, and annual load shifting energy savings across all project sites.
- Annual Greenhouse Gas Emissions Reduction
    - Achieve annual greenhouse gas emissions savings across all 10 project sites.
- Technology Transfer
    - Create several key technology transfer avenues including California's investor-owned and publicly owned utility incentive programs where customers may participate as early as 2025.
- Peak Kilowatt Grid Load Flexibility
    - Demonstrate an average peak demand reduction of 50 percent or more.

- Load Shifting
  - Achieve lengthened periods of load shifting ability for up to five hours during peak periods, resulting in load shifting annual energy savings across all project sites.
- Summer Months Utility Bill Cost Savings
  - Demonstrate annual utility cost savings per HVAC unit in a variety of buildings and configurations for a typical 5-ton rooftop unit during summer months.
- Non-Summer Months Utility Bill Cost Savings
  - Demonstrate $500 or more in annual utility cost savings outside of summer months per each 5-ton rooftop unit.

## Key Results

The project achieved promising results in terms of benefits to ratepayers, the public, and the environment. These results include:

- An average of 13 percent energy efficiency savings based on improving the rooftop units' coefficient of performance.
- An average reduced peak demand (in kilowatts) of 57 percent from baseline conditions.
- A shift in energy consumption by nearly 46 percent from summer peak demand to summer off-peak demand periods.
- A reduction of 5.13 $CO_2$ metric tons of GHG emissions across all sites.

Assuming a thermal energy storage system penetrates 1 percent of the commercial rooftop unit market, California could see more than 16.8 million kilowatt-hours of energy efficiency and 59.5 million kilowatt-hours of load shifting annual energy savings. This equates to reducing greenhouse gas emissions by 3,872 metric tons of carbon dioxide and 13,701 metric tons of carbon dioxide from energy efficiency and load shifting, respectively. Approximately 5 million tons of electric cooling come from rooftop units of less than 10 tons; assuming all rooftop units adopted thermal energy storage systems, California could realize a total of 2,300 MW of peak period load reduction, a substantial contribution to meeting the state's 7,000 MW 2030 goal.

Data collected during the three-year BRIDGE demonstration project demonstrates effective and robust performance when comparing baseline energy consumption against energy consumed after the thermal storage system was installed. Over the whole demonstration and including all project sites, energy efficiency (EE) was improved by 13 percent and 46 percent of peak energy use was shifted to off-peak. The reduction and shifting of energy consumption, measured in kilowatt-hours, are significant metrics. Furthermore, the reduction in peak period demand measured in kilowatts was 56 percent measured across all project sites.

The performance metrics were the result of novel controls and operations logic combined with in-duct thermal storage. The Stasis TESS system, installed in the supply ducting of the HVAC system, is charged during normal daily cooling operations of the HVAC system. Typically, during morning cooling operations, necessary to bring the occupied space to desired temperatures, the thermal storage system is charged while cold air is delivered to the building space. During these cooling periods, a small amount of energy is passively spent to prepare the thermal storage system, evidenced by solidification of the phase change material. Because the energy used to charge the system is early-day energy, the energy required to charge the system is less than late-day cooling, due to lower outdoor ambient temperatures. This is measured by an improved coefficient of performance and results in the 13 percent energy savings across all sites. As early day electricity is produced with a higher contribution from renewable energy sources, the greenhouse gas savings is significant when compared to late-day cooling.

During peak demand periods, typically 4–9pm, the Stasis system reduces compressor run times to provide peak demand relief. Reduced compressor run times result in less cooling supplied to the occupied space, but the reduction in compressor cooling is offset by releasing the stored cooling in the charged thermal storage media. Using the stored cooling energy from early day cooling, the late-day energy demands are reduced and peak demand savings, across all sites, was 56 percent. The Stasis product effectively and efficiently used early day and sustainably generated energy to charge the thermal storage media and then deployed the stored cooling late-day to reduce peak demand energy use and load. The result is a load flexible solution that, at scale, can lead to increased use of sustainably sourced energy during the early day and reduce the use of late-day traditionally generated electricity, which can help meet the 2030 load shift goals required by SB 846.

## Knowledge Transfer and Next Steps

The following provides a summary of actions taken by SEG within a technology knowledge transfer plan to share project information, foster broader adoption, and inform strategic policy and planning across key California stakeholders.

- Engagement from the project start with Blue Tech Valley Incubator in Fresno, with a specific goal to increase awareness and adoption of the technology into the retrofit market within disadvantaged communities.
- Submittal to the California Technical Forum as a measure package that, if approved, will result in a deemed measure offering within the IOU EE portfolio with a target of 2025.
- Collaboration with IOU Self Generation Incentive Program (SGIP) with the intent of gaining approval for thermal storage incentives specifically targeting disadvantaged communities.
- Submitted a CalNext proposal to identify non-EE related energy savings that coincide with load shifting and load flexibility load flexibility grid benefits to the CalNext Technology Assessment team
- Applied for inclusion into SCE CalFUSE Pilot program to demonstrate efficacy of technology in real-time and dynamic energy price markets.
- Collaboration with Lawrence Berkeley National Lab CalFlexHub initiative to develop pathways to introduce the thermal storage benefits to ratepayers

# CHAPTER 1: Introduction

## Relevant Project Background

Climate change, driven by greenhouse gas emissions, is increasing global average temperatures and causing erratic weather patterns. As a result, heat waves have affected and are projected to continue to impact electricity grid reliability, necessitating increased air conditioning use and risking systemwide electricity rotational outages.[1] Of particular concern in California is "peak demand," the period between 4:00 pm and 9:00 pm, especially during summer weekdays, when electricity use is highest just as renewable solar generation is decreasing and the use of fossil fuel energy increases.[2]

To address the grid reliability and GHG emissions challenges presented by peak demand, Senate Bill 846 (Dodd, Chapter 239, Statutes of 2022) required the California Energy Commission (CEC) to develop a statewide goal for load shifting to reduce net peak electrical demand. In response, the CEC established a load-shift goal of 7,000 MW by 2030. One approach to meeting this goal is to shift heating, ventilation, and air conditioning (HVAC) energy use from peak demand hours to off-peak hours. Stasis Energy Group LLC has developed a thermal energy storage system designed to simultaneously achieve energy efficiency savings and shift a significant portion of HVAC energy away from peak energy demand hours to off-peak hours when renewable energy is plentiful.

### Commercial Buildings and HVAC Market Potential

The Commercial Buildings Energy Consumption Survey estimates that there are 5.9 million buildings in California with 96 billion square feet of total commercial floorspace.[3] Warehouse and storage, office, and service buildings account for almost half of all commercial buildings.[4] Historical data from building code departments and officials suggest that new commercial construction represents approximately 1–2 percent of all building construction. According to IBIS World, commercial building construction in California is estimated to be a $30.9 billion industry across 7,097 businesses in approximately 6,960 commercial buildings.[5]

As much as 70 percent of California's commercial floor space is cooled by constant volume rooftop units (RTUs) up to and including 10 tons.[6] These packaged HVAC rooftop units have many years of useful life remaining and account for approximately 26.8% percent of total

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[1] California Independent System Operator: https://www.caiso.com/documents/rotating-power-outages-fact-sheet.pdf

[2] California Public Utilities Commission Energy Efficiency Policy Manual Version 6 pdf page 79.

[3] Commercial Building Energy Consumption Survey: https://www.eia.gov/consumption/commercial/

[4] California Energy Commission Commercial End Use Survey: https://planning.lacity.gov/eir/CrossroadsHwd/deir/files/references/C19.pdf

[5] IBIS World.

[6] UC Davis, https://wcec.ucdavis.edu/wp-content/uploads/2013/12/MTLC-Preliminary-Report.pdf

electric end use energy demand in commercial buildings.[7] In total, these systems make up approximately 95 percent of all rooftop units manufactured and are responsible for approximately 48% percent or 12.9 billion kilowatt-hours of energy use in California per year.[8] Few technologies target this existing retrofit market opportunity.

While it is important to address new construction opportunities, Stasis' technology was designed specifically to address the large market of existing units installed in California, which is estimated to be as much as 1.5 million units. By delivering a solution to remediate and improve the performance of existing HVAC units, the state and ratepayers are better served due to the immediate load shifting and energy efficiency benefits that retrofit installations of the thermal energy storage system described herein provides.

## Technology Current State and Technology Maturity

Thermal energy storage solutions (TESS) for small- and medium-sized commercial buildings are an emerging market with enormous potential for energy savings where successful adoption can help California meet its sustainability mandates. The product tested in this project focuses on rooftop packaged units and can address both new and existing installations. The combination of controls and use of phase change thermal storage is a novel approach to small scale thermal storage.

Phase change material (PCM) is a thermal energy storage product that releases and absorbs thermal energy during its phase transition. Specifically, when a PCM melts, it absorbs heat, and when it solidifies, it releases heat. PCMs can be categorized into organic, inorganic, and eutectic materials. Organic PCMs are typically derived from hydrocarbons, such as paraffin, while inorganic PCMs include materials like salt hydrates and metallic alloys.

New bio-based, non-toxic organic PCM products on the market propose to save energy by absorbing heat during peak hours and releasing heat in the cooler evening hours. This approach relies on specific conditions that allow both absorption and release of energy daily at a particular time and is geographic location and season dependent.

Historically, PCM technology has not been successful in widespread market adoption, including breaking into investor-owned utility (IOU) incentive and rebate programs, due to the uncertainty of benefits and historical prohibitive cost of adoption. Despite decades of prior research, using PCM to reduce energy consumption in commercial buildings has improved but is not well understood. Consequently, several field assessments have been conducted to determine PCM's potential energy savings in various commercial buildings.

## What Is a Thermal Energy Storage System and How Does It Work?

Stasis Energy Group's (SEG's) TESS is made up of two primary components: 1) bio-based non-toxic organic PCM within the ducting of the HVAC system and 2) a programmable thermostat controller, which is designed with flexible schedules and algorithms. TESS PCM is encapsulated

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[7] California Energy Commission Commercial End Use Survey, pg. 9: https://planning.lacity.gov/eir/CrossroadsHwd/deir/files/references/C19.pdf

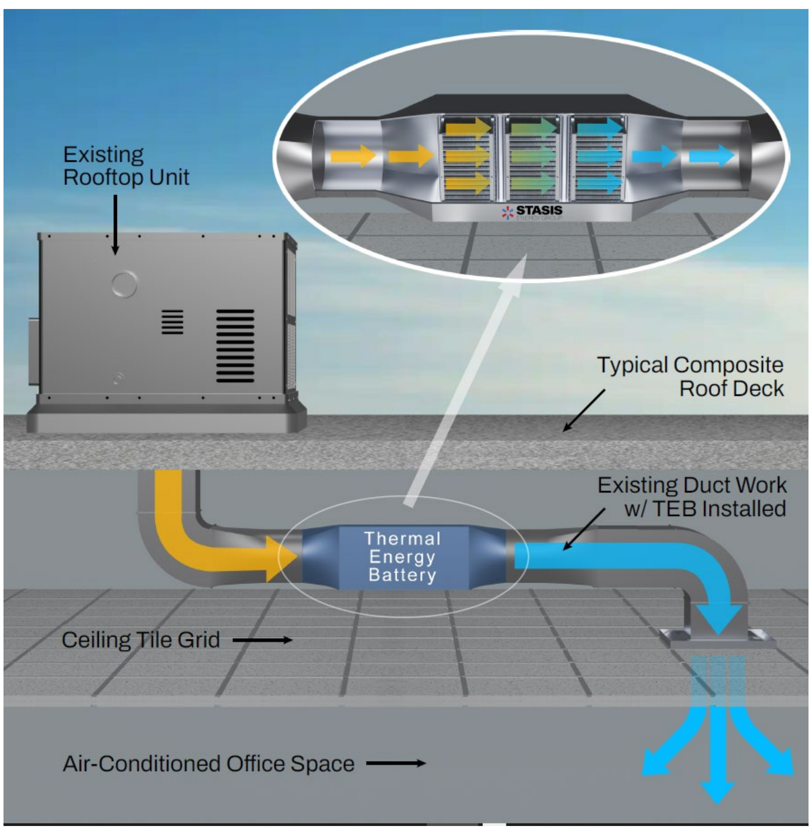
[8] Western Cooling Efficiency Center-UC Davis, https://wcec.ucdavis.edu/wp-content/uploads/2013/12/MTLC-Preliminary-Report.pdf

in aluminum plates where the PCM solidifies at 64°F (18°C), which allows the material to charge or freeze at a much higher temperature setpoint compared to water.

As shown in Figure 1, TESS stores latent energy from the supply air during normal cooling operations. TESS PCM acts like a thermal energy battery and charges (freezes) during the day when the air conditioner compressor runs when energy costs are lower. Between the 4:00 p.m. to 9:00 p.m. peak period, the TESS PCM works in concert with the supply fan and discharges (thaws) during the peak period to allow for conditioned space to cool while the air conditioning (AC) compressor remains off.

By using active controls rather than passive cooling strategies, TESS achieves more energy efficiency (EE) savings by improving the RTU's coefficient of performance, reduces peak demand, and has the ability to shift load in near real-time conditions based on those active controls. During summer peak periods, the programmable thermostat controller limits compressor operations, so that cooling is provided by TESS, and the HVAC compressor is only used to provide supplemental cooling when necessary. In other words, if user preferences require more cooling than the TESS can provide, AC compressors may come on as needed. Based on field observations, additional cooling is only required 20 percent of the time where the AC compressor is off 80 percent of the time. The reduction of compressor run time results in significant economic and grid benefits. Additionally, TESS achieved Class A plenum rating per ASTM E84/NFPA 285/UL 723, so the product is safe to use in buildings without concern of flammability.

**Figure 1: Thermal Energy Storage System Configuration**




Source: Stasis Energy Group

# Project Purpose

## Project Research Needs and Advancing Adoption

In 2022, the CEC approved a goal to make up to 7,000 MW of electricity available through load flexibility or load shifting, which complements the 38,000 MW of new clean electricity resources needed by 2030.[9] Therefore, advancing the adoption of load shifting technologies like TESS assists in filling the technology gap in existing load management programs. TESS simultaneously provides EE savings through improved coefficient of performance, reduces peak demand, and enables significant load flexibility and load shifting capabilities, which are all imperative to California's future electric grid.

Robust permanent load shifting (PLS) incentive programs were available in the 1990s, but they were short-lived. There was an attempt to bring back PLS programs between 2005 and 2008. Unfortunately, the PLS programs were discontinued because onerous measurement and verification (M&V) requirements resulted in low customer participation. Reinstating PLS programs is imperative to achieve California's 2030 SB 846 load shifting goals.

## Project Purpose, Scope Focus, and Intended Audience

Many commercial businesses located in California's Central Valley are located near gas-fired peaker plants, and the business owners do not have access to readily available resources including efficiency education and awareness programs that could help reduce burdensome utility costs. As tenants, not property owners, many of these commercial business owners interested in deploying new technologies are unable to make HVAC equipment changes.

Accordingly, this project scope focuses on deploying 18 TESS installations across 10 small commercial sites with 5 of those sites located in disadvantaged communities across several California climatic zones. Through this CEC research project, SEG helped some of California ratepayers simultaneously shift load and achieve both EE savings and peak demand reduction.

A comprehensive M&V plan that demonstrates both costs and benefits to California utilities and utility ratepayers is essential to TESS market adoption. Similarly, creating a technology transfer plan will accelerate commercialization of TESS, especially to small commercial facilities in hard to reach (HTR) and disadvantaged communities. Through this CEC research project, the project advanced the technology deployment and demonstration of TESS installations throughout California IOU territories and demonstrated peak shifting performance across a wide range of RTU types, climate zones, and buildings including those located in HTR and disadvantaged community locations.

## Technology Features

Figure 2 illustrates the TESS technology features. These technology features center on EE savings, load shifting, and load flexibility performance evidenced in field trials. Additionally, TESS technology features involve minimal maintenance and product lifetime benefits, including no performance degradation and eco-friendly materials.

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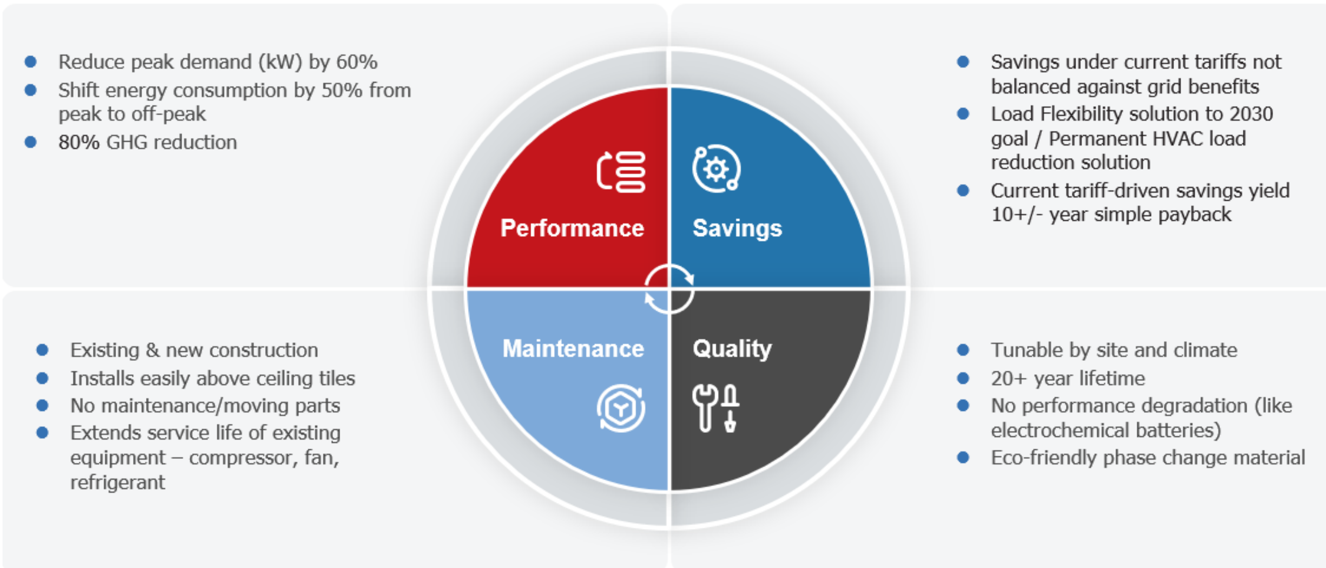
[9] https://www.californiaenergytransition.com/p/california-adopts-goal-for-smarter

**Figure 2: TESS Technology Features**




Source: Stasis Energy Group

## Energy and Grid Savings

Reducing energy use and peak demand in existing commercial buildings is important because commercial buildings account for approximately 35 percent of all energy use in California.[10] HVAC space cooling and ventilation accounts for 26.8 percent or 26.9 billion kilowatt-hours (kWh) of all California commercial building electric loads.[11] Through the use of TESS, HVAC systems can reduce peak demand and achieve annual EE savings compared to baseline energy use resulting in utility bill savings.

## Benefits Sought through Technology Improvement and Optimization

Historically, PCM was installed in the walls and ceiling plenum of a building resulting in significant labor and material costs. SEG formulated a novel approach by which the TESS PCM was encapsulated into aluminum casings. Using this encapsulating approach, SEG was able to install its TESS into the ducts of 18 RTUs among 10 small- to medium-sized commercial buildings throughout California at a much lower cost, compared to other PCM applications. As shown in Figure 3, SEG discovered that by encapsulating TESS into aluminum casings within the HVAC ducting, it could isolate the labor and materials to a couple of key locations in the building rather than within every wall and ceiling plenum. With TESS design and installation improvements and optimization, the costs of installing the system decreased without any degradation to system performance.

[10] California Energy Commission Database

[11] Ibid.

**Figure 3: TESS Full Side, End, and Installed Views**


Full Side View

End View

Installed View

Source: Stasis Energy Group

### Funding Needed to Achieve Clean Energy and Climate Goals

The CEC grant funding opportunity allowed SEG to collect nearly one year of baseline data and post retrofit measure case data to determine the AC load for each RTU. A desired outcome of this research project centered on the ability to adjust the AC load profile to align with dynamic rate price signals. Without the grant funding, the EE, load flexibility, and load shifting benefits would not have been found.

### Impact to California's Economy through Job Creation

SEG moved its manufacturing facilities from the Midwest to California, which proved to stimulate job growth. By moving its supply chain operations to California, SEG built a market presence for California ratepayers, created local job opportunities, and lowered the manufacturing and distribution supply chain costs by 20 percent. This decision ultimately lowers the product cost for California ratepayers.

## Hard to Reach Customer Segment

### Targeting Underserved Communities

Despite small commercial customers making up the largest portion of the non-residential customer base, this segment is considered HTR due to several factors, including historically low participation rates. Many small building businesses are tenants and not property owners and lack the ability to make changes without the building owners' support and authorization.

Energy costs are usually carried by the tenant and not the owner, and often the benefits of new technology take years to mature.

Disadvantaged and underserved communities often have the highest rates of tenancy, as opposed to ownership, of buildings. The HVAC equipment is often outdated and not replaced until unit failure; consequently, older units, running at less than current model code efficiency, cost more money to operate and emit greater GHG than more modern units.

Utility generational and delivery demand charges can account for more than 65 percent of a business owner's summer utility bill. This is especially critical during the 4:00 p.m. to 9:00 p.m. summer peak demand periods, when the electric grid is near or at capacity because renewable solar generation is typically unavailable for a majority of the summer peak period. Without solar generation or storage technologies like TESS, this results in more expensive energy utility bills for business owners.

However, adopting TESS at several small commercial facilities in HTR and disadvantaged community facilities across varying California climatic zones created significant interest and awareness for these small businesses because there were both economic and environmental benefits that helped ratepayers reduce costs while simultaneously achieving California's future load flexibility and load shifting goals.

A total of 21 potential site candidates were identified with a total of 10 project sites subscribed to the project. Five of the ten sites, or 50 percent, were located in disadvantaged communities. Table 1 provides a summary of the 10 participants who subscribed to the project. Project customers were anonymized to ensure privacy protection but were identified based on project city and climate zone locations.

**Table 1: Study Participants Recruitment Pools**

| City | Climate Zone | Disadvantaged Communities/HTR Region |
|---|---|---|
| El Monte | 9 | Yes |
| Long Beach | 8 | No |
| San Diego 1 | 7 | No |
| Monterey Park | 9 | No |
| San Diego 2 | 7 | Yes |
| Fresno | 13 | Yes |
| Redlands | 10 | No |
| Sacramento | 12 | Yes |
| Thousand Oaks | 9 | No |
| Orange | 8 | Yes |

Source: Stasis Energy Group

### Targeted Audiences Likely to Use Project Results

Statewide EE and demand response (DR) incentive programs are looking to deliver immediate and viable demand side management solutions in both existing and new construction commercial applications. Third-party implementers funded through IOU funds are responsible for delivering various innovative and cost-effective demand side management offerings, like TESS, across California to both small- and medium-sized businesses.

Provided that the project findings are deemed cost effective by California regulatory bodies, third-party implementers can deliver products like TESS to small- to medium-sized businesses, particularly in underserved disadvantaged communities.

# CHAPTER 2: Project Approach

## Specific Technology

TESS works in conjunction with an HVAC system to control room temperatures and reduce the need for mechanical cooling. TESS is made up of 1) phase change material (PCM) within the ducting of the HVAC system and 2) a programmable thermostat controller, which is designed with flexible schedules and algorithms.

### Functionality

TESS is installed in the supply duct and allows normal HVAC activity by charging (freezing) the PCM thermal energy storage during off-peak hours. The thermostat controller manages compressor operations and discharges (thaws) the PCM during peak periods, providing PCM cooling in lieu of compressor conditioned air and reducing the need for compressor use. This approach results in both EE and load shifting savings from on-peak to off-peak periods. Accordingly, this corresponds to reduced peak demand and to time-of-use (TOU) cost savings. All 10 participating project sites were located in IOU service territory where applicable TOU tariffs applied.

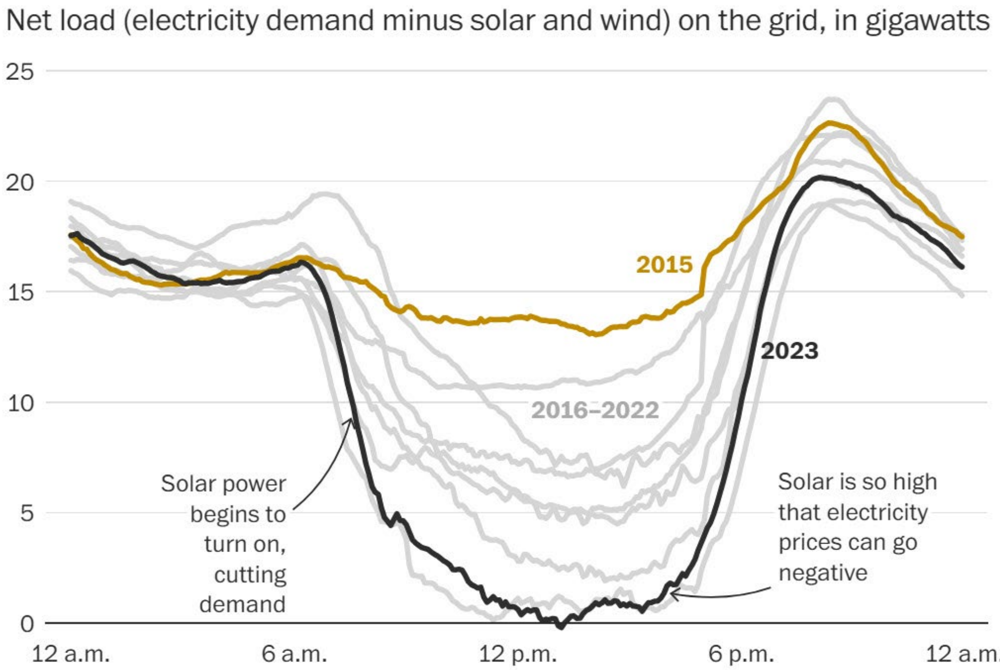
### Controls Capabilities

The TESS active design approach leverages a cloud-connected and remotely monitored platform combined with a programmable thermostat controller. Once installed, the new programmable thermostat controller can be updated and monitored remotely via the cloud. This allows continuous monitoring of the HVAC system for fault detection and supports the ability to implement real-time energy use strategies.

Accordingly, the TESS active design approach addresses both areas of the "duck curve problem", which is a graph in the shape of a duck's profile shown in Figure 4 that describes the power production in California over the course of a day, showing the imbalance between peak demand and solar generation. This is independent of the diurnal cycle because it can change temperature or air presented to the PCM using active controls when the PCM charges (freezes). Thus, TESS charges while cooling the building without exceeding the air conditioning capacity needs because TESS leverages PCM cooling instead of mechanical AC compressor cooling to mitigate late-day compressor usage. This active design approach makes the system suitable for customers to participate in real time pricing utility tariff programs.

Thus, from a mechanical standpoint, instead of waiting for the building to cool down at night, the active PCM approach controls when the PCM charges in order to target and focus when cooling is needed. TESS charges during morning and mid-day when there is surplus energy capacity and discharges (thaws) during peak periods via the programmable thermostat controller. Without the TESS active design algorithms, the PCM media would deplete, and unacceptable drift, or increase in room temperature that is not addressed by thermostat and cooling, would result.

**Figure 4: Duck Curve - Typical Spring Day**




Source: CAISO

## Project Partners, Advisors, and Project Participants

Table 2 is a stakeholder matrix that enumerates the relevant project partners, advisors, and participants relevant to this research project.

**Table 2: Project Partners, Advisors, and Participants Stakeholder Matrix**

| Stakeholder | Stakeholder Role |
|---|---|
| California Energy Commission | California's energy policy and planning agency committed to reducing energy costs and environmental impacts of energy use while ensuring a safe, resilient, and reliable supply of energy |
| Stasis Energy Group | Prime Recipient Contractor and Manufacturer of the Thermal Energy Storage System (TESS) |
| RMS Energy Consulting, LLC | Third Party Measurement and Verification Energy Consultant |
| Investor-Owned Utilities | Intended technology transfer stakeholders where future incentive and rebate programs could adopt TESS |
| Emcor Energy Services | HVAC Service Installer |
| Local Refrigeration Sheetmetal and HVAC Union | Local HVAC trade union project partner supporting customer enrollment |

Source: Stasis Energy Group

# Overall Approach Taken

## Pre-Installation Operations Planning

### Developed a List of Pilot Deployment Sites

SEG screened 21 potential participants and subscribed 10 potential retrofit pilot deployment sites across a wide variety of business and commercial facilities and climate zones using the following criteria:

- Suitable HVAC unit equipment characteristics
- Single and multiple RTU HVAC units
- Reasonable occupant loading
- Wide range of building construction types
- Wide range of business types and operating hours
- Different IOU rate schedules
- Prioritization of sites-based suitability and availability
- High-level schedule of implementation

### Telephone Screening or Kick-Off Call

Each prospective site selection entailed a telephone screening or kickoff meeting with relevant stakeholders to discuss the TESS installation opportunities and desired end result for the prospective customer and the project. During this interaction, preliminary information was gathered to gain an understanding of the site and the potential for EE savings and load shifting opportunities for adopting TESS. Other relevant information obtained included:

- Utility billing usage data
- Prospective customers' goals and expectations for TESS installation
- Customer authorization forms, where applicable

### Scheduling

Following the screening or kickoff meeting, prospective customers were contacted to establish a single point of contact and to schedule a site visit to determine project suitability. Between scheduling and site visit, utility billing usage data was reviewed where applicable to understand the site's historical base, seasonal loads, and overall energy consumption and load shifting potential.

## Developing the Controller Logic Refinement Plan

Next, SEG:

- Identified seasonal controller software improvements to be developed.
- Created high-level logic architecture for real-time weather data acquisition.
- Outlined scope of fault detection enhancements.
- Created high-level sequence of operations flowchart.

## Measurement and Verification

### Introduction

This M&V plan describes how EE savings, peak demand reduction, and load shifting potential were quantified. The M&V plan adheres to the specifications set forth in the International Performance Measurement and Verification Protocol (IPMVP) Core Concepts.

M&V involves the process of using measurements to reliably quantify actual energy savings from an energy savings project within a facility, a process, a building, or a building subsystem. M&V may be used to verify that an EE project is achieving its intended savings. M&V describes how savings are determined from measurements of energy use before and after the implementation of an energy savings project with appropriate adjustments made for changes in conditions. Such adjustments may be routine, while others are due to factors unrelated to the project.

This M&V plan describes how baseline energy use is documented, how it varies, and what factors are its primary drivers. The M&V plan also describes how adjustments to baseline energy use are made for unexpected events, such as added equipment or loads, or other unforeseen events that materially affect energy use and savings. The M&V plan was required to document and describe the approach to quantifying savings, the key measurements required and computation methods, the timing of these activities, roles and responsibilities of involved parties, and the quality assurance requirements associated with the process.

### IPMVP Option B Retrofit Isolation

The international performance measurement and verification protocol Retrofit Isolation Option B was consulted to ensure best practices and aid in the development of a solid M&V plan. The following tasks were implemented as part of the M&V plan:

- Collected nameplate data and operating information relating to each of the customer's equipment and systems.
- Interviewed staff, management, renters, owners, and/or clients/customers of the facility to characterize the facility's operational parameters.
- Took photographs of key systems, equipment, and controls.
- Obtained facility site plans and/or blueprints, where appropriate.
- Developed an appropriate instrumentation plan to collect robust and defensible information at the test site including:
    - Selecting and installing appropriate controllers, sensors, and monitoring equipment to monitor the performance of a variety of elements of the facility's systems and sub-systems, including human behavior.
    - Specifying data monitoring devices necessary to measure energy use.
    - Specifying wireless temperature sensors to monitor room temperatures.

    - Developing detailed installation plan for PCM controller, monitoring devices, and temperature sensor placement.
    - Verifying the test data is within acceptable accuracy and precision levels, including normalization due to occupancy levels, weather, and other relevant variables.
- Performed data and statistical analysis to achieve the final results in estimating energy savings, demand reduction and shift, and DR potential to produce the resulting load profiles. Analysis included:
    - Evaluating the effectiveness and performance of existing equipment.
    - Detailing field monitoring of pilot test sites pre- and post-TESS installation.
    - Identifying peak load (kilowatt) reduced.
    - Identifying peak period energy (kilowatt-hour) shifted out of peak periods.
    - Validating energy consumption (kWh) savings from increased HVAC efficiency through improved coefficient of performance with TESS charging in the cooler morning hours.
    - Outlining regression analysis models, where applicable.
    - Collecting accurate data suitable for calibrating spreadsheet energy models.
    - Confirming utility-grade data captured necessary for analysis.
    - Identifying indirect benefits of technology.
    - Determining the useful life and incremental cost of the technologies.
    - Performing error and removed performance uncertainty analysis of the final results.
    - Preparing the final report to document the procedures and assumptions used to derive the final results.

## M&V Analysis Approach and Recommendation

### M&V Analysis

The project team used HVAC weather bin temperature and interval metered data spreadsheets to perform a regression analysis to estimate annual energy consumption for both the baseline and post-retrofit measure case scenarios. Using these methods, the project team estimated annual energy and peak demand consumption for EE and load shifting measures based on the equipment data and the operating schedules collected during the site survey.

The various calculations provided a baseline to which EE and load shifting scenarios were compared. This was accomplished by modifying the input data to the calculations to reflect changes in efficiency or operation that would result in reduced energy consumption. Energy savings were calculated as the difference between the baseline and post-retrofit scenarios of the calculations.

Cost estimates were used to evaluate the cost effectiveness of the post-retrofit case based on manufacturing costs or industry literature such as RS Means Data or California's Database for Energy Efficiency Resources. All calculations and cost estimates were reviewed by a second engineer to provide quality control prior to completing the cost-effectiveness calculations.

### M&V Reporting

After all the data was collected, assessed, and synthesized, recommendations were provided to relevant stakeholders to make appropriate decisions. The project team documented the estimated energy savings from the various TESS installations including:

- Site installation findings
- M&V plans
- Calculation methodology
- Assumptions and supporting documentation
- Evaluation results and recommendations

The reporting underwent a report quality assurance peer review process to ensure a second set of eyes peer-reviewed the approach and findings, data analysis, recommendations, and conclusions.

# CHAPTER 3: Results

## Introduction

This project involved the evaluation of the 18 TESS installations at 10 sites across several California climate zones. Each site had at least one HVAC RTU, while three locations had two RTUs working together, and two locations had three RTUs working together to cool a shared space. For these locations, the data from all units were combined into one data set.

Baseline energy data were collected from the existing HVAC systems for six to eight months at each location. Post retrofit energy data was collected for an additional six to eight months at each location after TESS was installed.

### Energy Load Profiles

SEG used the industry standard, IPMVP Option B, to guide the data collection process and observed baseline and post retrofit data, averaged over 5-degree temperature buckets. A best-fit trendline was then applied to the data range. IPMVP recommends a best-fit trendline be used that may include linear, quadratic polynomial, or cubic polynomial. The trendline equation is applied to the 5-degree temperature buckets to create a best-fit energy use and peak demand profile.

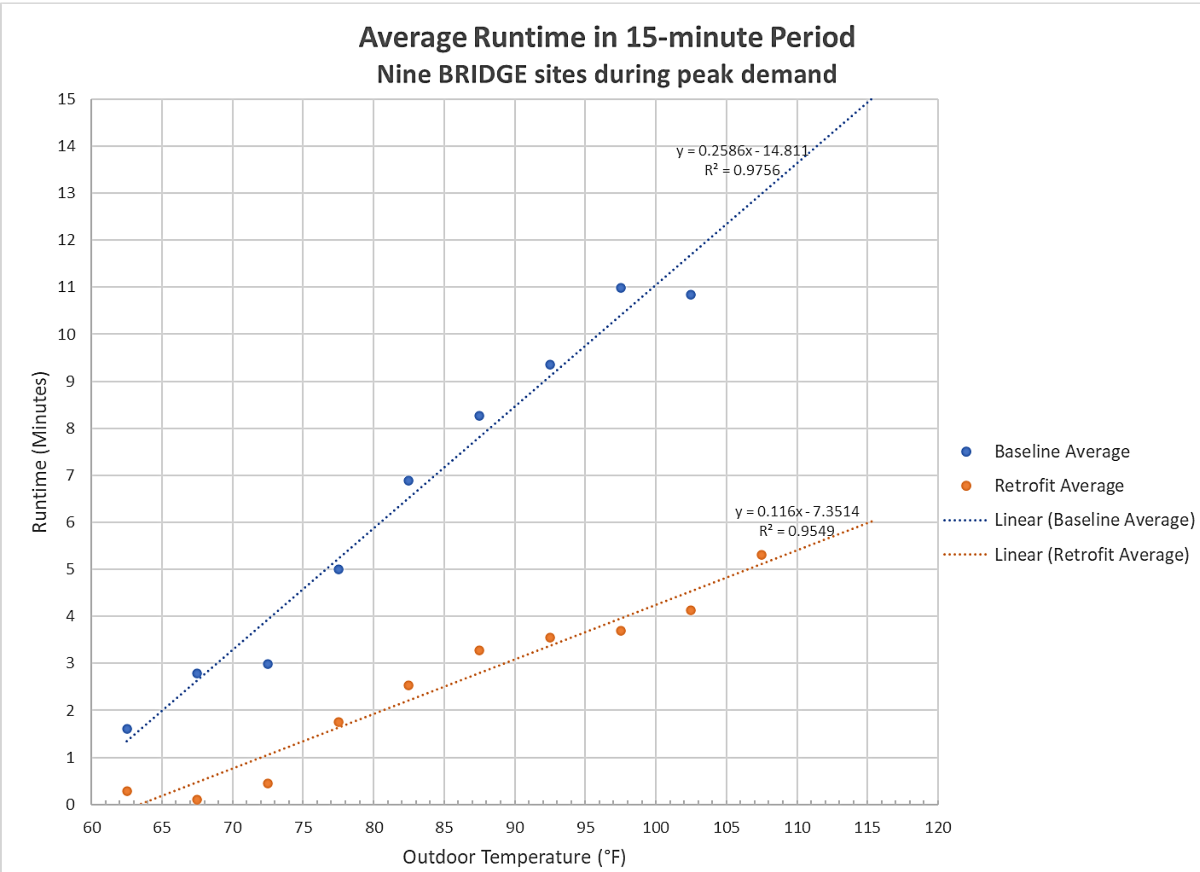
Energy use was summed over all the units for each time period analyzed. Three different time periods were captured including 1) total occupied kilowatt-hour (kWh), 2) occupied to closure kWh, and 3) 4:00 p.m. to closure kWh. A kilowatt-hour is a unit of measurement of electricity that measures how much energy a device uses over a period of time, or one kilowatt of power used for one hour. Kilowatt-hour is different from kilowatt (kW), which measures power, or the rate at which something uses energy. Kilowatt-hour factors in both how many watts a device uses and how often it is used.

- The first time period is the total occupied kWh period, which captured energy used while occupants were physically present at the facility.
- The second time period is the occupied to close kWh period, which captured energy used when occupants were physically present at the facility and all the way to facility closure, whether or not occupants remained present at the facility.
- The third time period is the 4:00 p.m. to closure kWh period, which captured energy used between the peak period starting at 4:00 p.m. all the way to facility closure.
- The coincidental peak kW was calculated by summing the individual maximum peak kW from each unit.

## Equivalency Curve

A simple illustration of peak demand reduction from TESS can be seen in the 'equivalency curve' labeled Figure 5. During peak hours (from 4pm forward), the average duty cycle of the compressor during any 15-minute period versus the outdoor ambient temperature for that period, for both baseline and retrofit.

**Figure 5: Load Shifting and Load Flexibility Achievements**




Source: Stasis Energy Group

During peak hours, when the system is instructed to discharge its thermal load, the slope of the curve drops by 55% for retrofit compared with baseline. This reduction in slope is commensurate with the reduction in power seen using more detailed analysis of the report. This equivalency curve thus provides a simple method for both analyzing and visualizing the performance of the TESS.

## Data Quality

A summary of the data quality was given for each TESS unit. This included the number of TESS performance period days excluded for data loss, holidays, and non-routine facility changes. Non-routine facility changes included days where abnormal facility behavior or hours took place. Examples are doors or windows being left open for extended periods of time, changes in lighting fixtures or machinery, and other factors. Facility changes were obtained through surveys sent to facility managers during the TESS performance period.

## Annual Energy Efficiency (EE) and Load Shifting Savings

Table 3 exhibits the estimated annual EE and load shifting savings attributable to the TESS product across all sites.

**Table 3: Estimated Annual Energy Savings**

| Site | Baseline Annual Energy Use (kWh) | Retrofit Annual Energy Use (kWh) | Estimated Annual Energy Efficiency Savings (kWh) | Estimated Annual Energy Efficiency Savings % | Estimated Annual Load Shift Savings (kWh) | Estimated Annual Load Shift Savings % |
|---|---|---|---|---|---|---|
| El Monte | 16,984 | 13,174 | 3,810 | 22% | 1,323 | 38% |
| Long Beach 1 | 6,514 | 3,731 | 2,783 | 43% | 546 | 44% |
| Long Beach 2 | 3,947 | 1,746 | 2,201 | 56% | 423 | 54% |
| San Diego 1 | 7,719 | 5,823 | 1,896 | 25% | 874 | 55% |
| Monterey Park | 8,093 | 9,060 | -966 | -12% | 582 | 23% |
| San Diego 2 | 12,035 | 9,948 | 2,088 | 17% | 1,871 | 65% |
| Fresno | 9,337 | 11,649 | -2,311 | -25% | 541 | 27% |
| Redlands | 5,002 | 5,437 | -435 | -9% | 299 | 49% |
| Sacramento | 10,963 | 10,669 | 294 | 3% | 383 | 42% |
| Thousand Oaks | 14,544 | 11,700 | 2,844 | 20% | 1,251 | 55% |
| Orange | 11,785 | 10,523 | 1,262 | 11% | 776 | 59% |
| **All Sites** | **106,924** | **93,459** | **13,465** | **13%** | **8,869** | **46%** |

Source: Stasis Energy Group

Three of the 10 sites had negative energy efficiency savings due to oversized storage with too much phase change material causing unnecessary overcharging, which cuts down on total energy efficiency benefit. At the time of project enrollment, there were several unknown variables at these sites such as unfamiliarity with the customer's rooftop unit configuration, unknown HVAC usage patterns and operational issues, broken economizers, improperly set fresh air ventilation settings, and broken ducting. Had these issues been identified during the screening process, other suitable sites would have been selected.

## Annual Estimated Greenhouse Gas Emission Savings

The GHG emissions associated with the use of electricity depend on the resource fuel mix used to generate the electricity and the emissions from each resource fuel mix that generated the electricity. An electric supplier's resource fuel mix changes from year to year. For example, renewable solar and hydropower generation resources typically do not emit GHG emissions, while natural gas and coal-fired power plants fuel mixes do. Thus, depending on an electric supplier's resource fuel mix in a given year, the annual estimated GHG emission savings will change accordingly.

Using the Climate Registry 2022 emission rates for calculating California's grid electricity emissions,[12] this study identifies three GHG emission reduction factor sources for potential use as shown in Table 4. This includes calculating 2022 GHG emission factors using either the Climate Leadership, SCE Portfolio, or U.S. Environmental Protection Agency (U.S. EPA) GHG's calculation approach.[13]

However, the project team selected the Climate Registry's GHG emission reduction savings approach to quantify GHG emission reduction benefits because the values include statewide values across California and are not specific to one geographic area.

**Table 4: Summary of 2022 GHG Emission Factors**

| Source | Electrical GHG Emission Factor (Co2e metric tons / MWh) | All SEG Field Test Sites Annual Energy Savings (MWh/yr.) | GHG Emission Reduction (CO2e/yr.) |
|---|---|---|---|
| Climate Leadership (CAMX California) | 0.23 | 22.33 | 5.13 |
| SCE Portfolio | 0.20 | 22.33 | 4.47 |
| U.S. EPA National Level | 0.37 | 22.33 | 8.26 |

Source: Stasis Energy Group

As shown in Table 4, both the Climate Leadership (0.23) and SCE Portfolio (0.20) GHG emission factors are similar while the U.S. EPA emission factor (0.37) is significantly different. These emission factor differences are attributed to the area represented by each entity listed above. California uses the Climate Leadership; SCE uses its SCE Corporate Responsibility Report for its service territory, and the United States uses U.S. EPA for its GHG emission reduction estimates. The SCE Portfolio emission factor was taken from SCE's 2022 Corporate Responsibility Report, while the U.S. EPA GHG emission factor was referenced for comparison purposes only.

## Example of Project Site Data Analysis

The following section illustrates the analysis results of 1 of the 10 locations studied in this project. The analysis results of the other nine project locations can be found in the appendix. The Orange project site is a commercial office space with an attached unconditioned storage warehouse that operates from 7:30 a.m. to 5:00 p.m. with three single compressor HVAC units. Two units are 3-ton units with heat pumps and the third unit is a 3.3-ton gas/electric unit.

[12] https://theclimateregistry.org/resources/protocols/

[13] https://www.epa.gov/egrid/power-profiler#/CAMX

As shown in Table 5, baseline data was collected between April 1, 2022, and December 23, 2022 (160 days in total). During that eight-month baseline data collection period, the daily max outside air temperature ranged between 55°F (13°C) and 101°F (38°C). Observed data was averaged over 5-degree increments through temperature buckets labeled as Max Outside Air Temp. A best-fit trendline was then applied to the data range. The best-fit trendline may be presented in the form of a linear, a quadratic polynomial, or a cubic polynomial. The trendline equation was then applied to the temperature range to create a best-fit energy usage and peak demand table.

**Table 5: Orange Project Site Baseline Performance Regression Summary**

| Max Outside Air Temp (°F) | Total Occupied kWh | Occupied to 4:00 p.m. kWh | 4:00 p.m. to Closure kWh | 4:00 p.m. to Closure kW |
|---|---|---|---|---|
| **62** | 17.02 | 15.64 | 1.38 | 1.14 |
| **67** | 17.16 | 15.64 | 1.53 | 2.86 |
| **72** | 21.44 | 19.26 | 2.18 | 4.43 |
| **77** | 28.83 | 25.62 | 3.21 | 5.83 |
| **82** | 38.33 | 33.85 | 4.49 | 7.09 |
| **87** | 48.93 | 43.06 | 5.88 | 8.18 |
| **92** | 59.61 | 52.37 | 7.25 | 9.12 |
| **97** | 69.37 | 60.90 | 8.47 | 9.91 |
| **102** | 77.19 | 67.78 | 9.41 | 10.53 |
| **107** | 82.05 | 72.12 | 9.94 | 11.01 |

Source: Stasis Energy Group

Table 6 provides the post-retrofit performance regression summary data.

**Table 6: Orange Project Site Post-Retrofit Performance Regression Summary**

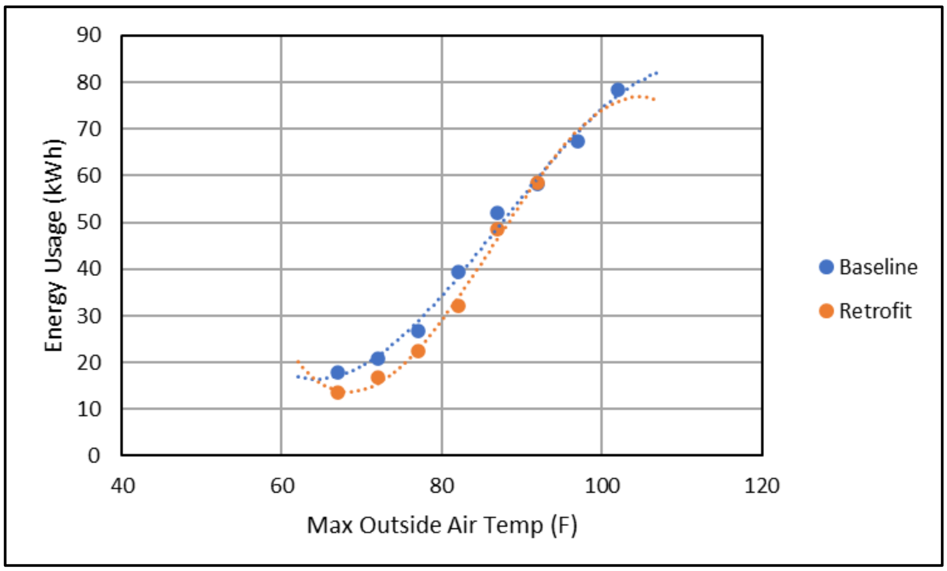
| Max Outside Air Temp (F) | Total Occupied kWh | Occupied to 4:00 p.m. kWh | 4:00 p.m. to Closure kWh | 4:00 p.m. to Closure kW |
|---|---|---|---|---|
| **62** | 20.19 | 19.68 | 0.12 | 0.21 |
| **67** | 13.99 | 13.38 | 0.58 | 0.88 |
| **72** | 15.51 | 14.55 | 1.03 | 1.49 |
| **77** | 22.76 | 21.31 | 1.48 | 2.04 |
| **82** | 33.78 | 31.79 | 1.94 | 2.53 |
| **87** | 46.58 | 44.12 | 2.39 | 2.97 |
| **92** | 59.19 | 56.41 | 2.84 | 3.35 |
| **97** | 69.63 | 66.79 | 3.30 | 3.67 |

| Max Outside Air Temp (F) | Total Occupied kWh | Occupied to 4:00 p.m. kWh | 4:00 p.m. to Closure kWh | 4:00 p.m. to Closure kW |
|---|---|---|---|---|
| **102** | 75.93 | 73.39 | 3.75 | 3.94 |
| **107** | 76.10 | 74.33 | 4.20 | 4.15 |

Source: Stasis Energy Group

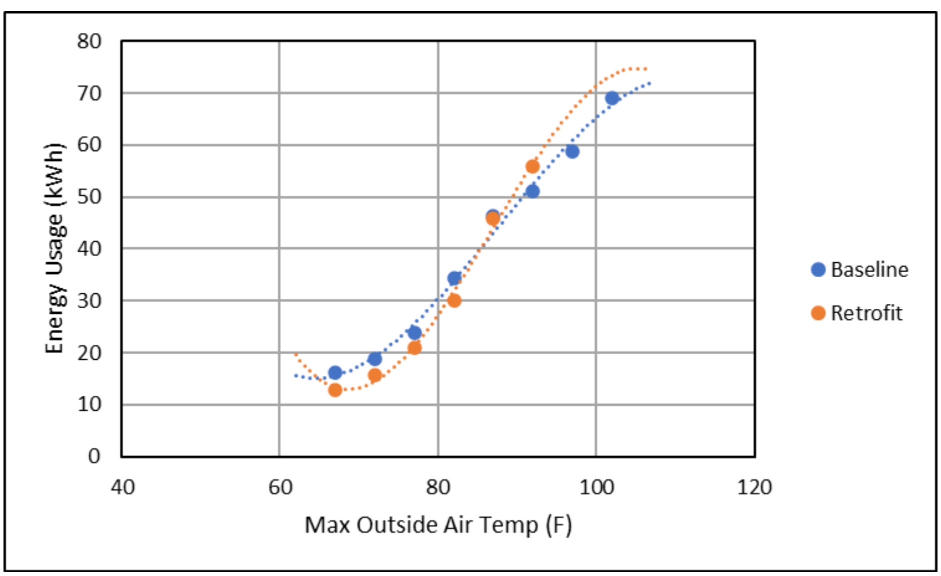
Figures 6 through 9 and Tables 7 and 8 provide various baseline and post-retrofit comparisons for regression performance graphs and supporting data demonstrating both peak load reduction and load shifting benefits.

**Figure 6: Orange Project Site Total Occupied kWh**



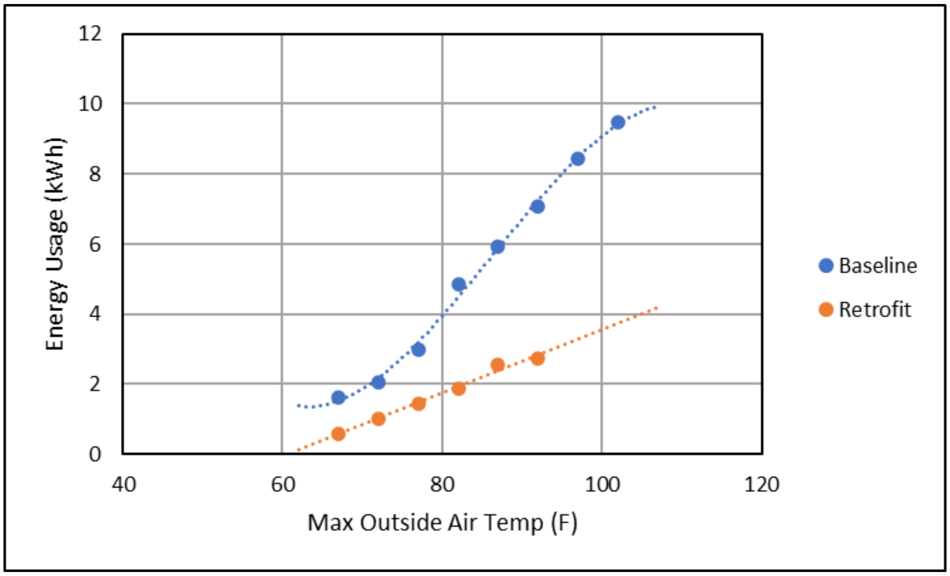

Source: Stasis Energy Group

**Figure 7: Orange Project Site Occupied to 4:00 p.m. kWh**



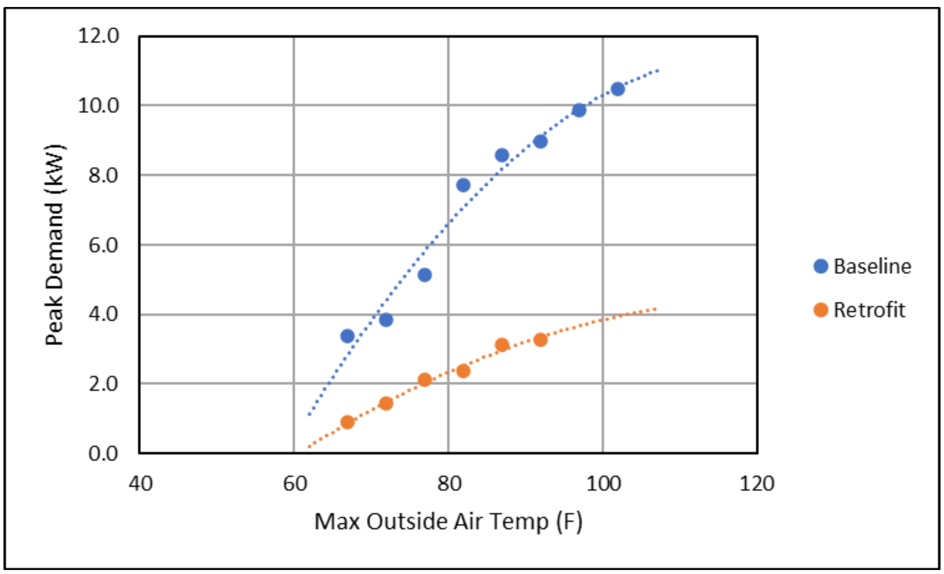

Source: Stasis Energy Group

**Figure 8: Orange Project Site 4:00 p.m. to Closure Peak kWh (Load Shifting)**




Source: Stasis Energy Group

**Figure 9: Orange Project Site 4:00 p.m. to Closure Peak kW (Load Reduction)**




Source: Stasis Energy Group

**Table 7: Orange Project Site Load Shifting Summary**

| Max Outside Air Temp (F) | Baseline kWh | Retrofit kWh | kWh Shifted | kWh Shifted % |
|---|---|---|---|---|
| **62** | 1.38 | 0.12 | 1.26 | 91% |
| **67** | 1.53 | 0.58 | 0.95 | 62% |
| **72** | 2.18 | 1.03 | 1.15 | 53% |
| **77** | 3.21 | 1.48 | 1.73 | 54% |

| Max Outside Air Temp (F) | Baseline kWh | Retrofit kWh | kWh Shifted | kWh Shifted % |
|---|---|---|---|---|
| **82** | 4.49 | 1.94 | 2.55 | 57% |
| **87** | 5.88 | 2.39 | 3.49 | 59% |
| **92** | 7.25 | 2.84 | 4.40 | 61% |
| **97** | 8.47 | 3.30 | 5.17 | 61% |
| **102** | 9.41 | 3.75 | 5.66 | 60% |
| **107** | 9.94 | 4.20 | 5.73 | 58% |

Source: Stasis Energy Group

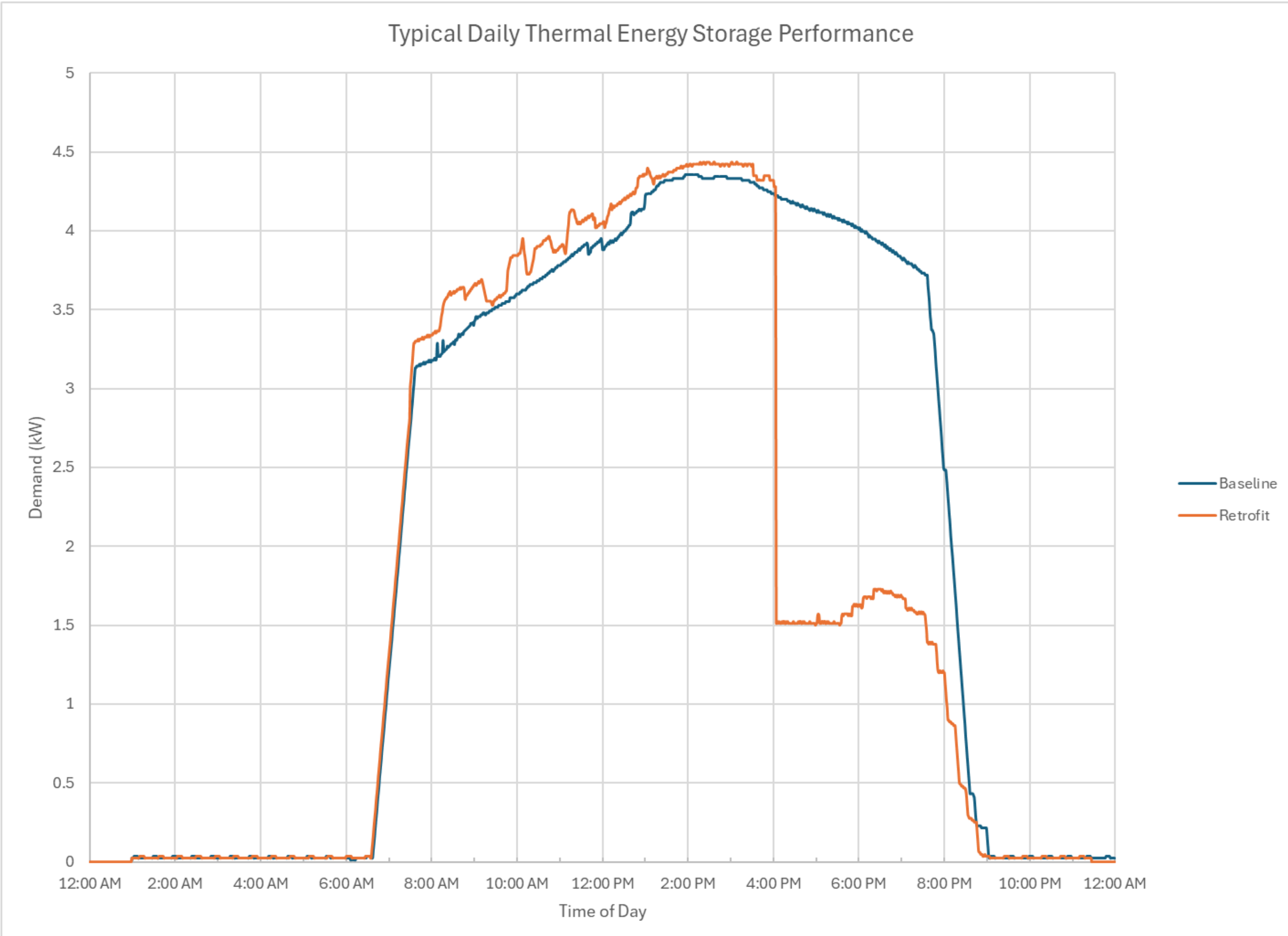
**Table 8: Orange Project Site Max kW Peak Load Reduction from 4:00 p.m. to Closure**

| Max Outside Air Temp (F) | Baseline Max kW | Retrofit Max kW | kW Reduction | kW Reduction % |
|---|---|---|---|---|
| **62** | 1.14 | 0.21 | 0.93 | 81% |
| **67** | 2.86 | 0.88 | 1.98 | 69% |
| **72** | 4.43 | 1.49 | 2.94 | 66% |
| **77** | 5.83 | 2.04 | 3.79 | 65% |
| **82** | 7.09 | 2.53 | 4.55 | 64% |
| **87** | 8.18 | 2.97 | 5.21 | 64% |
| **92** | 9.12 | 3.35 | 5.77 | 63% |
| **97** | 9.91 | 3.67 | 6.23 | 63% |
| **102** | 10.53 | 3.94 | 6.59 | 63% |
| **107** | 11.01 | 4.15 | 6.86 | 62% |

Source: Stasis Energy Group

Figure 10 shows the typical daily energy use profile of baseline versus energy use once the thermal storage system is installed. Typical energy consumption is modified significantly from baseline, in that more energy is used during early in the day to charge the thermal storage system and less energy is used later in the day to provide cooling during peak demand periods. The thermal energy use profile clearly shows the shift in consumption away from late-day and carbon-sourced energy to early-day and renewable-sourced energy. This change in use behavior is the most significant benefit of the Stasis thermal storage system – using more energy during the early day, when it is more efficient to create cooling due to lower ambient temperatures and when renewable energy is plentiful, and deploying late in the day when renewable energy is diminishing and reliance on carbon fuel sources increases.

**Figure 10: Load Shifting Sample Profile**




Source: Stasis Energy Group

In Table 9, the values are calculated using the maximum measured ambient temperature for each month and regression profiles are created for the baseline and post retrofit datasets. Summer utility TOU tariffs occur between June and September. The summer run time regression results are calculated using the regression profiles created using the average compressor run times.

**Table 9: Orange Project Site Peak Load Reduction Summary**

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | Summer Run Time Regression Results |
|---|---|---|---|---|
| Jan | 81 | 4.6 | 64% | |
| Feb | 90 | 5.8 | 63% | |
| Mar | 87.1 | 5.2 | 64% | |
| Apr | 100.9 | 6.6 | 63% | |
| May | 91.9 | 5.8 | 63% | |

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | Summer Run Time Regression Results |
|---|---|---|---|---|
| Jun | 96.1 | 6.2 | 63% | 62% |
| Jul | 90 | 5.8 | 63% | 63% |
| Aug | 100.9 | 6.6 | 63% | 61% |
| Sep | 109.9 | 6.9 | 62% | 61% |
| Oct | 95 | 6.2 | 63% | |

Source: Stasis Energy Group

Table 10 illustrates the kWh savings and shift values for the Orange project site where daily and seasonal (total summer and total winter) load shifting benefits and annual operational energy savings were generated from the regression values from the field data captured. For each temperature bin, the total kWh saved in summer was calculated by multiplying the number of summer days by the estimated daily occupied kWh savings generated from the regression models. The same methodology was applied to calculate the total kWh saved in winter.

The total kWh shifted in summer for each temperature bin was calculated by multiplying the number of summer days by the estimated daily 4:00 p.m. to closure kWh reduction value.

**Table 10: Orange Project Peak kWh Shift and Energy Savings**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Estimate Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Estimated Daily 4:00 p.m. to Closure kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 37 | -3.2 | 0.0 | -117.7 | 1.3 | 0.0 | 46.6 |
| 65 | 70 | 0 | 35 | 3.2 | 0.0 | 111.0 | 1.0 | 0.0 | 33.3 |
| 70 | 75 | 0 | 74 | 5.9 | 0.0 | 438.8 | 1.2 | 0.0 | 85.1 |
| 75 | 80 | 23 | 42 | 6.1 | 139.6 | 254.9 | 1.7 | 39.8 | 72.7 |
| 80 | 85 | 45 | 31 | 4.6 | 205.2 | 141.4 | 2.6 | 114.8 | 79.1 |
| 85 | 90 | 18 | 10 | 2.4 | 42.3 | 23.5 | 3.5 | 62.8 | 34.9 |
| 90 | 95 | 25 | 5 | 0.4 | 10.5 | 2.1 | 4.4 | 110.0 | 22.0 |
| 95 | 100 | 7 | 1 | -0.3 | -1.8 | -0.3 | 5.2 | 36.2 | 5.2 |
| 100 | 105 | 3 | 2 | 1.3 | 3.8 | 2.5 | 5.7 | 17.0 | 11.3 |
| 105 | 110 | 1 | 0 | 6.0 | 6.0 | 0.0 | 5.7 | 5.7 | 0.0 |

Source: Stasis Energy Group

### Utility Bill Operational Savings for the Building Owner

Installing TESS at the Orange project site facility yielded a 63 percent kW reduction and a 60 percent kWh shift. TESS also yielded an estimated annual energy savings of 11 percent. Financial savings were estimated using this performance data collected at the Orange project site. Based on SCE's tariff rates, this Orange project site experienced operational savings, which are broken out by peak demand kW reduction, energy load shifting kWh savings, and energy kWh savings as shown in Table 11.

**Table 11: Orange Project Site Utility Bill Operational Savings Benefit**

| Utility Bill Operational Benefit Description | Savings Benefit ($) |
|---|---|
| Peak Demand kW Reduction | $2,343.33 |
| Energy Load Shift kWh Savings | $88.35 |
| Energy Efficiency kWh Savings | $187.97 |
| **Total Utility Bill Operational Savings Benefit** | **$2,619.65** |

Source: Stasis Energy Group

## Lessons Learned

### Manufacturing Process Improvement

The panel design manufacturing process moved from Ohio to California in 2021. This significantly cut down supply chain delivery time and reduced transportation costs, which reduced the overall pricing for the project. Transitioning the manufacturing domestically allows for tighter controls and provides the opportunity for local oversight to ensure TESS is manufactured to the highest quality while also providing a local presence should equipment failure occur.

### TESS Design and Supply Chain Manufacturing Improvements

Throughout the project, TESS design was improved through adopting a more efficient and faster PCM filling process that reduced fluid loss. Moreover, manufacturing TESS in California allowed for tighter and more efficient quality control processes resulting in little to no product defects.

Additionally, pan fabrication was modified to increase volume and reduce costs. This modification allowed for multiple options for product deployment per site where product configuration occurred at each job more uniformly, avoiding customization. Lastly, the basic installation kits were developed to fix common installation issues that may have been missed during inspection.

### Future Site Selection Screening

Commonly, subsequent projects benefit from the "learning on the fly" mistakes experienced in the earlier projects. Some of the initial site selection enrollments experienced challenges in the screening process due to unknown or unanticipated variables during inspection.

Three of the ten sites had negative EE savings due to oversized storage with too much PCM causing unnecessary overcharging, which cut down on total EE benefit. Specifically, site variables at time of project enrollment included unknown HVAC usage patterns and operational issues, broken economizers, improperly set fresh air ventilation settings, and broken ducting. At one location, the project team was not familiar with HVAC configuration where a 4-ton HVAC unit was used in concert with a 6-ton HVAC unit. However, it was not known at the time of project enrollment that the 6-ton unit was oversized and rarely used, while the 4-ton unit did a majority of the cooling based on a couple of the perimeter office needs. The impact of the project resulted in negative EE savings. Had this fact been determined earlier in the screening process, there is a strong probability that negative annual energy savings would have occurred. Other key site selection criteria considerations included:

- RTU attributes such as use patterns, size, and occupancy.
- Operational issues such as non-working economizers, improperly set ventilation/fresh air, and broken ducting.
- Pre-installation considerations such as assessing the HVAC system before installing TESS to ensure optimum performance.

These were lessons learned as a direct result of this CEC-funded research. As indicated above, some preliminary site selection criteria issues were not known until the project was near completion. Had these site selection criteria issues been discovered earlier in the screening process, the project results for a couple of sites that experienced negative energy savings may have resulted in larger reduced peak kW demand, positive annual EE savings, and a more balanced and comfortable airflow for the occupants.

### Project Technical Barriers

Although SEG targeted numerous sites that were ready, willing, and able to enroll in the research project, a total of six potential sites were crossed off the list because the building configurations did not have siloed RTU zones and were influenced by adjacent spaces. This may be a common barrier for leased spaces that share an RTU.

### Project Financial Barriers

Nine of the ten field project sites indicated that they wanted to participate in the Bringing Rapid Innovation Development to Green Energy (BRIDGE) grant funding opportunity only if there was little to no upfront capital required from the customer to participate in the project. Therefore, future utility incentives play a critical role in influencing the purchasing decisions for small businesses.

### TESS Project Breakthroughs from CEC BRIDGE Research

As documented by previous field studies, PCM was used in building envelopes with limited success. Now, because of this project, there is data showing that changing the design of the PCM algorithm to an active approach is an improved application for PCM. This allowed TESS to simultaneously deliver significant load flexibility benefits, load shifting benefits, and annual EE savings to all potential end-use customers.

The passive PCM design approach relied heavily on the diurnal cycle to capture energy during the day and push that energy at night. In comparison, the active PCM design is not dependent on the diurnal cycle to address the load shifting market needs. Rather, when rapidly changing dynamic TOU patterns are combined with the programmable thermostat controller capabilities, the need to address the diurnal cycle has dissipated in comparison to the need to charge during the day and not at night.

### Active Design PCM Controls Approach

The TESS active design approach applied directly addresses both peak and off-peak periods of the "duck curve" problem. The belly of the duck is the excess renewable generation experienced by the grid, while the neck of the duck occurs when power plants start-up — going from shut down to fully operating. The TESS active design approach leverages a cloud-connected and remotely monitored platform that is combined with a programmable thermostat controller.

The TESS active design approach addresses both areas of the duck curve problem and is independent of the diurnal cycle because it can change temperature or air presented to the PCM using active controls when the PCM charges. Accordingly, TESS simultaneously charges while cooling the building without exceeding the air conditioning capacity needs because TESS leverages PCM cooling instead of mechanical AC compressor cooling to mitigate late-day compressor usage. This active design approach makes the system suitable for customers to participate in real time pricing utility tariff programs.

As described in **Chapter 2: Project Approach**, instead of waiting for the building to cool down at night, the active PCM approach controls when the PCM charges in order to target and focus when cooling is needed. TESS charges during morning and mid-day when there is surplus energy capacity and discharges during peak periods via the programmable thermostat controller. Without the TESS active design algorithms, the PCM media would deplete, and unacceptable drift would result.

### Product Safety

The PCM encapsulated by aluminum plates within TESS achieved the highest safety certification, Class A Plenum Fire Rating, which is 25 flame units and 50 smoke units. This makes TESS attractive for installers and building owners because TESS complies with applicable fire and building safety standards.

### Additional Lessons Learned

The following are additional lessons learned from this CEC-funded BRIDGE project.

- TESS is location agnostic.
- Healthy pre-installation conditions are imperative.
    - Airflow requirements, HVAC system balancing, fresh air, refrigerant, and so forth.
- Occupant comfort is key.
- Customer feedback is imperative.

- Room temperature does not necessarily correlate to occupant comfort.
- Next-generation TESS improvements were found in the data.
    - Example: oversized storage with too much PCM causes unnecessary overcharging, which cuts down on total EE benefit.
- New construction costs approximately 25 percent less than retrofits.
- Educating professional HVAC contractors on TESS is critically important to market adoption.

## Research Project Outcomes and Significance

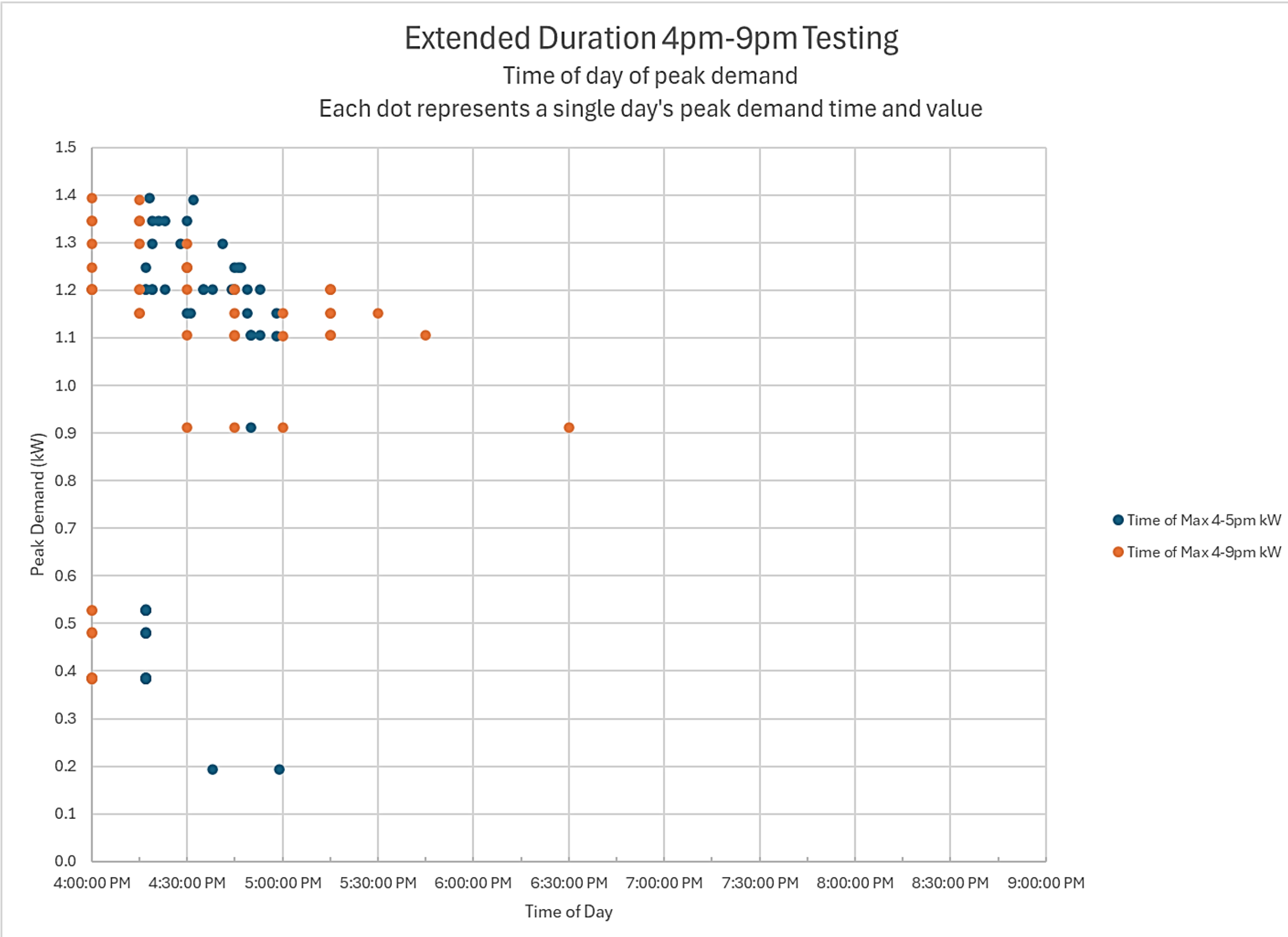
### Extended Duration

One of the primary objectives of this CEC-funded BRIDGE deployment was to reduce demand during peak periods. Peak demand occurs between 4:00 p.m. and 9:00 p.m. The study focused on reducing compressor operational run time during 4:00 p.m. to the end of the building's occupancy period as defined by the user. None of the sites enrolled had any occupancy for the entire duration of the peak demand period.

After fulfilling the requirements of the study, the project team decided to extend the duration of several sites to 9:00 p.m. to measure the impact of an extended deployment of TESS. With the external heat load on the building declining in the evening hours, the cooling load for TESS reduces. Accordingly, the window of peak kW measured with TESS was found between 4:00 p.m. and 5:00 p.m.

The data indicated that when TESS is sized for a peak day, the TESS operational duration can be extended to 9:00 p.m. while maintaining reduced demand. The data shown in Figure 11 illustrates extended TESS operational duration across several sites, which directly supports SB 846 statewide load shifting goals and future development of the statewide demand flexibility strategy and rates.

**Figure 11: Extended Duration Testing Capturing the Entire Peak Demand Period**




Source: Stasis Energy Group

# Broad Audience Awareness and Technology Transfer Opportunities

## 1. CalFUSE Dynamic Pricing Pilot Program

Governor Newsom issued an emergency proclamation in 2021 to ensure the reliability of electrical service during extreme weather events.[14] Accordingly, SCE was required to administer a Flexible Pricing Rate Pilot that is designed to demonstrate a dynamic pricing conceptual framework whereby near-term solutions address longer-term challenges associated with integrating renewables, reducing GHG emissions, improving system reliability, and reducing or minimizing cost of service.[15]

The California Public Utilities Commission (CPUC) issued several recommendations as part of its CalFuse roadmap, including important considerations related to a statewide demand flexibility strategy to encourage third parties, automation service providers, and other device manufacturers to be directly involved in the development of the statewide demand flexibility

[14] SCE's CalFuse Dynamic Rate Pilot website: https://www.dret-ca.com/dynamic-rate-pilot/

[15] Ibid.

strategy and rates.[16] These recommended roadmap strategies enable stakeholders to automate and scale responsiveness to dynamic rates and achieve the full potential of load flexibility while making the experience user friendly for less sophisticated customers.

Given the importance of the CalFuse Roadmap, TESS demonstrates the ability to shift peak electrical loads and directly supports California's SB 846 load shifting goals through demand flexibility pilot programs, including CalFuse as shown in Figure 16.

## 2. Self-Generation Incentive Programs

TESS was approved for California's Self-Generation Incentive Program (SGIP), which provides incentives to support existing, new, and emerging distributed energy resources. SGIP provides incentives for qualifying distributed energy systems installed on the customer's side of the utility meter.[17] Qualifying technologies include wind turbines, waste heat to power technologies, pressure reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells, and advanced energy storage systems.[18]

SEG developed a physics-based model of TESS in the TRNSYS modeling software. The TESS component has proven to have an R2 of greater than 0.95 in modeling the output temperature of TESS given a variety of inlet conditions. When coupled with a user-defined building model, this high-precision TESS model provides the ability to accurately model the performance of a building with a variety of conditions and input variables. The TRNSYS software package has a proven record with CEC in the following areas:

- Solar-heated swimming pools (developed rating tool for CEC)
- Solar domestic hot water commercial / multifamily (developed CEC rating tool)
- Solar Ratings and Certification Corporation (certification of OG-300 solar water heating systems was done using TRNSYS engine)
- Support of the Title 24 rewrite of the 2023 swimming pool regulations update
- Modeling in support of a submission to the International Association of Plumbing and Mechanical Officials (IAPMO) for Title 24 equivalency with regards to domestic hot water insulation requirements

In running a typical small- to medium-sized commercial building within the TRNSYS calibrated model (CEC-funded demonstration), the output was equivalent to the measured data from BRIDGE sites. Table 12 illustrates output results using the same methodology performed for the other BRIDGE analytics, but with energy data created from the TRNSYS model.

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[16] Ibid.

[17] CPUC's Self-Generation Incentive Program website: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/self-generation-incentive-program

[18] Ibid.

**Table 12: TRNSYS Calibrated Modeling Output Results Alignment with Measured Data from BRIDGE Sites**

| Month | Max Ambient (°F) | TRNSYS kW Reduction | TRNSYS % kW Reduction | Run Time Regression Results |
|---|---|---|---|---|
| Jan | 80.6 | 1.1 | 48% | |
| Feb | 78.8 | 0.4 | 30% | |
| Mar | 82.4 | 1.1 | 48% | |
| Apr | 93.2 | 1.9 | 51% | |
| May | 95.0 | 2.3 | 57% | |
| Jun | 100.4 | 2.7 | 58% | 61% |
| Jul | 100.4 | 2.7 | 58% | 61% |
| Aug | 102.2 | 2.7 | 58% | 61% |
| Sep | 104.0 | 2.7 | 58% | 61% |
| Oct | 96.8 | 2.3 | 57% | |
| Nov | 89.6 | 1.3 | 44% | |
| Dec | 84.2 | 1.1 | 48% | |

Source: Stasis Energy Group

Furthermore, the TRNSYS calibrated model has proven to have a high level of accuracy in predicting energy and thermal performance of a building with the TESS technology. SEG is currently working with Lawrence Berkeley National Laboratory (LBNL) to use Modelica to model thermal energy storage simulations to align the two platforms. Thus, TESS's thermal energy storage performance both in the field and calibrated in the TRNSYS energy models demonstrates that TESS has tremendous market potential in the statewide SGIP programs.

Accordingly, SEG is in current discussions with California's utilities on enrolling customers as part of the SGIP program using the results from the field data from this project and the TRNSYS model results. Both the field data and TRNSYS model results contributed to SEGs acceptance in the SGIP program. The results from this CEC-funded research were used as a jumping point to create a standardized approach to quantifying benefits for commercial customer adopters while complying with CPUC regulatory mandates. Figure 12 illustrates the TRNSYS calibrated modeling thermal performance output results using the BRIDGE sites' field data.

**Figure 12: TRNSYS Calibrated Modeling Level of Accuracy of Predicting Energy and Thermal Performance Output Results**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 42 | 0.0 | 0.0 | -1.2 | 0.0 | 0.0 | 0.0 |
| 65 | 70 | 1 | 45 | 0.0 | 0.0 | -2.0 | 0.0 | 0.0 | 0.0 |
| 70 | 75 | 2 | 35 | -0.2 | -0.5 | -8.1 | 0.0 | 0.0 | 0.3 |
| 75 | 80 | 9 | 42 | -0.2 | -2.2 | -10.5 | 0.2 | 1.6 | 7.4 |
| 80 | 85 | 15 | 32 | 0.7 | 10.0 | 21.4 | 0.9 | 13.1 | 28.0 |
| 85 | 90 | 32 | 16 | 1.8 | 56.8 | 28.4 | 1.8 | 56.4 | 28.2 |
| 90 | 95 | 32 | 6 | 2.6 | 84.4 | 15.8 | 2.9 | 92.0 | 17.3 |
| 95 | 100 | 17 | 3 | 2.9 | 49.8 | 8.8 | 4.1 | 69.2 | 12.2 |
| 100 | 105 | 14 | 0 | 3.9 | 55.1 | 0.0 | 5.2 | 72.8 | 0.0 |
| 105 | 110 | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Source: Stasis Energy Group

## 3. CalTF Energy Efficiency Deemed and Custom Measure Development

At the California Technical Forum (CalTF) measure screening meeting in March 2024, TESS was presented to subject matter technical experts who could opine on the technology capabilities and benefits. TESS benefits and costs were shared to determine cost effectiveness and potential viability for adoption into the statewide EE incentive programs. Stakeholder feedback indicated that TESS provided EE savings and significant load shifting benefits that may qualify for additional credits for EE cost-effectiveness calculation regulatory purposes.

Subsequently, TESS was presented at the April 2024 CalTF meeting and again in July 2024, where a larger audience of CPUC staff regulators, statewide program utility administrators, engineering decision makers, and EE third-party implementers provided their input on how TESS should move through the statewide EE portfolio.

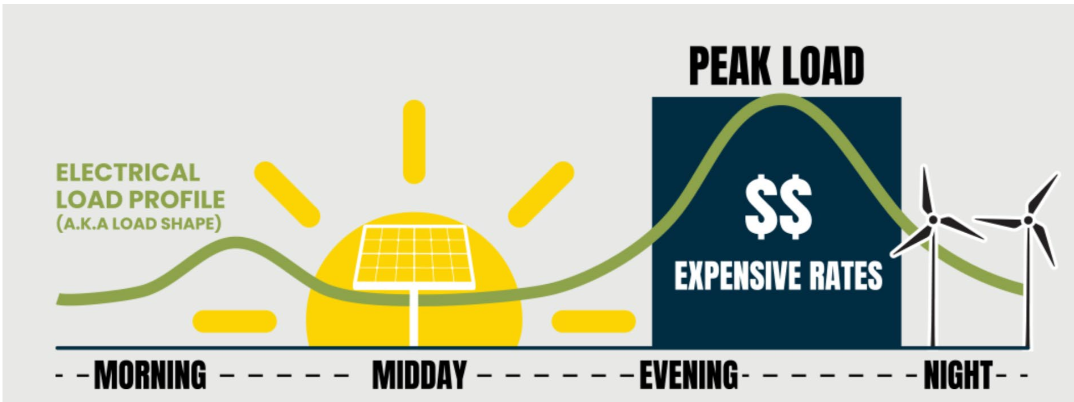
Based on this project's field research results, the CalTF recommended that TESS proceed to the development of a measure package in both statewide deemed rebates and custom incentive program offerings. Moreover, CalTF staff indicated that because the BRIDGE study installed TESS in several disadvantaged communities, the value TESS brings to California aligns with CPUC directives and supports customers with limited access to utility funding resources. With the support of various stakeholders, RMS Energy Consulting, LLC is leading the effort to collaborate with relevant stakeholders to get TESS vetted, approved, and adopted into statewide utility EE deemed rebate and custom incentive programs sometime in 2025 or 2026.

## 4. LBNL's CalFlex Hub and Partnership with SCE

The California Load Flexibility Research and Development Hub (CalFlexHub) is the innovation hub supporting the scaled adoption of affordable, equitable, and reliable load flexible technologies.[19] LBNL's CalFlexHub seeks to advance the capability of smart building technologies to provide flexible energy load for the State of California and beyond.[20]

Accordingly, CalFlexHub is partnering with SCE to conduct exploratory research to identify viable markets, quantify economic benefits and incentives, and determine market opportunities that allow for the successful adoption and deployment of affordable, equitable, and reliable load flexible technologies through regular dynamic price and greenhouse gas load shaping signals. Figure 13 is CalFlexHub's graphical depiction of the electrical load profile indicating when peak load occurs on the grid. SEG is currently working with CalFlexHub to investigate market drivers and identifying ways to remove market barriers to help scale TESS adoption.

**Figure 13: CalFlexHub's Electrical Load Profile Including Peak Load**




Source: LBNL

[19] Lawrence Berkley National Lab CalFlex Hub website: https://calflexhub.lbl.g
[20] Ibid.

# CHAPTER 4: Conclusion

## Technological Advancement and Breakthroughs

This Agreement is intended to lead to technological advancement and breakthroughs to overcome barriers to achievement of the State of California's statutory energy goals by supporting development of first-of-its-kind thermal energy storage technology. The project targeted a hard-to-reach segment of electricity usage, 4:00 p.m. -to 9:00 p.m., when energy demand is high and renewable contributions diminish.

As a result, GHG emissions savings of 5.13 metric tons of carbon dioxide were achieved annually across all sites, helping California meet its various statutory climate goals. This development and demonstration project can ensure this technology will reach maturity and be introduced significantly to the market.

This Agreement resulted in the ratepayer benefits of:

- **Greater Reliability:** The product aims to simplify the challenge facing grid operators by increasing use of daytime renewable energy and reducing use of late-afternoon and evening ramp-up energy, thus reducing the risk of energy shortages, public safety power shutoffs, brownouts, and blackouts.
- **Lower Costs:** The proposed technology is intended to lower the electricity costs of business owners by shifting their use out of peak periods. The Recipient's TESS should be capable of a wide range of energy shifting configurations to meet regional rate plans and grid challenges. It can save businesses electric bill expenses through reduced demand charges based on peak kW usage and by shifting kWh usage into lower priced periods.

## Benefits and Importance of TESS Research Project Outcomes

### Prepared for Commercialization at Scale (Project Purpose)

The project aimed to deploy 18 TESS installations across 10 different small commercial sites with 5 of those sites being located in disadvantaged communities across several California climatic zones. A desired outcome centered on implementing TESS with a comprehensive M&V plan that demonstrated cost benefits to California utilities and utility ratepayers. Another desired outcome entailed creating a technology transfer plan to accelerate commercialization of TESS, especially to small commercial facilities in HTR and disadvantaged communities. Through this research project, SEG helped California ratepayers simultaneously shift load and achieve both EE savings and peak demand reduction.

## Calculated Benefits to Grid Operators for Use in Developing Incentives to Drive Adoption (Technology Transfer Goals)

As part of the BRIDGE research effort, SEG created a Technology Transfer Plan and captured viable, immediate ways to accelerate the commercialization of the first of its kind TESS, especially to small commercial facilities in HTR and disadvantaged communities across several California climatic zones. The Technology Transfer Plan included key incentive stakeholder groups and mechanisms that can help policy makers move to a clean energy grid, support load shifting and load flexibility goals, and generate both EE savings and peak demand reduction.

## Demonstrated the Ability to Shift Electric Load Out of Peak Periods

This research is important to California because the state faces a significant challenge to transition to 100 percent renewable energy by 2045. Concurrently, SB 846 mandates 7000 MW of load flexibility by 2030. This goal is especially important during summer peak periods between 4:00 p.m. and 9:00 p.m. when solar renewable sources are not available, but HVAC energy use is necessary. Reducing HVAC energy use in existing buildings through the use of developed clean-energy technology such as TESS allows HVAC systems to shift air conditioning peak demand loads by an average of 46 percent during critical summer peak periods while achieving on average 13 percent EE savings on utility bills.

## Lowered Product First Costs to Less Than Five Years' Payback to Facilitate Market Adoption (Reduction in Cost)

Through this CEC-funded project, SEG increased installation efficiency enhancements through formfactor changes. These changes allowed for easier installation in the field, ramp up of assembly in the manufacturing facility to reduce expensive assembly time in the field, and leveraged off-the-shelf standard parts more frequently as opposed to custom parts.

Additionally, SEG was able to improve product and controller performance by incorporating better TESS shoulder season logic. This means, during the spring and fall months of the year when outdoor air temperature is lower, thermostats are programmed to bring in fresh air instead of AC compressor cooling.

As a result, SEG will modify and hard code future TESS algorithm logic to guarantee 60 percent load reduction for any facility's peak load design day and integrate ratepayer tariffs that yield better financial benefits for the same technology performance. Furthermore, SEG intends on deploying TESS with varying and refined thermal payload sizing algorithms that right-charge TESS to address both peak temperature days and cool days with minimal cooling.

Accordingly, the research findings indicate that TESS is viable not only in small business commercial markets, but that coupled with utility incentive programs, it could achieve significant grid and clean energy goals in other markets, such as commercial food service facilities and data centers.

## Market Opportunities

With transactive energy and flexible load management programs like CALFUSE, TESS can create a market opportunity that enables customers to choose when to use energy in a way that may be financially beneficial. More specifically, customers can now dynamically choose when to use or shift their energy load to help California's electric grid and their own bottom line through TOU dynamic rates. Listed below are the market opportunities where TESS can be installed and make immediate impacts.

### Residential

- TESS can be part of smart home appliances array for "set it and forget it" style of home management for users.
- TESS can be an additional system included in resources for a virtual power plant.
- TESS can be linked to communication to respond to DR utility programs.

### Permanent Load Shift or Similar Programs

- The CEC RAMP program can further accelerate TESS market adoption by providing financial assistance to help clean energy entrepreneurs successfully advance their emerging, innovative technology.
- Although statewide permanent load shift (PLS) programs are not currently available for TESS, there is interest in including TESS in other pilot programs such as CalFuse, CalNext, and statewide deemed and custom EE programs. There may also be opportunities to establish a statewide PLS program to meet current market demands as some IOU incentive programs are restrictive and siloed to focus on individualized program metrics, such as EE savings, only with consideration to load shift. Thus, bringing back a discussion around PLS may help bridge knowledge gaps and present viable market opportunities.

## Summary of Recommendations

The project team recommends that future research is funded to demonstrate that TESS can contribute to flexible DR programs, such as CALFUSE. Dynamic rates are the future to achieving the 100 percent clean energy grid California seeks to achieve. Additionally, demonstrating the benefits of TESS in the near future via pilot or incentive programs creates a pathway for TESS to be adopted into the codes and standards rulemaking process and become a requirement in future Title 24 Building Codes.

## Other TESS Recommendations

- TESS should be adopted into the SGIP program.
- Tariffs should better demonstrate load flexibility savings.
- Incentive programs should pay for load flexibility and deviate from outdated EE policies.

# GLOSSARY AND LIST OF ACRONYMS

| Term | Definition |
|---|---|
| AC | air conditioning |
| BRIDGE | Bringing Rapid Innovation Development to Green Energy |
| CalFuse | Flexible Unified Signal for Energy in California |
| CalFlexHub | California Load Flexibility Research and Development Hub |
| CalTF | California Technical Forum |
| CEC | California Energy Commission |
| CPUC (California Public Utilities Commission) | State agency responsible for regulating privately owned electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies. |
| disadvantaged community | A regulatory policy term used by federal and State agencies to identify communities eligible for different types of assistance. Different programs use different definitions and criteria to identify disadvantaged communities (for example, some target communities at risk for health and safety issues due to environmental and other factors, others target populations based on economic factors). |
| DR (demand response) | Short-term changes in electric usage made in response to price signals, incentives, or operating agreements to support electric reliability. |
| DSM (demand side management) | Programs that reduce energy and water usage through user (customer) conservation and efficiency. |
| EE (energy efficiency) | Using less energy to perform the same unit of work. |
| GHG (greenhouse gas) emissions | Any gas that absorbs infrared radiation in the atmosphere and contributes to global warming (for example, water vapor, methane, nitrous oxide, hydrochlorofluorocarbons, ozone, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride). |
| HTR | hard to reach |
| HVAC | heating, ventilation, and air conditioning |
| IOU | investor-owned utility |
| IPMVP | International Performance Measurement and Verification Protocol |
| kW | A measurement of power, or the rate at which something uses energy |
| kWh (kilowatt hour) | One kWh is the use of one kilowatt of electricity for one hour. |
| LBNL | Lawrence Berkley National Lab |
| M&V | Measurement & Verification |

| Term | Definition |
| --- | --- |
| MTCO2e (Metric Tonne of CO2 Equivalents) | One metric tonne (2204.6 pounds) of greenhouse gases |
| PCM | phase change material |
| PLS | permanent load shifting |
| RTU | rooftop package unit |
| SEG | Stasis Energy Group |
| SGIP | Self-Generation Incentive Program |
| TESS | thermal energy storage system |
| Title 24 | California Code of Regulations, Building Standards Code. California's Plumbing Code resides within Title 24, Part 5. |
| TOU | time of use |
| U.S. EPA | U.S. Environmental Protection Agency |

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# Project Deliverables

## Key Technical Tasks

The agreement scope of work included the following products, which were delivered to the CEC over the course of the project:

- TASK 2: Pre-Installation Operations Planning
  - List of Deployment Sites
  - Product Refinement Plan
  - Controller Logic Refinement Plan
- TASK 3: Measurement & Verification (M&V) Plan
  - Measurement & Verification Plan (draft)
  - Measurement & Verification Plan (final)
  - Baseline and TESS Instrumentation and Installation Plan (draft)
  - Baseline and TESS Instrumentation and Installation Plan (final)
- TASK 4: Product and Controls Improvement
  - TESS Design Summary Report
  - Controller Logic v 2.0 Design Summary Report
- TASK 5: Instrumentation Installation and Baseline Performance Monitoring
  - Baseline Data Monitoring Report (draft)
  - Baseline Data Monitoring Report (final)
- TASK 6: Product Installation and TESS Performance Monitoring
  - TESS Data Monitoring Report (draft)
  - TESS Data Monitoring Report (final)
- TASK 7: Demonstration Sites Analysis and Performance Review
  - Pilot Site Case Study Report (draft)
  - Pilot Site Case Study Report (final)

These project deliverables, including interim project reports, are available upon request by submitting an email to pubs@energy.ca.gov.

CALIFORNIA ENERGY COMMISSION

**ENERGY RESEARCH AND DEVELOPMENT DIVISION**

# APPENDIX A: BRIDGE Pilot Sites Summary Tables

**April 2025 | CEC-500-2025-015**

# APPENDIX A: BRIDGE Pilot Sites Summary Tables

The three figures below describe the highest level summary of technical performance, modeling, and financial results achieved under the CEC BRIDGE project.

### Figure A-1: Measured Technical Performance Results

| Specifications | | | | Measured Data | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| City | IOU | SQFT Per Ton | Total Units' Tonnage For Project | % Maximum kW Reduced | Maximum kW Reduced | % Annual kWh Load Shifted | Annual kWh Load Shifted | % Annual kWh Saved | Annual kWh Saved |
| Thousand Oaks | SCE | 330 | 10-tons | 70% | 6.4 | 53% | 981 | 18% | 2309 |
| Long Beach | SCE | 234 | 3-tons | 56% | 1.8 | 44% | 515 | 45% | 2799 |
| Long Beach | SCE | 367 | 3-tons | 51% | 1.0 | 55% | 411 | 58% | 2174 |
| El Monte | SCE | 500 | 15-tons | 50% | 7.1 | 36% | 1013 | 27% | 3787 |
| Monterey Park | SCE | 413 | 8-tons | 61% | 5.0 | 23% | 467 | -11% | -697 |
| Orange | SCE | 484 | 9.3-tons | 63% | 6.2 | 59% | 656 | 12% | 1207 |
| Redlands | SCE | 220 | 5-tons | 64% | 3.9 | 47% | 223 | -10% | -372 |
| Fresno | PGE | 185 | 10-tons | 52% | 4.9 | 22% | 378 | -28% | -2226 |
| Sacramento | PGE | 427 | 7.5-tons | 50% | 4.6 | 40% | 324 | 4% | 396 |
| San Diego | SDGE | 333 | 6-tons | 79% | 4.0 | 54% | 818 | 25% | 1854 |
| San Diego | SDGE | 294 | 8.5-tons | 67% | 3.2 | 67% | 1582 | 22% | 2146 |

### Figure A-2: Predictive Model Results

| Specifications | | | Measured | | | ASHRAE 0.1% Dry Bulb Design Day | | | | M&V Alternate |
|---|---|---|---|---|---|---|---|---|---|---|
| City | IOU | SQFT Per Ton | % Maximum kW Reduced | % Annual kWh Load Shifted | % Annual kWh Saved | Design Day Temp (°F) | Design Day % Peak kW Reduced | Design Day % Peak kWh Shifted | Design Day % kWh Saved | SEG Model kW % Reduction |
| Thousand Oaks | SCE | 330 | 70% | 53% | 18% | 103 | 67% | 56% | 8% | 61% |
| Long Beach | SCE | 234 | 56% | 44% | 45% | 97 | 56% | 47% | 25% | 62% |
| Long Beach | SCE | 367 | 51% | 55% | 58% | 97 | 51% | 45% | 40% | 62% |
| El Monte | SCE | 500 | 50% | 36% | 27% | 101 | 50% | 45% | 6% | 61% |
| Monterey Park | SCE | 413 | 61% | 23% | -11% | 101 | 57% | 56% | 8% | 61% |
| Orange | SCE | 484 | 63% | 59% | 12% | 100 | 63% | 60% | 2% | 61% |
| Redlands | SCE | 220 | 64% | 47% | -10% | 106 | 59% | 59% | 10% | 61% |
| Fresno | PGE | 185 | 52% | 22% | -28% | 104 | 52% | 48% | -11% | 61% |
| Sacramento | PGE | 427 | 50% | 40% | 4% | 104 | 52% | 55% | -6% | 61% |
| San Diego | SDGE | 333 | 79% | 54% | 25% | 97 | 81% | 70% | 34% | 62% |
| San Diego | SDGE | 294 | 67% | 67% | 22% | 97 | 41% | 54% | -8% | 62% |

### Figure A-3: Financial Results

| Specifications | | | Tariff In-place | | | AL-TOU Tariff | | |
|---|---|---|---|---|---|---|---|---|
| City | IOU | SQFT Per Ton | Annual Savings | Savings Per Ton | Tariff | Annual Savings | Savings Per Ton | Tariff |
| housand Oak | SCE | 330 | $1,202.33 | $120.23 | GS-1-TOU-E | $2,886.21 | $288.62 | SDG&E AL-TOU |
| Long Beach | SCE | 234 | $872.67 | $290.89 | GS-2-TOU-D | $1,115.01 | $371.67 | SDG&E AL-TOU |
| Long Beach | SCE | 367 | $602.93 | $200.98 | GS-2-TOU-D | $753.75 | $251.25 | SDG&E AL-TOU |
| El Monte | SCE | 500 | $2,229.38 | $148.63 | GS-2-TOU-D | $3,152.88 | $210.19 | SDG&E AL-TOU |
| Monterey Park | SCE | 413 | -$6.01 | -$0.75 | GS-1-TOU-E | $1,791.80 | $223.97 | SDG&E AL-TOU |
| Orange | SCE | 484 | $609.05 | $65.49 | GS-1-TOU-E | $2,619.65 | $275.75 | SDG&E AL-TOU |
| Redlands | SCE | 220 | $785.40 | $157.08 | SCE-TOU-8-D | $1,186.46 | $237.29 | SDG&E AL-TOU |
| Fresno | PGE | 185 | -$952.21 | -$95.22 | PG&E B-1 | $951.11 | $95.11 | SDG&E AL-TOU |
| Sacramento | PGE | 427 | $101.51 | $13.53 | PG&E B-10 | $1,179.09 | $157.21 | SDG&E AL-TOU |
| San Diego | SDGE | 333 | N/A | N/A | N/A | $1,782.90 | $297.15 | SDG&E AL-TOU |
| San Diego | SDGE | 294 | N/A | N/A | N/A | $1,466.87 | $172.57 | SDG&E AL-TOU |

## BRIDGE PILOT SITE PERFORMANCE SUMMARIES

As shown in Figure A-4, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section.

### Figure A-4: El Monte Peak Load Reduction

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run yielding a 50% kW reduction, 45% kWh shift, and a 6% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 71.6 | 2.6 | 46% | |
| Feb | 78.8 | 3.4 | 47% | |
| Mar | 75.2 | 3.4 | 47% | |
| Apr | 89.6 | 4.9 | 49% | |
| May | 82.4 | 4.1 | 48% | |
| Jun | 86 | 4.9 | 49% | 64% |
| Jul | 100.6 | 7.1 | 50% | 61% |
| Aug | 102.2 | 7.1 | 50% | 61% |
| Sep | 98.6 | 6.4 | 49% | 62% |
| Oct | 98.6 | 6.4 | 49% | |
| Nov | 87.8 | 4.9 | 49% | |
| Dec | 86 | 4.9 | 49% | |

As shown in Figure A-5, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

### Figure A-5: Energy Savings, Peak Load Reduction, and Peak kWh Shift Summary

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 38 | 8.8 | 0.0 | 333.6 | 1.1 | 0.0 | 42.6 |
| 65 | 70 | 8 | 61 | 14.8 | 118.5 | 903.4 | -0.1 | -0.7 | -5.5 |
| 70 | 75 | 7 | 35 | 13.5 | 94.7 | 473.6 | 1.4 | 9.6 | 48.0 |
| 75 | 80 | 19 | 30 | 12.3 | 232.9 | 367.8 | 2.8 | 53.6 | 84.6 |
| 80 | 85 | 28 | 25 | 11.0 | 307.7 | 274.8 | 4.3 | 119.8 | 107.0 |
| 85 | 90 | 22 | 11 | 9.7 | 213.8 | 106.9 | 5.7 | 126.3 | 63.1 |
| 90 | 95 | 22 | 4 | 8.4 | 185.7 | 33.8 | 7.2 | 158.2 | 28.8 |
| 95 | 100 | 13 | 4 | 7.2 | 93.2 | 28.7 | 8.7 | 112.5 | 34.6 |
| 100 | 105 | 3 | 0 | 5.9 | 17.7 | 0.0 | 10.1 | 30.3 | 0.0 |
| 105 | 110 | 0 | 0 | 4.6 | 0.0 | 0.0 | 11.6 | 0.0 | 0.0 |

## Conclusions and Comments

The El Monte exhibited performance lower than Stasis Energy Group's primary performance metric and model expectations. All three of the air conditioning units supply cooling to a shared open office space as well as offices in external zones. The thermostat location in the large, shared area exhibited issues with simultaneous heating and cooling calls due to variable solar loads.

Additionally, the offices on the southern wall lacked return ducting thus causing occupant comfort issues. SEG negotiated with client to remediate, post-BRIDGE, the duct layout to install return registers, commission the system, and expect performance to improve significantly.

As a result of challenging pre-retrofit conditions, it was determined early on during the project to treat all three RTUs as one system as opposed to managing each unit independently. It should be noted that one important lesson learned is that no TESS installation should occur without first correcting any system deficiencies prior to installation. As a result of poor pre-existing conditions, savings are less than expected.

As shown in Figure A-6, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section.

**Figure A-6: Long Beach 1 Unit Peak Load Reduction**

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding a 56% kW reduction, 47% kWh shift, and a 25% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 75 | 1.0 | 45% | |
| Feb | 84 | 1.2 | 49% | |
| Mar | 77 | 1.0 | 45% | |
| Apr | 89.1 | 1.4 | 51% | |
| May | 73.9 | 0.8 | 41% | |
| Jun | 81 | 1.2 | 49% | 66% |
| Jul | 96.1 | 1.8 | 56% | 62% |
| Aug | 97 | 1.8 | 56% | 62% |
| Sep | 95 | 1.8 | 56% | 62% |
| Oct | 98.1 | 1.8 | 56% | |
| Nov | 89.1 | 1.4 | 51% | |
| Dec | 86 | 1.4 | 51% | |

As shown in Figure A-7, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

**Figure A-7: Peak kWh Shift and Energy Savings**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 55 | 8.6 | 0.0 | 473.3 | 1.0 | 0.0 | 56.9 |
| 65 | 70 | 6 | 65 | 8.3 | 49.7 | 538.7 | 1.2 | 7.2 | 78.2 |
| 70 | 75 | 20 | 50 | 8.0 | 159.4 | 398.6 | 1.4 | 27.5 | 68.6 |
| 75 | 80 | 37 | 30 | 7.7 | 283.2 | 229.6 | 1.5 | 57.1 | 46.3 |
| 80 | 85 | 30 | 21 | 7.3 | 220.1 | 154.1 | 1.7 | 51.4 | 35.9 |
| 85 | 90 | 10 | 9 | 7.0 | 70.2 | 63.2 | 1.9 | 18.8 | 16.9 |
| 90 | 95 | 14 | 4 | 6.7 | 93.8 | 26.8 | 2.1 | 28.7 | 8.2 |
| 95 | 100 | 5 | 1 | 6.4 | 31.9 | 6.4 | 2.2 | 11.1 | 2.2 |
| 100 | 105 | 0 | 0 | 6.1 | 0.0 | 0.0 | 2.4 | 0.0 | 0.0 |
| 105 | 110 | 0 | 0 | 5.8 | 0.0 | 0.0 | 2.6 | 0.0 | 0.0 |

## Conclusions and Comments

The Long Beach 1 site exhibited performance at or above the Stasis Energy Group's primary performance metric and model expectations apart from demand reduction. The lower demand reduction value is attributed to the space being buffered as an interior zone.

It should be noted that this site has no drop ceiling or ceiling tile grid and can therefore be used to demonstrate cost savings typical of "new" construction as opposed to retrofit.

Installation costs were 60 percent lower for these units as a result. Access was unfettered and installation was much easier.

This RTU services an east-facing classroom with full height fenestration on the east-facing wall. Hence, there is increased solar gain and more energy consumption from this 3-ton unit as opposed to the other 3-ton unit at this site.

This unit used less energy than the other 3-ton unit as it is a buffered, internal space with zone influence from adjacent spaces.

As shown in Figure A-8, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section.

**Figure A-8: Long Beach 2 Unit Peak Load Reduction**

***SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding a 56% kW reduction, 47% kWh shift, and a 25% energy efficiency savings.***

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 75 | 1.0 | 45% | |
| Feb | 84 | 1.2 | 49% | |
| Mar | 77 | 1.0 | 45% | |
| Apr | 89.1 | 1.4 | 51% | |
| May | 73.9 | 0.8 | 41% | |
| Jun | 81 | 1.2 | 49% | 66% |
| Jul | 96.1 | 1.8 | 56% | 62% |
| Aug | 97 | 1.8 | 56% | 62% |
| Sep | 95 | 1.8 | 56% | 62% |
| Oct | 98.1 | 1.8 | 56% | |
| Nov | 89.1 | 1.4 | 51% | |
| Dec | 86 | 1.4 | 51% | |

As shown in Figure A-9, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

**Figure A-9: Peak kWh Shift and Energy Savings**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 55 | 8.6 | 0.0 | 473.3 | 1.0 | 0.0 | 56.9 |
| 65 | 70 | 6 | 65 | 8.3 | 49.7 | 538.7 | 1.2 | 7.2 | 78.2 |
| 70 | 75 | 20 | 50 | 8.0 | 159.4 | 398.6 | 1.4 | 27.5 | 68.6 |
| 75 | 80 | 37 | 30 | 7.7 | 283.2 | 229.6 | 1.5 | 57.1 | 46.3 |
| 80 | 85 | 30 | 21 | 7.3 | 220.1 | 154.1 | 1.7 | 51.4 | 35.9 |
| 85 | 90 | 10 | 9 | 7.0 | 70.2 | 63.2 | 1.9 | 18.8 | 16.9 |
| 90 | 95 | 14 | 4 | 6.7 | 93.8 | 26.8 | 2.1 | 28.7 | 8.2 |
| 95 | 100 | 5 | 1 | 6.4 | 31.9 | 6.4 | 2.2 | 11.1 | 2.2 |
| 100 | 105 | 0 | 0 | 6.1 | 0.0 | 0.0 | 2.4 | 0.0 | 0.0 |
| 105 | 110 | 0 | 0 | 5.8 | 0.0 | 0.0 | 2.6 | 0.0 | 0.0 |

## Conclusions and Comments

Long Beach 2 exhibited performance at or above the Stasis Energy Group's primary performance metric and model expectations apart from demand reduction. The lower demand reduction value is attributed to the space being buffered as an interior zone.

It should be noted that this site has no drop ceiling or ceiling tile grid and can therefore be used to demonstrate cost savings typical of "new" construction as opposed to retrofit. Installation costs were 60 percent lower for these units as a result. Access was unfettered and installation was much easier.

This RTU services an east-facing classroom with full height fenestration on the east-facing wall. Hence, there is increased solar gain and more energy consumption from this 3-ton unit as opposed to the other 3-ton unit at this site. This unit used less energy than the other 3-ton unit as it is a buffered, internal space with zone influence from adjacent spaces.

As shown in Figure A-10, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section.

**Figure A-10: San Diego 1 Peak Load Reduction**

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding a 51% kW reduction, 45% kWh shift, and a 40% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 75 | 0.8 | 54% | |
| Feb | 84 | 0.9 | 53% | |
| Mar | 77 | 0.8 | 54% | |
| Apr | 89.1 | 0.9 | 53% | |
| May | 73.9 | 0.8 | 56% | |
| Jun | 81 | 0.9 | 53% | 66% |
| Jul | 96.1 | 1.0 | 51% | 62% |
| Aug | 97 | 1.0 | 51% | 62% |
| Sep | 95 | 1.0 | 51% | 62% |
| Oct | 98.1 | 1.0 | 51% | |
| Nov | 89.1 | 0.9 | 53% | |
| Dec | 86 | 0.9 | 53% | |

As shown in Figure A-11, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

**Figure A-11: Peak kWh Shift and Energy Savings**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 55 | 6.1 | 0.0 | 333.3 | 1.0 | 0.0 | 56.1 |
| 65 | 70 | 6 | 65 | 6.1 | 36.4 | 394.6 | 1.1 | 6.4 | 69.6 |
| 70 | 75 | 20 | 50 | 6.1 | 121.8 | 304.5 | 1.1 | 22.6 | 56.5 |
| 75 | 80 | 37 | 30 | 6.1 | 225.7 | 183.0 | 1.2 | 43.7 | 35.4 |
| 80 | 85 | 30 | 21 | 6.1 | 183.3 | 128.3 | 1.2 | 37.2 | 26.0 |
| 85 | 90 | 10 | 9 | 6.1 | 61.2 | 55.1 | 1.3 | 12.9 | 11.6 |
| 90 | 95 | 14 | 4 | 6.1 | 85.8 | 24.5 | 1.3 | 18.8 | 5.4 |
| 95 | 100 | 5 | 1 | 6.1 | 30.7 | 6.1 | 1.4 | 7.0 | 1.4 |
| 100 | 105 | 0 | 0 | 6.2 | 0.0 | 0.0 | 1.5 | 0.0 | 0.0 |
| 105 | 110 | 0 | 0 | 6.2 | 0.0 | 0.0 | 1.5 | 0.0 | 0.0 |

## Conclusions and Comments

The San Diego 1 site exhibited performance at or above the Stasis Energy Group's primary performance metric and model expectations apart from demand reduction. The lower demand reduction value is attributed to schedule changes made during baseline at the occupant's request.

It should be noted that this site has no drop ceiling or ceiling tile grid and can therefore be used to demonstrate cost savings typical of "new" construction as opposed to retrofit. Installation costs were 60 percent lower for these units as a result. Access was unfettered and installation was much less time intensive than for a site with existing office furnishings to work around and ceiling tile grid to remove and remove before installation.

As shown in Figure A-12, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section.

**Figure A-12: San Diego 2 Peak Load Reduction**

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding an 81% kW reduction, 70% kWh shift, and a 34% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 71.1 | 2.0 | 65% | |
| Feb | 79 | 2.7 | 72% | |
| Mar | 75 | 2.7 | 72% | |
| Apr | 82.9 | 3.3 | 75% | |
| May | 72 | 2.0 | 65% | |
| Jun | 77 | 2.7 | 72% | 69% |
| Jul | 91 | 4.0 | 79% | 63% |
| Aug | 93.9 | 4.0 | 79% | 63% |
| Sep | 93 | 4.0 | 79% | 63% |
| Oct | 91 | 4.0 | 79% | |
| Nov | 84.9 | 3.3 | 75% | |
| Dec | 80.1 | 3.3 | 75% | |

As shown in Figure A-13, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

**Figure A-13: Energy Savings and Peak kWh Shift**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 3 | 62 | 9.4 | 28.3 | 585.3 | 2.2 | 6.7 | 137.6 |
| 65 | 70 | 15 | 54 | 5.6 | 84.6 | 304.6 | 2.1 | 30.9 | 111.2 |
| 70 | 75 | 28 | 38 | 3.3 | 93.2 | 126.5 | 2.2 | 60.8 | 82.5 |
| 75 | 80 | 35 | 21 | 2.5 | 87.5 | 52.5 | 2.6 | 89.3 | 53.6 |
| 80 | 85 | 21 | 17 | 3.2 | 66.6 | 53.9 | 3.2 | 67.4 | 54.6 |
| 85 | 90 | 14 | 2 | 5.3 | 74.6 | 10.7 | 4.1 | 58.0 | 8.3 |
| 90 | 95 | 6 | 2 | 9.0 | 53.8 | 17.9 | 5.3 | 32.0 | 10.7 |
| 95 | 100 | 0 | 0 | 14.1 | 0.0 | 0.0 | 6.8 | 0.0 | 0.0 |
| 100 | 105 | 0 | 0 | 20.7 | 0.0 | 0.0 | 8.6 | 0.0 | 0.0 |
| 105 | 110 | 0 | 0 | 28.9 | 0.0 | 0.0 | 10.6 | 0.0 | 0.0 |

## Conclusions and Comments

The San Diego 2 site exhibited performance at or above the Stasis Energy Group's primary performance metric and model expectations.

This site has open framing in the gym area, where the unit was installed. Installation time was significantly lower due to ease of access and no grid work, but labor was performed at night and during the weekend, due to the client's hours of operations.

This site also has numerous solar panels on the roof, and the rate in-effect, while necessary for photovoltaic, may not be ideal for thermal storage given the tariff restrictions. Hence, we are not reporting the financial benefit for the encumbered tariff and only showing what the savings should be for San Diego Gas and Electric's Agriculture and Large Time-of-Use tariff.

As shown in Figure A-14, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section.

**Figure A-14: Thousand Oaks Peak Load Reduction**

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding a 67% kW reduction, 56% kWh shift, and an 8% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 72 | 1.9 | 61% | |
| Feb | 80.1 | 4.9 | 74% | |
| Mar | 75 | 3.6 | 71% | |
| Apr | 91 | 6.2 | 72% | |
| May | 90 | 6.2 | 72% | |
| Jun | 91.9 | 6.2 | 72% | 63% |
| Jul | 102.9 | 6.3 | 67% | 61% |
| Aug | 106 | 5.9 | 64% | 61% |
| Sep | 99 | 6.4 | 70% | 62% |
| Oct | 100 | 6.3 | 67% | |
| Nov | 89.1 | 5.7 | 74% | |
| Dec | 84 | 4.9 | 74% | |

As shown in Figure A-15, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

**Figure A-15: Energy Savings and Peak kWh Shift**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 1 | 42 | -14.1 | -14.1 | -590.9 | -3.2 | -3.2 | -134.4 |
| 65 | 70 | 2 | 45 | 0.7 | 1.4 | 31.1 | 0.2 | 0.3 | 7.2 |
| 70 | 75 | 11 | 42 | 9.7 | 107.0 | 408.7 | 2.4 | 26.7 | 102.1 |
| 75 | 80 | 16 | 36 | 14.2 | 226.6 | 509.8 | 3.9 | 61.9 | 139.3 |
| 80 | 85 | 24 | 20 | 15.1 | 361.7 | 301.4 | 4.7 | 113.0 | 94.2 |
| 85 | 90 | 13 | 15 | 13.6 | 176.3 | 203.4 | 5.2 | 67.5 | 77.9 |
| 90 | 95 | 16 | 7 | 10.7 | 171.7 | 75.1 | 5.5 | 88.6 | 38.8 |
| 95 | 100 | 27 | 8 | 7.7 | 207.4 | 61.4 | 6.0 | 162.5 | 48.2 |
| 100 | 105 | 11 | 1 | 5.5 | 60.6 | 5.5 | 6.9 | 75.4 | 6.9 |
| 105 | 110 | 1 | 0 | 5.3 | 5.3 | 0.0 | 8.3 | 8.3 | 0.0 |

## Conclusions and Comments

The Thousand Oaks site performed very well, equaling or exceeding SEG's estimates of performance. No post-installation commissioning was required for this installation, due to the well-maintained condition and maintenance of the HVAC units, both during baseline and retrofit periods.

The performance recorded for this site should affirm that to achieve better than expected SEG TESS performance, the HVAC system and components should be in good condition and working order prior to installation of the SEG TESS.

The operational savings achieved for this facility, using the site's current Southern California Edison tariff, show less savings than the Operational Savings Estimate above. This is due to the fact that the tariff in place has no financial benefit for peak kW reduction.

As shown in Figure A-16, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section outlined below.

**Figure A-16: Monterey Park Peak Load Reduction**

***SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding a 57% kW reduction, 56% kWh shift, and an 8% energy efficiency savings.***

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 79 | 3.6 | 71% | |
| Feb | 90 | 6.2 | 72% | |
| Mar | 90 | 6.2 | 72% | |
| Apr | 98.1 | 6.4 | 70% | |
| May | 96.1 | 6.4 | 70% | |
| Jun | 102.9 | 6.3 | 67% | 61% |
| Jul | 97 | 6.4 | 70% | 62% |
| Aug | 109.9 | 5.9 | 64% | 61% |
| Sep | 109 | 5.9 | 64% | 61% |
| Oct | 95 | 6.4 | 70% | |
| Nov | 79 | 3.6 | 71% | |
| Dec | 82.9 | 4.9 | 74% | |

As shown in Figure A-17, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

**Figure A-17: Energy Savings and Peak kWh Shift**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 38 | 2.6 | 0.0 | 98.0 | 1.2 | 0.0 | 46.0 |
| 65 | 70 | 8 | 61 | 1.7 | 13.4 | 101.9 | 0.7 | 5.4 | 41.5 |
| 70 | 75 | 7 | 35 | -0.5 | -3.7 | -18.6 | 0.5 | 3.6 | 18.2 |
| 75 | 80 | 19 | 30 | -3.2 | -61.4 | -96.9 | 0.7 | 13.7 | 21.6 |
| 80 | 85 | 28 | 25 | -5.6 | -157.6 | -140.8 | 1.3 | 35.0 | 31.3 |
| 85 | 90 | 22 | 11 | -6.9 | -152.2 | -76.1 | 2.1 | 46.0 | 23.0 |
| 90 | 95 | 22 | 4 | -6.3 | -138.8 | -25.2 | 3.2 | 71.1 | 12.9 |
| 95 | 100 | 13 | 4 | -3.0 | -38.9 | -12.0 | 4.7 | 60.5 | 18.6 |
| 100 | 105 | 3 | 0 | 3.8 | 11.5 | 0.0 | 6.3 | 19.0 | 0.0 |
| 105 | 110 | 0 | 0 | 15.0 | 0.0 | 0.0 | 8.2 | 0.0 | 0.0 |

## Conclusions and Comments

The Monterey Park exhibited performance lower than Stasis Energy Group's primary performance metric and model expectations in regard to energy efficiency while still maintaining expected performance in demand reduction and energy shifting. The poor energy efficiency performance can be attributed to lack of fresh air intake on both air conditioning units and excessive humidity in the occupied space. The humid environment caused the occupants to aggressively change their setpoint. The client also requested reduced deadbands around the thermostat setpoint, which remained in effect for the baseline and retrofit phases.

Post-BRIDGE, SEG has installed fresh air intake in both units, and the client has expressed increased comfort and reduction in humidity. The lesson learned is to ensure that the HVAC system is set up and operating properly before installing SEG TESS technology.

As shown in Figure A-18, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section outlined below

**Figure A-18: San Diego 2 Peak Load Reduction**

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding a 41% kW reduction, 54% kWh shift, and a -8% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 71.1 | 3.2 | 67% | |
| Feb | 79 | 3.0 | 62% | |
| Mar | 75 | 3.0 | 62% | |
| Apr | 82.9 | 2.7 | 57% | |
| May | 72 | 3.2 | 67% | |
| Jun | 77 | 3.0 | 62% | 69% |
| Jul | 91 | 2.3 | 46% | 63% |
| Aug | 93.9 | 2.3 | 46% | 63% |
| Sep | 93 | 2.3 | 46% | 63% |
| Oct | 91 | 2.3 | 46% | |
| Nov | 84.9 | 2.7 | 57% | |
| Dec | 80.1 | 2.7 | 57% | |

As shown in Figure A-19, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections outlined below.

**Figure A-19: Energy Savings and Peak kWh Shift**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 3 | 62 | 11.5 | 34.5 | 713.6 | 3.6 | 10.7 | 220.7 |
| 65 | 70 | 15 | 54 | 9.2 | 137.7 | 495.7 | 4.3 | 63.8 | 229.5 |
| 70 | 75 | 28 | 38 | 6.8 | 191.5 | 259.9 | 5.0 | 138.6 | 188.1 |
| 75 | 80 | 35 | 21 | 4.5 | 157.9 | 94.7 | 5.6 | 197.4 | 118.4 |
| 80 | 85 | 21 | 17 | 2.2 | 45.6 | 36.9 | 6.3 | 132.9 | 107.6 |
| 85 | 90 | 14 | 2 | -0.2 | -2.2 | -0.3 | 7.0 | 98.3 | 14.0 |
| 90 | 95 | 6 | 2 | -2.5 | -15.0 | -5.0 | 7.7 | 46.3 | 15.4 |
| 95 | 100 | 0 | 0 | -4.8 | 0.0 | 0.0 | 8.4 | 0.0 | 0.0 |
| 100 | 105 | 0 | 0 | -7.2 | 0.0 | 0.0 | 9.1 | 0.0 | 0.0 |
| 105 | 110 | 0 | 0 | -9.5 | 0.0 | 0.0 | 9.8 | 0.0 | 0.0 |

## Conclusions and Comments

The San Diego 2 site exhibited performance lower than Stasis Energy Group's primary performance metric and model expectations. During the retrofit period, the unit had its economizer unit malfunction causing excessive hot humid air to be introduced to the return air and yielding an increase in energy use and occupant comfort issues.

The economizer issue has been remedied, and Stasis Energy Group would expect the performance of the unit to increase to the expected performance.

Additionally, the RTU at this site has two compressors, and during performance phase Stasis Energy Group identified a logic change that would improve performance, but no change was passed to site in order to maintain consistent data collection. Future deployments will show improved performance as a result.

As shown in Figure A-20, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section.

**Figure A-20: Redlands Peak Load Reduction**

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run yielding a 59% kW reduction, 59% kWh shift, and a 10% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 69.8 | -0.1 | -18% | |
| Feb | 75.2 | 0.8 | 50% | |
| Mar | 73.4 | 0.2 | 29% | |
| Apr | 93.2 | 3.1 | 68% | |
| May | 95 | 3.7 | 67% | |
| Jun | 98.6 | 3.7 | 67% | 62% |
| Jul | 107.6 | 3.8 | 59% | 61% |
| Aug | 108.7 | 3.8 | 59% | 61% |
| Sep | 98.6 | 3.7 | 67% | 62% |
| Oct | 100.4 | 3.9 | 64% | |
| Nov | 87.8 | 2.4 | 66% | |
| Dec | 80.6 | 1.6 | 61% | |

As shown in Figure A-21, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections.

**Figure A-21: Energy Savings and Peak kWh Shift**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 40 | 0.1 | 0.0 | 3.6 | 0.0 | 0.0 | 0.0 |
| 65 | 70 | 3 | 51 | -0.2 | -0.5 | -8.7 | 0.0 | -0.1 | -2.0 |
| 70 | 75 | 5 | 32 | -0.9 | -4.6 | -29.4 | 0.0 | 0.1 | 0.3 |
| 75 | 80 | 13 | 29 | -1.9 | -24.1 | -53.7 | 0.2 | 2.6 | 5.8 |
| 80 | 85 | 20 | 18 | -2.7 | -53.6 | -48.2 | 0.5 | 9.8 | 8.8 |
| 85 | 90 | 19 | 19 | -3.1 | -59.5 | -59.5 | 0.9 | 16.7 | 16.7 |
| 90 | 95 | 9 | 5 | -2.9 | -26.0 | -14.5 | 1.4 | 12.2 | 6.8 |
| 95 | 100 | 21 | 8 | -1.7 | -35.3 | -13.4 | 1.9 | 40.1 | 15.3 |
| 100 | 105 | 25 | 2 | 0.8 | 19.8 | 1.6 | 2.5 | 63.0 | 5.0 |
| 105 | 110 | 7 | 0 | 4.8 | 33.7 | 0.0 | 3.2 | 22.2 | 0.0 |

## Conclusions and Comments

The Redlands project site exhibited performance lower than Stasis Energy Group's primary performance metric and model expectations regarding energy efficiency while still maintaining expected performance in demand reduction and energy shifting. The poor energy efficiency performance can be attributed to an oversized thermal energy storage payload during the retrofit. For future installations, Stasis Energy Group will size the energy storage component based on the CFM and load requirements.

As shown in Figure A-22, the kW reduction data is generated from the regression values in the "Peak Load Reduction" section outlined below.

**Figure A-22: Sacramento Peak Load Reduction**

*SEG MODEL COMPARISON: The values shown above for SEG Model Comparison use the maximum measured ambient temperature for the four months of summer and the predicted percentage of kW savings using model values for baseline and retrofit compressor run times yielding a 52% kW reduction, 55% kWh shift, and a -6% energy efficiency savings.*

| Month | Max Ambient (°F) | kW Reduction | % kW Reduction | SEG Model Comparison |
|---|---|---|---|---|
| Jan | 66.9 | 0.1 | 10% | |
| Feb | 72 | 0.1 | 4% | |
| Mar | 68 | 0.1 | 10% | |
| Apr | 91 | 2.6 | 48% | |
| May | 95 | 3.4 | 51% | |
| Jun | 102.9 | 4.1 | 52% | 61% |
| Jul | 107.1 | 4.6 | 50% | 61% |
| Aug | 107.1 | 4.6 | 50% | 61% |
| Sep | 93.9 | 2.6 | 48% | 63% |
| Oct | 95 | 3.4 | 51% | |
| Nov | 82 | 0.9 | 32% | |
| Dec | 69.1 | 0.1 | 10% | |

As shown in Figure A-23, the kWh savings and shift values were generated from the regression values in the "Load Shifting Benefits" and "Operational Energy Savings" sections outlined below.

**Figure A-23: Energy Savings and Peak kWh Shift**

| Min Temp | Max Temp | # of Days in Summer | # of Days in Winter | Daily Occupied kWh Savings | Total Summer kWh Saved | Total Winter kWh Saved | Daily 4pm-Close kWh Reduction | Total Summer kWh Shifted | Total Winter kWh Shifted |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 65 | 0 | 65 | 1.0 | 0.0 | 61.8 | 0.8 | 0.0 | 52.7 |
| 65 | 70 | 1 | 28 | 3.3 | 3.3 | 92.7 | 0.2 | 0.2 | 5.0 |
| 70 | 75 | 0 | 23 | 4.3 | 0.0 | 98.0 | -0.1 | 0.0 | -1.2 |
| 75 | 80 | 6 | 24 | 4.1 | 24.6 | 98.4 | 0.1 | 0.4 | 1.7 |
| 80 | 85 | 26 | 13 | 3.1 | 80.1 | 40.0 | 0.5 | 12.2 | 6.1 |
| 85 | 90 | 21 | 12 | 1.5 | 31.1 | 17.8 | 1.1 | 23.1 | 13.2 |
| 90 | 95 | 30 | 10 | -0.4 | -12.9 | -4.3 | 1.9 | 56.7 | 18.9 |
| 95 | 100 | 21 | 2 | -2.4 | -50.0 | -4.8 | 2.8 | 58.4 | 5.6 |
| 100 | 105 | 9 | 0 | -4.1 | -36.9 | 0.0 | 3.7 | 33.5 | 0.0 |
| 105 | 110 | 8 | 0 | -5.3 | -42.6 | 0.0 | 4.6 | 37.1 | 0.0 |

## Conclusions and Comments

The Sacramento project site exhibited performance lower than Stasis Energy Group's primary performance metric and model expectations. It was found at the beginning of retrofit that the thermostat's temperature was being influenced by the wall's alternate side giving erroneous values. An offset was applied to better represent occupied space temperature and address comfort issues. Additionally, during retrofit performance period, a flaw in SEG logic was discovered. However, the flaw was fixed, and no changes were made to the site, which would have increased performance and adversely affected the M&V task. Going forward, the lessons learned are to properly assess the pre-installation site conditions and remediate before installation of SEG thermal storage system where applicable.