CALIFORNIA
ENERGY COMMISSION

Energy Research and Development Division

**FINAL PROJECT REPORT**

# Empowering Energy Efficiency in Existing Big-Box Retail/Grocery Stores (The Big-Box Efficiency Project)

**Gavin Newsom, Governor**

**MAY 2023 | CEC-500-2023-023**

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# DEDICATION

The Big-Box Efficiency Project team dedicates this final report in memory of Dhananjay (DJ) Mangalekar, P.E., CMVP, QCxP, who passed in February 2022. DJ was Senior Director of Engineering at TRC, with almost 20 years' experience in engineering management, business operations, energy efficiency project development and implementation, and distributed energy resources. On the Big-Box Efficiency Project, DJ led the TRC team in general contracting and construction management, working directly with technology vendors, installation contractors, project partners, and Walmart facilities team members to ensure a successful project outcome. DJ was an invaluable member of the project team and a pleasure to work with; the project wouldn't have reached a successful outcome without his hard work, wisdom, mentorship, and dedication throughout the entire project. The project team acknowledges DJ for his significant contributions to the project, and more importantly for his kindness and composure throughout the project. We are honored to dedicate this final report in his memory.

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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 CEC and the state's three largest investor-owned utilities — Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company — were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

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

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

*Final Project Report EPC-17-008: Empowering Energy Efficiency in Existing Big-Box Retail/Grocery Stores (the Big-Box Efficiency Project)* is the final report for the project (Contract EPC-17-008) conducted by the Center for Sustainable Energy. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the [CEC's research website](https://www.energy.ca.gov/research/) (www.energy.ca.gov/research/).

# ABSTRACT

The Big-Box Efficiency Project evaluated the impacts of installing an integrated suite of pre-commercial energy efficiency technologies to achieve at least a 20-percent reduction in electricity consumption. The multiyear project (early 2018 to January 2022) retrofitted an existing (since 1997) 134,285-square-foot Walmart Supercenter located in Covina, California, in Southern California Edison's service territory. The following five pre-commercial technologies were installed and evaluated.

- i2Systems' next-gen high-efficiency DC-capable LED lighting
- Turntide's Smart Switch Reluctance Motor System for refrigeration and HVAC motor systems
- Integrated Comfort Inc.'s DualCool system, which used both direct and indirect evaporative precooling to reduce electricity use by HVAC equipment
- Saya Life's Smart Water Management System, which evaluated water usage by DualCool and monitored system reliability
- Locbit's IoT platform, which analyzed all the data from the installed technologies and the on-site legacy control system

The total realized whole-building electric savings for the forecasted measurement and verification year (June 2021 to May 2022), when compared with the 2017 baseline (Feb 2017 to Jan 2018), were 1,042,277 kWh (30.2 percent), or 1,115,475 kWh (32.4 percent) after including DC lighting. This is above the project reduction target of 689,592 kWh or 20 percent. LED lighting (i2Systems), DC lighting, and HVAC (Integrated Comfort Inc.'s DualCool/Turntide Smart Motor) upgrades had forecasted savings of 775,111 kWh or 22.5 percent, with an additional 340,364 or 9.9 percent from unidentified end uses. The potential savings from DC-powered lighting were an additional 2.1 percent, or 73,198 kWh.

Lessons learned from this project include improving system submetering granularity and reliability, technology improvements for the installed technologies, and the importance of cybersecurity requirements to successfully deploy an Internet of Things platform. This project directly addressed barriers to California's ambitious energy goals by validating DC-capable lighting systems, as well as moving toward cost-effectiveness for holistic deep-energy efficiency upgrade projects.

**Keywords:** big-box; retail; energy efficiency; pre-commercial; technology demonstration; energy savings; direct current lighting; LED lighting; smart motors; switch reluctance motors; evaporative precooling; water use monitoring; IoT; emissions reduction

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# EXECUTIVE SUMMARY

## Introduction

California Senate Bill 350 mandates doubling statewide electricity and gas end-use savings from energy-efficiency and conservation measures by 2030. This is equivalent to a 20-percent reduction in projected statewide building energy use. Meeting this aggressive target will require that the commercial building industry install holistic energy-efficiency technology packages, specifically those that leverage emerging, pre-commercial products. Targeting savings in big-box retail stores will reduce energy consumption during the peak hours of 4 p.m. to 9 p.m., and lessons learned from this sector can be readily deployed at scale with other large retailers like Walmart.

The pre-commercial nature of, and interactive effects between disparate technologies and the complexity of both predicting and then apportioning savings to a specific product, make it difficult for building owners to confidently predict the technical and financial performance of technology packages. Because most building owners operate in a resource-constrained environment, they are often unable to afford the rigorous evaluation required to vet the technologies and technology packages that deliver deep energy savings. Unwilling to implement projects with uncertain benefits and unknown risks, deep energy savings remain elusive for many commercial building owners.

## Project Purpose

The project team designed and installed a holistic suite of pre-commercial energy-efficiency technologies in a big-box retail commercial building to deliver deep, cost-effective electricity savings of more than 20 percent in a retail/grocery big-box environment. The technologies that comprised the installation package included:

- i2Systems' next-gen LED lighting, which is high-efficiency, bright, and DC-capable, meaning it is ready to directly integrate with future energy-storage systems.
- Turntide's Smart Motor System, which combines higher efficiency switched-reluctance motors (compared to traditional variable frequency drives) and smart computing technology for refrigeration and HVAC motor systems that consume electricity only when needed. Turntide's Optimal Efficiency Motor™ is designed with optimal device physics and runs on patented motor-control algorithms that significantly reduce utility bills by enabling intelligent control systems for both savings and operations. The variable speed control platform significantly reduces the cost of ventilation, and air-conditioning, in addition to providing energy and peak-demand savings from rooftop units and air-handling units.
- Integrated Comfort Inc.'s DualCool system, which uses both direct and indirect evaporative precooling to reduce electricity use from HVAC equipment.
- Saya Life's Smart Water Management system, which evaluated water usage by DualCool and also monitored system reliability.

- Locbit's IoT platform, which analyzed data from installed technologies and the on-site legacy control system.

Robust pre- and post-measurement and verification and detailed energy modeling were used to design, monitor, and evaluate individual technologies and the package that ultimately determined whether the technologies studied reduced electricity consumption by more than 20 percent.

Understanding the opportunities for targeted, cost-effective energy and demand savings are key elements in the commercial sector, and achieving deep energy savings through the integration of system-level solutions is a crucial prerequisite for California's fulfillment of SB 350's ambitious energy-efficiency mandates.

## Project Approach

Beginning in 2018, the project team was assembled that included the site host (Walmart), the construction manager (TRC), the site's investor-owned utility Southern California Edison, the National Renewable Energy Laboratory, and innovative technology vendors. The original IoT provider was replaced by Locbit in 2019, and in 2020 the lighting vendor i2Systems was chosen, which successfully manufactured and installed DC-ready LED lighting.

Project design and energy modeling occurred from 2019 to 2020, and estimated 20.1-percent energy savings from lighting, DualCool precoolers, Turntide smart motors, and IoT controls. Equipment baseline-monitoring equipment was installed in 2019, and measurements were evaluated from June 2020 to November 2021 for each equipment subgroup. The project team also used historical utility-consumption and solar-production data to evaluate electric savings at the whole-building level.

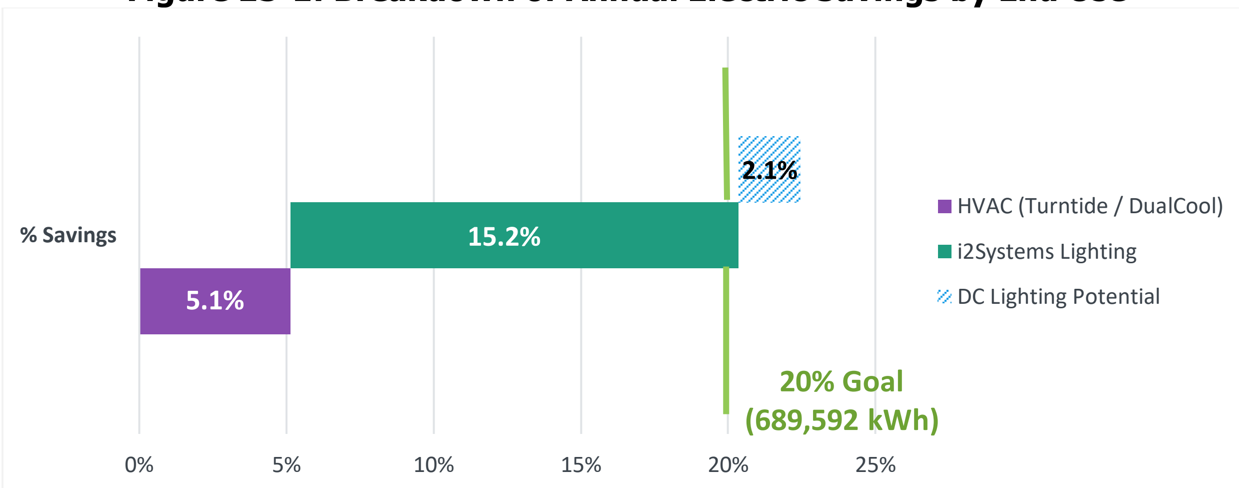
Due to COVID-related material delays, construction was divided into two phases. The first phase occurred from October 2020 to December 2020 and included installation of DualCool and Saya water meters and their associated plumbing, Turntide motors, and a small section of lighting. The second phase of construction was from January 2021 to June 2021 and included finalization of the Turntide motor installation, lighting installation for the rest of the store, installation troubleshooting, and commissioning. Throughout the project, a technical advisory committee was assembled to provide feedback, including suggestions for measurement and verification approaches that account for the impacts of COVID-19 in the submetering baseline.

Post-retrofit measurement and verification occurred from June 2021 to November 2021. The Center for Sustainable Energy team analyzed energy consumption for the next six months using existing data. Due to project timeline constraints and delays due to vendor replacement, contracting, and COVID-related impacts, the project team could not realize a full 12 months of measured savings.

## Project Results

Total whole-building electric savings for the forecasted measurement and verification year (June 2021 to May 2022), when compared with the 2017 baseline, were 1,042,277 kWh, or 30.2 percent (or 1,115,475 kWh; it rose to 32.4 percent when DC lighting was included). This is well above the project reduction target of 689,592 kWh, or 20 percent. LED lighting, DC lighting potential, and HVAC upgrades had a forecasted savings of 775,111 kWh or 22.5 percent, with an additional 340,364 (or 9.9 percent) from unidentified end uses. Potential savings from DC-powered lighting were an additional 2.1 percent, or 73,198 kWh. Figure ES-1 shows how these installed measures exceeded the reduction goal.

**Figure ES-1: Breakdown of Annual Electric Savings by End Use**




Source: Vogel et al., 2022. Big-Box Efficiency Project: *Technology Assessment Report*

Table ES-1 provides a breakout of estimated reduction values from baseline modeling performed by National Renewable Energy Laboratory (Houssainy et al., 2020) and what was forecasted during the measurement and verification period from June 1, 2021 to May 31, 2022.

**Table ES-1: Estimated End-Use and Gross-Site Electricity Savings**

| Efficiency Measure | NREL Estimated % Reduction | NREL Estimated kWh Reduction | M&V Forecasted % Reduction | M&V Forecasted kWh Reduction |
|---|---|---|---|---|
| Locbit IoT Platform | 1.9% | 64,405 | - | - |
| i2Systems Lighting | 10.9% | 374,726 | 15.2% | 524,737 |
| HVAC (Turntide/ICI) | 8.9% | 306,035 | 5.1% | 177,176 |
| DC Lighting Potential | - | - | 2.1% | 73,198 |
| Unidentified End uses | - | - | 9.9% | 340,364 |
| **Gross Site Total** | **21.7%** | **745,166** | **32.4%** | **1,115,475** |

Source: Vogel et al., 2022. Big-Box Efficiency: *Q3/Annual M&V Report*

Table ES-2 illustrates forecasted annual electric savings by end use when compared with corresponding monthly 2020 submetered data. Both lighting and HVAC delivered clear-cut savings from the metering strategy in place; it was more difficult, however, to report clearly defined savings for the refrigeration racks. As explained in the *Forecasted Results Methodology* *and Energy Efficien*cy section, it was assumed that the efficiency gain of the refrigeration system retrofitted with Turntide motors and controls would be offset by increased system demand when compared with the 2020 submetering baseline. In addition to these savings, the in-store DC-driven LED lighting yielded potential demand reductions of 9.3 percent, or 8.3 kW for all retrofitted fixtures.

**Table ES-2: Summary of Annual Electricity Savings**

| Electric Savings by End Use | Total Annual Savings |
|---|---|
| **Whole-Building:** Gross site consumption savings compared with the 2017 whole-building baseline | **1,042,277 kWh**<br>**30.2%** |
| **LED Retrofitted Lighting:** Fixture consumption savings compared with the 2020 submetering baseline | **186,539 kWh**<br>**28.9%** |
| **HVAC Upgrades:** DualCool and Turntide Motors RTU and AHU consumption savings compared with the 2020 submetering baseline | **128,799 kWh**<br>**34.4%** |
| **Refrigeration Upgrades:** Turntide Motors racks A through F consumption savings compared with the 2020 submetering baseline | **-650 kWh**<br>**-0.1%** |
| **Proposed DC Lighting[a]:** Extrapolated savings from DC-capable lighting in the garden center | **73,199 kWh**<br>**2.1% of 2017 Baseline** |

[a] **Calculated and represented as a stand-alone, potential savings metric unaccounted for in other savings metrics**

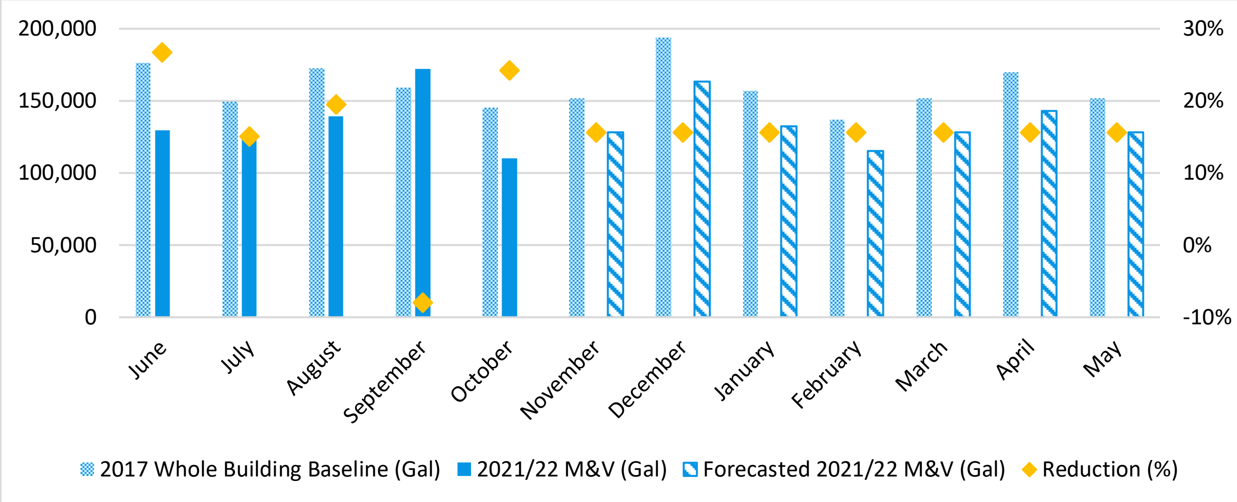
Source: Vogel et al., 2022. *Big-Box Efficiency: Q3/Annual M&V Report*

**The reduction in lighting energy was greater than projected. While HVAC savings were considerable during the summer months, they were less than predicted on an annual basis, as explained in the Water Savings**

The water billing and consumption data for the whole building were delayed by about two months. The M&V months of November 2021 through May 2022 were forecasted. Using historical trends and recent data, the two main water meter consumption forecasts for the remaining M&V months appear in Figure 9. Annual consumption for the M&V period was calculated to be 1,616,719.9 gallons, a reduction of 299,789.1 gallons (15.6 percent) when compared to the 2017 baseline year.

Water consumption was lightly correlated to energy and more heavily correlated to occupancy. The main consumers of water are the bathrooms, on-site cooking activities, and the garden center. The reduction could be a result of lower occupancy during the COVID pandemic and less need for water.

**Figure 9: Annual Whole-Building Water Consumption**




**Annual whole-building water consumption by month when compared to the whole-building baseline (Feb 2017 - Jan 2018) versus the M&V period (June 2021 - May 2022).**

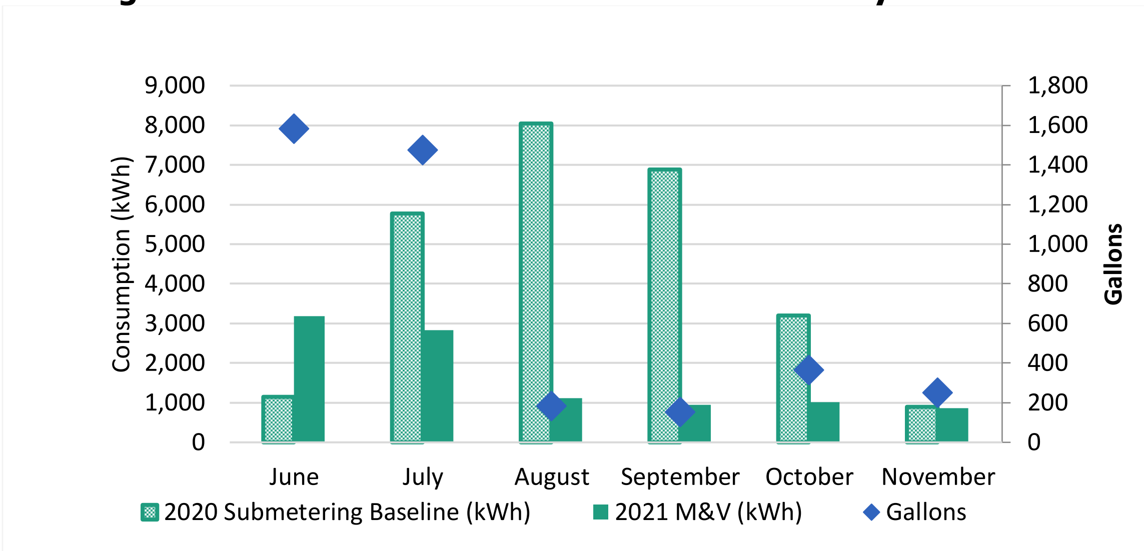
Source: Vogel et al., 2022. *Big-Box Efficiency Project: Technology Assessment Report*

The project team developed a water budget of 3.4 gallons per kWh saved through evaporative cooling. The Saya Life submetering water data measured all HVAC units from a single meter located on the main rooftop supply line as well as at each individual unit retrofitted with DualCool. To calculate this metric, water and energy consumption for the submetered AHU 2 was collected for July 2021 through November 2021 and compared to similar baseline months in 2020. This unit was being repaired in June 2021 so that month was excluded from the analysis.

The metric of gallons consumed per kWh saved for DualCool retrofitted HVAC units was not forecasted for Q4 (December 2021 to May 2022), so there is no annual result. There was insufficient data to confidently predict gal/kWh saved for the remaining six months of M&V. In lieu of forecasted data for Q4 and annual savings, a summary of Q1 through Q3 showed gallons consumed per kWh saved in

Figure 10. The total water consumed by AHU 2 between July and November 2021 was 2,423.2 gallons to save 18,053 kWh, which resulted in a metric of 0.13 gal/kWh saved, well below the project target of 3.4 gal/kWh saved.

**Figure 10: Annual Gallons of Water and Electricity Consumed**




Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*

Technology Assessment section. Overall, the building as a whole saved 30.2 percent, or 32.4 percent when DC lighting potential was included. This exceeded the project target of 20-percent electric energy savings from the 2017 whole-building baseline.

Cost savings for this project were $110,902 per year, with an overall simple payback of 16.2 years. This simple payback is mostly related to the cost of engineering and construction including commissioning, design, general contracting, and permit fees. Unfortunately, this project's IoT platform was unable to achieve documented energy savings for this project, so those savings were not evaluated. However, future projects that successfully integrate an IoT platform are likely to achieve energy savings that provide shorter payback. Due to the holistic nature of this project, engineering and construction costs were only considered on a whole-project level; simple payback per project technology was unavailable. In terms of water use, it was found that 0.13 gallons of water were used for each kWh saved on the project, though a full year of evaluation would be required to accurately determine the water cost of the energy saved.

## Advancing the Research to Market

The project team implemented several strategies to ensure knowledge transfer from this project to others in the commercial industry. These strategies included a project website, conferences and event presentations, a webinar, project fact sheet and additional marketing collateral, Technical Advisory Committee meetings, an in-store dashboard, and policy-tracking and comments. These activities resulted in more than 2,200 web-page visits, 110 conference presentation attendees, 40 stakeholders informed about the project through networking, 38 webinar attendees, and 10,600 impressions on social media. The Center for Sustainable Energy additionally held a project debrief meeting on January 19, 2022, where Walmart management discussed project successes, identified lessons learned, and explored similar energy-efficiency opportunities at other Walmart stores.

For individual technologies, one of the major pathways to commercialization is local utility rebates and incentives. The California Public Utilities Commission directed California's IOUs to procure energy-efficiency programs by third parties. Under these programs, Turntide smart motors and Integrated Comfort Inc.'s DualCool technology are both eligible for deemed measure savings under existing programs. At this time, energy management systems such as the Locbit system are difficult to obtain incentives for unless they can demonstrate savings through a whole-building retrofit or NMEC process based on specific activities, such as reducing hours of operations for lighting or changing thermostat setpoints to reduce energy usage. Additionally, certain project costs like commissioning and design fees could be covered by customized incentive programs. Finally, though Saya Life's smart water management system is not currently eligible for energy-efficiency incentives or rebates, local water districts and authorities could have rebate and incentive programs for other smart-water management systems. Post-project, the technologies studied and tested are gaining market share and moving toward full commercialization.

The project technologies post-project are gaining market share and moving toward full commercialization. i2Systems is continuing development on their technology prior to full commercialization; full commercialization is on the horizon as interest grows in the DC-ready LED lighting fixture for commercial buildings. Saya Life's smart water management system is currently deployed in 50+ commercial locations including multi-tenant buildings, hospitals, and schools and is continuing to gain market penetration. Integrated Comfort Inc., Turntide, and Locbit continue to share lessons learned from the project in support of market adoption.

Outside of incentives, Walmart is continuing to work with the project technology vendors to continue to advance these various technologies to market. Walmart is committed toward its goals of being 100 percent renewable by 2035 and achieving zero emissions across global operations in 2040. Walmart will be exploring ways to leverage the findings of this project:

- **Lighting -** Walmart is looking at how new lighting products, like i2Systems DC-ready LED lighting, can be aligned with current LED end-of-life cycles to streamline the timing of upgrades. Walmart is also working with i2Systems to further test their products. Walmart is interested in new LED products like i2Systems DC-ready LED lighting to further drive energy savings and increase resiliency beyond standard LED retrofits.
- **Smart Switch Reluctance Motors -** Walmart will continue to work with Turntide to monitor operations at Store 2292 to ensure communications issues with the supervisory controllers are resolved. They are also working on doing additional testing with other units at other Walmart stores.
- **Smart Water Meters -** Walmart is exploring the opportunity to further expand on smart water meter testing by exploring the ability to measure mineral content in blowdown and the possibilities for on-site water reuse.
- **Evaporative Precooling -** Integrated Comfort Inc.'s DualCool evaporative precooling technology has been installed in more than 280 Walmart stores across the United States. Walmart and Integrated Comfort Inc. are in talks on how to further leverage the data from the DualCool performance to further drive savings in its stores.

- **Internet of Things -** Over the past few years, Walmart developed an in-house Internet of Things team that is working on taking the findings of demonstration projects like Store 2292 to further streamline data integration from various building system vendors at Walmart stores.
- **Battery Storage Interconnection to DC Loads -** Based on the findings of this project, Walmart plans to better understand battery technology and how they can integrate at stores with solar and DC-based building loads like lighting, with the ultimate goal of achieving a building that can be self-sufficient with on-site energy generation and storage, increasing power reliability and resiliency.
- **Future Research Opportunities -** Walmart is open to exploring additional research opportunities to further drive building energy efficiency savings, increase store resiliency, and look toward the future of on-site distributed energy resources, demand response.

## Benefits to California

The Big-Box Efficiency Project demonstrated to retailers, California ratepayers, utilities, and operators that deep energy-efficiency savings through integrated technology packages will help California meet its ambitious greenhouse gas emissions reduction mandates. By reducing energy consumption, the proposed project would add valuable capacity to California's electrical transmission and distribution systems, especially during critical peak events. Based on this study’s results and conclusions, future iterations of deep energy efficiency retrofit projects will provide:

- Demonstrated real savings by retrofitting HVAC units with Integrated Comfort Inc.’s DualCool and Turntide’s smart switch reluctance motors. The demonstrated savings of 34.4 percent in HVAC consumption, when compared with the 2020 submetering baseline, target reducing power consumption from packaged HVAC systems, which disproportionately account for critical capacity shortfalls and congestion during summer heat waves. This project also confirmed that the DualCool technology is water-efficient, using only 0.13 gallons per kWh saved.
- Market transformation potential of DC lighting. Not only did i2Systems lighting save 28.9 percent when compared with existing systems; if the store were to be powered 100 percent by a DC power source like on-site battery storage, an additional 2.1 percent of savings could be achieved for the whole building. In a tight energy efficiency market where every kWh saved means cost savings, improved grid reliability, and enhanced environmental benefits, this could be the next generation of lighting solutions that replace LED lighting, which is nearing its end-of-life replacement.
- While unable to be demonstrated fully during this project, the Locbit IoT platform demonstrated the benefits of disparate technologies’ end-use data within a single unified system; future iterations could both capture additional energy savings through integrated automated controls and reduce preventive-maintenance costs.
- Finally, the project will directly benefit ratepayers who install the efficiency technologies by reducing both their energy and maintenance expenses.

# CHAPTER 1: Introduction

## Project Overview

### The Problem

California Senate Bill 350 mandates doubling statewide electricity and gas end-use savings from energy-efficiency and conservation measures by 2030. This is equivalent to a 20-percent reduction in projected statewide building energy use. Meeting this aggressive target will require that the commercial building industry move past its current practice of installing singular, available energy-efficiency (EE) technologies. Achieving these mandated savings instead requires the installation of holistic packages, specifically those that leverage pre-commercial EE technologies.

However, the pre-commercial nature, the interactive effects between disparate technologies, and the complexity of predicting and apportioning savings to a specific product, make it difficult for building owners to confidently predict the technical and financial performances of technology packages. Because most building owners operate in a resource-constrained environment, they often lack the ability to perform the rigorous evaluation required to vet technologies and technology packages that could provide deep energy savings. Unwilling to implement projects with uncertain benefits and unknown risks, deep energy savings remain out of reach for many commercial building owners.

### The Solution

The project team designed and installed a holistic suite of pre-commercial EE technologies in a big-box commercial building and used robust pre- and post-measurement and verification (M&V) and detailed energy modeling to design, monitor, and evaluate individual technologies as well as the package as a whole. Five pre-commercial technologies were evaluated in this project:

**DC-Ready LED Lighting**

The store’s existing fluorescent lighting fixtures were retrofitted with DC-ready LEDs. DC lighting can potentially to save an additional 4 percent to 8 percent in electricity over traditional AC LED fixtures.

**HVAC and Refrigeration Smart Motor System**

Turntide’s Smart Motor System replaced existing supply-fan motors in 28 RTUs. Six refrigeration condensers serving the medium- and low-temperature refrigeration systems were also retrofitted with 24 smart motors. Turntide’s Optimal Efficiency Motor™ was designed with optimal device physics and runs on patented motor control algorithms that significantly reduce utility bills while enabling intelligent control systems, which increase savings and improve operations.

**Direct and Indirect Evaporative Cooling**

Integrated Comfort Inc.'s (ICI) DualCool system precools air coming into the HVAC system to reduce energy use in HVAC units by approximately 20 percent. This was coupled with Saya's Smart Water System to optimize trade-offs between saving energy and increasing water usage in heating and cooling.

**Smart Water Management System**

Saya's Smart Water Management System assessed water used by the ICI DualCool system.

**Locbit IoT Platform**

Locbit's cloud-based platform integrated and analyzed data from both the different EE technologies and the legacy building-control system.

Understanding the opportunities for targeted, cost-effective energy and demand savings are important elements in this energy sector. Achieving deep energy savings through the integration of system-level solutions is a crucial prerequisite that will help California meet its aggressive EE goals. Project-specific goals and objectives follow.

## Goals

The goals of this project were to:

- Demonstrate the ability of a suite of pre-commercial EE technologies to deliver deep, cost-effective electricity savings in a big-box environment.
- Demonstrate the costs and demand reductions associated with installation of an integrated technology package consisting of pre-commercial technologies.
- Develop the technical documentation and other supporting materials necessary to catalyze development of utility rebates and other incentives to spur market adoption of pre-commercial EE technologies.

The project met these goals by achieving more than 20-percent electricity savings, demonstrating cost reductions of over $110,000 annually, and providing documentation to Southern California Edison for future DC-lighting savings measures (Refer to Chapter 3 for more detail). Additionally, in 2022, both ICI DualCool and Turntide smart-switched reluctance motors became eligible for incentives through the database for energy-efficiency resources (DEER). Demand response was ultimately not pursued as part of this project because the store's security constraints did not allow full controllability of the Locbit system.

## Objectives

The objectives of this project were to:

- Verify the real-world technical and financial potential of five separate pre-commercial EE technologies through pre- and post-installation M&V, system and whole-building commissioning, and calibrated energy models.

- Assess electricity, water, and cost savings from deployment of multiple discrete EE technologies as part of an optimized and integrated installation package.
- Verify the ability to achieve more than 20-percent electricity savings by applying a series of integrated EE technologies to an existing big-box retail building.
- Create and format the data necessary to support development of investor owned utilities (IOU) EE programs for each of the demonstrated pre-commercial EE technologies.
- Share lessons learned and other related project outcomes with California IOUs and other commercial buildings to speed up market adoption of the demonstrated pre-commercial EE technologies.

### Test Site

The selected test site for these technologies was Walmart Supercenter 2292, located in the town of Covina between the I-210 and I-10 interstate freeways in Los Angeles County. This location is within California Climate Zone 9 and Southern California Edison's (SCE) service territory. The store contained standard retail space with several in-store centers including auto care, photo, vision, garden, pharmacy, grocery sales, a deli and bakery, and a McDonald's fast-food restaurant. Originally constructed in 1997 as a standard Walmart, it was renovated to a Supercenter in 2010 and added a grocery section, deli, and bakery. The site featured fluorescent lighting, packaged HVAC with carbon dioxide sensors and economizers, and a basic energy-management system. In 2017, according to utility data, Store 2292 had gross-site electricity consumption of 3,447,959 kWh, 75-percent of which was supplied by SCE's electric grid and 25 percent of which was supplied by on-site, non-export photovoltaic (PV) solar. More detail on the test site and its existing equipment appears in the Site Characteristics section.

## Innovations

### Technological Advancement and Breakthroughs

This project contributed to technological advancement and breakthroughs for the five planned innovative technologies featured in the study. This project's methodology not only advanced development of the demonstrated pre-commercial technologies, but also established a new paradigm for rapid and deep levels of electricity savings that can apply to numerous classes of commercial buildings across California.

For specification sheets on products used in this project, see APPENDIX C: Product Specification Sheets.

#### i2Systems DC-Ready LED Lighting

*Innovations in Power*

The planned lighting installation at Walmart in Covina was planned to be a DC-powered LED lighting product. Ideally, this DC-powered LED lighting system would have been powered by an on-site DC energy source, such as on-site battery-energy storage. However, at the time of conceptualizing the lighting approach for the project, there was not a pathway for integrating with the existing battery-energy storage system at Store 2292 because of existing warranty and safety constraints.

Due to on-site DC power-source limitations, i2Systems created a hybrid power electronics system utilizing an LED driver that automatically detects whether incoming power is 277 V alternating current or 380 V DC and switches to the LED-based incoming current. Based on an 83+ color rendering index, at 5800 lumens, the AC lighting efficiency is 145 lumens/watt and the DC lighting efficiency is 155 lumens/watt. The AC/DC hybrid approach allows for a retrofit solution that can be broadly implemented with minimal changes to existing electrical distribution wiring in Walmart's stores, while maintaining future compatibility with DC-based electrical distribution systems that could be installed with battery energy storage systems. To the project team's knowledge, this is the only lighting fixture of its kind.

There is a test area in the garden center of Store 2292 featuring an electrical control panel, supplied by i2Systems, with the ability to switch between AC and DC voltage and measure the difference in energy consumption with simulated power to demonstrate the technology running on 100 percent DC power. Details on the layout of lighting fixtures, dimming zones, and dimming schedules appear in APPENDIX B:
LED Lighting System Details.

*Innovations in Connectivity*

The installed system consists of more than 600 wireless connected nodes creating a Bluetooth mesh network in the ceiling for inter-luminaire communication as well as capability for connection to sensors and other devices. Additionally, the system is dimmable through wireless controls set by zones and, in this project, integrated with the legacy control system per Walmart's request with 0 V to 10 V dimming. The system also contains the capability to wirelessly aggregate system faults and communicate them via BACnet for required maintenance and predictive maintenance analytics. Because all inter-luminaire communication is wireless, the installation team was not required to run any additional control wires, which saved on both material cost and installation time. For this demonstration project, the lights were hardwired to the Locbit system, but could alternatively be integrated wirelessly in future iterations.

*Innovations in Installation*

i2Systems' lighting solution also featured innovations that reduced material cost and waste during the installation process. First, because of the unique AC/DC hybrid solution and the fact that the lights run on 380-V DC power, no major rewiring was required for the new lamps; the new lamps also fit into the existing housing. These innovations reduced or eliminated labor costs for rewiring, reduced materials expenses for new wires, and also reduced material waste through using existing fixture housings. Secondly, the retrofit fixture aligned on the fluorescent tombstones that are industry-standard fixed dimensions. i2Systems is working on a newer revision that decreases the size of the housing so that the fixtures fit into as many applications as possible. Third, all lights were packaged in boxes that could be repurposed for collecting old bulbs for recycling, saving on packaging and material waste.

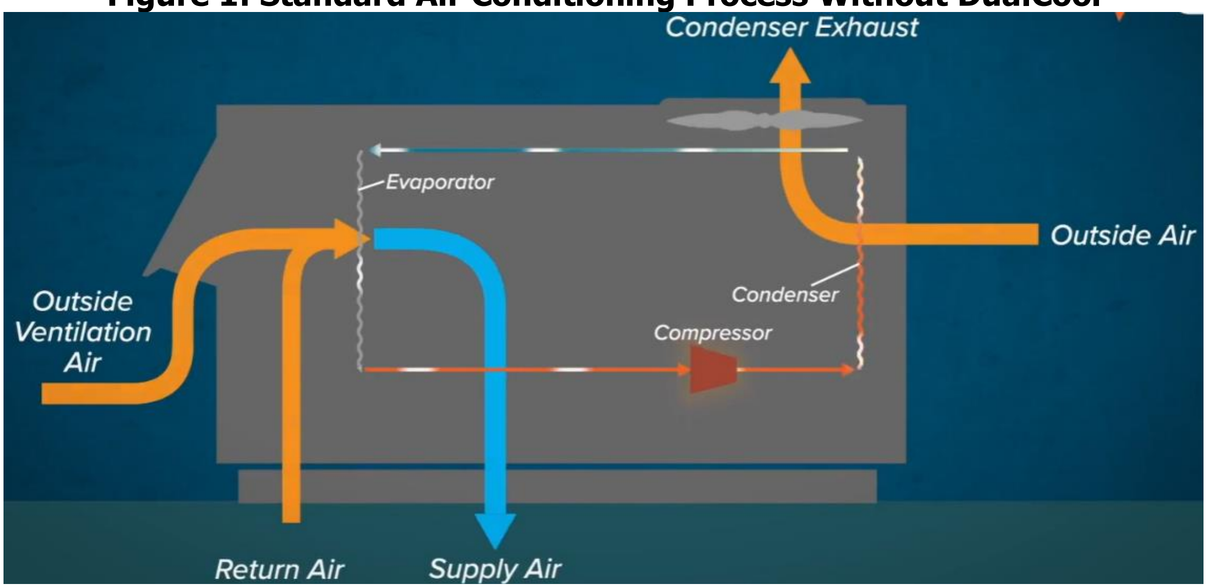
## ICI DualCool

DualCool evaporative precooling was a planned retrofit solution for commercial rooftop air conditioning units (RTUs) and air handling units (AHUs). Two parallel processes precool the condenser air and the ventilation air using water, improving RTU and AHU efficiency and capacity while also reducing the building's cooling load.

### *Innovations in Efficiency Retrofits*

DualCool provides a noninvasive retrofit option for existing packaged direct expansion units that improve cooling efficiency with add-on equipment that does not require modification of the original equipment. Air-cooled RTUs and AHUs are less efficient in both efficiency and capacity when outdoor temperatures rise. Hot summer temperatures make it difficult for RTUs and AHUs to expel heat, and the compressors do more work to meet set-point temperatures. At the same time, buildings continue to bring in hot outside air to satisfy ventilation requirements, further increasing cooling requirements under impacted performance conditions. Figure 1 illustrates this process.

**Figure 1: Standard Air Conditioning Process Without DualCool**

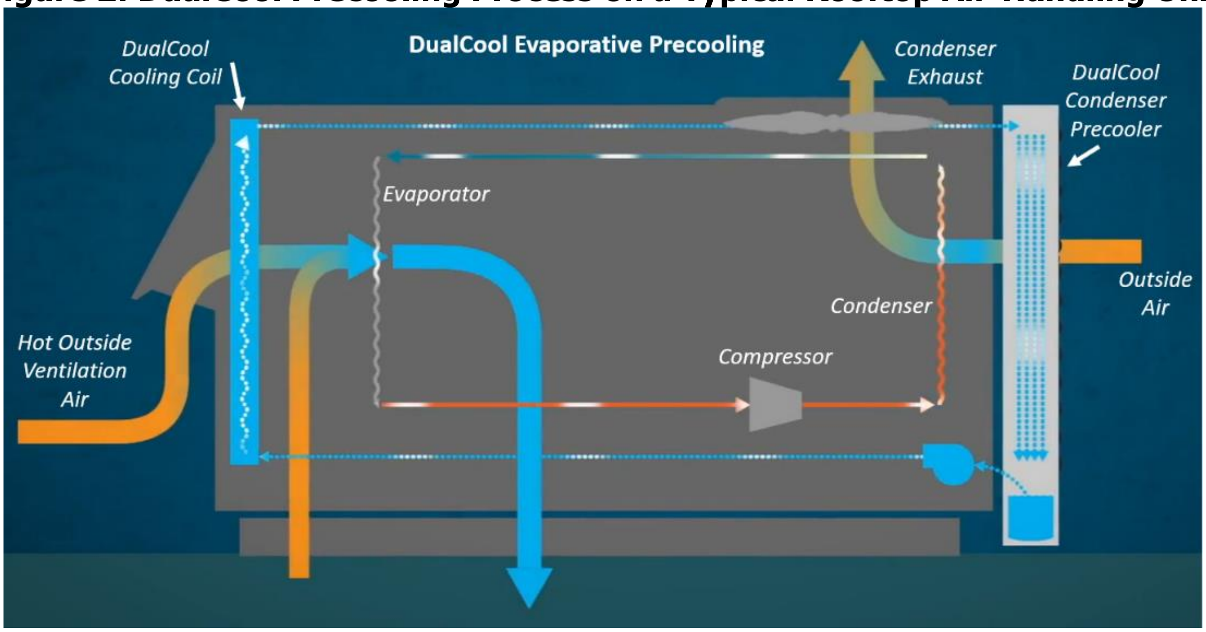



Source: Integrated Comfort, Inc.

DualCool increases RTU and AHU efficiency and capacity by precooling hot outside air before it arrives at RTU and AHU condensers. This direct evaporative process can achieve 85-percent cooling toward ambient wet-bulb temperatures. The process is especially effective in hot, dry climates such as the state's Central Valley and Inland Empire. Precooled air then passes through the RTU or AHU condenser, where it is able to extract more heat from the refrigerant. This translates to the RTU or AHU achieving a higher cooling capacity and reducing peak demand.

The precooling process, shown in Figure 2 for the condenser, produces cooled water, which is then collected in a reservoir. The cooled water is also used to operate a second simultaneous process—as a precooler. A heat exchanger is positioned in the flow path of the incoming ventilation air as the chilled water passes through it. This indirect evaporative cooling coil tempers the incoming hot outside air used for ventilation. By cooling this air before it enters the building, the overall cooling load is reduced while energy savings increase.

**Figure 2: DualCool Precooling Process on a Typical Rooftop Air-Handling Unit**




Source: Integrated Comfort, Inc.

### Turntide Smart Switch Reluctance Motors

Turntide's Smart Motor System replaced existing supply fan motors in 28 RTUs. The six refrigeration condensers serving the medium- and low-temperature refrigeration systems were additionally retrofitted with 24 smart motors.

*Innovation in Design*

Turntide's Optimal Efficiency Motor™ is designed with optimal device physics that run on patented motor control algorithms that significantly reduce utility bills while enabling intelligent control systems. The variable speed control platform significantly reduces the cost of HVAC and RTU/AHU operation through energy and peak-demand savings. A recent NREL study demonstrated that smart switched reluctance motor systems outperform traditional variable-frequency drive (VFD) retrofits in supply fan retrofits, delivering a 13-percent better performance than with a VFD.[1]

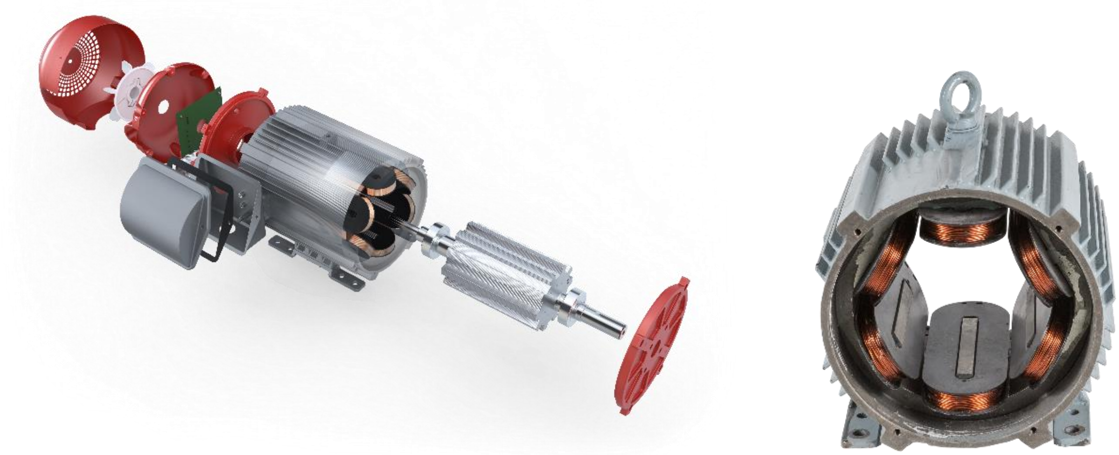
For fan systems, the Turntide Smart Motor System identifies which mode is required for RTU or AHU operation (heating or cooling), based on input from building sensors. The system then determines optimal fan speeds that balance operational effectiveness with maximum energy savings. For the refrigeration condenser systems, the Turntide Smart Motor System operates

[1] See Table 12, Case 1 (VFD) vs. Case 4 (SRM), for Warehouses (Woldekidan et al. 2020).

as before, but with the addition of Turntide's efficient switch reluctance motors integrated into the building's automation system.

Turntide motors also provide efficiencies through their simplified construction. There are not any permanent magnets or windings on the rotor, which improves reliability. Figure 3 illustrates an expanded view of the motor and a view of the rotor.

**Figure 3: Turntide Motor Expanded View (left) and Rotor (right)**



Source: Turntide

### Saya Life Smart Water Management System

The Saya Life Smart Water Management system shown in Figure 4 is an integrated and certified IoT remote platform that provides water monitoring, leak detection, and risk management for multi-tenant residential and commercial buildings. Saya Life supports LoRa, NB-IOT, and CAT-M network technologies and is an edge-computing data collector able to receive data from more than 2,000 smart meters and sensors. The Saya Life platform integrates with a seismic portal to automatically shut off water supplies during earthquakes, and can also disaggregate consumption, based on specific fixtures.

Saya Life also offers a wide variety of water meters for connection with the Saya Life Management System, including all-weather commercial-grade construction options for both indoor and outdoor use. Saya Life also offers flood detection devices. For this project, the LoRA technology, Saya Life Smart Water Meter (1" Ultrasonic cold water meter) and Gateway, a basic management system, together monitored the supply line that provides water to DualCool units, which in turn provide leak and water usage data to Locbit. The devices used overconsumption information based on set thresholds. A more comprehensive platform is available that shows the cost of both water use and usage by fixture.

The ultrasonic meter is a weights-and-measures-certified smart submeter with integrated pressure, temperature, ultrasonic flow sensors, and a built-in shutoff valve for leak management, all of which are easily integrated with a building management system or accessed through an online portal. The ultrasonic flow meter operates by alternately transmitting and receiving a burst of ultrasound between two transducers and measuring the transit time for sound to travel between the two transducers in both directions. Saya Life's smart water management system is gaining market traction and currently deployed at more than 50 locations including multi-tenant buildings, hospitals, and schools.

**Figure 4: Saya Life Smart Water Management Meter and Networking Gateway**


Source: Saya Life

## Locbit IoT Platform

*Innovations in Controllability*

Locbit is a cutting-edge IoT control platform that analyzes building energy efficiency across existing building subsystems including lighting, refrigeration, and HVAC. The platform can also implement demand-response (DR) strategies, shift loads, and respond to pricing signals. Most building energy-management systems are installed and operated locally and require dedicated hardware. Locbit is a cloud-based control system accessible through authorized local, remote, and mobile devices. The control system monitors all connected building systems and detects energy waste, equipment malfunctions, and other operational problems using a fault detection and diagnostics engine. The largest innovation on this project was the integration of all technology vendor system data, plus the legacy Walmart control system from Honeywell, all in a single platform that streamlines data collection and enhances visibility into store equipment operations. The foundation for the Locbit platform was deployed for this project and used for energy monitoring.

*Innovations in Responsiveness*

The Locbit platform is also capable of managing energy assets that communicate directly with the electric grid through OpenADR. OpenADR is an open, highly secure, two-way information exchange model and smart-grid standard recognized by a majority of global utility providers. OpenADR standardizes the message format used for automated demand response and distributed energy resource management so that dynamic price and reliability signals can be exchanged in a uniform fashion among utilities, independent system operators, and energy-management and control systems. However, due to project cybersecurity constraints, real-time management of Walmart's systems could not be pursued for this project.

# CHAPTER 2: Project Approach

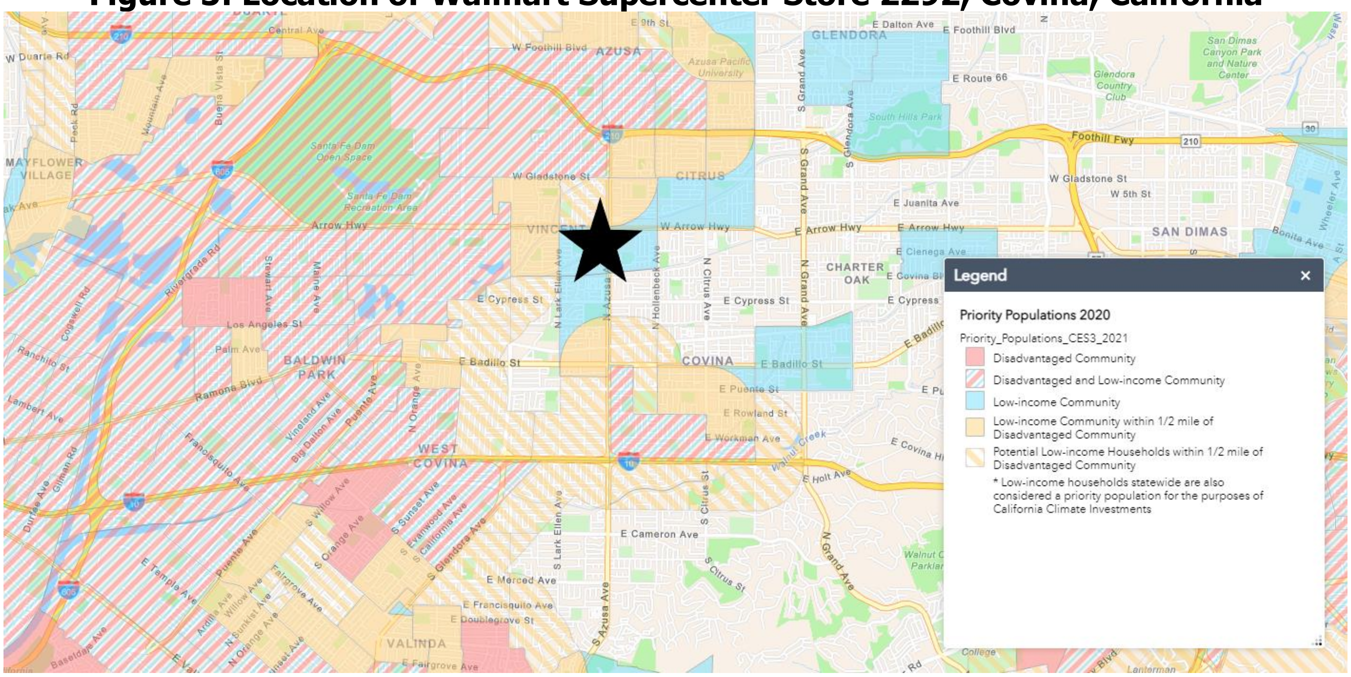
## Site Characteristics

### Location

The Walmart Supercenter Store 2292, located at 1275 N. Azusa Avenue, Covina, CA 91722, was built in 1997. The 134,733-square-foot, one-story building sits between the I-210 and I-10 freeways in Los Angeles County, just south of the town Azusa. The region sits in California Climate Zone 9.

As seen in Figure 5, the map shows disadvantaged communities and low-income communities as defined for California Climate Investments in relation to the store location (blue marker).[2]

**Figure 5: Location of Walmart Supercenter Store 2292, Covina, California**




Source: *California Climate Investments Priority Populations 3.0 by Census Tract*. California Air Resources Board. Available at https://webmaps.arb.ca.gov/PriorityPopulations.

### Facility Description

[2] Disadvantaged communities are identified by the California Environmental Protection Agency (CalEPA) as the top 25% most impacted census tracts in CalEnviroScreen 3.0, a screening tool used to help identify communities disproportionally burdened by multiple sources of pollution and with population characteristics that make them more sensitive to pollution. Low-income communities and households are defined as the census tracts and households, respectively, that are either at or below 80 percent of the statewide median income, or at or below the threshold designated as low-income by the California Department of Housing and Community Development's (HCD) 2016 State Income Limits.

Before this project, a 500-kW solar PV system was installed in 2007 under the terms of a utility power purchase agreement (PPA). The PV panels cover about 60 percent of the roof's surface and generate about 867,437 kWh of electricity per year, based on 2017 baseline data.

Additionally, battery energy storage was installed in 2019 using Tesla's Powerpack 5.3 model. It has a 300-kW power rating and a 510-kWh energy capacity. Efforts to integrate solar and storage directly to the DC-powered LED lighting system proved to be technically infeasible at this time due to limitations of the electrical components within each energy resource and contractual limitations. Potential benefits of direct DC integration are discussed in the Validation of DC-Capable Lighting Systems section of this report.

### HVAC & Refrigeration

There are a total of 27 Lennox packaged RTUs, ranging in size from 3 to 20 tons. The RTUs utilize electricity for air conditioning and natural gas for heating. Two 100-percent outside-air AHUs are located above the produce section of the building and have a cooling capacity of 25 tons each. These units provide ventilation and cooling for the space surrounding the deli, bakery, produce, and refrigerated aisles on the east side of the store. Four gas-fired space heaters currently serve the auto center's heating needs during the colder months. How often these units run each year is unknown. A series of six refrigeration systems, labeled Racks A through F, deliver cooling to the produce cooler, the grocery cooler, the grocery freezer, the dairy cooler, and all open refrigerated shelving within the grocery and produce sections.

### Lighting

The lighting on the main sales floor was mostly comprised of approximately 872 surface-mount, 1-foot by 8-foot linear fluorescent fixtures using four 48-inch 32 W T8 lamps. These fixtures utilized two 4-foot fixtures wired together with a single electronic ballast. These fixtures were mounted to the steel beams in the ceiling and run in contiguous rows from the front of the store to the back. In addition to these large rows of lights, 95 of these fixtures were used around the perimeter of the main sales floor for lighting along the walls, and illuminating the front wall were 55 4-foot one-lamp F54 T5 high-output wall wash fixtures.

In the stockroom a series of 36 fixtures, similar to those on the main sales floor, provided light for the back stockroom in the two main aisles and loading dock area. Several employee-occupied areas in the rear of the building, including storage, a janitor closet, a fixture room, and hallways, utilized the common surface-mount, 1-foot by 8-foot 4-lamp F32 T8 linear fluorescent fixtures. Other spaces labeled Marketing Manager, Alcove, Training Room and Breakroom used a 2-foot by 4-foot recessed troffer fluorescent fixture with two F32 T8 lamps per fixture. The areas mentioned above are the main areas that received LED retrofits, and all other lighting remained in place.

APPENDIX B provides more information on the post-retrofit dimming schedule (Table B-), dimming zone setting details (Table B-2), and a map of all fixtures retrofitted for this project (Figure B-).

## Store Operations

### Business Schedule

The main retail space and grocery section of the store is open year-round, seven days per week from 6 a.m. to 12 a.m. The store is only closed for business on Christmas Eve at 6 p.m. and reopens to the public on December 26 at 6 a.m., for a total of 6,546 business hours per year. Following are the operating hours for the main retail space and each department within the store. Detailed store hours can be found in APPENDIX D:
Project Baseline & Results Details.

### Occupancy Schedule

The store is open daily between 6 a.m. and 12 a.m., and occupied by overnight staff during other hours. The store is completely unoccupied from Christmas Eve at 6 p.m. until midnight on December 26, when overnight staff returns from the holiday break.

There are between 100 and 120 employees working during store hours, with an estimated seasonal increase to about 200 employees over the holidays. About 4,000 to 5,000 customers visit the store each weekday, and about 6,000 to 8,000 customers visit on each weekend day. During the holidays the customer count increases by about an additional 2,000 per day.

The interior lights in the main retail space remain on at all times to accommodate normal business hours and the overnight crew, which performs maintenance and restocking duties during nonbusiness hours. Lights within employee offices and breakrooms are controlled by manual switches.

HVAC RTUs and refrigeration compressor stacks operate based on a call for heating or cooling, as sensed by local temperature sensors tied to the energy management system. It is not apparent that these units are on any sort of time-based schedule, and they currently operate at all times since the building is always occupied.

### Operations During the COVID-19 Pandemic (March 2020 to Present)

**At the time of this report, no changes had been made to HVAC controls or setpoints, lighting schedules, or other energy-consuming end uses since the onset of the COVID-19 pandemic in March 2020. However, it was noted that the lack of refrigeration savings flagged by the project team, discussed further in Adjustments to the Original Design Approach**

### Construction Timeline

During construction to retrofit the refrigeration condensers with Turntide motors, TRC found that the condenser fan-control logic resided in the existing Danfoss fan VFD instead of in the condenser controllers, which required redesign of the motor retrofit. Installation of the Turntide motors in the HVAC units was slated for Phase I; however, this was delayed to Phase II when the team discovered that the fan-speed signal was stored on VFDs scheduled for removal.

TRC worked with the design firm P2S, the equipment manufacturer Turntide, and Walmart to identify the wiring changes on the existing condenser controllers and developed new wiring diagrams for the Turntide motor integration. This new wiring design was approved by Walmart before implementation. There was need to alter the permit since the Turntide motors could continue to receive control commands from the existing VFD-based controller; so the actual sequence did not change.

## Lighting

The original lighting scope was meant to introduce a full-building DC lighting system energized by the solar and a battery-energy storage system. The project team selected i2Systems as the lighting vendor because of both its history with Walmart and because the vendor was certain that it could develop a product that met the project's objectives. A battery-energy storage system was installed at the store without considering future connections to a DC lighting system. As a result, the DC lighting system developed for this project did not have a DC voltage source without voiding existing PPAs or warranties on costly equipment. The solution for the demonstration was to install a DC voltage power source as a DC power supply for a smaller number of lights in one sales department. This allowed demonstration of the voltage autosensing equipment and also allowed the project team to record the power-draw difference between the AC and DC modes. Demonstration of the DC power supply was limited to the garden center to avoid the unnecessary cost of installing DC power supplies throughout the store.

## Store BMS Controller Upgrade

The legacy NOVAR store controller had to be upgraded to enable communications from the legacy NOVAR control system to the Locbit system. Though this was not in the scope of the project, Walmart was already installing this upgrade across multiple stores. An additional controller upgrade was required for the AHUs, which were on a different controller from the central controller and had to be updated to communicate with the new ES-1 NOVAR controller.

## HVAC Maintenance

The existing HVAC units were 24 years old and original to the store. During preconstruction and construction, the construction team found numerous maintenance issues with the units including nonoperational HVAC units, nonoperational economizers, failed compressors, dirty filters, and failed condenser fan motors. Outside the scope of the project, but crucial to the project's success, were various maintenance issues that were addressed with Walmart's facilities team and maintenance vendor, CBRE. Maintenance issues addressed during the design and construction phase of the project included returning AHU1 to full-service operability (AHU1 was not operational during the submetering baseline M&V period) and repairing broken economizer dampers to increase full DualCool savings.

The trimmed data method used for comparing 2020 submetered data and 2021 post-retrofit data excluded any units that were not operational for an apples-to-apples comparison. These results still yielded substantial savings in kWh and kWh/Degree Day. Maintenance deficiencies were not directly accounted for in this analysis; however, the project team assumed that maintenance-related savings were minimal and could be included in the "unidentified savings" percentage.

### IoT Platform

Direct control of the store with an IoT platform provider was meant to both monitor real-time energy uses of modified equipment and optimize energy consumption of controlled equipment, considering time-of-use (TOU) energy pricing, weather, occupancy, and other monitored variables. When the scope was originally developed, the cyber-security requirements of Walmart were not fully understood, and once the project was underway the team needed to find an alternative to direct store control. The team developed this alternative with the IoT platform, Locbit, and NOVAR, the existing energy-management system. The final control strategy was to have the IoT platform monitor building energy use and provide notifications to the Walmart facilities team to make adjustments; however, in practice this did not work because of timeline constraints and an inability to identify singular triggers that could manually adjust set points in a timely manner.

## Installation of Technologies and Lessons Learned

The path to California's mandate to double electricity and gas savings by 2030, equivalent to a 20-percent reduction in projected statewide building energy use, still has many opportunities for expansion. The lessons and findings from this project can better inform future deep-energy-savings retrofit projects. A summary of lessons learned follows.

### System Submetering

Due to budget and technical constraints, HVAC units were submetered at the panel level, which did not provide granularity on a unit-by-unit basis. With additional budget, submetering could be performed at the individual HVAC-unit level. Because there were some units that received both the DualCool and smart switch reluctance motor technologies, the project also had to evaluate their combined effects.

For future research, it is recommended that submetering systems (for example, DENT submeters) have data-recovery features that are remotely accessible (versus on-site recovery).

### i2Systems DC-Ready LED Lighting

i2Systems created an innovative, brand-new AC/DC autosensing light fixture for this project in less than a year. In the implementation phase, i2Systems identified lessons learned in four main areas:

- **Mechanical Fit:** There was a raised surface between existing light fixtures that i2Systems did not account for and that caused an interference fit in the continuous run of the retrofit. Once i2Systems identified this issue it developed an accommodation in the housing design to fit the raised surface.
- **Red Indicator Lights:** i2Systems fixtures have a built-in fault detection system that signals a fault through a red indicator light. In certain situations, the red indicator lights were signaling a fault when one did not exist. This was due to an over sensitivity in the circuit design that caused false failures in the system.

- **Balancing of Circuits in the Store:** i2Systems fixtures can plug together for up to 300 feet on a single run; however, in a few circumstances, the original electric wiring was configured so that it could not accommodate the current draw. In these cases, the electrical wiring had to be changed to a maximum of two rows per circuit to avoid exceeding the rated electrical draw.
- **Signal Propagation:** The main sales floor is an expansive space that requires wireless signal propagation to all areas where lighting products were installed. Initially, i2Systems had some cases where the signal did not properly propagate, so fixtures did not respond to commands. i2Systems was able to make firmware modifications to correct this.

## ICI DualCool Evaporative Precooling

While the installation itself was straightforward for ICI, there were a couple of key lessons learned that would have reduced problems identified during commissioning:

- Check that each HVAC unit receiving DualCool retrofit is level both pre- and post-install and confirm that there are no issues for the extra weight on the roof.
- Conduct pre-project "commissioning" of HVAC units receiving retrofits to ensure the units are operating as intended. For example, economizer dampers are a frequent failure point on HVAC units; in this project, a few existing HVAC units had economizer dampers that required repairs to realize full savings from the DualCool technology.

## Saya Life Smart Water-Management System

The original iteration of Saya Life water meters was not waterproof and required an in-field solution to provide protection from the weather. Saya Life now has IP68 water meters that are rated for outdoor use.

Additionally, Saya Life had to adjust for a 5-V power requirement for water meters by installing low-voltage wiring in conduits. This solution was selected for the project.

## Turntide Smart Switch Reluctance Motors

Throughout the course of the project, Turntide implemented a robust root cause analysis and corrective process to resolve issues as they arose. Key issues encountered and their corrective actions follow:

- **Site Connectivity:** The original RMK (antenna) design encountered communication dropouts to the cloud. This has since been updated with new equipment to reduce those dropouts. This new solution improved communication reliability and is being evaluated for robustness at multiple sites.
- **Modbus Communication:** A firmware flaw was discovered related to RS-485 Modbus communication. This flaw was corrected with newer firmware and is being applied at other sites.
- **Motor Controller Reliability:** A high number of P04 motor controllers for the V01 series motors failed throughout the course of this project. Defective motor controllers across this and other customer sites were sent back to Turntide's Engineering group for

evaluation. Data collected from this project has been instrumental in developing Turntide's next-generation motor controller.

- **RTU Motor Noise:** An unacceptable level of motor noise from Turntide's V02 motor series was noticeable in the retail space. Noise-isolating motor mounting feet were installed that substantially reduced radiated noise. Data collected from this site and other customer sites are driving improvements on the current motor design.
- **Condenser Fan Motor Noise:** At certain motor operating frequencies, torque ripple from individual motors combined to create an unacceptable noise level from the condenser rack upon motor deceleration. Problematic operating frequencies are now being "skipped," all but eliminating this noise issue. Data from this site and other customer sites is being used to drive improved motor design.

Post-project, Turntide continues to work with the Walmart team to monitor installed motors to ensure that remaining communication issues are identified and promptly resolved.

## Locbit IoT Platform

Due to delays in the integration of Walmart legacy control system (NOVAR) into the Locbit platform, Locbit did not contribute savings during Q1 to Q3 of the M&V period. While Locbit successfully integrated data from all installed technologies, on-site solar, utility data, and the data from NOVAR, Locbit was unable to propose specific triggers and corresponding energy saving actions for Walmart to implement during the measured M&V period (Q1-Q3). This is due to a combination of factors, including:

- Locbit did not have full direct control of Walmart's read-only control system, so any identified triggers had to be sent to a Walmart team member to manually implement them. For maximum energy savings, Locbit's automation platform should have been based on reinforcement learning by completing a cycle of abstracting controls and data, analyzing the data, automating through control adjustments, and re-analyzing based on selected energy cycles.
- Many data points in Walmart's legacy system were not clearly labeled by subsystem (for example, Sensor 1 HVAC was listed instead of Sensor 1 RTU 8).
- Locbit's team also faced staffing challenges during the pandemic, which delayed integration of the NOVAR system for analysis, and caused issues including the lack of clarity in sensor labeling.

Due to the reasons stated, 0 percent electric energy savings were attributable to the Locbit technology during the measured M&V period; therefore, no electric energy savings were forecasted. The system did provide non-energy benefits through fault detection and diagnostics, such as allowing visibility when the on-site solar generation went offline and identifying when there were communication issues with any installed technology.

In future project iterations, one key lesson learned is to vet cybersecurity requirements and integration requirements upfront to ensure that the provider can meet the site hosts' security requirements and vetting process to fully integrate into existing legacy systems on the site hosts' internal network. If this is not possible, alternative communication methods may need to be explored to fully enable read/write access for new IoT platforms.

Another key lesson learned is that if energy savings are based on data from a legacy control system's sensors, then it is imperative that the legacy control system's data is accessible to the IoT platform and is usable, in that sensors and other data sources need to be labeled per equipment subgroup or unit (for example, HVAC, or RTU 1) and that all components of the legacy control system can be accessed using current communications protocols.

Additionally, Locbit made several contributions to additional actions that IoT providers can take to increase successful installation of IoT-type technologies:

- The in-store network should be analyzed and clearly defined before installation to ensure the connectivity of all devices, and that the network is sufficient.
- Accurately estimate incoming data loads to properly size the server. Locbit's Edge Server needed more resources to support the amount of data integrated through this project. Locbit found that the Edge Server was constantly running above 80 percent of its resources, which necessitated occasional rebooting of the device.
- Install power meters that store data in the event of a connectivity issue that can be remotely accessed and recovered if necessary. This would eliminate the loss of key energy data and reduce on-site troubleshooting/support time. On this project, the models of DENT submetering systems installed had data recovery, but it was only accessible on-site.
- Provide automated device offline messages from "day one" to project technology partners. By providing this information directly to the relevant technology partners, Locbit was able to reduce the times when technologies were out of communication with the Locbit system.

Finally, in selecting an IoT platform for future projects it is important to consider project needs like dashboards, M&V requirements for proof of savings for incentives, and adequate data, communication, and computing infrastructure to support multiple communication protocols and quickly resolve issues while integrating existing systems.

If future project sites rely on energy dashboards or IoT platforms for in-depth system control, a carefully thought-out monitoring plan is essential. The easiest time to implement monitoring is early in the design phase of a project, so working closely with the design team is crucial.

CHAPTER 3:
Project Results, could be due to a potential increase in refrigeration case usage from the 2020 submetering baseline and the 2021 M&V period. A secondary data point confirmed the assumed demand increase on the refrigeration racks and offset efficiency gains for the associated Turntide motors and controls. Confidential sales data provided to the project team showed an increase in food sales during the 2021 M&V period over corresponding months in 2020, which affects how often the freezer cases are accessed. It should be noted that an increase in sales does not directly correlate to a similar increase in energy demand.

# Baseline Energy Use & Modeling

## Baseline M&V Data

The utility data baseline for this project encompassed February 2017 to January 2018 electric-interval data from SCE. This baseline was then calibrated with interval whole-building and submetering data from July 2020 and used to complete energy model calibration during initial stages of the project for determining EEM reductions. It was also used to compare with post-retrofit energy profiles to analyze the effectiveness of EEMs. Subsystem monitoring was implemented in May 2020.

In 2017, Store 2292 had a gross site consumption of 3,447,959 kWh, of which 2,583,607 kWh, or 75 percent, was supplied by the state's electric grid, and 867,437 kWh, or 25 percent, was supplied by on-site, non-export PV. Electric energy loads were comprised of store lighting, HVAC systems, refrigeration for food, plug loads (such as electronic displays and checkout registers), and other ancillary equipment including food preparation and stockroom equipment. The electric profile follows a typical trend for a big-box retail store in this climate zone, with higher consumption in the summer months from increased air conditioning. Figures included in APPENDIX D represent the monthly baseline electrical consumption and production in kWh (Figure D-1) and peak kW (Figure D-2Figure D-2Figure D-2).

Natural gas consumption for this baseline was 11,073 therms. Natural gas is mainly used for space heating, domestic hot water heating, and a minimal amount for cooking. The thermal energy profile is typical for this type of facility where gas is consumed for space heating in the winter months. Figure D-3 (Appendix D) represents the monthly baseline natural gas consumption, in therms.

During the baseline, Store 2292 consumed 1,950,171 gallons of water. Water consumption, unlike occupancy, isn't dependent on weather though water consumption increased during the holiday months of November and December when more people were using the restrooms. Figure D-4 (Appendix D) represents the monthly water consumption, in gallons.

## Energy Modeling

To create the energy model, the baseline was calibrated with interval whole-building and submetering data from July 2020 and used to complete energy model calibration during the initial stages of the project to determine EEM reductions. It was also used to compare post-retrofit energy profiles to analyze the effectiveness of EEMs. Subsystem monitoring was implemented in May 2020.

NREL developed a calibrated baseline energy model of Walmart Store 2292 using the United States Department of Energy's (DOE) OpenStudio modeling platform. Calibration of the Walmart energy model was performed using monthly electric and gas consumption data, along with actual meteorological year weather data for the baseline year of February 2017 to January 2018. Hourly baseline M&V data for the month of July 2020 were used to fine-tune the baseline model for refrigeration and lighting. Furthermore, the collected baseline M&V data were useful for benchmarking two HVAC units in the baseline model.

DOE's OpenStudio modeling platform builds on DOE's EnergyPlus simulation engine and includes a collection of software tools that support whole-building energy modeling. OpenStudio is an open-source platform for the creation of desktop application or web services, which enables rapid creation of energy models for building design, retrofit performance assessment, and load analysis, at multiple scales. Models may be built with few or many inputs depending on the need for precision. Among these software tools are the OpenStudio Application and the Parametric Analysis Tool. OpenStudio Application is a fully featured graphical interface that facilitates construction and inspection of OpenStudio models including envelope, loads, schedules, and HVAC.

Including all energy efficiency technologies into one package produced the results shown in Table 1, produced by running all energy efficiency measures simultaneously, including interactive effects. The model approach informed the design approach by estimating savings from the different EEMs.

Table 1 represents anticipated individual EEM savings as a percentage of whole-building reduction, as well as annual kWh and cost savings.

**Table 1: Walmart Supercenter (Store 2292) Estimated EEM Savings**

| Efficiency Measure | % kWh Savings | Energy Savings (kWh/Yr.) |
|---|---|---|
| Locbit IoT Platform | 1.9% | 64,405 |
| i2Systems Lighting | 10.9% | 374,726 |
| Turntide Smart Motors | 6.1% | 210,091 |
| ICI DualCool Evaporative Precooling | 2.8% | 95,944 |
| **Total** | **21.7%** | **745,166** |

Source: Center for Sustainable Energy *Q1 M&V Report*, as based on data from NREL's *Final Optimization Report*

The model estimated that 2.8 percent of site electricity may be saved by retrofitting both AHUs and four of the 20-ton RTUs with DualCool. Turntide retrofits of all RTUs, AHUs, and refrigeration condenser fans were expected to deliver 6.1-percent savings. Through Locbit, shutting off the electronic department display monitors and laptops during unoccupied hours, lighting controls, and zone and refrigeration temperature setpoints are expected to contribute 1.9-percent site-electricity savings; upgrading to DC LED lighting through i2Systems could save as much as 10.9 percent more. As predicted by NREL's energy model, the total savings associated with these retrofits are slightly above the 20-percent reduction goal. A comparison of these modeled results with results measured and forecasted during the M&V period appears in the

Project Resultssection.

## Design Approach

The project design was developed to incorporate the inputs of all technology, code, and energy-efficiency requirements into a clear construction document set understandable by building officials, project stakeholders, installing contractors, and maintenance contractors. The design documents included information on existing equipment, each of the HVAC and lighting technologies, and on how they were designed to interact and communicate, both with each other and with Walmart's existing NOVAR building control system. The design documents also included upgrades to existing supporting utilities required by each technology including energy, water, and drainage systems. The basis for this design is summarized in this section.

## Mechanical HVAC Systems

RTUsare the most common mechanical systems in large commercial buildings because they are inexpensive, require minimal engineering design, and are easy to install. However, due to their low cost, in general they minimally meet code requirements for energy efficiency and often have inexpensive components that frequently need replacement, which leads to higher maintenance and energy costs. Building owners therefore typically want more efficient systems but do not replace existing RTUs before their useful lives end at 15 to 20 years. There are several newer technologies now available to improve the efficiency of existing RTUs.

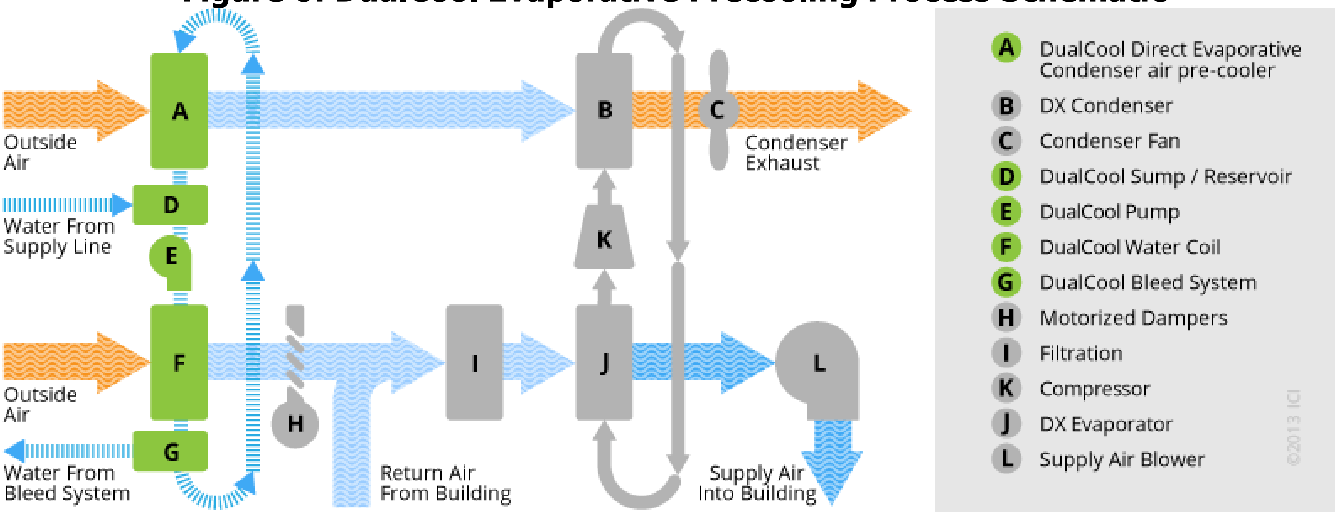
The design of the HVAC system included integration of several preselected EE technologies with existing RTUs and their dedicated outdoor AHUs. The mechanical upgrades addressed the overall objective of improving the energy efficiency of existing building while also maintaining a comfortable environment for occupants, minimizing maintenance costs, and preserving operational efficiency. One of the technology upgrades was a retrofit evaporative precooling system installed at four of the existing RTUs and two existing AHUs, which included the addition of water meters to monitor water use of the evaporative cooling systems. The RTUs selected for evaporative precooling are units already dedicated for building indoor air quality (IAQ). The evaporative cooling system, water meters, and existing RTUs and AHUs were integrated into Locbit to analyze energy usage. The system additions provided HVAC in conformance with applicable codes and specific requirements of design criteria.

The technology upgrades were sized in collaboration with technology partners considering statistical weather data from the California Energy Commission's (CEC) 2016 Joint APPENDIX 2 for Covina, California (CEC 2016). The summer design conditions were based on "1% Design Conditions" and winter conditions were based on "Winter Median of Extremes." The ambient design temperature in summer is 95°F (35°C), 69°F (21°C) dry bulb /mean coincident wet bulb, and in winter is 29°F (-2°C).

## Evaporative Precooling System

The building is served by 27 existing packaged RTUs and two existing 100-percent outside air, AHUs. The RTUs consist of a direct expansion (DX) cooling coil, gas heating section, and supply fan. The AHUs consist of a supply fan, DX cooling coil, and a gas heating and reheating section that allows cooling and heating of outside air and serves as the building's main dehumidifying units. The two AHUs and the four primary RTUs equipped with carbon dioxide sensors served the main retail area and were supplied with the retrofit evaporative cooling system DualCool, manufactured by ICI. Water is piped from the building's main cold water supply line to each of the four RTUs and two AHUs. The DualCool system essentially acts as a miniature cooling tower by supplying water over an evaporative media section attached to the condenser intake to precool the condenser air. The water cools as it passes over the media and is pumped to a coil attached to the outside air intake, which precools the outside air. The water continues back to the condenser section and the cycle repeats, as illustrated in Figure 6.

**Figure 6: DualCool Evaporative Precooling Process Schematic**




Source: Integrated Comfort, Inc.

The DualCool system consists of the following components:

*Direct Evaporative Condenser Precooler*

This is a stainless-steel enclosure attached to the condenser air intake section of an RTU or AHU. The enclosure contains the direct evaporative cooling media and an integrated water reservoir, as well as a submersible pump that pumps water through the system. This component of the precooling system cools the air entering the condenser while also cooling the water used in the outside air-cooling coil.

*Outside Air Cooling Coil*

This is a water coil attached to the outside air intake section of the RTU or AHU. Cool water is pumped through this coil from the reservoir to precool the outside air. The water warms up as it travels through the coil, where it then flows to the distribution pipe at the top of the evaporative media section.

*Bleed System*

This system limits the concentration of hard minerals by draining water out before minerals can build up on the media and in the coil. The bleed rate was determined in the field by measuring the hardness content of the supply water. A filter upstream of the bleed valve protects the system against clogging, and the filter must be cleaned regularly. Routine maintenance for HVAC systems and DualCool provides opportunities for adjustments, as needed, to the bleed rate.

Overall, bleed-system technology is simplified to balance performance and price. Other evaporative systems implement conductivity sensors but this increases cost, potentially reducing return on investment.

*Controls*

A thermostat was supplied with the system, which activates the DualCool pump when the outdoor air temperature exceeds a preset value. The evaporative cooling system is locked out when the ambient air dew point exceeds 58°F, which helps to avoid increased latent loads from bringing in ventilation air with high moisture content. The cooling coil imposes only a small 0.08" water column pressure drop to the outside air intake path, which has negligible impact to RTU fan energy and adds approximately 5 percent impact to AHU fan energy.

The changeover value to operate DualCool for this project site was determined to be 70°F. Each project site has specific optimized setpoints to ensure proper operations and minimize unnecessary buildup on the evaporative media.

The DualCool system requires minimal electric power for the circulation pump and needs water for both evaporation and bleeding. An SCE-sponsored study on DualCool estimated approximately 3.4 gallons of water may be used to save 1 kWh (SCE 2015 p.44). The report also indicates up to 2.76 gallons of water is required to generate 1 kWh of energy, therefore the net total water consumption is lower than what will be measured at the site. Actual gallons of water used per kWh saved was evaluated as part of the M&V period. More details can be found in the

Project Results section.

### Smart RTU and AHU Retrofits and Controls

All the existing RTUs and AHUs were retrofitted with switched reluctance motors and smart control systems to help reduce energy usage, as manufactured by Turntide, except RTU-6 because it had a fractional horsepower fan motor (0.5 hp). It was understood no replacement was available for the smaller motor. Some of the existing RTUs and AHUs had constant speed supply fans, which waste energy as the fans run at full speed even during part-load conditions. Other units had multispeed fans that may or may not operate in multispeed modes. The smart retrofit solution upgraded each of the following areas of existing RTUs and AHUs by:

- Providing variable speed operation to the RTU supply fan motors by replacing existing motors with switched reluctance motors. Fan speeds were based on compressor staging and supply air temperature setpoints.
- Updating and commissioning economizer controls for fixed dry-bulb, economizing logic and monitoring outdoor air dewpoint levels to avoid introducing unnecessary moisture into the space.
- Maintaining the store’s demand-control ventilation logic, which was limited to the four units serving the retail sales area. The purpose of this system was to maintain IAQ for the store overall. These units can operate in coordination with the evaporative pre-cooling system to minimize energy use impacts if needed to increase ventilation during non-economizer hours.

- Installing a DualCool evaporative cooling system.
- Controlling the Turntide system to maximize RTU and AHU efficiency.
- Coordinating smart RTU and AHU controls with Locbit energy optimization for optional temperature resets of up to 2°F (XXX°C) after business hours.

### Water Monitoring System

It was understood that the DualCool system would reduce electricity demand and increase energy savings; however, a significant amount of water is also required to run the evaporative cooling system. A water consumption monitoring system, supplied by Saya Life, was installed to provide water consumption data for each of the four RTUs and two AHUs installed with the DualCool evaporative-precooling systems. The evaporative cooling system operates only when energy savings can be realized. The data were also used in a fault-detection capacity to determine the reasonableness of the water usage.

The water meters are ultrasonic flow meters with integrated pressure sensors that provide data for a single gateway. This system consists of:

- One water meter on the main water line serving the RTUs.
- Two water meters at each RTU and AHU equipped with DualCool: one on the supply line and one on the bleed-off line at each unit. The differential reading is the amount of evaporated water. Flow meters were installed outdoors with weather cover.
- Meter information, sent via one gateway back to the Locbit platform to monitor water usage. Gateway was installed in an area capable of maintaining the manufacturer's operating temperature range.
- Communications sent from central Locbit system through available 4G/LTE wireless network to Saya Life's cloud-based network. A direct connection to local controls via Locbit was unavailable because of Walmart's cybersecurity constraints.

## Refrigeration System

The building has six pre-existing refrigeration systems that deliver cooling to various refrigerators, freezers, and walk-in coolers in the building. The systems consist of vertical-scroll compressor racks located indoors, and air-cooled condensers on the roof. Refrigeration systems in supermarkets accounts for a substantial portion of their overall energy use, so substantial savings can be realized by increasing their efficiency.

The main upgrades designed for the refrigeration rack systems included:

- Replacement of the existing air-cooled condenser fan motors with switched reluctance motors. (See the Smart RTU and AHU Retrofits and Controls section for additional information on Turntide motors.) Condensing fan motors are controlled for head pressure by existing refrigeration control systems.
- A refrigeration system that coordinates with Locbit energy optimization system for walk-in freezer system provided temperature-resets during nonbusiness hours of up to 2°F (1°C). This acceptable period was assumed to be between 1 a.m. and 5 a.m. However,

due to control integration limitations between Locbit and Walmart, this approach could not be implemented.

## Lighting System

With lighting systems moving toward controllability and efficiency, LEDs have emerged as primary light sources in the commercial lighting market. In the past, LEDs were limited to applications such as traffic signals, exit signs, automobiles, and electronics. Today's LEDs are more efficient and longer-lasting, allowing for growth into areas long dominated by more traditional lights. LEDs are solid-state light sources that are resistant to vibration and offer significantly longer operating lifetimes than most sources while using much less energy than either fluorescent or incandescent fixtures.

The upgraded lighting installed by i2Systems consisted of retrofitting more than 1,000 existing 32-W T8 linear fluorescent fixtures with 12 W/ft LED fixtures and integrated wireless controls. This system can operate on both 277 V AC and 380 V DC to accommodate a direct power source from on-site battery energy storage. The lighting is currently served by a standard AC panel, but in the future can integrate directly with on-site distributed energy resources. This approach allows for a retrofit solution that can be broadly implemented with minimal changes to existing electrical distribution wiring, while maintaining future compatibility with DC-based electrical distribution systems that could be installed with solar PV or energy storage systems.

The areas retrofitted included the main retail sales floor, the stock room, employee breakrooms, offices, and restrooms. Dimming controls further reduced lighting energy requirements by operating the fixtures at 80 percent of full capacity throughout retrofitted spaces while still providing enough light to meet Walmart's requirements. More details on the lighting system can be found in APPENDIX B:
LED Lighting System Details.

The lighting fixtures were powered from existing AC voltage electrical infrastructure. To demonstrate DC capability and the benefits of a DC lighting system, one small area of the store, the garden center, was retrofitted to DC electricity and consisted of:

- A test area with 48 luminaires, shown in Figure B-1.
- Light fixtures powered by an AC-to-DC power rectifier.
- A voltage converter powered by the existing AC-voltage infrastructure.

The installation allowed the project team to monitor this demonstration area to determine the energy input to the DC lighting, track the conversion efficiency of the rectifier and confirm that the lighting product provides the required illuminance on DC voltage. The data was used to estimate potential savings from all lighting from a DC bus energized by a battery energy storage system or other DC source. Figure B-1 in APPENDIX B shows the lighting layout of the store and dimming zones. Dimming Zone 4 is the garden center test area.

### Lighting Controls

The drivers were switched from incoming AC or DC power, which allowed energy reductions from the demonstration area to be directly compared with the same lighting in other areas of the store and then extrapolated from to demonstrate the savings and advantages of a storewide DC lighting system.

The lighting system was controlled by the existing Walmart Novar executive building management system (BMS). The lighting fixtures connected directly to the Novar system, and the lighting fixtures communicated with each other through a Bluetooth wireless mesh network, with hard-wired controls required only for final connection to Locbit's IoT platform. After business hours, lighting is uniformly dimmed store-wide to approximately 60 percent of normal foot-candle levels. The retail sales floor lights are needed for store stocking and maintenance activities after hours, so could not be either dimmed further or shut off completely.

#### Lighting Design Criteria

Horizontal and vertical foot-candles met or exceeded specifications for retail lighting in the recommended practices for retail lighting provided by the Illuminating Engineering Society of North America. LED lights perform especially well for highlighting specific products. The lighting in Store 2292 is a retail-space standard with a 3,500 K color temperature, vertical lighting level of 25 foot-candles, and horizontal lighting level at three feet above the floor of 60 foot-candles.

### IoT Platform

All the energy efficiency upgrades and technologies connect with Locbit's cloud-based IoT platform and are accessible through local, remote, and mobile devices. System monitors, using a fault-detection and diagnostics engine, connect all building systems and detect energy waste, equipment malfunctions, and other operational problems. The system was designed to recommend set-point adjustments to operating equipment for greater operating efficiency. However, due to limitations in project implementation (including the lack of direct access controls to Walmart's NOVAR system), Locbit was unable to contribute the measurable energy savings initially anticipated. Some individual control systems remained; for example, neither the smart RTU control system nor the existing legacy building systems were controlled by Locbit's platform. Locbit's design parameters included:

- A compatible system for all the technologies proposed in this project, with existing building systems.
- Graphic data for identified electric-utility end uses, for easier understanding of the data collected.
- Actionable fault detection for, and diagnostics reporting to, the building maintenance staff.
- Communication to the cloud through a 4G/LTE wireless gateway and adherence to Walmart data security protocols (such as Azure).

## End-Use Monitoring

The project team installed and commissioned DENT split-core current transformers (CTs), PowerScout 24DS power meters, and Locbit's edge server. The DENT PowerScout meters measured specific circuits using installed CTs (see Table A-1). Locbit's edge server collected that energy data through communication cables to a network switch, which was also connected with the Locbit server. Data were then sent through a cellular modem to the cloud, where it could be stored and accessed by Locbit and other parties.

To minimize any disruption to normal store operations, a portion of the DENT meter and CT installation activities required that some electrical panels (Table A-1) be de-energized and installed overnight, outside of business hours. The project team ensured that the de-energized electrical circuits were fully operational when re-energized.

## Construction

### Bid Process

Based on project design, construction tasks were broken down into the following elements for installation bidding:

Retrofit 26 existing RTUs, 2 AHUs and 6 air-cooled condensers with Turntide's switched reluctance smart motors and controllers.

- Retrofit 4, 20-ton RTUs (RTU 10, 12, 15, and 18), two AHUs (AHU 1 and 2) with ICI DualCool evaporative precooling system retrofit.
- Install 13 Saya Life ultrasonic water flow meters on four RTUs and two AHUs. Each unit has a meter on the supply side and drain side of the DualCool system. There is one meter on the main plumbing line entering the roof.
- Retrofit 2,084 T8 4-foot fluorescent fixtures with new i2Systems hybrid 380VDC/277VAC LED fixtures.
- Install Locbit's IoT controls platform to integrate Turntide, DualCool, Saya Life, and i2Systems technologies. Integrate DENT's submetering infrastructure and SCE's utility meter with Utility API and rooftop PV, via a PPA, also through Utility API. Integrate existing NOVAR HVAC, refrigeration, and the lighting control system through one-way communication that collects and analyzes system operation to provide optimization solutions.

TRC managed technology procurement from providers, led the request for proposal and bid processes, selected and contracted with specialty contractors for technology installation, oversaw installation activities, and supported commissioning and M&V activities.

Using the 90-percent design documents from the project designer, P2S and TRC compiled a bid package. TRC invited five contractors to bid on the project and received bids from three of them. TRC reviewed the bids and graded them based on completeness of response, budget, prior history of similar technologies, and experience working at Walmart sites. Based on this review, TRC conducted a bid review meeting and discussed each bid in detail. Only Emily Grene submitted a complete bid with the lowest overall bid price. Based on the completeness of the bid and the bid price, TRC, in consultation with CSE, awarded the bid to Emily Grene.

### Permitting and Work Schedule Preparation

Permitting for the project was conducted in parallel with the installation activities. Project design engineer P2S submitted 90-percent design drawings to the Covina building department for approval. The design drawings were approved by the city on August 7, 2020.

Installation for the project was completed in two phases. Phase 1 of the installation was completed in October 2020. Its scope included:

- Retrofitting 26 RTUs and 2 AHUs with new Turntide smart motors and controllers.
- Adding DualCool evaporative precooling systems and associated controls to RTUs numbered 10, 12, 15, and 18, and AHUs numbered 1 and 2.
- Installing 13 Saya Life water meters.
- Installing conduits, low-voltage wiring, and data cables to Turntide and DualCool controllers.
- Installing copper piping to the RTUs and AHUs to provide water for DualCool units, and connecting blowdown drains to existing condensate drain piping.
- Installing 48 i2Systems LED lighting fixtures, a gateway, and a DC box in the garden center to pilot the DC LED lighting capabilities.

Phase 2 of the installation was completed from March through June 2021. The scope included:

- Installing 24 Turntide smart motors and controllers on 6 refrigeration air-cooled condensers.
- Installing 2,036 i2Systems lighting fixtures and gateways on the sales floor and in support areas.
- Installing daylighting sensors in the vestibule area.
- Integrating new LED lighting into the existing NOVAR control system and dimming controls to dim lights to 60-percent during the overnight stocking hours of 12:00 a.m. to 5:00 a.m.
- Implementing the Locbit platform to integrate technologies.

Once Phase 2 of the project was completed and the project fully commissioned, TRC scheduled a permit closeout walk-through with the city building inspector. Based on the first walk-through, the inspector requested some minor revisions to the drawings to better reflect the actual installation. TRC worked with P2S to incorporate these changes and revised permits were approved in January 2022.

## COVID-19 Impacts

Due to COVID-19-related material delays, construction was divided into two phases. Phase I was from October 2020 to December 2020 and included installation of DualCool and Saya Life water meters and associated plumbing, Turntide motors, and a small section of lighting in the garden center, which became the test area for the DC-powered lighting. Phase II was from January 2021 to June 2021 and included finalization of the Turntide motor installation, lighting installation for the rest of the store, installation troubleshooting, and commissioning. The largest source of material delays was for lighting, where delivery of some key electronic components took longer than usual.

COVID-19 did not have any direct impacts on installation contractor labor. Installation teams were screened for temperature each day upon entry to the job site, and masks were worn inside the store.

## Commissioning

Commissioning is a systematic process of ensuring that all building systems perform interactively, according to the design intent, and in accordance with the owner's operational needs. This was achieved by beginning the commissioning process in the design phase, documenting the design intent, and continuing through construction, acceptance, and the warranty period, with actual verification of performance. The following sections describe the systems commissioned by DAVenergy Solutions on behalf of the Center for Sustainable Energy (CSE) and Walmart, as well as the phased processes used to execute the work.

### Systems Commissioned

The following systems were commissioned:

- **Mechanical Systems: HVAC Air Handling Systems**
  Air handling units, packaged rooftop AHU, rooftop condensing units, DualCool technology (AHU-1, AHU-2, RTU-10, RTU-12, RTU-15, RTU-18)
- **Electrical Systems: Lighting and Lighting Control Systems**
  Occupancy sensors, lighting control systems, architectural dimming systems

### Functional Testing and Site-Visit Findings

The goal of every commissioning project is to establish processes, procedures, and clear lines of communication to prevent and resolve issues. However, regardless of these efforts, issues still surface and require resolution to minimize impacts on everyone. Thirty-six such issues were documented during the project's construction and acceptance phases; brief descriptions of three of them follow:

- **ISSUE ITEM 1:** RTU-10 main DualCool control dewpoint temperature sensor was not wired correctly and showed a reading of 0°F (-18°C) dew-point temperature. The contractor reported this issue fixed.
- **ISSUE ITEMS 2-5:** The Dual-Cool was activated on RTU-10, RTU-12, RTU-15, and RTU-18, all without a call for cooling. A call for cooling should be made when the space temperature is above the zone temperature set point. The contractor reported this issue fixed.
- **ISSUE ITEM 30:** The smart motors minimum speed was found set to 25 percent rather than the 10-percent design speed. The team decided to maintain the speed at 25 percent.

## Adjustments to the Original Design Approach

## Construction Timeline

During construction to retrofit the refrigeration condensers with Turntide motors, TRC found that the condenser fan-control logic resided in the existing Danfoss fan VFD instead of in the condenser controllers, which required redesign of the motor retrofit. Installation of the Turntide motors in the HVAC units was slated for Phase I; however, this was delayed to Phase II when the team discovered that the fan-speed signal was stored on VFDs scheduled for removal.

TRC worked with the design firm P2S, the equipment manufacturer Turntide, and Walmart to identify the wiring changes on the existing condenser controllers and developed new wiring diagrams for the Turntide motor integration. This new wiring design was approved by Walmart before implementation. There was need to alter the permit since the Turntide motors could continue to receive control commands from the existing VFD-based controller; so the actual sequence did not change.

## Lighting

The original lighting scope was meant to introduce a full-building DC lighting system energized by the solar and a battery-energy storage system. The project team selected i2Systems as the lighting vendor because of both its history with Walmart and because the vendor was certain that it could develop a product that met the project's objectives. A battery-energy storage system was installed at the store without considering future connections to a DC lighting system. As a result, the DC lighting system developed for this project did not have a DC voltage source without voiding existing PPAs or warranties on costly equipment. The solution for the demonstration was to install a DC voltage power source as a DC power supply for a smaller number of lights in one sales department. This allowed demonstration of the voltage autosensing equipment and also allowed the project team to record the power-draw difference between the AC and DC modes. Demonstration of the DC power supply was limited to the garden center to avoid the unnecessary cost of installing DC power supplies throughout the store.

## Store BMS Controller Upgrade

The legacy NOVAR store controller had to be upgraded to enable communications from the legacy NOVAR control system to the Locbit system. Though this was not in the scope of the project, Walmart was already installing this upgrade across multiple stores. An additional controller upgrade was required for the AHUs, which were on a different controller from the central controller and had to be updated to communicate with the new ES-1 NOVAR controller.

## HVAC Maintenance

The existing HVAC units were 24 years old and original to the store. During preconstruction and construction, the construction team found numerous maintenance issues with the units including nonoperational HVAC units, nonoperational economizers, failed compressors, dirty filters, and failed condenser fan motors. Outside the scope of the project, but crucial to the project's success, were various maintenance issues that were addressed with Walmart's facilities team and maintenance vendor, CBRE. Maintenance issues addressed during the design and construction phase of the project included returning AHU1 to full-service operability

(AHU1 was not operational during the submetering baseline M&V period) and repairing broken economizer dampers to increase full DualCool savings.

The trimmed data method used for comparing 2020 submetered data and 2021 post-retrofit data excluded any units that were not operational for an apples-to-apples comparison. These results still yielded substantial savings in kWh and kWh/Degree Day. Maintenance deficiencies were not directly accounted for in this analysis; however, the project team assumed that maintenance-related savings were minimal and could be included in the "unidentified savings" percentage.

### IoT Platform

Direct control of the store with an IoT platform provider was meant to both monitor real-time energy uses of modified equipment and optimize energy consumption of controlled equipment, considering time-of-use (TOU) energy pricing, weather, occupancy, and other monitored variables. When the scope was originally developed, the cyber-security requirements of Walmart were not fully understood, and once the project was underway the team needed to find an alternative to direct store control. The team developed this alternative with the IoT platform, Locbit, and NOVAR, the existing energy-management system. The final control strategy was to have the IoT platform monitor building energy use and provide notifications to the Walmart facilities team to make adjustments; however, in practice this did not work because of timeline constraints and an inability to identify singular triggers that could manually adjust set points in a timely manner.

## Installation of Technologies and Lessons Learned

The path to California's mandate to double electricity and gas savings by 2030, equivalent to a 20-percent reduction in projected statewide building energy use, still has many opportunities for expansion. The lessons and findings from this project can better inform future deep-energy-savings retrofit projects. A summary of lessons learned follows.

### System Submetering

Due to budget and technical constraints, HVAC units were submetered at the panel level, which did not provide granularity on a unit-by-unit basis. With additional budget, submetering could be performed at the individual HVAC-unit level. Because there were some units that received both the DualCool and smart switch reluctance motor technologies, the project also had to evaluate their combined effects.

For future research, it is recommended that submetering systems (for example, DENT submeters) have data-recovery features that are remotely accessible (versus on-site recovery).

### i2Systems DC-Ready LED Lighting

i2Systems created an innovative, brand-new AC/DC autosensing light fixture for this project in less than a year. In the implementation phase, i2Systems identified lessons learned in four main areas:

- **Mechanical Fit:** There was a raised surface between existing light fixtures that i2Systems did not account for and that caused an interference fit in the continuous run of the retrofit. Once i2Systems identified this issue it developed an accommodation in the housing design to fit the raised surface.

- **Red Indicator Lights:** i2Systems fixtures have a built-in fault detection system that signals a fault through a red indicator light. In certain situations, the red indicator lights were signaling a fault when one did not exist. This was due to an over sensitivity in the circuit design that caused false failures in the system.
- **Balancing of Circuits in the Store:** i2Systems fixtures can plug together for up to 300 feet on a single run; however, in a few circumstances, the original electric wiring was configured so that it could not accommodate the current draw. In these cases, the electrical wiring had to be changed to a maximum of two rows per circuit to avoid exceeding the rated electrical draw.
- **Signal Propagation:** The main sales floor is an expansive space that requires wireless signal propagation to all areas where lighting products were installed. Initially, i2Systems had some cases where the signal did not properly propagate, so fixtures did not respond to commands. i2Systems was able to make firmware modifications to correct this.

## ICI DualCool Evaporative Precooling

While the installation itself was straightforward for ICI, there were a couple of key lessons learned that would have reduced problems identified during commissioning:

- Check that each HVAC unit receiving DualCool retrofit is level both pre- and post-install and confirm that there are no issues for the extra weight on the roof.
- Conduct pre-project “commissioning” of HVAC units receiving retrofits to ensure the units are operating as intended. For example, economizer dampers are a frequent failure point on HVAC units; in this project, a few existing HVAC units had economizer dampers that required repairs to realize full savings from the DualCool technology.

## Saya Life Smart Water-Management System

The original iteration of Saya Life water meters was not waterproof and required an in-field solution to provide protection from the weather. Saya Life now has IP68 water meters that are rated for outdoor use.

Additionally, Saya Life had to adjust for a 5-V power requirement for water meters by installing low-voltage wiring in conduits. This solution was selected for the project.

## Turntide Smart Switch Reluctance Motors

Throughout the course of the project, Turntide implemented a robust root cause analysis and corrective process to resolve issues as they arose. Key issues encountered and their corrective actions follow:

- **Site Connectivity:** The original RMK (antenna) design encountered communication dropouts to the cloud. This has since been updated with new equipment to reduce those dropouts. This new solution improved communication reliability and is being evaluated for robustness at multiple sites.

- **Modbus Communication:** A firmware flaw was discovered related to RS-485 Modbus communication. This flaw was corrected with newer firmware and is being applied at other sites.
- **Motor Controller Reliability:** A high number of P04 motor controllers for the V01 series motors failed throughout the course of this project. Defective motor controllers across this and other customer sites were sent back to Turntide's Engineering group for evaluation. Data collected from this project has been instrumental in developing Turntide's next-generation motor controller.
- **RTU Motor Noise:** An unacceptable level of motor noise from Turntide's V02 motor series was noticeable in the retail space. Noise-isolating motor mounting feet were installed that substantially reduced radiated noise. Data collected from this site and other customer sites are driving improvements on the current motor design.
- **Condenser Fan Motor Noise:** At certain motor operating frequencies, torque ripple from individual motors combined to create an unacceptable noise level from the condenser rack upon motor deceleration. Problematic operating frequencies are now being "skipped," all but eliminating this noise issue. Data from this site and other customer sites is being used to drive improved motor design.

Post-project, Turntide continues to work with the Walmart team to monitor installed motors to ensure that remaining communication issues are identified and promptly resolved.

### Locbit IoT Platform

Due to delays in the integration of Walmart legacy control system (NOVAR) into the Locbit platform, Locbit did not contribute savings during Q1 to Q3 of the M&V period. While Locbit successfully integrated data from all installed technologies, on-site solar, utility data, and the data from NOVAR, Locbit was unable to propose specific triggers and corresponding energy saving actions for Walmart to implement during the measured M&V period (Q1-Q3). This is due to a combination of factors, including:

- Locbit did not have full direct control of Walmart's read-only control system, so any identified triggers had to be sent to a Walmart team member to manually implement them. For maximum energy savings, Locbit's automation platform should have been based on reinforcement learning by completing a cycle of abstracting controls and data, analyzing the data, automating through control adjustments, and re-analyzing based on selected energy cycles.
- Many data points in Walmart's legacy system were not clearly labeled by subsystem (for example, Sensor 1 HVAC was listed instead of Sensor 1 RTU 8).
- Locbit's team also faced staffing challenges during the pandemic, which delayed integration of the NOVAR system for analysis, and caused issues including the lack of clarity in sensor labeling.

Due to the reasons stated, 0 percent electric energy savings were attributable to the Locbit technology during the measured M&V period; therefore, no electric energy savings were forecasted. The system did provide non-energy benefits through fault detection and diagnostics, such as allowing visibility when the on-site solar generation went offline and identifying when there were communication issues with any installed technology.

In future project iterations, one key lesson learned is to vet cybersecurity requirements and integration requirements upfront to ensure that the provider can meet the site hosts' security requirements and vetting process to fully integrate into existing legacy systems on the site hosts' internal network. If this is not possible, alternative communication methods may need to be explored to fully enable read/write access for new IoT platforms.

Another key lesson learned is that if energy savings are based on data from a legacy control system's sensors, then it is imperative that the legacy control system's data is accessible to the IoT platform and is usable, in that sensors and other data sources need to be labeled per equipment subgroup or unit (for example, HVAC, or RTU 1) and that all components of the legacy control system can be accessed using current communications protocols.

Additionally, Locbit made several contributions to additional actions that IoT providers can take to increase successful installation of IoT-type technologies:

- The in-store network should be analyzed and clearly defined before installation to ensure the connectivity of all devices, and that the network is sufficient.
- Accurately estimate incoming data loads to properly size the server. Locbit's Edge Server needed more resources to support the amount of data integrated through this project. Locbit found that the Edge Server was constantly running above 80 percent of its resources, which necessitated occasional rebooting of the device.
- Install power meters that store data in the event of a connectivity issue that can be remotely accessed and recovered if necessary. This would eliminate the loss of key energy data and reduce on-site troubleshooting/support time. On this project, the models of DENT submetering systems installed had data recovery, but it was only accessible on-site.
- Provide automated device offline messages from "day one" to project technology partners. By providing this information directly to the relevant technology partners, Locbit was able to reduce the times when technologies were out of communication with the Locbit system.

Finally, in selecting an IoT platform for future projects it is important to consider project needs like dashboards, M&V requirements for proof of savings for incentives, and adequate data, communication, and computing infrastructure to support multiple communication protocols and quickly resolve issues while integrating existing systems.

If future project sites rely on energy dashboards or IoT platforms for in-depth system control, a carefully thought-out monitoring plan is essential. The easiest time to implement monitoring is early in the design phase of a project, so working closely with the design team is crucial.

# CHAPTER 3: Project Results

## Measurement and Verification

The purpose of the M&V process was to collect whole-building and end-use data to evaluate project successes or deficiencies by each of the energy-efficiency measures (EEM) installed, to determine if kWh energy savings were 20 percent or greater at the whole-building level. This project did not have savings targets per subsystem; savings estimates per subsystem were provided to inform and identify systems over- or under-performing when compared with the October 2020 to November 2020 energy submetering baseline.

Data collected through the M&V plan were analyzed to determine electric-energy savings. Hourly interval data for six months of post-retrofit energy consumption and PV production were compared with baseline consumption and PV production to evaluate project benefits on a month-by-month basis. Additionally, submetering data was collected to evaluate subsystem performance at 15-minute intervals.

Lighting, HVAC equipment, and plug loads were separated and compared with the baseline OpenStudio energy model to evaluate new LED lighting, DualCool retrofitted RTUs, HVAC motor upgrades, and refrigeration control optimization. Monthly whole-building water consumption was also evaluated for additional DualCool performance analysis. Lighting loads were assumed to be based largely on scheduling, so weather normalization was not required for that particular end use. HVAC systems are weather dependent, so cooling-degree days (DD) were used to compare energy per day to validate energy reductions per unit. A regression analysis was performed to forecast the energy usage of the whole HVAC system beyond project completion.

Reporting requirements, originally set by the CEC, specified a quarterly report over a one-year M&V period, as well as an annual report with actual metered data (six months of actual utility data and six months of energy consumption projections). Quarterly reports were produced every two months (instead of three) due to project timing constraints.

### Methodology

This project evaluated technology performance and forecasted savings for the required full year of M&V from June 1, 2021, through May 31, 2022. Methodologies for each forecasted end-use consumption follow, along with attributable savings toward the project goal of 20-percent electric energy reduction from the 2017 whole-building baseline.

Timeline delays led to a shorter M&V period so that final report deliverables were delivered during the project period, which ended on January 31, 2022. By utilizing existing whole-building and submetering data, which supported Q1 to Q3 M&V reports, assumptions were made using various methodologies to forecast gross-site electric consumption and specific end uses.

Forecasting lighting energy use was performed by replicating the Q1 to  Q3 lighting energy already recorded for the second half of the year, based on a static light schedule. Forecasting for DualCool and Turntide on the HVAC equipment was done with a regression model, with all HVAC units aggregated to forecast total HVAC energy use for the remainder of the year. Energy savings were estimated using this method and were attributed to both the DualCool equipment and Turntide motors. Water consumption for November 2021 through May 2022 was forecasted using an average savings percentage of M&V data compared with corresponding 2017 baseline months, then applied to the remaining baseline timeframe.

## Summary of Findings

M&V began on June 1, 2021, after most pre-commercial energy-efficiency installation activities had concluded (some final lighting commissioning and schedule updates occurred in June 2021). Interval energy and water data were collected from several sources to determine Q-3 energy and water profiles to determine if the installed technologies were on track to reduce annual electric energy consumption by 20 percent at the whole-building level. Electric savings were identified and interpreted to the best of the team's ability given data limitations including submetering data reporting gaps, altered operations due to the COVID-19 pandemic, and technology implementation delays.

## Energy Performance Assessment

Energy consumption data were collected from the Locbit online platform to analyze M&V energy performance. The Locbit platform acted as a central portal for data collection, interpretation, and visualization. A list of the DENT metering points used in this report appears in Table A-1.

### Whole-Building Electricity Consumption

The Walmart Covina store consumed 957,440 kWh from SCE's grid and produced 320,123 kWh from on-site PV for the first six months (Q1 to Q3) of M&V for a gross-site electric consumption of 1,277,562 kWh. The calculated gross site electric consumption for the forecasted M&V period (December 2021 to May 2022) was 1,128,120 kWh, which resulted in an annual M&V gross-site electric consumption total of 2,405,682 kWh.

A summary of whole-building and end-use savings appears in Table D-1, along with Table D-an explanation of which baseline was used for comparison. Overall, electric energy savings were 20.4 percent, which exceeded the 20-percent electric savings target.

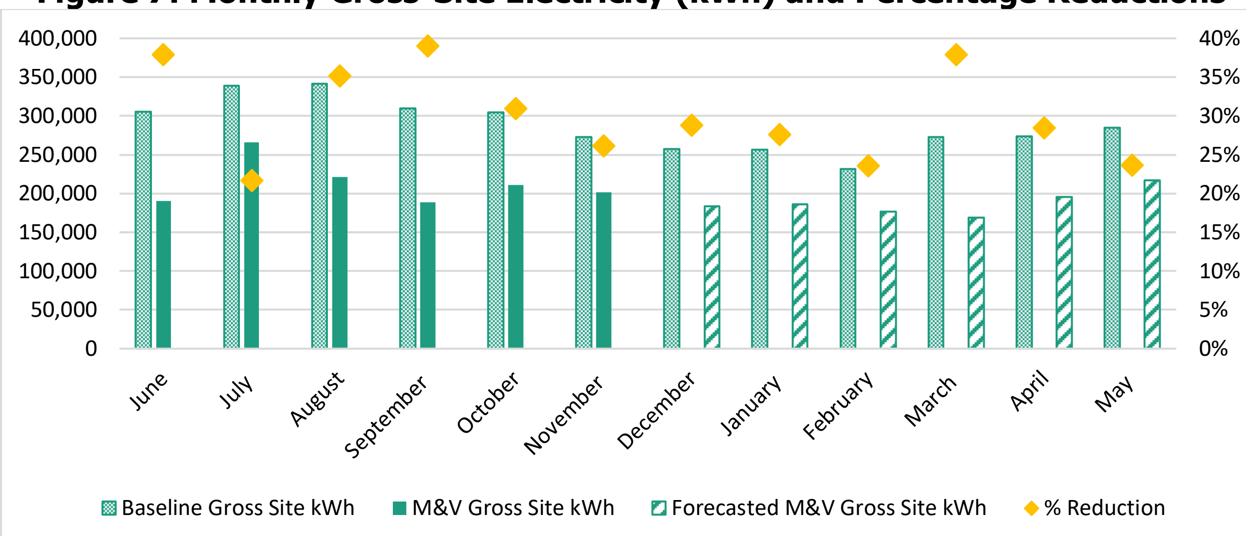
Both lighting and HVAC demonstrated clear-cut savings from the metering strategy in place, though it was more difficult to report clearly defined savings for the refrigeration racks. It was assumed that the efficiency gain of the refrigeration system retrofitted with Turntide motors and controls would be offset by an increased demand on the system when compared to the 2020 baseline. A secondary data point was used to confirm this assumed demand increase on the refrigeration racks and offset efficiency gains for the associated Turntide motors and controls. Confidential sales data provided to the project team showed an increase in food sales during the 2021 M&V period over corresponding months in 2020, which likely affected how often the freezer cases were opened. Importantly, an increase in sales did not directly correlate to a similar increase in energy demand. In addition to these realized savings, the in-store demonstration of DC-driven LED lighting yielded potential demand reduction of 9.3 percent, or 8.3 kW for all retrofitted interior lighting.

### Whole-Building Energy Goal Evaluation

The target was to reduce total on-site electrical consumption annually, which was 3,447,959 kWh, on an annual basis by 20 percent from the whole-building baseline year (February 2017 through January 2018). This amounts to a gross-site consumption reduction of 689,592 kWh at the whole-building level, which includes including solar PV generation on site (non-export).

The gross-site electric consumption reduction goal of 689,592 kWh was exceeded with annual savings of 1,042,277 kWh, or 30.2 percent of whole-building electric consumption when compared with the 2017 whole-building baseline. Figure 7 highlights monthly baseline kWh, M&V period kWh (both measured and forecasted), and the percent reduction between the baseline and both measured and forecasted results.

**Figure 7: Monthly Gross-Site Electricity (kWh) and Percentage Reductions**

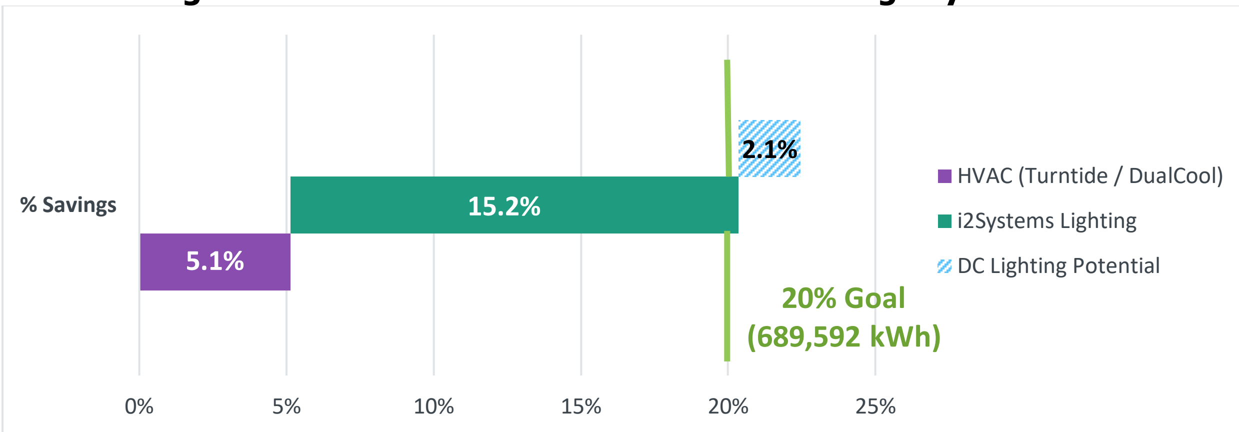



**Monthly Gross Site kWh & % Reduction Whole Building Baseline (Feb 2017 - Jan 2018) vs M&V Period (June 2021 - May 2022)**

Source: Vogel et al., 2022. *Big-Box Efficiency Project: Q3/Annual M&V Report*

A breakdown of savings by end use appears in Figure 8 and Table 2. Overall, the annual electric energy savings target of 20 percent was exceeded with lighting and HVAC upgrades accounting for a 20.4-percent (775,111 kWh) reduction when compared with the 2017 baseline. Realized savings from the IoT platform and DC lighting for the whole store ultimately could not be captured for this project since the IoT technology and DC functionality for the whole store were not fully deployed. Additionally, the whole building achieved a reduction of 30.2 percent when compared with the 2017 baseline, including 9.8-percent savings from occupancy and operational changes due to Covid and other unidentified sources.

**Figure 8: Breakdown of Annual Electric Savings by End Use**




Source: Vogel et al., 2022. *Big-Box Efficiency Project: Technology Assessment Report*

**Table 2: Estimated End-Use and Gross-Site Savings**

| Efficiency Measure | NREL Estimated % Reduction | NREL Estimated kWh Reduction | M&V Forecasted % Reduction | M&V Forecasted kWh Reduction |
|---|---|---|---|---|
| Locbit IoT Platform | 1.9% | 64,405 | - | - |
| i2Systems Lighting | 10.9% | 374,726 | 15.2% | 524,737 |
| HVAC (Turntide/ DualCool) | 8.9% | 306,035 | 5.1% | 177,176 |
| DC Lighting Potential | - | - | 2.1% | 73,198 |
| Unidentified End Uses | - | - | 9.9% | 340,364 |
| **Gross Site Total** | **21.7%** | **745,166** | **32.4%** | **1,115,475** |

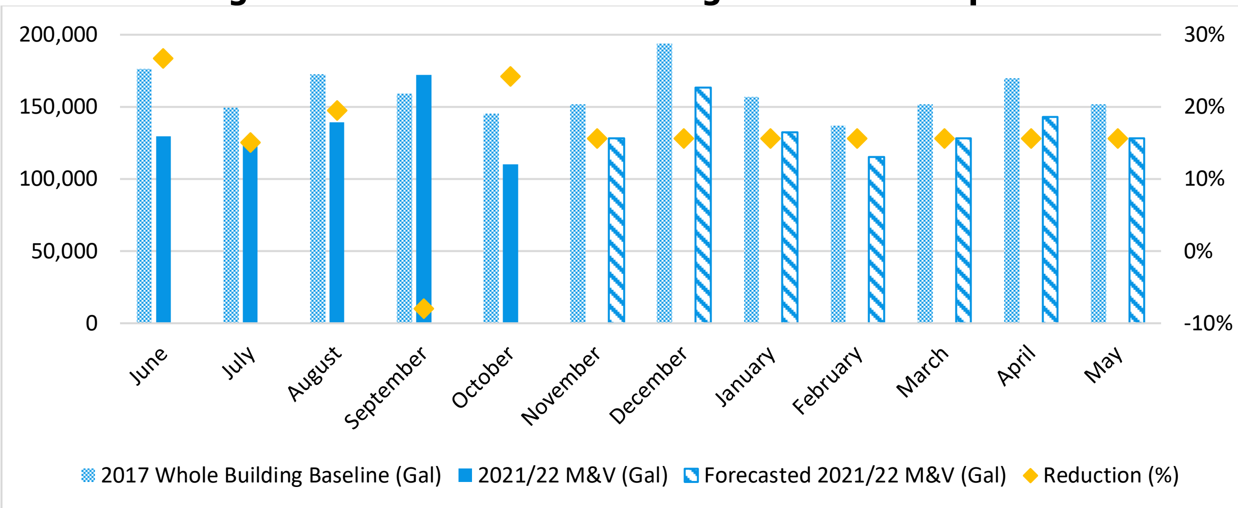
Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*

## Water Savings

The water billing and consumption data for the whole building were delayed by about two months. The M&V months of November 2021 through May 2022 were forecasted. Using historical trends and recent data, the two main water meter consumption forecasts for the remaining M&V months appear in Figure 9. Annual consumption for the M&V period was calculated to be 1,616,719.9 gallons, a reduction of 299,789.1 gallons (15.6 percent) when compared to the 2017 baseline year.

Water consumption was lightly correlated to energy and more heavily correlated to occupancy. The main consumers of water are the bathrooms, on-site cooking activities, and the garden center. The reduction could be a result of lower occupancy during the COVID pandemic and less need for water.

**Figure 9: Annual Whole-Building Water Consumption**




**Annual whole-building water consumption by month when compared to the whole-building baseline (Feb 2017 - Jan 2018) versus the M&V period (June 2021 - May 2022).**

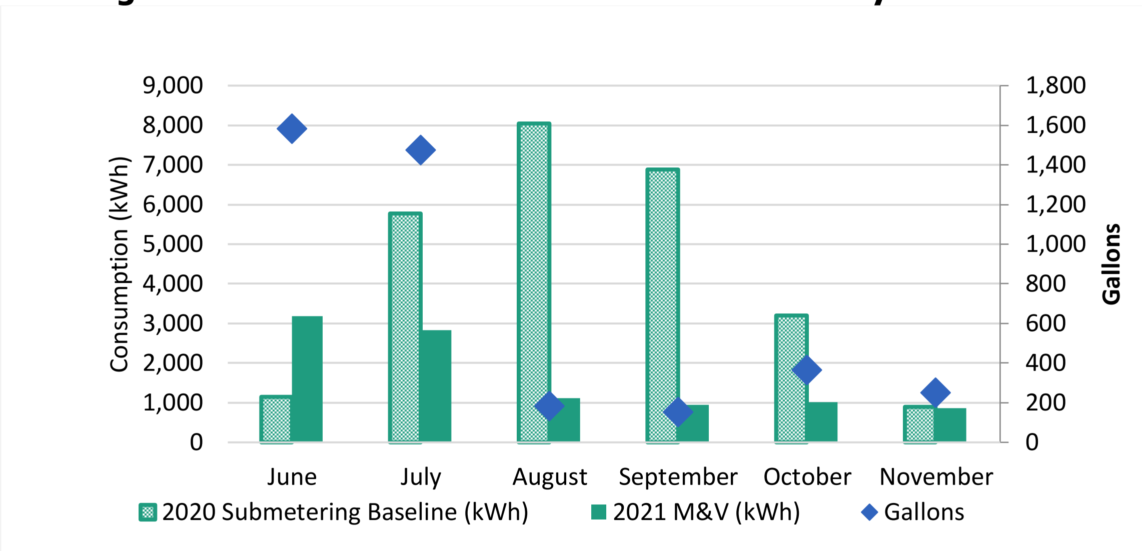
Source: Vogel et al., 2022. *Big-Box Efficiency Project: Technology Assessment Report*

The project team developed a water budget of 3.4 gallons per kWh saved through evaporative cooling. The Saya Life submetering water data measured all HVAC units from a single meter located on the main rooftop supply line as well as at each individual unit retrofitted with DualCool. To calculate this metric, water and energy consumption for the submetered AHU 2 was collected for July 2021 through November 2021 and compared to similar baseline months in 2020. This unit was being repaired in June 2021 so that month was excluded from the analysis.

The metric of gallons consumed per kWh saved for DualCool retrofitted HVAC units was not forecasted for Q4 (December 2021 to May 2022), so there is no annual result. There was insufficient data to confidently predict gal/kWh saved for the remaining six months of M&V. In lieu of forecasted data for Q4 and annual savings, a summary of Q1 through Q3 showed gallons consumed per kWh saved in

Figure 10. The total water consumed by AHU 2 between July and November 2021 was 2,423.2 gallons to save 18,053 kWh, which resulted in a metric of 0.13 gal/kWh saved, well below the project target of 3.4 gal/kWh saved.

**Figure 10: Annual Gallons of Water and Electricity Consumed**




Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*

# Technology Assessment

## Project Costs and Savings

Table 3 shows total project costs by technology, as well as cost savings per year from post-project modeling calibration and simple payback. The NREL baseline energy model was calibrated using M&V performance data for each installed technology. Costs are based on project expenses and include all costs associated with repeating this project at another location, including total engineering and construction costs. Costs associated with administration, energy modeling, M&V, and labor have been excluded. Overall costs are best shown with the entire suite of technologies for this comprehensive project because it is the most cost-effective way to approach deep holistic energy savings. Due to the holistic nature of this project, engineering and construction costs were considered only on the whole-project level; simple payback per project technology is therefore not available.

Estimated electricity savings were used to calculate total category cost savings per year using the site's blended electric utility rate of $0.158/kWh. The estimated simple payback is 16.2 years for the pre-commercial technologies. Other areas with higher electricity rates have a lower payback period. However, the project team anticipates that project financial performance could be significantly improved since certain aspects of the project did not show savings in this demonstration, but could show savings in future iterations, such as with Locbit's IoT platform and Turntide's refrigeration motors.[3] Additionally, when these pre-commercial technologies move toward commercialization and scale, costs could be further reduced.

[3] A recent NREL study showed that the smart switched reluctance motor system outperforms a traditional VFD retrofit in supply fan retrofits, providing 13% better performance than a VFD. See Table 12, Case 1 (VFD) vs. Case 4 (SRM), for Warehouses (Woldekidan et al. 2020).

**Table 3: Project Costs and Savings**

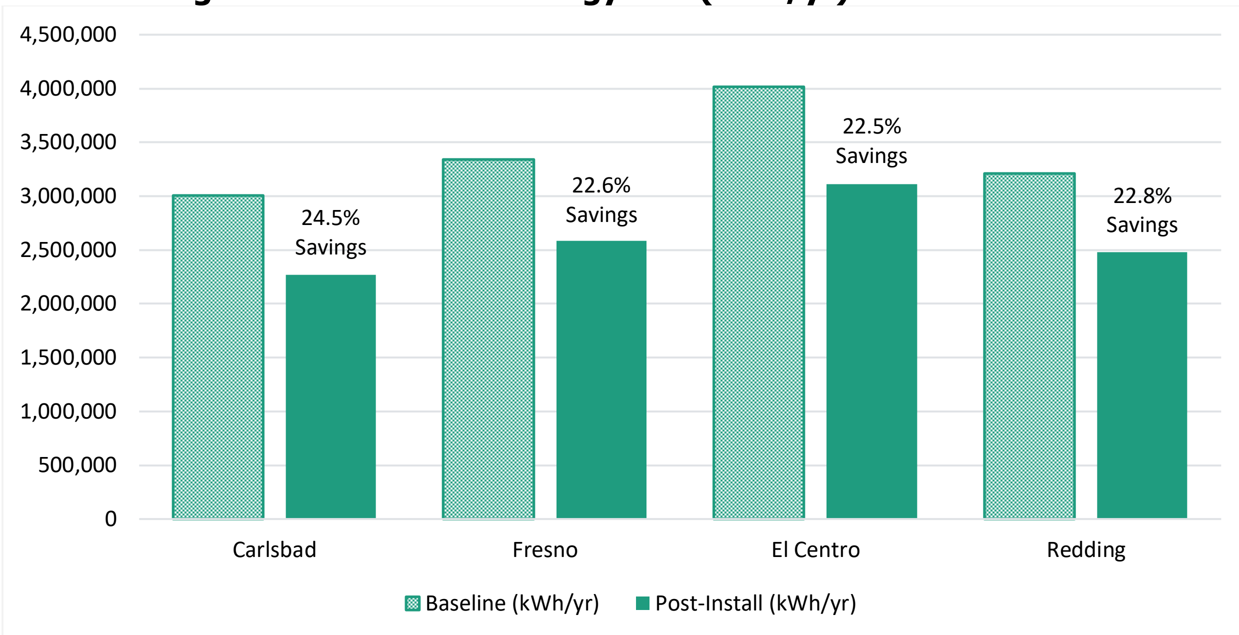
| Project Category | Total Category Cost | Total Category Cost Savings per Year |
|---|---|---|
| **HVAC** | **$176,980** | **$27,994** |
| Technology - ICI DualCool | $59,576 | |
| Technology - Saya Water Meters | $50,080 | |
| Technology – Turntide Smart Motors | $67,324 | |
| **IoT** | **$101,304** | **$0** |
| Technology - Locbit IoT | $101,304 | |
| **Lighting** | **$593,652** | **$82,908** |
| Technology - i2Systems Lighting | $593,652 | |
| **Refrigeration** | **$148,087** | **$0** |
| Technology – Turntide Smart Motors | $148,087 | |
| **Engineering & Construction** | **$779,685** | **$0** |
| Commissioning | $47,600 | |
| Construction (MEP) | $352,372 | |
| Design | $110,660 | |
| General Contracting | $264,677 | |
| Permit Fees | $4,376 | |
| **Grand Total** | **$1,799,707** | **$110,902** |

Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*.

## Project Costs and Savings in Other Locations

To better understand how this project would perform for a similar building in different utility rate scenarios and climate zones, four modeling sites were selected: two cities in San Diego Gas & Electric's (SDG&E) service territory and two cities in Pacific Gas and Electric Company's (PG&E) service territory. These locations were selected for a variety of climates and design temperatures and represent differences in electrical energy cost, by region. This project is located in Southern California Edison's (SCE) territory, in Climate Zone 9. Details on each regions' weather (Table E-) and utility costs (Table E-2) can be found in APPENDIX D. Figure 11 illustrates total energy and cost savings for baseline and post-install scenarios for the four additional sites; Carlsbad (SDG&E), Fresno (PG&E), El Centro (SDG&E), and Redding (PG&E). Monthly savings for site appear in APPENDIX A.

**Figure 11: Simulated Energy Use (kWh/yr) in Other Cities**




Source: Vogel et al., 2022. *Big-Box Efficiency Project: Technology Assessment Report*

## Utility & Climate Zone Details for Modeled Scenario Cities

Local dry bulb and wet bulb temperatures for each location in Table E-1 represent the varying weather conditions intended to mimic different climates throughout California.

**Table E-1: Weather Variables for Selected Cities**

| Utility | City | CA Climate Zone | Dry Bulb °F | Wet Bulb °F |
|---|---|---|---|---|
| SCE | Covina | 9 | 97 | 69 |
| PG&E | Fresno | 13 | 101 | 71 |
| PG&E | Redding | 11 | 103 | 68 |
| SDG&E | Carlsbad | 7 | 83 | 67 |
| SDG&E | El Centro | 15 | 111 | 73 |

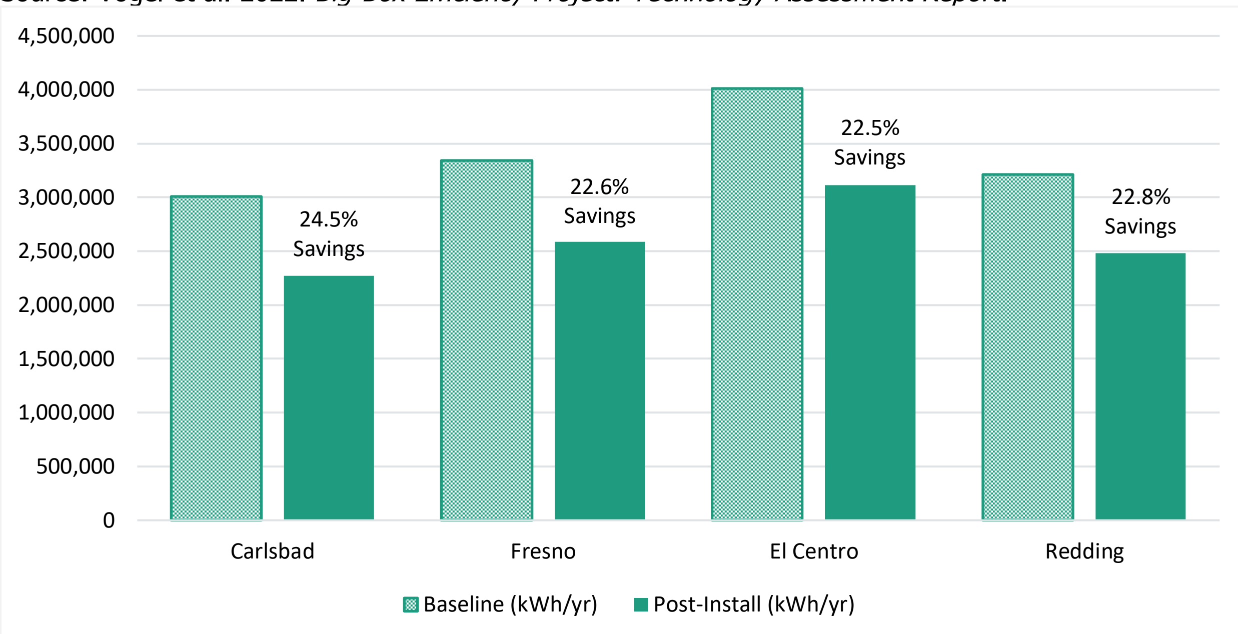
Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*.

By selecting for different climate types, the building simulations reveal varied performance of the measures by region. Furthermore, there are varying costs of electricity by utility. Table E-2 compares similar TOU rate tariffs for each utility and estimates a blended cost of electricity that includes transmission and deliver, generation, and peak demand charges.

**Table E-2: Blended Utility Rates by IOU**

| IOU | Cost | Cost Unit | Rate Tariff |
| --- | --- | --- | --- |
| SCE | $0.158 | $/kWh | TOU-8 B |
| PG&E | $0.191 | $/kWh | E-19 |
| SDG&E | $0.268 | $/kWh | AL-TOU |

Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*.



## Project & Cost Savings

Table E-3 provides a breakdown of project costs and annual cost savings and simple payback (SPB) for Covina and four modeled scenarios (Fresno, Redding, Carlsbad, and El Centro).

For Covina (Store 2292), metrics are based on actual M&V data (including six months of measured data and six months of forecasted data). Additionally, since the NREL energy model did not allow a breakout of Turntide energy and cost savings between HVAC and refrigeration, those savings for Turntide are combined in the table to facilitate an apples-to-apples comparison with the four modeled scenarios. Metrics for Fresno, Redding, Carlsbad, and El Centro are based on the energy model developed by NREL for this project. Due to the holistic nature of this project, engineering and construction costs can only be considered on the whole-project level; therefore, simple payback per project technology is not available (NA).

Table E- in APPENDIX D shows the cost-effectiveness (simple payback) of measures in other cities by rerunning the OpenStudio baseline model with appropriate weather data. These locations were selected for a variety of climates to represent a spectrum of electricity costs, by both region and utility. The NREL model does not differentiate between Turntide smart motors in the HVAC applications from the ones in the refrigeration applications, so for the following modeled simulations the Turntide smart motors for refrigeration were grouped with the HVAC, into HVAC+R.

Additionally, each building is unique and has its own performance parameters, with dependent and independent variables that drive energy consumption. Some of the measures included in this project will translate very reliably to other similar big-box stores and commercial buildings, and some will experience variable performance. The lighting retrofits, specifically the potential for DC-powered lighting energized from a local solar PV and battery energy storage system, will have similar 9.3-percent demand reductions. This demand reduction will result in similar energy savings for a store of equivalent size and operating hours. HVAC and refrigeration retrofits may have varying results depending on building occupancy, wind, exterior shading from trees or other buildings, and frequency of access to refrigerated cases or spaces. Savings from an IoT platform like Locbit will have a variety of variables including weather, occupancy, plug loads, and daylighting, which can all impact results.

Energy model simulations for the various cities revealed that energy savings ranged from 14,030 kWh in Redding, California, when compared with Covina, and up to 155,562 kWh more savings in El Centro, California, when compared with Covina. The greater savings in El Centro are likely related to higher ambient temperatures.

Table E-4 in APPENDIX D shows a breakout of modeled energy and cost savings by technology provider, and the large El Centro savings are attributed mostly to DualCool savings, followed by savings from i2Systems lighting. Lighting savings vary by location because of the impacts of interior lighting power on HVAC cooling. Projected cost savings in the other regions are notably higher because blended electric energy rates in PG&E are approximately 20-percent higher than in SCE, and rates in SDG&E are approximately 70 percent higher than in SCE.

# Barriers Addressed

## Validation of DC-Capable Lighting Systems

The existing solar PV system and connected battery energy storage system installed at the Walmart Covina store could not be configured to interconnect directly with DC loads. Battery energy storage vendors and manufacturers of power conversion (PC) systems were contacted to determine if a DC power bus solution was available. The consensus from vendors and manufacturers was that there isn't enough market demand for direct DC-powered systems to justify the research and development (R&D) and manufacturing costs associated with bringing a product to market at this time.

In the absence of a DC power connection to the battery energy storage system, a storewide DC-powered lighting installation would require installation of a separate large rectifier, or many smaller rectifiers to power the entire lighting system. Due to site constraints in electrical rooms a single large rectifier was deemed infeasible, and multiple rectifiers across the whole store would increase installation complexity and technical risk. The excessive cost and unnecessary complexity of a storewide demonstration offering only marginal benefits therefore favor an approach using a test section of the store. Furthermore, demonstration and validation of an autosensing AC or DC driver can accelerate deployment of a technology that, if adopted at scale, could drive market demand for PV and energy storage systems (ESS) with a DC-power bus solution.

The demonstration of an autosensing AC/DC system addresses market barriers, installation barriers, complexity, and risk for the site host. The hybrid architecture permits deployment of the DC system. The DC test area showed savings for the DC architecture for broader adoption of the autosensing LED driver technology in other stores. Autosensing also introduces a retrofit solution that addresses the technological barrier of PV and ESS manufacturers without DC power-bus options by maintaining the capability to retrofit luminaires to DC power in the rest of the store at a future date. The luminaires in the DC test area can also be directly compared with the same fixtures and drivers operating under similar conditions in the rest of the store. Information and lessons learned from the deployment of this system will guide development of improvements to the installation process, design, and operation of autosensing systems, which will deliver time and cost savings in future installations.

The team concluded that DC LED lighting is effective and competitive when compared to AC LED lighting. However, an autosensing AC/DC LED driver solution at scale does not currently exist. Large-scale DC power supplies are still cost-prohibitive at this time. An effective auto sensing AC/DC LED lighting product, demonstrated in a Walmart store, could however motivate the energy storage industry to develop a product with a DC load connection. This project addressed several market barriers: lack of PV/ESS systems on the market with direct DC bus solutions, retrofits that maintain DC lighting capability, and demand for DC distribution systems that can be adopted more widely, including at stores that do not currently have PV/ESS systems.

## Cost Effectiveness

The current payback period for this project in Covina, CA, (excluding grant administration costs) is 16.2 years. While this is a very high payback period, other climate zones, such as El Centro, showed a much more reasonable payback period (7.4 years). This project is the first step in increasing the cost-effectiveness of such holistic deep energy efficiency retrofit projects by demonstrating measured savings for the technology package. Several improvements could be pursued to further reduce costs and secure financing for future projects:

- Pursuit of available incentives for project technologies (as of January 2022, both Turntide's smart motors and ICI's DualCool evaporative precooling technologies were listed in the DEER).
- Conducting upgrades in conjunction with IOU large commercial incentive programs that offer performance-based incentives for a holistic package of technologies, which may include available financing options.
- Direct integration of DC-LED lighting with a DC-based power source (such as on-site battery storage) to realize additional energy savings, improving cost-effectiveness.
- Direct integration of the IoT platform, including providing full automated controllability.
- Working with an energy service company (ESCO) provider that will develop, design, build, and arrange financing for projects that save energy, reduce energy costs, and decrease operations and maintenance costs at customer facilities. In general, ESCOs act as project developers for a comprehensive range of energy conservation measures and assume the technical and performance risks associated with a project. When an ESCO implements a project, the company's compensation is directly linked to actual energy cost savings. (DOE n.d.).

# CHAPTER 4: Technology/Knowledge/Market Transfer Activities

CSE used a multifaceted approach to educate stakeholders about the Big-Box Efficiency Project, with the goal of driving market adoption of the pre-commercial technology package. Specific technology knowledge transfers undertaken by the project team included:

- A project website.
- Conferences and events.
- Webinars.
- Case study and fact sheet.
- Additional marketing collateral.
- A technical advisory committee.
- An energy dashboard and in-store display.
- Policy tracking and comments.

These activities targeted five primary audiences:

- In-store shoppers
- Store managers and facility staff
- Commercial industry leaders, with emphasis on big-box retail/grocery store owners and facility managers
- IOUs
- Policymakers and regulatory agencies

For each element, CSE developed key performance indicators. Additionally, CSE held a project debrief meeting with Walmart management on January 19, 2022, to discuss project successes, identify lessons learned, and explore opportunities to expand this project to other Walmart stores.

## Project Website

The primary communication channel for project information and updates is the dedicated Big-Box Efficiency Project website (https://sites.energycenter.org/bigbox). The project website went live in July 2019 and went through a design refresh in Q3 2021 to help streamline content and prepare the site layout for the integration of the energy dashboard. However, due to domain name registration issues, Locbit was unable to complete the energy dashboard task.

The project website has subpages detailing the technologies involved in the project, the project schedule and current phase in the schedule, details about the Walmart Covina, CA, store, links to results and resources, and an email sign-up and contact page to gather contact details from interested stakeholders for use in communicating future project updates.

As of January 2022, the project website has had more than 2,297 site visits, mainly from California. Additionally, there have been site visits from locations in Texas, Washington, Canada, and South Korea. Due to a technical issue when switching to Google Tag Manager, there was a gap in analytic data from September 2020 to October 4, 2021. This technical issue was corrected in October with all analytics actively reporting for Q4 2021.

CSE performed analytics to determine the top drivers of traffic to the project website based on marketing outreach activities. Overall, blog posts and social media posts to CSE's LinkedIn had the highest page views and click-throughs to the project website. A spike in website activity around September 23, 2021, followed the Greenbuild International Conference presentation. CSE distributes information to nearly 2,000 followers on Twitter, more than 22,000 on LinkedIn and close to 900 email subscribers.

The project team maintained an ongoing build out of the website throughout the project timeline. CSE's internal marketing team of professional web developers, creative and graphic designers, and marketing associates designed and implemented the website. All marketing tactics pointed visitors back to the website.

## Webinars

The project team originally anticipated hosting two webinars in 2021. However, due to budget and timing constraints from constructions delays, the project team (in conjunction with the CEC Contract Administration Manager) focused on one webinar at the end of the project. The final project webinar (*Unlocking Deep Energy Savings in Big-Box Retail: Findings from the Big-Box Efficiency Project*) was held January 11, 2022. Webinar attendees learned about various phases of the project including initial scoping, installation and commissioning, M&V, project management, and project partnerships. To advertise the webinar, CSE sent out four emails to advertise the event and posted information on social media. The webinar beat the industry standard of 30-percent attendance with an impressive 49-percent attendance rate. A recording of the webinar is available on the project website.

## Conferences and Events

The project team presented at three conferences during the project term, based on timing, available resources, and opportunities. These conferences were the ASHRAE Annual Conference (June 26-30, 2021), the Greenbuild International Conference and Expo (November 2021), and the Association of Energy Engineers Conference (October 20-22, 2021).

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Annual Conference and the Association of Energy Engineers Conference were both virtual and did not have online attendance metrics available for the project's session. At Greenbuild, the project team presented in-person, and a recorded version of the session is available on-demand. As of October 2021, a total of 110 attendees viewed the presentation in-person and online. Since Greenbuild was the only in-person conference, the project team was only able to network at that event. The CSE project manager met approximately 20 new contacts and 20 existing contacts at the event, whom she encouraged to attend the in-person project session. There were about 35 attendees in-person at the Greenbuild session. Additionally, CSE and NREL have submitted an abstract on the Big-Box Efficiency Project for presentation at the 2022 Summer Study.

## Fact Sheet

After the energy-efficiency measures were implemented and M&V activities were completed, CSE developed a fact sheet for the project. Using information collected from the assessment and verification period (Task 5), CSE assessed both project benefits and results. The fact sheet provides a clear snapshot of project objectives, design, performance, and results. The fact sheet contains the:

- Pre-commercial technology package.
- System design and performance.
- Project economics and cost savings.
- Lessons learned.

The fact sheet is available on the project website's *Results & Resources* page.

## Additional Marketing Material

To further raise general awareness of the project and drive traffic to the project website, CSE worked with the project team to develop additional marketing materials.

- **Employee Content Kit:** The project fact sheet will be distributed to store employees so they have an opportunity to learn about the project.
- **Store Management and Facility Staff Guide:** Store management and facility staff responsible for ongoing maintenance at the store received a detailed technical guide including information on the technologies installed, essential information or notes regarding operations, and preventive-maintenance and contact details if they have questions once the project was completed. This is an internal document for Walmart staff so is not publicly available.
- **Digital Content Kit: Project** partners received a comprehensive kit with content for emails, websites, and at events. This kit also directs viewers to the project website.
- **Blog Posts:** Posts are basically deeper dives into the project's progress. Project blog posts are also available on the project website.
- **Press Releases:** Media submissions will include details about the project and promotion of the project webinar. All releases will direct readers to the project website. Press releases will also be available on the website.

## Technical Advisory Committee

During the project's duration, CSE coordinated with technical advisory committee (TAC) members to share findings from this project. The TAC consisted of executives, researchers, consultants, and government and utility officials who represent public, private, and nonprofit organizations with expertise in energy efficiency, pre-commercial technologies and big-box retail energy-management disciplines. CSE held two TAC meetings on March 6, 2019, and June 9, 2020. Per the *Technology Knowledge Transfer Plan*, the project team initially planned to hold a third TAC meeting in Q2 2021. Because of timing constraints, the team did not hold this third, optional meeting.

## Energy Dashboard and In-Store Displays

Locbit worked with the project team to create four energy dashboard pages highlighting real-time energy monitoring of the store's energy consumption, general project information, energy savings, and graphs and descriptions of each of the installed technologies. However, as of December 17, 2021, Locbit encountered domain name registration issues on their website and was unable to complete this task. CSE will work further with the Walmart team to explore static project-summary slides featuring key details about the project for possible in-store displays.

## Policy Tracking and Comments

CSE used its recognized strengths to inform policy guidelines for the State of California. CSE's government affairs team provides elected officials in priority states with information to effectively shape clean-energy policies and programs. To this end, the government affairs team used project results to educate California government officials on the market integration of energy efficiency, integrated distributed energy resources, and demand response. A full list of proceedings and dockets tracked is available in the Policy Tracking section of APPENDIX F.

# CHAPTER 5: Conclusions/Recommendations

## Analysis of Goals and Objectives

The project team achieved project goals and objectives by generating more than 20-percent project-attributable savings in a big-box store (retail plus grocery environment). While the current payback period is more than 16 years, the project team is confident that future iterations of this project can realize greater cost savings through incentives, price reductions as technologies move toward commercialization, and full realization of potential savings from the IoT platform. The project additionally demonstrated cost and demand reductions through annual cost savings and moving loads, like lighting, to a DC power source with the flexibility to be powered from either AC or DC in the event of power outages.

The project team shared its findings from lighting savings with the store's local electric utility (SCE), and both Turntide's smart switch reluctance motors and ICI's DualCool technology now appear in the DEER for savings in utility-sponsored incentive programs. Finally, the project team successfully shared its findings through conferences, a webinar, and the website, in addition to a project blog, fact sheet, and press release.

## Costs and Benefits

The Big-Box Efficiency Project demonstrated to big-box retailers, California ratepayers, utilities, and operators the benefits of deep energy-efficiency savings through an integrated technology package tailored to meet California's aggressive greenhouse gas emissions reduction goals. This project supports California's loading order based on the *State of California Energy Action Plan*, which prioritizes energy efficiency and DR as the most cost-effective means to reach the state's ambitious greenhouse gas-reduction goals. By reducing energy consumption, the proposed project will add valuable capacity to California's electric transmission and distribution grids, especially during peak demand. Based on this study's results and conclusions, future iterations of deep energy-efficiency retrofit projects will provide the following benefits:

- Demonstrated real savings in retrofitting HVAC units with ICI's DualCool and Turntide's smart switch reluctance motors. The demonstrated savings of 34.4 percent (128,799 kWh) in HVAC consumption, as compared with the 2020 submetering baseline, target reducing power consumption from with packaged HVAC systems, which are disproportionately responsible for critical capacity shortfalls and congestion during summer heat waves. This project also confirmed that the DualCool technology is water-efficient, using just 0.13 gallons per kWh saved.
- The market transformation potential of DC lighting. The project demonstrated that i2Systems lighting saved 28.9 percent (186,539 kWh) when compared with existing conditions, but also predicted that if the store were to be powered 100 percent by a DC power source (like on-site battery storage), an additional 2.1 percent (73,199 kWh) of savings could be achieved for the whole building. In a tight energy-efficiency market

where every kWh saved means cost savings, improved grid reliability, and enhanced environmental benefits, this could represent the next generation of lighting solutions: to upgrade LED lighting as it nears its end-of-life replacement.

- While unable to be fully implemented, the Locbit IoT platform demonstrated the benefits of combining end-use data from disparate technologies into a single unified system. Future iterations could capture additional energy savings through both integrated automated controls and reduced costs from preventive maintenance.
- Increased cost savings and improved simple payback periods are possible through available incentives and lessons learned from this project. Continued commercialization of the technologies will also lower simple payback periods.
- Finally, the project will directly benefit ratepayers by reducing energy and maintenance expenses.

## Lessons Learned

The path to California's ambitious mandate to double statewide electricity and gas savings by 2030, equivalent to a 20-percent reduction in projected statewide building energy use, still has many opportunities for growth. The lessons learned and findings from this project can better inform future deep energy savings retrofit projects. Lessons learned from this project include the following items.

### System Submetering

Due to budget and technical constraints, HVAC units were submetered at the panel level, which did not provide granularity on a unit-by-unit basis. With additional budget, submetering could be performed at the individual-HVAC unit level. Because some units received both DualCool and smart-switch reluctance motor technologies, the project had to evaluate the combined effects of these measures as well.

In future iterations of this project, it is recommended that any submetering systems (for example, DENT submeters) have data recovery features that are remotely accessible rather than recoverable only on site.

### i2Systems DC-Ready LED Lighting

i2Systems created an innovative, brand-new AC/DC autosensing light fixture for this project in under a year. In the implementation phase, i2Systems identified lessons learned in four primary areas.

- **Mechanical Fit:** i2Systems didn't account for interference with the fixture fit. Once i2Systems recognized the issue, an accommodation was made to the housing design.
- **Red Indicator Lights:** In certain situations, the i2Systems fixtures signaled a fault when one did not exist. This was due to over-sensitivity in the circuit design.
- **Balancing Circuits in the Store:** Under a few circumstances, the original electrical wiring in the store could not accommodate the draw from the i2Systems fixtures as configured, requiring a change in the number of fixtures per circuit.

- **Signal Propagation:** i2Systems initially had some instances where the wireless signal did not propagate properly so fixtures did not respond to commands. i2Systems made firmware modifications to correct this problem.

## ICI DualCool Evaporative Precooling

While the installation itself was straightforward, the following actions could have reduced issues found during system commissioning by:

- Ensuring each HVAC unit receiving DualCool retrofit was level pre- and post-install and confirming that the roof could accommodate extra weight.
- Conducting pre-project "commissioning" of HVAC units receiving retrofits to ensure the units operated correctly. A few existing HVAC units had economizer dampers that required repairs before savings could be realized from the DualCool technology.

## Saya Smart Water Management System

One issue was that the original Saya Life water meters were not waterproof and required an in-field solution. Saya Life now has IP68 water meters rated for outdoor use. Additionally, Saya Life had to adjust for a 5-V power requirement for their water meters by installing low-voltage wiring in conduits.

## Turntide Smart Switch Reluctance Motors

Turntide encountered the following issues with implementation of its technology, so implemented a root-cause analysis and corrective process.

- **Site Connectivity:** The original RMK (antenna) design encountered communication dropouts, requiring new equipment.
- **Modbus Communication:** A firmware flaw was discovered related to RS-485 Modbus communication and was corrected with newer firmware.
- **Motor Controller Reliability:** A high number of P04 motor controllers for the V01 series motors failed, leading to development of a next-generation motor controller.
- **RTU Motor Noise:** An unacceptable level of motor noise was emitted in the retail space from Turntide's V02 motor series. Noise-isolating motor mounting feet were installed.
- **Condenser Fan Motor Noise:** At some motor operating frequencies an unacceptable noise level came from the condenser rack. Those problematic operating frequencies are now "skipped," alleviating the problem.

Post-project, Turntide continues to work with the Walmart team to monitor the installed motors to ensure that remaining communication and noise issues are identified and promptly resolved.

## Locbit IoT Platform

Due to delays in the integration of the Walmart legacy control system (NOVAR) into the Locbit platform, Locbit was unable to propose specific triggers so corresponding energy-saving actions did not contribute savings during Q1-Q3 in the M&V period. This was due to a combination of factors, including that:

- Locbit did not have full direct control of Walmart's legacy control system (read-only access), so set points could not automatically be adjusted.
- Many data points in Walmart's legacy system were not clearly labeled by subsystem (for example, Sensor 1 HVAC instead of Sensor 1 RTU 8).
- Locbit's team faced staffing challenges during the COVID-19 pandemic, which delayed integration of the NOVAR system.

The system did provide non-energy benefits through fault detection and diagnostics, such as allowing visibility when the on-site solar generation goes offline and identify communication issues with the installed technology.

One key lesson learned is to vet cybersecurity requirements and integration requirements upfront to ensure that the provider can meet the site host's security requirements and vetting process on the site host's internal network. Another key lesson is that if energy savings are based on data from legacy control system sensors, it is imperative that the system's data are accessible to the IoT platform, and that all components of the legacy control system can be accessed with current communications protocols. Finally, in selecting an IoT platform for future projects it is important to consider project needs for dashboards, M&V for proving savings for incentives, and adequate data, communication, and computing infrastructure to support multiple communication protocols to quickly resolve issues.

## Conclusion and Next Steps

The cost savings evaluated for this project can total $110,902 per year (energy savings of 775,111 kWh), with an overall simple payback of 16.2 years. This simple payback is mostly related to the cost of engineering and construction including commissioning, design, general contracting, and permit fees. Unfortunately, this project's IoT platform was unable to achieve documented energy savings, so those savings were not evaluated. Future projects that successfully integrate an IoT platform are likely to achieve energy savings that will provide better payback on the investment. Due to the holistic nature of this project, engineering and construction costs could only be considered on a whole-project level; simple payback-per-technology is therefore unavailable.

In terms of water use, it was found that 0.13 gallons of water were used for each kWh saved, but a full year of evaluation is required to accurately determine the water cost of the energy saved. There are several current incentives that apply to this project, such as SCE's whole-building retrofit program. In addition to existing incentives, findings from this project suggest that a utility incentive for DC lighting would be beneficial to encourage greater widespread use.

Looking beyond the Covina site, results from the building models in Carlsbad, El Centro, Fresno, and Redding revealed promising simulated savings for future projects. There was also a noticeable increase in potential savings in El Centro from the ICI DualCool, likely because of higher ambient temperatures in El Centro. Ambient temperature influences the coefficient of performance of the HVAC equipment, so reducing the temperature of the air cooling the air-conditioning condenser coils has outsized effects in hotter climates.

# LIST OF ACRONYMS

| Term | Definition |
|---|---|
| °C | degrees Celsius |
| °F | degrees Fahrenheit |
| 4G/LTE | fourth generation/long-term evolution |
| AC | alternating current |
| AHU | air handling unit |
| BMS | building management system |
| CEC | California Energy Commission |
| CSE | Center for Sustainable Energy |
| CT | current transducer |
| DC | direct current |
| DD | degree days |
| DEER | database for energy efficiency resources |
| DOE | United States Department of Energy |
| DX | direct expansion |
| EE | energy efficiency |
| EEM | energy efficiency measure |
| EPIC | Electric Program Investment Charge |
| HVAC | heating, ventilation, and air conditioning |
| IAQ | indoor air quality |
| ICI | Integrated Comfort, Inc. |
| IoT | Internet of Things |
| IOU | investor-owned utility |
| kW | kilowatt |
| kWh | kilowatt-hour |
| LED | light-emitting diode |
| M&V | measurement and verification |
| NREL | National Renewable Energy Laboratory |

| Term | Definition |
|---|---|
| PG&E | Pacific Gas and Electric |
| PPA | power purchase agreement |
| PV | photovoltaic, *also* solar photovoltaic |
| RTU | rooftop unit |
| SB | California Senate Bill |
| SCE | Southern California Edison |
| SDG&E | San Diego Gas & Electric |
| SPB | simple payback |
| TAC | Technical Advisory Committee |
| TOU | time-of-use |
| V | volt |
| VFD | variable frequency drive |
| W | watt |

# REFERENCES


Baptiste, R. and C. Josepher. 2022. Big-Box Efficiency Project, EPC-17-008: Final Technology Knowledge Transfer Report. https://sites.energycenter.org/sites/default/files/docs/microsites/bigbox/EPC-17-008_FINAL-Technology-Knowledge-Transfer-Report_v2.pdf. Center for Sustainable Energy.

Baptiste, R., C. Josepher, and K. Larson. 2020. Big-Box Efficiency Project, EPC-17-008: Final Technology Knowledge Transfer Plan. https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/EPC-17-008_final-technology-knowledge-transfer-plan.pdf. Center for Sustainable Energy.

California Energy Commission. 2016. California Energy Code 2016 Reference Appendices. https://www.energy.ca.gov/sites/default/files/2021-04/CEC-400-2015-038-CMF.pdf. California Energy Commission. CEC-400-2015-038-CMF.

Del Real, J. 2018. Baseline Measurement and Verification Plan. https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/EPC-%2017-008%20Final%20Baseline%20MV%20Plan_3-30-2018.pdf. Center for Sustainable Energy.

Gunther, S. 2022. Center for Sustainable Energy (CSE) Comments on Draft Scoping Order for the 2021 Integrated Energy Policy Report. https://efiling.energy.ca.gov/getdocument.aspx?tn=236847. Center for Sustainable Energy.

Houssainy, S., K. Nguyen Cu, and R. Faramarzi. 2020. Final Optimization Report: Empowering Energy Efficiency in Existing Big-Box Retail/Grocery Stores. https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/FINAL-Optimization-Report_2020-09-15.pdf. National Renewable Energy Laboratory. NREL/TP-5500-77695.

Kogan, G., J. Del Real, C. Vogel, and A. Kaufman. 2018. Walmart Supercenter 1275 N Azusa Ave, Covina, CA, Site Characterization Report. https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/EPC-17-008%20Final%20Walmart%20Draft%20Site%20Characterization%20Report%203-28-2018.pdf. Center for Sustainable Energy.

Mangalekar, D. 2021. EPIC-17-008 Walmart Installation Activities Progress Report. https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/Installation-Activities-Progress-Report_FINAL.pdf. TRC.

Shen, M. 2020. Walmart EPIC EPC-17-008 Basis of Design Report: Final Submittal. https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/FINAL-Basis-of-Design.pdf. P2S Inc.

Southern California Edison. 2015. Performance Evaluation for Dual-Evaporative Recooling Retrofit. https://ca-etp.com/sites/default/files/reports/et13sce1040_final_report_final_da.pdf. Southern California Edison. ET13SCE1040.

U.S. Department of Energy (DOE). n.d. Energy Service Companies. https://www.energy.gov/eere/femp/energy-service-companies-0.

Vogel, C., A. Beach, J. Woolsey and R. Baptiste. 2021. Big-Box Efficiency Project Measurement & Verification Report: Q1 June 1, 2021 – July 31, 2021 (EPC-17-008). https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/M&V-Report-Q1_Final.pdf. Center for Sustainable Energy.

Vogel, C., A. Beach, J. Woolsey, and R. Baptiste. 2022. Big-Box Efficiency Project Measurement & Verification Report: Q3 (October 1, 2021 – November 30, 2021) and Annual (June 1, 2021 – May 31, 2022) (EPC-17-008). https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/Task-05_2022-01-20-EPC-17-008-M&V-Report-Q3-Annual_FINAL_rev.pdf. Center for Sustainable Energy.

Vogel, C., A. Beach, J. Woolsey, R. Baptiste and K. Larson. 2021. Big-Box Efficiency Project Measurement & Verification Report: Q2 August 1, 2021 – September 30, 2021 (EPC-17-008). https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/05_2021-10-29-M%26V-Report-Q2_FINAL.pdf. Center for Sustainable Energy.

Vogel, C., A. Beach, J. Woolsey, R. Baptiste and K. Larson. 2022. Big-Box Efficiency Project Technology Assessment Report (EPC-17-008). https://sites.energycenter.org/sites/default/files/docs/microsites/bigbox/2022-03-02_Technology-Assessment-Report_v2.1.pdf. Center for Sustainable Energy.

Vogel, C., J. Woolsey and R. Baptiste. 2021. Big-Box Efficiency Project Post-Retrofit Measurement & Verification Plan (EPC-17-008). https://sites.energycenter.org/sites/default/files/images/site/bigbox/pdf/Task-05_FINAL-EPC-17-008_Post%20Retrofit-MV-Plan.pdf. Center for Sustainable Energy, 2021.

Woldekidan, K., D. Studer, and R. Faramarzi. 2020. Performance Evaluation of Three RTU Energy Efficiency Technologies. https://www.nrel.gov/docs/fy21osti/75551.pdf. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-75551.

# APPENDIX A:
# DENT Submetering Points by Installed EEM

**Table A-1: DENT Submetering Points by Installed EEM**

| DENT Meter | Panel ID (Metering Point) | Installed EEM | Equipment |
|---|---|---|---|
| **EDC1 Rear Elec Cage Serial # P481812023** | H1A1 (12 RTUs + 30A Spare) | Turntide Motor/Control | RTU 2, 3, 4, 5, 7 ,11, 13, 14, 19, 27 |
| | | Turntide motor/Control | RTU 10 & 12 |
| | | DualCool Evap | |
| | H1A2 (10 RTUs + 30A Spare) | None | RTU 6 |
| | | Turntide motor/Control | RTU 15 & 18 |
| | | DualCool Evap | |
| | | Turntide motor/Control | RTU 17, 20, 21, 22, 23, 25, 26 |
| | H1A3 (4 RTUs) | Turntide motor/Control | RTU 8, 9, 16, 24 |
| | H1C1/H1C2 | LED Retrofit | All Lighting (Except Deli/Produce) |
| **EDC3 Front Elec Room Serial # P4818182024** | RTU 1 | Turntide motor/Control | RTU 1 |
| **EDC4 Stockroom Elec Serial # P481812022** | AHU 1 | Turntide motor/Control | AHU 1 |
| | AHU 2 | Turntide motor/Control | AHU 2 |

Source: Center for Sustainable Energy, *Big-Box Efficiency Project Measurement & Verification Report: Q1 June 1, 2021 – July 31, 2021 (EPC-17-008).*

# APPENDIX B:
# LED Lighting System Details

Table B-1 outlines the post-retrofit dimming schedule by zone and hour.

**Table B-1: LED Fixture Post-Retrofit Dimming Schedule**

| Time | Dimming Zone 1 Sales Floor | Dimming Zone 2 Stock Room | Dimming Zone 3 Vestibule | Dimming Zone 4 Garden Center | Dimming Zone 5 Tire Storage | Dimming Zone 6 Auto |
|---|---|---|---|---|---|---|
| 12 AM | 5V | 7.2V | 5V | 5V | 5V | 6.3V |
| 1 AM | 5V | 7.2V | 5V | 5V | 5V | 6.3V |
| 2 AM | 5V | 7.2V | 5V | 5V | 5V | 6.3V |
| 3 AM | 5V | 7.2V | 5V | 5V | 5V | 6.3V |
| 4 AM | 5V | 7.2V | 5V | 5V | 5V | 6.3V |
| 5 AM | 6.8V | 8V | 6.8V | 6.8V | 7V | 6.3V |
| 6 AM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 7 AM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 8 AM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 9 AM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 10 AM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 11 AM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 12 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 1 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 2 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 3 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 4 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 5 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 6 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |

| Time | Dimming Zone 1<br>Sales Floor | Dimming Zone 2<br>Stock Room | Dimming Zone 3<br>Vestibule | Dimming Zone 4<br>Garden Center | Dimming Zone 5<br>Tire Storage | Dimming Zone 6<br>Auto |
|---|---|---|---|---|---|---|
| 7 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 8V |
| 8 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 6.3V |
| 9 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 6.3V |
| 10 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 6.3V |
| 11 PM | 6.8V | 8V | 6.8V | 6.8V | 7V | 6.3V |

Source: i2Systems

Table B-2 details the approximate percent dim and resultant light levels (footcandles at 36″ above finished floor) based on the 0-10V voltage setting outlined in the dimming schedule (Table B-1).

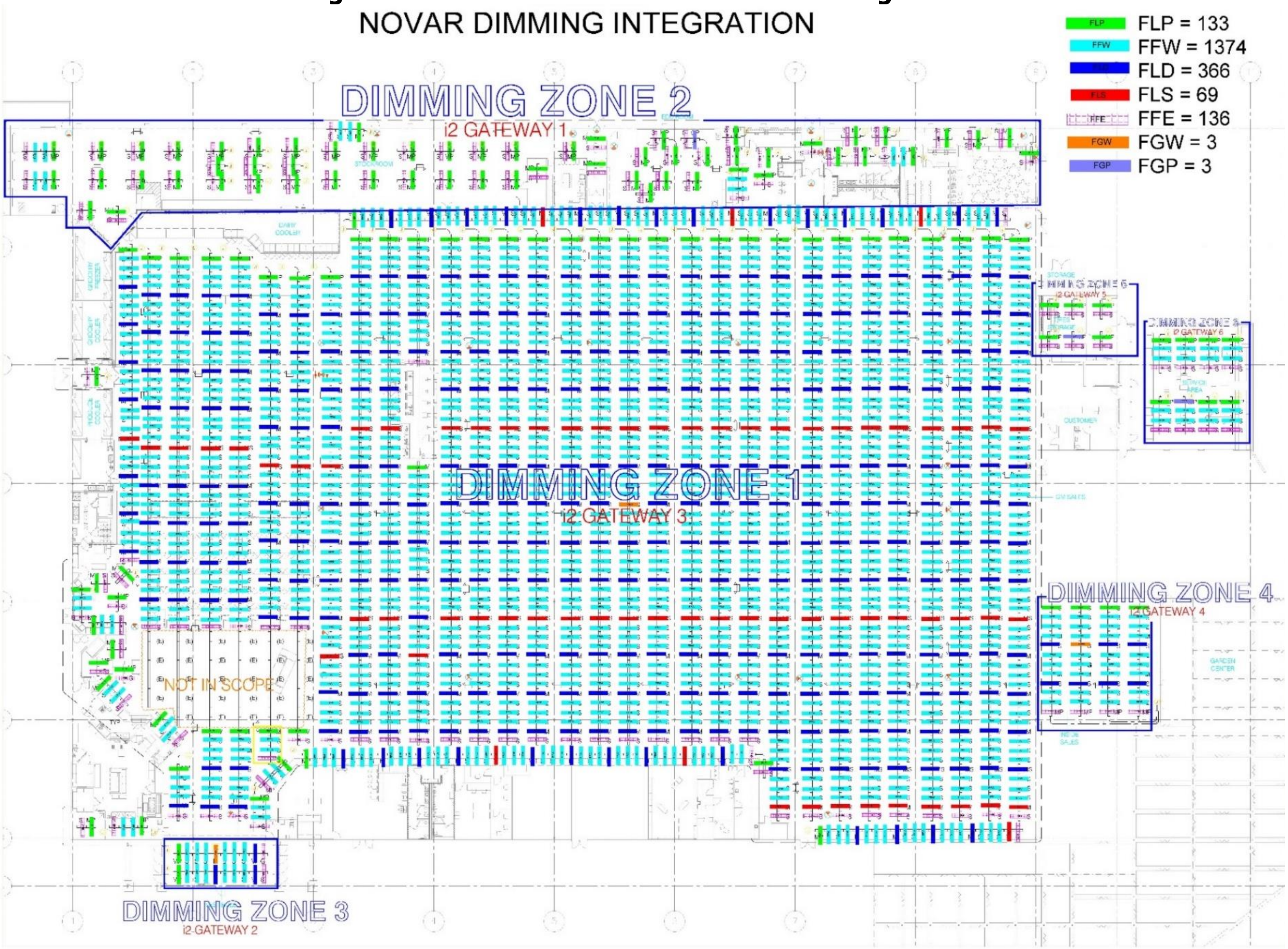
**Table B-2: LED Lighting Fixture Dimming Level Setting Details**

| Setting | % Dim (Approximate) | Approximate Light Levels (Fc at 36″ Above Finished Floor) |
|---|---|---|
| **2.5V** | 70% | 15 – 20 |
| **4V** | 50% | 25 – 30 |
| **5V** | 40% | 30 – 35 |
| **6.3V** | 25% | 50 – 55 |
| **6.8V** | 20% | 60 – 65 |
| **7.2V** | 10% | 65 – 70 |
| **8V** | 0% | 70+ |

Source: i2Systems

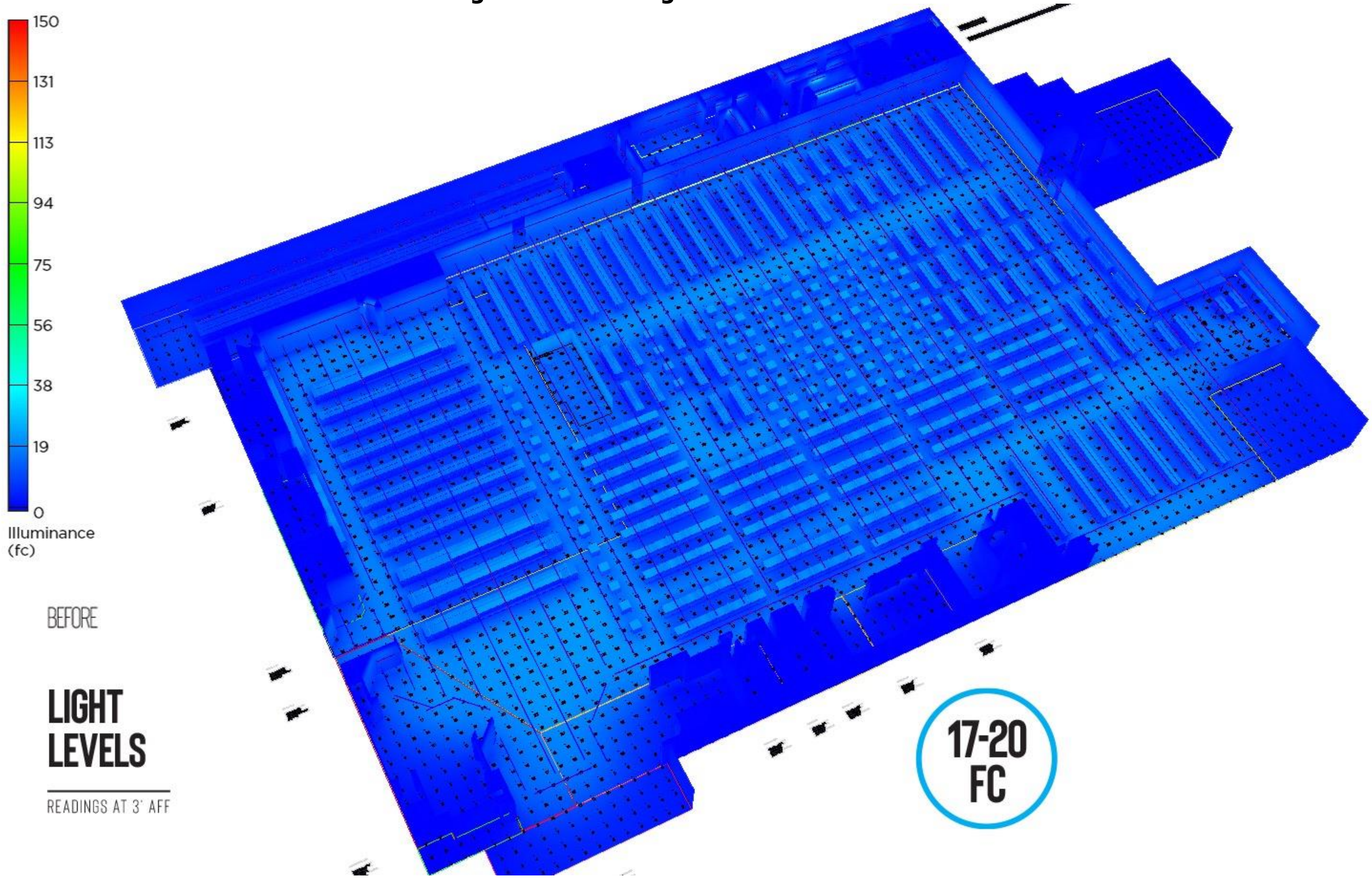
Figure B-1 shows the layout of the lighting in the store and associated dimming zones, as well as the specific fixture subtypes that were installed. There were six gateway units that controlled each zone, coupled with lead units (one per every four fixtures) and follower units.

**Figure B-1: LED Fixture Post Retrofit Dimming Zones**



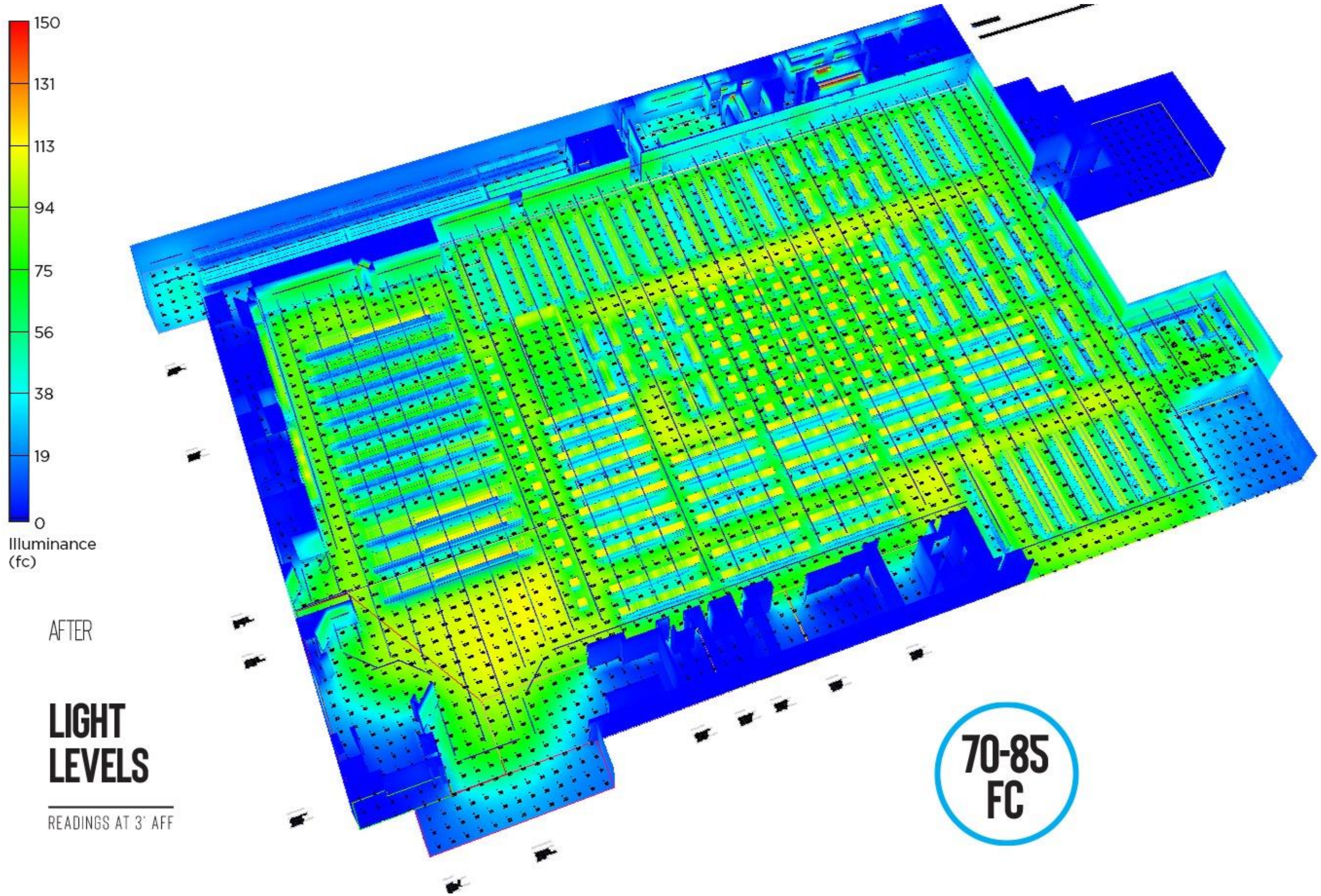

Source: i2Systems

**Figure B-2: LED Light Levels Pre-Retrofit**




Source: i2Systems

**Figure B-3: LED Light Levels Post-Retrofit**




Source: i2Systems

# APPENDIX C:
# Product Specification Sheets

## Saya Life Smart Water Meter (1") & Gateway

saya knowledge of water

### Ultrasonic Cold Water Meter SAYA-WMILSA0100-C

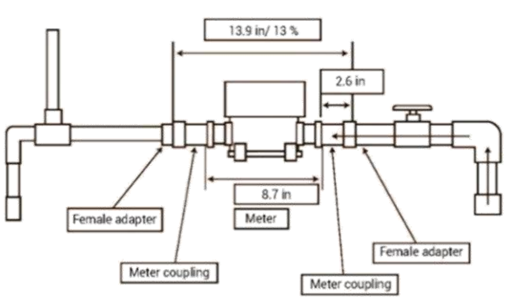

#### Features Include

- Wireless Ultrasonic flow meter for high accuracy and leak detection.
- Meets and exceeds AWWA C708 accuracy standards in a horizontal or vertical position.
- NSF/ANSI 61 & 372 Certified.
- NTEP Certified.
- 5 years warranty.
- No moving parts.
- Digital Display.
- Integrated remotely controllable shut-off valve to prevent damages caused by leaks.
- Integrated pressure sensor for anomaly detection.
- Integrated water temperature sensor.

#### Specifications

- Max flow Rate : **30 gpm**
- Normal flow range (+/- 1.5%) : **2-25 gpm**
- Min flow rate : **0.07 gpm**
- Max working pressure : **175 psi**
- Max working temp : **115° F**
- Nominal pipe size : **1"**
- Main Material : **Brass pipe body**
- Transmission : **Lora (915 Mhz)**
- Battery : **5V Lithium ion**
- External Power : **5v 2A** (for shutoff valve)
- Battery Life : **6-7 years**

#### Installation Recommendation




#### Pressure Loss Table

| SAYA-WMILSA0100 (Cold) | |
|---|---|
| Flow Rate (GPM) | Pressure Loss (PSI) |
| 0 | 0 |
| 2 | 0.04 |
| 5 | 0.2 |
| 10 | 0.72 |
| 15 | 1.59 |
| 20 | 2.75 |
| 25 | 4.35 |
| 30 | 6.23 |
| 35 | 8.41 |
| 40 | 10.15 |

Additional spec sheets for other pipe sizes are available at https://saya.life/productspecs.

# saya knowledge of water

## SAYA-GW-LI915-C


## Features Include

- ➪ Data Collector for Water meter & flood sensors
- ➪ Integration available with other IOT sensors
- ➪ Edge Computing using Machine Learning for Water risk management
- ➪ FCC certified transmission
- ➪ Alexa Integration
- ➪ 2 Year Warranty

## Specifications

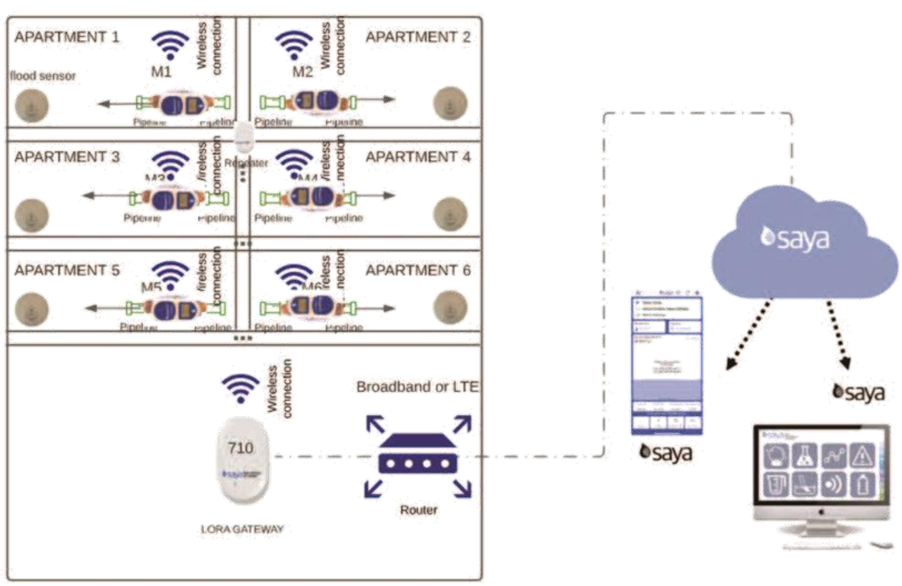
- ➪ LAN Transmission : **Lora 915 Mhz**
- ➪ Max Range ( OTA, LOS) : **2 miles**
- ➪ Enclosure Material : **Plastic (Indoor)**
- ➪ Max working temp : **$115^{0}$F**
- ➪ WAN Interface : **Ethernet, LTE**
- ➪ Power : **5V 2A**

## Antenna Option

**1. High Gain External Antenna**

**2. Internal Antenna**

## Installation Recommendation




Additional spec sheets for related products are available at [https://saya.life/productspecs](https://saya.life/productspecs).

## i2Systems LED Lighting


## THE LUMINAIRE AT A GLANCE

BACnet®

**01** 277VAC or 380VDC autosensing, Plug & Play

**02** Serviceable / Upgradeable LED Module and Electronics

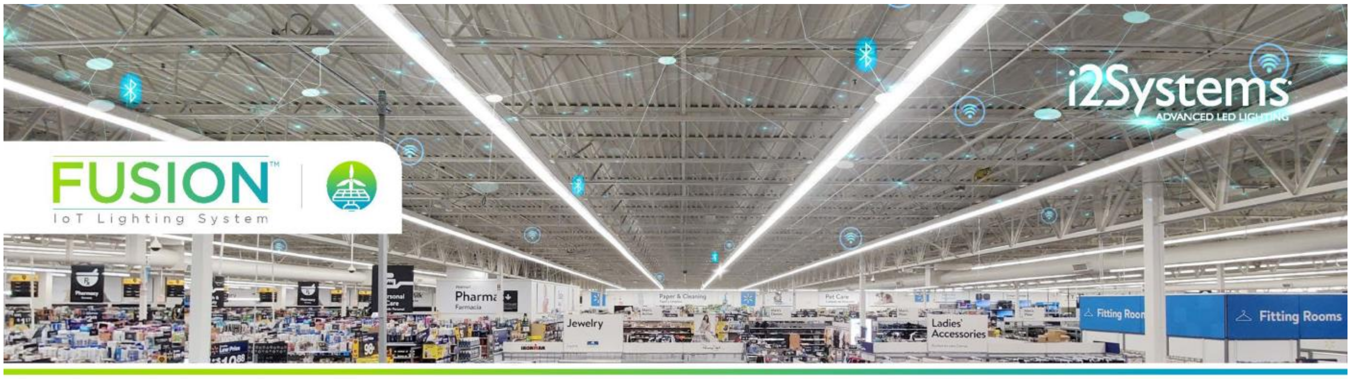
**03** Built-In Bluetooth Wireless Mesh Network for Inter Fixture Communication and Communication to the i2Systems Gateway

**04** LED Module Sealed against bugs and moisture

## SPECIFICATION CODE BUILDER

**EXAMPLE:** F-40W-35K-S-1-PD

| Series | Power | CCT | Color Quality | Voltage | Mounting | Run Length |
|---|---|---|---|---|---|---|
| F | | | | | | |
| F FUSION | **40W** | **27K** - 2700K | **S** - Standard (83+) | **1** - 277VAC / 380VDC | **PD** - Aircraft Cable Pendant | |
| | | **30K** - 3000K | **H** - High (92+) | | **RT** - Retro Fit | |
| | | **35K** - 3500K | | | | |
| | | **40K** - 4000K | | | | |
| | | **45K** - 4500K | | | | |
| | | **50K** - 5000K | | | | |




## FEATURES & BENEFITS

**REPLACEABLE PARTS**
Never throw out your luminaire.
Power Supply, LED Assembly - Replaceable in Minutes!

**ENERGY EFFICIENT**
No power conversion loss on DC .95 Power Factor on AC

**FUTURE PROOF**
Re-lampable and upgradeable with minimal investment

**CONTROLLABLE VIA BACNET**
- Set lighting schedules
- Automated fault alerts
- Built-In Preventative Maintenance Alerts

**ON-SITE SUPPORT**
National Installation & Support Team

**5 YEAR WARRANTY**

# COLOR QUALITY | R Values

### HIGH CRI 83+

| Color Temp | Ra | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 | R13 | R14 | R15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2700K | 85 | 84 | 92 | 98 | 85 | 84 | 91 | 85 | 64 | 20 | 82 | 86 | 81 | 86 | 99 | 77 |
| 3000K | 86 | 84 | 91 | 96 | 86 | 85 | 89 | 87 | 67 | 22 | 79 | 86 | 77 | 86 | 98 | 78 |
| 3500K | 86 | 85 | 90 | 94 | 87 | 85 | 87 | 88 | 70 | 26 | 76 | 87 | 75 | 86 | 96 | 79 |
| 4000K | 85 | 84 | 89 | 92 | 87 | 84 | 85 | 89 | 72 | 26 | 73 | 86 | 70 | 85 | 96 | 79 |
| 4500K | 84 | 83 | 86 | 89 | 85 | 83 | 82 | 88 | 73 | 23 | 68 | 86 | 67 | 83 | 94 | 78 |
| 5000K | 84 | 82 | 88 | 92 | 85 | 84 | 84 | 87 | 68 | 9 | 71 | 85 | 70 | 83 | 96 | 76 |

### HIGH CRI 92+

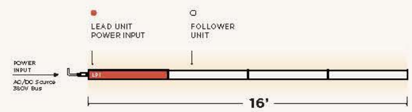
| Color Temp. | Ra | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 | R9 | R10 | R11 | R12 | R13 | R14 | R15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2700K | 91 | 92 | 92 | 91 | 93 | 91 | 88 | 94 | 86 | 55 | 81 | 92 | 60 | 93 | 95 | 89 |
| 3000K | 96 | 98 | 97 | 93 | 94 | 99 | 94 | 96 | 94 | 80 | 92 | 89 | 72 | 99 | 96 | 98 |
| 3500K | 93 | 95 | 94 | 94 | 95 | 94 | 92 | 96 | 88 | 62 | 86 | 93 | 66 | 95 | 96 | 90 |
| 4000K | 96 | 98 | 97 | 95 | 97 | 97 | 95 | 96 | 90 | 71 | 92 | 93 | 71 | 98 | 97 | 94 |
| 4500K | 96 | 95 | 99 | 97 | 92 | 96 | 95 | 98 | 96 | 88 | 97 | 85 | 81 | 95 | 97 | 98 |
| 5000K | 96 | 97 | 98 | 99 | 97 | 97 | 93 | 94 | 89 | 75 | 97 | 91 | 78 | 97 | 99 | 96 |

83+ CRI

92+ CRI

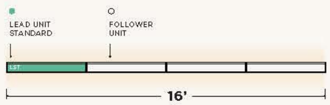
## SYSTEM Architecture

### POWER INPUT ASSEMBLY

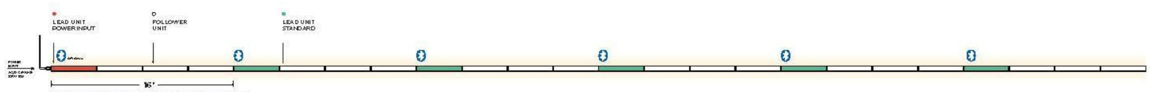


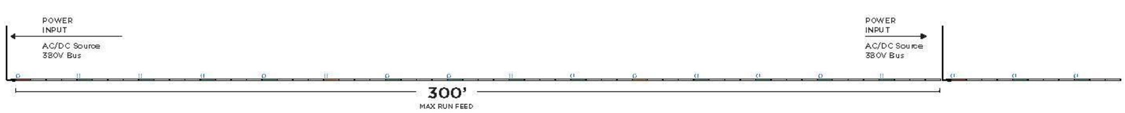

### ASSEMBLY TYPOLOGIES


### STANDARD ASSEMBLY




## RUN EXAMPLE



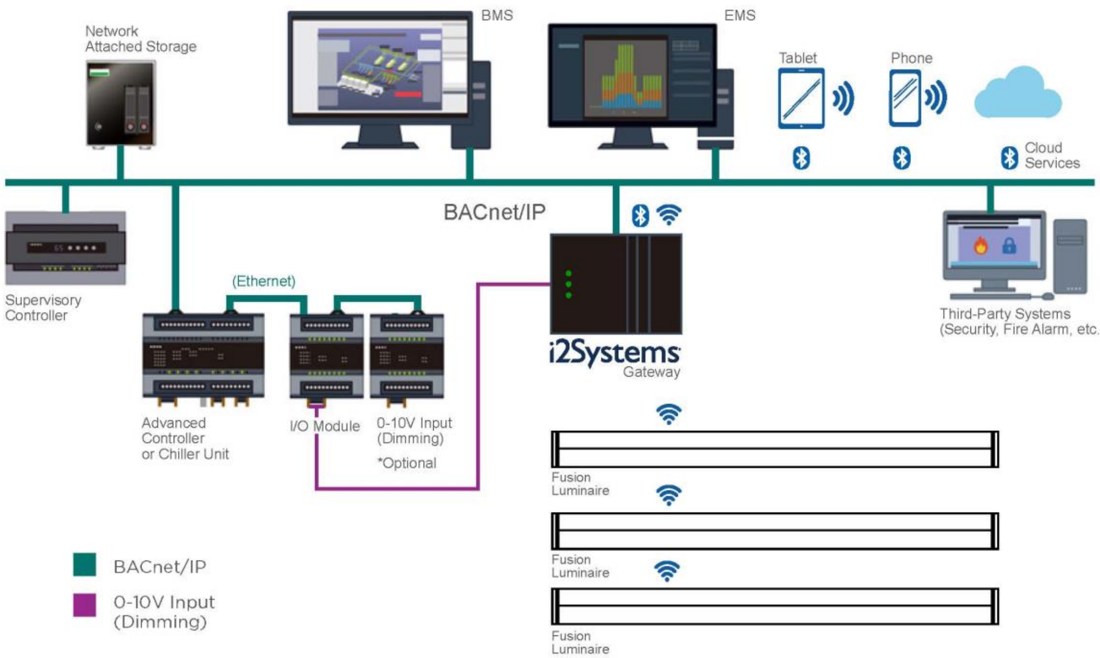




### GATEWAY LOCATION

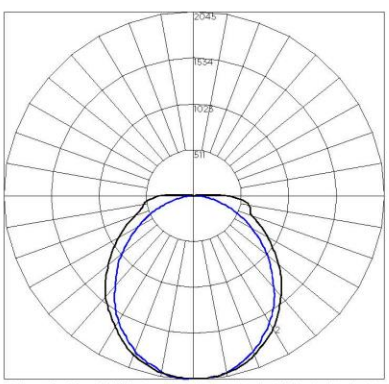
**GATEWAY:** For maximum performance, the Gateway should be installed central within the designation of the zone inside a space

TYPE: ___________

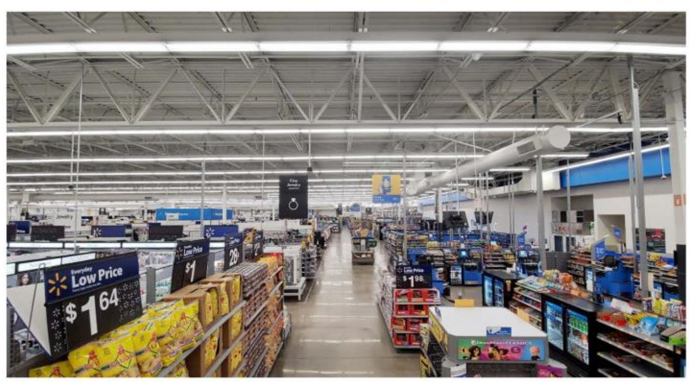
## Gateway Wiring Diagram




## LED Module Beam Angles




Maximum Candela = 2045.174 Located At Horizontal Angle = 172, Vertical Angle = 4
# 1 - Vertical Plane Through Horizontal Angles (172 - 352) (Through Max. Cd.)
# 2 - Vertical Plane Through Horizontal Angles (90- 270)



FUSION™ IoT Lighting System

TYPE: ___________

## Lumen Performance

| POWER | WATTS/FT | 83+ CRI | 92+ CRI |
|---|---|---|---|
| 277VAC | 10 | 1450 | 1300 |
| 380VDC | 10 | 1550 | 1400 |

up to **1500** LUMENS PER FOOT

Lumens per foot based on a 4' LED module @ 4000K.

## LED Module Technical Properties

**TEMPERATURE**
Operating/Storage:
(-20°C) - (+40°C)

**PROTECTION:**
Indoor Use Only

**INPUT VOLTAGE:**
277V AC & 380V DC

**SURGE PROTECTION:**
IEEE/ANSI Standard
C62.41 Category A

**LIFE:**
60,000hrs to L70

**HOUSING:**
Aluminum

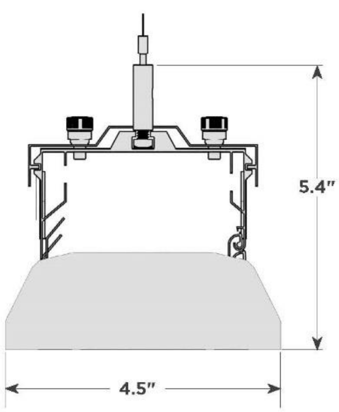
**TYPOLOGIES:**

| LEAD UNIT POWER INPUT | LEAD UNIT STANDARD | FOLLOWER UNIT |
|---|---|---|
| LPI | LST | F |

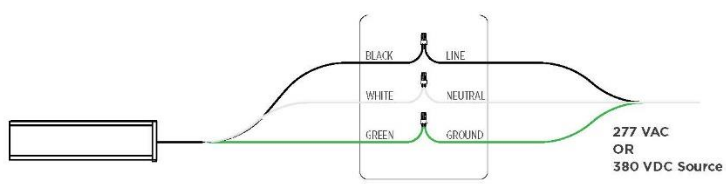
## LED MODULE Certifications

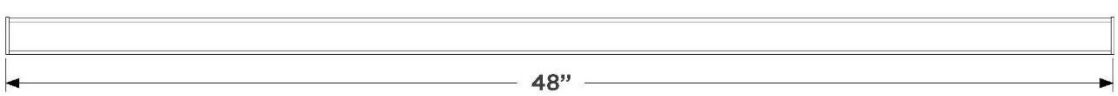
cULus · 5 YEAR WARRANTY · FC · RoHS compliant 2002/95/EC · AMERICAN DESIGNED & MANUFACTURED

## LED Module Dimensions



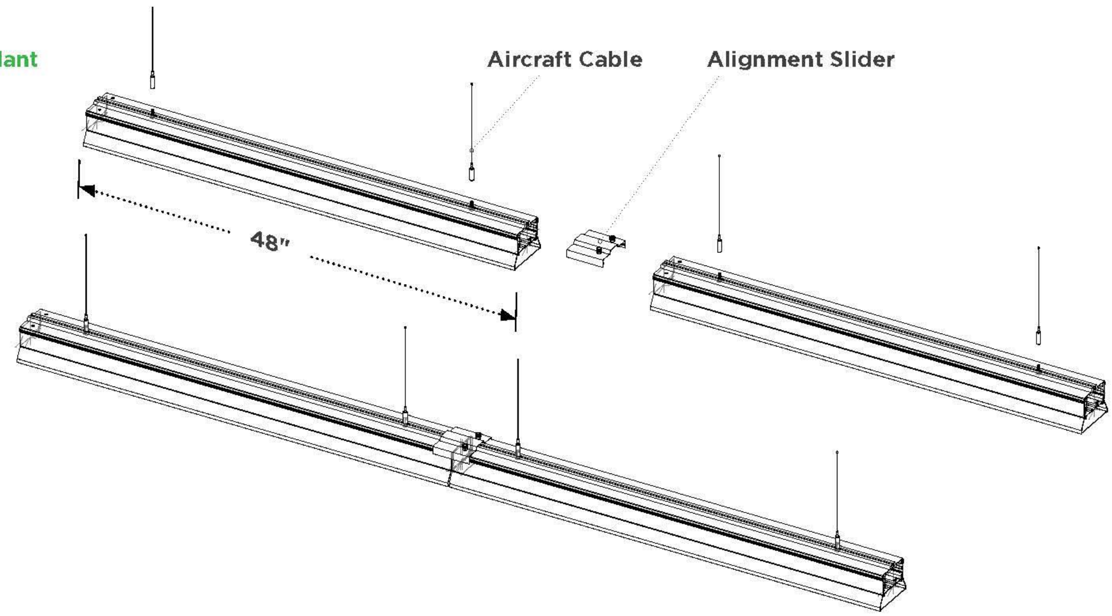

## LED MODULE Wiring Diagram



## Lumen Module Connection & Mounting

### Pendant




## BACNET WIRING Guidelines

### OVERVIEW

i2Systems Gateway is Bacnet IP compatible.

## WIRING

### NETWORK WIRE SPECIFICATIONS

For the BACnet IP network specific wire is required. Do not use standard power or "thermostat" wire. This wire does not have the necessary requirements for digital communications. While it's possible it may work (temporarily) the network will be unreliable and not operating at optimal.

**BACNET IP WIRE TYPE RECOMMENDATIONS**
**USE 1 BALANCED TWISTED PAIR**

- CAT5, CAT5E, CAT6 network cable has excellent specifications and will work in almost any BACnet IP application.

# ICI DualCool


***CoilCool Implementation Requirements***

The Customer is responsible for providing the following required elements in support of a CoilCool project.

**Electrical Requirements:** A 115v single phase outlet inside the controls cabinet of each rooftop unit where a CoilCool unit is installed.

**Water Requirements:** Water connection for the CoilCool makeup water. The makeup water line must deliver at least 1.5 gpm at 20 psi and should be valved so that it can be drained in winter, if necessary. ICI will provide a backflow preventer, and water distribution piping to each CoilCool unit as required.

**5 or 6 Ton Trane Precedent YHC Packaged Gas/Elec. DualCool**

| | |
|---|---|
| **Precooler Dimensions:** | 45" & 30"L x 48"H x 11"W |
| **Operating Weight:** | 309 lbs. (wet) |
| **Electrical:** | Voltage = 115V single phase<br>Power = 120 watts max |

INTEGRATED COMFORT INC.

## Product Description/Overview

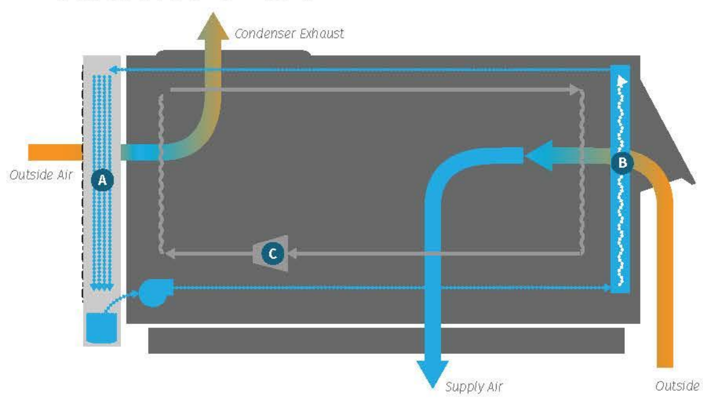
DualCool system components include stainless steel pre-cooler frames, rigid evaporative cooling media, a pump, and an appropriately sized ventilation air pre-cooling coil. The DualCool pump circulates water through the pre-cooling coil and over the evaporative media. A bleed system discharges a small portion of the water returning from the vent air coil to maintain water quality in hard water areas. To save water and energy, condensate from the evaporator coil drains to the DualCool sump.

## Service & Warranty

The service plan, carried out by trained service crews, includes three scheduled site visits per season: Within the warranty period, ICI will replace any defective components at no charge to the customer. As a "wear component" the evaporative media will be replaced if necessary on a pro-rated basis in comparison with its 5 year expected life. The warranty does
not cover:

- Damage to pumps if the water supply has been interrupted by a customer's agent
- Failure of the evaporative media if a customer's agent has reduced the required bleed flow rate

## DualCool Schematic

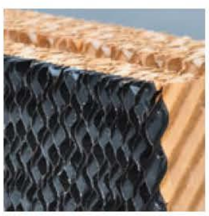



**A.** *Evaporative Condenser Pre-cooler reduces the workload for the compressor* **B.** *Water Coil uses cold sump water to cool incoming ventilation air* **C.** *The vapor compression system uses less energy to meet comfort demands*

## Included Materials Overview

***The Pre-Cooler Enclosure:*** is made from stainless steel and is custom-fit to each rooftop unit. The design facilitates an affordable "lifetime" enclosure that will outlast the rooftop unit to which it is attached. The design also facilitates easy removal of the evaporative media yet holds the media securely in windy conditions.

***A Submersible Pump:*** moves cool water from the reservoir beneath the evaporative media to, and through, the vent air pre-cooling coil, and then back to a distribution tube above the evaporative media. Water flowing through the coil cools the warm incoming fresh air stream, and water flowing by gravity downward through the media cools the air entering the large condenser coil through which refrigerant is discharging heat to the outside air.



***Evaporative Media:*** These 8" thick blocks of "cross-corrugated" treated cellulose are the highest quality evaporative media available, squeezing near-maximum cooling from the evaporative process. Both the airstream and the water are cooled evaporatively as water flows evenly downward from the stainless steel reflector above the perforated media.

***Ventilation Air Coil:*** This radiator-like heat exchanger cools the fresh air stream required by building codes to maintain indoor air quality in commercial buildings. It is also the feature that distinguishes the patented DualCool product from condenser-only air pre-coolers. Cool water is pumped directly from the DualCool reservoir through this efficient coil, typically cooling outdoor air almost to indoor air temperature. Water leaving the coil flows to the evaporative pre-cooler.


***Controls Solutions:*** The Standard DualCool control is a thermostat that activates the pump when outdoor temperature exceeds a preset value (typically 70°F to 75°F). Upgraded Controls options provide Fault Detection and greater integration with the RTU, including interlocks with Blowers, Fans, and Economizers.

***Bleed System:*** The DualCool "bleed" system limits the concentration of hardness minerals in the DualCool water loop. Without the bleed system, minerals can build up on all surfaces that the water contacts, compromising both appearance and function of the system.

# Turntide Smart Motors

TURNTIDE

## Turntide Smart Motor System™

- More efficient
- More intelligent
- Ultra reliable
- Simple drop-in solution
- Standard NEMA dimensions
- No rare earth materials

Reduce HVAC energy usage by an average of

**64%**

with Turntide's Smart Motor System

**Optimizing your HVAC efficiency is a high-impact energy conservation measure that delivers immediate and long-term savings**

**40%** of energy used in commercial buildings is from HVAC equipment

**30%+** of the energy that goes into powering HVAC is wasted in the average commercial building, according to the U.S Department of Energy

Source: U.S. Department of Energy

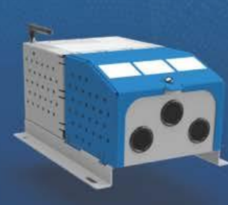
### What is the Smart Motor System?

**Advanced device physics and intelligence come together in a Smart Motor System that optimizes your HVAC energy usage**

#### Motor

Our patented high rotor pole switched reluctance motor with advanced device physics runs more efficientl and reliably.

Available for 1-10 HP



#### Motor Controller

The controller helps the variable-speed motor work at optimized efficiency across a broad range of speeds, control customized sequences of operation or application-specific functionality, and protect the system from damage or failure.

#### Turntide App

Web and mobile apps make remote monitoring and management of your building systems and equipment easy, with notifications, troubleshooting tools, and the ability to make service requests anytime, anywhere.

# The Smart Motor System

**The ultimate energy conservation measure**

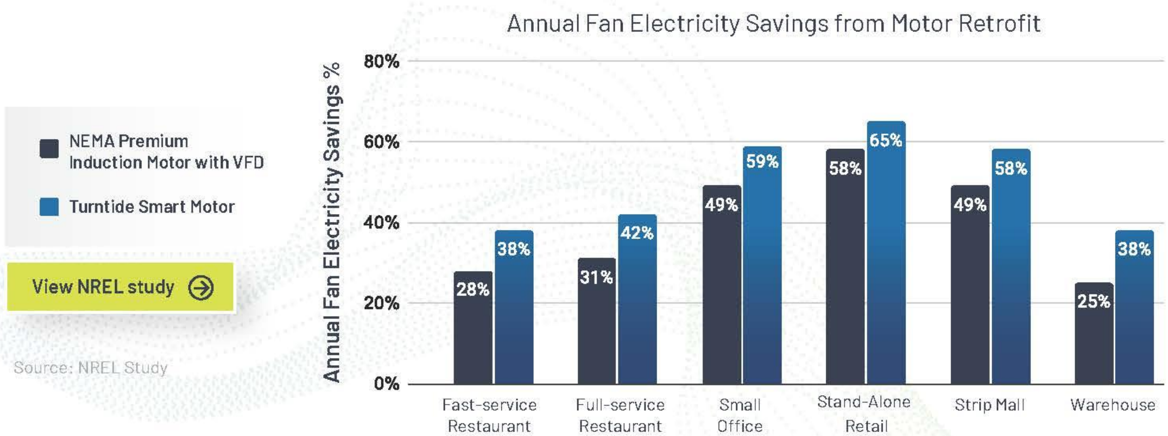
The Smart Motor System provides an HVAC setup that is more efficient, more intelligent, ultra reliable, and simple.

**13%**

Better performance than VFD retrofit

Source: NREL Study

## The Smart Motor System Outperforms VFD




### More Efficient

**Highly Efficient Design**
Minimal energy loss due to optimal rotor/stator design and control strategies over conventional switched reluctance motors

**Highly Versatile**
Software provides motor agility over varying loads and speeds

### More Intelligent

**24/7 Runtime Monitoring**
By monitoring speed and torque that helps identify equipment health and potential fault conditions, you have insights to remotely commission and optimize motor and HVAC to always run as efficiently as possible

### Ultra Reliable

**Reduced Failure Modes**
Bobbin stator coil design with uniform windings reduce failures in comparison to induction motors by 10%

**Optimized for Multispeed**
With all Turntide components designed to work together, it works as reliably at higher and lower speeds

### Simple

**Hassle-Free Install**
Retrofits and installations performed by experts from Turntide or our network of trusted FSP partners

**Proactive Insights**
Built-in fault detection and alerts enable preventative maintenance

## Proven Results

Grocery store Sprouts

75%

annual HVAC energy reduction

View case study

Retailer Wilko

60%

total energy reduction

View case study

Auto manufacturing plant

75%

annual HVAC energy reduction

## Intelligence, Automation, and Control

Turntide for Buildings brings together the Smart Motor System, Smart HVAC, and Smart Building Operations


### Smart HVAC

- Monitor and control HVAC and Smart Thermostats with BACnet integration
- Smart notifications via text and email for smart routing, prioritization, and escalation
- Troubleshooting tools like trends, charting, and playback features

### Smart Building Operations

- Building equipment management including metering, lighting control, monitoring indoor air quality (IAQ), and temperature monitoring in refrigeration and coolers
- Visibility and intelligence with customized reports you can create for compliance, executives, field teams, and more
- Remote management and service support with intelligence, smart notifications, and alerts to prevent downtime

## Want to learn more?

Visit our website *turntide.com* | Talk to our team *sales@turntide.com* | Read our *Quick Reference Guide*

TURNTIDE TECHNOLOGY FOR SUSTAINABLE OPERATIONS

Our breakthrough technologies accelerate electrification and sustainable operations for energy-intensive industries.

Turntide Technologies | 1295 Forgewood Avenue, Sunnyvale, CA 94089

TURNTIDE

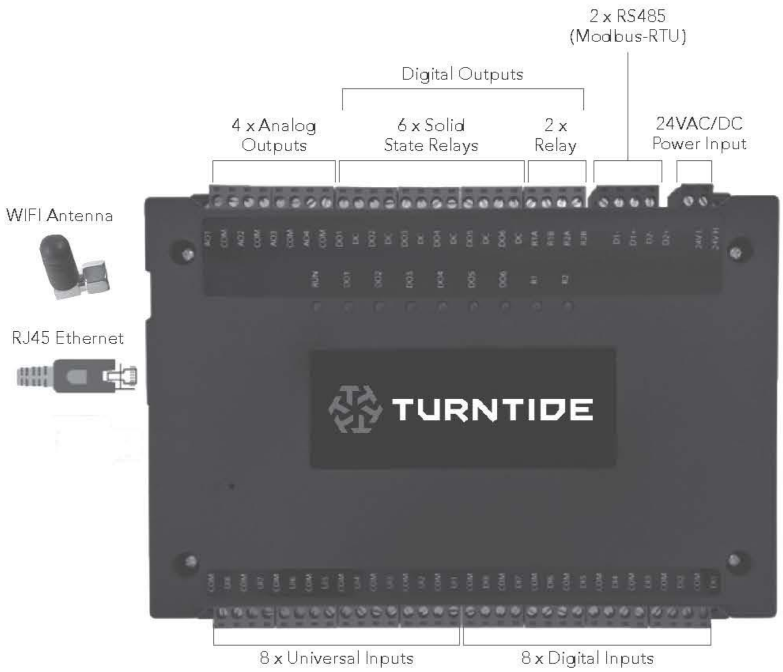
# Turntide™ Supervisor

The Turntide Supervisor is used to connect multiple Smart Motor Systems on a site and provide connectivity to the Turntide Cloud or a BMS system. With the ability to manage up to ten motor systems, it can coordinate operation, provide continuous real-time monitoring data to the Turntide Cloud, and enable direct control and monitoring capability via BACnet to BMS systems. The Supervisor communicates to Turntide Smart Motors via a twisted pair network or 802.11 Wifi.


The Turntide Supervisor provides connections for a multitude of physical I/O and is configurable with Turntide Cascade™ configuration software, completing a very flexible gateway product.

| FEATURES | TURNTIDE SUPERVISOR BENEFITS |
|---|---|
| Provides single communication connection for up to ten motors | Reduces field wiring and simplifies connection to BMS or Turntide Cloud. |
| Local or remote firmware upgrades for Turntide Smart Motors | System upgrades improve motor efficiency and operation, increasing Turntide Smart Motor energy savings over time. |
| Building management protocol support through native BACnet/IP | Leverages industry standard communications protocols, allowing for seamless integration with existing equipment and systems. |
| Supervises up to ten Turntide Motor Systems | Provides a single, scalable point of connection for remote monitoring and management of the motor systems. |
| Full complement of control and monitoring I/O:<br>• Eight universal (voltage, current or resistive) inputs<br>• Eight 24VAC digital inputs<br>• Eight digital outputs<br>• Four analog outputs<br>• Linux based system architecture and standards-based software | Reduces total cost of implementation by minimizing need for additional BMS equipment with no licensing requirements. |
| Pre-configured for Automatic Digital Economizer Control | Approved for rebates by several utilities in the United States. Reduces payback period for retrofits. |

III CE Certified to UL 60730-1 safety standard




| DIMENSIONS | LG | WD | HT |
|---|---|---|---|
| Supervisor | 7.95" | 6.1" | 1.4" |
| W/Antena | 8.66" | 6.1" | 1.4" |

| TYPE | QTY | SPECIFICATION | NOTES |
|---|---|---|---|
| Digital Output | 2 | 1A, 125VAC | 2 Relay contact output |
| | 6 | 2A, 24VAC | 6 Triac outputs |
| Digital Input | 8 | 0-24VAC | Isolated Inputs on Rev C |
| Analog Output | 4 | 0-10V, 20mA | Source follower buffered |
| Universal Input (Independently configurable as): | 8 | 0-10V | Single ended voltage mode |
| | | 0-20mA | Current loop mode |
| | | RESISTIVE | Resistive sensing, e.g. Thermistors |
| | | LOGIC | Open returns Logic 0 and shorted returns Logic 1 |

## Indemnity



TURNTIDE

1295 Forgewood Avenue, Sunnyvale, CA 94089
sales@turntide.com

Turntide Technologies (formerly Software Motor Company) has developed the world's most efficient and intelligent electric motor system. The revolutionary Smart Motor System is based on proven switched reluctance technology, now managed with advanced cloud software and connected to precise controls via IoT. Turntide's vision is to eliminate the 25% of global electricity consumption that is wasted by legacy motors, thus accelerating the world's transition from fossil fuels. Turntide is based in Sunnyvale, Calif., with offices in San Francisco; Arlington, Wash.; and Kennesaw, Ga. Turntide has installed Smart Motor Systems with dozens of customers, reducing their motor electricity consumption by an average of 64%, and is powering the systems of leading OEMs. For further information, visit www.turntide.com.

**POWER IS VALUABLE. USE IT INTELLIGENTLY.**

# Turntide™ Smart Motor System: V01 IEC (1.1 - 2.2 kW)


The Turntide Smart Motor System delivers unprecedented energy efficiency in a highly reliable switched reluctance design. This software-driven motor solution includes the Turntide Smart Motor and the Turntide Motor Controller, complete with networking and connection capabilities to Turntide Cloud. The patented Turntide Motor System is proven to significantly reduce energy consumption, dramatically reducing energy costs and carbon footprint resulting from electric motor operation.

The Turntide V01 IEC motors are suitable for a range of new and retrofit HVAC, refrigeration, and pumping applications in both fixed and variable speed.

## Turntide Smart Motor System

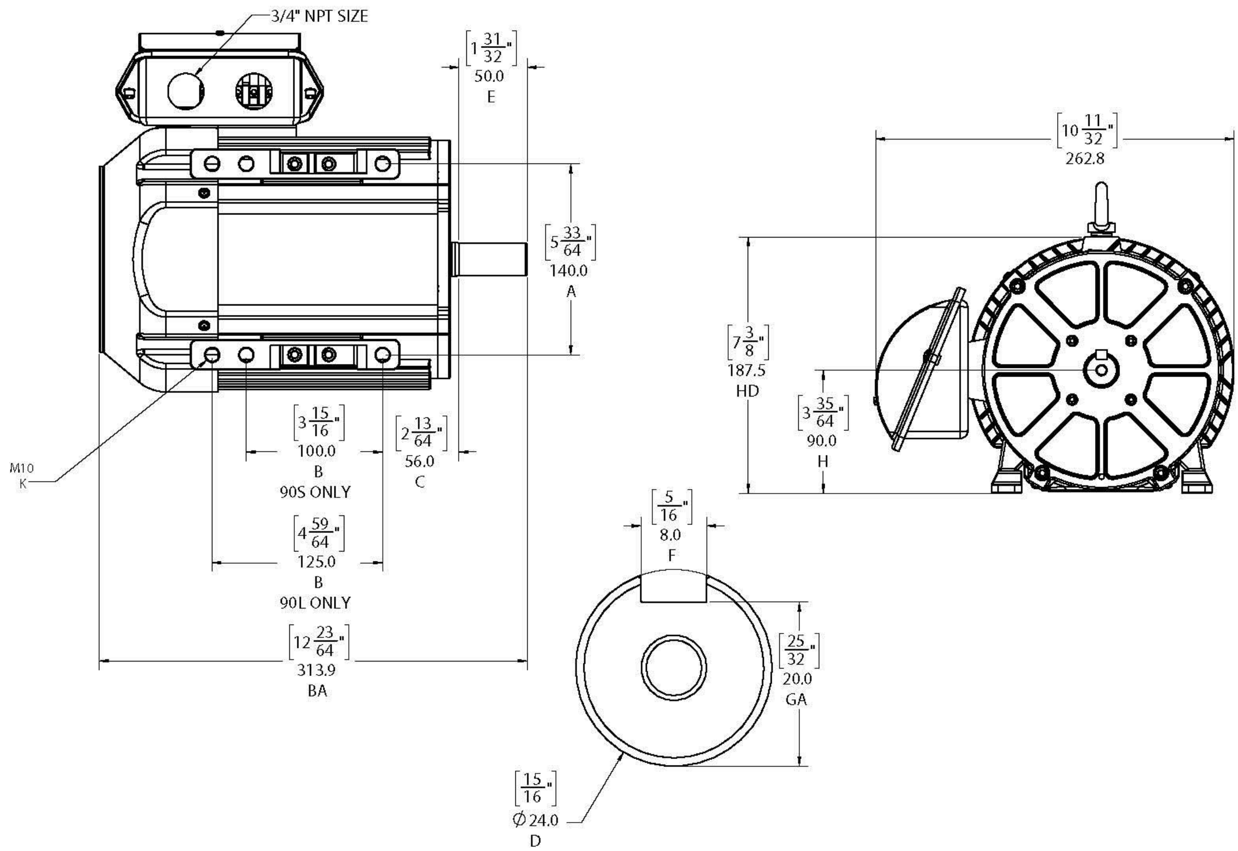
| FEATURES | TURNTIDE SMART MOTOR SYSTEM BENEFITS |
|---|---|
| Turntide Cascade® - PC graphic-based programming tool, part of the Turntide Controls Platform | Provides for customization to assure your motor control sequences can be accomplished for every application. |
| Configurable sequence of operation based on internal and external sensor feedback using up to 16 integrated I/O points | Reduces hardware needed to control HVAC and other equipment, reducing overall cost of system implementation. |
| Safe DC bus discharge | Ensures internal voltages of the Turntide Motor Controller are rapidly discharged for safe service and maintenance immediately after power down |
| "Fail Safe" mode | Keeps the Turntide Smart Motor running during phase loss, ensuring continuous operation and minimum downtime. |
| Turntide Cloud | Provides monitoring and remote reporting, enabling extended data logging and alerts and alarms based on selectable parameters, protecting equipment and assuring the most efficient operation. |
| Built-in soft start and brownout protection | Eliminates nuisance service calls and interruptions to building operation due to inadvertent circuit breaker trips, reducing maintenance costs. |

## Motor System Characteristics

| | | | | | |
|---|---|---|---|---|---|
| Motor Model SKU | V01-0150-2-ID00 | V01-0200-2-ID00 | V01-0300-2-IE00<br>V01-0300-2-IF00 | Supply Voltage/Frequency | 200-240VAC |
| | V01-0150-4-ID00 | V01-0200-4-ID00 | V01-0300-4-IE00<br>V01-0300-4-IF00 | | 380-415VAC |
| Motor Controller Model | P04W | | | Supply Frequency | 50 Hz |
| Rated Power | 1.1 kW / 1.5 HP | 1.5 kW / 2 HP | 2.2 kW / 3 HP | Motor Duty Rating | Continuous |
| Rated RPM | 1500 RPM | | | Motor Ingress Protection | IP20 Rating |
| Rated Service Factor | 1.15 | | 1.15 (-2) / 1.00 (-4) | Motor Controller Ingress Protec- | IP20 Rating |
| Operating RPM | 300-3000 RPM | | | Rotor Inertia | 0.100 lb-ft² (0.0042 kg-m²) |
| Peak System Efficiency | 87.9% | 89.1% | 87.9% | Motor to Controller Power Wire | 14 AWG |
| Peak Motor Efficiency | 91.0% | 91.4% | 89.8% | Insulation Class | F |
| Supply Phase | 3-Phase | | | Ambient Temperature Range | -10°C to +40°C |
| Power Factor | 0.65-0.80 across operating range | | | Relative Humidity | 95%, non-condensing |
| Motor Enclosure | TEFC | | | Motor Controller Weight | 3.2 kg (7.0 lb) |
| IEC Motor Frame Sizes | 90S / 90L | 100L (-IE00) / 112S (-IF00) | | Motor Weight | 24.5 kg (54 lb) |

CE RoHS COMPLIANT Certified to IEC 60204-1, IEC 60034-1, IEC 61800-5-1, IEC 61800-5-2, IEC 61800-3, and IEC 61000-4-5

## Motor Dimensions

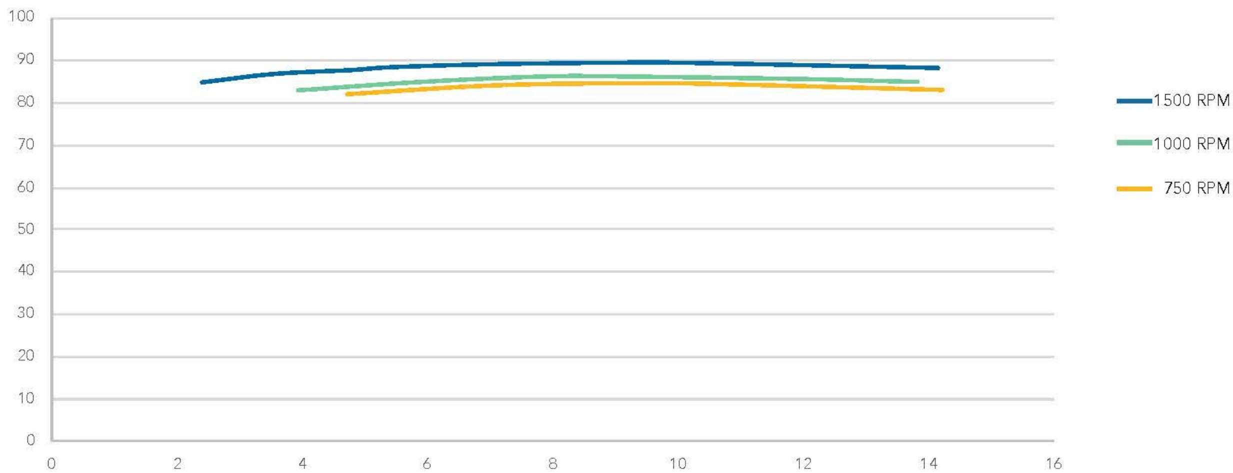



## Dimension Table (in millimeters)

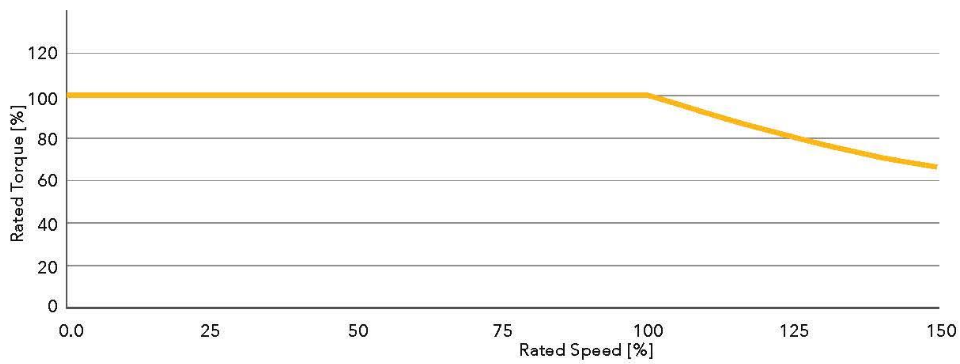
| IEC Frame | A | B | H | K | D | E | C | L |
|---|---|---|---|---|---|---|---|---|
| 90S | 140 | 100 | 90 | M10 | 24 | 50 | 56 | 313.9 |
| 90L | 140 | 125 | 90 | M10 | 24 | 50 | 56 | 313.9 |
| 100L | 160 | 140 | 100 | M12 | 28 | 60 | 38 | 323.9 |
| 112S | 190 | 140 | 112 | M12 | 28 | 60 | 38 | 323.9 |

A - distance between foot holes side-to-side
B - distance between foot holes front to back
H - height of shaft
K - foot hole size
D - shaft diameter
E - shaft length
C - distance from front foot hole to back of shaft horizontally
L - Overall length

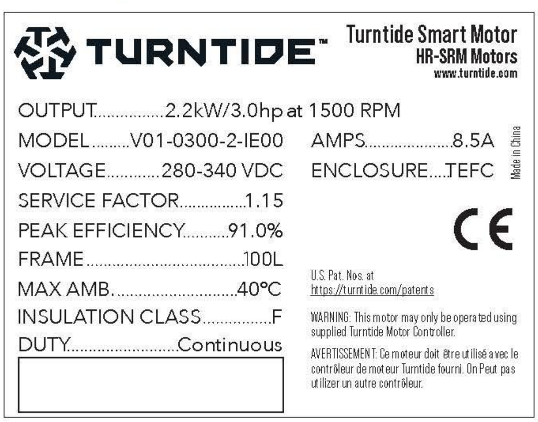
## System Efficiency vs Torque at Various Speeds

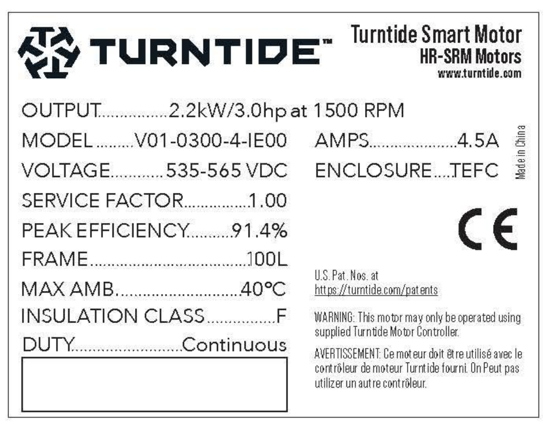



## Torque-Speed Curve




## Motor Nameplates (sample)

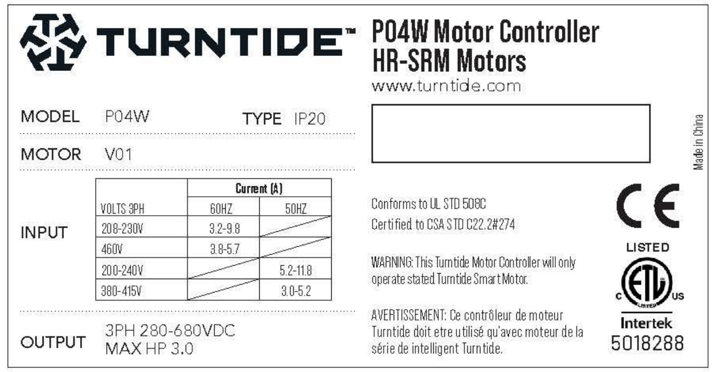


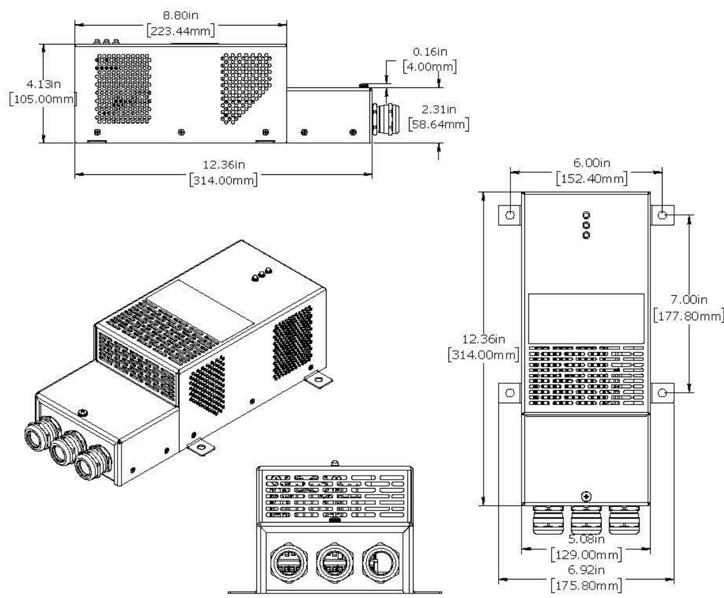
## Turntide P04W Motor Controller

The Turntide Motor Controller controls all operations of the Turntide Smart Motor and is required for motor operation. Its internal program assures that the motor is operating at the highest efficiency at any speed in any application. It does this by monitoring the internal sensors and feedback from the Smart motor and adjusting control signals for optimization. The Motor Controller provides physical connection for 16 sensors and relay output connections for control and monitoring of associated equipment such as RTUs, AHUs and pumps. The Motor Controller can be configured with Turntide Cascade software to operate under an infinite number of control scenarios. When connected with the Turntide Supervisor, remote configuration, updates, alerts, alarms, and system data logging can be delivered through Turntide Cloud or a BMS system.

## Motor Controller Nameplate




## Motor Controller Dimensions




## Motor Controller I/O

| QTY | Description |
|---|---|
| 7 | Programmable digital inputs |
| 1 | Programmable voltage output: 0-10V, 20mA limit |
| 4 | Relay outputs: 1A, 125VAC limit |
| 4 | Universal inputs, individually selectable as:<br>• Voltage Mode: 0-10V<br>• Current Mode: 0-20mA; or 4-20mA<br>• Resistive Mode<br>• External Logic Mode |

### Meeting IEC EMC Standards

To meet IEC 61800-3 and IEC 61000-4-5 standards it is mandatory to follow the installation guidelines for EMI/RFI Filter, Surge Arrester, and appropriate shielded conduit as detailed in the Turntide Meeting IEC EMC Standards document.

### Indemnity

The information in this document is subject to change without notice and should not be construed as a commitment by Turntide Technologies or Software Motor Company. Turntide Technologies assumes no responsibility for any errors that may appear in this document. In no event shall Turntide Technologies be liable for incidental or consequential damages arising from use of this document or the software and hardware described in this document.

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Turntide Technologies (formerly Software Motor Company) has developed the world's most efficient and intelligent electric motor system. The revolutionary Smart Motor System is based on proven switched reluctance technology, now managed with advanced cloud software and connected to precise controls via IoT. Turntide's vision is to eliminate the 25% of global electricity consumption that is wasted by legacy motors, thus accelerating the world's transition from fossil fuels. Turntide is based in Sunnyvale, Calif., with offices in San Francisco; Arlington, Wash.; and Kennesaw, Ga. Turntide has installed Smart Motor Systems with dozens of customers, reducing their motor electricity consumption by an average of 64%, and is powering the systems of leading OEMs. For further information, visit www.turntide.com.

**POWER IS VALUABLE. USE IT INTELLIGENTLY.**

 DOCT00086-4

# Turntide™ Smart Motor System: V02 IEC (4 kW)

The Turntide Smart Motor System delivers unprecedented energy efficiency in a highly reliable switched reluctance design. This software-driven motor solution includes the Turntide Smart Motor and the Turntide Motor Controller, complete with networking and connection capabilities to Turntide Cloud. The patented Turntide Motor System is proven to significantly reduce energy consumption, dramatically reducing energy costs and carbon footprint resulting from electric motor operation. The Turntide V02 IEC motors are suitable for a range of new and retrofit HVAC, refrigeration, and pumping applications in both fixed and variable speed.

## Turntide Smart Motor System

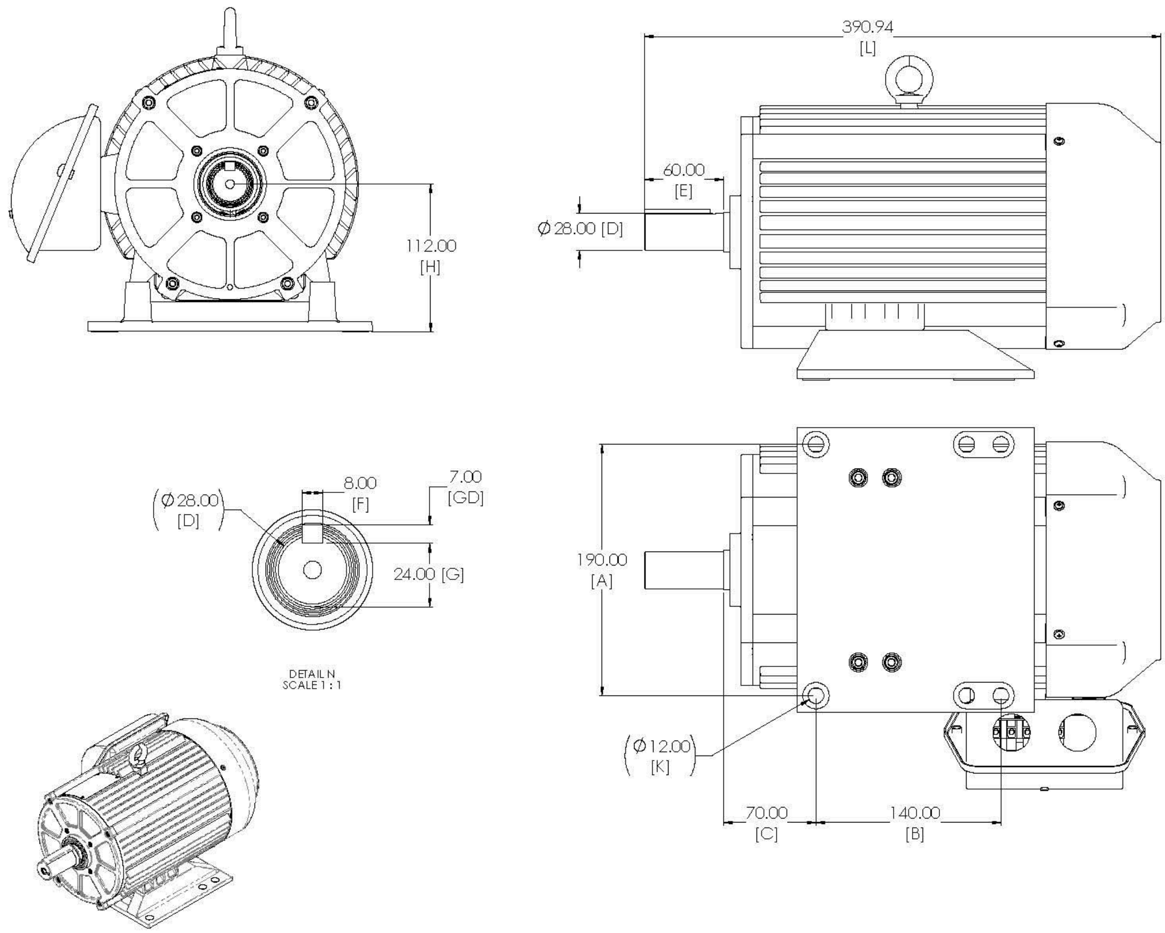
| FEATURES | TURNTIDE SMART MOTOR SYSTEM BENEFITS |
|---|---|
| Turntide Cascade® - PC graphic-based programming tool, part of the Turntide Controls Platform | Provides for customization to assure your motor control sequences can be accomplished for every application. |
| Configurable sequence of operation based on internal and external sensor feedback using up to 16 integrated I/O points | Reduces hardware needed to control HVAC and other equipment, reducing overall cost of system implementation. |
| Safe DC bus discharge | Ensures internal voltages of the Turntide Motor Controller are rapidly discharged for safe service and maintenance immediately after power down |
| Turntide Cloud | Provides monitoring and remote reporting, enabling extended data logging and alerts and alarms based on selectable parameters, protecting equipment and assuring the most efficient operation. |
| Built-in soft start and brownout protection | Eliminates nuisance service calls and interruptions to building operation due to inadvertent circuit breaker trips, reducing maintenance costs. |

## Motor System Characteristics

| | | | |
|---|---|---|---|
| Motor Model SKU | V02-0500-2-IG00<br>V02-0500-4-IG00 | Supply Voltage/Frequency | 200-240VAC<br>380-415VAC |
| Motor Controller Model | P05 | Supply Frequency | 50 Hz |
| Rated Power | 4.0 kW / 5.4 HP | Motor Duty Rating | Continuous |
| Rated RPM | 1500 RPM | Motor Ingress Protection | IP20 Rating |
| Rated Service Factor | 1.00 | Motor Controller Ingress Protection | IP55 Rating |
| Operating RPM | 300-3000 RPM | Rotor Inertia | 0.164 lb-ft² (0.0068 kg-m²) |
| Peak System Efficiency | 88.0% | Motor to Controller Power Wire | 12 AWG |
| Peak Motor Efficiency | 91.3% | Insulation Class | F |
| Supply Phase | 3-Phase | Ambient Temperature Range | -10°C to +40°C |
| Power Factor | 0.55-0.72 across operating range | Relative Humidity | 95%, non-condensing |
| Motor Enclosure | TEFC | Motor Controller Weight | 4.8 kg (10.5 lb) |
| IEC Motor Frame Sizes | 112M | Motor Weight | 32.7 kg (72 lb) |

CE RoHS COMPLIANT Certified to IEC 60204-1, IEC 60034-1, IEC 61800-5-1, IEC 61800-5-2, IEC 61800-3, and IEC 61000-4-5

## Motor Dimensions

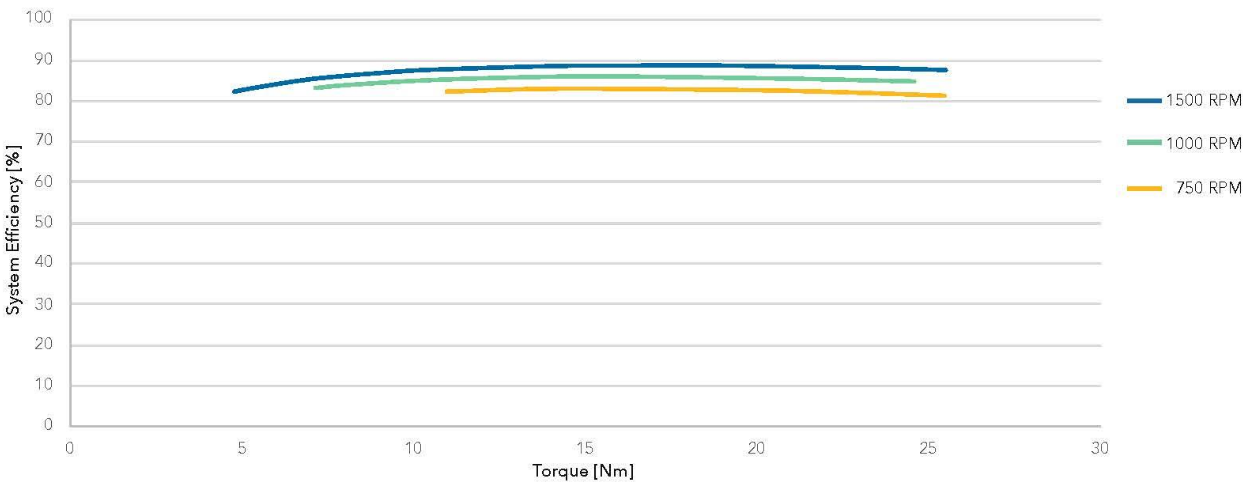



## Dimension Table (in millimeters)

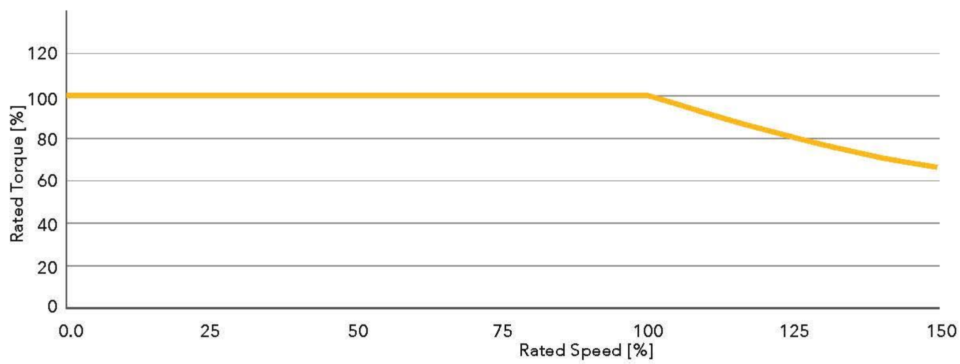
| IEC Frame | A | B | H | K | D | E | C | L |
|---|---|---|---|---|---|---|---|---|
| 112M | 190 | 140 | 112 | M12 | 28 | 60 | 70 | 390.94 |

A - distance between foot holes side-to-side
B - distance between foot holes front to back
H - height of shaft
K - foot hole size
D - shaft diameter
E - shaft length
C - distance from front foot hole to back of shaft horizontally
L - Overall length

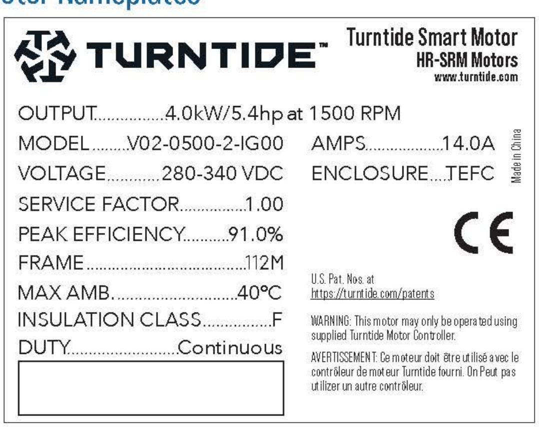
## System Efficiency vs Torque at Various Speeds

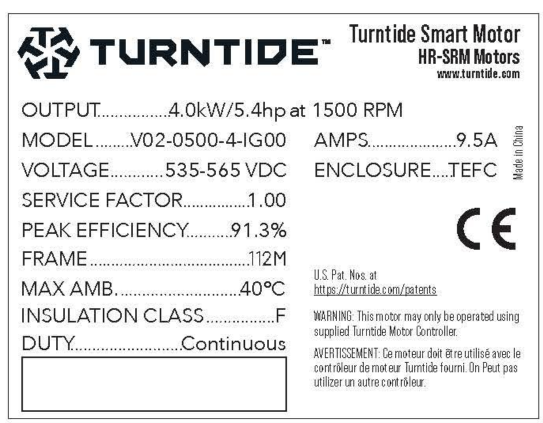



## Torque-Speed Curve




## Motor Nameplates



## Turntide Motor Controller

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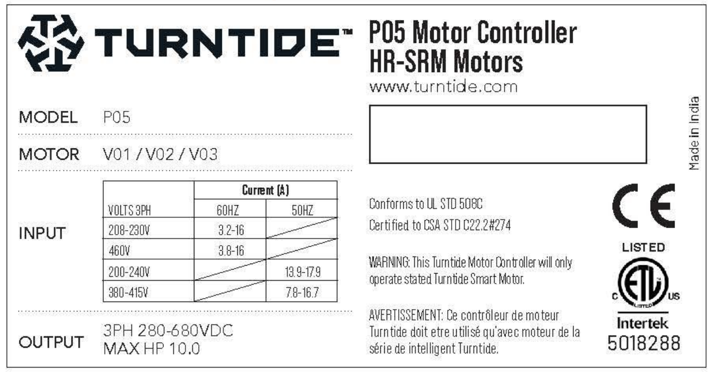
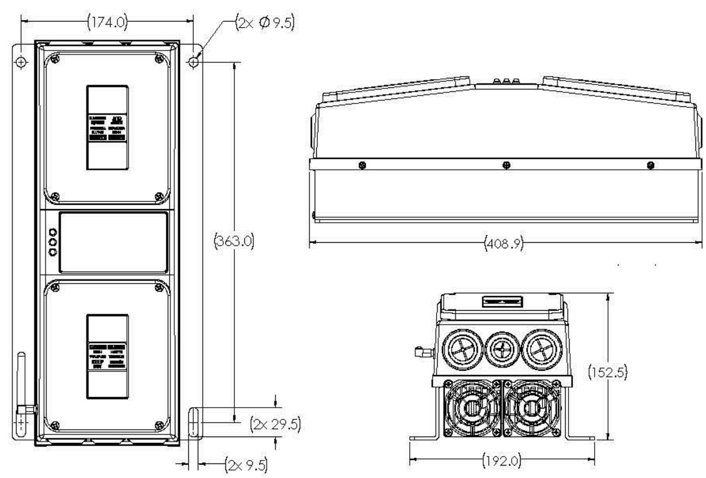
## Motor Controller Nameplate




## Motor Controller I/O

| QTY | Description |
|---|---|
| 7 | Programmable digital inputs |
| 1 | Programmable voltage output: 0-10V, 20mA limit |
| 4 | Relay outputs: 1A, 125VAC limit |
| 4 | Universal inputs, individually selectable as:<br>• Voltage Mode: 0-10V<br>• Current Mode: 0-20mA; or 4-20mA<br>• Resistive Mode<br>• External Logic Mode |

## Motor Controller Dimensions (in millimeters)




### Meeting IEC EMC Standards

To meet IEC 61800-3 and IEC 61000-4-5 standards it is mandatory to follow the installation guidelines for EMI/RFI Filter, Surge Arrester, Shielded enclosure (for P05), and appropriate shielded conduit as detailed in the Turntide Meeting IEC EMC Standards document.

### Indemnity



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Additional specs for related products are available at [https://turntide.com/learning](https://turntide.com/learning).

# APPENDIX D:
# Project Baseline & Results Details

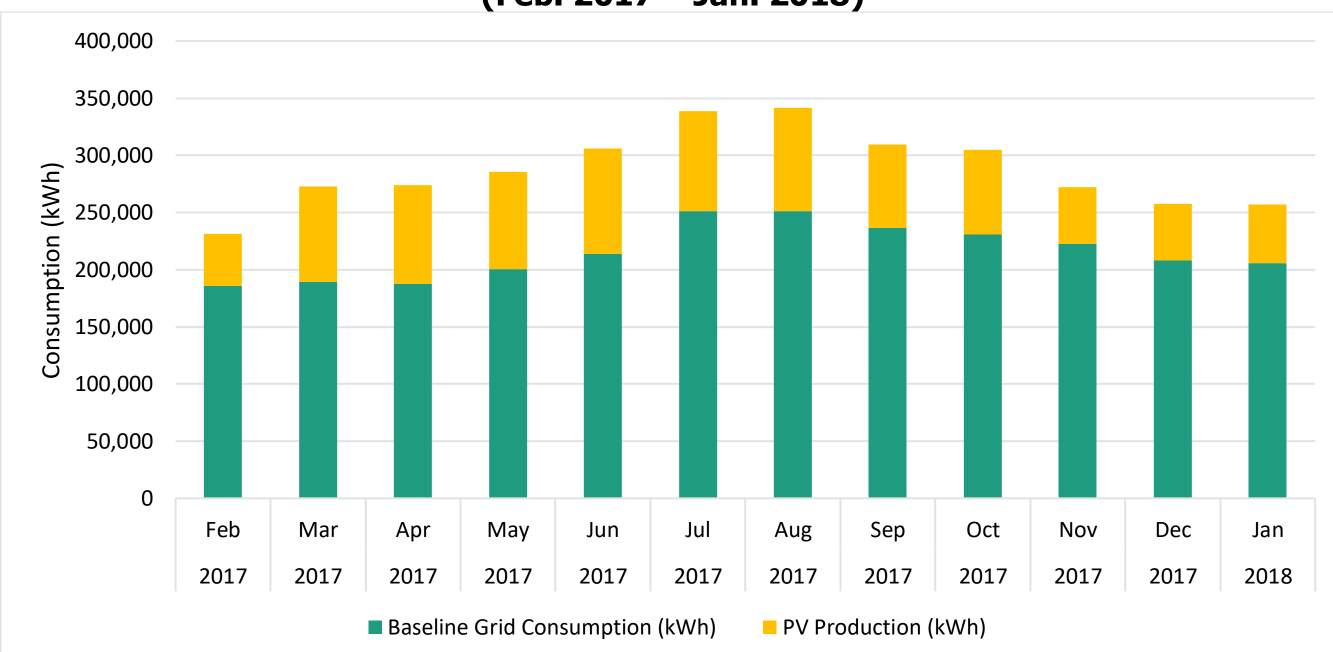
## Project Baseline

### Detailed Store Hours

- Store Hours: Mon – Sun 6 a.m. – 12 a.m.
- Bakery Hours: Mon – Sun 6 a.m. – 8 p.m.
- Deli Hours: Mon – Sun 10 a.m. – 8 p.m.
- Auto Care Center Hours: Mon – Sat 7 a.m. – 7 p.m.; Sun 7 a.m. – 6 p.m.
- Pharmacy Hours: Mon – Fri 9 a.m. – 9 p.m.; Sat 9 a.m. – 7 p.m.; Sun 10 a.m. – 6 p.m.
- Photo Center Hours: Mon – Sun 6 a.m. – 12 a.m.
- Vision Center Hours: Mon – Fri 9 a.m. – 9 p.m.; Sat 9 a.m. – 6 p.m.; Sun Closed

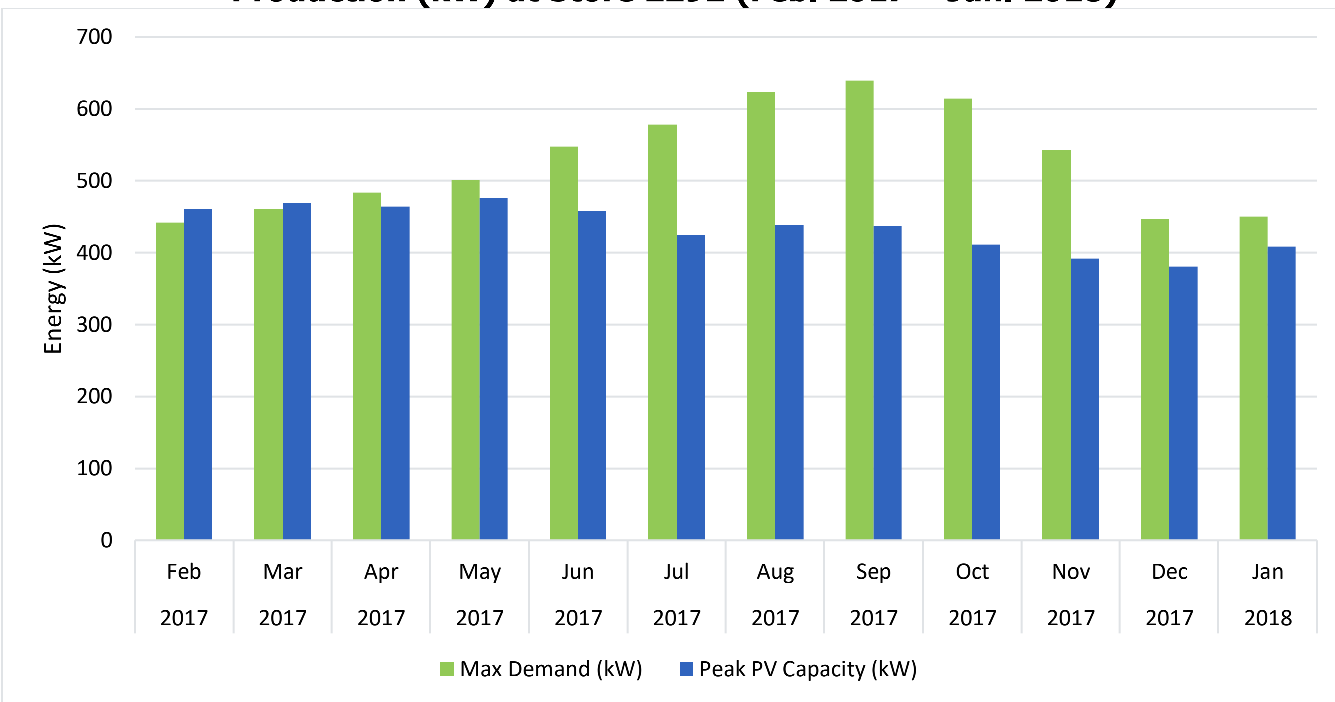
### Baseline Energy and Water Consumption

**Figure D-1: Baseline Whole-building Electrical Consumption at Store 2292 (Feb. 2017 – Jan. 2018)**



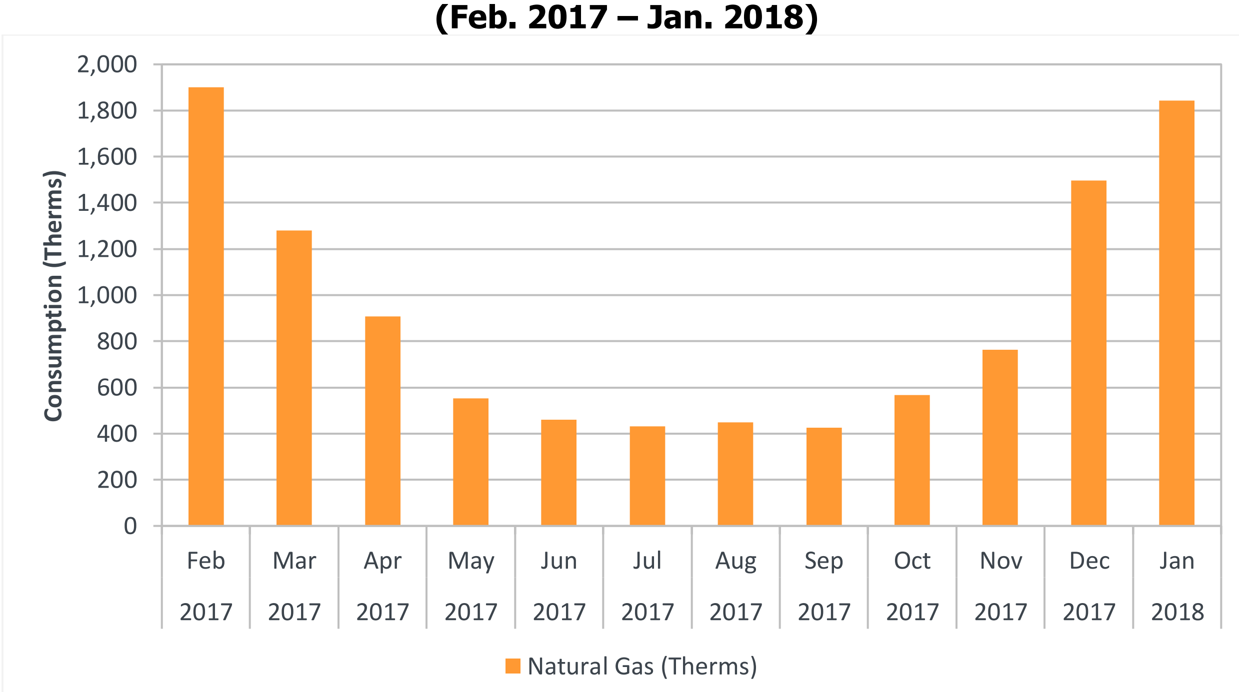

Source: Center for Sustainable Energy, *Big-Box Efficiency Project Measurement & Verification Report: Q1 June 1, 2021 – July 31, 2021 (EPC-17-008).*

**Figure D-2: Baseline Whole-building Electrical Monthly Demand and Peak PV Production (kW) at Store 2292 (Feb. 2017 – Jan. 2018)**



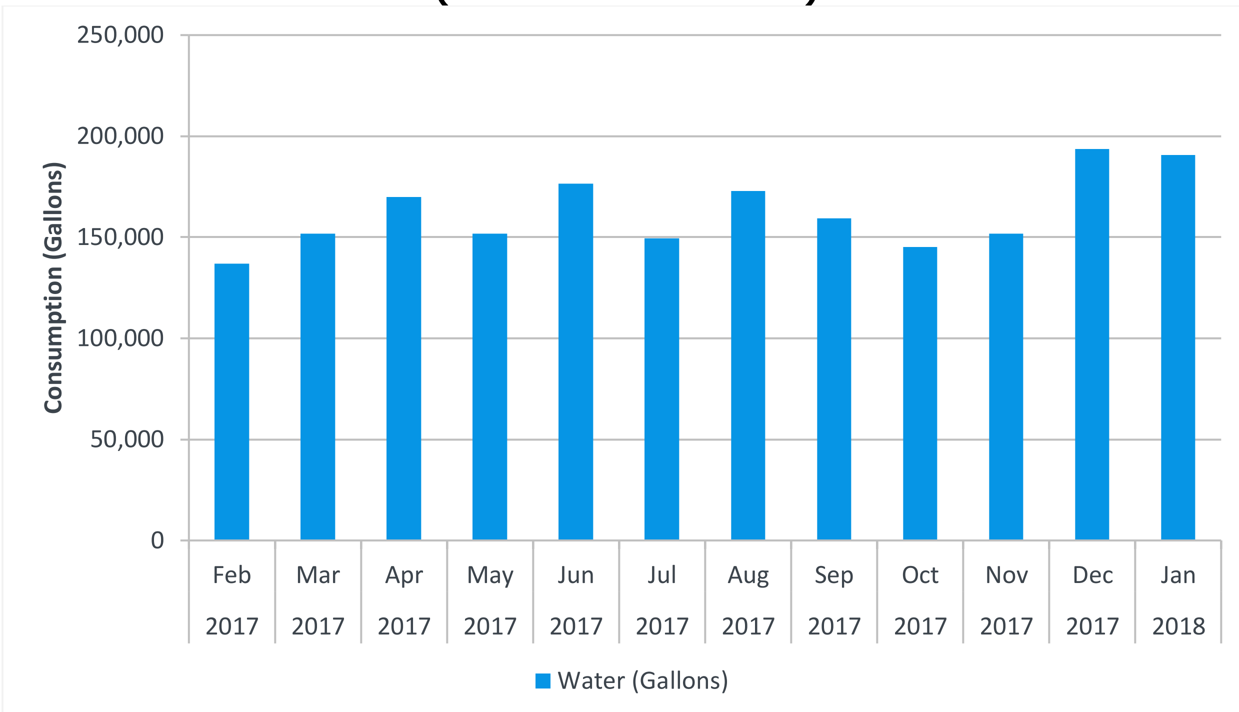

Source: Center for Sustainable Energy, *Big-Box Efficiency Project Measurement & Verification Report: Q1 June 1, 2021 – July 31, 2021 (EPC-17-008).*

**Figure D-3: Baseline Whole-building Natural Gas Consumption at Store 2292 (Feb. 2017 – Jan. 2018)**




Source: Center for Sustainable Energy, *Big-Box Efficiency Project Measurement & Verification Report: Q1 June 1, 2021 – July 31, 2021 (EPC-17-008)*

**Figure D-4: Baseline Whole-building Water Consumption at Store 2292 (Feb. 2017 – Jan. 2018)**




Source: Center for Sustainable Energy, *Big-Box Efficiency Project Measurement & Verification Report: Q1 June 1, 2021 – July 31, 2021 (EPC-17-008)*

## Project Results Details

**Table D-1: Summary of Electric Energy Savings Findings**

| Electric Savings by End use | Q1 | Q2 | Q3 | Q4 | Total |
|---|---|---|---|---|---|
| **Whole-building**<br>Gross site consumption savings compared to 2017 Whole-building Baseline | 124,034 kWh<br>19.2% | 178,177 kWh<br>27.4% | 165,253 kWh<br>28.7% | 574,813 kWh<br>36.5% | **1,042,277 kWh**<br>**30.2%** |
| **LED Retrofitted Lighting[a]**<br>Fixture consumption savings compared to 2020 Submetering Baseline | 26,419 kWh<br>25.8% | 37,315 kWh<br>31% | 28,310 kWh<br>28% | 94,495 kWh<br>29.5% | **186,538 kWh**<br>**28.9%** |

| Electric Savings by End use | Q1 | Q2 | Q3 | Q4 | Total |
|---|---|---|---|---|---|
| **HVAC Upgrades** (DualCool & Turntide Motors)<br><br>RTU & AHU consumption savings compared to 2020 Submetering Baseline | 1,308 kWh<br><br>1.6% | 66,340 kWh<br><br>50.5% | 37,341 kWh<br><br>56.2% | 23,809 kWh<br><br>25.7% | **128,798 kWh**<br><br>**34.4%** |
| **Normalized HVAC Upgrades**<br><br>RTU & AHU consumption savings compared to 2020 Submetering Baseline and normalized to weather (kWh/DD) | 20 kWh/DD<br><br>14.5% | 41 kWh/DD<br><br>30.2% | 46 kWh/DD<br><br>42.7% | N/A | **N/A** |
| **Refrigeration Upgrades** (Turntide Motors)<br><br>Rack A through F consumption savings compared to 2020 Submetering Baseline | -7,264 kWh<br><br>-8.2% | 3,354 kWh<br><br>3.2% | 3,260 kWh<br><br>3.9% | 0 kWh<br><br>0% | **-649 kWh**<br><br>**-0.1%** |
| **Proposed DC Lighting**<br><br>Extrapolated savings from DC-capable lighting in the Garden Center | N/A | N/A | N/A | N/A | **73,199 kWh**<br><br>**2.1% of 2017 Baseline** |

[a] **Lighting savings do not include additional potential savings from running on full DC power.**

Source: Vogel et al. 2021-2022. *Big-Box Efficiency Project Q1, Q2, and Q3/Annual M&V Reports.*

# APPENDIX E: Project Costs & Savings: Covina vs. Modeled Scenarios

## Utility & Climate Zone Details for Modeled Scenario Cities

Local dry bulb and wet bulb temperatures for each location in Table E-1 represent the varying weather conditions intended to mimic different climates throughout California.[4]

**Table E-1: Weather Variables for Selected Cities**

| Utility | City | CA Climate Zone | Dry Bulb °F | Wet Bulb °F |
|---|---|---|---|---|
| SCE | Covina | 9 | 97 | 69 |
| PG&E | Fresno | 13 | 101 | 71 |
| PG&E | Redding | 11 | 103 | 68 |
| SDG&E | Carlsbad | 7 | 83 | 67 |
| SDG&E | El Centro | 15 | 111 | 73 |

Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*.

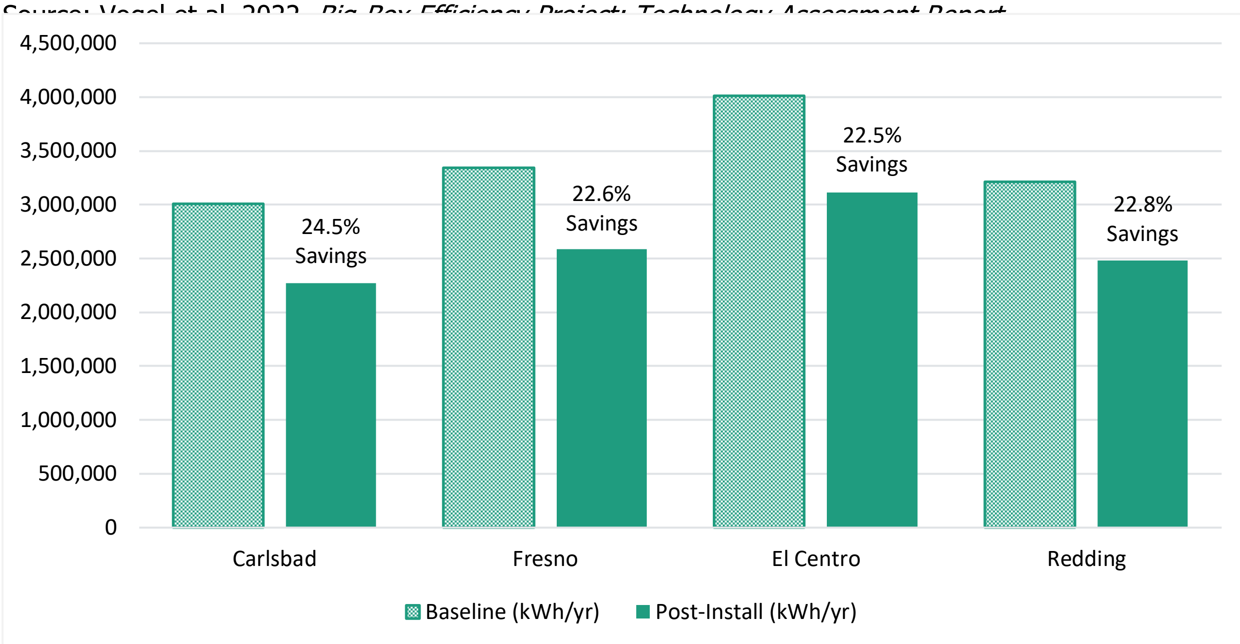
By selecting for different climate types, the building simulations reveal varied performance of the measures by region. Furthermore, there are varying costs of electricity by utility. Table E-2 compares similar TOU rate tariffs for each utility and estimates a blended cost of electricity that includes transmission and deliver, generation, and peak demand charges.

**Table E-2: Blended Utility Rates by IOU**

| IOU | Cost | Cost Unit | Rate Tariff |
|---|---|---|---|
| SCE | $0.158 | $/kWh | TOU-8 B |
| PG&E | $0.191 | $/kWh | E-19 |
| SDG&E | $0.268 | $/kWh | AL-TOU |

[4] Dry bulb temperature is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture. Wet bulb temperature is the lowest temperature to which air can be cooled by the evaporation of water into the air at a constant pressure.

Source: Vogel et al. 2022. *Big Box Efficiency Project: Technology Assessment Report*



## Project & Cost Savings

Table E-3 provides a breakdown of project costs and annual cost savings and simple payback (SPB) for Covina and four modeled scenarios (Fresno, Redding, Carlsbad, and El Centro).

For Covina (Store 2292), metrics are based on actual M&V data (including six months of measured data and six months of forecasted data). Additionally, since the NREL energy model did not allow a breakout of Turntide energy and cost savings between HVAC and refrigeration, those savings for Turntide are combined in the table to facilitate an apples-to-apples comparison with the four modeled scenarios. Metrics for Fresno, Redding, Carlsbad, and El Centro are based on the energy model developed by NREL for this project. Due to the holistic nature of this project, engineering and construction costs can only be considered on the whole-project level; therefore, simple payback per project technology is not available (NA).

**Table E-3: Project Costs, Annual Savings, and Payback by Location and Project Cost Category**

| Project Category | Total Cost | Covina Annual Cost Savings | Covina SPB (years) | Fresno Annual Cost Savings | Fresno SPB (years) | Redding Annual Cost Savings | Redding SPB (years) | Carlsbad Annual Cost Savings | Carlsbad SPB (years) | El Centro Annual Cost Savings | El Centro SPB (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **HVAC+R** | **$325,067** | **$27,994** | **NA** | **$61,192** | **NA** | **$60,805** | **NA** | **$87,328** | **NA** | **$114,043** | **NA** |
| ICI DualCool | $59,576 | | | | | | | | | | |
| Saya Water Meters | $50,080 | | | | | | | | | | |
| Turntide Smart Motors | $215,411 | | | | | | | | | | |
| **IoT** | **$101,304** | **$0** | **NA** | **$12,114** | **NA** | **$10,633** | **NA** | **$16,287** | **NA** | **$18,841** | **NA** |
| Locbit IoT | $101,304 | | | | | | | | | | |
| **Lighting** | **$593,652** | **$82,908** | **NA** | **$71,415** | **NA** | **$68,752** | **NA** | **$94,060** | **NA** | **$108,996** | **NA** |
| i2Systems Lighting | $593,652 | | | | | | | | | | |

| Project Category | Total Cost | Covina Annual Cost Savings | Covina SPB (years) | Fresno Annual Cost Savings | Fresno SPB (years) | Redding Annual Cost Savings | Redding SPB (years) | Carlsbad Annual Cost Savings | Carlsbad SPB (years) | El Centro Annual Cost Savings | El Centro SPB (years) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Engineering & Construction** | **$779,685** | **$0** | **NA** | **$0** | **NA** | **$0** | **NA** | **$0** | **NA** | **$0** | **NA** |
| Commissioning | $47,600 | | | | | | | | | | |
| Construction (MEP) | $352,372 | | | | | | | | | | |
| Design | $110,660 | | | | | | | | | | |
| General Contracting | $264,677 | | | | | | | | | | |
| Permit Fees | $4,376 | | | | | | | | | | |
| **Grand Total** | **$1,799,707** | **$110,902** | **16.2** | **$144,720** | **12.4** | **$140,189** | **12.8** | **$197,675** | **9.1** | **$241,879** | **7.4** |

Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*.

Table E-4 provides the details of the comparative analysis of climate impacts, utilities and rates, electric energy use and costs, and overall savings for the project. For Covina (Store 2292), metrics are based on actual M&V data (including six months of measured data and six months of forecasted data). Additionally, since the energy model did not allow a breakout of Turntide energy and cost savings between HVAC and refrigeration, those savings for Turntide are combined in the table to facilitate an apples-to-apples comparison with the four modeled scenarios. Metrics below for Fresno, Redding, Carlsbad, and El Centro are based on the energy model developed by NREL for this project.

**Table E-4: Detailed Comparative Analysis of Climate, Utilities, Costs, and Savings for Project**

| Metric | Covina | Fresno | Redding | Carlsbad | El Centro |
|---|---|---|---|---|---|
| **Climate Zone** | | | | | |
| Dry Bulb (°F) | 97 | 101 | 103 | 83 | 111 |
| Wet Bulb (°F) | 69 | 71 | 68 | 67 | 73 |
| **Utility** | **SCE** | **PG&E** | **PG&E** | **SDG&E** | **SDG&E** |
| Blended Rate ($/kWh) | $0.158 | $0.191 | $0.191 | $0.268 | $0.268 |
| Tariff | TOU-8 B | E-19 | E-19 | AL-TOU | AL-TOU |
| **Pre- & Post-Retrofit Annual Electric Energy Use (kWh)** | | | | | |
| Baseline Annual Electrical Energy Use (kWh) | 3,447,959 | 3,342,336 | 3,211,972 | 3,009,031 | 4,013,156 |
| Post-Retrofit Annual Electrical Energy Use (kWh) | 2,405,682 | 2,586,362 | 2,479,666 | 2,271,959 | 3,111,258 |
| **Pre- & Post-Retrofit Annual Electric Energy Cost ($)** | | | | | |
| Baseline Annual Electrical Energy Cost ($) | $544,778 | $639,842 | $614,886 | $806,989 | $1,076,284 |
| Post-Retrofit Annual Electrical Energy Cost ($) | $380,098 | $495,122 | $474,697 | $609,314 | $834,405 |
| **Annual Electric Energy Savings (kWh)** | **775,111**[a] | **755,974** | **732,306** | **737,073** | **901,898** |
| DualCool kWh Savings (kWh) | 177,176[b] | 106,281 | 105,023 | 49,853 | 217,778 |
| Turntide Motor Savings (kWh) | See DualCool[b] | 213,367 | 212,602 | 275,767 | 207,456 |

| Metric | Covina | Fresno | Redding | Carlsbad | El Centro |
|---|---|---|---|---|---|
| I2Lighting Savings (kWh) | 597,935 | 373,048 | 359,138 | 350,723 | 406,414 |
| Locbit IoT Savings (kWh) | 0 | 63,278 | 55,543 | 60,729 | 70,251 |
| **Annual Electric Energy Cost Savings ($)** | **$122,468** | **$144,720.44** | **$140,189.48** | **$197,674.83** | **$241,879.14** |
| DualCool kWh Savings (kWh) | $27,994 | $20,346 | $20,105 | $13,370 | $58,406 |
| Turntide Motor Savings (kWh) | See DualCool[b] | $40,846 | $40,700 | $73,958 | $55,637 |
| I2Lighting Savings (kWh) | $82,908 | $71,415 | $68,752 | $94,060 | $108,996 |
| Locbit IoT Savings (kWh) | $0 | $12,114 | $10,633 | $16,287 | $18,841 |
| **Simple Payback (years) for Project Cost of $1,799,707** | **16.2** | **12.4** | **12.8** | **9.1** | **7.4** |

**[a] Additional savings were realized beyond what the M&V analysis was able to account for with the monitored equipment. It is possible these additional savings can be attributed to this demonstration project, however, without support from M&V, those savings are not shown in this table.**

**[b] The measured savings at Walmart in Covina combines the savings from the DualCool evaporative cooling technology and the Turntide Motors.**

Source: Vogel et al. 2022. *Big-Box Efficiency Project: Technology Assessment Report*.

# APPENDIX F:
# Technology Knowledge Transfer Activities

## Timeline

**Table F-1: Timeline of Technology Knowledge Transfer Activities**

| Activity | Date |
|---|---|
| Blog #1 | April 25, 2018 |
| TAC Meeting #1 | March 6, 2019 |
| TAC Meeting #2 | June 9, 2020 |
| Project Website | July 2019 |
| 2021 ASHRAE Annual Conference | June 26 – 30, 2021 |
| Digital Media Kit | Q3 2021 |
| Project Website Refresh | Q3 2021 |
| Blog #2 | September 20, 2021 |
| Greenbuild International Conference and Expo | September 21 – 23, 2021 |
| Association of Energy Engineers Conference | October 20 – 22, 2021 |
| Project Webinar | January 11, 2022 |
| Fact Sheet | Q3 2022 |
| Blog #3 | Q3 2022 |
| Press Release | Q3 2022 |

## Policy Tracking

Following is the list of current California Public Utility Commission proceedings that are related to this demonstration project that CSE tracked and will continue to track to provide lessons learned from the Big-Box Efficiency Project:

- Demand Response (R.13-09-011/A.17-01-012 et al.)
- Energy Efficiency Rolling Portfolios (R.13-11-005)
- Integrated Distributed Energy Resources (R.14-10-003)
- Clean Energy Financing (R.20-08-022)
- Building Decarbonization (R.19-01-011)

- Microgrids and Resiliency Strategies (R.19-09-009)
- High DER Grid Planning (R.21-06-017)

Additionally, following is the list of current CEC dockets related to this demonstration project that CSE tracked and will continue to track to provide lessons learned from the Big-Box Efficiency Project:

- 2019 California Energy Efficiency Action Plan (Docket 19-IEPR-06)
- 2021 Integrated Energy Policy Report (Docket 21-IEPR-01).
    - CSE cited the Big-Box Efficiency Project in comments submitted to this docket (Gunther 2022)
- 2022 Building Energy Efficiency Standards Docket No. 19-BSTD-03
- Load Management Rulemaking (Dockets 19-OIR-01 and 21-OIR-03)