Big-Box Efficiency Project

Technology Assessment Report

Prepared for
California Energy Commission

Prepared by
Center for Sustainable Energy

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Introduction

The Center for Sustainable Energy (CSE) developed this *Technology Assessment Report* for a Walmart Supercenter in Covina, CA to show the overall cost, energy and water savings, and cost effectiveness (e.g., simple payback) of a suite of five pre-commercial energy efficiency technologies installed as part of the California Energy Commission (CEC) Electric Program Investment Charge (EPIC) grant program (EPC-17-008). This was a demonstration project to achieve deep (> 20%) electric energy savings in a big-box (retail plus grocery) or similar environment. The potential for utility and other incentives needed for large scale deployment of the technologies is discussed.

Walmart, Covina Site and Project Background

The Walmart Supercenter Store 2292, located at 1275 N. Azusa Avenue, Covina, CA 91722, was built in 1997 (Figure 1). 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, as seen in Figure 1. The region sits in California Climate Zone 9. This Walmart Supercenter includes standard retail space, grocery sales including a deli and a bakery, an auto care center, a photo center, a pharmacy, a vision center, a garden center and a McDonalds restaurant. The store is within a disadvantaged community, one of several Walmart stores in the area and part of the Southern California Edison (SCE) service territory. As seen in Figure 1, the map shows disadvantaged communities and low-income communities as defined for California Climate Investments in relation to the store location (blue marker).

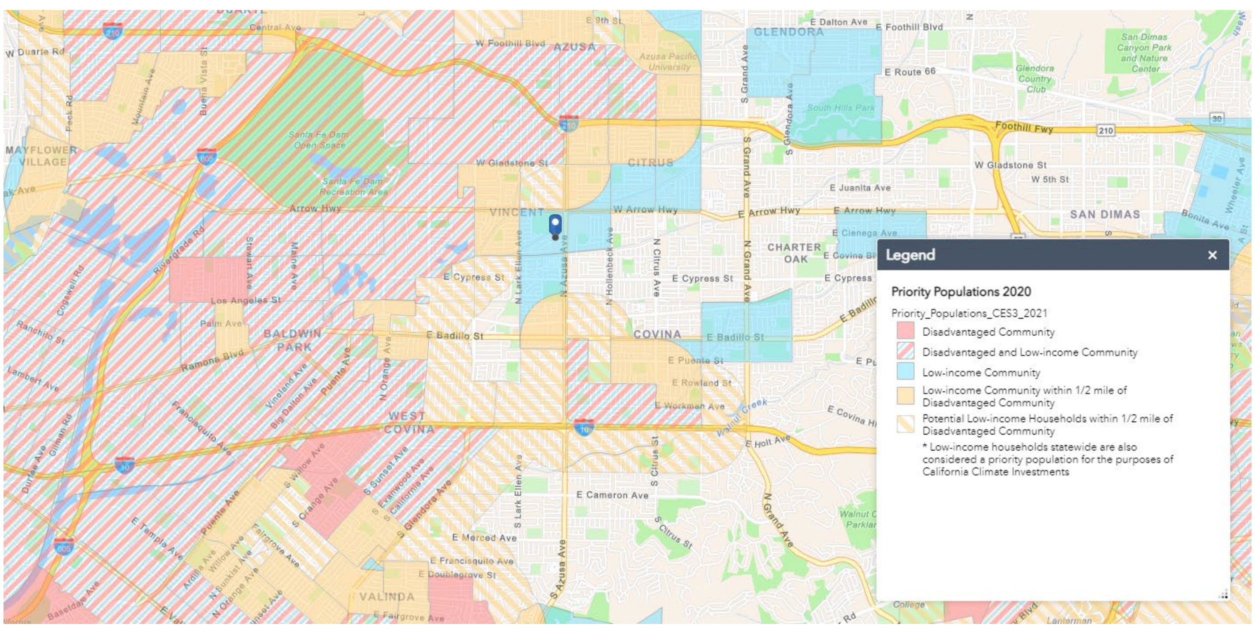

Figure 1. Walmart Supercenter Store 2292 Location in Relation to Low-Income and Disadvantaged Communities

Source: CARB. Available at https://webmaps.arb.ca.gov/PriorityPopulations.

Pre-retrofit Technologies

The store was constructed in 1997 and was renovated to a Walmart Supercenter in 2010, adding the grocery section of the store (including the deli and bakery). Prior to this renovation, a 500kW-AC solar photovoltaic (PV) system was installed in 2007. The PV panels cover about 60% of the roof's surface and generate about 867,437 kWh annually. 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.

HVAC & Refrigeration

There was a total of twenty-seven Lennox packaged rooftop units (RTUs) ranging in size from 3 to 20 tons. The RTUs utilize electric for air conditioning needs and natural gas for heating needs. Two air handling units (AHUs) were located above the produce section of the building and had a cooling capacity of 25-tons each. These units provided cooling for the space surrounding the deli, bakery, produce and refrigerated aisles on the east side of the store. Four gas-fired space heaters served the auto center's heating needs during the colder months. It was unknown as to how often these units run each year. A series of six refrigeration systems, labeled System A through F, served cooling needs for the produce cooler, the grocery cooler, the grocery freezer, the dairy cooler and all open refrigerated shelving within the grocery and produce section of the store.

Lighting

The lighting on the main sales floor was mostly comprised of about 872 surface-mount, 1'x8' linear fluorescent fixtures using four 48" 32W T8 lamps. These fixtures utilized two 4' 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, ninety-five of these same fixtures were being used around the perimeter of the main sales floor for lighting along the walls and illuminating the front wall were fifty-five of a 4' one-lamp F54 T5 high output wall wash fixture.

In the stockroom a series of thirty-six fixtures, like 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'x8' 4-lamp F32 T8 linear fluorescent fixtures for lighting. Other spaces labeled Marketing Manager, Alcove, Training Room and Breakroom used a 2'x4' recessed troffer fluorescent fixture with two F32 T8 lamps per fixture.

Building Management System (BMS)

The legacy sophisticated energy management controller, NOVAR, is the building management system (BMS) at this site and operates from a central Walmart operations facility. This system monitors, reports and controls the HVAC and refrigeration equipment through several data points and sensors in the store. This system is not automated and setpoints are adjusted based on maintenance staff feedback or established alarms.

Demonstrated Technologies

From Q4 2020 to Q2 2021, five different pre-commercial technologies were installed and evaluated in the Covina, CA store.

DC-Ready LED Lighting

The store's existing fluorescent lighting fixtures were retrofitted to DC-ready light-emitting diodes (LEDs) manufactured by i2Systems (Figure 2). DC lighting has the potential to save an additional 4-8% in electricity over traditional alternating current (AC) LED fixtures as verified in a pilot area of the store. However, the DC lights were not fully deployed for the full store as efforts to integrate solar and storage directly to the DC-powered LED lighting system proved to be technically infeasible due to limitations of electrical components within each energy resource as per the technology provider, as well as contractual limitations.[1]

Figure 2. i2Systems DC-Ready LED Lighting

The upgraded lighting installed by i2Systems consisted of retrofitting over 1,000 existing 32W T8 linear fluorescent fixtures with 12W/ft LED fixtures and integrated wireless controls. This system can operate on both 277 VAC and 380 VDC to accommodate a direct power source from onsite battery energy storage but is currently served by a standard AC panel with future intentions to integrate directly to onsite renewable resources. The areas that were retrofitted include the main retail sales floor including the front vestibule, the stock room, employee breakrooms, offices and restrooms. Dimming controls have further reduced lighting energy requirements by operating the fixtures at 80% of full capacity throughout retrofitted spaces and still providing adequate lumens as per Walmart standards.

[1] Vogel, C., A. Beach, J. Woolsey, and R. Baptiste. *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)*. Center for Sustainable Energy, 2022.

The targeted lighting systems for retrofit had a baseline energy draw of about 120 kW, assuming all fixtures were operational. It was observed in March 2021, prior to lighting installation, that approximately 25-30% of existing lamps were non-operational due to typical burnout which yielded a reduced power draw of about 92 kW. Post-retrofit lighting energy draw showed a significant drop in demand of about 45% from the 2017 baseline to a daytime average of about 65 kW once proper lumen levels were achieved through dimming in late June 2021. Fixtures are currently dimmed from 12-5 a.m. on the sales floor, stockroom, vestibule, garden center and tire storage as well as from 8 p.m.-6 a.m. in the auto center.

HVAC – Smart Motors

Turntide, formerly the Software Motor Company (SMC), has installed high rotor pole switched reluctance motors and smart control systems on all 27 RTUs and both AHUs serving the entire building. These motors provide efficiency benefits across full speed and torque ranges over standard induction motors and offer variable speed controls, replacing constant speed supply fan operation.

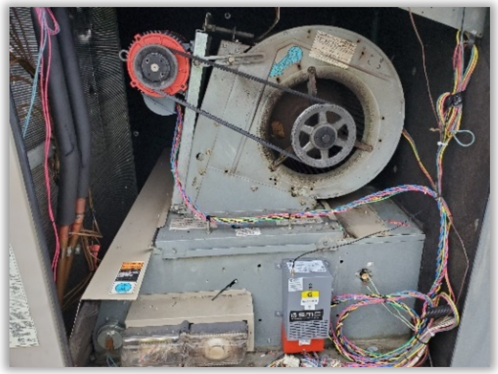

Figure 3. Turntide Smart Motor (HVAC)

Turntide's Smart Motor System replaced the existing supply fan motors across 28 rooftop units. Additionally, the six refrigeration condensers serving the medium and low-temperature refrigeration systems were retrofitted with 24 smart motors (Figure 3). These smart motors not only saved energy, but also featured advanced controls and analytics to improve savings and operations.

HVAC – DualCool Direct and Indirect Evaporative Coolers

The evaporative pre-cooling system, known as DualCool from Integrated Comfort Inc. (ICI), was implemented on four RTUs and the two air handling units (AHU) serving the main retail area. The DualCool system essentially acts as a miniature cooling tower by supplying water over an evaporative media section attached to the condenser intake to pre-cool condenser air and outside air. This effectively reduces energy consumption from the compressor operation, blower fan and condenser fan of the targeted RTUs and AHUs. DualCool reduced energy use in HVAC units by approximately 20% (Figure 4).

Figure 4. Integrated Comfort DualCool System (HVAC)

Smart Water Management System

The DualCool system was coupled with Saya's Smart Water System to optimize the trade-offs between saving energy and increasing water usage in heating and cooling. Saya's Smart Water Management System assessed water use for heating and cooling and could be used to further optimize water consumption in future installations (Figure 5).

Figure 5. Saya Life Smart Water Meter (HVAC)

Locbit Internet of Things Platform

The cloud-based internet of things (IOT) platform set the stage to integrate all data from the different energy efficiency technologies and building control system to run advanced analytics for identifying potential additional energy savings (Figure 6). While Locbit successfully integrated data from all installed technologies, onsite 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). See Lessons Learned for more details.

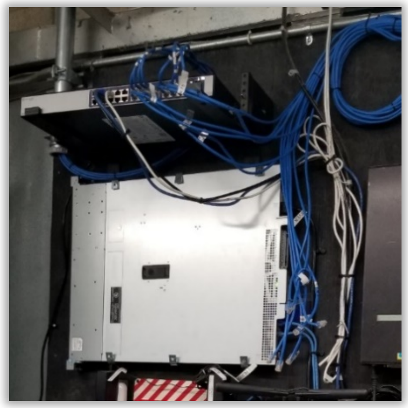

Figure 6. Locbit IoT Server (Electrical Room)

Cost and Savings of Installed Technologies

Energy Savings and Simple Payback

A breakdown of savings by end-use can be found in Figure 7 and Table 5 below. Overall, the annual electric energy savings target of 20% from demonstration technologies was exceeded with lighting and HVAC upgrades accounting for a 20.36% (775,111 kWh) reduction as related to 2017 baseline electric consumption. It is important to note realized savings from the IoT platform and the DC lighting function for the full store could not ultimately be captured for this project as the IoT technology and DC functionality for the full store were not fully deployed. Additionally, the whole building achieved a reduction of 30.23% when compared to the 2017 baseline including 9.8% savings attributed to various occupancy and operational changes due to Covid and other unidentified sources.

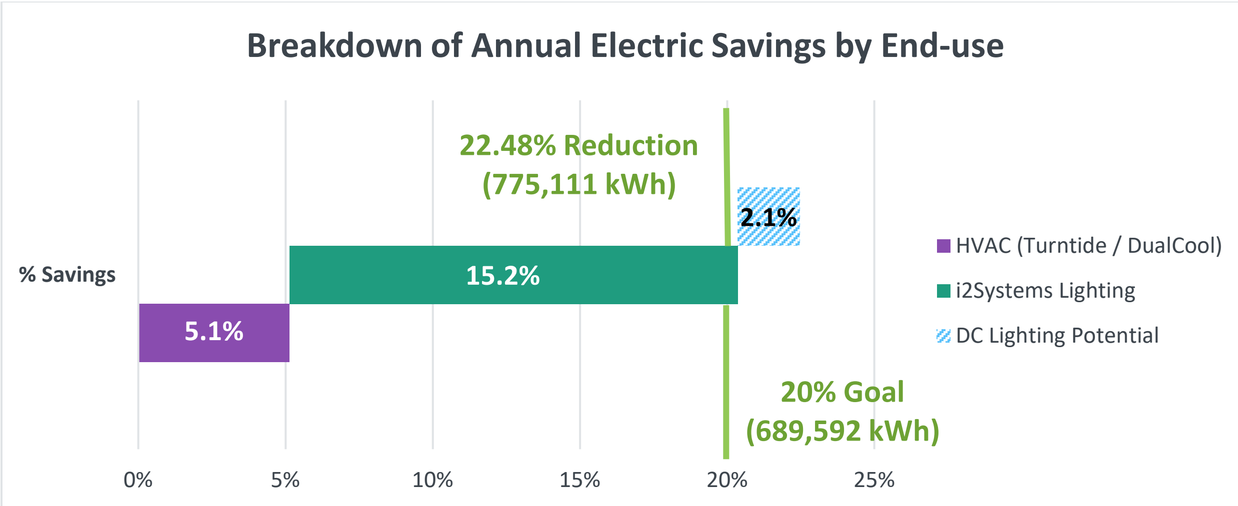

Figure 7. Annual Electric Savings by End-use

Efficiency Measure	NREL Estimated % Reduction	NREL Estimated kWh Reduction	M&V Forecasted % Reduction	M&V Forecasted kWh Reduction
Locbit IoT Platform	1.90%	64,405	-	-
i2Systems Lighting	10.90%	374,726	15.22%	524,737
HVAC (Turntide / DualCool)	8.90%	306,035	5.14%	177,176
DC Lighting Potential	-	-	2.12%	73,198
Unidentified End-uses	-	-	9.87%	340,364
Gross Site Total	**21.7%**	**745,166**	**32.35%**	**1,115,475**

Table 1. Walmart Supercenter Store 2292 Estimated End-use and Gross Site Savings

Table 2 represents the forecasted annual electric savings by end-use as compared to corresponding monthly submetered data from 2020.

Both lighting and HVAC had clear cut savings that could be identified with the metering strategy that was in place, however it was more difficult to report clearly defined savings for the refrigeration racks. It is assumed that the efficiency gain of the refrigeration system retrofitted with Turntide motors and controls was offset by an increase demand on the system as compared to 2020 baseline. A secondary data point was used to confirm 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 for Store 2292 showed an increase in food sales during the 2021 M&V period over corresponding months in 2020, which would affect how often the freezer cases are being accessed and the demand on associated equipment. It should be noted that an increase in sales does not directly correlate to a similar increase in energy demand of the system.

In addition to these realized savings, the in-store demonstration of DC-driven LED lighting yielded a potential demand reduction of 9.3%, or 8.3 kW for all retrofitted interior lighting at Store 2292.

Electric Savings by End-Use	Total Annual Savings
Whole Building Gross site consumption savings compared to 2017 Whole Building Baseline	**1,042,277.06 kWh** **30.23%**
LED Retrofitted Lighting Fixture consumption savings compared to 2020 Submetering Baseline	**186,538.93 kWh** **28.9%**
HVAC Upgrades (DualCool & Turntide Motors) RTU & AHU consumption savings compared to 2020 Submetering Baseline	**128,798.51 kWh** **34.4%**
Refrigeration Upgrades (Turntide Motors) Rack A through F consumption savings compared to 2020 Submetering Baseline	**-649.14 kWh** **-0.14%**
Proposed DC Lighting[2] Extrapolated savings from DC capable lighting in the Garden Center	**73,198.56 kWh** **2.12% of 2017 Baseline**

Table 2. Summary of Annual Electric Findings

Table 3 represents the total project costs by technology, as well as cost savings per year established by post-project modeling calibration efforts and simple payback. The baseline energy model, created by NREL, was calibrated using M&V performance data for each installed technology. The following costs are based on project expenses and include all costs associated with repeating this project at another location, including total engineering and construction costs. The costs associated with administration of the CEC grant, energy modeling, measurement and verification and labor performed by the technology providers associated with the demonstration project have been excluded from the following costs. Overall costs are best shown with the entire suite of technologies for a comprehensive project because that is the most cost-effective way to approach deep holistic energy savings as demonstrated by the Big-Box Efficiency Project. Due to the holistic nature of this project, engineering and construction costs can only be considered and the whole-project level; therefore, simple payback per project technology is not available.

[2] Calculated and represented as a stand-alone, potential savings metric that was not accounted for in any other savings metrics.

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**

Table 3. Project Costs and Savings (Store 2292, Covina)

The estimated electric savings were used to calculate total category cost savings per year using the sites blended electric utility rate of $0.158/kWh. The estimated simple payback is 16.23 years for the pre-commercial technologies. Other areas with higher electricity rates, such as SDG&E, have a lower payback period. However, the project team anticipates that project financial performance could be significantly improved in future iterations of the project as certain aspects of the project did not show savings in the demonstration at Store 2292 but could show savings in future project iterations, such as with Locbit's IoT platform and Turntide's refrigeration motors.[3] Additionally, when these pre-commercial technologies move towards commercialization and scale, costs potentially could be reduced further.

[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 in the study: Woldekidan, Korbaga, Daniel Studer, and Ramin Faramarzi. 2020. Performance Evaluation of Three RTU Energy Efficiency Technologies. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-75551. https://www.nrel.gov/docs/fy21osti/75551.pdf.

Water Savings

The water billing and consumption data for the whole building is delayed by about two months from the utility. Therefore, the measurement and verification (M&V) months of November 2021 through May 2022 have been forecasted. Using historical trends and recent data, the two main water meter consumption forecasts for remaining M&V months are in Table 4 and Figure 8. The annual consumption for the M&V period is expected to be 1,616,719.86 gallons, which is reduction of 299,789.12 gallons (15.64%) as compared to the baseline year of 2017.

It should be noted that water consumption at the store is lightly correlated to energy and more correlated to occupancy. The main consumers of water onsite are the bathrooms, onsite cooking activities and the garden center. The reduction mentioned above could be a result of lower occupancy during the COVID pandemic and reduced need for water related end-uses.

Month	2017 Whole Building Baseline (Gallons)	2021/22 M&V (Gallons)	Reduction (Gallons)	Reduction (%)
June	176,540.25	129,412.98	47,127.27	26.69%
July	149,610.38	127,168.82	22,441.56	15.00%
August	172,799.99	139,137.65	33,662.34	19.48%
September	159,335.05	172,051.94	-12,716.89	-7.98%
October	145,122.07	109,963.63	35,158.44	24.23%
November	*151,854.54*	*128,100.76*	*23,753.78*	*15.64%*
December	*193,745.44*	*163,438.89*	*30,306.55*	*15.64%*
January	*157,090.90*	*132,518.02*	*24,572.88*	*15.64%*
February	*136,893.50*	*115,479.99*	*21,413.51*	*15.64%*
March	*151,854.54*	*128,100.76*	*23,753.78*	*15.64%*
April	*169,807.78*	*143,245.67*	*26,562.11*	*15.64%*
May	*151,854.54*	*128,100.76*	*23,753.78*	*15.64%*
Total	**1,9,16,508.98**	**1,616,719.86**	**299,789.12**	**15.64%**

Table 4. Annual Whole Building Water Consumption

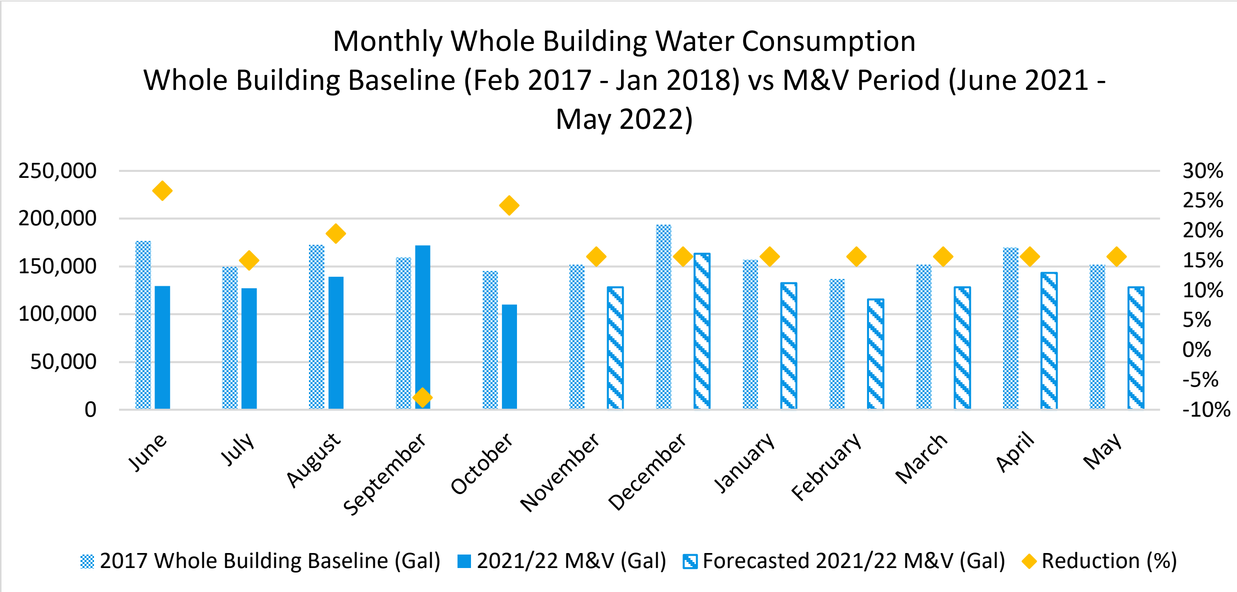

Figure 8. Annual Whole Building Water Consumption

The project team pursued a water budget of 3.4 gallons consumed per kWh saved for using evaporative cooling. The SAYA submetering water data measures all HVAC units from a single meter located at 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 sub metered AHU 2 was collected for the months of July 2021 through November 2021 and compared to similar baseline months in 2020. This unit was under repair in June 2021 and that month was excluded from the analysis.

The metric of gallons consumed per kWh saved regarding DualCool retrofitted HVAC units will not be forecasted for Q4 (December 2021 – May 2022) to yield an 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, the summary of Q1 through Q3 realized gallons consumed per kWh saved can be found in Figure 9. The total water consumed by AHU 2 between July and November 2021 was 2,423.15 gallons in order to save 18,053.19 kWh which resulted in a metric of 0.13 Gal/kWh saved, well below the project target of 3.4 Gal/kWh saved.

Month	2020 Submetering Baseline (kWh)	2021 M&V (kWh)	Reduction (kWh)	Gallons Consumed	Gallons/kWh Saved
July	5,771.78	2,825.32	2,946.46	1,474.87	0.50
August	8,048.92	1,115.38	6,933.54	182.27	0.03
September	6,888.59	939.86	5,948.72	151.11	0.03
October	3,206.27	1,019.08	2,187.19	365.61	0.17
November	896.65	859.37	37.28	249.29	6.69
Total	**24,812.21**	**6,759.01**	**18,053.19**	**2,423.15**	**0.13**

Table 5. M&V Period AHU 2 Gallons Consumed per kWh Saved

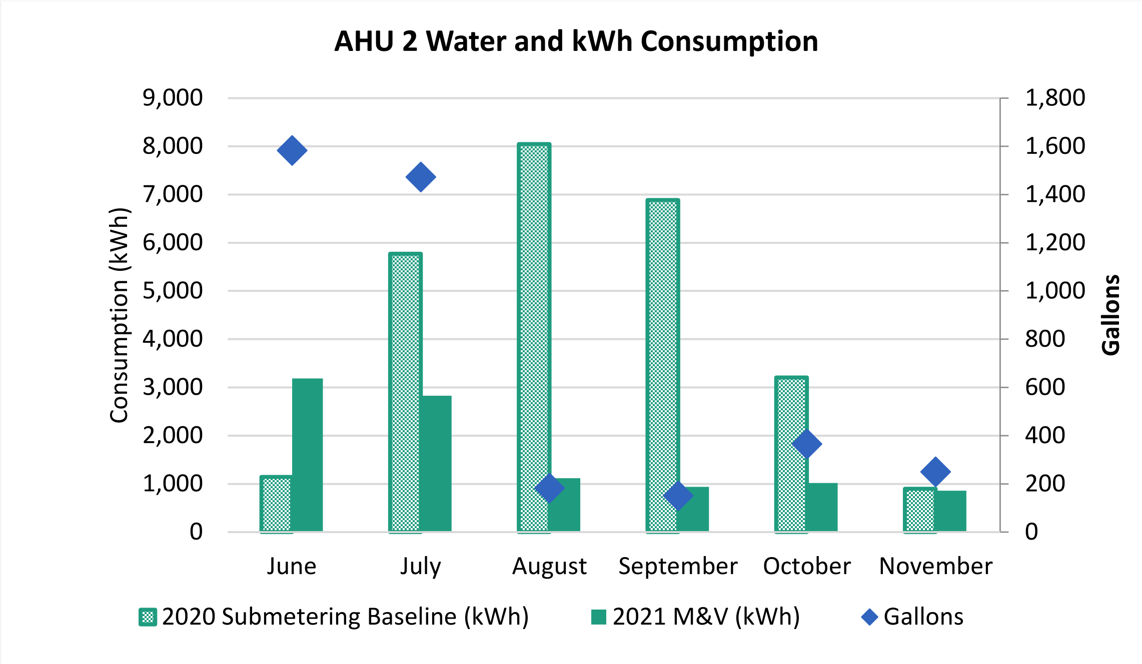

Figure 9. Annual AHU 2 Gallons and kWh Consumed

Baseline Model, Submetering, and Model Calibration

Energy modeling and subsystem interval data was also analyzed to calculate potential future savings to be realized, cost effectiveness for similar box stores, and potential for utility and other incentives needed for large scale deployment.

Baseline Energy Model

NREL utilized the U.S. Department of Energy's (DOE) OpenStudio modeling platform,[4] which builds on DOE's EnergyPlus Simulation engine,[5] and includes a collection of software tools that support whole building energy modeling to produce a calibrated baseline energy model of the Walmart store studied in this project. One of the platform's strengths is its modular approach to modeling and analysis automation. Such tasks are easily extended via small scripts called "OpenStudio Measures," so named because they are most often used to represent EE measures.[6] OpenStudio Measures can also be used to define custom reports, modifications to key model parameters for the purpose of calibration, or even wholesale creation of energy models from a few descriptive parameters. The team also developed

[4] DOE's OpenStudio modeling platform is available at https://www.openstudio.net.
[5] DOE's EnergyPlus simulation engine can be accessed at https://energyplus.net.
[6] More details about the coding and scripts used can be found at http://nrel.github.io/OpenStudio-user-documentation/getting_started/about_measures/.

OpenStudio Measures representing the emerging technologies of interest and applied them to the baseline model to assess the savings contributions each might make towards the project's performance goal.

NREL's building energy baseline model was calibrated using whole-building energy consumption combined with data from the end-use monitoring as described in the Site Characterization Report.[7] NREL used the whole-building and end-use energy data to adjust HVAC equipment, lighting, and other loads in the model so that the model's calculated energy reflected historical energy use. The confidence in the model increases as the calculated energy use from the model more closely matches the actual building energy use as well as the energy use of individual end-uses.

System Submetering

Subsystem electric energy consumption for the installed technologies was captured by installed DENT metering on an event basis and aggregated into a 15-minute interval basis and accessed through the Locbit platform to calibrate post-retrofit OpenStudio energy models and evaluate subsystem performance. Water consumption for Dual Cool retrofitted RTU's was be metered by Saya on a 1-minute interval basis using local flow meters. This data was evaluated in the project's Annual M&V Report[8] to compare water consumption to energy savings as it relates to the DualCool technology. Utility water consumption for the whole building was collected monthly and compared to the Baseline Water Consumption (Feb 2017 – Jan 2018).

The subsystem interval data was analyzed in this report along with overall costs in order to calculate potential savings to be realized, cost effectiveness for similar box stores, and potential for utility and other incentives needed for large scale deployment.

i2Systems DC-Ready LED Lighting

- Electric consumption (kWh) and demand (kW) metered by Dent on 15-minute interval basis through main lighting panel (Panel H1C1/H1C2).
- Manual readings of the Garden Center AC/DC power meter were taken to analyze the difference in the LED lighting load on different supply currents.

ICI DualCool

- Electric consumption (kWh) and demand (kW) of six retrofitted HVAC units metered by Dent on 15-minute interval basis through six panels (H4B1, H1A1, H1A2, H1A3 and HF1).

[7] Kogan, G., J. Del Real, and C. Vogel. *Walmart Supercenter, 1275 N Azusa Ave, Covina, CA: Site Characterization Report*. 2018, Center for Sustainable Energy.
[8] Vogel, C., A. Beach, J. Woolsey, and R. Baptiste. *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)*. Center for Sustainable Energy, 2022.

Turntide Smart Motors

- Electric consumption (kWh) and demand (kW) of all upgraded motors and controls as a portion of the corresponding retrofitted RTUs and AHUs metered by Dent on 15-minute basis through six panels (H4B1, H1A1, H1A2, H1A3 and HF1).

Refrigeration Systems

- Electric consumption (kWh) and demand (kW) of all six refrigeration racks and controls metered by Dent on 15-minute interval basis through six metering points (Racks A through F).

Saya Water Monitoring

- Makeup water (gallons) and drain water (gallons) consumed of all six DualCool retrofitted AHU's and RTU's metered by SAYA equipment on 1-minute interval basis at point of use.

Post-M&V Model Measure Calibration Methodology

The post-installation M&V demonstrated that the building energy model created by NREL under predicted the lighting energy savings by approximately 150,000 kWh per year and overpredicted the HVAC savings by approximately 126,000 kWh per year. The underperformance of the modeled lighting measure appears to be a result of the lighting energy being calibrated based on 2020 end-use monitoring data rather than incorrect assumptions about measure performance. In 2020 there were approximately 25% of the lamps in the existing fixtures that had burned out. This data was not available during the model calibration phase of the project and therefore was not accounted for in the model, leading to a decrease in modeled baseline lighting energy. Because the lighting measure for the OpenStudio model achieves its savings from a specified post-installation LPD (lighting power density), CSE believes that the underperformance of the measure was not because the measure was incorrect, but because the baseline model didn't capture all the lighting power present during the project baseline period in 2017.

Due to limitations in in scope and budget for detailed system monitoring, monitoring of HVAC performance was at the panel level as described above; therefore, the performance of ICI DualCool and Turntide Smart Motors are linked and cannot be separated for the purpose of this analysis. The underperformance of the HVAC system measures that include ICI DualCool and Turntide Smart Motors does not have a clear reason that can be connected to the energy model measures at this time. Therefore, the post-M&V energy measure for HVAC+R was not adjusted to account for these findings for the ICI DualCool and Turntide Smart Motors modeled measures.

Additionally, while savings were not realized for the Locbit IoT platform on this project, it is reasonable to assume that other providers of IoT platforms that are able to fully integrate into existing building systems and control those systems, would be able to realize the estimated energy savings predicted by the energy model. Therefore, no changes were made to the model in regard to the Locbit IoT energy savings measures.

As a result of these conclusions the modeled measures have not been modified from their previous specifications and accurate savings in other locations will be dependent on accurate baseline end-use energy monitoring where energy modeling is used, as well as other project-specific details such as building and equipment sizes and types, climate zones, and operating schedules.

Extrapolated Results to Other Utilities and Climate Zones

To better understand how this exact energy efficiency project would perform for the same building in different utility rate scenarios and climate zones, four modeling sites were selected: two cities in San Diego Gas & Electric (SDG&E)'s service territory and two cities in Pacific Gas & Electric's service territory. These locations were selected for a variety of climates and design temperatures and to represent the variety in electrical energy cost by region. The project site in Covina, CA is located in Southern California Edison (SCE) territory, Climate Zone 9. Locations of these sites in comparison to Covina, CA can be found in Figure 10.

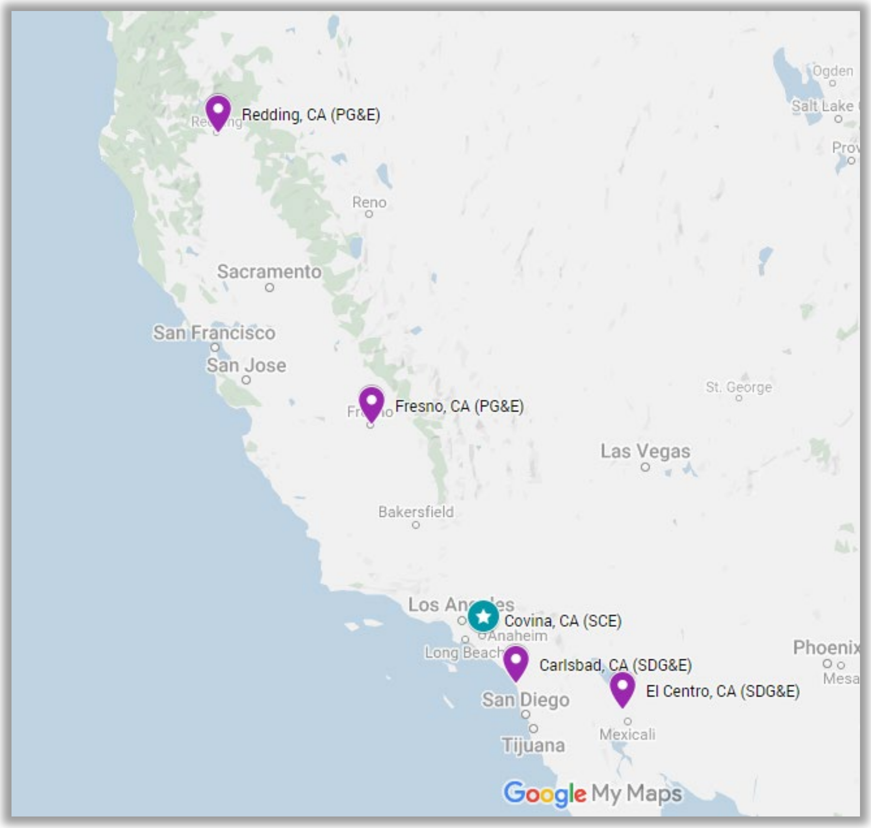

Figure 10. Location of Model Scenarios and Project Site

Local dry bulb and wet bulb temperatures for each location in Table 12 represent the varying weather conditions intended to mimic different climates throughout California.[9]

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

Table 6. Weather Variables for Selected Cities

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 7 compares similar time of use (TOU) rate tariffs for each utility and estimates a blended cost of electricity that includes transmission and deliver, generation and peak demand charges.

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

Table 7. Blended Utility Rates by IOU

Figure 11 highlights the total energy and cost savings for baseline and post-install scenarios for the four selected sites throughout California: Carlsbad (SDG&E), Fresno (PG&E), El Centro (SDG&E) and Redding (PG&E). Monthly savings for each scenario city are provided in Appendix A.

[9] 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.

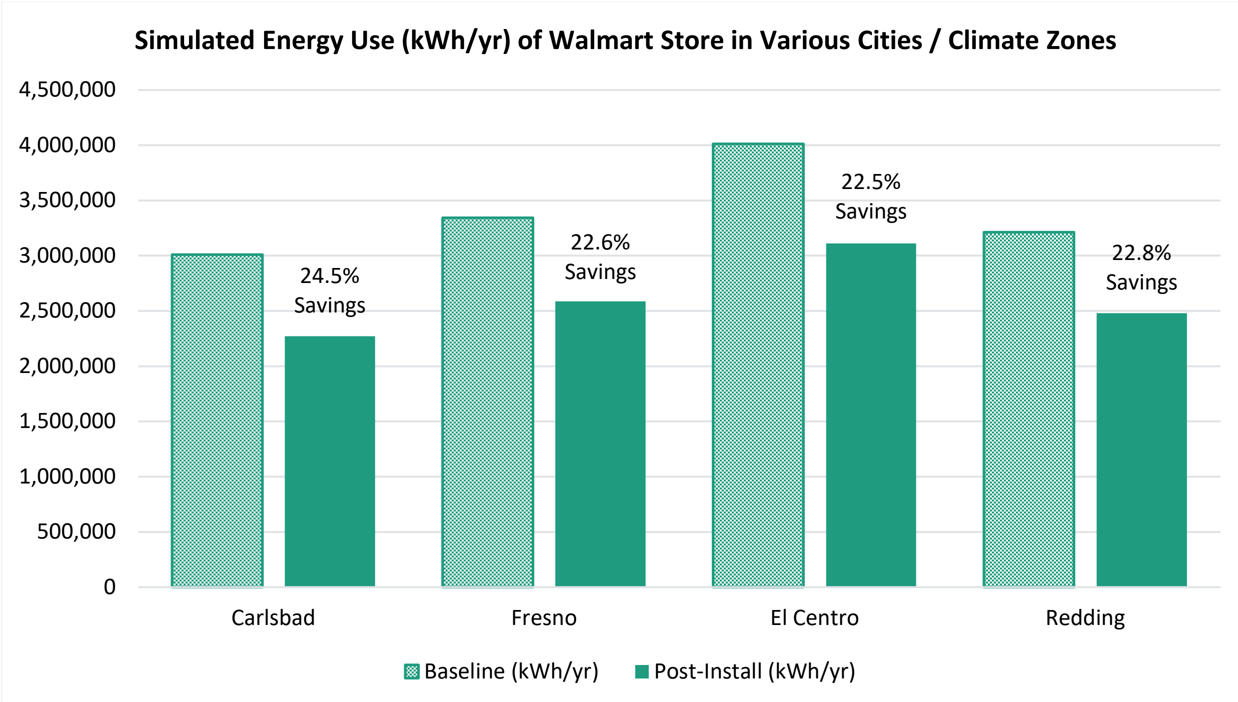

Figure 11. Pre- and Post-Install Annual Electric Consumption of Alternative Scenario Cities

Savings and Simple Payback Potential for Similar Commercial Buildings

Table 12 in the appendix shows the cost effectiveness (simple payback) of measures in other territories by rerunning the OpenStudio baseline model and measures in the selected cities with the appropriate weather data. These locations were selected for a variety of climates and design temperatures and to represent the variety in electrical energy cost by region and utility. The NREL model does not differentiate the use of 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 are grouped with the HVAC into HVAC+R.

Additionally, each building is unique and will have 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 box stores and commercial buildings and some will see variable performance. The lighting retrofits, specifically the potential for DC-powered lighting that is energized from a local solar PV and battery energy storage system will have very similar performance of 9.3% demand reduction realized at Walmart in Covina. This demand reduction will result in similar energy savings for a store of similar 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. The savings resulting from an IoT platform like Locbit will have a variety of variables such as weather, occupancy, plug loads and daylighting that can impact the results.

The energy model simulations for the various cities revealed that energy savings ranged from 14,030 kWh less savings in Redding, CA compared to Covina and up to 155,562 kWh more savings in El Centro, CA compared to Covina. The greater savings in El Centro is likely related to the higher ambient temperature that often occurs there.

Table 8 below shows a breakout of modeled energy and cost savings by technology provider and the large savings in El Centro are attributed mostly to DualCool savings followed by savings from I2S lighting. It should be noted that lighting savings vary by location because of the impact of interior lighting power on HVAC cooling. Cost savings in the other regions are notably higher than the cost savings in Covina because blended electric energy rates in PG&E are approximately 20% higher than in SCE and rates in SDG&E are approximately 70% higher than in SCE. Additional details on cost savings can be found in Table 12 located in Appendix B.

Scenario City	Total Modeled Energy Savings kWh	Variance from Covina kWh	DualCool Savings kWh	Turntide SM Savings kWh	I2Systems Lighting Savings kWh	IoT Savings kWh
Carlsbad	737,073	-9,263	49,853 **6.8%**	275,767 **37.4%**	350,723 **47.6%**	60,729 **8.2%**
El Centro	901,898	155,562	217,778 **24.1%**	207,456 **23.0%**	406,414 **45.1%**	70,251 **7.8%**
Fresno	755,974	9,638	106,281 **14.1%**	213,367 **28.2%**	373,048 **49.3%**	63,278 **8.4%**
Redding	732,306	-14,030	105,023 **14.3%**	212,602 **29.0%**	359,138 **49.0%**	55,543 **7.6%**

Table 8. Modeled End-Use Electric Energy Savings (kWh) by City

Potential for Utility and Other Incentives

Current Utility Incentive Opportunities

The California Public Utilities Commission (CPUC) ordered the California Investor-Owned Utilities (IOUs) to procure energy efficiency programs that are designed and implemented by third parties. As a result, each IOU entered into contracts with certain vendors, who were selected through competitive solicitation processes. Additionally, customers will now receive energy efficiency services, products, compensation, and/or installation directly or indirectly from such third-party implementers, based on individual agreements between the customer and such third-party implementers.

Types of Incentives

Generally, the types of incentives covered by third-party programs include rebates or deemed measure savings, custom incentives, and normalized metered energy consumption (NMEC). Each of these incentive types are described in greater detail below:

Rebates (Deemed Measures)

Rebates are paid in a dollar amount per unit, for example $2 per light bulb. Rebate values are established based on reliable, deemed savings for specific equipment when installed. Rebates are the easiest pathway to obtain incentives for energy efficient equipment, however equipment must be on a pre-approved list.

As of the writing of this report, two technologies demonstrated on this project are eligible for IOU rebates as deemed measures: Software-Controlled Switch Reluctance Motor (Measure ID: SWHC041-02)[10] and Evaporative Pre-Cooler System and Controls for Packaged HVAC Unit (Measure ID: SWHC042-02).[11] Eligibility and rebate amounts will vary depending on IOU territory and individual third-party program adoption (see Relevant Incentive Programs by IOU Territory for more details).

Additionally, i2Systems will be pursuing an application for the lighting fixture used on this project to be listed under Design Lights Consortium (DLC)'s qualified product list. The DLC qualifies commercial LED luminaires, retrofit kits, linear replacement lamps, mogul (E39 and E40) screw-base replacement lamps, and four pin-base replacement lamps for CFLs for inclusion in DLC Members' energy efficiency rebate and incentive programs. Available Primary Use Designations are prioritized and developed by DLC energy efficiency program Members. Any rebates or incentives are provided at the discretion of each individual energy efficiency program. Once listed as a qualified product, the i2Systems fixture would likely be eligible for deemed rebates under the programs outlined below.

Custom Incentives

Custom Incentives are for projects that install eligible equipment with efficiencies or efficacy that exceed code requirements and that do not qualify for a rebate. These incentives are paid on a project-by-project basis on actual energy savings. Custom Incentives are typically paid out in dollar amount per kW or kWh saved beyond what is required by code.

Normalized Metered Energy Consumption (NMEC)

NMEC is a meter-based program that focuses on whole building energy savings and bringing existing buildings up to current building code. This program requires one year of uninterrupted baseline data, and the incentive amount is based off 12 months of actual post-installation meter data. To qualify for

[10] https://www.caetrm.com/measure/SWHC041/02/
[11] https://www.caetrm.com/measure/SWHC042/02/

this, the energy efficiency measures must save at least 100,000 kWh or 10% of the customers metered electrical load. Custom Incentives are typically paid out in dollar amount per kW or kWh saved.

Relevant Incentive Programs by IOU Territory

Each incentive type has specific requirements regarding project documentation, measurement and verification based on the adopted program. Typically, it is recommended to apply and receive incentive approval prior to commencing construction. More details and the latest program requirements can be found at each program website, detailed below.

San Diego Gas & Electric (SDG&E)

With TRC's Comprehensive Energy Management Solutions (CEMS) program, there are three ways to save for customers on qualifying rate schedules with a monthly demand greater than 20 kilowatts. Fast-track incentives, pre-approval incentives, and direct install. Fast-Track Incentives provide cash payments to help customers upgrade specific equipment with established energy savings. Total incentive is based on the amount of energy saved, which can be calculated in the online application tool. Pre-Approval Incentives provide savings in addition to those covered by our Fast-Track Incentives, ensuring buildings can achieve optimal efficiency, no matter what is upgraded. Finally, TRC also provides eligible customers with low- or no-cost upgrades when installed by a pre-qualified Trade Professional. Direct Install projects are focused on select easy upgrade opportunities and provide business customers with a look at additional ways they can save through our Fast-Track and Pre-Approval Incentives. Learn more at the CEMS website.

Switch reluctance motors (such as Turntide's smart motors featured on this project) are currently eligible for fast-track incentives under this program as of the time of this report. ICI DualCool's evaporative pre-cooling technology is newly approved as a deemed measure and could potentially be added to eligible measures for fast-track incentives in 2022. Pre-approval incentives could potentially cover the suite of installed energy efficiency technologies from this project under either the custom or NMEC types, depending on specific program eligibility requirements.

Southern California Edison (SCE)

The Willdan Commercial Energy Efficiency Program (CEEP) provides comprehensive energy efficiency for all commercial customers with a monthly maximum demand of greater than 20 kW across Southern California Edison's (SCE's) service territory. This program uses Deemed, Custom Calculated and NMEC approaches to reach customers across Commercial NAICS codes including Lodging, Restaurants, Grocery Stores, Warehouses, Refrigerated Warehouses, Retail and Technology, Offices and others. Learn more at the Commercial Energy Efficiency Program website.

Switch reluctance motors (such as Turntide's smart motors featured on this project) are currently eligible for rapid rebates under this program as of the time of this report. ICI DualCool's evaporative pre-cooling technology is newly approved as a deemed measure and could potentially be added to eligible measures for rapid rebates in 2022. The suite of installed energy efficiency technologies from this project could potentially be incentivized under either the Custom Calculated or NMEC approaches, depending on specific program eligibility requirements.

Pacific Gas & Electric (PG&E)

In PG&E territory, there are several programs for building owners and managers to choose from to recuperate costs from this type of energy efficiency project. PG&E's direct rebate programs are closing in February 2022. It is likely new PG&E and/or third-party implementer programs will replace these direct rebates. The project team anticipates that similar to other IOUs, Turntide Smart Switch Reluctance motors would be covered under a direct rebate program, as well as potentially ICI's DualCool Evaporative pre-cooling technology since it is also an approved measure.

Custom Retrofit incentives are available directly with PG&E. Install high-efficiency equipment and systems to help reduce your peak demand in kilowatts (kW) and annual energy use (kWh and therm) and receive cash incentive payments. More details are available on the PG&E Custom Retrofit webpage.

CoolSave Grocery Comprehensive Retrofit & Commissioning, provided by KW Engineering, is an innovative, pay-for-performance, efficiency and demand response program targeting the energy-intensive grocery sector. KW Engineering utilizes a NMEC approach with real-time controls connectivity to deliver cost-effective capital, retrocommissioning, and demand-response results. More information on this program is available on the program website.

NetOne, provided by Ecology Action, will offer both Portfolio Planning and Implementation Services with a primary focus on commercial retail, real estate, hospitality, grocery, warehousing and manufacturing sectors. Program offers Custom, Deemed, and Meter-Based pathways to customer savings using product and controls equipment for Lighting, HVAC, and refrigeration equipment and demand response guidance. Program offers end to end support, from audit to project submission, providing customer focused engineering services and small customers have access to expedited rebate processing and service from trained installation contractor partners. As of the writing of this report, a program website is not currently available. Check PG&E's Partner Program page for updates.

As noted above, it is likely that custom-incentive and NMEC-based approaches would provide incentives for the holistic energy efficiency technologies installed by the Big-Box Efficiency Project.

Incentives at Store 2292

Table 9 summarizes the technologies installed at Walmart store for this project that could possibly utilize incentives. 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. i2Systems LED lighting would likely qualify for rebates once it is a qualified product under Design Lights Consortium and also may be eligible for custom or NMEC-based incentives.

Technology	Rebate/Incentives Available?
DC-ready LED Lighting (i2Systems)	Potentially
Smart Switch Reluctance Motors (Turntide)	✓
DualCool Evaporative Pre-Cooling (ICI)	✓
Internet of Things Platform (Locbit)	Potentially

Table 9. Available Rebates and Incentives by Energy Efficiency Technology

Additionally, certain project costs, like commissioning or design fees, could potentially be covered by customized incentive programs. The project team recommends those interested in learning more about rebates and incentives in their area to reach out to the program administrators listed above to gather more information and details about the latest available rebates and incentives, as well as financing options.

Finally, while Saya Life's smart water management system as deployed by this project is not eligible for energy efficiency rebates or incentives, local water districts and authorities could have programs that provide rebates and incentives for a smart water management system. For example, in Southern California, SoCal Water Smart offers The Water Savings Incentive Program (WSIP) is designed for non-residential customers improving their water efficiency through upgraded equipment or services that do not qualify for standard rebates. WSIP is unique because it provides an incentive based on the amount of water customers save. This "pay-for-performance" design lets customers implement custom projects for their sites. Any project that saves at least 10,000,000 gallons of water over the total product lifespan (up to 10 years) could qualify for WSIP funding. More information on this specific program is available on the SoCal WaterSmart website.

Incentives for On-Site Photovoltaics (PV) and Battery Energy Storage Systems (BESS)

The implementation of a switchable AC – DC voltage lighting system or a dedicated DC voltage lighting system requires a DC voltage source. The most common source for DC voltage in a commercial setting is a solar photovoltaics (PV) and battery energy storage system (BESS). PV and BESS have two main avenues for incentive funding. The Federal Income Tax Credits (ITC) for both PV and BESS, and the California Self Generation Incentive Program[12] (SGIP) for BESS only.

The Federal ITC applies to both battery energy storage systems and Solar Photovoltaics. For PV, the incentive received is based off the year construction started and cost of the installed system. For BESS, the incentive is also based off the year construction started, but in addition, the percentage of the tax

[12] https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/self-generation-incentive-program/participating-in-self-generation-incentive-program-sgip

credit received is also based off how much of the batteries charging is sourced from renewable energy (Table 13).

Technology	Rates
PV	• 26% for Projects that begin construction in 2021/22 • 22% for Projects that begin construction in 2023 • After 2021, Commercial drops to a permanent 10%
BESS	• Portion of 26% ITC if battery is charged by renewable energy system 75-99% • Full 26% ITC if battery is charged by renewable energy system 100%.

Table 10. ITC Rates for Solar PV and Battery Storage

The SGIP program provides an incentive for installing battery storage systems. The incentive is based on the size (in watt hours) of the system. For this program, the installed BESS must be charged by a minimum 75% renewable energy sources. Table 11 has 2021 incentive rates for SGIP.[13]

	SDG&E	SCE	SCG	PG&E
Large-Scale Storage	**Step 3**	**Step 4**	**Step 3**	**Step 4**
Energy Storage**	$0.35/Wh	$0.30/Wh	$0.35/Wh	$0.30/Wh
Energy Storage + ITC**	$0.25/Wh	$0.22/Wh	$0.25/Wh	$0.22/Wh
Non-Residential Storage Equity	**Step 5**	**Step 5**	**Step 5**	**Step 5**
Energy Storage**	$0.85/Wh	$0.85/Wh	$0.85/Wh	$0.85/Wh
San Joaquin Valley Non-Residential		**Step 5**		**Step 5**
Energy Storage**		$1.00/Wh		$1.00/Wh
** Energy Storage rates are subject to change if all PA territories close within 10 days after the step opens				

Table 11. SGIP Incentive Rates for Battery Storage (2021)

Future Recommended Incentives

Information collected from M&V at Walmart Store 2292 should be used to begin a work paper aimed at developing a standard rebate for the implementation of AC – DC voltage sensing lighting. The additional cost associated with developing and manufacturing an AC – DC voltage sensing light fixture makes the simple payback for this type of lighting system prohibitively long for some end-users in low energy cost regions. Further demonstration and validation of savings resulting from this technology when correctly applied can serve as the research basis to develop a DC lighting rebate that will help offset the cost of

[13] www.selfgenca.com

this lighting and accelerate market adoption. To support these efforts, CSE provided a copy of pre- and post-lighting retrofit submetering data to SCE.

Lessons Learned

The path to California SB 350's goal of doubling statewide electricity and gas savings by 2030, equivalent to a 20% reduction in projected statewide building energy use, still has many opportunities for growth. The lessons and findings from this project can better inform future deep energy savings retrofit projects. Lessons learned from this project include the following:

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 an individual HVAC unit level. Additionally, since there were some units that received both the DualCool and smart switch reluctance motor technologies, the project had to evaluate the combined effects of these measures.

As noted below, in future iterations of the project, it is recommended that any submetering systems (e.g., DENT submeters) have data recovery features that are accessible remotely, versus having to be recovered on-site.

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 the existing light fixtures that i2Systems didn't account for which caused an interference fit in the continuous run of the retrofit solution. Once i2Systems realized the issue, they made an accommodation in the housing design to fit around the raised surface.
- **Red Indicator Lights** – i2Systems fixtures have a built-in fault detection system which signals a fault through a red indicator light on the product. In certain situations, the red indicator lights were signaling a fault even when one did not exist. This was due to an over sensitivity in the circuit design that caused false failures to be reported in the system.
- **Balancing of Circuits in the Store** – i2Systems fixtures can plug together for up to 300' on a single run; however, in a few circumstances, the original electrical wiring in the store was configured such that it couldn't accommodate the current draw. In these cases, the electrical wiring needed to be changed to a maximum of 2 rows per circuit in order not to exceed the rated electrical draw.
- **Signal Propagation** - The main sales floor is an expansive space which requires wireless signal propagation to all areas where our lighting products were installed. Initially, i2Systems had some instances of the signal not propagating properly and fixtures not reacting to commands; however, i2Systems was able to make firmware modifications to correct this.

ICI DualCool Evaporative Pre-Cooling

While the installation itself was a straightforward installation for ICI, there were a couple key lessons learned that would have reduced items found in the commissioning of the systems:

- It would be best to check that each HVAC unit receiving DualCool retrofit is level pre- and post-install and confirm that there are no issues anticipated for the extra weight in those specific areas 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; on this project, a few existing HVAC units had economizer dampers requiring repair in order to realize the full savings from the DualCool technology.

Saya Smart Water Management System

One issue encountered during construction was that the original iteration of Saya Life water meters were not waterproof and thus required an in-field solution to provide protection from the elements. Saya Life now has IP68 water meters that are rated for outdoor use.

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

Turntide Smart Switch Reluctance Motors

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

- **Site Connectivity** – the original RMK (antenna) design encountered communication dropouts to the cloud. This has since been updated with new equipment to reduce communication dropouts to the cloud. This new solution has improved communication reliability and is being evaluated for robustness across multiple sites.
- **Modbus Communication** - a firmware flaw was discovered related to RS-485 Modbus communication. This flaw has been corrected with newer firmware and is being applied to other applicable sites.
- **Motor Controller Reliability** - A high number of P04 motor controllers for the V01 series motors have 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 radiated motor noise was discovered in the retail space, from Turntide’s V02 motor series. Noise isolating motor mounting feet were installed to substantially reduce radiated noise. Data collected from this site and other customer sites is driving improvements on the current motor design.
- **Condenser Fan Motor Noise** - At certain motor operating frequencies, torque ripple from individual motors combine 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 is continuing to work with the Walmart team to monitor the installed motors to ensure any remaining communication issues are identified and promptly resolved.

Locbit Internet of Things Platform

Due to delays in the integration of the 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, onsite 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 does not have full direct control of Walmart’s legacy control system (read-only access), so any identified triggers would have to be sent to a Walmart team member to manually implement (versus automatically adjusting setpoints). To achieve energy savings, Locbit’s automation platform would be based on reinforcement learning by completing a cycle of abstracting controls and data, analyzing the data, automating trough control adjustments, and re-analyzing based on the selected energy cycle.
- Many data points in Walmart’s legacy system aren’t all clearly labeled by subsystem (e.g., sensor says Sensor 1 HVAC instead of Sensor 1 RTU 8)
- Locbit’s team has also faced staffing challenges during the continued pandemic, which delayed integration of the NOVAR system for analysis and causing issues, such as the lack of clarity in sensor labeling, to not to be identified until too late in the project timeline.

Due to the reasons stated above, 0% 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 onsite 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 in order 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 in order to fully enable read/write access for new IoT platforms.

Another key lesson learned is that if energy savings are to be 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 (e.g., HVAC, or RTU 1) and that all components of the legacy control system can be accessed using current communications protocols.

Additionally, Locbit had several contributions on additional actions IoT providers can take to increase success of installation of IoT-type technologies:

- The in-store network should be analyzed and clearly defined prior to installation to ensure connectivity throughout the store of all devices and that the network is sufficient.
- Properly estimate incoming data amounts and size the server appropriately. Locbit's Edge Server needed more resources to support the amount of data integrated by this project. Locbit found that the Edge server was constantly running above 80% of its resources, which resulted in having to occasionally reboot 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 reducing 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 where technologies were out of communication with the Locbit system.

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

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

Conclusions and Next Steps

The cost savings evaluated for this project that be confidently attributed is $110,902 per year (energy savings of 775,111 kWh) with an overall simple payback of 16.23 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 and those savings were not evaluated, and future projects that successfully integrate an IoT platform are likely to achieve energy savings that will provide a payback on the investment. Due to the holistic nature of this project, engineering and construction costs can only be considered and the whole-project level; therefore, simple payback per project technology is not available.

In terms of water use, it was found 0.13 gallons of water were used for each kWh saved on the project so far, but one full year of evaluation would be required to accurately determine the water cost of the energy saved. There are several current incentives that are applicable 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 its widespread use.

Looking beyond the Covina site, the results from the building models in Carlsbad, El Centro, Fresno and Redding, CA revealed promising simulated savings to this project. There was also a noticeable increase in potential savings in El Centro, CA from the ICI DualCool, likely because of the higher ambient temperature and number of cooling days in El Centro compared to the other modeled regions. Ambient temperature influences the COP of the HVAC equipment so reducing temperature of the air cooling the air conditioning condenser coils will have exaggerated effects in hotter climates.

Walmart is committed towards its goals of being 100% renewable by 2035 and achieving zero emissions across global operations in 2040. Walmart will be leveraging the findings of this project in several ways:

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 in a store in Florida.

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 re-use.

Evaporative Pre-Cooling
ICI's DualCool evaporative pre-cooling technology has been installed in over 400 Walmart stores across the United States. Walmart and ICI 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 has 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 will have conversations with battery storage manufactures 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 towards the future of on-site distributed energy resources, demand response, and vehicle-to-grid integration.

Appendix A. Pre- and Post-Installation Electric Energy Consumption for Modeled Scenarios

Figure 12 through Figure 15 show the modeled energy consumption pre- and post-installation for the selected alternative city scenarios.

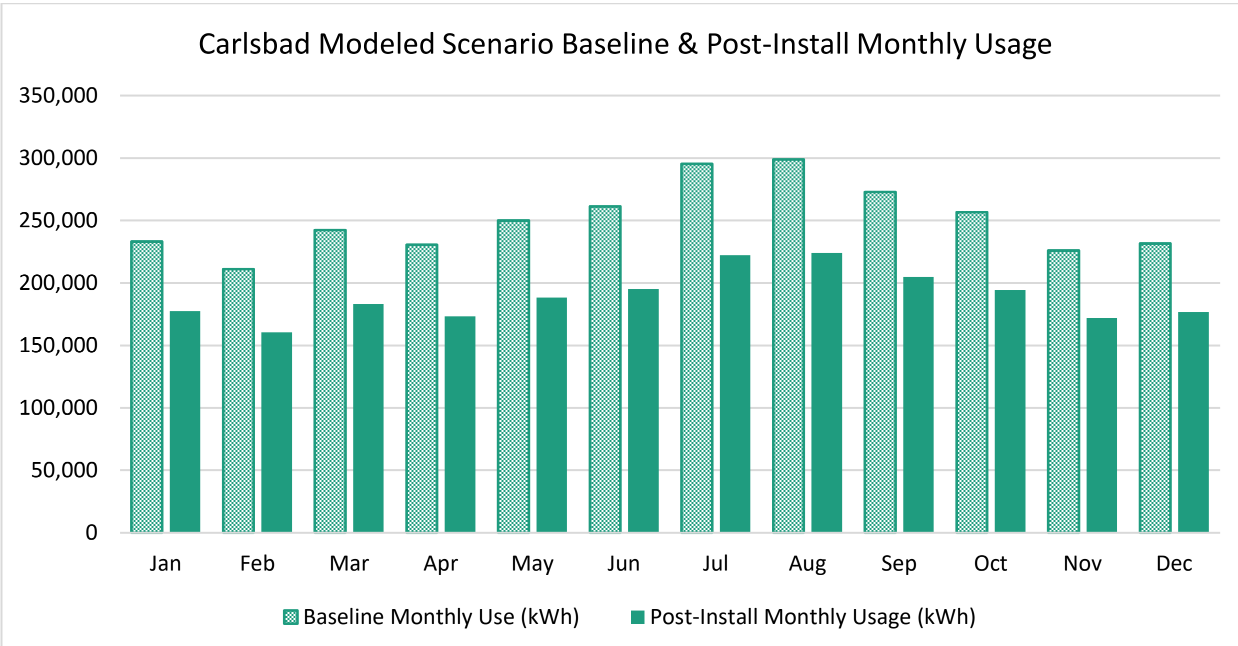

Figure 12. Pre- and Post-Install Monthly Electric Consumption, Carlsbad (SDG&E)

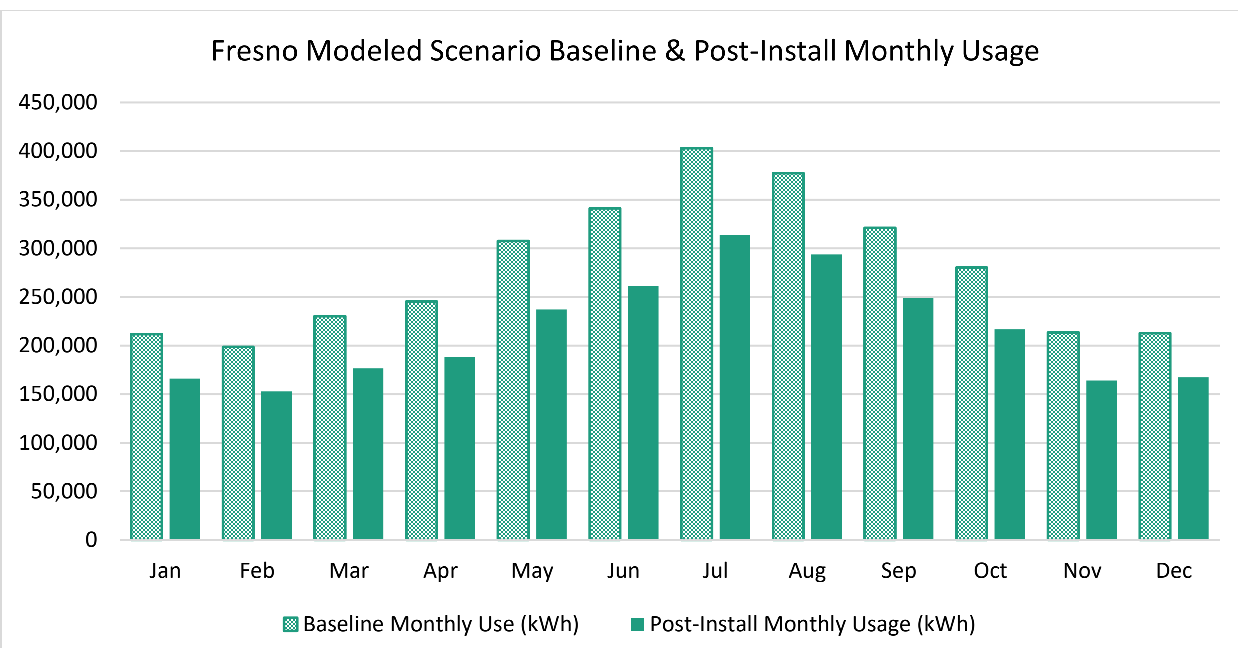

Figure 13. Pre- and Post-Install Monthly Electric Consumption, Fresno (PG&E)

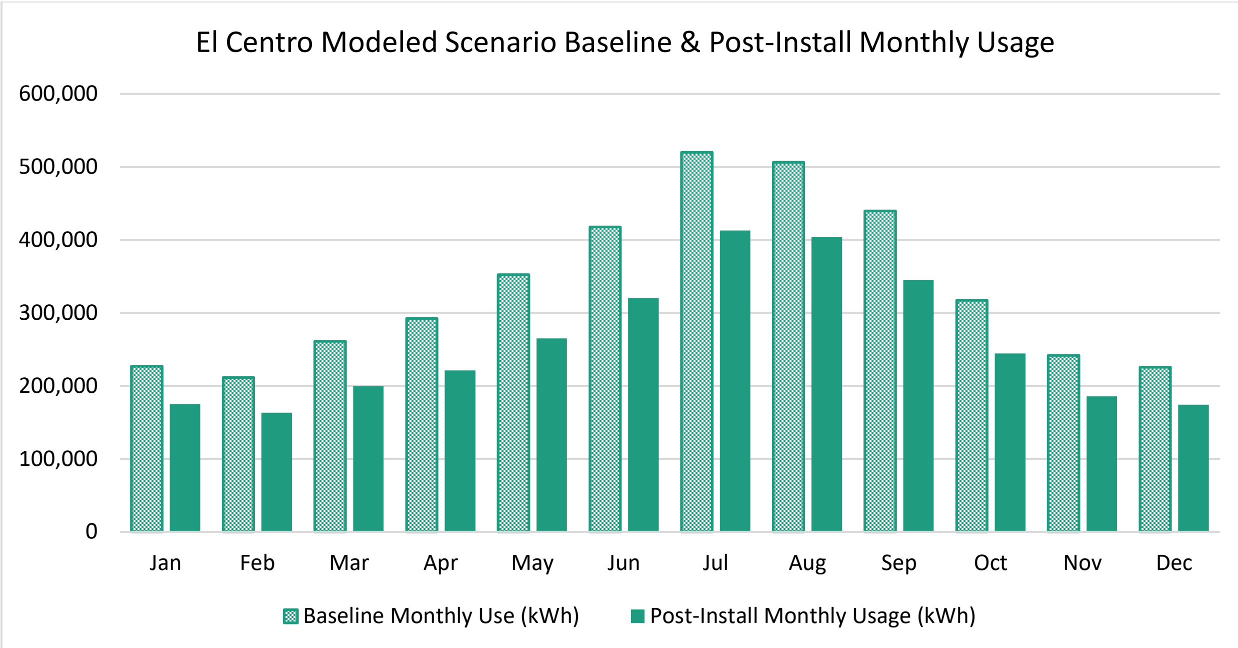

Figure 14. Pre- and Post-Install Monthly Electric Consumption, El Centro (SDG&E)

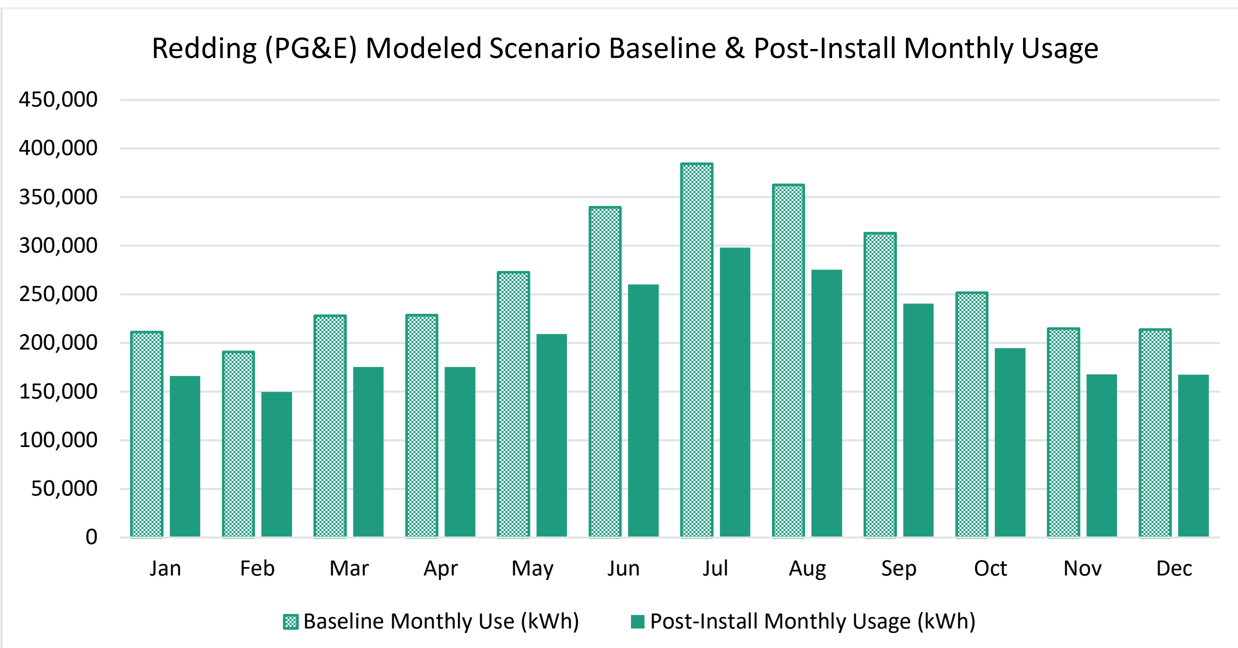

Figure 15. Pre- and Post-Install Monthly Electric Consumption, Redding (PG&E)

Appendix B. Project Costs and Savings: Covina vs. Modeled Scenarios

Table 12 below 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 measurement and verification 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 below 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. Due to the holistic nature of this project, engineering and construction costs can only be considered and the whole-project level; therefore, simple payback per project technology is not available (NA).

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

Table 12. Project Costs, Annual Savings, and Payback by Location and Project Cost Category

Table 13 below 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 measurement and verification 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 below 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.

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**[14]	**755,974**	**732,306**	**737,073**	**901,898**
DualCool kWh Savings (kWh)	177,176[15]	106,281	105,023	49,853	217,778
Turntide Motor Savings (kWh)		213,367	212,602	275,767	207,456
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

[14] 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.

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

Metric	Covina	Fresno	Redding	Carlsbad	El Centro
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[15]	$20,346	$20,105	$13,370	$58,406
Turntide Motor Savings (kWh)		$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**

Table 13. Detailed Comparative Analysis of Climate, Utilities, Costs and Savings for Project

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