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Energy Research and Development Division

FINAL PROJECT REPORT

San Diego Libraries Zero-Net Energy and Integrated Demand Side Management Project

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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.

San Diego Libraries Zero Net Energy and Integrated Demand Side Management is the final report for the San Diego Libraries Zero Net Energy and Integrated Demand Side Management Project (Contract EPC-15-085) was 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 (www.energy.ca.gov/research/) or contact the CEC at ERDD@energy.ca.gov.

ABSTRACT

The Center for Sustainable Energy in partnership with the California Energy Commission, City of San Diego, Mazzetti Inc., M+NLB Construction Services, San Diego Green Building Council and San Diego Gas & Electric completed a multiyear project to test, verify, and publicize the integration of energy efficiency, onsite renewable power and other demand-side resources to convert three public libraries to near zero-net energy buildings. Energy conservation measures implemented included light-emitting diode lighting, lighting controls, plug load management devices, heating, ventilation, and air conditioning controls and whole-building automation platforms that measure demand trends to optimize equipment operations. The project also engaged and educated library staff, volunteers, and community members through interactive, in-library kiosks on zero-net energy and integrated demand side management strategies, sustainable energy and associated environmental benefits, extending energy savings beyond the three project sites. To measure success, the project team conducted pre- and post-construction surveys of library staff and volunteers. The team also conducted nine months of post-retrofit measurement and verification with a three-month projection to estimate annual post-retrofit energy consumption due to COVID-19 shut down of the libraries. The project results indicated that the energy efficiency measures reduced electric consumption at the libraries from 13 to 30 percent. Photovoltaics were installed at each of the libraries independent of the grant. As a result, two of the libraries were able to achieve near zero net energy due to combining the photovoltaics and energy efficiency measures. The project demonstrated a blue print to achieve near zero net energy for other City of San Diego municipal buildings along with the benefits and challenges of retrofitting existing buildings.

Keywords: zero net energy, ZNE, demonstration, City of San Diego Libraries, integrated demand side management, IDSM, energy conservation

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EXECUTIVE SUMMARY

Introduction

California has set aggressive policy goals around buildings achieving zero net energy. According to the United States Energy Information Administration residential and commercial buildings consume about 40 percent of California's total energy and the state's policymakers and utilities are looking for effective ways to reduce demand on the electric grid by converting existing buildings to zero-net energy.

California's ambitious climate and energy goals, include Senate Bill 350, which requires the state to double statewide energy efficiency savings in electricity and natural gas end uses by 2030. This will require decarbonizing existing buildings, as most savings are expected to come from the residential and commercial sectors. Through robust, sustainable marketplaces, California can achieve its energy and climate goals and deliver benefits to California residents.

Project Purpose

The City of San Diego is a national leader in sustainability planning and implementation with strong support from elected officials. The city manages more than 7.6 million square feet of infrastructure, including libraries, police stations, treatment plants and other critical facilities. The project demonstrated a blueprint to achieve near zero-net energy at three public libraries through cost-effective energy efficiency upgrades, enhanced building automation, pre and post-installation monitoring, and occupant behavior analysis.

Project Approach

To develop a blueprint for other existing commercial buildings to reach the state's zero net energy target, the Center for Sustainable Energy selected three libraries owned and operated by the City of San Diego: Serra Mesa-Kearny Mesa, Valencia Park/Malcolm X and Point Loma Hervey Branch Libraries, all in California Climate Zone 7 and in the San Diego Gas & Electric (SDG&E) service territory. The project used the California Energy Commission's *Zero-Net-Energy Code Building* definition to establish methods and evaluation criteria. The project was broken into three phases: baseline monitoring, design and construction planning, installation, and post-retrofit measurement and verification.

A technical advisory committee was formed and met three times to evaluate the benefits of the project and provide recommendations. The team was comprised of representatives from SDG&E's- Emerging Technologies Program, U.S. Green Building Council-San Diego chapter, City of San Diego, architects, and service provider, ABM Building Services. These individuals served as a sounding board as project progress was reporting, and identified linkages between the project and other public and private projects.

The energy conservation measures that were implemented included LED lighting and controls, plug load management devices, heating, ventilation, and air conditioning controls and whole-building automation platforms to optimize equipment operations. The library staff, volunteers, and community members were engaged and educated through interactive, in-library kiosks on sustainable energy and associated environmental benefits, which extended the energy savings beyond the three project sites.

Several challenges were encountered during the project. This included navigating emerging technologies across many different disciplines, City contracting requirements, identifying building cybersecurity and network requirements, and site locations which had cool zone requirements. In addition, the emergence of the COVID-19 global pandemic in the final year of the project created some difficulties with in-person work at the sites, but the project team was able to resolve these in a timely and safe manner.

Project Results

Measurement and verification project occurred in an atypical year, during the COVID-19 pandemic. 9 months of performance data was collected, however due to the closure of the libraries, 3 months were estimated using energy models. The performance and savings measured and estimated included the LED lighting, controls, plug load management devices, heating, ventilation and air conditioning (HVAC) controls and whole-building automation platforms The estimates were done assuming a normal building occupancy during regular business hours, based on data from the baseline monitoring period. The estimated savings indicated the reduction in electricity consumption during normal operation would represent 239,704 kilowatt-hours (kWh), and a reduction in peak demand by 84 kilowatts (kW). This equates to an estimated $33,655 in savings and a 170 metric tons of carbon dioxide equivalent (MTCO2e) annual reduction. The percent kWh reductions at each library site were represented as follows: 13 percent at Serra-Mesa Kearny Mesa, 28 percent at Valencia Park/Malcolm X and 29 percent at Point Loma/Hervey Library.

During the project, the city installed solar photovoltaic (PV) systems that were not funded by the grant. Including the PV, the estimated kWh energy reductions were estimated as follows: 78.2 percent at Serra-Mesa Kearny Mesa, 79.1 percent at Valencia Park/Malcolm X and 31.1 percent at Point Loma/Hervey. Table 4 illustrates additional data regarding the PV generation. Two of the libraries, the Valencia Park/Malcolm X and Serra-Mesa Kearny Mesa Libraries were projected to achieve near zero-net energy with a potential 10 and 15-year simple payback, respectively. The data analysis at the third site, the Point Loma/Hervey Library, revealed an unknown natural gas use increase during the post retrofit periord and coupled with lower electricity savings resulted in no payback for the project. However, the energy issues experienced at the Point Loma/Hervey Library reflect the importance and need for ongoing retrocommissioning to ensure energy using equipment is operating properly and as-designed.

The demonstration uncovered existing implementation barriers for installing building automation systems citywide, including utility program eligibility, technology requirements such as Wi-Fi signal for connected controls. These lessons learned will be used as a blueprint for the City of San Diego as they work to meet state and local energy GHG reduction targets by implementing similar measures at their other 200+ buildings as initially outlined in their Municipal Energy Strategy Plan. Furthermore, education and outreach activities encouraged visitors to incorporate energy efficiency measures within their own residences.

Technology/Knowledge Transfer

Throughout the project, the Center for Sustainable Energy conducted technology/knowledge transfer activities to inform the City of San Diego elected officials, Sustainability Department staff, library department staff, other local governments, related industry stakeholders and the community about the benefits of transforming existing municipal buildings into zero-net energy or near-zero net energy facilities. The activities reached over 1,000 people and

included online media and energy dashboards, a dedicated project website, webinars, case studies, fact sheets, conference presentations, building tours and policy comments.

Benefits to California

The project demonstrated cost-effective existing and emerging integrated demand side management technologies. This project provided the necessary steps to to achieve near-zero net energy in similar applications. Commercial buildings outfitted with integrated demand-side management technologies can provide energy and cost savings, and help promote greater reliability, and environmental and public health benefits to California's ratepayers. The addition of an on-site renewable system can further provide an overall reduction to grid consumption and shift loads away when demand is at its highest which can achieve lower greenhouse gases emissions.

CHAPTER 1: Introduction

The San Diego Libraries Project, also known as San Diego ZN3 or SD ZN3, was a California Energy Commission Electric Program Investment Charge[1] demonstration project, led by the Center for Sustainable Energy. The project demonstrated cost-effective, zero-net energy (ZNE) and integrated demand-side management (IDSM) technologies that were installed, tested, and measured in three existing buildings with the goal of achieving ZNE or near-ZNE. ZNE refers to homes, buildings, and communities that generate as much renewable energy onsite as they consume annually.

Problem

California has set aggressive policy goals around buildings achieving ZNE. Residential and commercial buildings are responsible for 40 percent of total U.S. energy consumption,[2] and the State of California is searching for ways to reduce this strain on the electric grid and increase reliability to reduce costs for communities and businesses. ZNE buildings and IDSM technologies increase grid reliability, lower customer energy cost's and reduce greenhouse gas (GHG) emissions. ZNE strategies include integrating a high level of energy efficiency with on-site solar power generation to capture excess generated energy at peak generation times for later use. Cost-effective pathways to achieving ZNE through maximum energy efficiency paired with IDSM have not been widely proven and need further demonstration to determine market viability and long-term sustainable savings.

California's *2008 Long Term Energy Efficiency Strategic Plan*[3] also outlines four "Big Bold Energy Efficiency Strategies," one of which requires all new commercial construction to be ZNE and 50 percent of existing commercial buildings to be retrofitted to ZNE by 2030. As a result, local governments are engaging in municipal energy strategies to achieve these goals. Validation from proven projects that successfully demonstrate technology integration and associated revenue models is needed for local governments, policymakers and utility executives to gain confidence in accelerating the transition to local clean energy and to achieve California's ambitious goals.

Solution

The project installed and tested integrated energy efficiency and emerging measures and solar photovoltaic (PV) generation at three public libraries. This multiyear, flexible and transparent collaboration aimed to uncover, test, verify, and publicize strategies. The aim included demand-side resources to encourage ZNE and to prove cost-effective pathways to maximum energy efficiency in the municipal building sector. The project had the following primary goals:

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[1] *Electric Program Investment Charge*. 2018. California Energy Commission. https://www.energy.ca.gov/research/epic/

[2] U.S. Energy Information Administration. https://www.eia.gov/tools/faqs/faq.php?id=86&t=1

[3] *California Energy Efficiency Strategic Plan, January 2011 update.* 2011. California Public Utilities Commission. http://www.cpuc.ca.gov/General.aspx?id=4125

- Demonstrate the value of emerging technologies such as advanced building control and automation systems and IDSM technologies in existing commercial buildings.
- Demonstrate the technical capacity of IDSM technologies to deliver ZNE in existing small commercial buildings and municipal buildings.
- Demonstrate the value of revenue models through IDSM and DR for small commercial buildings in municipal and private sectors.
- Create a replicable blueprint for local governments to achieve ZNE in 50 percent of existing buildings by 2030.

Approach

The City of San Diego manages more than 7.6 million square feet of infrastructure, including libraries, police stations, treatment plants and other critical facilities. The city's climate action plan (CAP),[4] adopted in 2015 set a goal of 15 percent energy reduction from municipal operations by 2020 and an additional 25 percent by 2035. The city is committed to achieving this goal by reducing the energy consumption of existing municipal facilities and by developing a ZNE policy for newly constructed municipal buildings and with overarching municipal energy strategy (MES) that will establish a plan for implementing energy projects in existing buildings over the next several decades. Furthermore, the project coincided with the City's plan to install solar PV on three of its existing libraries. The project sites were Serra Mesa-Kearny Mesa, Valencia Park/Malcolm X and Point Loma/Hervey Branch libraries.

Sites

Each of the libraries have different site characteristics. The Serra Mesa-Kearny Mesa Library is located at 9005 Aero Drive and serves residents in the Serra Mesa and Kearny Mesa neighborhoods. The library was constructed in 2006, is 15,626 square feet and has an estimated 5,000-10,000 visitors each month. The Valencia Park/Malcolm X Library is in a disadvantaged community at 5148 Market Street and serves residents in the Valencia Park, Lincoln Park and Encanto neighborhoods. Built in 1995, the library is 26,328 square feet with an estimated 25,000 visitors each month. The Point Loma/Hervey Branch Library is located at 3701 Voltaire Street and serves residents in the Point Loma neighborhood. Built in 2003, the library is 22,480 square feet and has an estimated 19,000-22,000 visitors each month.

Project Team

Several other project partners to achieve all project goals and objectives. Mazzetti, Inc. and M+NLB Construction Services provided ECM design and construction management. ABM and Climatec provided the installation of ECMs. Bert provided their plug load management devices. The San Diego Green Building Council supported the interactive energy dashboards at each library for visitor outreach. The SDG&E Emerging Technologies Program assisted in identifying energy conservation measures and utility incentive programs. Acuity Brands, Inc provided data visualization integration through their energy dashboard.

[4] *City of San Diego Climate Action Plan*. City of San Diego. https://www.sandiego.gov/sites/default/files/final_july_2016_cap.pdf

CHAPTER 2:
Baseline Energy Use and Modeling

Energy Audits

An American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Level II audit was conducted at the three libraries. These audits identified the existing conditions at each library, established baseline energy profiles, benchmarked against similar facilities, and created a list of potential energy efficiency measures with estimated potential savings. The baselines enabled calculation of energy reduction toward ZNE to identify energy efficiency measures that would address the highest consuming end uses.

The three libraries receive electricity and natural gas service from SDG&E. The majority of interior lighting in each library consisted of linear fluorescent fixtures paired with occupancy sensors in meeting rooms and offices. Exterior pole lights were common with 100-watt and 250-watt lamps controlled with a basic timer. Most space cooling and heating consisted of packaged units controlled by programmable thermostats. The Point Loma/Hervey and Valencia Park/Malcolm X libraries have chillers. The chiller at Point Loma/Hervey serves the whole building's cooling requirements, and at Valencia Park/Malcolm X serves only the Multipurpose Room.

The three libraries had a typical energy profile with seasonal trends: an increase in electric use during the summer for cooling and an increase in gas use during the winter for heating. Table 1 shows energy use intensity (EUI) or energy used per square foot per year, energy consumption and cost for the initial baseline year of October 2015 to September 2016 used for all three libraries.

Table 1: Baseline Energy Consumption and Costs

Library	EUI	Electric (kWh)	Electric Cost	Avg. Cost per Unit ($/kWh)	Natural Gas (therms)	Natural Gas Cost	Avg. Cost per Unit ($/therm)
Serra Mesa-Kearny Mesa	67.3	273,259	$65,473	$0.240	1,201	$1,098	$0.91
Point Loma/ Hervey	70.4	409,469	$99,392	$0.239	1,058	$978	$0.92
Valencia Park/ Malcom X	41.1	285,794	$74,342	$0.260	1,857	$1,636	$0.88

Source: Center for Sustainable Energy

The recommended measures outlined in the audits were not indicative of all possible efficiency solutions for the project. Lighting fixture and controls upgrades were the only capital investment measures recommended. HVAC upgrades were not estimated to pay back with in the effective useful life (EUL) of the equipment. Table 2 shows savings estimated from the measure recommendations for the three libraries.

Table 2: Energy Audit Recommendations and Savings Estimates

Measure Description	Peak Demand Savings (kW)	Electricity Savings (kWh)	Total Cost Savings	Net Measure Cost	Simple Payback (yr.)
EEM-1 Install Occupancy Sensors	0	16,379	$20,966	$132,840	6.3
EEM-2 Replace Existing Fixtures w/ LEDs	47.3	150,708	$48,455	$240,819	5.0
Total	**47.3**	**167,087**	**$69,421**	**$373,659**	**5.4**

Source: Center for Sustainable Energy

Additional "low-cost/no-cost" measures recommended included replacing HVAC thermostat controls, adjust heating/cooling setpoints, repairing malfunctioning economizers and implementing automated controls. The appendix to each audit included a comparison of existing equipment to proposed retrofit equipment, HVAC equipment details, other mechanical equipment such as exhaust fans and hot water heaters as well as major plug loads such as computers, printers, and miscellaneous equipment.

Energy Models

Two sets of EnergyPro™ models were created for each library: baseline energy models and calibrated energy models. The baseline models represented each library's current energy use and 12 months of utility data (January–December 2017). These models were then used to generate the calibrated energy models that incorporated actual meteorological year (AMY) weather data aligned to utility-metered energy consumption for baseline year 2017. The calibrated models' results were within 3 percent accuracy of the Kw utility data baseline and within 5 percent of the therms.

Initially, the calibrated models were created using typical meteorological year (TMY) weather data that resulted in several unsuccessful attempts to calibrate the models. The models were eventually calibrated successfully using AMY weather data and specific adjustments that included the following.

- Adjusted the internal base loads in attempt to accurately reflect the conditions inside the libraries for lighting power density, receptacle load density and approximate number of occupants.
- Adjusted occupancy, lighting, HVAC and receptacle schedules to match library hours and estimated occupancy patterns as reported by library staff.

- Derated the recovery efficiencies of the boilers and domestic hot water equipment to account for their age and state of repair.
- Derated the efficiencies of the heating and cooling equipment to account for their age and state of repair, where appropriate.

Initial model observations showed a typical consumption pattern at two libraries that followed usual temperature patterns in San Diego. Contrarily, the Point Loma/Hervey library revealed an unexpected pattern in electrical demand between February and May 2017. This coincided with an unexpected increase in natural gas consumption, estimated to be nearly 400 therms (>600 percent) more than expected during February 2017. It is suspected the anomalies in early 2017 were due to simultaneous heating and cooling, which would cause a spike in electrical demand and natural gas consumption, during this time period.

Finally, additional modeling was done during this reporting period to supplement CSE's baseline energy analysis. A generous in-kind donation from New Building Institute (NBI), one of the project's technical advisory committee members was provided to assist with the diagnosis of possible energy improvements. Using the project's 2017 baseline data, NBI developed "FirstView Energy Models" using their FirstView® software engine. The NBI FirstView software is a fee-based instrument that can be used in the early stages of an energy efficiency project, or to conduct a portfolio analysis for initial building energy analysis that "reveals underlying patterns in building end-use consumption…[and] allows you to invest audit resources where they will be most effective."

Table 3 provides a diagnostic snapshot of the major building systems and a general assessment of each.

Table 3: New Building Institute FirstView Results

Library & Diagnostic Category	Serra Mesa-Kearny Mesa	Point Loma/Hervey	Valencia Park/Malcolm X
Heating and Ventilation Efficiency	Poor	Poor	Typical
Cooling Efficiency	Good	Good	Typical
Controls	No apparent problems	No apparent problems	No apparent problems
HVAC Reheat	No apparent problems	No apparent problems	No apparent problems
Thermal Baseload	Typical	Typical	Typical
Light and Plug Load	Typical	High	Low
External Process Load	No apparent problems	No apparent problems	No apparent problems
Data Consistency	Orderly	Orderly	Orderly

Source: Center for Sustainable Energy

These findings helped determine the most cost-effective and feasible ECMs to inform design. These were selected by projecting proposed energy reductions and calculating equipment sizing and calibrating the building management system tolerances. For instance, the Point Loma/Hervey HVAC equipment and ventilation controls needed to further investigate to

address its poor efficiency. Also, Point Loma/Hervey library had a high energy consumption, even when solar PV production was accounted for in the design. After ECMs were finalized, models were used to evaluate and determine what should be installed to achieve enough reduction in energy consumption to meet ZNE or near-ZNE.

After ECMs were installed, the measurement and verification (M&V) period began. During this period, end-use monitoring devices were used to continuously evaluate end-use energy consumption compared to the EnergyPro™ calibrated models and the library's monthly utility metered data. This enabled the project team initiate adjustment recommendations to ECM controls and determine if each library had achieved ZNE or near-ZNE.

End-Use Monitoring

The strategy for end-use monitoring data collection was implemented at each library by using facility site characteristics, 2017 utility metered data and PV system production information. Electrical and mechanical energy uses were monitored at the submeter or system level. This section discusses the end-use monitoring strategy, hardware and software installed, the collected data and how that data was applied.

Site visits were conducted to develop an end-use monitoring strategy for electrical panels and mechanical systems at each library. Solar PV monitoring was provided by the city's power purchase agreement (PPA) provider. Autani Wireless Packaged Meters were proposed for every electrical panel to monitor lighting, plug load, miscellaneous load and smaller HVAC components and report to a single Autani Manager at each facility. However, the team discovered the HVAC systems could not be metered with Autani devices because each library's HVAC equipment was powered by a series of breakers installed on the main switch gear panels or on larger, multiple circuit panels.

To enable HVAC monitoring, several different approaches were used: 1) a Trane™ Tracer© Supervisory Controller (Tracer SC) Building Automation System (BAS) already installed at Serra Mesa-Kearny Mesa would need trends set up, 2) the existing Trane Summit BAS at Point Loma/Hervey would need to be upgraded to a Tracer SC BAS and 3) Pelican PEARL economizer devices would need to be installed at Valencia Park/Malcolm X as well as reconnection of the existing Pelican Wireless Gateway (Pelican Gateway) to the city's internal network. Each monitoring device is explained in more detail in the following subsections.

End-use consumption monitoring and modeling findings were utilized during ECM design to help determine the most cost-effective and feasible ECMs by projecting energy reductions of the proposed ECMs, calculating equipment sizing and calibrating building management system tolerances.

Autani Wireless Packaged Meter and Autani Manager

The Autani monitoring system consists of Veris Industries E50 Series Wireless Packaged Meters installed adjacent to the electrical panels where current transducers (CTs) measure total panel energy consumption. The Veris meters collect multiple data points and transmit wirelessly to a central Autani Manager that reports on-site meter data to the Autani Cloud platform. The following is a description of the different targeted end uses that were monitored with this method.

- ***Lighting*** – Lighting fixtures throughout all rooms and spaces at the library as well as exterior perimeter lighting, decorative fixtures, wall packs and parking lot poles.
- ***Plug Load*** – All receptacle loads included but not limited to computers, printers/copiers, task lighting, various office equipment and outlets serving common spaces often used for powering visitor laptops and devices.
- ***Miscellaneous*** – Various, infrequent loads that could not be easily defined by another category include hand dryers, instant hot water heaters and range ovens.
- ***HVAC*** – Smaller components of the HVAC system connected to local panels being metered included exhaust fans, variable air volume (VAV) boxes and similar equipment.

Trane Tracer SC

An upgrade to the existing Trane Summit BAS to Trane Tracer SC at Serra Mesa-Kearny Mesa allowed for an easy approach to monitoring the main HVAC equipment. City facilities staff, coordinationg with Trane service technicians, configured the system to report metrics related to energy consumption and system performance. At Point Loma/Hervey, the BAS was upgraded to a Trane Tracer SC, and the system configured to match Serra Mesa-Kearny Mesa's metrics. The equipment metered by the Tracer SC system at each location were:

- ***Serra Mesa-Kearny Mesa Library*** – Ten Trane rooftop units (RTUs) ranging from 2 to 12.5 tons of refrigeration (TR) serving all interior spaces (Unit ID AC-1 through AC-10).
- ***Point Loma/Hervey Library*** – Ten Petra rooftop air handling units (AHUs) with local gas heat and district cooling served by a central Trane Chiller with a 90 TR capacity (Unit ID AH-1 through AH-10; CU-1).

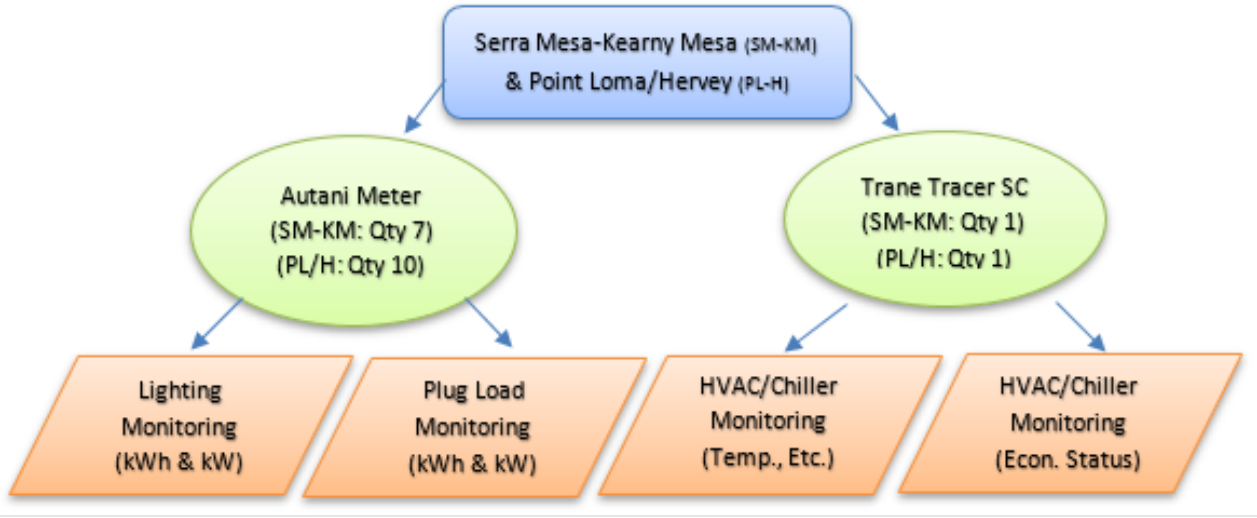
Pelican Thermostat & PEARL

At Valencia Park/Malcolm X Library, a BAS system was not used. Instead, HVAC units respond to calls for heating and cooling from local Pelican Thermostats throughout the building. These thermostats communicate through a wireless mesh network to their corresponding units, each other and a central control unit located on-site called the Pelican Gateway. One Pelican PEARL device was installed on each RTU to enable control and monitoring of the economizer damper position. These devices are also connected to the wireless mesh network and can report system status. The equipment and metrics monitored by each set of devices were:

- ***Pelican Thermostats*** – Measuring area temperature, current setpoints, call for heating or cooling and systems status for 11 Carrier RTUs ranging from 2-15 TR serving all interior spaces, except the Multipurpose Room (Unit ID AC-1 through AC-11). Similar metrics are monitored by a Pelican Thermostat that controls a 24 TR chiller, associated air handler and duct heater serving the Multipurpose Room (Unit ID CH-1, AH-1 and DH-1).
- ***PEARL Economizers*** – Measuring status and position of economizer dampers on all HVAC RTUs, indicating when the dampers are open and cooler outside air is being used in place of air conditioning.

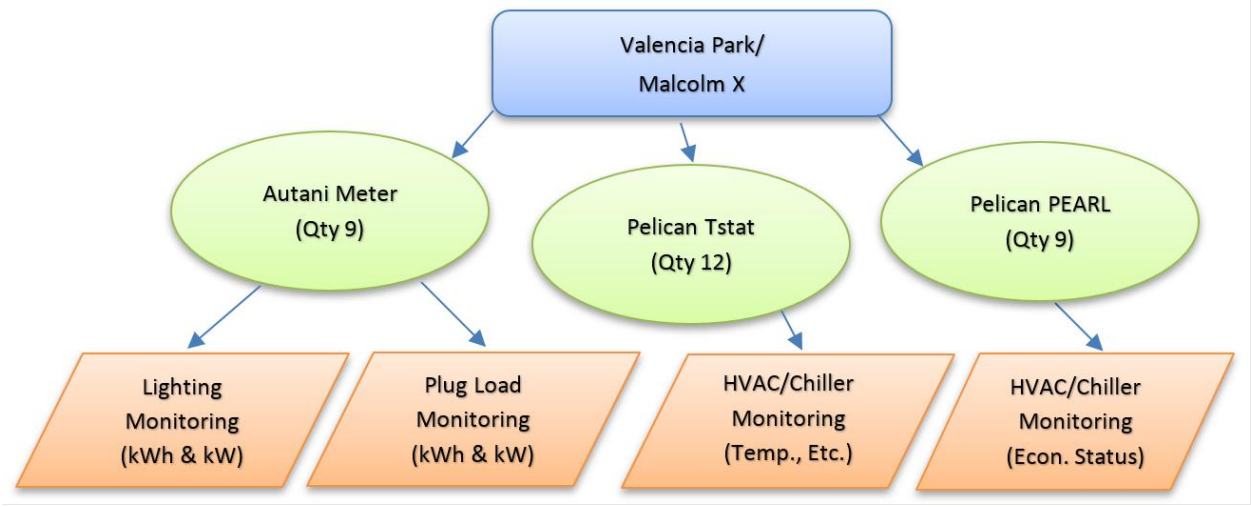
Figures 1 and 2 provides a graphic representation of the end-use monitoring approaches. Serra Mesa-Kearny Mesa and Point Loma/Hervey had similar monitoring arrangements, shown in Figure 1, while the monitoring arrangement for Valencia Park/Malcolm X is in Figure 2.

Figure 1: Serra Mesa–Kearny Mesa End-use Monitoring Approach



Source: Center for Sustainable Energy

Figure 2: Valencia Park/Malcolm X End-use Monitoring Approach



Source: Center for Sustainable Energy

Photovoltaic Production

The PV system installed at each facility offsets a portion of each site's electrical demand and consumption. Table 4 lists the size, mounting type and estimated production for each PV system.

Table 4: Library Photovoltaic Systems

Library	PV System Capacity (kW-DC)	Mounting Type	Estimated Annual PV Production[5] (kWh-AC)	Estimated Annual Offset (% of 2017 kWh)
Serra Mesa- Kearny Mesa	138.69 kW	Ground (Carport)	204,014.2 kWh	78.2%
Point Loma/Hervey	84.42 kW	Roof	129,698.5 kWh	31.3%
Valencia Park/Malcolm X	138.69 kW	Ground (Carport)	230,283.0 kWh	79.1%

Source: Center for Sustainable Energy

Actual solar PV production at the three libraries was metered by an Accuenergy 9100 device and shared by the city's PPA provider. These data reports contain PV production metrics and were an integral part of the project's M&V strategy.

San Diego Gas & Electric Company Utility Data

Each library has one electric utility meter served by SDG&E. Interval data representing site demand and consumption is currently not accessible on a real-time basis. It can be obtained through a request to SDG&E by an authorized party. Efforts to streamline data acquisition in real-time were explored for post-retrofit M&V. The display of the utility data imported into the energy dashboard encounters a 24-48-hour delay.

[5]Estimated Annual PV Production was calculated using PV Watts.

CHAPTER 3:
Design

End-use monitoring and calibrated energy model results were used to identify retrofits to determine the optimal IDSM energy conservation measure (ECM) packages. The team considered the end-use needs of the sites, as well as the restrictions imposed by the scope of the project, the budget and additional city needs and plans.

Coupled with existing photovoltaic (PV) systems, the ECMs identified and installed were expected achieve close to ZNE. A replicable ECM blueprint was created for other jurisdictions to consider ZNE retrofit projects in their own existing building portfolios. The following section describes the ECMs identified and installed, an overview of estimated energy and cost savings resulting from the ECMs and anticipated ZNE results.

Selection of Energy Conservation Measures and Emerging Technologies

The following ECMs were identified to reduce energy consumption, improve occupant comfort, reduce building maintenance, and extend equipment life.

- LED lighting
- Lighting controls
- HVAC controls & whole-building automation
- HVAC unit replacements including demand-controlled ventilation and a heat recovery ventilator
- Plug load management devices
- Minor weatherization

PV system sizing and installation is typically performed after energy efficiency improvements, are completed. However, the City had signed a power purchase agreement (PPA) before ECMs could be selected and installed. Therefore, the technical specifications for each PV system installed were taken into consideration when the ECMs were identified and ZNE performance estimates were made.

The ECMs selected were determined by the project team based on several factors including cost, estimated associated savings and availability. The project also required installation of an emerging technology.

Emerging Technology Selection

The project team evaluated eight emerging technologies, including pre-commercial efficiency technologies, to deliver ZNE in existing commercial buildings. Most of the emerging technologies explored were recommended by project partner SDG&E through their Emerging Technologies Program. Table 5 displays the emerging technologies that were evaluated.

Table 5: Emerging Technologies Evaluated

Vendor	Technology Description
SkyCool	• Renewable cooling panel
Ventacity	• Master controller for HVAC equipment and sensors, heat recovery ventilator and dedicated outdoor air system
Meazon	• IoT energy meters & controllers
Parans	• Solar lighting/daylight harvester
75F	• Zone control system
Bert Plug load	• Plug load devices & building automation system integration
Aclima	• Demand-controlled ventilation with air quality sensor
Solxenergy	• Efficient refrigeration system

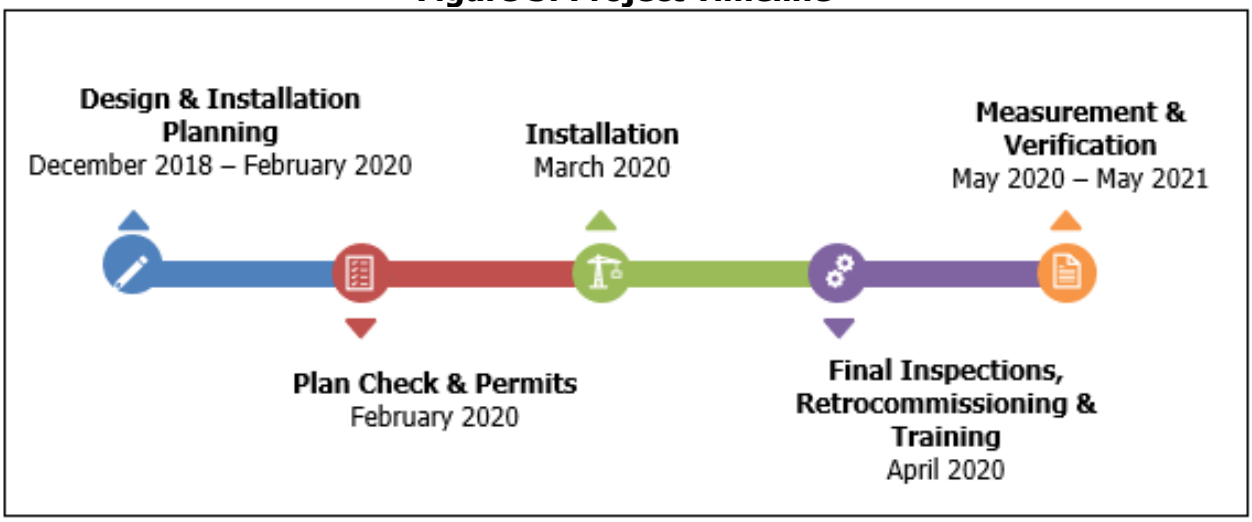
Source: Center for Sustainable Energy

Only one emerging technology, the Bert plug load device, was feasible. The equipment had the highest return on investment and was demonstrated at the three sites. The remaining emerging technologies were infeasible for several reasons such as cost-effectiveness, energy savings potential and other factors such as vendor availability in California.

Design Changes

To accommodate additional project requirements, the project design was created and refined from March 2019 into early 2020. Utility programs were evaluated, subcontractors selected, a pre-installation meeting held and public notification for work was presented to initiate ECM installations. The installation planning activities are described in more detail and a project timeline is provided in Figure 3.

Figure 3: Project Timeline



Source: Center for Sustainable Energy

The HVAC replacements to new high-efficiency units were not deemed as feasible due a high payback in cost savings. At Serra Mesa-Kearny Mesa and Valencia Park/Malcolm X, a select

rooftop unit (RTU) was not replaced, and at Point Loma/Hervey, an air handler unit (AHU) was not replaced as originally proposed by the designer.

To provide support for energy storage planning at the libraries, the team conducted an energy storage analysis for each library in Energy Toolbase™ for the City. The preliminary analysis results recommended a potential battery storage system at Serra Mesa-Kearny Mesa (90 kW/360 kWh) and Valencia Park/Malcolm X (116 kW/464 kWh) to use excess PV production throughout the year and discharge during peak times when energy is typically consumed from the utility grid. With Point Loma/Hervey's smaller PV system, there is not enough excess PV production to justify the cost of installing battery storage. Due to schedule constraints and the long lead time to acquire battery systems, energy storage was not installed at any of the sites under the project.

The updated designs, ECM costs and energy savings omitting the HVAC replacements were provided to the Energy Commission and the City for approval.

Costs and Estimated Energy Savings

ECM installation (only excluding minor weatherization), construction management and permit costs were budgeted and identified in Table 6. The costs do not include baseline monitoring, design, ongoing maintenance, etc. Total energy consumption and peak demand were estimated to be reduced by 239,704 kWh and 84 kW, equal to an estimated $33,655 in savings per year using energy models.

The cost of the measures, including construction management and permit costs are identified in Table 6. The costs do not include the baseline monitoring, design, ongoing maintenance, etc. Total energy consumption and peak demand were estimated to be reduced by 239,704 kWh and 84 kW using the energy modeal, equal to an estimated $33,655 in savings per year and a 170 metric tons of carbon dioxide equivalent (MTCO2e) reduction per year. The percent kWh reduction was 13 percent at Serra-Mesa Kearny Mesa, 28 percent at Valencia Park/Malcolm X and 29 percent at Point Loma/Hervey Library.

Table 6: Estimated Total Library Energy Conservation Measures Bill Savings versus Project Cost

Energy Conservation Measure	Electricity Savings (kWh/yr.)	Total Energy Savings (kBtu/yr.)	Electricity Savings ($)	Peak Demand Savings (kW)	Est. Retrofit Costs ($)
Lighting Retrofit	160,662	548,179	21,864	39.1	442,149
Lighting Controls	24,528	83,690	2,908	6.5	347,403
HVAC Controls + Tridium Building Automation	38,813	135,365	7,124	33.3	194,353
Plug Load Management Devices	14,002	47,775	1,485	4.3	12,900
TOTAL	**239,704**	**821,099**	**33,655**	**83.9**	**1,322,364**

Source: Center for Sustainable Energy

The libraries were evaluated for eligibility under SDG&E's Technology Incentives (TI) Program to provide incentives for the purchase and installation of certain automated demand response measures.[6] Participants in the program receive 60 percent incentive payment upfront and then the 40 percent remainder payment after the demand response savings are verified. SDG&E provided a one-time payout estimate based on the pre-retrofit demand of each library. They estimated approximately $15-20,000 in one-time savings per library. Unfortunately, since the libraries are designated as "Cool Zones," they were unable to enroll. Cool Zones are public places for the public to escape mid-day summer heat between May to October. Thus, each library's electricity load may not be able to be reduced enough during peak grid days due to maintaining a cool building.

Furthermore, the libraries were evaluated for eligibility in additional SDG&E energy efficiency incentive programs. SDG&E provided cost-savings estimates. Unfortunately, the ECMs planned were not eligible or the savings from the program were not great enough submit the application and verification required.

[6] *Save on Upgrades with the Technology Incentives Program.* San Diego Gas and Electric. https://www.sdge.com/businesses/savings-center/energy-management-programs/demand-response/technology-incentives

CHAPTER 4: Construction

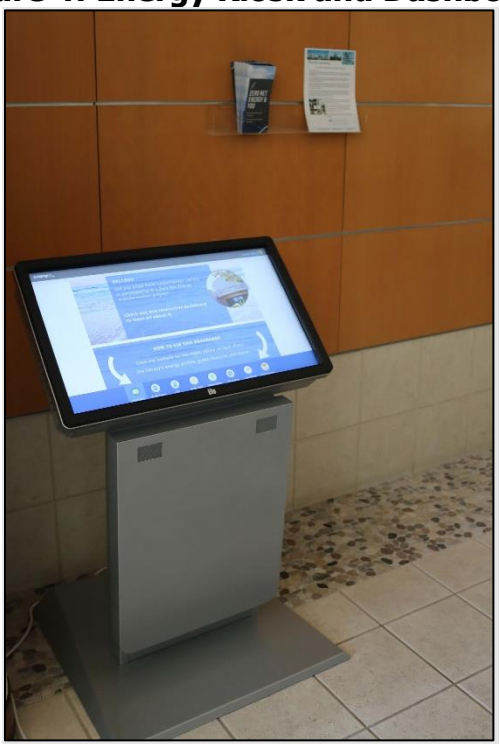
While designs were being adjusted and utility programs evaluated, a bidding package, budget and project schedules were finalized with the City. Due to lighting bids that exceeded the project budget, a value engineering lighting package was developed to bring the project within budget.

It was very important for the project team to schedule work that avoided library closures and to inform visitors about possible disruptions. Furthermore, work would occur at all three libraries simultaneously, with different crews would be assigned to each library. Visitors were notified of ongoing work. The Library managers alerted those with conference room reservations of possible schedule changes, and the presence of dust/debris as well as noise during the installation period. The public was also appreciative that the library would remain open during installation.

Prior to installation, the San Diego Green Building Council held presentations with information tables events at each library. They held 12 separate information table events, spoke with 253 visitors and handed out marketing collateral. Most of the public responses were positive and they expressed approval that the libraries were going to have better lighting and become energy efficient.

To further engage and educate library patrons, kiosks were installed that displayed project information, near real-time total energy use and PV generation to educate visitors (Figure 4).

Figure 4: Energy Kiosk and Dashboard



Source: San Diego Green Building Council

Energy Conservation Measure Installation

ECM installation began in February 2020 and was completed in April 2020, upon final inspections. All three libraries received lighting retrofits and controls, plug load management devices and the Tridium building automation system (BAS) with BACnet to integrate HVAC controls, lighting controls, plug load devices and energy monitoring equipment. Valencia Park/Malcolm X also received HVAC controls that were BACnet-capable unlike the other two libraries that already had BACnet HVAC controls.

Lighting Retrofits and Controls

LED lighting fixtures and/or lighting retrofit kits/lamps were installed. Lighting control panels were replaced with systems capable of BACnet communication for integration to the BAS and with additional local programming capabilities. The lighting controls integration allow for remote control of the lighting with on/off function of various zones preprogrammed and aligned for each library's operating hours.

Overall, lighting levels were significantly increased. The new central lighting control systems and programmed lighting schedules ensure lights shut off to conserve energy, whereas before the retrofit, lights were left on after hours.

Plug Load Management

To manage and control the energy consumption of plug loads, the Bert smart plugs was a recommended as an emerging technology (Figure 5). The plugs were installed between the power cables for various devices such as copiers and printers, and the wall receptacle. They were also connected to the Wi-Fi network to integrate with the Tridium BAS and enable a programmable daily schedule aligned with staff arrival. Two smart plugs were installed at Serra Mesa-Kearny Mesa, eight at Valencia Park/Malcolm X and four at Point Loma/Hervey.

Figure 5: Bert Plug Load Management Device

Source: City of San Diego

Tridium Building Automation and Heating, Ventilation, and Air Conditioning Controls

Viconics HVAC controllers were installed at Valencia Park/Malcolm X and each library had a Tridium Niagara N4 BAS installed. The Tridium control system includes a supervisory-level control front-end system installed on a centralized city server along with a JACE (Figure 4) with BACnet drivers and additional LON drivers to communicate to the existing Trane controls. The system manages all HVAC controls (existing Trane and new Viconics), on/off lighting controls and the Bert smart plugs. It also reports real-time energy data from the Autani energy monitoring devices installed at the libraries. The BAS upgrade is able to reveal additional control strategy opportunities once energy trends are evaluated and control sequences are optimized.

Figure 6: Tridium Building Automation System JACE

Source: City of San Diego

Challenges Encountered

During installation, several challenges were encountered including a change to a planned chiller replacement outside the project, Title 24 energy efficiency requirements, completing building envelope improvements, Bert device connectivity, and the need to schedule overnight work and planning due to COVID-19 impacts.

Point Loma/Hervey Chiller Replacement

The City initially planned to replace the chiller at Point Loma/Hervey library during the installation of the project's ECMs, but it was not able to be replaced in tandem. The City is working on a revised schedule to complete the installation, likely within the next year.

Title 24 Requirements

The timing of the CEC's updates to the Building Energy Efficiency Standards (Title 24) did not allow the project's permitting applications to be submitted prior to the code change effective on January 1, 2020.[7] As a result, lighting designs must be updated to meet the new code to obtain building permits, which delayed installation work by about three weeks. Lighting retrofits were installed at 80 percent of the 2019 Title 24 baseline requirements.

[7] *Building Energy Efficiency Standards-Title 24.* California Energy Commission. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards

Building Envelope

Valencia Park/Malcolm X features a large cylindrical glass window with two glass doors which is responsible for a large solar heat gain during the day. A half-inch gap was found along the perimeter of the doors resulting in air infiltration and heat loss. Installation of window film and weather-stripping were planned to reduce solar heat load and improve occupant comfort. However, due to Title 24 requirements and additional design efforts, this improvement was deemed to have the least impact on savings This measure was not completed to allow the project to remain within budget and complete on time.

Bert Wi-Fi Connectivity and Site Constraints

Due to a low Wi-Fi connectivity and site constraints identified in a site assessment, only 14 of the originally planned 21 plugs were installed. The City will determine whether any other Bert plugs can be installed with a boost to the Wi-Fi signal and/or if they can be installed at other plugs locations.

Overnight Work and COVID -19

Following the library closures, a statewide shelter-in-place order was issued for California on March 19, 2020, which led to a temporary work stoppage as all partners needed to ensure compliance with the order. This delayed installation completion by about a week, but work continued as it was deemed essential work. COVID-19 project impacts included some crew members being unable to continue working, lighting control panel shipments being delayed, masks and social distancing were required on site and an on-site training was conducted with a mix of in-person and virtual attendees.

CHAPTER 5:
Commissioning and Retrocommissioning

Commissioning

To ensure all the modified or new systems were functioning within designed operational requirements, commissioning was performed. Further, the compliance of these systems with the design intent was verified by a commissioning agent. Most critically, the initial commissioning of the building systems will ensure the success of near-ZNE outcomes, ensure financial and environmental savings, potentially increase the equipment lifespan, improve occupant comfort and reduce maintenance callbacks.

The commissioning verification process included testing all lighting devices and Controls, HVAC operation, programming temperature setpoints and setbacks, and required airflow to each HVAC zone. Proper configuration and operation of the building management system was performed to ensure network connectivity and transfer of data associated with M&V.

Retro-commissioning and Energy Conservation Measure Training

Retro-commissioning was also performed after the ECM installation to optimize equipment operation and functionality of existing and dynamic energy-consuming systems, such as lighting and heating, HVAC and associated controls. The process evaluated the need for repair or calibration of certain equipment and helped provide recommendations for necessary capital improvements and ongoing operations and maintenance (O&M) best practices.

Existing equipment was inspected and evaluated by a qualified commissioning agent based on the originally intended operation of each building. All sequences of operations for the selected equipment, including alarms and rated equipment efficiencies, were verified. Lastly, all operations that affected energy use were identified, and alternative operations will be recommended and implemented. The following systems were retro-commissioned at each library:

- Building automation systems
- Cooling systems
- Heating systems
- Ventilation
- Lighting systems
- Domestic hot water

The retro-commissioning had the following main goals

- Bring equipment and associated systems to their proper operational state
- Increase equipment reliability and lifespan to reduce emergency service calls
- Reduce energy and demand costs
- Increase staff and visitor comfort levels within the space
- Identify any necessary capital improvements or O&M opportunities

Efforts included a pre-function checklist and testing parameters, a list of O&M opportunities, a master list of improvements and a continuous plan for monitoring and function testing. The roles and responsibilities were collaborative and carried out by multiple members from the project team including CSE, City of San Diego and the retro-commissioning agent. Several ongoing O&M and retro-commissioning efforts were identified and will be addressed after the project's end. Additionally, on-site and online trainings for ECMs were provided in April 2020 to City library, facility and sustainability staff.

Ongoing Maintenance

The PV systems installed through a power purchase agreement will follow maintenance recommended by the power purchase provider.

Following the BAS installation, the City of San Diego Facilities Department entered an annual software maintenance contract with Climatec for the new equipment. They will provide manufacturer-released patches and updates, on a quarterly basis, to the Tridium Niagara software and JACE devices at all three libraries. This contract also includes the cost of the annual software subscription for Tridium Supervisor and the licensing renewal cost per JACE.

Software support was included for the installed plug load management devices by BERT® Plug Load Control for three years following the completion of the project and is therefore covered for that time period. However, there were several plug load management devices listed in the Report of Installation Activities[8] that could not be connected. Once the signal issue is addressed, the remaining devices can be installed and connected to BACnet and the BAS.

Additional preventative maintenance services were recommended quarterly for the year for the BAS main operator workstation, network and global control modules. The preventative maintenance includes analyzing the number of operator or system change occurrences for impact on performance, analyzing network communication, reviewing trend and alarm logs, monitoring LED sequencing, inspecting wiring for signs of fraying and removing excessive dust from internal surfaces. It is recommended that the City of San Diego consider adding these additional maintenance services.

LED Lighting

The LED lighting includes a five-year factory warranty. The LED lighting installer, recommended cleaning fixtures on a regular basis (about every three months) to prevent failures. Dust buildup and precipitation or a jolt or knock to the lighting fixtures, could cause the wiring connections to become malfunction.

Kiosks and Submeters, HVAC and Lighting Controls, and HVAC Units

The City of San Diego has an additional seven-year pre-paid subscription (until 2028) with AcuityBrands® to maintain the energy dashboard displays.

Climatec and ABM did not note preventative maintenance for HVAC and lighting controls or submeter equipment for all libraries. However, during commissioning and retro-commissioning

[8] Report of Installation Activities. 2020. Center for Sustainable Energy: https://sites.energycenter.org/sites/default/files/docs/microsites/sdzn3/Final_EPC-15-085_Report_of_Installation_Activities.pdf

of the HVAC controls, the following maintenance activities were recommended for HVAC units at all libraries. Additionally, recommendations for each individual library were provided such as repairing economizer dampers, install air temperature sensors, repair air sensors, repair HVAC units and rebalance airflow.

All Library Units

1. Change HVAC air filters every three to four months. This causes healthier indoor air quality for library occupants, increased efficiency for air conditioner units, and reduced energy cost for the supply fans operations (with clean filters compared to dirty filters).
2. All AC, Chiller and air handler units should receive regular maintenance as identified in the operations and maintenance manuals.

Ongoing Retro-commissioning

Retro-commissioning can reduce operating costs and improve functionality of building systems that have deviated from their original design or operations. Retro-commissioning for commercial buildings is recommended about every three-five years. This can identify irregularities attributable to set points, schedules, sequencing, and controls programming. Furthermore, it is recommended that to the City of San Diego should consider optimal demand shifting and shedding adjustment when retro-commissioning.

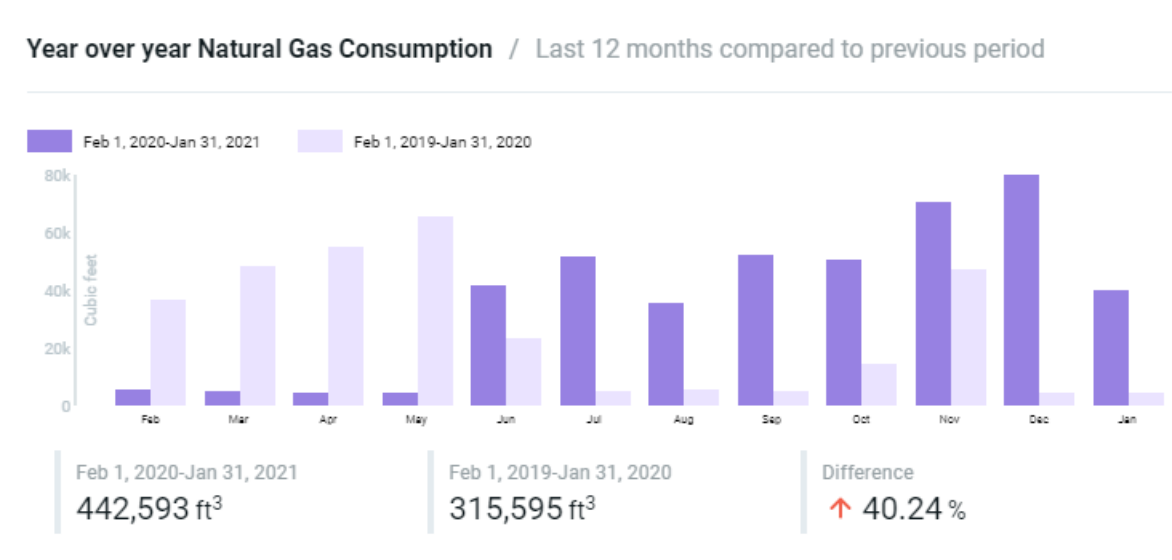
Point Loma/Hervey Library Retrocommissioning Recommendations

Starting in June 2020, the building OS energy dashboard for the Point Loma/Hervey Library identified that there was a large increase in gas use that continued through January 2021 (Figure 7). HVAC controls and units at the library were serviced in September 2020 to identify and fix the issue but the increase in gas use has continued through January 2021.

A deeper analysis was completed with the Point Loma/Hervey BAS data to identify the issue. The findings were:

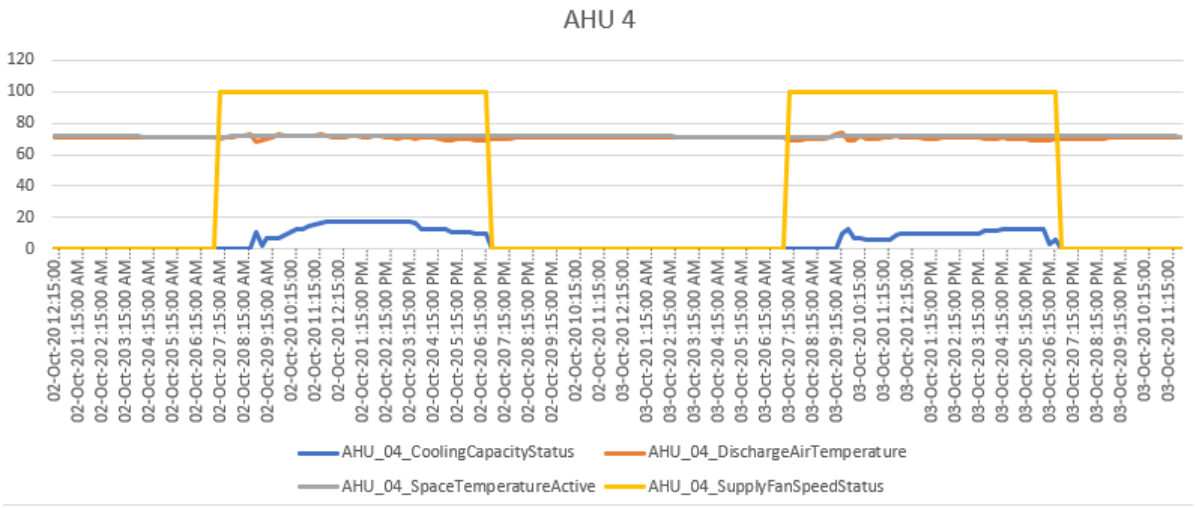
- Five air handler units (AHU)'s had heating turning on during unoccupied hours (AHU 1, 3, 5, 8 and 9). Figure 8 shows how an AHU was running as expected (AHU 4), while Figure 9 shows an AHU that turned heating on during unoccupied hours (AHU 5).
- Many units had inaccurate values reported (specifically cooling capacity at 100 percent during unoccupied times when unit was off). Reporting values for each unit were static and not reporting properly or were otherwise defaulting to 100 percent, instead of 0 percent when off.
- AHU 1 and 10 was reported to be cooling during some of the nighttime hours.
- Although the space temperatures for the units were good, mostly between 72-74 degrees Fahrenheit, the AHU-1 ‘s space temperature dropped to 61 degrees Fahrenheit. This indicated that cooling might have been running during night hours.

Figure 7: Point Loma/Hervey Year over year Natural Gas Consumption (February 2020 – January 2021)



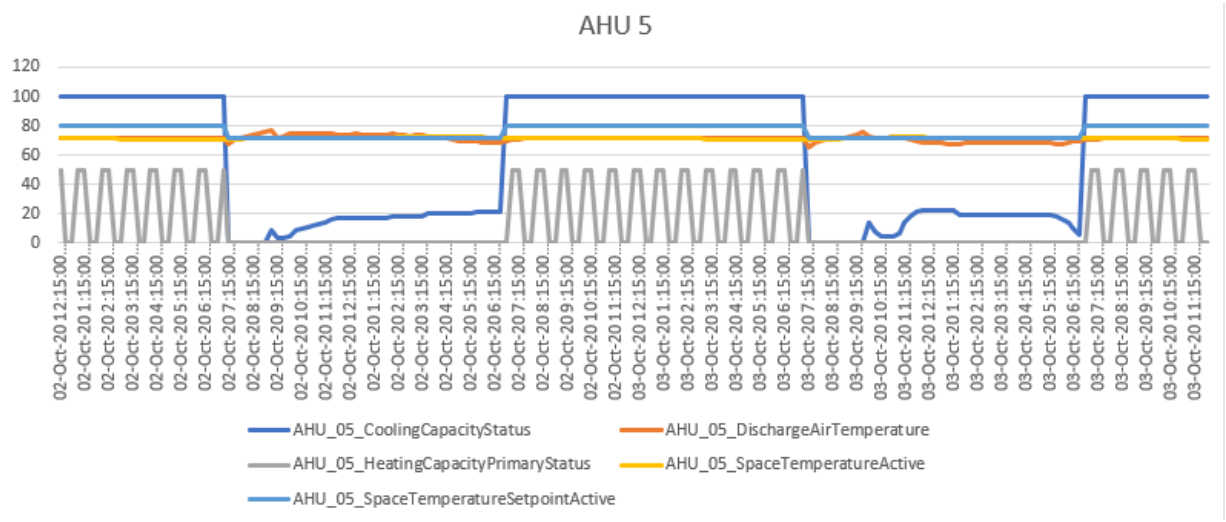
Source: Center for Sustainable Energy

Figure 8: Point Loma Hervey Air Handler Unit 4 Operation Analysis (October 2-3, 2020)



Source: Center for Sustainable Energy

Figure 9: Point Loma Hervey Air Handler Unit 5 Operation Analysis (October 2-3, 2020)



Source: Center for Sustainable Energy

Optimal Demand and Load-Shifting Recommendations

The 2017 baseline electric time-of-use (TOU) energy consumption data was compared to the 2020 post-retrofit measurement and verification electric TOU data from May to October. This confirmed that the retrofits decreased energy consumption and demand during high-energy use (on-peak) times as defined by SDG&E. As a result, the three libraries have less on-peak (4 p.m.- 9 p.m.) and off-peak (9 p.m.-12 a.m. and 6 a.m. – 4 p.m.) consumption, and some consumption was shifted to super off-peak (12 a.m. – 6 a.m.). As a result, the cost is reduced.

For optimal demand and load shifting/shedding, all systems should be verified as being off when they should be, even if this would require an after-hours visit to confirm. HVAC pre-cooling/heating prior to occupied morning hours or the 4 p.m. on-peak TOU period could be programmed. However, this would require additional approval from the City of San Diego, as this was not included in the energy models.

CHAPTER 6:
Measurement and Verification

After energy efficiency retrofit activities were concluded, the M&V began on May 1, 2020. The first (Q1), second (Q2), third (Q3) and fourth quarter (Q4) detailed M&V findings are documented in the *May-July 2020 Measurement & Verification Report, August-October 2020 Measurement & Verification Report and November 2020-April 2021 Measurement and Verification Report.*[9] All quarterly data were combined to form an annual projection of library energy use.

Energy consumption data was collected from the BuildingOS online platform to analyze Q1-Q3 M&V energy performance. The BuildingOS Energy Dashboard implemented at each library acts as the central portal for data collection, interpretation and visualization. The following data points were identified from the BuildingOS portal for November 1, 2020 through January 31, 2021:

- Autani Panel Meter kWh – 26 Total (15-min Intervals)
    - 10 at Point Loma/Hervey
    - 7 at Serra Mesa-Kearny Mesa
    - 9 at Valencia Park/Malcolm X
- SDG&E Grid Consumption kWh (Hourly Intervals)
- PV Production kWh (15-min Intervals)
- Natural Gas Consumption therms (Monthly Intervals)

Due to the extenuating circumstances of COVID-19 closures and changing occupancy schedule during the M&V period, the remaining Q4 energy consumption estimates were forecasted using the energy consumption from Q1 through Q3 of the M&V period. The estimated Q4 energy consumption was combined with an estimated solar PV production for Q4 using PV Watts.

Annual Energy Performance Assessment

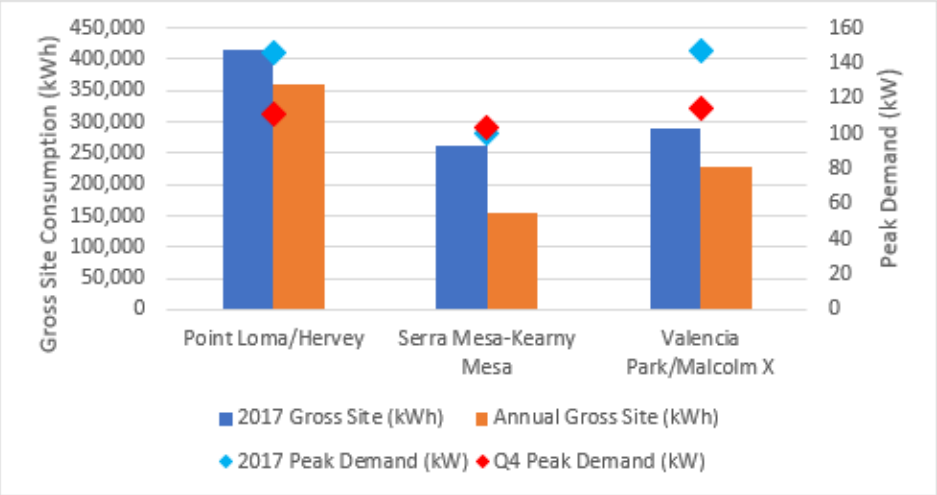
Electric Consumption

As estimated in the *Report of ECM Integration Activities and Financial Considerations*[10], all libraries are expected to decrease their annual electric consumption (Figure 10).

[9] *EPC-15-085: May-July 2020 Measurement and Verification Report*. 2020. Center for Sustainable Energy.; *EPC-15-085: August-October 2020 Measurement and Verification Report*. 2020. Center for Sustainable Energy.; *EPC-15-085: November 202-April 2021 Measurement and Verification Report. 2020*. Center for Sustainable Energy.

[10] *EPC-15-085: Report of ECM Integration Activities and Financial Considerations for City of San Diego Public Library ZNE Demonstration Project*. 2019. Center for Sustainable Energy.

Figure 10: Projected Annual Gross Site Electric Consumption Comparison (May 2020-April 2021 vs. 2017)

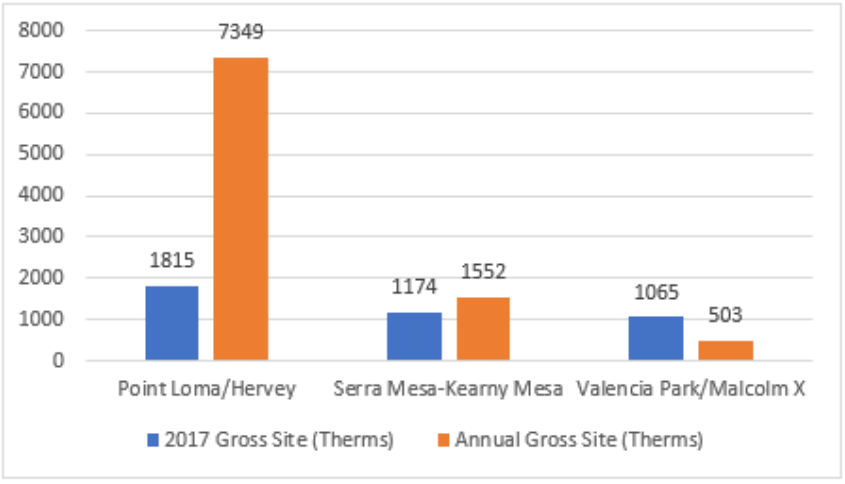


Source: Center for Sustainable Energy

Gas Consumption

Natural gas consumption and savings were not the focus of this project, however, when calculating ZNE valuations, it is important for energy expenditures. Point Loma/Hervey Library is projected to have the highest annual gross gas consumption post-retrofit (Figure 11). The gas consumption at Point Loma/Hervey is still uncharacteristically high when compared to previous years without Covid-19 operations and weather conditions as noted in the *Ongoing Retro-commissioning and Maintenance Plan*.[11] Serra Mesa-Kearny Mesa will have the lowest annual gross gas consumption.

Figure 11: Projected Annual Natural Gas Consumption Comparison (May 2020-April 2021 vs. 2017)



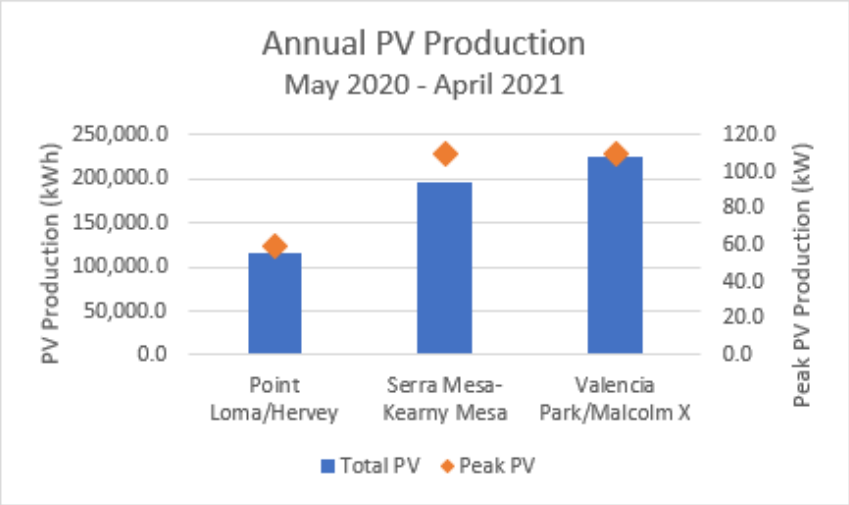
Source: Center for Sustainable Energy

[11] *EPC-15-085: Ongoing Retrocommissioning and Maintenance Plan*. 2021. Center for Sustainable Energy.

Photovoltaic Generation

The onsite PV systems provided a source of generation that offset grid consumed electric and is critical to achieving ZNE or near-ZNE status. During the libraries' COVID-19 shutdown and as measured during Q1-Q3, PV accounted for a larger-than-estimated portion of the site's electrical consumption (Figure 12). It should be noted that in both Q2 and Q3, the PV system at Point Loma/Hervey was underperforming based on measured data. The PPA provider was notified for further investigation. Annual PV generation projections are provided in Figure 6. Point Loma/Hervey is projected to generate the least PV energy (116,836 kWh), followed by Serra Mesa-Kearny Mesa (195,634 kWh) and Valencia Park/Malcolm X (224,615 kWh).

Figure 12: Projected Annual Photovoltaic Production (May 2020-April 2021)



Source: Center for Sustainable Energy

Cost-Benefit Analysis

A cost-benefit analysis was performed by using the upfront cost of the ECMs by library and estimating the annual energy costs by library using Q1-Q3 utility bills and monthly power purchase agreement payments ($/kWh of PV production) to estimate Q4 energy costs (Table 7 and 8). Pre-retrofit, the libraries were enrolled in SDG&E's AL-TOU-CP2 electric tariff and GN-3 gas tariff.[12] Post-retrofit, the libraries were enrolled in the SDG&E's Time of Use Plus - ALDG-R-Commercial and stayed enrolled in the GN-3 gas tariff.

Valencia Park/Malcolm X had the highest retrofit cost and realized the most cost savings. Conversely, Point Loma/Hervey had the lowest retrofit cost and did not realize cost savings due to an increase in natural gas use likely caused by a controls issue. The LED lighting had the highest savings at all three libraries. In terms of benefits/savings, due to COVID-19 health restrictions during the M&V period, cost savings under post-COVID operations will need continued measurement and verification. However, under COVID-19 operations, Valencia Park/Malcolm X had a simple payback of approximately 10 years and Serra Mesa-Kearny Mesa

[12] *EPC-15-085: Building Energy Baseline & Modeling Report for the City of San Diego Public Library ZNE Demonstration Project*. 2018. EPC-15-085_Baseline_and_Modeling_Energy_Report.pdf (energycenter.org).

approximately 15 years including the installation of PV. Under current conditions, Point Loma/Hervey did not reflect a positive payback.

Table 7: Cost of Energy Conservation Measures Retrofit by Library

Measure	Point Loma/Hervey	Serra Mesa-Kearny Mesa	Valencia Park/Malcolm X
Permits & Management	$108,519.35	$108,519.40	$108,519.35
LED Lighting	$115,398.00	$127,392.70	$199,358.72
Lighting Controls	$90,669.86	$100,094.30	$156,638.99
BAS & HVAC Controls	$46,150.00	$44,450.00	$103,753.35
Smart Plugs	$4,690.90	$3,518.18	$4,690.90
Total	**$365,428.11**	**$383,974.58**	**$572,961.31**

Source: Center for Sustainable Energy

Table 8: Projected Annual Cost Savings by Library

Type of Cost/Savings	Point Loma/Hervey	Serra Mesa-Kearny Mesa	Valencia Park/Malcolm X
Pre-retrofit Electric Cost	$ 95,366.00	$ 65,282.66	$ 79,737.00
Pre-retrofit Utility Gas Cost	$ 1,140.31	$ 931.54	$ 858.82
Post-retrofit Utility Electric Costs & PPA Payments	$ 91,170.13	$ 27,573.98	$ 41,443.85
Post-retrofit Gas Cost	$ 7,971.15	$ 1,778.46	$ 657.78
Total Electric Savings	$ 4,195.87	$ 37,708.68	$ 38,293.15
Total Gas Savings	$ (6,830.84)	$ (846.92)	$ 201.04
Total Energy Savings	**$ (2,634.97)**	**$ 36,861.76**	**$ 38,494.19**

Source: Center for Sustainable Energy

Zero-Net Energy Verification

The project team used the Energy Commission definition of a ZNE building,[13] also known as ZNE Time-Dependent Valuation (TDV) definition to assess whether the libraries achieved ZNE

[13] *Reducing Costs for Communities and Businesses through Integrated Demand-side management and Zero Net Energy Demonstrations.* California Energy Commission. 2015. GFO-15-308, page 3. http://www.energy.ca.gov/contracts/GFO-15-308/01_Application_Manual_GFO-15-308_2015-11-02.docx

or near-ZNE. In addition, "ZNE Site" and "ZNE Source" definitions[14] were evaluated to enable comparison to other ZNE projects who use these industry metrics.

Considering the seasonal variations in energy consumption and onsite PV production, ZNE status must be evaluated on an annual basis. There were four ZNE calculations evaluated: TDV [15], Site, Source[16], and Electric Only/ZNE Electric.[17] Pre-M&V ZNE estimates indicated that Valencia Park/Malcolm X would achieve ZNE, Serra Mesa-Kearny Mesa would be near-ZNE and Point Loma would be a high-performance building (Table 9). Post-ZNE projections indicate Serra Mesa-Kearny Mesa will reach ZNE, Valencia Park/Malcolm X will be near ZNE, and Point Loma will be a high-performance building, although not as close as estimated (Table 10).

Table 9: Pre-Measurement and Verification Estimated Library Net Zero Ner Energy Values Values (Post-Retrofit Consumption Minus Photovoltaic Generation)

ZNE Value	Serra Mesa	Valencia Park	Point Loma
TDV (kBtu/ft^2/yr.)	62	29	178
Site (kBtu/yr.)	291,100	159,661	734,938
Source (kBtu/yr.)	367,803	80,886	1,915,877
Electric Only (kWh)	19,555	-3,245	159,621

Source: Center for Sustainable Energy

[14] *ZNE Definitions and Key Considerations*. New Buildings Institute. 2013. https://gettingtozeroforum.org/wp-content/uploads/sites/2/2017/08/ZNE_Definitions.pdf

[15] Reducing Costs for Communities and Businesses through Integrated Demand-side management and Zero Net Energy Demonstrations (GFO-15-308). 2015. California Energy Commission. Page 3.

[16] Used same Energy Start multiplier (2.80) for electricity and onsite PV production to match Pre-M&V calculation. State of California uses 3.15 and same multiplier for electricity and onsite PV production. https://www.dgs.ca.gov/-/media/Divisions/OS/ADA-Checked/ZNE-Calculator/StateofCAZeroNetEnergyCalculator.xlsx?la=en&hash=5BE1AAAF86A1C39B29B0D85FB3E0C44B721F9EB9&hash=5BE1AAAF86A1C39B29B0D85FB3E0C44B721F9EB9

[17] The Vocabulary of ZNE: A Guide to Zero Net Energy Terminology. 2015. New Buildings Institute. https://gettingtozeroforum.org/wp-content/uploads/sites/2/2017/08/ZNE_NBI_CommsToolkit_Terminology_.pdf

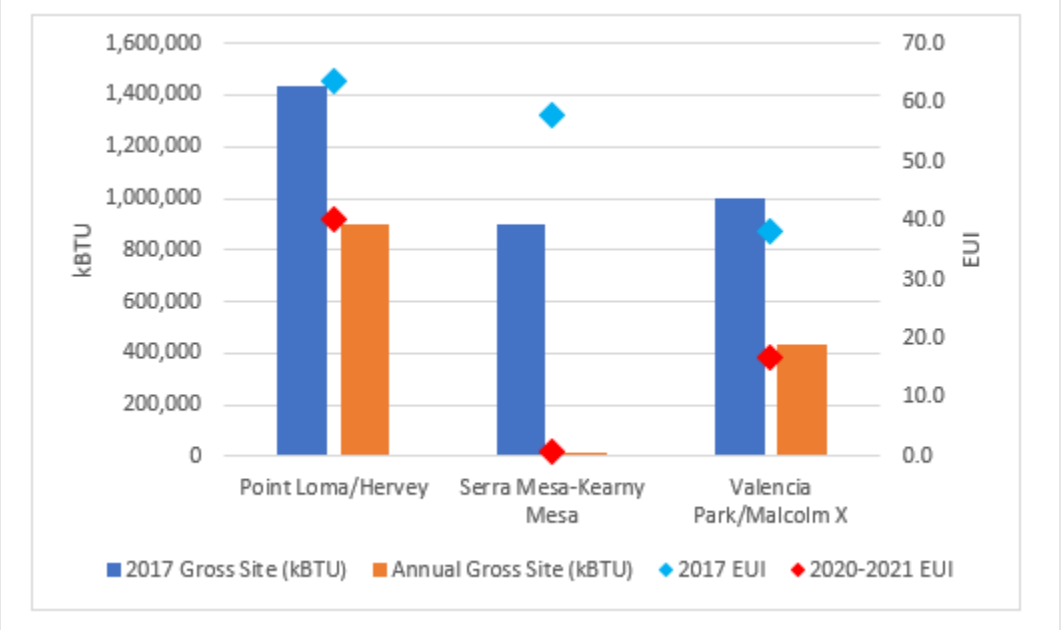
Table 10: Post-Measurement and Verification Projected Library Net Zero Net Energy Values (Post-Retrofit Consumption Minus Photovoltaic Generation)

ZNE Value	Point Loma/Hervey	Serra Mesa -Kearny Mesa	Valencia Park/Malcolm X
TDV (kBtu/ft^2/yr.)	305.7	-26.7	92.5
Site (kBtu/yr.)	835,803	-138,139	7,925
Source (kBtu/yr.)	2,327,389	-389,506	21,310
Electric Only (kWh)	242,806	-40,941	2,175

Source: Center for Sustainable Energy

EUI is another important indicator to compare energy-efficient buildings. Pre-retrofit EUIs and post-retrofit net EUIs (PV generation accounted for) for each library are detailed in Figure 13.

Figure 13: Pre-Retrofit Versus Post-Retrofit Net Energy Use Intensity



Source: Center for Sustainable Energy

Ongoing Efforts

One of the three libraries is projected to achieve ZNE between May 2020 to April 2021. The Serra Mesa-Kearny Library, and the Valencia Park/Malcolm X Library are expected to achieve near-ZNE. However, the Point Loma/Hervey Library will not achieve full estimated savings due to an unidentified issue, as noted in Chapter 5. It is recommended that City of San Diego continue to investigate the natural gas spike at Point Loma as well as monitor the energy consumption and PV generation at the libraries into 2022 to verify ZNE status, individual ECM savings, and simple payback of all measures of the libraries under post-COVID library operations.

CHAPTER 7:
Behavior Analysis

A behavior analysis was conducted to identify interactions between building energy consumption (baseline and post-construction), weather/climate patterns and building occupant behavior at each library.

CSE used a mixed methods research approach to better understand the role human behavior has on energy conservation measures (ECMs) by surveying various building occupants to assess their knowledge and understanding of ECMs and their interactions with them. CSE combined this information with a quantitative analysis of time-series cross-sectional data for each of the three libraries to explore how various factors affected energy demand across time. The results of these tasks are summarized in two behavior analysis summary reports, one pre-construction, one post. These summaries provided insights on ways to improve occupant behavior to ensure savings and assist building operators to increase or maintain high levels of comfort and satisfaction among occupants.

Occupant surveys were completed to explore occupant behaviors, perceptions and relationships with ECMs with the goal of identifying building occupants' motivations and to leverage opportunities for more efficient use of ECMs to ensure sustainable energy savings.

The primary questions the surveys attempted to answer were:

- What were the occupants' pre-construction perceived comfort levels?
- What were the occupants' pre-construction observations regarding areas to address with ECMs?
- How did building occupants interact with the ECMs?
- How did building occupants think their interaction with ECMs impacted building performance?
- What motivated occupants to engage in energy saving behaviors?
- What is the post-construction occupant comfort level and were there any perceived changes?

The pre-retrofit survey took place between April–May 2018 and the post-retrofit took place from October-November 2020. The provided the following key findings.

- **Awareness of energy conservation measures:** There was an increase in the percentage of library staff, who were aware of energy conservation measures after retrofits were complete.
- **Thermal Comfort:** After retrofits, most respondents reported an increase in thermal comfort at the front desk and workroom areas, where staff spends much of their time. Comfort levels varied between specific spaces at the three libraries, and some reported discomfort.
- **Lighting brightness:** Respondents at Point Loma/Hervey and Valencia Park/Malcolm X staff seem satisfied with lighting brightness after the retrofits. Serra Mesa-Kearney Mesa reported the dimmest or too bright areas.

- **Lighting sufficiency:** Lighting sufficiency varied in different workspaces at the libraries, but overall, respondents from all three libraries responded more positively about daylight and lighting sufficiency. Brighter lights were still desired in some areas, while excessive direct sunlight was still reported in others.
- **Lighting controls:** Most respondents still do not know, or were not familiar with, lighting controls at their libraries.
- **Plug load management:** Responses were mixed on if the smart plugs were working properly and some respondents noted they removed them. More education is needed regarding operation of the smart plugs.
- **Daytime temperatures:** Although Serra Mesa-Kearny Mesa and Valencia Park/Malcolm X Libraries reported overall comfortable temperatures, daytime temperature imbalances were identified as a continued problem in all three libraries. Point Loma/Hervey Library reported the most uncomfortable areas.
- **Temperature controls:** Respondents at the three libraries reported an increase of temperature controls at front desk areas but there were still many areas that lacked temperature controls.
- **Behavior:** Half of all library respondents agreed their behaviors helped conserve energy after retrofits were complete. This was an increase from the pre-retrofit surveys, where more than half of respondents at the three libraries felt neutral.

Awareness of energy conservation measures could be further increased among library staff, maintenance workers and library patrons by consolidating and extending the lessons learned through the retrofit experience to a broader audience. Some respondents are engaged in energy-saving practices which can be expanded upon for further awareness, education. These three libraries This could in turn motivate new staff, visitors and community members.

Some recommendations include:

- Extend ZNE education to new employees and volunteers when they return, as well as library customers.
- Follow up with library managers on thermal and lighting sufficiency concerns in work areas that were reported with the most issues.
- Further educate library staff on existing lighting and temperature controls.
- Follow up with library managers on which smart plug devices have been removed and see if the devices needed more time to learn on-off patterns.
- Work with library managers to investigate, develop and enact environmental policies.

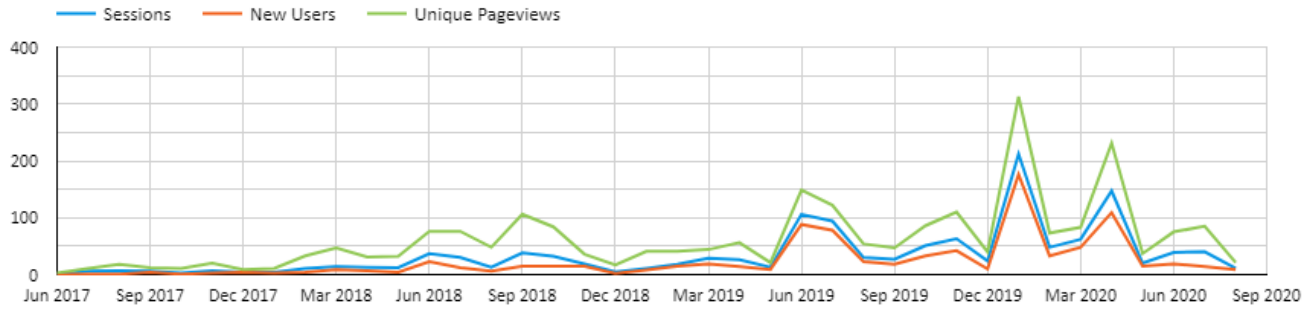
CHAPTER 8:
Technology/Knowledge Transfer Activities

One of the goals of technology and knowledge transfer was to educate the City's elected officials, sustainability department staff, library department staff, other local governments, related industry stakeholders and the community to show the transformation of municipal buildings into ZNE or near-ZNE facilities. The activities included a project website, policy development, webinars, conference presentations, case studies and fact sheets, building tours, energy dashboards, sponsored events, and a technical advisory committee (TAC).

Website

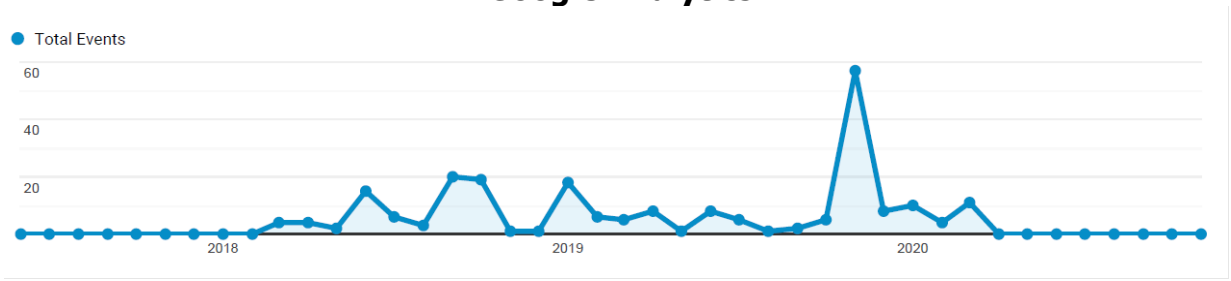
The dedicated project website was the primary communication pathway for project information to facilitate ongoing knowledge transfer and education. The dedicated website (https://energycenter.org/sdzn3) had 2,410 site visits from June 1, 2017 to November 18, 2020. It consists access to each energy dashboard, ZNE activities, technology descriptions, frequently asked questions and other relevant information. Project reports, webinars, events and other collateral were posted to the website as appropriate. Figure 14 provides the Google Analytics project webpage total views over time graph. Figure 15 provides a visualization for product downloads, referenced as "events," since files were available in February 2018.

Figure 14: Total Views - SD ZN3 Project Webpage
Google Analytics



Source: Center for Sustainable Energy

Figure 15: Total PDF Downloads - SD ZN3 Project Webpage
Google Analytics



Source: Center for Sustainable Energy

The page had more than 1,000 unique visits. Information about the project (including the website link) was shared through City of San Diego marketing channels such as the San Diego County News[18] and San Diego Newspaper Group[19] to notify elected officials, sustainability and the community about the work being conducted at the three libraries. The highest number of downloads occurred at the time as well, and a breakout of report downloads is shown in Table 11.

Webinars

Two webinars were held to provide local government/policymaker and industry stakeholder target audiences with an opportunity to benefit from project successes and lessons learned. Attendees learned about various phases of the project. Table 12 describes the completed webinar topics and timeframes. Webinar speakers included project managers from CSE and project partner representatives from the City of San Diego, San Diego Green Building Council and SDG&E.

Table 11: SD ZN3 Total PDF Downloads from Project Webpage by Document Google Analytics

PDF Downloaded	Unique Events (Downloads)*
Other**	46
Point Loma Library Audit	32
Serra Mesa Library Audit	35
Valencia Park Library Audit	21

*** Unique Events are interactions with content by a single user within a single session that can be tracked separately from pageviews or screen views. In this instance, a Unique Event refers to a download of a report by a single user. Downloads, mobile-ad clicks, video plays and interactions with gadgets, Flash elements and AJAX embedded elements are all examples of interactions you might want to track as Unique Events.**

**** "Other" represents all remaining posted reports including the Baseline & Modeling Report, Integration and Installation Reports posted most recently.**

Source: Center for Sustainable Energy

[18] *San Diego tackles climate change with zero net energy project at three libraries*. 2020. San Diego County News. https://sandiegocountynews.com/san-diego-tackles-climate-change-with-zero-net-energy-project-at-three-libraries/

[19] *Point Loma Library being retrofitted to attain zero net energy*. 2020. San Diego Newsletter Group. http://sdnews.com/view/full_story/27701415/article-Point-Loma-Library-being-retrofitted-to-attain-zero-net energy#:~:text=Point%20Loma%2FHervey%20is%20among%20three%20City%20libraries%20about,buildings%20to%20be%20retrofitted%20to%20ZNE%20by%202030

Table 12: Center for Sustainable Energy Hosted Webinars

Topic	Date & Results
Live Webinar #1: How to Approach Zero Net Energy Projects for Existing Municipal Buildings	August 2019 ~ 19 attendees
Live Webinar #2: Making the Case for Municipal Retrofit: The City of San Diego "ZN3" Project (Hosted by the Local Government Sustainable Energy Coalition)	November 2019 ~20 attendees

Source: Center for Sustainable Energy

Conferences and Events

CSE participated in two conference events throughout the project term based on timing, resources and opportunities. The conference descriptions and results are outlined in Table 13.

Case Study

CSE developed three case studies for the project. Using information collected from the M&V period and behavioral surveys, CSE assessed project benefits and results. The case studies provide a clear snapshot of project objectives, design, performance and results. The case studies contained the following information.

- Technologies and energy conservation measures (ECMs) implemented
- System design and performance
- Project economics and cost savings
- Library manager testimonials
- Occupancy behavior survey results
- Lessons learned

The case studies are available on the project website, energycenter.org/sdzn3.

Table 13: Conference Presentations

Conference	Description	Date	Target Audience
New Buildings Institute ZNE Forum	An annual forum for leading designers, building owners, operators, commercial real estate professionals, policymakers, technology manufacturers and others to share perspectives on the growth of zero net energy (ZNE), discuss the policies driving new projects, engage in best practices for successful outcomes and collaborate on opportunities for ZNE to transform the built environment.	October 2019	Building owners, policymakers ~100 attendees
San Diego Green Building Council	Annual Green Building Conference and Expo with attendees including local public and private organizations. The expo has a focus on emerging trends in sustainability and green buildings.	October 2019	government officials, building owners, policymakers ~100 attendees

Source: Center for Sustainable Energy

Building Tours

CSE and the City of San Diego hosted four library tours provided a hands-on learning experience for stakeholders and community members with the tours taking place in early 2018 through fall 2020. Attendees included representatives from the Energy Commission, City elected officials and staff and the project's TAC. The tours provided a before and after representation of the libraries, illustrating the transformation to convert to ZNE or near-ZNE buildings. It is important to note the COVID-19 pandemic limited post-retrofit building tours to one opportunity for City of San Diego elected officials and staff.

Energy Dashboards

Kiosks with energy profile dashboards were created to allow the public to visualize each library's energy consumption based on information collected from SDG&E and end-use monitoring equipment. Each library features their own dashboard with energy consumption, solar generation, energy savings and carbon offsets. Library and project website visitors can access individual dashboards in person and view building performance data for each library. The City will continue to maintain and update the kiosks and have paid in advance to have a BuildingOS subscription though 2028. CSE will continue to host the project website until at least 2022.

Sponsored Events

The City of San Diego participated in the 2017 EPIC Symposium as a panel presenter. The event had included approximately 200-250 attendees, including government officials and industry stakeholders. Information about the project was shared by a rotating slide at SDG&E's 2019 Energy Showcase event at the San Diego Convention Center that had about 380 attendees and targeted a similar audience as the Symposium.

Technical Advisory Committee

CSE leveraged the expertise of TAC members to transfer findings from this demonstration project. The TAC consisted of executives, researchers, consultants and government officials representing public, private and nonprofit organizations with expertise in energy efficiency, ZNE projects, renewable energy generation and demand side management and response disciplines.

Policy Development

CSE tracked several open and relevant California Public Utilities Commission (CPUC) and CEC proceedings throughout the project and will continue to track them as project findings could be used as resources in future public comments.

- Energy Efficiency Proceedings (R.13-11-005)
- Energy Efficiency Strategic Plan Update and Action Plans (D.10-09-047)
- Building Decarbonization (R.19-01-011)
- Integrated Distributed Energy Resources (R.14-10-003)
- CEC Load Management Rulemaking (Docket No. 19-OIR-01)
- CEC Building Energy Efficiency Standards: Triennial updates to the California Code of Regulations, Title 24, Part 6

Information about library project lessons learned was included in comments from CSE on the CEC 2021 Integrated Energy Policy Report.[20] On a local policy level, the City of San Diego has already been using lessons learned from the project in the development of their *Municipal Energy Strategy Plan*[21] and has reported on the project in their *2019 Climate Action Plan Annual Report*.[22]

[20] *Center for Sustainable Energy (CSE) Comments on Draft Scoping Order for the 2021 Integrated Energy Policy Report*. 2021. Center for Sustainable Energy. https://efiling.energy.ca.gov/getdocument.aspx?tn=236847

[21] *Municipal Energy Strategy*. 2020. City of San Diego. https://www.sandiego.gov/sites/default/files/municipal_energy_strategy_implementation_report_10-23.pdf

[22] Climate Action Plan Annual Report. 2019. City of San Diego. https://www.sandiego.gov/sites/default/files/2019_cap_digital_version.pdf

CHAPTER 9: Conclusion

Project Results

The project successfully created a blueprint that can be replicated to achieve ZNE or near-ZNE in existing municipal buildings. It also demonstrated the technical capacity and value of IDSM technologies, and illuminated barriers to implementing DR for buildings designated as cool zones, and the need for ongoing retro-commissioning. Demand trends were measured in to optimize equipment operations. The project also engaged and educated library staff, volunteers and community members through interactive, in-library kiosks on ZNE and IDSM strategies, sustainable energy and environmental benefits. The project team also successfully conducted pre- and post-construction surveys of library staff and volunteers and a year of post-retrofit measurement and verification.

Lessons Learned

Many lessons remain to meet California's goal of 50 percent ZNE of existing commercial buildings. However, those learned from this project can better inform future ZNE projects. The most relevant and applicable are identified as the following.

- Identify the change to ZNE (difference in building energy consumption and energy generation).
- Conduct pre-retrofit sub metered monitoring (such as measure building end uses separately: lighting, plug loads, HVAC).
- Isolate energy reductions by end use to achieve maximum savings (target energy efficiency measures that will reduce end uses with higher energy consumption first).
- Identify the correct energy modeling tool for the project and perform additive modeling (many tools are available but some are better at identifying savings for individual measures).
- Identify building cybersecurity and network requirements early on (these requirements vary and will impact install and material costs).
- Know the budget requirements (lighting upgrades and building controls are cost-effective ECMs for existing buildings but many emerging technologies are still too expensive).
- Plan for unanticipated repairs in existing buildings to bring systems into full operation (HVAC repairs may be needed to implement controls for example).
- Perform 12 months of post-retrofit monitoring (do not rely on "ZNE design" as there are many factors such as occupant behavior that impact a ZNE calculation).
- Develop plans for ongoing maintenance and retro-commissioning (additional budget will be required post-retrofit to maintain equipment and operations).
- Be adaptable and be prepared to learn new things (ZNE is a new design concept and as such, expect unanticipated design and construction challenges).

LIST OF ACRONYMS

Term	Definition
AC	air conditioner
ADR	automated demand response
AHU	air handling unit
AMY	actual meteorological year
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	building automation system
BMS	building management system
CAP	climate action plan
CEC	California Energy Commission
CSE	Center for Sustainable Energy
CT	current transducer
DR	demand response
ECM	energy conservation measure
EUI	energy use intensity
EUL	effective useful life
GHG	greenhouse gas
HVAC	heating ventilation and air conditioning
IDSM	integrated demand side management
kW	kilowatt
kWh	kilowatt-hour
M&V	measurement and verification
MES	municipal energy strategy
NBI	New Building Institute
O&M	operations and maintenance
PLCP	programmable lighting control panels
PPA	power purchase agreement
PV	photovoltaic, *also* solar photovoltaic
RTU	rooftop unit
SAT	supply air temperature

Term	Definition
SD ZN3	San Diego Libraries Zero-Net Energy and Integrated Demand Side Management Project
SDG&E	San Diego Gas & Electric
SDGBC	San Diego Green Building Council
TAC	technical advisory committee
TDV	time dependent valuation
TI	Technology Incentives program (San Diego Gas & Electric)
TMY	typical meteorological year
TR	tons of refrigeration
VAV	variable air volume
ZNE	zero net energy