University of San Diego

USD SUSTAIN

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UNIVERSITY OF SAN DIEGO

Energy Master Plan

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WILLDAN

Engineering & Planning | Energy Efficiency | Sustainability

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1. Background

With the growing urgency to address and mitigate climate change, the University of San Diego (USD) helms a culture on campus that is committed to taking a holistic approach to sustainability and reducing the University's carbon footprint. The Office of Sustainability has spearheaded programs and initiatives to educate its students, faculty and staff on ways to reduce greenhouse gas emissions on campus and in the community at large. Building off the goals made in 2019 through the Climate Action Plan (CAP), the University's President set a more ambitious GHG reduction target of zero by 2035. With the continued support from San Diego Gas & Electric (SDG&E) Local Institutional Energy Efficiency Partnership (LIP), USD set forth to create a 15-year Energy Master Plan (EMP) that reduces energy consumption and GHG emissions through recommendations aimed at achieving carbon neutrality by 2035. Through the collaboration of USD staff, faculty, students, and a team of consultants, the EMP reflects the culmination of experiential learning opportunities, research, analysis, and a strategic roadmap towards ensuring USD remains a leader in sustainability.

This Energy Master Plan (the Plan) was prepared for USD by Willdan Energy Solutions (Willdan) in partnership with Michael Wall Engineering (MWE) and Michael Akavan Engineering (MAE). These local consulting partners have brought mechanical, plumbing, and electrical engineering design for over 75 projects across the USD campus. USD partnered with Willdan to create guiding principles to delineate what the EMP would encompass. This scope of work is followed by driving factors, which are reflected in the SDG&E LIP, the 2016 Climate Action Plan, and the USD Envisioning 2024 Strategic Plan. USD also aims to align campus goals with the City of San Diego Climate Action Plan and California GHG reduction targets and assembly bill mandates.

Over the course of this project Willdan, MWE and MAE met with various faculty and staff at USD to assess current operations, master planning, facilities maintenance budgets and sustainability planning. These meetings informed the staging process of our recommendations. Willdan, MWE and MAE also visited the campus to conduct a baseline analysis of existing systems, conditions, and energy usage on campus. The site visits involved surveying the campus and evaluating existing buildings and systems. USD stakeholders provided historic energy consumption data and baseline GHG inventory from 2019 (through the Energy Policy Initiatives Center- EPIC). By evaluating baseline energy expenditures and the campus' current carbon footprint, the EMP is able to frame what business as usual looks like and ways USD stands to improve towards a more sustainable campus.

The recommendations provided in the Plan encompass energy efficiency measures, energy conservation measures, carbon reduction measures and facility improvement measures; incorporating projects for a staged implementation over the next 15 years to meet USD's 2035 carbon neutrality goal. The EMP also provides recommendations for ensuring campus resiliency and potential renewable generation projects to optimize clean energy on campus. The EMP provides a recommended Ongoing Commissioning plan to evaluate and monitor building performance and maximize energy savings. Finally, the EMP provides experiential learning opportunities and initiatives to incorporate student involvement in realizing a carbon neutral campus by 2035.

2. Guiding Principles & Goals

To highlight the intention of this EMP and its focus, the EMP team (including USD Sustainability staff) created guiding principles for the Plan. The listed areas of focus were determined based off the scope of work in the original RFP. The consulting team's efforts are meant to support the ongoing sustainability and climate mitigation work the University of San Diego is committed to, with the joint effort of students, faculty, and staff.

2.1.1 Guiding Principles

The Energy Master Plan aims to:

- Utilize long-term University energy and sustainability plans and agreements, including the SDG&E Local Institutional Partnership, the USD Climate Action Plan, and the USD Envisioning 2024 Strategic Plan to inform goals.
- Optimize campus energy consumption via energy efficiency, energy conservation and demand management.
- Identify the resources necessary to optimize the ongoing operation and maintenance of the campus energy system, including the proposed commissioning program, to ensure efficiency gains are sustained.
- Evaluate campus electrical, mechanical and controls software infrastructure
- Determine the most effective, efficient, and clean methods to supply power to the campus during extended outages and/or disasters.
- Identify the best energy source or combination of sources to meet the University's needs and goals.
- Include a detailed schedule and plan for implementation of the program, including measurement and verification of the cost savings as well as energy and greenhouse gas emission reductions.
- Delineate a fifteen-year plan to make the campus carbon neutral by 2035.
- Identify experiential learning opportunities for students
- Include an analysis of the greenhouse gas emission reductions that will be achieved with EMP
- Identify financial cost/benefit analysis of the proposed programs
- Identify additional environmental benefits aside from GHG reductions
- Provide an M&V of the cost savings, energy and GHG emission reductions

2.1.2 Driving Factors & Goals

The Office of Institutional Effectiveness and Strategic Initiatives (IESI) facilitates the implementation of the Envisioning 2024 strategic plan and is focused on five goals to realize the 2024 Vision[1] of USD. Building on

[1] "By 2024, USD will set the standard for an engaged, contemporary Catholic university by focusing on our six interconnected Pathways and delivering on the Promise of our University by achieving 5 goals"; USD Strategic Plan: https://www.sandiego.edu/iesi/strategic-plan/goals-and-opportunities/

the initiatives from the 3rd goal of "Improving Structural & Operational Effectiveness" and inspired by the "Care for our Common" pathway[2], the Plan presents recommendations that embody institutional sustainability and works towards providing the best built environment for USD staff, students, faculty, administrators and visitors. Of note are the Renaissance Plan; the Climate Action Plan and the target goal of carbon neutrality by 2035[3].

In 2016, The Renaissance Plan[4] emerged from a combined effort by various USD stakeholders (USD's Space Working Group) to determine priority areas and buildings on campus in need of renovation and maintenance. This resulted in three key areas that would be the focus for the following 10 years: Annual deferred maintenance projects, restoration of select legacy buildings and strategic new construction. The Plan took into consideration the priority buildings included in the deferred maintenance plan and in staging recommended efficiency and conservation measures.

The 2016 Climate Action Plan (CAP) goals set the stage for a focus on reducing energy consumption and greenhouse gas reduction at USD. With over half of (55%) of GHG emissions stemming from energy, the USD CAP focused on increasing energy efficiency and the use of cleaner and renewable energy to reduce energy consumption and optimize energy sourcing.[5] EPIC inventoried the campus GHG emissions from 2010 through 2015 and 2010 emissions were used in the CAP as a baseline for goal setting. The CAP set a 2020 goal for 15% GHG reduction; a 40% GHG reduction by 2030; and a 50% reduction by 2035. In 2019, during Global Climate Change week, the President of USD joined faculty and students in committing to a "shared responsibility to help the University achieve its 2035 carbon neutrality goal.[6]" With this new target in place and through the support of SDG&E, the Office of Sustainability selected Willdan to create this Energy Master Plan.

2.1.2.1 Regional Driving Factors & Goals

USD is a partner of the San Diego Regional Climate Collaborative (Climate Collaborative), which connects public agencies in the region to advance climate change solutions. Through the support of the San Diego Regional Energy Partnerships (SDREP), the Climate Collaborative created a story map[7] that showcases and highlights regional Climate Action Planning. USDs Energy Policy Initiatives Center team assisted in aggregating regional Climate Action Plans (CAP) as a tool to quantify local GHG emissions. The CAPs were assessed and mapped based on energy efficiency measures and projects. These efforts demonstrate a

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[2] Care for Our Common Home - Demonstrate care for all creation by embodying the urgent call of "Laudato si" through teaching, scholarship, campus culture, and community partnerships: https://www.sandiego.edu/envisioning-2024/pathways/care-for-our-common-home.php

[3] *Strategic Plan Annual Report 2019-20, Envisioning 2024, Because the World Needs Changemakers:* https://www.sandiego.edu/iesi/documents/Sept%202020%20Placemat.pdf

[4] The Renaissance Plan: https://www.sandiego.edu/university-operations/renaissance-plan/overview.php

[5] University of San Diego Climate Action Plan (CAP), https://issuu.com/universityofsandiego/docs/nov21_usd_climate_action_plan, 2016 P. 13-15

[6] President Harris, Students Sign, Support Climate Leadership Commitment; Ryan T. Blystone; USD News Center; October 18, 2019: https://www.sandiego.edu/news/detail.php?_focus=74189

[7] *Climate Leadership in the San Diego Region.* The San Diego Regional Climate Collaborative: https://storymaps.arcgis.com/stories/60fd19c2ad4f4a4ebd4eb1cf176ba088

focus on local collaboration to reduce GHG emissions by focusing on energy efficiency initiatives in the San Diego region.

In 2015, the City of San Diego implemented a Climate Action Plan with the support of EPIC to quantify the City's GHG baseline emissions and project emissions through 2035. Similar to other Southern California cities, this CAP demonstrates that the GHG emissions breakdown is led by transportation (55%) and followed by the energy sector (40%; electricity and natural gas combined). The five local strategies to address emission reductions target energy and water efficient buildings; clean and renewable energy; bicycling, walking, transit & land use; zero waste; and climate resiliency. These strategies align with the focus of USDs CAP and the Plan, which prioritizes energy efficiency, demand reduction and decarbonization.

2.1.2.2 State Goals:

As a leader in climate mitigation policy, California has some of the most ambitious and stringent targets for renewable supply of electricity, GHG emission reduction and energy codes and standards. Energy efficiency has been central to energy policy in California and will continue to be a focus for building decarbonization. The California Energy Commission, the lead policy and planning agency of California, is overseeing the following key targets[8]:

- Global Warming Solutions Act: A reduction of GHG emissions to 40% below 1990 levels by 2030 (SB 32).
- A requirement of 60% of electricity to come from renewable supplies by 2030 and 100% of electricity to come from carbon-free sources by 2045 (SB100).

A doubling of the energy efficiency savings and demand reductions in natural gas and electricity end uses by 2030 from a 2015 baseline (SB35).

[8] Ibid.

3. Executive Overview

This report evaluates the potential to meet the campus' goal of zero GHG emissions by FY35. It focuses on the energy use of the campus and its contribution to the GHG emissions.

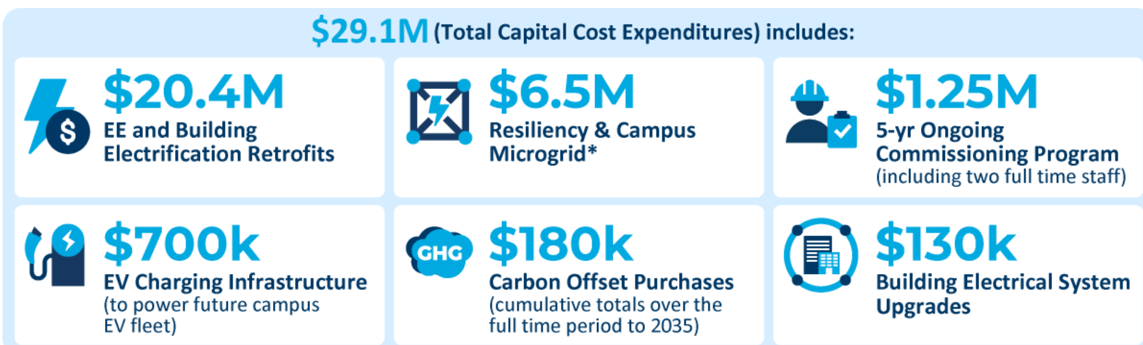
Between the baseline year of FY19 and the target year of FY35 the campus is projected to spend close to **$113 million on energy bills** (see [Section 10.1.4 Business as Usual Energy Costs](#)**.** This is based on a conservative assessment of campus load growth and a relatively small 3% escalation projected for utility rates beyond 2022 anticipated increases.

The Energy Master Plan estimates <u>$7.58M in net savings</u> for energy-related expenditures over the 2035 timeframe relative to this "do nothing" business as usual projection. This net program cost is especially notable for the following reasons:

- Includes additional energy-related infrastructure not directly tied to energy bill savings, such as new generators, electrical system upgrades, microgrid and generator controls, carbon offsets, and EV charging infrastructure.
- Significant savings despite projections of much higher energy costs in 2035 (60+% for electricity and 120% for gas, compared to FY19 prices).

Our analysis provides a **15-year roadmap for the campus to meet its zero GHG goal** through the following actions:

- $29.1 of energy master plan capital cost expenditures (an avg of $2.08M/yr from 2022 – 2035)[9]



* Including 1.5 MW of energy storage, 4MW of new backup generators, and comprehensive campus control system

[9] It is important to note that measure cost is defined differently depending upon the measure. For capital-intensive mechanical retrofits, such as kitchen electrification, gas boiler to heat pump or major renovations to VRF HVAC systems, incremental cost was used. Incremental cost (IMC) is defined as the additional cost beyond a business as usual, like for like replacement. Since the equipment for these IMC measures will have to be updated during these next 15 years due to age/deterioration, it was considered more realistic to compare these decarbonization measures to the standard case of their BAU replacements and only include the incremental additional cost beyond what USD would have already had done absent the Energy Master Plan. For all other measures which do not greatly exceed business as usual requirements and are less capital intensive, full measure cost (FMC) is used. For a breakdown of which measures used IMC vs. FMC, see Table 17 - Mechanical and Electrical Efficiency Measure Summary

- New Power Purchase Agreement (PPA) for 2.45 MW of Solar, which is an estimate of the remaining feasible rooftop PV footprint.
- Stay with Calpine as electricity provider vs. 100% renewable options such as San Diego Community Power CCA due to Calpine's significantly lower price of electricity. By taking advantage of low Calpine rates for their 30% renewable power, Willdan estimates a $6M economic benefit over 15 years which can easily cover the $200k of carbon offset costs and a great deal of energy efficiency retrofits.

Pursuing the recommendations of this Energy Master Plan will result in deep and persistent energy and carbon savings to the campus, summarized below:

- **20%** Reduction in Electricity Usage
- **72%** Reduction in Gas Usage
- **36%** Reduction in Campus Annual Energy Bill
- **77%** Carbon Emission Reduction Before Offsets (~10,400 - ~2,400 MT)

Aside from achieving carbon and energy savings, the energy master plan leads to significant campus sustainability and resiliency benefits. Following this roadmap leads to a USD campus that in 2035 will consist of:

- **3.62 MW** Solar PPA (2.45MW new + 1.17MW existing)
- **4 MW** Backup Power (two 1MW gas + one replaced 2MW diesel generator)
- **1.5 MW** Energy Storage
- A robust microgrid control-center system & fully integrated BAS
- **Three** Additional FTEs (focusing on microgrid control management and ongoing commissioning*)
- **No** Third-party Fuel Cell or Battery Contracts

* Assuming ongoing commissioning program adopted full time. Current analysis assumes a 5 year pilot program from 2022 to 2026 for two FTEs.

Investments in energy-efficient infrastructure during the timeframe of the energy master plan have significant "spillover" benefits that persist long beyond 2035. Major HVAC renovations, equipment replacements, and solar PPA contracts recommended as part of this Energy Master Plan result in the following benefits beyond 2035:

- **37,000** MWh from Solar*
- **27,000** MWh from Energy Efficiency
- **2.7M** Therms
- **17,000** Metric Ton CO_2
- **$25.6M** Energy Cost Benefits **

* From new 25 year PPA in 2022
** Not taking into account campus energy usage from '36-'55

The remainder of this report can be grouped into two sections: Baseline Conditions (Sections 4-9) and Recommendations (Sections 10-20).

- **Baseline Conditions**
  - Analysis of USD estimated carbon footprint and energy expenditures under a business as usual projection.
  - System-wide summary of USD's buildings and infrastructure
  - Analysis of Historical Electricity and Natural Gas Usage
- **Recommendations**
  - GHG reduction opportunities through energy purchases, building retrofits, and energy conservation measures.
  - Detailed Resiliency and Microgrid recommendations, including comprehensive building controls, additional energy storage, and a generator replacement plan
  - Identification of electrical deficiency and potential self-generation projects, as well as recommendations on zero-net energy policy.
  - A Campus Continuous Commissioning Plan
  - Experiential Learning Initiatives on the short, medium, and long-term.

4. USD Baseline Information & Existing Conditions

This section provides a description of current campus-level conditions and details a methodology for determining USD's baseline energy expenditures and carbon footprint for which the recommendations of the Energy Master Plan can be compared against. Recent historical energy data is analyzed and projected for the duration of the 15-year period of the study and used to calculate both a cumulative energy expenditure cost, as well as projected emissions trajectory under business as usual conditions. This analysis informs our recommendations and timeline for how USD is to achieve their carbon neutrality goals by 2035 and substantiates the $113 million cost figure that the Energy Master Plan's projected expenditures are compared against.

4.1.1 Baseline Business as Usual

The Business as Usual (BAU) assumptions for operation of the campus energy users are delineated in this section. In this BAU baseline analysis, the campus projects loads between FY19 (the baseline operations year) through FY35 (the target date for zero carbon emissions).

The following tables and graphs project the electric and gas purchase quantities for BAU. This begins with the total energy purchased by the campus in FY19 and includes:

1. Electricity purchased through the main SDG&E meter with the commodity provided by Calpine through Direct Access
2. Electricity purchased directly from SDG&E at smaller meters
3. Electricity purchased from the solar modules on campus through a PPA
4. Electricity purchased through the fuel cell on campus through a PPA.

Natural gas use includes:

1. Fuel cell use (ending in FY32)
2. Building gas, which includes commodity service from Calpine for six meters and service from SDG&E for the rest of the meters.

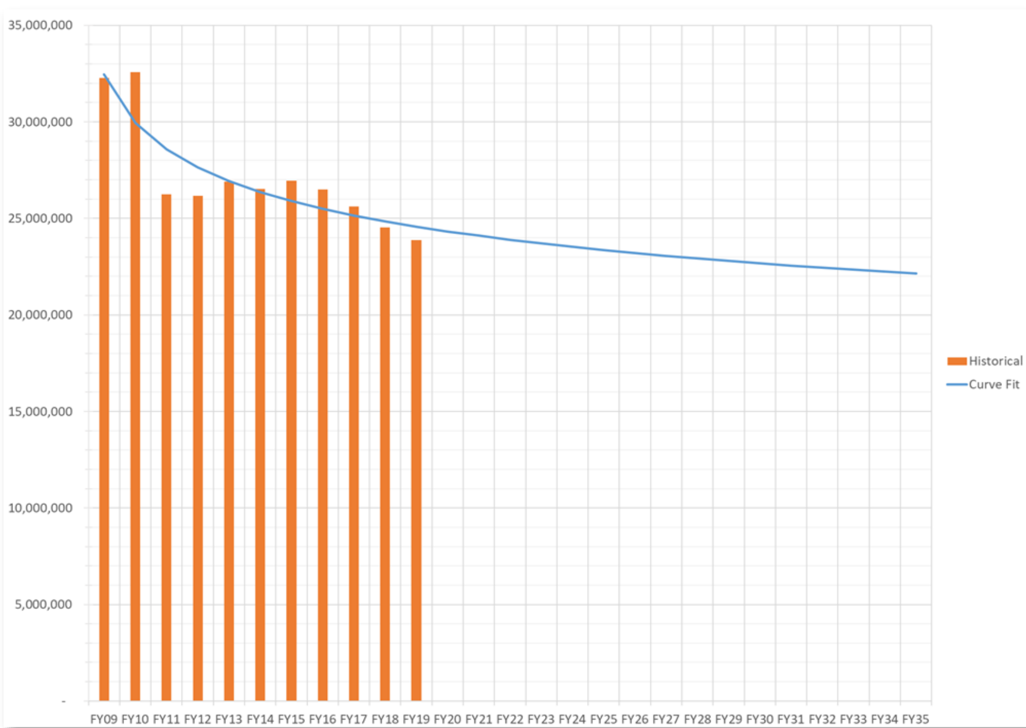
4.1.2 Campus Load Growth

The projections of energy use in future years are based on trend models calibrated to historical energy use. Influences of past years' growth include expanded student body, construction of new buildings, and a variety of energy efficiency efforts. Based on conversations with USD staff, these factors are expected to influence load growth in similar ways in the future.

Initially USD campus load growth was correlated to campus growth based on the 2017 University Master Plan update, including both projects approved in the past and potential future projects. However, some of the projects approved in the past are not currently on track to be built because of shifting priorities, or more recently, COVID-19 uncertainties. The growth curves for both electricity and natural gas based on historical data show slow declines in loads in the coming years which seem to be a reasonable projection for campus load growth at this time. In Section 18 of this report, recommendations are provided regarding new construction zero net energy (ZNE) standards to help USD keep load growth neutral. As things change in the future, adjustments can be made to the model.

Total electric purchases are projected to follow the trend established from FY09 through FY19 into future FY20 through FY35, as shown in the following graph[10].

Figure 1: Historic and Projected Annual Electricity Use at USD (kWh/Year)

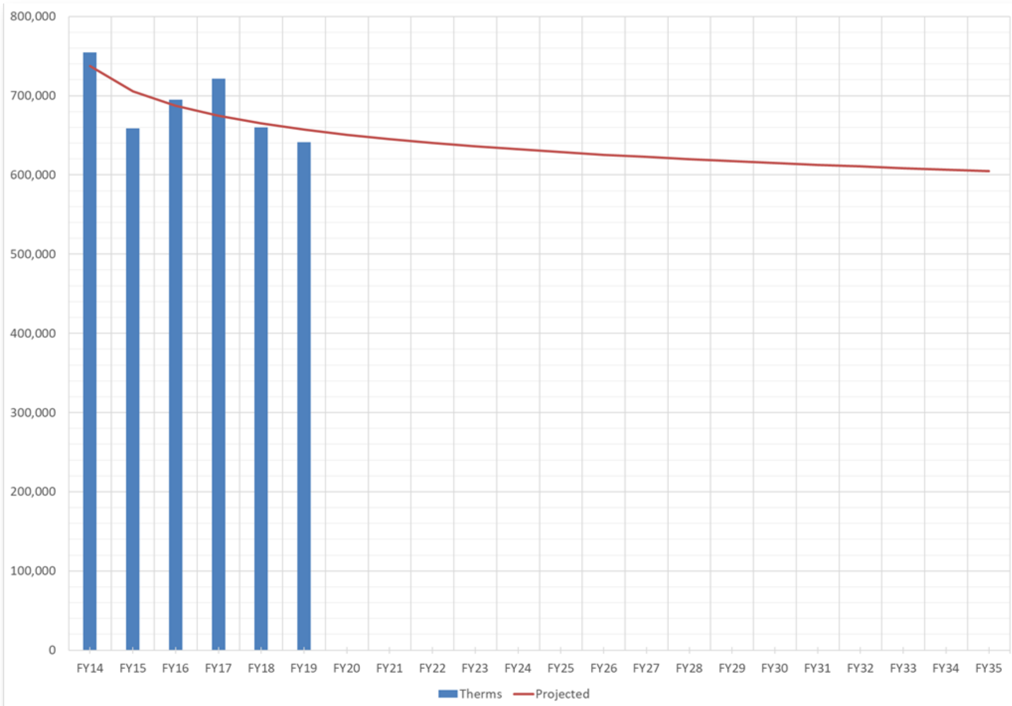


Total natural gas purchases (for buildings, excluding the fuel cell) are projected to follow the trend established from FY14 through FY19 into future FY20 through FY35, as shown in the following graph[11].

[10] The equation is y = 32.453x^(-0.116). $R^2 = 0.7745$.

[11] The equation is y = 737201x^(-0.064). $R^2 = 0.4608$.

Figure 2: Historic and Projected Annual natural Gas Use at USD (th/yr)



The above trend reflects the efficiency efforts and slow campus load growth that have led to a decline in electricity consumption for the last 10 years. The projected slow decline in electric load in the future implies there are no significant jumps (large new construction) or drops (COVID-19 activities) expected in future years.

Note that predicting the future without considering the effects of COVID-19 on buildings and campus operations invites inaccuracy. However, the potential short and long term impacts of the pandemic are presently unknown. Projections are not modified to account for COVID-19 effects. If campuses do not return to normal operation in the near future, assumptions for this analysis can be modified accordingly.

The USD Master Plan Update from 2017 lists Previously Approved Projects which include about 539,000 square feet of conditioned space. The proposed projects in this report cover about 717,000 square feet of conditioned space. Significant new construction does not appear imminent. New buildings are expected to be significantly more efficient than the existing stock. See Section 18 for recommendations on new construction ZNE design standards.

The Business as Usual projected electrical purchases to meet this electrical load are shown in the following figure. This represents the projected performance of the PV output (-0.5% degradation per year) through its remaining life. Electric purchases from the utility are assumed to make up any shortfall with the PV or fuel cell system, including at the end of the fuel cell contract.

4.1.3 Business as Usual Utility Purchases

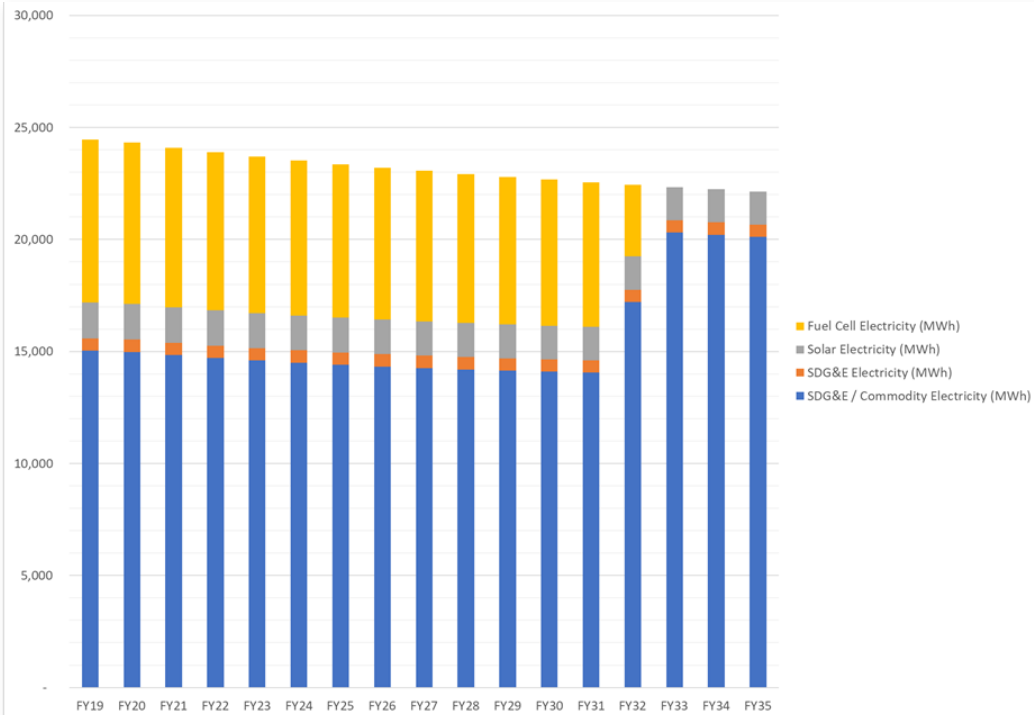
Table 1: BAU Utility Purchases FY19-FY35

Fiscal Year	SDG&E / Commodity Electricity (MWh)	SDG&E "Eco Choice" Electricity (MWh)	Solar Electricity (MWh)	Fuel Cell Electricity (MWh)	Total Electricity Use (MWh)	Building Gas (therm)	Fuel Cell Gas (therm)	Total Gas Use (therm)
			-0.5%	0%	Curve Fit	Curve Fit	0%	
FY19	15,035	552	1,593	7,281	24,462	641,425	540,676	1,182,101
FY20	14,907	552	1,585	7,281	24,326	650,878	570,577	1,221,455
FY21	14,690	552	1,578	7,281	24,101	645,339	570,577	1,215,916
FY22	14,492	552	1,570	7,281	23,895	640,493	570,577	1,211,070
FY23	14,309	552	1,562	7,281	23,704	636,189	570,577	1,206,766
FY24	14,140	552	1,554	7,281	23,528	632,320	570,577	1,202,897
FY25	13,983	552	1,546	7,281	23,363	628,808	570,577	1,199,385
FY26	13,837	552	1,539	7,281	23,208	625,595	570,577	1,196,172
FY27	13,699	552	1,531	7,281	23,063	622,635	570,577	1,193,212
FY28	13,570	552	1,523	7,281	22,926	619,892	570,577	1,190,469
FY29	13,448	552	1,516	7,281	22,797	617,337	570,577	1,187,914
FY30	13,333	552	1,508	7,281	22,674	614,946	570,577	1,185,523
FY31	13,224	552	1,500	7,281	22,558	612,701	570,577	1,183,278
FY32	16,761	552	1,493	3,641	22,447	610,584	285,289	895,873
FY33	20,303	552	1,485	-	22,341	608,583	-	608,583
FY34	20,209	552	1,478	-	22,239	606,686	-	606,686
FY35	20,119	552	1,471		22,142	604,882		604,882
TOTAL	**260,062**	**9,381**	**26,032**	**98,299**	**393,774**	**10,619,295**	**7,672,889**	**18,292,183**

In addition to electrical load growth projected from baseline campus operations, load growth is factored in from projected campus vehicle fleet electrification. Due to current California policy requiring all new passenger vehicles to be electric vehicles (EVs) by 2035, combined with campus sustainability priorities, the assumption is made that USD will transition its current fleet to all-electric by 2030. While the GHG emissions associated with USD's current gasoline-powered fleet are not included as part of this report, the cost of ESVE (Electric Vehicle Supply Equipment) is included in this analysis as well as the cost and GHG impact of this charging infrastructure. As a result, ~$700k of ESVE infrastructure, as well as an increased annual load of 366,000 kWh are integrated into the yearly electrical bill analysis, with the assumption that ESVE spending and energy use scale with a fleet conversion beginning in 2022 and linearly increasing to full replacement over 9 years until 2030. For more details on this analysis and SDG&E programs to support electric vehicles, please see Appendix G– Fleet Vehicle Types, EVSE Load, Costs and Annual kWh.

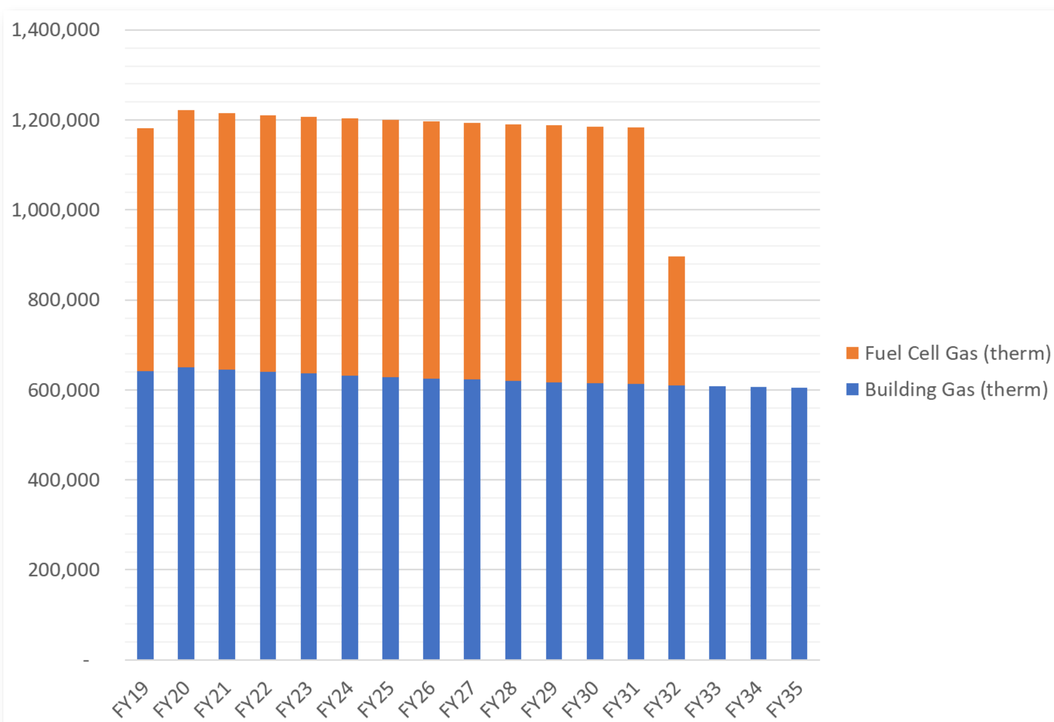
Fuel Cell electricity is projected to drop off in FY32 at the end of the contract, to be replaced by more commodity electricity purchases. PV electric purchases are projected to continue through FY35, although they are projected to decline from present levels by 0.5% per year.

Figure 3: BAU Projected Electric Purchases (MWh/yr)



The Business as Usual projected natural gas purchases are shown in the following graph. This shows the slowly declining building natural gas use, as well as the end of the fuel cell natural gas purchases.

Figure 4: BAU Projected Natural Gas Purchases (th/yr)



4.1.4 GHG Emissions

The following table presents projected GHG emissions related to these energy purchases. The USD emissions tally for FY lists the following conversion factors:

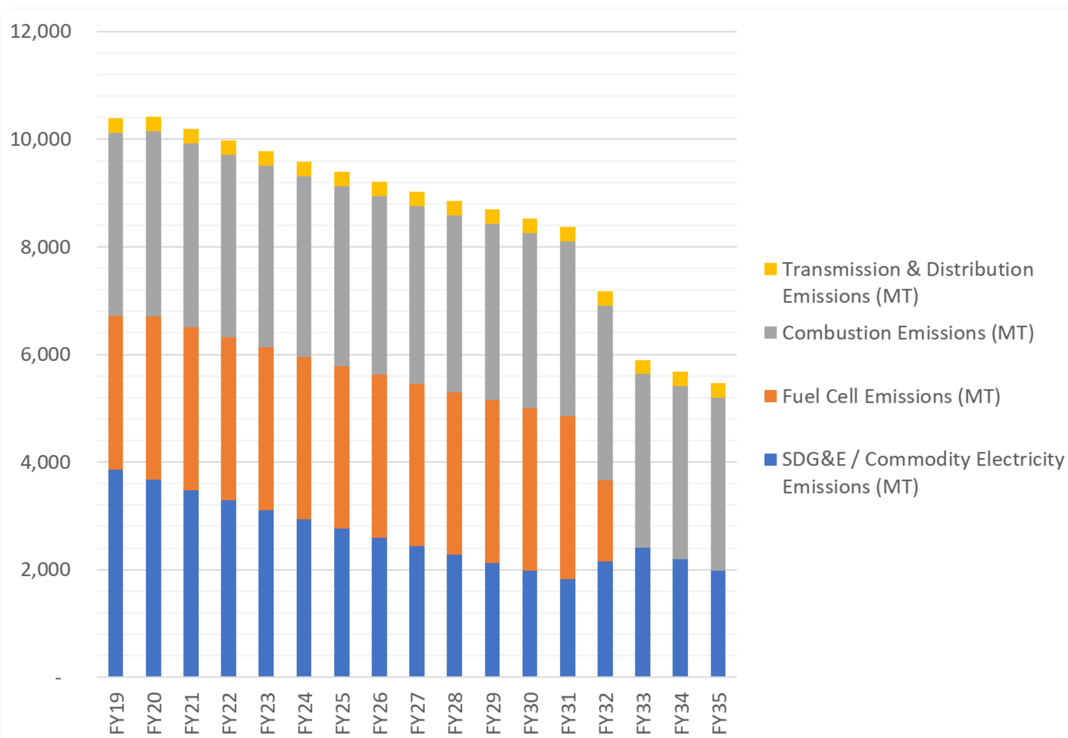
- California Grid Conversion (EPIC for FY2018) 566 lb CO2e / MWh
- Natural Gas Combustion 11.69 lb CO2e / therm

GHG emissions projections begin with the FY18 emissions levels used in the campus reporting which was completed for that year. Since natural gas combustion technology is not expected to change significantly in the near future, the emissions factor for combustion of natural gas is expected to remain the same through FY35.

Electricity, however, is a different case. The California state policy is to remove all carbon from the electric grid by 2045. This is being done by incorporating more renewable (PV, wind, geothermal) power into utility operations and supplementing it with large scale storage. Community Choice Aggregation providers in California already offer customers up to 100% renewable electricity today (see Section 11.1.6) and are expected to procure more renewable energy than the three electric IOUs by 2027.

The electric utility emissions are projected to drop from the current level (566 lb CO2e) in FY19 to zero in 2045, moving down at a linear rate. This would put electric grid emissions in FY35 at 218 lb / MWh. The effect of this is that even though electric consumption will increase with growth and the eventual termination of the fuel cell contract, GHG emissions from electricity will remain fairly constant. This puts FY35 emissions at about 19% below the FY19 baseline.

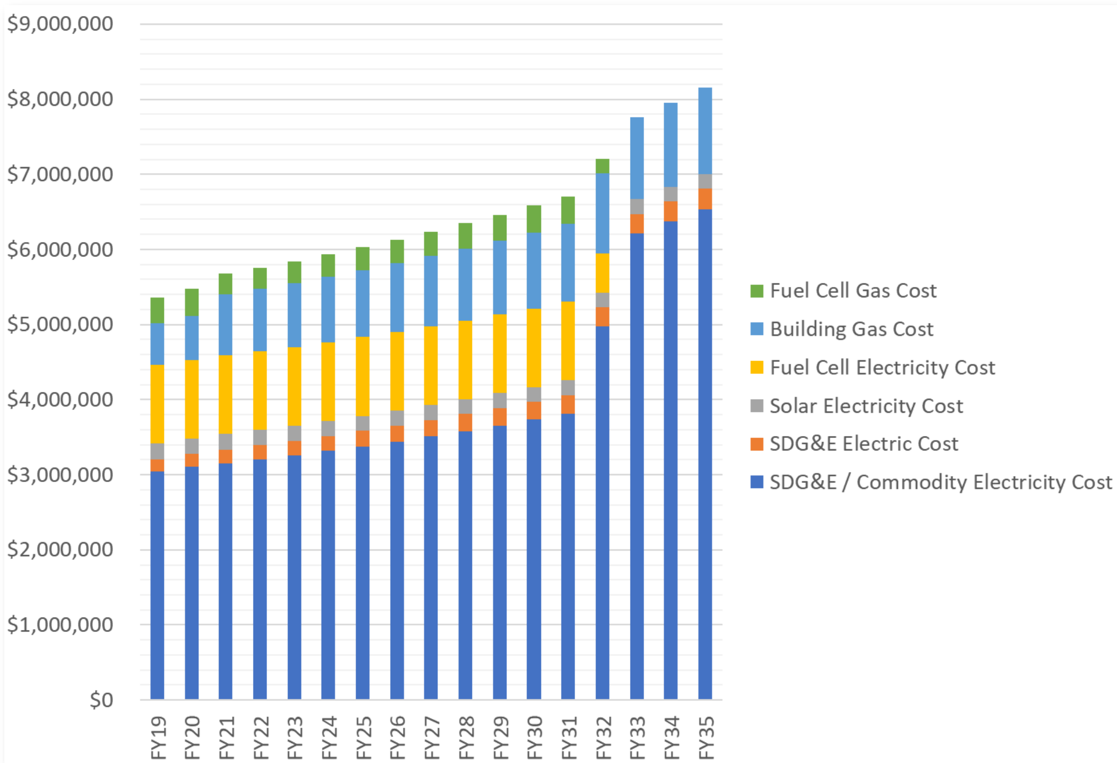
Figure 5: BAU Projected Emissions (MT/yr)



4.1.5 Business as Usual Energy Costs

The projected cost of future energy purchases for buildings is shown in the following chart. This is based on the anticipated quantity of future purchases times the per kWh or per therm cost of energy. The cost of electricity and gas purchased through SDG&E is projected to increase at 3% per year, in line with historical increases. The cost for the PV and Fuel Cell energy have annual rate escalations applied as per their contractual terms.

Figure 6: BAU Utility Costs ($/yr)



The cumulative spend on utility bills from the baseline year through the target year of FY35 (with a conservative escalation rate) is $113 million.

This projected total cost will be compared with the total costs of alternative plans to reduce energy use, generate more renewable energy, and acquire low carbon energy to meet the campus goals.

4.1.6 Recent Building Updates

The 2020 Strategic Plan Annual Report notes advancements in Goal 3: Improving Structural and Operational Effectiveness; worth noting is the Renaissance Plan, with construction and renovation projects having been completed and entered pre-construction phase. The buildings completed in 2019 included Learning Commons, Copley Library, and those begun this year included Founders Hall and Camino Hall. Through discussion with key stakeholders involved in deferred maintenance planning (see Appendix A for list of key stakeholders) and referring to the 2017 Master Plan, our team was able to review the historic campus maintenance projects and upcoming plans for building maintenance. The focus of these discussions was to understand and decipher priorities, tracking systems and planning processes. Due to COVID-19, the campus put various building maintenance projects on hold and decreased its original $6M maintenance budget to $1M. The deferred maintenance Sightlines report is revisited annually and serves as a tool between the Office of Planning Design and Construction and Facilities Management.

The following table lists the main buildings on the campus. The total conditioned space of the campus is 2.78 million square feet, with about a half million square feet of unconditioned parking garage.

4.1.7 Campus Buildings

Table 2: Campus Buildings

Building	Gross SF	Conditioned SF	Parking Garage	SDG&E Electric Meter
Alcala Vistas - Borrego Hall	34,104	34,104		Main
Alcala Vistas - Cuyamaca Hall	49,946	49,946		Main
Alcala Vistas - Laguna Hall	49,946	49,946		Main
Alcala Vistas - Palomar Hall	49,878	49,878		Main
Alcala West (Avila)	6,863	6,863		Multiple SDG&E Meters
Alcala West (Barcelona)	26,214	26,214		Multiple SDG&E Meters
Alcala West (Coronado)	14,673	14,673		Multiple SDG&E Meters
Alcala West (Durango)	6,697	6,697		Multiple SDG&E Meters
Alcala West Storage (North Coke)	14,112	14,112		Individual SDG&E Meter
Alcala West Storage (South Coke)	21,841	21,841		Individual SDG&E Meter
Belanich Engineering Complex	56,792	56,792		Main
Beyster Institute for Nursing Research	24,385	24,385		Main
Bosley Café and Fitness Center	9,103	9,103		Main
Camino Hall	133,651	133,651		Main
Casa de Alcala - President's Residence	5,157	5,157		Individual SDG&E Meter
Casa de la Paz	5,431	5,431		Main
Central Plant	6,447	6,447		Main
Copley Library	45,862	45,862		Main
Degheri Alumni Center	31531	31,531		Main
Facilities Complex - Warehouse	6,607	6,607		Main
Facilities Complex - Admin Bldg.	5,066	5,066		Main
Facilities Complex - Services Bldg.	8,140	8,140		Main
Facilities Complex - Shops Bldg.	2,088	2,088		Main
Field House	5,653	5,653		Main
Founder's Hall	89,002	89,002		Main
Fowler Park	16,985	16,985		Main
Guadalupe Hall	9,938	9,938		Main
Hahn School of Nursing	22,829	22,829		Main
Hughes Administration Center	34,992	34,992		Main
Jenny Craig Sports Pavilion	171,416	171,416		Main
Kroc Institute for Peace & Justice	188,147	99,040	89,107	Main
Maher Annex	5,379	5,379		Main
Maher Hall	110,418	110,418		Main
Main Parking Structure	292,247	0	292,247	Main
Manchester Family Child Development Ctr	5,705	5,705		Main
Manchester Hall	17,134	17,134		Main

Building	Gross SF	Conditioned SF	Parking Garage	SDG&E Electric Meter
Manchester Village #1 and #2	240,992	134,178	106,814	Main
Mata'yuum Crossroads	7,692	7,692		Main
Mission and Ministry	7,068	7,068		
Olin Hall	46,671	46,671		Main
Pardee Legal Research Center	66,384	66,384		Main
Presidio Terrace Apartments	19,327	19,327		Multiple SDG&E Meters
Sacred Heart Hall	19,011	19,011		Main
San Antonio de Padua	50,222	50,222		Main
San Buenaventura	92,969	92,969		Main
School of Leadership and Educational Science SOLES (Mother Rosalie Hall)	146,203	77,244	68,959	Main
Shiley Center for Science & Technology	160,312	160,312		Main
Shiley Theater	61,875	61,875		Main
Sports Center	61,751	61,751		Main
Sports Center Swimming Pool	0	0		Main
Student Life Pavilion	76,109	76,109		Main
Tekakwitha and Serra Hall	77,439	77,439		Main
University Center	76,541	76,541		Main
University Terrace Apartments #1	4,583	4,583		Multiple SDG&E Meters
University Terrace Apartments #2	5,725	5,725		Multiple SDG&E Meters
University Terrace Apartments #3	5,725	5,725		Multiple SDG&E Meters
University Terrace Apartments #4	5,725	5,725		Multiple SDG&E Meters
University Terrace Apartments #5	5,725	5,725		Multiple SDG&E Meters
University Terrace Apartments #6	5,725	5,725		Multiple SDG&E Meters
University Terrace Apartments #7	5,725	5,725		Multiple SDG&E Meters
University Terrace Apartments #8	4,583	4,583		Multiple SDG&E Meters
Valley Residence A - San Diego	13,920	13,920		Main
Valley Residence A - San Fernando	17,085	17,085		Main
Valley Residence A - San Francisco	9,288	9,288		Main
Valley Residence A - San Gabriel	9,288	9,288		Main
Valley Residence A - San Jose	4,650	4,650		Main
Valley Residence A - Santa Inez	4,650	4,650		Main
Valley Residence B - San Luis Obispo	17,310	17,310		Main
Valley Residence B - San Miguel	17,310	17,310		Main
Valley Residence B - San Rafael	17,310	17,310		Main
Valley Residence B -San Juan Capistrano	17,310	17,310		Main
Warren Hall	61,560	61,560		Main
Weight Room	4,790	4,790		Main
West Hills Parking Structure	292,127	292,127		Main
5325 Metro St.	15,000	15,000		Individual SDG&E Meter
TOTAL	**3,332,991**	**2,775,864**	**557,127**	

4.1.8 Campus Infrastructure

The following table summarizes the following heating and cooling systems by building: Chilled Water (CHW), Space Heating Water (SHW) and SHW Boilers, Domestic Hot Water (DHW), Steam Heat Exchanger (HX), and type of Direct Expansion cooling systems (DX).

Table 3 - USD Heating and Cooling Systems by Building

Building	CHW[1]	SHW	SHW BOILER	DHW[2]	HX[3]	DX[4]
Alcala Vista Apartments	N	Y	Y	Y	N	N
Alcala Park West Apartments	N	Y	Y	Y	N	N
Camino Hall	Y	Y	N	Y	Y	AC
Copley Library	Y	Y	N	S	N	N
Degheri Alumni	Y	Y	Y	S	Y	AC
Founders Hall	NB	Y	Y	Y	Y	AC
Hahn School of Nursing	NB	Y	Y	S	N	N
Hahn University Center	Y	Y	Y	Y	N	R
Hughes Administration	Y	Y	Y	Y	N	N
Jenny Craig Pavilion	Y	Y	Y	Y	N	N
Joan B Kroc IPJ	Y	Y	Y	S	N	R
Loma Hall	Y	Y	Y	S	N	N
Maher Hall	NB	N	N	Y[5]	Y	AC
Manchester Conference Center	Y	Y	Y	S	N	N
Manchester Village Apartments	N	Y	Y	Y	N	N
Mother Rosalie Hill Hall	Y	Y	Y	S	N	R
Olin Hall	Y	Y	Y	S	N	N
Pardee LRC	Y	Y	Y	S	N	N
Sacred Heart hall	Y	Y	N	S	N	N
Serra Hall	NB	Y	Y	S	N	AC
Shiley Science Center	Y	Y	Y[6]	S	N	R
Student Life Pavilion	Y	Y	Y	Y	N	R
Sports Center / Pool	N	N	N	Y	N	N
Valley Residences	N	Y	Y	Y	N	N
Warren Hall	Y	Y	N	S	N	N
Central Plant	Y	N	Y	N	Y	N
Maher Boiler Plant	N	N	Y	Y	Y	N

[1] Y=Yes; N=No; NB=Nearby and will/may require extension to connect to existing campus loop

[2] Y=Considerable amount, such as residences and/or cooking; S=Smaller system such as faucets

[3] Y=Steam-to-Heating Water Heat Exchanger

[4] AC=Packaged / Split System Cooling Only and/or Heat Pump Units; R=Refrigeration; N=No

[5] Served by Maher Steam Plant through Indirect Fired Water Heaters

[6] Served by Space Heating Water Boilers at Joan B Kroc Institute for Peace and Justice

4.1.9 Boiler Plants

The campus currently operates two steam plants, one at the Central Plant and one at Maher Annex. The rest of the campus is heated by gas fired satellite space heating hot water boilers and distributed gas fired domestic hot water heaters.

The Central Plant is located in the Facilities Management Complex. It includes two steam boilers that were installed near 2004, rated at 8,000 pounds per hour each. The plant delivers low pressure steam and space heating hot water to nearby buildings. (Hot water to Copley and Shiley Theater; Steam to Camino, Founders, Sacred Heart Hall, and Ministry Center.) The space heating hot water loop is heated by a steam heat exchanger.

There is a steam heat exchanger for a domestic hot water storage tank as well, which is distributed to the same group of buildings.

At one time the Central Plant delivered space heating hot water to Olin and Manchester Hall, but those now use satellite boilers. That hot water distribution system is no longer functional.

Maher is heated by a steam plant located in the Maher Annex, which delivers steam only to Maher. It had once also provided space heating hot water to University Center, the Pavilion, Pardee and Degheri, but those now use satellite boilers. The hot water distribution system is no longer functional.

The campus has made a concerted effort to reduce steam and hot water distribution between buildings by installing satellite space heating hot water boilers in numerous facilities. This has likely resulted in significant savings from reduced distribution losses throughout the year.

4.1.10 Domestic Hot Water

The Central Plant includes a domestic hot water tank (1,200 gallons) that is heated by steam. The water is circulated to local buildings by an 80 gpm (gallons per minute) circulating pump.

4.1.11 Chiller Plant

The Central Plant has three electric centrifugal chillers rated at 1,000 tons each, for a capacity of 3,000 tons. These were installed in 2002. The plant operates continuously.

The chillers serve 18 buildings on campus, from Kroc School of Peace Studies in the southwest to the Jenny Craig Pavilion in the northeast. The chilled water loop serves most buildings except for residential buildings (Manchester Village Apartments, Alcala Vista Apartments, Valley Residences, University Terrace Apartments, or Presidio Terrace Apartments) or southwest portion of campus.

The chilled water plant utilizes a VFD on two of the three chiller compressors, all cooling tower fans (50 hp), the primary (50 hp) and secondary (100 hp) chilled water pumps, as well as the three 50 hp condenser water pumps.

5. USD Electric Infrastructure

5.1.1 Campus Electricity Use

Electricity is delivered to most of the USD campus through an SDG&E meter at the main service entrance located at the West Parking Structure in the southwest end of the campus. Power is distributed from there to the campus buildings through four 12 kV medium voltage feeds. Buildings typically are tied to one feeder, with a backup feeder available if the normal feeder is unavailable.

This main SDG&E electric meter serves nearly all of the electric loads at the campus, with the exception of approximately 20 residential buildings that have their own SDG&E electric meters. These buildings include: four buildings in Alcala Park West (30 meters), three adjacent small warehouses, the Presidio Terrace Apartments, the University Terrace Apartments, and 5325 Metro St. These buildings are fed directly by SDG&E with multiple utility transformers and do not interact with the main campus medium voltage service. USD pays the electricity bills for all of these buildings through EcoChoice (with the exception of 5325 Metro St.) and procures electricity for the main campus meter from Calpine through a direct access arrangement, which allows them to purchase commodity power from sources other than SDG&E. SDG&E, however, is responsible for transmission and distribution of the electricity to the main campus meter. For all the SDG&E meters besides the one large meter, the campus pays SDG&E for the transmission, distribution, and the generation expenses.

The Immaculata and the St. Francis Center for Priestly Formation are served by the main campus meter, though they are not operated by the University. There is a billing arrangement for these in place. The energy use of these is partially metered. It is such a small portion of the overall campus load that it will not be addressed separately.

5.1.2 12kV Distribution System

The main service and utility meter enters the campus at the West Parking Garage at 12kV on service rated switchgear with a relay controlled main circuit breaker. This substation and new generators were installed in 2004. Four circuits leave this service with relay-controlled circuit breakers. The design intent of the four circuits is to have two circuits at each transformer that serves a building load, and therefore a redundant circuit for all loads. If one of the circuits needs to be serviced or fail, the loads served by that circuit can be switched to the alternate circuit by operating the manual switch at the building transformer. For this purpose, the loads attached to either circuits 1 or 2 should not exceed the capacity of one circuit, and the same for circuits 3 and 4. Circuits 1 and 2 are one set of loads, and circuits 3 and 4 are another set of loads. All four circuits route through one conduit duct bank and manhole system up to the intersection of Marian Way and Camino San Diego. From this point, circuits 1 and 2 continue east to feed all loads on the east side of the campus. Circuits 3 and 4 head north and south from this intersection to feed the Central Plant, Sacred Heart, School of Leadership and Education Sciences (SOLES), Shiley Center for Science and Technology, and the Joan B. Kroc Center. In 2017, circuits 3 and 4 were extended east and now have the flexibility to move the following buildings to circuits 3 or 4 by way of relocating terminations in new manholes: Manchester Hall, Olin Hall, Founders Hall, Nursing, and Hughes.

5.1.3 Photovoltaics

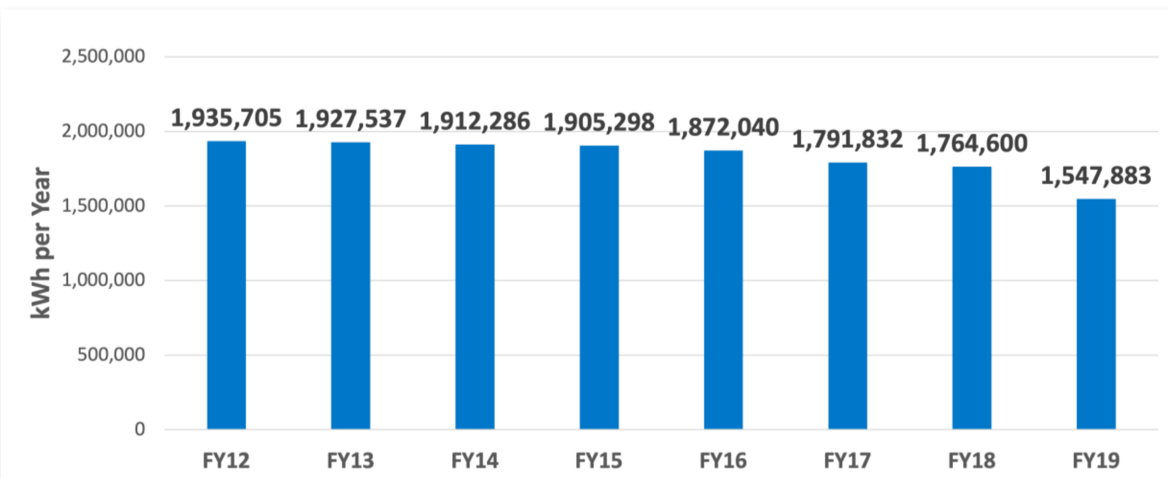
In addition to power procured from SDG&E / Calpine, electricity is also generated on campus through rooftop photovoltaic (PV) systems on 11 buildings, including a parking garage canopy. Each of the PV systems have individual inverters connected to the building electrical switchboard downstream of the 12 kV to 480 V transformers serving the buildings. GCL Solar ultimately owns the PV systems, and sells the power produced to USD through a Power Purchase Agreement (PPA). The PV capacity for these systems totals to approximately 1,170 kW DC. The PV systems were installed in 2010 and started operation in February 2011. The 25-year PPA contract will extend through the end of calendar year 2035.

Each PV system delivers electricity to the electrical panel in the host building. This electricity is metered and reported through an internet-based DECK Monitoring Data Acquisition Systems (DAS) which is operated by GCL Solar. DECK Monitoring has been acquired by Also Energy and the DAS platform for USD is expected to be transitioned to the Also Energy PowerTrack tool, which should provide a more robust DASs tracking platform.

The annual electrical output of these photovoltaic systems around campus is shown in the following figure. Degradation in performance can be seen in every year. In the first few years the degradation is about half a percent per year, which is typical. The degradation increases until in FY19 there is a 12% drop from the previous year, leading to a 20% drop from Year 1 through Year 8.

The performance guarantee for the PV system starts with an expected output of 1,900,000 kWh in Year 1, with a 1% decrease every year after that for equipment degradation. The guaranteed delivery is 90% of the degraded number for the first 10 years and 85% for the next 15 years. The actual performance during Year 8 (FY19 in the figure) is about 1.6% higher than the guaranteed output for Year 8. Part of the reduced output this year was due to the unavailability of Copley Library, Camino Hall and Founder's Hall PV systems for part of the year due to renovation work so these shortfalls are not the responsibility of the provider. FY20 solar production is tracking about 10% above FY19 production most of the way through the year, so the output is recovering after these interruptions. The PV production should be evaluated each year to verify the performance relative to the guaranteed levels.

Figure 7: Historic PV Output



5.1.4 Fuel Cell

A 1,000 kW Bloom fuel cell was installed in early 2017 at the SDG&E service entrance, tied into the main campus electric meter. The fuel cell system is comprised of (4) 250kW generators to create a 1MW generation system to offset a significant portion of the campus electricity purchases and reduce campus energy costs. The 250kW generators are connected to a 480V distribution system that is fed into a 12kV transformer and connected to circuit 2 of the 12kV distribution. The fuel cell uses natural gas as a fuel, which is purchased from SDG&E (distribution) and from Calpine (commodity). This solid oxide fuel cell reforms natural gas into carbon dioxide and hydrogen, which is oxidized in the fuel cell to make electricity and water. The solid oxide fuel cell has a higher electric conversion efficiency than other fuel cells, but as a result there is no waste heat available to be recovered, unlike other fuel cell technologies. USD's contract with Bloom has a 15-year term and runs through Calendar Year 2031. Bloom Energy maintains the fuel cells and is contracted to remove this system at the end of the PPA.

5.1.5 Energy Storage System:

USD has contracted with STEM, an energy storage solution (battery) company, to receive electrical utility bill demand charge savings. STEM has installed a 528kW/940kWh battery system that discharges energy into USD's electrical grid during high demand charge time periods and recharges when there is no demand charge impact. The STEM system is connected to a 480V -> 12kV transformer feeding into the same circuit as the fuel cell system. USD pays annual fees of $59,223 to STEM and receives demand savings on their SDG&E electric bill. USD is guaranteed a minimum annual utility bill demand savings of $59,223. Initial startup of this system occurred January through March of 2020 and USD's10-year contract with STEM extends into 2030.

5.1.6 Generator System

USD's electrical main service bus includes a relay-controlled main generator circuit breaker that feeds a generator system bus. Three 2MW 12kV diesel generators are connected with individual relay-controlled circuit breakers to the generator system bus. The generators were originally installed as part of an SDG&E program with a controller that is programmed to respond to Demand Response events by decreasing USD's electric demand. This arrangement also provided USD with campus backup capability when the utility power grid goes down. However, the SDG&E Demand Response program has ended and USD must now incur the costs of testing, maintaining, and refueling the generators. The controls have not been upgraded since the system was installed. All three generators are designed to start up, synchronize with each other, and transfer power to the campus grid. In a demand response event, this would remove the campus load from the SDG&E circuit. In an outage, this would back up the campus. The generators run most efficiently with a near-full load and when the load is low, their exhaust gas scrubbers will quickly accumulate particulates and require an expensive maintenance procedure to clean. The monthly testing of these engines is addressed later in this report.

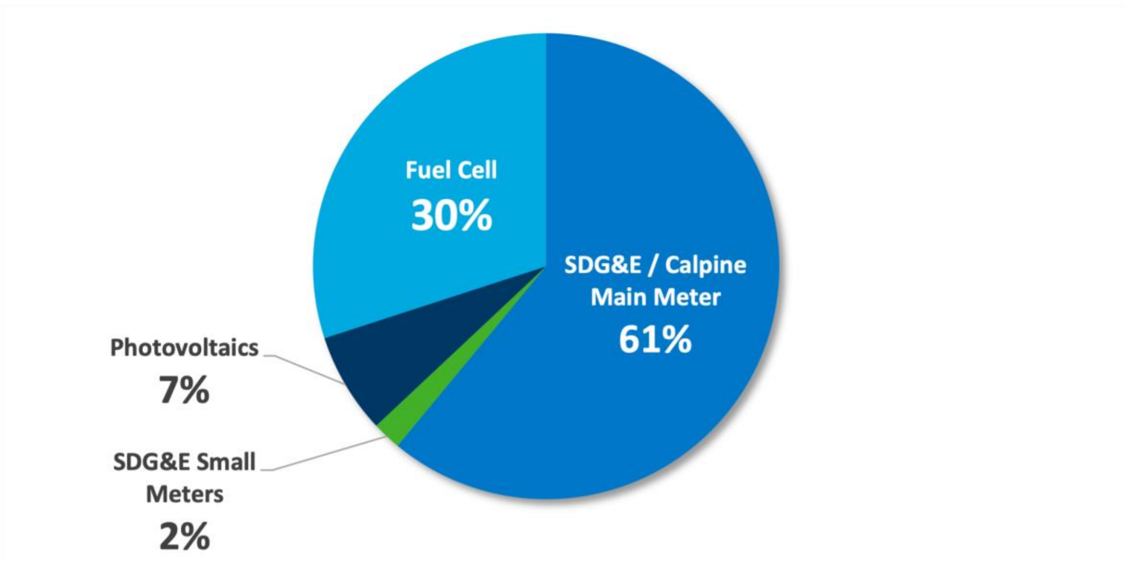
5.1.7 Total Electricity Use

The sum of these four sources of electricity is equal to the total electricity use of the buildings, as shown in the following table and pie chart. (This excludes the small amount of electricity generated by the emergency generators, which do not have metering data available.) The sources of electricity used at the campus in FY19 are shown in Table 4 below.

Table 4: Campus Sources of Electricity

Electricity Source	FY19 Use (kWh)	Location
SDG&E / Calpine Main Meter	15,035,369	SDG&E Service Entrance at West Parking Garage
SDG&E Meters	551,852	Multiple SDG&E Meters at Alcala Park West, PTA, UTA
Photovoltaics	1,593,461	Installed on 11 Campus Buildings
Fuel Cell	7,281,384	West Parking Garage
Total Building Electricity Use	**24,462,066**	

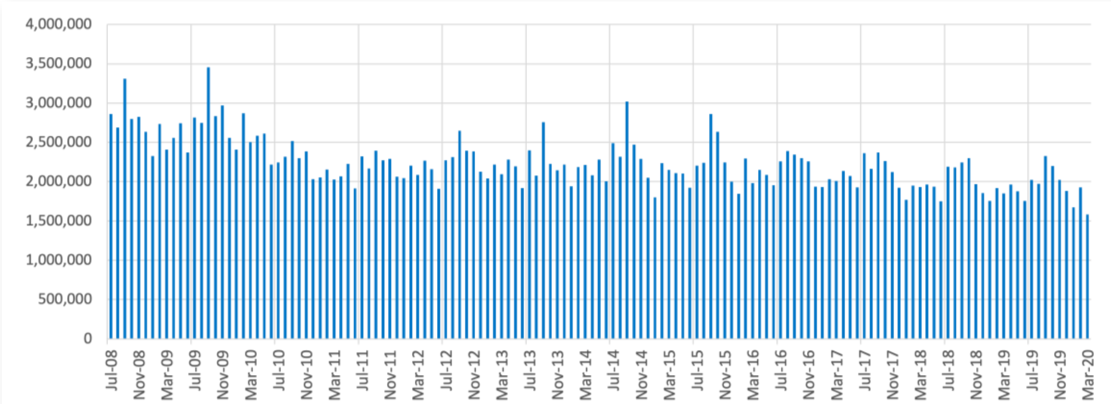
Figure 8: Campus Electricity Purchases FY19



USD building monthly electricity use is shown since FY09 in Figure 9. This represents the electricity purchased from SDG&E and Calpine at the main meter, plus the PV generated on the buildings since early 2010, plus the electricity generated by the fuel cell starting in early 2017.

Note that the total electricity use in FY19 is 26% lower than the total electricity use in FY09. USD should be commended for their significant improvement in efficiency of the campus. During that time the campus area has increased by 117,479 conditioned square feet (4.4%), making this achievement even more impressive.

Figure 9: Monthly Electricity Usage



5.1.8 Benchmarking

When the FY19 building electricity use is compared with the conditioned area of the campus buildings, the result is an electricity use intensity of 8.6 kWh/sf-yr.

This compares to an annual electricity use of 12.3 kWh/sf-yr for all “colleges” in California in the 2006 California Commercial End Use Survey (CEUS) conducted by the California Energy Commission. Note that in FY09 (closest data to 2006) the USD annual electricity use was 12.1 kWh /sf-yr, much closer to other campuses of that day. A new CEUS survey is underway but results are about a year away.

The 2006 CEUS database allows comparison with college campuses in the San Diego Lindberg Field Climate Zone 7. The average electric intensity of the Climate Zone 7 colleges was 19.0 kWh/sf-yr in 2006, significantly higher than the statewide average of the time. While the mild climate in Zone 7 might suggest a lower electricity use, it appears that the large research-oriented campuses with continuously operating heating and cooling plants of UC San Diego and San Diego State University skew the results upward significantly.

The US Energy Information Administration collects energy use of buildings throughout the country, with 2012 data the most recent available. The national average electricity use intensity of Education (classroom) buildings is 11.0 kWh/sf-yr. Offices average 15.9 kWh/sf-yr; Public Assembly buildings average 14.5 kWh/sf-yr; Lodging averages 15.3 kWh/sf-yr.

In comparison to these facility types, the electricity use at the USD buildings is considerably lower than the average university building.

5.1.9 Building Electric Meters

Many campus buildings have electric submeters that measure campus electricity that is delivered to the building. While the majority of campus buildings (such as many of the residences) are not connected to a BMS, the majority of total campus electrical load is monitored on the Siemens building management system through the Insight program. PV systems in the 11 buildings typically tie into the electrical system downstream of the Insight meter artificially reducing submeter readings due to solar PV production. In these cases, it is necessary to add the electric load seen by the Insight submeter to the electrical output of the PV meter to determine the actual electricity use of the building.

6. USD Electricity Expenses

The following tables represent the average cost USD pays for electricity from different sources in FY19. These blended rates are calculated from the total dollar cost divided by the total energy purchased, irrespective of the time of use or demand charges.

The following table shows the cost of purchasing electricity in FY19 at the main meter, using Calpine for commodity. The effective average price is given in $/kWh but in this case most of the SDG&E expense is generated from demand charges ($/kW).

Electricity is delivered by SDG&E using the AL-TOU rate schedule, Primary Voltage, which has high demand charges (April 2020 rates: $23.94 /kW Non-Coincident Demand; $18.95 /kW Summer On-Peak Demand; $19.12 /kW Winter On-Peak Demand) and low energy charges. Summer includes June through October and On-Peak lasts from 4 pm to 9 pm every day.

Table 5: Cost of Purchasing Electricity on Main Meter (Calpine) FY19

Main Electric Meter	15,035,369	kWh	
Electricity Generation (Calpine)	$1,181,149	$ 0.0786	$/kWh
Electricity Transmission and Distribution (SDG&E)	$1,859,257	$ 0.1237	$/kWh
Total/Average	**$3,040,406**	**$ 0.2022**	**$/kWh**

The following is the cost of purchasing solar electricity in FY19.

Table 6: Cost of Purchasing Solar Generated Electricity on Main Meter FY19

Solar Generated Electricity (On Main Meter)	1,593,461	kWh	
Solar Generation (GCL – PPA)	$207,787	$ 0.1304	$/kWh

The following is the cost of purchasing fuel cell electricity in FY19.

Table 7: Cost of Purchasing Fuel Cell Electricity FY19

Fuel Cell Electric Production (On Main Meter)	7,281,384	kWh	
Fuel Cell Electricity Generation Charges (Bloom)	$713,734	$0.0980	$/kWh
Natural Gas Consumption Charge (SDG&E + Calpine)	$332,746	$0.0457	$/kWh
Total/Average	**$1,046,480**	**$0.1437**	**$/kWh**

The following is the cost of purchasing electricity from SDG&E on the smaller electric meters in FY19.

Table 8: Cost of Purchasing Electricity on Other Meters (SDG&E) FY19

SDG&E Electric (Other Meters)	551,812	kWh	
SDG&E Electric Charges (SDG&E Eco Choice 100% Solar)	$165,224	$0.2994	$/kWh

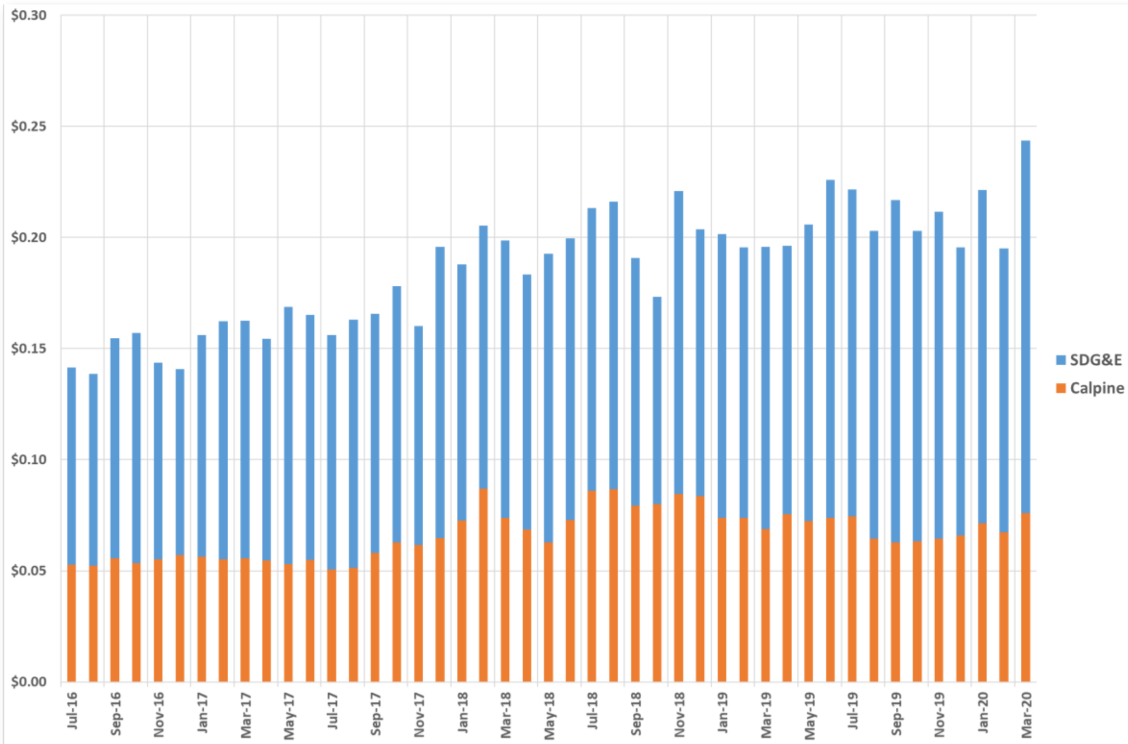
The combined cost for each of these sources of electricity for FY19 is shown here.

Table 9: Cost of Combined Electricity Sources FY19

Total Electricity Use at Buildings	24,462,066	kWh
Total Cost of Electricity	$4,459,897	
Average Cost of Electricity	$0.1823	$/kWh

The average cost of SDG&E main meter electricity each month is shown in the following table since FY17 for the main electric meter. The cost of Calpine's commodity generation is seen to escalate slowly. The cost of Transportation and Distribution from SDG&E can be seen escalating at a higher rate. The SDG&E Account Representative indicated that higher rates should be anticipated in the near future due to their increase in costs incurred as a result of natural disasters in recent years.

Figure 10: Historic Electric Price Breakdown



7. USD Electric Load Profile

This section addresses the 15-minute electrical load data at the main utility service, inclusive of power purchased from SDG&E, the solar PV generation and fuel cell contributions. The sum of these three sources represents the energy use by the USD buildings.

A fourth source of electricity serving building loads at USD is the emergency generators that supply backup power to the entire campus, as they are typically exercised several hours a month. However, there is no known log of their power output during their test periods. Since the generator load profiles would be approximately 3,000 kW for several hours a month, metered imported electricity would drop to zero as the site is disconnected from the grid.

7.1.1 Photovoltaic (PV) System

PV systems are installed on the roofs of eleven campus buildings. The combined capacity of these systems is 1,170 kW DC of PV module capacity. During FY19, solar PV at USD produced 1,593,448 kWh AC of electricity, for an overall performance of 1,362 kWh AC / kW DC. This is not a particularly good performance for a PV system in Southern California, as the PVWatts calculator from the National

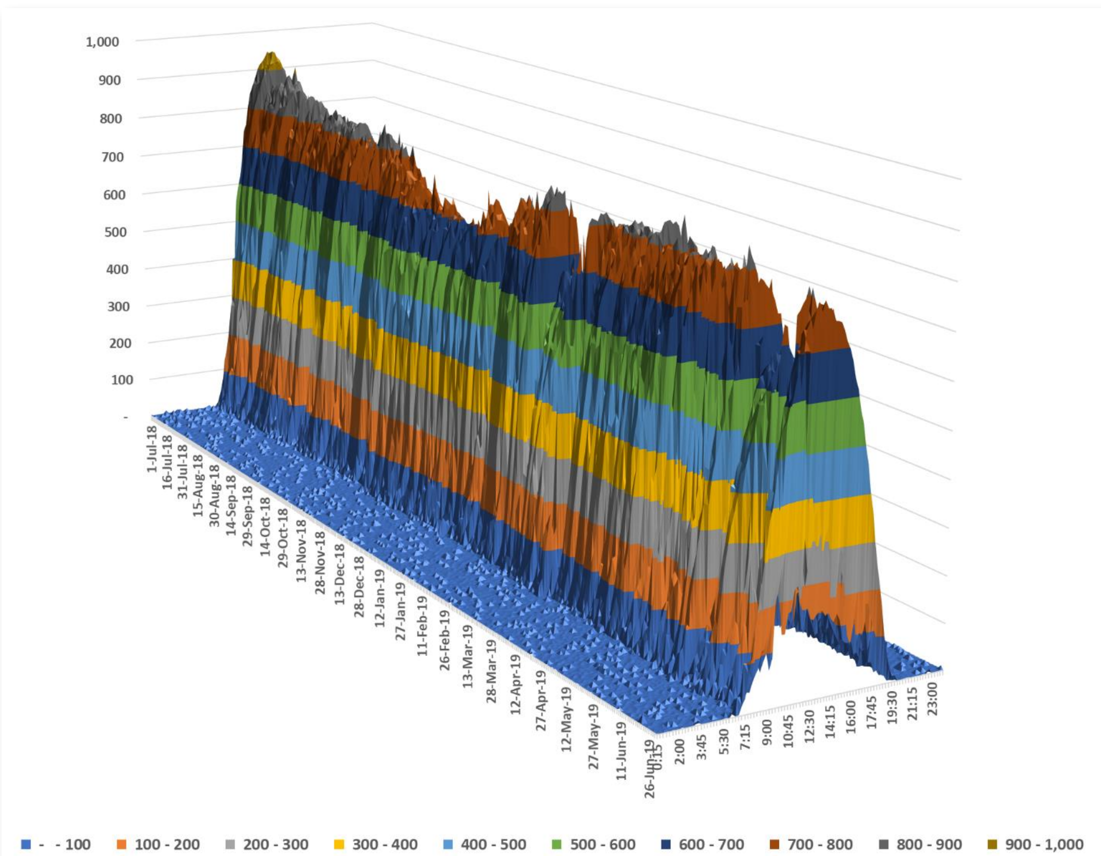
Renewable Energy Laboratory (NREL) estimates performance levels ranging from 1,519 to 1,590 for the latitude and longitude of the USD campus (see Appendix B). Additionally, as was previously mentioned in Section 5.1.3 that output is down 20% in 8 years, and down 12% from the previous year alone. The reduced output is at least partially due to the unavailability of some PV systems when their building is under renovation and the electrical systems are not active. It is recommended that the campus track the performance each year relative to the guaranteed performance for that year.

PV data collection issues are discussed in Appendix B. It is recommended that USD address data logger or communications issues so that data is collected reliably during each 15-minute period.

It is also recommended that USD evaluate system performance relative to weather or other parameters allowing USD to determine if there are deficiencies that need to be addressed by PPA provider. The data collection equipment that was installed with the PV system should include a measurement of Global Horizontal Irradiation (GHI) against which the performance can be evaluated.

The FY19 performance of the PV system is shown in Figure 11. The high production for the year was just over 900 kW AC at the beginning of July. After a drop off in the winter, the peak in the spring is just over 800 kW AC.

Figure 11: Solar Output Profile FY19

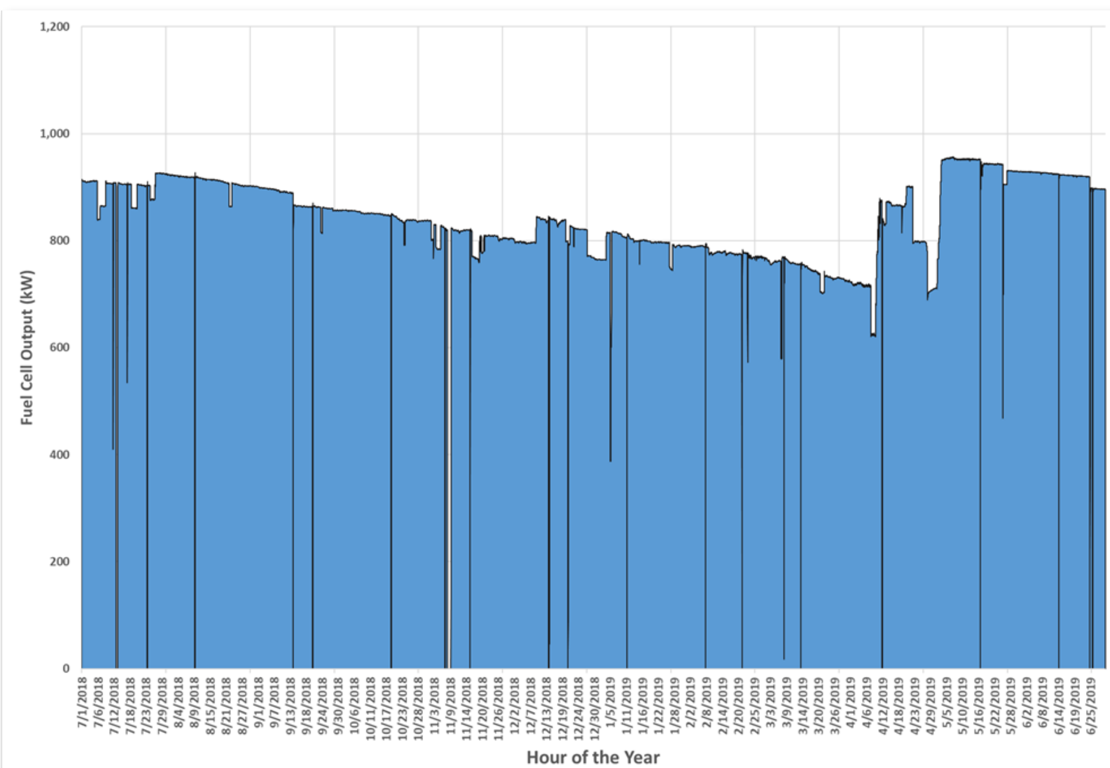


7.1.2 Fuel Cell System

The campus has a Bloom fuel cell plant with a nominal output of 1,000 kW. The 15-minute metered output of the fuel cell for FY19 is shown in Figure 12. During FY19 the plant output ranged from about 700 to 950 kW, with an average of 834 kW. The performance appears to degrade during normal operation, with a reset every year or so. The rate of degradation is approximately 1.9% per month without the resets.

The steady state operation of the fuel cell appears fairly stable. However, as seen in Figure 12, the fuel cell was down 22 times during FY19 either for operational issues or electrical interruptions. Periods of fuel cell unavailability occurred at least once per billing cycle. These periods of unavailability had significant impacts on USD's total demand and SDG&E electric billing, as the University's payment to SDG&E is almost entirely based on the On-Peak and Non-Coincident demand (vs. the commodity payment that goes to Calpine). For instance, 76% of the February 2019 SDG&E electric bill consisted of demand charges, representing $120,977 of the total $158,723 bill. These demand charges range from about $19/kW measured during the On-Peak period (4 to 9 pm every day), to $24/kW for the Non-Coincident demand periods. In addition to these demand-related charges, USD also incurs "deemed power" charges when the fuel cell is shut off for reasons not under Bloom's control, resulting in annual charges ranging from $2,000 - 5,000. Recommendations to avoid these charges by maintaining fuel cell availability are detailed in Section 15.2, resulting in the potential for over $100,000 in annual energy bill savings.

Figure 12: Fuel Cell Output FY19

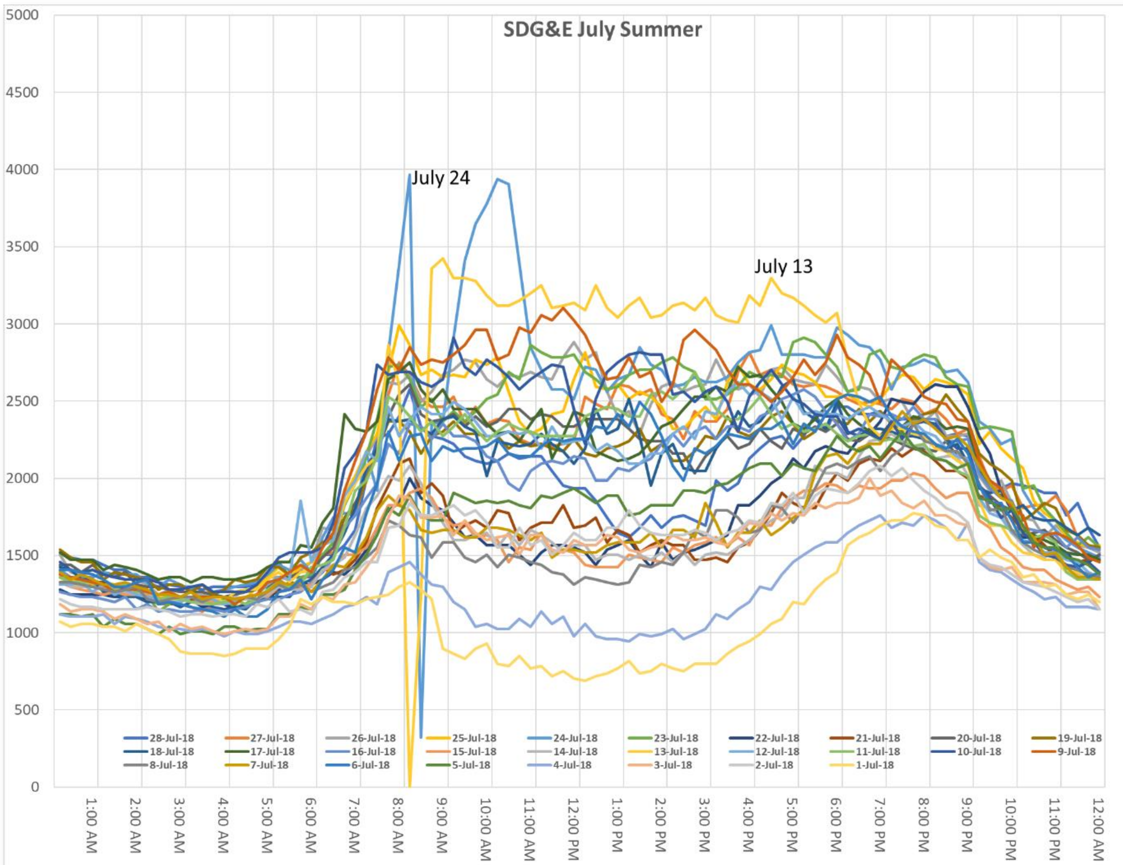


7.1.3 SDG&E Electric Load Profile

The 15-minute profile of electric purchases from SDG&E is available for all of FY19. This data is shown graphically for every day of the year in the Appendix C.

The 15-minute electric profile for the main campus SDG&E meter is shown here in Figure 13 for one typical month, July 2018.

Figure 13: Electric Load Profile for Typical Month



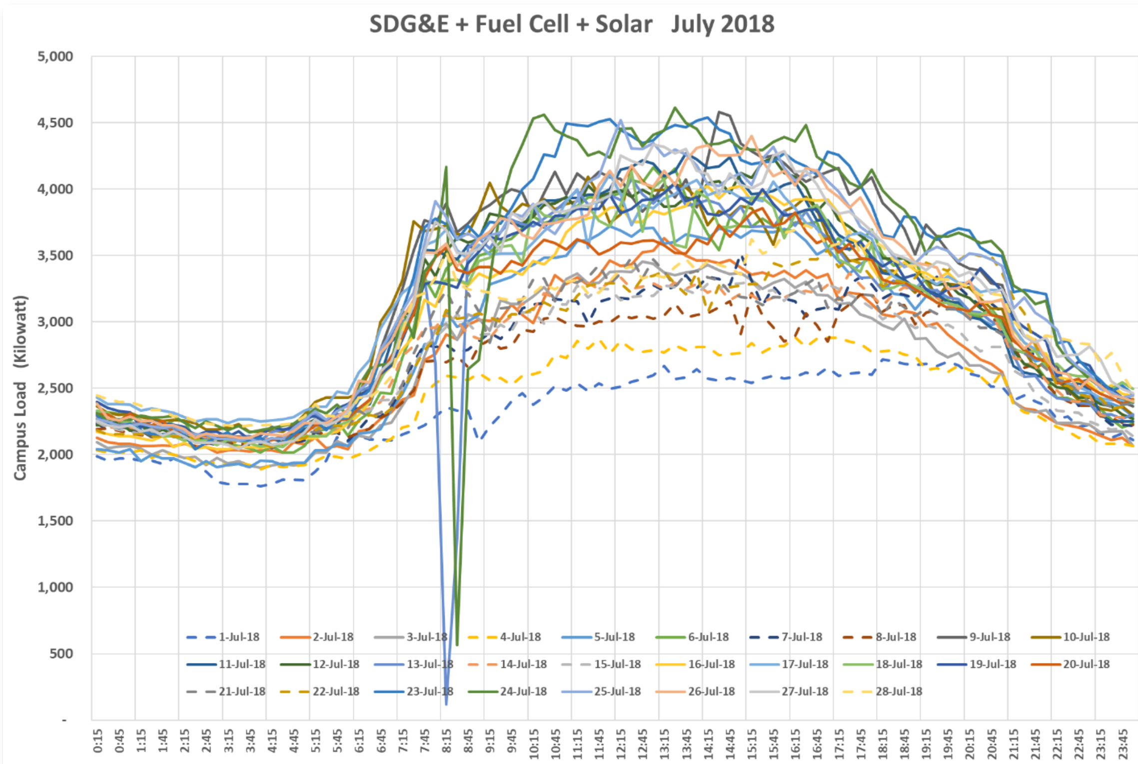
This graph shows consistent power purchases at night, but there are large changes in the purchases around 8:30 am on days with emergency generator testing. The purchases during the day range from under 1,000 kW to over 3,000 kW. The daytime purchases typically sag as the solar contribution peaks in the early afternoon.

The wide variations in these loads make it difficult to interpret what is happening with loads in the buildings and utility charges. The following section consolidates purchased power data, so a clearer picture is available for the whole campus electric load.

7.1.4 Building Electric Load Profile

The 15-minute electric load profiles from the three sources (photovoltaic systems, fuel cell and SDG&E main meter) are added together in Figure 14 to give a clearer picture of campus buildings electricity use profile.

Figure 14: Combined Electric Load Profile for Sample Month



This graph presents the cumulative electric load at USD buildings during the billing period of July. There is still missing data where the emergency generators are being tested (twice in this month) when it appears the campus meter load goes close to zero. The load is actually being met by the emergency generators during these intervals but emergency generator output data is not available.

These graphs use dashed lines to show energy use for weekend days, holidays, and campus breaks. The solid lines (weekday loads) cluster closely together at the top of the graph. The weekend days and holidays have a fairly wide variation in loads, suggesting the opportunity to shut down these buildings more completely on some of these low occupancy days. It cannot be determined from this data alone what causes the variations in the site electrical load. A systematic review is suggested. For example, if low campus loads are observed on some days, such as, perhaps, July 4 in this graph, why couldn't the load be as low on other weekend days during this month? Are these load variations caused by automatic load shifts, such as the load of the chilled water plant? Or are they caused by manual intervention into the operation of air handlers or other loads?

The building load profiles are shown for every day of the baseline year in Appendix D.

8. USD Natural Gas Use

8.1.1 Building Natural Gas Use

Natural gas is used in buildings throughout the campus in steam boilers, hot water boilers, domestic hot water heaters, kitchen equipment, laboratories, and studios. This analysis addresses natural gas which is used in buildings for these purposes and does not address the natural gas used in the fuel cell, which is addressed separately in Section 8.1.3.

Six main gas meters supply the bulk of the campus building load using SDG&E transportation and Calpine commodity. The gas use of these meters is shown in the Table 10.

Table 10: Metered Gas Usage

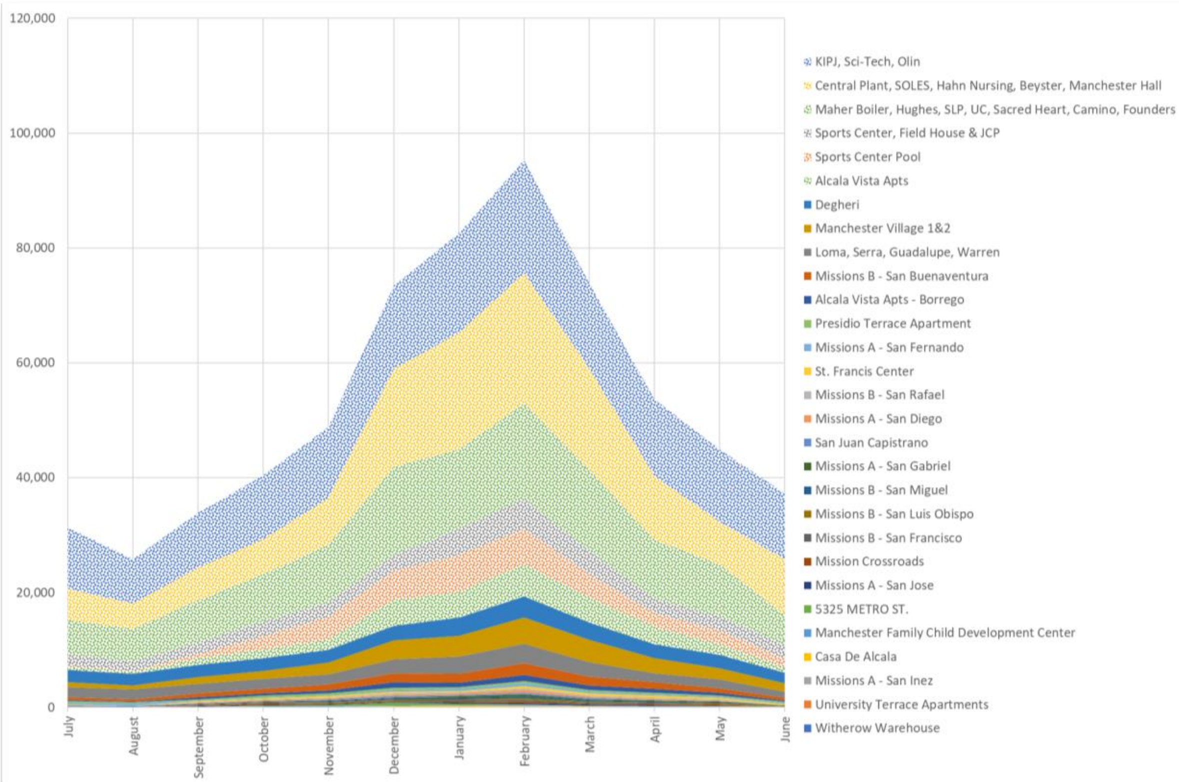
Direct Access Gas Meters – Calpine	FY19 Therms
Kroc Institute for Peace and Justice, Shiley Sci-Tech, Olin	155,368
Central Plant, SOLES, Hahn Nursing, Beyster, Manchester Hall	135,237
Maher Boiler, Student Life Pavilion, University Center, Hughes, The Immaculata	121,889
Sports Center, Field House & JCP	34,931
Sports Center Pool	34,807
Alcala Vista Apartments	30,704
Total	**512,936**

There are approximately 23 SDG&E natural gas meters that serve buildings around campus but provide smaller quantities of SDG&E commodity natural gas. In FY 19 these supplied a total of 128,509 therms of natural gas. These meters are listed in the following graph of monthly natural gas use.

The following chart illustrates the use of building natural gas throughout the year. The six larger Calpine meters are shown on top, in the lighter colors. These six meters use 80% of the building natural gas on campus. Campus gas use peaks in February and is at its lowest, one quarter of the peak month, in August. The largest three gas meters use significant gas during the summer as well as the winter for reasons explained at the end of this section.

The total gas use in buildings, compared to the area of conditioned buildings gives a natural gas use index of 0.231 th/sf-yr, which is well below the 2006 CEC's California End Use Survey (CEUS) average value of 0.43th/sf-yr for colleges in San Diego area. Note that 2006 was the most recent year this comprehensive standard study was conducted by the CEC.

Figure 15: FY19 USD Building Natural Gas Use by Meter (Therms)



The buildings served by these gas meters are listed in the following table, including the six Direct Access meters first. Where metered gas is distributed to multiple buildings, these are grouped together as shown on the graph. The exceptions to this rule are noted if heating is delivered by steam or hot water.

In several cases, a boiler in one building may provide hot water to an adjacent building. There is only one plant (Central Plant) that serves multiple buildings with hot water and steam. The campus has made a concerted effort to install distributed gas fired space heating hot water boilers and gas fired domestic hot water heaters to reduce the losses and maintenance associated with steam and hot water distribution around a campus.

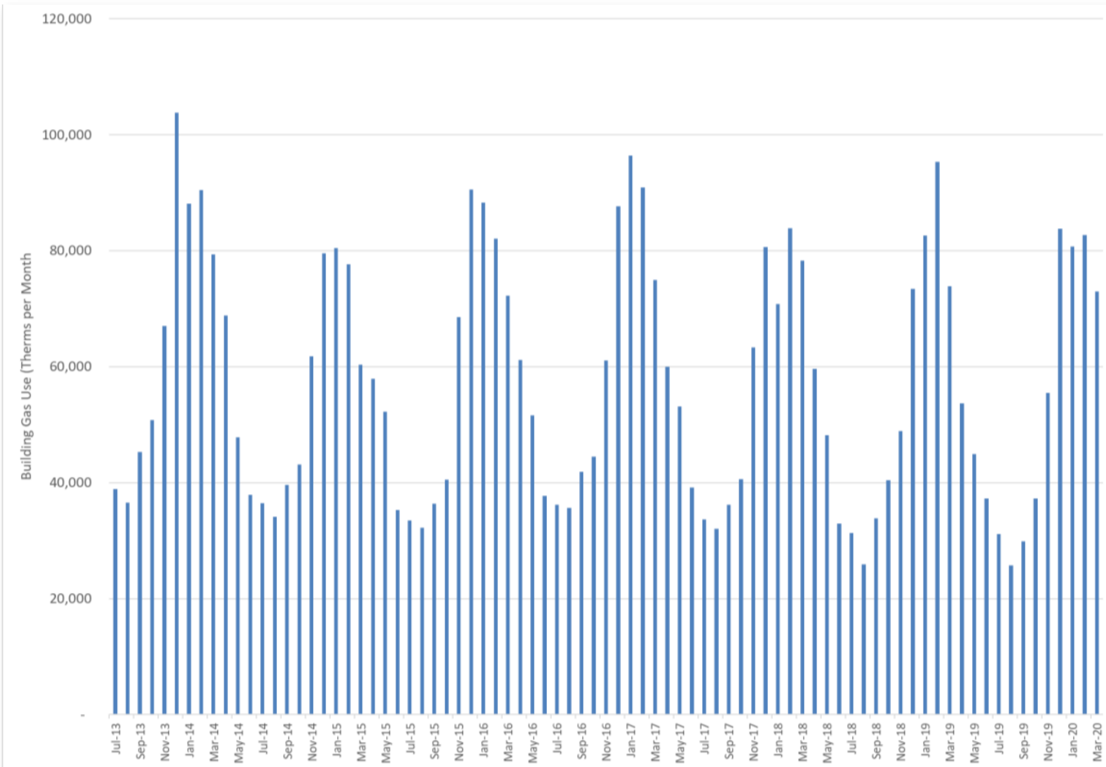
8.1.2 USD Gas Meters and Associated Buildings

Table 11: USD Gas Meters and Associated Buildings

SDG&E Account	Address	Location
5601009844	5697 MARIAN WAY	KIPJ, Olin, Shiley Sci-Tech (Hot water from KIPJ)
9884802545	5697 LINDA VISTA RD	Central Plant, Hahn Nursing, Beyster, Manchester Hall, SOLES, Copley (Hot water from CP), Camino (Steam from CP), Founders (Steam), Sacred Heart (Steam), Ministry (Steam)
98848069548	5697 LINDA VISTA RD	Maher Boiler, Student Life Pavilion, University Center, Hughes, The Immaculata
9884734186	6120 LINDA VISTA RD	Sports Center, Field House & JCP
9884736386	6120 LINDA VISTA RD	Sports Center Pool
8759737854	1502 VIA LAS CUMBRES	Alcala Vista Apts
5945524484	5911 MARIAN WAY	Degheri
4670555123	1720 VIA LAS CUMBRES	Manchester Village 1&2
8759809159	5697 LINDA VISTA RD	Belanich, Serra, Guadalupe, Warren (Hot water from Belanich)
9711500087	6030 SAN DIMAS AVE	Missions B - San Buenaventura
8887981097	1520 VIA LAS CUMBRES	Alcala Vista Apts - Borrego
7634853256	5702 LINDA VISTA RD HM	Presidio Terrace Apartment
3134794454	5921 SAN DIMAS AVE	Missions A - San Fernando
4259757709	1624 SANTA PAULA DR HM	St. Francis Center
2009801809	6015 SAN DIMAS AVE	Missions B - San Rafael
7634794458	5927 SAN DIMAS AVE	Missions A - San Diego
3134801801	6025 SAN DIMAS AVE	San Juan Capistrano
6509794456	5963 SAN DIMAS AVE	Missions A - San Gabriel
4259801800	6045 SAN DIMAS AVE	Missions B - San Miguel
5384801802	6065 SAN DIMAS AVE	Missions B - San Luis Obispo
8759794457	5981 SAN DIMAS AVE	Missions B - San Francisco
9884794459	5989 SAN DIMAS AVE REC	Mission Crossroads
4259794453	5951 SAN DIMAS AVE	Missions A - San Jose
8759925283	5325 METRO ST.	5325 METRO ST.
4259743009	1752 VIA LAS CUMBRES	Manchester Family Child Development Center
8759801804	1475 CUSHMAN AVE	Casa De Alcala
5384794455	5957 SAN DIMAS AVE	Missions A - San Inez
6510272201	1333 GOSHEN ST HM	University Terrace Apartments
6386437409	1001 MORENA BLVD	Witherow Warehouse

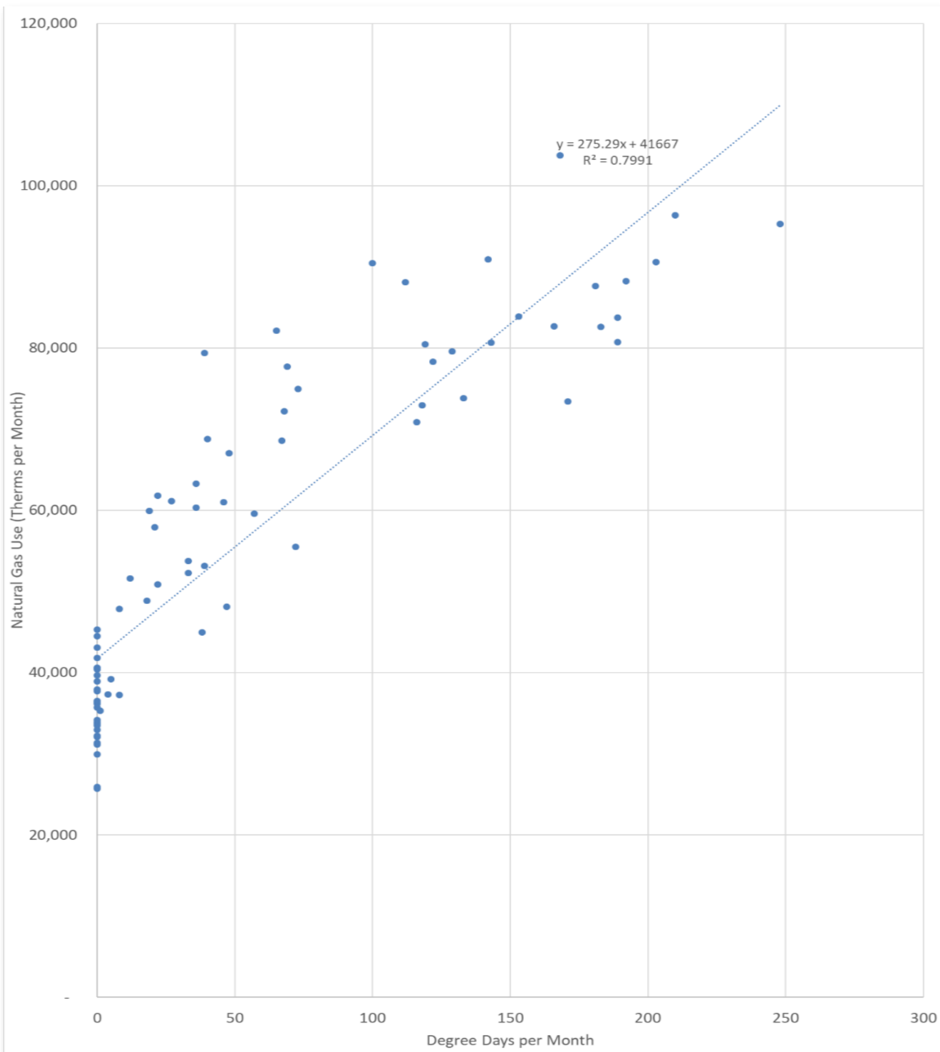
The monthly building natural gas use for the above meters is shown in the following graph since FY14. The natural gas use in FY 19 is 15% lower than that of FY14. The higher winter loads are due to the space heating required during cooler weather as well as higher campus occupancy.

Figure 16: USD Building Gas Use FY14 to Present



The following graph plots the building natural gas use by month since FY14 versus the heating degree days recorded for that month. A zero-heating degree day month is typically considered to have no space heating requirement. A trend line crosses the zero-heating degree day axis at 41,667 therms per month. The "minimum" monthly gas use of 41,667 therms can be attributed to domestic hot water heating, cooking, kilns, distribution losses, and potentially to some amount of HVAC reheat that happens even during warm weather. Note that minimum monthly loads once were about 40,000 therms but in recent years monthly natural gas use has dropped to as low as 25,000 therms occasionally, so this graph does not necessarily reflect the latest campus loads.

Figure 17: USD Gas Meter Monthly Natural Gas Use vs. Heating Degree Days (FY14 to FY20)



8.1.3 Fuel Cell Natural Gas

Natural gas is also used to generate electricity on the campus through a 1,000 kW solid oxide fuel cell. The fuel cell used 540,676 therms of natural gas in FY19. This is more gas than is used by the six main campus building gas meters combined.

The fuel cell is designed to run at a steady full load continuously. However, performance data logs show that its capacity drops slowly over time and can be reset higher during maintenance procedures.

The fuel cell produced 7,281,384 kWh of electricity in FY19, with an average output of 831 kW. The efficiency of this process can be calculated in several ways. A therm represents 100,000 Btu of natural gas energy, so the gas energy purchased in the year was 54,078 Million Btu. A kWh represents 3,412 Btu of electric energy, so the electric energy produced was 24,844 Million Btu. The ratio of these two is the efficiency of the electricity generation relative to the higher heating value of the natural gas, or 45.9%.

Generation efficiency is sometimes measured by the lower heating value of natural gas, which would give an efficiency of 51.0%. This can be compared to a legacy utility steam turbine power plant which has an LHV efficiency of perhaps 35%, while a modern combined cycle utility power plant can have an LHV efficiency up to 60%.

8.1.4 Fuel Cell Contract

The fuel cell contract includes an Efficiency Warranty which warrants that the system will operate at an "Efficiency of at least 8,394 Btu/kWh during each calendar quarter." A payment would be made to the University if the gas use is higher than the warranty level.

The fuel cell contract also includes a Lifetime Efficiency Performance Guaranty that the equipment will "maintain an average Efficiency over the Term of not more than 7,264 Btu/kWh." This Guaranty includes a running tally so that gas savings in one quarter can offset increased gas use in a later month.

The heat rate for FY19 is calculated (540,6676 therms to generate 7,281,384 kWh) is 7,425 Btu/kWh HHV. (We assume that the contract is referring to the higher heating value of the fuel.) This is a slightly higher gas use than the Lifetime Efficiency Performance Guaranty above. It is recommended that the university continue to track this value, as they may qualify for reimbursement in the near future if the gas use continues to trend above the Efficiency Performance Guaranty.

8.1.4.1 Natural Gas Expenses

The FY19 cost components of natural gas use are shown in the following tables. This shows the Calpine accounts which provide the commodity for the six largest building meters, the sum of the smaller gas meters, as well as the fuel cell meter.

Table 12: Cost of Natural Gas Use at Six Largest Calpine Building Meters

Natural Gas (Six Calpine Building Meters)	512,936	therm	
Gas Commodity (Calpine)	$254,346	$0.4959	$/therm
Gas Transmission and Distribution (SDG&E)	$195,040	$0.3802	$/therm
Total	**$449,386**	**$0.8761**	**$/therm**

Table 13: Cost of Natural Gas Use at Other Calpine Building Meters

Natural Gas (Other Building Meters)	128,509	therm	
Gas Commodity (SDG&E)	-	-	$/therm

Gas T&D and Commodity (SDG&E)	$109,380	$0.8511	$/therm
Total	**$109,380**	**$0.8511**	**$/therm**

The total gas use for buildings on campus (not including the natural gas use in the fuel cell for generating electricity) is listed here.

Table 14: Total Natural Gas Use at Buildings

Total Natural Gas Use at Buildings	641,445	therm
Conditioned Building Area	2,775,864	sf
Natural Gas Use Intensity	0.231	Th/sf-yr

The cost for the natural gas used in the fuel cell to generate electricity is listed here.

Table 15: Total Cost of Natural Gas to Generate Electricity (Calpine Fuel Cell Meter)

Natural Gas (Calpine Fuel Cell Meter)	540,676	therm	
Calpine Commodity	$238,160	$0.4405	$/therm
SDG&E T&D	$94,586	$0.1749	$/therm
Total	**$332,746**	**$0.6154**	**$/therm**

9. Greenhouse Gas from Energy Purchases

USD's 2020 Energy Policy Initiatives Center (EPIC) report indicated total GHG emissions in FY18 to be 21% lower than FY2010 and 4% lower than FY2017. The top GHG emission was attributed to *purchased electricity*, with 6,609 MT CO_2e for FY18 out of the total 23,851 MT CO_2e; or 28% (with *commuting* leading with 29% CO2 emissions). This report also indicated a steady decline in the *stationary combustion* (from natural gas) emission from 2010 with the addition of fuel cells increasing the therms consumed at the beginning of 2017.

This Energy Master Plan analysis finds the total GHG emissions of all purchased energy in FY19 is 10,394 MT CO_2e, assuming the GHG equivalencies are the same as in FY18. A breakdown of all the different sources of energy contributing to USD's GHG emissions can be seen below in Table 14. Emissions are shown in the standard term of metric tons (MT), which are metric tons that weigh 1,000 kg. These metric tons (or tonnes) are each equivalent to 2,205 pounds of GHG emissions, or 10% more than the typical American ton.

Table 16: GHG Emissions Based on Energy Purchase at USD FY19

Energy Purchase	Quantity	Units	Equivalency	GHG MT CO2e
SDG&E / Calpine Power	15,035,369	kWh	0.000257 tonne / kWh	3,859
SDG&E Power (100% Renewable)	551,852	kWh	0 tonne / kWh	0
Solar electricity generation	1,593,461	kWh	0 tonne / kWh	0
SDG&E / Calpine Natural Gas	512,916	Therm	.0053 tonne / therm	2,719
SDG&E Gas for Buildings	128,509	Therm	.0053 tonne / therm	681
SDG&E / Calpine Gas for Fuel Cell	540,676	Therm	.0053 tonne / therm	2,866
Total				**10,394 MT**

The main campus SDG&E electric meter measures the electric commodity purchased from Calpine. The fuel mix from Calpine determines the pounds of GHG emissions (CO_2 equivalent) that are released in the generation of one kWh. This equivalency is multiplied by all of the electricity purchases from Calpine to determine the associated GHG emissions.

The electricity purchased from smaller SDG&E meters has no associated GHG emissions because USD has elected to purchase 100% carbon free electricity. This SDG&E 100% renewable option is not available for the main campus SDG&E meter.

Note that electricity generated by the PV systems reduces the amount of electricity that must be purchased from the utility, reducing GHG as there is no GHG associated with the operation of the PV systems.

Natural gas is purchased for the campus use and for the fuel cell use, and therefore has a GHG impact, whether it is being burned to generate heat or oxidized in a fuel cell to generate electricity.

The equivalencies for GHG production from Calpine Power come from the University of San Diego EPIC Fiscal Year 2018 Greenhouse Gas Emissions Inventory and Trend Summary, May 2020, Energy Policy Initiatives Center (Calpine power: 566 lbs. CO2e/MWh, or 0.000257 tonne/kWh)[12] as well as the US Energy Information Administration (5.3 kg CO2e/therm)[13] . These values are only associated with the generation of the power, an additional factor of 270 MT[14] is then added in the EPIC report to account for transmission and distribution losses associated with the transportation of the energy.

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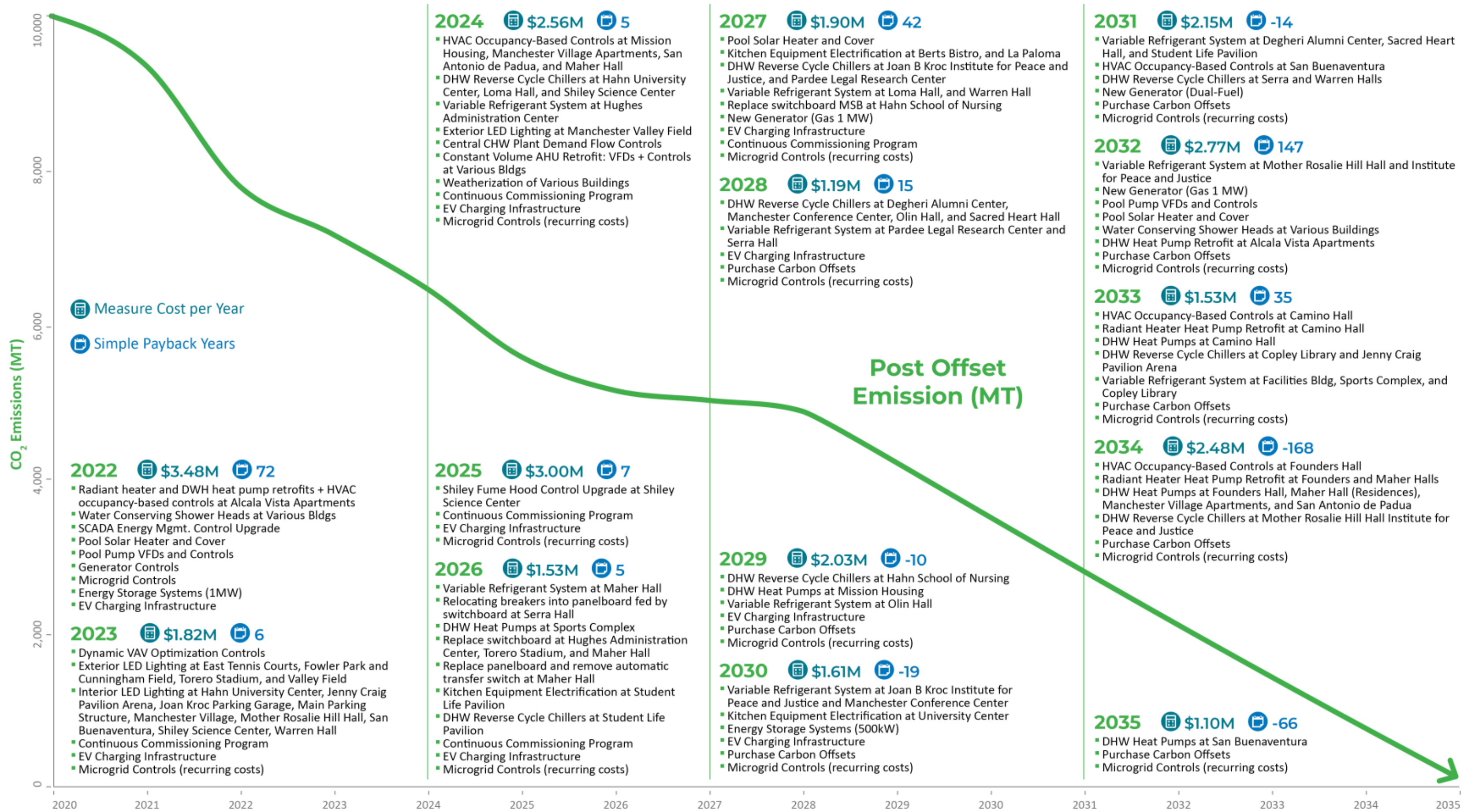
[12] EPIC University of San Diego FY18 GHG Inventory and Trend Summary May 2020

[13] US Energy Information Administration, "Carbon intensity of energy use is lowest in U.S. industrial and electric power sectors", https://www.eia.gov/todayinenergy/detail.php?id=31012. May 1, 2017, Accessed 2/12/21.

[14] EPIC University of San Diego FY18 GHG Inventory and Trend Summary May 2020

10. Energy Master Plan Recommendations

The graphic below provides a timeline depiction of the various Energy Master Plan recommendations detailed within this second half of the report, including annual estimated costs as well as their suggested staging.



Note: See Appendix F "Master Measure Table" with individual measure cost per year

When selecting the various energy efficiency measures the following methodology was used for priority and staging:

- **Short Payback / High Savings:** Projects with high estimated gas and electric savings and shorter paybacks were prioritized in Years 1-5. This ensures that energy savings and carbon reduction opportunities are secured early and can lead to long-term savings. These measures include:
    - Pool retrofits (Variable pumping, solar heating, cover)
    - Interior and Exterior LED retrofits
    - Controls Measures (Central Plant demand flow, VAV optimization, Residential HVAC Controls)
- **Deferred Maintenance Priorities:** Through multiple meetings with Facilities Management and Grounds Staff, campus priorities were noted in relation to buildings with most urgent construction and upgrade needs. Additionally, the Sightlines Deferred Maintenance Master Spend List Spreadsheet was cross-referenced, alongside a list of buildings with the highest Energy Usage Intensity.
- **Yearly Budgeting:** Drawing upon our meetings with Facilities staff, it was determined that deferred maintenance spending is commonly budgeted at approximately ~6M/yr. With this figure in mind an effort was made to limit yearly EEM cost projections to 50% of the total deferred maintenance spending budget: ~$3 million or below.
- **Grouping of Common Measures / Buildings:** When possible with budgeting constraints and building prioritization, common measures were grouped together for the district to pursue economies of scale in contracting.

The second half of Energy Master Plan consists of the following recommendation areas:

- GHG Reduction Opportunities for Energy Purchases
    - A discussion regarding renewable natural gas and hydrogen alternatives to natural gas, on-site power generation through fuel cells and cogeneration, options for emergency power generation, 100% renewable power procurement options: including San Diego Community Power, and the use of carbon offsets and Renewable Energy Credits (RECs).
- Energy Efficiency and Building Electrification Measures
    - This section leverages Michael Wall Engineers and Michael Akavan Engineers extensive knowledge of USD's electrical and mechanical systems to provide over $32M of building retrofits to reduce the campus energy usage and carbon footprint while converting the vast majority of campus equipment to electric.

The following table provides a measure-level breakdown of the mechanical and electrical efficiency measures, which are expanded on in detail in Section 12.1 and Section 12.2 and Appendices H-J.

It is important to note that measure cost is defined differently depending upon the measure. For capital-intensive mechanical retrofits, such as kitchen electrification, gas boiler to heat pump or major renovations to VRF HVAC systems, incremental cost was used. Incremental cost (IMC) is defined as the additional cost beyond a business as usual, like for like replacement. Since the equipment for these IMC measures will have to be updated during these next 15 years due to age/deterioration, it was considered more realistic to compare these decarbonization measures to the standard case of their BAU replacements and only include the incremental additional cost beyond what USD would have already had done absent the Energy Master Plan.

For all other measures which do not greatly exceed business as usual requirements and are less capital intensive, full measure cost (FMC) is used.

Due to the estimated useful lifetime of some measures implemented early on in the energy master plan, replacements are required before 2035. For these projects (pool cover, water conserving shower heads, pool pump VFDs, and residential DHW heat pumps at Acala Vista), replacement costs are listed as well.

Table 17 - Mechanical and Electrical Efficiency Measure Summary Table

Measure Description	Building	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback	IMC or FMC	Replacement Costs
Mechanical Efficiency Measures								
Pool Solar Heater and Cover	Pool	-	28,170	$23,975	$129,028	5	FMC	$258,056
Central Steam Plant Heat Pump Conversion	Facilities Bldg	(948)	201	-$21	$36,500	-1764	IMC	
Weatherization of Various Buildings	Multiple Buildings	424,850	58,000	$135,268	$550,000	4	FMC	
Water Conserving Shower Heads	Multiple Buildings	-	18,307	$15,581	$21,700	1	FMC	$21,700
Constant Volume AHU Retrofit: VFDs + Controls	Multiple Buildings	237,331	1,083	$48,910	$182,382	4	FMC	
Kitchen Equipment Electrification	Multiple Buildings	(410,615)	74,292	-$19,796	$340,071	-17	IMC	
Pool Pump VFDs and Controls	Pool	89,355		$18,068	$27,403	2	FMC	$27,403
Air Handler Controls: Dynamic VAV Optimization	Multiple Buildings	502,280	12,304	$112,033	$250,000	2	FMC	
Residential Heating Electrification: Heat Pump Retrofit	Multiple Buildings	(59,805)	11,602	-$2,219	$674,850	-304	IMC	
Residential HVAC Occupancy-Based Controls	Multiple Buildings	60,858	8,439	$19,488	$542,500	28	FMC	
Residential Domestic Hot Water	Multiple Buildings	(674,169)	78,687	-$69,346	$5,605,879	-81	IMC	$1,127,806

Electrification: Heat Pumps								
HVAC Major Renovation: Variable Refrigerant System	Multiple Buildings	2,344,289	7,632	$480,511	$4,526,870	9	IMC	
Non-Residential Domestic Hot Water Electrification: Heat Pumps or Reverse Cycle Chillers	Multiple Buildings	(117,656)	101,930	$62,962	$2,004,162	32	IMC	
Central Chilled Water Plant Pumping - Demand Flow Controls	Central Plant	287,974		$58,228	$330,000	6	FMC	
Shiley Fume Hood Control Upgrade	Shiley Science Center	1,108,187	37,066	$255,622	$2,500,000	10	FMC	
Electrical Efficiency Measures								
Interior LED Lighting Retrofit	Multiple Buildings	366,163		$74,038	$277,904	4	FMC	
Exterior LED Lighting Retrofit	Multiple Buildings	772,887	-	$156,278	$872,558	6	FMC	
Garage LED Lighting Retrofit	Kroc and Main Parking Structures	96,264		$19,465	$68,365	4	FMC	
Total Energy Efficiency /Electrification Measures		**5,027,245**	**437,713**	**$1,389,047**	**$18,940,171**	**14**	**-**	**$1,434,965**
Total Costs (Retrofits + Replacements)					**$20,375,136**			

- Energy Conservation Measures in Lighting Control
  - Provides recommendations regarding occupancy sensors, daylight capture, and plug load controls for USD to take into account for future major renovations and new construction projects.
- Energy Conservation Measures for Power Systems
  - Provides guidance to inform USD operational decision-making on a variety of power systems, ranging from the immediate recommendation to upgrade generator controls and testing to realize over $100k of annual bill savings to the more generalized and mid-term recommendation to implement EV Charge Control Management to manage peak electrical demand. Also includes guidance regarding energy storage for PV system harvesting and peak-demand management, fuel cell & generator optimization, demand response, and SCADA System Integration.
- Electrical Resiliency Recommendations
  - Provides cost estimates and recommended timeline for the replacement of USD's existing diesel generators which are approaching their end of life. Provides a framework for a campus microgrid, with estimated costs for the total cost of ownership of the additional energy storage, control systems, and trained staff to properly maintain power to the campus during extended outages in a sustainable manner.

The table below summarizes the compiled resiliency and microgrid cost estimates, further detailed in Section 15.

Table 18 - Resiliency and Microgrid Cost Estimates

Generator Controls	$85,000
Microgrid Controls (one-time costs: initial setup & staff training, computer systems and dashboard setup)	$215,000
Microgrid Controls (recurring costs through 2035: dedicated staff hire, controls software subscription, and dashboard maintenance)	$2,380,000
SCADA / Siemens energy management control upgrade	$25,000
New Generator (Diesel 2MW)	$1,000,000
New Generator (Gas 1 MW)	$500,000
New Generator (Gas 1 MW)	$500,000
Energy Storage Systems (1.5 MW total of batteries)	$1,800,000
Total Resiliency & Microgrid Cost Estimates	**$6,505,000**

- Electrical Deficiency Projects
  - Identifies major building-level electrical infrastructure deficiencies while providing cost estimates and recommended timeline for resolution.
- Potential Self-Generation Projects
  - Identifies over 2.4 MW of additional PV capacity utilizing remaining available campus roof-space and includes discussion on USD considerations at the end of its existing PPA after 2035.

- New Construction ZNE Policy
  - Recommends that USD commit to capping overall campus energy usage and revise their design standards to maximize energy efficiency and renewable on-site generation.
- Building Commissioning
  - Provides detailed background on building commissioning initiatives while recommending an ongoing commissioning plan to secure and maintain additional energy savings through the addition/training of qualified staff and implementation of campus-wide building maintenance policies which involve multiple campus stakeholders, including students.
- Experiential Learning
  - Includes various energy-related experiential learning initiatives for students in the short, mid, and long-term timeframes. Also includes a summary of the internship scope of work contributing to this Energy Master Plan

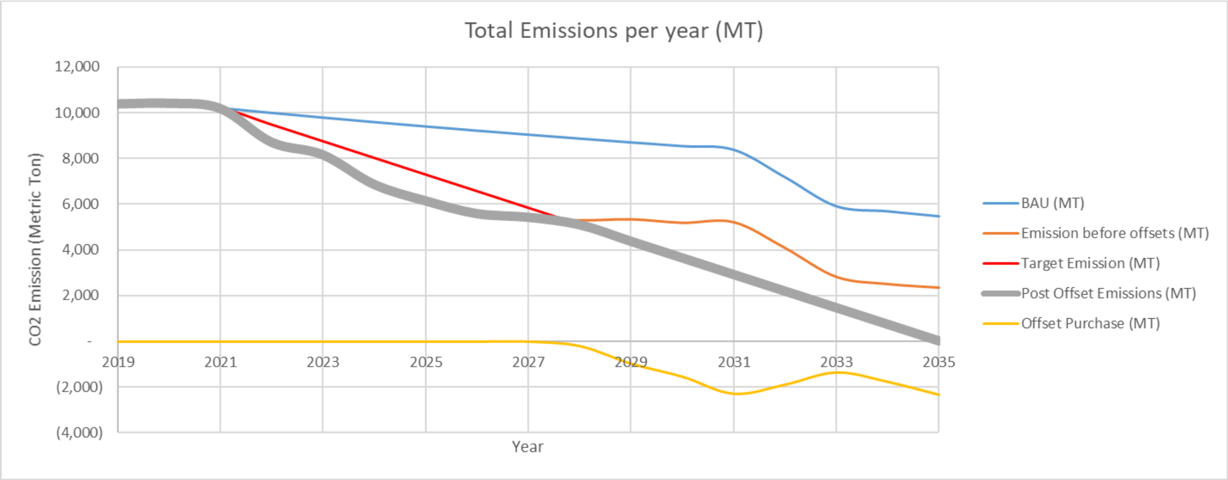
As detailed in the BAU Section, the business as usual projected energy-related expenditures for USD through 2035 total to around $113M. Through the implementation of the recommendations of this Energy Master Plan, USD can expect to pay around $7.5M less than this BAU scenario while also achieving its carbon neutrality goals, as well as a host of associated electrification, resiliency, campus infrastructure, and experiential learning benefits. The tables below summarize the cumulative cost and savings projections of this Energy Master Plan.

Table 19 - Energy Master Plan Expenditure Summary

Energy Master Plan Program Costs (Rounded Costs)	
Total Energy Efficiency /Electrification Measures Cost	$20,400,000
Continuous Commissioning (5-yr Pilot Program)	$1,250,000
Total Resiliency & Microgrid Cost Estimates	$6,500,000
Building Electrical System Upgrades	$130,000
Electric Vehicle Charging Infrastructure	$700,000
Carbon Offsets (Cumulative over 2035 period)	$180,000
Total Energy Master Plan Program Costs	**$29,100,000**
Electricity and Gas Purchases	
Electricity Purchases (Calpine, SDG&E, Solar, and Fuel Cell)	$67,800,000
Natural Gas Purchases (Building Gas and Fuel Cell Gas)	$12,900,000
Total Energy Utility Costs	**$80,700,000**
Total 2035 Spending	
BAU Case	$113,000,000
Energy Master Plan (Program Costs + Energy Utility Costs)	$109,800,000
Capital Cost Savings (BAU- Energy Master Plan)	$3,200,000
Bill Savings from Batteries and Generator Controls	$4,300,000
Net Program Savings	**$7,500,000**

Figure 18 below details total emissions per year, depicting five different trend lines. The top light blue line shows the BAU emissions projections for USD, and linearly decreases till 2031 due to the overall CA grid becoming less carbon intensive. In 2031 there is a steep drop-off when the high carbon intensity fuel cell power is replaced by grid electricity. The dark orange trendline shows the emissions-reduction impact of the energy efficiency measures from BAU. Next, a red line shows the target emission trendline, which is a linear decrease to zero by 2035. The energy master plan analysis considers it a requirement that USD reaches this red "target emission" line on an annual basis. There are several years when energy efficiency measures aren't enough to bring USD to this red "target emission" line (such as in 2021 and from 2027 to 2035. In these years, carbon offsets are required to be purchased to bring USD to its annual target emissions level, and the grey "post offset emissions" trendline diverges from the orange "emissions before offsets line". The dark orange line below the X-axis shows the negative carbon emissions represented by the purchase of carbon offsets to make up this difference. For years in which energy efficiency measures are able to meet the target emissions (2022-2027), you are able to see the red "target emissions" line and the orange "emissions before offsets" line is equal to the grey post offset emissions line since there are no offset purchases.

Figure 18: Total Emissions (MT/yr)



11. GHG Reduction Opportunities for Energy Purchases

The low carbon future is not likely to include significant natural gas use. Applications that consume natural gas to heat spaces in moderate temperature applications are projected to be replaced by electric heat pumps powered by renewable or carbon free electricity. A switch is expected to renewable natural gas (RNG) or hydrogen combustion in higher temperature applications. These fuels are likely to replace diesel and natural gas for on-site power generation (emergency power and cogeneration).

An array of heat pump systems are commercially available now. Widescale use and availability of RNG and hydrogen lags, as the sources and distribution are developed, and as the hydrogen engines and fuel cells are developed.

11.1.1 Renewable Natural Gas

RNG is methane that is produced through a process such as the decomposition of organic materials in a landfill or the digestion of waste products in a wastewater treatment plant. The collection and combustion of RNG does not add any additional carbon to the atmosphere, other than by leakage.

The use of RNG to offset natural gas is one approach to minimizing the campus' carbon footprint. UCSD, for example, has opted to purchase RNG from the Point Loma Wastewater Treatment Plant. The plant produces methane that would previously have been burned in a flare to convert methane, a potent GHG to CO_2, a less potent GHG. The plant cleans the methane that it generates and injects it into the utility pipeline. UCSD withdraws the same amount of natural gas from its pipeline and uses it as fuel in a fuel cell.

USD could find a source of RNG and purchase it to offset emissions from its boilers and water heaters. However, there is not an abundance of RNG available for purchase today. The UC system is a large user of natural gas (7 central cogeneration plants) and they have pursued RNG via long term contract. Currently, they buy RNG as a relatively small portion of their total natural gas use, purchasing it from other states. However, they are investigating creating their own plant to produce RNG. Large landfills and wastewater treatment plants typically already collect their methane production and use it to power engines or turbines to make power. Smaller plants that don't have enough fuel to generate significant power typically flare the methane. Dairies and feedlots are small or medium sources of waste that can be processed into methane but they are usually small by comparison to landfills, making economic generation of methane difficult. It is difficult to think that RNG will be produced in adequate quantities to meet the demands of GHG free fuel.

The purchase of RNG is a straightforward way to offset a site's natural gas GHG emissions so RNG is likely to always be in high demand. SDG&E and Southern California Gas are proposing to sell RNG through a rate schedule that is being considered by the Public Utilities Commission. SCG would acquire gas for the two utilities from sources potentially outside of California. However, it is not known how much RNG may be available from the utilities in the future. The user would pay for the RNG commodity, for the transportation, and for the operation of the program. This is the current CPUC filing's comment on price:

> "For illustrative purposes, the Utilities estimate that the RNG Commodity Charge would be $1.51 / therm. The RNG Commodity Charge would be about four times higher than the non-RNG

> Commodity Charge of $0.36 / therm. Under the participant's regular gas tariff…the Utilities estimate that the Program Charge would be…$1.42 / therm for SDG&E."[15]

This is the early stages of a utility RNG program, showing combined commodity and Program Charges of about 8 times the commodity cost of natural gas. Presumably the Program Charge would drop significantly or disappear if this becomes a significant part of the utility procurement. Commodity costs are likely to drop over time, assuming more resources for RNG can be developed. In the coming 5 or 10 years, however, RNG purchase through the utility is not likely to provide an economic approach to offsetting natural gas use. As a result, RNG purchases were not included in our analysis.

11.1.2 Hydrogen

While RNG is a fuel that could replace wells and combustion of natural gas, hydrogen is a different story. Hydrogen is not a fuel that is collected and burned. Rather it is an energy delivery mechanism. One needs a source of energy, typically electricity, to create hydrogen through hydrolysis. The hydrogen is transported to the end user through a pipeline or in a boat/truck. Once it gets to the site it can be burned for heat, burned to power an engine/generator, or consumed in a fuel cell to generate power.

It is projected that hydrogen will be created through hydrolysis during times when there is excess electricity available on the grid. During some summer days, for example, the PV systems in California make more power than can be used in the state. The marginal electricity price drops very low (or goes negative). On the East Coast it is anticipated that large offshore wind farms will create similar periods when electricity is abundant and nearly free. During these hours hydrolysis plants would create large quantities of hydrogen (and oxygen, which would be sold separately). The hydrogen would be stored in underground vaults so that it could be used during the night when the sun is not shining. Hydrogen could also be stored seasonally, generated with excess solar power in the summer and used in the winter for combustion loads. Batteries typically have too great a standby loss to be used for seasonal storage.

This approach to creating a renewable fuel is taking hold most significantly in Australia, where dozens of projects are in early stages of development. These projects will use PV power, and sometimes wind, to create large quantities of hydrogen through hydrolysis. The "green" hydrogen will be delivered to users primarily in Asia to provide a carbon free fuel. The Australian government projects a $10 billion industry in 2040.

The hydrogen economy is something that has been discussed in the US for many years. Hydrogen powered cars with fuel cells, for example, compete with battery powered cars for carbon free operation. Battery powered cars have a larger share of the market than hydrogen powered cars, but large manufacturers like Toyota are still betting on hydrogen. Additionally, hydrogen is likely to be supported by the oil and gas industry to make use of the extensive pipeline distribution systems that may not be needed to deliver large quantities of natural gas. While it is not clear that the existing pipelines could convert to hydrogen transport without significant upgrades, the rights of way do exist.

The hydrogen future is not guaranteed but it is one likely scenario. Due to its uncertainty and lack of a commercially viable solution for USD, it is not considered in the recommendations for this report.

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[15] PROPOSED DECISION OF ALJ LIANG-UEJIO (Mailed 10/27/2020) BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA. Application of Southern California Gas Company (U904G) and San Diego Gas & Electric Company (U902G) for Renewable Natural Gas Tariff. Application 19-02-015

11.1.3 Power Generation at USD

The ability of USD to generate power currently is tied to the use of carbon-based fuels – diesel oil and natural gas. Long term generation without a carbon penalty will likely be based on a carbon free fuel, such as RNG or hydrogen.

The use of RNG, if it is available, would involve a reciprocating engine or fuel cell designed to operate on natural gas. There are many engines available that are designed to burn natural gas, which chemically is identical to RNG. There are also many fuel cells available to use natural gas or RNG as well.

Note that a pure fuel cell, such as in a car, uses hydrogen as a fuel. Most nonmobile fuel cells are designed to use natural gas because they can be connected directly to a utility gas pipe. However, these fuel cells, such as the Bloom Energy unit, typically have to create hydrogen from natural gas through a reformer. In the future if hydrogen were available in a pipeline or stored on site, the fuel cells would be simpler, not needing the reformer piece.

11.1.4 Emergency Power Generation

In the near term (as the existing diesel engines extend beyond their useful life) it is recommended that emergency power be provided by reciprocating engines burning pipeline natural gas. This reduces the noise and odor drawbacks of storing and burning diesel oil, while providing a somewhat higher reliability backup power. Natural gas reciprocating engines are less expensive to purchase than other generators such as gas turbines and fuel cells and are used for backup power more frequently than these other options. The engines' ability to handle step load increases are typically significantly better than fuel cells.

The reciprocating engines would operate infrequently, not consuming large quantities of natural gas. They could use either utility natural gas or RNG wheeled through the natural gas pipeline. The difference in carbon contribution for the whole campus would be relatively small.

In the long term the carbon free fuel of choice may be hydrogen. This may be delivered in pipelines or delivered by trucks and stored on site. It is not common to find a power generator that uses either natural gas or hydrogen, as this is an area of development for today's engine manufacturers. At least one engine manufacturer (Jenbacher) is offering an engine that should be able to burn either methane (natural gas) or hydrogen. This capability should be priced out at the time the diesel engines are being replaced, which this analysis assumes to first occur in 2027. While the engines are approaching the end of their anticipated useful life, their condition and escalating maintenance requirements will determine when it is best to replace them.

11.1.5 Cogeneration

Cogeneration means the simultaneous production of electricity and useful heat. Typically, heat is recovered from the prime mover. A gas turbine or engine would be turning a generator to make electricity. The exhaust from the turbine, or the jacket water from the engine, would typically be a source of heat that is captured to heat the campus, thereby improving efficiency of the entire system.

The success of cogeneration systems depends on the existence of a significant heating load for most or all hours of the year. The USD campus is in such a mild climate that it should not need space heating for many hours of the year. There will be a continuous load in some lab spaces, but not enough to base a cogeneration system on. The campus has taken the right course in the past to minimize centralized heating equipment with large distribution systems because they often lose more heat in the distribution than they deliver to the buildings. The replacement of these steam or hot water distribution systems with local heat pump systems will reduce the last of the central heating loads at USD.

The Bloom fuel cells are unique among on-site power generators in that they do not produce waste heat that can be captured for use on campus. All of the heat generated by a Bloom fuel cell is used within the unit to make the reformation process more efficient. The result is a higher electric generation efficiency than other fuel cells, and no thermal energy to use. This increased electric output and lack of thermal output makes it a good match for the USD campus in the future, with higher electric loads and no central heating loads.

11.1.6 100% Renewable Power Procurement

Community Choice Aggregators (CCAs) are locally run agencies that enter contracts with electric power suppliers to procure typically higher amounts of renewable power than their Investor Owned Utility (IOU) counterparts. IOUs continue to provide delivery, billing, and power infrastructure maintenance. San Diego Community Power (SDCP) procures its renewable power from solar, wind, and large hydro; and states that they support the local community through job creation of local renewable energy projects as well as reinvestment of revenues into community programs. SDCP aims to provide renewable electricity service to around 770,000 customers in the San Diego when they are fully launched in the second half of 2021 and has recently released their proposed energy rates.

Calpine is the current electricity source provider for the main campus electric meter, delivering around 30% renewable power. Conversations with the Calpine representative to USD revealed that a 100% renewable option is available for a cost adder.

Using detailed FY19 interval electricity usage data, a rate analysis was conducted for the Calpine and SDCP 100% renewable options. SDCP had a slightly higher projected cost, at $260/MWh compared to Calpine's $255/MWh. These rates represent around a 20% cost premium to the standard 30% renewable Calpine rate of $215/MWh. In our economic analysis, this cost premium exceeds the cost of typical carbon offsets available to USD, leading us to recommend USD stay with the lowest cost standard Calpine electricity rate and use the savings to invest in energy-efficiency projects and carbon offsets to meet their 2035 goals.

11.1.7 Carbon Offsets and RECs

Carbon offsets and renewable energy credits (RECs) can be purchased to offset emissions after all other clean energy and energy efficiency options are incorporated. Carbon offsets are on a cost per ton of carbon dioxide basis. Revenue from carbon offset purchases fund projects to reduce carbon dioxide content in the atmosphere, such as reforestation, renewable energy projects, and methane capture projects. RECs represent the rights to the environmental attributes of a renewable energy system, including its carbon-free generation, and are purchased on a cost per MWh basis. Revenue from RECs fund the operation of renewable energy producers such as wind and solar power plants. To learn more about Offsets and RECs and how they are different, see this EPA Green Power Partnership guide[16].

The Green-e$_{TM}$ certification is one of the highest standards in terms of policies and consumer protection. For that reason, they are one of the most widely accepted and used certification in US for carbon offset

[16] https://www.epa.gov/sites/production/files/2018-03/documents/gpp_guide_recs_offsets.pdf

and RECs. In this study, the price of carbon offset and RECs is sourced from Terrapass, a Green-e certified vendor. Terrapass currently sets the price of carbon offsets at $11/metric ton, and RECs at $5/MWh.

There is no universally accepted escalation rate for these costs. Estimates for the escalation rate generally range from 2.5% to 5%/yr[17], with an extreme case estimating a sevenfold increase in 10 years (implying a roughly 32% rate)[18]. For this study, we've used a 2.5% escalation rate.

Carbon offsets represent quantified emission reduction activities and may help lower costs of GHG emission strategies overall. RECs, by providing added value to the environmental attributes of renewable energy generation, support renewable electricity development and help expand electricity service choices.

While carbon offsets can be used to address direct and indirect GHG emissions, RECs can only be used to address indirect GHG emissions associated with purchased electricity (scope 2 emissions). Therefore, while It is possible to offset the campus' electricity emissions by purchasing carbon offsets or RECs, for gas emissions USD is limited to carbon offsets, since renewable natural gas is not financially viable now.

Carbon offsets can be derived from a multitude of sources, ranging from tree-planting and forest management to landfill gas capture, as well as clean energy generation through wind power. RECs are limited to renewable electricity sources such as wind, solar, and hydropower.

From the scenario analysis, it was determined that using carbon offsets for both electricity and natural gas emissions is more cost effective than purchasing RECs for electricity and carbon offset for natural gas.

A further key difference between carbon offsets and RECs are what is referred to as "additionality test requirements". Carbon offsets, unlike RECs, are required to prove that the carbon reduction activity for which the offsets pay for are beyond business as usual – in other words, that the carbon would not have been reduced unless the offset was purchased. In this way, through USD's purchase of carbon offsets the campus can be sure that the funds it spends go towards real and permanent carbon reductions that wouldn't have occurred otherwise and are verified and enforced.

Therefore, it is recommended to offset all remaining emissions after the recommended energy conservation measures with carbon offsets. For more details on carbon offsets, see Appendix K: Carbon Offsets Details (Terrapass).

12. Energy Efficiency and Building Electrification Measures

The following table summarizes the mechanical and electrical efficiency measures recommended as the core foundation of the carbon reduction strategies of this energy master plan. In each case, the full measure cost of the measure was included to best estimate the capital planning expenditures USD can expect to budget for implementation.

[17] https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc_tsd_final_clean_8_26_16.pdf

[18] https://www.spglobal.com/en/research-insights/articles/considering-the-risk-from-future-carbon-prices

Table 20 - Mechanical and Electrical Energy Efficiency Measures

Measure Description	Building	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback	IMC or FMC	Replacement Costs
Mechanical Efficiency Measures								
Pool Solar Heater and Cover	Pool	-	28,170	$23,975	$129,028	5	FMC	$258,056
Central Steam Plant Heat Pump Conversion	Facilities Bldg	(948)	201	-$21	$36,500	-1764	IMC	
Weatherization of Various Buildings	Multiple Buildings	424,850	58,000	$135,268	$550,000	4	FMC	
Water Conserving Shower Heads	Multiple Buildings	-	18,307	$15,581	$21,700	1	FMC	$21,700
Constant Volume AHU Retrofit: VFDs + Controls	Multiple Buildings	237,331	1,083	$48,910	$182,382	4	FMC	
Kitchen Equipment Electrification	Multiple Buildings	(410,615)	74,292	-$19,796	$340,071	-17	IMC	
Pool Pump VFDs and Controls	Pool	89,355		$18,068	$27,403	2	FMC	$27,403
Air Handler Controls: Dynamic VAV Optimization	Multiple Buildings	502,280	12,304	$112,033	$250,000	2	FMC	
Residential Heating Electrification: Heat Pump Retrofit	Multiple Buildings	(59,805)	11,602	-$2,219	$674,850	-304	IMC	
Residential HVAC Occupancy-Based Controls	Multiple Buildings	60,858	8,439	$19,488	$542,500	28	FMC	
Residential Domestic Hot Water Electrification: Heat Pumps	Multiple Buildings	(674,169)	78,687	-$69,346	$5,605,879	-81	IMC	$1,127,806
HVAC Major Renovation: Variable Refrigerant System	Multiple Buildings	2,344,289	7,632	$480,511	$4,526,870	9	IMC	
Non-Residential Domestic Hot Water Electrification: Heat Pumps or Reverse Cycle Chillers	Multiple Buildings	(117,656)	101,930	$62,962	$2,004,162	32	IMC	
Central Chilled Water Plant Pumping - Demand Flow Controls	Central Plant	287,974		$58,228	$330,000	6	FMC	
Shiley Fume Hood Control Upgrade	Shiley Science Center	1,108,187	37,066	$255,622	$2,500,000	10	FMC	
Electrical Efficiency Measures								

Interior LED Lighting Retrofit	Multiple Buildings	366,163		$74,038	$277,904	4	FMC	
Exterior LED Lighting Retrofit	Multiple Buildings	772,887	-	$156,278	$872,558	6	FMC	
Garage LED Lighting Retrofit	Kroc and Main Parking Structures	96,264		$19,465	$68,365	4	FMC	
Total Energy Efficiency /Electrification Measures		**5,027,245**	**437,713**	**$1,389,047**	**$18,940,171**	**14**	**-**	**$1,434,965**
Total Costs (Retrofits + Replacements)					**$20,375,136**			

12.1 Mechanical Efficiency Measures

A variety of mechanical efficiency measures are recommended to contribute to efficient utilization of energy for space heating/cooling, domestic hot water, and cooking. Detailed measure descriptions for each of these recommended measures are included later in this section.

- Weatherization of buildings to reduce air infiltration, increase overall wall and roof insulation values, and increase the performance of fenestration.
- Reduction of domestic hot water use through the installation of flow showerheads.
- Residential electrification of space heating and domestic hot water, with the addition of occupancy-based HVAC controls.
- Kitchen electrification through replacement of gas-burning equipment.
- Pool Efficiency measures, including a pool cover, variable speed pumping, and addition of rooftop solar thermal heating.
- Upgrade of Central Cooling Plant controls to allow for chilled water demand flow optimization.
- Upgrade of laboratory fume hood controls for increased turndown airflow.
- Air Handler controls for VAV and CAV systems to better regulate operation based on static pressure and supply air temperature resets.
- Replace the steam boiler and HHW heat exchanger serving the Facilities Maintenance Building with a Reverse Cycle Chiller.
- Conversion of HVAC systems to low exergy systems (i.e. CAV Air Handlers to Variable Refrigerant Volume Systems). This has the impact of increasing the heating and cooling production efficiency, reducing transmission losses, reducing ventilation load, etc. by decoupling the ventilation load from the sensible loads.
- Implement Reverse Cycle Chiller and/or Space Heating Water Heat Pump technology for comfort cooling/heating. These technologies can only be utilized if systems are converted to low exergy systems (low temperature heating / high temperature cooling).

Table 21 - Summary of Mechanical Energy Conservation Measures

Measure Description	Building	kWh Saving	therm Saving	Bill Saving	Measure cost	Payback
Pool Solar Heater and Cover	Pool	-	28,170	$23,975	$129,028	5
Central Steam Plant Heat Pump Conversion	Facilities Bldg	(948)	201	-$21	$36,500	-1764
Weatherization of Various Buildings	Multiple Buildings	424,850	58,000	$135,268	$550,000	4
Water Conserving Shower Heads	Multiple Buildings	-	18,307	$15,581	$21,700	1
Constant Volume AHU Retrofit: VFDs + Controls	Multiple Buildings	237,331	1,083	$48,910	$182,382	4
Kitchen Equipment Electrification	Multiple Buildings	(410,615)	74,292	-$19,796	$340,071	-17
Pool Pump VFDs and Controls	Pool	89,355		$18,068	$27,403	2
Air Handler Controls: Dynamic VAV Optimization	Multiple Buildings	502,280	12,304	$112,033	$250,000	2
Residential Heating Electrification: Heat Pump Retrofit	Multiple Buildings	(59,805)	11,602	-$2,219	$674,850	-304
Residential HVAC Occupancy-Based Controls	Multiple Buildings	60,858	8,439	$19,488	$542,500	28
Residential Domestic Hot Water Electrification: Heat Pumps	Multiple Buildings	(674,169)	78,687	-$69,346	$5,605,879	-81
HVAC Major Renovation: Variable Refrigerant System	Multiple Buildings	2,344,289	7,632	$480,511	$4,526,870	9
Non-Residential Domestic Hot Water Electrification: Heat Pumps or Reverse Cycle Chillers	Multiple Buildings	(117,656)	101,930	$62,962	$2,004,162	32
Central Chilled Water Plant Pumping - Demand Flow Controls	Central Plant	287,974		$58,228	$330,000	6
Shiley Fume Hood Control Upgrade	Shiley Science Center	1,108,187	37,066	$255,622	$2,500,000	10
Total Mechanical Measures		**3,791,930**	**437,713**	**$1,139,266**	**$17,721,344**	**16**

In some cases, electrification measures were chosen for implementation even if they resulted in negative net energy cost savings. This is because in some fuel-switching measures, the equivalent cost of electric energy to provide the same amount of useful work (such as heating) is more expensive than when provided through combustion of natural gas. This is the case for many of the air-to-water heat pump measures for the production of hot water, as well as kitchen electrification. However, since these measures save a significant amount of natural gas, they are included in this scenario to support USD's goals for GHG reduction. Electricity that USD draws from the grid to make up the difference from on-site generation will increasingly become less carbon intensive over time, with current California policy projecting state-wide zero-emission electricity by 2045. Therefore, the more USD can maximize its use of electricity over gas, the more it sets itself on a path towards a continued trajectory for reduced carbon emissions.

In selecting measures a few measures were eliminated based on increased cost-effectiveness and overall feasibility between two competing options:

- **Major HVAC Renovation:** Variable Refrigerant Flow systems were selected over Radiant Systems due to lower costs, unique energy-saving benefits of transferring heat or cooling from zones with opposing heating/cooling needs, and increased construction feasibility.

- **Residential Heating System Retrofit:** Replacing boilers with electric heat pumps and upsized radiators over electric resistance radiator retrofits, which are less energy-efficient and would result in significant electrical demand increases.

Appendix J – Mechanical Assessed Building Recommendation contains descriptions of current (at time of walk-through and survey) building conditions, building size, buildings systems, main equipment, graphics of mechanical systems, and automation system capability.

This Appendix J is intended to assist the University of San Diego with context both historical and for future attempts at implementing the scope of this report in achieving its overall goals of energy use reduction, efficient utilization of energy, and decarbonizing its energy use.

12.1.1 From Boilers to Heat Pumps – Feasibility and Future Advances

One of the main ways to be able to decarbonize the mechanical systems on campus, specifically the HVAC systems, is converting as many buildings as possible to low exergy HVAC systems. By utilizing these systems, low temperature heating / high temperature cooling that operate with cooling and space heating water temperatures of 60°F – 68°F and 95°F – 115°F respectively that decouple the ventilation loads from the sensible loads, the University will have the potential of operating HVAC systems more efficiently than how they currently operate and provide improved indoor environmental quality. These technologies and systems will allow the University to convert gas burning boilers to refrigeration cycle hot water generation, since this equipment is limited to generating hot water below 120°, though has the ability of generating chilled water at the required campus temperatures.

This system operates with closed systems and as such will require "standard practice" water treatment like Chilled Water, Heating Hot Water and Process Cooling/Heating Water systems. If the systems utilized open systems, water treatment and biocide controls would be critical due to the possibility of human contact. The system does not have any additional health risk than other systems currently operating at the USD campus.

These technologies have been utilized for various decades with no health concerns and have been proven to perform and provide adequate comfort conditions.

The utilization of either Air-to-Water or Reverse Cycle Chiller for domestic water applications, especially at residences, has the potential of eliminating gas burning equipment for this use. The type that is utilized should be considered depending on proximity to chilled water infrastructure since water-to-water heat exchange has the capability to simultaneously generate chilled water and hot water thus increasing the overall campus efficiency.

The proposed measures are currently presented with technologies that are readily available in the US market and as such are familiar to local trade related contractors and personnel providing maintenance and support.

The equipment and technologies proposed for the measures are as follows:

- Air Source Heat Pump Water Heaters – usually limited to operation above 40°F with supply water temperature limited to 120°F.
- Water Source Heat Pump Water Heater and/or Reverse Cycle Chillers – selected to operate with condenser water between 45°F – 55°F to match the CHW loop, and limited to supply water temperature limited to 120°F.

- Variable Refrigerant Flow – Utilizes a system like DX Split System technologies with variable refrigerant flows through variable speed compressors and heat recovery at the refrigerant level.

This report does not venture into upcoming technologies/equipment that are currently available in foreign markets (Europe, Asia, Oceania) due to the maintenance issues associated with a current lack of distribution and replacement parts network.

However, we feel that the University should be aware of technologies that will become available and are currently being tested at various geographic locations throughout the country with the participation utility companies. Below is a list of technologies that should be considered when they become available in the US and local market. Some will become available while others have limited availability.

- CO2 (R744 based) Heat Pump Water Heater (AERMEC, MAYEKAWA)
  - Limited manufacturers in the US market
  - High temperature water generation (194°F)
  - Ambient temperature lower limit of 14°F
- Water-to-Water Heat Pump Water Heater (R134a based) (AERMEC)
  - Limited manufacturers in the US market
  - High temperature water generation (176°F)
  - Can be combined with Air Source Heat Pump Water Heaters and/or Water-to-Water Heat Pump Water Heater and/or Reverse Cycle Chiller and will increase the Hot Water supply temperature, usable for "standard" systems (e.g. VAV reheats, AHU heating, Fan Coil Units, etc.)

12.1.2 Chiller Recommendations

The mechanical equipment at the central chilled water plant contain VFDs to operate efficiently at part load. Section 12.1.10 includes the recommendation for implementing demand flow controls to the secondary chilled water pumps to further improve efficiency.

During the course of developing this energy master plan, discussion regarding the installation of a pony chiller to shift to under light campus load was further considered. However, the team's determination is that operating an existing VFD-equipped chiller under light (~25%) load, is significantly more efficient (~2x) than operating a pony chiller under full load. We recommend the installation of a pony chiller only if USD has difficulty keeping one of the existing VFD chillers operating reliably during actual light load conditions. We are not aware of any such issues with operating their current chillers. Further analysis details can be found in Appendix L: Chiller Analysis (Pony vs. Low-Load VFD Chiller).

Over the next 15 years, it is possible that even with good maintenance one or more chillers will need to be replaced. At this time, USD should evaluate the best available technology and efficiency and size the new chiller based on campus cooling loads at the time of replacement. The new chiller should be selected to maximize cost-effective incremental efficiency versus code minimum at the time of replacement. Currently, this would be exemplified as an oil-less centrifugal compressor with magnetic bearings and a VFD as offered by Daikin, Smardt, and other manufacturers.

12.1.3 MEASURE 002 & 005: Residential Heating Electrification: Heat Pump Retrofit

The buildings being proposed for this EEM are currently served by Hydronic Wall/Baseboard Heaters in the residential units. The proposal is to abandon the HHW generation and distribution system and utilize upsized wall heaters. The proposed EEM also incorporated replacement of the gas fired HHW boilers with Air Source Heat Pump Water Heaters to generate Heating Hot Water. The purpose of following this path is to promote the University's plan to decarbonize on site systems and utilizing Air Source Heat Pump Water Heaters in lieu of Gas-Fired Heater.

This measure will not reduce the operating costs since electrical utilities are several times more costly than gas.

The buildings are currently served by Hydronic Wall/Baseboard Heaters in the residential units, made to operate with an average HHW temperature of 165°F. The proposal intends to replace the gas fired HHW boiler with an Air Source Heat Pump Water Heater (with average temperature of 120°F). The proposal also intends to upsize the existing heaters (approximately 50% more capacity) to accommodate lower heating water temperatures.

This measure is being calculated anticipating that EEM 003, 004 & 007 have been implemented, thus the BASELINE energy usage already anticipates the savings from these measures.

Incremental costs are used for this measure, with the project costs being additional costs beyond an assumed baseline replacement of gas-fired boilers.

Building	Year Implemented	kWh Savings	Therm Savings	Cost Savings	Estimated Project Cost	Simple Payback
Alcala Vista Apartments	2022	-28,352	5,500	-$1,052	$306,520	-291
Camino Hall	2033	-6,940	1,346	-$257	$84,590	-329
Founders Hall	2034	-10,632	2,063	-$394	$125,840	-319
Maher Hall	2034	-13,881	2,693	-$515	$157,900	-307
Total Measure Summary		**-59,805**	**11,602**	**-$2,219**	**$674,850**	**-304**

12.1.4 MEASURE 003, 4, 7: Residential HVAC Occupancy-Based Controls

Currently the residences have manual thermostatic controls for the Radiant Heaters, Fan Coil Unit or Forced Air Furnace. This can cause the equipment to stay on when the spaces are not occupied, or windows are left open.

Roughly 15% - 20% savings can be achieved by implementing occupancy-based controls that either disable heating and/or setback the setpoint.

This measure proposes replacing stand-alone manual thermostatic controls with programmable thermostats that have the capability of receiving an input from either occupancy sensors and/or window sensors.

This measure proposes the use of occupancy based controls in all zones that have comfort equipment to determine occupancy in each zone in conjunction with the lighting controls and/or the utilization of an access control system and be able to setback the setpoint and eventually turn HVAC unit OFF after extended period of vacancy.

There are various ways to implement such a strategy:

- In conjunction with access controls (if implemented, and recommended)
- Dual technology (PIR/US)
- Wireless / wired controls
- Stand-alone / Connected to Campus Automation for monitoring

Individual metering for each room would be a significant cost barrier. Another barrier is that it is illegal to indirectly bill tenants based on their consumption instead of them paying the SDG&E bill directly. For these reasons, this is not recommended strategy.

This measure has synergies with Lighting energy savings since they will be operating in unison.

Lighting savings are incorporated into this measure, with an assumption that lighting operating hours will be decreased on average by 20%.

Building	Implementation Year	kWh Saving	Therm Saving	Bill Saving	Measure Cost	Payback
Alcala Vista Apartments	2022	17,691	2,088	$5,354	$96,000	18
Camino Hall	2033	659	511	$568	$23,500	41
Founders Hall	2034	1,009	783	$870	$36,000	41
Maher Hall	2024	5,317	1,022	$1,945	$47,000	24
Manchester Village Apartments	2024	10,943	1,120	$3,166	$51,500	16
Mission Housing	2024	12,545	1,958	$4,203	$180,000	43
San Antonio de Padua	2024	5,228	-	$1,057	$20,500	19
San Buenaventura	2031	7,466	957	$2,324	$88,000	38
Total Measure Summary		**60,858**	**8,439**	**$19,488**	**$542,500**	**28**

12.1.5 MEASURE 006: Residential Domestic Hot Water Electrification: Heat Pumps

Currently the building's domestic hot water loads are taken care of by gas-fired DHW heaters and pumps that serve domestic hot water needs. The utilization of an Air Source Heat Pump Water Heater to provide the domestic hot water requirements will achieve a reduction in Green House Gas emissions and energy usage; however, current rates for gas and electricity will not produce a reduction in energy cost expenditures.

An inspection of the existing domestic hot water storage tank is recommended to determine its remaining useful life prior to implementation of the measure, if selected.

A determination will have to be made relevant to the reutilization of the existing domestic hot water recirculation pumps prior to implementation of the measure, if selected.

Incremental costs are used for this measure, with the project costs being additional costs beyond an assumed baseline replacement of gas-fired boilers.

Due to the estimated useful life of the equipment being 10 years, the energy master plan assumes that the Acala Vista Apartments equipment will need to be replaced again in 2032, and incorporates an additional $1.1M of project costs into the plan.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Alcala Vista Apartments	2022	-119,300	21,686	-$5,666	$1,127,806	-199
Camino Hall	2033	-29,204	5,309	-$1,387	$267,615	-193
Founders Hall	2034	-44,738	8,132	-$2,125	$411,488	-194
Maher Hall	2034	-58,407	10,617	-$2,774	$553,769	-200
Manchester Village Apartments	2034	-63,999	11,634	-$3,039	$579,769	-191
Mission Housing	2029	-223,688	13,295	-$33,914	$1,515,622	-45
San Antonio de Padua	2034	-25,476	1,514	-$3,862	$257,874	-67
San Buenaventura	2035	-109,358	6,500	-$16,580	$891,935	-54
Total Measure Summary		**-674,169**	**78,687**	**-$69,346**	**$5,605,879**	**-81**

12.1.6 MEASURE 008: HVAC Major Renovation: Variable Refrigerant System

When a Major Renovation is planned by the University the following calculations can be considered for the possibility of replacing the baseline system with a Variable Refrigerant System:

Includes Various Exterior Condensing Units, Multiple Indoor Fan Coil Units and/or Air Handler Units, Air-to-Air Energy Recovery Ventilator

Incremental costs are used for this measure, with the project costs being additional costs beyond an assumed baseline replacement of VAV systems.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Copley Library	2033	29,754	140	$6,135	$231,870	38
Degheri Alumni Center	2031	60,349	169	$12,346	$140,000	11
Hughes Administration Center	2024	62,217	256	$12,798	$175,000	14
Loma Hall	2027	136,663	451	$28,017	$230,000	8
Maher Hall	2026	271,325	971	$55,688	$550,000	10
Manchester Conference Center	2030	51,114	159	$10,471	$75,000	7
Mother Rosalie Hill Hall Institute for Peace and Justice	2032	88,982	567	$18,475	$765,000	41
Olin Hall	2029	152,478	456	$31,219	$205,000	7
Pardee Legal Research Center	2028	245,453	734	$50,255	$330,000	7
Sacred Heart Hall	2031	37,647	148	$7,738	$95,000	12
Sports Complex	2033	187,533	623	$38,449	$320,000	8
Student Life Pavilion	2031	146,510	487	$30,039	$250,000	8
Warren Hall	2027	110,214	453	$22,671	$310,000	14
Serra Hall	2028	148,605	584	$30,545	$375,000	12
Joan B Kroc Institute for Peace and Justice	2030	615,445	1,434	$125,663	$475,000	4
Total Measure Summary		**2,344,289**	**7,632**	**$480,511**	**4,526,870**	**9**

12.1.7 MEASURE 009: Non-Residential Domestic Hot Water Electrification: Heat Pumps or Reverse Cycle Chillers

Currently the building's domestic hot water loads are taken care of by gas-fired DHW heaters and pumps that serve domestic hot water needs.

The utilization of an Air Source Heat Pump Water Heater or Reverse Cycle Chiller to provide the domestic hot water requirements will achieve a reduction in Green House Gas emissions and energy usage, though at current rates for gas and electricity will not produce a reduction in energy cost expenditures.

An inspection of the existing domestic hot water storage tank is recommended to determine it remaining useful life prior to implementation of the measure, if selected.

A determination will have to be made relevant to the reutilization of the existing domestic hot water recirculation pumps prior to implementation of the measure, if selected.

When selecting a Reverse Cycle Chiller, the evaporator shall also serve the campus CHW loop, saving CHW generation energy by having the INLET take water from the CHWR (55°F) and the OUTLET feeding the CHWS (45°F).

Incremental costs are used for this measure, with the project costs being additional costs beyond an assumed baseline replacement of gas-fired boilers.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Copley Library	2033	-1,615	237	-$125	$53,170	-426
Degheri Alumni Center	2028	-975	143	-$75	$53,170	-705
Hahn School of Nursing	2029	-592	87	-$46	$53,170	-1162
Hahn University Center	2024	-17,032	30,482	$22,499	$212,703	9
Jenny Craig Pavilion Arena	2033	-6,687	3,272	$1,433	$319,169	223
Joan B Kroc Institute for Peace and Justice	2027	-9,925	486	-$1,594	$101,690	-64
Loma Hall	2024	-1,602	235	-$124	$53,170	-429
Maher Hall	2034	-3,831	562	-$296	$53,170	-180
Manchester Conference Center	2028	-522	77	-$40	$70,950	-1757
Mother Rosalie Hill Hall Institute for Peace and Justice	2034	-15,985	782	-$2,567	$101,690	-40
Olin Hall	2028	-1,428	210	-$110	$53,170	-482
Pardee Legal Research Center	2027	-2,298	337	-$178	$53,170	-299
Sacred Heart Hall	2028	-662	97	-$51	$53,170	-1040
Serra Hall	2031	-2,612	383	-$202	$317,046	-1570
Shiley Science Center	2024	-27,860	43,460	$31,355	$122,429	4
Sports Complex	2026	-4,458	1,948	$757	$65,754	87
Student Life Pavilion	2026	-17,413	18,816	$12,493	$214,203	17
Warren Hall	2031	-2,159	317	-$167	$53,170	-319
Total Measure Summary		**-117,656**	**101,930**	**62,962**	**2,004,162**	**32**

12.1.8 MEASURE 010: Kitchen Equipment Electrification

The campus' kitchens are currently served by gas fired appliances. This proposal is to electrify as many gas-fired kitchen appliances as possible. Some appliances are not feasible candidates (i.e. tortilla maker).

Incremental costs are used for this measure, with the project costs being additional costs beyond an assumed baseline replacement of gas-fired kitchen equipment.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Student Life Pavilion	2026	-107,499	29,558	$3,421	$94,595	28
University Center	2030	-231,722	33,580	-$18,274	$185,954	-10
Berts Bistro	2027	-10,950	2,190	-$350	$10,965	-31
La Paloma	2027	-60,444	8,964	-$4,593	$48,557	-11
Total Measure Summary		**-410,615**	**74,292**	**-$19,796**	**$340,071**	**-17**

12.1.9 MEASURE 012 & 013: Pool Pump VFDs and Controls

Currently the pool recirculation/filtration pumps operate at constant speed. Energy conservation will be achieved by running the pump at full speed for approximately 2 hours and then run at set low speed for the period calculated to turn over the water in the pool once in a 24-hour period. The addition of a check valve at each one of the pump discharge pipes is highly recommended to ease operations by not having to manually open and close pump valves every time the pumps alternate.



Photos above show two 20 hp pool recirculation pumps missing check valve at discharge, forcing manual rotation by operating personnel.

Due to the 10 year estimated useful life of this measure, the energy master plan assumes that this equipment will need to be replaced again in 2032 and incorporates an additional $27k in project costs to the plan.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Pool	2022	89,355	-	$18,068	$27,403	2

12.1.10 MEASURE 014: Central Plant Chilled Water Plant Pumping - Demand Flow Controls

Upgrade the sequences of operation for the secondary chilled water pumps from the previous generation/legacy Siemens "Demand Flow" system to the latest version of this approach. These revisions would improve chilled water pumping efficiency due to changes to the chilled water loop configuration, the addition of an inline sediment filtration system, the addition of new building loads, and enhancements to the control sequence since the current version of Demand Flow was implemented nearly ten years ago. The scope of work includes total system recommissioning, programming, upgrade of several key sensors to higher accuracy and reliability, bi-annual sensor calibration, and five years of ongoing service.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Central Plant	2024	287,974	-	$58,228	$330,000	6

12.1.11 MEASURE 018: Pool Solar Heater and Cover

Currently the pool is heated to 79°F with a gas-fired water heater and is uncovered. A pool cover will reduce evaporative thermal losses, and a solar thermal water heater will generate hot water without using fossil fuels. Savings and cost assume a rooftop solar thermal system of equivalent area to the pool (~8,000 sf) and use of the pool cover 11hrs/day. The existing boiler should remain and only be used on cold, cloudy days the solar is insufficient to meet heating needs. Piping and pumping systems will need to be evaluated by the installer.

Due to the 5 year estimated useful life of this project, this measure is estimated to be replaced twice in 2027 and 2032.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Pool	2022	0	28,170	$23,975	$129,028	5

12.1.12 MEASURE 019: Shiley Fume Hood Control Upgrade

Replace existing pneumatic venturi-type air valves and controls with new high-turndown (100:1 from full to minimal airflow) valves and fully BAS-integrated controls, as offered by Siemens with their "GoLo" line of fume hood controls. This measure would provide lower minimum airflow performance for the fume hood systems, which will reduce the loss of cooled or heated air through the fume hood exhaust system. This measure would also include implementing a lab-specific version of Siemens' Dynamic VAV Optimization sequences to intelligently reset static pressure and supply temperature on an on-going, cloud-based basis. The new system would also be integrated with the Desigo master EMS.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Shiley Science Center	2025	1,108,187	37,066	$255,622	$2,500,000	10

12.1.13 MEASURE 020: Air Handler Controls: Dynamic VAV Optimization

Implement "Dynamic VAV Optimization" for existing variable-air-volume air handling units and fan coil units. DVO is a cloud-based static pressure and supply air temperature reset control strategy, as offered by Siemens. The scope of work will include an initial inspection and analysis of the air handling systems, installation of required hardware and software, and configuration for ongoing cloud-based system optimization. The implementation cost includes both the initial work and five years of the on-going maintenance charges to be paid to Siemens for the cloud-based services. Note that some version of this measure can be implemented without the cloud-based optimization and associated maintenance fees. The sequences of operation and associated performance will be different until the self-implemented approach.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Total Measure Summary	2022	502,280	12,304	$112,033	$250,000	2

12.1.14 MEASURE 021: Central Steam Plant Heat Pump Conversion

The building is currently served by a Fan Coil Unit System and as such is considered the Baseline system. The Steam Boiler plant is scheduled to be decommissioned and as such will require that the Facilities Building seek a solution to space heating since it utilized a steam-to-water heat exchanger for the Fan Coil Units serving the spaces.

The proposal is to utilize a decentralized Water-to-Water Heat Pump Water Heater with the condenser side interconnected to the central plant’s condenser water loop through a heat exchanger. This will achieve HHW temperatures of 170° with COP in the lower 3 range.

Another advantage of implementing this proposed measure is saving on the expenditures related to maintenance, water treatment (chemicals), distribution losses, etc. at the Steam Central Plant once it is fully decommissioned.

Incremental costs are used for this measure, with the project costs being additional costs beyond an assumed baseline replacement of a gas-fired boiler.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Facilities Bldg	2024	-948	201	-$21	$36,500	-1764

12.1.15 MEASURE 022: Weatherization of Various Buildings

Various buildings require weatherization (weather stripping, caulking, sealing, upgraded exterior insulation, upgraded fenestration, upgraded air barrier, etc).

These upgrades/renovations of drafty single pane window and loose exterior doors will minimize the energy usage for heating and cooling spaces. These upgrades have the additional benefit of increased occupant comfort due to maintaining uniform space temperature within the building.

The measure is applicable to the following buildings: Camino Hall, Founders Hall, Maher Hall, Sports Center; all of which currently do not have CHW.

The measure is also applicable to the following buildings: Olin Hall, Manchester Executive Conference Center, Serra hall, Warren hall, Hughes Administration, Hanh School of Nursing, Hahn University Center.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Total Measure Summary	2024	424,850	58,000	$135,268	$550,000	4

12.1.16 MEASURE 023: Water Conserving Shower Heads

Various buildings, most of them residential may be equipped with shower head that meet the maximum code allowed flow of 2.50 gpm. Changing these to low flow (1.50 gpm) shower heads has the potential to reduce water usage by 40% and energy required to generate domestic hot water by 16%.

The measure is applicable to the following buildings: All residential buildings, Sports Center, Jenny Craig Pavilion.

Due to the 10 year estimated useful life of this project, it is assumed that this project will need to be implemented again in 2032 and additional costs are incorporated into the energy master plan.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Total Measure Summary	2022	0	18,307	$15,581	$21,700	1

12.1.17 MEASURE 024: Constant Volume AHU Retrofit: VFDs + Controls

Conversion of constant volume AHUs to "pseudo-VAV" through a combination of equipment add-ons and additional programming of the Building Automation System (BAS). The retrofit approach includes adding VFDs to the existing fan motors, and then Siemens adding programming and cloud-based optimization to regulate fan speed and supply temperature based on load requirements. Combined, these action result in approximately 50% fan energy savings, as well as a small amount of cooling and heating savings.

The measure is applicable to the following buildings: Warren Hall, Joan B Kroc IPJ, Sacred Hall, Shiley Theatre, Manchester Village Apartment Common Areas, and University Center. The two CAV unit heaters at the Sports Center are not reasonable candidates since the 3hp motors are small.

Building	Implementation Year	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Total Measure Summary	2024	237,331	1,083	$48,910	$182,382	4

12.1.18 Not Recommended: MEASURE 001: Replace Hydronic with Electric Radiant Heaters

The building is currently served by Hydronic Wall/Baseboard Heaters in the residential units. The proposal is to abandon the HHW generation and distribution system and utilize electric resistance heaters.

The reason why this measure is not recommended for implementation is because the electric resistance heating is an old technology with low energy-efficiency, and as a result increases ongoing operational cost. Additionally, the addition of so much electrical resistance heating would result in significant electrical demand increases. This report instead recommends installation of Measure 2 and 5, which are the heat pump retrofit measures.

Building	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Alcala Vista Apartments	(50,688)	7,593	$(3,786.71)	$151,680	(40)
Camino Hall	(12,408)	1,859	$(926.96)	$64,680	(70)
Founders Hall	(19,008)	2,847	$(1,420.02)	$79,680	(56)
Maher Hall	(24,816)	3,717	$(1,853.91)	$92,880	(50)
Total Measure Summary	(106,920)	16,016	$(7,987.59)	$388,920	(49)

12.1.19 Not Recommended: MEASURE 015 & 016: Converting Existing HVAC system to radiant comfort system

These buildings are currently served by a VAV System and as such is considered the Baseline system. When a Major Renovation is planned by the University the following calculations can be considered for the possibility of replacing the baseline system with a Radiant Comfort System:

4-Pipe Radiant Beams in areas with that do not benefit from DCV with low temperature heating water and high temperature cooling water, heat exchangers on the HHW and CHW to achieve the required radiant system temperatures, Fan Coil Units and/or VAV Terminal units at areas that cannot utilize radiant systems (i.e. high humidity loads), DOAS and/or existing AHUs modified as DOAS for cost and energy utilization

The reason why this measure is not recommended for implementation is because radiant beam cooling systems are very costly and infeasible when implemented within existing buildings. Additionally, there are special humidity and space temperature control considerations that add additional complexity to the retrofit process. This report instead recommends installation of the alternative variable refrigerant system, which conserves energy by redistributing thermal energy around a building (e.g. taking heat from one area and giving it to another area) as opposed to generating the thermal energy on demand (e.g.

generating cold air for one area, discarding the waste heat to the outdoors, and generating hot air for another area).

Costs reported below are full measure cost. Incremental cost estimates can be found in the measure calculations.

Building	kWh Saving	therm Saving	Bill Saving	Measure Cost	Payback
Copley Library	9,440	140	$2,027.94	$1,112,976	548.8
Degheri Alumni Center	6,516	169	$1,461.41	$672,000	459.8
Hahn University Center	14,732	611	$3,499.16	$1,944,000	555.6
Hughes Administration Center	15,651	256	$3,382.54	$840,000	248.3
Joan B Kroc Institute for Peace and Justice	34,557	1,434	$8,207.90	$2,280,000	277.8
Loma Hall	22,284	451	$4,889.73	$1,104,000	225.8
Manchester Conference Center	7,251	159	$1,601.44	$360,000	224.8
Mother Rosalie Hill Hall Institute for Peace and Justice	44,585	567	$9,497.69	$3,672,000	386.6
Olin Hall	19,654	456	$4,362.18	$984,000	225.6
Pardee Legal Research Center	31,638	734	$7,022.00	$1,584,000	225.6
Sacred Heart Hall	8,739	148	$1,892.95	$456,000	240.9
Shiley Science Center	9,847	3,115	$4,642.48	$3,840,000	827.1
Student Life Pavilion	24,211	487	$5,310.04	$1,200,000	226.0
Warren Hall	27,725	453	$5,991.51	$1,488,000	248.4
Multiple Buildings	**276,831**	**9,181**	**$63,789**	**$21,536,976**	**337.6**

12.2 Electrical Efficiency Measures

The following energy efficiency measures are focused on opportunities to replace or retrofit existing electrical equipment in order to reduce the kilowatt-hour (kWh) consumption and kilowatt (kW) demand for the campus. There are the following sources of electrical consumption for the campus: Mechanical heating and cooling equipment (HVAC), kitchen equipment, receptacle and process loads, and lighting systems. The HVAC systems and kitchen equipment are described in the Mechanical Systems section of this Energy Master Plan with associated energy efficiency measures. Many receptacle and process loads are powered devices that are necessary for a specific user function and are not able to be audited for energy efficiency. An example would be TV's and computers in residential units, teaching equipment in classrooms and lab equipment. Some of these items are often consuming energy by being left on when they are not being used, but the solution is addressed in the Energy Conservation Measures section. Therefore, lighting energy efficiency measures have been provided.

12.2.20 Exterior Lighting fixture replacements to LED

The USD campus has hundreds of exterior post top fixtures lighting the driveways, courtyards, and pathways. These fixtures have been installed during many retrofits and upgrades over time. Fixtures that have a screw-in lamp that can be retrofitted with LED lamping have already been done, or are scheduled to be done, so this will not be included as an energy efficiency measure. The bulk of post top and wall mounted fixtures not included in this category are induction lamping. Induction lamps have a long lamp-life and have high efficiency. Though they are not as efficient as LED, the cost-benefit to install new LED fixtures or use LED retrofit kits to replace the induction lamping that is currently in good operating condition would not have a return on investment and should be replaced with LED fixtures when they fail. Therefore, the remaining exterior fixtures that should be programmed as an energy efficiency measure are the sports field and court lighting.

For the savings calculation, the kWh rate is based on the Calpine commodity rate, which is a negotiated rate for the campus. SDG&E assesses delivery and transmission charges based on kW demand values that are non-coincident for the entire billing period, and coincident demand, which is currently during the 4PM to 9PM time period in the summer months. In order to evaluate the energy savings for exterior lighting, the kW demand savings is based on the coincident demand since the lighting will be scheduled during the coincident demand time period. The non-coincident demand will not be included since the exterior lighting is off during the daytime when the non-coincident demand value is accrued each month.

A summary of the recommended exterior lighting replacements is presented in the table below. More details are included in Appendix H – Electrical Efficiency Projects & Recommendations.

Table 22 - Summary of Exterior Lighting Replacements by Building

Building	kWh Savings	Cost Savings	Estimated Project Cost	Simple Payback
East Tennis Courts	50,319	$10,174.57	$28,977.60	2.8
Fowler Park and Cunningham Field	319,056	$64,513.12	$373,284.88	5.8
Joan Kroc Parking Garage	50,642	$10,239.81	$38,125.00	3.7
Main Parking Structure	45,622	$9,224.77	$30,240.00	3.3
Manchester Valley Field	121,992	$24,666.78	$141,398.40	5.7
Torero Stadium	206,448	$41,743.79	$241,537.28	5.8

Valley Field	75,072	$15,179.56	$87,360.00	5.8

12.2.21 Interior Lighting fixture replacements to LED

The interior lighting throughout the campus varies widely and there have been fairly recent audits for the campus lighting that evaluated energy reduction by completing lamp replacements or retrofits with LED lighting as a category 1 audit. Therefore, only a consolidated look at interior lighting retrofits with focused replacement or retrofit options has been included for energy efficiency measures in this plan. The assumption is that any fixtures that have screw-in base sockets would already have LED lamp equivalents installed or will be installed when the current lamping fails. The selection of fixtures to retrofit or replace in these measures are limited to a quick return on investment of less than 10 years. It is expected that non-LED lighting with less payback will most likely be replaced by a major redesign in the next 10 years.

For the savings calculation, the kWh rate is based on the Calpine commodity rate, and the kW demand savings is based on the non-coincident demand since the lighting will be on during the non-coincident demand time period, and much of it will be off during the coincident demand time period. The project cost for each of these measures is based on a per-fixture retrofit or replacement cost, and a per-fixture labor cost.

Access to the existing category 1 audit allowed for streamlining the process of selecting what areas in a building would have good returns for replacing or retrofitting fixtures via data filtering and queries. This is a great example of a process that can be performed by USD staff and interns. In this case, an experiential learning process was implemented where an internship student performed the data mining process by manipulating the spreadsheet provided by the category 1 audit and applied the filtering and queries once the parameters were described by the mentor. This can be an ongoing process as projects are completed, technologies change, retrofit/replacement costs decrease, and buildings change use or schedule of occupancy. Students can gain experience and USD can benefit from the data without requiring 3rd party reports and audits.

A summary of the recommended interior lighting replacements is presented in the table below. More details are included in Appendix H – Electrical Efficiency Projects & Recommendations.

Table 23 - Summary of Interior Lighting Replacements by Building

Building	kWh Savings	Cost Savings	Estimated Project Cost	Simple Payback
Hahn University Center	42,984	$8,691.36	$35,645.00	4.1
Jenny Craig Pavilion Arena	122,360	$24,741.19	$84,000.00	3.4
Manchester Village	37,100	$7,501.62	$36,300.00	4.8
Mother Rosalie Hill Hall	30,926	$6,253.24	$25,458.71	4.1
San Buenaventura	43,332	$8,761.73	$34,450.00	3.9
Shiley Science Center	63,435	$12,826.56	$43,650.00	3.4
Warren Hall	26,026	$5,262.46	$18,400.00	3.5

12.2.22 Parking Garage Lighting fixture replacements to LED

Lighting energy utilization with LED is 50% less or better compared to fluorescent lamping. Therefore, garages that have fluorescent lighting and remain on 100% of the time should be retrofitted with LED lighting.

A summary of the recommended parking garage lighting replacements is presented in the table below. More details are included in Appendix H – Electrical Efficiency Projects & Recommendations.

Table 24 - Summary of Parking Garage Lighting Replacements by Building

Building	kWh Savings	Cost Savings	Estimated Project Cost	Simple Payback
Joan Kroc Parking Garage	50,642	$10,239.81	$38,125.00	3.7
Main Parking Structure	45,622	$9,224.77	$30,240.00	3.3

13. Energy Conservation Measures In Lighting Control

Recent upgrades in lighting control technology can take advantage of the widespread adoption and increased controllability of LED lighting compared to previous lamp types. Programmable and dynamically adjusting lighting controls are now the standard. At USD, there are only a few buildings that are in the process of being remodeled with these latest controls capabilities (e.g. Knauss Center, Camino Hall, Founders and Sacred Heart Halls). Therefore, even though much of the campus was designed to exceed the current California Energy Commission Title 24 lighting standards, requiring high efficiency lighting with lighting controls, these requirements were not nearly as effective as the latest control technology. Most non-residential buildings on campus do have a lighting control panel, but that only allows timeclock control for zoned-circuit shut-off. This is very limited and results in many areas of the building remaining uncontrolled for many hours of the year to avoid turning off lighting during instructional / occupied hours. Occupancy sensors have also been incorporated in some areas which are much more efficient in turning off lighting in un-occupied zones, but they are not tied in with a SCADA system and not integrated with a central control capability.

13.1.1 Occupancy sensor use

Occupancy sensing devices for control of lighting to minimize the operating time of the lights is an example of effective lighting energy conservation. An expansion of this capability is to utilize the occupancy sensors for receptacles and equipment that commonly gets left on as users leave that space. In an educational environment, studies have shown that students and staff frequently leave devices on, assuming others will turn it off. Newer control systems integrate occupancy sensor technology on both lighting and receptacles, turning lights and devices off when spaces are unoccupied. In the past, the occupancy sensor only activated a switching contactor. Now these contactors are smart devices that can be programmed for other uses as well by being interconnected to the campus SCADA system. Controllable loads throughout the campus that are integrated with the SCADA system will support USD's Demand Response capability. As the remainder of lighting is converted to LED, the capability of having programmable LED drivers interconnected with dimming control will create the flexibility to have multiple Demand Response scenarios, including:

- Peak demand savings by load reduction without interruption of tasks
- Demand Response option triggered by SDG&E
- Interaction with mechanical systems to enhance savings and comfort.

While these associated benefits are not calculated in this energy master plan due to the variability of load prediction - in order to calculate the savings potential, a tally of demand loads attached to a controllable zone that is accessible to the SCADA system would need to be maintained. Then USD could have a periodic review of utility rates and SDG&E programs to trigger when the SCADA programming should be modified with a way to enact the Demand Response event.

13.1.2 Lighting controls to include daylight capture

The intent of indoor lighting is to provide adequate and uniform lighting for the building occupants. It is only recently, with the industry-wide adoption of LED's and highly flexible lighting controls, that the lighting technology can cost-effectively reduce the energy use without diminishing the light levels in a space. Daylight sensors and intelligent lighting controllers can dynamically adjust the lighting energy to maintain comfortable light levels in a space. With system pricing where it currently resides in the market, retrofitting an existing system to include these capabilities may not have a good return-on investment value that justifies the upgrade, but as prices continue to drop, USD should consider these capabilities in all future projects.

Daylight capture is provided by installing a photocell that recognizes the amount of light in the space and the dimming controller reads this value and adjusts the dimming to match a programmed value of required ambient light. In many cases, the current energy codes require this capability to be installed for new construction, and therefore, part of the mandatory upfront costs to the project. Lighting control systems such as *Wattstopper* by Legrand, *nLight Controls* by Acuity Brands, and APOGEE Lighting Controls by Siemens are all examples of these products. The integration of these products and the compatibility to communicate with other building automation is not a proprietary concern, so designers and contractors can specify any of these products and their associated gateways will allow the existing Siemens BMS system on campus to communicate. **The campus design standards should be reviewed and updated often to include lighting controls with daylight capture as minimum requirement for new building and tenant improvement designs.**

14. Energy Conservation Measures for Power Systems

The following measures represent USD's opportunities to reduce the use or need to power an electrical device and therefore conserve the amount of energy consumed on campus.

14.1 Plug Load Controls

Controlling plug loads is another tool for turning off unnecessary loads when spaces are unoccupied or when devices are unused and also for reducing campus load dynamically as part of a demand response event. These devices can be installed in classrooms, dorms, office, and administrative areas, etc. and with proper education on the technology, users can control what equipment is controlled via occupancy or demand response signals. It is recommended that TV's, radios, printers, and other non-essential devices are connected to the controlled plugs. Computers, refrigerators, medical devices, and similar essential devices are not recommended to be connected to plug load control occupancy devices. Controllers used to operate plug load control devices are usually the same for the lighting control, so there is no longer a compatibility or complexity concern to include this into new projects. **Cost increases for plug load control**

devices are also minimal for the benefit of granular device control and it is recommended that USD add this to their campus design standards.

14.2 EV Charge Control Management

With USD's plans to electrify their fleet of vehicles and the increased proliferation of EVs from students, faculty, and staff parking on campus, uncontrolled EV charging could become a major source of demand and cost for USD. Therefore, EV Charging Control Management can smartly deploy EV charging to respond to or reduce on peak period demand while still ensuring that priority vehicles receive adequate charge. Existing Electric Vehicle Supply Equipment (EVSE) charger systems on campus are not integrated with charge management software at this time, but most major EV charger product manufacturers have the capability to upgrade the equipment so that it can adjust the output to the vehicle. Additionally, EVSE manufacturers are developing product solutions which integrate batteries into the EVSE to quickly charge vehicles with DCFC capability while "appearing" like a much lower wattage load to the building, avoiding costly upgrades to building electrical service capacity. Any new installations of chargers on the campus, such as those detailed in Appendix F, should have the capability of applying charge management software so that the campus SCADA system will be able to network and communicate with the charger system. Implementation of charge management software should be implemented when EV charging on campus starts to set noticeable on peak demand spikes in the campus load profile. Accordingly, metering should be added to the panelboards serving the EV chargers and logged in order to create the historical data to decide when control software is warranted. There are currently about 30 chargers connected to the main campus grid system and at a full charge rate of 6kW, could equal up to 180kW of demand.

14.3 Energy storage for PV system harvesting and peak-demand management

At 6.5% of the average overall campus load, currently USD's existing PV systems do not significantly contribute to a dip in overall campus load during the day. However, as additional PV is installed, the dip in peak-demand for the campus during the solar production window timeframe will grow. Currently, since USD procures energy (kWh) at a fixed rate (non-TOU) from Calpine, there is no financial benefit to storing energy produced from solar to deploy at peak rate, 4pm-9pm, times. Only the peak-demand charges are impacted by SDG&E's time-of-use structure, so battery storage could be advantageous in helping to reliably offset peak demand. As the solar PV output grows, any excess solar production could be stored in a battery, instead of being exported to the grid, and deployed during peak times to reliably offset peak loads and further reduce monthly peak demand charges.

15. Campus Electrical Resiliency Recommendations

Resiliency in an electrical system is to harden the system against, and recover from power-loss events, including loss of grid and failure of on-site electrical distribution. USD's current resiliency capability includes existing protection from grid-loss with a full-system diesel generator backup system when the grid fails. For on-site electrical distribution, there are redundant circuits in the 12kV distribution and each building transformer has the capability to switch between two circuits. For diagnosis of trouble, there is a site-wide monitoring of building meters to provide alerts that voltage or frequency is out of range. USD currently has a fuel cell system, PV systems, and a battery system installed on-site, but since these systems are under

PPA contracts and not owned by USD, the campus lacks the ability to customize their control to provide robust resiliency to the electrical system.

Another area of concern for resiliency is the integrity of the 12kV distribution system throughout the site. For example, though there are (2) circuits distributed through the campus, with (2) additional circuits for redundancy, all (4) circuits are routed together which creates a single-point-of-failure source. This is true for the duct bank and manhole system from the main service switchgear at the West Parking Garage, to the intersection of Marian Way and Alcala Park Way (approximately 1,500 feet). If the duct bank or manholes are damaged, all (4) circuits would need to be deactivated in order to repair the system. One solution for this would be to install another route of duct bank and manholes paralleling the existing system with an appropriate distance apart that will minimize the chance that both routes would have damage at the same time. A second solution would be to have a second SDG&E service with associated switchgear and generators on the east side of campus and be connected to the 12kV distribution as a loop system. A study would need to be performed including detailed correspondence with SDG&E and the allocation of land area and access would need to be established. Since the cost is highly variable for these solutions, this report focuses on the approach of microgrid components to create flexibility instead.

The table below outlines the various microgrid components recommended for USD, their estimated costs and suggested staging in the Energy Master Plan analysis. Each component is explained in detail in the following subsections:

Table 25 - Resiliency / Microgrid Total Cost of Ownership

Resiliency / Microgrid Total Cost of Ownership	$	Year	Notes
Generator controls	$85,000	2022	Will allow for Fuel Cell to remain on during generator testing, leading to ~$100k of annual cost savings through lower demand charges. Will also allow for proper staging of generators to maximize their lifetime.
SCADA / Siemens energy management control upgrade	$25,000	2022	Assuming approximately 10 buildings where Siemens equipment interface is not complete
Microgrid Controls - 1st yr setup/staff training contract	$100,000	2022	one-time contract
Microgrid Controls - Annual Software Subscription	$30,000	2022	yearly ongoing cost
Microgrid Controls - Dedicated Staff Hire	$125,000	2022	yearly ongoing cost
Microgrid Controls - Computer Dashboard - initial cost	$50,000	2022	One time dashboard design and setup
Microgrid Controls - Computer Dashboard - Maintenance	$15,000	2022	yearly ongoing cost (Could be offset by USD experiential learning / interns/ work study)
Microgrid Controls - Hardware (computer systems)	$65,000	2022	$25k for computer server/ database system, $8k/ea for industrial computers at 5 microgrid equipment locations
Demand Response Energy Storage for STEM Battery (500kW, 1MWh)	$600,000	2022	$500/kWh and the balance of system could be around $100k

Resiliency Energy Storage buffer for Fuel Cell (500kW, 1MWh)	$600,000	2022	$500/kWh and the balance of system could be around $100k
New Generator (Gas - 1MW)	$500,000	2027	Replaced upon 1st generator failure
Energy Storage replacement for STEM Battery (500kW, 1MWh)	$600,000	2030	$500/kWh and the balance of system could be around $100k
New Generator (Dual-Fuel) - 2MW)	$1,000,000	2031	Replaced upon 2nd generator failure
New Generator (Gas - 1MW)	$500,000	2032	To replace fuel cell for emergency back-up generation after Bloom contract expiration
TOTAL COSTS	**$4,295,000**		

15.1 Microgrid Design for Resiliency

A microgrid is defined by IEEE Task Force as "…a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid." A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected and island mode. Therefore, the existing campus architecture is technically a microgrid with the primary generator system connected at the SDG&E point of connection with the capability to power the campus when the grid is out. The distinction in today's implementation of a microgrid is to include renewable energy systems and energy storage systems that allow microgrids to be designed to minimize the use of the grid and use distributed energy generation to function as more than just a cost savings tool or an emergency backup system that only runs when the grid is not available.

The campus has installed multiple distributed energy resources in the last 10 years for economic reasons and to reduce carbon emissions, including solar PV systems, a fuel cell system, and a lithium battery system. Each of these systems is a stand-alone use and do not have any control capability to be implemented as part of a microgrid. There is a need to interconnect these systems and install a microgrid control system to utilize these resources in a manner that can expand resiliency, reduce the dependency on the diesel generators for emergency power, and improve economics. The following are some definitions to clarify the type of control equipment and systems for a microgrid:

15.1.1 Definitions:

Programmable Logic Controller (PLC):
Commonly used to describe low-level protection systems with basic logic, such as generator and switch controls. A PLC is a high-speed controller with little or no software that is very robust, and therefore, does not need to be consistently upgraded or maintained.

Supervisory control and data acquisition (SCADA):
A SCADA system is commonly used to describe the networked energy management system used for monitoring building energy meters, HVAC systems status and controls, and lighting controls. There is a computer database for collecting the data, a front-end software dashboard to view the data, and a programming system to customize the dashboard and initiate controls. The SCADA equipment consists of PLC cards in each building that read and control mechanical equipment set-points and data values and reports them to the master central controller. Other devices, such as lighting controllers can also be connected to this SCADA system.

The campus currently has a Siemens SCADA system installed. This SCADA system is currently transferring from their branded Insight software to the Desigo software. The term Building Management System (BMS) is another example of a SCADA system.

Microgrid Controller:
A microgrid controller is a specialized SCADA system for optimizing energy systems to improve a power system stability and economics. Controllers for cogeneration systems and emergency backup systems were essentially a microgrid controller, but with the recent adaption of distributive energy resources, such as renewable energy and energy storage systems, the development of a more sophisticated controller has now been known as a microgrid controller.

Smart Grid:
As electrical systems become more dynamic and interact with smart controllers and Internet-of-Things (IoT) devices, the California electrical grid is driving the industry to adapt equipment and controls that will follow a Smart Grid protocol to be resources to the grid. The California Energy Commission (CEC) and California Independent Service Operator (CAISO) are initiating standards for the utility companies, like SDG&E, to have customer owned Smart Grid devices networked and visible to the grid operators.

Due to this new initiative, the campus will be required to integrate their distributed energy resources and building energy management systems with SDG&E network devices for benefit to grid operation. For all new building designs and existing building remodels, CEC-mandated Title 24 mandatory measures require that building energy management systems are installed to network mechanical and lighting systems to be capable of receiving a demand response signal from the grid operator to control the energy use in the building. USD can take advantage of these control capabilities and form microgrid controls that aggregate each building into a single resource for the grid operator. This can create a cost reduction and revenue generation opportunity by participating in programs offered by SDG&E and CAISO.

15.2 Generator Controls

The current site 12kV system generators are 16 years old and have a life expectancy of about 25 years. The generator and 12kV substation PLC and SCADA controller are only expected to have a 15-year life expectancy and should be scheduled for replacement soon. The current system is by Cummins and was installed with the new electrical equipment in 2004. The original design documents for the fuel cell refer to maintaining the use of the fuel cell when the generators are running and that there are controls available to trigger a shut-off to protect the generators if needed. Due to assumed lack of protection from power backflow, fuel cells are scheduled with Bloom to remotely shut off before generator testing and restarted once test is complete. This reduces savings on fuel cell system and relies on Bloom to be part of the generator testing procedure.

A new DMC 8000 Cummins controller could be installed with a price-range of $85,000 and provide the following added capabilities:

- Ability to avoid turning off the fuel cell system during generator testing, greatly reducing demand charges by over $100,000/yr
- Ability to stage the generators when the demand does not require all 3 generators, increasing the lifetime of equipment and decreasing maintenance costs.
- Ability to stage testing of the generators such that they are burning fuel at their more-efficient load during the test.

- Ability to utilize an on-site battery to maintain load-flow for added protection and efficiency.

These capabilities and described in greater detail in the following subsections.

15.2.1 Generator Testing and Fuel Cell Integration

There is currently a 1MW fuel cell system installed by Bloom Energy under a PPA agreement. This system includes an early termination penalty charge for USD if this system is removed or decommissioned prior to 2031. As previously discussed in Section 7.1.2, USD also incurs a significant demand bill charge and "deemed power" charge whenever the gas is turned off the fuel cells, which they incur whenever they test their generators.

Our understanding is that the generator tests are conducted in the following manner:

1. First the power output from the fuel cells is ramped down to zero over about half an hour.
2. The three 2,000 kW diesel engines are started and paralleled with the utility.
3. The utility breaker is opened and the diesel generators quickly load up to meet the campus load. There may be a voltage sag of around 8% for several seconds, but presumably most campus loads handle this without tripping off.
4. After a half hour or so the diesel generators are synced with the utility and the utility breaker is closed.
5. The diesel generators are shut down and the utility picks up the bulk of the load. The solar systems are believed to operate through the typical tests, although at 9 am they are at a low power output.
6. After an hour or so the fuel cell is brought back up to temperature, synced and tied into the grid, and gradually brought back up to full output.

Recommendations:

Fuel Cell system optimization removes the need to turn off the system as much as possible. Strategies for eliminating the need to turn off the fuel cell during the shutdown and start up procedures for generator testing are described below in detail.

Install new generator control system and expand algorithms for generator testing, with the following steps:

1. Discharge battery prior to generator test to have 30-minutes of full battery charge capability during test.
2. Verify utility meter is importing above 1.5MW.
3. Start generators, sync, and transfer power to generators.
4. Command battery to charge at full charge capability for 15-minutes (duration of generator testing period.)
5. Generators can be staged during test to have one or two dominant generators to increase the demand on an individual generator, then rotate to the other generators before completing the test.
6. At the end of testing period, return battery algorithm to peak-shave utility.
7. Transfer power back to utility.
8. Cool down and turn off generators.

These changes will allow fuel cell system to remain operational with the battery system creating enough load to avoid power flow reversal if the fuel cell suddenly disconnects during the generator test.

Other options considered, but <u>not recommended</u> are the following:

A. Installing a 1MW load bank in place of energy storage to compensate for fuel cell generation if the site load suddenly drops. This has been eliminated due to the cost-effectiveness of generator controls vs. an additional piece of equipment to purchase and maintain in a load bank.
B. A no-cost option to avoid demand charge costs during the testing is to perform the generator test earlier in the morning to not have a utility demand spike when the fuel cell is turned off. This has been eliminated due to complaints of sound with neighbors.

Each month of FY2019 was investigated to determine what the demand for the month would be if the fuel cell were 100% available, so that its absence never set costly demand peaks on the monthly SDG&E bills (See Appendix E). This level of operation may be more than can be achieved in most years but is theoretically possible because fuel cells are typically highly reliable. The On-Peak and Non-Coincident demands were calculated each month assuming the fuel cell was available and the effect on the utility bills was determined. In some months the billing would not change, but in others the full benefit of the fuel cell (up to 864 kW) would be realized. In FY19 the resulting savings from full availability of the fuel cell would be $106,477.

15.2.2 Generator Staging

Since there is an existing generator system that can completely backup the entire site, there is an expectation that this is a baseline standard and therefore, the concept of having certain buildings not powered during an outage is not an acceptable option. To extend the life of the generators, and improve the efficiency and maintenance costs, it is recommended to reduce the load to only require 2 generators and have the 3rd generator programmed to remain off. The load profiles presented in Appendix C show that this is achievable. The generators can be staged so that one generator is designated as spare based on runtime hours. In order to accomplish this, a new control system would need to be installed that has a robust and redundant low-level protection Sequence of Operation (SOO), and the capability to dynamically toggle between multiple SOO's based on current real-time measurements. This should be installed as soon as possible and facilitate the fuel cell remaining on during routine generator testing.

15.3 SCADA System Upgrade & Microgrid Tie-In

There are existing SCADA systems on campus and USD is in the process of increasing the capability of an overarching Siemens system to consolidate the control and reporting. That said, the concept of true integration is to have the capability to integrate multiple disparate systems for data acquisition and control and only interact with a single reporting and programming dashboard. The below recommendations assume a cost of $2,500 per building, with approximately 10 buildings where the Siemens equipment interface is not complete.

Recommendations:

- USD should consider upgrade their campus network to a fiber backbone to buildings and gigabit Ethernet to SCADA devices within the building. Coordination with Campus IT to utilize the existing fiber optic network between buildings will minimize infrastructure costs.
- Each building should have an energy management controller for the mechanical system, lighting, system, metering, and other demand response equipment to interface as one system. This controller can be programmed with multiple automated 'modes' based on the campus needs and opportunities. This will allow for equipment on different control protocols to interact seamlessly

and not require proprietary products to be installed. The master Siemens controller currently utilized on campus can be programmed to enact the modes without having all of the intelligence in the Siemens system.

- Expand the demand response capability by upgrading building SCADA system to a robust singular network system. This is further detailed below and will allow staffing to have a consistent implementation policy and have a new construction standard that is well detailed and economical to install and warranty. The SCADA system will interact with a minimum of three items: metering, HVAC, and lighting/load control. Currently available metering equipment is now much more agnostic to the data protocol used thereby broadening USD's choices for metering manufacturer. Therefore, a two or three name specification, including the manufacturer of the SCADA system can be standardized without a concern of programming difficulties, incompatibility, etc. For the HVAC systems, refer to the Mechanical controls sections. The lighting/load control equipment is also agnostic to data protocols and compatibility through standardization efforts of CEC Title 24 mandatory requirements to interact with future utility company Smart Grid and SCADA equipment.

15.3.1 SCADA Tie-In to Microgrid Equipment

The existing USD SCADA/BMS system by Siemens has been on campus and maintained for many years. It is in the process now of being upgraded to a BACNET protocol that increases its functionality. Its primary use is to manage the buildings mechanical systems, collecting and storing electrical metering data, and acting as a scheduler for building and exterior lighting systems. Technically speaking, this is a SCADA system that communicates with PLC's, whether they are a Siemens product, or another product, such as a digital meter or lighting control panel. This system should continue to be used for the current functions and does not require any major changes for a microgrid implementation. Whatever Microgrid Controller is selected (see Section 15.4 below), this system would be accessed for data acquisition, and some additional SOO's or modes would be programmed to implement the needs of the Microgrid Controller algorithms.

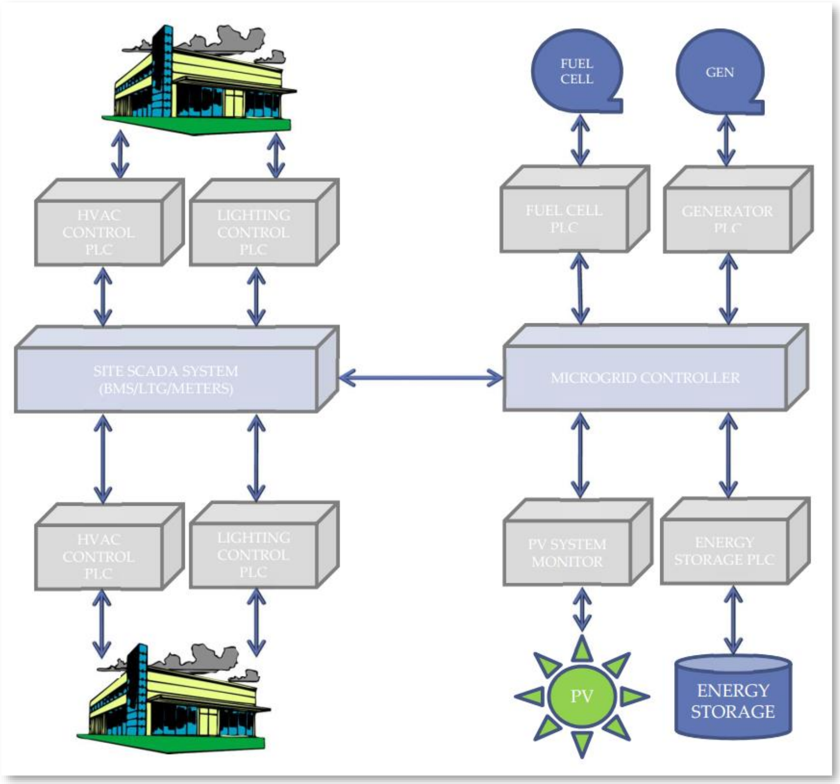
Microgrid Controls Architecture

In order to manage the new electrical system products there will need to be a layered software microgrid control system with intelligent, dynamic mid-level control logic that adjusts to variables provided by a microgrid optimization controller. In the past, there were very distinct and isolated control systems for specific electrical equipment. For example, the generator controller provided all of the logic for backing up a power system and maintaining the health of generators and testing. The mechanical system controller provided all of the logic for use of the mechanical system in a building and did not interact with the generator system, battery system, and any other systems. Many times, these controllers are proprietary and are difficult to interconnect. Furthermore, these systems may have warranty and maintenance contracts that have rules against programming modifications or interaction with other controls.

A modern microgrid control system architecture should be designed such that these separated discrete control systems can remain functioning as designed and not interfere with their low-level control sequences. Generator controllers autonomously activate backup sequences and testing as needed. BMS systems continue to optimize equipment performance, and demand-management battery systems continue to optimize demand savings. These controllers can be considered the PLC's for their system. A microgrid needs another software system to monitor the status of these resources by monitoring the status of the PLC's. This monitoring software is considered a SCADA system. The SCADA system should be considered the mid-level monitoring and control system that an operator can use and program for troubleshooting, data acquisition, and equipment scheduling. A third level, or high-level software system should be installed to optimize and integrate all of the discrete systems into a holistic microgrid system. This software is fairly new to the market and therefore is still fuzzy in its use and how much interaction it has with the individual equipment within the microgrid. This product is separate from the PLC's and SCADA systems and should be considered the actual Microgrid Controller.

Microgrid Implementation
Electrical equipment included in the microgrid will have their PLC's for protection and low-level operation. Some of electrical equipment will have a SCADA system that monitors the equipment performance, provides alerts, and is used for generic scheduling.

Figure 19 - Microgrid Control Levels



The following subsections describe the controls details for the various key microgrid equipment:

15.3.1.1 Fuel Cell System

Based on the nature of the fuel cell system as a base-load generator, it is best if this system maintains its own PLC/SCADA system for protection and optimization. Other systems will only need to monitor the fuel cell status, but no additional controllers are needed.

15.3.1.2 PV Systems

There are 11 existing PV systems that are under a PPA contract and do not have any controls for the campus. The inverters connected to the campus electrical system are UL 1741 rated for power protection and are considered their own PLC. The PPA contract holder has a SCADA system installed for monitoring of production in order to maintain the terms of the PPA contract. It is recommended that USD network to this SCADA system and store the production data in their own Siemens SCADA system. Due to the nature of PV power production, and the current combined size of the systems, it is not necessary for USD to control these systems.

As USD installs new PV systems, it is recommended that the PPA contract incorporates operation with an energy storage system. These new systems could then be interconnected to local energy storage systems that provide demand management and create load-flow control. The energy storage would have a PLC/SCADA system installed that will integrate with the PV production directly, so the PV system itself will not need any additional separate controls.

15.3.1.3 Energy Storage Systems

USD has one existing lithium ion battery system which is installed and owned by STEM and provides demand management for power bill savings. This system has its own PLC/SCADA system for protection and management of use. It is recommended that this system remain in place until end of the contract with no change in programming. STEM should be informed when additional battery equipment is installed on campus to avoid a conflict of charge/discharge algorithms.

This report recommends that new energy storage systems be installed. The use of the new systems will be to enhance the saving of peak-demand charges, expand new PV system capabilities to include local backup and building demand management, and utilize control of power flow to assist in generator testing, critical power backup, and ensure the fuel cell system can remain on when the utility grid is out. The use of the energy storage systems become a flexible tool, similar to a swiss-army-knife, for the resiliency of the electrical system. Therefore, it is a key component for the campus microgrid. The controls installed include a PLC/SCADA system by the product manufacturer for protection, testing, and monitoring. The SCADA programming should include multiple SOO's or 'modes' that perform a specific option that the manufacture can approve the use and maintain warrantees for the life of the product. The Microgrid Controller will activate and use these modes but should not need to be responsible for the protection and performance of the energy storage.

15.4 Microgrid Controller & Equipment

The Microgrid Controller will be an entirely new software product that interacts with all of the SCADA systems described above. The controller will need to monitor that status and have historical data for the microgrid resources and build custom algorithms. The algorithms will make dynamic autonomous decisions based on real time data and should include weather, utility rates, and other similar outside factors to adjust the power flow of the system. Financial priorities, system reliability priorities, and user-defined priorities will be ongoing and changing variables that will need to be factored each hour of each day, and therefore, a very complex system. That said, it is best to start with a few simple priorities and develop the complexity over time. It is recommended that the campus interview and implement a Microgrid Controller designer contract at first and insist that the developer use a non-proprietary industrial automation software like Ignition by Inductive Automation, such that the campus staff can be trained and constantly update and expand going forward. The cost of this initial Microgrid Control contract is estimated to be \$100,000, while the software is subscription based and is estimated to be \$2,500/month or \$30,000/yr. The dedicated microgrid control staff member is estimated to have an annual salary of \$125,000/yr. The concept is for a highly programmable SCADA platform that many industry-savvy controls engineers could implement and maintain. USD will also want a developer of a computer software dashboard to provide streaming real time data, reports from historian databases, and a query engine to find trends, anomalies, and beneficial opportunities in energy management. Since this industry is evolving, it is best not to get locked in with a proprietary or intellectual property protected system that will be unusable if the contract is terminated or the company goes out of business. The cost of this initial microgrid dashboard is assumed to be an initial $50,000, with $15,000/yr to maintain with customized reports and software tweaks. USD can save on these maintenance costs by utilizing work study programs to build upon and maintain the dashboard instead of contracting out.

The initial controls designer should be given very specific criteria and a defined product to build, with a measurable result and list of milestones with discrete amounts of time. The dashboard developer may be the same company or separate, but the two products should be designed with good collaboration to avoid rewriting of one to implement the other. Eventually, USD staff should own and maintain the Microgrid Controller and software.

The hardware products necessary for the Microgrid Controller should not be proprietary either and mainly consists of a computer server / database system, industrial computers at the microgrid equipment locations, such as the energy storage, generators, and substation, and a network system to communicate with the equipment and all of the SCADA systems that will be included in the microgrid. Costs are estimated to be $25,000 for the server and database system and $8,000/ea for industrial computers located at 5 sites, totaling $65,000.

A summary of the total cost of the recommended microgrid controls for USD is including in the table below.

Table 26 - Total Cost of Microgrid Controls

Microgrid Cost Component	$	Year	Notes
Microgrid Controls - 1st yr setup/staff training contract	$100,000	2022	one-time contract
Microgrid Controls - Annual Software Subscription	$30,000	2022	yearly ongoing cost
Microgrid Controls - Dedicated Staff Hire	$125,000	2022	yearly ongoing cost
Microgrid Controls - Computer Dashboard - initial cost	$50,000	2022	One time dashboard design and setup
Microgrid Controls - Computer Dashboard - Maintenance	$15,000	2022	yearly ongoing cost (Could be offset by USD experiential learning / interns/ work study)
Microgrid Controls - Hardware (computer systems)	$65,000	2022	$25k for computer server/ database system, $8k/ea for industrial computers at 5 microgrid equipment locations
Total cost of Microgrid Controls	**$385,000**		

15.5 Install 1.5 MW of Energy Storage for Demand Response and Resiliency

15.5.1 Energy Storage & Demand Response

There is a 500kW STEM battery installed at the main utility service that will predict USD's peak demand for the billing month, then discharge and flatten the utility meter demand whenever the site exceeds that demand value. The deficiency in this system is that there is a 1MW spike when the fuel cell is turned off and the 500kW battery cannot maintain the predicted peak demand. Eliminating the routine shut off of the fuel cell is a good first step in optimizing the STEM battery's ability to effectively shed peak demands.

USD's current demand response capability relies on manual reduction in lighting and mechanical loads by the use of the Siemens SCADA software. However, since many buildings are either not connected to the SCADA or connected via an antiquated twisted-pair cabling and lower grade Ethernet wiring board, automated demand response is not, and cannot be broadly implemented across campus. In a bind, USD does have the capability to reduce campus demand by triggering a building HVAC system from occupied to unoccupied modes or turning off lighting.

Recommendations:

- Install at least 500kW of new battery to bridge the deficiency of the existing battery system. The new battery algorithm can monitor the existing battery and add peak demand management when the STEM battery is exporting at its peak and there is still a load above the designated threshold. This will allow the STEM business model to stay intact until the contract is completed. Once the campus has completed the contract with STEM, a replacement battery of an additional 500kW or more can be purchased and integrated with the existing battery to have a total of at least 1MW of energy storage. The use of the combined battery system may now be used for expanded benefits, such as microgrid flow management, backup capabilities, and power quality enhancements and generator testing capabilities. The cost per new 500kW storage system is approximately $600k and is recommended to occur ASAP in 2022.

15.5.2 Energy Storage & Resiliency

USD's current fuel cell is used for cost savings and is not part of the backup capability for the site. Fuel cells are most efficient when they maximize their output and do not get shut off. Therefore, fuel cells in general have been difficult to integrate into a backup system in the past because once a power system is separated from the grid, excess power cannot be exported and fuel cells cannot modulate their power output. Now that energy storage has become more economical and more readily available on the market, energy storage can be the buffer of energy fluctuations to compensate for the fuel cell's base load characteristic tied to a variable load.

One scenario would be to install a total of 1.5MW, 3MWh (or more) energy storage system. This would result in the installation of an additional 500kW of storage beyond the 1MW of combined energy storage included in the above subsection. This energy storage system would be installed on the same circuit as the existing fuel cell with the capability to transfer to "grid-forming" without an interruption in service, allowing the energy storage to keep the inverters within the circuit on during an outage and continue power generation when the utility grid goes down. This would be the microgrid-supported circuit. Then re-organize the building loads for an average of 1MWh of usage to be connected to this circuit. If the utility power goes out, the energy storage can continue the grid on this microgrid circuit while the other circuits drop out. The existing generator system can start up and transition to pick up the rest of the campus, but the microgrid circuit will not see interruption in service. If necessary, the generator system could synchronize with the battery-driven grid signal and transfer without interruption. Once the utility grid returns, all site loads can seamlessly transfer back to grid. The benefits to this configuration would be:

1. Use of fuel cell during a power outage and no interruption of fuel cell. This reduces use of diesel fuel during and outage and increases reliability of the fuel cell.

2. Microgrid circuit is protected by an uninterrupted power source (UPS).
3. Seasonal adjustment to what loads are on the microgrid circuit via manual switching of loads between circuits.
4. With key buildings connected to the microgrid circuit, local backup generators on buildings, such as the Shiley Science and Technology Center would not see a power interruption and would never need to be used unless there is an interruption in the circuit itself. This would increase the reliability of service on these key buildings.

The suggested size of the energy storage is based on the 1MW fuel cell system that would become the generator for the circuit and maintain the average load for a net on average near zero. This would allow the fuel cell, energy storage, and load combination to be self-sustaining as long as the fuel cell gas source is not interrupted. If the fuel cell is not available, the kWh sizing of the energy storage could maintain this circuit for about 2 hours if fully charged prior to the outage. Note that this system is only maintaining one 12kV circuit and could not backup the entire campus, only the loads attached to this circuit. Energy storage systems are currently budgeted around $500/kWh and the balance of system could be around $ 100k, so this 500kW system would be approximately $600k total. It is recommended that this storage also be installed in 2022.

Finally, when the STEM battery contract ends in 2030, it is recommended for USD to purchase another $600k, 500kW system as a replacement.[19]

Table 27 - Total Energy Storage Costs and Cumulative Bill Savings

Microgrid Cost Component	$	Year
Demand Response Energy Storage for STEM Battery (500kW, 1MWh)	$600,000	2022
Resiliency Energy Storage buffer for Fuel Cell (500kW, 1MWh)	$600,000	2022
Energy Storage replacement for STEM Battery (500kW, 1MWh)	$600,000	2030
Total Energy Storage Costs	**$1,800,000**	
Cumulative Bill Savings (till 2035)	**$2,335,750**	

[19] The battery storage bill savings benefit (beyond those contracted through STEM) was determined by running an analysis on Energy Toolbase, a widely used solar and storage analysis tool in the energy industry. Based on the electric load, electric rate tariff, the solar generation of the campus, and the user specified battery size, the software calculates the estimated annual bill savings.

For this report, only the immediate demand reduction financial benefits of the batteries were considered. An additional benefit not analyzed is the ability for the battery to reduce carbon emission. It does so by storing electricity when demand charge is low (in the off-peak hours, which coincides with the time when the grid is the least carbon intensive), and releasing electricity when demand charge is high (in the peak hours, when the grid is the most carbon intensive). Therefore, the campus will purchase less dirty electricity, and use more clean electricity. It is worth noting that SDG&E electricity usage increases slightly with the addition of the battery due to charge / discharge inefficiencies, which are modeled at 85%.

15.1 Existing Generator Replacement Plan

The existing generators are 17 years old and nearing their life expectancy of 25 years+/- depending on how well they are maintained. The service company should be consulted as to which unit will need an expensive upcoming service and is least reliable. Since the generators are not used very often, there is not an immediate return-on-investment of replacing one unless it has a large repair. It is expected that all generators will reach the end of their useful life in the next 7-10 years, and that only two of the three will need to be replaced to correspond to decreased campus load and increased solar and storage.

Around 2027, USD should be prepared to remove an existing 2MW generator and replace it with a 1MW natural gas driven generator for an estimated cost of $500,000. The new generator will allow additional staging benefits to reduce the uses of the 2MW generators and reduce the on-site fuel storage dependency. As well, resiliency is improved by the flexibility of the additional fuel source.

The second generator replacement should remain a 2MW generator system that is able to store fuel onsite locally for resiliency. Hopefully by the time this installation is made, there is a renewable fuel option that is able to be locally stored, but we will use diesel as the assumed fuel option for simplicity. The onsite storage option may be possible with a dual-fuel (natural gas and diesel) option so that there is always on-site fuel storage in case the natural gas fuel system is unavailable during an outage. It is estimated that this second replacement will occur around 2031 for an estimated cost of $1,000,000. Without at least one generator on locally stored fuel, a utility outage and an interruption in natural gas access would render the campus without backup capabilities. The only other onsite generation is PV and there is not currently enough identified space necessary to install the needed generation capacity to entirely backup the campus. As well, the concept of installing enough energy storage to avoid the use of a generator is only valid for 2-4 hours. For example, if the site has an average 2MW load, that is 2MWh of energy consumed every hour. A 24-hour period would need 48MWh of storage capacity since there is no adequate on-site generation and there is not an economical energy storage technology available at this point (Approximately $28M based on $600K/1MWh). This emphasizes the importance of reducing the building loads by utilizing the EEM's described in this report and minimizing a building's peak demand. Reducing the demand load on an electrical circuit provides resiliency by reducing the 'stress' to the electrical equipment. Note that even with the addition of a PV and energy storage system installed to minimize the demand load as much as possible, it is unlikely that any building could have the capability to zero out the electrical load entirely because the maximum PV size for a building is based on the square footage of area available for PV, and there is typically not enough daily kWh generation.

Once the Bloom fuel cell PPA contract is complete at the end of 2031, an evaluation should be made to review the latest technology at that time and replace the existing system. This analysis does not recommend renewing the PPA and installing a new fuel cell for electricity generator due to the carbon-intensity of this electricity production, and instead recommends the installation of another 1MW generator to compensate for the fuel cell generator. This is estimated to cost $500,000 and occur in 2032. This analysis assumes the installation for a natural gas generator due to the higher potential for RNG a decade from now.

A summary of the total cost and staging of the recommended generator replacements for USD is included in the table below.

Table 28 - Total Generator Replacement Costs and Staging

Generators	Cost ($)	Year	Notes
New Generator (Gas - 1MW)	$500,000	2027	Replaced upon 1st generator failure
New Generator (Dual-Fuel - 2MW)	$1,000,000	2031	Replaced upon 2nd generator failure
New Generator (Gas - 1MW)	$500,000	2032	To replace fuel cell for emergency back-up generation after Bloom contract expiration
Total Generator Costs	**$2,000,000**		

16. Electrical Deficiency Projects

During project site visits, the following building system deficiencies were found that are not part of energy efficiency or energy conservation measures. Refer to the Appendix I for Site Visit Electrical Infrastructure Notes for more information.

Table 29 - Electrical Deficiency Projects

Building	Project	Median Cost Estimate	Timeline
Maher	Replace switchboard MSB-2	$40,000	2023
Maher	Replace panelboard E1. Remove automatic transfer switch.	$6,000	2023
Torero Stadium	Replace switchboard TSF	$30,000	2023
Serra Hall	Relocating breakers into panelboard fed by switchboard.	$6,000	2026
Hahn School of Nursing	Replace switchboard MSB	$20,000	2026
Hughes Administration Center	Replace switchboard.	$30,000	2024
TOTALS		**$132,000**	

Maher Hall:

1. There are 2 electrical services fed from the main building transformer. Switchboard MSB-2 located in room 100K is old and needs to be replaced. The 'ISES Facilities Renewal Needs Assessment' states this switchboard is original to the construction of the building in 1954. There is a panel distribution in this room labeled E1 and 'Emergency' with lighting circuits. This distribution is connected to an automatic transfer switch that does not appear to be operational. This equipment is old, missing deadfront covers, and should be replaced. It is assumed that the lighting fed by this equipment utilized for egress has been replaced or retrofitted with emergency battery packs and this panel no longer needs to be qualified as emergency use.

A. Replace switchboard MSB-2 located in room 100K service as soon as possible. The budget for this equipment replacement is approximately $35,000 to $45,000. An audit of the distribution panels downstream is also recommended.

B. Remove automatic transfer switch and replace panelboard E1 and distribution labeled 'Emergency'. Reference to emergency use should be removed to avoid confusion for future improvements. The budget for this equipment replacement is approximately $4,000 to $8,000.

Switchboard MSB-2 and Panelboard E1

Torero Stadium:

1. Electrical service switchboard TSF for the field is more than 20 years old, has been exposed to weather and should be considered past its life expectancy. Corrosion and rusting may be degrading breakers from operating properly.

   A. Replace switchboard TSF as soon as possible. The budget for this equipment replacement is approximately $25,000 to $35,000.

Switchboard TSF

Serra Hall:
Switchboard MSA and MSB lacks space to provide new distribution. To increase breaker space in MSA and MSB, relocating breakers less than 100A into panelboard fed by switchboard is suggested. This can be done during next building remodel and budget for this is approximately $6,000.

Switchboards MSA and MSB

Hahn School of Nursing / Beyster Institute for Nursing Research:
Existing interior Switchboard MSB (HSN_ELECT_Swbd1 & 2) is old (1978) and past its life expectancy. It may be difficult finding and adding or replacing circuit breakers. This board should be replaced during next building remodel. This board should be relabeled to no longer state 'MAIN' switchboard because the existing main exterior Switchboard MSB fed by service transformer (HSN_ELECT_Swgr1 / HSN_ELECT_Transf1) feeds other services and is the main disconnect for the building.

A. Replacement can be done during next building remodel. The budget for this equipment replacement is approximately $20,000.

Interior Switchboard MSB

Exterior Switchboard MSB

Hughes Administration Center:

Electrical service transformer is located in a room without recommended clearance. This transformer should be relocated during the next major building renovation.

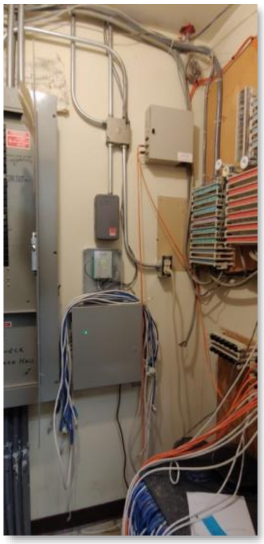
Electrical switchboard is old (installed 1995) and should be considered past its life expectancy. Corrosion and rusting may be degrading breakers from operating properly.

A. Replace switchboard as soon as possible. The budget for this equipment replacement is approximately $25,000 to $35,000.

Service Transformer and Switchboard

Guadalupe Hall:

Electrical service fed from Serra Hall. Electrical room is overcrowded due to telecommunications use and equipment in room. Recommend relocating telecommunications equipment. A detailed review of where equipment can be relocated and what equipment is still active would be needed to estimate this scope.



Electrical room with Telecommunications Equipment

17. Potential Self-Generation Projects

As discussed in detail in Section 5.1.3, the campus has approximately 1,170 kW DC of existing rooftop photovoltaic (PV) systems across 11 buildings on campus. Total generation from existing solar PV provides about 6% of the campus kWh consumption. Electricity produced by the existing systems is subject to a 15-year Power Purchase Agreement that extends through the end of calendar year 2035. Upon the end of this PPA agreement, USD may have a number of options depending upon the terms of their contract. If there is a buy-out option for the existing system, a performance analysis should be undertaken to determine whether it is more economically favorable for USD to maintain the existing system or install new PV modules. Since the original panels are 215-230W and current panels now are available in the 400W range, by 2035 solar technology will have advanced to the level where the existing roof space could generate significantly more energy for USD. In the event where the terms of the contract involves the PPA provider removing solar equipment after 2035, USD should consider an arrangement where only a portion of the total PV system equipment is removed and some components remain. For instance, if the solar module rooftop racks can be re-used, this may secure significant financial advantages for USD, as additional rooftop penetrations will be minimized.

It is recommended that the campus track the performance each year relative to the guaranteed performance for that year. PV data collection issues are discussed in Appendix B. It is recommended that USD address data logger or communications issues so that data is collected reliably during each 15-minute period.

It is also recommended that USD evaluate system performance relative to weather or other parameters allowing USD to determine if there are deficiencies that need to be addressed by PPA provider. The data collection equipment that was installed with the PV system should include a measurement of Global Horizontal Irradiation (GHI) against which the performance can be evaluated.

17.1.1 Additional Solar PV Growth

For a high-level analysis, Willdan modelled solar panels on top of all roofs that were deemed as appropriate for additional solar power installations. The campus currently has many flat roof spaces that are empty except for a few HVAC units. These sites are excellent candidates for solar power. On the contrary, poor candidates for solar power are roof spaces that are covered in Spanish roof tiles, which pose considerable mounting challenges and should also be kept uncovered for aesthetic reasons. After the solar PV layout was modelled on Helioscope, the annual energy generation was valued at $0.10/kWh. This value was determined by comparing the time of generation of the solar system in comparison to the price of the electricity that would have had to been purchased if the solar was not there. Since the peak period pricing for electricity purchased from SDG&E and Calpine occurs from 4pm to 9pm, the bulk of solar generation would not occur during this period and therefore would not offset the most expensive peak demand periods of USD's electricity bill, resulting in a lower valuation than the average SDGE&E/Calpine electricity rate in $/kWh.

The $0.10/kWh is equal to the first-year bill savings per kWh generated by the PV system. This means that on the first year, if USD pays $0.10 per kWh generated, the campus would break even. However, on a 25-year timeline, considering a 3% escalation on the electricity purchased from the grid, the PV generation is worth $0.158/kWh. Therefore $0.158/kWh would represent a 25-year PPA rate that would lead to no change in overall utility bills, given what USD currently pays for direct access electricity (all inclusive, T&D

included). Any PPA rate lower than $0.158/kWh would lead to cost savings to USD over the 25 year PPA term. For the energy master plan analysis, additional solar PPA contracts are conservatively assumed to be $0.1304/kWh, which is the same as the current PPA contracts

The system costs ($7.9M total) presented in the table below represent the total cost of the 3rd party installer, or USD if the campus decided to purchase the systems. Unit costs of the solar panels were projected to be $2.80/W-dc for rooftop spaces, and $3.80/W for the carpark canopy modelled on top of Mission parking Structure. These costs are based upon industry pricing for similar size and scope projects in universities.

***Table 30*: Additional PV Analysis by Building**

Building	Number of Modules	System Size (kW)	Annual Generation (kWh)	Annual Revenue ($)	PV Type	System Cost ($)	kWh/kW	Payback
Alcala Vista Apartments	757	299.02	519,008	$ 47,511	Rooftop	$837,242	1,736	17.62
Beyster Institute for Nursing Research	121	47.80	81,217	$ 7,435	Rooftop	$133,826	1,699	18.00
Facilities Management Complex	360	142.20	247,134	$ 22,623	Rooftop	$398,160	1,738	17.60
Hahn School of Nursing and Health Science	127	50.17	83,375	$ 7,632	Rooftop	$140,462	1,662	18.40
Hughes Administration Center	114	45.03	74,320	$ 6,803	Rooftop	$126,084	1,650	18.53
International Center, School of Engineering and Law	595	235.03	393,712	$ 36,041	Rooftop	$658,070	1,675	18.26
Maher Hall	185	73.08	124,262	$ 11,375	Rooftop	$204,610	1,700	17.99
Main parking Structure	2,749	1,085.86	1,654,526	$ 151,458	Carpark	$4,126,249	1,524	27.24
Manchester Hall - Admissions Office	71	28.05	46,817	$ 4,286	Rooftop	$78,526	1,669	18.32
Pardee Legal Research Center	88	34.76	55,811	$ 5,109	Rooftop	$97,328	1,606	19.05
School of Business	324	127.98	221,473	$ 20,274	Rooftop	$358,344	1,731	17.67
Shiley Center	402	158.79	265,346	$ 24,290	Rooftop	$444,612	1,671	18.30
Sports Center	315	124.40	207,886	$ 19,030	Rooftop	$348,320	1,671	18.30
Total	**6,208**	**2,452**	**3,974,887**	**$363,868.28**		**$7,951,833**	**1,621**	**21.85**

If USD purchased or entered into new PPA agreements for the full estimated additional PV systems presented in this analysis, the campus would more than triple their total installed solar capacity. This analysis assumes the University will enter a new solar PV PPA contract at $0.13/kWh for an additional 2.45 MW beginning in 2022.

18. New Construction & ZNE Design Standards

To ensure the trend of declining overall campus load growth, USD should continue to invest in ZNE analysis and sustainable design for its new buildings, building upon the example of the recent business school ZNE study. **We recommend that USD's Office of Sustainability, in collaboration with Facilities Management develop Zero Net Energy guidelines (or Zero Net Carbon), as many campuses and institutions have for new construction**, such as the University of Oregon.

One core aspect of the University of Oregon's ZNE policy is the capping of overall campus energy usage at a specific date, making the commitment that all prior years will not exceed this baseline energy usage. Under this capped energy use policy, USD would maximize energy efficiency and on-site solar generation in building design. For buildings which are unable to fully offset their predicted usage, this policy would include a requirement to implement an equivalent number of energy-efficiency retrofits within existing buildings to compensate for the new building's usage. As a result, USD's ZNE policy will involve a shift away from a building-by-building approach to new construction towards a campus-wide systemic planning process.

In order for ZNE building design to truly be successful and sustainable, the design team should include broad representation from multiple stakeholders beyond Facilities Management, including the Sustainability Office, Buildings & Grounds, Mechanical and Electrical Engineering designers, faculty & staff, as well as student representatives to the extent feasible.

USD should integrate their ZNE campus policy into their mechanical, electrical and associated design standards. During the course of developing this Energy Master Plan, it was made evident that recently completed or in-progress major renovation projects at Maher, Copley Library, Founders, and Camino Hall were not consistent with the recommendations provided in this report, namely the installation of new gas-firing boilers. It is strongly recommended that USD revisit and revise their design standard documentation to align with the Energy Master Plan, as these documents serve as the chief instructions to the various design teams as to what energy-efficiency and carbon reduction targets to build their design around.

Not only would a ZNE policy cancel any anticipated load growth from new facilities, but it would help USD qualify for significant incentives through the SDG&E-sponsored statewide new construction efficiency programs. The California Investor-Owned Utilities (IOUs) submitted two advice letters to the California Public Utilities Commission (CPUC) on February 19th, 2021, seeking approval of two innovative statewide new construction programs. The advice letters seek commission approval for Willdan to implement both programs. Both programs will serve all 5 non-residential customer sub-sectors (commercial, public, industrial, agriculture, and multifamily high-rise), including private universities, for all 4 IOU service territories. One program is a "Mixed-Fuel" program, allowing for gas and electric efficiency projects. The other program is an "All-Electric" program that includes additional incentives for the design and construction of all-electric facilities that do not have any gas service nor gas meter installed. Assuming CPUC approval, the all-electric new construction program will offer technical services and financial incentives to lower the barrier for USD to pursue ZNE construction. The anticipated program launch dates will be in the latter half of 2021.

19. Building Commissioning

The following is a brief description of some of the types of commissioning that are implemented on buildings in university settings. **It is recommended that USD establish an ongoing commissioning practice to reduce GHG emissions**, which is further explained below. Through the creation of a dedicated team, monitoring and verification of building performance, use of tools to track energy data and continual maintenance of equipment when needed, **USD's OCx efforts are projected to cost $250,000 per year (based on two FTE employees) and to deliver new project savings of 1,000,000 kWh per year.**

Ongoing Commissioning (OCx) – This is an in-house process to commission multiple buildings initially to collect energy savings, and then a long term monitoring process to ensure the energy savings persist. "Continuous Commissioning" is a similar approach developed by Texas A&M University and licensed by the University. For USD the Ongoing Commissioning (OCx) approach best fits the campus needs.

This approach is described in detail for a project that has been going on since 2016 at Lawrence Berkeley National Laboratory (LBNL). This is described in "Generating Significant and Persistent Energy Savings in Building Operations Using and Ongoing Commissioning Approach," by John Elliott, et. al., from the 2020 ACEEE Summer Study on Energy Efficiency in Buildings. This paper describes the OCx project that LBNL is implementing at its own facilities to reduce GHG emissions.

The program has four main elements.

1. A cross functional and dedicated team
2. A repeated cycle to select opportunities, complete and verify savings
3. Regular feedback for continual improvement
4. Tools and process to maintain savings

The OCx process relies on teamwork, and the first step is to establish a cross-functional, dedicated team. The initial goal in creating a cross-functional team is to include a minimum set of skills necessary to solve the complicated problems that are often encountered in malfunctioning building mechanical systems. For the LBNL, this team was developed by matrixing approximately six existing full-time equivalents (FTE) from various departments, including:

- Two dedicated Controls Engineers - with skills in diagnosing mechanical system issues, troubleshooting meters, modifying building automation system control sequences.
- Two dedicated and up to four HVAC and Controls Technicians to investigate in the field and complete a range of tasks from hardware repairs to control loop tuning.
- One-half FTE of an Energy Engineer to take a lead role in identifying building faults and energy- or water-saving opportunities, verifying proper operation of the completed work, and calculating savings.
- One-half FTE developing data analytics capabilities.
- Part-time support by an Energy Manager (0.2 FTE) to ensure that priorities are being set correctly given a broad understanding of energy and water uses at the Lab, to incorporate learning from OCx into other energy management activities, and support work of the team.
- Part-time support by a Chief Sustainability Officer (0.1 FTE) to ensure that the system is working well and receiving the resources and support needed from the Lab's top management.

- Additional support (0.3 to one FTE) from undergraduate students. [20]

The following additional roles are often needed and could likely be more effectively accessed if they are formally associated with the team:

- Electricians to run conduit and cable and install submeters
- IT personnel to provide ethernet drops, networking and address cyber-security
- Building and facilities area managers who can represent priorities of building occupants
- Work planning and control specialists to coordinate multi-craft support
- Environmental Health and Safety (EH&S) specialists to coordinate work safety
- Staff involved in developing preventative maintenance procedures

OCx programs rely on collecting and analyzing performance data for each building. LBNL opted to use SkySpark Building Analytics as the basis for their ongoing building analysis. There are a variety of Fault Detection and Diagnostics software packages that can be used at USD which would connect well with the information available through the Siemens control system.

New Building Commissioning (NBCx) – A commissioning agent, often hired by the building owner, is involved throughout the new building design and construction process to ensure that the building envisioned is the building constructed. A commissioning agent would work with the client to establish project goals and priorities in the Owner's Project Requirement (OPR) Document and be involved in the design and construction process to support conformity of facility progress to the OPR. After construction, the commissioning agent would review the operation of key building systems before it is turned over to the owner to ensure it is functioning correctly. This often includes Functional Testing to verify the basics like operation of a valve or damper. More advanced testing of systems would verify if the Sequence of Operations was properly implemented and if the Owner's Project Requirement are being met. This typically covers all operations of the building, not focusing specifically on energy savings. The commissioning agent typically verifies the corrected conditions before the building is accepted by the owner from the General Contractor.

Retrocommissioning (RCx) – A commissioning agent is hired by the building owner (or utility program) to review operations of a building, focused on improving energy efficiency. Trend logs are often analyzed to verify the functionality of air side economizers, chiller sequences, and so on. Modifications to the control sequences and calibrating sensors are often implemented by the building EMS operator. A contractor may be hired to fix inoperable dampers, valves, etc. Energy savings are typically projected through engineering calculations, building energy simulations or savings at the meter.

Monitoring Based Commissioning (MBCx) – This is a process developed for the UC/CSU Utility Partnership for applications at campuses with minimal building energy metering. It starts with the installation of electric and Btu meters at an existing building, which tend to be unmetered. Baseline energy use is collected by the meters over months to observe operation during a variety of weather types. Performance trends are collected, improvements are identified, discussed, and implemented, and post implementation energy use is monitored by the meters during a period of representative weather.

[20] Incorporating students as part of this team is recommended and discussed as part of the Experiential Learning initiatives in section 11.2.

Energy savings are measured at the building meter, with weather adjustments. The campus monitors energy use trends into the future. This is the type of project which CSU San Marcos has been implementing at Kellogg Library. With the launch of future statewide SDG&E-sponsored programs, metering infrastructure will be valuable for claiming energy-efficiency project savings through NMEC (Normalized Metered Energy Consumption).

19.1.1 Building Commissioning: Energy Savings and Costs

In the LBNL example, where the team undertook a comprehensive OCx process, they were focused on about 2 million square feet of facilities that were complex, laboratories and data centers. Through their efforts, they have reduced energy use in buildings by an average of 16% and found significant water savings as well. Monetary savings totaled about $800,000 per year, which is substantial, considering the lab buys electricity at a low rate, paying $0.06 per kWh. At USD electric rates, this savings might represent $1,200,000 per year.

LBNL's cost for the six FTE staff to support OCx was estimated at $125,000 per person per year, or $750,000 per year. Given these economics, the program has essentially broken even throughout its tenure, even at the low electric rates. At USD rates, there would have been a significant net savings from implementing such a program.

Texas A&M's Continued Commissioning program has been in practice for 15 years, giving another source of data on the benefits of OCx. They have invested $10 million in the commissioning effort and $8 million in capital improvements. A total savings of $60 million has been observed in those 15 years.

Given the positive results of both the LBNL and Texas A&M examples, it is recommended that USD dedicate a team to achieving energy savings through Ongoing Commissioning. The recommended approach is for USD to start the OCx effort with as large a team as possible and to rigorously document energy savings from high savings projects (e.g. Shiley Science Center) to justify the cost effectiveness of the team. This approach maximizes the potential that the energy savings from OCx exceed the cost of the team in the future years, and the team can be continued and expanded as savings warrants.

The initial OCx effort at USD is projected to cost $250,000 per year (based on two FTE employees) and to deliver new project savings of 1,000,000 kWh per year. This represents about 4% savings of the historical electricity use. The second year savings would be $180,000; the third year savings would be $360,000 based on projects done in the first and second year; and so on. For the purposes of this report it is assumed that the effort will cost $250,000 each year for 5 years of OCx. It is assumed that each year of OCx will produce new savings of 1,000,000 kWh every year and that each year's savings last for 3 years. Each year's effort would cost $250,000 and is projected to save $540,000 over the following 3 years, showing a worthwhile investment on the part of USD. The process will be evaluated every year to verify its value.

Table 31 - Summary of OCx Cost and Savings

		2023	2024	2025	2026	2027	2028	2029	2030
Annual Electric Savings (kWh)	OCx Year 1	-	1,000,000	1,000,000	1,000,000	-	-	-	-
	OCx Year 2	-	-	1,000,000	1,000,000	1,000,000	-	-	-
	OCx Year 3	-	-	-	1,000,000	1,000,000	1,000,000	-	-

	OCx Year 4	-	-	-	-	1,000,000	1,000,000	1,000,000	-
	OCx Year 5	-	-	-	-	-	1,000,000	1,000,000	1,000,000
Total electricity saving (kWh)		-	1,000,000	2,000,000	3,000,000	3,000,000	3,000,000	2,000,000	1,000,000
Cost ($)		$250,000	$250,000	$250,000	$250,000	$250,000	-	-	-

19.1.2 Building Commissioning: Experiential Learning

As part of the Experiential Learning Section in this EMP, there are two short-term initiatives that offer opportunities for synergies between experiential learning and commissioning. Through the involvement of students in campus building optimization practices, USD can inspire students to understand and learn about mechanical systems and controls, while ensuring a larger support system to maintain optimal operating practices.

1. **Including Students as part of the OCx Team:** There is a need to capture and assess the HVAC inventory on campus. With a work study program or independent student project, students would have the opportunity to experience field work, using USD as the work site (or Campus Lab). This project would serve as a baseline inventory of all HVAC equipment on campus and influence the replacement schedule for needed upgrades.
2. **BMS Conservation & Commissioning Corps:** As part of finalizing the Building Management System over to Desigo, there will be needed support in understanding how to operate and manage the software and energy data. A team of students could be trained on how the Desigo software works, how to interpret discrepancies and be incorporated into a process for handling needed adjustments. The training could be offered on an annual basis, ensuring the longevity and sustainability of the OCx program.

20. Experiential Learning Opportunities

USD values encouraging students in utilizing the campus as a laboratory; to learn inside and outside the classroom. Through the integrated courses and projects that make up the Campus as a Living Lab initiative, students use an interdisciplinary approach to learning about sustainability, energy and environmental challenges and solutions. The Office of Sustainability has a history of facilitating internships with students as part of their required Capstone Project for graduation. A notable research project that utilized the existing *Palomar Energy Project*[21], showed that male residents used more energy than female residents over the course of the 2019-2020 school year. The presence of an energy information feedback system has the potential for additional behavioral research studies, with energy data readily available to students and faculty. The campus is also launching an *Environmental Integration Lab*, bringing faculty and experts on real estate sustainability, sustainable supply chain, green design, climate justice and environmental science to address issues of climate change and sustainability. In line with the existing collaboration amongst faculty and aimed at providing opportunities for USD students, our team held various meetings to discuss possible learning, research, and internship initiatives to include in the EMP.

Over the course of the fall semester, Willdan met with faculty from the Environmental & Ocean Sciences, Chemistry, Communications Studies and Behavioral Sciences departments. These meetings served to learn from faculty about previous research and project experiences that engaged students with experiential learning opportunities and set the foundation for new potential initiatives. Some highlights from these exchanges were:

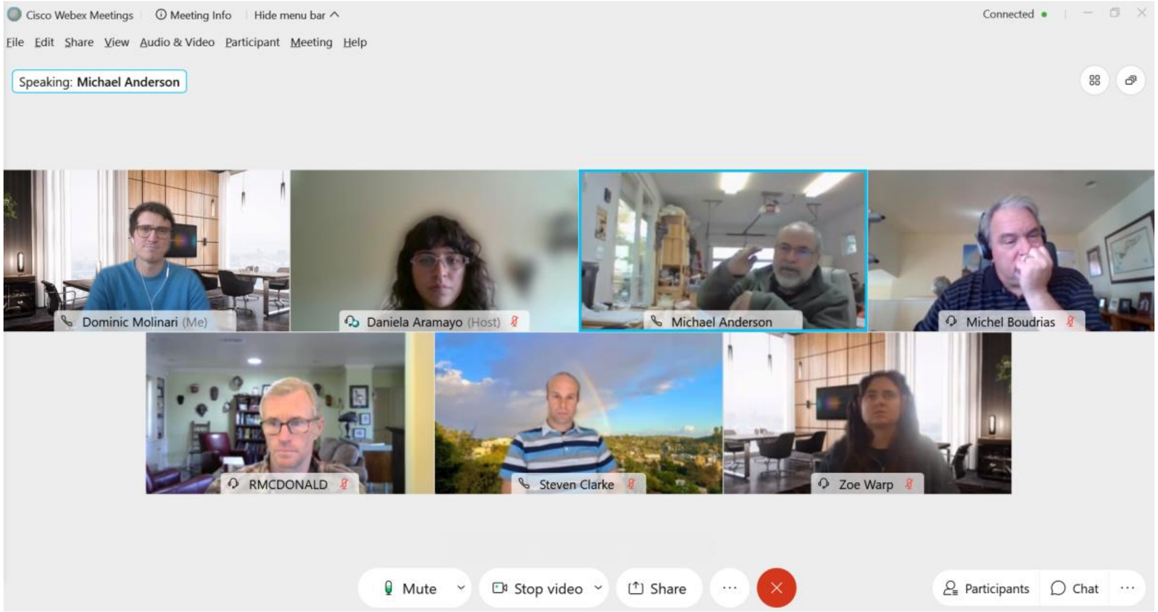
- Set up a framework for formalizing student involvement in facility operations.

[21] Palomar Energy Project: https://www.sandiego.edu/sustainability/initiatives/energy/projects-and-programs.php

- The desire to bring students of non-science majors into working on solutions and research on energy use challenges.
- Incorporate concepts into curricula via "Science in the Public Domain" course, bringing curricula to local community.
- USD needs to leverage student organizations and facilitate connection between groups, identifying redundancies and establishing synergies.
- Provide incentives for faculty to participate in organizing student groups; part of USDs "Urgent Challenges" program.
- Student opportunities could take the shape of an independent study, internship, or work study program with incentives in the form of course credit and/or stipends.

Through these conversations and leveraging Willdan's experience working in higher education we delineated short-term, medium-term, and long-term initiatives for USD to pursue.

Figure 20 - Experiential Learning Meeting held 11.3.20



21. USD Experiential Learning Initiatives, Internship & Timeline

Task	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
SHORT-TERM INITIATIVES												
Engineering / Technical Intern or Work Study Program												
▪ HVAC inventory updates; Point of Contact (POC): David Smith, Business Technology Applications Manager ▪ Students would match serial numbers, decoding model numbers to tonnage – on-site equipment verification, clean up equipment inventory and identify equipment in need of replacement (oldest). ▪ This effort would be an initial step in data gathering for the Ongoing Commissioning Team; engaging students at this stage offers work experience in field work, working alongside HVAC specialists and can lead to a work study program.	3 months											
▪ BMS Conservation & Commissioning Corps/Work Study Program; retro-commissioning work; POC: Bill Mcleod, HVAC Automation Controls Specialist ▪ SIEMENS installed a learning lab on campus, focused on training staff; could be used to train students on controls monitoring and maintenance ▪ Staff would determine job description and tasks ▪ This training could be completed once the Desigo software has been fully integrated with the support of a Siemens representative. ▪ Students would learn to pull trend data, graph it, look for potential efficiency opportunities with guidance from Facilities Management; through the Desigo platform.	3 months											

Task	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
▪ Autoclave study; POC: Keith Macdonald, Biology Lecturer and Shiley Center Building Manager												
▪ Financial assessment of replacing current, older models with new, more efficient versions ▪ Timing of operations – feasibility of limiting time periods when autoclaves may be run. Peak demand for USD is 4 pm – 9 pm.	3 months											
MEDIUM-TERM INITIATIVES												
Social Science & Communications Student Independent Project:												
▪ Shiley Center and Kroc Institute for Peace & Justice (KIPJ) - Behavioral Study & Campaign												
▪ The scope of this project would span two semesters; with the first being dedicated to establishing a plan of action for a research phase, survey phase and implementation phase. This would be developed through the collaboration of faculty. ▪ Students would interview faculty and staff to understand building constraints and usage patterns. ▪ Students would research best practices around messaging strategies in behavior change marketing. ▪ Students would analyze building patterns and compare behavior and utility usage; would also be able to work with BMS data analysis ▪ Students would perform on-the-ground investigations at the building at different times – peak use, off hours and analyze/visualize individual schedules. ▪ Based on surveys, students would work with the Building Manager to identify opportunity for changes and develop action items to reduce energy consumption.	3-6 months											

Task	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
Business Student Intern / Econ Student Intern: ▪ Students would create or use a utility rate calculator program to understand how utilities are billed – different components of billing and time of use savings. ▪ Comparison of fuel cell vs. grid analysis – Student would analyze economic vs GHG benefits	3-6 months											
Policy & Law Student Intern ▪ Energy Policy Initiatives Center (EPIC) – Collaborate with a student/department to understand GHG methodology and previous analysis; POC: Scott Anders	3-6 months											
Communications Student Intern/Team ▪ Student could help present the energy master planning work ▪ Market the results, how to present for faculty, staff, community	3-6 months											
LONGER-TERM INITIATIVES												
GIS Student Intern ▪ Student models university in GIS and creates dashboard for campus submeters ▪ Data-driven accompaniment to the virtual campus map available via USD website ▪ Story map or infographic about campus energy sources – grid, fuel cell, solar, batteries, energy consumption in real time ▪ Creation of dashboards of student housing to facilitate a dorm energy battle ▪ UCSD example: https://sustain.ucsd.edu/units/utilities-sustainability/dashboards.html	6-12 months											

Task	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
U.S. Department of Energy Solar Decathlon Participation[20] ▪ A team of faculty and students would work over the course of a year (fall-spring) to compete in the Design Challenge. ▪ This is an opportunity for both students and faculty to learn the skills needed for entering the clean energy workforce. ▪ This project team would work with industry partners to provide guidance and allow for real world experience with the ability to integrate building science, energy efficiency and renewable energy solutions.	6-12 months											
Community Microgrid ▪ Students would develop a project that involves surveying the local community ▫ Develop SDG&E and CCA partnership with USD ▪ Establish USD's role as a community influencer ▫ Revamp past neighborhood ambassador role • Can claim carbon offsets for influencing community actions ▫ Outreach locations: Kearny High School (Bill Gates academy), Montgomery Elementary ▫ Leverage connections with city with their sustainability plan (councilwoman) ▪ Develop climate change mitigation plan with Diocese ▪ Potential microgrid partner in Diocese	6-12 months											

[20] The Solar Decathlon is a collegiate competition that challenges student teams to design and build highly efficient and innovative buildings powered by renewable energy, https://www.solardecathlon.gov/

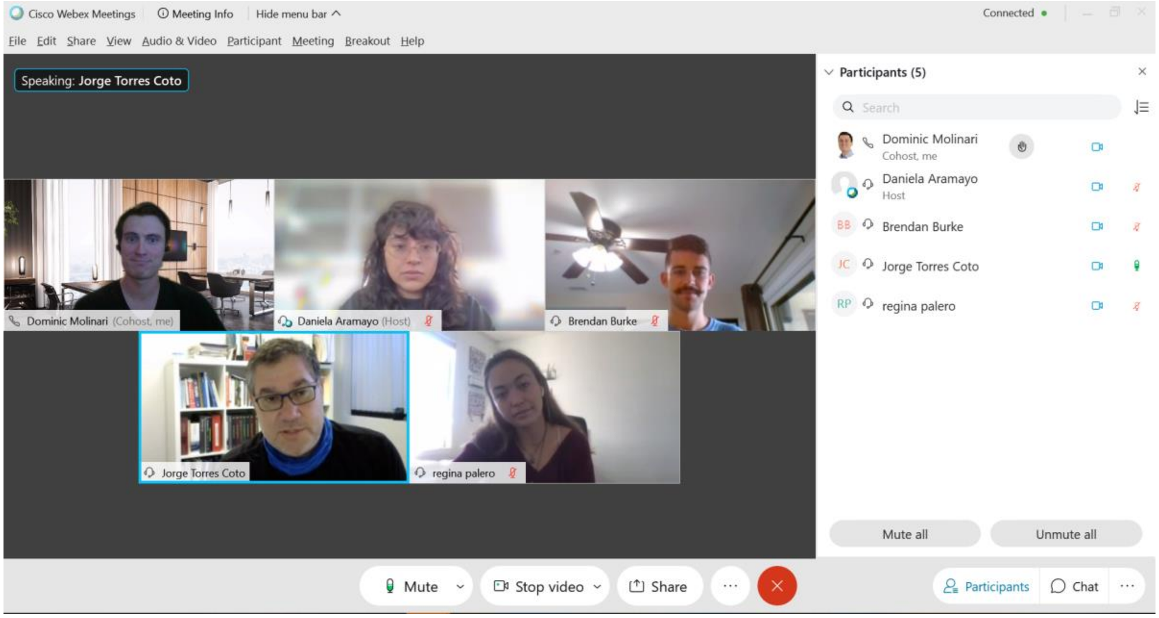
21.1.1 USD Internships

The Office of Sustainability and Willdan partnered with the engineering firms (MAE & MWE) to oversee two internship opportunities focused on an analysis of kitchen electrification and lighting energy efficiency, respectively. The scope of work included conducting background research, field work, data gathering and organizing, analysis of conversion to electric, calculations and a final presentation. These findings were included in this report.

The students had weekly check-in meetings with the engineering firms and were introduced to energy conservation and efficiency measure analysis. The energy savings calculations are incorporated in the EMP baseline energy analysis and recommendations.

This internship highlights how USD can leverage local industry partners and engineering companies to provide critical skills for a career in clean energy work.

Figure 21 - Internship Meeting held 10.21.20



APPENDICES

Appendix A – Key Stakeholders

Name	Title	Role
Trey McDonald	Director of Sustainability	Lead point of contact; Participated in kick-off meeting; Deferred Maintenance meetings
Andre Hutchinson	Asst. VP Facilities Management	Participated in kick-off meeting; Deferred Maintenance meetings
Robert Brauer	Director of Building & Grounds Operations	Participated in kick-off meeting
Bill McLeod	HVAC Automation Controls Specialist	Participated in kick-off meeting
Terri Miller	Superintendent of Electricians and HVAC	Participated in kick-off meeting
Jeff Hardick	Electrician	Participated in kick-off meeting
Steven Glover	Plant Operations & Maintenance Engineer	Participated in kick-off meeting
Michel Boudrias	Associate Professor, Environmental and Ocean Sciences	Lead in Experiential Learning; Participated in kick-off meeting
Theresa Harris	Director of Procurement	Participated in kick-off meeting
Ky Snyder	Vice President, University Operations	Participated in kick-off meeting
Lynne Morris	Director of Budget and Administration	Participated in Deferred Maintenance meetings

Appendix B – Solar Performance Analysis

Data Collection from the PV Systems

USD Solar Meter Datalogging																				
Start date:	7/1/2018		17 Meter Total		1,593,448	kWh/yr														
End date:	6/30/2019				1,170	kW avg														
																		System Total kWh		
Total kWh ac/y	20,183	106,996	20,430	87,777	111,271	167,371	110,318	107,785	87,642	150,495	168,243	170,230	19,752	19,952	87,325	93,169	64,509	1,593,448		Ratio
																		-		2.1581
Combined kWh ac/y	80,318	445,469		87,777	278,642		218,103		87,642	150,495					180,493		64,509	1,593,448		
kW dc	57.96	296.24		58.48	209.30		192.64		58.48	110.08					125.88		61.18	1,170	Good kWh	Total kWh
kWh ac / kW dc	1,386	1,504		1,501	1,331		1,132		1,499	1,367					1,434		1,054	1,362	738,373	1,593,448
	Not Collected Cleanly	Not Collected Cleanly	Not Collected Cleanly				Not Collected Cleanly	Not Collected Cleanly		Not Collected Cleanly	Not Collected Cleanly	Not Collected Cleanly								
Timestamp	**Alcala Borrego Meter 1 (Vista B) (Received)**	**Camino Hall Meter (Received)**	**Alcala Borrego Meter 2 (Vista B) (Received)**	**Manchester A Meter (Received)**	**Jenny Craig Pavillion Meter 1 (Received)**	**Jenny Craig Pavillion Meter 2 (Received)**	**West Hills Parking Meter 1 (Received)**	**West Hills Parking Meter 2 (Received)**	**Manchester B Meter (Received)**	**Kroc Meter (Received)**	**Founders Meter 1 (Received)**	**Founders Meter 2 (Received)**	**Alcala Laguna Meter 1 (Vista A) (Received)**	**Alcala Laguna Meter 2 (Vista A) (Received)**	**Soles Meter 1 (Received)**	**Soles Meter 2 (Received)**	**Copley Library Meter (Received)**		**Sum of Good Meters Profile**	**Total Meters Projected Profile**
Count	**4338**	**34207**	**3807**	**34957**	**34902**	**34918**	**33330**	**33323**	**34947**	**32058**	**31916**	**31825**	**34992**	**35009**	**34989**	**34993**	**34996**			
Percent	**12.38%**	**97.62%**	**10.86%**	**99.76%**	**99.61%**	**99.65%**	**95.12%**	**95.10%**	**99.73%**	**91.49%**	**91.08%**	**90.82%**	**99.86%**	**99.91%**	**99.85%**	**99.87%**	**99.87%**			
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh		kWh	kW
7/1/2018 0:00:00				0	0	0			0.1	0	0	0	0.1	0	0.1	0	0		0.3	3
7/1/2018 0:15:00				0	0	0			0	0	0	1	0	0	0	0	0		0	-
7/1/2018 0:30:00				0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 0:45:00			0	0	0	0			0	0	0	0	0	0.1	0	0	0		0.1	1
7/1/2018 1:00:00				0	0	0			0.1	0	0	0	0	0	0	0	0		0.1	1
7/1/2018 1:15:00	0			0	0	0			0	0	0	0	0	0	0	0.2	0		0.2	2
7/1/2018 1:30:00			0	0	0	1			0	0	0	0	0	0	0	0	0		1	9
7/1/2018 1:45:00				0	0	0			0	0	0	0	0	0	0.1	0	0		0.1	1
7/1/2018 2:00:00				0.1	0	0			0	1	0	0	0	0	0	0	0		0.1	1
7/1/2018 2:15:00				0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 2:30:00	0		0	0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 2:45:00				0	0	0			0.1	0	0	0	0	0	0	0	0		0.1	1
7/1/2018 3:00:00				0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 3:15:00				0	0	0			0	0	0	0	0	0	0.1	0	0		0.1	1
7/1/2018 3:30:00	0.1			0.1	0	0			0	0	0	0	0	0	0	0	0		0.1	1
7/1/2018 3:45:00				0	0	0			0.1	0	0	0	0	0	0	0	0		0.1	1
7/1/2018 4:00:00			0	0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 4:15:00				0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 4:30:00				0	0	0			0	0	0	0	0	0	0	0.1	0		0.1	1
7/1/2018 4:45:00				0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 5:00:00				0.1	0	0			0	0	0	0	0	0	0	0	0		0.1	1
7/1/2018 5:15:00				0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 5:30:00			0	0	0	0			0	0	0	0	0.1	0	0	0	0		0.1	1
7/1/2018 5:45:00				0	0	0			0	0	0	0	0	0.1	0	0	0		0.1	1
7/1/2018 6:00:00				0	0	0			0	0	0	0	0	0	0	0	0		0	-
7/1/2018 6:15:00	0			0	0	0			0	0	0	0	0	0	0	0.1	0		0.1	1
7/1/2018 6:30:00			0.1	0.1	0	0			0.1	0	0	0	0	0	0	0	0		0.2	2
7/1/2018 6:45:00				0.1	0	1			0.1	0	0	0	0	0	0	0.1	0		1.3	11
7/1/2018 7:00:00				0.1	1	0			0.2	0	1	1	0	0	0.4	0.4	0.4		2.5	22
7/1/2018 7:15:00				0.4	1	1		0	0.5	1	1	1	0	0	0.7	0.6	0.6		4.8	41
7/1/2018 7:30:00	0.2		0.1	0.7	1	2		0.9	0.6	2	2	1	0.2	0.1	0.9	0.9	0.8		7.2	62
7/1/2018 7:45:00	0			0.8	2	2		1.4	0.8	2	2	2	0.2	0.2	1.1	1	1.1		9.2	79
7/1/2018 8:00:00				1.2	3	3		1.7	1.2	2	3	3	0.3	0.4	1.5	1.5	1.5		13.6	117
7/1/2018 8:15:00				1.7	3	3		2.2	1.7	3	3	4	0.4	0.4	2	1.9	2		16.1	139
7/1/2018 8:30:00				2.3	5	5		2.7	2.3	4	6	5	0.6	0.6	2.6	2.6	2.6		23.6	204
7/1/2018 8:45:00				3.5	6	4		0	3.1	7	13	12	0.7	0.7	5.1	4.5	5.3		32.9	284
7/1/2018 9:00:00				3.8	8	5			3.7	15	15	16	1.4	1.6	9.7	9	8.4		50.6	437
7/1/2018 9:15:00				5.8	12	12			6.4	14	15	15	1.5	1.5	8.9	8.2	7.7		64	552
7/1/2018 9:30:00				6.6	14	13			7	14	16	16	1.7	1.7	8.6	8.1	7.8		68.5	591
7/1/2018 9:45:00				7.4	14	14			7.5	14	16	16	1.9	1.9	8.5	8	8.7		71.9	621
7/1/2018 10:00:00	9.7			8.1	15	15			8.3	14	17	17	1.9	2	9.5	8.8	8.6		77.2	666
7/1/2018 10:15:00				8.8	17	16			8.8	16	19	18	2.2	2.2	10.5	10	10.1		85.6	739
7/1/2018 10:30:00				9.1	16	17			9.2	18	19	20	2.2	2.2	11	10.4	10.6		87.7	757
7/1/2018 10:45:00				9.7	18	18			9.7	18	20	19	2.3	2.3	11.3	10.8	11.1		93.2	805
7/1/2018 11:00:00				10	19	19			10	20	20	21	2.4	2.5	11.7	11.2	11.4		97.2	839
7/1/2018 11:15:00	10.8			10.4	19	19			10.3	20	21	20	2.5	2.5	11.9	11.2	11.5		98.3	849

There are 17 electric meters that collect information about PV production on USD campus roofs. There are dataloggers that collect the performance data. These dataloggers deliver production information to the cloud-based DECK database. It appears that these meters correctly measure electricity production from the PV systems but eight of these meters often do not report on energy use during every 15-minute period. This data is apparently accumulated and delivered during a period perhaps hours later. As a result, the reported electricity production for the year appears correct but individual time periods do not have accurate information.

This figure shows the meters where the dataloggers do not collect data consistently highlighted in yellow.

The PV system was evaluated by using the average load profile from the nine electric meters that record continuously and then scaling the profile up to effectively include the electric use from the 8 meters that do not record in a timely manner. This introduces some uncertainty in the data, but it is assumed that all the PV systems (fixed, moderate tilt, roof mounted) operate in a similar manner.

It is recommended that this delay in logging data be corrected so that the PV data system gives a correct picture of the system performance.

Representative PV System Performance for San Diego – NREL's PVWatts Calculator

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at https://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

1,580 kWh/Year*

System output may range from 1,519 to 1,590 kWh per year near this location.

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Value ($)
January	4.49	108	15
February	4.58	100	13
March	6.19	144	19
April	6.43	149	20
May	6.23	149	20
June	6.59	149	20
July	6.50	150	20
August	6.93	158	21
September	6.34	139	19
October	5.49	128	17
November	4.54	104	14
December	4.14	102	14
Annual	**5.70**	**1,580**	**$ 212**

Location and Station Identification

Requested Location	san diego
Weather Data Source	Lat, Lon: 32.73, -117.18 1.4 mi
Latitude	32.73° N
Longitude	117.18° W

PV System Specifications *(Commercial)*

DC System Size	1 kW
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt	20°
Array Azimuth	180°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.2

Economics

Average Retail Electricity Rate	0.135 $/kWh

Performance Metrics

Capacity Factor	18.0%

Appendix C – SDG&E Electric Load Profile

The graphs in this Appendix illustrate the hourly load profile of electric purchases from SDG&E, as compared to purchases from the campus fuel cell and the campus PV system. The sum of these three purchases (plus the emergency generators which do not have 15 minute load data) equals the total campus electrical load. The operation of the PV system and fuel cell affect the SDG&E purchases, particularly the demand charges. This Appendix shows when Non-Coincident and On-Peak demands were established for each monthly bill in the baseline year FY19.

Electricity is billed by SDG&E for the main campus meter using the AL-TOU rate schedule, Primary Voltage. This rate schedule has high demand charge rates (April 2020 rates: $23.94 /kW Non-Coincident Demand; $18.95 /kW Summer On-Peak Demand; $19.12 /kW Winter On-Peak Demand). These demand charges represent the main portion of the SDG&E bill, as the commodity cost for this electricity is billed by Calpine. Summer includes June through October and On-Peak lasts from 4 pm to 9 pm every day.

This Appendix illustrates how the demands are established and the influence that the operation of the fuel cell has on the monthly demand billing. The load profile is shown for every day when a peak demand is established for the month, and other days when the fuel cell is shut down but monthly demands are not created.

Note that the billing months are off a few days from the calendar month.

July

The July electric purchases from SDG&E are shown for every day of the month in the first graph. It can be seen that the maximum Non-Coincident peak occurred the morning of July 24. The maximum On-Peak (4 to 9 pm) demand occurred on July 13.

The components of the electric purchases for July 24 are shown in the next graph, the bar graph. The three components shown are electricity purchased from SDG&E (blue), electricity purchased from the PV systems (grey), and electricity purchased from the fuel cell (orange). These are stacked bar graphs, showing the sum of these three sources, peaking just over 4,500 kW on this day.

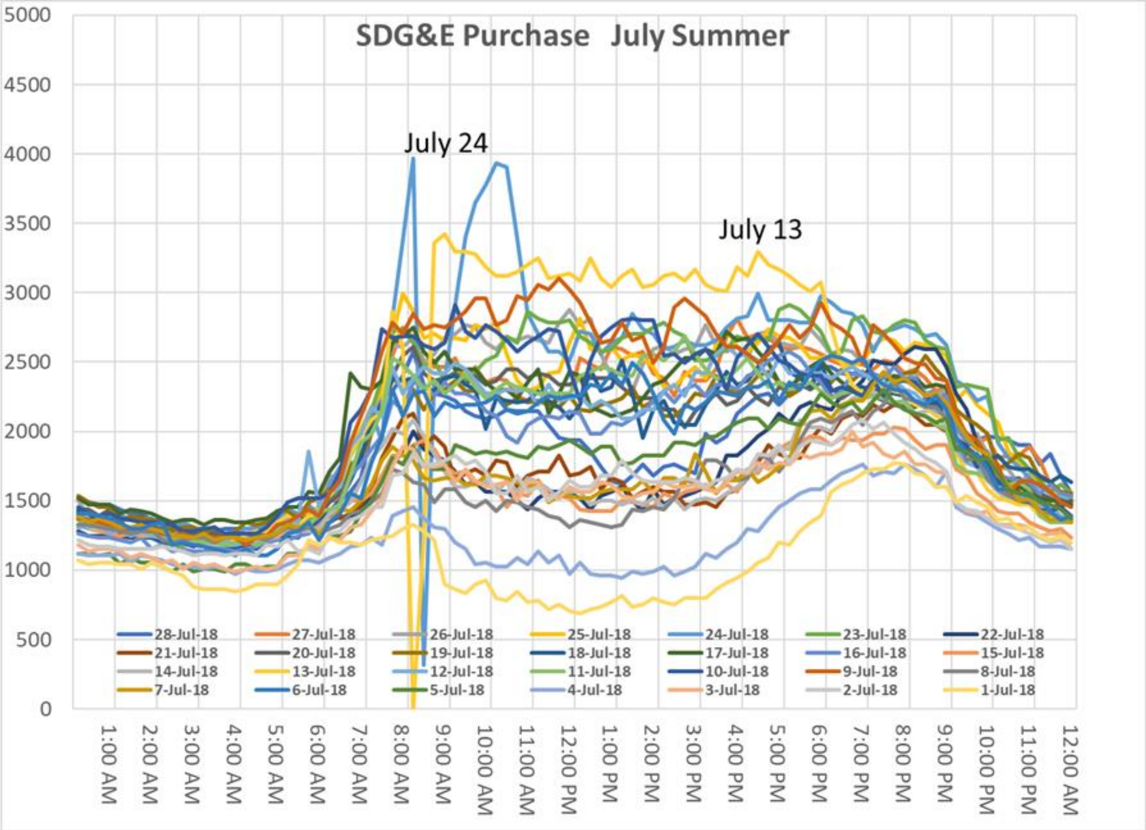
The blue bars in this graph (the SDG&E purchases) show the same data as the July 24 line the previous page. The previous graph shows the PG&E purchases for every day of the month (including July 24) while the second graph shows the SDG&E purchases just for July 24, but stacks in the purchases of fuel cell electricity and solar electricity for that day as well.

One electricity source does not appear in the second graph because the data is not available. That is the output from the emergency diesel generators. When it looks like the electric load is very low around 8:30 am, the diesel generator is actually working at this time, making up the rest of the actual electric load of the campus, about 3,500 kW.

It can be seen that around 8 to 9 am the diesel was being tested, as it often is on Friday (or other) mornings. It is usually the practice to disable the fuel cell during the diesel test for some time before and after the test. In some months, like this one, the fact that the fuel cell was not operating during the diesel test caused the maximum non-coincident peak to be established on this day. Suggestions are made elsewhere for options to allow the fuel cell to operate during diesel generator tests to help reduce monthly electric demands and their contribution to the electric bill.

The electric load purchases are shown for July 13 in the next graph, the day that the monthly On-Peak demand was established at just after 4 pm. It can be seen that the fuel cell was shut down before 8 am that day, presumably in conjunction with a diesel generator test. The fuel cell did not fire up again, however, until 6 pm. In the meantime, the On-Peak electric demand was established for that month.

In July FY19 the Non-Coincident and On-Peak demand were both established when the fuel cell was not operating.


SDG&E Purchase July Summer
July 24
July 13
28-Jul-18
27-Jul-18
26-Jul-18
25-Jul-18
24-Jul-18
23-Jul-18
22-Jul-18
21-Jul-18
20-Jul-18
19-Jul-18
18-Jul-18
17-Jul-18
16-Jul-18
15-Jul-18
14-Jul-18
13-Jul-18
12-Jul-18
11-Jul-18
10-Jul-18
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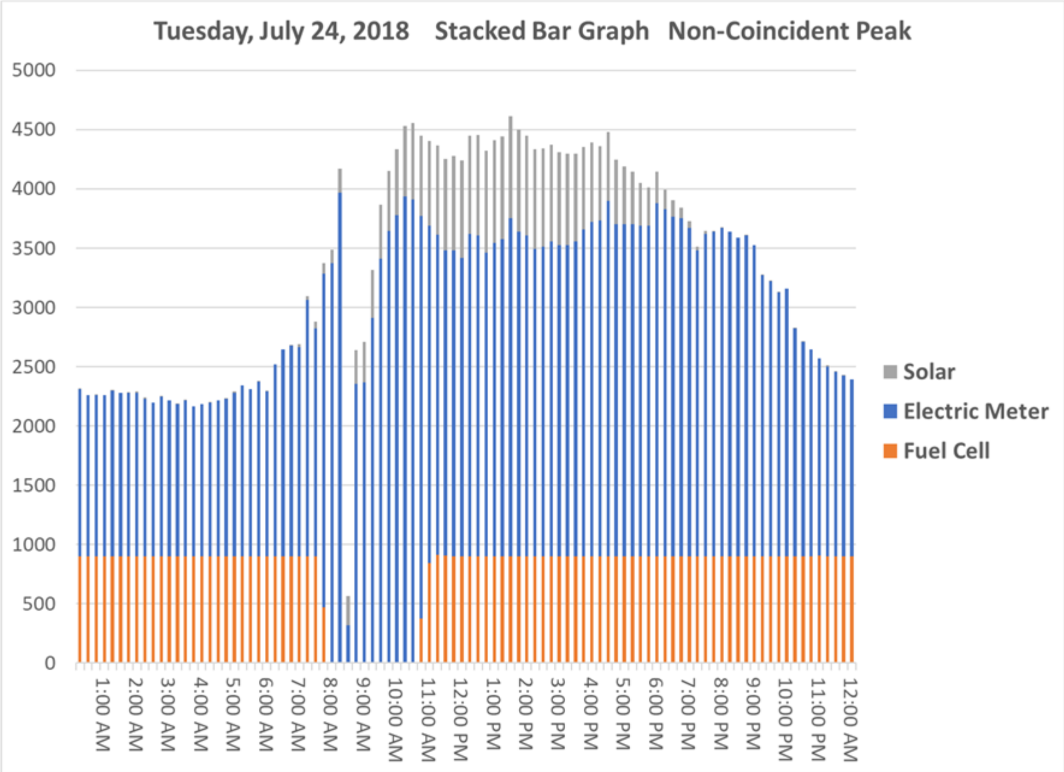
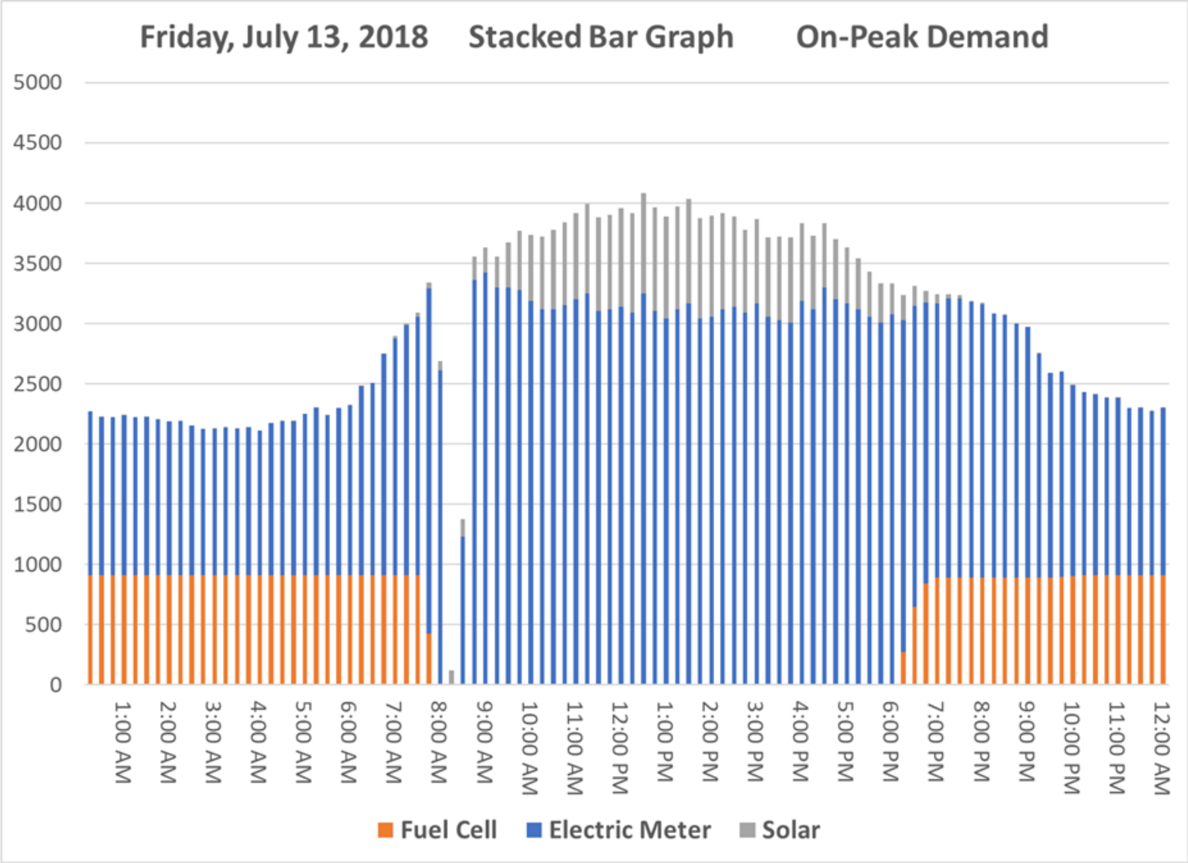
5-Jul-18
4-Jul-18
3-Jul-18
2-Jul-18
1-Jul-18

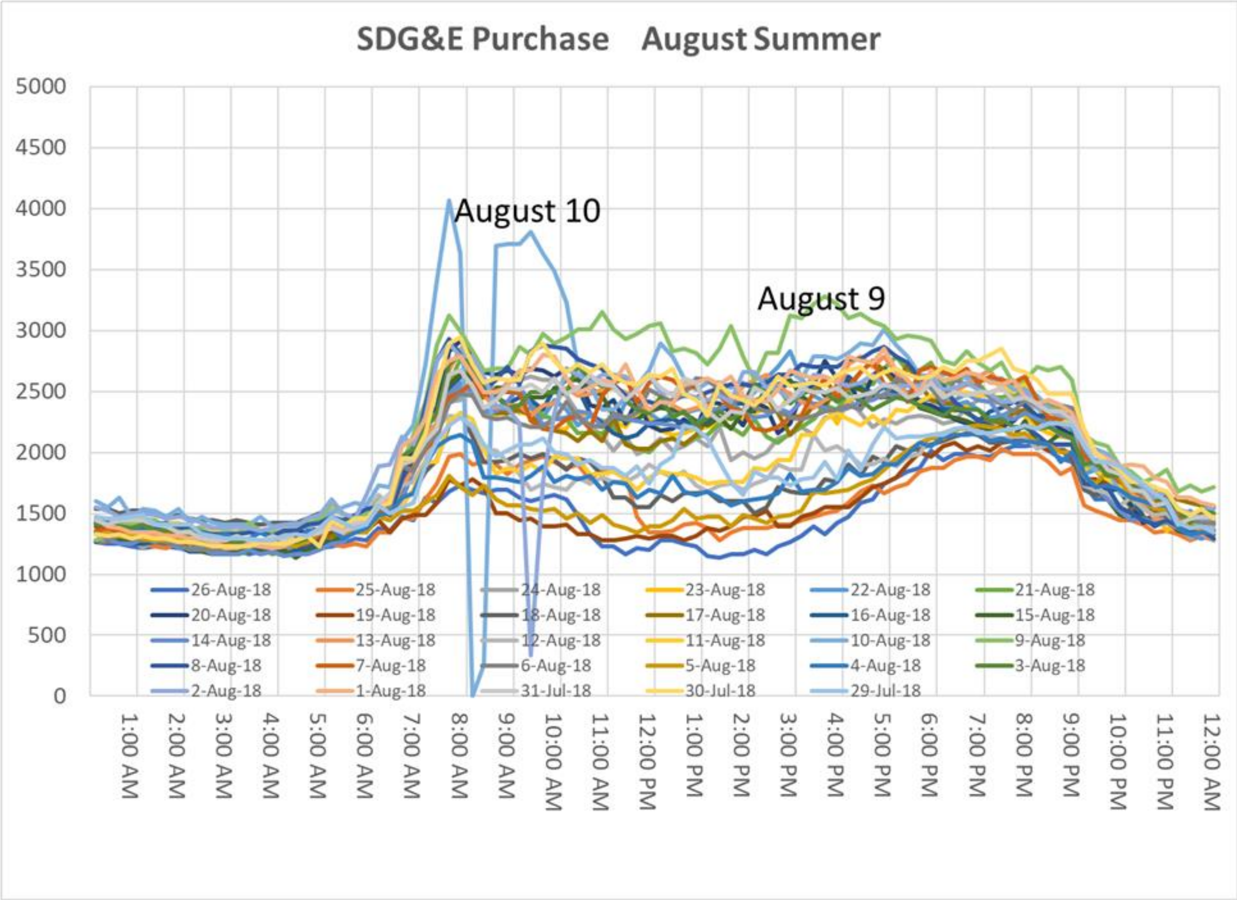

Tuesday, July 24, 2018 Stacked Bar Graph Non-Coincident Peak
Solar
Electric Meter
Fuel Cell

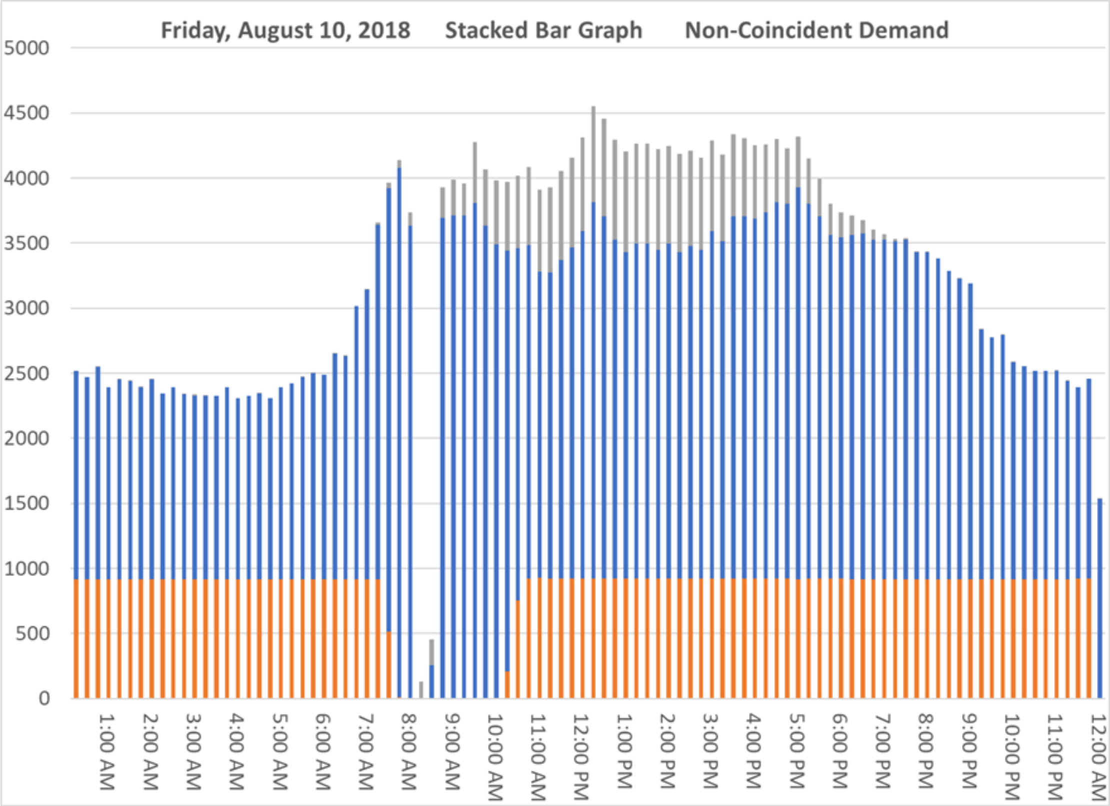


Friday, July 13, 2018 Stacked Bar Graph On-Peak Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

August

The next graph shows the SDG&E purchases for every day in the month of August FY19. The Non-Coincident demand was established on August 10 and the On-Peak demand was established on August 9. It can be seen in the next graph (August 10) that the fuel cell was not operational during the diesel engine test this Friday morning and that this contributed to the Non-Coincident demand being established for that month. On August 9 (next graph) the On-Peak demand for the month was established at while the fuel cell was operating. This month the fuel cell operations contributed to the Non-Coincident demand but did not contribute to the On-Peak demand.




Friday, August 10, 2018 Stacked Bar Graph Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
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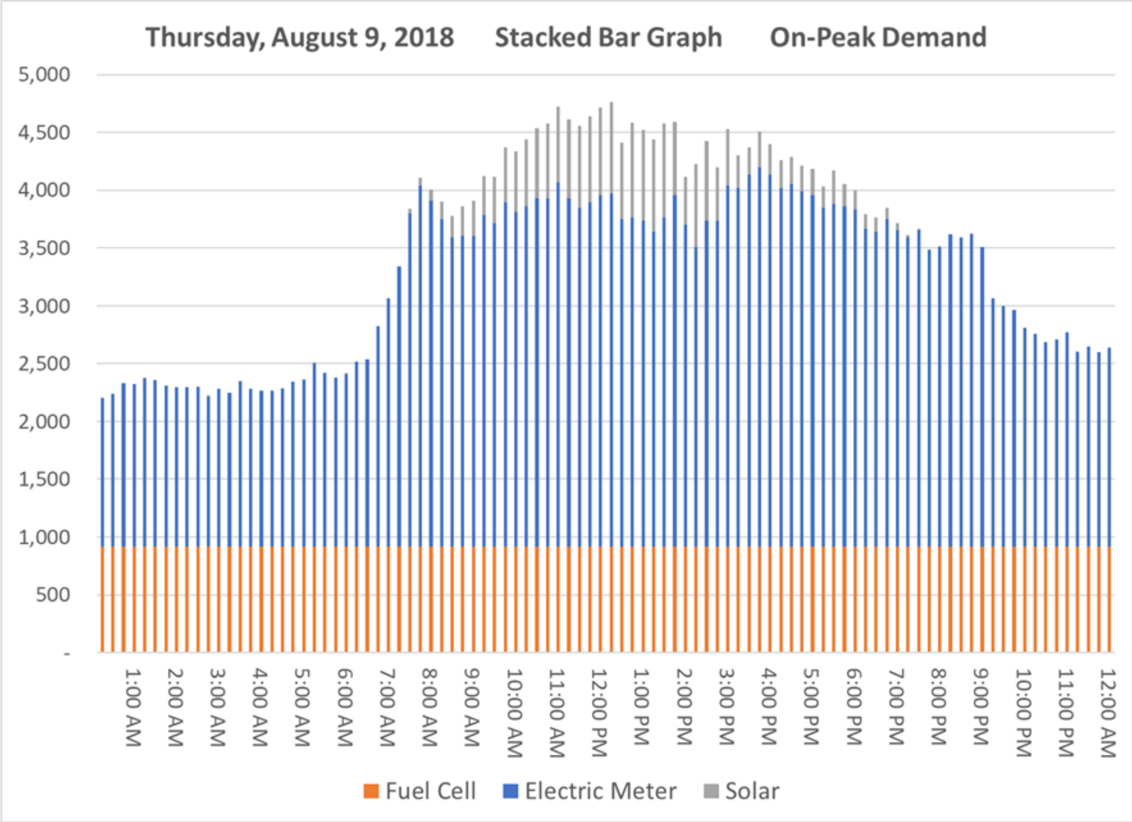
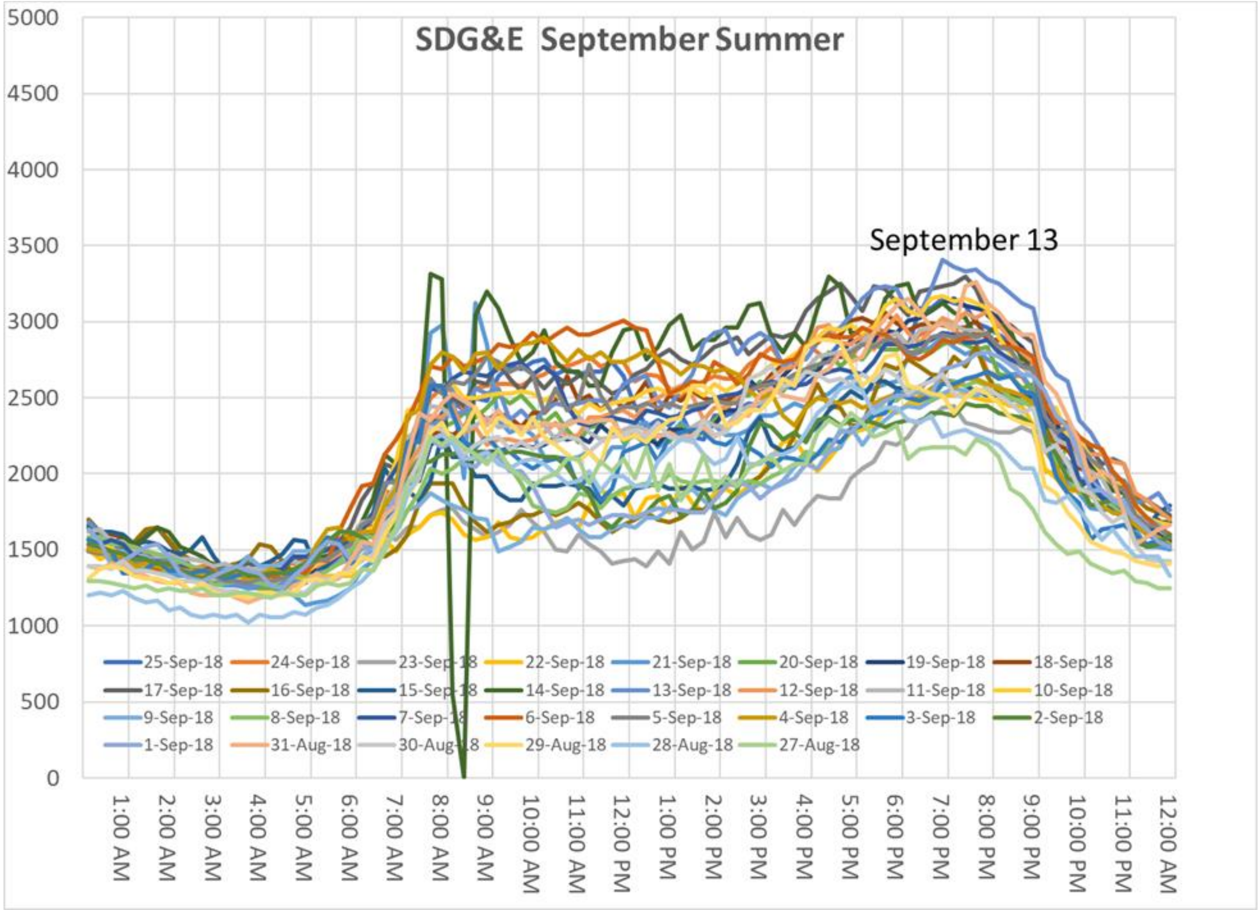
9:00 PM
10:00 PM
11:00 PM
12:00 AM

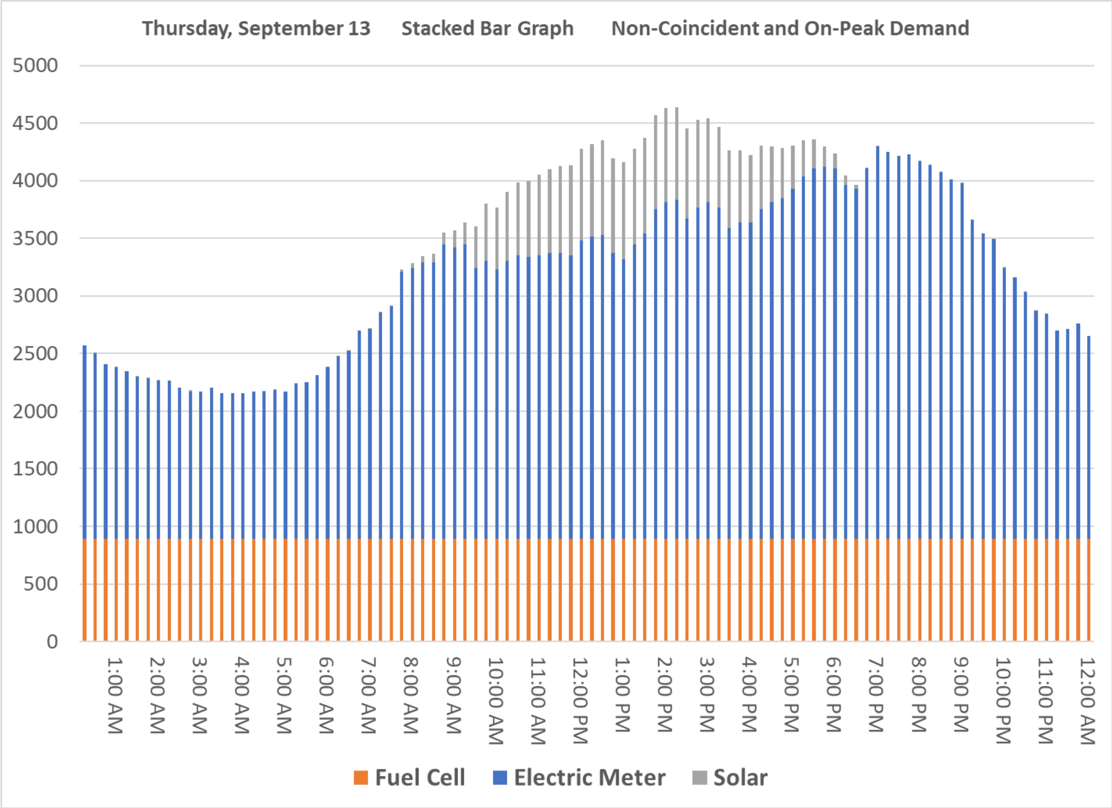

Thursday, August 9, 2018 Stacked Bar Graph On-Peak Demand
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
-
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

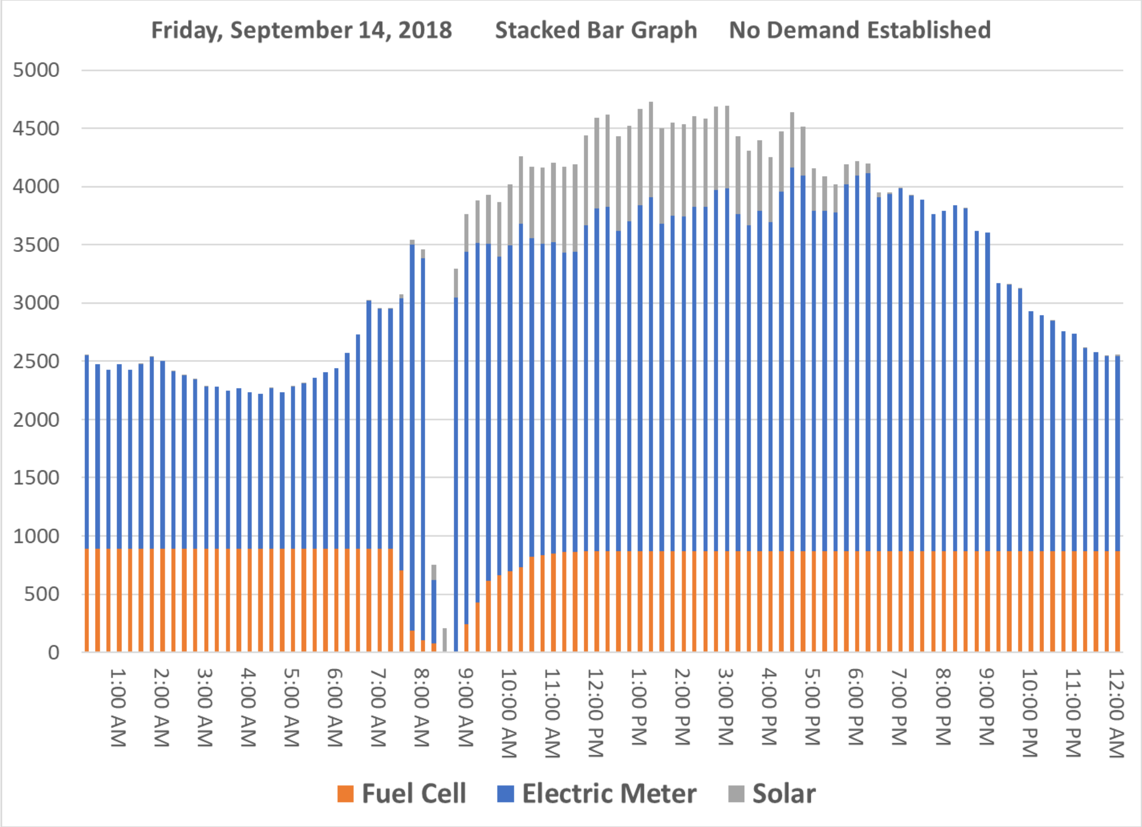
September

The next graph shows the SDG&E load profile every day in the month of September FY19. The Non-Coincident peak and the On-Peak demand for this month were both established on same day, September 13. The graph for September 13 shows that at the time the peak Non-Coincident and On-Peak demands were established for the month, the fuel cell was operating properly. Fuel cell operations did not contribute to the peak demand charges this month.

The next two graphs show the fuel cell operation was limited twice this month, apparently for two more diesel generator tests on Friday mornings, September 14 and 21. The SDG&E peak established at these times did not exceed the demand from September 13 when the fuel cells were operational all day. In this month the fuel cell shutdowns did not affect the peak billing demands.



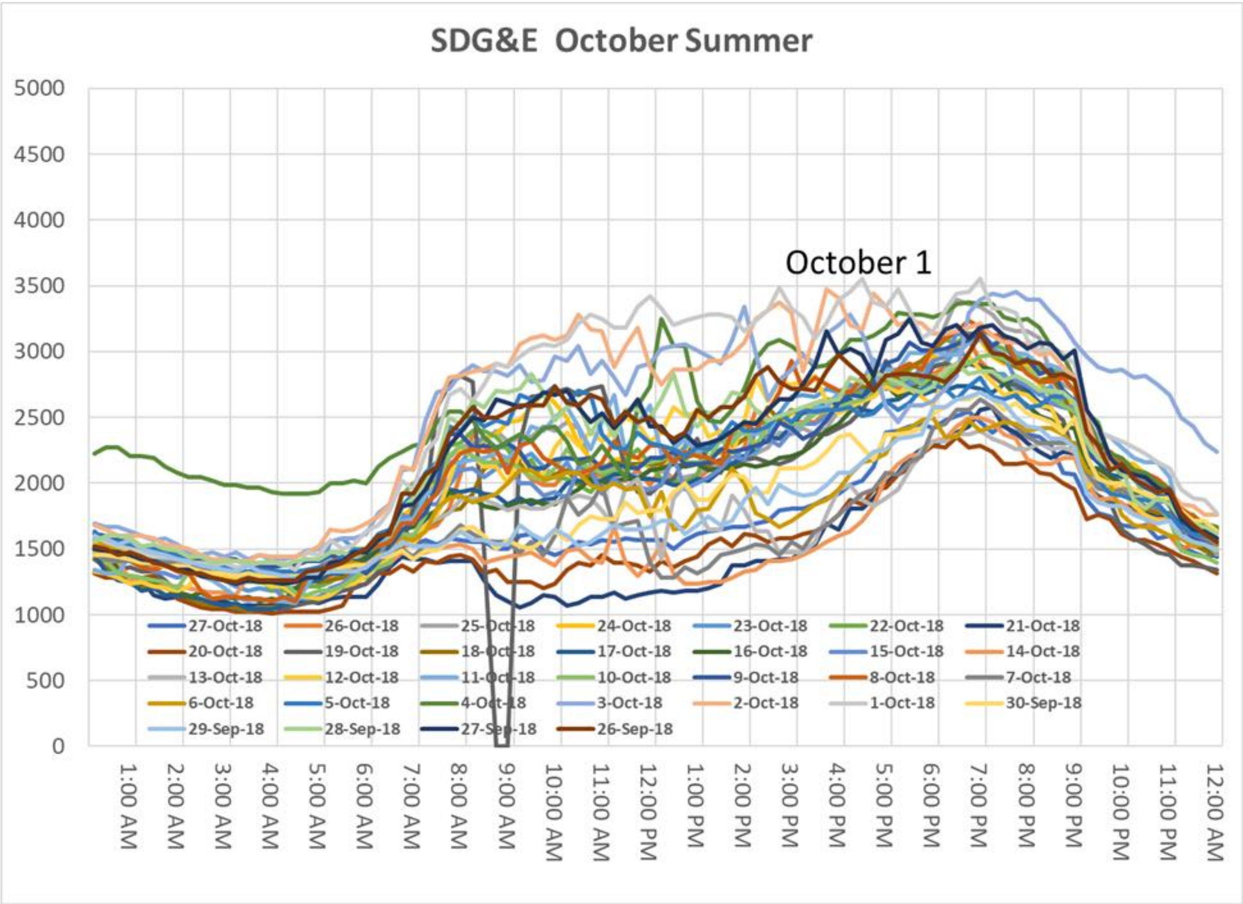

Thursday, September 13 Stacked Bar Graph Non-Coincident and On-Peak Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

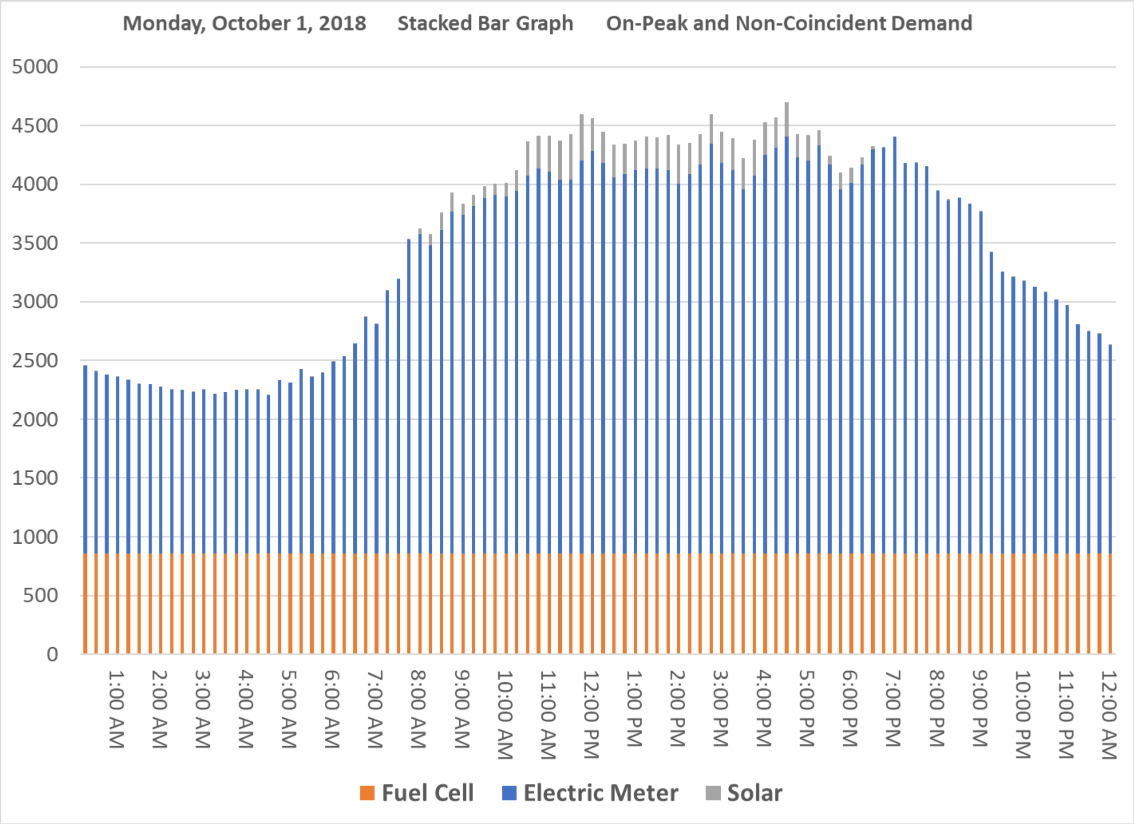

Friday, September 14, 2018 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

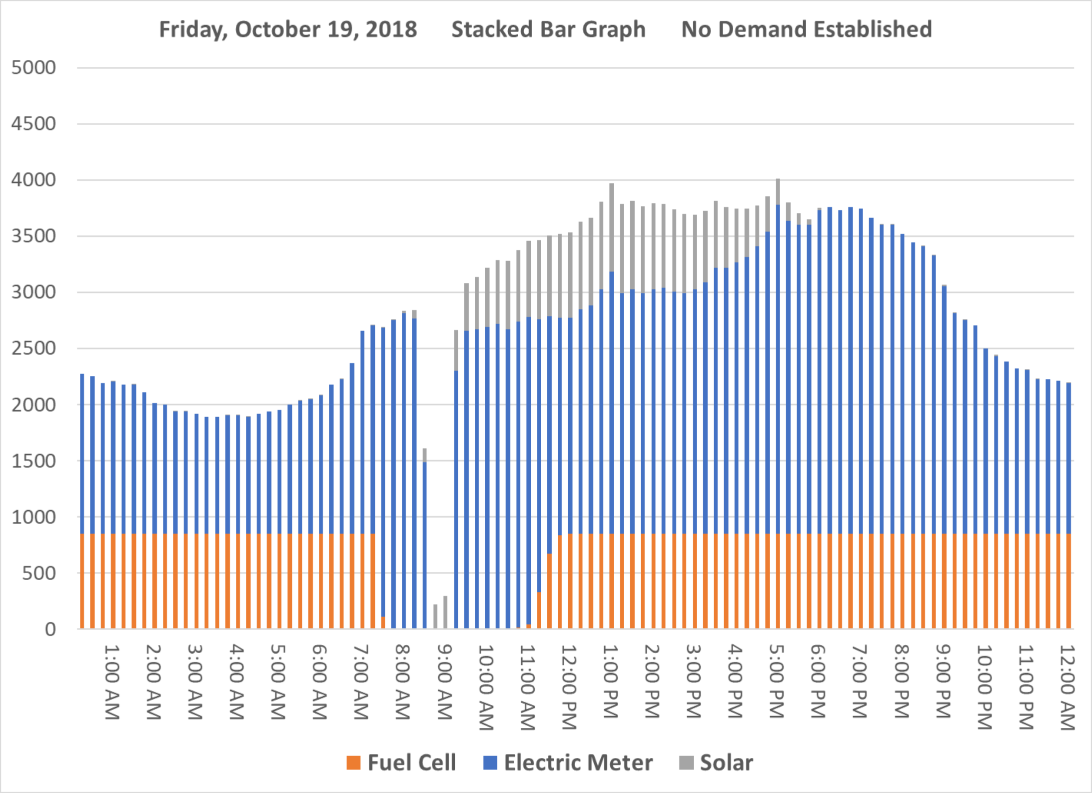
October

The October graph shows the SDG&E load profile for every day of October FY19. The Non-Coincident and On-Peak demands for this month were both established the same day, October 1. The graph for October 1 shows that at the time the peak Non-Coincident and On-Peak demands were established, the fuel cell was operating properly. Fuel cell operations did not contribute to the peak charges this month.

The next graph is for Friday, October 19. There apparently was a diesel generator test on this day and the fuel cell was down for several hours. The SDG&E peak established at these times was less than the peak established on October 1 with the fuel cell operating.




Monday, October 1, 2018 Stacked Bar Graph On-Peak and Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

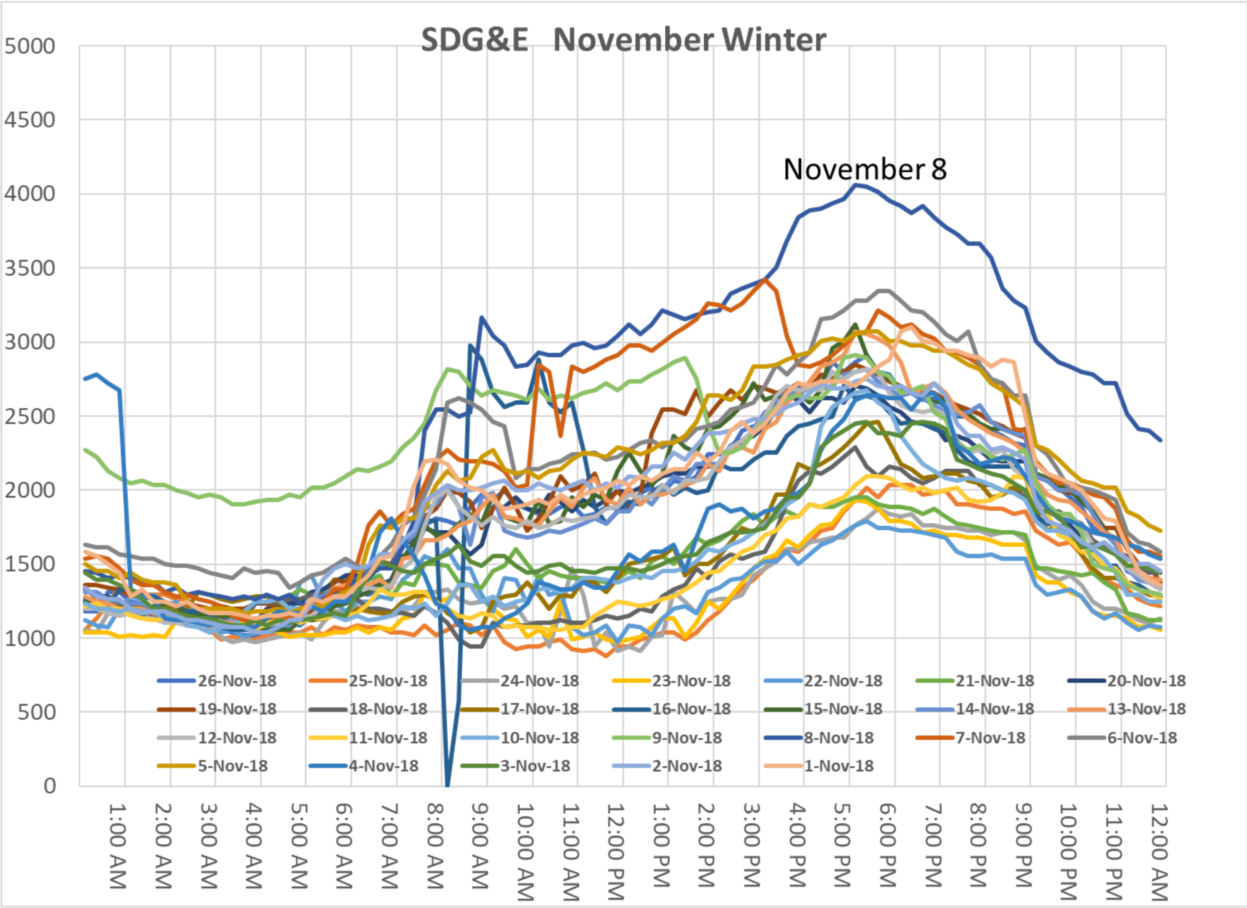

Friday, October 19, 2018 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

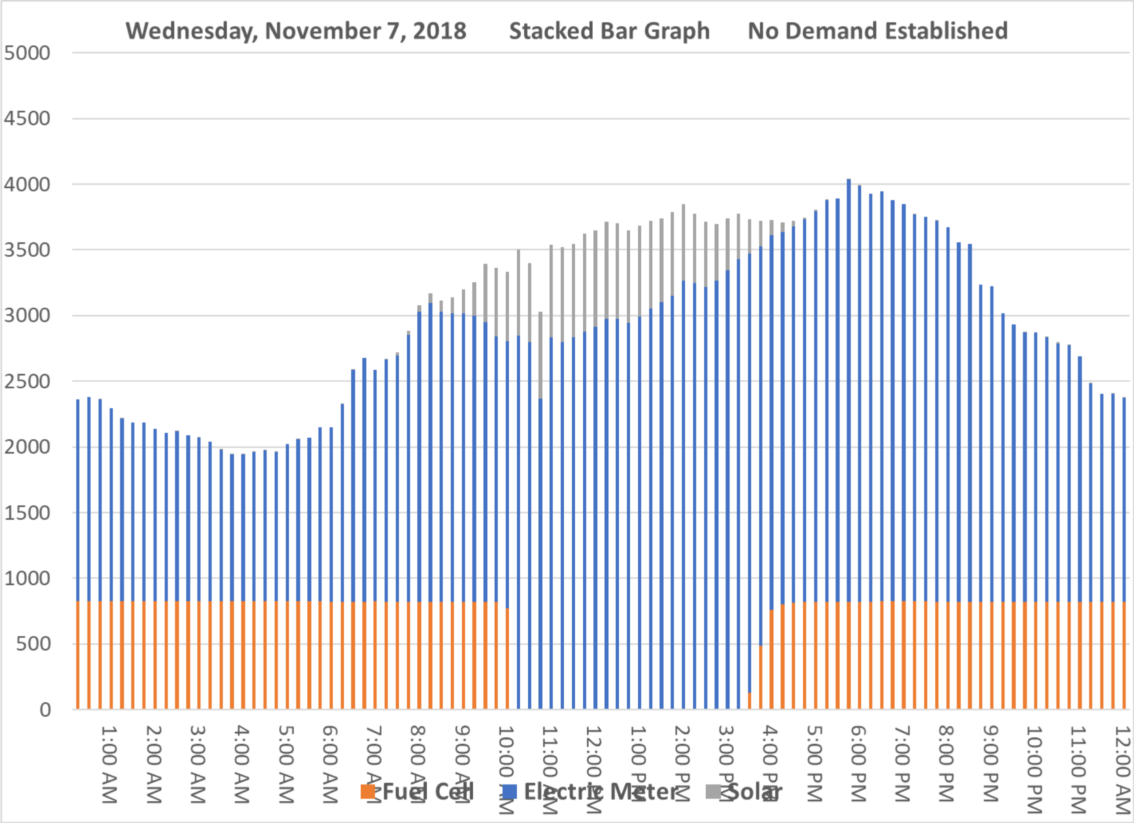
November

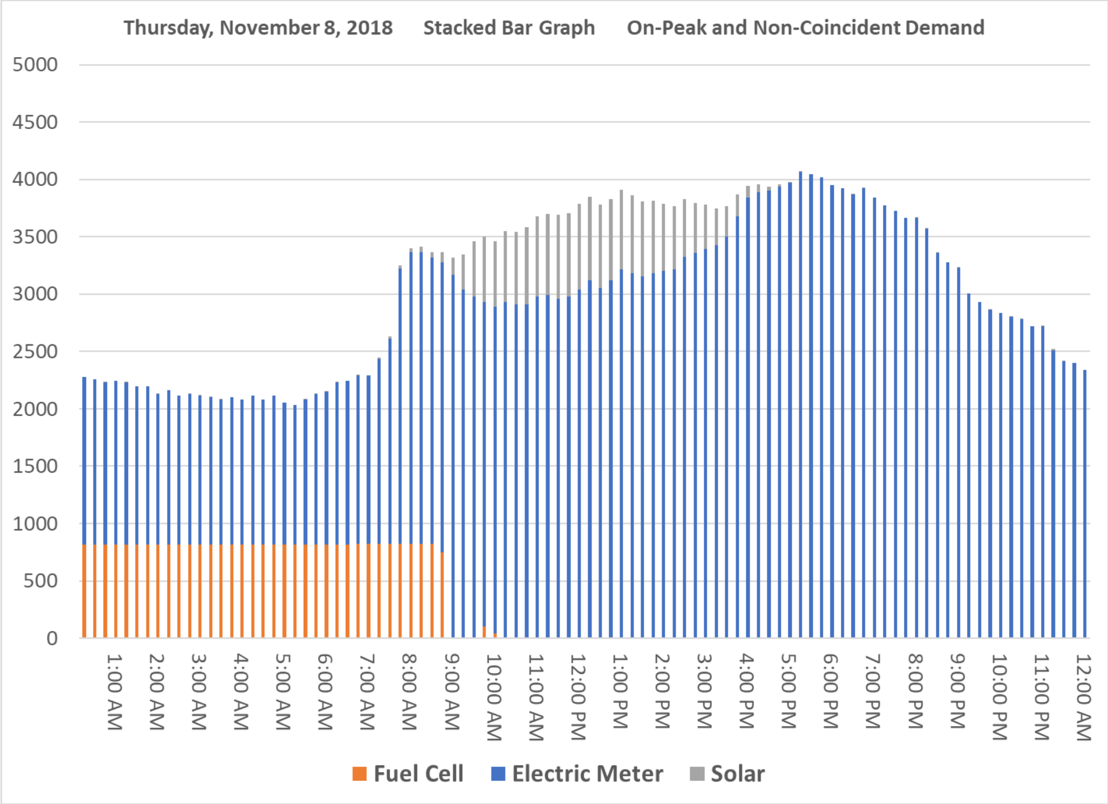
The November graph shows the SDG&E load profile for every day of November FY19. The Non-Coincident and On-Peak demands for this month were both established the same day, November 8. The graph for November 7 shows that the fuel cell was not operational for about 5 hours midday, but this did not contribute to the peak demands for the month. The graph for November 8 shows that the fuel cell was off at 9 am and remained off the rest of the day. It was during these hours that the monthly peak Non-Coincident and On-Peak demands were established at about 5 pm.

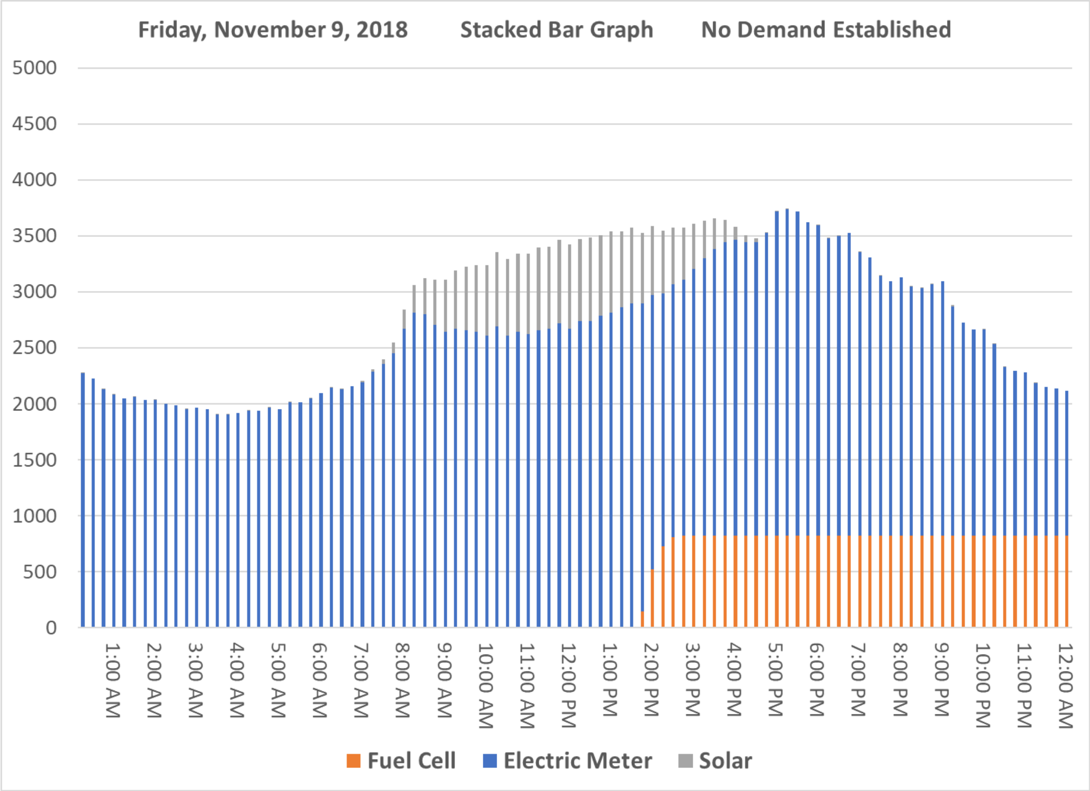
The next graph for November 9 shows that the fuel cell remained off until 2 pm the following day. This fuel cell outage does not appear to be related to diesel generator testing, but is apparently due to some other operational issues.

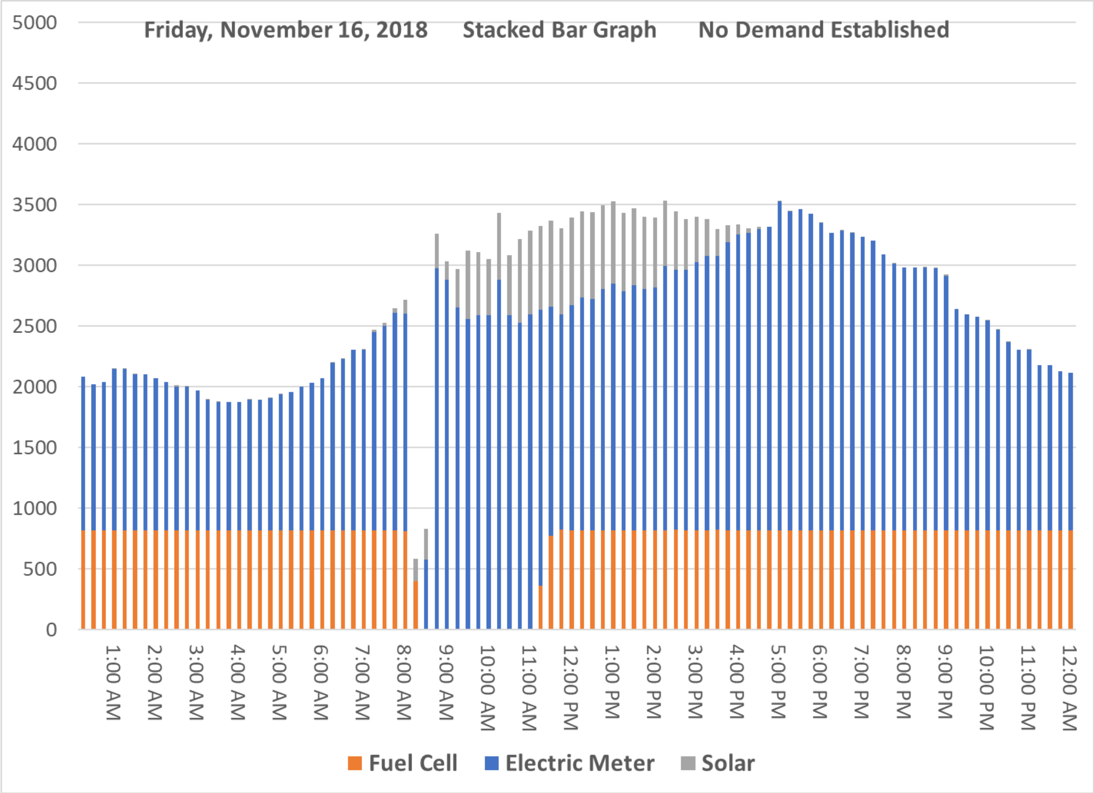
The graph for November 16 shows a Friday morning with a diesel test and the normal shutdown of the fuel cell. This did not cause the demand peaks this month, which were related to the operational shutdown.




Wednesday, November 7, 2018 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar


Thursday, November 8, 2018 Stacked Bar Graph On-Peak and Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar


Friday, November 9, 2018 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

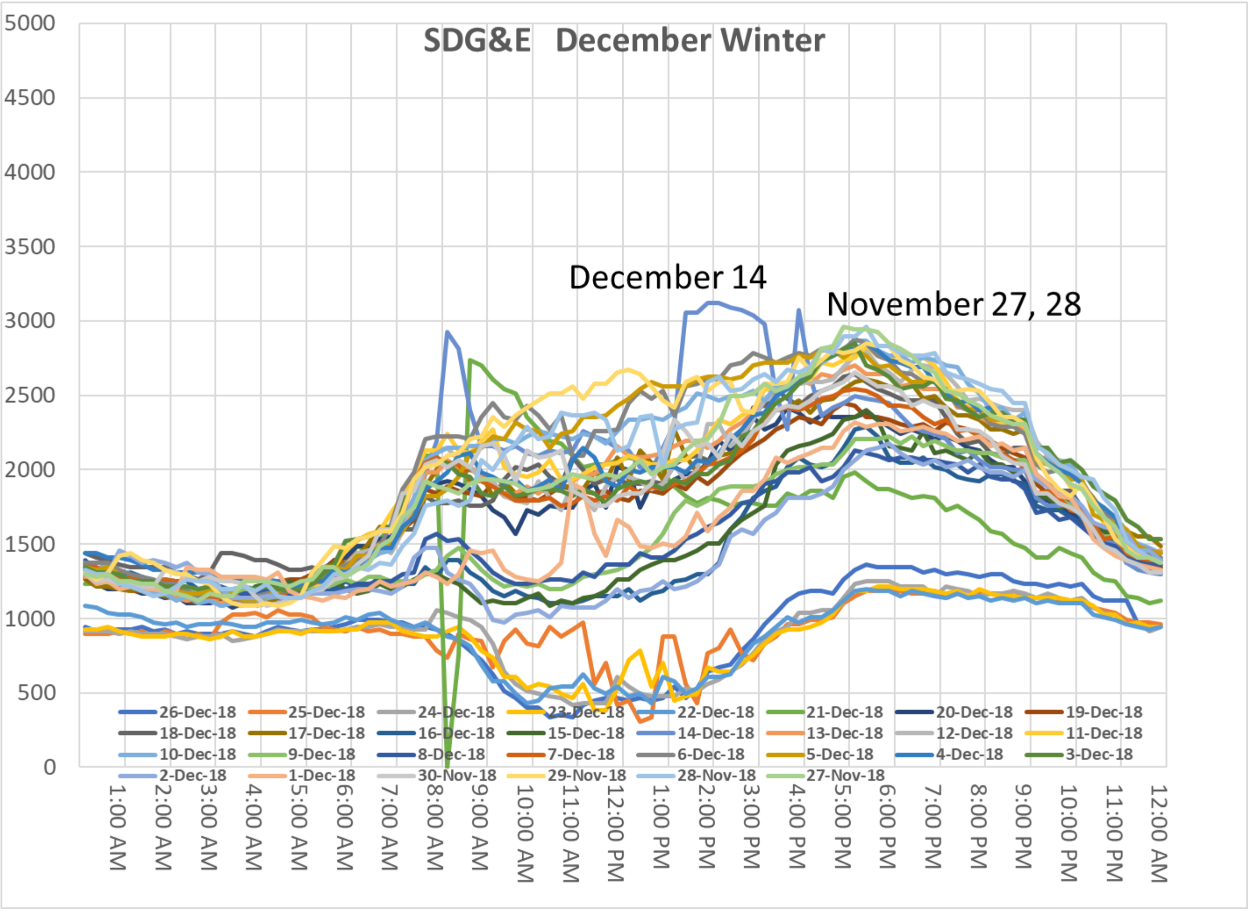

Friday, November 16, 2018 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

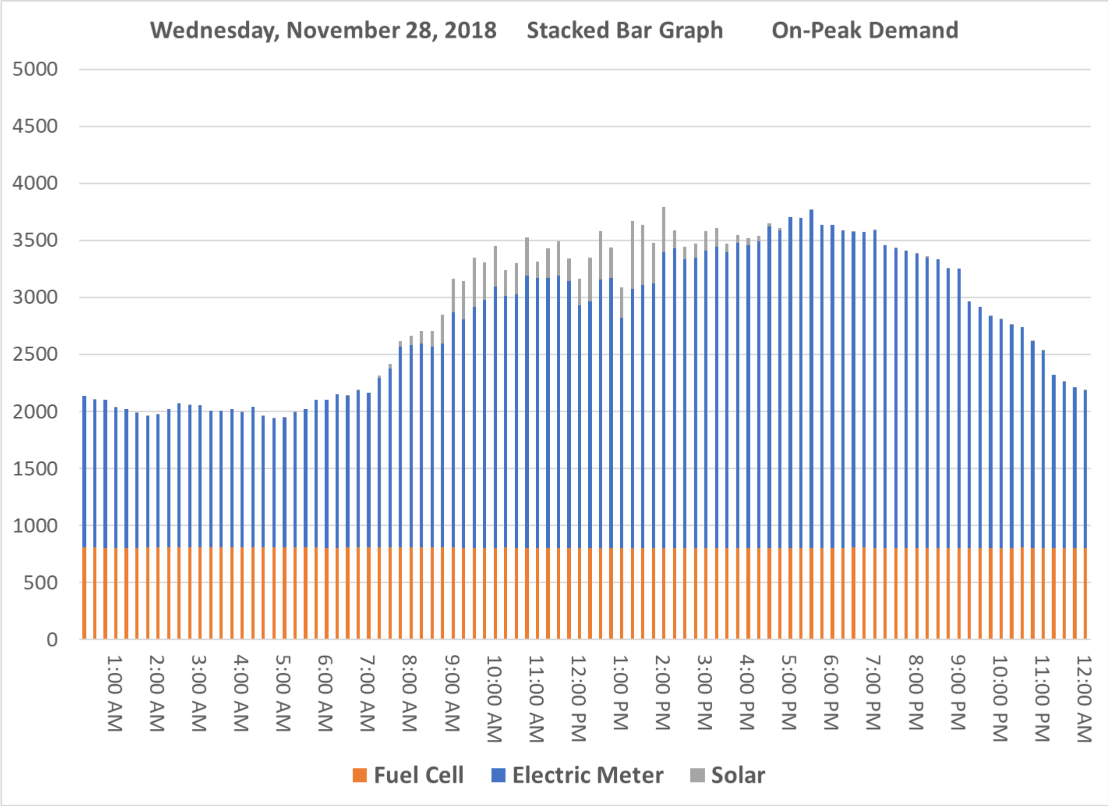
December

The December graph shows the SDG&E load profile leading up to a vacation period. The Non-Coincident peak was established on December 14, while the On-Peak demand for this billing month was established on November 27 (the first day of the December billing period) and matched on November 28. The next graph of November 28 shows that the fuel cell was operational all day, as is true for November 27 as well.

The next graph of December 14 shows that there was a brief interruption of fuel cell operation on Friday morning, but then a 2 hour disruption during Friday afternoon. Perhaps the diesel engine test was delayed to the afternoon that day. This apparent afternoon test led to the creation of the Non-Coincident peak for this month.

The load profile graph for December 21 is also included. There was apparently an engine test on this Saturday morning, which did not contribute to any monthly demands.




Wednesday, November 28, 2018 Stacked Bar Graph On-Peak Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
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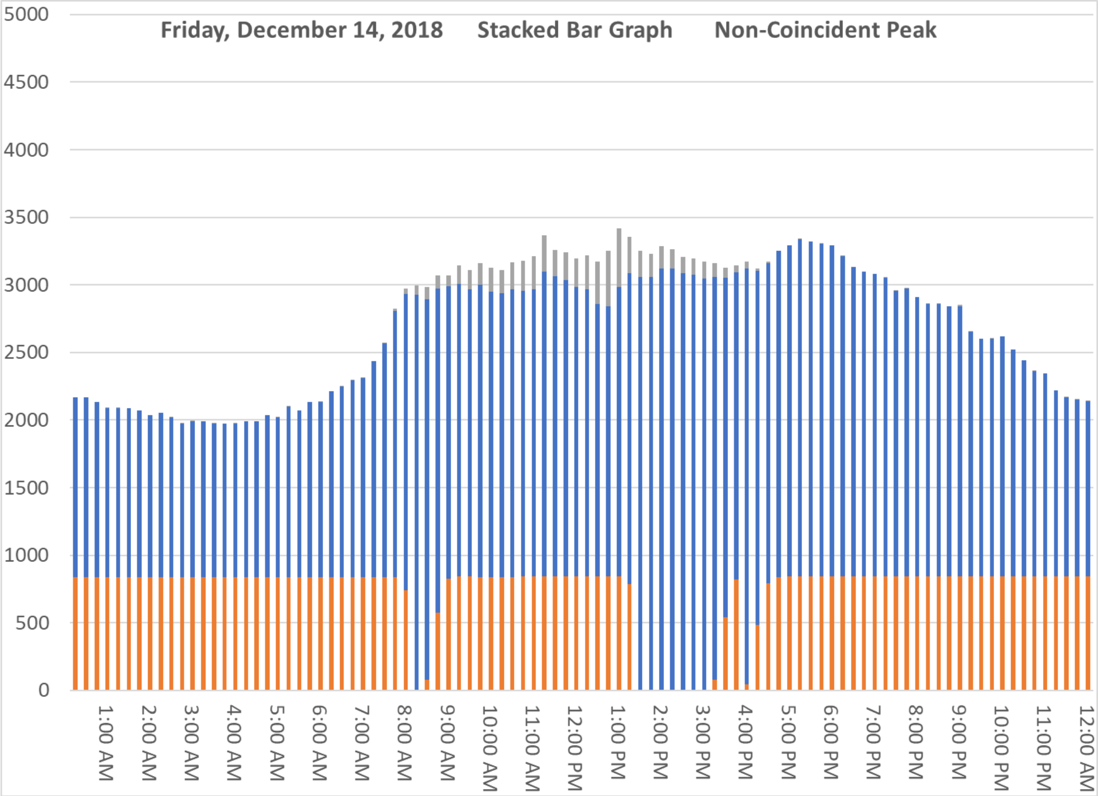
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar


Friday, December 14, 2018 Stacked Bar Graph Non-Coincident Peak
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
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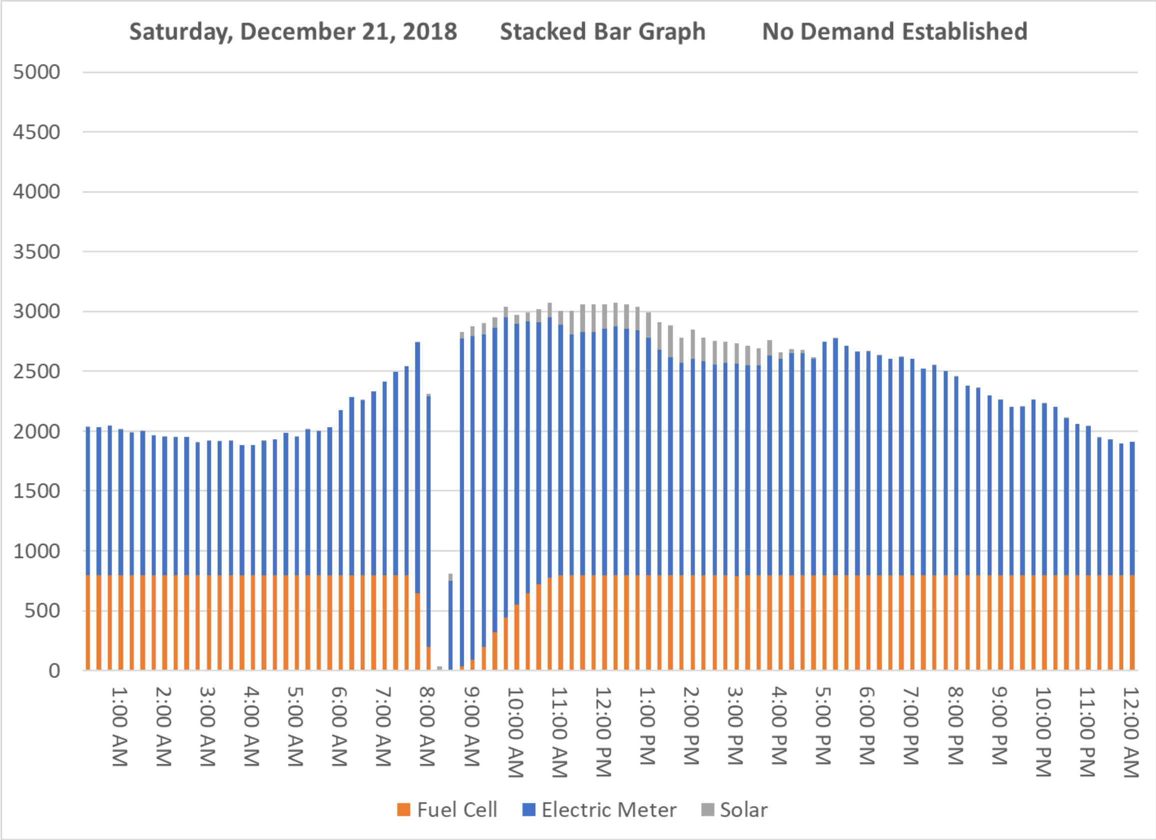
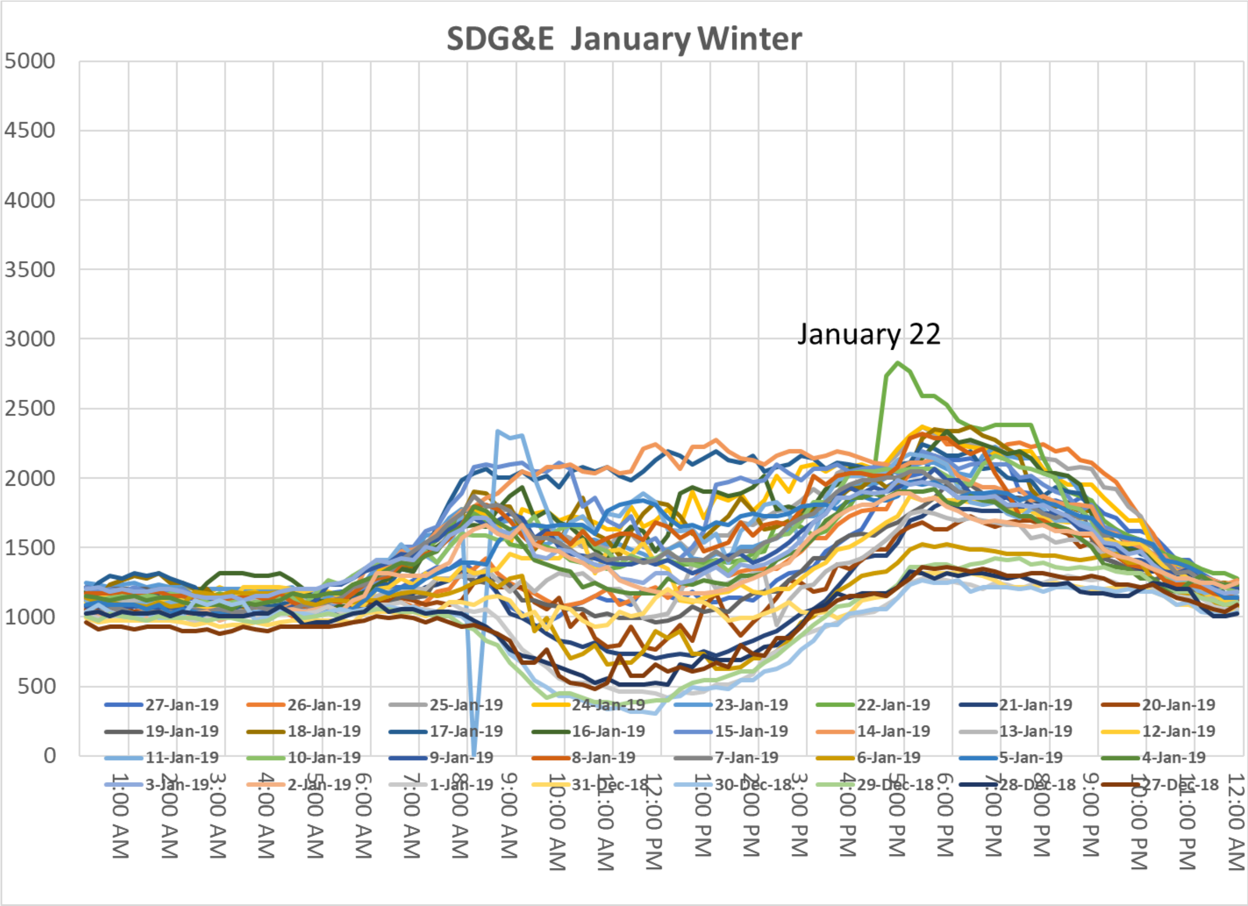
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

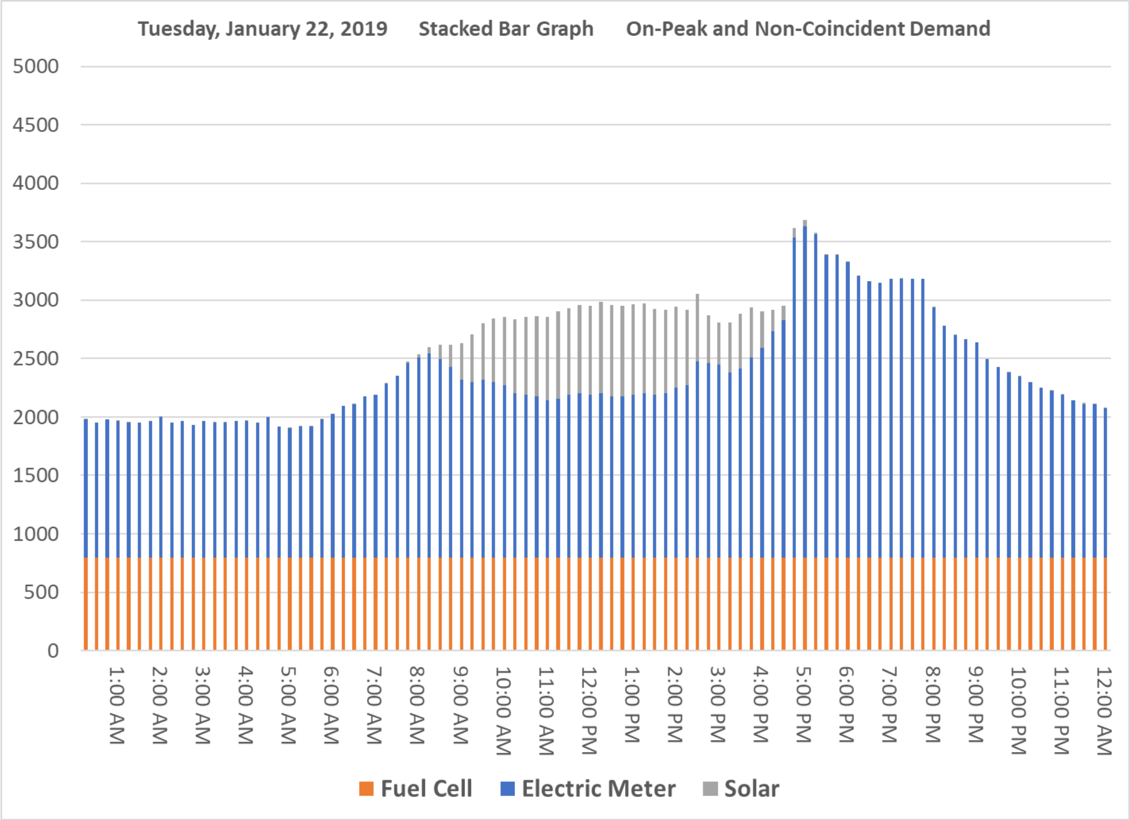

Saturday, December 21, 2018
Stacked Bar Graph
No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

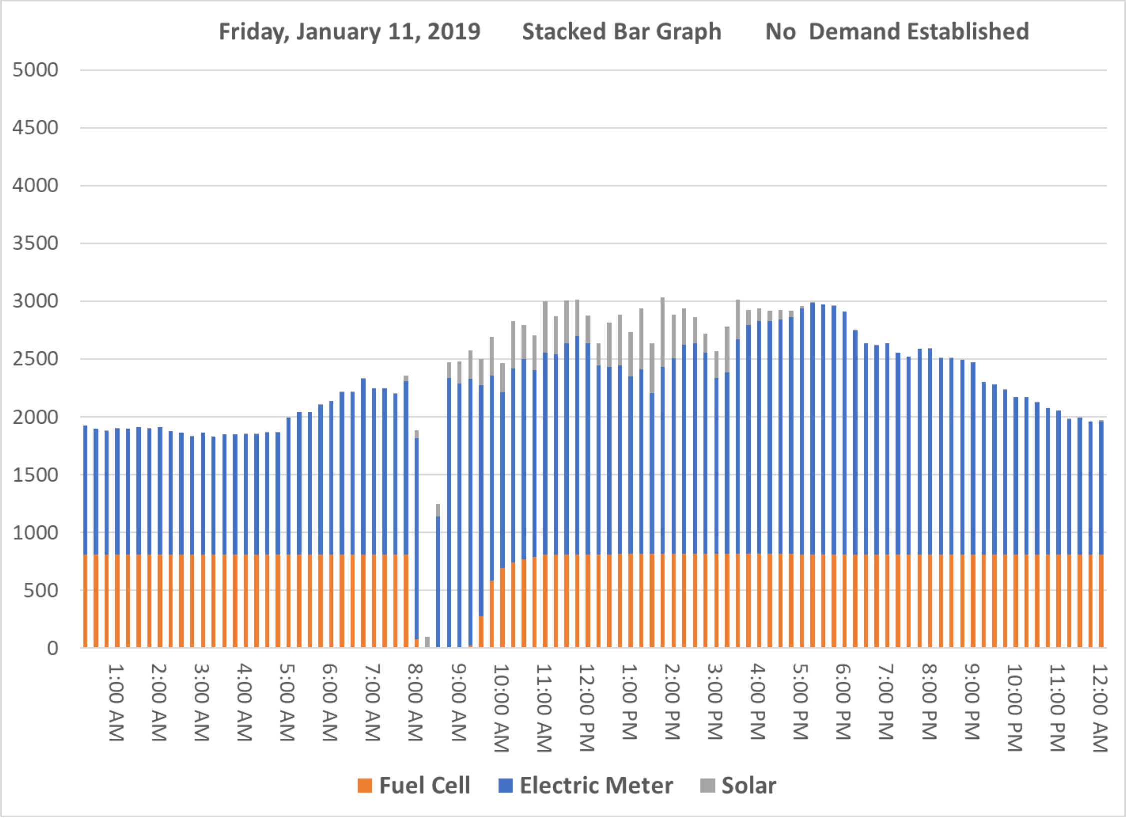
January

The January graph shows the SDG&E load profile for every day of a low load period. The Non-Coincident and On-Peak billing demands were both created on January 22. The daily load profile graph for January shows that during the fuel cell operated all day, so it did not contribute to the billing demand this month.

The January 9 electric load profile shows that the fuel cell stopped for almost 2 hours during a normal Friday morning generator test without establishing a billing peak for this month.



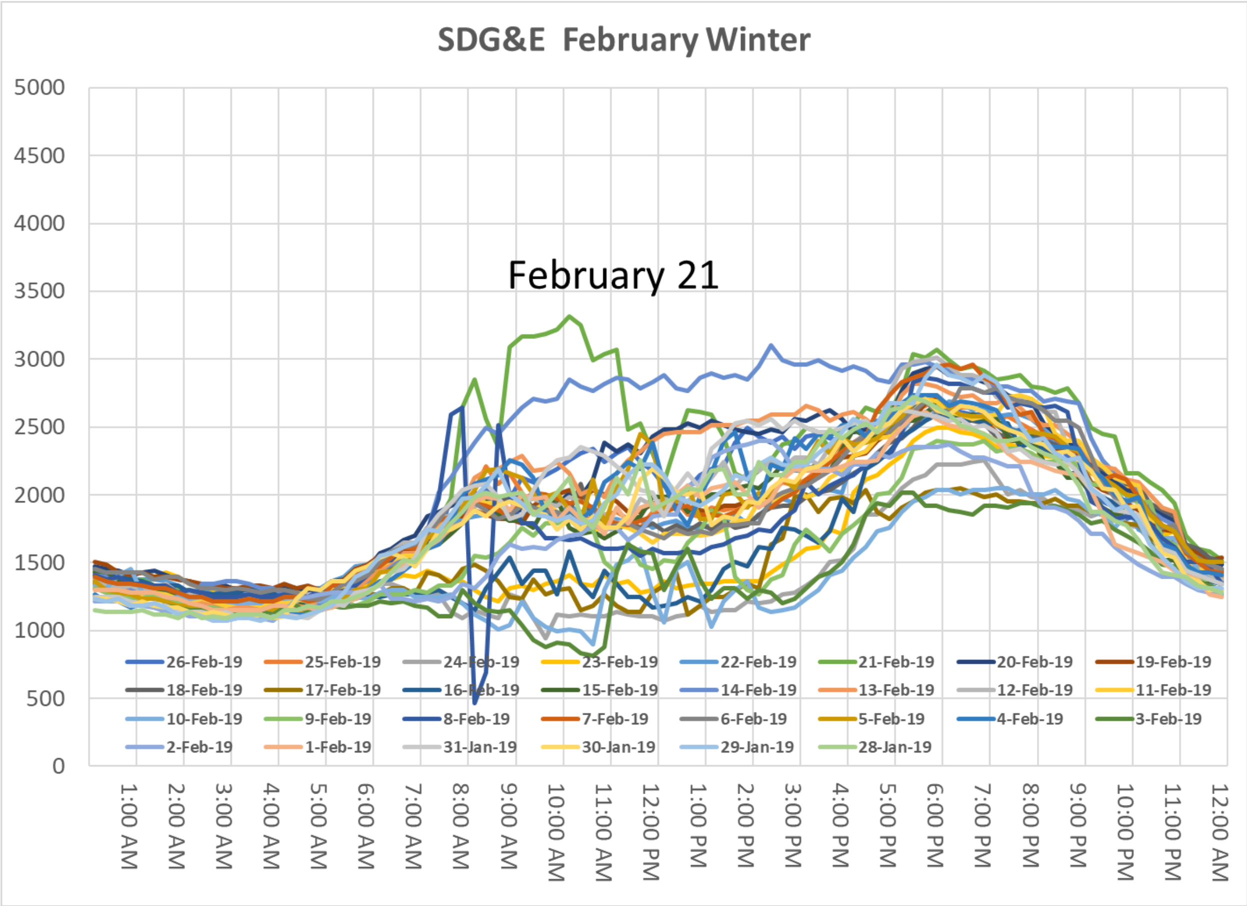

Tuesday, January 22, 2019 Stacked Bar Graph On-Peak and Non-Coincident Demand
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

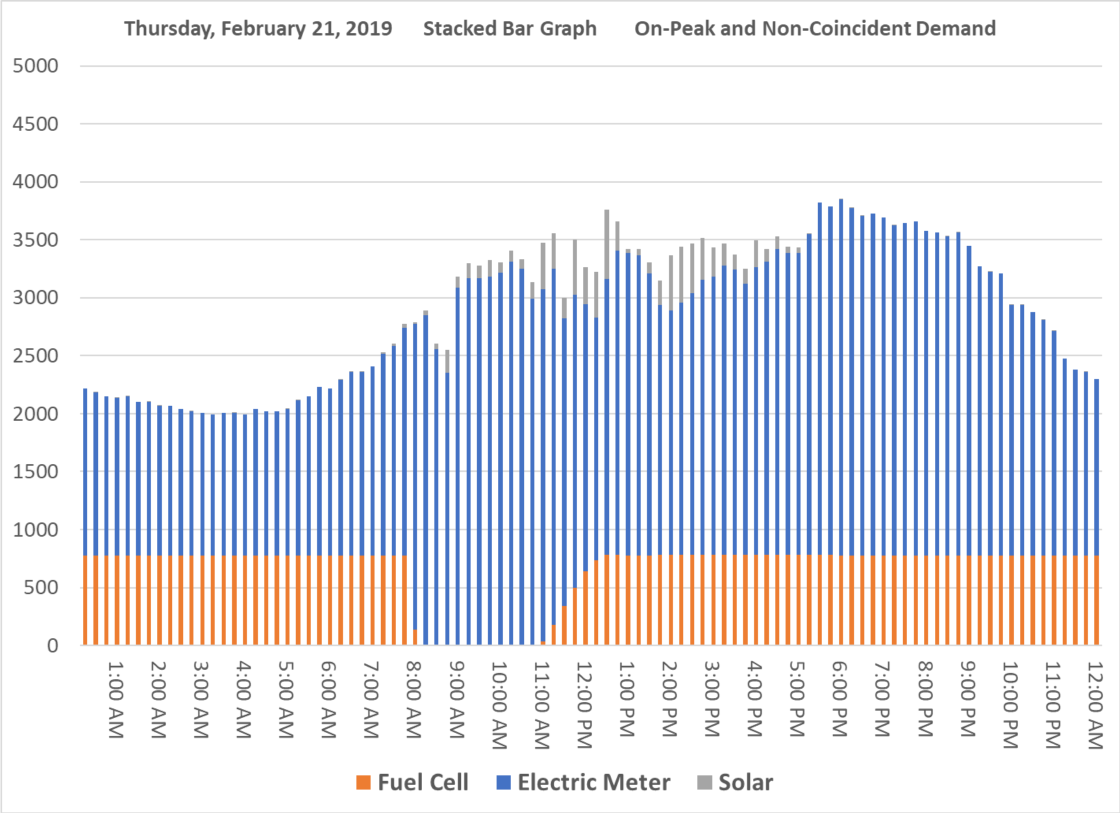

Friday, January 11, 2019 Stacked Bar Graph No Demand Established
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

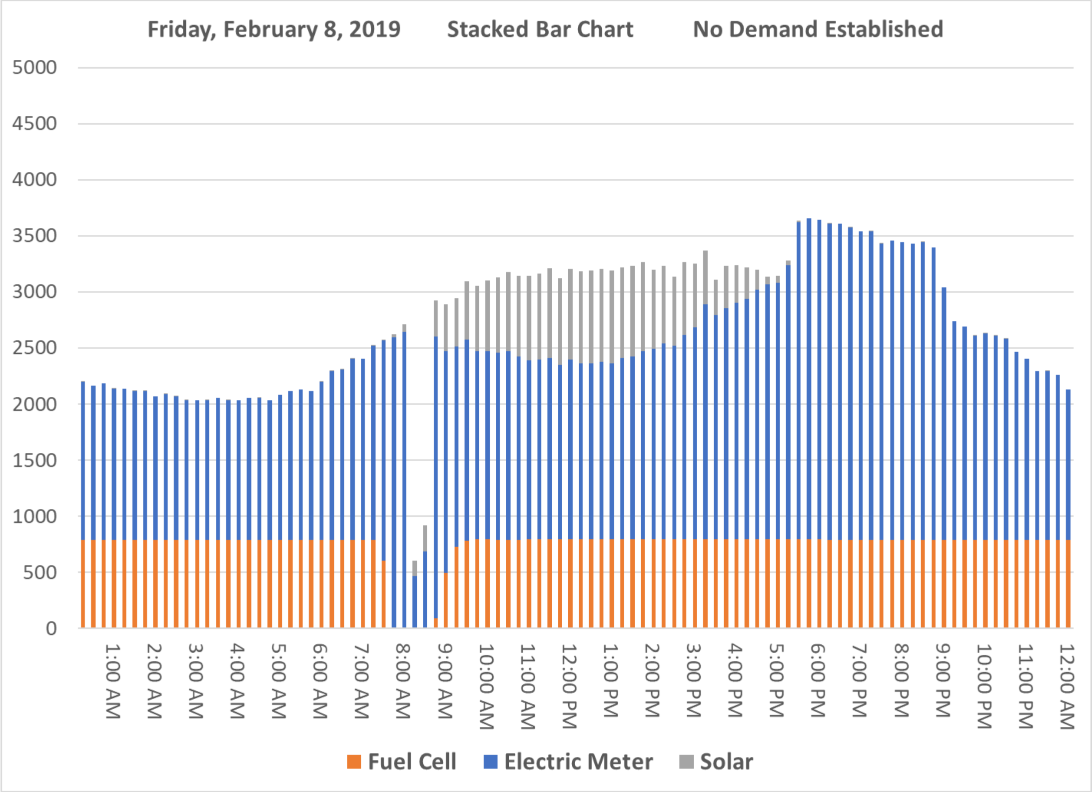
February

The February graph shows that the SDG&E Non-Coincident and On Peak demands were both established on Thursday, February 21. The Non-Coincident demand was established about 10 am, during the time when the fuel cell was down from 8 am to 11 am. The PG&E demand never dropped significantly during these hours, indicating that the emergency generator did not successfully start during the test. The demand would still have been set during these hours assuming the generator operated for its typically short period of time.

A successful generator test appears to take place on the February 8 graph, in this case not contributing to the monthly demands.

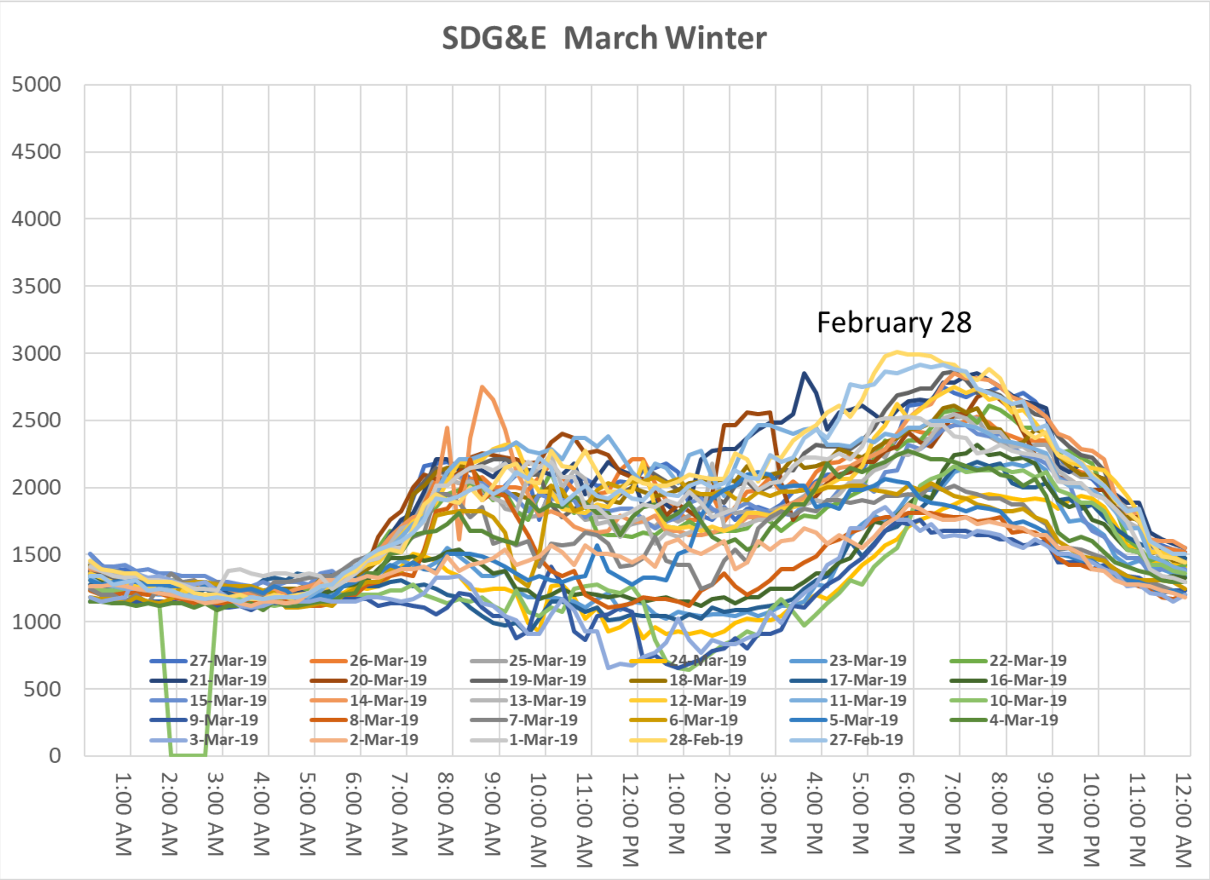


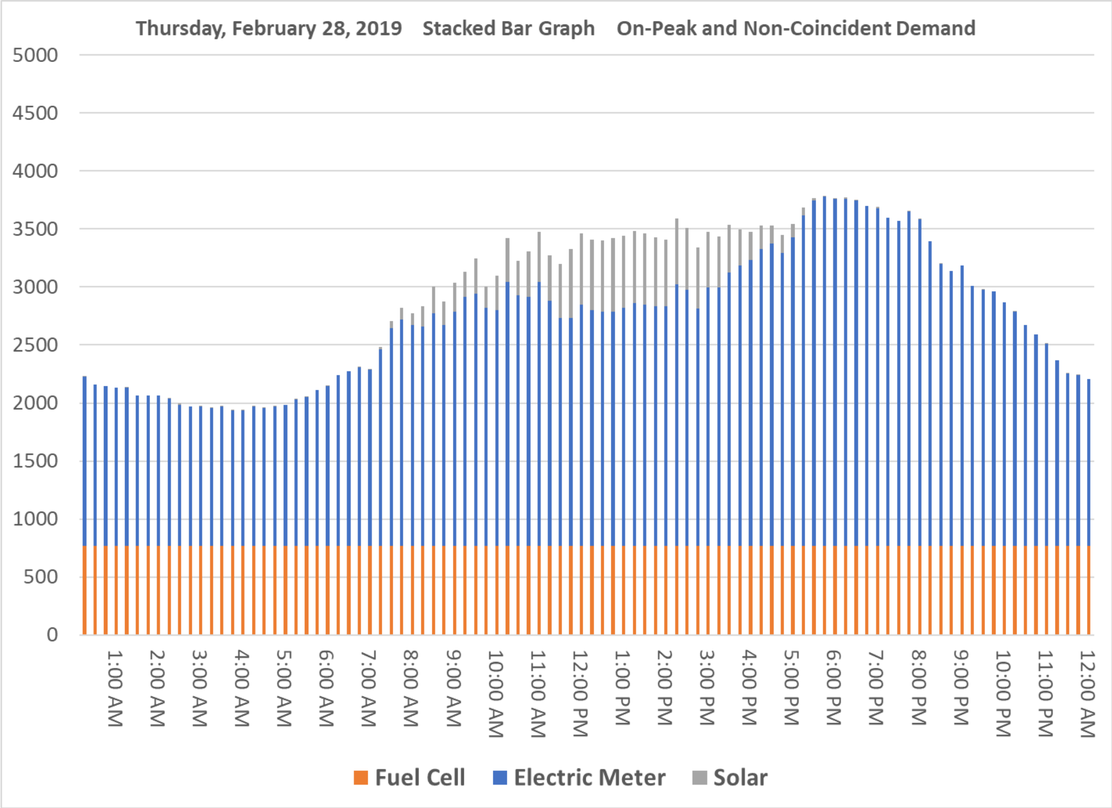

Thursday, February 21, 2019 Stacked Bar Graph On-Peak and Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

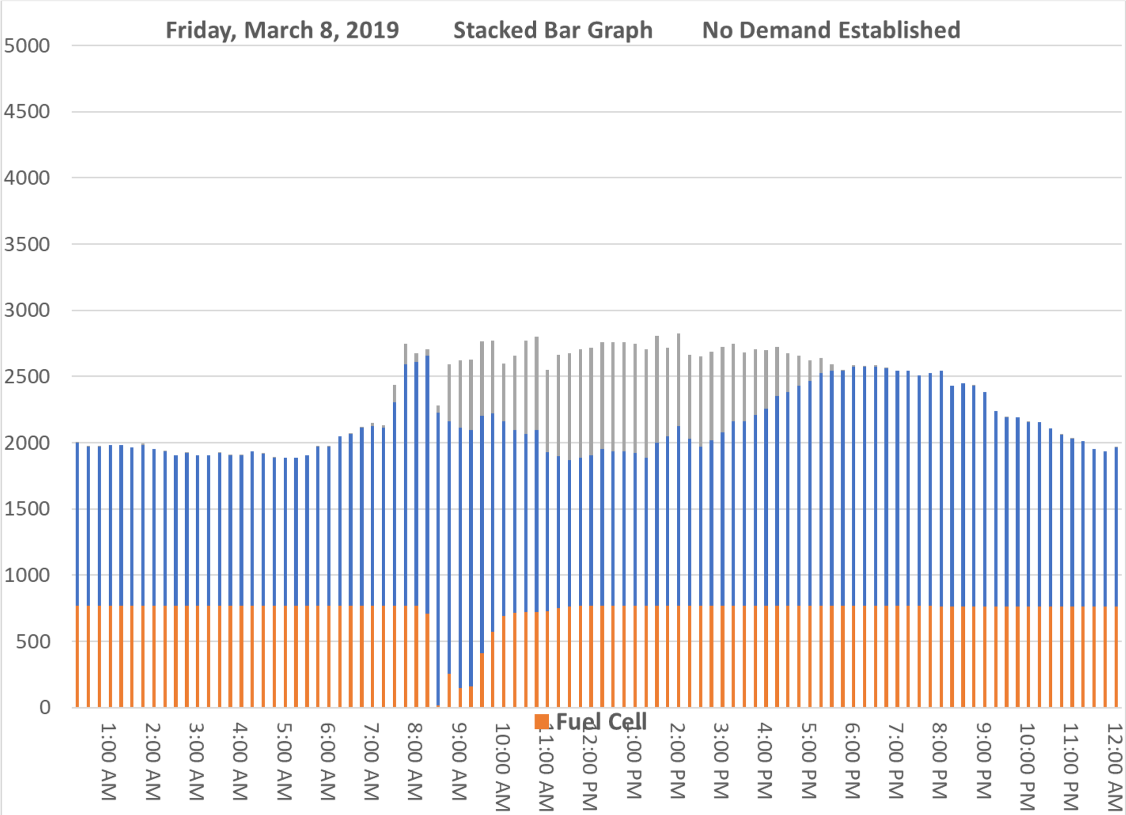

Friday, February 8, 2019 Stacked Bar Chart No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

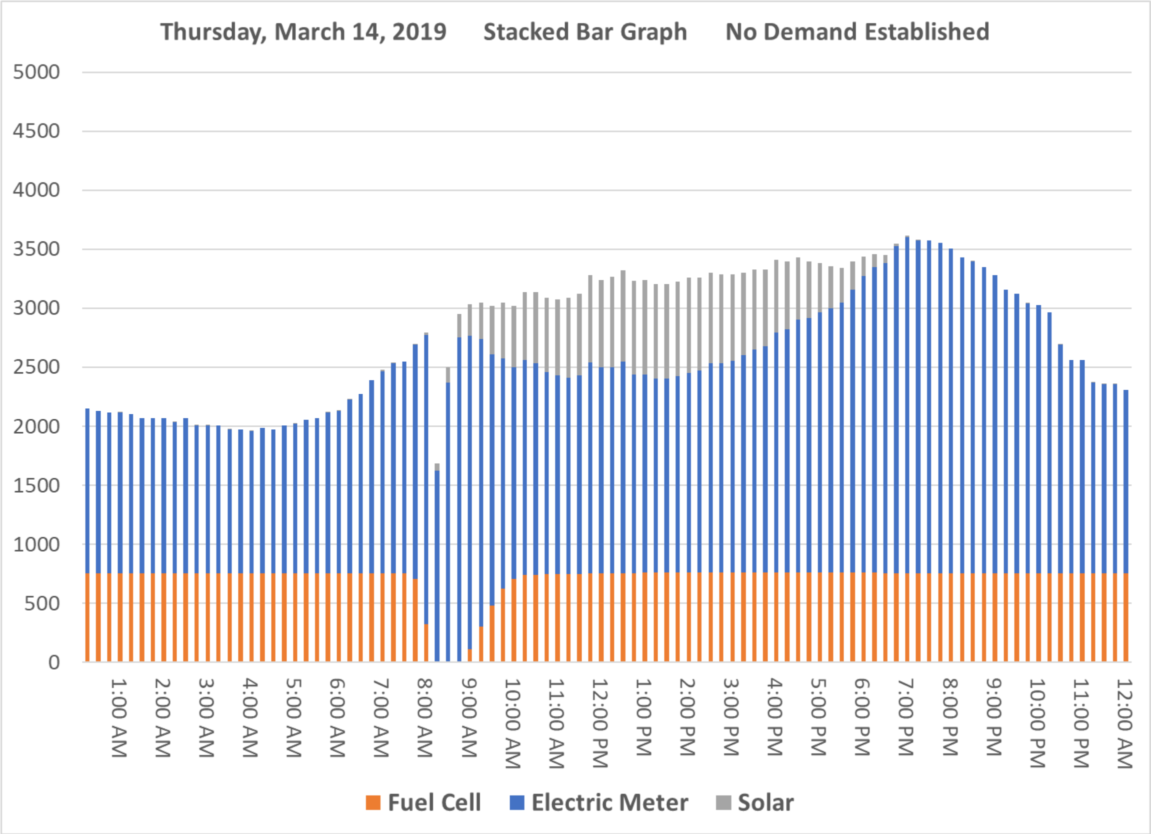
March

The March SDG&E graph shows that the Non-Coincident and On-Peak demands were created at the same hour on February 28. The fuel cell operated continuously this day, per the February 28 graph, so it did not contribute to the peak demand during this month. The load profile graphs for March 8 and 14 are included as well. These are days when the fuel cell was stopped for apparent engine tests, but this did not create any monthly demand peaks.



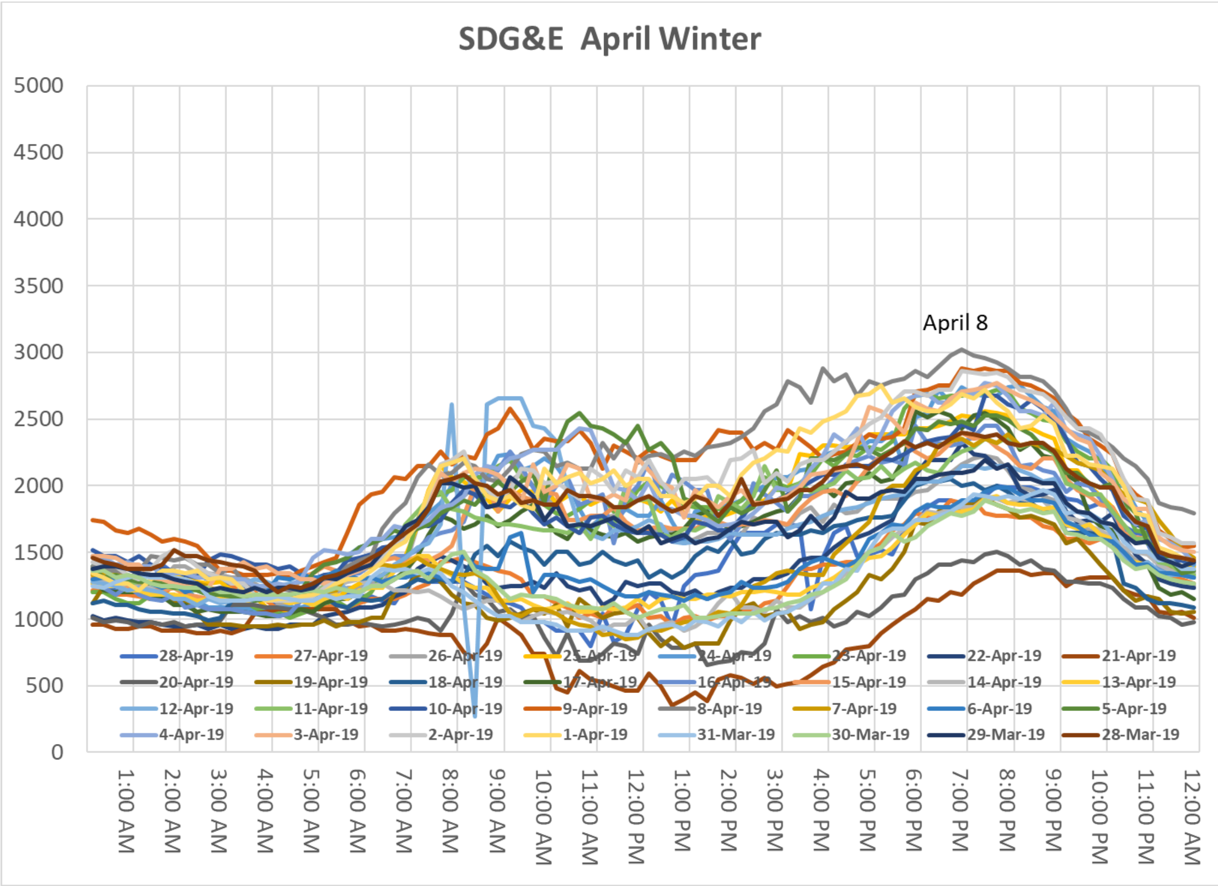

Thursday, February 28, 2019 Stacked Bar Graph On-Peak and Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

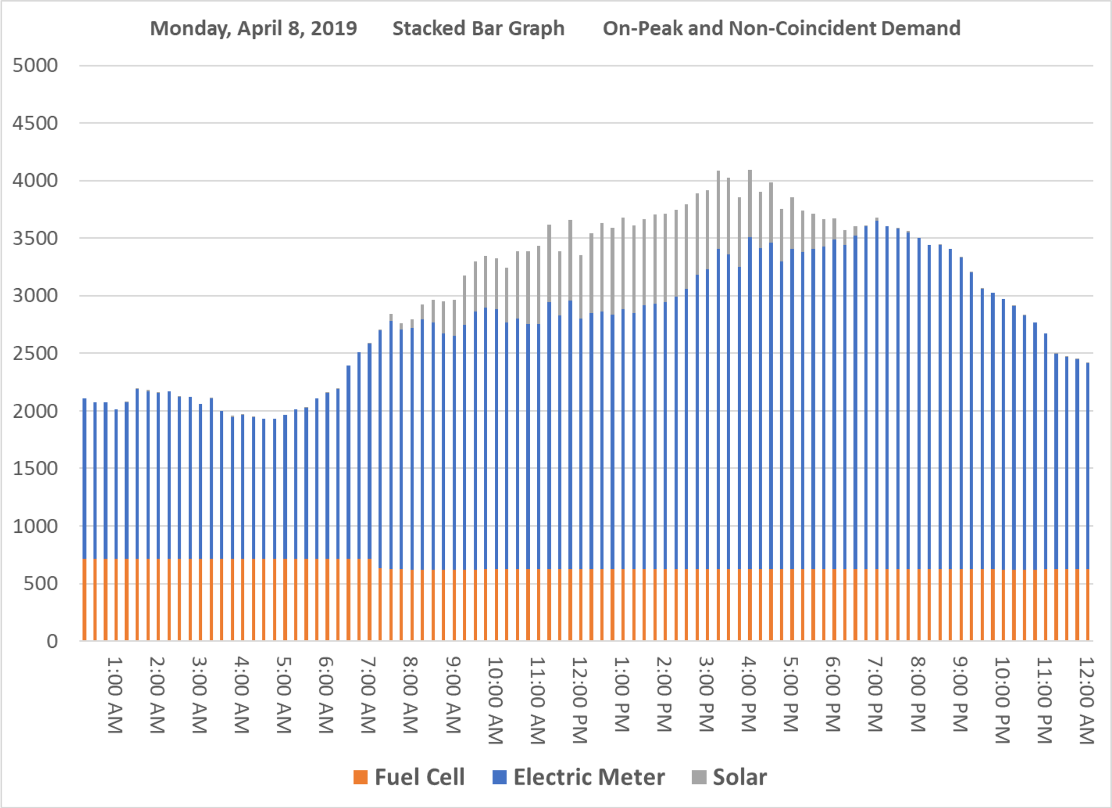

Friday, March 8, 2019 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Fuel Cell
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM

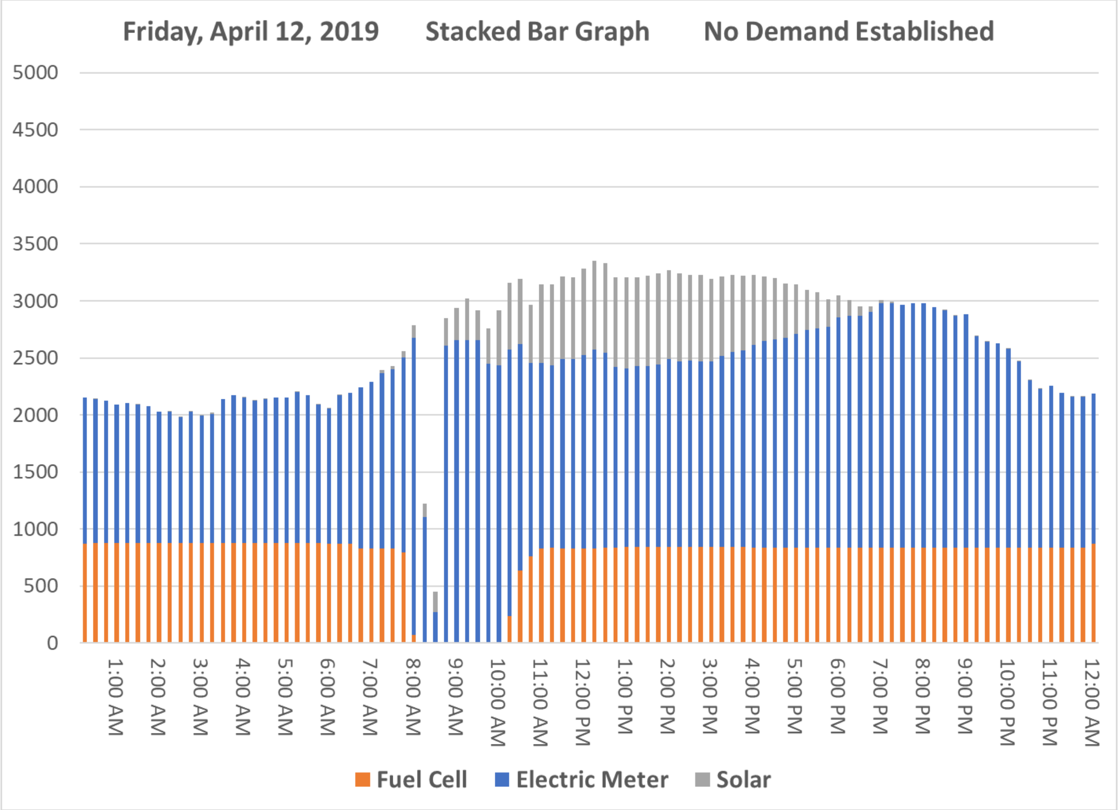

Thursday, March 14, 2019 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

April

The April SDG&E graph shows the Non-Coincident and On-Peak demands were created at the same hour on April 8. The fuel cell operated continuously this day, per the April 8 graph, so it did not contribute to the peak demand during this month. The load profile graph for Friday, April 12 indicate there was an engine generator test that day, but it did not contribute to demand charges for the month.



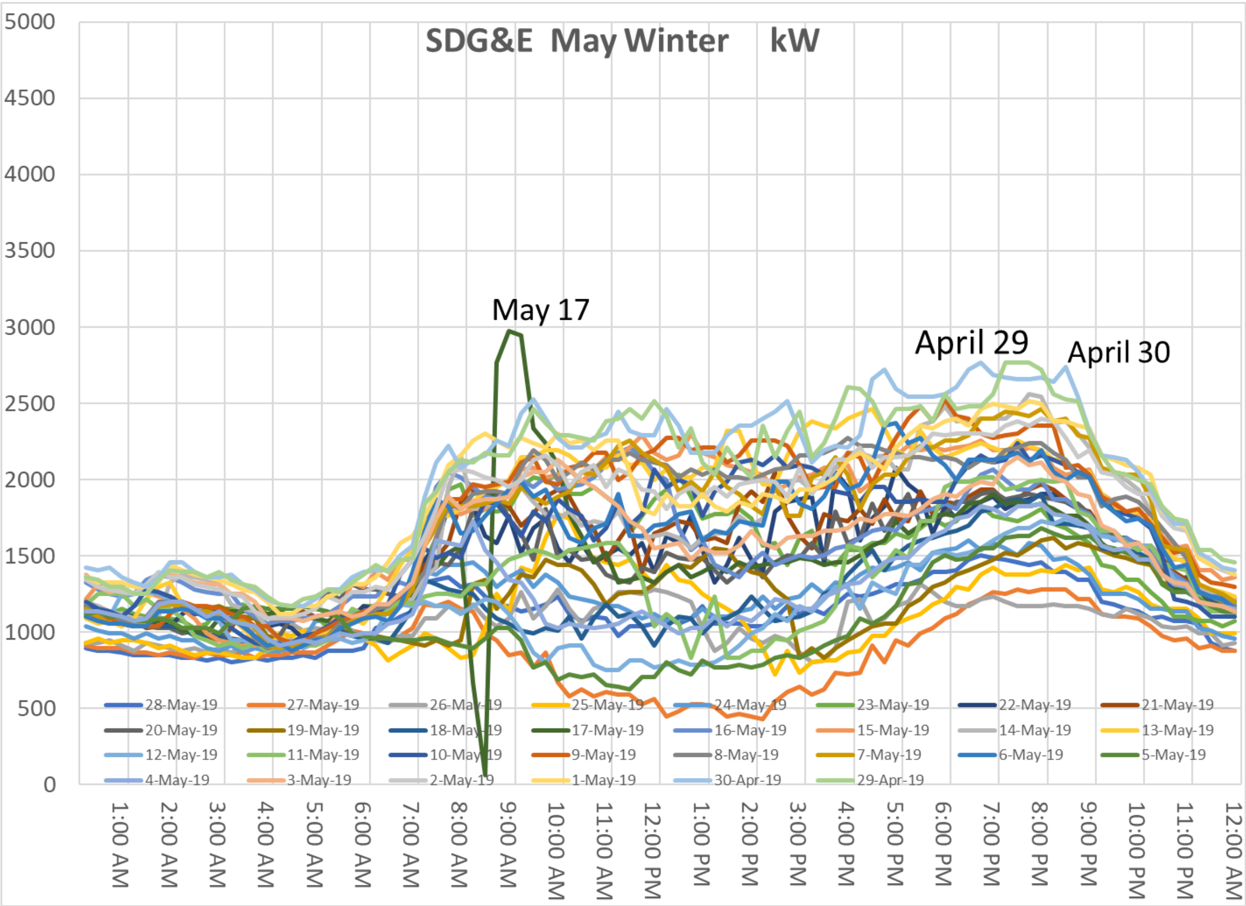

Monday, April 8, 2019 Stacked Bar Graph On-Peak and Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

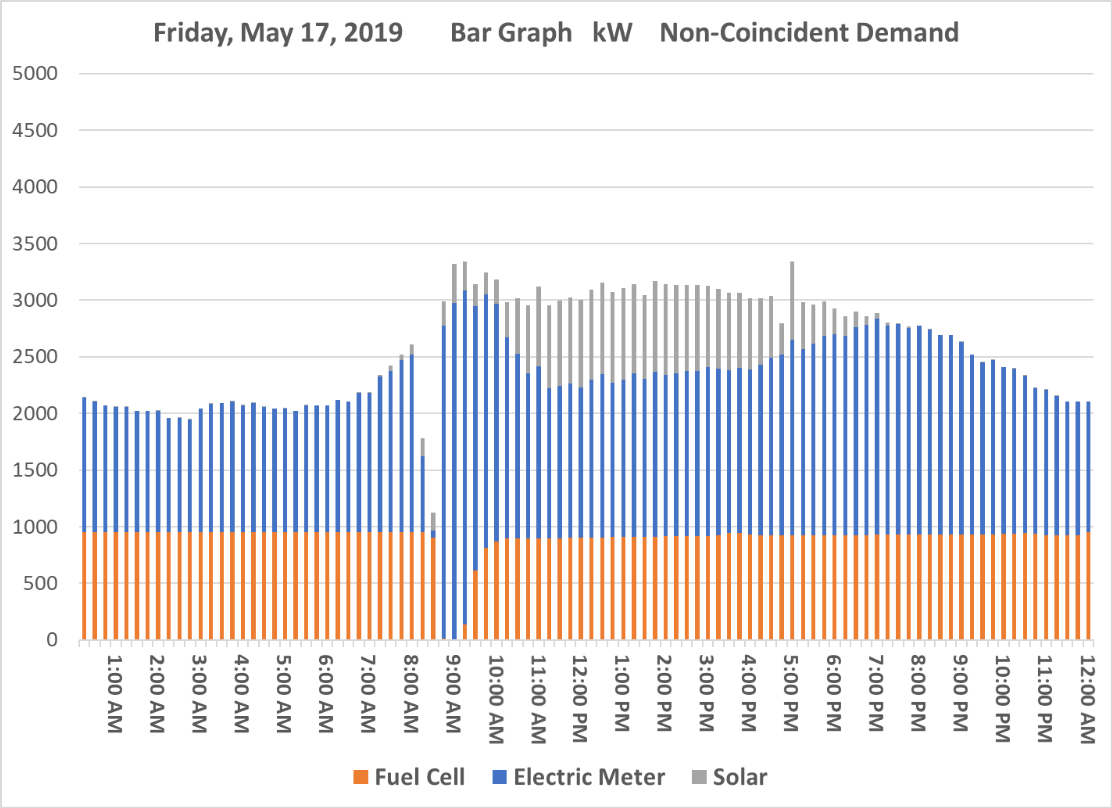

Friday, April 12, 2019 Stacked Bar Graph No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

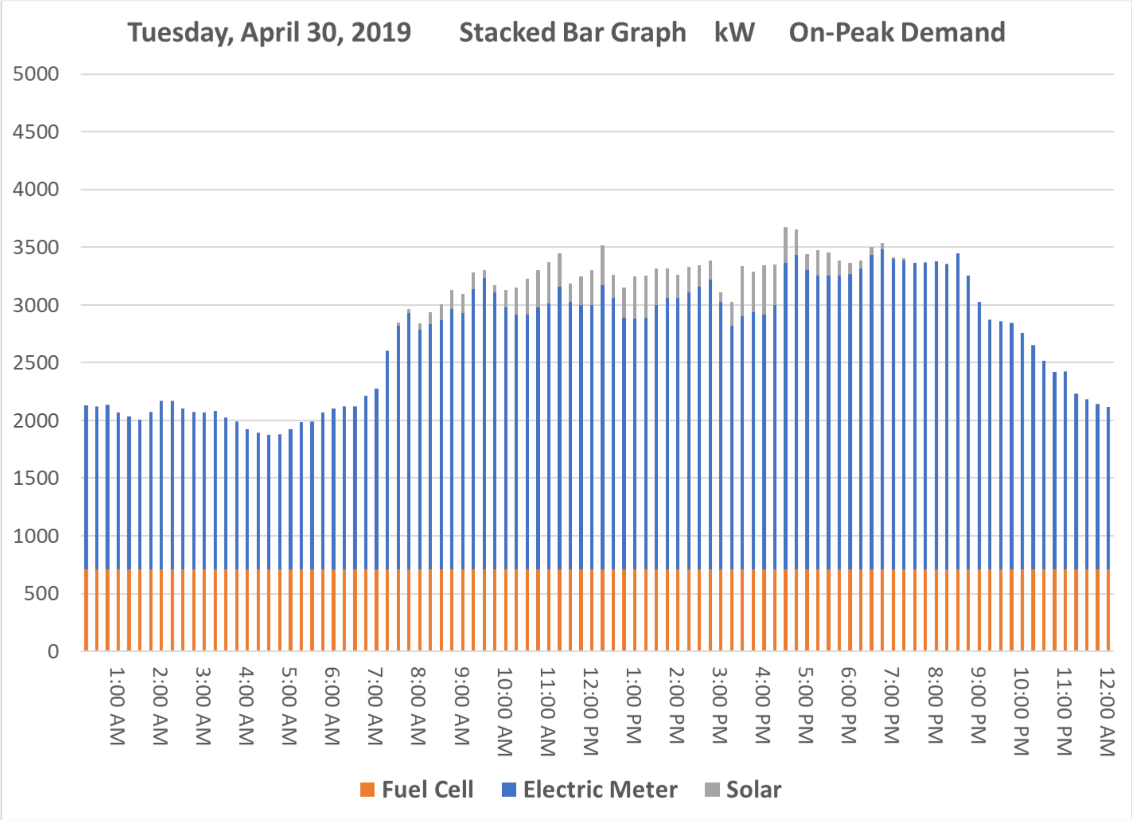
May

The May SDG&E graph shows the Non-Coincident demand was created on May 17. The May 17 graph shows that this demand was created during a diesel engine generator test.

The On-Peak demand was established on April 29 and again on April30. The fuel cell was operating continuously these two days, as illustrated in the April 30 graph.




Friday, May 17, 2019 Bar Graph kW Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

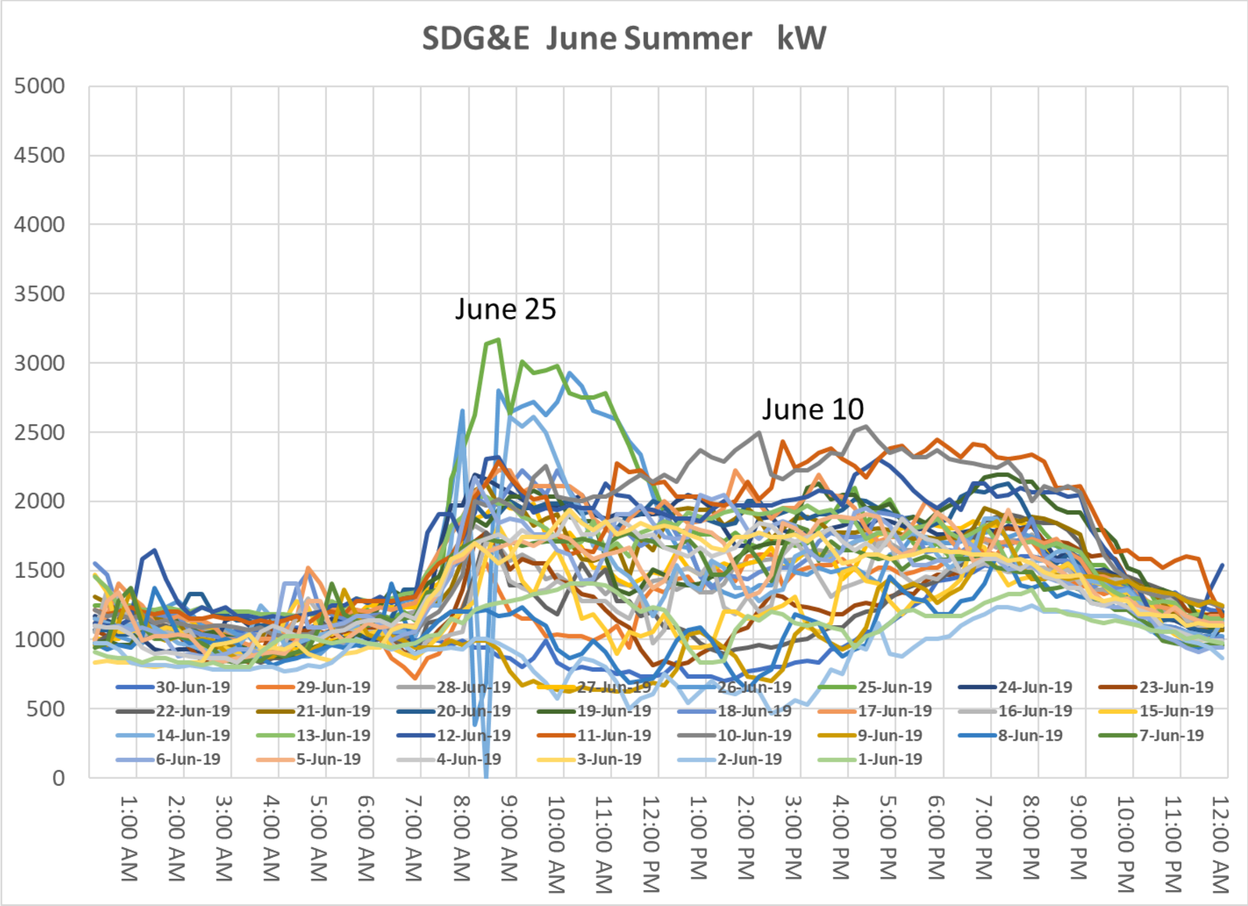

Tuesday, April 30, 2019 Stacked Bar Graph kW On-Peak Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

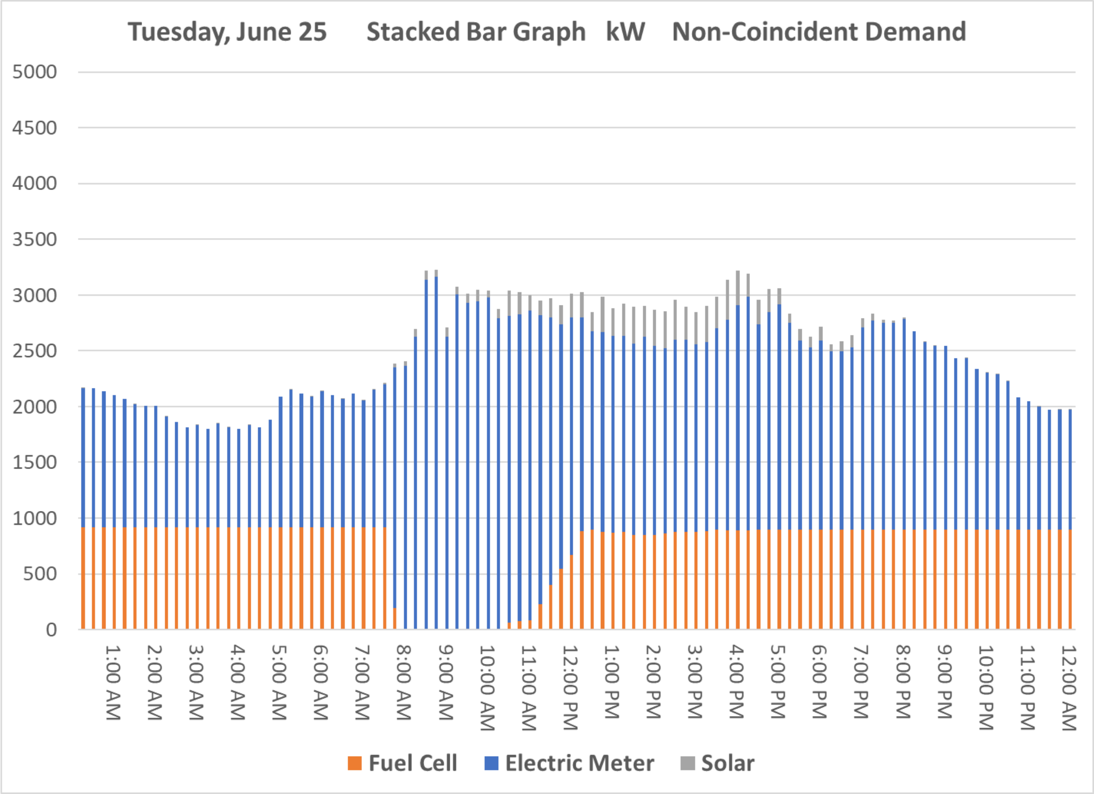
June

The June SDG&E graph shows that the Non-Coincident peak for the month was established on June 25. The June 25 graph shows that the fuel cell was not operating from 8 am to 11 am. It looks like a generator test was intended for this morning, though the test did not happen. Nonetheless the monthly Non-Coincident demand was established this morning.

The On-Peak demand for this month was established on June 10. The June 10 graph indicates that the fuel cell was operating every hour that day, so it did not contribute to the On-Peak demand.

There appear to be diesel engine generator tests on both June 14 and 26. However, monthly demands were not established during these tests.




Tuesday, June 25 Stacked Bar Graph kW Non-Coincident Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
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7:00 PM
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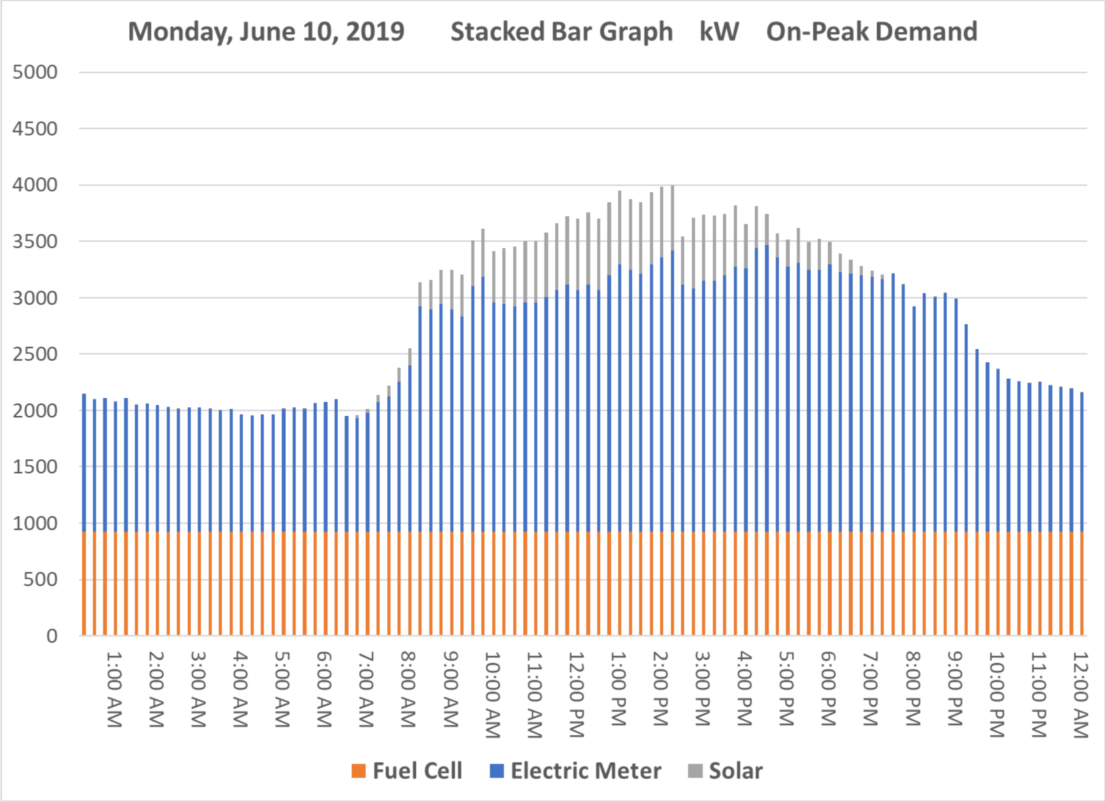
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar


Monday, June 10, 2019 Stacked Bar Graph kW On-Peak Demand
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
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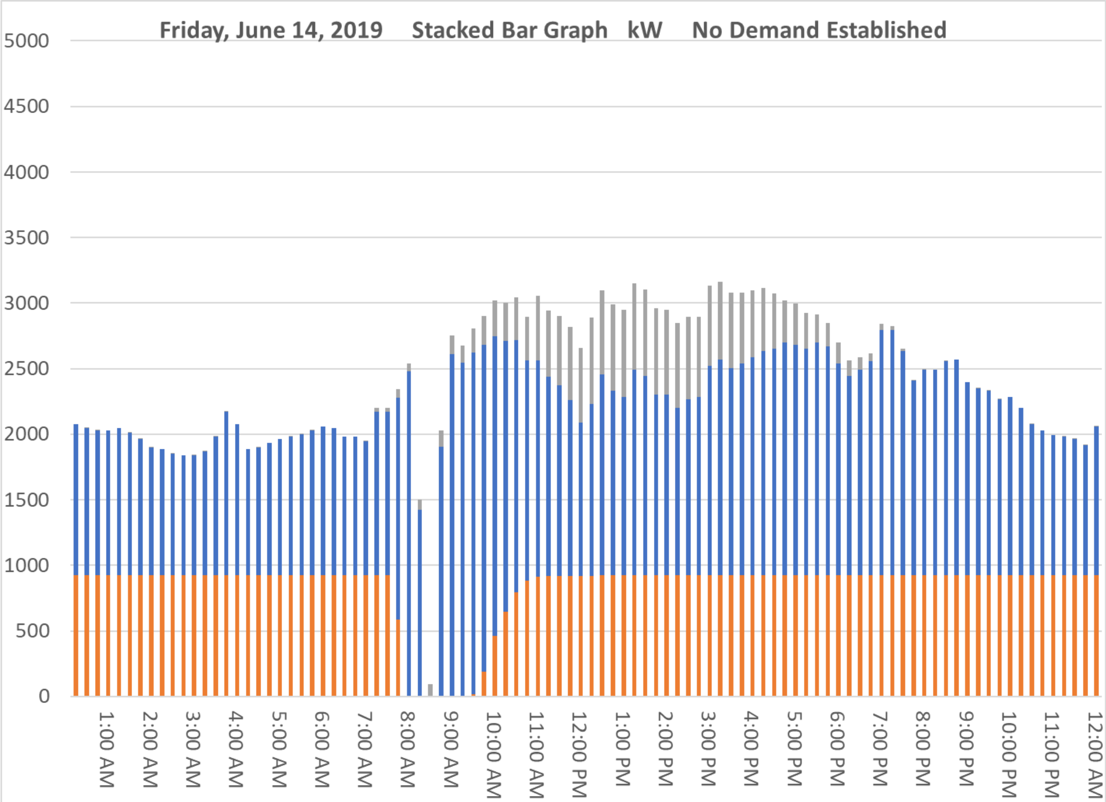
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar



Friday, June 14, 2019 Stacked Bar Graph kW No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
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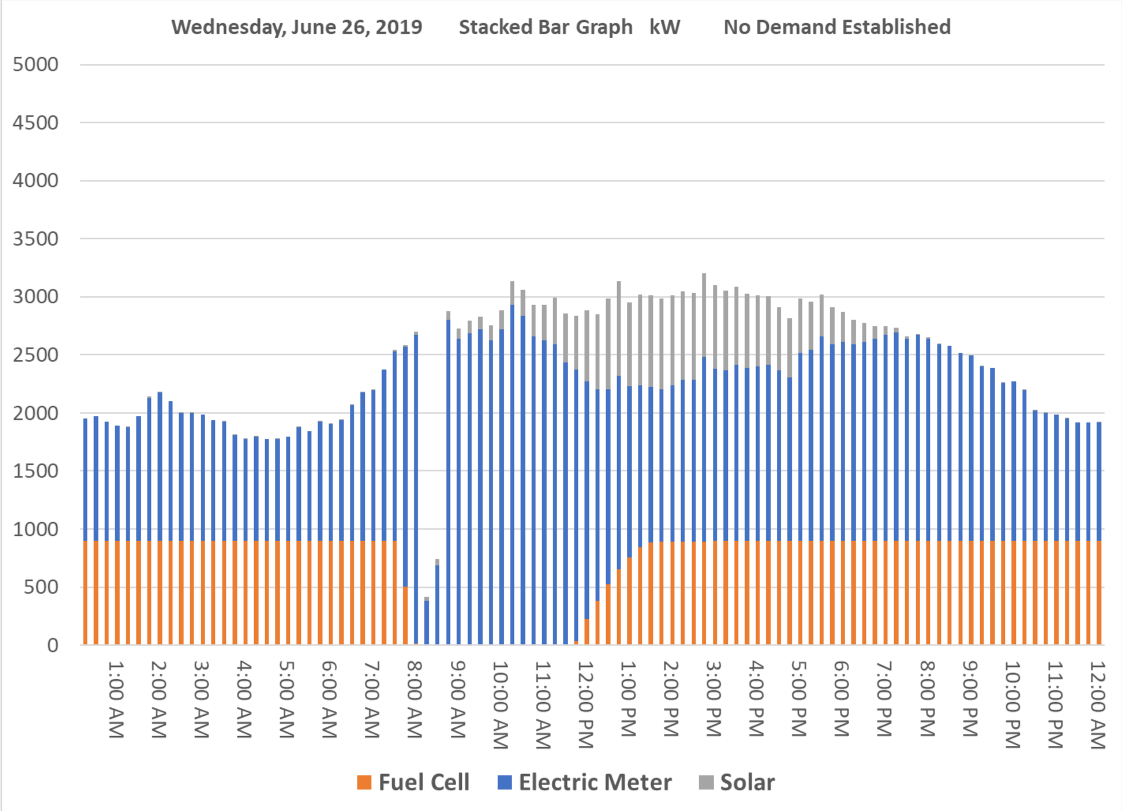
5:00 PM
6:00 PM
7:00 PM
8:00 PM
9:00 PM
10:00 PM
11:00 PM
12:00 AM



Wednesday, June 26, 2019 Stacked Bar Graph kW No Demand Established
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1:00 AM
2:00 AM
3:00 AM
4:00 AM
5:00 AM
6:00 AM
7:00 AM
8:00 AM
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
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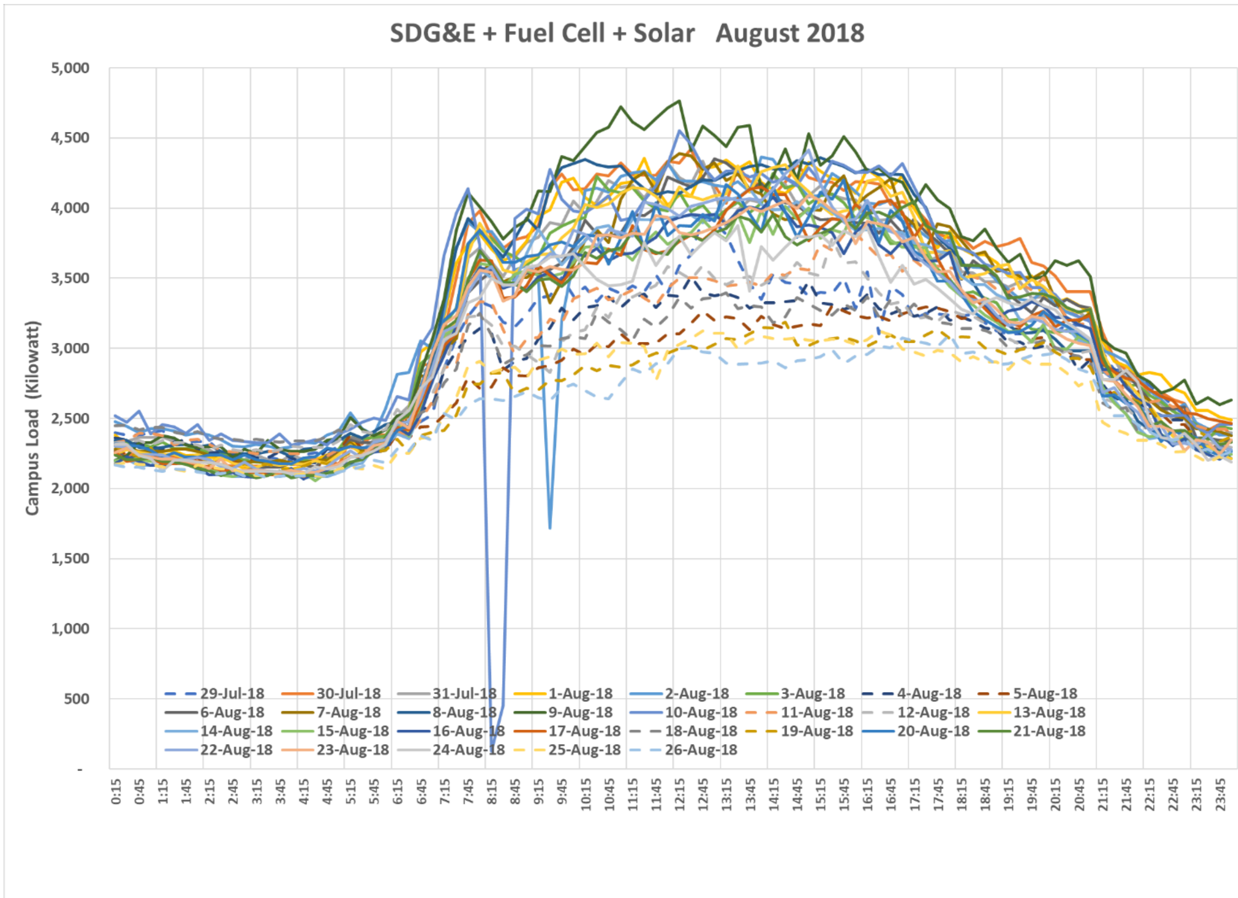
11:00 PM
12:00 AM
Fuel Cell
Electric Meter
Solar

Appendix D – Building Electric Load Profile

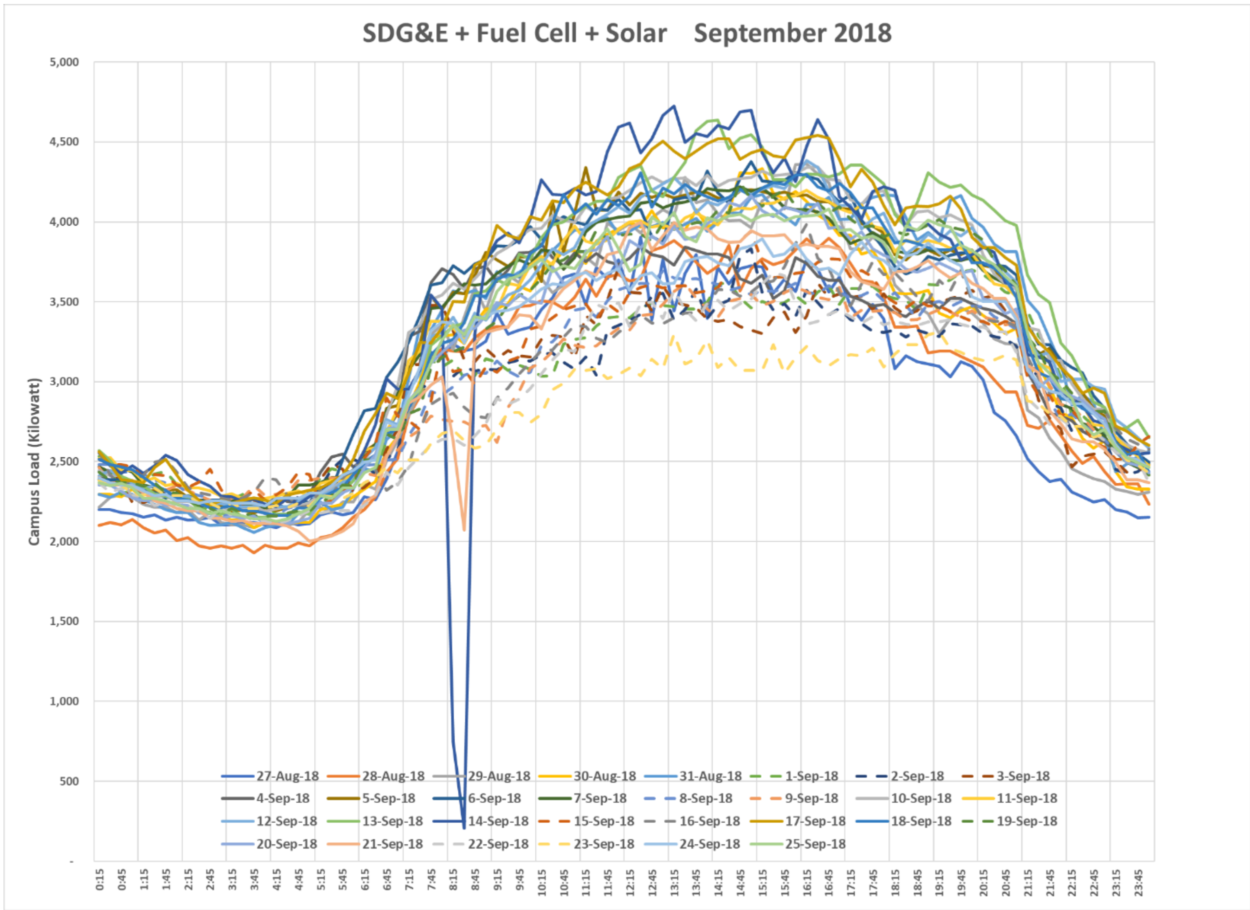


The July graph of campus electric load from buildings is shown in Section 7.1.4 in the main body of this report. The electric load from buildings is compiled by adding the 15 minute purchase of electricity from SDG&E/Calpine, the fuel cell and the campus PV system. The output from the diesel generators would complete this picture if it were available.

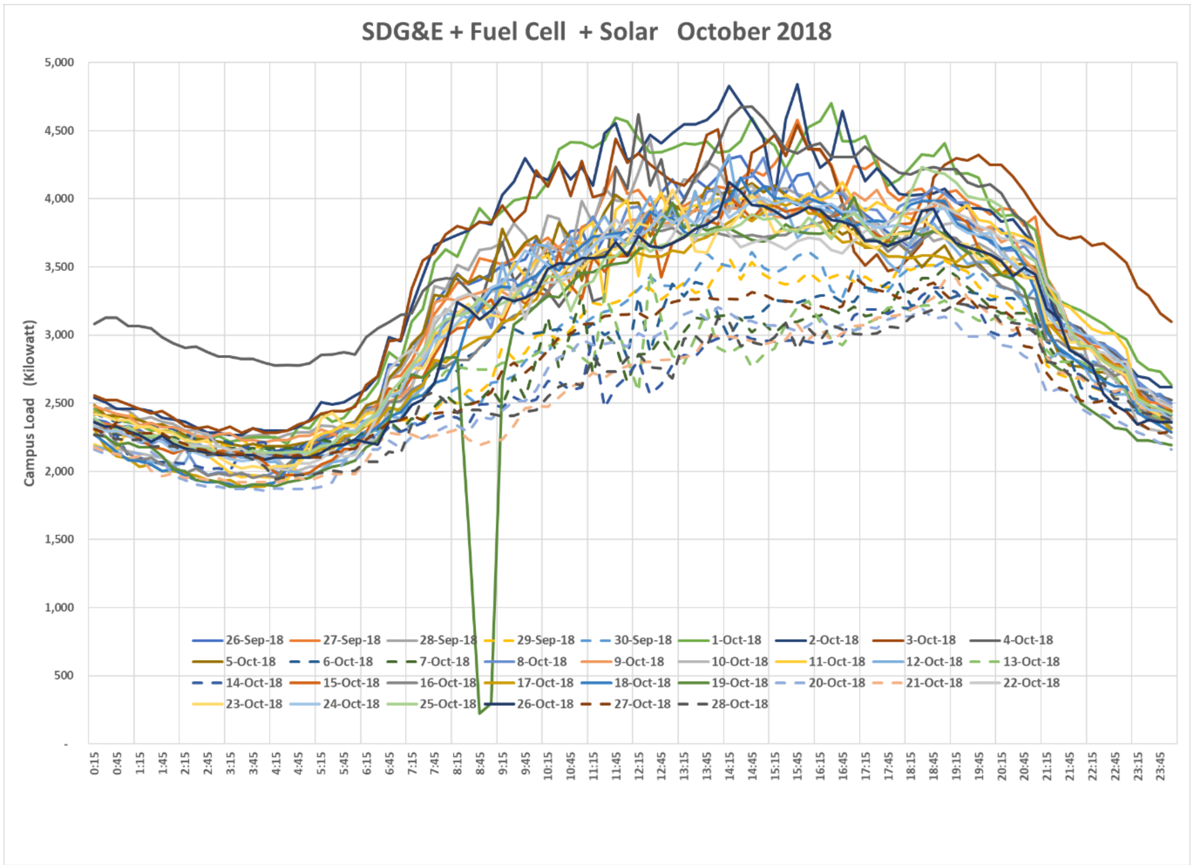
The August graph of campus building loads shown in this Figure is similar to the July load profile. There is at least one emergency generator test performed. When one of the 15-minute period data points drops without going all the way to zero, this could represent a period where the load actually was zero for a portion, but not all, of the 15-minute period.

Most of the weekday electricity use is fairly tightly clustered day and night. The weekend loads are somewhat varied. The load profile does not have the sag it did when we were looking only at the utility meter load.

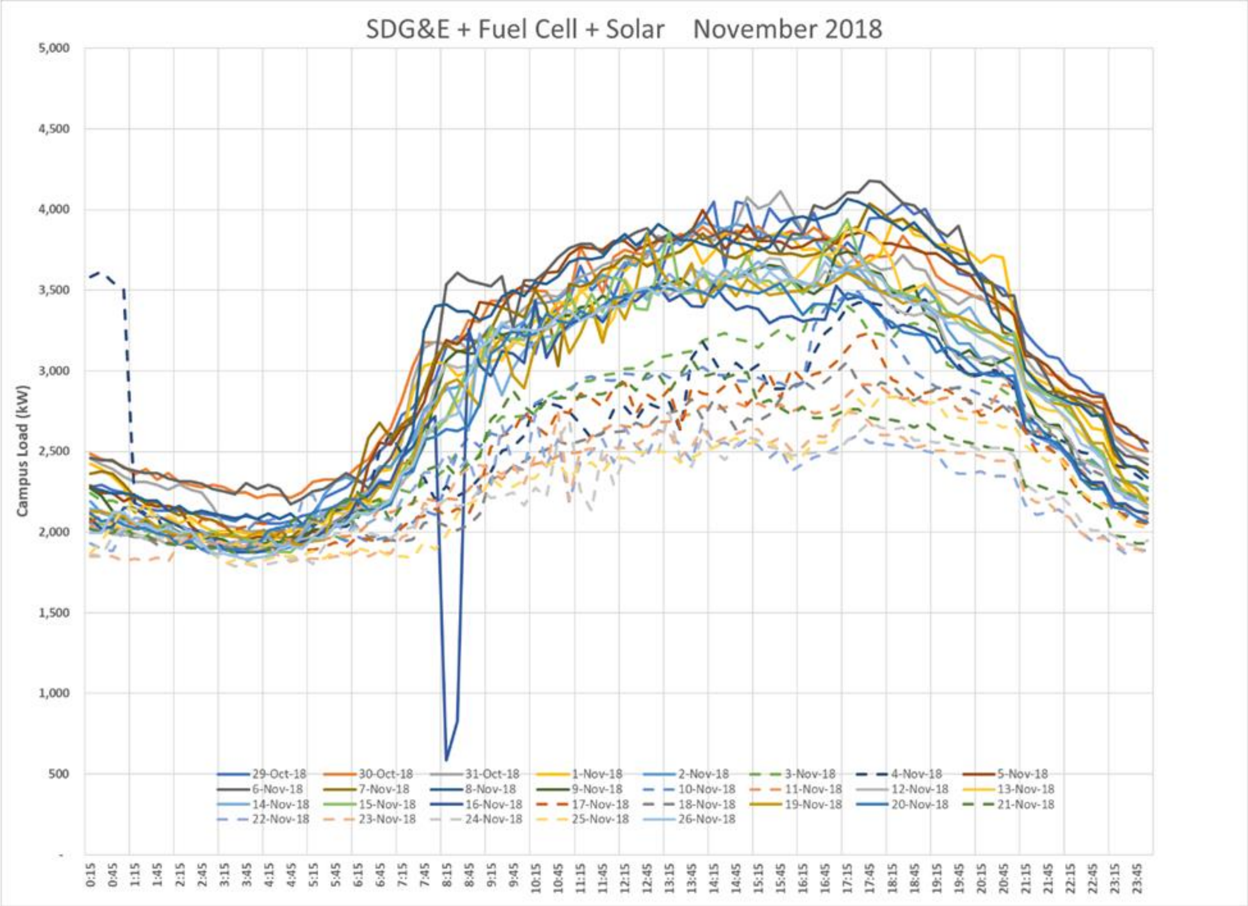
This graph shows one day (August 9) whose electric load is up to 500 kW above normal loads for a number of hours. This is the first of a number of building load profiles that have unexplained periods of significant load increases.



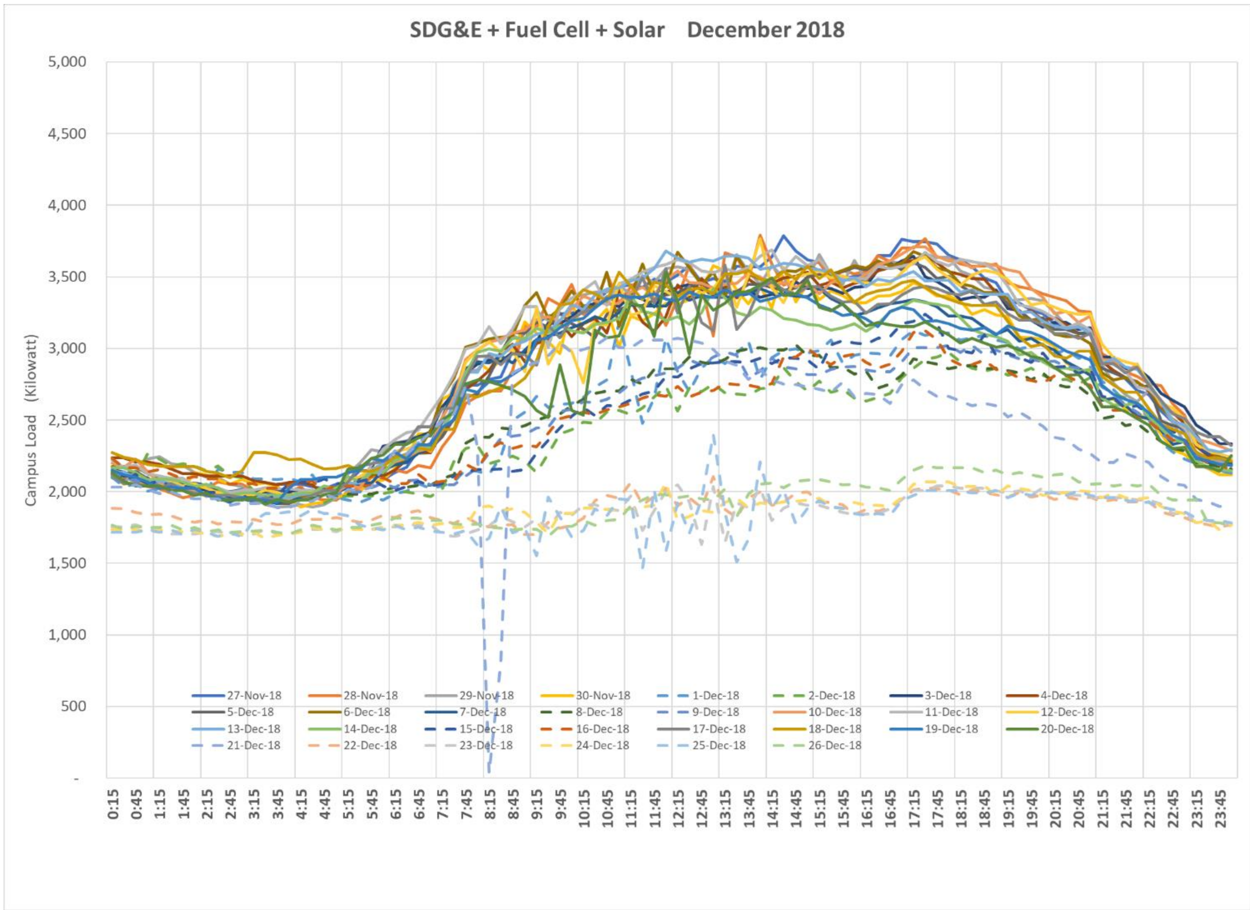
This figure of September's electric load is similar to August, with less of a load reduction during weekend days. The weekend/holiday load is almost as high as the weekday load for most days.



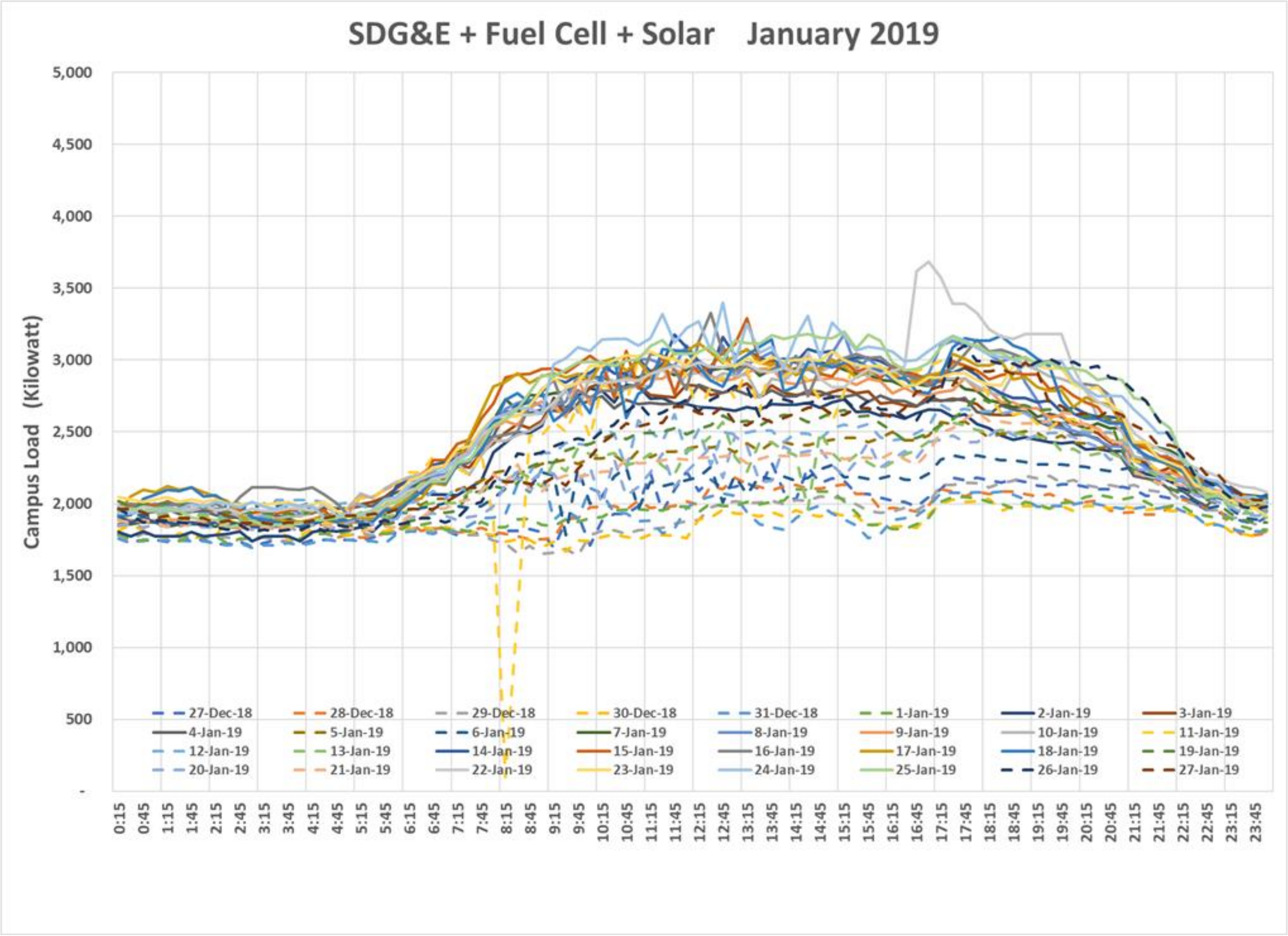
This figure of the electric load profile of October has several days that show significant departure from the typical loads. This includes one night with an extra 500 kW load, and multiple days with a similarly increased load. It is not clear from these graphs what the source of these extra loads are. We hope that analysis of the 15-minute data from electric meters on individual buildings will help identify where these additional loads are occurring.



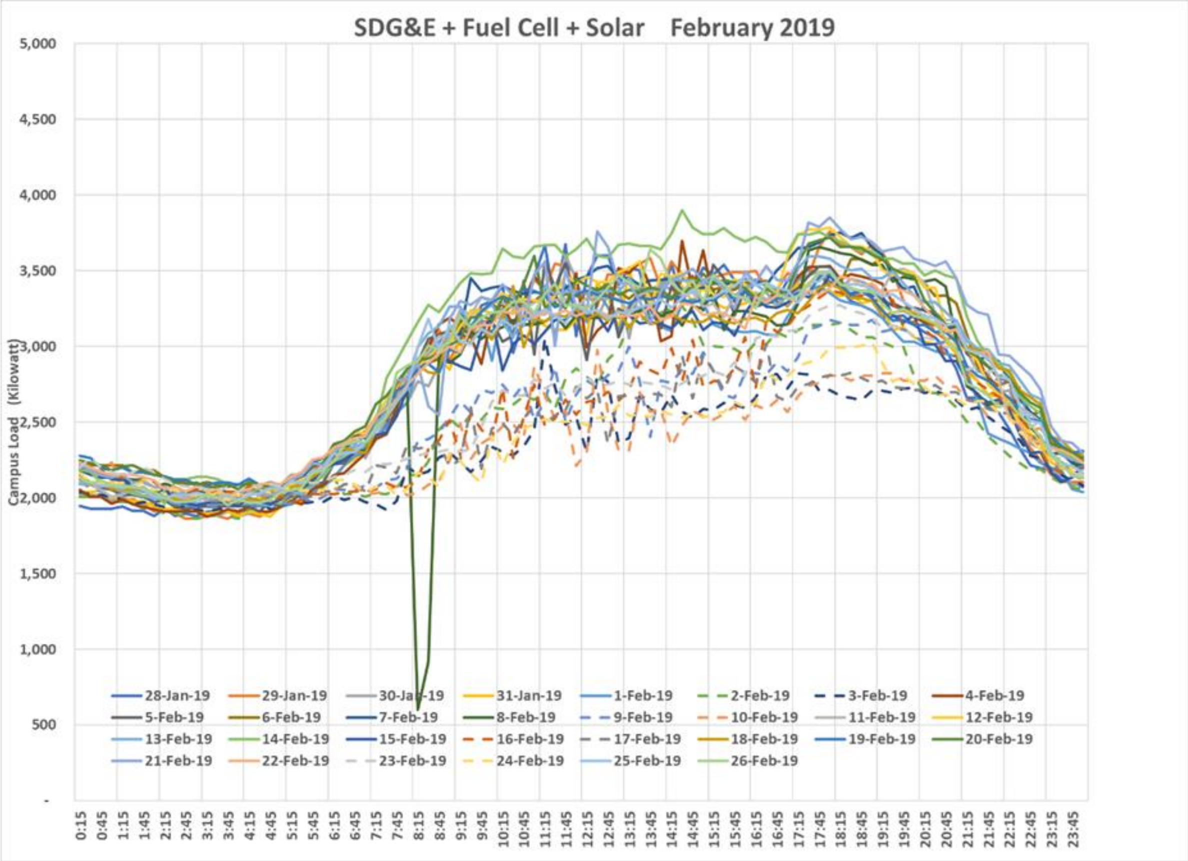
This figure of the electric load profiles for days in November show a fairly uniform pattern during weekdays, and a similar, though lower, cluster during weekends and holidays. There is a separation between the two, as opposed to September, for example, when they overlapped. There is also an unidentified 1,000 kW load that appears for an hour during the middle of the night on November 4.



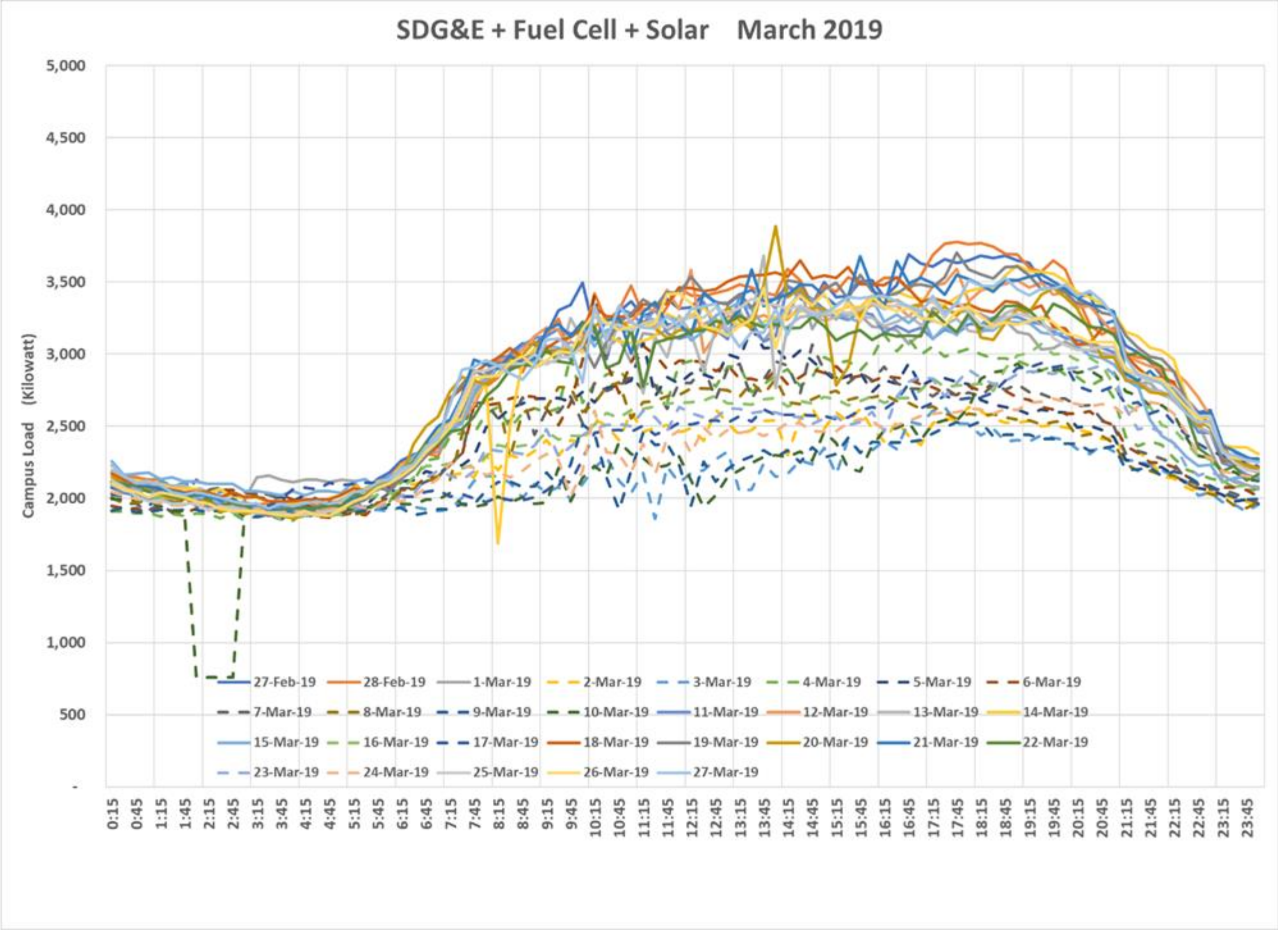
This figure of the December electric load profiles fall into three categories. These include weekdays, weekend days, and vacation days. The vacation days around Christmas are the lowest loads of the year, averaging 1,800 kW during the night and 2,000 kW during the day. The loads on the weekend days are closer to the weekday loads than the vacation loads. Presumably this is because the dorms are still occupied on weekend days, even if there are lower loads in classroom and lab buildings.



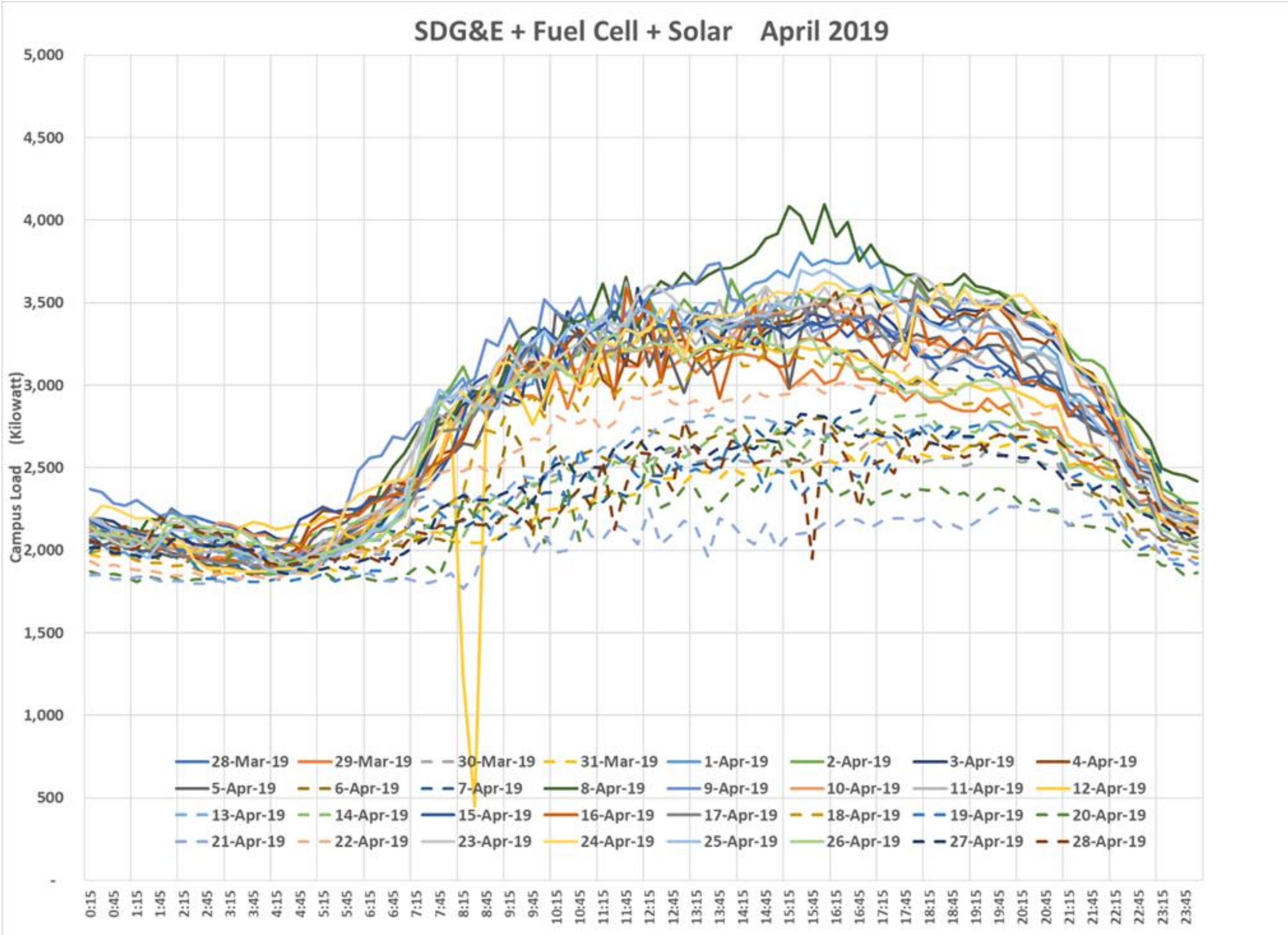
This figure of the January electric load profiles are very similar to December's. The early days match the vacation loads during the last days of the December bill. The weekday loads are lower than in December, presumably due to the level of activities during the Intersession which lasts 3 weeks in January.



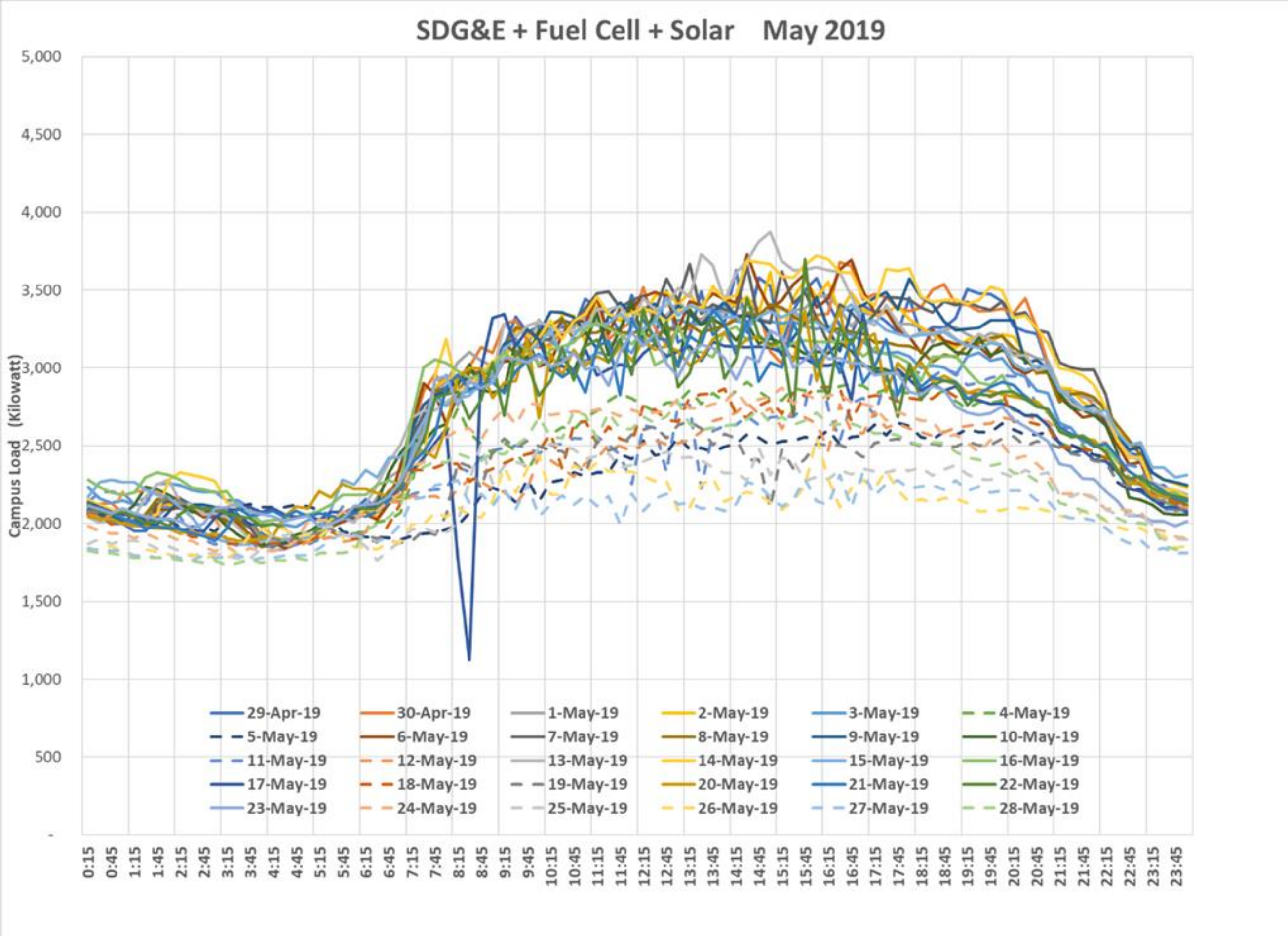
This figure of February shows the weekday electric loads jumping up during weekdays, and especially weekday nights, presumably because of nighttime courses. The weekend loads jump up as well, typically over 2,500 kW. It is not clear why the weekend and vacation electricity ramps up during each day. It is also noted that the weekend days tend to have load swings of 500 kW or greater in an hour or so.



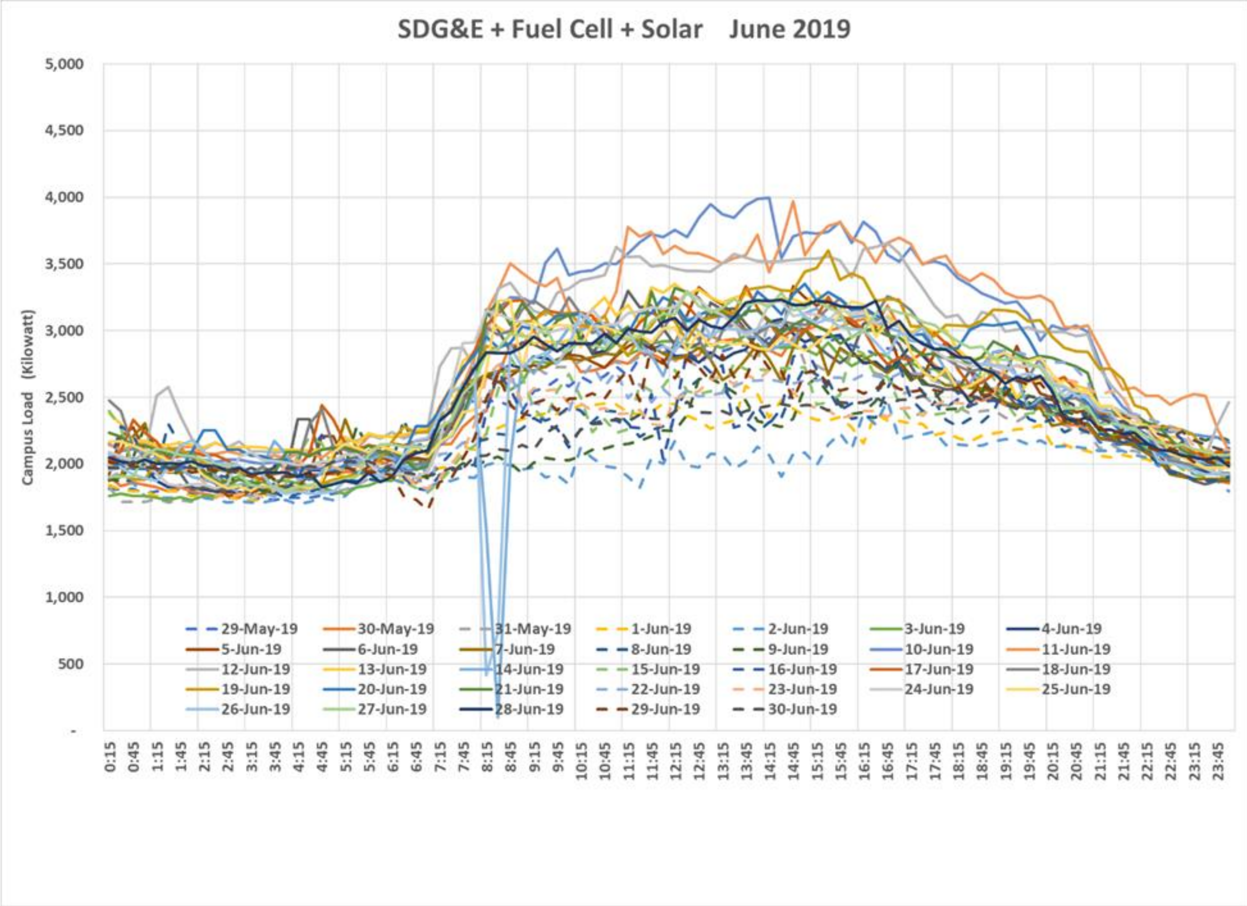
This figure of the electric load profile during the month of March is relatively consistent, with a uniform weekday load and an evenly spread weekend load.



This figure of the electric load profile in April is quite similar to that of March, with the exception of one peak day (April 8) that exceeds 4,000 kW.



This figure of the electric load profile for the month of May tracks has some weekdays with cyclic variations in load of several hundred kW.



This figure of the electric load profile in June closely follows that of May, with the exception of June 10, 11 and 12, which have an additional load of 500 to 1,000 kW during the day till midnight. These are days of the summer sessions when loads might be expected to be lower.

Appendix E – Fuel Cell Bill Savings through Generator Controls

USD FY19 Demand Charges

Potential Demand Savings if Fuel Cells had 100% Availability	$ 106,477	Rate Schedule: AL TOU Primary — 2020 Rates
"Deemed Power" charge savings (assumed to be $3,500/yr)*	$ 3,500	
	$ 109,977	Total Potential Savings

*USD incurs "deemed power" charges when the fuel cell is shut off for reasons not under Bloom's control. We've seen $2,000 - 5,000 in annual charges due to this.

		Summer				Winter							Summer	Total
Month		Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	
On-Peak Demand	Actual	3,296	3,136	3,408	3,552	4,064	2,960	2,832	3,072	3,008	3,024	2,768	2,544	
On-Peak Demand	Potential	2,992	3,136	3,408	3,552	3,344	2,960	2,832	3,072	3,008	3,024	2,768	2,544	
On-Peak Demand	Delta	304	-	-	-	720	-	-	-	-	-	-	-	
On-Peak Demand	Rate ($/kW)	$ 18.95	$ 18.95	$ 18.95	$ 18.95	$ 19.12	$ 19.12	$ 19.12	$ 19.12	$ 19.12	$ 19.12	$ 19.12	$ 18.95	
On-Peak Demand	Savings	$ 5,761	$ -	$ -	$ -	$ 13,766	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 19,527
Caused by Generator Test?		No				No								
Fuel Cell On?		No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Non-Coincident Demand	Actual	3,968	4,064	3,408	3,552	4,064	3,120	2,832	3,312	3,008	3,024	2,976	3,168	
Non-Coincident Demand	Potential	3,104	3216	3,408	3,552	3,344	2,960	2,832	3,104	3,008	3,024	2,768	2,544	
Non-Coincident Demand	Delta	864	848	-	-	720	160	-	208	-	-	208	624	
Non-Coincident Demand	Rate ($/kW)	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	$ 23.94	
Non-Coincident Demand	Savings	########	$ 20,301	$ -	$ -	$ 17,237	$ 3,830	$ -	$ 4,980	$ -	$ -	$ 4,980	$ 14,939	$ 86,950
Caused by Generator Test?		Yes	Yes			No	No		No			Yes	No	
Fuel Cell On?		No	No	Yes	Yes	No	No	Yes	No	Yes	Yes	No	No	
Days with Fuel Cell Shortfall		2	1	2	1	4	2	1	2	2	1	1	3	22

Appendix F – Measure Summary Table

Fiscal Year Implemented	Measure Description	Building	Building Cost	Measure Cost	Total Year Cost
2022	Generator Controls	Campus-wide	$85,000	$85,000	**$3,480,941**
	Microgrid Controls (One time costs)	Campus-wide	$215,000	$215,000	
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	SCADA / Siemens energy mgmt control upgrade	Campus-wide	$25,000	$25,000	
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Demand Response Energy Storage for STEM Battery (500 kW)	Campus-wide	$600,000	$600,000	
	Resiliency Energy Storage for Fuel Cell (500kW)	Campus-wide	$600,000	$600,000	
	Pool Pump VFDs and Controls	Pool	$27,403	$27,403	
	Pool Solar Heater and Cover	Pool	$129,028	$129,028	
	Residential Heating Electrification: Heat Pump Retrofit	Alcala Vista Apartments	$306,520	$306,520	
	Residential Domestic Hot Water Electrification: Heat Pumps	Alcala Vista Apartments	$1,127,806	$1,127,806	
	Residential HVAC Occupancy-Based Controls	Alcala Vista Apartments	$96,000	$96,000	
	Water Conserving Shower Heads	Various Bldgs	$21,700	$21,700	
2023	Continuous Commissioning (5-yr Pilot Program)	Campus-wide	$250,000	$250,000	**$1,824,967**
	Lighting Fixture Replacement	East Tennis Courts	$28,978	$1,077,483	
		Fowler Park and Cunningham Field	$373,285		
		Hahn University Center	$35,645		
		Jenny Craig Pavilion Arena	$84,000		
		Joan Kroc Parking Garage	$38,125		
		Main Parking Structure	$30,240		
		Manchester Village	$36,354		
		Mother Rosalie Hill Hall	$25,459		
		San Buenaventura	$34,450		
		Shiley Science Center	$43,650		
		Torero Stadium	$241,537		
		Valley Field	$87,360		
		Warren Hall	$18,400		
	Air Handler Controls: Dynamic VAV Optimization	All VAV AHUs except Shiley	$250,000	$250,000	
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	

Fiscal Year Implemented	Measure Description	Building	Building Cost	Measure Cost	Total Year Cost
2024	Central Chilled Water Plant Pumping - Demand Flow Controls	Central Plant	$330,000	$330,000	$2,563,566
	Constant Volume AHU Retrofit: VFDs + Controls	Various Bldgs	$182,382	$182,382	
	Continuous Commissioning (5-yr Pilot Program)	Campus-wide	$250,000	$250,000	
	HVAC Major Renovation: Variable Refrigerant System	Hughes Administration Center	$175,000	$175,000	
	Lighting Fixture Replacement	Manchester Valley Field	$141,398	$141,398	
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Hahn University Center	$212,703	$388,302	
		Loma Hall	$53,170		
		Shiley Science Center	$122,429		
	Residential HVAC Occupancy-Based Controls	Mission Housing	$180,000	$299,000	
		Maher Hall	$47,000		
		Manchester Village Apartments	$51,500		
		San Antonio de Padua	$20,500		
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Weatherization of Various Buildings	Various Bldgs	$550,000	$550,000	
2025	Continuous Commissioning (5-yr Pilot Program)	Campus-wide	$250,000	$250,000	$2,997,484
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Shiley Fume Hood Control Upgrade	Shiley Science Center	$2,500,000	$2,500,000	
2026	Continuous Commissioning (5-yr Pilot Program)	Campus-wide	$250,000	$250,000	$1,534,036
	HVAC Major Renovation: Variable Refrigerant System	Maher Hall	$550,000	$550,000	
	Kitchen Equipment Electrification	Student Life Pavilion	$94,595	$94,595	
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	Non-Residential Domestic Hot Water Electrification: Heat Pump	Sports Complex	$65,754	$65,754	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Student Life Pavilion	$214,203	$214,203	
	Replace panelboard E1. Remove automatic transfer switch.	Maher Hall	$6,000	$6,000	
	Replace switchboard	Hughes Administration Center	$30,000	$30,000	
	Replace switchboard MSB-2	Maher Hall	$40,000	$40,000	
	Replace switchboard TSF	Torero Stadium	$30,000	$30,000	
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Relocating breakers into panelboard fed by switchboard.	Serra Hall	$6,000	$6,000	

Fiscal Year Implemented	Measure Description	Building	Building Cost	Measure Cost	Total Year Cost
2027	HVAC Major Renovation: Variable Refrigerant System	Loma Hall	$230,000	$540,000	$1,900,894
		Warren Hall	$310,000		
	Kitchen Equipment Electrification	Berts Bistro	$10,965	$59,522	
		La Paloma	$48,557		
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	New Generator (Gas 1 MW)	Campus-wide	$500,000	$500,000	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Joan B Kroc Instute for Peace and Justice	$101,690	$154,860	
		Pardee Legal Research Center	$53,170		
	Continuous Commissioning (5-yr Pilot Program)	Campus-wide	$250,000	$250,000	
	Pool Solar Heater and Cover	Pool	$129,028	$129,028	
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Replace switchboard MSB	Hahn School of Nursing	$20,000	$20,000	
2028	HVAC Major Renovation: Variable Refrigerant System	Pardee Legal Research Center	$330,000	$705,000	$1,185,543
		Serra Hall	$375,000		
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Carbon Offsets	Campus-wide	$2,599	$2,599	
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Degheri Alumni Center	$53,170	$230,460	
		Manchester Conference Center	$70,950		
		Olin Hall	$53,170		
		Sacred Heart Hall	$53,170		
2029	HVAC Major Renovation: Variable Refrigerant System	Olin Hall	$205,000	$205,000	$2,034,591
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Hahn School of Nursing	$53,170	$53,170	
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Carbon Offsets	Campus-wide	$13,315	$13,315	
	Residential Domestic Hot Water Electrification: Heat Pumps	Mission Housing	$1,515,622	$1,515,622	

Fiscal Year Implemented	Measure Description	Building	Building Cost	Measure Cost	Total Year Cost
2030	HVAC Major Renovation: Variable Refrigerant System	Joan B Kroc Instute for Peace and Justice	$475,000	$550,000	$1,605,194
		Manchester Conference Center	$75,000		
	Kitchen Equipment Electrification	University Center	$185,954	$185,954	
	Energy Storage replacement for STEM Battery (500kW)	Campus-wide	$600,000	$600,000	
	EV Infrastructure	Campus-wide	$77,484	$77,484	
	Carbon Offsets	Campus-wide	$21,756	$21,756	
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
2031	HVAC Major Renovation: Variable Refrigerant System	Degheri Alumni Center	$140,000	$485,000	$2,146,387
		Sacred Heart Hall	$95,000		
		Student Life Pavilion	$250,000		
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	New Generator (Diesel 2MW)	Campus-wide	$1,000,000	$1,000,000	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Serra Hall	$317,046	$370,216	
		Warren Hall	$53,170		
	Carbon Offsets	Campus-wide	$33,171	$33,171	
	Residential HVAC Occupancy-Based Controls	San Buenaventura	$88,000	$88,000	
2032	HVAC Major Renovation: Variable Refrigerant System	Mother Rosalie Hill Hall Institute for Peace and Justice	$765,000	$765,000	$2,768,996
	Pool Pump VFDs and Controls	Pool	$27,403	$27,403	
	Pool Solar Heater and Cover	Pool	$129,028	$129,028	
	Water Conserving Shower Heads	Various Bldgs	$21,700	$21,700	
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	Residential Domestic Hot Water Electrification: Heat Pumps	Alcala Vista Apartments	$1,127,806	$1,127,806	
	Carbon Offsets	Campus-wide	$28,059	$28,059	
	New Generator (Gas 1 MW)	Campus-wide	$500,000	$500,000	

Fiscal Year Implemented	Measure Description	Building	Building Cost	Measure Cost	Total Year Cost
2033	HVAC Major Renovation: Variable Refrigerant System	Copley Library	$231,870	$588,370	$1,527,024
		Facilities Bldg	$36,500		
		Sports Complex	$320,000		
	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Copley Library	$53,170	$372,339	
		Jenny Craig Pavilion Arena	$319,169		
	Residential Domestic Hot Water Electrification: Heat Pumps	Camino Hall	$267,615	$267,615	
	Residential Heating Electrification: Heat Pump Retrofit	Camino Hall	$84,590	$84,590	
	Carbon Offsets	Campus-wide	$20,610	$20,610	
	Residential HVAC Occupancy-Based Controls	Camino Hall	$23,500	$23,500	
2034	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	$2,475,059
	Non-Residential Domestic Hot Water Electrification: Heat Pump	Maher Hall	$53,170	$53,170	
	Non-Residential Domestic Hot Water Electrification: Reverse Cycle Chillers	Mother Rosalie Hill Hall Institute for Peace and Justice	$101,690	$101,690	
	Residential Domestic Hot Water Electrification: Heat Pumps	Founders Hall	$411,488	$1,802,900	
		Maher Hall	$553,769		
		Manchester Village Apartments	$579,769		
		San Antonio de Padua	$257,874		
	Residential Heating Electrification: Heat Pump Retrofit	Founders Hall	$125,840	$283,740	
		Maher Hall	$157,900		
	Carbon Offsets	Campus-wide	$27,559	$27,559	
	Residential HVAC Occupancy-Based Controls	Founders Hall	$36,000	$36,000	
2035	Microgrid Controls (Recurring Costs)	Campus-wide	$170,000	$170,000	$1,099,266
	Carbon Offsets	Campus-wide	$37,331	$37,331	
	Residential Domestic Hot Water Electrification: Heat Pumps	San Buenaventura	$891,935	$891,935	
		Total	**$29,143,947**	**$29,143,947**	**$29,143,947**

Appendix G – Fleet Vehicle Types, EVSE Load, Costs and Annual kWh

Vehicle Types

The provided fleet data shows three major vehicle types - **Cars and Light Duty Trucks, Medium and Heavy-Duty Vehicles and Golf Carts**. Each vehicle type is replaced with an appropriate proxy vehicle commercially available in the market today.

The table below shows the assumed replacements for each vehicle type along with representative efficiencies. The efficiency figures for the proxy vehicles are determined using figures from EPA's Fuel Economy website.

Existing Vehicle Type	Proxy Vehicle	Efficiency (kWh/100 mil)
Sedan	2020 Tesla Model S Standard Range	31
Minivan	2020 Chrysler Pacifica Hybrid	41
Van	Ford E Transit	60
Pickup Truck	Rivian R1T 135kWh	45
Food Truck	Electric UPS Delivery Van	65
Hybrid Sedans	2020 Chevy Bolt EV	29
SUV	2020 Tesla Model Y Performance AWD	28
Diesel Bus	BYD C10M Coach	232
Paratransit Bus	Lightning Systems Electric Ford Transit (120 mil Range)	107.5

Using efficiency figures for the existing proxy vehicles, the daily energy (kWh) required was calculated using the formula -

$$Daily\ kWh\ energy\ required\ \left(\frac{kWh}{day}\right) = Daily\ Vehicle\ Miles\ Travelled\ \left(\frac{miles}{day}\right) * Efficiency\ \left(\frac{kWh}{100miles}\right)$$

For the **Golf Carts,** an internet study was used to determine representative efficiency figures. Estimated efficiency per hour of runtime falls in the range of **2.5 kWh/h – 2.7 kWh/h**. The daily energy (kWh) was then estimated as -

$$Daily\ kWh\ energy\ required\ \left(\frac{kWh}{day}\right) = Daily\ Vehicle\ Hours\ Travelled\ \left(\frac{hours}{day}\right) * Efficiency\ \left(\frac{kWh}{hours}\right)$$

EVSE Description -

Assumptions regarding EV charging loads (kW) were developed using the proxy vehicles listed above and EVSE commercially available today for representative charging efficiencies and respective pricing. Also, the selected EVSE's are based on products that qualify for the [SDG&E Power Your Drive for Fleets Program](). More information on this program is provided later in this appendix.

The table below shows the description, features and the costs estimates for individual charger types. Chargepoint hardware was selected as a conservative estimation of project cost since these more fully featured products are also more expensive than simpler competitors.

Proxy Charger Description	Charger Type	Maximum Power (kW)	Unit Cost ($)	Installation Cost ($)	O&M Cost ($)	Total Cost ($)	Potential Incentive (S)
ChargePoint CT4011-GW1 Gateway Unit	L2 Single Port Charger	7.2	$5,010	$4,220.00	$625.00	**$9,855**	$3,000
ChargePoint CT4021 - GW1 Gateway Unit	L2 Dual Port Charger	14.4	$7,210	$5,220.00	$650.00	**$13,080**	$3,000
ChargePoint Express 250	L3 Dual Port Charger	62.5	$40,800	$17,500.00	$1,600.00	**$59,900**	$45,000
EZGO RXV & TXT, FORM 15 AMP, 48V	Golf Cart Charger	0.72	$290	-	-	**$290**	n/a

- The installation costs include cost for labor, trenching total 10 ft. (8 feet of asphalt and 2 feet of soil), service upgrades, permitting, inspection and engineering review.
- The O&M Cost include maintenance, repair and charging network fee costs.
- Incentives shown are through SDG&E's Power My Drive Fleets Program and are subject to availability for qualifying vehicles.

Golf Cart Chargers can be plugged in at 110V plugs and can be considered as L1 chargers. Since, they don't require heavy installation and maintenance as compared to L2 and L3 chargers, the costs are assumed to be negligible.

EVSE Load, Costs and Annual kWh -

Assumptions regarding EV charging loads for each department were developed using existing proxy vehicles and EVSE commercially available today for representative efficiency figures and respective pricing.

The table below shows the quantity and total costs for the chargers, the kW load, daily kWh (with and without charging losses) and the annual kWh required.

Vehicle Type	Chargers Required	Quantity	Total Charger Costs	kW	Daily kWh (w/o charging losses)	Daily kWh (with losses)	Annual kWh
	L2 Single-Port	2	$19,710.00				
	L2-Dual Port	16	$209,280.00	432	363.13	417.60	152,422

Cars and Light Duty Trucks	L3 Dual-Port	3	$179,700.00				
Medium and Heavy Duty	L2 Dual-Port	2	$26,160.00				
	L3 Dual-Port	4	$239,600.00	279	455.40	523.71	191,154
Golf Cart	Golf Cart Charger	79	$22,906.05	130	52.77	60.68	22,149
Total			**$697,356.05**	**841**	**871.29**	**1001.99**	**365,725**

- The annual kWh is estimated using a charger efficiency of 85%.
- Due to the low power output of the golf cart chargers, each golf cart is assigned one charger.

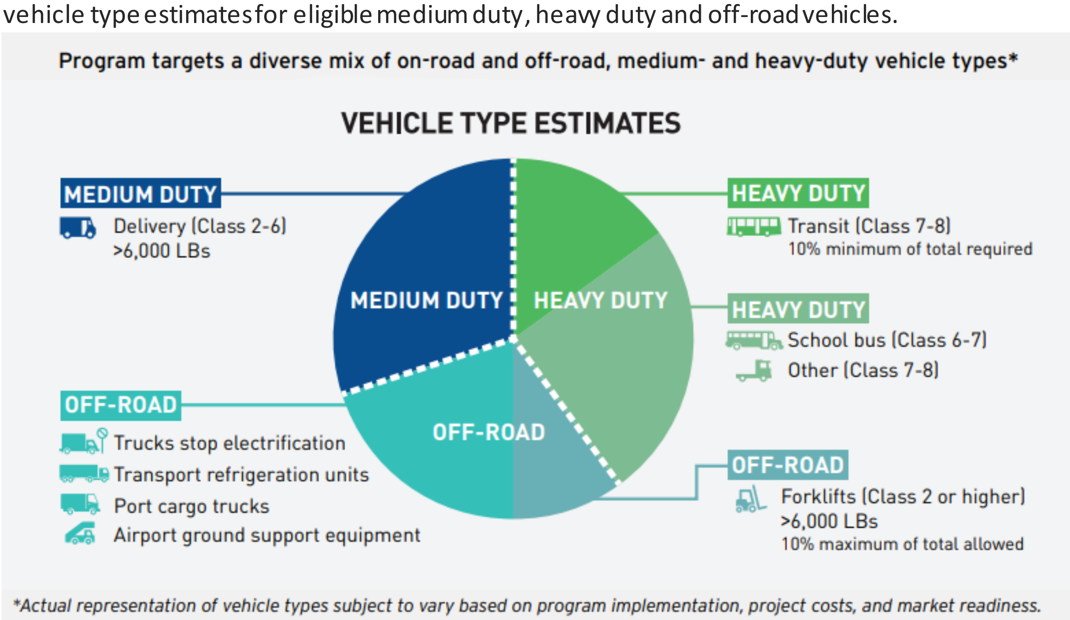
<u>**Incentive Programs**</u> –

Power Your Drive *for* Fleets is an incentive program by SDG&E to support their customers converting their fleets of vehicles to electric.

Program Intent –
Power Your Drive for fleets helps fleet owners and operators reduce fuel and operational costs, eliminate emissions, help meet sustainability goals and simplify vehicle maintenance by transitioning to electric vehicles.

How it Works?
SDG&E helps install make-ready charging infrastructure for medium- and heavy-duty electric vehicles, working with fleets from the initial infrastructure planning through to design, construction, and ongoing site-maintenance.
The goal of the program is to serve a minimum of 3,000 medium- and heavy-duty on-road and off-road class 2-8 vehicles at 300 customer sites throughout SDG&E's service area.

Program Eligibility -
Power Your Drive is applicable to Class 2-8, on-road and off-road vehicles. The snip below shows the vehicle type estimates for eligible medium duty, heavy duty and off-road vehicles.

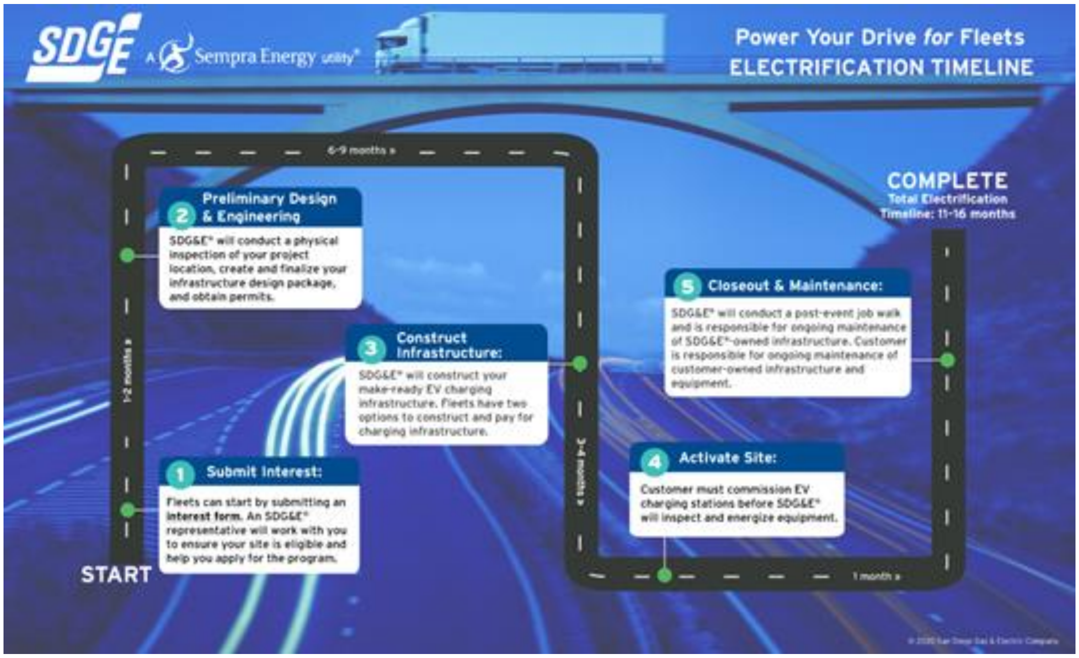


Program Requirements –

To be eligible to receive funding through the Power Your Drive *for* Fleets Program, fleets must first meet the four basic criteria below:

- Demonstrate commitment to procure **a minimum of 2 electric vehicles**
- Demonstrate **long-term electrification growth** plan and schedule of load increase
- **Provide data** related to charger usage for a minimum of **5 years**
- Own or lease the property where chargers are installed, and operated and maintain vehicles and chargers **for minimum of 10 years**

Electrification Timeline –



Infrastructure Installation Options –

Fleets have two options to construct and pay for charging infrastructure.

Option 1: SDG&E Owned, No Cost Installation

- SDG&E pays for, constructs, owns, and maintains all infrastructure up to the charging station.
- Customer pays for, constructs, owns, and maintains charging stations.

Option 2: Customer Owned, Rebates to Reduce Installation Costs:

- SDG&E pays for, constructs, owns, and maintains all infrastructure up to the meter.
- Customer pays for, constructs, owns, and maintains "customer-side infrastructure" and charging stations. See the list of program-approved vendors for charging equipment.
- SDG&E provides a rebate of up to 80% of the cost of "customer-side infrastructure" is available.

See Infrastructure Installation Options for more details

Understanding Charging Infrastructure -

There is more to powering an electric fleet than simply charging the vehicle. Proper infrastructure considerations are critical to the success of medium- and heavy-duty fleet electrification.

Below are the most common infrastructure terms used throughout the Power Your Drive *for* Fleets Program.

Make-Ready Infrastructure	All electrical infrastructure required to "make" a commercial site "ready" for EV charging not including the actual charger. This can include upgrades to transformers, concrete work, and increases to service capacity.
Utility-Side Infrastructure	This includes all electrical infrastructure up to the customer's meter.
Customer-Side Infrastructure	This includes all electrical infrastructure on the customer's property.
EV Charging Station	The equipment that physically plugs into and charges the electric vehicle. In either ownership option, the fleet owner/operator is responsible for purchasing, constructing, and maintaining the EV charging stations. Also referred to as "EVSE" or electric vehicle supply equipment. See our list of program-approved vendors for charging equipment.

Charging Rates and Rebate Amounts Available -

For fleets that are currently electrifying their vehicles, SDG&E offers an Interim EV Charging Rate that helps provide relief from demand charges.

Additionally, SDG&E has proposed a new optional high powered EV (EV-HP) rate for separately metered commercial EV customers that will replace demand charges with a new subscription pricing plan. If approved, the proposed EV-HP rate will become available in 2021.

Maximum Rebate Amounts Available

EVSE power	Max. rebate amount*
Up to 19.2 kW	$3,000 per charger
19.3 kW up to 50 kW	$15,000 per charger
50.1 kW up to 150 kW	$45,000 per charger
150.1 kW and above	$75,000 per charger

**Eligible sites will receive a rebate for each qualified charger for the lesser of 50% of the cost of the charger or the maximum amount based on power output as detailed above, not to exceed 50% of the cost of the charger*

Fleet Resources –

In addition to funding, site planning and construction support available through the Power Your Drive *for* Fleets program, SDG&E connects fleets with below resources to help navigate EV infrastructure, charging rates, and funding opportunities. More information on these resources can be found here.

While Power your Drive for Fleets only covers EVSE infrastructure and not the vehicles themselves, there are a number of other incentive programs that help defer the additional cost of purchasing an electric vehicle vs. a standard internal combustion one. SDG&E lists those programs here.

Appendix H – Electrical Efficiency Projects & Recommendations

MICHAEL WALL ENGINEERING

21.1.2 Exterior Lighting Projects

1. **Torero Stadium**

Torero Stadium		
EEM LTG E1	**Lighting Fixture Replacement**	
There are currently 4 sports lighting poles with a total of 88 metal halide fixtures lighting the field. The recommendation is to replace the fixtures with high efficiency LED lighting. The existing sports lighting manufacturer, Musco Sports Lighting would replace existing light fixture heads without replacing the structural pole for the best economical solution.		
Projected Savings:		
Existing Annual Energy Usage:		327,900 kWh
Proposed Annual Energy Savings:		206,500 kWh
Proposed Annual Cost Savings:		$36,700
Implementation Requirements:		
Proposed Project Costs:		$240,000
Simple Payback:		6.53 years

2. **Fowler Park and Cunningham Field**

Fowler Park and Cunningham Field		
EEM LTG E2	**Lighting Fixture Replacement**	
There are currently 8 sports lighting poles with a total of 136 metal halide fixtures lighting the field. The recommendation is to replace the fixtures with high efficiency LED lighting. The existing sports lighting manufacturer, Musco Sports Lighting would replace existing light fixture heads without replacing the structural pole for the best economical solution.		
Projected Savings:		
Existing Annual Energy Usage:		506,700 kWh
Proposed Annual Energy Savings:		319,000 kWh
Proposed Annual Cost Savings:		$56,700
Implementation Requirements:		
Proposed Project Costs:		$373,300
Simple Payback:		6.58 years

3. **Manchester Valley Field**

Manchester Valley Field		
EEM LTG E3	**Lighting Fixture Replacement**	
There are currently 7 sports lighting poles with a total of 52 metal halide fixtures lighting the field. The recommendation is to replace the fixtures with high efficiency LED lighting. The existing sports lighting manufacturer, Musco Sports Lighting would replace existing light fixture heads without replacing the structural pole for the best economical solution.		
Projected Savings:		
Existing Annual Energy Usage:		193,700 kWh
Proposed Annual Energy Savings:		122,000 kWh
Proposed Annual Cost Savings:		$21,700
Implementation Requirements:		
Proposed Project Costs:		$141,400
Simple Payback:		6.51 years

4. **Valley Field**

Valley Field		
EEM LTG E4	**Lighting Fixture Replacement**	
There are currently 4 sports lighting poles with a total of 32 metal halide fixtures lighting the field. The recommendation is to replace the fixtures with high efficiency LED lighting. The existing sports lighting manufacturer, Musco Sports Lighting would replace existing light fixture heads without replacing the structural pole for the best economical solution.		
Projected Savings:		
Existing Annual Energy Usage:		119,200 kWh
Proposed Annual Energy Savings:		75,000 kWh
Proposed Annual Cost Savings:		$13,300
Implementation Requirements:		
Proposed Project Costs:		$87,000
Simple Payback:		6.54 years

5. **East Tennis Courts**

East Tennis Courts			
	EEM LTG E5	**Lighting Fixture Replacement**	
	There are currently 4 tennis courts with 24 metal halide shoebox-style poletop mounted fixtures lighting the courts that use 1080W per fixture. The recommendation is to replace the fixtures with high efficiency LED lighting and add photocell and dimming control that automatically maintains lighting levels while harvesting the ambient light. Additionally, the lighting will be minimized to 6 fixtures at 50% output during unoccupied times and a rheostat timer to be used by the participant with a 2-hour maximum time.		
	Projected Savings:		
	Existing Annual Energy Usage:		56,500 kWh
	Proposed Annual Energy Savings:		50,000 kWh
	Proposed Annual Cost Savings:		$8,200
	Implementation Requirements:		
	Proposed Project Costs:		$29,000
	Simple Payback:		3.54 years

21.1.3 Interior Lighting Projects

1. **Manchester Village**

Manchester Village		
	EEM LTG E6	**Lighting Fixture Retrofit or Replacement**

	There are currently approximately 197 fixtures with fluorescent T8 lamps that can be retrofitted or replaced with an LED equivalent fixture. This savings only includes upgrading the lighting controls for the stairwells to have 50% output when unoccupied by an occupancy sensor integral to the fixture, and therefore part of the fixture cost. The project cost is based on a per-fixture retrofit or replacement cost, including labor cost.	
	Projected Savings:	
	Existing Annual Energy Usage:	56,200 kWh
	Proposed Annual Energy Savings:	37,100 kWh
	Proposed Annual Cost Savings:	$5,600
	Implementation Requirements:	
	Proposed Project Costs:	$36,300
	Simple Payback:	6.48 years

2. **Shiley Science and Technology**

Shiley Science and Technology		
	EEM LTG E7	**Lighting Fixture Retrofit or Replacement**
	There are currently approximately 194 fixtures with fluorescent T8 lamps or downlights with non-LED lamps that can be retrofitted or replaced with an LED equivalent fixture. This savings only includes upgrading the lighting controls for the fixtures that are not currently controlled to have 50% output when unoccupied by an occupancy sensor integral to the fixture, and therefore part of the fixture cost, excluding elevator lighting.	
	Projected Savings:	
	Existing Annual Energy Usage:	80,800 kWh
	Proposed Annual Energy Savings:	63,435 kWh
	Proposed Annual Cost Savings:	$7,600
	Implementation Requirements:	
	Proposed Project Costs:	$43,650
	Simple Payback:	5.74 years

3. **Mother Rosalie Hill Hall**

Mother Rosalie Hill Hall		
	EEM LTG E8	**Lighting Fixture Retrofit or Replacement**
	There are currently approximately 110 fixtures with fluorescent T8 lamps, chandeliers or downlights with non-LED lamps that can be retrofitted or replaced with an LED equivalent fixture.	
	Projected Savings:	
	Existing Annual Energy Usage:	47,114 kWh
	Proposed Annual Energy Savings:	30,926 kWh
	Proposed Annual Cost Savings:	$4,500

	Implementation Requirements:	
	Proposed Project Costs:	$25,450
	Simple Payback:	5.66 years

4. **Jenny Craig Pavilion Arena**

Jenny Craig Pavilion Arena		
	EEM LTG E9	**Lighting Fixture Retrofit or Replacement**
	There are currently approximately 70 fixtures with 1000W metal halide lamps that can be replaced with an LED equivalent fixture. Calculated savings does not include reduced hours, but new capability of instant on/off and dimming will increase savings opportunity.	
	Projected Savings:	
	Existing Annual Energy Usage:	173,880 kWh
	Proposed Annual Energy Savings:	122,360 kWh
	Proposed Annual Cost Savings:	$25,000
	Implementation Requirements:	
	Proposed Project Costs:	$84,000
	Simple Payback:	3.35 years

5. San **Buenaventura**

San Buenaventura		
	EEM LTG E10	**Lighting Fixture Retrofit or Replacement**
	There are currently approximately 248 fixtures with fluorescent T8 lamps or compact fluorescent lamps that can be retrofitted or replaced with an LED equivalent fixture.	
	Projected Savings:	
	Existing Annual Energy Usage:	71,894 kWh
	Proposed Annual Energy Savings:	43,332 kWh
	Proposed Annual Cost Savings:	$5,000
	Implementation Requirements:	
	Proposed Project Costs:	$34,500
	Simple Payback:	6.9 years

6. **Hahn University Center**

Hahn University Center		
	EEM LTG E11	**Lighting Fixture Retrofit or Replacement**
	There are currently approximately 314 fixtures with fluorescent T8 lamps or compact fluorescent lamps that can be retrofitted or replaced with an LED equivalent fixture.	

	Projected Savings:	
	Existing Annual Energy Usage:	62,566 kWh
	Proposed Annual Energy Savings:	42,984 kWh
	Proposed Annual Cost Savings:	$6,700
	Implementation Requirements:	
	Proposed Project Costs:	$35,600
	Simple Payback:	5.32 years

7. **Warren Hall**

Warren Hall	
EEM LTG E12	**Lighting Fixture Retrofit or Replacement**
There are currently approximately 92 fixtures with fluorescent T8 lamps that can be retrofitted or replaced with an LED equivalent fixture. This savings only includes upgrading the lighting controls for the fixtures that are not currently controlled to have 50% output when unoccupied by an occupancy sensor integral to the fixture, and therefore part of the fixture cost.	
Projected Savings:	
Existing Annual Energy Usage:	33,849 kWh
Proposed Annual Energy Savings:	26,026 kWh
Proposed Annual Cost Savings:	$2,700
Implementation Requirements:	
Proposed Project Costs:	$18,400
Simple Payback:	6.84 years

21.1.4 Parking Garage Lighting Projects

8. **Joan Kroc Parking Garage**

Joan Kroc Parking Garage	
EEM LTG E13	**Lighting Fixture Retrofit or Replacement**
There are currently approximately 207 fixtures with fluorescent T8 lamps or compact fluorescent lamps that can be retrofitted or replaced with an LED equivalent fixture.	
Projected Savings:	
Existing Annual Energy Usage:	95,817 kWh
Proposed Annual Energy Savings:	50,642 kWh
Proposed Annual Cost Savings:	$5,700
Implementation Requirements:	
Proposed Project Costs:	$38,000
Simple Payback:	6.67 years

9. **Main Parking Structure**

Main Parking Structure	
EEM LTG E14	**Lighting Fixture Retrofit or Replacement**
There are currently approximately 168 fixtures with fluorescent T8 lamps that can be retrofitted or replaced with an LED equivalent fixture.	
Projected Savings:	

	Existing Annual Energy Usage:	91,244 kWh
	Proposed Annual Energy Savings:	45,622 kWh
	Proposed Annual Cost Savings:	$5,150
	Implementation Requirements:	
	Proposed Project Costs:	$30,200
	Simple Payback:	5.87years

Appendix I –Site Visit Electrical Infrastructure Notes

MICHAEL WALL ENGINEERING

Note: The information below reflects existing conditions of electrical infrastructure as observed during site visit in May of 2020. Potential Projects notes reflect high level initial findings, many of which were further expanded upon within this report, while others could be of future consideration to USD.

General Campus Information

Existing Conditions

- Campus is fed primarily by a single SDG&E meter service at 12kV and serves most of the USD electrical loads.
- There are many individual meters for approximately 20 residential buildings that are on and off campus. These sites have not been reviewed for the electrical conditions or for energy conservation measures.
- The main campus primary electrical feeder is backed up by (3) 2MW 12kV diesel generators. Bill told me these generators have a controller that is programmed to respond to a Demand Response event and has the capability to feed back to the grid. Not sure if this is active or if they are signed up for a utility company Demand Response program.
- There are digital meters located at the main metered service. There are individual meters for each of the 4 load circuits to the campus and each of the 3 generators.
- There are currently approximately 38 meters throughout the campus that are metering individual buildings. According to the Siemens software product, about half of these have operable breakers to turn the building on and off. This function is not confirmed.
- Bloom Energy system is generating equivalent power to approximately a 4MW PV system.
- STEM battery system is 500kW/1000kWh utilized to lower demand charges on electric bill. This is a contract that bills USD for the reduced savings. For example, if the bill has $5000 less in monthly demand charges compared to the cost without the battery, STEM may bill USD for $2700, so USD sees a $2200 savings for allowing STEM to install their system on the campus for that month. They usually have a 5-year minimum contract. This contract most likely started in January 2019 when the battery was energized. Battery cannot be controlled by USD and therefore, cannot act backup system, etc.

Potential Projects

- Upgrade the existing mix of RS-485 twisted pair and Ethernet wiring at all of the existing meter locations to an Ethernet network that can communicate with the meters and a demand response system separately.

- Establish a common software product to communicate with existing/upgraded and new lighting control and create standardize time-clocking, override, and dimming programs for building and exterior lighting circuits.
- Create a demand-response control capability for non-lighting devices, such as receptacles and other process loads to shut off on scheduled and un-scheduled events.
- Re-lamp exterior lighting to LED with partial dimming capability.

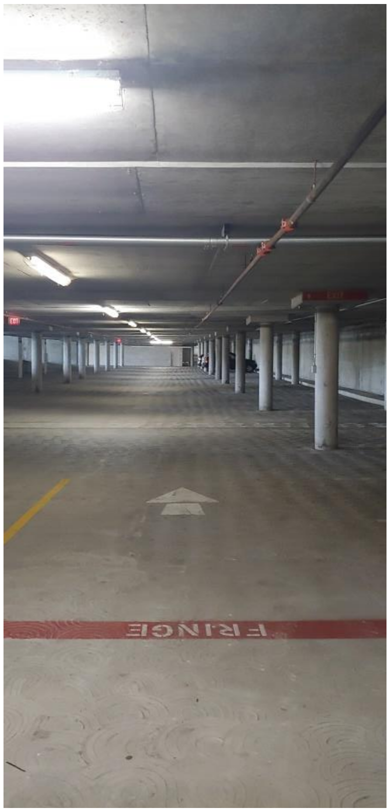
West Parking Structure

Existing Conditions

- Location of Primary SDG&E meter.
- Origination point for the (4) 12kV circuits distributed throughout the campus.
- Location of Primary Diesel Generator system for campus backup.
- Location of a 177kWAC/192kWDC PV system with 215W solar panels installed in 2010/11 by AM Solar / Designed by MWE.
- Existing garage lighting has motion sensors at each fixture.

Potential Projects

- Upsize solar panels to 400W range and achieve adding 165kWDC with the same footprint.
- Replace existing T8 fluorescent lamps with LED lamps.
- Parking lot may be candidate for PV canopy carports.



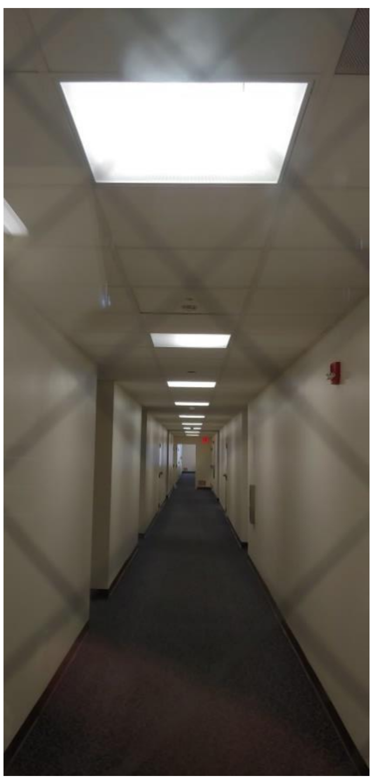
Manchester Village Apartments

Existing Conditions

- Electrical service appears to be in good condition.
- Electrical service has capacity to increase load.
- Location of a 60kWAC/58kWDC PV system on building A and duplicate PV system on building B with 215W solar panels installed in 2010/11 by AM Solar / Designed by MWE.
- Existing 'Blink' EV charging stations.
- Replace existing fluorescent lighting with LED lamps.

Potential Projects

- Upsize solar panels to 400W range and achieve adding 50kWDC with the same footprint.
- Replace existing T8 fluorescent lamps with LED lamps.
- Upgrade lighting controls and network to common management software.



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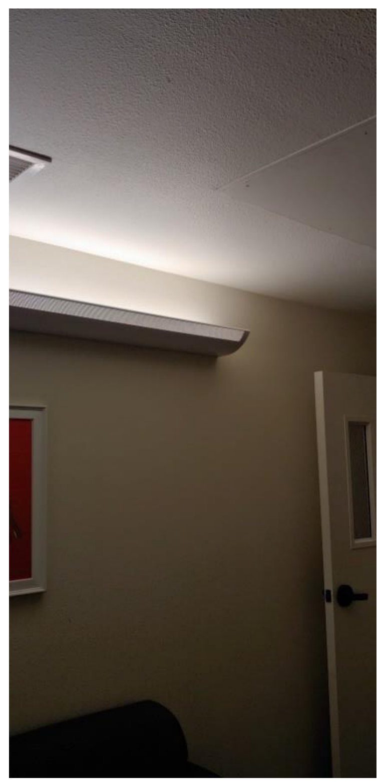


Jenny Craig Pavilion

Existing Conditions

- Electrical service appears to be in good condition.
- Electrical service has capacity to increase load.
- There is a mechanical unit that has been installed in front of the main 12kV->480Y/277V transformer that is impeding on the necessary clearance for the termination and switch cabinet.
- Existing 200kW generator. Appears to be old. Need to confirm testing history.
- Location of a 190kWAC/209kWDC PV system with 230W solar panels installed in 2010/11 by AM Solar / Designed by MWE.
- Existing fluorescent lighting in lockers and corridors
- Existing metal halide highbay lighting fixtures in stadium

Potential Projects

- Upsize solar panels to 400W range and achieve adding 154kWDC with the same footprint.
- Replace existing fluorescent lighting with LED lamps.
- Provide motion sensors and dimming in locker rooms and corridors
- Replace existing metal halide highbay lighting with LED and dimming capability.



Mission Parking Structure

Existing Conditions

- Electrical service appears to be in good condition.
- Electrical service has capacity to increase load.
- Existing fluorescent lighting
- Existing 'Blink' EV charging stations.
- Existing generator.

Potential Projects

- Replace existing fluorescent lighting with LED lamps.

Shiley Science and Technology Building

Existing Conditions

- Electrical service appears to be in good condition.
- Building has (3) primary services to the building. USS1 12kV->480Y/277V on north side of building. USS1 is normal source for emergency system. USS2 12kV ->208Y/120V on north side of building. USS3 12kV->208Y/120V on south side of building.
- Electrical services have capacity to increase load.
- Existing generator for Life-Safety and Legally Required Standby. Concerns with start time were brought up and testing / maintenance schedule should be reviewed. Based on reviewed programming of campus generator system installation. Emergency generator system at this building receives a signal from campus generator system so that building generator remains on and does not transfer back to 'normal' power until utility power is restored.
- Most lighting is fluorescent and facilities have replaced a minor amount of lighting with LED fixtures.
- This building is critical to campus for labs and research activity.

Potential Projects

- Replace existing fluorescent lighting with LED lamps.
- Labs are most of the energy draw, so defer to mechanical solutions for mechanical loads.
- Plug-load controls could be added in to turn of students equipment and un-necessary loads during off-hours. User would need to provide more information.
- The building does appear to have some PV space on the roof, but not enough to fuel a battery in an extended outage. If a battery system is planned on campus for overall grid power demand response or load-shifting, this location would be good to offer an optional backup feature. This would be in 2025 time-frame because STEM battery is already installed to provide lower utility demand charges.

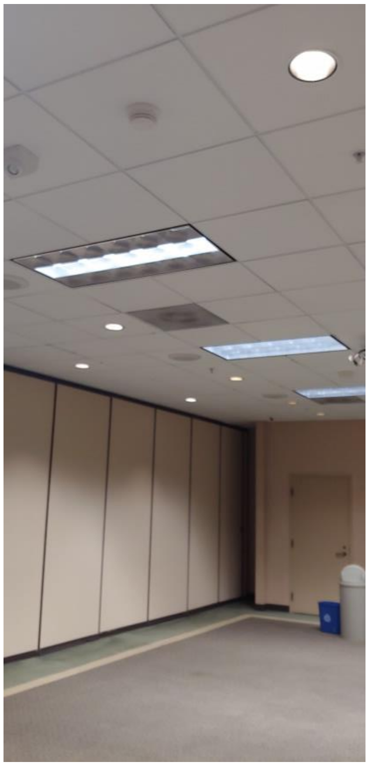
Kroc Center Building

Existing Conditions

- Electrical service appears to be in good condition.
- Electrical service has capacity to increase load.
- Existing fluorescent lighting.
- Existing conference and meeting rooms have multiple light fixture types for function and dimming capabilities. May be difficult to suggest lamp replacements only.
- Existing ‘Blink’ EV charging stations.
- Location of a 95kWAC/110kWDC PV system with 215W solar panels installed in 2010/11 by AM Solar / Designed by MWE.

Potential Projects

- Replace existing fluorescent lighting with LED lamps. They have been slowly replacing portions of the lighting with LED already. There are many decorative fixtures that may not be cost-effective if needing to purchase an entirely new fixture.
- Upsize solar panels to 400W range and achieve adding 94kWDC with the same footprint.



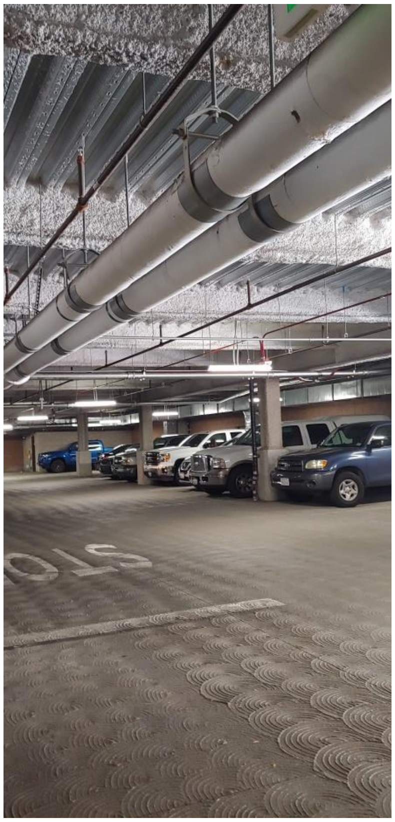
Mother Rosalie Hill Hall

Existing Conditions

- Electrical service appears to be in good condition.
- Electrical service has capacity to increase load.
- Existing LED lighting in garage (did not walk building)
- Location of a 120kWAC/125kWDC PV system with 230W solar panels installed in 2010/11 by AM Solar / Designed by MWE.

Potential Projects

- Upsize solar panels to 400W range and achieve adding 93kWDC with the same footprint.



Central Utility Plant

Existing Conditions

- Electrical service appears to be in good condition.
- Electrical service has capacity to increase load.
- There is a desktop style UPS plugged in within the switchboard cabinet that is feeding a terminal block and controller.

Potential Projects

- A proper permanent solution for the controller power and UPS should be installed.

Maher Hall

Existing Conditions

- Electrical service appears to be old and should be considered past its life expectancy.
- Electrical service has capacity needs to be reviewed with historical demand data, but adding equipment would be difficult due to equipment location and lack of space.
- Existing antiquated timeclock system.
- Existing antiquated panelboards and switching labeled 'Emergency' that have missing bus protection barriers.
- It appears one switchboard in room 100G label 'Maher #2' has been replaced recently and the new equipment is in good condition.
- Existing fluorescent lighting throughout. Minimal controls.

Potential Projects

- Replace Electrical service during next renovation of building.
- Replace timeclock system with digital controls and network to common management software.
- Replace panelboard distribution labeled 'Emergency' with code compliant and reliable power system.
- Replace existing fluorescent lighting with LED lamps and add controls.



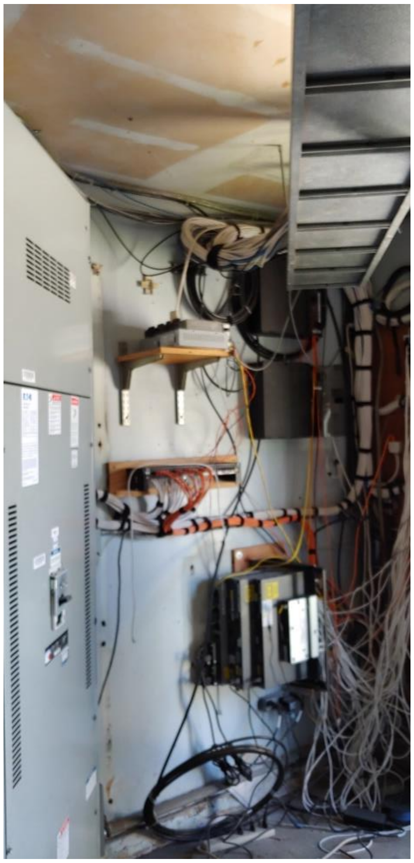

Sports Center

Existing Conditions

- Electrical service appears to be in good condition.
- Electrical service has capacity to increase load.
- Only viewed electrical room
- This building is on the east edge of the campus. Bill described that meter cabling is old RS485 spliced and routed through planters and needs to be converted to network cabling that is controlled by IT department.

Potential Projects

- There is roof space available for PV system. Team to discuss benefits of power generating vs. solar water heating PV system for pool.



Torero Stadium

Existing Conditions

- Electrical service appears to be old and should be considered past its life expectancy. Corrosion and rusting may be degrading breakers operating capabilities.
- Electrical service capacity will need to be reviewed when Siemens metering access is available.

Potential Projects

- Replace old metal halide field lighting with LED lighting. Allows for quicker on-off capabilities and avoids the need to leave lighting on or turning on lighting early to wait for re-strike and heating of fixture before operating.
- Provide networked energy management control.




Manchester Hall

Existing Conditions

- Electrical service appears to be in older but well maintained and in good condition. Though it is past it's life expectancy, replacement only necessary when compatible circuit breakers are not available or the building has a major remodel.
- Electrical service for mechanical system is MCC Hand-Off-Auto style and it is not clear if much of it has been bypassed or switch to Manual 'Hand' do to controls issues.
- Existing lighting, particularly in meeting rooms are older fluorescent and not as effective as newer lighting options.
- Existing lighting controls need to be upgraded.
- Some office areas have been recently remodeled with efficient lighting.

Potential Projects

- Replace existing fluorescent lighting with LED lamps and add controls.
- Replace timeclock system with digital controls and network to common management software.

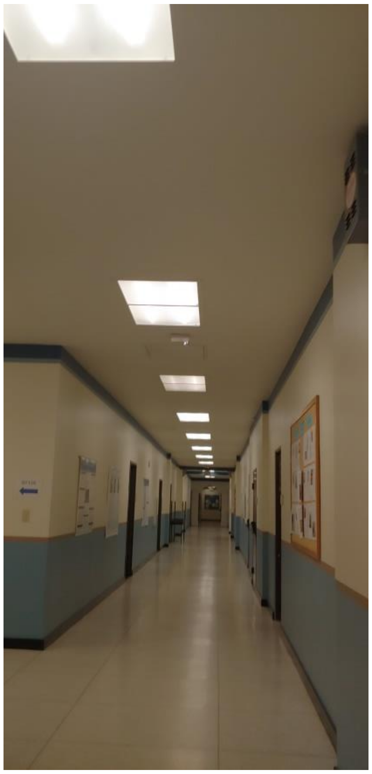
Serra Hall

Existing Conditions

- Electrical service appears to be in older but well maintained and in good condition.
- Switchboard MSA lacks space to provide new distribution.
- Switchboard MSB lacks space to provide new distribution.
- Existing fluorescent lighting.

Potential Projects

- To increase breaker space in MSA and MSB, relocating breakers less than 100A into panelboard fed by switchboard is suggested.
- Replace existing fluorescent lighting with LED lamps and add controls.
- Replace timeclock system with digital controls and network to common management software.



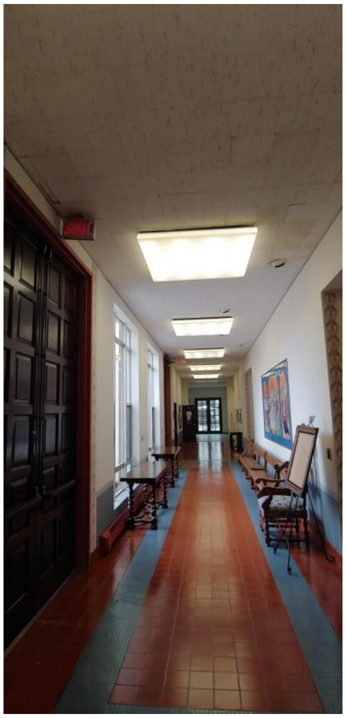
Hahn School of Nursing / Beyster Institute for Nursing Research

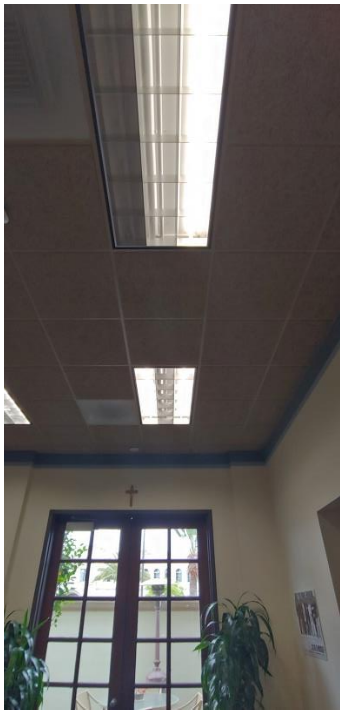
Existing Conditions

- Electrical service appears to be in good condition.
- Existing interior Switchboard MSB (HSN_ELECT_Swbd1 & 2) is older and may have trouble adding or replacing circuit breakers. This board should be relabeled because the existing main exterior Switchboard MSB fed by service transformer (HSN_ELECT_Swgr1 / HSN_ELECT_Transf1) feeds other services and is the main disconnect for the building.
- Existing fluorescent lighting in corridors and common areas.
- Recent tenant improvements with LED and controls are throughout building.

Potential Projects

- Replace existing fluorescent lighting with LED lamps and add controls.
- Integrate existing digital lighting controls with common management software.





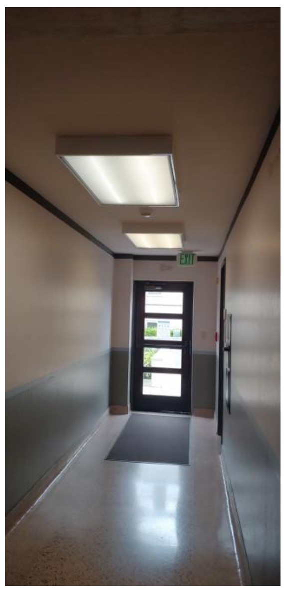
Hughes Administration Center

Existing Conditions

- Electrical service transformer is located in a room without proper clearance and ventilation.
- Electrical switchboard is old and should be considered past its life expectancy. Corrosion and rusting may be degrading breakers operating capabilities.
- Existing fluorescent lighting throughout. Minimal controls.

Potential Projects

- Electrical service should be evaluated for replacement.
- Replace existing fluorescent lighting with LED lamps and add controls.
- Replace timeclock system with digital controls and network to common management software.



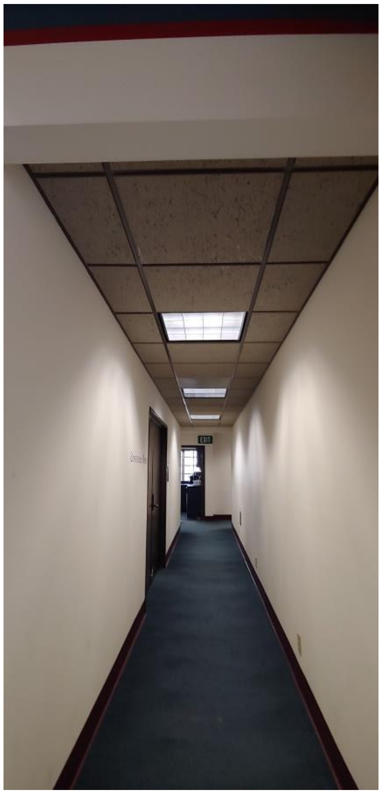
Guadalupe Hall

Existing Conditions

- Electrical service fed from Serra Hall. Electrical room is overcrowded due to telecommunications use and equipment in room.
- Existing fluorescent lighting throughout. Minimal controls.

Potential Projects

- Telecommunications equipment in electrical room should be relocated.
- Replace existing fluorescent lighting with LED lamps and add controls.
- Replace timeclock system with digital controls and network to common management software.



The following list is of buildings that have solar PV systems installed and have a description of current size and an estimate of increased wattage if panels were upgraded.

Alcala Vista Building A and B

- Building A - location of a 26kWAC/29kWDC PV system with 230W solar panels installed in 2010/11 by AM Solar / Designed by MWE.
- Building B - location of a 26kWAC/29kWDC PV system with 230W solar panels installed in 2010/11 by AM Solar / Designed by MWE.

Potential Projects

- Upsize solar panels to 400W range and achieve adding 21kWDC with the same footprint for each building.

Copley Library

- Location of a 60kWAC/61kWDC PV system with 230W solar panels installed in 2010/11 by AM Solar / Designed by MWE.

Potential Projects

- Upsize solar panels to 400W range and achieve adding 45kWDC with the same footprint.

Founders Hall

- Location of a 190kWAC/225kWDC PV system with 230W solar panels installed in 2010/11 by AM Solar / Designed by MWE.

Potential Projects

- Upsize solar panels to 400W range and achieve adding 166kWDC with the same footprint.

Camino Hall

- Location of a 60kWAC/70kWDC PV system with 230W solar panels installed in 2010/11 by AM Solar / Designed by MWE.

Potential Projects

- Upsize solar panels to 400W range and achieve adding 52kWDC with the same footprint.

Appendix J – Mechanical Assessed Building Conditions

This Appendix contains descriptions of current (at time of walk-through and survey) building conditions, building size, buildings systems, main equipment, graphics of mechanical systems, and automation system capability.

This Appendix is intended to assist the University of San Diego with context both historical and for future attempts at implementing the scope of this report in achieving its overall goals of energy use reduction, efficient utilization of energy, decarbonizing its energy use.

Mechanical Systems
Assessed Building Conditions

University of San Diego
5998 Alcalá Park

San Diego, California 92110

Prepared By:
MA Engineers
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San Diego, CA 92121
(858) 200-0030
February 22, 2021
Project No.: 6112

ASSESSED BULDING RECOMMENDATIONS

Alcala Vista Apartments

Building Information

Four residential buildings totaling 184,000 sq.ft. with 192 apartments, laundry facility and shared areas:

- Palomar
- Cuyamaca
- Borrego
- Laguna

Mechanical equipment serving the building and operating conditions:

- Three (3) 325,000 btu SHW boiler with six (6) constant speed SHW pumps
- Three (3) 625,000 btu DHW heaters
- Rooftop unit ventilators for hallways
- Manual stand-alone controls in each room for hydronic fin-tube radiator

Additional Comments

Space Heating Water Plant (Boiler, Pumps, sensors, etc.) is monitored by SIEMENS Automation System

Camino Hall

Building Information
Two buildings interconnected by interior patio 117,000 sq.ft. with library reading room, university archives, second floor serving as dormitory apartments. The building has operable windows that are connected to the HVAC equipment via the BAS to deactivate cooling/heating when the windows are open

Mechanical equipment serving the building and operating conditions:

- Two (2) hydronic heating/cooling VAV air handler units
- One (1) condensing HHW boiler (150°F – 180°F)
- Two (2) HHW pumps
- Two (2) 4-pipe hydronic vertical heating / cooling constant air fan coil units
- Five (5) 4-pipe hydronic horizontal heating / cooling constant air fan coil units
- One (1) split system heat pump unit
- Two (2) split system air conditioning units
- Seventy-Two (72) variable air volume terminal units with hydronic reheat
- Sixteen (16) exhaust fans
- One (1) supply fan
- Radiant heaters for the residential areas
- Four (4) computer room air conditioning units
- Controls via building automation system, monitored by SIEMENS Automation System

Copley Library

Building Information
45,000 sq.ft. building recently renovated (2020), it houses printed material and computer workstations.
Mechanical equipment serving the building and operating conditions:

- Three (3) existing Cooling Only Air Handler Units Systems
- One (1) new Cooling Only Air Handler Units Systems
- VAV terminal units with SHW reheat
- SHW provided to the building from Learning Commons project, once completed

Additional Comments

Space Heating Water System (Heat Exchanger, Control Valve, Pumps, etc.) are monitored by SIEMENS Automation System

Building has recently been renovated (2020)

Degheri Alumni Center

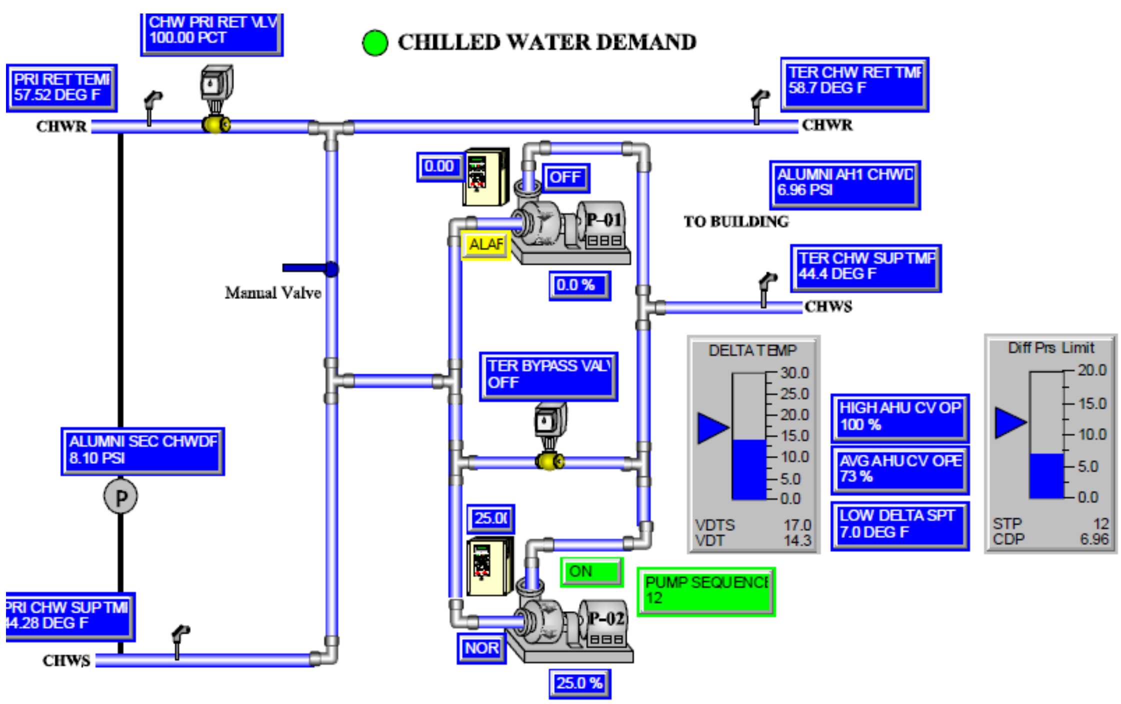
Building Information
28,000 sq.ft. building
Mechanical equipment serving the building and operating conditions:

- Six (6) VAV Air Handler Units
- VAV terminal units with SHW reheat
- One (1) gas fired SHW boiler
- Two (2) SHW variable speed tertiary pumps
- Two (2) CHW variable speed tertiary pumps from Central Plant loop

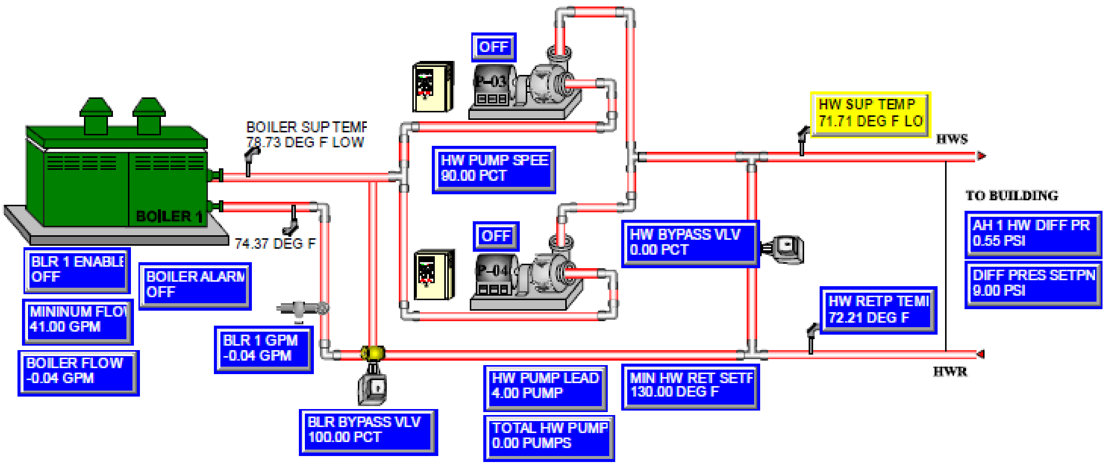
Additional Comments

Space Heating Water System (Boiler, Pumps, etc.) are monitored by SIEMENS Automation System

Chilled Water Pumping is monitored by SIEMENS Automation System



DEGHERI TERTIARY CHILLED WATER PUMPING SYSTEM



DEGHERI DECENTRALIZED SPACE HEATING WATER SYSTEM

Founders Hall (Residence)

Building Information

90,000 sq.ft. Building in which the second floor is dedicated to residences (similar to Camino Hall).

The building has operable windows that are connected to the HVAC equipment via the BAS to deactivate cooling/heating when the windows are open.

Mechanical equipment serving the building and operating conditions:

- Three (3) hydronic heating/cooling VAV air handler units
- One (1) condensing HHW boiler (150°F – 180°F)
- Two (2) HHW pumps
- Six (6) 4-pipe hydronic heating / cooling constant air fan coil units
- Four (4) split system heat pump units
- Forty (40) variable air volume terminal units with hydronic reheat
- Radiant heaters for the residential areas
- Controls via building automation system, monitored by SIEMENS Automation System
- Manual stand-alone controls in each room for hydronic fin-tube radiator

Hahn School of Nursing and Health Sciences

Building Information
17,000 sq.ft. building with office and instructional spaces
Mechanical equipment serving the building and operating conditions:

- Three (3) CAV space heating only Air Handler Units
- Thirteen (13) split system HVAC units
- Baseboard hydronic radiant heaters
- 419,000 btu/h SHW boiler for the baseboard heaters and Air Handler Unit

Additional Comments

HVAC equipment controlled by standalone thermostats

Hahn University Center

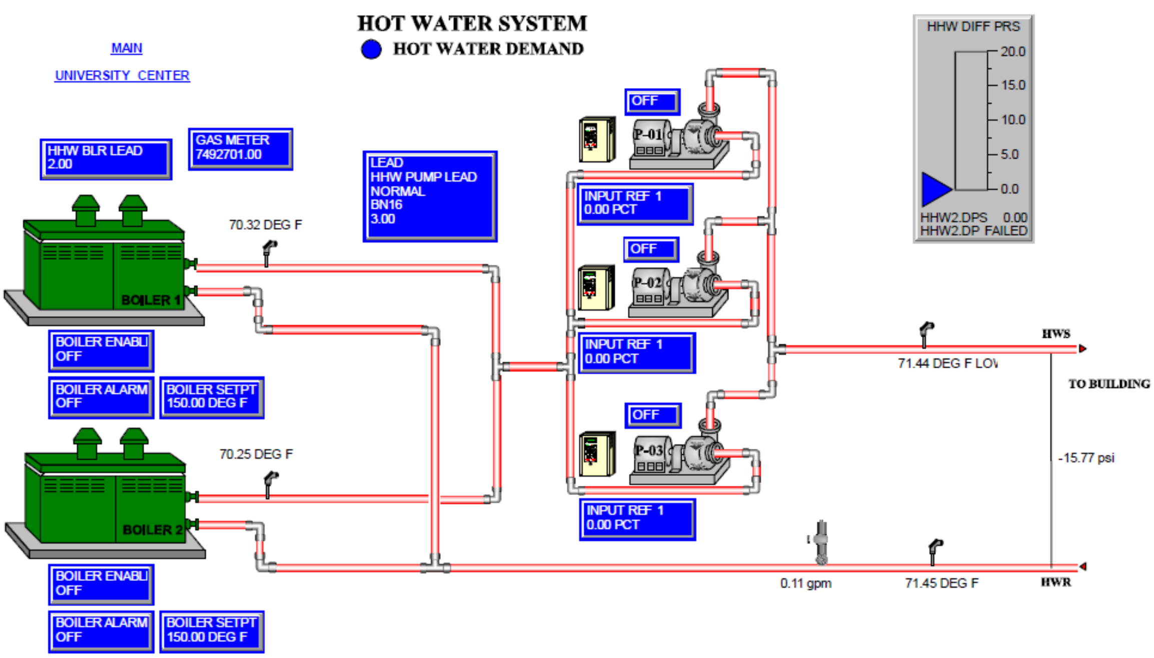
Building Information
81,000 sq.ft. building with office space for various needs, a large kitchen and dining areas.

Mechanical equipment serving the building and operating conditions:

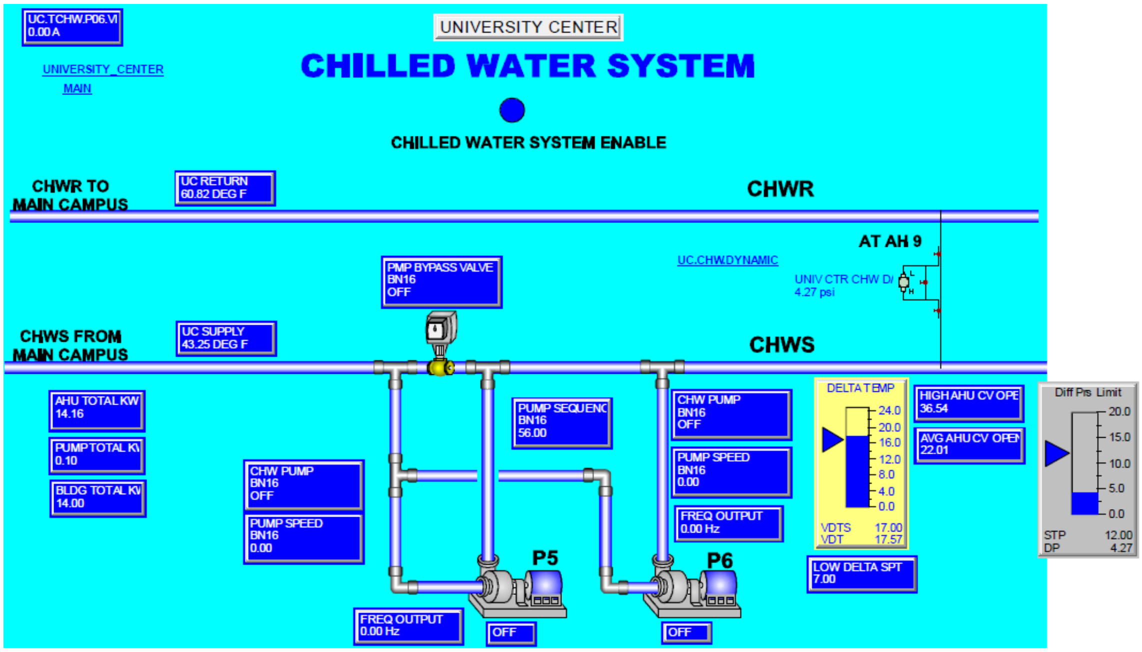
- Fourteen (14) VAV hydronic Air Handler Units
- SHW Boiler Plant
- Three (3) variable speed SHW pumps
- Two (2) constant speed tertiary CHW pumps

Additional Comments

HVAC Systems controlled by SIEMENS Building Automation System



UNIVERSITY CENTER HEATING HOT WATER SYSTEM



UNIVERSITY CENTER CHILLED WATER SYSTEM

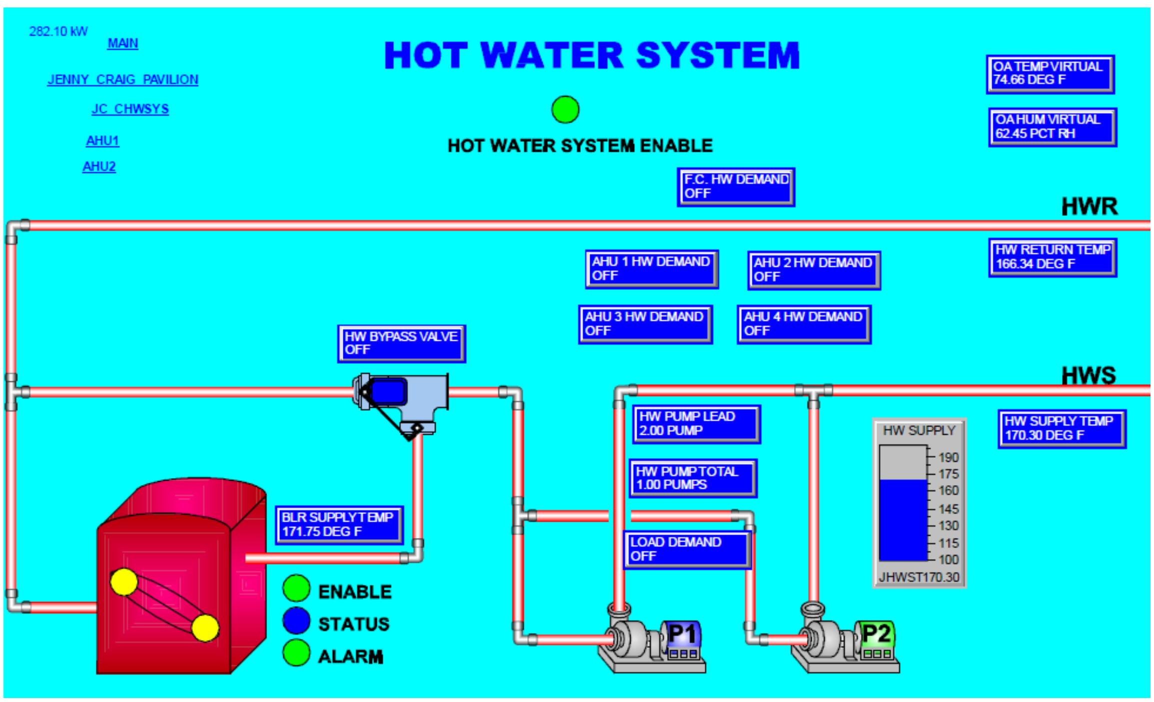
Jenny Craig Pavilion

Building Information
172,000 sq.ft. building dedicated as a 5,100-seat sports venue, with ancillary spaces (parlor, lockers, sports medicine, weight room, etc.)
Mechanical equipment serving the building and operating conditions:

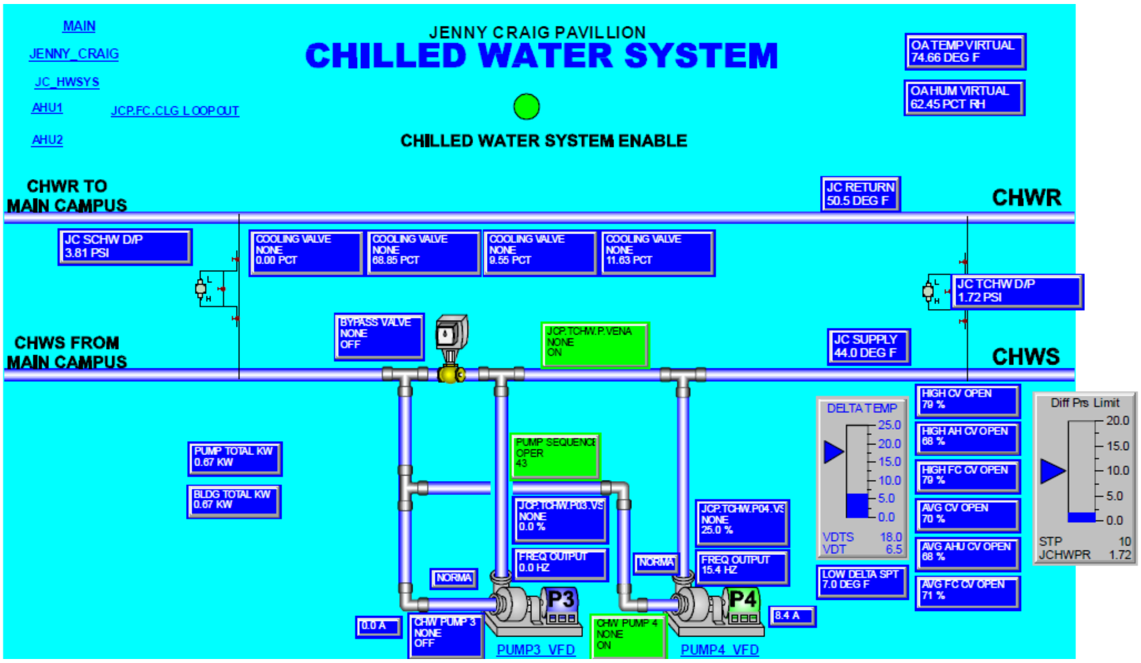
- Two (2) hydronic VAV Air Handler Units
- Two (2) hydronic CAV Air Handler Units
- SHW Boiler Plant (5,000,000 btu/h) @ 80%
- Two (2) constant speed SHW pumps
- Two (2) variable speed tertiary CHW pumps

Additional Comments

HVAC Systems controlled by SIEMENS Building Automation System



JENNY CRAIG PAVILION SPACE HEATING WATER PLANT



JENNY CRAIG PAVILION CHILLED WATER PUMPING

Joan B. Kroc Institute for Peace and Justice

Building Information

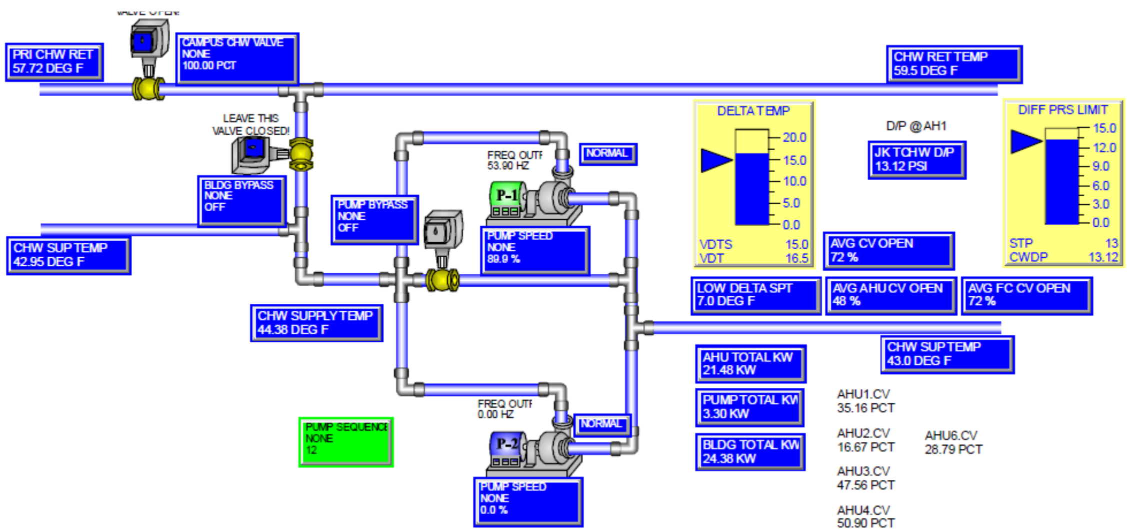
95,000 sq.ft. building in two levels with administrative and academic spaces, with an auditorium (300 occupants), kitchen and dining facilities

Mechanical equipment serving the building and operating conditions:

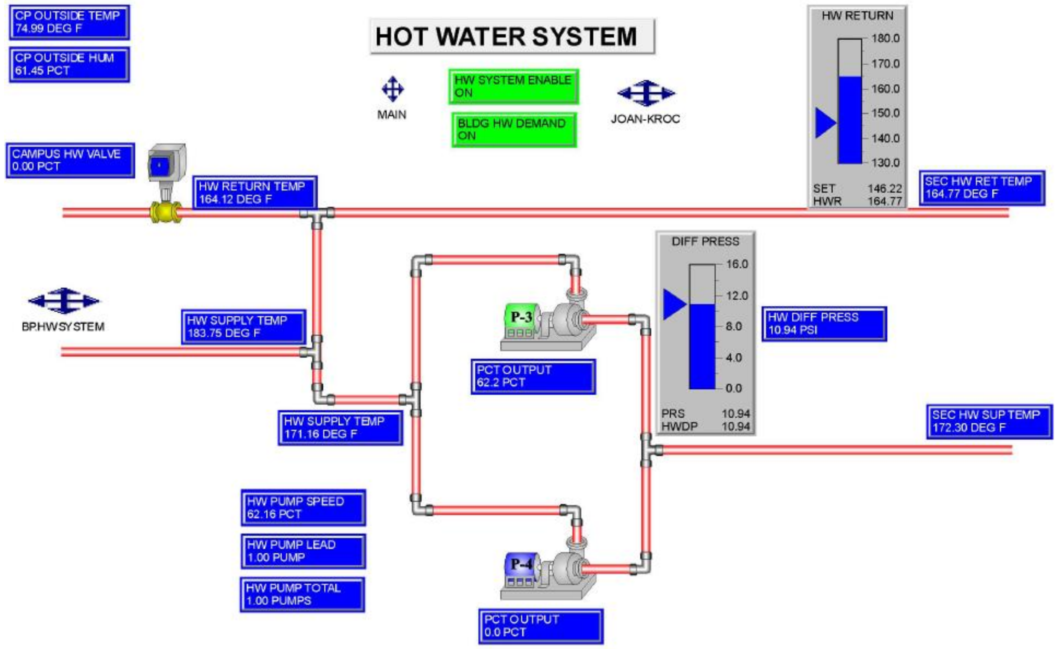
- Six (6) hydronic VAV Air Handler Units
- VAV terminal units with SHW reheat
- Two (2) variable speed SHW pumps (served by the campus SHW loop)
- Two (2) variable speed tertiary CHW pumps

Additional Comments

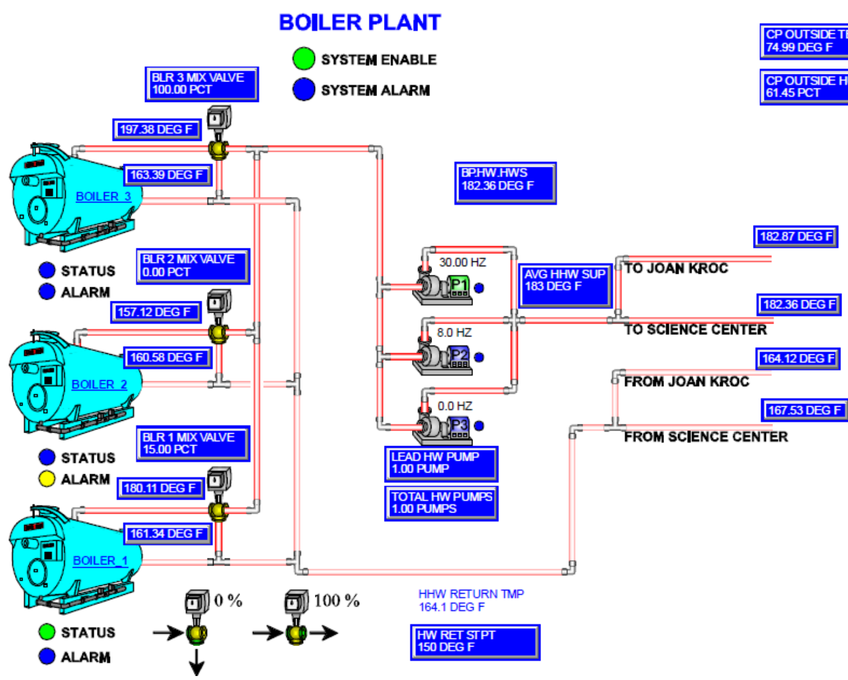
HVAC Systems controlled by SIEMENS Building Automation System



JOAN B. KROC INSTITUTE FOR PEACE AND JUSTICE CHILLED WATER PUMPING SYSTEM



JOAN B. KROC INSTITUTE FOR PEACE AND JUSTICE SPACE HEATING WATER PUMPING SYSTEM



JOAN B. KROC INSTITUTE FOR PEACE AND JUSTICE SPACE HEATING WATER BOILER PLANT

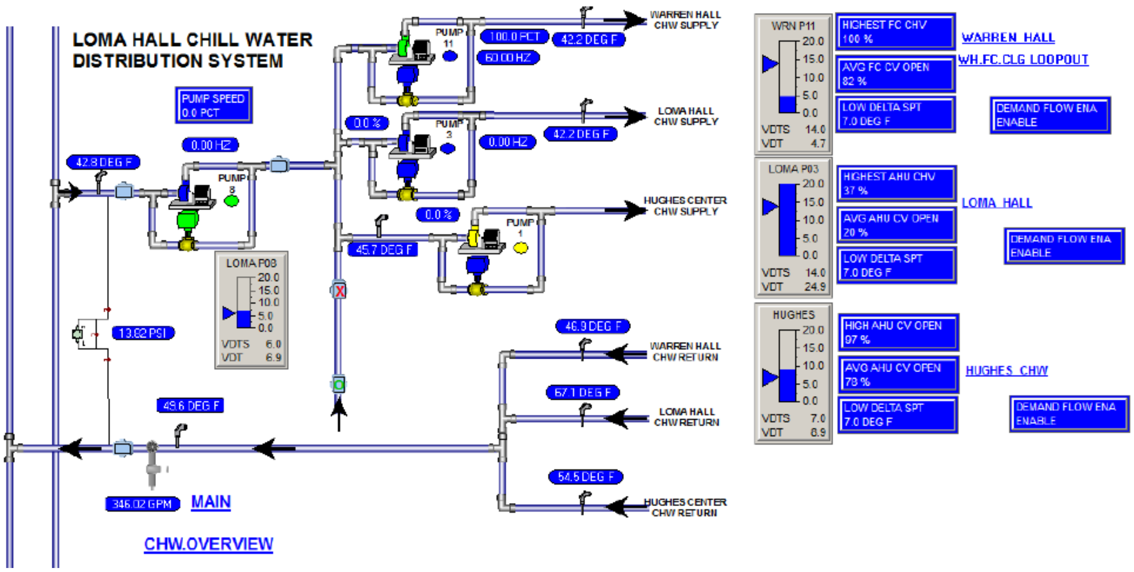
Loma Hall

Building Information
46,000 sq.ft. building is split into four levels with classrooms, bookstore, mail center

Mechanical equipment serving the building and operating conditions:

- Six (6) hydronic Cooling Only VAV Air Handler Units
- VAV terminal units with SHW reheat
- One (1) 1,000,000 but/h SHW boiler
- One (1) constant speed SHW pump
- Two (2) variable speed tertiary CHW pumps

Additional Comments



LOMA HALL CHILLED WATER PUMPING SYSTEM

Maher Hall

Building Information
110,000 sq.ft. building is split into four levels with the first floor dedicated to a Café, catering and offices, while the top three floors are residences.

Mechanical equipment serving the building and operating conditions:

- Twenty-six (26) split system heat pump systems
- One (1) 3,400,000 but/h steam-to-water heat exchanger
- Two (2) constant speed SHW pumps for the residences

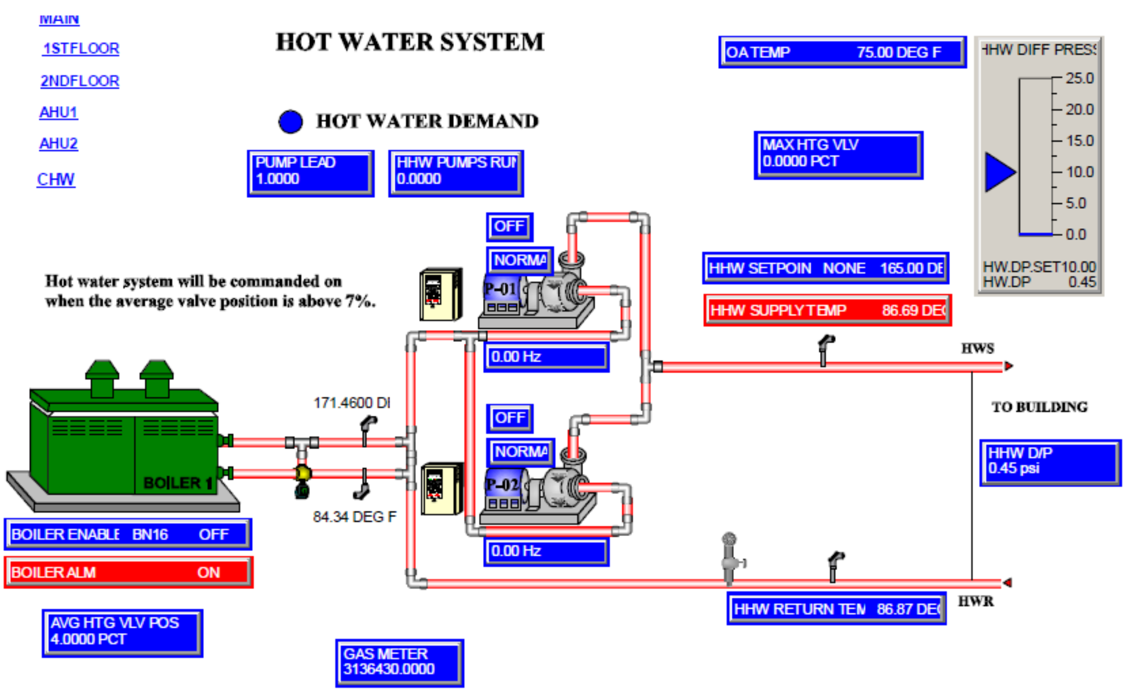
Additional Comments

Manchester Conference Center

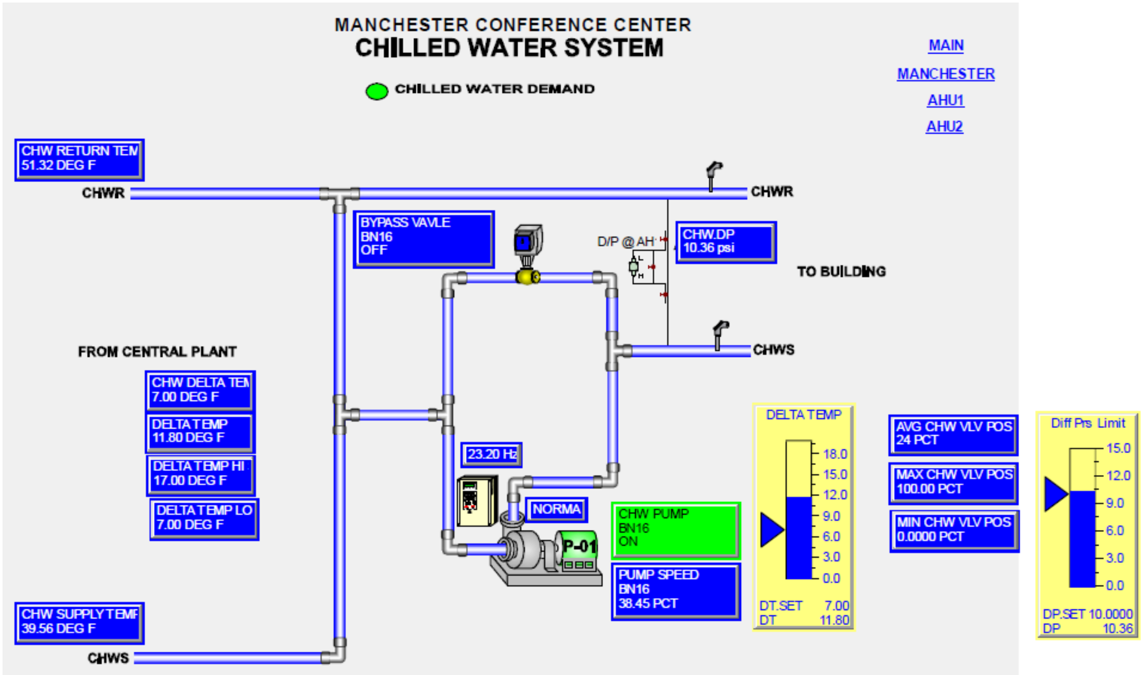
Building Information
15,000 sq.ft. building with conference facilities and auditorium.
Mechanical equipment serving the building and operating conditions:

- Two (2) McQuay SZ Hydronic Air Handler Units
- One (1) variable speed tertiary CHW pump
- One (1) SHW boiler
- Two (2) variable speed SHW pumps

Additional Comments



MANCHESTER CONFERENCE CENTER SPACE HEATING WATER SYSTEM



MANCHESTER CONFERENCE CENTER CHILLED WATER PUMPING SYSTEM

Manchester Village Apartments

Building Information
133,000 sq.ft. two three and four level buildings that offer 103 apartments. The building also has offices, convenience store, study lounges, computer lab, conference rooms and underground parking.

Mechanical equipment serving the building and operating conditions:

- Three (3) CAV space heating only hydronic Air Handler Units
- Twenty-two (22) Fan Coil Units with hydronic space heating and DX cooling.
- Hydronic space heating only Fan Coil Units serving the apartments.
- Three (3) SHW boilers: one (1) 2,340,000 btu/h and two (2) 1,530,000 btu/h
- One (1) constant speed SHW pump

Additional Comments

Mission Housing Complex (Valley Housing)

Building Information
135,000 sq.ft. mostly apartments with ancillary spaces
Mechanical equipment serving the building and operating conditions:

- Common area served by five (5) split system units
- Mission Crossroads served by three (3) split system units
- Residences are served by gas-fired forced air furnaces
- SHW provided by two (2) 500,000 btu/h SHW boilers.
- Three (3) variable speed SHW pump

Additional Comments

Mother Rosalie Hill Hall

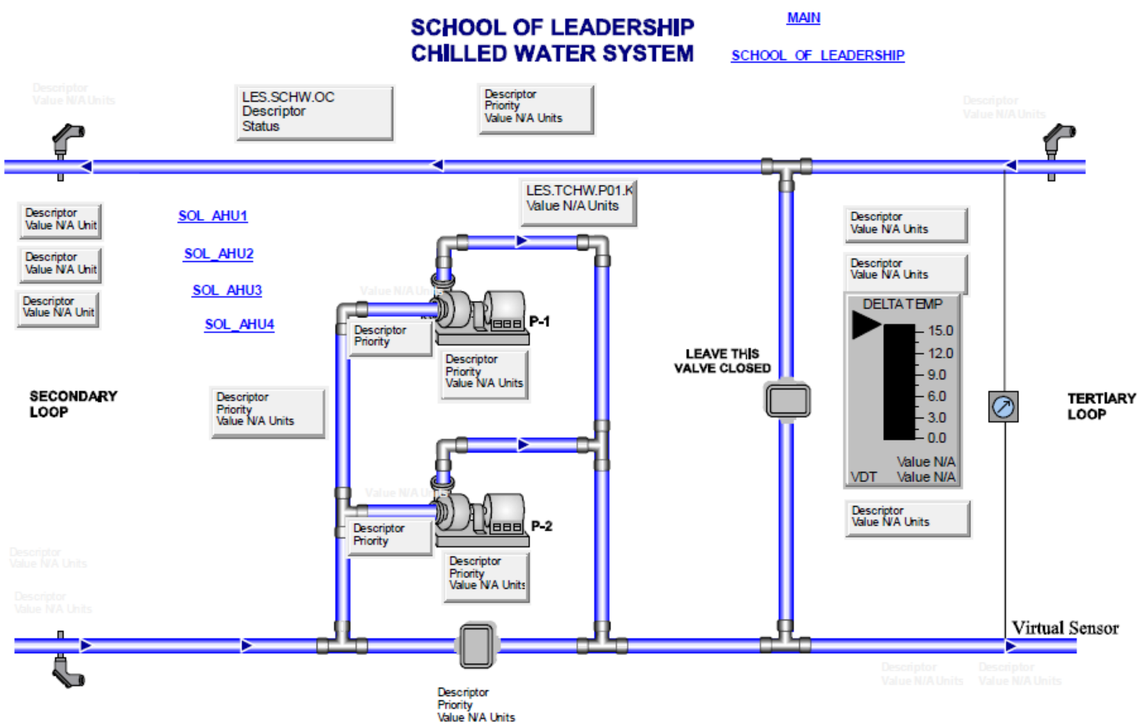
Building Information

153,000 sq.ft. building with classrooms, offices, auditorium and bistro.

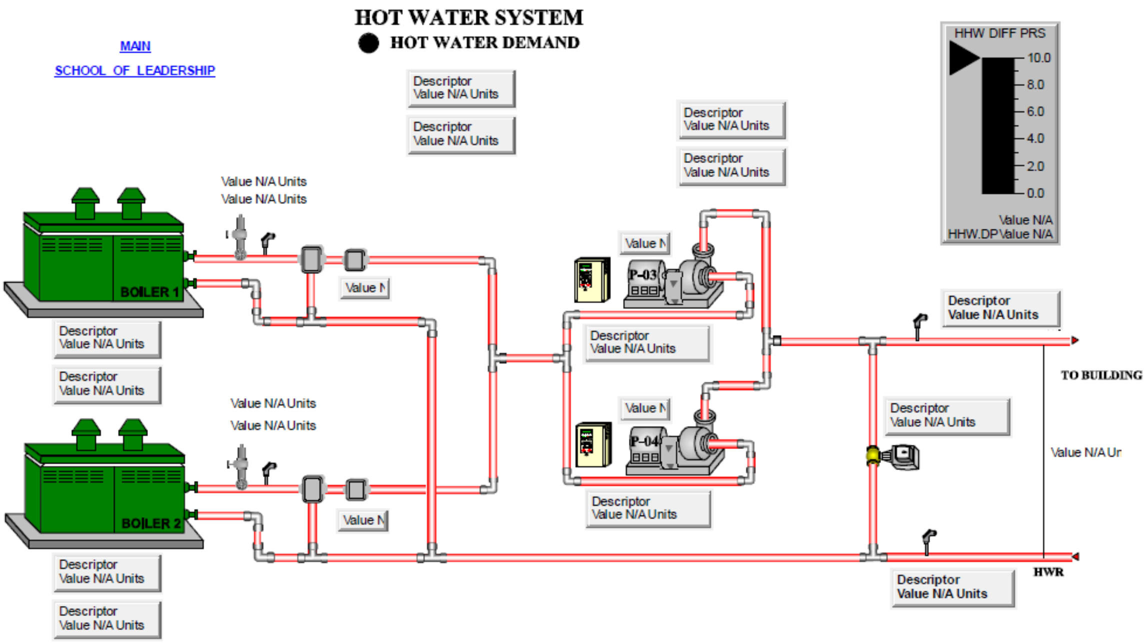
Mechanical equipment serving the building and operating conditions:

- Common area served by four (4) hydronic air handler units
- Variable Air Volume terminal units
- SHW provide by two (2) 1,440,000 btu/h SHW boilers
- Two (2) variable speed SHW pumps
- Two (2) tertiary variable speed CHW pumps from the campus loop

Additional Comments



MOTHER ROSALIE HILL HALL CHILLED WATER PUMPING SYSTEM



MOTHER ROSALIE HILL HALL SPACE HEATING WATER SYSTEM

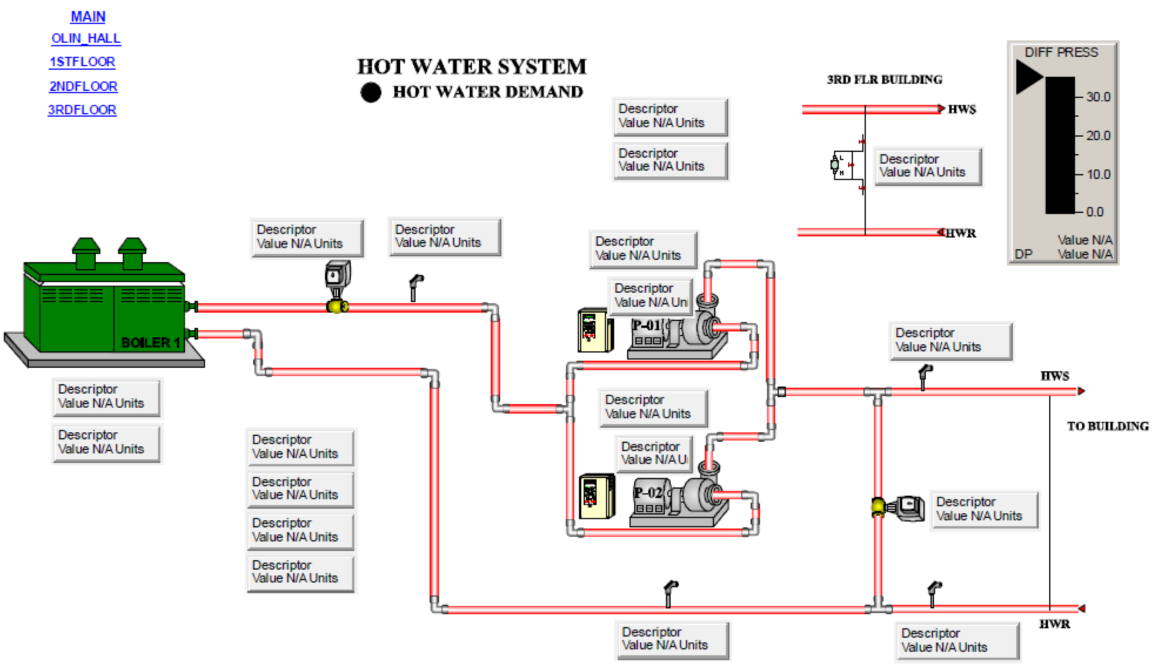
Olin Hall

Building Information
41,000 sq.ft. three story building with mostly classrooms
Mechanical equipment serving the building and operating conditions:

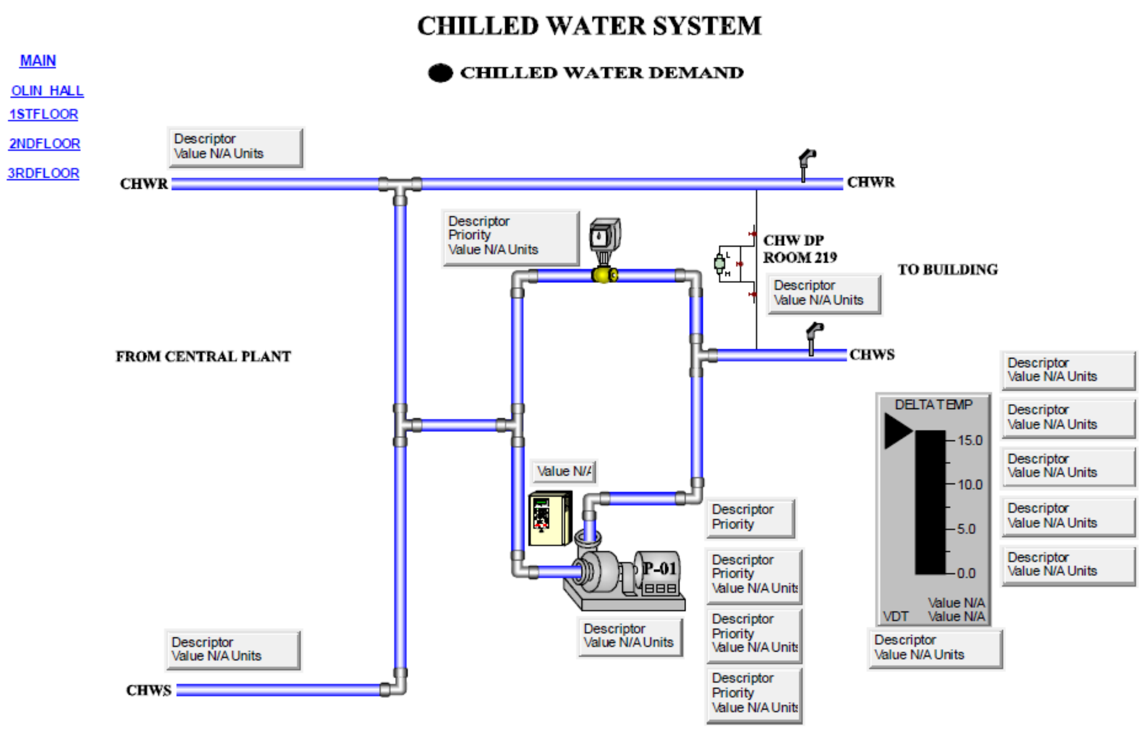
- Forty (40) hydronic fan coil units
- SHW provide by one (1) 1,530,000 btu/h SHW boiler
- Two (2) variable speed SHW pumps
- One (1) tertiary variable speed CHW pumps from the campus loop

Additional Comments

The Building Automation System is mostly pneumatic and consumes a considerable amount of energy due to air leak, as observed during investigation phase, with air compressor continuously running.



OLIN HALL SPACE HEATING WATER SYSTEM



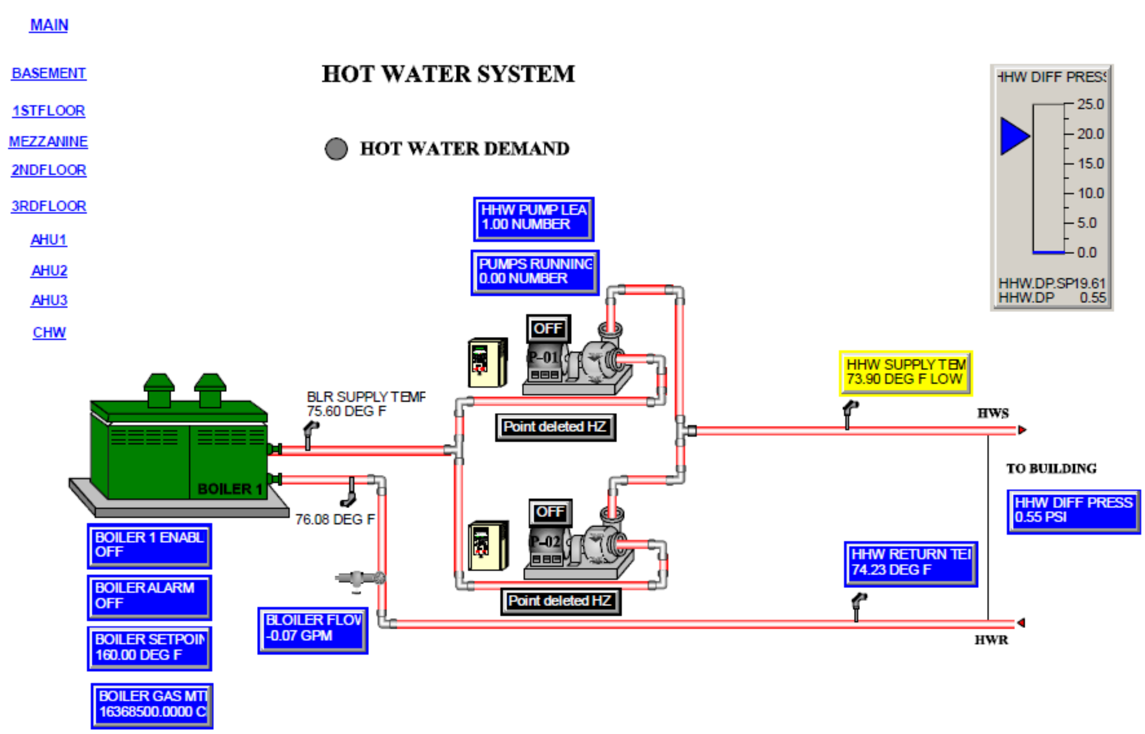
OLIN HALL CHILLED WATER PUMPING SYSTEM

Pardee Legal Research Center

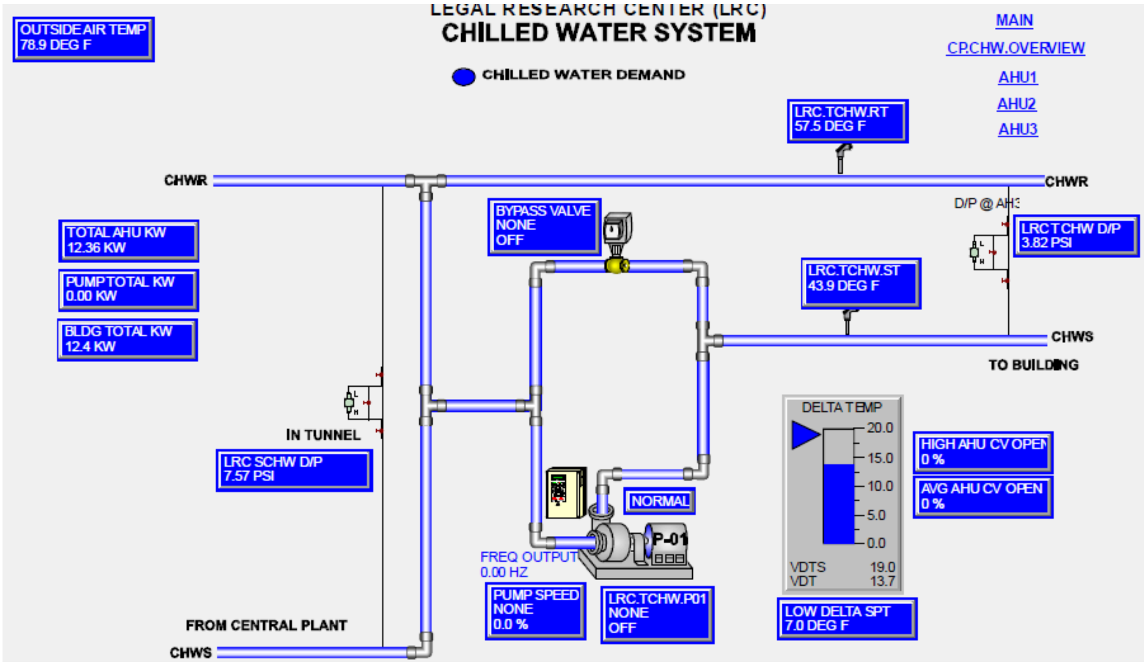
Building Information
66,000 sq.ft. three story building with work and study space, law library and computer research areas.
Mechanical equipment serving the building and operating conditions:

- Three (3) VAV hydronic cooling only air handling units
- VAV terminal units with SHW reheat
- SHW provide by one (1) SHW boiler
- Two (2) variable speed SHW pumps
- One (1) tertiary variable speed CHW pumps from the campus loop

Additional Comments



PARDEE LEGAL RESEARCH CENTER SPACE HEATING WATER SYSTEM



PARDEE LEGAL RESEARCH CENTER CHILLED WATER PUMPING SYSTEM

Sacred Heart Hall

Building Information

19,000 sq.ft. three story building with work and study space, law library and computer research areas.

Mechanical equipment serving the building and operating conditions:

- Five (5) CAV hydronic air handling units
- One (1) constant speed SHW pumps with SHW provided by campus loop
- One (1) constant speed CHW pumps from the campus loop

Additional Comments

San Antonio de Padua

Building Information

50,000 sq.ft. three story building with 41 living units, laundry room, study lounge and recreation room.

Mechanical equipment serving the building and operating conditions:

- Electric baseboard heaters in residential units

Additional Comments

San Buenaventura

Building Information

60,000 sq.ft. three story building with 176 living units (88 single 76 double 12 apartments), laundry room, study room, multipurpose room. It also houses Mission Café and Fitness Center.

Mechanical equipment serving the building and operating conditions:

- Seven (7) split system heat pumps
- Hydronic space heating only fan coil units in residential units
- SHW provided by two (2) 420,000 btu/h boilers
- SHW distributed by two (2) SHW variable speed pumps

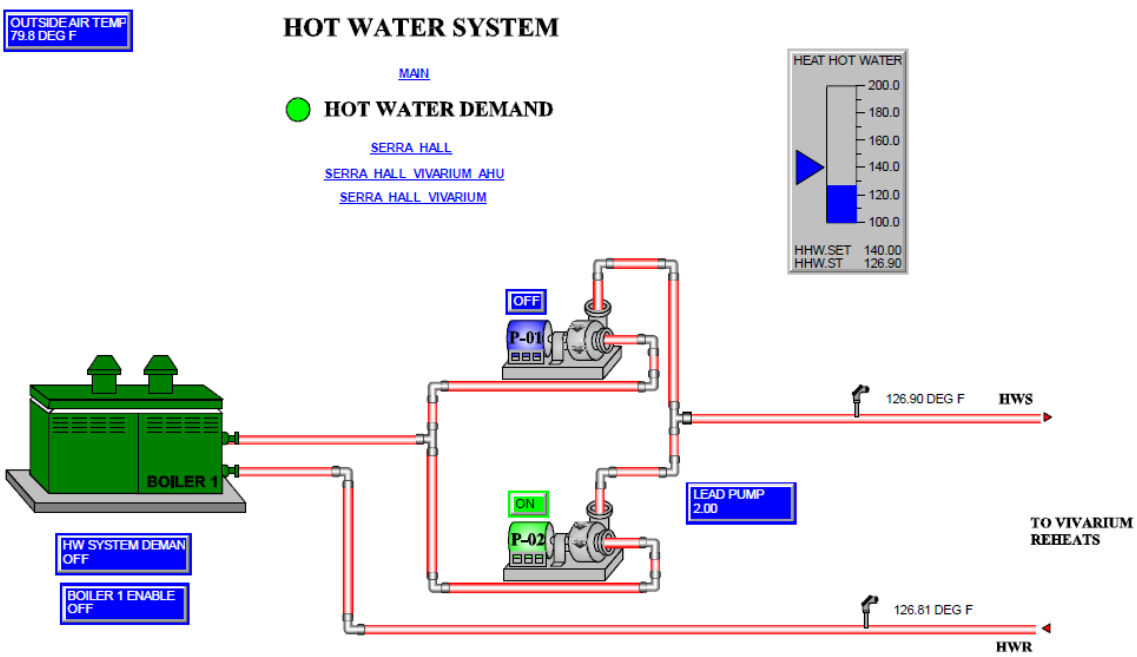
Additional Comments

Serra Hall

Building Information
75,000 sq.ft. two story building with office space and computer labs..
Mechanical equipment serving the building and operating conditions:

- One (1) DX make-up air unit
- Eighteen (18) packaged heat pump units
- Seventeen (17) split system heat pump units
- Multiple steam radiators supplied from the Maher steam plant
- SHW provided by one (1) 399,000 btu/h boilers
- SHW distributed by two (2) SHW constant speed pumps

Additional Comments



SERRA HALL SPACE HEATING WATER SYSTEM

Shiley Center for Science and Technology

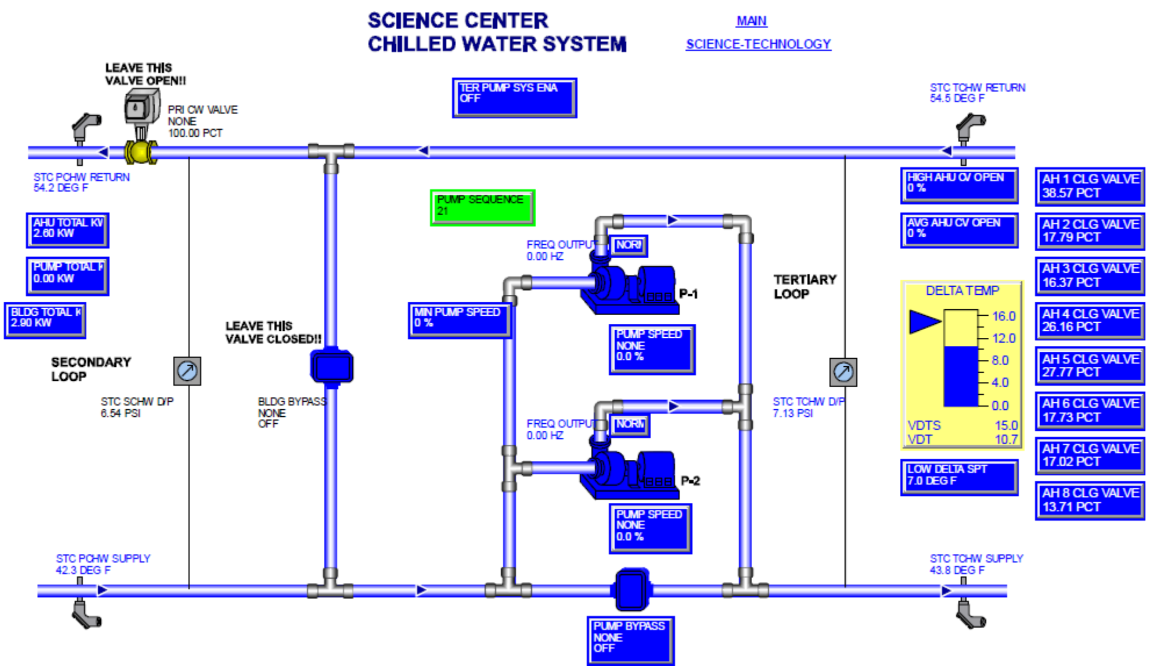
Building Information

160,000 sq.ft. four story building with a large amount of laboratory space requiring 100% outside air due to fume/chemical/biological hoods, and classrooms.

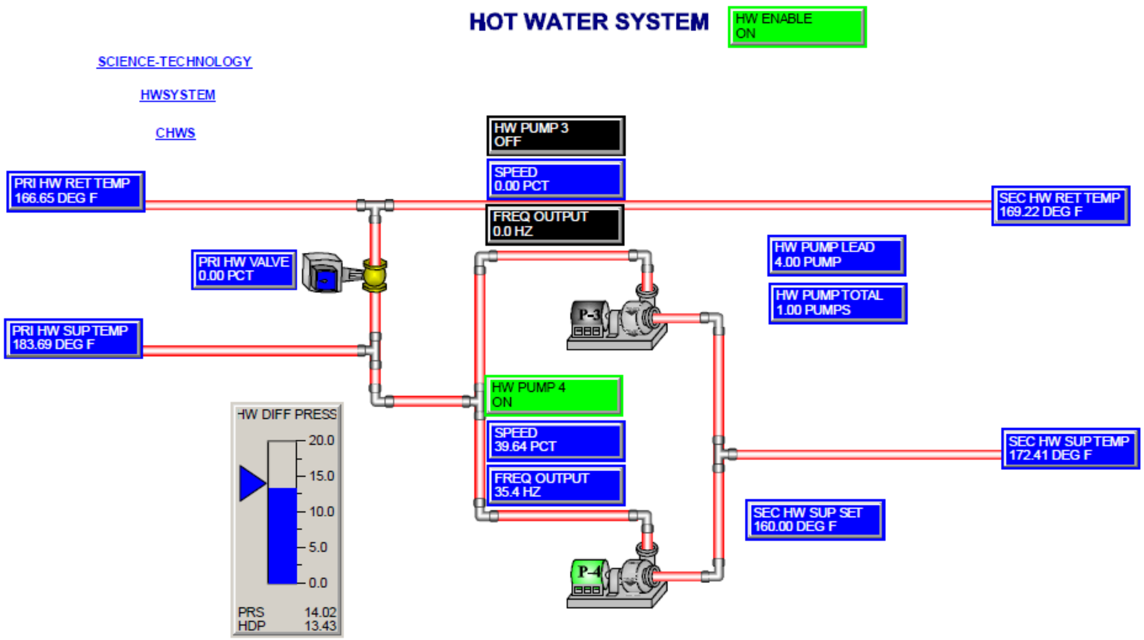
Mechanical equipment serving the building and operating conditions:

- Eight (8) 100% outside air VAV hydronic air handler units
- VAV terminal units with SHW reheat
- SHW provided by two (2) variable speed pumps from the campus loop
- CHW provided by two (2) variable speed tertiary pumps from the campus loop

Additional Comments



SHILEY CENTER FOR SCIENCE AND TECHNOLOGY CHILLED WATER PUMPING SYSTEM



SHILEY CENTER FOR SCIENCE AND TECHNOLOGY SPACE HEATING WATER SYSTEM

Sports & Pool Center

Building Information

64,000 sq.ft. building with a gymnasium, stage, offices, classrooms, locker rooms, training rooms and two residences, and an open 9,000 sq.ft. pool.

Mechanical equipment serving the building and operating conditions:

- Gymnasium served by two (2) gas fired furnaces
- Offices served by two (2) split system heat pump units
- Pool is heated by two (2) 1,500,000 btu/h gas fired heaters
- Pool filtration system has a constant speed pumping system

Additional Comments

Student Life Pavilion

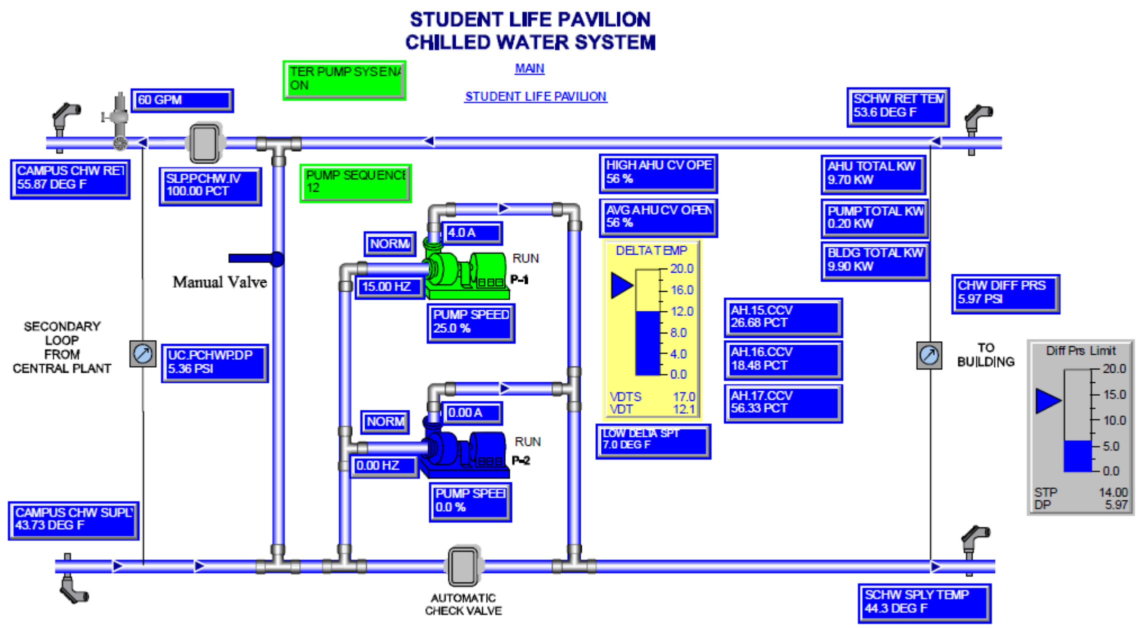
Building Information

50,000 sq.ft. four story building with a large full-service kitchen, dining areas, grocery store, office space, meeting spaces.

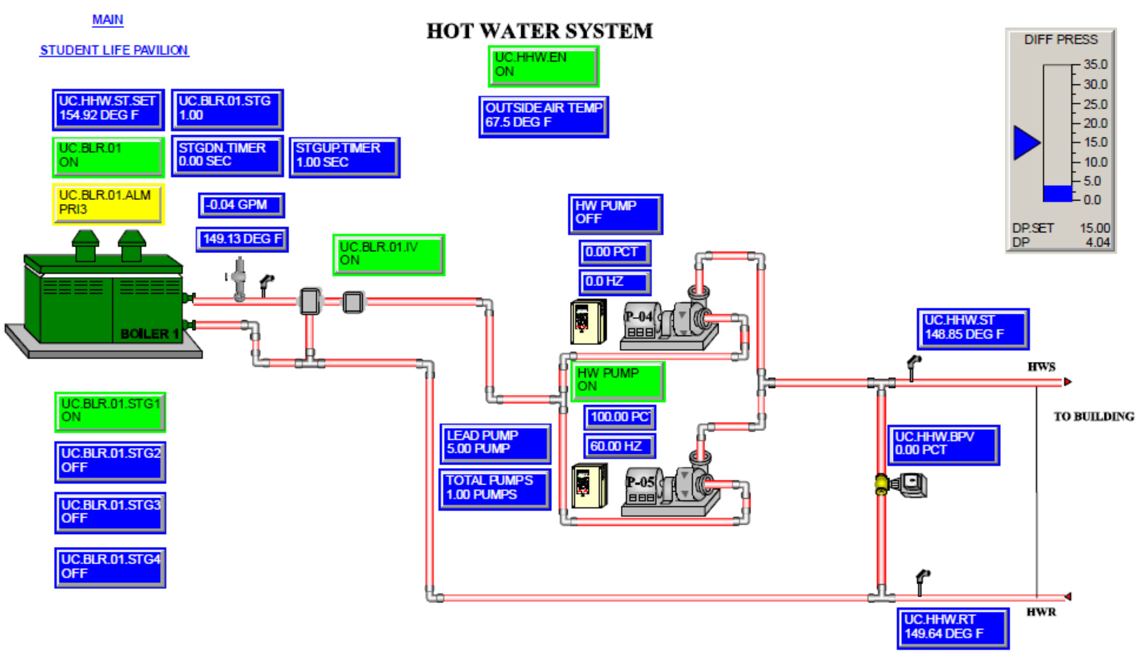
Mechanical equipment serving the building and operating conditions:

- Three (3) hydronic air handler units
- Three (3) make up air units for the kitchen
- VAV terminal units with SHW reheat
- SHW served by one (1) 1,530,000 btu/h boiler
- SHW distributed by two (2) variable speed pumps
- CHW distributed by two (2) variable speed pumps served by the campus loop

Additional Comments



STUDENT LIFE PAVILION CHILLED WATER PUMPING SYSTEM



STUDENT LIFE PAVILION HEATING HOT WATER SYSTEM

Warren Hall

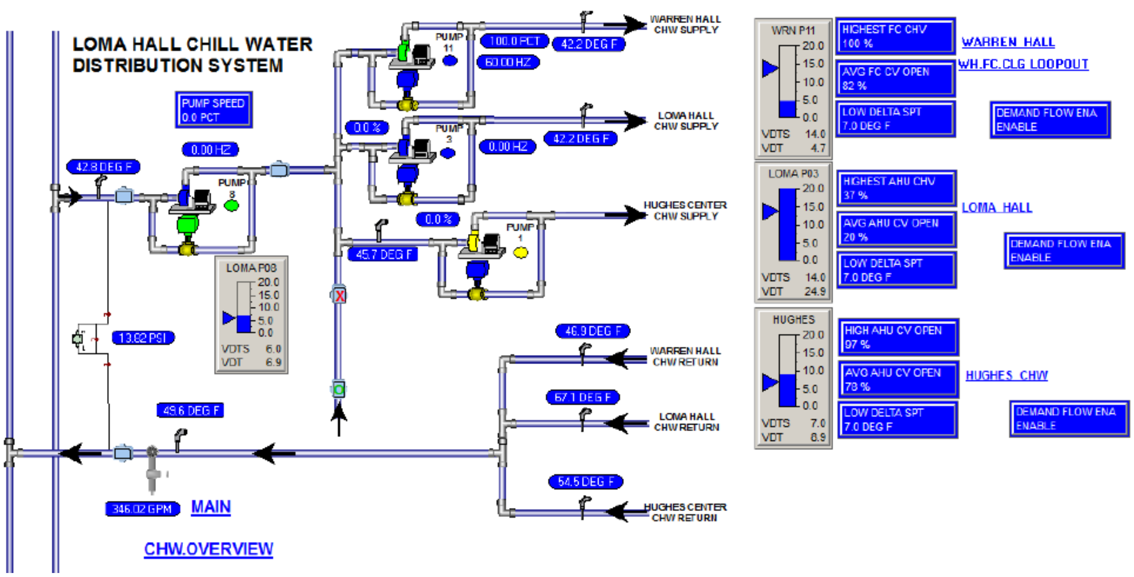
Building Information

62,000 sq.ft. three story building with offices, study rooms, conference rooms, classrooms, lecture halls, courtrooms.

Mechanical equipment serving the building and operating conditions:

- Six (6) CAV hydronic air handler units
- Three (3) make up air units for the kitchen
- VAV terminal units with SHW reheat
- SHW provided by the campus loop
- CHW provided by the campus loop

Additional Comments



CHILLED WATER PUMPS LOCATED IN LOMA HALL – SERVING WARREN HALL

Central Plant

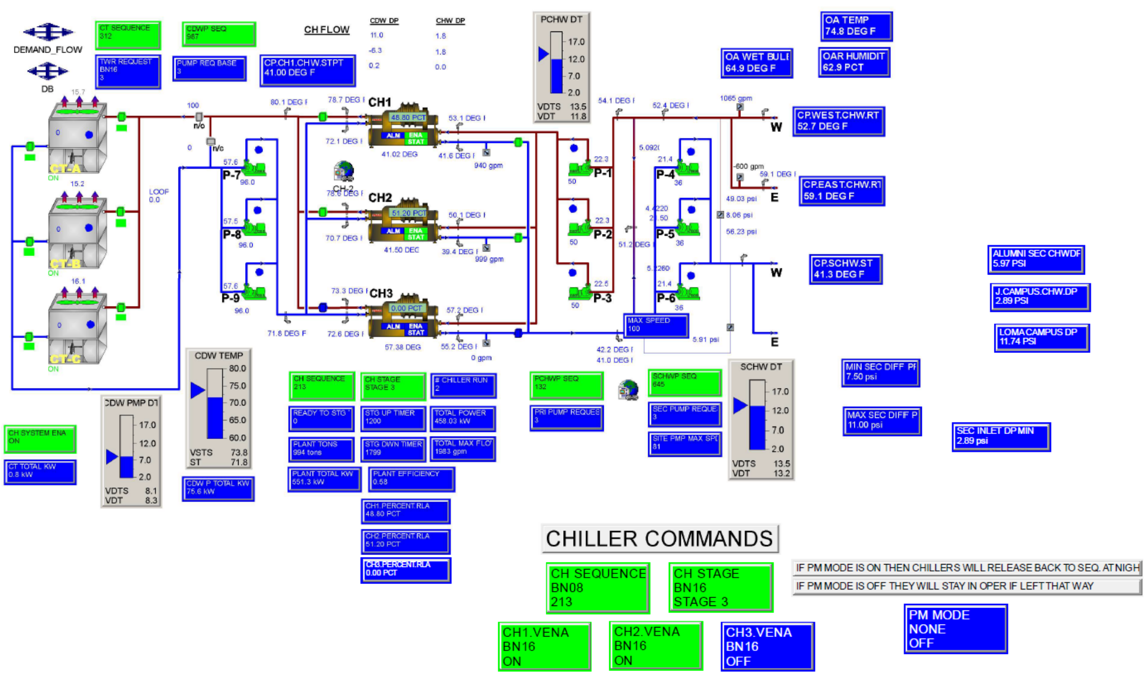
Building Information

Building housing the main campus CHW and SHW generation equipment that supplies CHW to the campus loop, steam to heat exchangers located at various buildings, SHW to the campus loop via large heat exchangers located in the central plant, space heating water via heat exchanger to a partial campus loop.

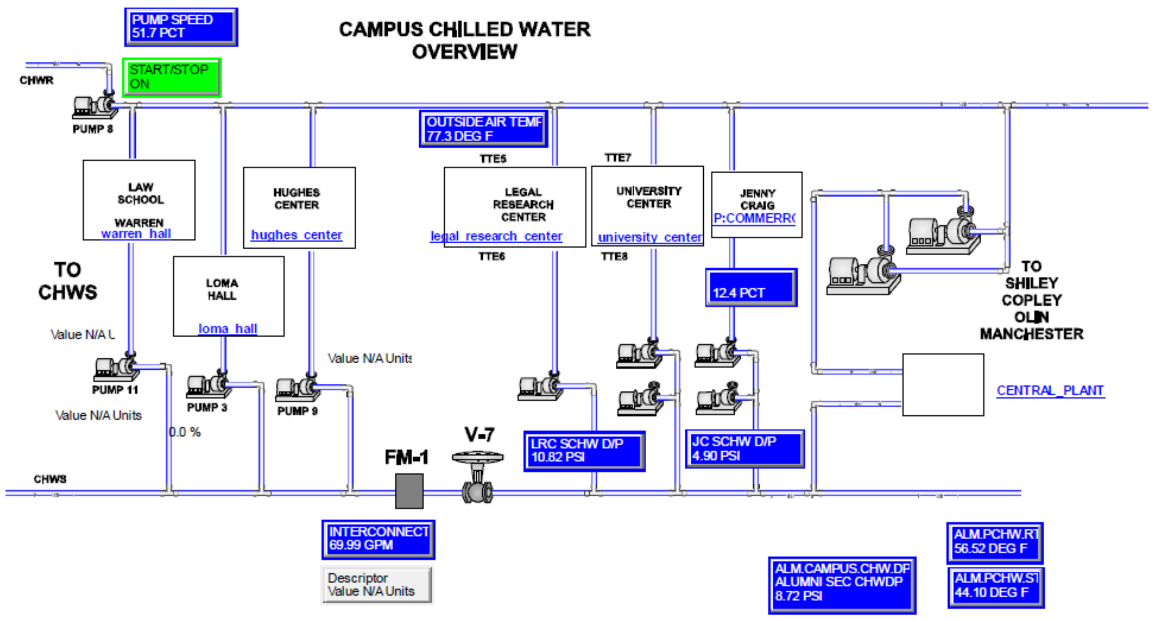
Mechanical equipment serving the building and operating conditions:

- Three (3) water cooled centrifugal chillers with variable speed compressor
- Primary CHW pumps with variable speed controls
- Secondary CHW pumps with variable speed controls
- Three (3) counterflow cooling towers with variable speed-controlled fans
- Three CDW pumps with variable speed controls
- Two (2) 10,206,000 btu/h gas-fired low-pressure steam boilers
- Two (2) SHW steam-to-water heat exchangers
- Two (2) SHW constant speed circulation pumps
- One (1) DHW steam-to-water heat exchangers
- Two DHW constant speed circulation pumps

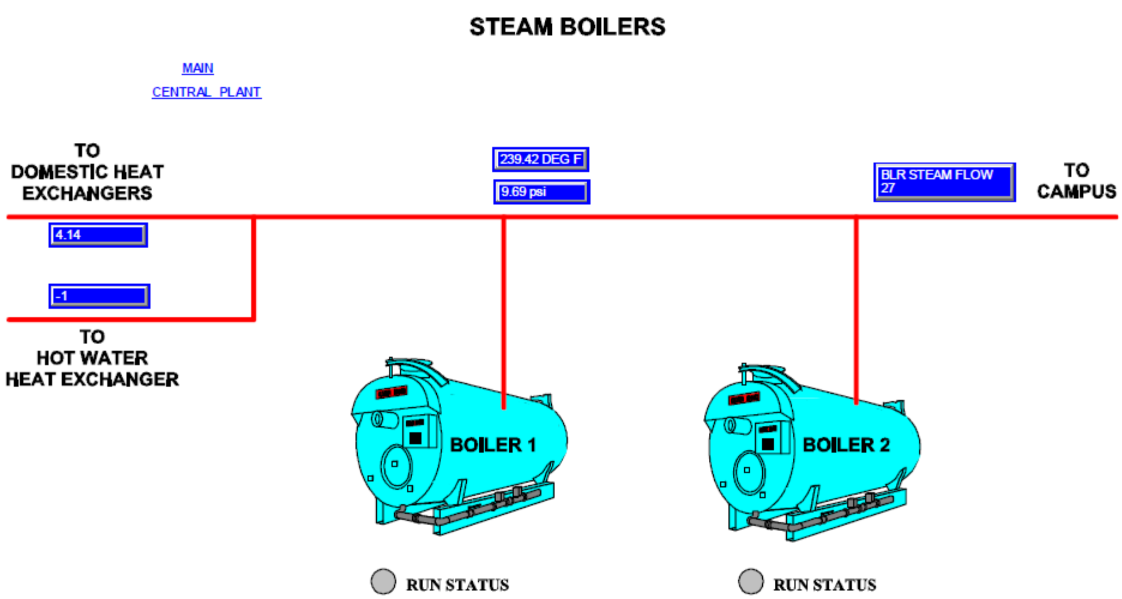
Additional Comments



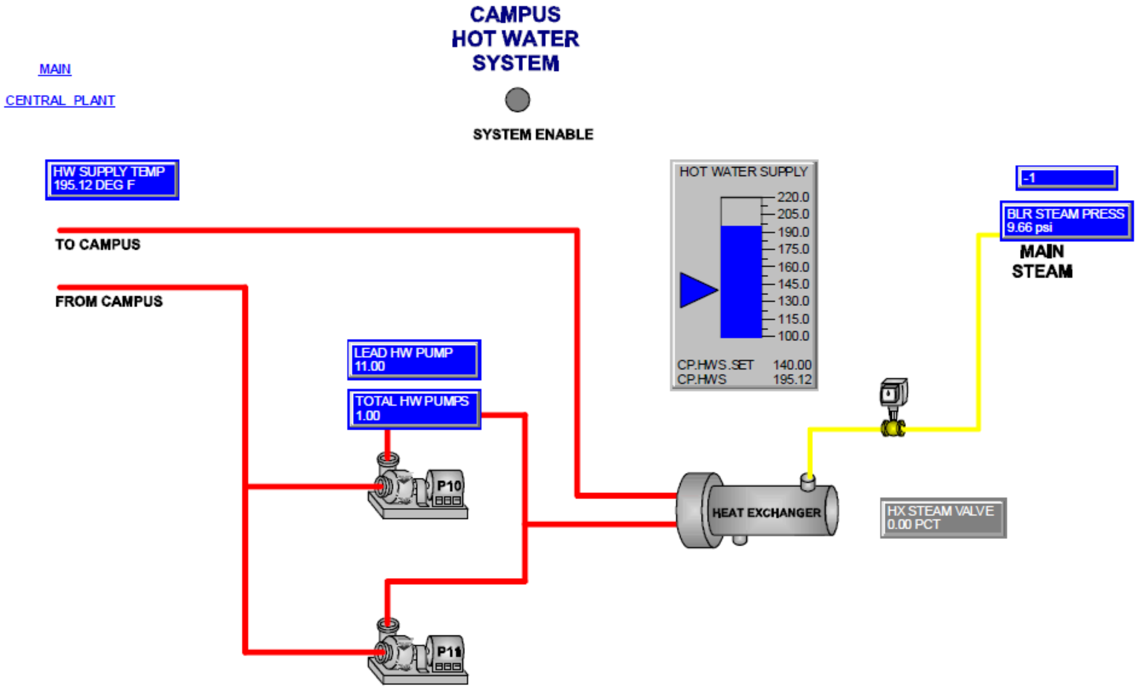
CAMPUS CHILLED WATER GENERATION SYSTEM



CAMPUS CHILLED WATER DISTRIBUTION OVERVIEW

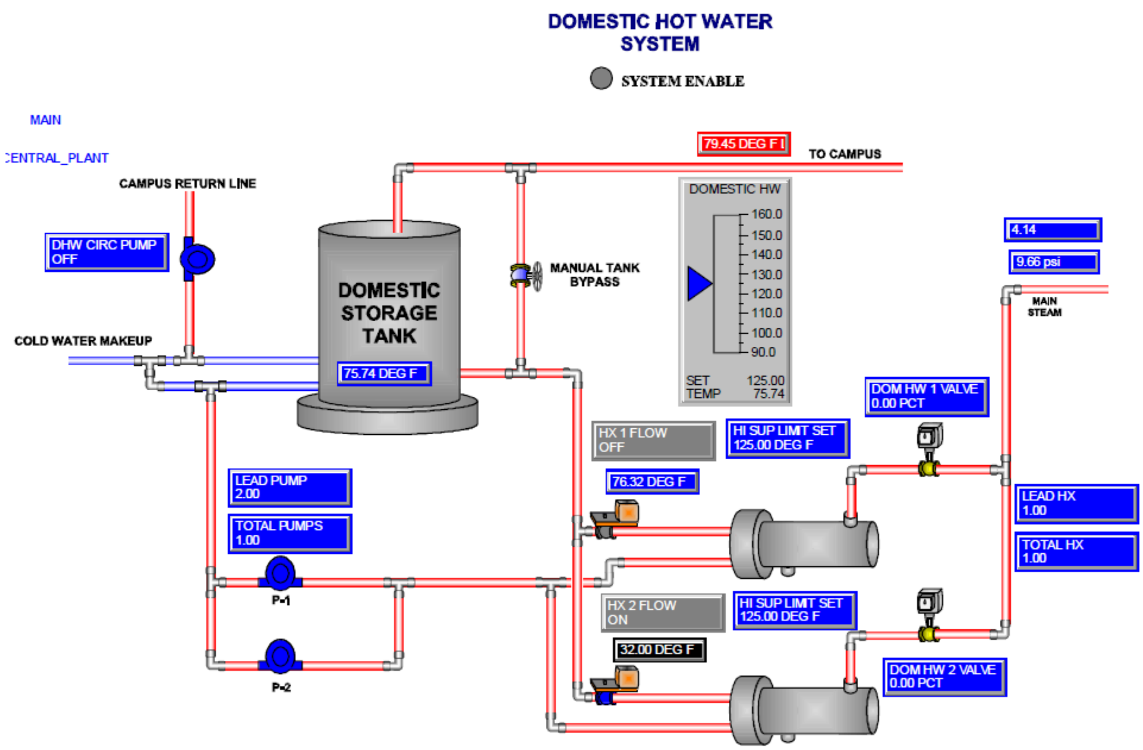


STEAM GENERATION SYSTEM



CAMPUS SPACE HEATING WATER DISTRIBUTION SYSTEM

FROM STEAM BOILERS / HEAT EXCHANGER



DOMESTIC HOT WATER GENERATION SYSTEM

FROM STEAM BOILERS / HEAT EXCHANGER

BUILDING	BUILDING SUPPLY
ALCALA VISTA	79.81 DEG F AVA HWSYS
ALUMNI CENTER	70.74 DEG F LC ALUMNI_HWSYS
HUGHES CENTER	177.60 DEG F HUGHES_HWS
JENNY CRAIG PAVILION	171.78 DEG F JC_HWSYS
JOAN KROC	160.57 DEG F JK.HWS
LEGAL RESEARCH CENTER	73.47 DEG F LC LRC_HWSYS
LOMA HALL	74.16 DEG F LC LOMA_HWS
MANCHESTER CONFERENCE CENTER	68.36 DEG F LC MCC_HWSYS
MISSION HOUSING	Value N/A Units MSH HWSYS
OLIN HALL	Value N/A Units OLIN.HW.SYS
SERRA HALL	121.63 DEG F SERRA_HALL
SCIENCE & TECHNOLOGY	172.01 DEG F STC_HWS
SCHOOL OF LEADERSHIP	Value N/A Units SOL HWSYS
SCHOOL OF NURSING	162.05 DEG F BR_HWSYS
STUDENT LIFE PAVILION	154.11 DEG F UC.HAHN.HWSYS
UNIVERSITY CENTER	71.44 DEG F LC UC_HWSYS
MAHER BOILERS	237.00 DEG F MAHER BOILER1
IMMACULATA	73.2 DEG F IMMACULATA.HHW

DECENTRALIZED SPACE HEATING WATER SUPPLY SYSTEM TEMPERATURES

Maher Steam Boiler Plant

Building Information

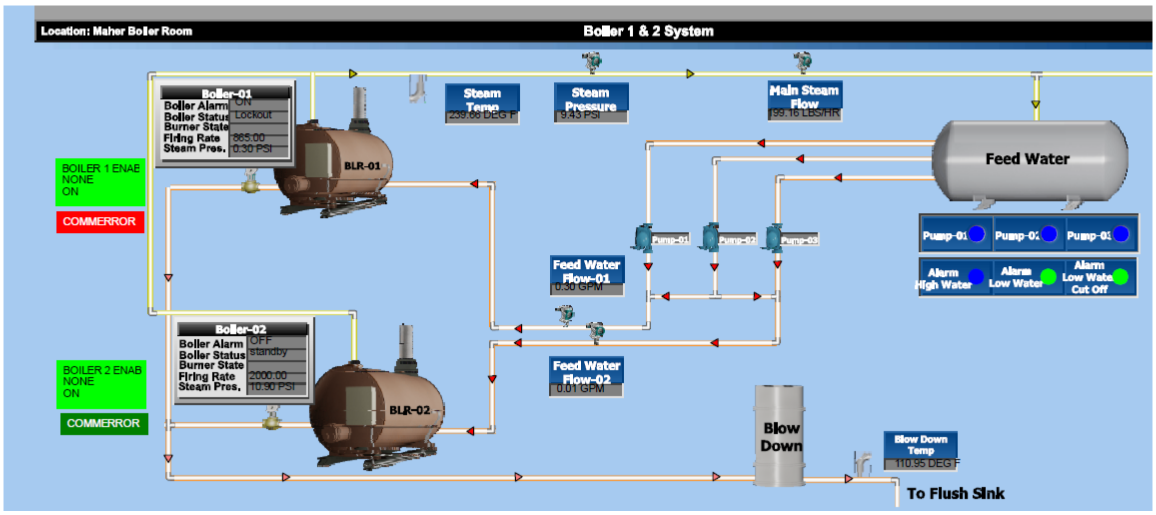
The Steam Boiler plant is in the basement of campus Mail Center

The Maher Boiler Plant steam boilers heat Maher Hall and make domestic hot water for the 1st, 2nd 3rd and 4th floors of Maher and the restrooms of the Print Shop.

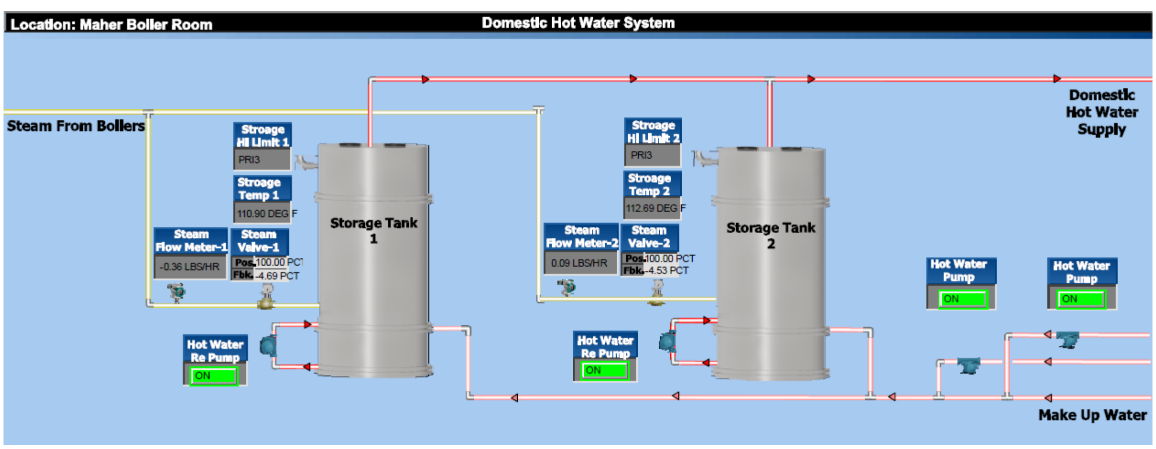
Mechanical equipment serving the building and operating conditions:

- Two (2) 1,999,000 btu/h gas-fired low-pressure steam boilers
- Two (2) indirect fired water heaters (heat exchangers) for DHW
- Two (2) DHW recirculation pumps

Additional Comments



MAHER STEAM BOILER PLANT



MAHER STEAM-TO-DOMESTIC HOT WATER PLAN

Appendix K: Carbon Offsets Details (Terrapass)

https://www.terrapass.com/climate-change/carbon-offsets-explained

Farm power

Terrapass works with farms in communities across the United States to make the best possible use of animal waste. Through the use of anaerobic digesters, methane is captured as the manure breaks down and is then destroyed when it is burned as a fuel to produce electricity. Additionally, these digesters can produce a variety of other products that help the farm and reduce environmental impact. The fibrous material can be separated, dried, and used as bedding, while the liquid effluent can be used as fertilizer. Anaerobic digestion also aids local communities by helping to reduce water pollution and odor associated with animal husbandry.

Landfill Gas Capture

Landfill gas capture projects turn garbage into power. As organic waste breaks down, it releases methane, a greenhouse gas 84 times more powerful than CO2. According to the EPA, landfills are the third largest source of methane emissions in the United States. Through the installation of gas collection and control systems, these projects result in the destruction of powerful greenhouse gases, and the gas can be burned in a generator to create renewable electricity.

Clean Energy from Wind Power

Wind energy displaces electricity that is generated by dirty fossil fuels like gas and coal (the way that most power is currently generated in the United States). In this sense, the amount of carbon dioxide emissions that are avoided depends upon the “carbon profile” of the electricity grid where the energy is produced. The carbon profile of each regional grid is calculated periodically by the US Environmental Protection Agency by adding up the weighted average of carbon dioxide emissions from all commercial energy sources on that regional grid.

Improved Forest Management

Forests can sequester carbon dioxide (C02) in a variety of ways. Carbon is stored in the trunks, leaves, branches, and roots of trees. Carbon is also stored in the forest soil, understory plants, and green “litter” on the forest floor. An Improved Forest Management Project under the CAR Forest Project Protocol involves changing forest management practices to increase carbon stocks on forested land relative to baseline (or “business as usual”) levels of carbon stocks. In other words, Improved Forest Management helps forests sequester more carbon.

How do I know these are high quality projects?

Terrapass supports specific carbon offset standards, which assure transparency and quality in the creation, quantification, and verification of offset projects. These standards require that offsets be real, additional (i.e., they wouldn’t have happened under a “business as usual” scenario), permanent, quantifiable, never double-counted or double-sold, and independently verified.

Currently, Terrapass uses the Verified Carbon Standard and the Climate Action Reserve as our only carbon offset standards.

How do I know that the projects are actually making a difference?

Terrapass ensures our offsets are making a difference in several ways. Prior to adding a project to our portfolio, we perform due diligence to fully understand the impact of each project. Once the project is in our portfolio, we monitor and verify all of the emissions reductions that are taking place. Finally, all projects in our portfolio must pass the "additionality" test. Additionality refers to the concept of whether your carbon offset purchase really brings about carbon reductions, or whether the reductions would have happened anyway. If the purchase of carbon offsets is a critical factor in making the reductions happen, the reductions are said to be "additional" to the business-as-usual case. By verifying and checking at each step in the process, we are committed to making sure our projects are restoring the balance.

https://www.terrapass.com/portfolio-audits

To ensure maximum transparency and accountability, every TerraPass offset purchase is verified in a periodic review conducted by an independent and accredited third party. We were the first, and remain the only, carbon offset provider in the U.S. to undergo such a review of our carbon purchase and supply.

The review covers several aspects of our business:

Offset quantity: Did we actually source the necessary amount of carbon offsets on behalf of our customers? To ensure that we did, the accountant examines and verifies our retail sales records and offset supply contracts.

Offset quality: Did we adhere to the quality benchmarks that we say we support? The accountant examines our carbon offset portfolio to ensure that it meets our stated standards.

Transparency and Verification: Our published project portfolio list is part of our submittals to the independent accountant. We publish details on the full portfolio for each period once it has been verified by our accountant. Partners such as Expedia or Enterprise Rent-A-Car are included as a subset of the overall portfolio.

Each year TerraPass retires the offsets it sold during the previous year. The time lag between sale and retirement occurs because of the process required to have third parties verify the exact amount of offsets generated and retired on behalf of our customers. Each year we compile a list of every sale, check it in detail (and have our outside accountants check it in detail as well), and add up all the numbers to make sure that everything aligns.

Appendix L: Chiller Analysis (Pony vs. Low-Load VFD Chiller)

To aid in campus decision-making in how best to serve the chilled water loop under low load conditions, the following technical analysis was conducted, supporting by the details in the following pages. A comparison was made between a 200-ton pony chiller at full load versus an 800-ton chiller @ 25% load to show the typical efficiency difference. The selection for the larger chiller is a 900-ton but the efficiency at low load will be comparable.

For a 100% loaded 200 ton chiller that meets current Title 24 standards, the efficiency is about 0.60 to 0.65 kW/ton. A modern 800-to-900-ton VFD chiller operating at 25% load will have efficiency of about 0.25 kW/ton, which is more than twice as efficient.

Smardt Inc.

1840 Trans Canada Highway
Dorval Quebec,
Canada H9P 1H7

Tel: +1 514 426 8989
Fax: +1 514 426 5757

PRIMARY DESIGN CONDITION

900 TonR NPLV.IP – 0.3248 kW/TonR

Load (%)	Capacity (TonR)	Efficiency (kW/TonR)	Power (kW)	CHW Flow (gpm)	Evap PD (psi)	CHWR (°F)	CHWS (°F)	Cond PD (psi)	COW Flow (gpm)	COWR (°F)	COWS (°F)	Sound Pressure dB(A)
100	900.0	0.5406	486.6	1605	5.68	55.99	42.00	3.49	1668	80.00	95.00	80.10
75	675.0	0.4034	272.3	1605	5.65	52.50	42.00	3.56	1668	72.50	83.35	79.10
50	450.0	0.2931	131.9	1605	5.60	49.00	42.00	3.63	1668	65.00	72.01	78.40
25	225.0	0.2482	55.84	1605	5.55	45.51	42.00	3.64	1668	65.00	68.46	75.50

Sound Data @ 3 ft

Note that even though this chiller selection is for a 900-ton model, the performance for an 800-ton will be very close.

Description	Global	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Lp(A) @ 100% Load	80.1	40.0	54.3	65.8	71.3	75.8	76.1	65.3	62.1

WE350.2XX1K.F2AYNB.F2BJNB.TS0

*API version: WC20_07_0_AV_02 - Dec 29, 2020

2019 Title 24 Chiller Efficiency: 200-ton water-cooled chiller = 0.68 kW/ton full load, 0.440 IPLV
800-ton water-cooled chiller = 0.585 kW/ton full load, 0.380 IPLV

@ ~200 ton load, pony chiller is fully loaded @ ~0.6 kW/ton vs. 25% loaded 800 VFD chiller @ ~0.25 kW/ton

MULTISTACK

Job Name	200 Ton Pony - MA Engineers	Job Number	
Location	San Diego	Quote Number	QRDIXON03192021-1
Engineer	MA Engineers	Representative	Ross Dixon
Contractor		Rep Office	San Diego

Performance Data

Chiller Model Number	Frame Type	Rated Capacity
MSF0202MCHBDGBAHCABAHE-ALAG-G	Frame 1 TT-300 & 1 TT-350	200.0

PERFORMANCE DATA

				Evaporator			Condenser			
Load	Capacity (tons)	kW	kW/Ton	Flow Rate (GPM)	Entering Temp. °F	ΔP (PSI)	Cond Flow (GPM)	Entering Temp. °F	Leaving Temp. °F	ΔP (PSI)
100%	200.0	127.1	0.6357	480.0	54.00	8.110	609.0	85.00	94.30	9.130
90%	180.0	98.19	0.5455	480.0	53.00	8.110	609.0	81.00	89.37	9.130
80%	160.0	75.76	0.4735	480.0	52.00	8.110	609.0	77.00	84.44	9.130
75%	150.0	66.12	0.4408	480.0	51.50	8.110	609.0	75.00	81.98	9.130
70%	140.0	57.32	0.4094	480.0	51.00	8.110	609.0	73.00	79.51	9.130
60%	120.0	42.19	0.3516	480.0	50.00	8.110	609.0	69.00	74.58	9.130
50%	100.0	30.21	0.3021	480.0	49.00	8.110	609.0	65.00	69.65	9.130
40%	80.00	23.98	0.2997	480.0	48.00	8.110	609.0	65.00	68.72	9.130
30%	60.00	17.27	0.2879	480.0	47.00	8.110	609.0	65.00	67.79	9.130
25%	50.00	14.48	0.2896	480.0	46.50	8.110	609.0	65.00	67.33	9.130
20%	40.00	11.18	0.2796	480.0	46.00	8.110	609.0	65.00	66.86	9.130

With Tower Relief (per AHRI 550/590) | IPLV.IP | 0.3482

EVAPORATOR DESIGN DATA	(Based on Water)
Entering Temperature °F	54.00
Leaving Temperature °F	44.00
Design Flow (GPM)	480.0
Pressure Drop (Full Load)	8.110 PSI / 18.73 ft H2O
Chiller Minimum Flow (GPM)	160.0
Minimum ΔP(ft)	0.7900 PSI / 1.825 ft H2O
Number Of Passes	2
Tube Type	3/4" diameter 0.025" Copper Enhanced
Fouling Factor (h-ft2-°F/Btu)	0.000100
Connection Size (in.)	5"
Connection Type	Grooved Coupling
Head Style	Dish
Head Mounting	Inlet: Right Outlet: Right

CONDENSER DESIGN DATA	(Based on Water)
Entering Temperature °F	85.00
Leaving Temperature °F	94.30
Design Flow (GPM)	609.0
Pressure Drop (Full Load)	9.130 PSI / 21.09 ft H2O
Chiller Minimum Flow (GPM)	170.0
Minimum ΔP(ft)	0.7500 PSI / 1.733 ft H2O
Number Of Passes	2
Tube Type	3/4" diameter 0.025" Copper Enhanced
Fouling Factor (h-ft2-°F/Btu)	0.000250
Connection Size (in.)	6"
Connection Type	Grooved Coupling
Head Style	Dish
Head Mounting	Inlet: Right Outlet: Right

PHYSICAL DATA	
* Length (Shell Only)	120
Width (in.)	34
Height (in.)	78
Estimated Shipping Weight (lbs.)	7350
Estimated Operating Weight (lbs.)	7860
Refrigerant Type	134A
Refrig. Charge (lbs per circuit)	425
Shell Configuration	Stacked

ELECTRICAL DATA	
Voltage	460-60-3
Power Input	127.13
Compressor RLA (per comp.)	73.5/106.2
MCA	207
MOP	300

Parallel feeds not required (Assumes no larger than 300 MCM/kcmil wire)

Performance Run Date: 3/19/2021 1:17:26 P Software Version #: 1.04435.62000

*** See Head drawing for additional length for the heads**

Certified in accordance with the AHRI Water-Cooled Water-Chilling and Heat Pump Water-Heating Packages Certification Program, which is based on AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI). Certified units may be found in the AHRI Directory at www.ahridirectory.org.

AHRI CERTIFIED® www.ahridirectory.org Water-Cooled Water Chilling and Heat Pump Water-Heating Packages AHRI Standards 550/590 and 551/591