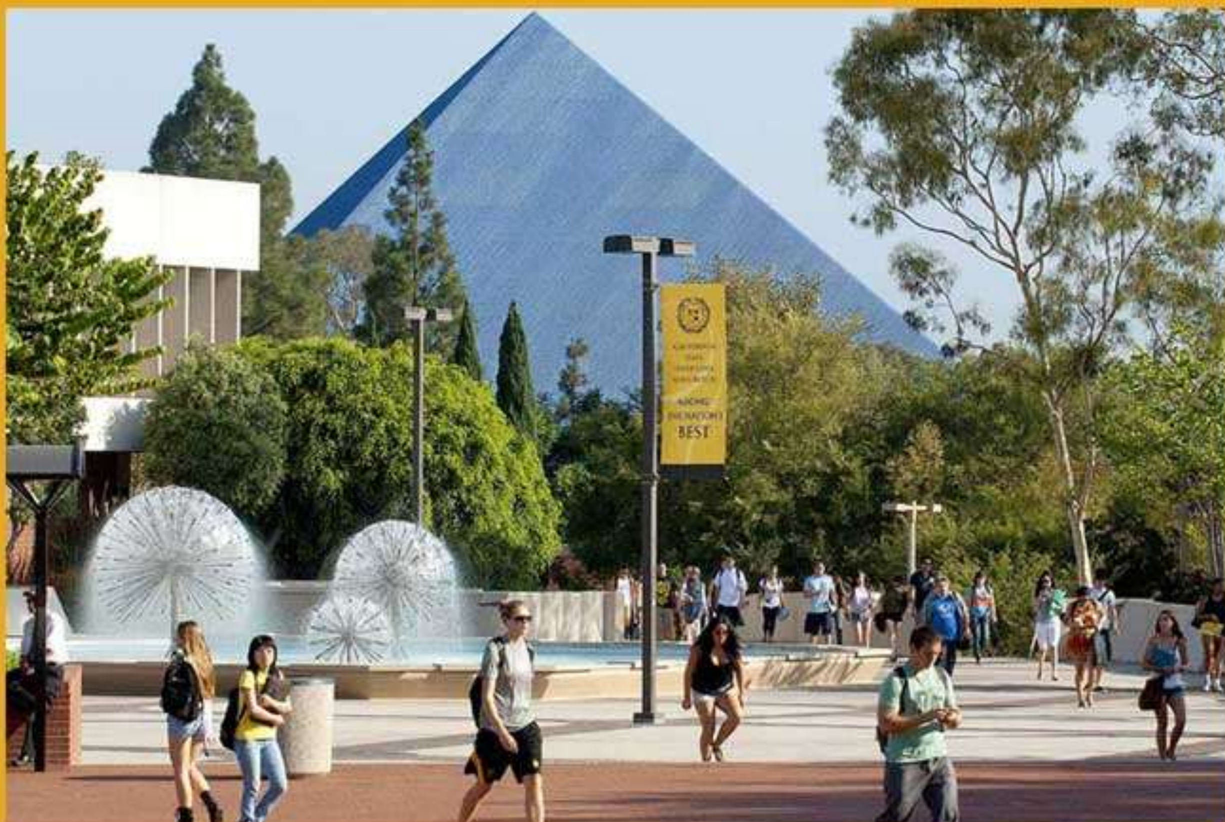
CALIFORNIA STATE UNIVERSITY **LONG BEACH**



CLEAN ENERGY MASTER PLAN

September 2018

PRESENTED BY

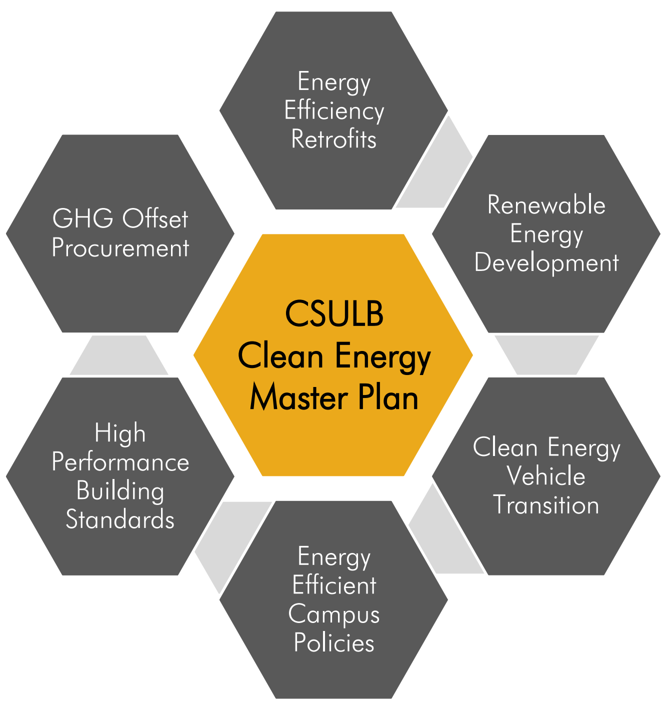
GLUMAC
A TETRA TECH COMPANY

1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

California State University of Long Beach (CSULB) has undertaken several initiatives to demonstrate their commitment to environmental stewardship by committing to reduce greenhouse gas (GHG) emissions on campus. In 2014, CSULB's sustainability task force developed a Climate Action Plan (CAP) which outlined a framework to drive future efforts in reducing the carbon footprint of the campus. The strategies discussed in the CAP were intended to lead the campus to become operationally carbon neutral by year 2030. As outlined in the CAP, reducing campus Scope 1 & 2 emissions from energy and fuel usage will be critical to achieving carbon neutrality for the campus.

In the Fall of 2017, CSULB engaged a team of consultants, Glumac | ARC Alternatives | EcoShift | Seed Consulting Group, to develop a Clean Energy Master Plan (CEMP) for the campus. The intent of the CEMP project was to develop a strategic roadmap for GHG emission mitigation measures to not only reduce CSULB's Scope 1 & 2 emissions, but also drive operational savings and improve campus facilities and infrastructure. The findings of this CEMP will help guide CSULB's energy strategy over the next 12 years as the institution works toward becoming carbon neutral by 2030. This engineering study included a robust assessment of campus energy sources, demands, and utilization to identify clean energy alternatives and strategies to improve the efficiency of campus operations. Through the course of their investigation, the consultant team identified numerous clean energy projects to reduce GHG emissions. The CEMP project focused on the following strategies:



The next step in the CEMP was to translate the identified clean energy projects and carbon mitigation measures into a planning tool that would aid in the development of a strategic roadmap for GHG reductions in support of achieving carbon neutrality. To accomplish this, the consultant team developed a custom-built CSULB planning, visualization and tracking tool to inform their recommendations for pursuing various GHG emission reduction projects. After the site investigation and energy analysis phases of the project were completed, all the clean energy projects identified across campus were input into this scenario analysis tool.

This tool allows for users to develop multiple clean energy implementation plans to reach the CSULB's 2030 carbon neutrality target. As users are developing these prospective implementation scenarios, the tool continually tracks key metrics such as energy savings, emissions reductions, total project cost, net present value, etc. The CEMP team developed five (5) potential strategic energy plan scenarios and conducted a sensitivity analysis in the tool to help shape and guide the recommendation outlined in this report. The scenario analysis tool was developed to be a dynamic asset that will be turned over to CSULB's sustainability department at the conclusion of the project for their continued analysis and tracking of progress.

The strategic energy recommendations and scenarios developed in the CEMP report are based on the best available information provided to the consultant team at this time. The project deliverables were developed with the intention and ability to be a dynamic resource for CSULB as the university navigates towards their 2030 carbon neutrality target. The team understands CSULB is a dynamic, growing institution and needs an energy strategy that is flexible and can adapt to an ever-changing environment. It is recommended that CSULB continually tracks their progress towards carbon neutrality on an annual basis and updates their CEMP every five years, as outlined in the campus Climate Action Plan.

1.2 ENERGY USAGE AND EMISSIONS

2017 ENERGY USE

The following table shows a breakdown of the total campus energy use in 2017. This includes all electrical/natural gas services on the main campus, Beachside Housing complex and Blair Field sports complex. In 2017 the total cost of energy for CSULB was $6.2 million to provide over 303,000 MBTU of site energy – natural gas and electricity.

Table 1: Campus Energy Use Breakdown – 2017

	Energy Cost [$]		Site Energy [MBTU]		Source Energy [MBTU]		GHG Emission [MTE]	
Electricity	$5,399,317	87%	182,443	60%	574,696	82%	13,837	70%
Natural Gas	$838,299	13%	120,702	40%	126,737	18%	6,050	30%
Total Energy	$ 6,237,616	-	303,145	-	701,433	-	19,887	-

While natural gas use only accounted for 13% of the total campus energy cost, it represents 40% of the site energy use and 30% of the overall energy related emissions. Due to the low cost of natural gas per unit of energy compared to electricity, it will be more difficult for CSULB to cost effectively reduce natural gas use.

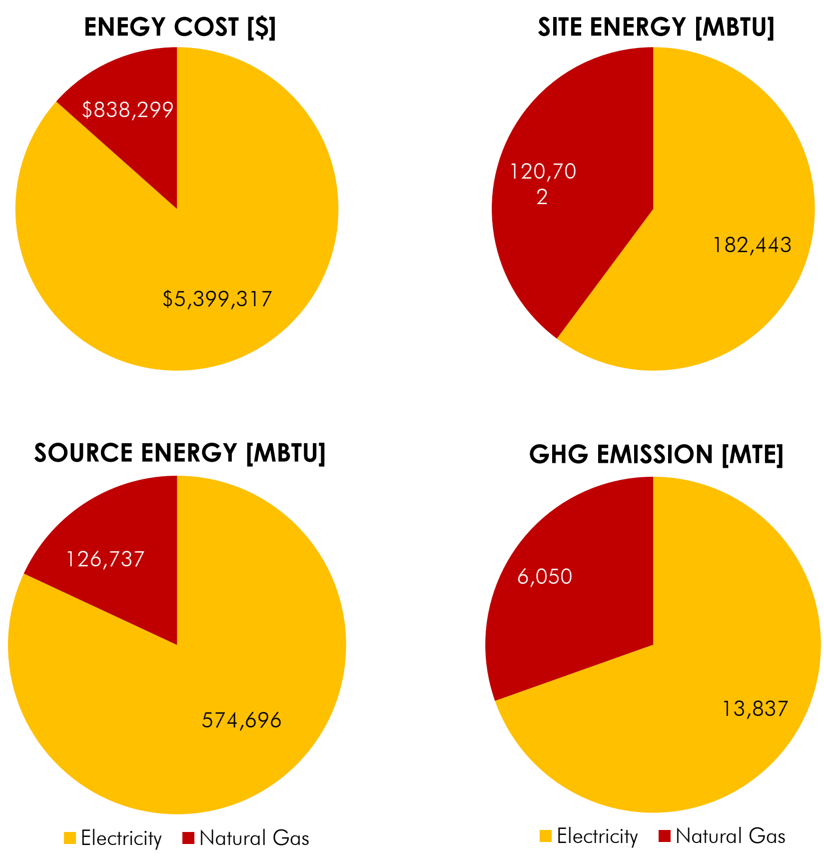


Figure 1: Campus Energy Use Breakdown – 2017

HISTORICAL ENERGY USAGE

Over the past 27 years CSULB has taken significant strides to reduce the university's environmental impact through improving the efficiency of energy use across campus. The overall energy usage for the campus in 2017 was 9% lower compared to 1990 levels, despite the total building area on campus increased by 42% - 1.2 million gross square feet. The overall campus Energy Use Intensity (EUI), a measure of how much energy a building uses per square foot, in 2017 was 36% lower compared to 1990 levels, meaning the campus uses less than two thirds the energy to operate the campus. The following table shows the historical campus energy usage at CSULB dating back to 1990, compared to the 2017 calendar year. This is a result of CSULB's investment in energy efficiency projects and having higher standards for energy performance on new construction buildings.

Table 2: Historical Campus Energy Use[1]

Year	Building Area [sf]	Electricity [kWh]	Natural Gas [therms]	Energy Usage [MBTU]	Delta [%]	Site EUI [kBtu/sf]	Delta [%]
1990	2,850,000	48,531,845	1,664,834	332,074	-	116.5	-
2004	3,450,000	61,275,291	1,656,991	374,770	-13%	108.6	7%
2009	3,682,423	50,223,070	1,218,983	293,259	12%	79.6	32%
2017	**4,052,474**	**53,471,081**	**1,207,016**	**303,145**	**9%**	**74.8**	**36%**

A breakdown of the campus EUI between natural gas and electricity is shown below. The 36% reduction in EUI between 1990 and 2017 was primarily a result of natural gas energy reductions on campus.

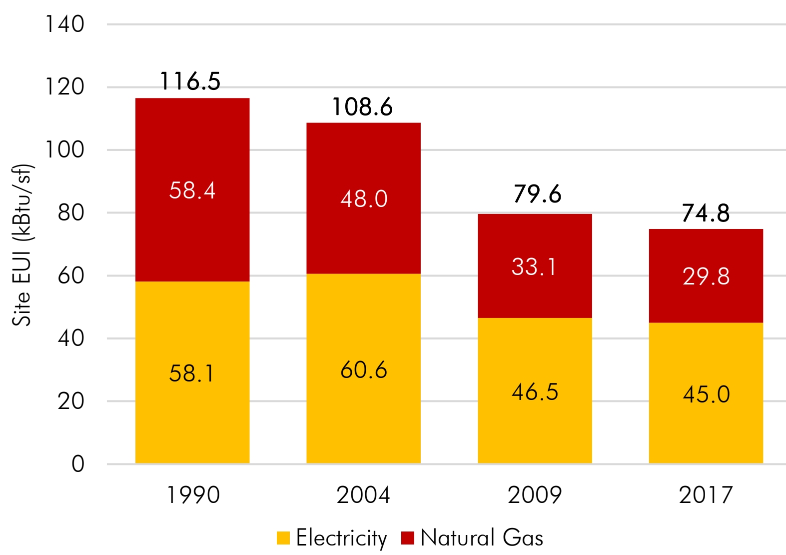


Figure 2: Historical Campus Site EUI Breakdown

[1] Historical energy use and building area data provided from 2011 CSULB Strategic Energy Plan

RENEWABLE ENERGY

CSULB installed their first solar PV projects in 2008. This phase of solar projects totaled 409 kW-dc of installed capacity and included rooftop systems on the following buildings:

- **Brotman Hall:** 240.2 kW-dc
- **Corporation Yard:** 118.6 kW-dc
- **Vivian Engineering:** 50.4 kW-dc

In additional to the first phase of PV projects developed in 2008, the campus also completed a significant renewable energy project that came online in early 2018. The SunPower carport solar system totaled 4,794 kW-dc in installed capacity and is estimated to bring the total self-generation at CSULB to 14.8% in 2018.

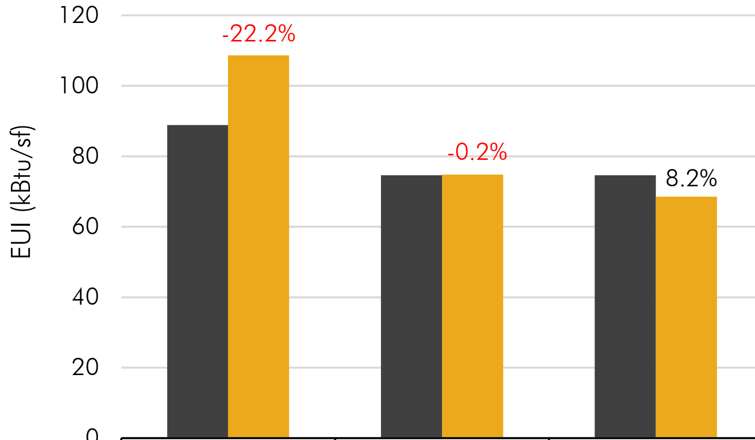
Table 3: Historical Renewable Energy Generation

Year	Total Capacity [kW-dc]	Estimated Generation [kWh]	Self-Generation [%]
2009	409	501,616	1.0%
2017	409	484,321	0.9%
2018	**5,203**	**7,973,409**	**14.8%**

The recently completed 4.8MW carport solar system was developed under an No Export agreement with SCE, meaning CSULB cannot export excess generation back to the grid. An assessment of the first three months of operation during 2018 showed that electricity was exported (over generation) on multiple occurrences, usually on Sunday's around noon when electrical demand was low. This can potentially make it difficult to add additional PV capacity to the main SCE service, without curtailing PV generation (shutting off PV arrays during over generation periods).

CAMPUS ENERGY BENCHMARKING

CSULB's campus energy usage was benchmarked against the overall CSU system to better understand how efficient the campus is currently operating compared to the rest of the CSU system. The following chart shows CSU Systemwide Site EUI compared to CSULB's campus. During the calendar year of 2017 CSULB site EUI was on par with the overall CSU system; however, this was significant improvement compared to 12 years prior when the campus used 22% more energy compared to its peers.



	2004/2005	2016/2017	2018
CSU Systemwide	88.9	74.6	74.6
CSU Long Beach	108.6	74.8	68.5

Figure 3: CSULB vs. CSU Systemwide Energy Use[2 3]

During the period of 2004/2005 to 2016/2017 CSU systemwide has seen an overall EUI reduction of 16%. Whereas, CSULB has seen a 31% reduction in their campus EUI. This indicates that CSULB has doubled the pace of energy efficiency compared to the overall CSU system as result of higher performance new construction projects and energy efficient investments. With the addition of the 4.8 MW solar array recently added to campus, CSULB is expected to surpass the CSU systemwide Site EUI for purchased utilities in 2018 and operate using 8% less purchased energy.

VEHICLE FUEL USAGE

CSULB's vehicle fleet comprises of 354 different vehicles, which are operated by over 76 departments across campus. 185 of these are electric carts (52%), with the remainder consisting of gasoline and diesel fueled vehicles. CSULB has prioritized transitioning vehicles to electric carts where possible to reduce their operational impact on the environment.

The majority of vehicle fuel use at CSULB are from two university departments, the Facilities Maintenance (FM) department and the University Police (UP). The largest fleet is operated by the Grounds Department, who operate a range of 67 electric and gasoline/diesel vehicles. The University Police operate the second largest fleet, comprised almost entirely of gasoline vehicles. These groups respectively use 53% (FM) and 29% (UP) of the gasoline and diesel fuel on campus. The following graphs show a full breakdown of unleaded gasoline and diesel fuel use by department from 2017.

[2] Energy usage includes on campus renewable energy production

[3] 2018 energy was estimated based on 2017 use and expected generation from the 4.8 MW solar array. CSU Systemwide EUI data was provided from: *Sustainability in the California State University: The First Assessment of the 2014 Sustainability Policy (2014-2017)*

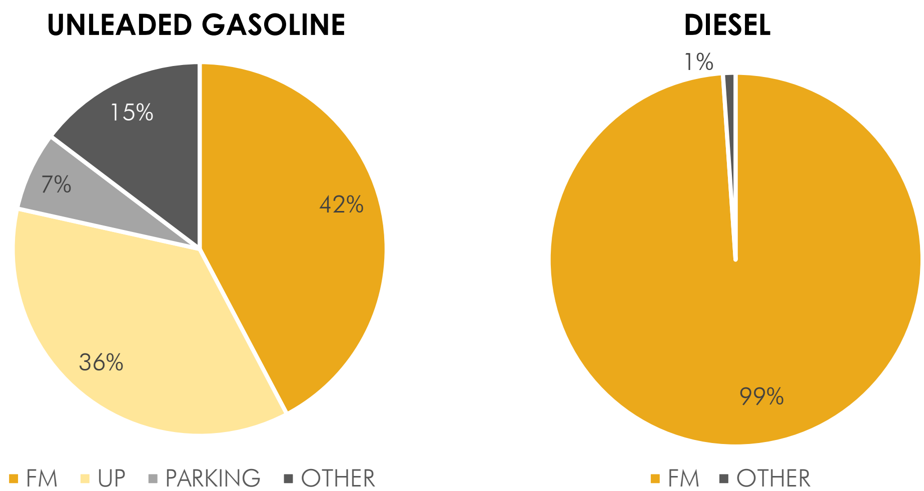


Figure 4: Vehicle Fuel Use by Department[4]

The following graphs show a full breakdown of unleaded gasoline and diesel fuel use by vehicle type from 2017. Pickups and Trucks on campus were the biggest consumers of gasoline (43%), followed by Autos (37%) and Vans (13%). Diesel fuel use was almost exclusively by the Ground Department, which included Sweepers (52%) and Mower (30%), followed by the Auto Department, which included Forklifts (7%).

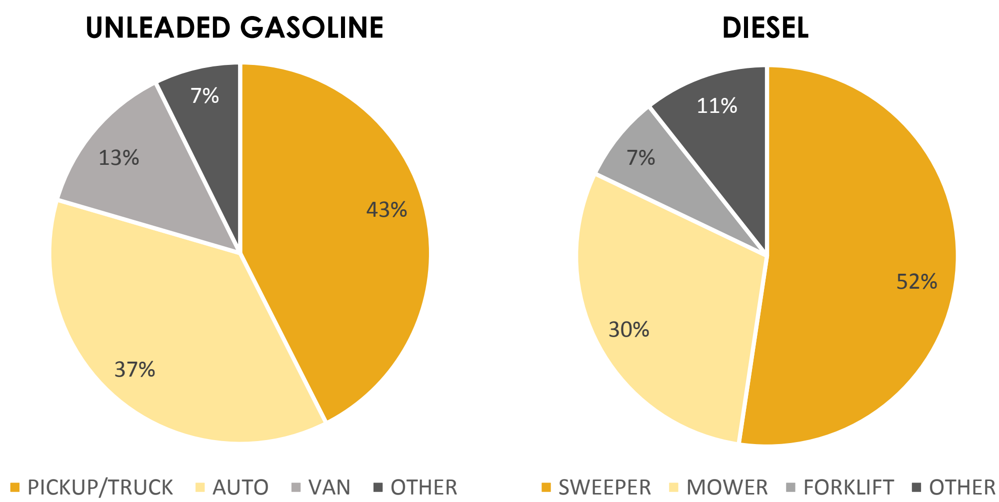


Figure 5: Vehicle Fuel Use by Vehicle Type[5]

The remainder of the campus vehicle fleet is primarily comprised of electric carts, with gasoline and diesel vehicles being operated sporadically by different departments.

GHG EMISSIONS

The CSU Systemwide sustainability guidelines aim for campuses to reduce their facility GHG emissions to 1990 levels, or below, by 2020. This is consistent with California's emissions reduction targets outlined in AB 32, the Global Warming Solutions Act of 2006. CSULB is currently on track to exceed these requirements and has reduced the total campus Scope 1 & 2 emissions by 7% compared to

[4] 2017 fuel use data was provided by CSULB Campus Fleet Administrator
[5] 2017 fuel use data was provided by CSULB Campus Fleet Administrator

1990 levels. Emissions for 2018 are expected to be roughly 16% lower than 1990 levels with the recently completed 4.8 MW solar project. CSULB has shown a 41% reduction in their GHG emissions per square foot of building area across campus compared to 1990 Levels. Greenhouse gas emissions due to the vehicle fleet emissions have reduced by 18% since 2009. This is primarily due to the increase in the number of electric vehicles operated on campus.

Table 4: Historical Energy Related GHG Emissions

Year	Building Area [SF]	Electricity Emissions [MTE]	Natural Gas Emissions [MTE]	Vehicle Emissions [MTE]	Total Energy Emissions [MTE]	Reduction [%]	Total Emissions [MTE/sf]	Reduction [%]
1990[6]	2,850,000	-	-	-	22,060	-	0.0077	-
2009[7]	3,682,423	13,340	6,050	390	19,780	10%	0.0054	31%
2017	4,052,474	13,837	6,410	318	20,565	7%	0.0051	34%
2018[8]	4,052,474	11,899	6,410	318	18,627	16%	0.0046	41%

The CSULB Climate Action Plan (CAP) from 2014 has a stated goal to reduce GHG emissions to achieve climate neutrality by 2030 at the latest. This includes not only directly energy related emissions, but also indirect emission (Scope 3) which include sources such as student/faculty/staff commuting. The following table shows a breakdown of the total campus emissions which CSULB will need to address to achieve full carbon neutrality.

Table 5: Total Campus GHG Emissions – CO_2 Equivalent Metric Tons [MTE][9]

GHG Emissions Source		Emissions [MTE]	Breakdown [%]	Data Source [Year]	CEMP Scope
Scope 1	Stationary Combustion	6,598	10.4%	2017	YES
	Vehicle Fleet Fuels	320	0.5%	2017	YES
	Fugitive Emissions	3,245	5.1%	2015/2016	-
Scope 2	Purchased Electricity	14,430	22.8%	2017	YES
Scope 3	Student Commuting	31,843	50.2%	2015/2016	-
	Faculty/Staff Commuting	5,284	8.3%	2015/2016	-
	Air Travel	1,756	2.8%	2015/2016	-
	Solid Waste	-102	-0.2%	2015/2016	-
	Total GHG Emissions	63,374	100%	-	-

The following graph show a simplified breakdown of the total GHG emissions sources of the campus. The CEMP project addresses GHG mitigation measures for majority of the direct campus operational emissions (electricity, natural gas and fuel use). While addressing direct energy related emissions is an essential part of a campus carbon neutrality plan, it is important to keep that in context to the overall

[6] 1990 total Scope 1 & 2 emissions were provided from the CSULB Climate Action Plan. Fugitive emissions were not broken out; therefore, they were estimated for 1990 to be the same as in 2009
[7] 2009 emissions values were provided from the 2011 Strategic Energy Plan
[8] 2018 emissions were estimated based on 2017 use and expected mitigation from the 4.8 MW solar array
[9] Data for emissions sources outside of CEMP scope was provided from the 2015/2016 campus inventory

campus carbon footprint. These emissions only account for 33.7% of the total campus emissions. As outlined in the CSULB CAP, Scope 3 emissions will also need addressed by 2030.

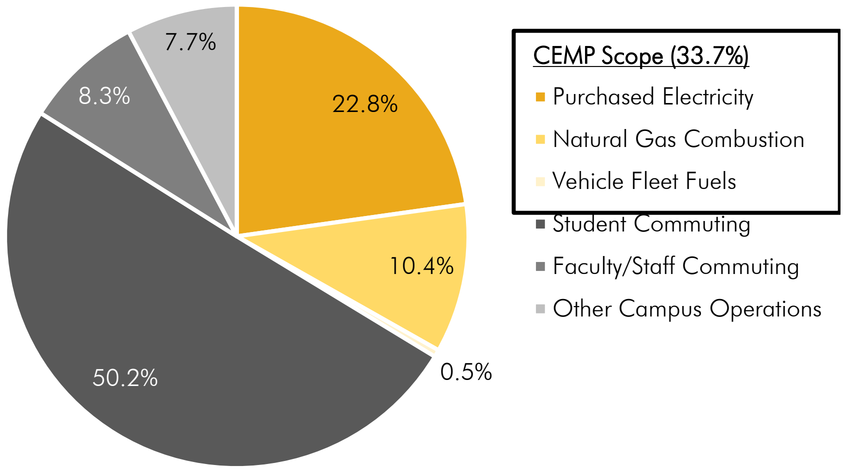


Figure 6: Total Campus GHG Emissions Breakdown[9]

1.3 SUMMARY OF KEY FINDINGS

Through our assessment of the existing conditions at CSULB and analysis of various clean energy project, we have identified numerous mitigation measures to reduce Scope 1 & 2 emissions. These projects include:

- **Energy Efficiency (EE):** The CEMP identified over 567 energy efficiency projects across campus. A combination of all potential EE projects, accounting for overlapping/alternative measures, could result in annual energy savings of up to 20,280,000 kWh and 658,000 therms. This would reduce annual energy cost by $2,600,000 annually, based on 2017 utility rates. These projects include:
  - 279 capital improvements (HVAC, Lighting, DHW)
  - 57 general commissioning (Retro-Cx, MBCx, etc.)
  - 217 energy efficiency operational policy opportunities
  - 14 deep energy retrofits/building modernization projects
- **Renewable Energy (RE):** The CEMP identified an additional 9.99 MW of solar PV in additional to the existing 4.79 MW carport solar array. The additional PV projects are estimated to generate 15,970,000 kWh annual.
- **Clean Vehicle Fleet (VF):** The CEMP identified clean vehicle transition options for all campus vehicles. It is estimated that 85% of gasoline and 73% of diesel fuel use could be eliminated through fleet electrification.
- **Carbon Offsets:** Carbon offsets were treated as a last result GHG emission mitigation measure throughout the analysis. The cost for the carbon offset was used to quantify true operational cost after 2030 when CSULB will need to mitigate all GHG emissions. Based on a market assessment of carbon offsets purchased in 2017, the expected cost in 2030 was estimated.

The following graph shows the potential for energy savings for all EE and RE projects that were identified across campus. It is estimated that CSULB's annual energy use can be reduced by up to 60% by 2030.

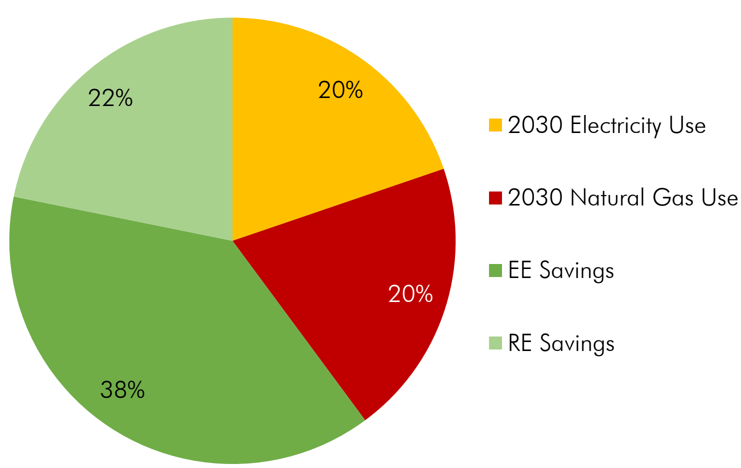


Figure 7: Potential Campus Energy Savings [MBTU]

SCENARIO ANALYSIS CARBON PLANNING

Scenario analysis carbon planning helped the consultant team to plan for and visualize the multidimensional impacts of the implementing various energy efficiency, renewable energy and clean vehicle fleet projects over the next 12 years leading up to 2030. The following five scenarios were assessed as part of our strategic planning analysis. These scenarios were developed in conjuncture with CSULB Sustainability Task Force. Under all scenarios, all remaining GHG emissions were assumed to be offset by carbon offsets.

Table 6: CSULB 2030 Carbon Neutrality Scenarios

Scenario Name	Energy Efficiency (EE)	Renewable Energy (RE)	Vehicle Fleet (VF)
(1) Business as Usual (BAU)	Maintain current average investment rate to **$1-1.5 million annually**. All EE projects completed by 2035	Invest in most economical PV projects (**2.28 MW**)	**None** – rely on incremental efficiency improvements
(2) Increased Investment	Increase average investment rate to **$2.8 million annually**. All EE projects completed by 2030	BAU + Main Campus Curtailment Option 1 (**5.36 MW**)	**Fleet Electrification** - transition most vehicles by 2030. Excludes diesel fuel grounds equipment
(3) Operational/Policy Changes	Lower than average investment rate – **$0.6 million annually**. Prioritize only cost-effective EE projects and implement ambitious energy savings operational policies	**None** – no additional PV projects	**Fleet Electrification** - transition most vehicles by 2030. Excludes diesel fuel grounds equipment
(4) Cost-Effective Investment Strategy	Lower than average investment rate – **$1 million annually**. Prioritize only cost-effective EE projects.	**None** – no additional PV projects	**None** – rely on incremental efficiency improvements
(5) Ambitious NZE Investments	Increase average investment rate to **$4.4 million annually**. Includes numerous electrification projects	All Potential PV Projects: BAU + Main Campus Curtailment Option 3 (**7.71 MW**)	**Fleet Electrification** – transition ALL vehicles by 2030. Includes diesel fuel grounds equipment

The scenarios assessed in the CEMP were not intended to be specific project portfolios that CSULB should look to pursue. This analysis was used to better understand the financial and environmental impacts of various potential investment strategies on campus. This helped to develop strategic recommendations to support CSULB's path towards cost effectively achieving 2030 carbon neutrality.

The following chart shows the potential campus EUI of the campus in 2030 for various potential EE & RE investment scenarios. Under the Business as Usual (BAU) investment scenario CSULB is expected to have a year over year EUI reduction of 2.16% with an investment of $1-1.5 million on EE projects annually. The Ambitious NZE investment scenario was used as a bounding case and includes numerous electrification projects across campus. This would increase the average year over year EUI reduction to 5.33%, and would result in an overall campus EUI reduction of 48% compared to projected 2018 energy use (including 4.8MW solar system).

Table 7: Scenario Analysis Energy Savings Potential

Year	Site EUI [kBtu/sf]	EUI Reduction (Relative to 1990)		EUI Reduction (Relative to 2018)		Average Year Over Year Reduction
1990	116.5	-	-	-	-	-
2017	74.8	41.7	36%	-	-	-
2018 (Projected)	68.5	48.0	41%	-	-	-
2030 (BAU)	52.7	63.8	55%	15.8	23%	**2.16%**
2030 (Increased)	46.3	70.2	60%	22.2	32%	**3.21%**
2030 (Ambitious)	35.5	81.0	70%	33.0	48%	**5.33%**

The following graph shows the EUI breakdown of the various scenarios that were assessed as part of the CEMP. The Ambition NZE scenario sees a more significant reduction in natural gas use through electrification projects on campus.

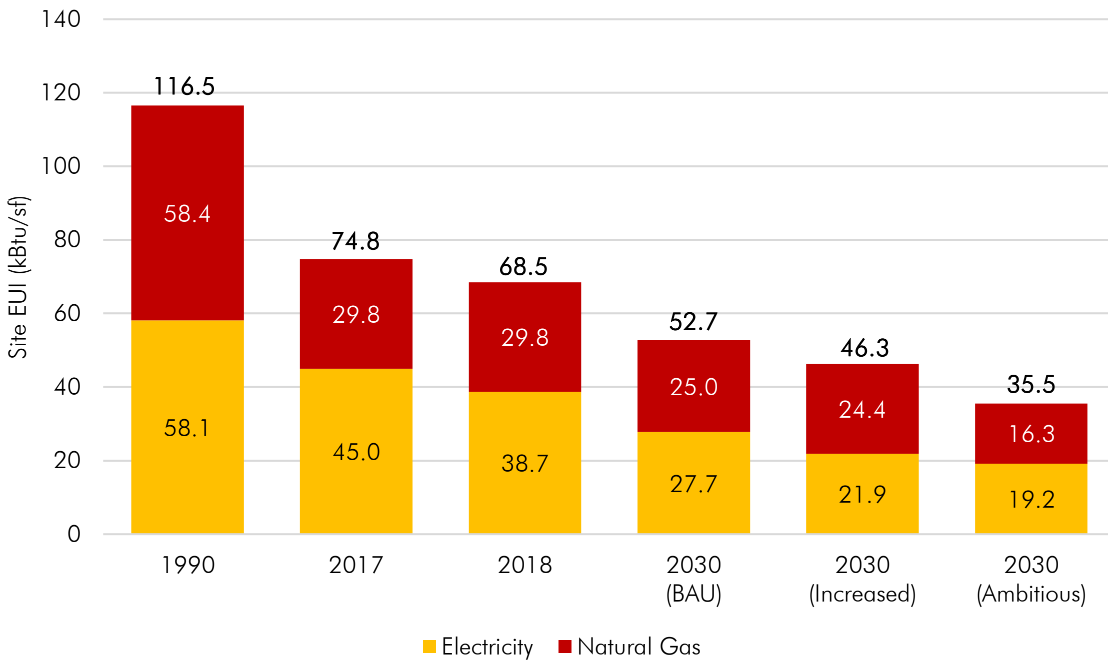


Figure 8: Campus Site EUI – Scenario Analysis Projections

The following graph shows total Scope 1 & 2 emissions under all five of the scenarios assessed as part of the CEMP project. The Baseline scenario shows the emissions should CSULB not invest any further in energy efficiency or renewable energy projects on campus. This accounts for future campus growth and the estimated emissions reduction from grid electricity. Increasing investment in energy efficiency and renewable energy has the potential to increase the rate of GHG emissions reduction by 50-100% compared to the expected business as usual (BAU) on campus.

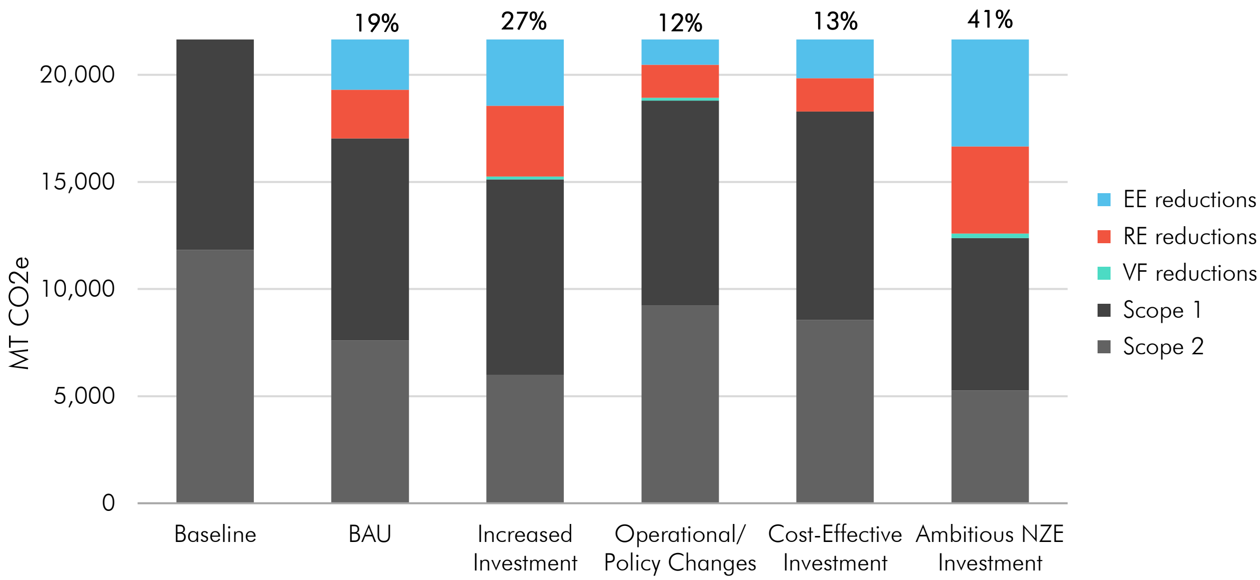


Figure 9: Scenario Analysis Results – Scope 1 & 2 Emissions (2030)

The following graph shows the potential reduction in GHG emissions over time for each five scenarios. The drop in emissions between the Baseline and all five scenarios is a result of the 4.8MW carport solar system that went online in the beginning of 2018.

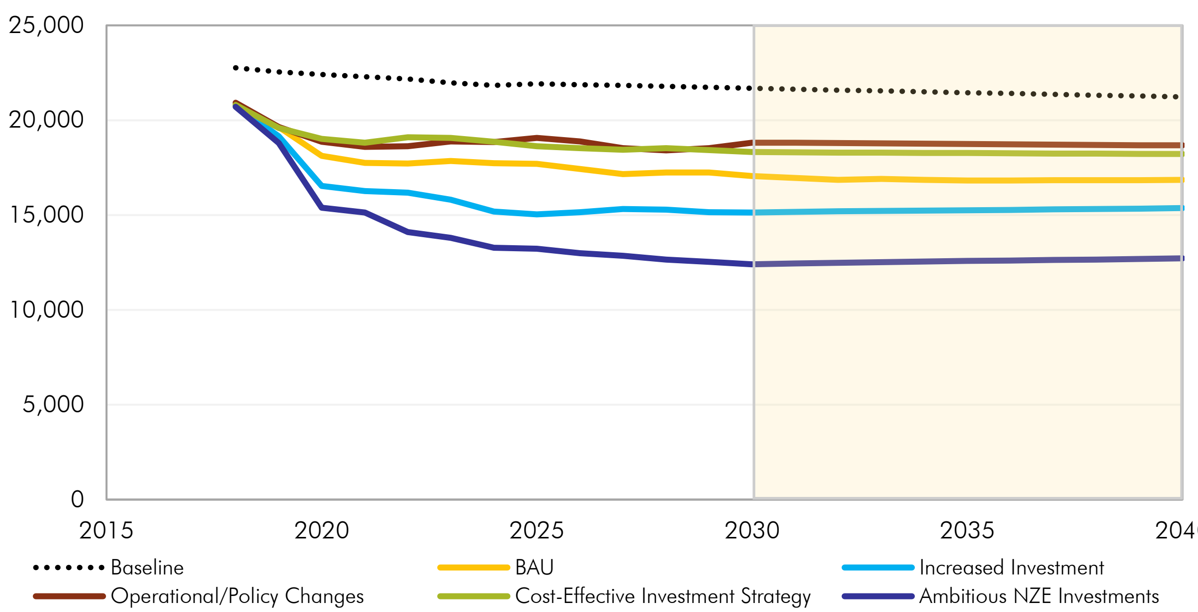


Figure 10: Scenario Analysis Results – Scope 1 & 2 Emissions

The Scenario Analysis and Visual Insight (SAVI) tool that was developed for the CEMP to gain insights on the potential GHG emissions reduction and financial impact of various investment strategies. The individual scenarios that were assessed during the scenario analysis were not intended to be specific project portfolios. The results and strategic recommendations below should be used to by CSULB to guide their strategic energy planning over the next five years.

1.4 STRATEGIC RECOMMENDATIONS

The following strategic recommendations for CSULB have been identified based on the investigation and analysis that was provided throughout the Clean Energy Master Plan project. These are intended to guide the energy and sustainability strategy of the university over the next 12 years as the university works towards 2030 carbon neutrality.

ENERGY EFFICIENCY

Reducing the energy use in existing buildings is central to a creating a sustainable university campus. In 2017 electricity and natural gas usage accounted for 86% of Scope 1 & 2 emissions, and 33% of the total campus emissions. This presents both a huge opportunity for CSULB to reduce its environmental impact and a challenge given the increasing energy demand of a growing campus. Investing in energy efficiency projects on campus will be a critical strategy for CSULB to achieve 2030 carbon neutrality.

ACCELERATE INVESTMENT ON ENERGY EFFICIENCY PROJECTS

It is recommended that CSULB accelerates their investment strategy in EE Projects beyond the current spend rate on campus ($1-1.5 million annually). The increased investment scenario that is well within the means for CSULB to finance with available external funding/financing sources. Some key finding and considerations for an accelerated investment in EE are:

1. Implement all EE projects with a reasonable payback periods prior to 2030. Refer to the CSULB Energy Efficiency Project Database or the SAVI Tool for a full list of projects.
2. Increase investment in EE projects to roughly $2.8 million annually on average leading up to 2030, at least doubling the current pace of investment. This is estimated to reduce the site EUI of campus by roughly 28.5 kBtu/sf, a 38% reduction compared to the overall campus energy use in 2017.
3. Prioritize projects with lower paybacks up front and with external financing. Establish a revolving green fund to fund future clean energy projects on campus and track energy savings of EE projects.
4. Combine capital intensive retrofit projects with larger building renewal projects to reduce net project cost for EE project and limit impact to campus operations.
5. Establish a campus wide retro-commissioning/control optimization initiative. Numerous operational improvements were identified across campus, as noted in the Level 2 Audit Reports (*Appendix*). Economies of scale can be achieved with a campus wide approach given the number of similar buildings and HVAC systems across campus.

Investing in energy efficiency on campus has the potential to be the a very cost-effective carbon reduction strategy on campus. EE projects can also have additional benefits to the campus including: improved comfort, health, resiliency and safety.

The *Ambitious NZE Investment* scenario was developed as a bounding case for maximum site energy use reduction on campus. This ambitious strategy is estimated to result in an additional 10.8 kBtu/sf savings across campus beyond increased investment, resulting in an overall campus energy saving of 53% compared to 2017. In addition to traditional energy efficiency projects, this also includes numerous electrification projects across campus. While this scenario has the greatest potential for GHG emissions reductions on campus, the return on investment is not economically favorable given the high cost of electricity and low cost for natural gas

UTILIZE INTERNAL CSU FINANCING TO FILL THE INVESTMENT GAP

The investment required for likely scenarios is well within means for the campus. The BAU case could be covered by current funding sources. The Increased Investment scenario would require approximately an additional $15M by 2030, which could be funded through the CSU Chancellor's Office Internal Central Bank. Including the TES costs into either scenario would increase the funding needs by approximately another $15M. With the TES included, the CSU Central Bank is still likely the best option to fund the amount beyond the current funding sources in use ($15M-$30M). The specific project mix to be financed would need to consider the requirements of Central Bank funding, such as loan term. Refer to the Clean Energy Financing Matrix in *Section 9.3* for a full list of additional low-cost financing mechanisms available to CSULB, such as SCE On-Bill Financing (0% interest, 10-year loan).

IMPLEMENT ENERGY SAVING OPERATIONAL POLICIES

There are various operational policies CSULB can enact to reduce their Scope 1 & 2 emissions on campus. In general, these are low or no cost energy efficiency measures and should play a sizable role in CSULB's 2030 carbon neutrality plan. It is recommended that CSULB implement additional energy savings operational policies in additional to increasing investment in EE projects.

While these policy measures are very cost effective, in practice it can be difficult to successfully implement without the buy in and commitment from numerous campus groups. Some key finding and considerations for enacting energy savings operational policies are:

1. Reducing the number of hours buildings are unnecessarily operational or underutilized can have significant energy savings. Currently, almost all buildings are scheduled to be operational from 6am - 10pm resulting in wasted energy to condition unoccupied spaces. For every 6 hours per week a building's HVAC system can be scheduled off, CSULB can on average expect a 2% annual energy savings. Campus wide implementation (6 hour per week per building) is estimated to save $60,000 annually.
2. The following energy savings policies were identified as feasible options for CSULB and were assessed as part of the Operational/Policy scenario analysis. These should be investigated further to determine to what extent each can implemented on campus.
    - Summer Building Shutdown - Buildings with low utilization during the summer are shutdown. Program is consolidated with other buildings on campus.
    - Friday/Saturday Shutdowns - As an alternative to full summer shutdown of a building, three options were quantified to consolidate or schedule programs such that a building would be vacant and shutdown on certain days. These options include Fridays year-round, Saturdays year-round, and Fridays during the summer.
    - Class Schedule & Space Utilization - Optimization can occur in one of two ways, or a combination of both. First, EMS scheduling can be optimized to more closely align building HVAC schedules with actual occupancy. Second, scheduling of classes could be optimized to reduce the required hours of operation for buildings.
    - Additional Energy Savings Policies - Refer to Section 6.2 for a full list of additional operational policy measures.
3. Maintain current ZNE standards for new construction and major renovation projects. Provide design teams with aggressive EUI targets and prioritize maximizing additional, incremental on-

site renewable energy when possible. Refer to the ZNE Building and Model Energy Retrofit Guidelines provided in Sections 12 & 13.

RENEWABLE ENERGY

Renewable Energy can provide significant reductions in the GHG footprint of the campus, and be a key component of an integrated strategy to reach the campus carbon neutrality goals. In addition to the existing 4.7MW of solar power on campus, the study identified the potential for over 10 MW of solar PV on campus generating over 16 million kilowatt hours per year. These systems in total have the potential to save nearly $36M in energy bills over their lifetimes and reduce the campus carbon footprint by contributing nearly 4,000 MT CO2e per year savings.

ADDRESS POTENTIAL ECONOMIC CHALLENGES

There are several challenges to an economical implementation of additional solar PV at the Campus. It is important for CSULB address these potential challenges for any future PV projects on campus to maximize the return on investment.

1. The campus has recently implemented a large PV project on the main campus meter, which has maxed out the capacity under the Campus' non-export agreement with the utility. Any additional generation capacity installed on the main campus meter will require curtailment during several hours annually to avoid export, which affects the project's cost effectiveness.

2. The forthcoming rate policy changes that shift peak power rates out of the peak solar production time reduce the overall benefit from any solar. The systems identified in this study, whether on campus or on ancillary properties, will be governed by the forthcoming rules and thus have lower projected savings.

3. The costs used in the study are based on the recent campus procurement experience. The Campus' recent costs and pricing from several in hand proposals for additional solar are higher than might be expected under a competitive bid in the current market place. The higher pricing could be in part uncertainty related to panel and steel tariffs as well as inclusion of additional campus defined additive features (e.g. added security features) in PPA prices.

ESTABLISH A COMPETITIVE PROCUREMENT PROCESS

It is recommended that if moving forward with solar PV, as is likely under any scenario analyzed in the CEMP, the campus bundle solar projects together in a competitive procurement process to both leverage economies of scale and to drive down pricing through competition. The CSU Chancellor's Office (CO) has an established, vetted request for proposals that was developed to streamline the competitive bid process for CSU campuses and CSULB should engage the CO as it evaluates these projects further. Additionally, if the costs of campus defined additive features are funded or considered outside of the PV costs, market data suggests that PPA rates could approach $0.1050-0.1150/kWh for a 20-year PPA or $0.0850-0.0950/kWh for a 25-year PPA. Reducing costs to this range brings the projects to, or beyond, their financial breakeven point for energy bill savings, and economics are more attractive when considered as part of the path to carbon neutrality.

CLEAN ENERGY VEHICLES

While vehicle fuel use accounts for only 0.5% of the overall GHG emissions of the university, transitioning to alternative clean vehicles should be an important part of CSULB's clean energy master plan. Reducing the operation of fossil fuel-based engines will reduce both GHG and smog forming emissions to improve the local air quality.

IMPLEMENT A CLEAN ENERGY VEHICLE POLICY

It is recommended that CSULB implements well defined clean energy vehicle policy to begin transitioning existing fossil fuel to more environmentally friendly alternatives as the campus works towards 2030 carbon neutrality. Some key considerations for establishing a clean energy vehicle replacement policy on campus are:

1. Prioritize purchasing fully electric vehicles long term. Electric vehicles were determined to be the best clean vehicle option for CSULB given their price, mature technology, range and infrastructure requirements. Based on the typical annual mileage of vehicles at CSULB, it is expected that electric vehicles will have adequate range to replace almost all fossil fuel vehicles on campus by 2030.
2. Establish a clean energy vehicle standard for all replacement vehicles. Standards should be established to determine the vehicle type that will replace each of the existing vehicles in the fleet. These standards should determine a target efficiency standard for each vehicle type. Replacing vehicles with electric equivalents will not significantly reduce overall Scope 1 and 2 emissions. More efficient vehicles should be purchased when replacing the existing fleet.
3. Establish interim electrification targets between now and 2030. Replacing all vehicles at one time is not economically viable and should be spread out as vehicles are required to be replaced.
4. Prioritize highly used and older inefficient vehicles. Vehicles that consume the largest quantities of gasoline or diesel both contribute the largest portion of the total fleet emissions and place a large financial burden on the university. They should be prioritized for replacement before the less utilized vehicles in the fleet are replaced. Refer to the *CSULB Clean Vehicle Database* for a prioritized list for the campus fleet.
5. Assess using electric shuttle busses in five years when the current third-party provider's contract expires. Request proposals from multiple vendors for both compressed natural gas (CNG) and electric shuttles to determine the economic viability.
6. Continue to track and pursue funding opportunities for clean energy vehicles. There are numerous incentives, grants and other funding sources CSULB could leverage to finance their clean energy vehicle transition. Outlined in *Section 7.4* are a range of clean vehicle funding opportunities currently available to CSULB.

DEVELOP AN ELECTRIFICATION PILOT PROGRAM

A pilot program offers the university a means of testing a variety of clean energy vehicles and equipment to ensure performance is acceptable. The following strategies should be included:

1. Establish a pilot electric vehicle program. Ensuring buy in from each university department that a clean energy vehicle replacement will meet the requirements of their existing vehicle will be required. A pilot program in which several fully electric vehicles are purchased and used across campus will provide an economical method to determine the most effective vehicle for each application. Introducing certain vehicles in a pilot program will allow their performance to be analyzed against the existing vehicles in terms of both efficiency and effectiveness.
2. Establish an electric grounds equipment pilot program with the grounds department. Small off-road engines used in grounds equipment produce significant smog-forming emissions and contribute to poor air quality in Long Beach. It is recommended CSULB implement a pilot program of purchasing a limited quantity of such equipment and comparing its effectiveness

against the current equipment. If successful, CSULB should transition to a fully electric fleet of ground equipment.

CARBON OFFSETS

CSULB should continue to follow the carbon management hierarchy and reduce its emissions through owned and operated projects before purchasing offsets. In addition, CSULB should explore policies and programs that could cost effectively reduce Scope 3 emissions. Ultimately, a part of CSULB's carbon neutrality pathway will include purchasing of carbon offsets. Once the campus has reduced emissions as much as possible, carbon offsets that meet the Second Nature Standard and are certified reputable body should be purchased to cover the remaining emissions. A clear offset purchasing policy will ensure a strategic and effective approach to including offsets in the carbon neutrality strategy. The policy should include the following elements:

1. Establish a Carbon Management Hierarchy
   The generally accepted best practice in carbon neutrality planning is to implement all feasible internal GHG mitigation strategies first and to use offsets to reduce remaining emissions. This is known as the carbon management hierarchy. Following this hierarchy will ensure that CSULB takes all the action it can to reduce its own emissions and will also ensure that the campus maximizes the co-benefits from carbon reduction projects.

2. Determine Timing of Offset Purchase
   It is possible to begin purchasing offsets to reduce CSULB's footprint right away or to wait until 2030 when all of the carbon reduction projects have been implemented. One potential benefit of purchasing, investing or developing offsets earlier than 2030 is that it is likely that the cost of carbon is expected to increase overtime. The trade-off, however, is that any funds used to purchase offsets now cannot be used to invest in internal projects. The scenario analysis tool developed for CSULB can help the university determine the most opportune time to begin purchases or investments.

3. Determine Make-up of Offset Portfolio
   CSULB can acquire offsets through purchase, investment or development. It is likely that most carbon offsets will come from purchases. However, there could also be opportunities for investment or development of offset projects. Investing in offset projects can be difficult and is not an avenue that is recommend pursuing unless an opportunity presents itself. It is however recommended reaching out to the larger CSULB community regarding the option for peer-reviewed offset development. CSULB should investigate the level of opportunity available for such projects and establish targets for what percentage of its offsets come from campus developed projects (e.g. 10%).

4. Determine Sources for Offset Purchases
   Purchased offsets will be a part of CSULB's portfolio and a reputable supplier is critical to ensuring offset quality. The offset market is continually changing and there will likely be many options in 2030 that do not exist today. The most important step in ensuring the quality of offsets purchased is to follow the guidelines set forward by Second Nature. Second, purchasing offsets through a widely-respected and long-standing organization will help to ensure the quality of the offset. Most notably, the Climate Action Reserve, sets standards for both voluntary and regulatory offset protocols. The reserve hosts an Offsets Marketplace on its website which provides a listing of offset brokers (for larger purchases), retailers and wholesalers that will meet the criteria set forth by second nature. Other high-quality offset registries and verifiers include, the Verified Carbon Standard, Gold Standard and the American Carbon Registry.

5. Clear Communication with Stakeholders
The final component of an offset policy is to establish a strong communication protocol that describes both the high standards of the offsets CSULB uses and the wide range of benefits that the offsets create. Offsets are sometimes derided as a way to “buy down” carbon emissions. When carefully purchased, however, offsets can be a powerful tool to reduce GHG emissions. These benefits, along with all the other on campus GHG emission mitigation measures, need to be clearly and effectively communicated to the greater CSULB community.

1.5 NEXT STEPS

The scope of the CEMP focused on identifying and quantifying clean energy projects to inform CSULB's carbon neutrality. The team utilized scenario analysis planning to establish a strategic roadmap for CSULB and developed the necessary tools for the campus track their progress moving forward. The five scenarios developed during the CEMP can provide the basis for high level decision making for the most desirable path to achieving the campus carbon neutrality goal. Because purchasing of offsets seems inevitable, in large part due to Scope 3 emissions, the campus must determine the level of investment desired and costs tradeoffs they are able to undertake. Scenarios can be fine-tuned, and progress tracked in the scenario planning tool as the project implementation plan firms up. With the preferred mix of energy efficiency, renewable and vehicle fleet projects selected, the campus can start funding and implementing projects.

BEST PRACTICES

The following section outlines some additional best practices for GHG emissions mitigation for CSULB. While an in-depth assessment of these mitigation measures was not included as part of the CEMP project, these strategies could become a critical element of CSULB's overall carbon neutrality plan and should be investigated further.

DEVELOP A SCOPE 3 EMISSIONS MITIGATION PLAN

It will be essential for CSULB to address their Scope 3 emissions as the university works towards 2030 carbon neutrality. Based on the latest campus inventory, Scope 3 emissions accounted for 61% of the total campus GHG emissions. This is comprised of student commuting (50%), faculty/staff commuting (8%) and air travel (3%). While these emissions are an indirect result of the campus operations, they are equally important and often have a direct impact on the local community. Some potential Scope 3 mitigation measures for CSULB are:

1. Additional On-Campus Housing - CSULB is in the process of expanding their on-campus housing portfolio and should continue to invest in this area. This will help reduce emissions from students commuting to campus.
2. Sustainable Transportation Plan - Develop and invest in alternative, sustainable transportation options for students and faculty/staff to commute to campus.
3. Parking Permit Emissions Fee - Carbon mitigation fees can be added to all university issued parking permits to offset GHG emissions from commuting to campus. Additionally, CSULB can offer discounts for students driving qualifying clean energy vehicles.
4. Online Education - CSULB can offer more online classes to limit student commuting and reduce building operational hours.
5. Air Travel Mitigation Fund - Carbon mitigation fees can be added to all university related air travel to fund carbon offsets or other local projects producing long lasting and measurable GHG emission reductions. Refer to UCLA's pilot program.[10]

ESTABLISH AN INTERNAL ACCOUNTABILITY STRUCTURE

Even with an ambitious investment strategy on campus, implementing all EE and RE projects identified on campus is expected to require at least 10 years. It will be essential to continually track the

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[10] UCLA Air Travel Mitigation Fund Program Guidelines - *https://www.sustain.ucla.edu/wp-content/uploads/Air-Travel-Mitigation-Fund-Program-Guidelines.pdf*

universities progress to stay on track to achieve carbon neutrality. It is recommended that CSULB establish a reporting process to maintain accountability and produces an annual report summarizing the progress of the campus (GHG emissions, energy use, capital investment, etc.). The CSULB Scenario Analysis and Visual Insight (SAVI) Tool, developed as part of this project to assess different pathways to achieving campus climate goals, is designed to be updated in the future as new data becomes available. The process of incorporating additional data such as historical energy use and other emission sources in future years will be included in the user manual and covered in the training for the tool.

TRACK CHANGES IN THE ENERGY MARKET

The energy and carbon spaces are constantly changing landscapes, and it goes without saying that staying up to date with changes in technology, regulatory policy, cost trends and availability of resources will benefit CSULB going forward. While the efforts under the CEMP cannot predict all the coming changes, there are two items reasonably likely to be available for consideration in the near future. The first is the availability of power source options. There are discussions ongoing for formation of a local Community Choice Energy (also called Community Choice Aggregation or CCA) in Long Beach. Goals of Community Choice Energy (CCE) programs are often to provide more renewable power content in the electricity supplied to its customers and to reduce GHG emissions. Such goals would align with the campus' goals.

Southern California Edison has also received approval from the Public Utilities Commission (PUC) to launch the Clean Energy Optimization Pilot (CEOP) program. The CEOP is designed to break out of the traditional incentive programs by taking a holistic look at a campus' total GHG footprint, as measured by purchased energy, and provide an incentive for reductions at the campus level. This allows all project types to contribute to the carbon reduction and in essence, receive incentives. The campus could take advantage of energy efficiency, renewable generation, behavioral measures, energy conservation and electrification measures while obtaining incentives and furthering the campus' climate goals simultaneously. The campus should consider this if it becomes available to CSULB.

EDUCATE AND PROMOTE STUDENT/STAFF ENGAGEMENT

CSULB should continue to promote engagement and education of energy conservation on campus. The people on campus (students, staff, faculty) are ultimately responsible for the bulk of energy use required to run a university. By engaging and empowering the CSULB community, they can become part of the solution.

2. Background Information

2.1 CAMPUS OVERVIEW

LOCATION

California State University, Long Beach was founded in 1949 and is located in Long Beach, California. The campus is situated just three miles from the ocean and stretches across 322 acres of land with 105 buildings. The total building footprint on campus is 4,052,474 square feet, and over 5,727,814 square feet including parking structures.

Figure 11: CSULB Campus Location[11]

FUNDING SOURCES

Buildings across campus are owned and financed from different sources, resulting in CSULB Facilities Department not having direct control over all building on campus. However, all buildings on campus

[11] Offsite Beachside Housing and Blair Field not pictured here

contribute to the overall energy usage and therefore all must be accounted for in the campus GHG emissions. Building ownership falls under either State owned or Non-State owned. The campus has 6 groups on campus that each independently provide funding to their facilities. These include:

- State
- Housing
- Foundation
- 49ers Shops
- Parking
- Associated Students Inc
- College of Continuing and Professional Education (CCPE)

WEATHER

The CEMP included an assessment local weather conditions in Long Beach to better understand the impact of changing weather patterns. The following analysis uses was based on actual weather conditions at Long Beach AP Daughtry Field. This is the closet weather station to CSULB and was used given the quality of data available at airports. These actual weather conditions were compared to Title 24 design conditions and the Typical Meteorological Year weather file (1991-2005). It was determined that on average weather in Long Beach over the past two years has been warmer compared to historical conditions from the period of 1991-2005.

- **Average Historical Temperature (TMY3):** 62.2 degrees F
- **Average 2016 Temperature (Airport):** 65.3 degrees F (5.1% warmer)
- **Average 2017 Temperature (Airport):** 64.8 degrees F (4.2% warmer)

The following graph shows the hourly temperature distribution in 2017. While the weather is generally fairly temperate in Long Beach (5,852 hours between 60-80F – 67% of the time), there are many hours throughout the year when the outside air temperature is significantly warmer or cooler.

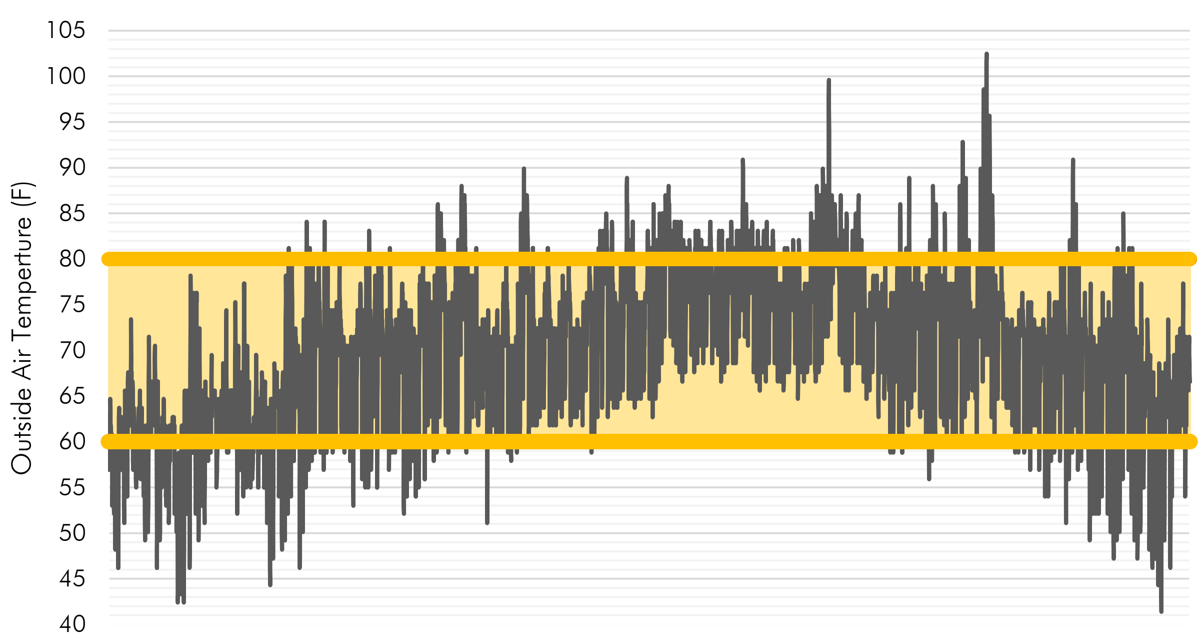

Figure 12: Hourly OSA Temperature (Dry Bulb) – Actual 2017 Weather

The graph below shows the distribution annual outside air temperatures in 2017 compared to the Title 24 Long Beach weather file, used in energy modeling annual simulations. It was found that the outside air temperature was consistently warmer in recent years. The numbers above 2017 bars show the delta in number of hours within the temperature range compared to typical historical conditions. It is apparent there is a significant shift in 2017, with more hours in the warmer temperature ranges. This is also apparent in 2016.

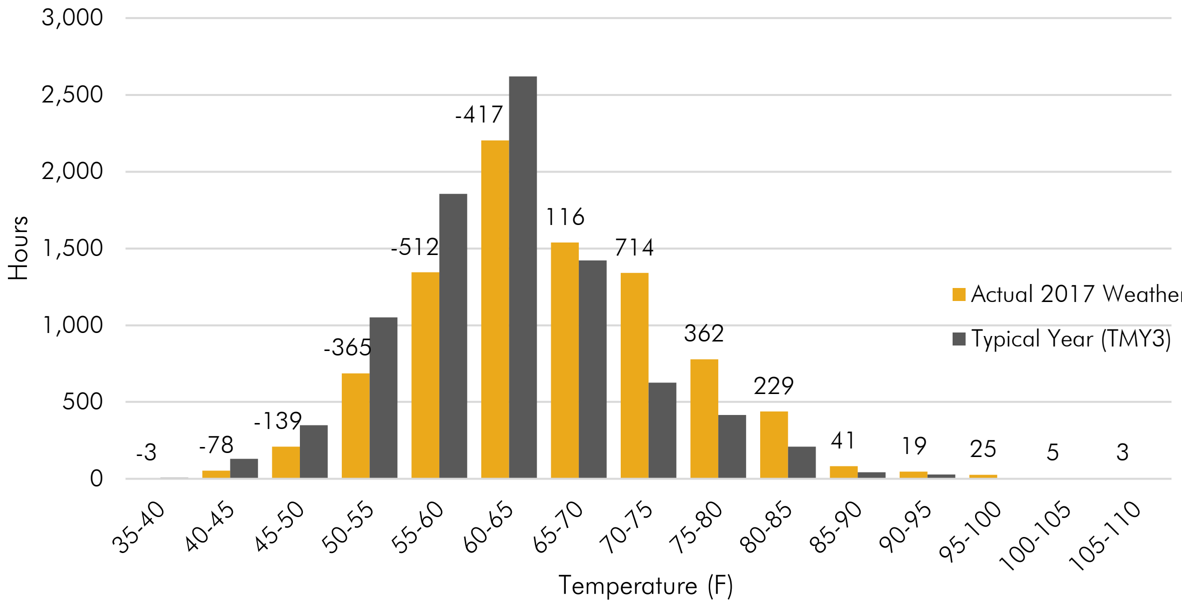

Figure 13: Annual Temperature Distribution – Actual 2017 Weather vs. TMY Weather File

2.2 CAMPUS SUSTAINABILITY

2.2.1 CSU SYSTEMWIDE SUSTAINABILITY

In May 2014 the California State University released a sustainability policy aimed to reduce the university's impact on the environment. This included the following policies that will be applicable to CSULB's clean energy master plan. These systemwide goals should

REDUCE EMISSIONS TO 1990 LEVELS BY 2020
"The CSU will strive to reduce systemwide facility greenhouse gas (GHG) emissions to 1990 levels, or below, by 2020 consistent with AB 32, California's Global Warming Solutions Act of 2006 (HSC §38550). Emissions will include both state and auxiliary organization purchases of electricity and natural gas; fleet, marine vessel usage; and other emissions the university or self-support entity has direct control over."

REDUCE EMISSIONS TO 80% BELOW 1990 LEVELS BY 2040
"The CSU will strive to reduce facility GHG emissions to 80 percent below 1990 levels by 2040. Campus tracking and reporting of their GHG inventory will be grounded in the American College and University President's Climate Commitment guidelines or equivalent, with consideration to campus requested improvements."

ENCOURAGE AND PROMOTE CLEAN ENERGY TRANSPORTATION
"The CSU will encourage and promote the use of alternative transportation and/or alternative fuels to reduce GHG emissions related to university associated transportation, including commuter and business travel."

PROCURE ON-SITE RENEWABLE ENERGY SOURCES
"The CSU shall pursue energy procurement and production to reduce energy capacity requirements from fossil fuels, and promote energy independence using available economically feasible technology for on-site and/or renewable generation."

2.2.2 CSULB CAMPUS SUSTAINABILITY

California State University Long Beach is a diverse, student-centered, globally-engaged public university committed to providing highly-valued undergraduate and graduate educational opportunities through superior teaching, research, creative activity and service for the people of California and the world.

In 2011, CSULB took a bold step in fighting climate change by signing on to the American College and University Presidents Climate Commitment pledging to conduct a comprehensive greenhouse gas inventory and to develop a Climate Action Plan that will serve as a framework for climate neutral operations. In December 2014, CSULB's Climate Action Plan was endorsed and signed by President Jane Conoley setting in place a goal of climate neutrality by 2030 and laying out a plan to reduce campus greenhouse gas emissions to meet this goal.

2.3 CEMP PROJECT

2.3.1 HISTORY, VISION AND GOALS

The Clean Energy Master Plan (CEMP) project was launched in late Spring of 2017 with the issuance of a Request for Qualifications and Proposals from qualified engineering firms to assist CSULB in developing a comprehensive roadmap that will guide the campus' energy strategy to achieve the goals of the Climate Action Plan.

The intent of the Clean Energy Master Plan is to mitigate all scope 1 and 2 emissions through a comprehensive strategic plan that will include detailed mitigation measures that will not only result in greenhouse gas emission reductions but will also result in operational savings and improvement of campus facilities and infrastructure.

2.3.2 SCOPE AND DELIVERABLES

The project was broken into the following three phases. Phase 1 and 2 was intended to prepare the consultant the team for developing the CSULB Clean Energy Master Plan in Phase 3, which included the majority the project scope.

PHASE 1 – DISCOVERY

The Discovery Phase of the project helped the team develop a clearly defined vision for the clean energy master plan and better understand CSULB's key performance indicators for future investments in energy efficiency. This scope included numerous conversations with key CSULB stakeholders, research of best practices for GHG mitigation and reviewing previous CSULB climate and energy reports.

PHASE 2 – INVESTIGATION

The Investigation Phase of the project helped the team develop a deeper understanding of CSULB's operations, infrastructure and energy usage. This was accomplished through providing ASHRAE Level 1 energy audits for 28 buildings across campus, totaling 2.2 million square feet. Refer to Section 5. Building Energy Efficiency for a detailed account of the energy audits process and results.

PHASE 3 – CLEAN ENERGY MASTER PLAN

During the Clean Energy Master Plan Phase, the team developed an actionable strategic energy plan and a living tool for CSULB to continually track the progress of their 2030 carbon neutrality goals. Phase 3 of the project included the following key tasks:

1. Assessment of current energy sources, utilization, and associated emissions
2. Inventory building EUIs and identify remaining energy savings opportunities
3. Inventory of Energy Efficiency Measures (EEMs)
4. Renewable energy plan for the campus
5. Multi-year clean energy implementation plan
6. Model deep energy retrofit plan for existing campus buildings
7. Model funding plan

8. Net Zero Energy (NZE) strategy for new construction and existing buildings
9. Clean energy fuels transition plan for the campus fleet
10. Carbon offset program
11. Planning and visualization tool

FINAL DELIVERABLES

At the completion of the CEMP project, the following seven deliverables will be provided to CSULB, as outlined in the original RFP:

1. Clean Energy Master Plan Report
2. Database of Energy Efficiency Measures (EEMs)
3. Database of Energy Projects
4. Planning, Visualization & Tracking Tool
5. 5-Year Project Portfolio
6. Financial Implementation Plan
7. Final Presentation on Findings

2.3.3 SCHEDULE AND PROCESS

The table below outlines the final project schedule for the CEMP over the 8-month timeline. The original RFP called for a 5-month schedule from start to finish. However, the final schedule was extended to due to more time required during the data collection phase and to allow for more interaction/feedback from the campus with the consultant team.

Table 7: CEMP Project Schedule

Task		December	January	February	March	April	May	June	July	August	September
PHASE 1 - Discovery											
1	Kick-off/Discovery										
PHASE 2 - Investigation											
1	Level 1 Energy Audits										
PHASE 3 - Clean Energy Master Plan											
1	Level 2 Energy Audits										
2	Campus EE Extrapolation										
3	Renewable Energy										
4	Financial/Funding										
5	5-year Project Plan										
6	GHG Guideline										
7	Clean Energy Vehicles										
8	Scenario Analyis (SAVI) Tool										
9	Final Report										
	Final Presentation										
10	NZE Guidelines										
11	Model Retrofit Guidelines										

The timeline above does not capture the period between when the project was awarded in July 2017 and when it was kicked off in December 2017. During this time the project scope was finalized, and the final contract was executed. The scope revisions included reducing the energy audit scope from 28 ASHRAE Level 3 audits to a combination of ASHRAE Level 1 & 2 audits for 28 buildings. The campus extrapolation of EE projects was added to the scope to better plan for carbon neutrality on campus. The renewable energy scope was limited due to the campus having just installed a large 4.8 MW PV system.

2.3.4 EXCLUSIONS FROM SCOPE

The following scope was not included as part of the CEMP

1. Scope 3 Emission Mitigation Strategies
2. Scope 2 Fugitive Emissions
3. Central CHW / HHW Plant Assessment
4. Full Cost Estimates - opinion of probable cost provided

Since the campus has just installed a large PV system, the scope of the Renewables Energy was limited. Specific site assessments for project construction issues, modeling of individual solar systems, evaluation of different PV technologies, analysis of non-PV technologies, and analysis of offsite PPA arrangements or other wholesale power procurement approaches were excluded.

2.3.5 CAMPUS RESOURCES & PREVIOUS STUDIES

The following documents were provided to the consultant team during the course of the CEMP project, among many others.

- Strategic Energy Plan - 2011
- CSULB Climate Action Plan – December 2014
- Central Plant Study – April 2017
- Existing Foundation Building Utility Study – June 2015
- Cafeteria Building MEP Utility Infrastructure Study – November 2015
- Campus-wide HVAC Study – June 2016
- University Student Union MEP Utility Infrastructure Study – November 2015
- Microbiology HVAC and Lab Infrastructure Study – February 2016
- Library Chiller Replacement Study – January 2017
- ECS EPIC Grant Project Narrative – November 2016

3. UTILITY INFRASTRUCTURE

3.1 ELECTRICITY

ELECTRIC UTILITY

CSULB is supplied electricity from Southern California Edison (SCE) through multiple electrical services across campus. The following tables displays all the known SCE meters on campus. There is a main electrical distribution loop on campus that supplies power to most of the campus, highlighted below in yellow. The main 66kV electrical service enters campus at an outdoor switchyard located in the Corporation yard. This is transformed into a 12kV services and distributed across campus, where it is further stepped down to usable voltages for each building. This SCE service accounted for 91% of the total annual electricity usage at CSULB in 2017.

The following table shows all SCE electrical services for CSULB. The meter location and average annual blended electricity rates [$/kWh] were identified for the larger electrical services on campus.

Table 8: SCE Electrical Meters Serving CSULB Campus

Service Account	Meter Address	SCE Rate Structure	Campus Area	2017 Annual Use [kWh]	Percent of Total Campus	Blended Rate [$/kWh]
3-008-5488-21	5700 E ATHERTON ST	TOU-GS-2-B	-	46,866	0.1%	-
3-000-0018-35	5700 E ATHERTON ST	TOU-GS-2-B	-	103,625	0.2%	-
3-033-5269-15	4825 E PACIFIC COAST	TOU-GS-3B	Beachside Housing	1,603,889	3.0%	$0.132
3-034-9202-35	4700 DEUKMEJIAN DR	TOU-GS-2-B	Blair Field	108,403	0.2%	$0.173
3-034-9202-56	4700 DEUKMEJIAN DR	AL-2	Blair Field	114,843	0.2%	
3-000-0018-43	5900 E ATHERTON	TOU-GS-3B	Parkside Housing	1,364,074	2.6%	$0.130
3-001-3609-74	1401 PALO VERDE	TOU-8-B	Main Campus	48,656,088	91.0%	$0.097
3-005-0768-89	1401 PALO VERDE AVE	TOU-GS-1-A	-	4,904	0.0%	-
3-034-9202-94	4819 E 7TH ST	TOU-GS-1-A	-	24,065	0.0%	-
3-000-0018-37	CAMPUS/7TH	TOU-GS-1-A	-	364	0.0%	-
3-000-0018-39	E CAMPUS RD N/O 7TH	TOU-GS-2-B	Faculty Office 4	104,702	0.2%	$0.190
3-000-0018-40	E CAMPUS RD N/O 7TH	TOU-GS-2-B	Faculty Office 5	100,959	0.2%	
3-000-9784-53	1605 EARL WARREN DR	TOU-GS-1-A	-	34,263	0.1%	-
3-005-0768-88	1401 PALO VERDE AVE	TOU-GS-1-A	-	274	0.0%	-
3-002-9272-88	1430 EL MIRADOR AVE	DOMESTIC	-	-	-	-
2-02-073-9496	6300 E STATE UNIVERSITY DR	TOU-GS-3B	Foundation	1,203,762	2.3%	$0.154

The following graph shows for the monthly blended energy rate ($/kWh) of the four largest electrical services on campus, at least 1,000,000 kWh annual usage. This monthly blended electricity rate includes both the usage (kWh) and demand changes. The Main Campus SCE meter has a significantly lower electricity rate compared to the smaller electrical services, averaging $0.097 per kWh during the calendar year due to the TOU-8-B rate structure and aggregation of multiple buildings onto one meter. Electricity is significantly more expense from June to September during SCE summer billing rates, primarily due to higher demand changes. On average CSULB pays 50% more during the summer month per kWh compared to non-summer months.

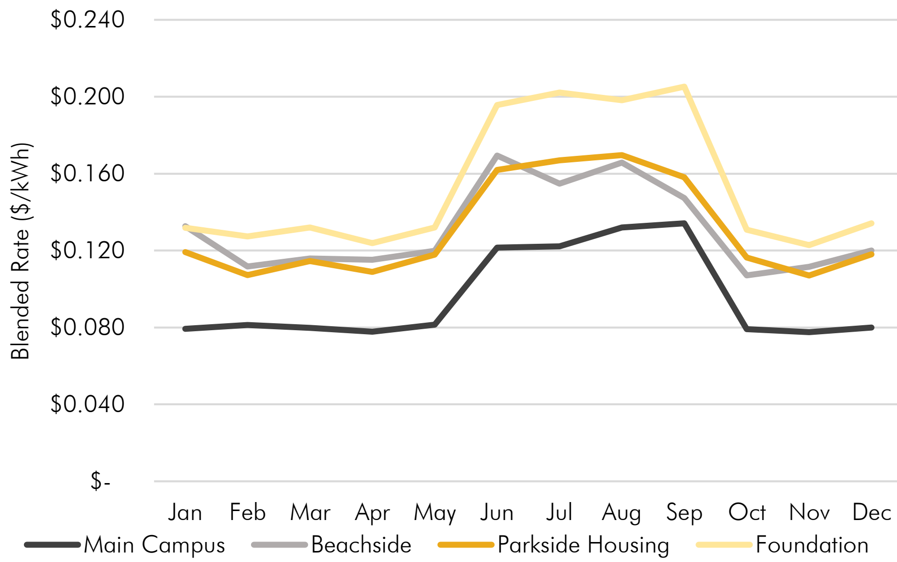

Figure 14: CSULB Total Monthly Blended Utility Rates

The graph below shows the average annual electricity rates for all major electrical services at CSULB. These average annual electrically rates were applied to the applicable portions of campus during the CEMP analysis. The Main Campus electrical rate is significantly lower electricity rates compared to the smaller SCE services across campus.

- Beachside Housing: 37% higher
- Parkside Housing: 35% higher
- Foundation: 60% higher

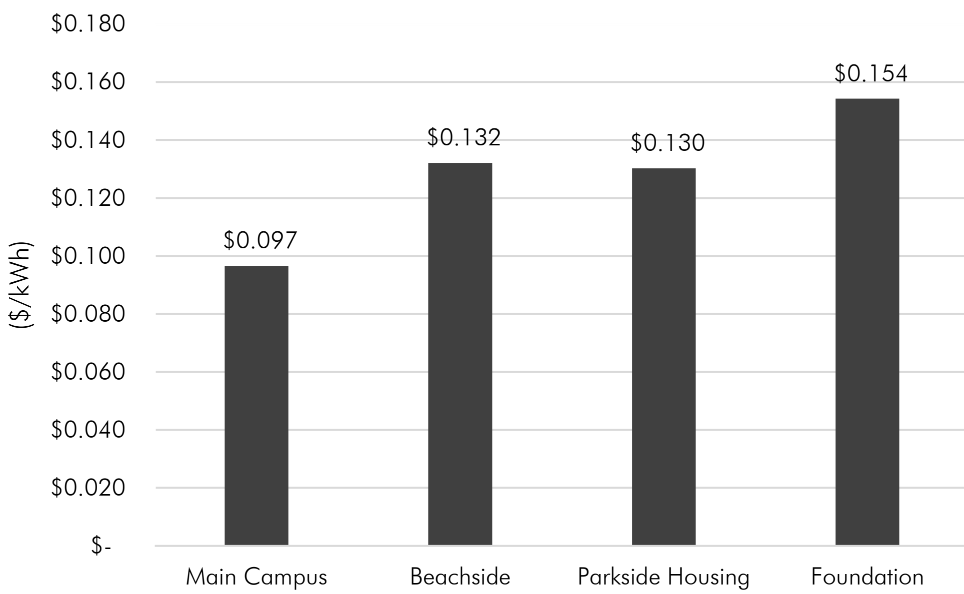

Figure 15: CSULB SCE Electrical Rates

The following tables shows the blended electricity rates for all SCE services for July 2017. Electricity rates for the smaller SCE services across campus can be significantly higher than the main service. Combining the smaller services with the main electrical distribution loop offers an opportunity to reduce electrical bills. The economic variability of this depends on the annual usage and cost to integrate with the Main Campus meter.

Table 9: SCE Electrical Rates as Compared to Main Campus Service

Service Account	Meter Address	SCE Rate Structure	Campus Area	July '17 Blended Rate [$/kWh]	Rate Relative to SCE Main [%]
3-008-5488-21	5700 E ATHERTON ST	TOU-GS-2-B	-	$0.297	243%
3-000-0018-35	5700 E ATHERTON ST	TOU-GS-2-B	-	$0.308	252%
3-033-5269-15	4825 E PACIFIC COAST	TOU-GS-3B	Beachside Housing	$0.155	127%
3-034-9202-35	4700 DEUKMEJIAN DR	TOU-GS-2-B	Blair Field	$0.191	157%
3-034-9202-56	4700 DEUKMEJIAN DR	AL-2	Blair Field	$0.080	65%
3-000-0018-43	5900 E ATHERTON	TOU-GS-3B	Parkside Housing	$0.167	137%
3-001-3609-74	1401 PALO VERDE	TOU-8-B	Main Campus	$0.122	-
3-005-0768-89	1401 PALO VERDE AVE	TOU-GS-1-A	-	$0.203	166%
3-034-9202-94	4819 E 7TH ST	TOU-GS-1-A	-	$0.176	144%
3-000-0018-37	CAMPUS/7TH	TOU-GS-1-A	-	$0.847	694%
3-000-0018-39	E CAMPUS RD N/O 7TH	TOU-GS-2-B	Faculty Office 4	$0.252	207%
3-000-0018-40	E CAMPUS RD N/O 7TH	TOU-GS-2-B	Faculty Office 5	$0.233	191%
3-000-9784-53	1605 EARL WARREN DR	TOU-GS-1-A	-	$0.186	152%
3-005-0768-88	1401 PALO VERDE AVE	TOU-GS-1-A	-	$2.497	2045%
3-002-9272-88	1430 EL MIRADOR AVE	DOMESTIC	-	-	-
2-02-073-9496	6300 E STATE UNIVERSITY DR	TOU-GS-3B	Foundation	$0.202	166%

ON-SITE GENERATION

The following table shows an overview of existing PV systems on campus, including new 4.7 MW array

Table 10: On-site Renewable Energy Generation

Year	Annual Electricity Use [kWh]	Annual Renewable Generation [kWh]	Renewable Self-Generation [%]
2009	50,223,070	501,616	1.0 %
2017	53,471,081	484,321	0.9 %
2018	53,471,081	7,973,409	14.8 %

Impact on utility blended rates - used $0.11 to account for main campus PV system

CEMP ELECTRICITY RATES

Electricity rates were used throughout the CEMP in order to calculate saving amounts from each energy efficiency measure. Almost all of the building analyzed are metered on the main campus service, with a combined utility rates of $0.11/kWh. Analysis of the Foundation and residential buildings used a blended utility rate calculated from utility bills, which are outlined in the Figure 14: CSULB Total Monthly Blended Utility Rates.

3.2 NATURAL GAS

NATURAL GAS UTILITY

CSULB purchases natural gas from the California Department of Government Services (DGS). The natural gas is transported through the City of Long Beach Utility Department. CSULB pays a commodity/administration fee to DGS and a transportation fee to the City of Long Beach. The campus natural gas main is branched from the city's main High-Pressure Gas (HPG) line and is reduced to Medium Pressure Gas (MPG) on campus before being distributed across campus.

There are six natural gas services located across the CSULB campus, shown in the following table. There is a Main Campus natural gas distribution loop supplies gas to the majority of campus, highlighted below in yellow. This gas distribution loop accounted for 92% of the total annual natural gas usage at CSULB in 2017. There are limited individual building gas meters in addition to those outlined below, therefore natural gas usage at each building must be benchmarked based on building conditions.

Table 11: Natural Gas Meters Serving CSULB Campus

Meter Address	Campus Area	Annual Usage [therms]	Percent of Total Campus [%]
5841 State University Dr	Main Campus	1,104,423	91.5%
5710 Atherton St	Los Cerritos	4,284	0.4%
6251 State University Dr	Pyramid/CPAC	13,194	1.1%
6200 Atherton St	Parkside	36,296	3.0%
5821 State University Dr	Hillside	44,874	3.7%
5800 State University Dr	Los Alamitos	3,945	0.3%

Given CSULB's direct purchase arrangement through DGS, the campus does not pay different gas rates for the various meters on campus. The monthly usage of each is aggregated to a campus total. The following graph shows for the monthly natural gas rate ($/therm) for CSULB from July 2016 to December 2017. During this year and a half period the four-month rolling average rate decreased by 41%, from $0.960 to $0.565 per therm. The reduction in natural gas rates through 2016-2017 was due to an unfavorable future contract expiring.

CEMP NATURAL GAS RATES

As CSULB purchase gas directly from the DGS, the same utility rate was used throughout the CEMP to calculate savings amount from the different EEM analyzed. CSULB recently came to the end of a long-term contract with DGS to purchase gas. This has resulted in a significant reduction in the gas utility rate the campus pays, which is now $0.55/therm. This value was applied to all gas utility rates throughout the CEMP.

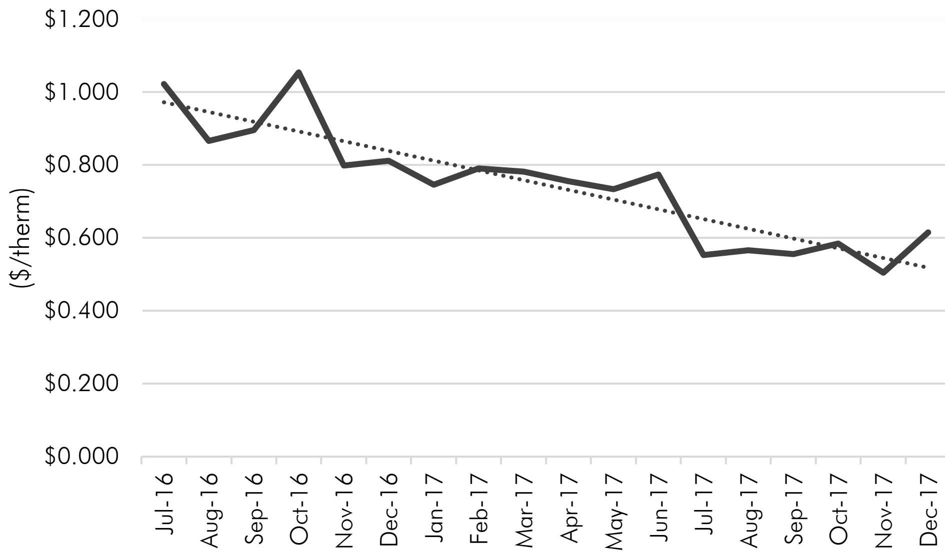

Figure 16: CSULB Main Campus Natural Gas Rates

3.3 CENTRAL UTILITY PLANT

Refer to supplemental report attached in Appendix A – Central Plant Electrification for a more in-depth assessment of the CSULB central plant.

The campus central utility plant was completed in 1996 and provides heating and cooling to a majority of the campus' buildings. Almost all educational and office buildings on campus are served by the central plant, with some exceptions. None of the residential buildings are connected and have onsite sources of heating and cooling, where applicable.

Chilled Water (CHW) and Heating Hot Water (HHW) are distributed throughout campus by means of three separate distribution loops, a North, South and West loop. Both CHW and HHW have a common supply and return header located in the central plant, from which the loops separate and combine back into one system. The North and South loops are sized almost equally in capacity and serve most of buildings connected to the central plant. The West loop is isolated to five buildings and has a significantly smaller capacity than the other two.

CHILLED WATER

Chilled water is provided by four, 1,250-ton electric chillers that were originally installed in 1996 and one, 576-ton electric chiller, installed in 2008 to aide central plant efficiencies during periods of low cooling loads. Five electric ice harvesters, with a total capacity of 1,275 tons, aide the chillers through replenishing a 34,000 ton-hr thermal energy storage tank.

A chilled water system kW/ton accounts for all the energy required to supply chilled water to campus buildings and not just the energy required to generate chilled water, such as the energy required for pumping and heat rejection. Glumac received information regarding the efficiency of the central plant from CSULB, this is outlined below. This data was used extensively throughout calculations to determine building EUI. Lowering the chilled water kW/ton will have significant impacts on campus energy usage, and although outside the scope of the CEMP, strategies to reduce this should be researched to help CSULB achieve its energy goals.

- Chilled Water Efficiency = 1.2 kW/ton[12]

HEATING HOT WATER

Hot water from the central plant is provided by ten non-condensing natural gas fired boilers, each with an output capacity of 529 MBH. The boilers on campus are shutdown during August and September when the HHW loads on campus are small. The average annual plant efficiency is outlined below.

- Hot Water Efficiency = 82%[13]

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[12] Central chilled water plant efficiency was provided by CSULB

[13] Central heating hot water plant efficiency was provided by CSULB

3.4 BUILDING SUB-METERING

Buildings on campus have been retrofitted with sub-meter(s) to measure electrical, HHW and CHW usage. Information from these meters is fed to JACE controller(s), which have been installed in existing and all new buildings across campus. Along with data logging and trending, these controllers allow for full communication between the campus EMS and each building. This allows building schedules, setpoints and other HVAC items to be monitored and controlled centrally. The sub-meters on campus trend 15-minute interval data continuously throughout the year. A full audit of the EMS was undertaken and an overview of this is outlined in Section 5.1.3 Energy Management System Audit.

As individual meters are required for electrical, CHW and HHW metering, not all buildings have been installed with all three. Typically, all building that are connected to the central plant and state owned have all three meters installed and this information is available on the EMS. However, for non-state-owned buildings, although meters have been installed they have not been tied into the EMS. For example, the buildings owned by the 49ers Shops are sub-metered electrically, however this information is not available on the EMS. It is assumed as these are non-state funded buildings that this data is only used for billing purposes. Similarly, the Los Cerritos and Los Alamitos hall have building electrical meters, but this information is not readily available on the campus EMS.

4. HISTORICAL ENERGY USAGE & EMISSIONS

4.1 CAMPUS ENERGY USAGE

Energy usage data for CSULB was obtained for the calendar year of 2017 (January – December) for the CEMP campus energy assessment. This data was provided through utility bills for each of electricity and natural gas services on campus.

4.1.1 ELECTRICITY

CSULB is supplied electricity from Southern California Edison (SCE) through multiple electrical services across campus. A summary of the total campus electricity usage during the 2017 calendar year is provided below.

- Use: 53,471,081 kWh
- Cost: $5,398,945

The following graph shows a monthly breakdown of total campus electricity usage at CSULB, including all SCE meters. Overall, there is not a huge deviation in monthly electricity usage between the winter and summer months. The difference between the lowest usage month (January) and the higher usage month (September) is 27%. However, the electricity costs were 110% higher in September due to the SCE rate structure.

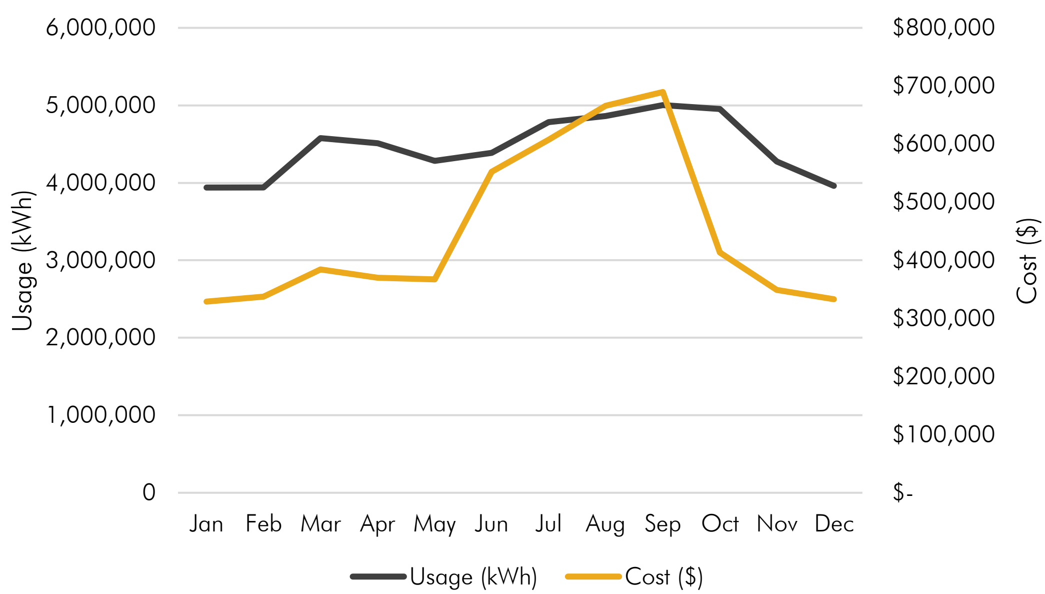


Figure 17: CSULB Total Campus Electricity Use – 2017

4.1.2 NATURAL GAS

In total, CSULB used 1,207,016 therms during the 2017 calendar year. The following graph shows a monthly breakdown of total campus natural gas usage at CSULB, including all gas meters outlined in Section 3.2 Natural Gas. As expected, there is a significant deviation in monthly natural gas usage between the winter and summer months with significantly more usage during the colder time of year.

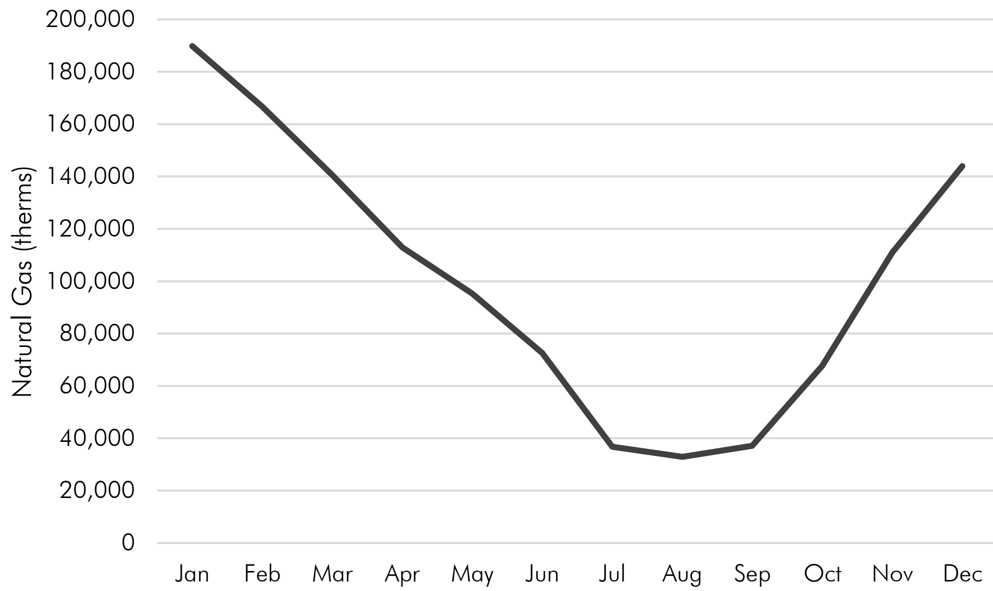


Figure 18: CSULB Total Campus Natural Gas Usage - 2017

4.1.3 TOTAL ENERGY

The following chart summarize the total energy usage on campus in 2017.

Table 12: CSULB Total Energy Usage – 2017

	Usage (kWh/therms)	Energy Cost ($)		Site Energy (MBTU)		Source Energy (MBTU)		GHG Emission (MTE)[14]	
Electricity	53,471,081	$5,399,317	87%	182,443	60%	574,696	82%	13,837	70%
Natural Gas	1,207,016	$838,299	13%	120,702	40%	126,737	18%	6,050	30%
Total		$6,237,616	-	303,145	-	701,433	-	19,887	-

The campus uses significantly more electricity than natural gas, as would be expected due to the climate in Long Beach being cooling driven. However, the campus natural gas EUI is significant given the temperate climate.

The energy breakdown shown above outlines the large differences in the price of electricity and natural gas. Although Electricity accounts for 60% of campus energy usage, its costs accounts for 87% of total expenditure on utilities. This is due to the higher costs of electricity as compared to natural

[14] Based on current emissions for CAMX grid

gas. Similarly, although natural gas usage results in Scope 1 GHG emissions, electricity production also results in large Scope 2 GHG emissions. This results in the GHG emissions from campus being dominated by electricity, with 70% of the total GHG emissions. Both factors indicated that CSULB should focus on reducing electricity over reducing natural gas consumption as it will have a larger impact on cost and GHG emission savings. However, as the emissions factor associated with electricity production is reduced due to the increase in renewable energy production across the grid, this ratio will decrease and CSULB should therefore also invest in natural gas reduction methods on campus.

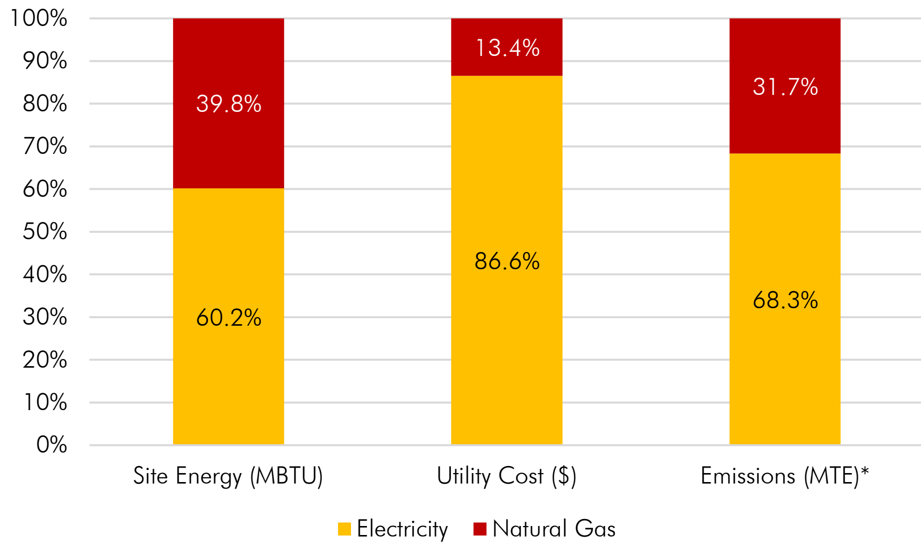


Figure 19: CSULB Total Energy Usage – 2017

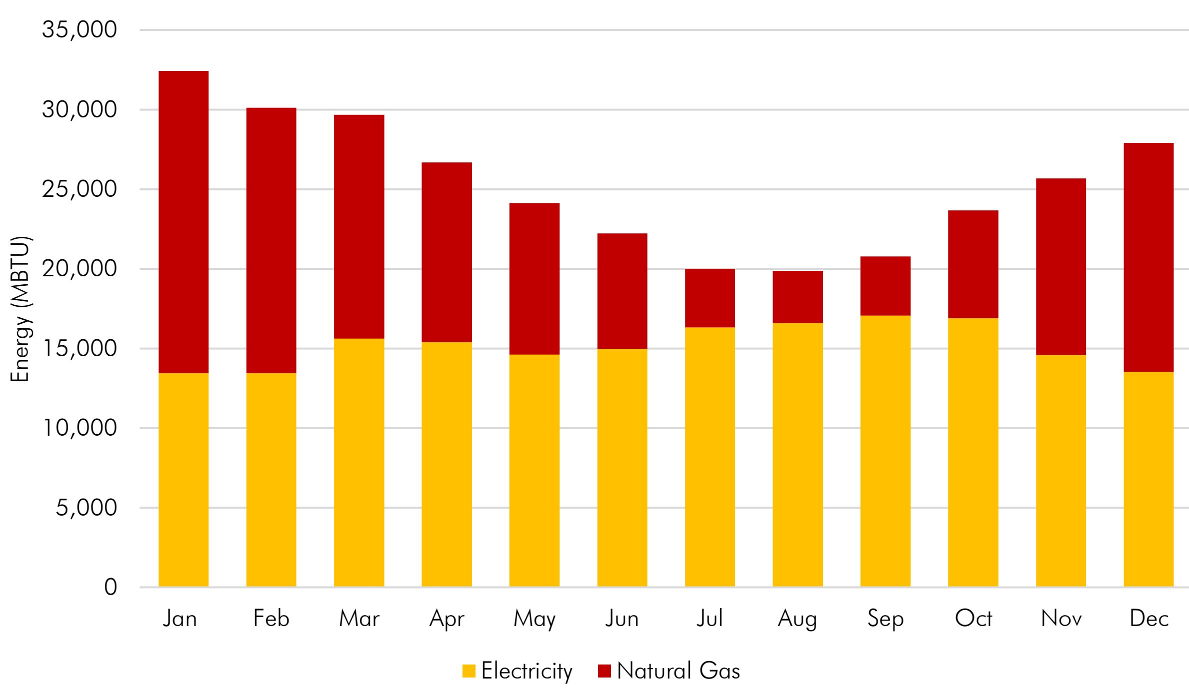


Figure 20: CSULB Monthly Energy Breakdown – 2017

4.2 HISTORICAL ENERGY USAGE

Energy usage on campus has been recorded since at least 1990, allowing for overall campus EUI to be assessed. This information is outlined below.

Table 13: CSULB Historical Energy Usage

Year	Building Area (sf)	Electricity (kWh)	Natural Gas (therms)	Energy Usage (MBTU)	Delta	Site EUI (kBtu/sf)	Delta
1990[15]	2,850,000	48,531,845	1,664,834	332,074	-	116.5	-
2004[15]	3,450,000	61,275,291	1,656,991	374,770	-13%	108.6	7%
2009[15]	3,682,423	50,223,070	1,218,983	293,259	12%	79.6	32%
2017	4,052,474	53,471,081	1,207,016	303,145	9%	74.8	36%

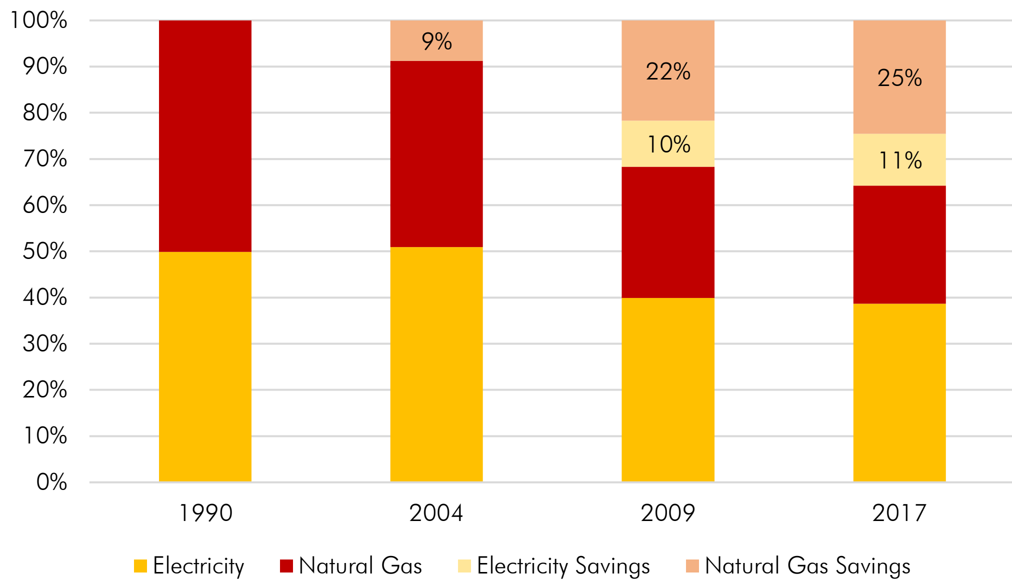


Figure 21: CSULB Historical EUI Savings Breakdown

The CSULB campus has grown by 42% since 1990, however energy usage has dropped by 8.7% in that time. 68% of the savings over this timeframe are attributed to natural gas savings, with the remainder electricity. Electrical savings are a result of increased energy efficiency in existing building, such as installation of LED lights, and the installation of renewable energy projects on campus. Natural gas savings are likely due to the addition of buildings to the central utility plants HHW loops and decommissioning of onsite boilers.

The following table shows the energy related GHG emissions of CSULB since 1990. In 2018, the campus is expected to have seen an overall 16% reduction in GHG emissions compared to 1990 levels, which represents a 41% reduction per SF of building area. CA Assembly Bill 32 (AB 32) targets the state's GHG emissions to be lower than 1990 levels by 2020. Currently CSULB is on track to exceed this target.

[15] Historical energy data was provided from the 2011 CSULB Strategic Energy Plan

Table 14: Historical Energy Related GHG Emissions

Year	Building Area [SF]	Electricity Emissions [MTE]	Natural Gas Emissions [MTE]	Vehicle Emissions [MTE]	Total Energy Emissions [MTE]	Reduction [%]	Total Emissions [MTE/sf]	Reduction [%]
1990[16]	2,850,000	-	-	-	22,060	-	0.0077	-
2009[17]	3,682,423	13,340	6,050	390	19,780	10%	0.0054	31%
2017	4,052,474	13,837	6,410	318	20,565	7%	0.0051	34%
2018[18]	**4,052,474**	**11,899**	**6,410**	**318**	**18,627**	**16%**	**0.0046**	**41%**

The following graph shows the total energy related GHG Emissions over time compared to the campus building footprint. The energy related GHG emissions have steadily reduced even with the growth the campus has seen over the past 28 years. This is largely due to CSULB's increased investment in energy efficiency, and in part to lower emissions factors from grid supplied electricity.

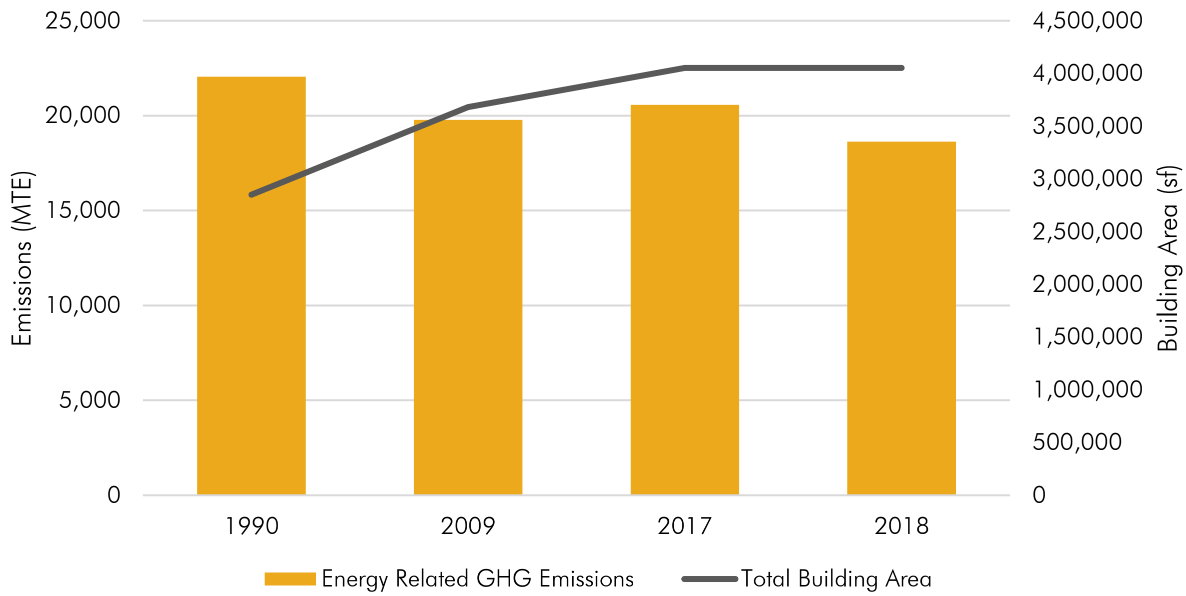


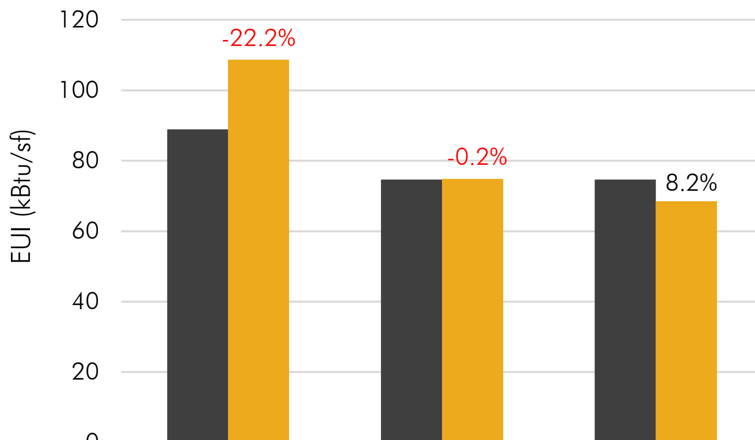
Figure 22: Campus GHG Emissions vs. Campus Building Area

[16] 1990 total Scope 1 & 2 emissions were provided from the CSULB Climate Action Plan. Fugitive emissions were not broken out; therefore, they were estimated for 1990 to be the same as in 2009
[17] 2009 emissions values were provided from the 2011 Strategic Energy Plan
[18] 2018 emissions were estimated based on 2017 use and expected mitigation from the 4.8 MW solar array

4.3 CAMPUS BENCHMARKING

CSULB campus energy usage was benchmarked against the overall CSU system to better understand how efficient the campus is currently operating compared to the remainder of the CSU campuses. The following chart shows CSU Systemwide Site EUI compared to CSULB's campus. During the calendar year of 2017 CSULB site EUI was on par with the overall CSU system; however, this was significant improvement compared to 12 years prior when the campus used 22% more energy compared to its peers.

During the time-period of 2004/2005 to 2016/2017 CSU systemwide has seen an overall EUI reduction of 16%. Whereas, CSULB has seen a 31% reduction in their campus EUI. This indicates that CSULB has doubled the pace of energy efficiency compared to the overall CSU system as result of higher performance new construction projects and energy efficiency investments. With the addition of the 4.8 MW solar array recently added to campus, CSULB is expected to surpass the CSU systemwide Site EUI for purchased utilities in 2018 and operate using 8% less purchased energy.



	2004/2005	2016/2017	2018
CSU Systemwide	88.9	74.6	74.6
CSU Long Beach	108.6	74.8	68.5

Figure 23: CSULB vs. CSU Systemwide Energy Use[19]

[19] 2018 energy was estimated based on 2017 use and expected generation from the 4.8 MW solar array. CSU Systemwide EUI data was provided from: *Sustainability in the California State University: The First Assessment of the 2014 Sustainability Policy (2014-2017)*

4.4 BUILDING ENERGY USAGE

4.4.1 BUILDING ENERGY PROFILE – 2017 CALENDAR YEAR

Energy usage data for the building on campus for the calendar year 2017 (January – December) was taken from the campus Energy Management System (EMS). Building level meters provide electrical, HHW and CHW data that allow for a building EUI to be calculated.

Table 15: CEMP Audited Building EUI – 2017

Building Name	2017 EUI (kBtu/gsf)	Building Name	2017 EUI (kBtu/gsf)
01_E. JAMES BROTMAN HALL[20]	83.2	27_UNIVERSITY THEATRE	62.1
03_NURSING	64.5	46_SOCIAL SCI/PUB AFFAIRS	61.1
05_FAMILY AND CONSUMER SCIENCES	56.7	50_VIVIAN ENGINEERING CTR	45.4
08_BOOKSTORE	36.4	56_ENGINEERING TECHNOLOGY	49.7
09_PSYCHOLOGY	61.9	61_LOS CERRITOS HALL	32.3
10_LIBERAL ARTS 5	47.5	62_RESIDENCE HALL E	47.2
14_LIBERAL ARTS 1	73.7	71_UNIVERSITY MUSIC CENTER	50.4
15_FACULTY OFFICE #3	52.8	72_CARPENTER PERFORMING CTR	34.0
19_ACADEMIC SERVICES	59.7	73_MIKE AND ARLINE WALTER PYRAMID	46.3
20_LIBRARY	44.1	83_ENGINEERING/COMPUTER SCI	64.9
24_MCINTOSH HUMANITIES BLDG	66.2	85_BUSINESS ADMINISTRATION	59.2
25_LANGUAGE ARTS	40.4	200_CSULB FOUNDATION	79.3
Building Name	2017 EUI (kBtu/gsf)	Building Name	2017 EUI (kBtu/gsf)
07_CAFETERIA	271.5	47_KINESIOLOGY	114.2
41_MICROBIOLOGY	188.7	95_HALL OF SCIENCE	162.2

The breakdown of each of the audited buildings EUI is outlined above. As natural gas meters are not installed at each building, natural gas usage was benchmarked for a significant number of buildings. Where inconsistencies in EMS data were prevalent, other sources of data were used. These included historical MBCx reports, calculated data using information from the EMS, such as using HHW and CHW temperatures and flowrate to calculated capacity, and EUI data from energy models. The buildings in which EUI data had to be taken from sources other than the EMS are outlined in *Section 5.1.3* outlines the buildings that have inconsistencies in their sub-meters, in order to help CSULB identify the source of errors in their EMS.

Of all the building audited there was typically not a large fluctuation in the EUIs, with four exceptions that are separated from the main table above. This indicates that the buildings on campus are typically operated on similar schedules with similar HVAC equipment type and age. This was confirmed during the onsite audits.

[20] Brotman Hall EUI does not include PV production

Table 16: Sources of Data for Audited Building EUI

Building Number	Building Name	EUI	Central Plant: HHW	Central Plant: CHW	On-Site Usage: Electrical	On-Site Usage: Natural Gas
01	E. JAMES BROTMAN HALL[21]	83.2	25.6	15.8	41.8	-
03	NURSING	64.5	13.6	25.9	25.0	-
05	FAMILY AND CONSUMER SCIENCES	56.7	18.9	11.2	17.4	9.2
07	CAFETERIA	271.5	-	-	149.3	122.2
08	BOOKSTORE	36.4	-	-	33.3	3.1
09	PSYCHOLOGY	61.9	17.9	15.2	28.3	0.5
10	LIBERAL ARTS 5	47.5	14.4	13.7	18.9	0.5
14	LIBERAL ARTS 1	73.7	38.8	9.5	25.4	-
15	FACULTY OFFICE #3	52.8	17.1	11.6	23.6	0.5
19	LIBRARY	59.7	18.8	14.6	26.3	-
20	ACADEMIC SERVICES	44.1	9.3	6.7	27.6	0.5
24	MCINTOSH HUMANITIES BLDG	66.2	21.8	14.3	29.6	0.5
25	LANGUAGE ARTS	40.4	9.3	5.6	25.0	0.5
27	UNIVERSITY THEATRE	62.1	25.0	11.5	25.4	0.2
41	MICROBIOLOGY	188.7	61.2	29.2	83.0	15.3
46	SOCIAL SCI/PUB AFFAIRS	61.1	25.9	9.7	25.0	0.5
47	KINESIOLOGY	114.2	26.3	7.3	70.4	10.2
50	VIVIAN ENGINEERING CTR	45.4	9.2	6.1	29.6	0.5
56	ENGINEERING TECHNOLOGY	49.7	18.7	5.6	24.9	0.5
61	LOS CERRITOS HALL	32.3	-	-	22.8	9.5
62E	RESIDENCE HALL E	47.2	-	-	18.5	28.7
71	UNIVERSITY MUSIC CENTER	50.4	9.6	3.0	37.3	0.5
72	CARPENTER PERFORMING CTR	34.0	-	-	23.8	10.2
73	MIKE AND ARLINE WALTER PYRAMID	46.3	-	13.2	31.8	1.3
83	ENGINEERING/COMPUTER SCI	64.9	17.8	15.1	31.5	0.5
85	BUSINESS ADMINISTRATION	59.2	-	-	59.2	-
95	HALL OF SCIENCE	162.2	68.4	16.3	62.2	15.3
200	CSULB FOUNDATION	79.3	-	-	64.7	14.6

White = EMS/Utility Bill Data
Orange = Predicted/Benchmarked Data
Grey = MBCx Data
Blue = Calculated Data
Yellow = Energy Model Data

[21] Brotman Hall EUI does not include PV production

4.4.2 BUILDING BENCHMARKING

To determine a reference energy usage for each building, a benchmarked building EUI was determined. Using data from provided by the following two resources, a benchmark based on occupancy distribution, location and building size was created.

- 2012 Commercial Building Energy Consumption Survey (CBECS) - US EIA
- Building Performance Database – Lawrence Berkeley National Laboratory

Benchmarking provides reference point to which all building on campus could be compared. This allowed the project team to identify buildings that were performing poorly. For CSULB to achieve their goal by 2030, all campus buildings should be at worst equal to their benchmark. The plot below can help CSULB identify which building need to be focused on. Additionally, it is expected that the building with the highest EUI will require deep retrofit work in order to lower EUI. With funding being critical for deep energy retrofits, Benchmarking can therefore be used by CSULB as a tool to plan funding projects over the next ~10 years.

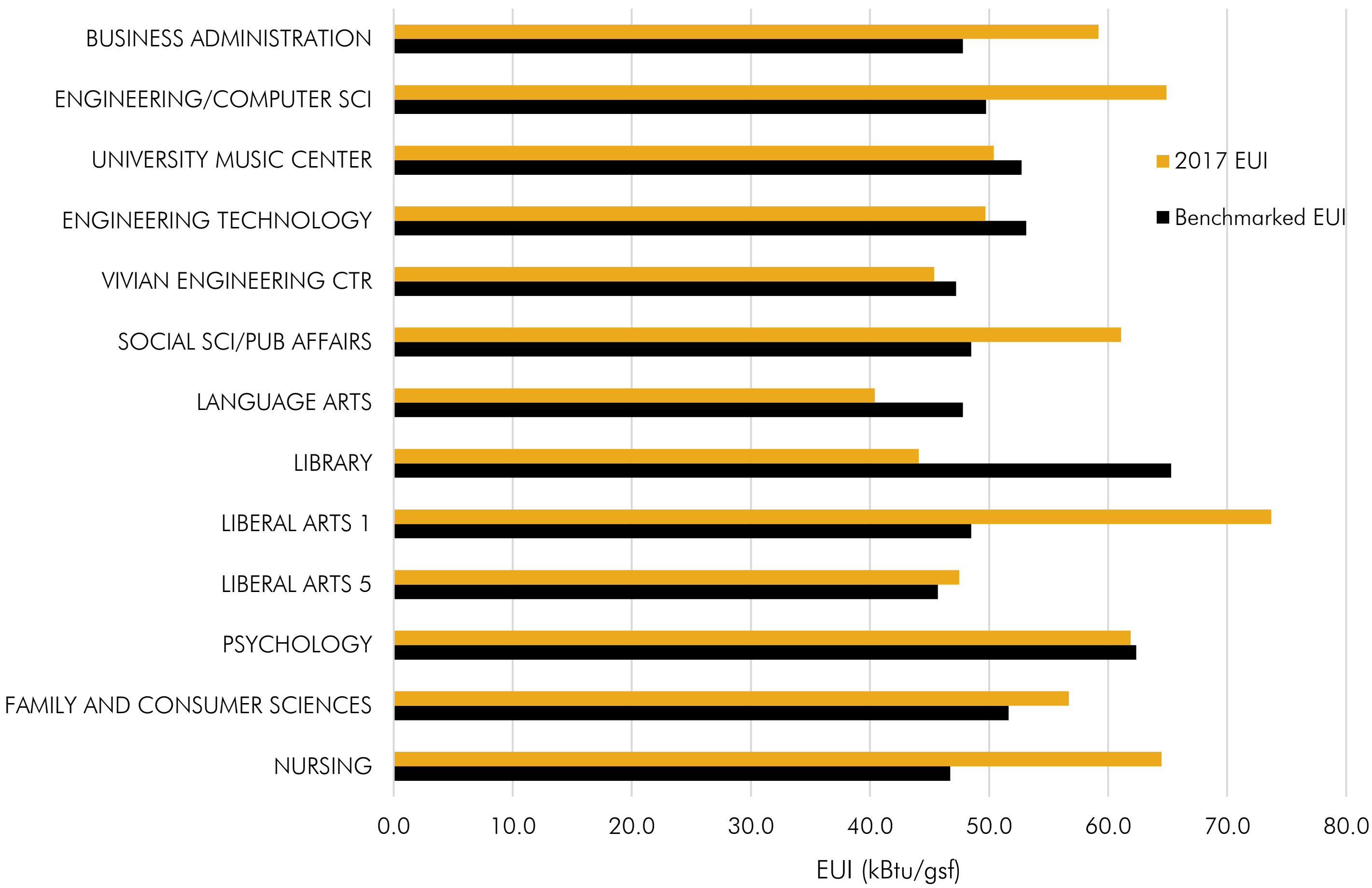


Figure 24: Education Buildings – Actual 2017 vs. Benchmarked EUI

Liberal Arts 1 consumes the highest energy per sf of all the academic buildings on campus, and has the largest percentage above its benchmark at 152%. Many academic building operate efficiently around their benchmarked value. This is typically due to HVAC retrofits, such as conversion of VAV systems from CAV.

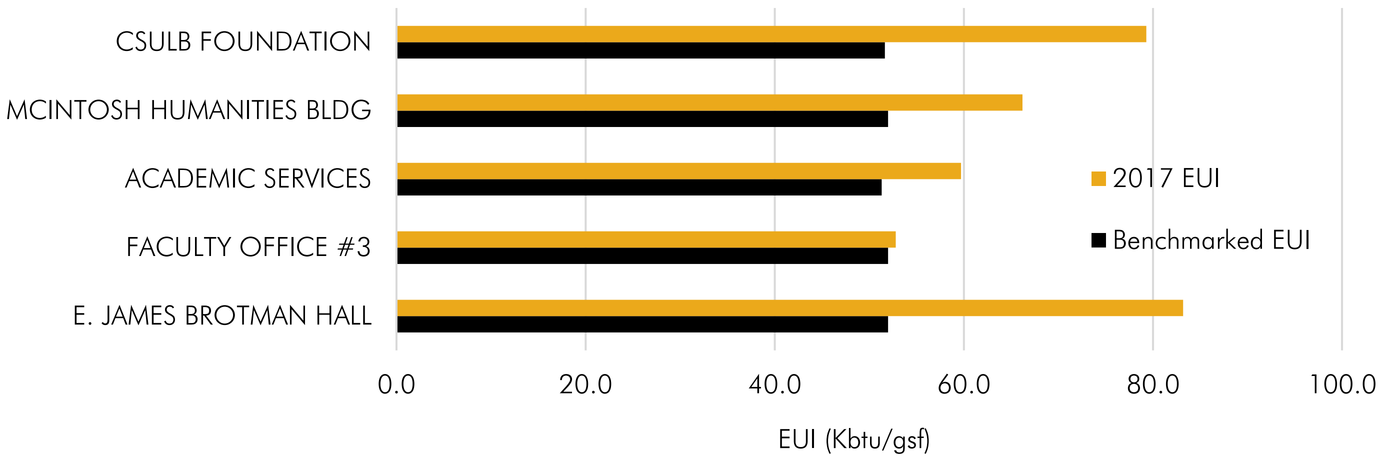


Figure 25: Administrative Buildings – Actual 2017 vs. Benchmarked EUI

Administrative offices on campus, with the exception of Faculty Office 3, all perform significantly worse than their benchmarked building. This is likely due to the age of the equipment, and due to the HVAC scheduling. Unlike many of the benchmarked office building that have well defined operating schedules, building on CSULB's campus do not appear to have their schedules optimized, likely leading to hours of HVAC operation outside of typically office occupancy

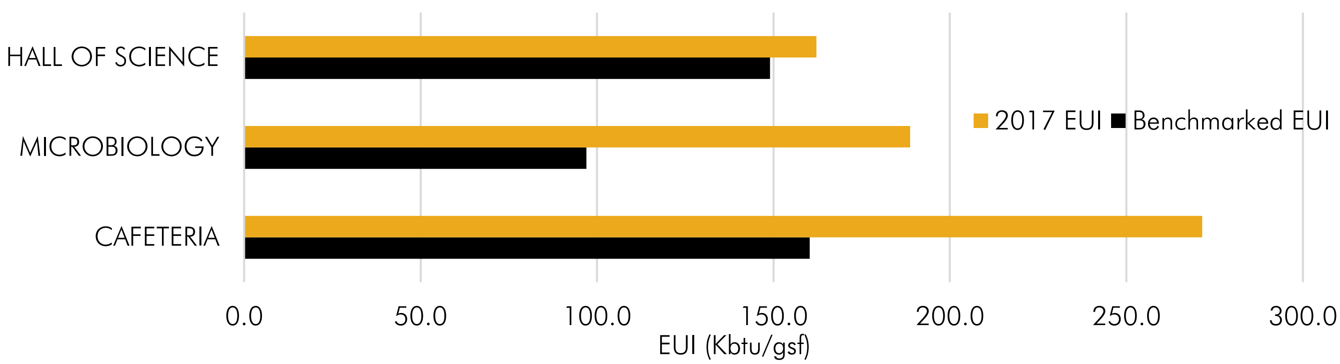


Figure 26: Laboratory & Food Sales Building – Actual EUI vs. Benchmarked EUI

Laboratory and food sales buildings also perform poorly as compared to their benchmark, with both the Cafeteria and Microbiology buildings having an EUI far greater than their benchmarked. This is likely due to the age of the HVAC equipment serving the buildings and a lack of control on older exhaust fan for both kitchen hoods or fume hood.

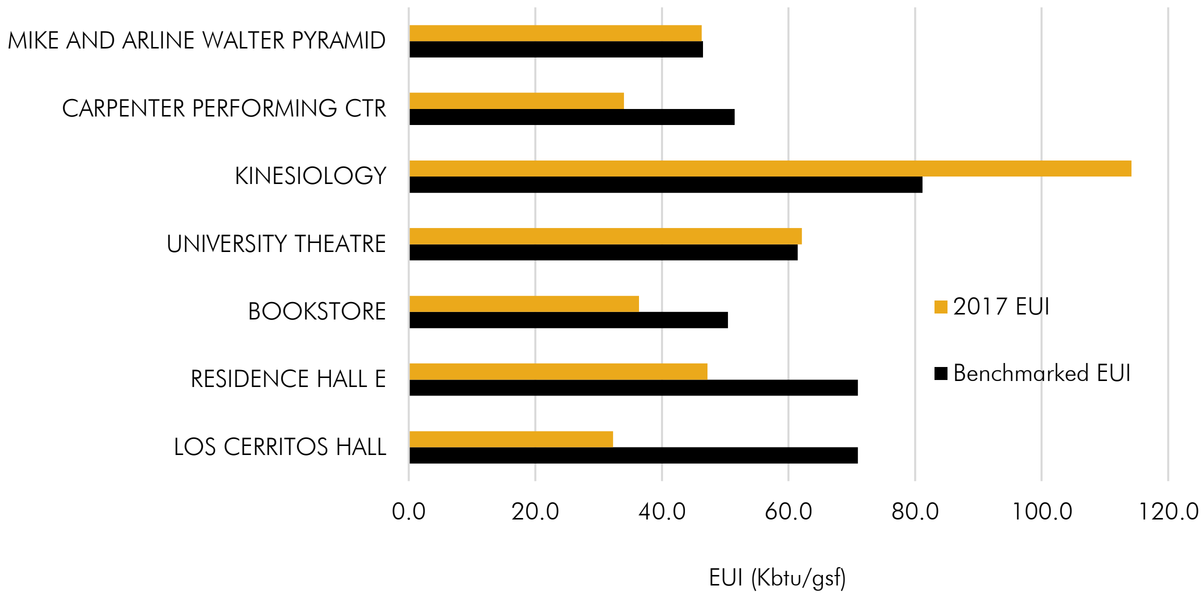


Figure 27: Remaining Campus Buildings – Actual EUI vs. Benchmarked EUI

The residential building audited perform significantly better than would be expected and are the best performing building on campus in relation to their benchmark.

Excluding the laboratory and food sales buildings, the building type with the highest average EUI of 68 are the administrative and office buildings. High occupant density and large plug loads are likely the reason for this. Academic buildings, and the buildings classified as remaining, which includes arenas, music center and theatre buildings have similar average EUIs of 55 and 53 respectively. This is likely due to the occupancy rate of these buildings being lower than an administrative office.

Outlined below are the building EUI's broken down by system type, and the following conclusion can be drawn from this data:

- Constant volume systems have a higher building EUI than the variable volume systems. This is clearly shown by the Dual Duct systems, in which the DDC, VAV buildings all have a lower EUI than the pneumatic, CAV systems.
- Dual duct buildings have, in general, a higher EUI than conventional VAV buildings.
- Regardless of parents HVAC system, any building with large exhaust fans has an extremely high EUI
- Buildings without central HVAC systems in general have lower EUIs than building with. This is likely due to a number of areas in the buildings not being conditioned, e.g. buildings 72.

Table 17: Audited Building EUI by HVAC System Type

Building Name	2017 EUI (kBtu/gsf)	Building Name	2017 EUI (kBtu/gsf)
Dual Duct / Multizone Systems			
01_E. JAMES BROTMAN HALL	83.2	14_LIBERAL ARTS 1	73.7
03_NURSING	64.5	15_FACULTY OFFICE #3	52.8
09_PSYCHOLOGY	61.9	25_LANGUAGE ARTS	40.4
10_LIBERAL ARTS 5	47.5	50_VIVIAN ENGINEERING CTR	45.4
FCU Systems			
05_FAMILY AND CONSUMER SCIENCES	56.7	61_LOS CERRITOS HALL	32.3
41_MICROBIOLOGY	188.7	62_RESIDENCE HALL E	47.2
VAV / CAV Systems			
19_ACADEMIC SERVICES	59.7	56_ENGINEERING TECHNOLOGY	49.7
20_LIBRARY	44.1	73_MIKE AND ARLINE WALTER PYRAMID	46.3
24_MCINTOSH HUMANITIES BLDG	66.2	83_ENGINEERING/COMPUTER SCI	64.9
27_UNIVERSITY THEATRE	62.1	95_HALL OF SCIENCE	162.2
46_SOCIAL SCI/PUB AFFAIRS	61.1	200_CSULB FOUNDATION	79.3
RTU & Additional HVAC Systems			
07_CAFETERIA	271.5	71_UNIVERSITY MUSIC CENTER	50.4
08_BOOKSTORE	36.4	72_CARPENTER PERFORMING CTR	34.0
43_KINESIOLOGY	114.2	85_BUSINESS ADMINISTRATION	59.2

4.5 CAMPUS VEHICLE FUEL USAGE

4.5.1 FACILITIES VEHICLE FLEET

CSULB's facilities vehicle fleet has been analyzed using use data for the year 2017. The fleet has been assessed from a high level to determine "business as usual" performance as well as evaluate potential energy saving initiatives. Currently, annual fleet consumption of unleaded gasoline and diesel is approximately 28,500 and 7,000 gallons, respectively, contributing roughly 318 MTCO2.

A "Road to 2030 Vehicle Fleet Analysis Tool" has been developed to test strategies for replacing vehicles, this is outlined in Section 7. Clean Energy Vehicles. Due to inconsistencies in odometer readings, this information has been generally excluded from the analysis. The vehicle fleet is diverse. There are 354 vehicles catalogued, ranging from street sweepers to lighting trailers and serving 76 departments. A breakdown of all vehicles by type is shown below:

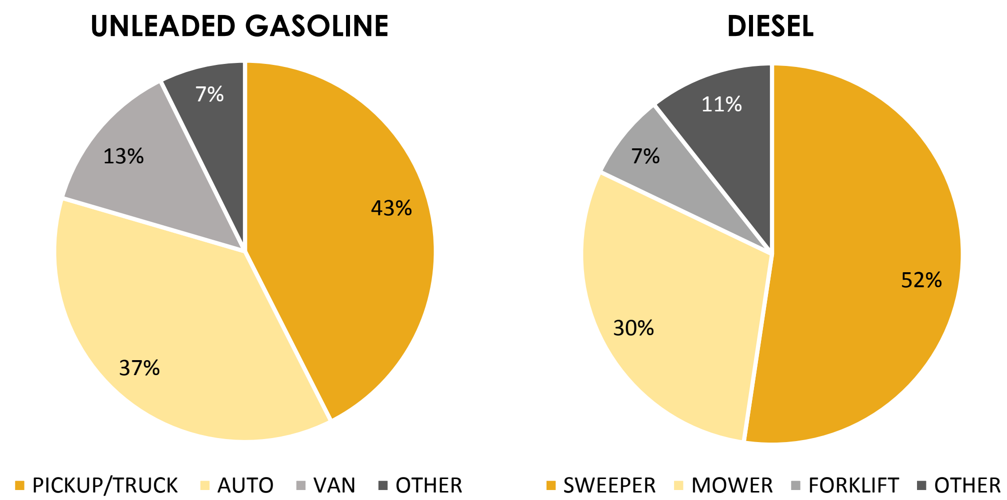


Figure 28: Vehicle Fuel Use by Vehicle Type[22]

Over 50% of the campus facilities vehicles are already electric vehicles; with most common vehicle in the fleet being the electric cart. In total, there are 185 electric vehicles. Although the electric vehicles contribute to campus GHG Scope 2 emissions, analysis in this section has primarily focused on the remaining non-electric vehicles and associated Scope 1 emissions.

EMISSIONS BREAKDOWN

Perhaps more important than type of vehicle is vehicle department, as it pertains to university operations and available funding.

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[22] 2017 fuel use data was provided by CSULB Campus Fleet Administrator

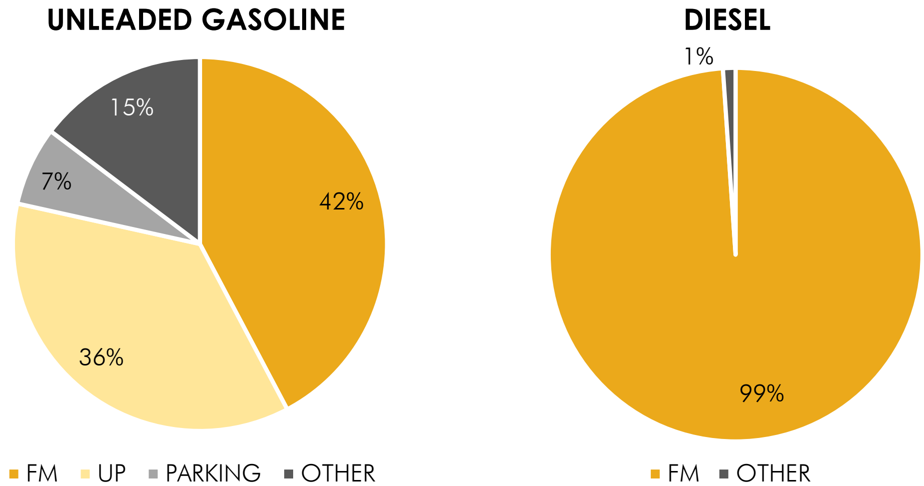


Figure 29: Vehicle Fuel Use by Department[23]

The highest consumer is the Facilities Management department. This group has 42% of the total campus vehicles including the highest single consumer in the fleet, a street sweeper that consumed over 3,000 gallons of diesel fuel last year alone. University Police (UP) have the second most cumulative gasoline and diesel usage. Two 2016 Ford Explorer SUVs are the second and third highest consumers in the fleet. This contrasts with the older sedans in the group that are significantly more fuel efficient. The third largest fleet accounts for 7% of the total campus fleet and is primarily gasoline auto vehicles. These three departments make up 88% of the university fleet consumption. Each of the remaining departments contribute 12% to overall fleet emissions.

FUTURE OUTLOOK

The primary factor that will influence future vehicle fleet emissions is expected to be budget. Budgetary considerations were not provided by CSULB, as such, each vehicle was ranked based on emission contributions (and CSULB-provided ranks when available) where the greatest emitters are to be replaced soonest. This ranking value along with age and replacement rank, outlined in Section

[23] 2017 fuel use data was provided by CSULB Campus Fleet Administrator

7.5 Transition PlanError! Reference source not found., can be used to inform studies within the vehicle fleet analysis tool. Another method of identifying vehicles to replace is "Replacement Rank". Ranks have been provided by CSULB from 1-3 for vehicles primarily based on age and whether they will be able to pass smog test. This ranking was originally provided in the CSULB "Master Fleet Book" (2018) and was expanded to apply to more vehicles in the fleet.

4.5.2 BUS SHUTTLE FLEET

The CSULB campus shuttle fleet currently consists of eleven (11) Compressed Natural Gas (CNG) vehicles with an estimated cumulative of 185,000 miles driven per year. The campus phased out the Anaheim Shuttle route in May 18, 2018 due to under-capacity ridership, which reduces the total annual mileage driven by approximately 16,000 miles.

Currently, CSULB has contracted the campus shuttle fleet to three contractors: El Dorado, Starcraft and Elkhart. The currently fleet are manufactured by Ford and runs on compressed natural gas (CNG) with an average fuel economy of 5.67 miles per gallon. Below are the emission factors for various fuel types:

4.5.3 CAMPUS GROUNDS EQUIPMENT OVERVIEW

The University grounds department currently utilizes a fleet of gasoline powered landscaping equipment to maintain the campus grounds. New technologies are becoming available to the market that allow conversion of this gas-powered equipment to battery powered with minimal impact on equipment performance.

CSULB OPPORTUNITIES

There is a wide range of opportunities for CSULB to implement battery powered products on campus. Input from the ground staff will be key in determining the appropriate equipment and it is suggested that a pilot program is initiated in which one of each equipment type is purchased and performance reviewed against the existing equipment.

4.6 TOTAL CAMPUS EMISSIONS

Scope 3 emissions from the campus have a significant impact on the overall campus GHG emissions, accounting for 66.2% of total emission in 2017[24]. Although outside the scope of the CEMP, Scope 3 emissions must be accounted for when accessing carbon neutrality as CSULB has committed to including these emissions in the overall 2030 carbon neutrality goal.

50% of the total GHG emissions from CSULBs campus can be attributed to student commuting, with a further 8.3% attributed to faculty commuting. With CSULB being primarily a commuting school, these values are unlikely to decrease without significant changes to campus policies. However, it should be noted that as clean energy vehicles become more prevalent in the market it is expected that this value will be reduced. This however cannot be guaranteed and CSULB must introduce policies to encourage the use of clean energy vehicles by their student and staff.

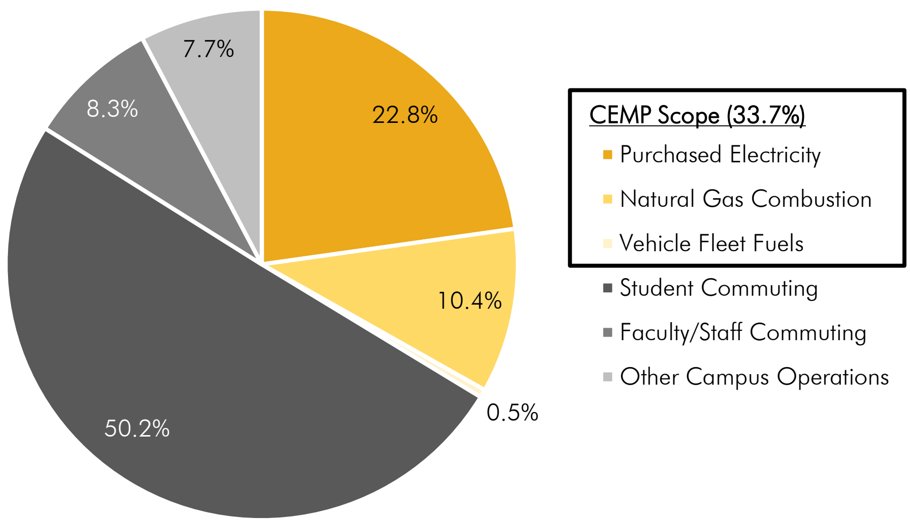


Figure 30: Total Campus GHG Emissions Breakdown

[24] Data for emissions sources outside of CEMP scope was provided from the 2015/2016 campus inventory

4.7 FUTURE CAMPUS ASSUMPTIONS

As CSULB moves towards 2030 carbon neutrality, future energy markets must be analyzed to ensure the accuracy of the SAVI tool outputs. Additionally, as new buildings are constructed on campus, or major retrofits are completed, campus energy usage will be altered from the current baseline. For this reason, the SAVI tool includes all Capital Projects CSULB currently has funded as well as a range of growth and escalation rates.

Capital Improvement projects included new constructions and major renovations to existing buildings. The table below outlines these projects and their expected impact on campus energy usage.

Table 18: Planned Capital Improvement Projects

Name	Description	Year	Additional GSF	Comments
CCPE Classroom Building	New Building - Net Zero Energy	2018	35,000	NZE Building
PH2 Student Success Center	Renovation	2019	1,200	Assumed 40 EUI
Atherton Housing Complex	New Building	2021	130,000	Assumed 37 EUI
International House Replacement	Replacement	2023	100,000	Assumed 37 EUI
PH1 Replacement Building	Renovation	2025	55,000	Assumed 40 EUI
Alumni Center	New Building	2023	15,000	Assumed 30 EUI
Library Chiller Plant	Dedicated Library Chiller Plant	2018	0	Estimated Savings - 95,000 kWh

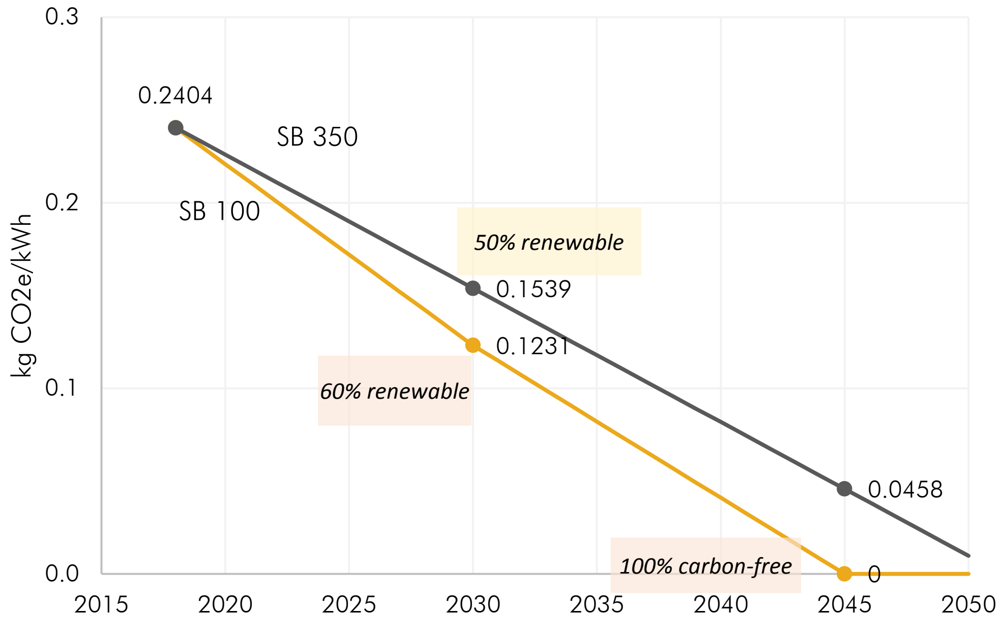
In addition to the capital improvement projects, the growth and escalation rates included in the SAVI tool were determined through conversation with CSULB and through analysis of historical market trends, expected future trends and policy changes. These are outlined below.

Table 19: Growth and Escalation rates used in SAVI Tool

Parameter	Growth / Escalation Rate
Campus Building Footprint	1% growth (2025-2030)
Campus Energy Consumption	0.25% increase (2025-2030)
Student & Faculty Commuting Emissions	1% annual growth

Emissions factors were also analyzed as these have a large impact on the campus GHG emissions. Scope 2 emissions are directly driven by the emissions factors on the electricity that CSULB purchases, for this reason these, the following decreases in emissions factor are built into the SAVI tool. Per California Senate Bill 350, signed into law in October 2015, the California grid will produce 50% of its electricity from renewable sources by 2030. Senate Bill 100 was passed by the California State Assembly in August 2018 and is awaiting signing into law at the time this report is written. If signed into law, California will commit to producing 60% of electricity from renewable sources by 2030 and 100% by 2045. This has significant potential to alter CSULBs over Scope 2 GHG emissions and should be closely followed and updated in the SAVI tool over the next 12 years.

Figure 31: California Grid Electricity Emission Factors Over Time



5. BUILDING ENERGY EFFICIENCY

5.1 ENERGY AUDIT PROCESS

The energy audit process for the CEMP was a collaborative effort between CSULB and the consultant team. The CEMP project scope was intentionally left flexible, with guarantees on the number of buildings and total footprint audited, to allow for CSULB to adjust which building would be assessed as the insights were gained throughout the audit process. The CEMP energy assessment process included the following progressive steps:

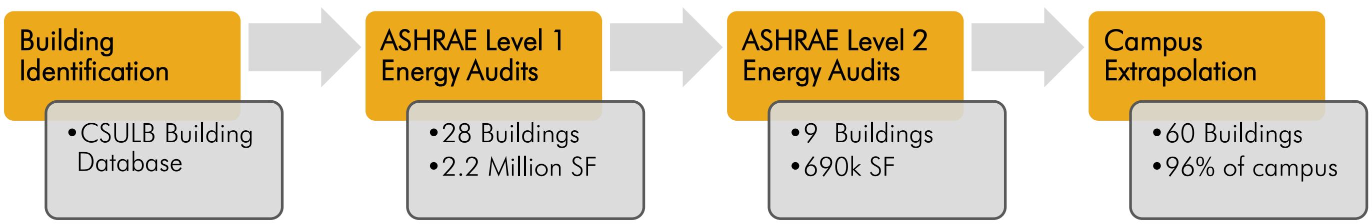


Figure 32: CEMP Energy Audit Process

The CEMP project included energy audits for roughly 2.2 million square feet of building area across campus (55% of the total campus footprint) to identify energy efficiency retrofit projects. Results from the energy audits were extrapolated across campus for similar building types to provide estimated savings and allow for scenario planning beyond the more audited projects. In total, 96% of the campus square footage was included in the CEMP analysis.

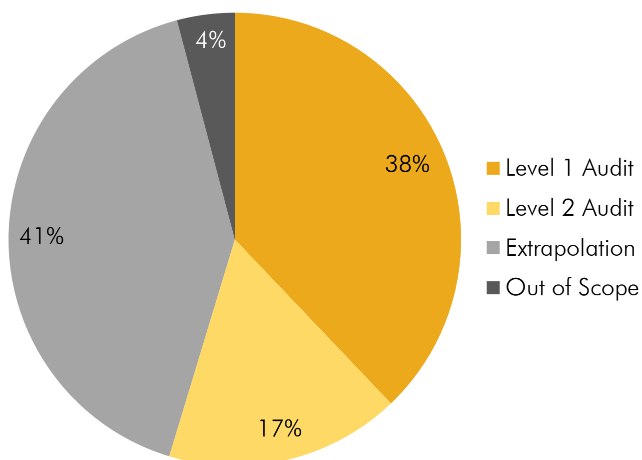


Figure 33: CEMP Energy Audit Scope

5.1.1 BUILDING IDENTIFICATION

The first phase in the energy audit process identified which buildings would undergo an ASHRAE Level 1 energy audit. This process was a collaboration between the Glumac and CSULB. CSULB provided the consultant team with a preliminary list of 28 buildings and the *2011 CSULB Strategic Energy Plan*, which included each building's energy usage from 2011. Utilizing this information, the consultant team worked with CSULB to determine which buildings should be audited based on the following criteria.

> **High Energy Use Buildings** – prioritize buildings with a greater potential for energy savings
> **Occupancy Type and Operation** – audit at least one building for each occupancy category
> **Building Size** – audit a combination of small to large buildings

The 9 buildings which underwent an ASHRAE Level 2 audits were not selected until the Level 1 audits had been completed and the results had been revised. This allowed for informed decisions on which buildings presented the biggest potential for savings and were most likely to undergo an energy retrofit in the next 5 years.

> **Ability to Extrapolate** – prioritize to extrapolated EEMs to other similar campus buildings
> **Retrofit Likelihood** – prioritize building more likely to be retrofit within the next 5-years
> **Potential Energy Savings** – prioritize buildings with a greater potential for energy savings

HVAC system type also played a large role in determining the nine Level 2 buildings. The project team wanted to ensure that HVAC system types that are common across campus were selected and used for extrapolation to the remaining campus buildings. The building selected to undergo energy analysis are outlined below, along with the distribution of the building across campus. Highlighted in yellow are the buildings that underwent ASHRAE Level 1 Energy Audits and highlighted in red are those that underwent ASHRAE Level 1 and 2 Energy Audits.

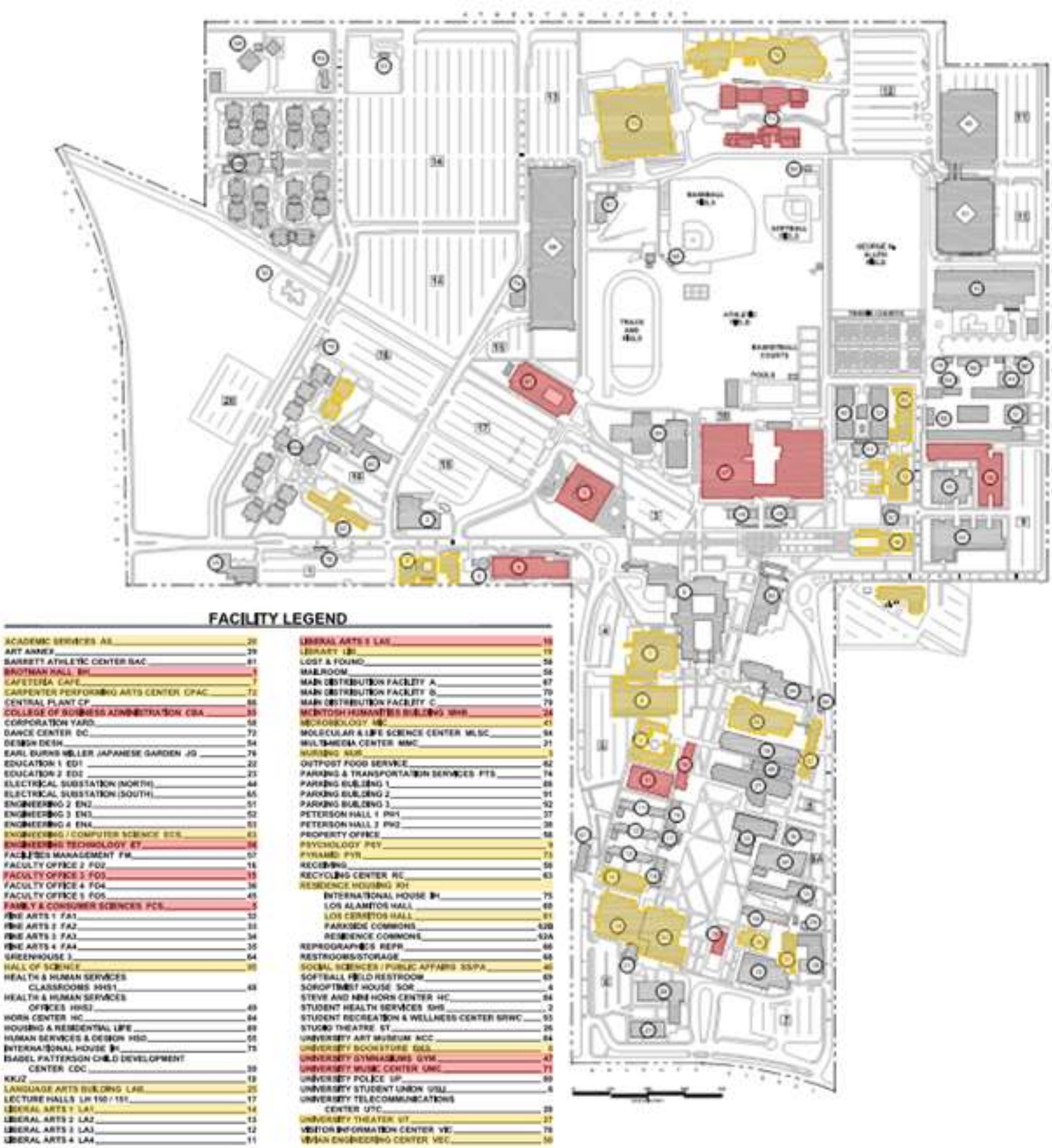


Figure 34: Energy Audit Scope (Yellow = Level 1, Red = Level 1 & 2)

5.1.2 BUILDING AUDITS

Once the 28 building were selected, preparation for the ASHRAE Level 1 Energy Audits involved:

- Development of an audit checklist to be used for every building audit. This ensured every building underwent the same auditing process
- Review of building floor plans and as built, where possible
- Discussed buildings with CSULB facilities staff to understand any existing concerns or maintenance issues and any known opportunities for energy savings in each building
- Arranged for facilities staff to be present during all the audits to ensure access was provided to all mechanical rooms.

The ASHRAE Level 1 Energy Audits were completed over the span of two weeks by Glumac. Each audit included:

- A full building walkthrough, identifying any issues with HVAC or lighting
- HVAC system identification and nameplate data collection. HVAC controls type, and operability observed.
- Number and operability of additional HVAC equipment, such as pumps and exhaust fans, recorded
- Lighting take-off – including a lighting fixture and bulb count and control system identification
- DHW system type observed
- Building occupancy schedule and diversity of space types noted
- Identification of potential sources of high energy usage, such as fountains, elevators, large computer labs, etc.

After completion of the ASHRAE Level 1 Energy Audits the information was combined into Excel spreadsheets for each building, where calculations could be completed. This process is outlined further in the report. Only then were nine buildings selected for ASHRAE Level 2 Energy Audits. These audits were completed over the span of one week by Glumac. Each audit included:

- All activities involved in Level 1 audits confirmed and where information was missing, such as nameplate data, deeper review of HVAC systems conducted. This including shutting down of AHUs to identify fan motor sizes, coil conditions, etc.
- Review of building constructions, glazing, shading and floor to floor heights – information required for energy modeling
- Interior site conditions reviewed such as ceiling type and space above ceiling – information required to analyze costs and feasibility of EE projects

5.1.3 ENERGY MANAGEMENT SYSTEM AUDIT

Key to understanding how each of the buildings operate was to analyze the Energy Management System (EMS). A Siemens TALON EMS provides real time and trended data for each building. The level of detail for each building depends on the existing controls. Buildings with full DDC controls allow the user to observe and trend individual data points at each zone level controller, whereas buildings that are limited to DDC at the AHU level only allow observation at this level.

The EMS tracks electrical, Heating Hot Water (HHW) and Chilled Water (CHW) usage at the building level, allowing a building EUI to be calculated. 15-minute interval data spanning back to when trending began was downloaded for each building and analyzed. The EMS tracks water flowrates, supply temperatures and return temperatures to determine building load. However, several buildings data contained irregularities, such as:

- Periods of time where no data was collected
- Chilled water supply temperatures being higher than return temperatures
- Data being either unrealistically high or low, providing values for electrical usage or CHW/HHW load that was clearly incorrect
- Building trended data jumping significantly between one month to the next, with no justifiable reason for such large increases in load.

All identified discrepancies in the EMS data were discussed with CSULB, and feedback on the proposed assumptions and benchmarking were verified. Specific issues with the buildings audited are outlined below:

Table 20: Identified EMS Data Irregularities

Building Name	Number	EMS Data Irregularity
E. JAMES BROTMAN HALL	01	CHW and HHW meter data incorrect. Assumed issue with temperature sensors providing unrealistic loads on building
NURSING	03	Electrical data unavailable
PSYCHOLOGY	09	Building CHW and HHW metered in multiple locations, onsite and at FO3. Total usage used as guide for benchmarking
LIBERAL ARTS 5	10	Building CHW and HHW metered in multiple locations, onsite and at FO3. Total usage used as guide for benchmarking
FACULTY OFFICE #3	15	Building CHW and HHW meters include data from LA5 and PSY. Total usage used as guide for benchmarking
LIBRARY	19	No CHW or HHW data available
ACADEMIC SERVICES	20	Electrical meter data inaccurate
MCINTOSH HUMANITIES BLDG	24	No CHW or HHW data available
UNIVERSITY THEATRE	27	Building submeters combined with Building 26 and 28. Total usage used as guide for benchmarking
SOCIAL SCI/PUB AFFAIRS	46	CHW meter data incorrect. Assumed issue with temperature sensors providing unrealistic loads on building
KINESIOLOGY	47	CHW meter data incorrect. Assumed issue with temperature sensors providing unrealistic loads on building
ENGINEERING TECHNOLOGY	56	CHW meter data incorrect. Assumed issue with temperature sensors providing unrealistic loads on building
CARPENTER PERFORMING CTR	72	CHW and HHW meter data incorrect. Assumed issue with temperature sensors providing unrealistic loads on building
HALL OF SCIENCE	95	CHW data incorrect. Total load calculated from EMS data

The back end of the EMS also allows the user to view the control methodology behind AHU operations, such as supply air resets, VFD setpoints and economizer controls. Understanding how such operations were being controlled allowed the project team to identify potential energy inefficiencies within each building. Additionally, using this information the project team could incorporate accurate controls into each of the energy models, aiding with the calibration of each to actual energy usage for the Level 2 buildings that were modelled. When possible, zone level controls were assessed, this included analysis of zone setpoints and whether terminal boxes were operating. Understanding how both zone level and system level controls operate was key for the project team in both identifying potential EEMs and to provide an understanding of the reasoning behind current building energy usage.

5.2 ENERGY EFFICIENCY PROJECTS

Outlined below are all the building audited and applicable EEMs to each building. For each EEM, calculations were completed to provide an estimated energy savings. Results from these calculations for each building are outlined in the Energy Audit Summary Reports provided in the Appendix.

Table 21: Overview of EEMs Identified for Each Building Audited

		DHW_01 - DHW – Condensing Boiler	DHW_02 - DHW - Air-to-Water Heat Pump	DHW_03 - Renewables - Solar Hot Water	GCX_01 - General Commissioning	HVC_01 - AHU - Fan Wall Array Retrofit	HVC_02 - Rooftop Unit - Replacement	HVC_03 - Dual Duct - VAV Boxes	HVC_04 - Dual Duct - Dual Fan AHU Retrofit	HVC_05 - VFD Installation	HVC_06 - Multizone - VAV Retrofit	HVC_07 - Multizone - Dual Fan AHU Retrofit	HVC_09 - Kitchen - VAV Exhaust Retrofit	HVC_10 - DEEP HVAC Retrofit	HVC_11 - Controls - HVAC Occupancy Sensors	HVC_12 - HVAC Retrofit	LTG_01 - Lighting - LED Fixture Replacement	LTG_02 - Lighting - LED Fixtures + Controls
01	BH				Y			Y	Y								Y	Y
03	NUR				Y						Y			Y				
05	FCS				Y											Y		
07	CAF	Y	Y				Y						Y				Y	
08	BKS						Y										Y	
09	PSY				Y	Y	Y										Y	Y
10	LA5				Y			Y	Y						Y		Y	Y
14	LA1				Y	Y		Y	Y								Y	Y
15	FO3				Y						Y	Y					Y	Y
19	LIB				Y												Y	Y
20	AS										Y			Y			Y	Y
24	MHB					Y								Y		Y	Y	Y
25	LAB								Y								Y	Y
27	UT				Y											Y	Y	Y
41	MIC																Y	Y
46	SSPA				Y	Y										Y	Y	Y
47	KIN				Y					Y	Y					Y	Y	Y
50	VEC				Y	Y			Y								Y	Y
56	ETC				Y	Y									Y	Y		
61	LCH		Y	Y													Y	
71	UMC													Y			Y	Y
72	CPAC		Y		Y		Y			Y						Y	Y	Y
73	PYR					Y				Y							Y	Y
83	ECS													Y				
85	CBA				Y					Y				Y		Y	Y	Y
95	HSCI				Y											Y	Y	Y
200	FOUN				Y											Y	Y	Y
62E	RHE		Y	Y													Y	

5.2.1 INDIVIDUAL BUILDING PROJECTS

HVC_01: AHU – FAN WALL ARRAY RETROFIT

Description – For existing belt driven fan motors in built-up air handler units (AHUs), retrofit AHUs with a higher performance fan wall array. Inefficiencies due to both older motor technology and the inherent inefficiency of a belt drive increase the fan energy usage for the building. A fan wall array is comprised of an array of direct drive motors, working together to deliver the necessary CFM to meet building loads. Additional benefits included reduced noise from the AHUs, increased building resiliency and easier maintenance for facilities staff. If one motor fails, the unit can remain operational and replacement is easier for facilities compared to removing one larger fan.

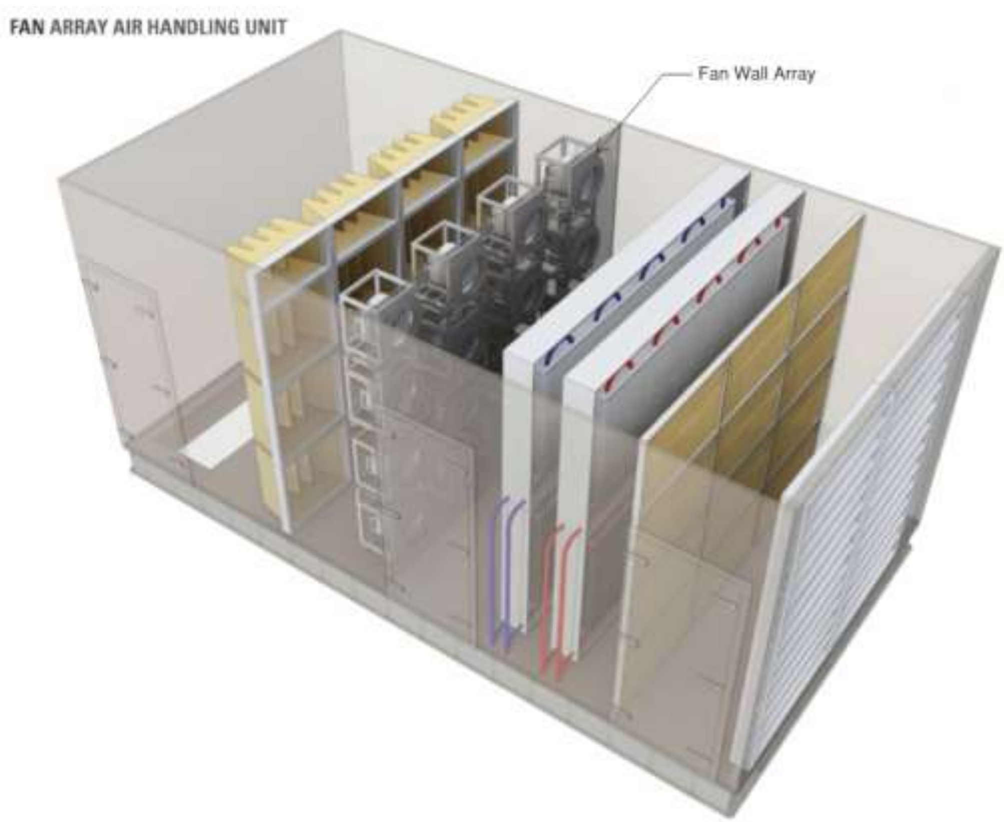


Figure 35: Fan Wall Array AHU

Savings – Fan energy savings due to increase efficiency of modern direct drive motors. Additional savings can be achieved if sound attenuators can be removed from the building through a reduction in static pressure

Scope – Demolition of existing fan and motor assembly and the installation of fan wall array. Removal of sound attenuation device, if applicable

HVC_02: ROOFTOP UNIT REPLACEMENT

Description – For building with RTUs in poor condition, in some cases with extensive damage to the condensing coils, replace with new high performance RTUs. Many of the rooftops units (RTUs) across campus were installed over 20 years ago and are past their expectant life. The efficiency of older units is significantly worse than modern heat pump units. Heat pump units can replace existing heat pumps, or direct expansion (DX) cooling and gas heating units, reducing campus Scope 1 GHG emissions and decreasing the overall campus energy usage. EEM assumes

Figure 36: Modern RTUs Recently Installed on Roof of Psychology Building

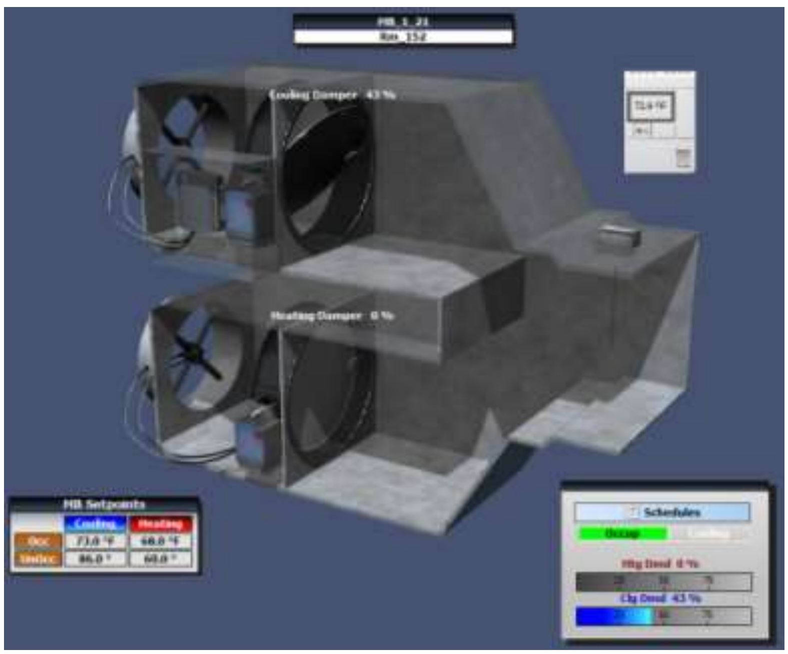
Savings – There are a variety of different RTUs on campus, with different efficiencies. Typical RTUs on campus have a cooling EER in the range of 7-9 and a COP ~2-3. Modern units can achieve EERs around 13-14, with COPs exceeding 3.

Scope – Demolition of existing RTUs and gas lines serving units. Installation of new units and connection to existing ductwork. Project cost has been assumed that new RTUs will not require curb adaptions and will meet structural requirements.

HVC_03 – DUAL DUCT – VAV BOXES

Description – For building with pneumatic CAV dual duct boxes, retrofit with VAV dual duct boxes with DDC controls. Pneumatic dual duct boxes do not allow for full modulation of the airflow to zones, resulting in the AHUs operating at constant volume, or only turning down a small amount. The existing pneumatic dual duct boxes operate as mixing boxes in which a single damper modulates between the hot and cold deck based on zone loads. This requires the thermal zone to have a single temperature set point compared to VAV systems which typically control to between 70-75F. Lack of communications between thermostats and AHUs limits the ability to reset supply air temperatures often leading to reheating cold air at zone boxes. Modern dual duct boxes have individual dampers for both the hot and cold deck and can modulate the airflow from each from 0-100% depending on loads, allowing for full VAV operation.

Figure 37: Variable Volume Dual Duct Box as seen on EMS



Savings – Zone dual duct box dampers can individually modulate air flow through cold/hot ducts, reducing the amount of simultaneous heating/cooling. This also allows for greater supply airflow turndown during low load conditions. Communication between zone boxes and AHUs with DDC controls allow for more robust supply air temperature resets. This EEM has the potential to significantly reduce fan energy and CHW / HHW usage.

Scope – Removal of all existing boxes throughout the building and installation of new VAV dual duct boxes with DDC controllers at each box. Installation of VFD at the AHU, if not already provided, and control points added to EMS. Project scope assumes that all existing duct work will remain. If ductwork requires replacement due to age or condition, project costs will be significantly higher.

HVC_04 & HVC_07 – DUAL FAN AHU RETROFIT

Description – For built up dual duct and multizone AHUs with a single supply fan, retrofit units to have dedicated cooling and heating fans. All existing dual duct and multizone AHUs on campus have a single supply fan that sits within the air stream of a common mixed air plenum. This mixed air is a combination of return from the building and outside air. In these single fan systems, the supply fan is unable to modulate to meet cooling and heating loads individually. Splitting the AHU return plenum and installing dedicated heating and cooling deck fan wall arrays will allow the fans to operate at their peak efficiency for both heating and cooling loads. Outside air can be introduced into the cold deck only, ensuring the heating coil only receives return air. This warmer return air will reduce the amount or reheat required, lowering HHW usage. Similarly, the outside air will cool the return air and lower CHW usage whenever the OSA temperature is lower than the return, which in 2017 was 75% if the year. This EEM is only applicable to built-up AHUs.

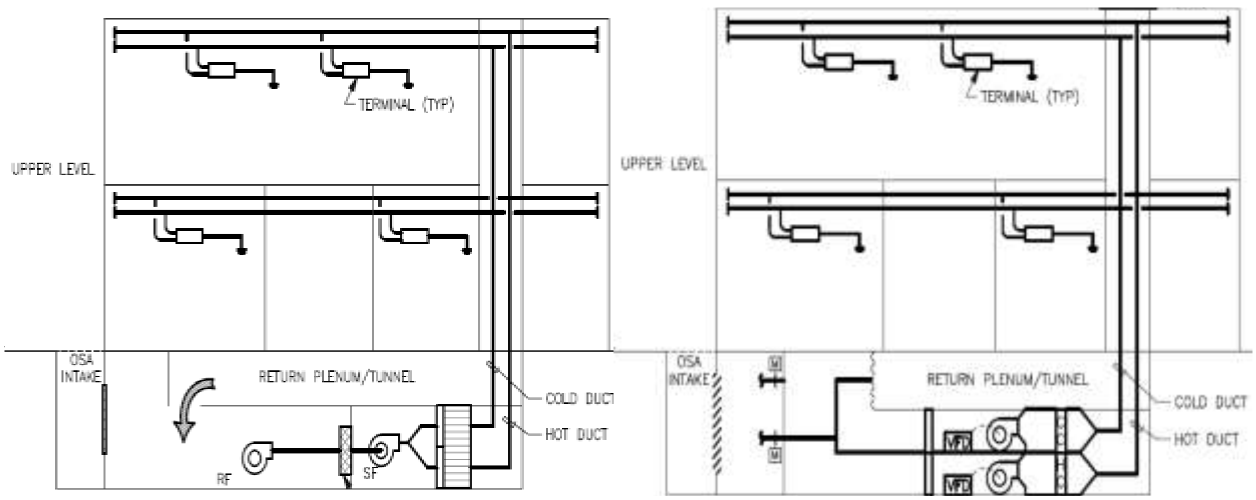


Figure 38: Old (left) vs New (right) AHU Design

Savings – CHW and HHW savings can be realized due to better airflow control across the cooling and heating coils. Dedicated cooling/heating fans allow for better supply air temperature reset and control of the AHU. Additionally, introducing a dedicated cooling deck OSA economizer is a more energy efficient economizer operation compared to what is possible with a single fan configuration. Fan energy saving is also expected due to improved efficiencies of direct drive fan motors and increased fan turndown during low load conditions.

Scope – Demolition of existing supply fan and installation of plenum walls within AHU to separate hot and cold decks within the AHU. Installation of dedicated hot and cold deck supply fan wall arrays Installation of ductwork from outside air louvers to the cold deck. Project scope assumes a built-up AHU has adequate space to allow for the installation of plenum walls and separate fan wall arrays…

HVC_05 – VFD INSTALLATION - PUMPS

Description – Install Variable Frequency Drives (VFDs) on constant speed pumps to convert system to variable flow. Replace three-way valves with two-way values, when applicable.

Savings – VFDs will lower pump energy during times when a building is at part load via lowering the pump motor speed, and therefore reducing the flow. Savings were calculated on a building by building bases and are dependent on the type of system in each building. Typical savings through converting constant flow hydronic systems to variable flow are expected to be roughly 60% in pumping energy.

Scope – Install VFDs on pump, install a differential pressure sensor in pipe to control VFD and add control points to the campus EMS to control pump operation. When applicable, replace all three-way valves with two-way valves.

HVC_05 – VFD INSTALLATION – FANS

Description – Install VFDs on constant volume supply and return fans. Many single zone AHUs across campus currently operate at constant volume. Installation of VFDs on the AHU fans will allow the fan speed to vary flow. Variable flow allows system to meet space load with greater precision, helping to improve occupant comfort and lower energy usage.

Savings – VFDs can modulate fan speed during time when the building is in part load, resulting in large fan energy savings.

Scope – Installation of VFD(s) on AHU supply and return fans. Addition of control points to tie VAV AHUs into the EMS and if applicable, conversion of zone controls to DDC.

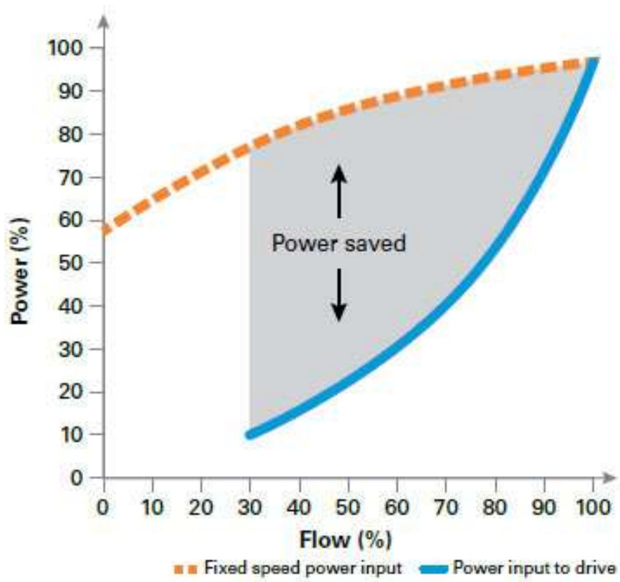


Figure 39: VFD Fan/Pump Energy Savings[25]

[25] Image provide from Gozuk

HVC_06 – MULTIZONE – VAV RETROFIT

Description – For pneumatic multizone dampers that do not allow for full modulation of the airflow. The existing dampers modulate between the hot and cold deck based on zone loads but keep a constant volume to each zone. Individual dampers for both the hot and cold deck can be installed and are able to modulate the airflow from each from 0-100% depending on loads, allowing for full VAV operation.

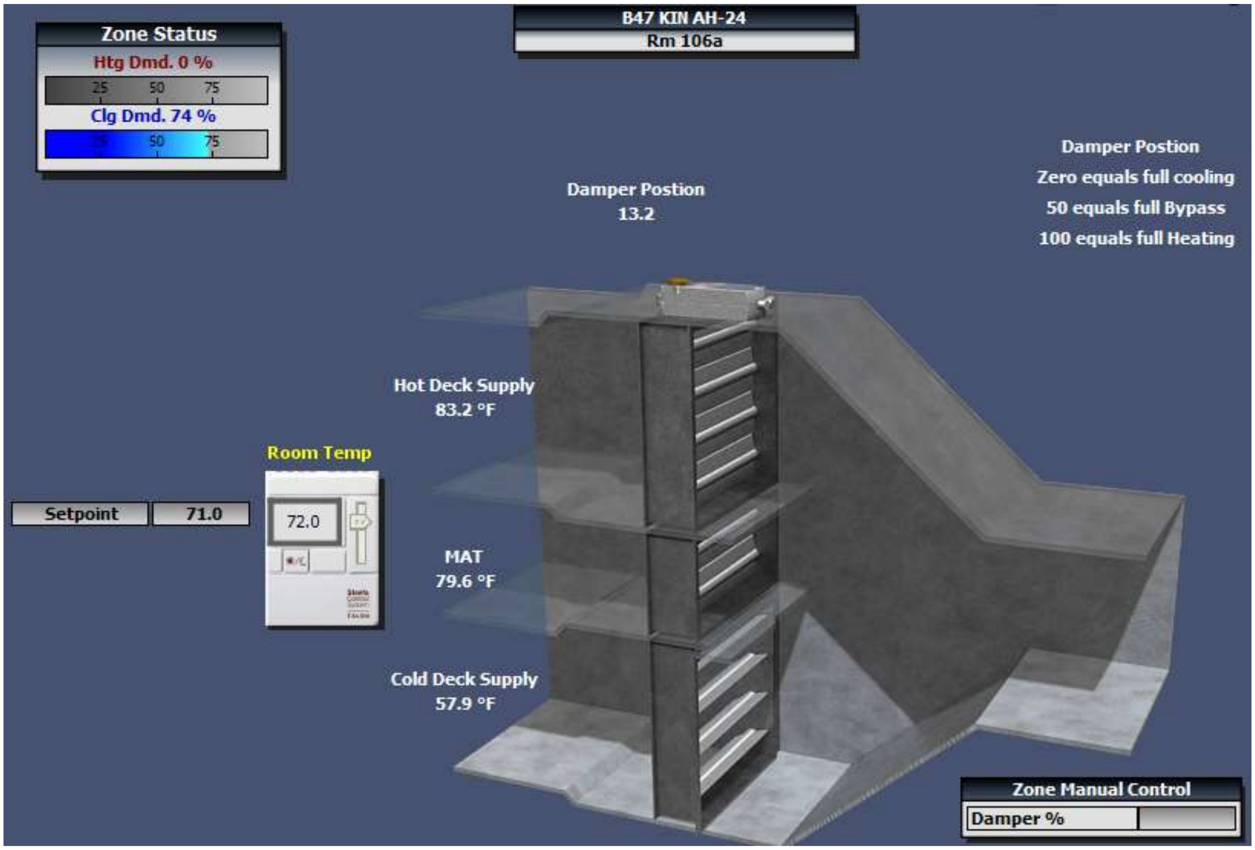


Figure 40: Variable Volume Multizone Damper as seen on EMS

Savings – VAV multizone dampers can individually modulate air flow to each zone, reducing the amount of simultaneous heating/cooling. This also allows for greater supply airflow turndown during low load conditions. Communication between zone boxes and AHUs with DDC controls allow for more robust supply air temperature resets. This EEM has the potential to significantly reduce fan energy and CHW / HHW usage.

Scope – Removal of all existing dampers at the AHU and the installation of new VAV dampers with DDC controllers. Installation of VFD at the AHU, if not already provided, and control points added to EMS. Project scope assumes that all existing duct work will remain. If ductwork requires replacement due to age or condition, project costs will be significantly higher.

HVC_09 – KITCHEN – VAV EXHAUST RETROFIT

Description – For existing kitchen exhaust fans and make-up air units that operate at constant volume. Installation of VFD(s) and controls that will allow the exhaust fans and MAU to operate on a demand basis.

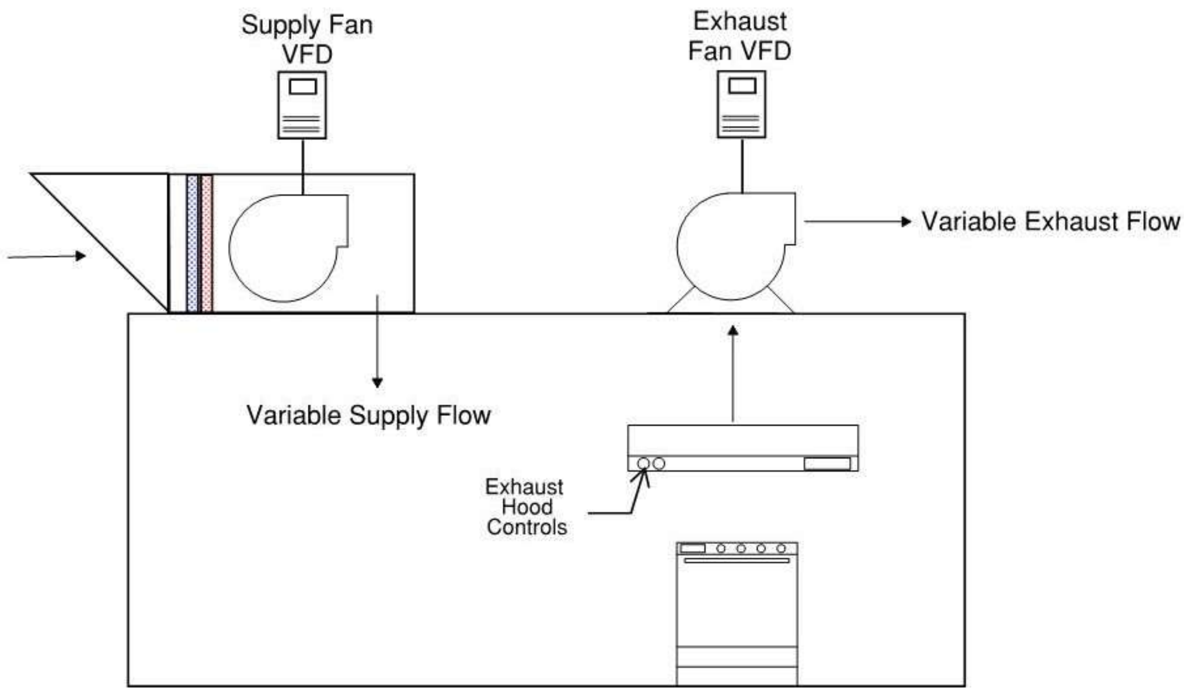


Figure 41: Variable Volume Kitchen Exhaust Schematic

Savings – Fan energy savings resulting from reduction in airflows are expected to be in the range of 30-50% against current baseline.

Scope – Installation of VFD(s) on exhaust fans and MAU, controls and sensors to allow for demand response.

HVC_10 – DEEP HVAC RETROFIT

Description –For buildings on campus that are in need of large capital improvement projects that will significantly reduce energy usage, whilst extending the life of the building. These projects involve converting HVAC systems, or fully replacing entire systems with modern equipment. Projects that would be considered deep retrofits include:

- Converting old multizone AHUs to dedicated outside air units, and installing fan coil units at a zone level (chilled water or VRF)
- Replacing WSHPs with a water-cooled VRF system that is provided ventilation air from a dedicated outside air unit.
- Converting constant volume AHU system to VAV through CAV box replacement and AHU upgrades

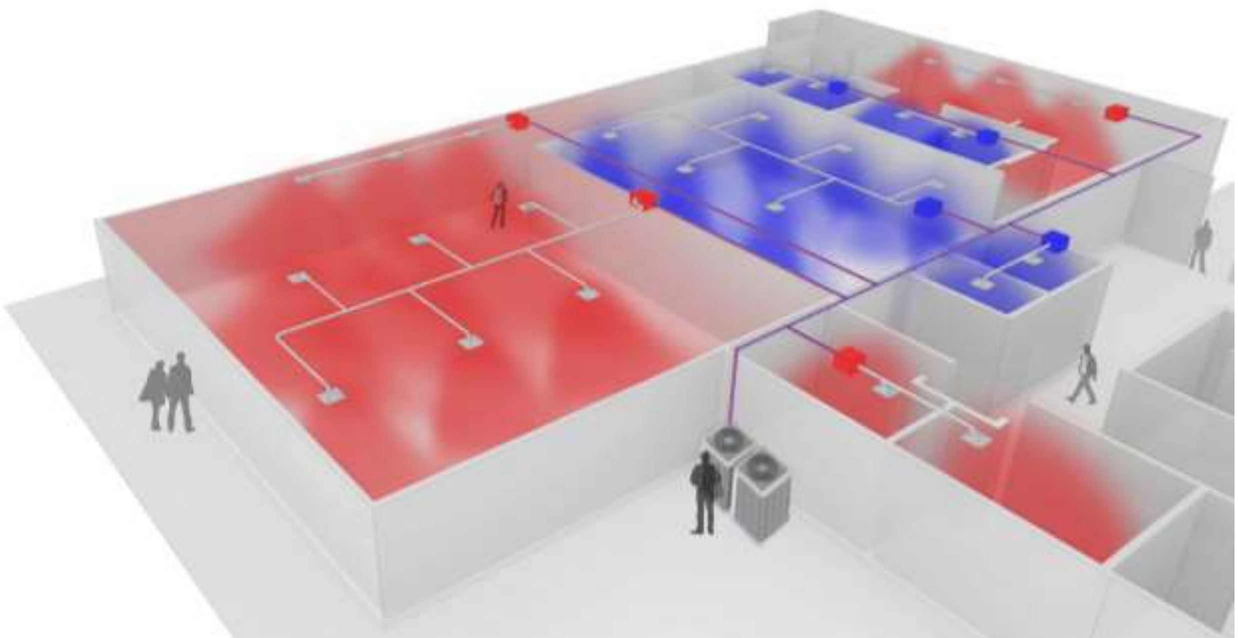


Figure 42: VRF Fan Coil Units

Savings – Deep HVAC retrofits are outlined in Section 11 as retrofit projects that result in savings of over 50%. Additional benefits of undertaking these large capital improvement projects are also included in this section. At CSULB, the deep HVAC EEMs researched for this report display extensive simple payback periods. This is due to the low electricity and gas rates CSULB pay as compared to smaller facilities and the increased costs of undertaking large retrofits on older buildings.

Scope – Extensive retrofit or replacement of building HVAC system and integration of building systems with innovative technologies.

HVC_11 – CONTROLS – HVAC OCCUPANCY SENSORS

Description – For building in which zones have periods of inoccupancy, such as classrooms. Occupancy and carbon dioxide sensors can detect when classrooms are unoccupied for a period of time, allowing HVAC setpoints to be setback.

Figure 43: Ceiling Occupancy Sensors

Saving – Savings vary on a building-by-building basis and buildings with a large number of classrooms have the greatest potential for savings. This EEM savings can be amplified through smart scheduling of classrooms, ensuring that the same rooms are used constantly throughout the day and unoccupied rooms remain that way until occupancy is necessary.

Scope – Installation of occupancy sensors in classrooms and control wiring to thermostats and terminal units. Note – This EEM is only possible with DDC controls, therefore must be combined with another EEM if the existing building has pneumatic.

HVC_12 – HVAC RETROFIT – REPLACE CONSTANT VOLUME FCUS WITH VAV UNITS

Description – Applicable to constant volume FCUs are currently installed across campus. These constant volume units result in high energy usage as the existing supply fans cannot modulate to meet zone loads. Modern FCUs can be fitted with variable speed ECM motors for VFDs that allow for high precision in meeting loads through varying supply airflow.

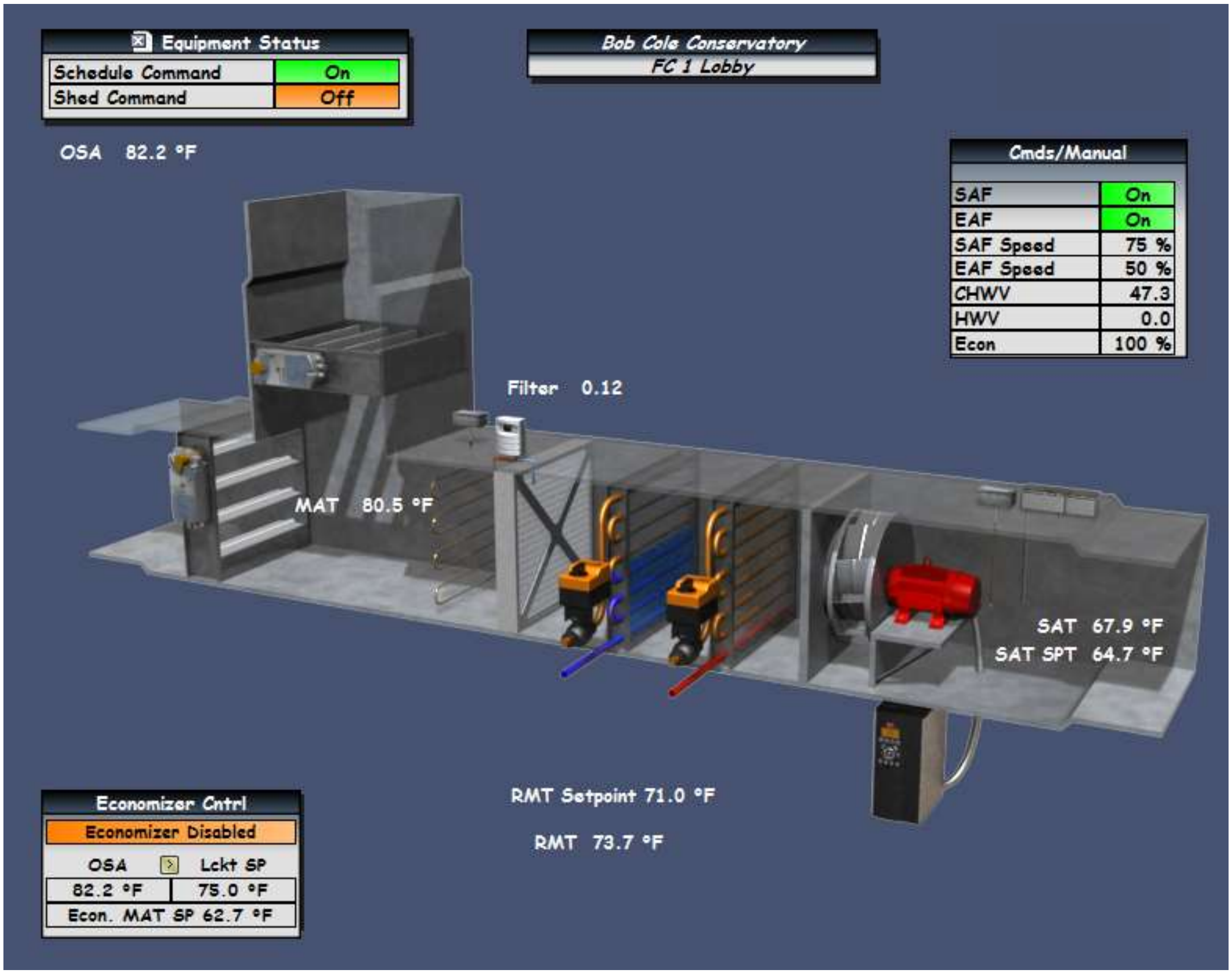


Figure 44: Volume Single Zone Units, as seen on CSULB EMS

Savings – Large savings are expected in fan energy as the fan motor will modulate to meet loads. ECM motors also operate at higher efficiencies than the existing permanent split capacitor motors when at full capacity (reference from Price), further reducing fan energy. HHW and CHW usage will also be reduced due to new coils in the FCUs resulting in improved heat transfer.

Scope – Demolition of existing FCUs and installation of upgraded units.

DHW_01 – BOILER / DHW HEATERS - CONDENSING BOILER

Description – For buildings that have onsite heating hot water boilers / domestic hot water heaters. Both the existing boilers and DHW heaters are typically standard efficiency, non-condensing with efficiencies around 80%.

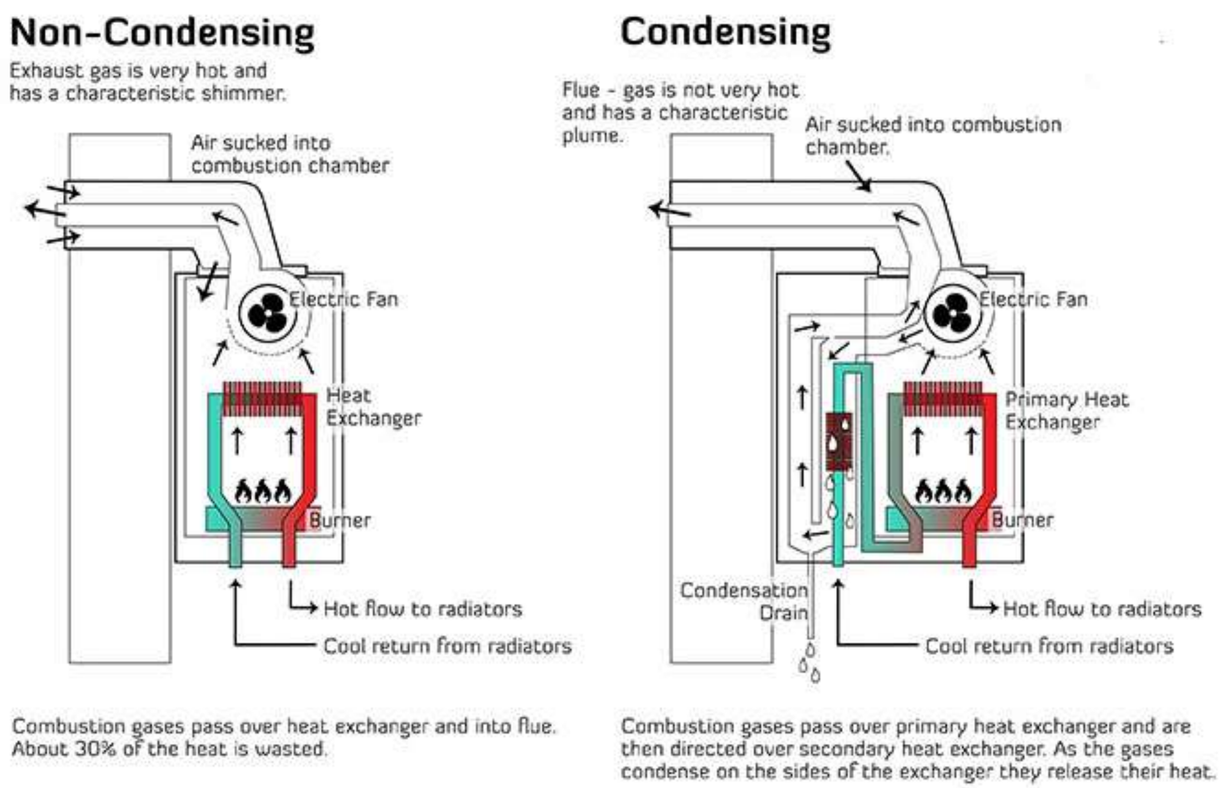


Figure 45: Condensing Boiler Operations[26]

Savings – When conditions allow, condensing boiler can operate at up to 95% efficiency, and when the return water temperatures do not allow for condensing, modern boilers operate at around 88% efficiency, higher than the existing boilers and DHW heaters are operating. This reduction in natural gas usage will also lower campus GHG emissions, helping CSULB achieve its carbon neutrality goals.

Scope – Removal of existing boilers and installation of condensing boilers. Installation of condensate drain with condensate neutralizer. New exhaust flue and gas piping and fittings may also be required to accommodate new boilers. These would be assessed on a project by project basis.

[26] Photo Credit - http://thegreenhome.co.uk/heating-renewables/heating-systems/best-household-boiler/

DHW_02 – DHW HEATER – AIR-TO-WATER HEAT PUMP

Description – For buildings that have domestic hot water heaters. Campus standard DHW heaters are instantaneous gas heaters, with significant scope 1 GHG emissions. Air-to-water heat pumps electrifies the production of domestic hot water, therefore reducing scope 1 emissions significantly.

Figure 46: Air-to-Water Heat Pump, Installed in LA1

Savings – The energy usage of new heat pumps was calculated using the coefficient of performance (COP) of the heat pumps. However, the largest benefit of these DHW heaters are their alternative to gas as the source of energy, resulting a large reduction in scope 1 GHG emissions.

Scope – demolition of existing heat pumps, capping of gas supply lines and installation of new heat pumps.

DHW_03 – RENEWABLES – SOLAR HOT WATER

Description – For buildings that have high DHW loads. Solar hot water heaters offer a renewable method to deliver DHW to campus buildings with high DHW demand. Collectors on rooftops can be used to heat DHW, offsetting the capacity of gas or electric DHW heaters.

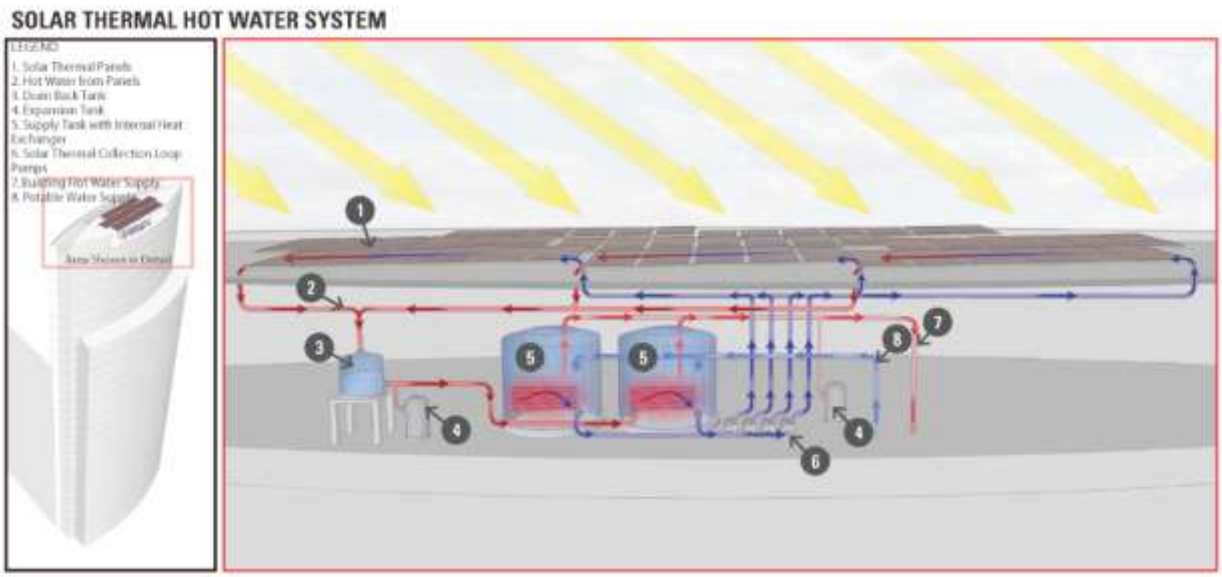


Figure 47: Solar Thermal Hot Water Design Principles

Savings – The predominant savings associated with this EEM are the lowering of scope 1 GHG emissions from the campus and the resultant reduction in the required GHG offsets and/or renewable energy projects installed.

Scope – Installation of solar hot water systems include a range of rooftop equipment, including the collectors and support, and indoor pumps and storage tanks.

GCX_01 – GENERAL COMMISSIONING

Description – For all buildings on campus. As buildings operate over time, often the HVAC system controls are altered from design conditions. This is often done to maintain occupant comfort, however can also often lead to zones and HVAC systems not operating to their optimal efficiencies. Commissioning is therefore recommended both after any capital improvement projects are completed and as a general task in existing buildings, to ensure the existing systems are operating to their peak efficiency and any operational issues are addressed.

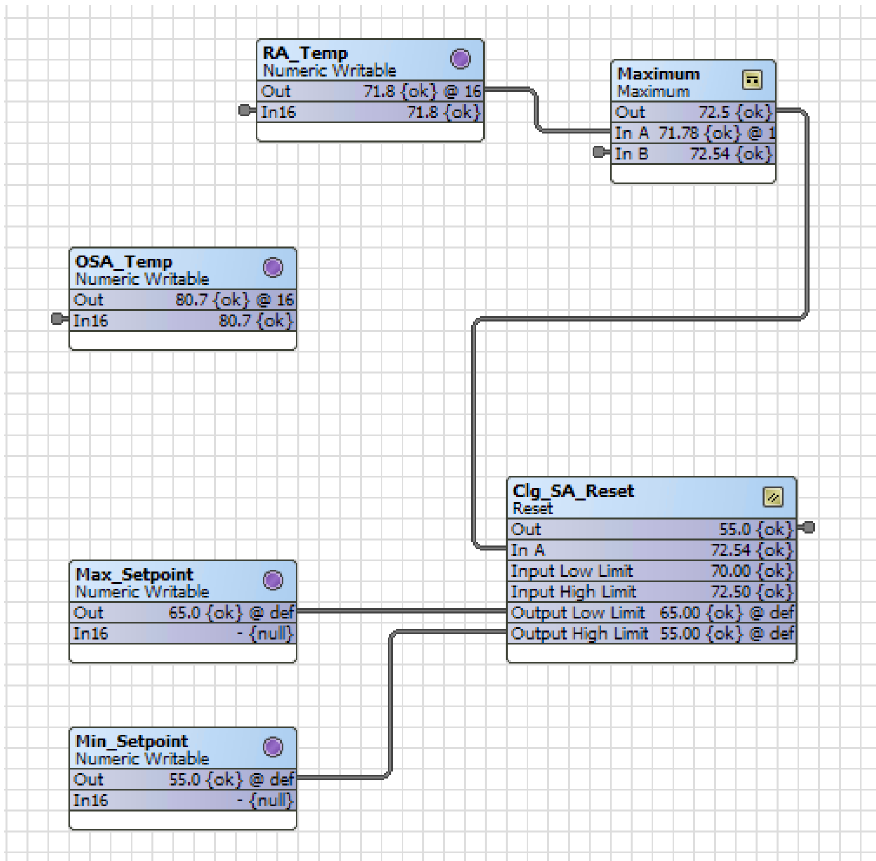


Figure 48: Programmable EMS Backend where Sequence of Operations can be Adjusted

Savings – Savings from commissioning projects vary widely and are highly dependent on the existing conditions. However, it can be expected that savings between 5-15% in HVAC energy usage will result from a thorough review and optimization of the building systems.

Scope – Commissioning both new and existing HVAC systems includes a wide range of activities and is not limited to specific tasks. However, general commissioning of existing HVAC systems often includes activities such as optimizing supply air reset temperatures, reviewing economizer lockout temperatures and ensuring the economizer is operating correctly and ensuring zone setpoints are acceptable.

LTG_01 – LIGHTING – LED FIXTURE REPLACEMENT

Description – For buildings on campus with non-LED fixtures. T8 and T5 linear fixtures can be replaced by linear LED fixtures and screw and plug-in CFL bulbs can be replaced by equivalent LED lamps. LED retrofit kits provide a cost-effective method to replace high energy usage fixtures with minimal impact on building infrastructure.

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Savings – A typical T8 bulb uses 32W per bulb, versus 16W for an equivalent LED lamp. Savings are intensified as typical T8 troffer fixtures contain 3 or 4 bulbs, whereas an LED retrofit kit will use two bulbs only. Lighting take offs were completed during the energy audits and energy savings per space type were determined from the existing lighting fixtures in each space.

Scope – Removal of existing troffer fixture and installation of a LED retrofit kit, designed to be installed in place of existing fixtures with minimal additional work required.

LTG_02 – LIGHTING – LED FIXTURE REPLACEMENT & CONTROLS UPGRADE

Description – For buildings on campus with simple lighting controls such as switches only. When undergoing lighting retrofits, lighting controls should also be upgraded. With the installation of advanced lighting controls, the overall hours of operation can be reduced, further lowering energy usage. Controls include occupancy sensors to turn off lighting during period of inoccupancy and daylight sensors to dim lighting levels when natural light is at adequate levels.

Savings – Advanced lighting controls such as occupancy sensors and daylighting will help reduce the total number of hours that each fixture is on, lowering overall energy consumption in addition to that of just replacing fixtures. I

Scope – EEM LTG_01 plus the installation of advanced controls, including occupancy sensors and control wiring to each sensor. Office spaces fitted with wall mounted sensors and open area with ceiling mounted.

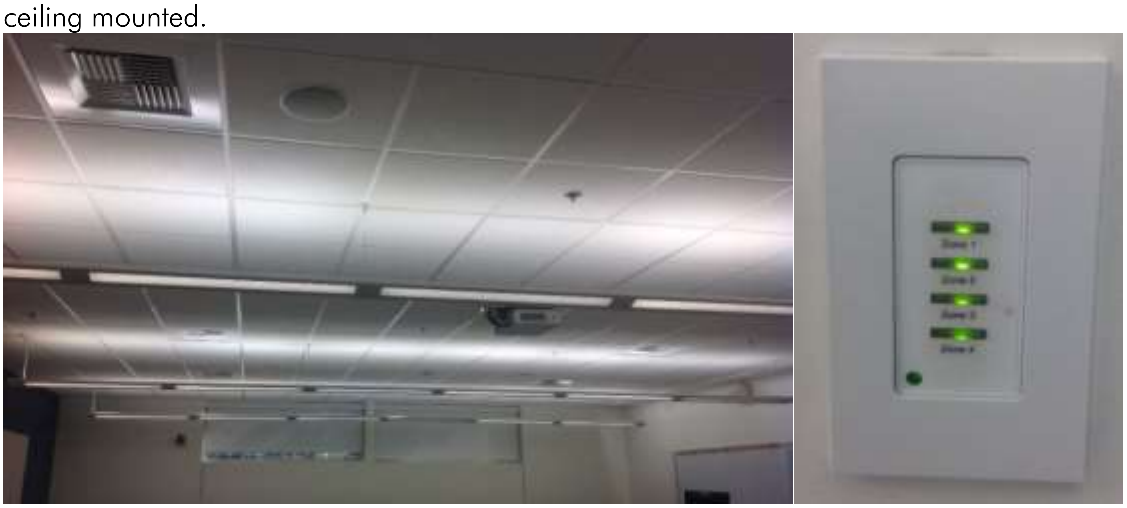

Figure 49: LED Lighting and Controls as Installed in the Nursing Building

5.2.2 CAMPUS WIDE PROJECTS

In an effort to capture the ongoing efforts of the campus, several additional projects outside of the buildings in the scope of this project for Level 1 or 2 audits were gathered and included. The following projects were compiled from a variety of sources including campus provided information, estimation or extrapolation of typical projects across campus and past or ongoing studies.

POOL VFDS

Description: The campus has a couple of pools on campus including the main Competition and Diving Pools located adjacent to Kinesiology, and a recreation pool at the Student Wellness and Recreation Center (SWRC). The campus had previously evaluated a project to retrofit the Competition and Diving Pool with variable frequency drives (VFDs) to reduce the circulation pump flow. Energy savings calculations and costs were provided by the campus for this project, and incorporated as a project for selection in the list of energy efficiency projects with additional contingency and CSULB admin costs added. The calculation was also scaled by pool volume to a create a similar measure for the SWRC pool.

Savings: Energy savings are achieved by reducing flow of the circulation pumps to a minimum level when the pool is unoccupied. VFDs control the pump speed which reduces the flow linearly with speed, and pump demand is reduced exponentially - often referred to as the cube law, but more practically to an exponent of 2.3 to the percent speed in real systems.

Scope: Refurbishment of the existing filtration system and installing VFD control for the pumps to allow for reduced pump speed when the pools are unoccupied.

ULTRA LOW TEMPERATURE (ULT) FREEZERS

Description: Replace Ultra Low Freezers found in labs with Stirling High Efficiency Freezers. The campus provided an inventory of the existing freezers that can be replaced.

Savings: Full size high efficiency ultralow freezers use about two-thirds less energy than a standard freezer, and savings are applied to freezer counts provided by the campus and broken into two increments to allow for a phased replacement approach.

Scope: Replace existing -80°C lab freezers with high efficiency freezers (60-70% more efficient than conventional ultralow freezers) such as the Stirling Ultracold freezers which are the gold standard in the marketplace that achieve this high level of efficiency. In addition to replacing existing freezers, it is highly recommended that Stirling Ultracold freezers be adopted as the standard for new (future) ULT freezer purchases.

PARKING LOT LED

Description: The campus has begun replacing existing high intensity discharge (HID) lights in parking lots with LED, using internal staff. The school has adopted the Cree OSQ fixture, has completed a little over half of the parking lots on campus, and indicated the 8 remaining lots to be retrofit. Fixture quantities were obtained by review of campus lighting plans provided by the school in the Parking Lot Lighting Study (dated 4/6/11).

Savings: Energy savings are calculated based on the existing HID fixture (predominantly 250W HPS) changing to Cree OSQ LED fixtures with bi-level lighting control. The campus also provided historical costs for the fixtures, which were incorporated into the project.

Scope: Continue replacing existing HID pole lights in parking lots with Cree OSQ LED fixtures using campus resources. A total of 8 parking lots with 85 poles with a total of 173 luminaires remain.

AREA LIGHT LED

Description: The campus has begun replacing existing HID lights in walkways and exterior locations with LED using internal staff, with an estimated 75% complete. Fixture quantities were obtained by review of campus lighting plans provided by the school in the Exterior Lighting Improvements 2008, Photometric Report.

Savings: Energy savings are calculated based on the existing HID fixture (the majority ranging from 75W to 400W HPS or MH) changing to Cree OSQ LED fixtures, for appropriate fixtures, or typical LED fixture wattages to match light output for other fixtures. To account for the progress to date, 25% of the total existing and proposed loads were calculated from the fixture types and quantities identified. The campus also provided historical costs for fixtures, which were incorporated into the project.

Scope: Continue replacing existing HID lights in walkways and other exterior areas with LED fixtures using campus resources. A total of 417 luminaires remain and have been broken up into 5 equal increments in the project list to allow for a phased approach.

CAMPUS-WIDE SCHEDULING

Description: During the building audits and review of the EMS, the CEMP team reviewed schedules of buildings and found the majority of building HVAC schedules do not align with building occupancy schedules, and an opportunity exists to reduce scheduled hours campus-wide to more closely match occupancy.

Savings: Savings are calculated by adjusting the building energy models in four typical audited buildings to reduce hours or operation by six hours per week, for both morning and evening (i.e. one morning hour per day in the morning for one measure and one hour in the evening for another measure). These average savings extrapolated across campus to similar building types that are could be scheduled. Excluded buildings include buildings under 5000 sf, residential, lab, retail and cafeteria type buildings.

Scope: Reduce HVAC hours of operation by more aggressive scheduling through the EMS to match building occupancy.

PC POWER MANAGEMENT

Description: During the building audits, the CEMP team observed a majority of the desktop computers on and not taking advantage of power settings. The campus provided an estimate of 6,000 computers on campus

Savings: Savings are estimated using the ENERGY STAR Computer Power Management Savings Calculator using default inputs and the total quantity of computers.

Scope: Enforce PC Power Management use campus-wide, or deploy a network solution to manage PC power settings to Energy Star standards.

STAIRWELL LIGHTING

Description: As a potential targeted campus-wide lighting retrofit, campus stairwell lights were identified by the team. Existing stairwell lights are generally two lamp T8 and operate continuously. These can be replaced with bi-level LED fixtures that reduce to low light levels when the stairwells are unoccupied. Fixture quantities were estimated based on quantities found in buildings the team audited, extrapolated to applicable buildings.

Savings: Savings are achieved through both a reduced fixture wattage from the LED in the occupied state, as well as a low level operation during unoccupied hours

Scope: Replace the estimated 538 existing stairwell lights with bi-level LED fixtures campus-wide. Targeting this project across campus would allow economy of scale in procurement and represents a small amount of overlap in the savings potential for the other lighting projects identified in individual buildings.

POLICY MEASURES:

During initial review of the CEMP scenario planning tool, the campus expressed an interest in quantifying measures that could be driven by policy or extreme out-of-the-box thinking. The team discussed the possible measures, and aside from best practices that affect potential future load growth, such as only purchasing Stirling ULT Freezers and NZE capital projects, HVAC setpoints and shutting down buildings on low-use days were identified as quantifiable opportunities. The concept of demolishing buildings and reducing the overall campus square footage was also discussed, but determined to be so unlikely that a that a simple calculation for a 'what if' scenario was justified, but not focused on as a possible in one of the five scenarios.

SETBACK HEATING/COOLING SETPOINTS

Description: HVAC setpoints were observed during the building audits to vary mostly from 70-75 degrees for cooling on campus. The campus standard is reportedly 68-degree setpoint for heating 78 degrees for cooling, although many exceptions and special circumstances are acknowledged. If temperature standards were more strictly enforced, it is likely the average temperature setpoints across campus could be setback a couple of degrees at minimum. Aggressive setpoint management could get to the 68-78 setpoints, or beyond with policy support.

Savings: Savings are quantified based on the cooling and heating energy use intensities determined by the team during the benchmarking phase, and applied to campus square footage. Residential, utility and small buildings (<5000 sf) were excluded from the savings potential. Measures are included in the measure list representing a setback of either heating or cooling one degree Fahrenheit and can be scaled to show cumulative impacts.

Scope: Setback heating and cooling setpoints campus-wide (excluding residential, utility and small buildings). To begin, it is possible to achieve this by enforcement of the current temperature setpoint standards as significant variances were observed. Beyond enforcement, the campus could adopt a policy that further sets back the temperature setpoint standards.

BUILDING SHUTDOWN

Description: During the summer the campus is generally less occupied, and it may be possible to consolidate programs and activities to keep a few buildings completely unoccupied and schedule them off. If complete building shutdown is not possible then it may be reasonable to shut the building down one day per week, on Fridays. Additionally, through smart scheduling of classes during the semester it may be possible to shut buildings down on Fridays or Saturdays throughout the year.

Savings: Shutting a building completely with result in large electrical, CHW and HHW savings. It would be expected some electrical loads would be maintained at all times, such as plug loads for servers, and associated server room cooling. However, lighting loads will be minimal. As HVAC would be shutdown, CHW and HHW usage would be negligible during these times.

Scope: Scheduling of HVAC to be off on selected days or months.

BUILDING DEMOLITION

Description: Kinesiology, McIntosh and University Dining Plaza (aka Cafeteria) were identified as possible buildings to demolish in this extreme 'what if' measure, as a possible step towards reducing the campus footprint and consolidating facilities.

Savings: Based on the current energy consumption of the three buildings, demolishing and not replacing with any facility would net approximately 2,019 metric tons CO2 equivalent savings. It's likely that displaced activities would yield a minor increase in energy consumption in other buildings, but this effect is not quantified.

Scope: Demolish the Kinesiology, McIntosh and University Dining Plaza buildings.

DEEP BUILDING RETROFITS / MODERNIZATION

Description: Deep building retrofits are aggressive, comprehensive overhauls to all building systems (HVAC, lighting, envelope) to achieve a target of reducing the EUI of the building by 60%.

Savings: For buildings that did not achieve 60% reduction in EUI from the identified projects in the audit and extrapolation process, an alternate measure is calculated to reduce the building electric, heating and cooling energy by 60% at a minimum cost of $50/sf.

Scope: A comprehensive, deep approach is envisioned that addresses the infrastructure of the building. As such, the specific projects of the deep building retrofits are not identified, but rather anticipated to be gut rehabilitations of buildings that removed the constraints of working with existing systems and allow innovation and incorporation of the best available technologies.

5.2.2 OPINION OF PROBABLE COST

The opinion of probable cost for each EEM were developed using a range of sources available to the team. These included Glumac's internal database of projects and input from project consultants, who included cost estimating consultants and contracting firms familiar with retrofit projects. Using this information, a pricing strategy for each EEM was developed and a total opinion on construction cost calculated per EEM. The following mark-ups were then added to this to calculate a final opinion of project cost.

- CSULB Contingency – 10%
- Design Costs – 8%
- Contractor O&P/Bonding/Insurance – 22%
- CSULB Admin Costs – 7.5%

The opinion of probable cost is not intended to provide a fixed budget for each project and should not be taken as an exact EEM cost. Unknown building conditions will have a large impact on the final cost of a project and could not be fully accounted for in the analysis.

Table 22: Pricing Strategy used for each EEM

EEM ID	EEM	Pricing Strategy
HVC_01	AHU - Fan Wall Array Retrofit	$/cfm
HVC_02	Rooftop Unit - Replacement	$/ton + $/unit for controls
HVC_03	Dual Duct - VAV Boxes	$/zone
HVC_04	Dual Duct - Dual Fan AHU Retrofit	$/cfm
HVC_05	VFD Installation	$/VFD
HVC_06	Multizone - VAV Retrofit	$/zone
HVC_07	Multizone - Dual Fan AHU Retrofit & VAV	$/cfm
HVC_09	Kitchen - VAV Exhaust Retrofit	$/hood
HVC_10	Deep HVAC Retrofit	Derived on a project-by-project basis
HVC_11	Controls - HVAC Occupancy Sensors	$/room
HVC_12	HVAC Retrofit	Derived on a project-by-project basis
GCX_01	General Commissioning	$/sf + $/hour for control contactor
LTG_01	Lighting - LED Fixture Replacement	$/sf
LTG_02	Lighting - LED Fixture Replacement + Controls Upgrade	$/sf
DHW_01	DHW Heater - Condensing Boiler	$/MBH
DHW_02	DHW Heater - Air-to-Water Heat Pump	$/MBH
DHW_03	Renewables - Solar Hot Water	$/panel

5.3 ENERGY ANALYSIS PROCESS

After completion of the EEM identification, a database was created that identified which EEM was applicable to each of the 28 buildings that underwent ASHRAE Level 1 Energy Audits. Excel based calculation were used for all Level 1 buildings, and subsequently energy models were developed for the nine Level 2 buildings. The audit level scope of work definition is consistent with the description defined by ASHRAE. Level 3 audits are not included in the project scope of work. The summarized description of these levels is described below:

1. Level 1: identify no-cost and low-cost energy saving opportunities, and a general view of potential capital improvements. Activities include an assessment of energy bills and a brief site inspection of your building.
2. Level 2: identify no-cost and low-cost opportunities, and provide EEM recommendations in line with your financial plans and potential capital-intensive energy savings opportunities. Level 2 audits include an in-depth analysis of energy costs, energy usage and building characteristics and a more refined survey of how energy is used in your building.
3. Level 3: considered an investment grade audit. Level 3 Audits provide solid recommendations and financial analysis for major capital investments. In addition to Level 1 and Level 2 activities, Level 3 audits include monitoring, data collection and engineering analysis

5.3.1 ENERGY ANALYSIS CALCULATIONS

ASHRAE LEVEL 1 ENERGY AUDITS

Savings for the Level 1 EEMs used engineering judgement and excel based calculations. Using the campus EMS, data such as HVAC operating hours could be determined, and calculations could be completed from this information. Common templates were created for the Level 1 audit analysis calculations that ensured commonality between all buildings. The assumptions made during these calculations are outlined below. The Level 1 audit outputs are also common for all the buildings and include:

- A summary sheet outlining the building baseline energy usage and trends, notes made during the audits, and in-depth summary sheet about each EEM. The notes provide input on the HVAC and lighting systems, general information about the building such as operating schedule and occupancy, and additional information regarding the building. Outlined is also where the energy data has been provided. This is important as on some buildings, benchmarked data had to be used as the EMS did not provide accurate energy data. CSULB can therefore use this document to identify errors in the EMS that should be addressed. The EEM summary sheets provide detailed information on each EEM, including name, description and ID, energy summary, all financials related to the measure and the simple payback of the EEM.
- An EEM summary sheet that summarizes in one table all the EEMs identified, their energy savings and the key financials related to the EEM. Potential combinations of EEMs are provided to give CSULB an idea of realistic savings through combining various EEMs. This sheet also includes an overview of energy audit findings.

Included on the detailed EEM summary pages are EEM and CEMP IDs that are used in the Scenario Analysis Tool. The CEMP ID included the building number, a three-letter code giving an overview of the EEM category (i.e. HVAC, Lighting, DHW or Commissioning) and the EEM number associated with the building. Whether the EEM is an individual, alternate or overlapping measure is also outlined, and if alternate or overlapping, a letter is assigned to each measure to clarify that both EEMs should not be selected.

The data provided from the building level meters only accounts for CHW and HHW loads at the building level and does not account for the energy required at the central plant to provide this to each building. Therefore, to analyze the energy usage of each building, central plant efficiencies had to be included in the calculations. Using these efficiencies, the total energy usage in kBtu could be calculated and a true building EUI determined. In addition, to predict energy cost savings the project team had to use accurate utility rates paid by CSULB. The project team received the following data from CSULB regarding the central plant efficiencies and utility rates:

- Chilled Water Efficiency = 1.2 kW/ton
- Hot Water Efficiency = 82%
- Electrical Utility rate = $0.11/kWh
- Natural Gas utility rate = $0.55/therm

The building electrical meters provided an overall electrical usage profile for each building, however not the energy end uses. Using information taken from the audits, a lighting, miscellaneous loads and DHW EUI were determined. Benchmarked data was used for the DHW and miscellaneous loads, considering if any high energy end uses or high DHW loads were observed during the audit. The remaining electrical energy was then assumed to be HVAC energy.

After all energy calculations had been completed, estimated construction and final costs were developed based on the Opinion of Probable Costs outlined in Section 4.2.1. Included in the final costs were the incentives available for each EEM, which for all EEMs except lighting was calculated at $0.24/kWh saved. Lighting was calculated with the same rate, however as the kWh saved under Title-24 requirements.

All 28 building that's underwent ASHRAE Level 1 Energy Audits have their Energy Audit Summary sheets included in the Appendix.

ASHRAE LEVEL 2 ENERGY AUDITS

To establish a more robust prediction of savings for the ASHRAE Level 2 Energy Audits, a full building energy model was created for each building. This included creating a building geometry in Revit 2017 and importing that into eQuest 3.65, where all building parameters could be input. Once the baseline model was calibrated to the energy usage determined from the Level 1 audits, a range of EEMs were modeled and their impact on the overall energy usage of the building analyzed. A full overview of the energy modelling process is included in the ASHRAE Level 2 Energy Audit report, included in the Appendix.

Using the savings from the energy models, savings that could be extrapolated across campus were developed in a kWh/sf and therm/sf basis.

5.4 CAMPUS WIDE EXTRAPOLATION

OVERVIEW

In order to project savings of projects identified by the CEMP team to buildings not audited under this scope, the team extrapolated measures and savings from the audited buildings to applicable buildings across campus. The team worked closely with the CSULB Energy Manager to identify similar distinguishing characteristics to group buildings together to that most closely represented one of the audited buildings. These included building type, vintage, predominant lighting types and HVAC systems. The process also identified buildings which were not good candidates for measures, and excluded those from the extrapolation of certain or all measures. For instance, recently renovated buildings were removed completely, while lighting measures were not quantified for buildings identified as having LED lights already. Three major categories of projects were extrapolated, and are discussed in more detail below.

EXTRAPOLATED HVAC PROJECTS

Existing HVAC systems were the primary factor influencing selection of the similar building from which HVAC projects were projected, along with consideration of the building type and vintage. Additionally, preference was given to buildings that received Level 2 audits, to take advantage of the level of effort expended and certainty of the savings. The resulting buildings forming the basis of extrapolation are shown in the table below.

Table 23: Campus Building Extrapolation Overview – HVAC EEMs

Facility	Facility Name	HVAC EEMs Extrapolated From
02	STUDENT HEALTH SERVICES	E. JAMES BROTMAN HALL
16	FACULTY OFFICE #2	BOOKSTORE
17	LECTURE HALL 150-151	BOOKSTORE
18	COLLEGE OF LIBERAL ARTS ADMINISTRATION	BOOKSTORE
21	MULTIMEDIA CENTER	FO3
26	THEATRE ARTS	E. JAMES BROTMAN HALL
28	UNIV TELECOMMUNICAT CTR	FO3
300	BEACHSIDE RESIDENTIAL COLLEGE	RESIDENCE HALL E
32	FINE ARTS 1	ENGINEERING TECHNOLOGY
33	FINE ARTS 2	ENGINEERING TECHNOLOGY
34	FINE ARTS 3	ENGINEERING TECHNOLOGY
35	FINE ARTS 4	E. JAMES BROTMAN HALL
36	FACULTY OFFICE #4	BOOKSTORE
37	PETERSON HALL 1	LIBERAL ARTS 5
45	FACULTY OFFICE #5	BOOKSTORE
48	HEALTH & HUMAN SERVICES - HHS1	FO3
51	ENGINEERING 2	LIBERAL ARTS 5
52	ENGINEERING 3	FO3
53	ENGINEERING 4	FO3
54	DESIGN	FO3
55	HUMAN SERVICES & DESIGN	LIBERAL ARTS 5
59	PATTERSON CHILD DEVELOPMENT	BOOKSTORE
60	LOS ALAMITOS HALL	LOS CERRITOS HALL
62A	RESIDENCE HALL A	RESIDENCE HALL E
62B	RESIDENCE HALL B	RESIDENCE HALL E
62C	RESIDENCE HALL C	RESIDENCE HALL E

62D	RESIDENCE HALL D	RESIDENCE HALL E
62F	RESIDENCE HALL F	RESIDENCE HALL E
62G	RESIDENCE HALL G	RESIDENCE HALL E
62H	RESIDENCE HALL H	RESIDENCE HALL E
62J	RESIDENCE HALL J	RESIDENCE HALL E
62K	RESIDENCE HALL K	RESIDENCE HALL E
62L	RESIDENCE HALL L	RESIDENCE HALL E
62M	RESIDENCE HALL M	RESIDENCE HALL E
62N	RESIDENCE HALL N	RESIDENCE HALL E
62P	RESIDENCE HALL P	RESIDENCE HALL E
62Q	RESIDENCE HALL Q	RESIDENCE HALL E
62S	RESIDENCE HALL S	BOOKSTORE
62T	RESIDENCE HALL T	BOOKSTORE
62V	RESIDENCE HALL V	BOOKSTORE
66	REPROGRAPHICS	BOOKSTORE
74	PARKING & TRANSPORTATION SERVICES	BOOKSTORE
75	INTERNATIONAL HOUSE	RESIDENCE HALL E
81	NEIL & PHYLLIS BARRETT ATHLETIC ADMIN CENTER	FO3
82	OUTPOST	CAFETERIA
89	HOUSING & RESIDENTIAL LIFE OFFICE	BOOKSTORE

The modeled savings per square foot for each measure in the audited buildings were extrapolated to the rest of the buildings according to gross square feet, and potentially scaled where adjustment factors were identified. For project costs, the cost per square foot of each measure was calculated from an average of a wider set of buildings to get a more representative average cost.

EXTRAPOLATED COMMISSIONING PROJECTS

Commissioning project savings were extrapolated from the same buildings as HVAC projects as discussed above, except where commissioning measures were not quantified in the audited building. In the case of these four buildings, which included Cafeteria, Bookstore, Academic Services and ECS, the average of commissioning measures in a larger set of audited buildings was used. Statistical analysis was performed to check for outlying savings values, which excluded the high EUI buildings (Hall of Science, for example) from the average used. The buildings forming the basis of extrapolation are shown in the table below.

Table 24: Campus Building Extrapolation Overview – Commissioning EEMs

Facility	Facility Name	Cx EEMs Extrapolated From
02	STUDENT HEALTH SERVICES	E. JAMES BROTMAN HALL
11	LIBERAL ARTS 4	ACADEMIC SERVICES
12	LIBERAL ARTS 3	ACADEMIC SERVICES
13	LIBERAL ARTS 2	ACADEMIC SERVICES
16	FACULTY OFFICE #2	BOOKSTORE
17	LECTURE HALL 150-151	BOOKSTORE
18	COLLEGE OF LIBERAL ARTS ADMINISTRATION	BOOKSTORE
21	MULTIMEDIA CENTER	FO3
22	BOB AND BARBARA ELLIS EDUCATION BUILDING	FO3
23	EDUCATION 2	E. JAMES BROTMAN HALL
26	THEATRE ARTS	E. JAMES BROTMAN HALL
28	UNIV TELECOMMUNICAT CTR	FO3
32	FINE ARTS 1	TBD
33	FINE ARTS 2	TBD
34	FINE ARTS 3	TBD

35	FINE ARTS 4	E. JAMES BROTMAN HALL
36	FACULTY OFFICE #4	BOOKSTORE
37	PETERSON HALL 1	LIBERAL ARTS 5
45	FACULTY OFFICE #5	BOOKSTORE
48	HEALTH & HUMAN SERVICES - HHS1	FO3
49	HEALTH & HUMAN SRVCS 2	FO3
51	ENGINEERING 2	LIBERAL ARTS 5
52	ENGINEERING 3	FO3
53	ENGINEERING 4	FO3
54	DESIGN	FO3
55	HUMAN SERVICES & DESIGN	LIBERAL ARTS 5
57	FACILITIES MANAGEMENT	E. JAMES BROTMAN HALL
59	PATTERSON CHILD DEVELOPMENT	BOOKSTORE
62S	RESIDENCE HALL S	BOOKSTORE
62T	RESIDENCE HALL T	BOOKSTORE
62V	RESIDENCE HALL V	BOOKSTORE
66	REPROGRAPHICS	BOOKSTORE
74	PARKING & TRANSPORTATION SERVICES	BOOKSTORE
80	UNIVERSITY POLICE BLDG	ET
81	NEIL & PHYLLIS BARRETT ATHLETIC ADMIN CENTER	ACADEMIC SERVICES
82	OUTPOST	CAFETERIA
84	STEVE AND NINI HORN CENTER	ECS
89	HOUSING & RESIDENTIAL LIFE OFFICE	BOOKSTORE
93	STUDENT RECREATION AND WELLNESS CENTER	MIKE AND ARLINE WALTER PYRAMID
94	MOLECULAR & LIFE SCIENCES CENTER	HALL OF SCIENCE

EXTRAPOLATED LIGHTING PROJECTS

Similar to the HVAC projects, each lighting measure in the audited building was extrapolated on a square foot basis to determine energy savings in the candidate building. However, to be slightly conservative the interactive effects were not included in the extrapolated savings. Project costs were taken from a larger set of buildings, leveraging all of the audited buildings to get a more representative average. The resulting buildings forming the basis of extrapolation are shown in the table below.

Table 25: Campus Building Extrapolation Overview – Lighting EEMs

Facility	Facility Name	Lighting EEMs Extrapolated From
02	STUDENT HEALTH SERVICES	E. JAMES BROTMAN HALL
16	FACULTY OFFICE #2	FO3
21	MULTIMEDIA CENTER	LIBERAL ARTS 5
22	BOB AND BARBARA ELLIS EDUCATION BUILDING	FO3
23	EDUCATION 2	E. JAMES BROTMAN HALL
26	THEATRE ARTS	LIBERAL ARTS 5
28	UNIV TELECOMMUNICAT CTR	FO3
300	BEACHSIDE RESIDENTIAL COLLEGE	RESIDENCE HALL E or LOS CERRITOS
32	FINE ARTS 1	LIBERAL ARTS 5
33	FINE ARTS 2	LIBERAL ARTS 5
34	FINE ARTS 3	LIBERAL ARTS 5
35	FINE ARTS 4	LIBERAL ARTS 5
36	FACULTY OFFICE #4	FO3
37	PETERSON HALL 1	LIBERAL ARTS 5
45	FACULTY OFFICE #5	FO3
48	HEALTH & HUMAN SERVICES - HHS1	LIBERAL ARTS 5
49	HEALTH & HUMAN SRVCS 2	FO3

51	ENGINEERING 2	LIBERAL ARTS 5
52	ENGINEERING 3	LIBERAL ARTS 5
53	ENGINEERING 4	LIBERAL ARTS 5
54	DESIGN	LIBERAL ARTS 5
55	HUMAN SERVICES & DESIGN	LIBERAL ARTS 5
57	FACILITIES MANAGEMENT	E. JAMES BROTMAN HALL
58	CORPORATION YARD	FO3
59	PATTERSON CHILD DEVELOPMENT	E. JAMES BROTMAN HALL
60	LOS ALAMITOS HALL	LOS CERRITOS HALL
62A	RESIDENCE HALL A	RESIDENCE HALL E
62B	RESIDENCE HALL B	RESIDENCE HALL E
62C	RESIDENCE HALL C	RESIDENCE HALL E
62D	RESIDENCE HALL D	RESIDENCE HALL E
62F	RESIDENCE HALL F	RESIDENCE HALL E
62G	RESIDENCE HALL G	RESIDENCE HALL E
62H	RESIDENCE HALL H	RESIDENCE HALL E
62J	RESIDENCE HALL J	RESIDENCE HALL E
62K	RESIDENCE HALL K	RESIDENCE HALL E
62L	RESIDENCE HALL L	RESIDENCE HALL E
62M	RESIDENCE HALL M	RESIDENCE HALL E
62N	RESIDENCE HALL N	RESIDENCE HALL E
62P	RESIDENCE HALL P	RESIDENCE HALL E
62Q	RESIDENCE HALL Q	RESIDENCE HALL E
62S	RESIDENCE HALL S	BOOKSTORE
62T	RESIDENCE HALL T	BOOKSTORE
62V	RESIDENCE HALL V	BOOKSTORE
63	RECYCLING CENTER	FO3
66	REPROGRAPHICS	BOOKSTORE
74	PARKING & TRANSPORTATION SERVICES	E. JAMES BROTMAN HALL
75	INTERNATIONAL HOUSE	RESIDENCE HALL E or LOS CERRITOS
80	UNIVERSITY POLICE BLDG	FO3
81	NEIL & PHYLLIS BARRETT ATHLETIC ADMIN CENTER	FO3
82	OUTPOST	CAFETERIA
84	STEVE AND NINI HORN CENTER	E. JAMES BROTMAN HALL
89	HOUSING & RESIDENTIAL LIFE OFFICE	BOOKSTORE
94	MOLECULAR & LIFE SCIENCES CENTER	HALL OF SCIENCE

5.5 SUMMARY OF KEY FINDINGS

The CEMP identified over 567 energy efficiency projects across campus. A combination of all potential EE projects, accounting for overlapping/alternative measures, could result in annual energy savings of up to 20,280,000 kWh and 658,000 therms, which results in a 38% reduction in 2017 energy usage. This would reduce annual energy cost by $2,600,000, based on 2017 utility rates. These projects include:

- 279 capital improvements (HVAC, Lighting, DHW)
- 57 general commissioning (Retro-Cx, MBCx, etc.)
- 217 energy savings operational policy opportunities
- 14 deep energy retrofits/building modernization projects

Through analysis of the 28 buildings, several common issues arose that result in higher than expected energy usage. These were predominantly related to the building sequence of operations or building metering. Outlined below are key recommendations that should address these common issues identified.

- Building level submeters should be audited and calibrated on a regular basis. Numerous meters appeared to be calibrated incorrectly, or not operating. Accurate building level meters are required to ensure building EUI is calculated correctly and post-project measurement and verification can be conducted.
- A campus wide schedule optimization process should be completed. Numerous building audited had schedules that were not optimized for the building occupancy. High energy usage is a result of HVAC operation outside of building occupied hours.
- Setpoints should be optimized in all buildings across campus. It is recommended this is 75F for cooling and 70F for heating.
- Dual Duct and Multizone AHUs have significant opportunities for energy savings when supply air reset temperatures are currently implemented. Correct implementation includes ensuring supply air resets programmed correctly at the AHU level and that zone setpoints are acceptable to ensure no zones(s) drive the heating and cooling supply air temperatures in the building.
- All HVAC systems across campus should be converted to variable volume systems, which includes conversion from pneumatic to DDC controls. Variable volume systems result in significant energy savings as well as increased thermal comfort.

The following table summarizes the key findings from each energy audit. It also outlines which of the audited buildings are best suited to different energy efficiency projects. These are ranked in High, Medium and Low, and this table should be used in combination with the Energy Audit Summary Reports. This will allow CSULB identify which buildings can be prioritized and grouped together for larger campus commissioning projects.

Table 26: Summary of Energy Audit Findings

L	Low Priority (Not Recommended)
M	Medium Priority (Potential Projects)
H	High Priority (Recommended Projects)

	Commissioning	Capital Improvement	Lighting Upgrades	Summary of Energy Audit Findings
01 - BH	M	H	H	Building has an old Dual Duct HVAC system which is nearing the end of its expected useful life. HVAC energy higher than benchmarked office building.
03 - NUR	M	M	L	Old Nursing building has (2) Multizone AHUs which are nearing the end of their expected useful life. One VAV AHU serves the New Nursing building and is in good condition.
05 - FCS	M	M	L	Building served by VAV AHU and 4 pipe fan coils located indoors and on the roof. The fan coils are constant volume are in poor condition and nearing the end of their expected useful life. HVAC schedule optimization provides opportunity for significant savings as building occupancy and HVAC schedule do not align.
07 - CAF	L	H	H	Building served by combination of RTUs and direct evaporative coolers. RTUs are in poor condition and nearing the end of their expected useful life.
08 - BKS	L	M	H	Building served by combination of heat pump and DX with gas heating rooftop units. A 40 ton unit serves the central bookstore areas and is past its expected useful life. All older rooftop units should be replaced with modern heat pumps.
09 - PSY	H	L	H	Building has an old Dual Duct HVAC system which is nearing the end of its expected useful life. New RTUs and exhaust fans were installed in 2017 to serve lab spaces.
10 - LA5	H	M	H	Building has an old Dual Duct HVAC system which is nearing the end of its expected useful life. Constant volume dual duct boxes serve building
14 - LA1	H	M	H	Building has an old Dual Duct HVAC system which is nearing the end of its expected useful life.
15 - FO3	M	H	H	Building has an old multizone HVAC system which is nearing the end of its expected useful life. Constant volume multizone dampers serve building
19 - LIB	M	L	M	Building is served by VAV AHUs, installed in 2016 and appear in good working condition. An onsite chilled water central plant is currently undergoing a renovation
20 - AS	L	L	H	Building is served by a combination of (2) multizone units and (2) VAV AHUs. The multizone AHUs is nearing the end of its expected useful life. The VAV AHUs appear in good working condition.
24 - MHB	L	H	H	Building is served by a single 100% outside air CAV AHU which is nearing the end of its expected useful life. Zones served by pneumatic CAV boxes. Infrastructure past its expected use of life. Recommend retrofit projects over commissioning.
25 - LAB	L	L	H	Building has a Dual Duct HVAC system. It appears that the building underwent significant upgrades to convert it to a fully DDC building.
27 - UT	L	H	H	Building served by single zone AHUs. Audit indicated the AHUs were 100% OSA as exhaust fan did not appear operational.
41 - MIC	L	H	H	Building to undergoing a full HVAC retrofit
46 - SSPA	H	L	L	Building has a VAV HVAC system which is nearing the end of its expected useful life. The CHW data is benchmarked from similar VAV buildings on campus

	Commissioning	Capital Improvement	Lighting Upgrades	Summary of Energy Audit Findings
47 - KIN	H	H	M	Building served by a combination of multizone, VAV, single zone and constant volume heating only units. Large infrastructure projects are required to replace existing older AHUs, FCUs and heating ventilators. Infrastructure upgrades to include AHU replacement and retrofit of all pneumatic controls.
50 - VEC	L	L	H	Building has a Dual Duct HVAC system serving every floor. It appears that the building underwent significant upgrades to convert it to a fully DDC building. Rooftop solar PV in installed, lowering the building EUI.
56 - ETC	H	M	L	Main building served by VAV AHU that appears to be nearing the end of its expected useful life. Engineering workshops served by heating only units that provide make-up air for large exhaust fans serving workshops. This results in a high heating EUI for the building. Heating profile benchmarked off 2014-2016 data.
61 - LCH	L	L	H	Residential building served by 2 Pipe Fan Coil system. Heating and cooling EUI low, however EMS indicates boilers operate at their minimum firing rates when operational and cooling not operational during significant portion of summer months. Boiler and Chillers were both replaced within the past 10 years and due to operational schedule, replacement or retrofit have not been suggested. DHW EUI lower than benchmarked expected values
71 - UMC	L	H	H	Building served by a combination of VAV and constant volume single zone units. Large infrastructure projects recommended to modernize HVAC system that have yet to be upgraded.
72 - CPAC	H	H	H	Onsite boilers and chillers provide HHW and CHW to AHUs. Small, rooftop AHUs provide cooling to a significant portion of the building, with heating being provided by gas furnaces.
73 - PYR	L	L	H	Building served by a combination of VAV and single zone AHUs. MBCx was performed on the building in 2012, confirming extremely low gas usage. Onsite boilers provided all heating for the building and onsite chillers provide additional capacity to the campus CHW loop during peak conditions. Low EUI due to building occupancy schedule.
83 - ECS	L	L	H	Building has a VAV HVAC system which appeared in good condition. Building operates well with low EUI for building occupancy
85 - CBA	M	H	M	Fully electric building not connected to central plant. Constant volume WSHPs serve the building.
95 - HSCI	H	L	H	Building served by a combination of CAV and VAV terminal units. Two 100% OSA AHUs serve the Labs and Vivarium and one conventional AHU serves the non-lab spaces. A significant amount of additional lab equipment is located throughout the building, resulting in a high EUI. All mechanical equipment appeared in good working condition
200 - FOUN	M	L	H	Water Cooled AC units serve a VAV system with hydronic reheat. Cooling tower has significant scaling and is in need or cleaning or replacement
62E - RHE	L	L	H	Residential building served by fan coils and induced draft heaters. Heating EUI low due to operational schedule. DHW EUI similar to other residential buildings benchmarked against.

6. RENEWABLE ENERGY

6.1 RENEWABLE ENERGY ANALYSIS PROCESS

The identification of renewable energy (RE) opportunities for CSULB was limited to solar photovoltaics. Opportunities for solar were considered at each CSULB electrical utility account. In the analysis, the electrical utility accounts are grouped by physical locations that translate to a single aggregated solar project for the group. All electric meters considered are served by SCE. SCE allows for the aggregation of meters, providing an opportunity to centralize solar installations and offset all aggregated meters. Aggregation arrangements can only contain meters served by the same provider at the same or immediately adjacent properties. The table below includes a description electric meters and their project group.

Table 27: Campus Utility Meters and Identified Solar Projects

Project Group	Utility Account Number	Account Service Address
Blair Field	3-034-9202-35	4700 DEUKMEJIAN DR
	3-034-9202-94	4819 E 7TH ST
Beachside Housing Complex	3-033-5269-15	4825 E PACIFIC COAST HWY
CSULB Research Foundation	3-008-5509-28	6300 E STATE UNIVERSITY DR
South Campus	3-000-0018-39	E CAMPUS RD N/O 7TH
	3-000-0018-40	E CAMPUS RD N/O 7TH
Main Campus Meter	3-001-3609-74	1401 PALO VERDE AVE
Parkside College/Isabel Patterson Child Development Center	3-000-0018-43	5900 E ATHERTON ST
	3-000-0018-35	5700 E ATHERTON ST
	3-008-5488-21	5700 E ATHERTON ST
	3-000-9784-53	1605 EARL WARREN DR

Meters with no associated solar PV project		
No Project, Lighting	3-034-9202-56	4700 DEUKMEJIAN DR
	3-033-9502-30	4835 E PACIFIC COAST HWY
No Project, Too Small	3-005-0768-89	1401 PALO VERDE AVE
	3-000-0018-37	CAMPUS/7TH
	3-005-0768-88	1401 PALO VERDE AVE
No Project, Residence	3-002-9272-88	1430 EL MIRADOR AVE

For each group of meters, potential solar PV locations are identified that will offset 100% of the annual load. The exception to this is at the main campus meter where interconnection restrictions limit the size of future projects. The solar PV locations are preliminary in nature and are simply to identify the rough available area. In some instances, there may be more desirable locations for the campus to install a system. If the Campus were to locate a solar PV system in physically different location and maintain the overall size, the projected benefit will remain largely the same. It is recommended that the Campus conduct a detailed review of the appropriateness of a solar PV location prior to moving forward with any of the projects identified.

Using a solar production model, the solar system lifecycle benefits are calculated based on local utility rate structures. Where available, interval data utility was used as a model for a typical year of usages. Where interval data was unavailable, use was modeled or extrapolated based on annual consumption and interval data for a similar location. The solar model uses the upcoming utility changes to Time-of-Use (TOU) and rate structures as proposed by SCE as a basis for the analysis. This is a key assumption, as the value of solar production in the future is anticipated to be very different than historical costs. As shown in the figure below, the proposed TOU periods shift the peak hours to later in the day, largely out of the solar production period.

Figure 50: SCE Time-of-Use Rate Change

Demand savings for all projects is limited to 10% of the binned TOU period peak power. This limit is imposed as a conservative constraint around claiming too much cost savings relative to actual demand impacts from the solar systems. The conservative estimate is appropriate when considering the forthcoming TOU changes. To calculate real demand savings, a time match load and production model is needed, which is beyond the level of detail included in this analysis.

Solar system costs are identified by mapping system size to a matrix of costs that reflect anticipated cost of installation of the projects. The table below identifies a solar PV system size range and the cost metric for either a direct purchase system as cost per watt or a PPA as cost per kWh generated. Cost ranges are informed by experiences with recent competitive procurements for similar sized systems and adjusted to incorporate the Campus' most recent procurement results and additional Campus defined additive features (e.g. added security features). PPA costs are shown for both anticipated 20 and 25-year agreement term lengths. The PPA financial analysis is conducted using the 20-year rates. If the Campus pursues any of the identified projects, the longer term of the 25-year rates can be used to reduce annual costs and improve cash flow in the early project years. All PPA rates considered utilize a 0% escalation rate, which is a current industry standard. The purchase cost metrics identified include all system operation and maintenance, performance guarantees, and overhead costs. If the projects were procured as a full portfolio, economies of scale could reduce the total project cost.

Table 28: Estimated Solar Power Purchase Agreement (PPA) Rates

System Size Range	Purchase Metric [$/W]	20 Year PPA Rate [$/kWh]	25 Year PPA Rate [$/kWh][27]
Under 50 kW	$5.25	$0.2514	$0.2011
50 kW - 100 kW	$4.25	$0.2186	$0.1749
100 kW - 250 kW	$3.50	$0.1901	$0.1521
250 kW - 500 kW	$3.00	$0.1653	$0.1323
500 kW - 1,000 kW	$2.50	$0.1438	$0.1150
Over 1,000 Kw	$2.00	$0.1250	$0.1000

[27] 25-Year PPA rates is illustrative only, and was not used in the scenario analysis. Based on a recent market survey of 25-year PPA rates, lower $/kWh rates are achievable

6.2 RENEWABLE ENERGY PROJECTS

6.2.1 BLAIR FIELD

ANNUAL UTILITY CONSUMPTION

The Blair Field Complex is an off-campus baseball field facility. The facility has two meters that can be aggregated for a solar system. The larger of the two meters has a service address at the ballpark and the smaller of the two has a service address in the adjacent park. The solar system would likely interconnect to the larger of the two meters, 3-034-9202-35. Annually in total the complex uses roughly 128 thousand kWh per year at a cost of roughly $22 thousand, yielding an effective blended utility rate of roughly $0.17 per kWh. The primary facility meter is on the TOU-GS-2B for small commercial facilities. The table below includes the annualize meter details.

Table 29: Blair Field – Utility Service & Annual Electricity Use

Utility Account Number	Most Recent Meter	Most Recent Rate	Annualized Usage [kWh]	Annualized Cost [$]	Blended Utility Rate [$/kWh]
3-034-9202-35	256000-179142	TOU-GS-2-B	104,816	$18,448	$0.1760
3-034-9202-94	259000-003986	TOU-GS-1-A	23,632	$3,779	$0.1599

IDENTIFIED SOLAR PROJECTS

Roughly 75 kW of solar capacity is required to produce the 127 thousand kWh per year required for the complete annual offset of the facility. The parking area in front of Blair Field has ample room to site the system and a parking shade structure appears to be the best system type for the facility. The system is sited in the second row of parking away from the stadium area to avoid the necessity for tree trimming. Any other location in this parking lot is equally as good so long that it avoids shade. The Campus noted that this facility is co-operated by the City of Long Beach which may present some implementation challenges that would have to be investigated in more detail. The table and figure below include the system details and the identified locations, respectively.

Table 30: Blair Field – Potential Solar PV Generation

Project Name	Identified System Size [kW-dc]	First Year System Production [kWh/yr]	System Yield [kWh/kW]	Solar Degradation Rate [%/yr]	Lifetime Solar Production [kWh]
Blair Field	75	128,448	1,714	0.50%	3,025,715

Figure 51: Blair Field – Potential PV Site Plan

FINANCIAL BENEFIT

The Blair Field project is projected to generate roughly $300 thousand of utility bill savings over its 25 years of operation. Given the size of the system and the costs projected for CSULB, the project is project to lose roughly $230 thousand for the PPA scenario and $130 thousand in the purchase scenario through the analysis period. If this project were competitively bid with a package of larger projects, the price would likely be lower than included in this analysis. The table below includes the detailed results for the financial analysis.

Table 31: Blair Field – Solar PV Financial Summary

		PPA Scenario			Purchase Scenario			
Project Name	Life Cycle Savings [$]	PPA Rate [$/kWh]	Total Cost [$]	Net Benefit [$]	Costs [$]	O&M Cost [$]	Total Cost [$]	Net Benefit [$]
Blair Field	$301,622	$0.2186	$535,747	-$234,124	$371,087	$60,398	$431,485	-$129,863

6.2.2 BEACHSIDE HOUSING COMPLEX

ANNUAL UTILITY CONSUMPTION

The Beachside Housing Complex is an off-campus housing apartment building. Annually the complex uses roughly 1.5 million kWh per year at a cost of roughly $200 thousand, yielding a blending utility rate of roughly $0.13 per kWh. The primary facility meter is on the TOU-GS-3B for medium commercial facilities. There is an additional meter at the facility but is on a lighting rate-structure, making it ineligible for solar benefit aggregation. The table below includes the annualize meter details.

Table 32: Beachside Housing – Utility Service & Annual Electricity Use

Utility Account Number	Most Recent Meter	Most Recent Rate	Annualized Usage [kWh]	Annualized Cost [$]	Blended Utility Rate [$/kWh]
3-033-5269-15	V349N-011388	TOU-GS-3B	1,548,514	$199,699	$0.1290

IDENTIFIED SOLAR PROJECTS

The Beachside facility is space constrained, meaning that there is more load at the site than the available room for solar is able to generate. The facility has opportunities on the roof and in the front and rear parking areas, all of which have obstacles for implementation. The layout below shows all of the areas considered for solar, which yields about 581 kW of solar capacity which would produce roughly 60% of the required energy annually. The table and figure below include the system details and the identified locations, respectively.

Table 33: Beachside Housing – Potential Solar PV Generation

Project Name	Identified System Size [kW-dc]	First Year System Production [kWh/yr]	System Yield [kWh/kW)	Solar Degradation Rate [%/yr]	Lifetime Solar Production [kWh]
Beachside Housing Complex	581	915,478	1,575	0.50%	21,564,955

Figure 52: Beachside Housing – Potential PV Site Plan

FINANCIAL BENEFIT

The Beachside project is projected to generate roughly $1.8 million of utility bill savings over its 25 years of operation. Due to the assumed high project costs for CSULB, the project is projected to lose roughly $720 thousand for the PPA scenario and $385 thousand in the purchase scenario through the analysis period. If this project were competitively bid with a package of larger projects, the price would likely be lower than included in this analysis. The table below includes the detailed results for the financial analysis.

Table 34: Beachside Housing – Solar PV Financial Summary

		PPA Scenario			Purchase Scenario			
Project Name	Life Cycle Savings [$]	PPA Rate [$/kWh]	Total Cost [$]	Net Benefit [$]	Costs [$]	O&M Cost [$]	Total Cost [$]	Net Benefit [$]
Beachside	$1,791,191	$0.1438	$2,510,651	-$719,461	$1,708,183	$468,463	$2,176,646	-$385,455

6.2.3 CSULB FOUNDATION BUILDING

ANNUAL UTILITY CONSUMPTION

The CSULB Research Foundation is a large office/lab complex adjacent to the main CSULB campus. Annually the complex uses roughly 1.2 million kWh per year at a cost of roughly $180 thousand, yielding a blending utility rate of roughly $0.15 per kWh. The primary facility meter is on the TOU-GS-3B for medium commercial facilities.

Table 35: Research Foundation – Utility Service & Annual Electricity Use

Utility Account Number	Most Recent Meter	Most Recent Rate	Annualized Usage [kWh]	Annualized Cost [$]	Blended Utility Rate [$/kWh]
3-008-5509-28	V349N-002663	TOU-GS-3B	1,194,069	$179,815	$0.1506

IDENTIFIED SOLAR PROJECTS

The CSULB Foundation Building has opportunities for solar both on the roof and in the front and rear parking areas. The layout below shows all of the areas considered for solar. The combination of the two mounting areas appear to have ample room for the identified 704 kW of necessary solar capacity. The majority of available capacity is of the shade structure type. The table and figure below include the system details and the identified locations, respectively.

Table 36: CSULB Foundation Building – Potential Solar PV Generation

Project Name	Identified System Size [kW-dc]	First Year System Production [kWh/yr]	System Yield [kWh/kW]	Solar Degradation Rate [%/yr]	Lifetime Solar Production [kWh]
CSULB Foundation Building	704	1,194,069	1,695	0.50%	28,127,425

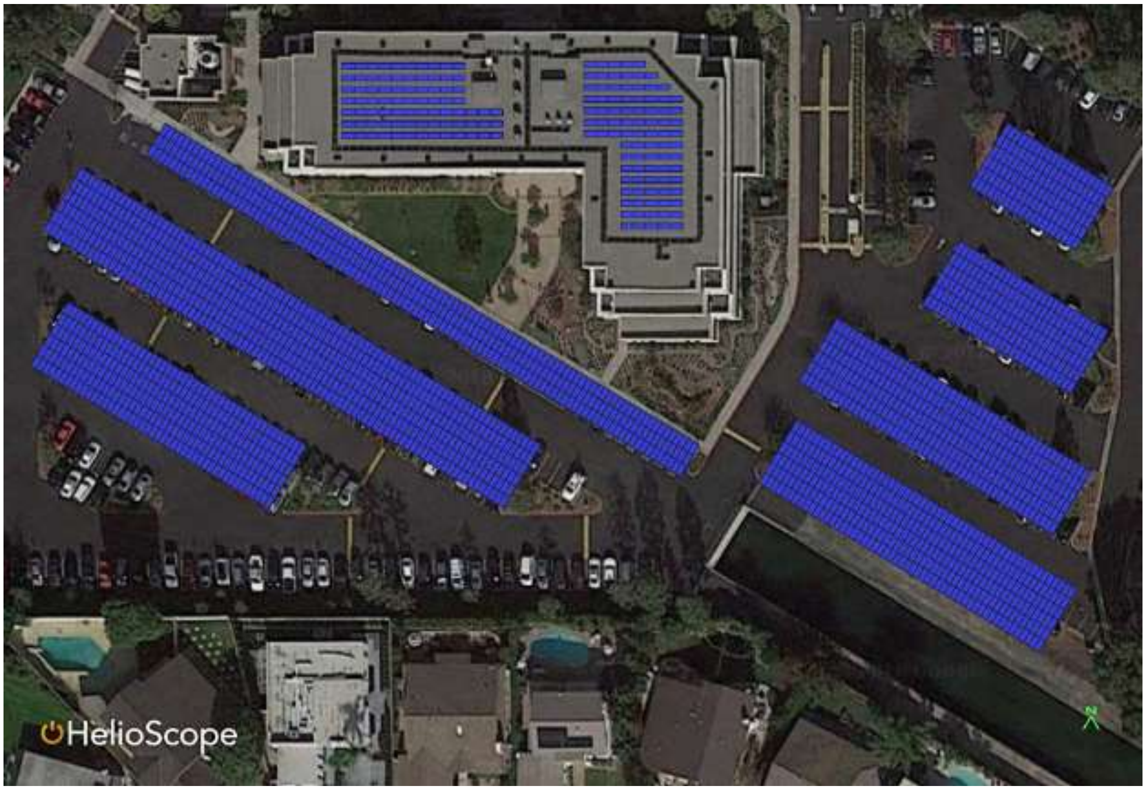

Figure 53: CSULB Foundation Building – Potential PV Site Plan

FINANCIAL BENEFIT

The Foundation project is projected to generate roughly $2.96 million of utility bill savings over its 25 years of operation. Due to the assumed high project costs for CSULB, the project is projected to lose roughly $308 thousand for the PPA scenario and save roughly $330 thousand in the purchase scenario through the analysis period. If this project were competitively bid with a package of larger projects, the price would likely be lower than included in this analysis. The table below includes the detailed results for the financial analysis.

Table 37: CSULB Foundation Building – Solar PV Financial Summary

		PPA Scenario			Purchase Scenario			
Project Name	Life Cycle Savings [$]	PPA Rate [$/kWh]	Total Cost [$]	Net Benefit [$]	Costs [$]	O&M Cost [$]	Total Cost [$]	Net Benefit [$]
Foundation	$2,966,126	$0.1438	$3,274,672	-$308,546	$2,069,441	$567,536	$2,636,977	$329,149

6.2.4 SOUTH CAMPUS

ANNUAL UTILITY CONSUMPTION

The South Campus solar project is identified to offset the load of two meters located in the southern portion of the CSULB main campus. The two meters are large enough to warrant separate consideration for a project that targets their load specifically. Together the two meters uses roughly 210 thousand kWh per year at a cost of roughly $40 thousand, yielding a blending utility rate of roughly $0.19 per kWh. Both meters are on the TOU-GS-2-B rate structure for small commercial facilities. The intent for this solar project would be interconnect to the most easily accessed meter while sizing a system to offset the load for both meters under an NEM aggregation arrangement. The table below includes the annualized meter details.

Table 38: South Campus – Utility Service & Annual Electricity Use

Utility Account Number	Most Recent Meter	Most Recent Rate	Annualized Usage [kWh]	Annualized Cost [$]	Blended Utility Rate [$/kWh]
3-000-0018-39	259000-078734	TOU-GS-2-B	106,106	$20,375	$0.1920
3-000-0018-40	259000-078705	TOU-GS-2-B	103,467	$19,485	$0.1883

IDENTIFIED SOLAR PROJECTS

The South Campus project does not have any particular area assigned to it and can be sited in any location with easy access to one of the identified meters. The meters only had a general service address and were not specifically sited. There are ample opportunities to locate the roughly 128 kW of solar capacity needed for the systems nearby. The layout included below locates the solar system in one of the south campus parking lots for use in this study and for illustrative purposes. The table and figure below include the system details and the identified locations, respectively.

Table 39: South Campus – Potential Solar PV Generation

Project Name	Identified System Size [kW-dc]	First Year System Production [kWh/yr]	System Yield [kWh/kW)	Solar Degradation Rate [%/yr]	Lifetime Solar Production [kWh]
South Campus Solar	128	209,573	1,633	0.50%	4,936,684

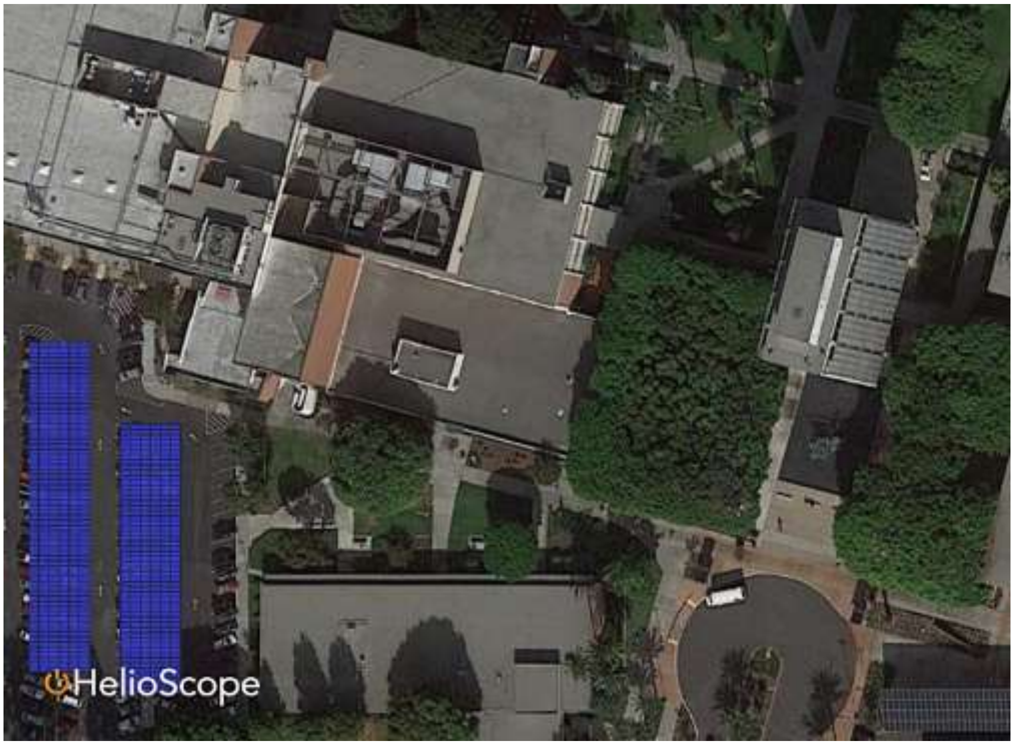

Figure 54: South Campus – Potential PV Site Plan

FINANCIAL BENEFIT

The South Campus project is projected to generate roughly $500 thousand of utility bill savings over its 25 years of operation. Due to the assumed high project costs for CSULB, the project is projected to lose roughly $260 thousand for the PPA scenario and $129 thousand in the purchase scenario through the analysis period. If this project were competitively bid with a package of larger projects, the price would likely be lower than included in this analysis. The table below includes the detailed results for the financial analysis.

Table 40: South Campus – Solar PV Financial Summary

		PPA Scenario			Purchase Scenario			
Project Name	Life Cycle Savings [$]	PPA Rate [$/kWh]	Total Cost [$]	Net Benefit [$]	Costs [$]	O&M Cost [$]	Total Cost [$]	Net Benefit [$]
South Campus	$498,792	$0.1901	$760,097	-$261,305	$524,529	$103,384	$627,913	-$129,122

6.2.5 MAIN CAMPUS

ANNUAL UTILITY CONSUMPTION

The main campus does not represent an ideal target load for solar due to the recently completed 4.8MW solar project and the restrictive non-export utility agreement, which does not allow the campus to feed electricity back to the grid in any significant way. The figure below shows that campus is currently at the limit to which it will export power with additional solar capacity.

While the mean electrical demand has dropped after the additional of the solar system, the pre-solar monthly peak demand is equivalent to the 2018 measured values. After the solar system installation, the campus has some periods of export with negative demand.

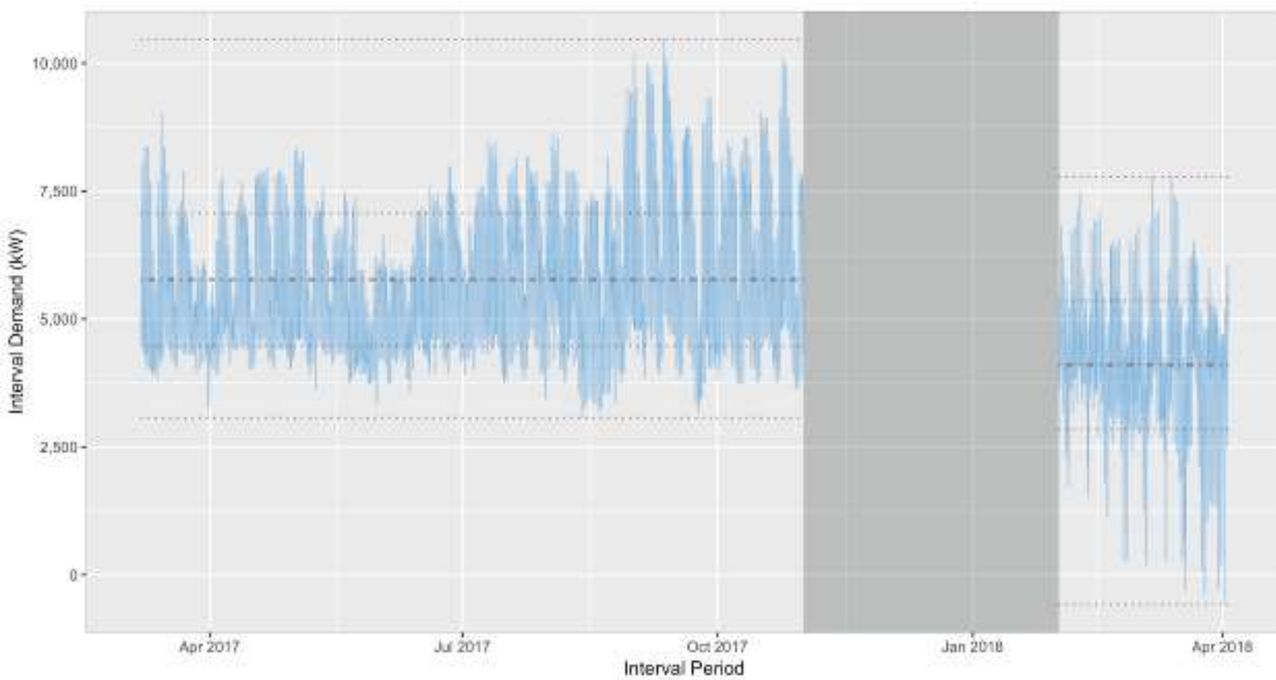

Figure 55: Main Campus Electric Meter 15-Minute Interval Demand

The dark grey region demotes the period when the interval electrical demand data was corrupted. The heavy dashed red lines depict the mean demand. The lighter dashed red lines some the +/- standard deviation and min/max electrical demand. These are shown for periods before and after the solar installation.

The campus still has a significant net load on the main meter and does have a proposal in hand for the construction of a curtailed system that would shut off during times of electrical export to the grid. The table below shows the details of the main campus meter accounting for the recently completed solar system.

Table 41: Main Campus – Utility Service & Annual Electricity Use

Utility Account Number	Most Recent Meter	Most Recent Rate	Annualized Usage [kWh]	Annualized Cost [$]	Blended Utility Rate [$/kWh]
3-001-3609-74	X345P-006152, X345P-006153	TOU-8-B	48,656,088	$4,701,678	$0.0966

IDENTIFIED SOLAR PROJECTS

The solar projects identified on the main campus meter for this study are limited to the recently completed solar system and the non-export systems for which the campus has proposal for. It is important to note that the three non-export options are overlapping and not additive (i.e. the campus would only select one).

Table 42: Main Campus – Potential Solar PV Generation

Project Name	Identified System Size [kW-dc]	First Year System Production [kWh/yr]	System Yield [kWh/kW)	Solar Degradation Rate [%/yr]	Lifetime Solar Production [kWh]
Main Campus Existing Systems	4,794	7,489,088	1,562	0.25%	181,716,575
Main Campus Non-Export Opt. 1	3,084	4,949,820	1,605	0.25%	120,103,320
Main Campus Non-Export Opt. 2	3,861	6,054,048	1,568	0.25%	146,896,507
Main Campus Non-Export Opt. 3	5,226	8,319,792	1,592	0.25%	201,872,926

The additional main campus non-export PV projects include the following site locations on campus.

Main Campus Non-Export Option 1

- Parking Structure 2: 1,550 kW-dc
- Parking Structure 3: 1,540 kW-dc

Main Campus Non-Export Option 2

- Parking Structure 2: 1,550 kW-dc
- Parking Structure 3: 1,540 kW-dc
- Parking Lot 11A/11B: 730 kW-dc

Main Campus Non-Export Option 3

- Parking Structure 2: 1,550 kW-dc
- Parking Structure 3: 1,540 kW-dc
- Parking Lot 11A/11B: 730 kW-dc
- Parking Lot 12: 730 kW-dc

Figure 56: Main Campus – Potential PV Site Plan

FINANCIAL BENEFIT

Due to the low cost of energy at the main campus meter and the relatively high costs of the projects, all of the projects are projected to lose money over their lifetimes. Only PPA scenarios are included for these projects as that is the financing mechanism used for the existing system as well as the plan included in the in-hand proposals. It is important to note that the benefit calculated as part of this study differs significantly from the benefit as presented in the proposals the Campus has. The reasons for this can likely be attributed to assumptions regarding future rate structures in SCE service territory. The results from this study can be utilized as a likely worst-case outcome for planning purposes, while the proposal's values may be seen as a more optimistic outcome.

Table 43: Main Campus – Solar PV Financial Summary

		PPA Scenario			Purchase Scenario			
Project Name	Life Cycle Savings [$]	PPA Rate [$/kWh]	Total Cost [$]	Net Benefit [$]	Costs [$]	O&M Cost [$]	Total Cost [$]	Net Benefit [$]
Existing	$16,509,530	$0.1349	$19,732,800	-$3,223,270	NA	NA	NA	NA
Non-Export (1)	$10,584,416	$0.1325	$12,810,117	-$2,225,701	NA	NA	NA	NA
Non-Export (2)	$12,892,251	$0.1310	$15,490,484	-$2,598,233	NA	NA	NA	NA
Non-Export (3)	$17,625,508	$0.1390	$22,587,860	-$4,962,353	NA	NA	NA	NA

6.2.6 PARKSIDE COLLEGE/ISABEL PATTERSON CHILD CENTER

ANNUAL UTILITY CONSUMPTION

The Parkside College area project is an area of housing on the northwest corner of campus. The area has four meters that could be aggregated for benefit from a single solar system. Together, the meters use roughly 1.54 million kWh per year at a cost of roughly $212 thousand, yielding a blending utility rate of roughly $0.13 per kWh. The primary (Account 3-000-0018-43) facility meter is on the TOU-GS-3B for medium commercial facilities.

Table 44: Parkside/Patterson – Utility Service & Annual Electricity Use

Utility Account Number	Most Recent Meter	Most Recent Rate	Annualized Usage	Annualized Cost	Blended Utility Rate
3-000-0018-43	V349N-002595	TOU-GS-3B	1,361,307	$174,140	$0.1279
3-000-0018-35	259000-071633	TOU-GS-2-B	102,390	$20,628	$0.2015
3-008-5488-21	256000-179142	TOU-GS-2-B	46,583	$12,093	$0.2596
3-000-9784-53	256000-115720	TOU-GS-1-A	34,626	$5,667	$0.1637

IDENTIFIED SOLAR PROJECTS

The Parkside Area project does not have any particular area assigned to it and can be sited in any location with easy access to the primary meters. The primary meter only has a general service address and were not specifically sited. There are ample opportunities to locate the roughly 1 MW of solar capacity needed for the system. The layout included below locates the solar system in voids left by the Lot 14 solar project. The table and figure below include the system details and the identified locations, respectively.

Table 45: Parkside/Patterson – Potential Solar PV Generation

Project Name	Identified System Size [kW-dc]	First Year System Production [kWh/yr]	System Yield [kWh/kW]	Solar Degradation Rate [%/yr]	Lifetime Solar Production [kWh]
Parkside College/IPCDC	993	1,544,906	1,555	0.50%	36,391,724

Figure 57: Parkside/Patterson – Potential PV Site Plan

FINANCIAL BENEFIT

The Parkside project is projected to generate roughly $3.27 million of utility bill savings over its 25 years of operation. Due to the assumed high project costs for CSULB, the project is projected to lose roughly $966 thousand for the PPA scenario and $449 thousand in the purchase scenario through the analysis period. If this project were competitively bid with a package of larger projects, the price would likely be lower than included in this analysis. The table below includes the detailed results for the financial analysis.

Table 46: Parkside/Patterson – Solar PV Financial Summary

		PPA Scenario			Purchase Scenario			
Project Name	Life Cycle Savings [$]	PPA Rate [$/kWh]	Total Cost [$]	Net Benefit [$]	Costs [$]	O&M Cost [$]	Total Cost [$]	Net Benefit [$]
Parkside/ IPCDC	$3,270,188	$0.1438	$4,236,825	-$966,636	$2,918,920	$800,503	$3,719,422	-$449,234

6.3 SENSITIVITY ANALYSIS

The costs used for the analysis in this report reflect recent pricing experience at CSULB to provide a conservative set of financials for planning. However, shifts in the marketplace are ongoing, and as the impacts of panel and steel tariffs settle out and cost for components continue to decline, better pricing is expected. One of the benefits of the scenario analysis tool is the ability to conduct sensitivity analysis on key variables, including project costs. For the three recommended NEM projects, a sensitivity analysis was conducted to see the effects of a 25% reduction in costs, and the resulting economics are shown, along with the default economics for comparison, in the table below.

Table 47: Solar PPA Rate – Sensitivity Analysis Results

Project Name	Identified System Size [kW-dc]	First Year Production [kWh]	Default Pricing		Market Rates (25% Reduction)	
			PPA Rate [$/kWh]	Net Benefit [$]	PPA Rate [$/kWh]	Net Benefit [$]
Beachside Housing	581	915,478	$0.1438	-$719,461	$0.1078	-$91,798
CSULB Foundation	704	1,194,069	$0.1438	-$308,546	$0.1078	$510,122
Parkside/IPCDC	993	1,544,906	$0.1438	-$966,636	$0.1078	$92,570
Blair Field	75	128,448	$0.2186	-$234,124	$0.1640	-$100,188
South Campus Solar	128	209,573	$0.1901	-$261,305	$0.1426	-$71,281
Non-Export Opt. 3	5,226	8,319,792	$0.1390	-$4,962,353	$0.1426	$684,612
Total	**7,707**	**12,312,266**		**-$7,452,425**		**$1,024,037**

Recent market data points suggest that these prices are within reach, with PPA pricing seen in recent proposals below the rates shown in the table. The swing of nearly $8.5M in lifetime benefit in this scenario, with realistically achievable pricing, suggests solar could still be pursued cost effectively and yields the recommendation to conduct a refreshed competitive procurement for future phases of solar.

6.4 SUMMARY OF FINDINGS

There are ample opportunities for the addition of solar PV throughout the CSULB facilities, which are summarized in the table below for the 20-year PPA options. In total, this study identified up to roughly 12 MW of solar capacity that could generate close to 20,000,000 kWh per year. If implemented these projects could generate roughly $42 million in life cycle utility bill savings before costs are considered.

Table 48: On-Site Solar PV Financial Results (Default Pricing)

Project Name	Identified System Size [kW-dc]	First Year Production [kWh]	PPA Rate [$/kWh]	Total PPA Cost [$]	Life Cycle Bill Savings [$]	Net Benefit [$]
Existing Solar Projects						
Main Campus Existing	4,794	7,489,088	$0.1349	$19,732,800	$16,509,530	-$3,223,270
Recommended NEM Projects						
Beachside Housing	581	915,478	$0.1438	$2,510,651	$1,791,191	-$719,461
CSULB Foundation	704	1,194,069	$0.1438	$3,274,672	$2,966,126	-$308,546
Parkside/IPCDC	993	1,544,906	$0.1438	$4,236,825	$3,270,188	-$966,636
Other NEM Projects						
Blair Field	75	128,448	$0.2186	$535,747	$301,622	-$234,124
South Campus Solar	128	209,573	$0.1901	$760,097	$498,792	-$261,305
Main Campus Meter Curtailment Options[28]						
Non-Export Opt. 1	3,084	4,949,820	$0.1325	$12,810,117	$10,584,416	-$2,225,701
Non-Export Opt. 2	3,861	6,054,048	$0.1310	$15,490,484	$12,892,251	-$2,598,233
Non-Export Opt. 3	5,226	8,319,792	$0.1390	$22,587,860	$17,625,508	-$4,962,353
Total[29]	**10,360**	**16,431,381**	**$0.1399**	**$43,860,909**	**$35,921,865**	**-$7,939,043**

While the costs used in this study show that the projects will likely lose money over their life cycles, competitively bid projects at the scale of those identified, could yield pricing that makes the projects more attractive financially. A competitive process allows the market at large to determine the project price rather than an individual vendor, and generally results in lower pricing than sole source efforts. The CSU Chancellor's Office (CO) has an established, vetted request for proposals that was developed to streamline the competitive bid process for CSU campuses and CSULB should engage the CO as it evaluates these projects further.

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[28] Main Campus Non-export project are mutually exclusive and should not be all be considered as possible together as shown.

[29] Total includes Main Campus Export Opt. 1 and excludes the others.

Additionally, if the costs of Campus defined additive features (transportation allocations, security cameras) could be funded or considered outside of the PV costs, market data suggests that costs could approach $0.105-0.115/kWh for a 20-year PPA ($0.085-0.095/kWh for a 25-year PPA). Reducing costs to this range brings the projects to their financial breakeven point for savings based heavily on energy bill savings alone (i.e. excluding demand savings). The scenario analysis tool can also be used to compare the impacts of GHG reduction goals and offsets, potentially making the projects more attractive as a part of the path to carbon neutrality. All projects identified in this study will need detailed studies to identify specific risks and benefits if they are selected for implementation.

6.5 ALTERNATIVES TO ON-SITE SOLAR

6.5.1 RES-BCT SOLAR SYSTEMS

Renewable Energy Self-Generation Bill Credit Transfer (RES-BCT) is an alternative interconnection method available to the Campus that affords the ability to install a large off-site solar system to generate credits for Campus owned utility accounts. Generally, RES-BCT systems are typically ground mount system types that are installed on more remote brownfield properties that may not be necessary for other development purposes. RES-BCT systems are limited to generating credits based on the generation portion of the interconnecting rate structure, which is roughly half of the full tariff amount. RES-BCT interconnection also limits the benefitting accounts to those that do not already have a system installed under other methods, such as Net Energy Metering. In the case of CSULB, this would eliminate the main campus meter from consideration, as it has an existing solar system tied to it. RES-BCT was not studied in depth as part of this project, but does not appear to be a good fit for the Campus.

6.5.2 SCE GREEN RATE PLANS

An alternative to the on-site solar PV projects identified in this report, SCE offers a renewable offset rate plan that the Campus could opt into. The "Green Rate" plan requires SCE to procure solar energy for 100% of the energy supplied to each opted in customer, on an annual basis. The cost of participation depends on the rate tariff of a particular meter, and ranges from an additional 1.96 cents per kWh for TOU-GS1 accounts up to 4.13 cents per kWh for other account types. The current rates are shown in the table below, as provided by SCE. The Campus may evaluate the carbon benefits of opting into the "Green Rate" on a meter by meter basis as an alternative to on site solar until the cost of a particular solar project becomes less prohibitive.

Green Rate Premium Summary per ($/kWh)

Rate	Total Credits	Indifference Charges	Other Charges	Premium Total*
Residential	(0.07926)	0.01952	0.09109	0.03135
TOU-GS-1	(0.08406)	0.01252	0.09109	0.01955
TOU-GS-2	(0.07839)	0.01628	0.09109	0.02898
TOU-GS-3	(0.07489)	0.01348	0.09109	0.02968
TOU-8-Sec	(0.07055)	0.01177	0.09109	0.03231
TOU-8-Pri	(0.06636)	0.01091	0.09109	0.03564
TOU-8-Sub	(0.06010)	0.01040	0.09109	0.04139
TOU-8-S-Sec	(0.07093)	0.00241	0.09109	0.02257
TOU-8-S-Pri	(0.06695)	0.00250	0.09109	0.02664
TOU-8-S-Sub	(0.05934)	0.00148	0.09109	0.03323
PA-1	(0.07267)	0.01212	0.09109	0.03054
PA-2	(0.07267)	0.01212	0.09109	0.03054
TOU-PA-2	(0.07267)	0.01212	0.09109	0.03054
TOU-PA-3	(0.05807)	0.00787	0.09109	0.04089
St. Lighting	(0.04448)	0.00002	0.09109	0.04663
TC-1	(0.06490)	0.00886	0.09109	0.03505

Figure 58: SoCal Edison Green Power Rate Plans

6.5.3 VIRTUAL POWER PURCHASE AGREEMENT (VPPA)

Given the constraints to add additional on-site PV to the main campus SCE meter without curtailing power generation, an off-site virtual power purchase agreement (VPPA) could be an effective avenue for CSULB to procure 100% renewable energy and reduce Scope 2 emissions. Assessing off-site VPPAs was not included as part of the CEMP project. This section serves only to provide a high-level overview of what a VPPA is. A full assessment and vetting of a VPPA would be required in the future.

A VPPA is a financially settled agreement between a renewable energy developer and a buyer (CSULB), who would retain all the renewable energy credits (RECs) associated with the project. The renewable energy developer would build and operate the system on behalf of CSULB. The "additionality" of the renewable energy project (wind, solar, etc.) to the grid and retainment of RECs would allow CSULB to offset the electricity related GHG emissions. A VPPA can be considered as an alternative path to procuring carbon offsets for electricity usage. The following diagram shows the contractual structure of a VPPA.

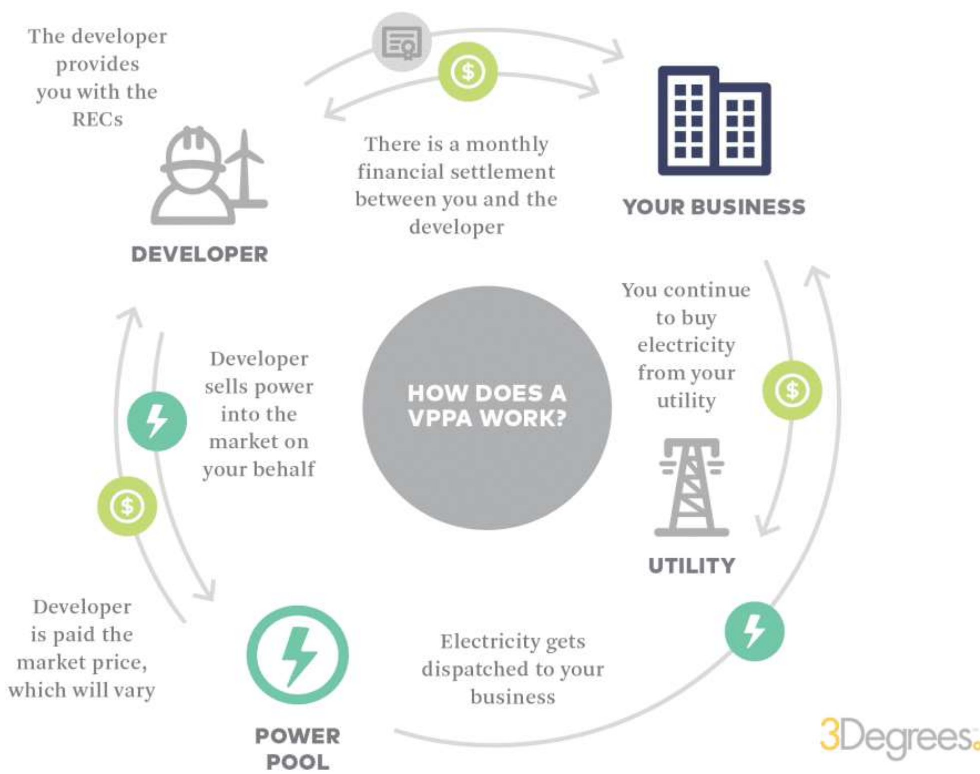

Figure 59: Virtual Power Purchase Agreement Structure[30]

Under the agreement CSULB would sign a contract with a Developer to build a new, additional, renewable energy project and agree to a fixed rate ($/kWh). The Developer would sell CSULB's power into the wholesale electricity market at real time market rates. At the end of the month, the Developer and CSULB would financially settle the outstanding balance (average wholesale price minus fixed rate). CSULB would continue to purchase electricity from SCE and would use the RECs to offset Scope

[30] Image from the 3Degrees article - Renewable energy power purchase agreements: *https://3degreesinc.com/ppas-power-purchase-agreements/*

2 emissions. There are potential risks associated with a VPPA due to the contract relying on floating market electricity prices, which can be influenced by unforeseen forces. The renewable energy system does not necessarily need to be built in the same grid region; however, there could be benefit for the CSULB to build in California as a state school.

If CSULB looks to pursue a VPPA, it is recommended that they partner with other organizations to improve the economics of the project. This could potentially be done through the CSU Chancellors Office with other CSU campuses. Massachusetts Institute of Technology (MIT) signed a VPPA in 2016, in partnership with Boston Medical Center, for a 60 MW solar farm that would have otherwise not been built to reduce their campus GHG Emissions[31].

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[31] MIT Solar Energy Purchase Addresses Carbon Emissions: *http://web.mit.edu/facilities/environmental/solar-ppa.html*

7. CLEAN ENERGY VEHICLES

7.1 CLEAN ENERGY VEHICLES SUMMARY

As part of the CEMP, a clean energy vehicle transition plan was developed for the campus vehicle fleet. The clean energy vehicles assessment for CSULB is intended to provide the university with the necessary information to make informed decisions about the future of their vehicle fleet. This includes the following:

RESEARCH OF BEST PRACTICES FOR TRANSITIONING TO CLEAN ENERGY VEHICLES

The best practices outlined in this report are based on research of other universities/agencies, including UC Los Angeles (UCLA), UC Berkeley (UCB), and the San Pedro Bay Ports. The clean vehicle transition plans developed by these entities were guided by the principals set forth in their respective Climate Action Plans. UCLA and UCB have set targets as to what percentage of their vehicle fleet should be zero emission by certain dates, along with other strategies such as rightsizing, reducing vehicle miles traveled, and car sharing. The San Pedro Bay Ports focused on placing strict fuel standards on vehicles entering the ports. It is recommended CSULB uses a combination of these approaches, and both establish targets for transitioning to clean energy vehicles and place stricter fuel standards on all campus vehicles.

ASSESSMENT OF CLEAN ENERGY VEHICLE TECHNOLOGY AND INFRASTRUCTURE

The CEMP report provides an overview of the available clean energy vehicle technology, including battery or plug-in electric, compressed natural gas, and hydrogen fuel cell vehicles. Information is provided on the availability and costs of each technology, and how applicable/relevant the technology would be to CSULB based on their fleet of vehicles. Based on a review of the current market for clean energy vehicles, it was determined that battery electric vehicles are the best option for CSULB to transition to clean energy vehicles in the near term. CSULB can continue to explore advancing technologies, such as hydrogen fuel cell vehicles, over the next 5 to 10 years as the technology develops further.

INVENTORY AND ANALYSIS OF CSULB'S VEHICLE AND SHUTTLE BUS FLEETS

CSULB's facilities vehicle fuel usage data was assessed for the full 2017 calendar year. CSULB has already taken significant strides to reduce the environmental impact of their vehicle fleet already contains 180 electric vehicles, primarily electric carts, which account for 52% of all vehicles. Annual fleet consumption of unleaded gasoline and diesel is approximately 28,500 and 7,000 gallons, respectively, which contributes roughly 318 metric tons of emissions. It was determined that four departments consume roughly 70 percent of university's fuel consumption and offer the greatest opportunity for reducing vehicle emissions. These departments include Facilities (Grounds & Plumbing), University Police and Parking.

REVIEW OF FUNDING OPPORTUNITIES FOR CLEAN ENERGY VEHICLE ALTERNATIVES

The funding opportunities identified in this report were categorized based on vehicle type (i.e. passenger or heavy-duty vehicles), supportive infrastructure, and general funding opportunities to cover any associated costs with implementing clean energy vehicles. It was determined that that rebates and tax credits are the most readily available funding sources for light-duty vehicles, are easy to apply for, and generally operate on a first-come first-serve basis. There are also rebate vouchers for heavy-duty vehicles, but the market availability for these vehicle types is still quite limited. Additionally, there are various grant opportunities available to CSULB that fund a variety of projects relating to alternative vehicle fuels, for example the Carl Moyer Memorial Air Quality Standards Attainment Program. This program specifically can be a useful resource for funding CSULB's vehicle transition over the next several years.

2030 CLEAN VEHICLE TRANSITION ROADMAP

With this tool, CSULB will have the ability to assess test which strategies or scenarios can contribute to the most efficient reduction in greenhouse gas emissions. This tool contains the campus vehicle fleet inventory, greenhouse gas emission calculations, rebate and tax credit information, and more. These inputs can be manipulated to create an output that will inform CSULB on the feasibility of transitioning to clean energy vehicles.

7.2 BACKGROUND INFORMATION

7.2.1 CLEAN ENERGY VEHICLE POLICIES

CSU SYSTEMWIDE POLICIY

The CSU System has the established targets for zero emission vehicles (ZEV) purchases for all campus. 10% of all light-duty fleet purchases by campuses and CSU shall be zero emissions vehicles (ZEV) in FY 2017/18, increasing by 5% annually through FY 2024/2025 to a total of 50% of light duty fleet vehicles purchases. For the purposes of this section, ZEVs are fuel cell vehicles (FCV), battery electric vehicles (BEV).

Table 49: CSU Light Duty ZEV Purchase Requirements

	ZEV Requirements [% of Light Duty Purchases]
2017/2018	10%
2018/2019	15%
2019/2020	20%
2020/2021	25%
2021/2022	30%
2022/2023	35%
2023/2024	40%
2024/2025	45%
2025/2026	50%

Additionally, sufficient charging/fueling infrastructure are required to be available to support ZEV purchases and utilization. Campuses shall strive to maintain a ratio of charging/fueling infrastructure as described in the table below:

Table 50: CSU Charging/Fueling Infrastructure Requirements

Type of Vehicle Fuel	Charging/Fueling Infrastructure	Number of vehicles
Level 1 EV port (120V)	1	1
Level 2 EV port (240V)	1	2.5-4
Level 3 port (Fast charge)	1	16
Hydrogen	1 within 20 miles	Unlimited
Ethanol	1 within 10 miles	Unlimited
Biodiesel	1 within 10 miles	Unlimited
CNG slow fill (Or Renewable Gas)	1	1
CNG quick fill (Or Renewable Gas)	1	Unlimited

Exemption to ZEV/BEV Charging/Fueling Requirement: If the campus has Telematics in 100% of ZEV fleet including Plug-in Hybrid Electric Vehicle (PHEV)[32] with quarterly reports demonstrating proper charging and use of PHEV vehicles. PHEV vehicles shall be considered ZEVs for purchasing vehicles.

Purchasing of light duty vehicles shall follow a priority order. If purchasing other than priority 1 vehicle type, justification in writing must but submitted for each lower priority order type of vehicle.

Table 51: CSU Vehicle Purchase Priority

Priority	Vehicle type
1	Pure Zero Emissions Vehicles (ZEV)[33]
2	Plug-in Hybrid ZEVs
3	Hybrid-Electric vehicles
4	Internal Combustion and Flex Fuel[34]

CSU LONG BEACH POLICY

CSULB's Climate Action Plan (CAP) identified clean energy vehicle fleets as an operational GHG mitigation measures. As part of the CAP, the sustainability task force approved a clean fleet policy requiring the cleanest vehicles available to be purchased. The campus has prioritized electrical vehicle carts as an alternative to gasoline powered vehicles whenever possible.

7.2.2 CASE STUDIES FOR CLEAN VEHICLE TRANSITION PLANS

Various other universities across California have similar carbon neutrality goals for their campus, which also required an assessment of the carbon emissions due to campus vehicle fleets. University of California, Los Angeles and University of California, Berkeley have been two such universities which have planned and implemented vehicle fleet transition plans to meet their carbon neutrality goals. CSULB should take the lessons learned and best practices for establishing clean energy vehicle policies for the campus fleet of vehicles.

UNIVERSITY OF CALIFORNIA, LOS ANGELES (UCLA)

In UCLA's Climate Action Plan from 2008, the campus identified various initiatives for reducing fleet GHG emissions based on vehicle type, fuel type, and miles traveled[35]. They established interim clean energy vehicle transition targets leading up to their climate neutrality date of 2025 and goals to decrease fleet vehicle miles traveled through rightsizing, increase car sharing. Additionally, at the end of 2016 UCLA transitioned two of their shuttle bus to be fully electric busses. Their interim clean energy vehicle targets included:

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[32] Plug in Hybrid Electric Vehicle (PHEV) *https://www.afdc.energy.gov/vehicles/electric_basics_phev.html*
[33] Pure ZEVs include low-speed vehicles
[34] Internal combustion engine vehicles must meet MPG requirements: 22.2 MPG for light duty trucks & 38 MPG for light duty vehicles
[35] UCLA Climate Action Plan: *https://www.sustain.ucla.edu/wp-content/uploads/2013/04/UCLA-Climate-Action-Plan.pdf*

Table 52: UCLA – Clean Energy Vehicle Transition Targets

Year	ZEV/ATPSEV/PZEV[36]	AFVs[37]
2014	40%	50%
2020	70%	75%

UNIVERSITY OF CALIFORNIA, BERKELEY (UCB)

Due to the current age of the vehicle fleet, Berkeley determined up to 80% of the vehicles could be replaced over the next decade. If half of these vehicles were replaced by standard gas/electric hybrids and a fifth were replaced with zero-emission low speed vehicles, fleet emissions could be reduced by 20%. Additionally, the campus shuttle vehicles are on a lease program with the current lease period ending in 2022; there are opportunities to increase the use of biofuels or consider electric, hydrogen or other zero emission shuttle vehicles. As an example, if the shuttle fleet became zero emissions, along with the vehicle fleet becoming less carbon intensive as described above, overall fleet emissions could be reduced by 35%.

SAN PEDRO BAY PORTS

The Port of Los Angeles and the Port of Long Beach released the approved Clean Air Action Plan in 2006 which included the development of the Clean Truck Program to replace and/or retrofit polluting diesel trucks with cleaner technology within five (5) years. The vehicles in question include ships, trains, trucks, cargo handling equipment and harbor craft. The program included a tiered, progressively stricter, ban of vehicles from entering the port based on emission standards starting in 2008 through 2012. In the first year of implementation, the Clean Truck Program, reduced 70% of truck emissions, and in 2012, the reduction increased to 80%. Per the San Pedro Bay Ports Clean Air Action Plan 2017 update, by 2036 the vehicle standards are targeting to comprise of 0-44% near-zero emission vehicles and 55-100% zero-emission vehicles.

[36] Advanced Technology Partial Zero Emissions Vehicles (ATPZEVs), Partial Zero Emissions Vehicles (PZEVS)
[37] Alternative Fueled Vehicles (AFVs)

7.3 TECHNOLOGY ASSESSMENT

The research provided below assesses various alternative clean fuel vehicle options, which can help reduce CSULB's dependence on fossil fuel and lower their carbon emissions. The focus of this research was on the three most prominent clean vehicle technologies: electric, compressed natural gas (CNG), and hydrogen fuel cell. These alternatives should be considered by CSULB as they transition their vehicle fleet operations to align their vehicle fleet with their campus-wide goals of achieving carbon neutrality by 2030.

7.3.1 BATTERY ELECTRIC VEHICLES (BEV) AND PLUG-IN ELECTRIC VEHICLES (PEV)

SUMMARY

Battery electric vehicles (BEV) replace existing internal combustion engine of a gas-powered vehicle with an electric motor. The battery component of the electric vehicle obtaining its power and refueling from a charging port. It was determined that battery electric vehicles are an extremely viable option for CSULB's fleet transition plan through reducing the campus' dependence on oil, as well as producing zero tailpipe emissions.

TECHNOLOGY OVERVIEW

BEV's are highly efficient, do not produce tailpipe emissions, have good acceleration, and can be charged overnight at a low electricity rate.

There are however limitations with battery electric vehicles which include: time consuming measures to recharge, expenses associated with electricity storage within the battery, lower travel range than gas-powered vehicles, negative impact to the electric grid, and need for electric charging infrastructure installation, which would increase associative costs.

In the current car market, there is a premium for purchasing a BEV compared to their internal combustion engine counterparts. This is primarily due to the cost of the battery, which is the most expensive component of the vehicle. The competitiveness of electric vehicles in the car market is highly dependent on the battery cost. From now until 2030, the costs for battery manufacture are expected to significantly decrease, making the first cost of an electric vehicle substantially cheaper in the future. Currently, battery costs are decreasing at a rate of 19% per year as shown in the forecast below.

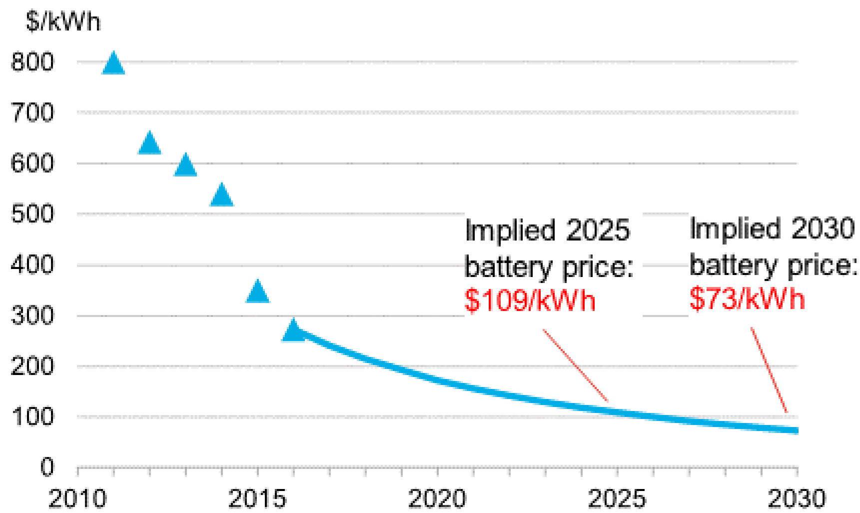

Figure 60: Historical and Forecasted Average EV Lithium-ion Battery Price

According to Bloomberg study (2017), electric vehicles and gas vehicles will reach price-parity as early as 2025 for all vehicle types (i.e. small vehicle, medium vehicle, large vehicle, SUV) based on the expected reduction in battery cost and improvement in electric vehicle technology.[38] However, over the next 5-7 years it is still expected that battery electric cars will carry a slight premium.

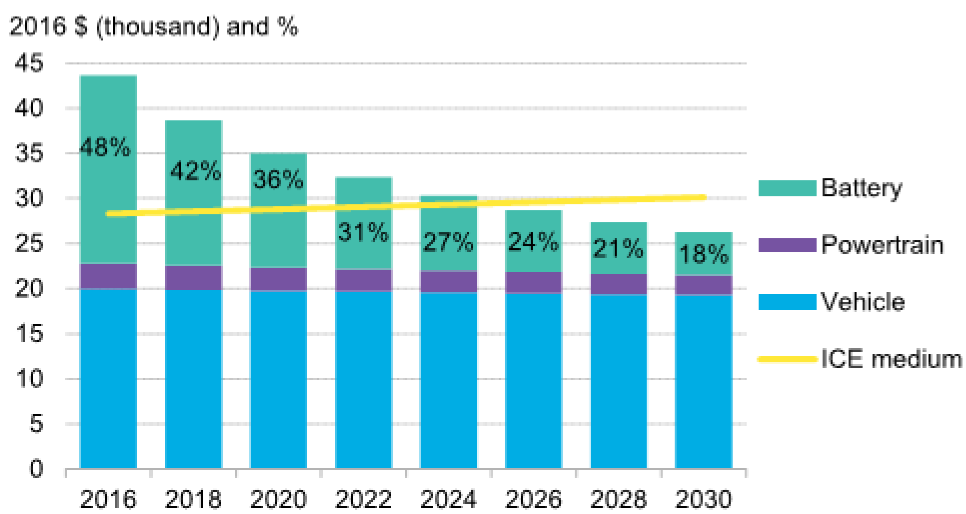

Figure 61: US Medium BEV Price Breakdown

Additionally, due to decreased battery costs, improvements in material efficiencies, and improved electric vehicle engineering that accompanies improvements in technology, electric vehicle are

[38] Bloomberg. (2017, April 12). When will electric vehicles be cheaper than conventional vehicles? New Energy Finance

expected to achieve a greater value. For example, the technological improvement of the battery density is expected to double by 2030, reaching more than 200Wh/kg.[39]

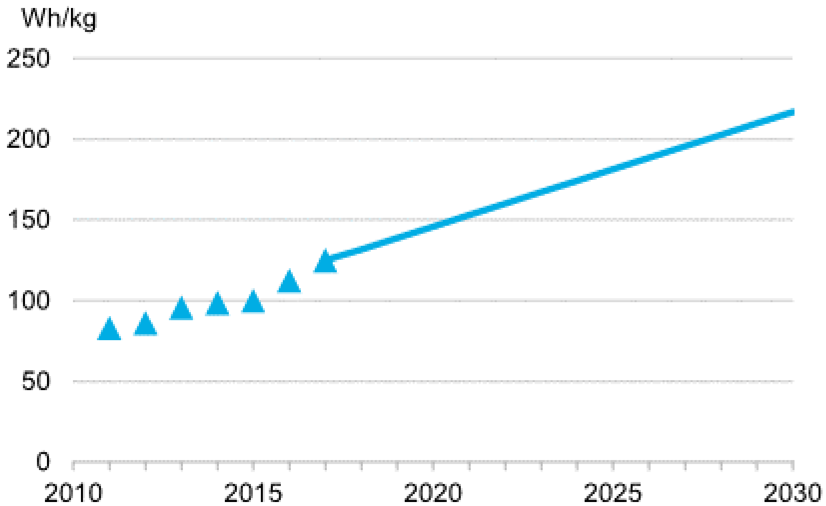

Figure 62: Historical and Forecasted Weighted Average Battery Energy Density

VEHICLE AVAILABILITY

BEV's are growing in popularity, as they are a promising technological advancement for alternative fuel driving options. Of the BEV's that are on the market, passenger or light-duty vehicles are the most popular and most developed.

INFRASTRUCTURE REQUIREMENTS

As CSULB considers integrating more BEV's within their fleet, they should also consider installing more electric charging ports at their fleet holding site to support their growing electric fleet. These additional recharging sites can reduce the burden placed on charging stations and/or electric grids on CSULB's campus, if dispersed appropriately within the fleet transition holding site. For BEV's, CSULB should consider the criteria below before selecting if an electric vehicle charging station is appropriate for their transition fleet.

ELECTRIC VEHICLE CHARGING

<u>Stand-alone vs. Networked Charging Station</u>

Stand-alone chargers are not connected to a service network, which prevents oversight, services, and support for the electric charging station. When a charging station is stand-alone, it essentially serves as an electric outlet with circuitry to safe charge the vehicle. This option does not allow the charging station to process payment, which makes it appropriate for residential or fleet operations. Stand-alone chargers also tend to have lower costs, simpler designs, and no recurring fees for features that are available on the network chargers (i.e. payment processing, customer support, etc.).

If CSULB intends to install electric charging stations within their fleet housing site that are not available to the public, it is recommended they consider a standalone electric charging station to support their

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[39] Andwari, A. M., Pesiridis, A., Rajoo, S., Martinez-Botas, R., & Esfahanian, V. (2017). A review of Battery Electric Vehicle technology and readiness levels. Renewable and Sustainable Energy Reviews, 78, 414-430.

fleet. If CSULB in interested in public access options, CSULB should consider a network charging station and review California state policies and University regulations associated with public charging stations.

<u>Operational and Installation Costs</u>
Cost might play the largest role in determining the type of charging station that is appropriate. Costs that can be accrued with an electric vehicle charging station include: maintenance, accessories, equipment, and installation. Of these costs, equipment and installation are of the largest cost, and of the most variable between all three types of chargers (Level 1, Level 2, DCFC). Installation costs will be dependent on the type of site host, wiring, number of circuits and electric vehicle charging stations being installed, and trenching.

Operational costs associated with charging stations can be derived from a variety of factors. This includes costs such as, monthly utility meter fees, monthly cell service fees, or service network subscriptions. The first and foremost operational cost associated with charging stations is the purchase of electricity. This purchase includes both the per-kWh charge for electricity directly used by the charger, and potential demand charges if the charger increases the peak demand. Lower level chargers are unlikely to accrue a demand charge as they are not typically using thousands of kWh during peak hours as DCFC type chargers do.

Maintenance of the charging station is also a cost component of charging station ownership which should be considered prior to the purchase of a charging station. Although maintenance of charging equipment is minimal, with an average cost of $400 per station per year, there is a cost associated with replacement or repair of broken charging units if it is not under warranty.

Operational, installation, equipment, and maintenance costs of the charging station should be taken into consideration when developing a charging station purchase plan. These associative costs of charging stations need to be determined and agreed upon by the charging station manufacturer and is at the responsibility of the CSULB fleet management team to determine, prior to the purchase of a charging station. Incentives and rebate programs can help offset the costs associated with electric vehicle infrastructure.

<u>Electric Vehicle Load Management System</u>
EV load management systems incorporate a driver input and real time electrical load monitoring to distribute charging capacity between the vehicles. This allows for owners to reduce the electrical infrastructure required for electric vehicle chargers and is a good solution for vehicle fleet charging stations, where all vehicles are owned and operated by the campus. The diagram below shows the peak electrical demand for throughout the day with and without an electrical load management system.

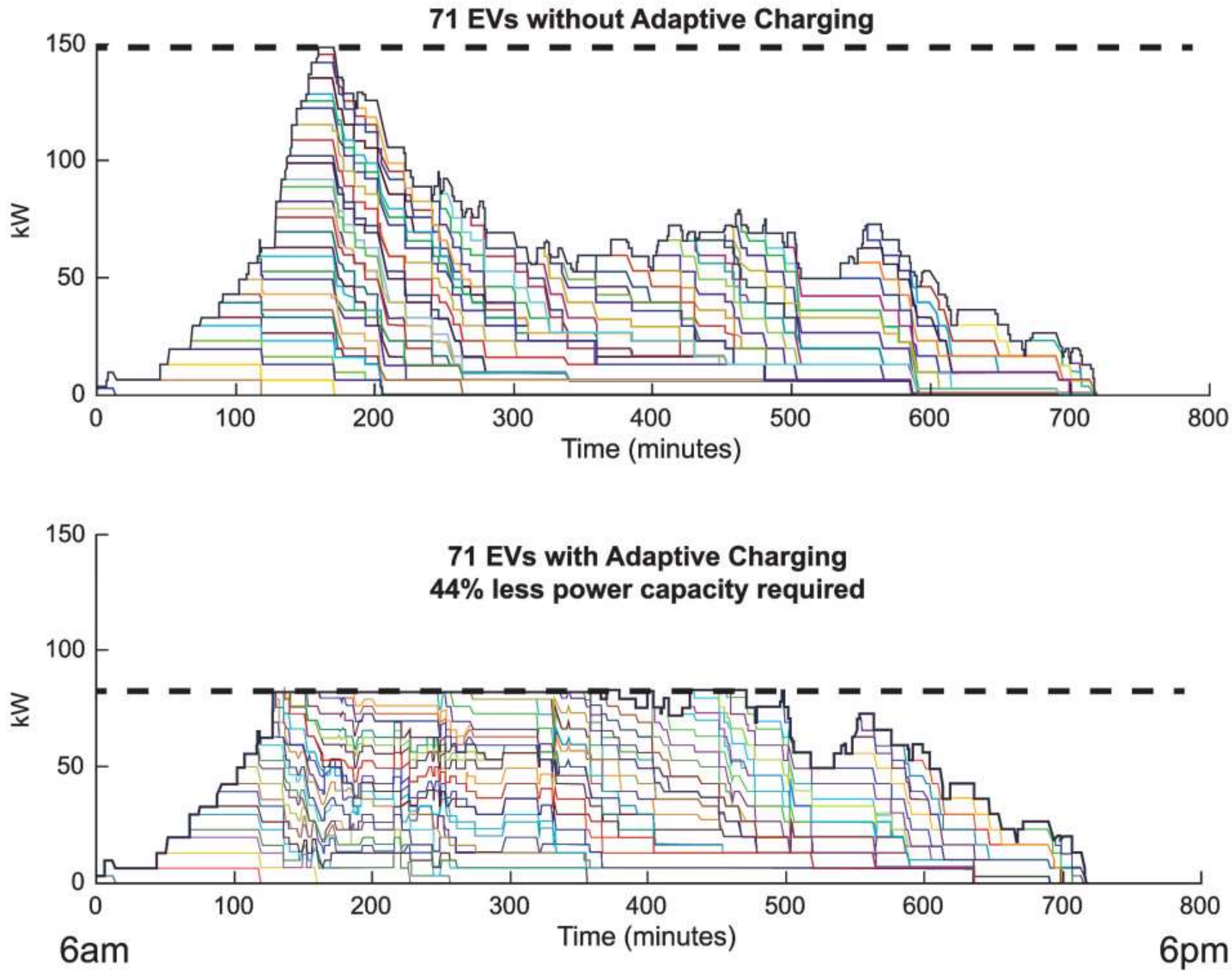


Figure 63: EV Load Management[40]

In addition to recording every charging session, EV load management controllers can also integrate into a larger smart grid system that tracks overall campus electrical load, solar generation, and battery storage systems. This system would also allow for vehicles to be charged strategically based on time of use (TOU) electric rates. Given the smart grid infrastructure in place already at CSULB, this type of electric vehicle charging system for fleet vehicles is recommended.

<u>Electric Vehicle-to-Grid (V2G)</u>

V2G systems allow for electric vehicles to both charge from the grid and discharge electricity back to the electric grid. A V2G systems can communicate with the campus power grid to contribute to peak electrical load shedding by either discharging EV batteries or by throttling back EV charging rates. This would increase the battery storage capacity on campus for CSULB and could improve the challenges of the solar system exporting electricity. V2G systems are still relatively new and there are few systems currently operational in the US. In the future V2G systems are expected to become more common place, particularly for fleets of vehicles with the same owner. There are local demonstration/research projects at both UCLA and UCSD.

[40] Image provided from PowerFlex's Adaptive Load Management System

The system requires a bi-directional inverter and central control system. The following diagram shows the flow of electricity between an electric vehicle and the grid.

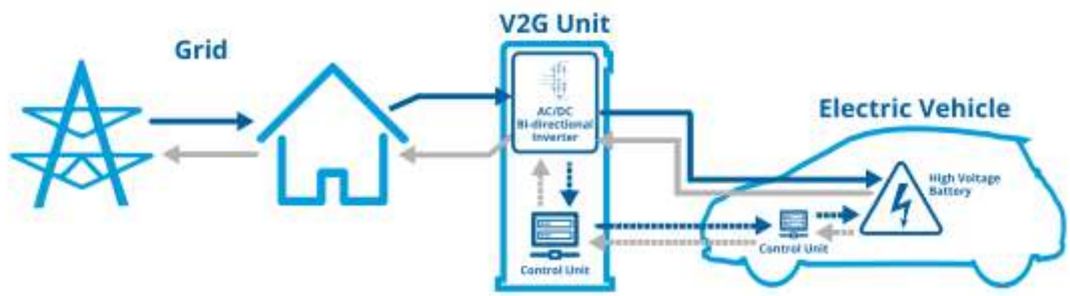


Figure 64: Electric Vehicle to Grid (V2G) Charging Diagram[41]

SOLAR ELECTRIC CHARGING

Due to the University's non-export agreement with the utility provided South California Edison (SCE), adding additional solar capacity in the form of solar electric vehicle charging stations is not recommended at this time. For this reason, the university should prioritize standard grid connected EV chargers as opposed to an EV Solar Charging system, until an alternative agreement with utility can be reached.

APPLICATION TO CSULB

Based on currently available technology and trends in the market, BEV's will become a competitive option to fulfill CSULB's clean fuel fleet transition. As electric vehicles are expected to decrease in cost over the next 5 years and as there are readily available purchase options for light-duty vehicles.

In addition, of the battery options that are available for electric vehicles, the lithium-ion battery is considered the most promising battery technology for the future as it has a high energy density due to lithium possessing the highest electrochemical potential and low equivalent mass. Given this, the lithium-ion battery should be heavily considered by CSULB as they explore and purchase/lease specific battery electric vehicles options for their fleet.

7.3.2 COMPRESSED NATURAL GAS (CNG)

Compressed Natural Gas is created by compressing a methane-based natural gas to less than 1% of its original volume at standard atmospheric pressure. It is odorless, colorless and tasteless. They are competitively priced, domestically produced and commercially available vehicles that operate off CNG fuel. While CNG is still a fossil fuel-based source of energy, it is significantly cleaners compared to gasoline and diesel.

Given the infrastructure requirements for CNG vehicles and the size of the CSULB vehicle fleet, it is not recommended to invest in CNG vehicles.

VEHCILE OVERVIEW

[41] Image provided from FleetCarma, A Geotab Company

CNG is stored onboard a vehicle at a pressure of up to 3,600 pounds per square inch, which allows a greater fuel efficiency [GS3]. Vehicles utilizing CNG achieve the same fuel economy as those utilizing conventional gasoline which is expressed in gasoline gallon equivalent (GGE). One GGE equals approximately 5.66 pounds of CNG.

VEHICLE AVAILABILITY

Compressed natural gas can be applied to fuel light, medium and heavy-duty vehicles. The Alternative Fuels Data Center lists vehicle types and fuel types that are available on the market. It lists a wide range of vehicles from trucks, vans, buses and street sweepers that is currently on the market.

INFRASTRUCTURE REQUIREMENTS

The infrastructure design for CNG fueling stations requires calculating the pressure and storage based on the vehicle types in the fleet. Currently there are two types of CNG stations, time-fill and fast fill. At time-fill stations, a fuel line from a utility delivers CNG at a low pressure to a compressor on site. The compressor size is dependent on the size of the vehicle fleet. The financial advantage of a time-fill infrastructure is that vehicles can be filled during off-peak hours when electricity rates are reduced.

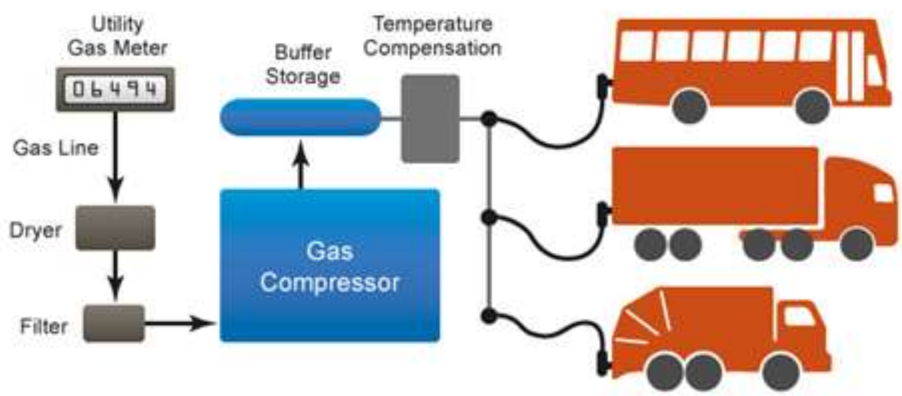


Figure 65: Time-Fill Station Schematic

Fast-fill stations are designed for scenarios where vehicles are needed to fuel at unpredictable and random times. Fuel is obtained from a local utility line at a low pressure and an on-site high-pressure compressor processes the fuel to CNG. The CNG moves to storage vessels, ready for vehicles to fill-up at any given time.

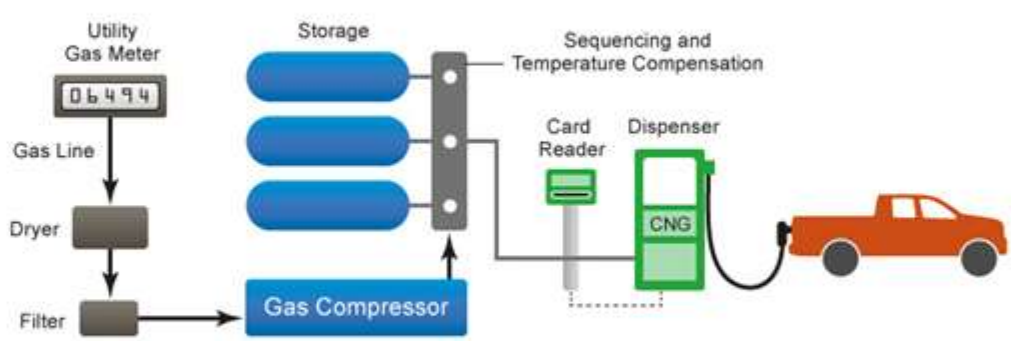


Figure 66: fast-Fill Station Schematic

APPLICATION TO CSULB

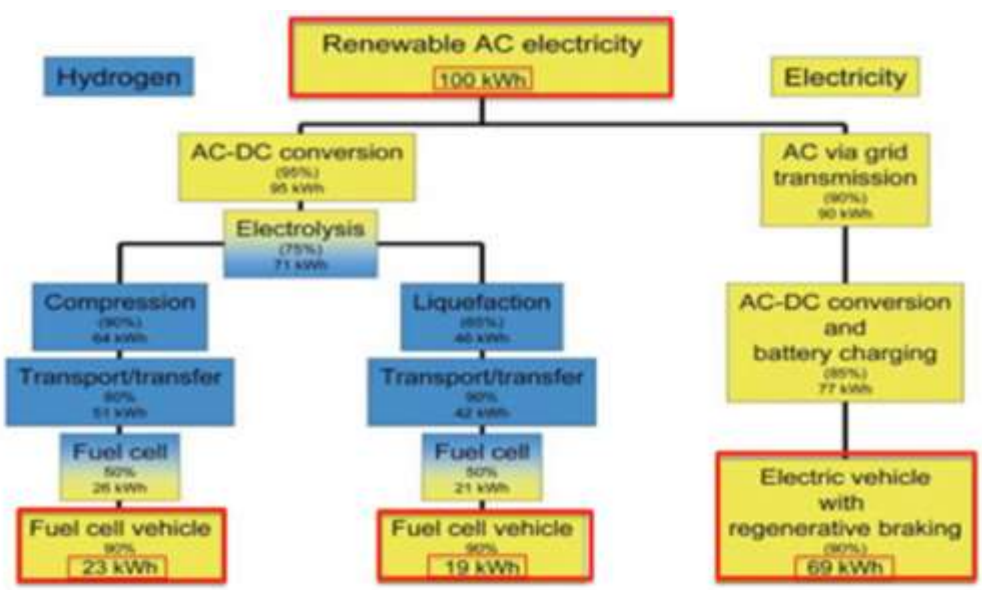
As vehicle fuel, CNG can improve greenhouse gas emissions as compared to conventional fuels and can reduce various of tailpipe emissions such as hydrocarbon, CO and NO2 because it is a low-carbon and cleaner burning fuel. The U.S. Environmental Protection Agency (EPA) has required fuel and vehicle types to meet lower thresholds for tailpipe emissions of air pollutants and particulate matter over time. CNG meets these standards without the installation of additional emission controls within the vehicle.

7.3.3 HYDROGEN FUEL CELL VEHICLES (HFCV)

Hydrogen fuel cell vehicles (HFCV) are considered zero emission vehicles, making them viable vehicle candidates for CSULB as they transition their vehicle fleet towards their carbon neutrality goals for 2030. HFCV's rely on compressed hydrogen gas stored within a fuel cell "stack" or a series of individual fuel cell units that have the capability to hold enough power to run the vehicle. These hydrogen fuel cell units store hydrogen gas as 'fuel,' analogous to traditional internal combustion engines that run on gasoline.

TEHCNOLOGY OVERVIEW

Each fuel cell of the HFCV has an anode and cathode, which catalyzes the reaction between hydrogen gas and oxygen, to produce water vapor as a byproduct and release the energy necessary to run the vehicle system. However, despite hydrogen being the most abundant element on earth, obtaining pure hydrogen that HFCV's rely on, can be an energy-intensive process, based on how it is produced, stored, and transported.



The process of obtaining hydrogen usable for HFCV's can require more energy input than hydrogen yields. For example, hydrogen can be synthesized through natural gas compression or liquefaction, which yields about 25% available hydrogen for practical use. Given this, hydrogen is arguably an alternative fuel-type that is seen as less feasible than other alternative energies, like electricity.

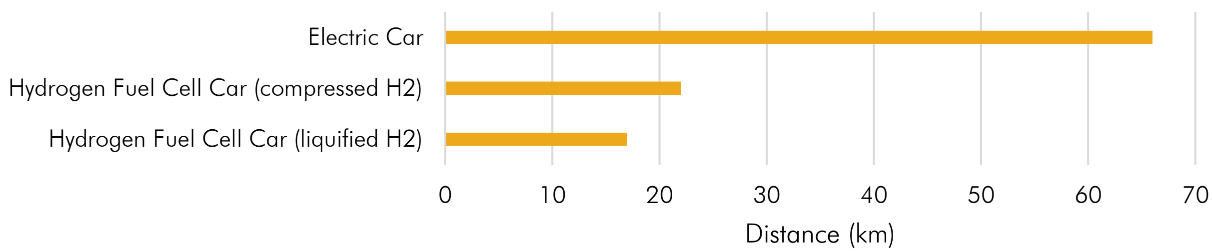


Figure 67: Relative Distance traveled by vehicle type per kWh of electricity consumed (km)

Additional improvements remain to be developed in order to determine economic feasibility, technology use, practicality, and competitiveness with other alternative fuel types.

VEHICLE AVAILABILITY

HFCV's are twice as efficient as internal combustion engines, have a driving range of about 300 miles per filled tank, and do not have associated maintenance costs such as oil changes as they do not have 'moving parts,' only fuel cell stacks. An additional benefit of HFCV's include fueling time, which is comparable to that of a gasoline vehicle, and many current leasing packages offer fueling, maintenance, service, and damage protection for up to three-years of the lease. Despite the perceived benefits of HFCV's, these vehicles can have high initial costs for lease/purchase, fuel cell unpredictability and unreliability, especially in harsh environmental conditions, limited access to public refueling stations, and higher price fuel cost for hydrogen ($12.85-16/kg or operating cost of $0.21/mile). Additionally, as hydrogen-fueled vehicles are newer to the market than other alternative fuel vehicles, there is a need for increased support of technology development and implementation options for HFCV's.

Currently, hydrogen capable vehicles are a developing alternative fuel technology being employed for passenger vehicles, forklifts, and shuttle buses. Of the HFCV's that have been produced, they have either been available for lease or incorporated into fleet programs. By 2020 and beyond, automakers intend to increase production of HFCV's for the public and integrate more hydrogen capable options into the market. There are utility vehicles and warehouse machinery that are available from select vendors, with pick-up trucks and other medium to heavy duty equipment within the next decade[42].

INFRASTRUCTURE REQUIREMENTS

Hydrogen fueling stations are currently being operated by several universities in Southern California, as well as several stations around Long Beach that are available for public use. Currently, the state of California has an assembly bill (AB 8) to install 100 hydrogen fueling stations across the state, under the Alternative and Renewable Fuel and Vehicle Technology program. This statewide investment in hydrogen fueling infrastructure would influence and alter the presence of hydrogen fueling stations

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[42] *Sources: U.S. Environmental Protection Agency; https://www.fueleconomy.gov/feg/fcv_benefits.shtml; California Fuel Cell Partnership. https://cafcp.org/*

across Southern California. Additionally, this expansion in hydrogen fueling stations might also encourage improvements in HFCV development, manufacture, and sale.

APPLICATION TO CSULB

HFCV's are a potentially an option om the future for CSULB to explore as they consider ways to decrease carbon emissions from their fleet and aim to meet their carbon neutrality goals of 2030. HFCV's can be expensive in cost and novel in technology, it is recommended that CSULB explore HFCV's in the next 5 to 10 years, to allow for hydrogen technology to develop, infrastructure requirements to be enhanced, and viability of HFCV's to be improved. However, if current HFCV's on the market prove to be financially feasible and appropriate for the fleet, CSULB should explore HFCV's as a potential improvement of their fleet.

7.3.3 SHUTTLE BUSSES

Electric busses have started to gain prominence in the market and are increasing in prevalence. For example, LA Metro recently approved the purchase of 95 electric busses and has a goal to have an entire zero emissions fleet by 2030. It is recommended that reassess battery electric shuttle busses in five years when the existing shuttle bus contract has expired, and electric bus technology continues to improve.

7.3.3 GROUND EQUIPMENT

Battery powered equipment significantly reduces scope 1 emissions; however, scope 2 emissions result from additional use of electricity on campus. Although the emissions must be accounted for, the air quality on campus must also be considered. Small off-road engines (SORE), such as those in landscaping equipment, have significant smog-forming emissions. Smog-forming emissions are emissions from internal combustion engines that include nitrogen oxide, carbon monoxide, formaldehyde and other particulate matter. These emissions typically stay close to ground level and have significant impacts on air quality at a local level. Smog-forming emissions are also in addition to GHG emissions, such as carbon dioxide, which have a larger impact on the environment.

Research conducted by the California Air Resources Board (CARB) indicate that an hour of lawn mower operation has the equivalent smog forming emissions than a passenger car driving approximately 300 miles. Air quality on campus therefore can be significantly improved through conversion to an entirely battery powered fleet of ground equipment.

Table 53: Battery Powered Ground Equipment Runtime

Equipment Type	Runtime
String trimmer	4 hours
Hedge trimmer	5.7 hours
Lawn edger	7 hours

7.4 FUNDING OPPORTUNITIES

Various funding opportunities have been identified to financially support transitioning campus vehicles to clean fuel vehicles. Most of the funding sources are administered by government agencies at either the federal, state, or local level. Each funding opportunity was categorized by vehicle type, infrastructure to support clean fuel vehicles, and other general funding opportunities to cover any costs associated with implementing clean fuel vehicles.

7.4.1 PASSENGER VEHICLES

Passenger vehicles make up most of the zero-emission vehicles on the market and subsequently have a variety of funding opportunities available. The most common types of funding available for the purchase of clean fuel passenger vehicles include rebates and tax credits. It is recommended that CSULB apply for rebates from the California Clean Vehicle Rebate Project and federal tax credits [GS9] from the Plug-In Electric Drive Motor Vehicle Credit (IRC 30D), as both incentives can be used in combination for the purchase of new clean fuel vehicles. The following gives a programs overview and eligible vehicles covered by each incentive.

CALIFORNIA CLEAN VEHICLE REBATE PROJECT

This program is administered by the Center for Sustainable Energy for the California Air Resources Board (CARB). Available funding for the Clean Vehicle Rebate Project (CVRP) is determined before the beginning of a new fiscal year (in California fiscal year begins in July) and applicants can apply for funds at the beginning of the calendar year. There were $80 million available for the rebate program for FY 2017-2018. The CVRP websites provides live statues updates on available funding throughout the year[43]

Eligible applicants include individuals, businesses, and public/government entities. The program also has the Public Fleet Pilot Project, which increases rebate amounts for public fleets operating in disadvantaged communities, as determined by CalEnvironScreen Tool developed by the California Environmental Protection Agency. According to this tool, CSULB is not located in a disadvantaged community. Public fleets are limited to 30 rebates per calendar year, whereas rental and car share fleets are capped at 20 rebates per calendar year.

Rebate amounts vary depending on the type of vehicle fuel and only three fuel types are covered by the program; plug-in hybrid electric, battery electric, and hydrogen fuel cell.

- Plug-in hybrids receive the lowest rebate amount of $1,500
  - The more affordable vehicles covered in this category include:
    - 2017-2018 Toyota Prius Prime; MSRP $27,995
    - 2013 - 2017 Ford C-Max Energi; $29,195
    - 2018 Hyundai Ioniq PHEV; $32,935
- Battery electric vehicles receive a rebate amount of $2,500
  - The more affordable vehicles in this category include:

[43] *https://cleanvehiclerebate.org/eng*

    - 2012-2018 Ford Focus; $31,345
    - 2017-2018 Hyundai Ioniq Electric; $31,460
    - 2011-2018 Nissan Leaf; $36,845
- Hydrogen fuel cell vehicles receive the highest rebate amount of $5,000
  - The only vehicles covered in this category include:
    - 2016-2018 Toyota Mirai Fuel Cell
    - 2017-2018 Honda Clarity Fuel Cell
    - 2015-2017 Hyundai Tucson Fuel Cell

Applications are accepted throughout the year until funds are exhausted. Applicants can submit applications after taking possession of and registering the eligible vehicles. It is recommended that CSULB purchase their vehicles as early as possible and apply at the beginning of the calendar year, since rebates are issued on a first-come first-served basis and is contingent on available funding. The application process is straightforward. CSULB will need to submit a signed copy of the CVRP application form (available at the CVRP website), copy of executed purchase agreement, and proof of vehicle registration. Rebates are issued 90 days after the application is approved.

PLUG-IN ELECTRIC DRIVE MOTOR VEHICLE CREDIT (IRC 30D)

This incentive is a federal tax credit used to incentivize the purchase of electric passenger vehicles. Eligible applicants include individuals and businesses. The tax credit is claimed when the individual or business files their tax return. However, sellers i.e. car dealerships can claim the tax credit if they are selling the vehicles to a tax-exempt organization or a governmental unit (IRS Form 8936). The County of Alameda in California purchased their vehicles using this method. Essentially, the County released a Request for Quotation for the purchase of an electric vehicle fleet and encouraged bidders to utilize the tax credit for them to offer a lower and more competitive price.

The tax credit can amount from a minimum of $2,500 to a limit of $7,500 for vehicles purchased after December 31, 2009. This tax credit, however, will phase out once an eligible manufacturer sells at least 200,000 of their qualifying vehicles. The manufacturer and car models are like those covered by the CVRP.

The Vehicle Fleet Analysis Tool that has developed lists the eligible vehicles for both the CVRP and Federal Tax Credit. Sensitivity studies depending on replacement vehicle reflected an estimated contribution of 1% to 6% from these sources relative to initial capital costs. A greater benefit is reflected in vehicles eligible for the Federal Tax Credit than the CVRP.

For CSULB to be eligible to use the tax credit, a similar strategy to that which the County of Alameda used should be adopted, which is to release an RFQ encouraging car dealers to include the tax credit in their bids. It is important to note, that car dealers will only be able to claim the tax credit when they file their tax return, so they might view offering the tax credit as taking an initial loss. CSULB should also be aware and consistently check in with the IRS on the status of the phaseout of eligible vehicles. This can ensure that the tax credit will still be applicable to the vehicles being purchased[44].

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[44] *Source: http://evsmartfleets.com/wp-content/uploads/2017/04/Capturing-the-Federal-EV-Tax-Credit-for-Public-Fleets.pdf*

7.4.2 HEAVY-DUTY VEHICLES

Heavy duty vehicles, to this day, do not comprise a significant share of clean fuel vehicles available on the market. This has also made funding for such vehicles scarce. However, there are a few programs in the state of California and at the federal level that aim to encourage and accelerate the deployment and development of zero-emission heavy duty vehicles either through first-come first-served vouchers or competitive grants. It is recommended that CSULB seek out the funding opportunities from the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Program (HVIP) and the Carl Moyer Memorial Air Quality Standards Attainment Program. The following gives an overview of program details.

HYBRID AND ZERO-EMISSION TRUCK AND BUS VOUCHER INCENTIVE PROGRAM (HVIP)

The HVIP is a voucher incentive program that makes it more affordable for fleets to purchase clean trucks and buses. Fleets are given voucher discounts at the point of sale to be used for purchasing vehicles from HVIP-approved vendors and dealers. The program is administered by CARB and CALSTART. The HVIP website at californiahvip.org, provides a live status update on available funds. As of June 2018, total funding for all approved technologies is $121,315,688.

Eligible applicants include fleet and vehicle purchasers. Vendors and dealers are responsible for applying and working with HVIP to get their vehicles approved and available to fleet purchasers. Fleet and vehicle purchasers can choose which vendors or dealers they wish to purchase from an approved list. They will then work with the vendor of their choice on submitting the vouchers.

The voucher amount varies depending on the Gross Vehicle Weight Rating. The base voucher can range from $20,000 to $110,000. Heavier vehicles receive higher voucher amounts. Fleets located in disadvantaged communities can also receive a boost in the voucher amount. There is no minimum for fleet size, but there is a maximum limit of 200 vouchers.

Since the current clean vehicle market is lacking in zero-emission heavy-duty vehicles such as trucks and vans, these vouchers can help support the purchase of the vehicle types. These vouchers could also help cover costs for a zero-emission bus fleet, which could be important to consider once the contract with CSULB's bus fleet contractor has terminated. CSULB can apply for these vouchers at any time but should consider applying for vouchers in the first few years, since these vouchers are first-come first served and can help cover the costs for trucks and vans. Additionally, CARB encourages that HVIP funds be leveraged with other financial incentives. CSULB can combine this with other grant opportunities identified for heavy-duty vehicles.

CARL MOYER MEMORIAL AIR QUALITY STANDARDS ATTAINMENT PROGRAM

This program is administered by CARB, which provides grant funding for cleaner than required engines and equipment. The grants are overseen by the local air districts, so CSULB falls within the jurisdiction of the South Coast Air Quality Management District (SCAQMD). The program has been in effect since 1998 and continues to provide significant financial support for the deployment of clean fuel vehicles. SCAQMD's total available funding in 2018 was $25 million. Funding for the overall Carl Moyer Program is expected to double in January 2019 due to recent bill approvals by the California State Assembly.

Eligible applicants include any owner of an eligible heavy-duty on-road or off-road project. Projects must be in surplus of existing emission reduction regulations, so funded projects must not be required by any federal, state, or local rule or regulation. Typical eligible project types include:

- Replacement of an older vehicle with a cleaner vehicle or piece of equipment
- Repower of a newer, cleaner engine in place of a higher polluting engine
- Retrofit of an emission control system in an in-use engine, vehicle or piece of equipment
- Infrastructure implementation for alternative fuels or energy sources

The amount awarded by the grant depends on the project type. Each project type has special calculations limiting the amount awarded. The maximum grant amount awarded to any project is the lowest of three following calculations:

- The potential grant amount at the cost-effectiveness limit
    - The cost benefit of the project's emission reductions
- The potential grant amount based on maximum percentage of eligible cost
- The potential grant amount based on funding cap specified for each project category

Additionally, grants be leveraged with other grant awards, but the grantee must pay at least 15% of the total project cost from non-public sources.

Applications for the Carl Moyer Program open during the Spring and the deadline to submit is in the Summer, typically early June. Various workshops are available to assist applicants during the application period. The application packets consist of a general application form, application form for the specific project type, and any applicable supporting documents.

CSULB should use the Carl Moyer Program to help fund a variety projects and is a funding source that can be tapped into over several years, particularly since the Program's budget is expected to increase in January 2019. The Carl Moyer Program Guidelines is a good resource to refer to for more details on project types, eligibility criteria, and how to calculate funding award amounts. Furthermore, the Carl Moyer Program is also a likely source to help fund the transition of miscellaneous vehicles or equipment that tend to be difficult to finance.

7.4.3 INFRASTRUCTURE

The funding opportunities discussed in this section can apply to electric vehicle charging infrastructure and/or hydrogen fueling stations. CSULB should consider applying to the Carl Moyer Program and the Volkswagen Environmental Mitigation Trust.

CARL MOYER MEMORIAL AIR QUALITY STANDARDS ATTAINMENT PROGRAM

As discussed in the previous section, an eligible project type covered by the Carl Moyer Program includes infrastructure implementation for alternative fuels or energy sources. This essentially includes any type of infrastructure used to support alternative vehicle fueling, such as battery charging, hydrogen fuel, or compressed natural gas.

The eligible costs covered by the program include:

- Cost of design and engineering
- Cost of equipment
- Cost of installation directly related to the construction of the station
- Meter/data loggers
- On-site power generation system that fuels or powers covered sources

The amount awarded is calculated in the same manner as mentioned previously. The Carl Moyer Program is a valuable funding resource for CSULB that is flexible enough to cover a wide range of transportation projects to help the campus transition to a clean vehicle fleet.

VOLKSWAGEN ENVIRONMENTAL MITIGATION TRUST

The Volkswagen Environmental Mitigation Trust is the result of a settlement with Volkswagen for illegally cheating emission testing on their diesel vehicles. A $3 billion national trust has been established, with CARB being the lead agency for California's share of the pot. As of April 2018, CARB staff is developing a plan to help distribute the State's $423 million allocation over the course of 10 years. Staff has proposed five main project categories to fund, which includes a category for light-duty zero emission vehicle infrastructure. They have proposed setting aside $5 million for charging stations and $5 million for hydrogen fueling stations.

The potential award amounts to recipient seeking funding for charging stations has been proposed to be:

- 100 percent of the costs be covered for publicly accessible charging stations at government owned properties
- Up to 80 percent for public charging stations at privately owned properties
- Up to 60 percent for non-public charging stations at workplaces and multi-unit dwelling

The potential award amount for hydrogen fueling stations has been proposed to be up to 33 percent of the cost to purchase, install, and maintain a hydrogen fueling station.

No other information on how to apply has been provided as this is still under development. CSULB should consistently monitor the status of this program to stay up to date on when funds and program requirements are made available, as this will potentially come online towards the end of 2018 or beginning of 2019.

7.4.4 GENERAL GRANTS

As part of the research into funding opportunities, a financing program was identified that provides funding opportunities for a variety of projects that promote alternative fuels in transportation, known as the Alternative and Renewable Fuel and Vehicle Technology Program.

ALTERNATIVE AND RENEWABLE FUEL AND VEHICLE TECHNOLOGY PROGRAM

The California Energy Commission (CEC) oversees the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). Over the past 10 years, the program has provided "more than $757 million to 600 projects covering a broad spectrum of alternative fuels and technologies." The program has an annual budget of approximately $100 million to financially support a comprehensive package of projects that includes alternative fuel production, infrastructure, operations and maintenance, and other related needs. Prior to beginning of the fiscal year, the CEC releases the Investment Plan that determines the amount of funding available for project categories. Once the Plan is adopted, the CEC releases several grant funding opportunities throughout the fiscal year. There are several ways in which the CEC determines funding awards. Three of the most common ones are described below:

- Competitive Solicitation for Grants
  - This is the most common funding mechanism the Program utilizes and is usually used in funding larger projects. CEC staff carefully reviews and competitively scores these applications to ensure proposals adequately meet the solicitation purpose and goal. Therefore, applicants should be diligent and critical in their proposals to competitively vie for solicitations.
- Competitive Solicitation for Federal Cost-Sharing
  - This is similar to the competitive solicitation for grants, except proposals that can leverage the award with federal funds are scored more favorably.
- First-Come, First Served
  - This mechanism is more commonly used for vehicle incentives. Applicants that apply as soon as solicitations are released are likely to be awarded funding.

The funding opportunities offered by the program vary throughout the fiscal year. It is recommended that CSULB monitor on a regular basis what opportunities become available to ensure no relevant opportunities are missed. These opportunities are posted on the program's website, which can be accessed at energy.ca.gov/contracts.[45]

[45] *Source:http://docketpublic.energy.ca.gov/PublicDocuments/17-ALT-01/TN222123_20180110T093146_20182019_Investment_Plan_Update_for_the_Alternative_and_Renewab.pdf*

7.5 TRANSITION PLAN

7.5.1 TWELVE-YEAR PLAN - PATH TO 2030

CSULB is in the process of developing guidelines for procuring clean vehicles for their campus fleet. This is an important step into identifying what can be done currently to reduce greenhouse gas emission from the university's vehicle fleet. In the draft guidelines, campus departments must demonstrate that the vehicle they are seeking to procure supports CSULB's policies in promoting alternative fuels and reducing greenhouse gas emissions. The guidelines have also identified that 10% of all light-duty fleet purchases be zero emissions vehicles by Fiscal Year 2017/18 and increase by 5 percent every year thereafter. The school has prioritized what type of vehicle should receive priority when purchasing. This priority is as follows:

- **Priority 1:** Pure zero emissions vehicles (ZEV) including electric low-speed vehicles
- **Priority 2:** Plug-in Hybrid ZEVs
- **Priority 3:** Hybrid-Electric Vehicles
- **Priority 4:** Internal combustion and flex fuel vehicles meeting MPG requirements

As part of the research conducted for the CEMP, the project team found vehicles that fit into the Priority 1 and 2 categories as well as funding opportunities to help with purchasing these vehicles.

The draft guidelines also developed standards on which campus fleet vehicles are eligible to be replaced in the near term. These standards are essentially based on either the age or mileage of the vehicle. These standards are described in the table below:

Table 54: Vehicle Replacement Standards

Vehicle type	Age	Mileage
Authorized emergency vehicles as defined in Section 165 of the Vehicle ode, that are equipped with emergency lamps or lights described in Section 2252 of the Vehicle code.	7	100,000
Sedans, station wagons, vans and light duty trucks or vehicles having a GVWR of 8500 pounds or less	8	120,000
Heavy Duty trucks of vehicles (Class 3 or under) having a GVWR of 8501 pounds of greater	9	150,000
4-wheel drive vehicles	9	150,000

Based on these draft guidelines, CSULB can focus in the near-term on transitioning light-duty vehicles first, especially since there is an existing and growing market of light-duty ZEVs. The availability of funding for these vehicle types can also make the transition easier. Rebates and tax credits, such as those discussed earlier in the report, are available every calendar year. CSULB should aim to secure these funds at the beginning of every year before funds become exhausted towards the end of the calendar year.

Other potential strategies to reduce emissions in the current term is to decrease vehicles miles travel and to right-size the vehicle fleet. Decreasing vehicles miles travel ensures vehicles are being used as efficiently as possible for their intended purposes. Right-sizing the fleet also ensures that excess vehicles are not kept in the fleet and vehicles that are not heavily used can be retired.

TRANSITION STUDIES

Several studies were performed using the "Road to 2030 Vehicle Fleet Analysis Tool".

First, a "bounded study" was performed to analyze the range of potential based on use and vehicle efficiency factors should all non-electric vehicles be electrified.

Additional analysis ("Rank-based") was performed to study vehicles being transitioned in three phases using the "Replacement Priority" (1-3).

An "ambitious" replacement plan expands upon rank-based analysis by transitioning another five vehicles in each phase based on fuel consumption.

BOUNDED STUDIES

A study of the "best-case scenario" was completed to develop an understanding of potential environmental benefit and its cost. Two variables bound the emission reduction of fleet projects: replacement vehicle efficiency and usage.

Replacement vehicle efficiency is the ratio of existing fuel efficiency to replacement fuel efficiency. For example, if a police Ford Explorer has a fuel efficiency of 20 MPG and its hybrid replacement has a fuel efficiency of 100 MPGe, the replacement vehicle efficiency would be 20/100 = 0.2.

The upper bound estimate of emissions takes all of the electricity from the transitioned vehicles and uses an electricity emissions factor based on the local Southern California grid. This is realistic but does not take into consideration potential gained efficiencies during the transition or sourcing electricity from on-site solar electricity generation.

As an approximate lower bound, an efficiency ratio of 20% has been estimated. This means that the replacement energy required by the replacement vehicle will be 20% less than that of the existing vehicle energy use (from fossil fuels). The efficiency ratio was estimated by comparing a representative fleet vehicle (2016 Ford Explorer) with an analogous hybrid vehicle model. Overall, this may be an overestimation because some replacements, such as lighting towers, will potentially not have any additional fuel efficiency because they are performing the same task.

Emissions were reduced from 318 MT CO_2 per year to 289 MT and 58 MT CO_2 per year for upper bound and lower bound studies, respectively. That is to say, if using the same amount of energy in the form of electricity, the university is expected to see a reduction of only 58 MT CO_2 per year (9% overall) at an estimated cost of $3M. Conversely, with efficient use-changes, there is a potential reduction of approximately 260 MT CO_2 per year (82% overall). This would come at a cost of approximately $12,000 for each MT CO2 reduced per year - a significantly higher price than the market value of carbon offsets.

Main takeaways from this analysis are: the source of replacement energy (i.e. electric grid versus on-site generation) as well as user behavior (including selecting energy efficient replacements) are sensitive factors for reaching a desirable outcome. A desirable outcome may still come at a higher cost than purchasing offsets.

Lower bound expected emission assumptions are applied for the remaining studies.

7.5.2 REPLACEMENT RANKED TRANSITION

A transition scenario using the replacement priority established by CSULB fleet manager. This scenario reaches approximately 55% expected GHG reduction at an estimated cost of replacing vehicles ranging from $100k to $180k per year. A summary table and plots are provided below, and the full scenario model is provided as an appendix.

Table 55: Potential Transition Scenario Output

				Consumption		Reduction		GHG Emissions	GHG Reduction from Current
	Start	End	Years	Gas	Diesel	Gas	Diesel		
	-	-	-	gal/yr	gal/yr	gal/yr	gal/yr	MT CO2/yr	%
Current		2017	1	28,467	6,696	--	--	318	--
Phase 1	2018	2023	6	23,755	6,654	4,712	42	278	-13%
Phase 2	2024	2028	5	13,837	6,614	9,918	40	195	-39%
Phase 3	2029	2030	2	7,691	6,523	6,146	91	142	-55%

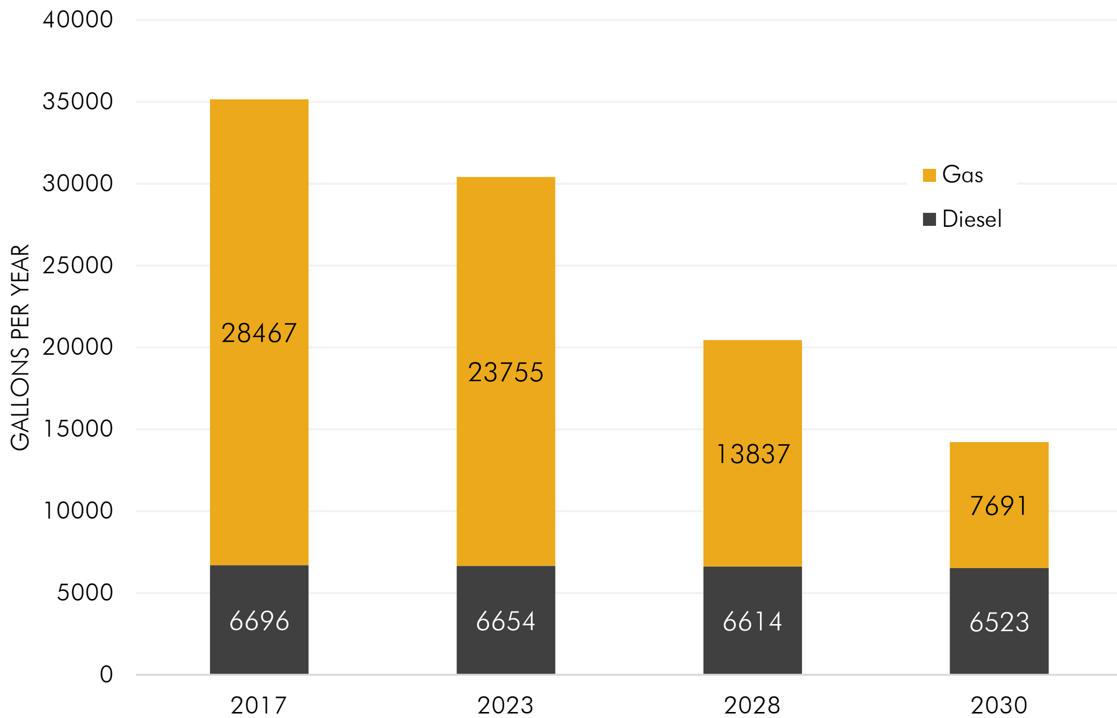

Figure 68: Total Fuel Consumption

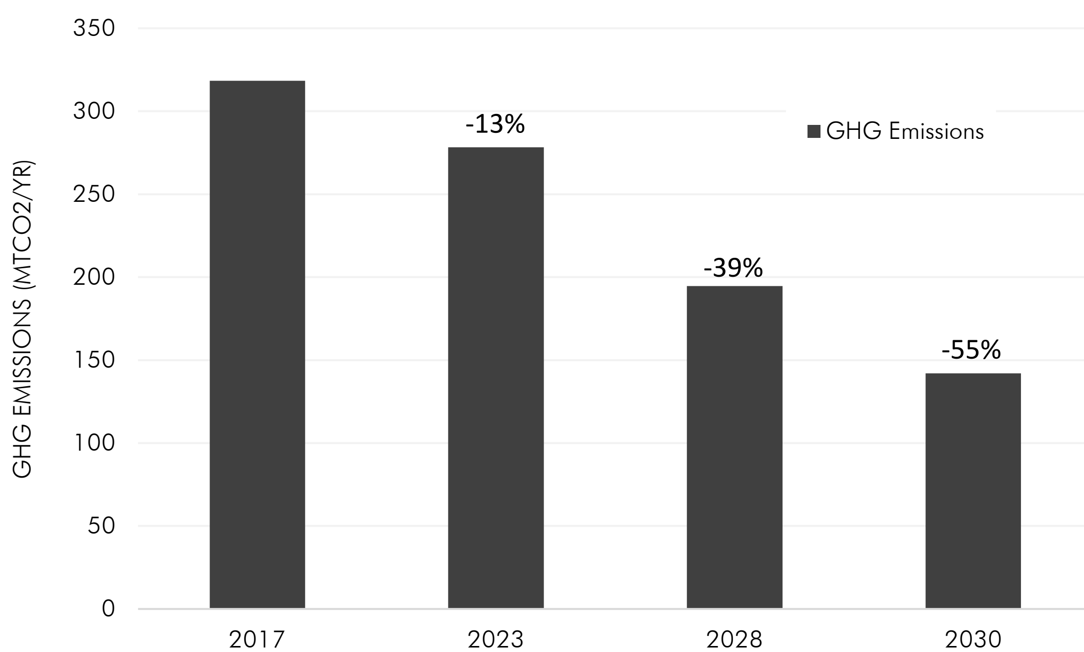

Figure 69: Total GHG Emissions

7.5.3 AMBITIOUS VEHICLE TRANSITION

An “aggressive” transition scenario was developed by expanding Section 5.2.3 by transitioning an additional five of the worst polluting vehicles in each Phase.

This scenario reaches nearly two-thirds expected GHG reduction at an estimated cost of replacing vehicles ranging from $160k to $205k/year. These additional 15 replacements come at a cost of approximately $200k overall.

This result reflects the importance of selecting the high-impact vehicles for replacement to maximize value.

A summary table and plots are provided below, and the full scenario model is provided as an appendix.

Table 56: Ambitious Transition Scenario Output

				Consumption		Reduction		GHG Emissions	GHG Reduction from Current
	Start	End	Years	Gas	Diesel	Gas	Diesel		
	-	-	-	gal/yr	gal/yr	gal/yr	gal/yr	MT CO2/yr	%
Current		2017	1	28,467	6,696	--	--	318	--
Phase 1	2018	2023	6	16,873	3,636	11,594	3,060	213	-33%
Phase 2	2024	2028	5	7,319	2,972	9,554	664	143	-55%
Phase 3	2029	2030	2	4,215	1,811	3,104	1,161	112	-65%

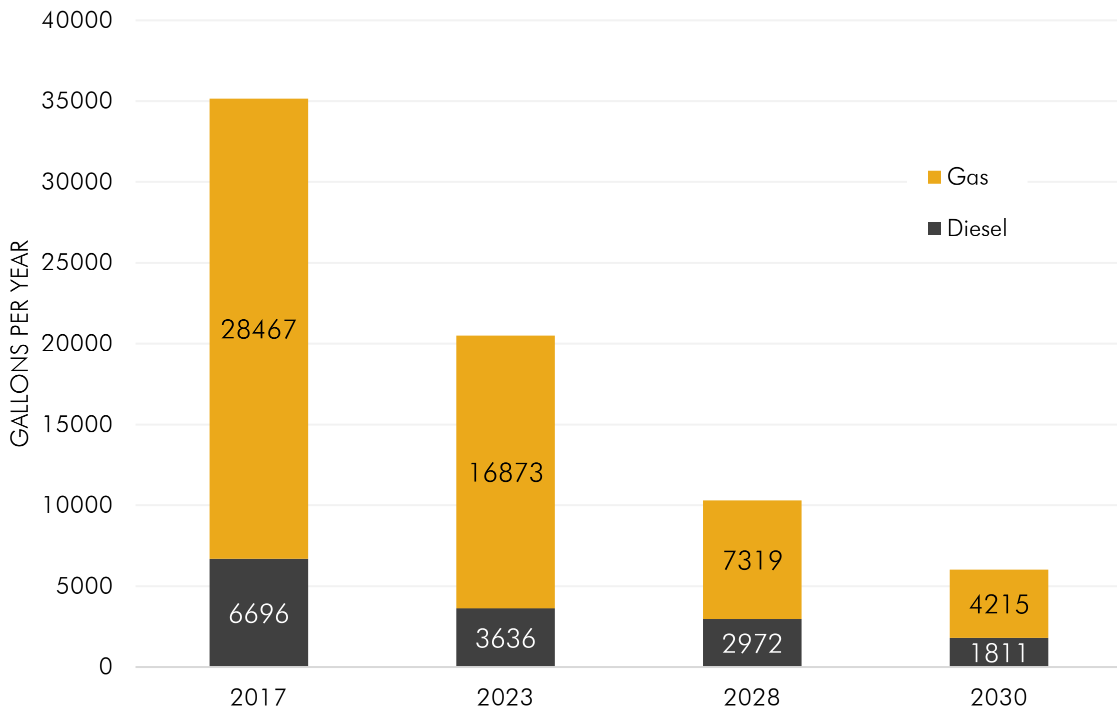

Figure 70: Total Fuel Consumption – Ambitious Scenario

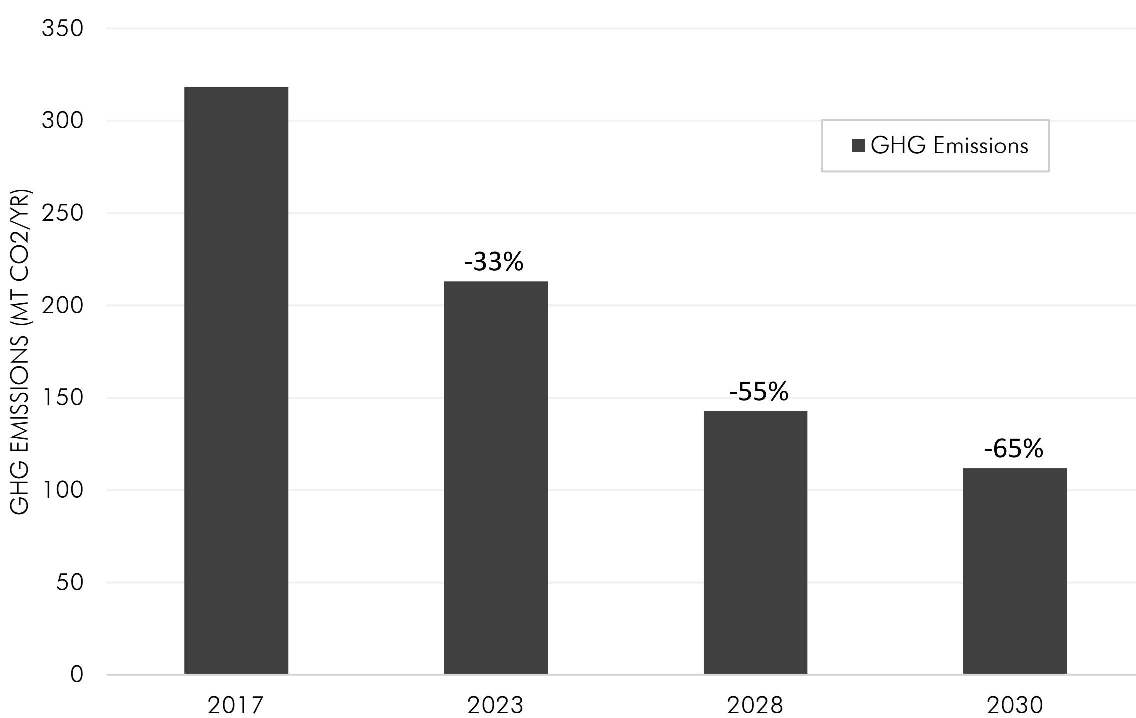

Figure 71: Total GHG Emissions – Ambitious Scenario

7.6 CONCLUSIONS

An evaluation of the California State University of Long Beach (CSULB) vehicle and shuttle fleet has been completed as part the University Climate Action Plan (CAP) to reach carbon neutrality by 2030. From 2017 data, there is potential for approximately 318 MT CO2 per year reduction via fleet transition. Replacement vehicles will likely not be the most cost-effective method to reduce emissions on campus. Research and analysis has led to the following recommendations and suggested best practices.

To reach desired emissions, tiered targets should be set as percentages of the final goal: carbon neutral by 2030. The project team has broken down the remaining time leading up to 2030 into three phases. Goals and projections

8. CARBON OFFSETS

The purpose of this chapter is to provide information and guidance to CSULB in utilizing carbon offsets as part of its strategy to reach carbon neutrality. This includes an overview of the key concepts in carbon offsetting, the requirements offsets must meet to qualify under the Second Nature commitment, recommendations for setting a carbon offset policy, and an overview of current market rates for voluntary carbon offsets.

The topic of carbon offsets can quickly become complicated; however, it is not necessary to understand all of the details of carbon markets to develop a robust offset program. Rather CSULB simply needs to understand the core characteristics for quality offsets, the most reputable suppliers, and the mechanisms for acquiring credits. This report aims to clearly and concisely communicate the information necessary for CSULB staff to make utilize offsets to meets carbon neutrality goals.

More detailed information on carbon offsets, policies, and strategies can be found in Second Nature's Carbon Markets and Offsets Guidance paper. The resource was developed specifically for commitment signatories and address the specific needs of universities.

8.1 CARBON OFFSET BACKGROUND INFORMATION

OFFSET DEFINITION

Carbon offsets play an important role in the rapid reduction of global greenhouse gas emissions. Many entities, like CSULB, aim to reach carbon neutrality, but cannot feasibly reduce 100% of their emissions. Carbon offsets provide a mechanism for entities to achieve credit for reductions that are made through projects outside of their GHG reporting boundary and thus achieve carbon neutrality. It should be noted at the outset that CSULB will be purchasing carbon offsets on the voluntary market, not the regulatory market. In other words, there is no legal authority requiring CSULB to purchase offsets. Thus, the offsets that CSULB will be to achieve an internally set goal, not a regulatory requirement.

As defined by the David Suzuki foundation:

"A carbon offset is a credit for greenhouse gas reductions achieved by one party that can be purchased and used to compensate (offset) the emissions of another party. Carbon offsets are typically measured in tonnes of CO2-equivalents (or CO2e) and are bought and sold through a number of international brokers, online retailers and trading platforms."[46]

It is important to note that a fundamental element of an offset is that the GHG reductions occur outside of the entities own boundary. Thus, any energy efficiency, renewable energy, or other campus projects used to reduce CSULB's own emissions cannot also be used as offsets.

[46] David Suzuki Foundation (2017). Carbon Offsets, < https://davidsuzuki.org/what-you-can-do/carbon-offsets/>.

The voluntary offset market is ever evolving, and offsets vary in type and quality. So beyond just a basic understanding of the definition, it is important that CSULB puts in place a policy to ensure the quality and credibility of any offsets it uses to meet its goals.

VOLUNTARY OFFSETS

As shown in the scenario analysis section of this report, CSULB will most likely need to purchase a large number of offsets to achieve its carbon neutrality goal- estimating the cost of offsets is thus fundamental to understanding the full financial costs of carbon neutrality.

The voluntary offset market however is highly fluctuating. As with all markets cost is determined by a combination of supply, demand, and policy signals. However, within the offset market place, both demand and policy signals can change rapidly and without warning which adds to future price uncertainty.

With an understanding of the above caveats, Ecosystem Marketplace published a report in May 2017 that provides the best overview available on voluntary carbon offset costs. The report, Unlocking Potential: State of the Voluntary Carbon Markets 2017, reviews all voluntary carbon offset transactions in 2017 and provides a comparison of the cost by offset type, location, and verifying authority. The authors found that offset prices varied from .50/MT CO2e to $50/MT CO2e. The average price across all transactions was $3/MT CO2e.

As described in the sections below, the quality of offsets can vary and to meet the Second Nature requirement, CSULB must purchase offset that meet high quality standards (see below). To ensure this, we recommend CSULB purchase offsets certified through a recognized standard. Ecosystem Marketplace also reviewed the price of certified offsets in their report and found that the price ranged from $1.6/MT CO2e to $4.6/MT CO2e. Given the fluctuating nature of the voluntary offset market, we recommend assuming offsets would cost CSULB $4.6/MT CO2e if they were purchased in 2018 and that this rate will increase 3% per year.

SECOND NATURE GUIDANCE ON OFFSETS

As a signatory to the Second Nature Climate Commitment, it is important that CSULB's offset strategy meets Second Nature's requirements. All of the recommendations in this report are consistent with signatory standards. This section, provides a concise overview of Second Nature's rules for using offsets to support carbon neutrality. A full report on these requirements is available in Second Nature's document *Carbon Markets and Offsets Guidance*[47].

Second Nature allows universities to use offsets to help achieve carbon neutrality goals. The organization does not set limits on the percentage of emissions that universities can offset, nor does it require that offsets be purchased from specific offset providers. However, to qualify all offsets must meet the standards listed below. The one exception to this is that 30% of the university's emissions can be offset by developing projects following the guidance of The Offset Network's peer review process. More about The Offset Network and the peer review process follows the list of requirements.

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[47] Second Nature (2015). Carbon Markets and Offsets Guidance , http://secondnature.org/wp-content/uploads/Carbon-Markets-and-Offsets-Guidance-1.pdf.

To be eligible carbon offsets must meet the following standards. This list is taken directly from Second Nature's *Carbon Markets and Offsets Guidance*[47]

1. Offset projects are real and emissions reductions are additional: Projects result in actual reductions of GHG emissions and that would not have otherwise occurred under a reasonable and realistic business-as-usual scenario.
2. Offset projects are transparent: Project details (including project type, location, developer, duration, standard employed, etc.) are known to the institution and communicated to stakeholders in a transparent way to help ensure validity and further the goal of education on climate disruption and sustainability.
3. Emissions reductions are measurable: Projects result in measurable reductions of GHG emissions.
4. Emissions reductions are permanent: Projects result in permanent reductions of GHG emissions.
5. Emissions reductions are verified: Projects result in reductions of GHG emissions that have been verified by an independent third-party auditor.
6. Offset projects are synchronous: Projects result in reductions of GHG emissions that take place during a distinct period of time that is reasonably close to the period of time during which the GHG emissions that are being offset took place.
7. Offset projects account for leakage: Projects take into account any increases in direct or indirect GHG emissions that result from the project activity.
8. Offset projects include Co-Benefits: Projects should consider educational, social, economic development, and resiliency benefits of an offset.
9. Credits are Enforceable: It is important that purchase of offsets be backed up by enforceable contracts.
10. Credits are registered: Credits produced from project activities are registered with a well-regarded registry that has been evaluated using the accompanying criteria.
11. Credits are not double-counted: Credits produced from project activities are not double counted or counted and claimed by any other party.
12. Credits are retired: Credits are retired before they are claimed to offset an institution's annual greenhouse gas inventory, or a portion thereof.

While Second Nature does not require that offsets come from specific providers, to meet the above standards CSULB will need to purchase from a reputable and recognized outlet. More information on offset providers is in the *Offset Suppliers* section of this report.

EXCEPTION FOR PEER-REVIEWED OFFSETS

Second nature makes one exception to meeting the strict offset standards above. Thirty percent of a university's emissions can be offset utilizing the peer-review method developed by The Offset Network. The Offset Network grew out of Second Nature and is a voluntary group of colleges and universities committed to climate leadership who are working together minimizing the costs and burdens of offset development for educational institutions while maintaining the integrity of offset projects used to meet Second Nature's commitment.

The purpose of the peer-review option is to reduce the cost and burden for universities to develop their own offset projects. Instead of paying for third-party verification, projects can be verified through third-party review process set forth by The Offset Network. It is important to note that although developing offsets through this process is easier and less expensive then developing third-party offsets that could be sold on the open market, it still requires significant expertise and resources. Purchasing offsets will always be easier and likely less expensive than developing offsets. However, there are valuable research and educational co-benefits from developing offset projects. The Offset Network's peer-review process provides a means for universities to realize these additional benefits without the burden of full third-party verification.

The opportunities to develop peer-reviewed offsets will be rare, however, it worth including this as an option in CSULB's offset policy as these projects present an opportunity for additional benefits and an opportunity for cross-campus collaboration. The best way to identify potential opportunities is to reach out to the wider campus community and develop partnerships with students, researchers and staff that bring mutual benefit. For example, a study abroad program may be interested in developing a forestry offset project in its country of study. Students would gain education, researchers would gain expertise and the campus could utilize the credits to meet neutrality goals.

It should be noted that peer-reviewed offsets cannot be sold.

8.2 PURCHASING OFFSET CREDITS

There are three ways that CSULB can obtain offset credits. It is possible to use one or a combination of these options.

1. **Purchase:** Purchasing offsets from a retail or wholesale provider,
2. **Invest:** Invest in an offset project underdevelopment,
3. **Develop:** Initiate and develop offset projects.

Each of these options has its own benefits and challenges. To be eligible under the Second Nature requirement all offsets whether purchased, invested in, or developed must meet the requirements spelled out in the next section of this report. In general, purchasing offsets is the simplest and likely most cost-effective way to acquire offsets. However, it is also worth investigating opportunities to invest in or develop offset projects as a part of the offset portfolio to create additional educational benefits and possibly revenue. Revenue would come, if the organization developed an offset project that created more carbon reductions than the campus needed to reduce its own emissions and it sold the additional credits.

Assessing opportunities for offset development is beyond the scope of this report and the cost and benefits of offsets varies widely, such assessment is best done on a case by case basis.

Investing in and developing offsets requires significant expertise and the greatest benefit would likely come through a cross-campus collaboration aimed at meeting campus carbon neutrality goals, providing educational opportunity and supporting campus research objectives.

A detailed description on offset requirements and options for purchasing offsets is in the following sections.

8.3 DEVELOPING AN OFFSET POLICY

This section provides a short summary of these components and then summarizes key recommendations.

Establishing an offset policy, will:

1. Ensure that the offsets used to meet neutrality goals are of a high standard,
2. Purchases are cost effective, while also maximizing other campus benefits,

The benefits and validity of the offset purchases are understood and accepted as an important part of the carbon reduction process. There are four components to a sound offset policy.

1. **Establish a Carbon Management Hierarchy**
   The generally accepted best practice in carbon neutrality planning is to implement all feasible internal GHG mitigation strategies first and to use offsets to reduce remaining emissions. This is known as the carbon management hierarchy. Following this hierarchy will ensure that CSULB takes all the action it can to reduce its own emissions and will also ensure that the campus maximizes the co-benefits from carbon reduction projects.
2. **Determine Make-up of Offset Portfolio**
   As discussed in the previous section CSULB can acquire offsets through purchase, investing or development. It is likely that the majority of offsets will come from purchases. However, there could also be opportunities for investment or development of offset projects. Investing in offset projects is difficult and is not an avenue that is recommended pursuing unless an opportunity presents itself. However, it is recommended reaching out to the larger campus community regarding the peer-reviewed offset development. CSULB could set a target that a percentage of its offsets come from educational campus developed projects (e.g. 10%) or could simply investigate the level of opportunity available for such projects.
3. **Determine Sources for Offset Purchases**
   Purchased offsets will be a part of CSULB's portfolio and a reputable supplier is critical to ensuring offset quality. The offset market is continually changing and assuming CSULB makes the majority of its purchases in ten to twelve years there will be many options that do not exist today. The most important step in ensuring the quality of offsets purchased is to follow the guidelines set forward by Second Nature. Second, although the market is evolving there are organizations who set the gold standard, have been in the game a long time and will likely continue to be leaders in the future. Purchasing offsets through a widely-respected and long-standing organization will help to ensure the quality of the offset. Most notably, the Climate Action Reserve, sets standards for both voluntary and regulatory offset protocols. The reserve hosts an Offsets Marketplace on its website. This resource provides a listing of offset brokers (for larger purchases), retailers and wholesalers that sell offsets that will meet all of the criteria set forth by second nature. Other high-quality offset registries and verifiers include, the Verified Carbon Standard, Gold Standard and the American Carbon Registry.
4. Communicate the Benefit of Offsets to Stakeholders
   The final component of an offset policy is to establish a strong communication protocol that describes both the high standards of the offsets CSULB uses and the wide range of benefits that the offsets create. Offsets are sometimes derided as a way to "buy down" carbon

emissions. When carefully purchased, however, offsets are a powerful tool to reduce carbon emissions cost effectively while increasing social and community benefits across the globe.

8.4 STRATEGIC RECOMMENDATIONS

Offsetting will be necessary for CSULB to meet its carbon neutrality goals. The SAVI tool can help to determine the most cost-effective time and total scale for offset purchases. However, it is also likely that CSULB may develop offset projects that are not merely cost effective, but also bring educational and other benefits to the campus. Ultimately combining cost effective offset purchases from a reputable supplier with a few select campus developed projects will lead to an offset portfolio that is cost effective and maximizes benefit to the community.

The above section summarizes the key components of an offset policy. CSULB should work with key campus stakeholders to finalize the offset policy, to begin the conversation our strategic recommendations are as follows:

1. Follow a carbon management hierarchy that invests in internal campus mitigation projects first.
2. Investigate opportunities to develop offset projects using The Carbon Network's peer-review process.
3. Purchase offsets from a reputable and recognized supplier, ideally through the Climate Action Reserve's Offset Marketplace.
4. Clearly community both the criteria for offset selection and the benefits (local and globally) that the offset purchases create.

9. FUNDING AND FINANCING

9.1 ENERGY PROJECT FUNDING AND FINANCING

The purpose of this section is to identify the primary methods available to CSULB to fund capital Energy Efficiency project investments identified through the CEMP. The Renewable Energy (RE) portion of the CEMP relies on Power Purchase Agreements (PPA) for all scenarios, therefore, there is no associated campus capital cost. PPAs are discussed in detail in the RE Section, 7.1. Investment and funding for Clean Transportation and Carbon Offsets are discussed in their respective sections of this report.

To provide some context, the overall level of investment for the Energy Efficiency (EE) portion of the CEMP identified technical potential between $29M and $37M worth of projects for the most likely scenarios ("Business as Usual (BAU)" and "Increased Investment") through 2035 and 2030 respectively, without TES. Including the TES costs into either scenario would increase the funding needs by approximately another $15.5M.

Default years of project implementation are selected for all projects. The Increased Investment scenario includes both investing more money, and doing it sooner, to accelerate energy savings benefits. The option to accelerate investment further is available to increase the pace of project implementation in future scenarios the campus may develop as well, subject to other implementation constraints.

A comprehensive list of financing approaches available to CSULB was developed and is included in Section 10.3. The summary table documents current approaches employed by the campus, potential approaches that are not currently in use, and for completeness, a list of approaches that often come up, but are not viable options for one or more reasons. The table provides information on the suitability of each approach for the campus as well CSULB experience with it, if any. Dependencies, limitations and impacts are also identified. When available, key terms such as interest rate, loan term and amounts available are also provided. Finally, the options are qualitatively ranked against each other on a scale from A to D, with A rankings being the most attractive and appropriate options.

The selection, prioritization and timing of EE projects were explored within the Scenario Analysis Tool. The current and potential future financing approaches informed the options and parameters in the Tool, enabling the University to evaluate among other things, the impact of financing choices on the potential scenarios. Now that potential strategies have been identified, the next step is for the campus to decide which to pursue.

In all scenarios, a significant volume of EE projects play a key role. The annual implementation pace of energy efficiency under the BAU Scenario would be consistent with current annual dollar volume of what the campus has accomplished through the UC/CSU/IOU Energy Efficiency Partnership. However, the accelerated pace of the Increased Investment Scenario represents approximately two times the current annual dollar volume of projects implemented, requiring $15M additional funding over a shorter period than the BAU case. Utility incentives could reduce need by $2M to $2.3M in the

BAU and Increased Investment scenarios, respectively. The inclusion of TES accounts for a significant amount of unfunded investment need (approximately $15.5M). To fund these projects, we recommend the following sources, which is a mix of currently used and new approaches:

- **Annual Energy Projects Budget** – Continue to use the existing process to fund $1M-$1.5M in projects per year through operating funds
- **Deferred Maintenance (DM) and Capital Renewal** – Expand use of DM funds for energy projects by finding synergies with projects on the DM list, target approximately $1M per year for Increased Investment or to supplement Annual Energy Projects Budget if needed
- **UC/CSU/Utility Energy Efficiency Partnership** – Continue to pursue incentives through the UC/CSU/Utility Energy Efficiency Partnership for all eligible projects
- **On-Bill Financing (OBF)** – For incentive eligible projects, consider up to $1M of 0% OBF loans from Southern California Edison (SCE). This option will have no interest costs, but there are soft costs and delays associated with additional loan paperwork and process, so it may simpler to roll these projects into the CSU Systemwide Internal Central Bank pool.
- **CSU Systemwide Internal Central Bank** – For the balance of projects not covered through the above methods, the campus should pursue the new CSU internal central bank facility. CSUCO Energy and Sustainability encourages this approach. The low rate, amount available and internal loan nature are advantages to the campus. As this is a new facility, there would be some learning curve as new processes and agreements may need to be developed.

9.2 NEXT STEPS

Once the implementation scenario has been decided, the campus needs to undertake a straightforward budgeting exercise to match annual project volume successively to the available funding sources as discussed in the previous section. We recommend starting by allocating projects to the most restrictive funding sources. For example, Deferred Maintenance (DM) funding considers energy savings as just one of several factors. Identifying those projects that meet DM requirements first, and allocating them to the DM pool, will enable the campus to maximize the effectiveness of that budget.

Next, if Utility OBF is going to be used, we recommend the campus identify the set of projects that meet that program's eligibility and payback requirements and allocate up to the maximum amount available ($1M). Within the OBF eligible pool, shorter payback projects should be allocated first, which will enable the loan funds to be paid back sooner and redeployed for additional projects. OBF can act like a revolving loan pool, with a maximum of $1M outstanding at any time.

The remaining dollar amount would be funded via the Annual Energy Budget and Internal Central Bank. The campus should engage the CSU Chancellor's office to arrange the Central Bank portion of the funding, using the Annual Energy Budget, Partnership Incentives, and possibly the DM funded projects to provide the "campus match" portion. As the following figure illustrates, the steps can be done somewhat in parallel, with some iteration within and between steps.

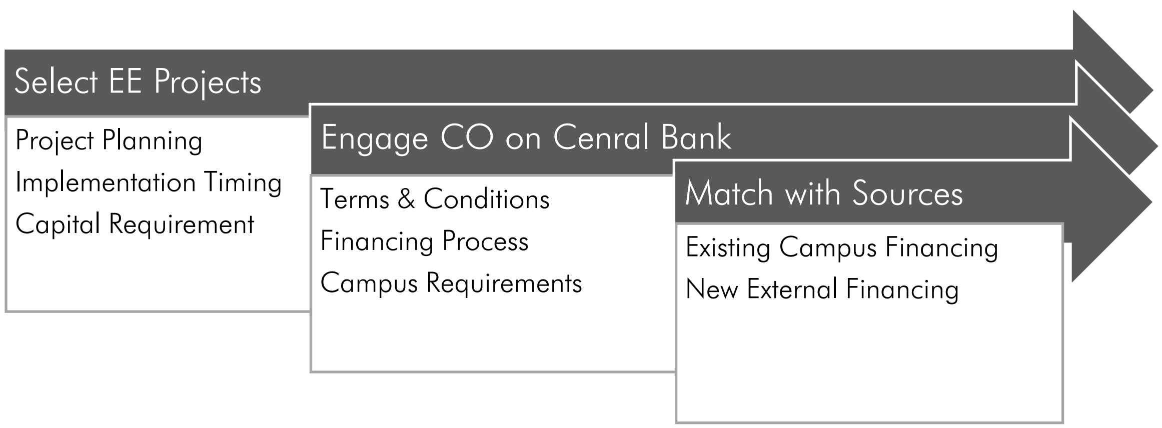

Figure 72: CSULB External Financing Process

9.3 FINANCING OPTIONS MATRIX

SUMMARY OF CURRENT APPROACHES

The approaches in below under the category "Current Financing Approaches" available to the campus at this time, although the campus may or may not be taking advantage of all approaches or have experience with them. A discussion of limitations and impacts are provided, and over time, the limitations may become less of a barrier. A qualitative ranking is assigned to each approach, with "A" being the most suitable and higher priority, then decreasing by grade.

SUMMARY OF POTENTIAL FUTURE APPROACHES

The approaches in below under the category "Future Potential Financing Approaches" are less concrete at present than those options listed in the "Current" section, or have some remaining work to be set up for campus use; however, there are viable options among them that bear monitoring and/or action to bring into use. A qualitative ranking is assigned to each approach, with "A" being the most suitable and higher priority, then decreasing by grade.

SUMMARY OF NON-APPLICABLE APPROACHES

The approaches in this section are not applicable to CEMP at present, but are included in Appendix E for completeness as questions about their applicability often come up. Some of these approaches could move into the "Potential" category if, for example, eligibility rules change.

CURRENT FINANCING APPROACHES

The following clean energy financing approaches that CSULB is currently utilizing to fund GHG emissions reduction projects on campus.

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
Campus Discretionary Operating Funds	Business as usual practice, have been using for ongoing program out of general utilities fund. Potential source for Green Revolving Fund seed capital.	Annual energy project list presented to CFO in early June for the following Fiscal Year. Show reduction in utility operating expense and position as low-cost way to meet goal Clean Energy Goal to make case to increase this amount.	Historically \$800K-\$1.5M per year over last ~10 yrs. Limited by operating fund availability and other uses.	Cash	Approx. \$1.0M per year, potential for more	A
Campus Deferred Maintenance (DM) and Capital Renewal.	Could be used for energy improvements related to other maintenance and renewal projects. Energy office hasn't pursued this in the past since they have own energy project budget (see Campus Discretionary Operating Funds). Campus maintains a running list of DM projects.	List reviewed annually and prioritized primarily based on safety, access, and academic enhancement. Energy/sustainability criteria somewhere in the middle.	Competition with other uses of limited funds. Would need to address other priority issues in addition to energy.	Cash	Approx. \$1.0M per year	A

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
Self-Support Auxiliaries[48] – Operating, Capital and SRB funding	These "Self-Support" (formerly "non-state") units have their own processes for budgeting operating funds and are part of the university Capital Plan. Can use their own reserves, operating budgets, and SRBs to do projects. Mainly use SRB.	Operating funds governed by business unit decisions. Capital must be part of Capital Plan. SRB also in Capital Plan, but can be amended easily.	Varies depending on Unit, for that Unit only. Central plant type projects could be prorated and allocated to auxiliary proportional to their benefit	Varies by unit	Varies by unit.	A
UC/CSU Partnership Program (Southern California Edison (SCE) incentives)	Combine with any other funding mechanism for eligible EE projects. Not a standalone funding source.	Must meet Partnership program requirements: program applications, utility review, payment terms, etc.	Based on approved energy savings, up to a maximum percentage of eligible project cost. Applies to electric savings only.	$0.24/kWh	Unlimited to date – based on eligible projects	A
PPA/Solar Lease	Statewide Solar Energy Phase IV. Specifically called out as an option in Systemwide Capital Outlay Program. Current 4.7MW solar project is PPA.		No campus debt impact.	Cost is approx. $0.13/kWh for 20 yrs. See PPA section of main report for detail.		A
Systemwide Revenue Bond (SRB)	Available for anything with an income stream, or repayment source. Has not been used for standalone energy projects, but common for other projects.	Needs to be presented to Board of Trustees (BOT), can be amended over time, not constrained by capital planning	High demand. Systemwide and campus debt to income ratios apply, though currently not a constraint.[49] Could be funded by directing energy cost savings to bond rather than reducing energy spend.	2017 offering ranged from 3%-5% by term; tax-exempt; Use 4%; 28 years	Based on repayment stream	B

[48] Includes Housing and Residential Life, 49er Shops (concessions), CSULB Foundation, Parking and Transportation, and Associated Students
[49] Note: for all debt financing, debt ratio assigned from CSUCO and additional debt would require review approval by DAF (CSULB Division of Administration and Finance)

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
Capital Project Budgets, State Funds – GO Bonds – General Funds (State)	Five Year Facilities Renewal and Capital Improvement Plan. State provided funding. Either straight general funds or GO bond for which State pays debt service. Currently funding a Micro-Biology HVAC Retrofit.	Capital Planning Process	High demand, limited availability.	N/A – costs covered by State	Request Per Capital Plan	B
Energy Services Agreement	PPA structure applied to energy efficiency/demand. Current AMS/Tesla Battery deal is essentially an ESA (12 years, shared savings beyond threshold)		No campus debt impact.	12 years, shared savings beyond threshold		C

POTENTIAL FUTURE FINANCING APPROACHES

The following approaches are less concrete at present than those options presented above, however, they bear watching, particularly Specific Grants that align with the CEMP mission as they may become available in the near term.

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
CSU Systemwide Internal Central Bank	CSUCO reported that this facility is ready to go and would like to see campuses use for EE projects. Funded by CSU Financial Reserves	New review and approval process.	New approach, so some ramp up expected. Internal loan so should not impact campus debt capacity.	Estimated 2.5% Term matched to asset	TBD	A

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
CA I-Bank CLEEN SWEEP	Municipal market rate loan based on type of asset financed.		Debt ratios apply	Ave ~3.5% in 2017. Market rate EUL or 30yrs 1% origination 0.3% annual servicing	$30M	A
On-Bill Financing – SCE program where SCE loans money for EE projects with repayment through utility bill	Other CSUs have used (Pomona, SLO, Bakersfield, Fullerton, San Marcos)	Must meet Partnership program requirements (for incentive) and SCE OBF program requirements for loan	Debt ratios apply, limited funding	0% rate Term based on savings payback (assume 10yr)	$1M per government customer	A
California Energy Commission (CEC) Loans Available to Public College or University (except community colleges).	Rolling funding authorization from State that is fairly popular and available on first come first served basis, sometimes fully subscribed.	Projects with proven energy and/or demand cost savings are eligible	17-year max simple payback. Loan repaid from energy savings within a max of 20 years. $3M per applicant or less subject to availability. Total pool of $6M/yr historically available. Debt ratios apply	1% rate Term based on savings payback (must be less than EUL of equipment assume 10 year)	Sep 2017 notice of $7M available in FY2017/18;	B
CEOP – Clean Energy Optimization Pilot	Combine with any other funding mechanism for eligible projects. Not a standalone funding source. New campus-level meter, year-over-year, carbon reduction incentive program in development with SCE, UC and CPUC.	Needs regulatory approval.	May be two or more years from being operational as a pilot program.	Estimated incentive on the order of UC/CSU Partnership incentive, but more flexible, applied to carbon savings related to reduced power use	TBD	B

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
Green Revolving Loan Fund	Campus explored in climate action plan, not currently operating. Could use Energy Office funds as seed capital. Some universities fund with cash reserves that would otherwise be invested, or Alumni Foundation funds.[50]	Need to establish campus management and accounting infrastructure. Would need to pitch it from overall sustainability point of view.	Need seed capital. Likely small in early years - need time to grow funding and payback with savings. Could use for small, short-term projects so capital doesn't remain tied up for long.	Depends on implementation approach – could be interest free or require equivalent short-term cash investment return.	Small at first, (<$1M) depending on seed capital.	B
Tax Exempt Bond Financing	Specifically called out as an option in Systemwide Capital Outlay Program for energy projects. Likely a funding approach from the Systemwide level.	Systemwide coordination.	Deal specific	Deal specific, usually equivalent to Municipal Debt rates	Deal specific	C
Tax Exempt Lease-Purchase	Master Enabling Agreement (MEA) for Tax Exempt Lease-Purchase was used extensively CSUs in mid-2000's for many energy projects. However, old ECSO MEA didn't work well and was very expensive. Tax Exempt lease is one of the funding sources identified in the new MEA. Paul W. on new MEA working group. Shawn Higbee at CSUCO new energy procurement lead.	New MEA still underdevelopment – possibly available in 2019	Timing of new MEA	Deal specific, usually equivalent to Municipal Debt rates	Deal specific	C

[50] For Green Revolving Fund examples and resources see *https://betterbuildingssolutioncenter.energy.gov/toolkits/green-revolving-funds*

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
SCE Third Party EE Programs	SCE bidding out many programs in 2018/19 for marketplace innovation – some may involve financing or use a direct install approach; Some existing programs - CSULB has been approached by vendor for LED tubes/retrofits. Take advantage of opportunistically.	Likely many program requirements including measure eligibility, savings accounting and loan security/payback (for financing)	Piecemeal solution. May apply to specific technologies (lighting) or approaches (direct install). Not a full financing solution.	Varies	Varies	C
Private Capital via Investor Confidence Project (ICP) approach	ICP now part of GBC – some extra structure along with extra fees. Whole Building IPMVP Option C savings approach.			Market rate loans. Some initial and ongoing fees		C
Prequalified CSU Project Finance	Private banks with standing agreement with CSU. Considered using for TES.		Debt ratios apply	Market rate loans, with discounted fees		C
Specific Grants – DOE, CEC for Net Zero, ARB C&T, specific technologies, GHG, other	Opportunistic as they arise	Specific grant requirements	Grant specific	Grant specific	Grant specific	C
SCE Fleet Electrification Funding/Grants	Potential funding source for transportation elements.					C
MEETS	A specific type of ESA structure. "Energy tenant" (like an ESCO) pays rent to campus for right to do energy improvements and brings own financing, campus continues to pay energy bill for use at historical level,		MEETs structure requires utility participation. Potentially complex operational constraints and termination clauses. Reduced control of energy	Deal specific.	Deal specific	C

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
	utility pays energy tenant for saved energy.		infrastructure. Likely a more expensive option.			
Internal Bridge Loans	Campus and auxiliaries can borrow money from other auxiliaries for short-term needs.	Internal considerations make this an unlikely path.	Systemwide and campus debt to income ratios do not apply to internal bridging loans. Short term, medium amounts	5% rate for planning 5 years	$5-$10M	D
Energy Savings Performance Contract (ESPC)	Did an ESCO in 2004-06 under original CSU MEA, haven't done one since, but still an option. Expect the new MEA to allow this approach. See discussion under Tax-Exempt Lease-Purchase.	See discussion under Tax-Exempt Lease-Purchase.	See discussion under Tax-Exempt Lease-Purchase.	Deal specific	Deal specific	D
SCAQMD Rule 1304.1 Funds	Funding for emission mitigation 10 miles of repowered Electricity Generating Facility and certain Environmental Justice areas	RFP released when at least $1M in repowering fees have been collected at a given location.	Limited funds, Competitive bidding, timing uncertain. Evaluation is 50% of $ for proximity, 50% of $ for EJ.	Unknown	Up to $1M, if single award and meet both criteria	D
CEC EPIC grant	Building Internet of Things (IOT) – pre-commercial energy management system with ubiquitous sensing and controls for networked system including smart lighting, HVAC, and plug loads – Using for a retrofit for Engineering Computer Science building	CEC grant process	Current grant is spoken for - monitor for additional future funding	Grant specific.	Potential future amount TBD	D

TABLE OF NON-APPLICABLE APPROACHES

The following approaches are not applicable to CEMP at present, but they are listed here for completeness as questions about their applicability often arise.

Option/Approach	CSULB Suitability and Experience	Dependencies	Limitations and Impacts	Key Terms	Amount Available	Rank
Property Assessed Clean Energy (PACE)	Not Applicable. PACE programs can only provide financing to publicly owned buildings if they receive a property tax bill, of which CSULB receives none (confirm)		Form of loan secured by real property administered through property tax collection authority.		N/A	N/A
Cap & Trade Funds (Allocation from CA Air Resource Board)	Beyond potential targeted program grants mentioned above, there are no specific annual allocations for energy efficiency	Must show CO2 impact. Commit within year and expend by next			none	N/A
Proposition 39 – CA Clean Energy Jobs Act.	Not Applicable. Provides funding to K-12 and CA Community Colleges only.				N/A	N/A
Long Beach Gas	No applicable incentive program – residential rebates only				N/A	N/A
OBF Alternative Pathway	PG&E Pilot program, not available in SCE territory	May become available with new incentive programs			N/A	N/A
San Onofre settlement	RD&D, not applicable to project expenditures		Competitive process among campuses		$12M over 5yrs total	N/A
Public Private Partnerships (P3)	Mostly applicable in New Construction, but may apply in housing, dorms, and parking for some retrofits. Have not used, not doing any P3's near term	Deal specific. Would need to incorporate energy within broader project.	Low priority / no interest	Deal specific	N/A	N/A
Higher Ed CCA	Vey early stages – not a fit due to timing				N/A	N/A

Energy Efficiency Master Enabling Agreement	CSUCO working on MEA for service providers/contractors to do energy efficiency projects, but there is no financing attached				N/A	N/A
Systemwide Energy Bond	Occasionally discussed. Current efforts are around the "CSU Internal Central Bank" discussed in Section 2.				N/A	N/A

10. PLANNING & VISUALIZATION SCENARIO ANALYSIS TOOL

10.1. TOOL OVERVIEW

EcoShift developed the CSULB Scenario Analysis and Visual Insight (SAVI) Tool to help the university plan for and visualize the multidimensional impacts of the various options presented by the research in this report. This tool is based on a similar tool developed by EcoShift for the University of California, Santa Cruz as part of their 2017 Climate & Energy Strategy.[51]

Designed in Microsoft Excel, the CSULB SAVI Tool combines user inputs with existing data, performs a series of calculations, and provides output in the form of comparative tables and graphs. By selecting bundles of emission mitigation projects, the user can analyze the outcomes of different scenarios and assess multiple pathways towards reaching carbon neutrality by 2030. The tool is designed to be updated as newer data becomes available.

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[51] Climate, Energy & Carbon Neutrality at UCSC: https://sustainability.ucsc.edu/initiatives/climate-energy--carbon-neutrality.html (report: https://drive.google.com/file/d/0B6RCGpLt7QdUblB3M3RGcHk0aGs/view)

10.2. SUMMARY OF FINDINGS

The CSULB 2014 Climate Action Plan sets out an ambitious goal to achieve carbon neutrality by 2030. Fulfilling this commitment requires all campus greenhouse gas (GHG) emissions to be reduced or offset, including emissions in Scope 1 (direct), Scope 2 (indirect from purchased electricity), and Scope 3 (all other indirect). Emissions under CSULB's direct control (i.e., Scope 1 and 2 emissions) can be reduced by implementing a variety of projects in energy efficiency, renewable energy, and vehicle fleet electrification. Any remaining campus emissions, both direct and indirect, must be negated by purchasing voluntary GHG offsets in the year 2030 and beyond.

To explore the different ways of achieving CSULB's climate and energy goals, five scenarios were created (detailed descriptions of each scenario can be found in Section 10.4:

1. Business as Usual (BAU)
2. Increased Investment
3. Operational/Policy Changes
4. Cost-Effective Investment
5. Ambitious NZE Investment

10.2.1. OVERALL RESULTS

The following chart shows the scenario analysis results of the energy efficiency projects.

Table 57: Detailed EE Results

	(1) Business as Usual (BAU)	(2) Increased Investment	(3) Policy/ Operational Strategy	(4) Cost Effective Investment	(5) Ambitious NZE Investment
Investment period	2018–2035	2018–2030	2018–2030	2018–2030	2018–2030
Total project cost	$26,926,922	$34,444,823	$6,302,581	$12,805,709	$55,017,897
Average cost per year	$1,495,940	$2,649,602	$484,814	$985,055	$4,232,146
Energy cost savings	$2,458,773	$3,323,227	$1,381,649	$1,938,228	$3,782,624
Simple payback	10.95	10.36	4.56	6.61	14.54
In 2030:					
Electricity savings (kWh)	9,155,451	12,082,517	5,180,496	8,120,798	12,012,494
Natural gas savings (therm)	73,375	97,337	13,162	15,943	455,095
Total energy savings (MBtu)	38,575	50,959	18,992	29,303	86,487
Campus energy reduction	13%	17%	6%	10%	28%
Emission reduction (MT CO2e)	1,801	2,379	868	1,335	4,279
Reduction as % of energy emissions	10%	13%	5%	7%	23%

Table 58: Detailed RE Results

	(1) Business as Usual (BAU)	(2) Increased Investment	(3) Policy/ Operational Strategy	(4) Cost Effective Investment	(5) Ambitious NZE Investment
Total capacity (kW)	7,073	10,157	4,794	4,794	12,502
Total generation (kWh/yr)	11,143,540	16,093,360	7,489,088	7,489,088	19,801,353
% on-site generation in 2030	24%	39%	15%	15%	53%

The following table shows the economics of the various scenarios that were assessed as part of the CEMP.

Table 59: Scenario Analysis Tool Outputs – Net Present Value (NPV)

	Net present value (NPV) (million $)			
Scenario name	Scenario	EE projects	RE projects	VF projects
BAU	($4,906,972)	($124,562)	($4,782,410)	--
Increased Investment	($11,095,730)	($3,325,235)	($7,020,801)	($749,695)
Operational/Policy Changes	$669,396	$5,126,535	($3,707,445)	($749,695)
Cost-Effective Investment	$1,299,199	$5,006,644	($3,707,445)	--
Aggressive NZE Investment	($27,782,977)	($17,701,554)	($9,482,529)	($598,894)

The Figure below displays each scenario represented as a bubble, with total project investment[52] on the x-axis (more investment to the right), Net Present Value along the y-axis (better economics to the top), and total GHG reductions represented by the width of the bubble.

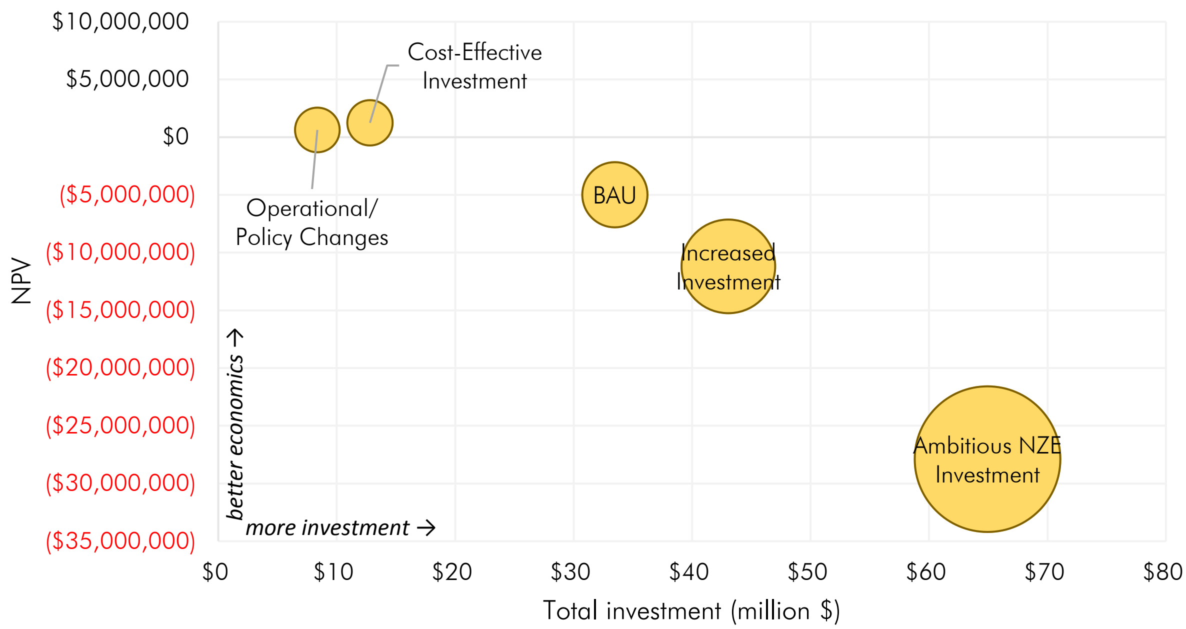


Figure 73: Scenario Analysis Summary – Overall Scenario

[52] This value includes the costs of EE, RE, and VF projects. Though PPA rates are used in RE financial calculations, the net RE project costs (capital less incentive) are used here to quantify the level of investment using units that are consistent with EE and VF projects.

The Ambitious NZE Investment scenario has the largest project investment and most emission reductions, but also the least favorable NPV. Both the Cost-Effective Investment and Operational/Policy Changes scenarios show positive NPV but the lowest total emission reductions.

EE project results are summarized below using the same units as in Figure 56, but with the cost of EE projects along the x-axis.

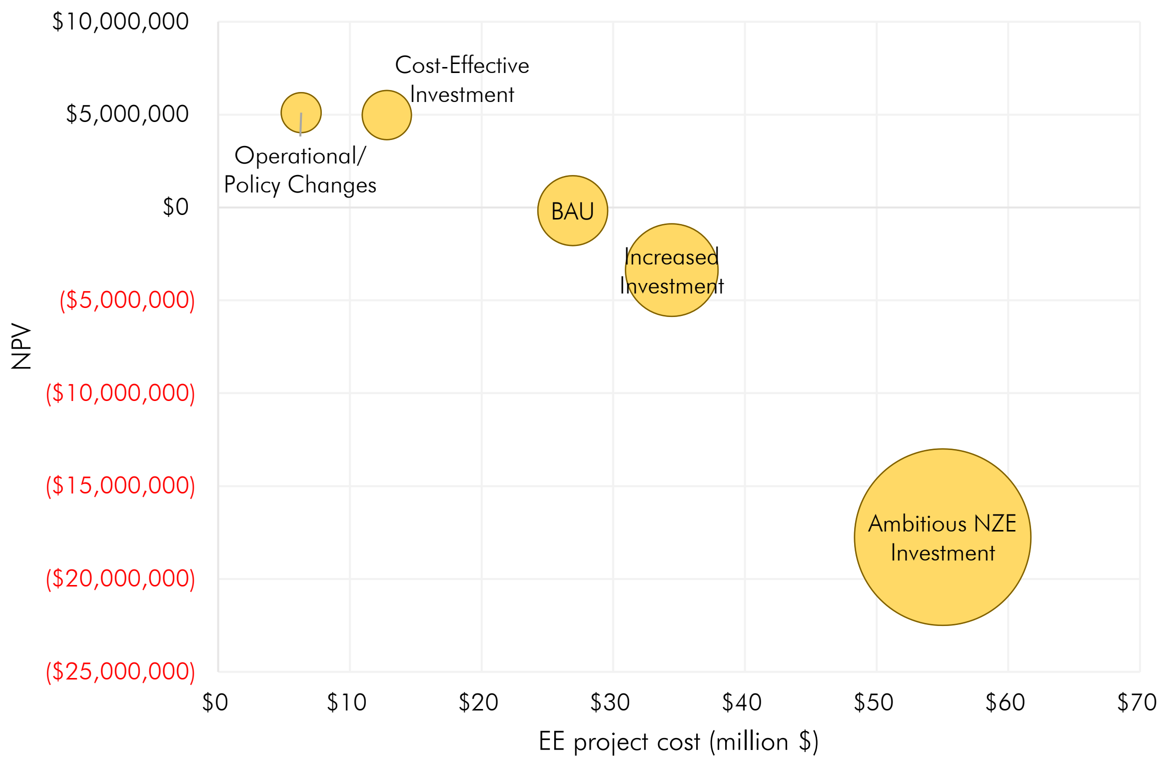


Figure 74: Scenario Analysis Summary - EE Projects

It is apparent that both the Operational/Policy Changes and Cost-Effective Investment scenarios show large positive returns, indicating that these EE project bundles contain "low-hanging fruit" that can reduce emissions economically. The BAU scenario is nearly cost-neutral, while the Increased Investment scenario shows a cost of about $44 per MT CO2e reduced.

The renewable energy projects were found to have the potential to be economical based on recent PPA rates seen in the market.

10.2.2. 2030 RESULTS

Figure 75 shows baseline Scope 1 and 2 emissions in 2030, as well as the calculated emission reductions from EE, RE, and VF projects for each scenario.

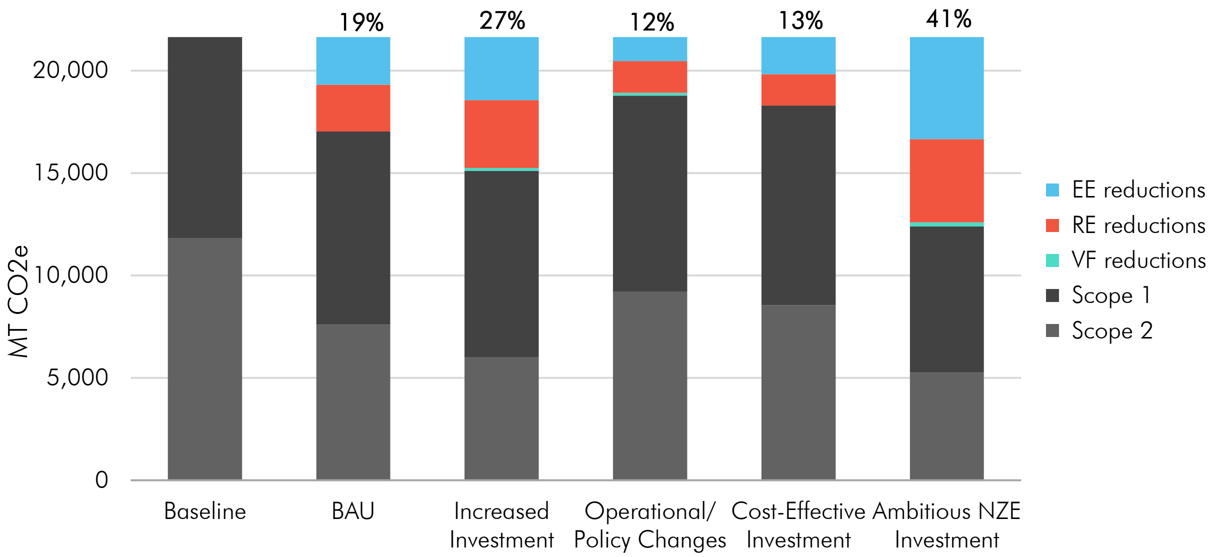


Figure 75: 2030 Scope 1+2 Emissions (EE/RE/VF Projects)

The Increased Investment scenario results in a 36% reduction in energy related GHG emissions. When considering the total emission from the campus, this scenario results in a 10% reduction in total campus GHG emissions. In general, the majority of campus emissions come from Scope 3 sources out of the university's direct control (predominately student, faculty, and staff commuting).

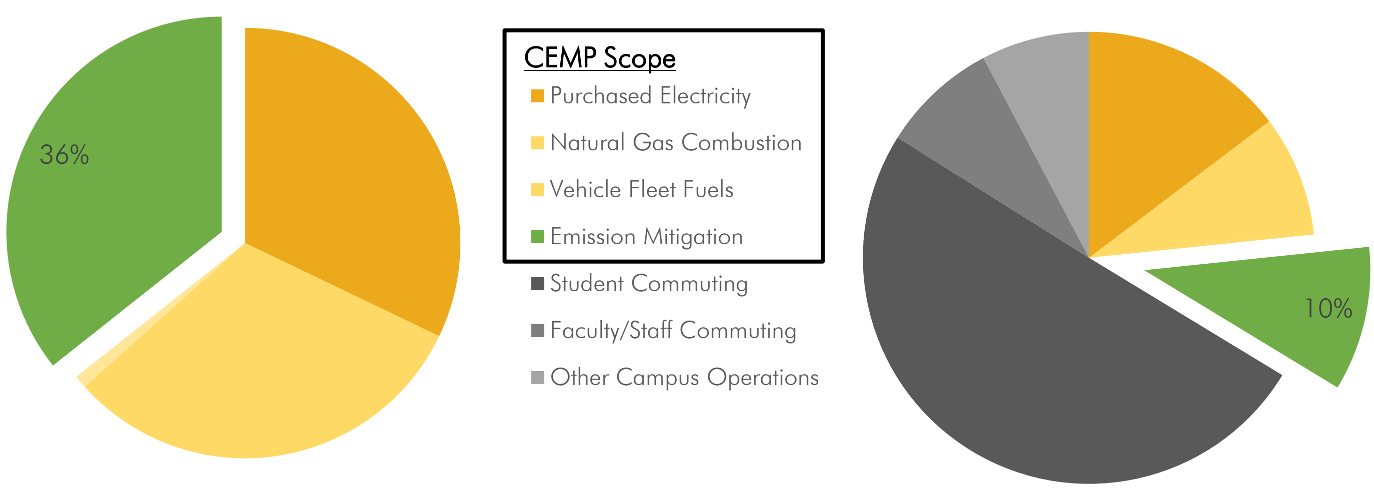


Figure 76: Overall Campus GHG Emission Reductions – Increase Investment Scenario

Large numbers of GHG offsets will therefore have to be purchased every year starting in 2030. However, the campus can still take active measures to reduce emissions by increasing EE investments, choosing strategic RE projects, and electrifying the fleet as older vehicles need replacement. These measures, alongside efforts to reduce Scope 3 emissions such as encouraging low-carbon methods of commuting, can achieve significant emission reductions and reduce the number of offset purchases needed in the future.

10.3. METHODOLOGY

10.3.1. BACKGROUND DATA

The calculations in the SAVI Tool are based on the following background datasets:

- Building data
  - Electricity and natural gas consumption
  - Gross square ft
  - Building type
  - Other attributes: location, ownership, funding source
- Campus data
  - Vehicle fleet gasoline and fuel consumption
  - Capital projects
  - Other emission sources (fugitive, air travel, solid waste) – from CSULB's 2013–14 Greenhouse Gas Inventory
- Project data
  - EE projects (cost, kWh/therm savings, etc.)
  - RE projects (capacity, kWh production, PPA rate, etc.)
  - VF projects (cost, gasoline/diesel reduction, additional kWh, etc.)

10.3.2. ASSUMPTIONS

The tool also incorporates several assumptions that affect environmental and energy calculations, shown in Table 60.

Table 60. Assumptions used in the SAVI Tool.

Assumption	Value	Source
Economic assumptions		
Discount rate	5%	--
Inflation rate	2%	--
Electricity price	$0.11–0.19/kWh (3% escalation rate)	CSULB
Natural gas price	$0.55/therm (3% escalation rate)	CSULB
Gasoline price	$3.39/gal (2% escalation rate)	average (Aug17 to Jul18) from EIA[53]
Diesel price	$3.59/gal (2% escalation rate)	

[53] *https://www.eia.gov/dnav/pet/ pet_pri_gnd_dcus_y05la_m.htm*

Assumption	Value	Source
Carbon offset price	$4.79/MT CO2e (2% escalation rate)	Forest Trends' Ecosystem Marketplace[54]
Annual growth rates		
Energy consumption[55]	0.2%/year	CSULB
Gross sq. ft[55]	1%/year	CSULB
Student/faculty commute	1%/year	CSULB
Emission factors (EFs)		
Natural gas EF	5.341 kg CO2e/therm	EPA[56]
Gasoline EF	8.78 kg CO2e/gal	
Diesel EF	10.21 kg CO2e/gal	
Propane EF	5.741 kg CO2e/gal	
Electricity EF (2018 baseline)	0.2404 kg CO2e/kWh	eGRID 2016[57]

Electricity emission factors

To reflect the variable nature of the electricity grid, emission factors (EFs) for electricity are calculated as a function of time, unlike EFs for other energy sources which are modeled as constant. The eGRID 2016 database reports a California (CAMX) EF of 0.2404 kg CO2e/kWh from a grid mix containing 21.7% renewable sources (10.6% solar, 7.0% wind, 4.1% geothermal); this EF was used for the 2018 baseline.

As of September 2018, California has set a goal to acquire 50% of its electricity from renewable sources by 2030. Assuming a growth from the 2018 baseline of 21.7% renewables (and a similar mix of non-renewables), the 2030 electricity EF was calculated as 0.1539 kg CO2e/kWh. For years between 2018 and 2030, EFs were interpolated by assuming a linear decrease in per-kWh emissions of 0.00721 kg CO2e per year. The same linear decrease was assumed to continue past 2030, resulting in a 100% renewable grid in 2051.

Though this simple linear model does not consider the myriad complexities of projecting emissions from the future electricity grid (such as independent scaling of each energy source), the SAVI Tool contains the flexibility to adjust electricity emission factors as updated data and more sophisticated modeling becomes available. (See Section 10.5 Sensitivity Analysis for a sensitivity analysis using electricity emission factors based on more aggressive state renewable energy targets.)

54 *https://www.cbd.int/financial/ 2017docs/carbonmarket2017.pdf*
55 Annual growth rates for energy consumption and gross sq ft used to model campus growth after capital projects cutoff (2025)
56 *https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf*
57 *https://www.epa.gov/sites/production/files/2018-02/documents/egrid2016_summarytables.pdf*

10.3.3. CALCULATIONS

Calculations in the SAVI Tool are performed as follows:

1. Baseline energy consumption and emissions are calculated.
2. Energy savings and emission reductions from selected EE, RE, and VF projects are calculated for the years 2018–2050 and subtracted from the baseline.
3. Net cash flow is calculated for each project based on energy prices, PPA rates (for RE projects), and avoided carbon offset purchases (for emission reductions in 2030 and beyond).
4. Net present value (NPV) is calculated for each project using net cash flows and a default discount rate of 5%.
5. Cost per metric ton of CO_2e reduced ($/MT CO_2e) is calculated by dividing NPV by total emission reductions.

10.4. SCENARIO DEFINITIONS

Table 61 below gives the details of the five scenarios that were developed with input from the CSULB Sustainability Task Force.

Table 61. Scenario definitions.

Scenario	Energy Efficiency (EE)	Renewable Energy (RE)	Vehicle Fleet (VF)
(1) Business as Usual (BAU)	Maintain current average investment rate of **$1–1.5 million annually**. All EE projects completed by 2035.	Invest in most economical PV projects (**2.28 MW**).	**None** – rely on incremental efficiency improvements.
(2) Increased Investment	Increase average investment rate to **$2.8 million annually**. All EE projects completed by 2030.	BAU + Main Campus Curtailment Option 1 (**5.36 MW**).	**Fleet electrification** – transition most vehicles by 2030. Excludes diesel fuel grounds equipment.
(3) Operational/ Policy Changes	Lower than average investment rate – **$0.6 million annually**. Prioritize only cost-effective EE projects and implement ambitious energy savings operational policies.	**None** – no additional PV projects.	**Fleet electrification** – transition most vehicles by 2030. Excludes diesel fuel grounds equipment.
(4) Cost-Effective Investment	Lower than average investment rate – **$1 million annually**. Prioritize only cost-effective EE projects.	**None** – no additional PV projects.	**None** – rely on incremental efficiency improvements.
(5) Ambitious NZE Investment	Increase average investment rate to **$4.4 million annually**. Includes numerous electrification projects.	All potential PV projects: BAU + Main Campus Curtailment Option 3 (**7.71 MW**).	**Fleet electrification** – transition ALL vehicles by 2030. Excludes diesel fuel grounds equipment.

10.5 SENSITIVITY ANALYSIS

Two sensitivity analyses were conducted to understand the impacts of certain key variables on the final results. First, the impacts of more competitive PPA prices for renewable energy projects were investigated. The second sensitivity analysis looked at the effects of more aggressive renewable portfolio standards for the California electricity grid.

10.5.1. COMPETITIVE PPA RATES

The quoted PPA rates of 12.5–21.9 ¢/kWh for proposed RE projects resulted in suboptimal economics for all scenarios. To test the impacts of more competitive PPA rates, results were recalculated with costs for future projects reduced by 25%. The new rates of 9.4–16.4 ¢/kWh are more in line with the PPA rates seen elsewhere, and well within CSULB's reach for a competitive bid. Since two of the scenarios do not include any RE projects other than the existing 4.8 MW system (which is locked into a rate of 13.5 ¢/kWh and therefore not adjusted), only three scenarios are included in this sensitivity analysis.

Outlined below is the impact of competitive PPA rates on the potential future RE projects. With this competitive PPA rates, the economics improve dramatically and the BAU scenario actually exhibits a net present value of benefit of $150,000

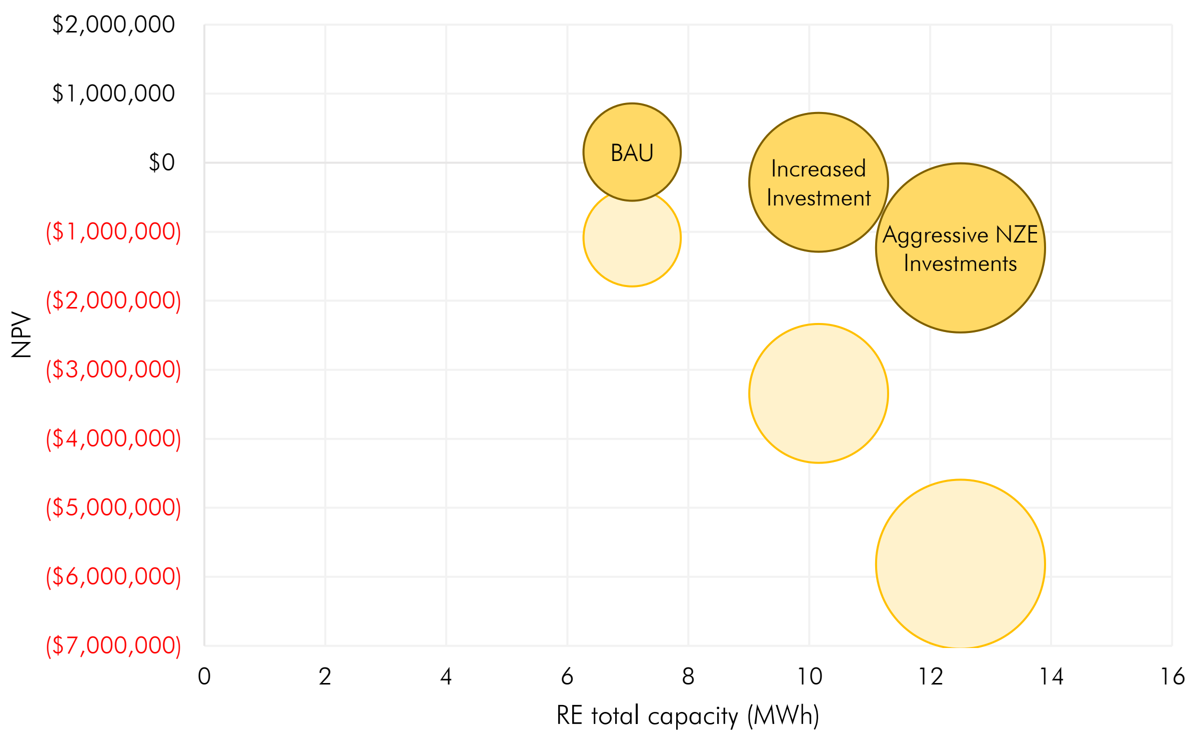


Figure 77: Sensitivity Analysis: 25% lower PPA rates (Future RE projects)

Figure 78 shows the effects of lowered PPA rates on the economics of the entire scenario, including EE projects, VF projects, and the existing RE system.

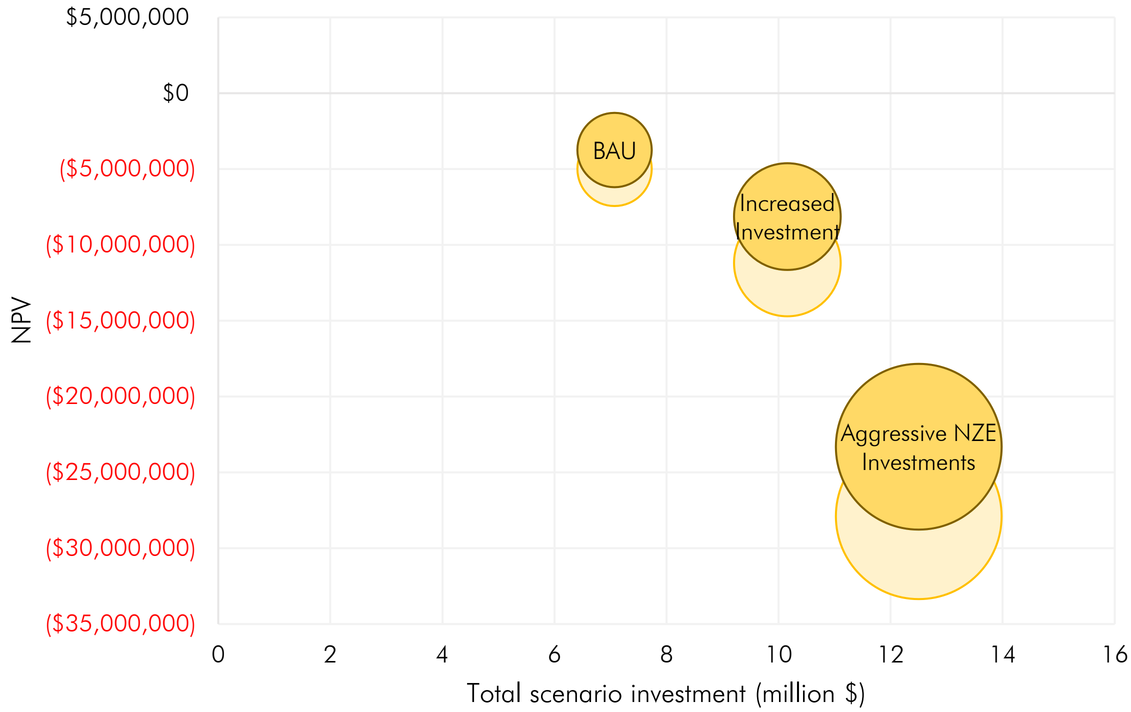


Figure 78. Sensitivity Analysis: 25% lower PPA rates (scenario total).

This analysis demonstrates the importance of securing competitive PPA rates for future RE projects.

10.5.2. ELECTRICITY EMISSIONS (CA SB 100)

In late August 2018, the California legislature voted to pass Senate Bill 100, putting the state on a course to achieving a 100% carbon-free electricity grid by 2045. The bill also set an intermediate goal of generating 60% of electricity from renewable sources by 2030, updated from the previous target of 50%. At the time of this writing (September 2018), SB 100 is awaiting a signature from Governor Jerry Brown before it becomes law.

To assess the bill's potential impacts on CSULB's own emissions, scenario results were re-calculated with new electricity EFs reflecting SB 100's more aggressive renewable targets. Using the same methodology described above, electricity EFs were calculated as 0.1231 kg CO2e/kWh in 2030 and 0 kg CO2e/kWh in 2045. The differences in EF values over time are shown in Figure 79.

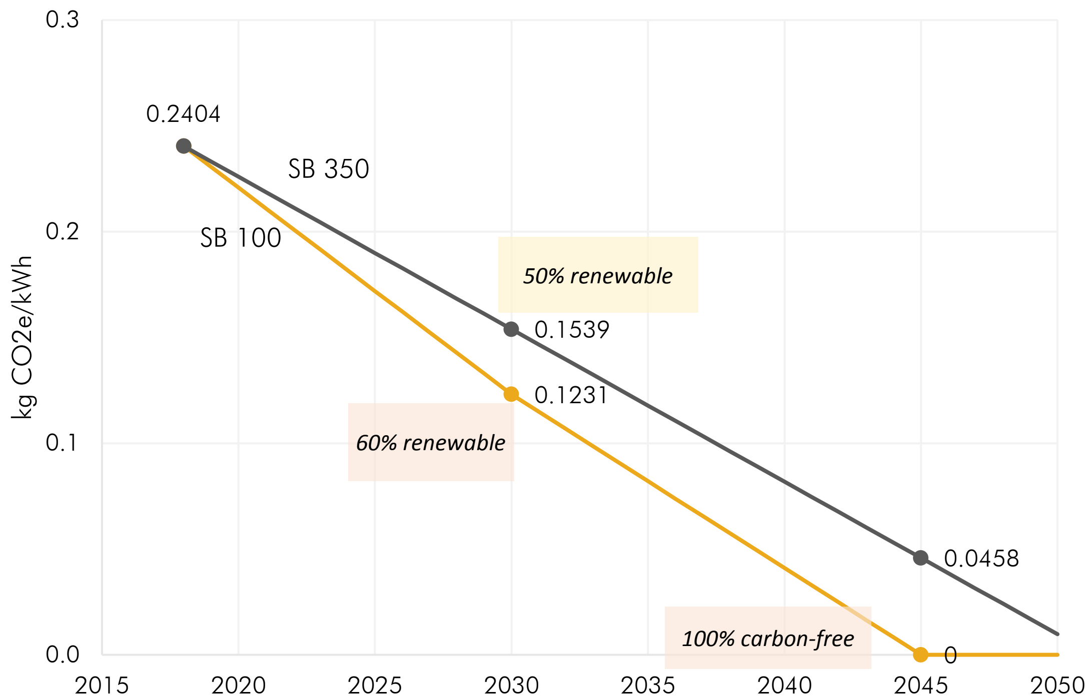


Figure 79: California Grid Electricity Emission Factors Over Time

The Figure below outlines the impact that EFs have on Scope 2 emissions. One consequence of a more rapidly decarbonizing grid is a decrease in total emission reductions by about 17–19%. This is as the electricity savings translate to lower carbon savings, especially further into the future.

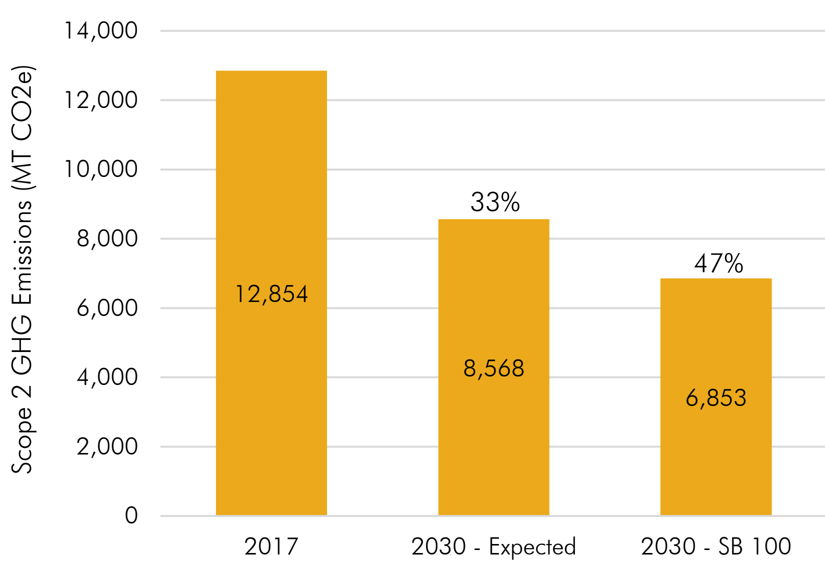


Figure 80: Sensitivity Analysis – SB 100 Electricity Emission Factors.

While carbon-free electricity is a plausible goal in the next few decades, the same cannot be said for fossil-derived energy. As the California grid gets cleaner and electricity EFs continue to fall, it is important for CSULB to prioritize electrification projects that reduce the combustion of fossil fuels (natural gas, gasoline, and diesel) to reap the benefits of the state's continued leadership in renewable energy.

10.6 NEXT STEPS

The CSULB SAVI Tool has been designed to provide insight and decision support, both for the current CEMP efforts and further down the line. The continued value of the tool is dependent on two main factors: the ability for CSULB staff to create additional scenarios for analysis, and an accountability structure to ensure the tool remains up-to-date as new and updated data becomes available over time.

A training session has been scheduled to engage potential users of the CSULB SAVI Tool and empower them to create new scenarios informed by their respective fields of expertise. The training will be geared towards two audiences:

- **Regular users**: casual users with the ability to navigate the prepopulated tool, create new scenarios by adjusting the various levers and switches, and explore the rich dataset of calculated results through tables and graphs
- **Advanced users**: more sophisticated users with password access to the inner workings of the tool, and responsible for updating and maintaining the underlying datasets

Some examples of advanced user tasks include:

- Replacing calculated project performance data with measured values through the years
- Adding additional EE, RE, and VF projects for scenario selection
- Updating electricity EFs based on newly released data or more accurate models
- Making sure the carbon offset price reflects the market reality as the target year for carbon neutrality (2030) approaches

A detailed user manual will be available at the training session. It is the hope of the consultant team that the CSULB SAVI Tool will continue to be a valuable asset for the university as it plans for a future of clean energy and carbon neutrality in the years to come.

11. CSULB ENERGY RETROFIT GUIDELINES

CSULB already has a well-developed process for energy efficiency projects, displayed by the $1-1.5 million / year budget for energy efficiency projects campus wide. This section outlines guidelines for energy retrofit projects moving forward, both for smaller retrofit and deep retrofit projects, in order to ensure all retrofit projects achieve the highest possible energy savings. When undertaking energy efficiency projects, CSULB should review the checklist outlined in this section and incorporate all applicable EEM measures into the retrofit project.

11.1 DEEP ENERGY RETROFIT

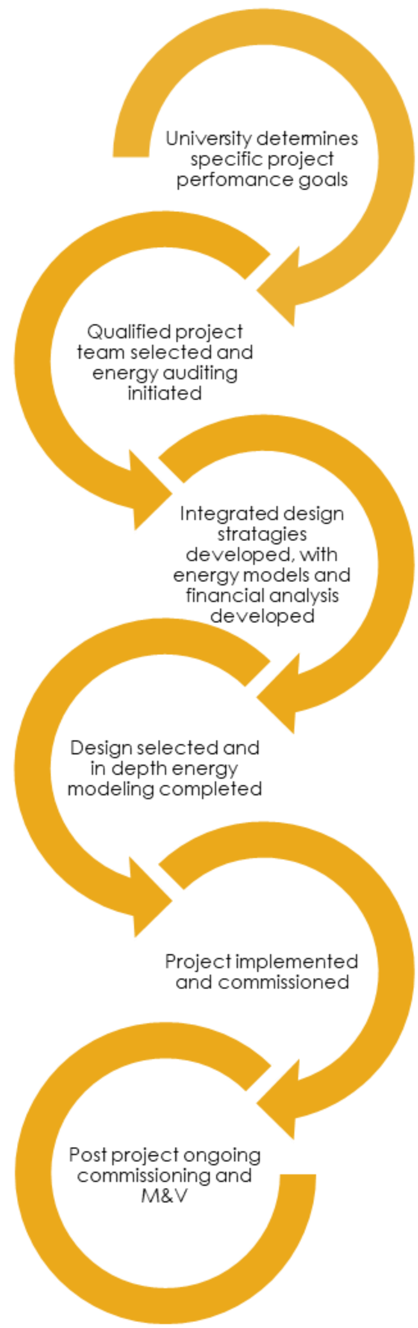
The definition of a deep energy retrofit projects should be defined by CSULB before any projects are considered. A commonly acceptable definition is that deep energy projects result in a minimum 50% reduction in building energy usage and extended a building lifetime. To achieve this 50% savings there will be no single solution. Comprehensive and integrated retrofits that are tailored for each building will be required and multiple projects and measures within each building should be targeted.

Many buildings across campus contain aging HVAC systems that are original to the building. These systems are in poor condition, with major pieces of equipment, ductwork and zone level controls needing replaced as the systems are beyond their expected useful life. Deep energy projects require a large investment and may have significant payback periods; however, the University must decide to invest in capital improvement projects, extending the life of buildings, over improving building performance of old systems in the short term. Other factors will influence this decision, including existing system not being able to maintain occupant comfort, the inability to procure parts for old AHUs, the desire to add cooling to heating only systems and ongoing maintenance cost. Most significantly, the “co-benefits” of deep energy projects should be account for in the decision. These projects can significantly reduce the amount of deferred maintenance in a building. Additionally, benefits in indoor air quality and occupant productivity due to this should be considered. As CSULB expands it campus the energy infrastructure will need to be upgraded. Reducing energy usage in existing building through deep energy projects may reduce costs in upgrading energy infrastructure, such as the central utility plant and these costs should be realized.

This section outlines a deep energy retrofit plan and the best practices for implementation on higher education campuses and summarizes the different deep energy retrofit projects CSULB should consider.

11.2 DEEP ENERGY BEST PRACTICES

To ensure the success of a deep energy retrofit project, a holistic, integrated design approach must be adopted from project inception. Existing buildings present several challenges for large scale retrofits. Fixed footprints limit modern high-performance HVAC strategies, both passive and mechanical, and hinder access to and from mechanical rooms where large pieces of mechanical equipment will require replacement. Any deep retrofit projects must be compatible with the existing building, and therefore early in the project lifecycle, engineers must work together to identify strategies that account for project constraint and meet the goals of the University. Overly complicated design strategies in existing buildings can result in complex control systems that facility staff are not accustomed to maintaining, therefore the design team must understand this. The costs associated with demolition of existing equipment must be included in the analysis. Similarly, the impact construction will have on building occupants must be accounted for.



Establishing the correct project team, with appropriate experience in energy projects is key for project success. The owner must be invested in the project and set clear project performance goals such as a specific reduction in building EUI. The project engineers and designers must be fully invested in an integrated design approach and understand the constraints that each discipline face.

In depth building energy auditing must be completed to fully establish how the building is operating and the existing conditions. Often the as-built drawings for older buildings are inaccurate due to changes in the building layout occurring over time. A common reason for a large retrofit project being overbudget or delayed is changes in design occurring due to field conditions not matching drawings, and therefore a successful deep energy retrofit project must begin with thorough building auditing. Once building energy auditing is completed, the design team must develop integrated design strategies for the university to review. These design strategies should be modeled, and lifecycle cost analysis completed to ensure the optimal design moves forward. Once selected an in-depth energy model must be developed and further economic analysis completed to ensure project payback and the universities energy targets are met. Changes to a building HVAC and lighting systems often result in unforeseen interactions between building systems. Energy models help capture these to ensure building systems will be operating optimally once the project is complete. Post project completion, ongoing commissioning and performance measurement and verification (M&V) should be completed to confirm the building operates and continues to operate as designed and project energy goals have been met. Ongoing commissioning offers a low return on investment as it ensures system performance and reduces operations and maintenance (O&M) costs. Both ongoing commissioning and M&V rely on building operations being readily available to engineers, and therefore the infrastructure for this must be accounted for during the design process and included during construction.

11.3 ENERGY RETROFIT PROJECT RECOMMENDATIONS

When looking into energy retrofit projects, the entire building, should be analyzed and everything that consumes energy should be reviewed. Identifying candidate projects can be hard when significant buildings require upgrades. Therefore, pilot projects for certain building types should be competed first, before applying these pilots across similar building on campus. Deep energy project should also be prioritized over others that do not result in such significant energy savings.

11.3.1 BUILDING ELECTRIFICATION

CSULB should focus on the electrification as a priority when retrofitting campus buildings. Minimizing all scope 1 emissions will be key for CSULB to minimize GHG emissions, and although emissions are associated with electricity generation currently, the GHG emissions factor from electricity generation in California will be reducing between now and 2030. This reduction in emissions factors will help increase the importance of electrification on campus.

Outlined below is the current EUI of a typical residential hall on campus, Residence Hall E. This building is representative of 27 other residential buildings on campus and can be used to represent the large impacts that electrification can have on campus GHG emissions. The current EUI of 46.7 is dominated by the natural gas usage, used for HHW and DHW. Replacing the natural gas boilers with air-to-water heat pumps will decrease the overall EUI by 43% and the GHG emissions by 33%[58]. Moving forward, as the emissions factors in California are lowered in line with Senate Bill 100, converting to a fully electric HHW and DHW system in Residence Hall E will reduce the GHG emissions by up to 56% with no other energy efficiency projects implemented.

[58] Assuming a COP of 3.5 for the air-to-water heat pump

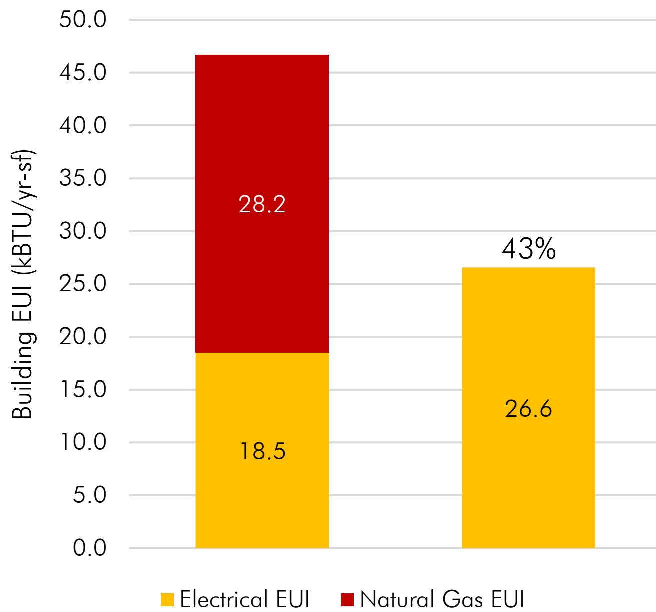


Figure 81: EUI Reduction – Electrification of DHW and HHW Systems

In addition, to it is recommended that the following checklist is used to identify potential energy efficiency measures should be considered if

Table 62: Energy Retrofit Checklist

EEM Name	Potentially Applicable	Not Applicable	EEM Notes
Control & Commissioning			
Building schedule optimization			Ensure building only operates during required morning warm up and occupied hours. Customized schedules for each building based on program and class schedules
Supply air temperature reset optimization			Review supply air reset control strategy and ensure controls are operating correctly
Static pressure reset control optimization			Review static pressure reset controls on VAV systems and ensure controls are operating correctly
Outside Air Economizers			Applicable to buildings with AHUs that do not have full OSA economization capability
Zone Setpoint optimization			Set point temperature dead band should be updated to meet local energy codes
Zone Occupancy & CO2 sensors			BAS connected occupancy & CO2 sensors to set back zone setpoints and OSA rates. Applicable for classrooms or conference rooms with long periods of no occupancy
Replace pneumatic zone controllers with DDC controls			All pneumatic controls across campus should be phased out and replaced with DDC controls.
Zone CO2 sensors & demand controlled ventilation			Applicable to high occupancy spaces
Chillers / Boilers - SOQ and controls optimization			Applicable for buildings with onsite CHW and HHW equipment. Ensure units operating per sequence of operations
Energy Submeters			Install whole building level energy submeters (electricity, natural gas, chilled water, hot water) if not currently provided
General EMS Upgrade			Applicable to all buildings in which EMS data is inaccurate
Installation / Calibration of HHW, CHW and Electrical submeters			Should be completed for every building connected to central plant
HVAC window interlock switches			Applicable to all building in which there are operable windows. HVAC can be setback when windows opened to minimum ventilation rates
Lighting			

EEM Name	Potentially Applicable	Not Applicable	EEM Notes
Interior Lighting - LED Retrofit			Replace all lighting fixtures or bulbs with LED alternatives (includes: Troffers, CFLs, etc.)
Specialty Lighting LED Retrofit			Replace specialty lighting systems (Arena, Theatre, etc) with LED or lower wattage alternative
Interior Lighting Controls - Install Title 24 required lighting controls			
Exterior Lighting - LED Retrofit			
Lighting controls/schedule optimization			Ensure exterior and interior lighting schedules are optimized for building occupancy
Stairwell Lighting - LED Retrofit			
Task lighting - reduce required over head lighting required (open office only)			Applicable for open office spaces to reduce LPD and improve occupant comfort
Fans/Motors			
AHU Motor replacement			Install direct drive fan wall array. Replace standard motors with ECM motors whenever possible. Applicable to old, belt driven fan motors
VFD - AHU fans			
VFD - Buildings pumps			
VFD - Cooling tower			
Building exhaust fan replacement			Replacement of all building rooftop exhaust fans where necessary. Replace standard motors with ECM motors whenever possible.
HVAC Systems			
Replace CHW/HHW coils			Oversized coils to improve dT and allow for future central plant CHW/HHW resets controls. Applicable when significant work is required on AHU.

EEM Name	Potentially Applicable	Not Applicable	EEM Notes
Replace 3-way valves with 2-way valves			Applicable to all buildings with 3-way valves. Replacement will lower pumping energy at central plant. Replace valves with low differential pressure control valves whenever feasible.
Rooftop unit replacement			Replace existing RTUs with high performance VAV units
Single zone systems - installation of high performance systems			Applicable to buildings with old single zone systems serving electrical and other unique zones
Full VAV system type conversion			To be completed where pneumatic constant volume systems still installed
VAV kitchen hood exhaust			Retrofit of kitchen exhaust and MAU to ensure full VAV operation when possible
AHU replacement			Where significant upgrades are required to AHU coils and fans, full unit replacement should be analyzed
Boiler replacement			Non-condensing boilers to be replaced by condensing
Air side heat recovery			Potential on buildings with large exhaust systems
DHW Systems			
Water Heater Replacement - condensing DHW heaters			
Solar Hot Water			Largest potential for buildings with large DHW loads such as housing
Water Heater Replacement – air-to-water heat pumps			Preferential from a GHG Emission prespective
Capital Projects			
Replace single pane windows			Install double pane window systems – only to be completed when full building retrofits are being undertaken
Insulate building exterior walls			Only to be completed when full building retrofits are being undertaken
Installation of window film			Only to be completed when full building retrofits are being undertaken

EEM Name	Potentially Applicable	Not Applicable	EEM Notes
Weather stripping on windows			Only to be completed when full building retrofits are being undertaken
Shading Assessment			Installation of building shades (interior or exterior) to lower solar loads
Roof Upgrades			Potential on all old building on campus – replace and upgrade standard built up roofing with high performance reflective roofing systems (cool roof)
Rooftop Solar PC			Assess curtailment required with SCE non-export agreement
General Enhancements			
Energy Star Fridges/Freezers			To be considered for any building with fridges and should be installed when replacement units required campus wide
Server Virtualization			Applicable to any building with onsite server rooms.
Computer Power Management			Applicable to all computer labs. Computers can be programmed to lower energy consumption overnight
Filter replacement scheduling			Dirty filters increase fan power requirements. Filters should be replaced on set schedules optimized for each building
Testing & balancing air flow			Applicable when any work in being completed in a building. Central HVAC system should be tested and balanced to design documents to ensure all zones receive adequate airflow and do not restrict AHU turndown
Review VAV minimum air flows			
Dedicated FCUs for zone with constant high loads			Applicable to buildings in which the central AHU serves zones such as Elec/Data rooms, restricting AHU from setting back
Duct leakage testing			When work is being completed on a building, all ductwork should be tested for leaks and repaired.
Duct insulation			Duct insulation inspection should be completed when any work in being completed in building and insulations should be replaced if damaged.
Installation of low flow fixtures			Low flow fixtures in buildings will lower water consumption and DHW loads
Laboratory Projects			

EEM Name	Potentially Applicable	Not Applicable	EEM Notes
Replace high pressure valves with low pressure drop alternative			
VAV Conversion - constant volume fans to VAV			Applicable to any constant volume fume hoods. Emphasis on single hoods in older buildings.
Airflow Rates - Reduce minimum air change requirements			Review space programing
Airflow Rates - Reduce air flow velocity on flume exhaust			
Exhaust Discharge Velocity Reduction			Consult with wind engineer consultants
Fume hood controls - Occupancy sensors			Installation of occupancy sensors on fume hoods to ensure exhaust fans are setback to minimums when possible

12. NET-ZERO ENERGY BUILDING - CSULB GUIDELINES

12.1 BACKGROUND INFORMATION

DEFINITIONS

Net Zero Energy (NZE), also known as Zero Net Energy, is defined by numerous different sources:

The U.S. Department of Energy defines a Zero Energy Building (ZEB) as *"an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy"*.

Likewise, the State of California defines NZE as an *"energy efficient building that produces as much energy as it consumes over the course of a year, when accounted for at the energy generation source."* (Executive Order B-18-12,2012).

The key in both definitions is the accounting of source energy for a building. Source energy includes energy consumed at the building level as well as the energy consumed in the extraction, processing, and transport of primary fuels (i.e., coal, oil, natural gas). While precise measurement of energy consumption at the building level is readily achieved, accurate measurement of energy associated with producing this end-use energy is more difficult. The U.S. Department of Energy recommends using national-average site to source conversion factors both for consistency and because over one quarter of California's energy is imported from other states.

REQUIREMENTS

As outlined above, the State of California requires buildings to achieve NZE at a source level to be deemed a NZE building. In addition to this, the following requirements have been placed on state agencies.

i. State agencies are to take actions to reduce entity-wide greenhouse gas emissions by 20% by 2020, as measured against a 2010 baseline (Executive Order B-18-12, 2012).

ii. All new State buildings and major renovations beginning design after 2025 will be constructed as Zero Net Energy facilities with an interim target for 50% of new facilities beginning design after 2020 to be Zero Net Energy. State agencies shall also take measures toward achieving Zero Net Energy for 50% of the square footage of existing state-owned buildings area by 2025 (Executive Order B-18-12, 2012).

iii. State agencies will participate in "demand response" programs to obtain financial benefits for reducing peak electrical loads when called upon, to the maximum extent that is cost-effective for each State-owned or leased facility and does not materially adversely affect agency operations (Assembly Bill No. 327, 2013).

iv. Any proposed new or major renovation of State buildings larger than 10,000 square feet use clean, on-site power generation, such as solar photovoltaic, solar thermal and wind power generation, and clean back-up power supplies, if economically feasible (Executive Order B-18-12, 2012).

v. New or major renovated State buildings and build-to-suit leases larger than 10,000 square feet obtain LEED "Silver" certification or higher, using the applicable version of LEED (Executive Order B-18-12, 2012).

vi. State agencies must reduce overall water use at the facilities they operate by 20% by 2020, as measured against a 2010 baseline (Executive Order B-18-12, 2012).

vii. Potable water may not be used for the following (Executive Order B-37-16, 2016):

a. Hosing off sidewalks, driveways, and other hardscapes;
b. Washing automobiles with hoses not equipped with a shut-off nozzle;
c. Using non-recirculated water in a fountain or other decorative water feature;
d. Watering lawns in a manner that causes runoff, or within 48 hours after measurable precipitations; and,
e. Irrigating ornamental turf on public street medians

viii. State entities are to support and facilitate the rapid commercialization of zero-emission vehicles. Additionally, state departments are to purchase at least 25% replacement fleet vehicles as zero-emission vehicles by 2020 (Executive Order B-16-12, 2012).

The CSU system has adopted these requirements and definitions and as such, buildings on the CSULB campus must achieve net zero energy at a source level to be classified as NZE. Given CSULB's commitment to 2030 carbon neutrality, it is also recommended that all NZE buildings are all designed to have net-zero carbon emission. Both based on current emission factors and emissions factors after 2030.

12.2 DESIGN GUIDELINES

APPROACH TO NET ZERO ENERGY

Designing new construction and major renovation projects on campus to be NZE can be an important strategy for reducing emissions. NZE buildings will offset all energy use through on-site renewable energy systems or procuring offsite clean energy. To achieve NZE, new constructions should incorporate a range of high performance building design strategies to minimize the required energy use, to the extent that is economically feasible. The following interrelated-opportunities for reducing energy use of the building should be assessed iteratively, before offsetting with renewable energy generation:

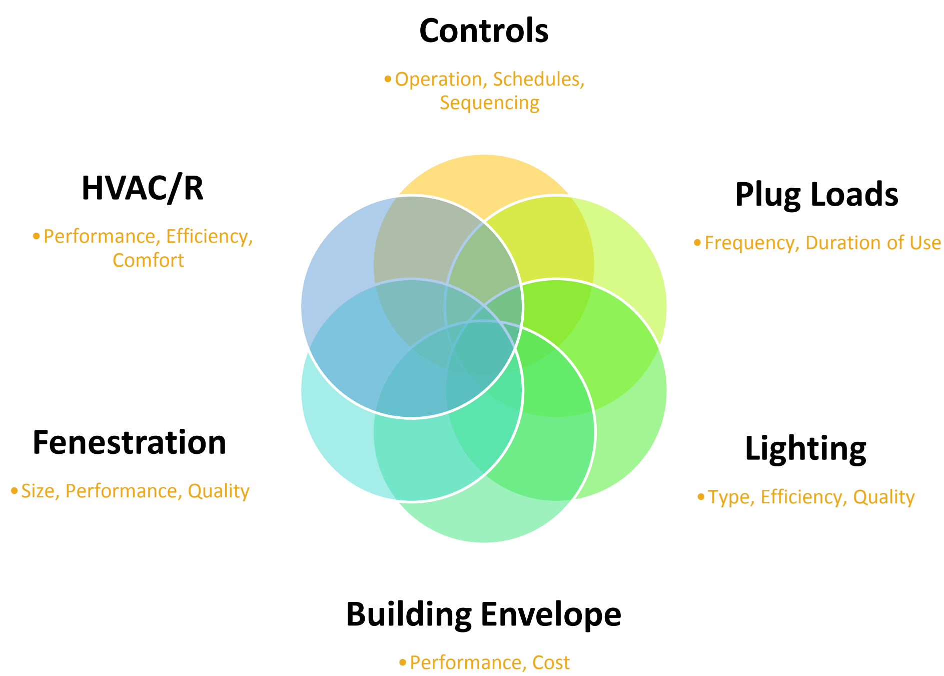


Figure 82: Net-Zero Energy Building Design Strategies

California's Title-24 energy code requires strict requirements for new construction buildings. To achieve NZE economically, it is recommended that designs aim to minimize energy use to be significantly less than a baseline Title 24 baseline building. Reducing the size of the renewable energy system or the amount of offsite renewable energy required is key in ensuring an economically viable building. A building that performs 50% better than current energy code will help minimize these costs whilst ensuring the upfront construction costs are not excessive.

It is recommended that design teams establish an energy use intensity (EUI) target for the building early in the design process. The EUI is the total energy consumed by a building over a year divided by its square footage (kBtu/ft^2-yr). EUI is a useful metric as it is normalized for building size and allows for direct comparison of performance amongst widely differing buildings.

ELECTRIFICATION

CSULB should prioritize electrification for any NZE buildings on campus. Reducing scope 1 emissions will be key for CSULB to minimize the direct impact of their campus. All new construction buildings should be investigated to assess the possibility of having no fossil-fuel based energy systems. Negating the need for natural gas usage at a building level will significantly reduce CSULBs scope 1 emissions, which is key in achieving carbon neutrality. Some of these strategies include:

1. Heat pump heating systems
2. Variable Refrigerant Flow (VRF) system
3. Air to water heat pump (heating and domestic hot water)
4. Induction cooking stoves
5. Heat pump clothes dryers

ON-SITE SOLAR

Any additional solar added to CSULB should to be assessed to understand how it will impact the overall campus electrical system. Depending on the SCE electrical service supplying power to the NZE building, different design consideration need to be review, as outlined below.

Main SCE Electrical Service

As noted in the Renewable Energy Section, *6.2.5 MAIN CAMPUS*, the existing PV on campus at times is producing more power than there is demand on campus. This is a significant concern given CSULB's non-export agreement with SCE, which does not allow them to send electricity back to the greater SCE grid. This requires PV systems to curtail power generation during times they would over generation electricity. Any new PV system should assess how much of the new generation would need to be curtailed based on the last full year's 15-minute interval data.

Other SCE Electrical Services

There is less concern for buildings that are provided power from other SCE services. It is recommended the solar systems installed on these buildings should negotiate a net energy metered (NEM) agreement, which allows CSULB to be credited back for over generation.

POST OCCUPANCY MEASUREMENT & VERIFICATION

All buildings with NZE targets should include a post occupancy measurement and verification (M&V) plan as part of the design phase of the project. Post occupancy M&V and on-going commissioning is essential for ensuring the building performs to the same level of energy efficiency as designed. This should include providing enough energy sub-meters throughout the build to determine causes for discrepancies between the projected and actual energy use of the building. It is recommended that the M&V plant follow the requirements outlined in the International Performance Measurement and Verification Protocol (IPMVP), under Option D (calibrated energy model).

ENERGY MODELLING GUIDELINES

Advanced building Energy Modeling is a means of predicting energy consumption in buildings via software and greatly informs a wide variety of design decisions and CSULB should budget for this with any new construction project. Energy modeling should be completed throughout the duration of the design process to validate design concepts and help guide the design team. Early in the design process energy modeling can guide building massing and orientation decisions to ensure reduced energy consumption. As the design progresses different HVAC systems, or similar HVAC systems with different efficiencies can be modeled.

Weather Files

The energy model should be simulated with both typical weather files (TMY3, EPW, etc.) and actual weather conditions from recent years. The building must meet the EUI target for both weather conditions.

Summary of Inputs

Energy modeling reports should be provided that include all the following information for all NZE projects. This will improve the ability for the campus and designers to identify any discrepancies between the actual energy performance and energy model projections during post occupancy verification.

- Energy Modeling Software: name and version

- Building Geometry
  - Images of 3D energy model
  - Images of energy modeling zoning diagrams (not required for all typical office floor plans, if applicable)

- Opaque Envelope Assemblies: provided the following information for each unique opaque envelope assembly
  - Description of assembly
  - Calculations of the assembly U-value (degradation from insulation attachments shall be accounted for)

- Window Assemblies: provided the following information for each unique opaque envelope assembly
  - Description of assembly
  - NFRC rated performance values

- Space Summary: breakdown of modeled spaces/occupancy type and respective area

- Internal Gains: provide the following information for each space type modeled in the building
  - Lighting
    - Power density (W/sf)
    - Summary of lighting system and controls
    - Profiles/schedules
  - Receptacles/Misc Equipment
    - Power density (W/sf)
    - Summary of any advanced controls
    - Profiles/schedule
  - Occupancy
    - People density (sf/person)
    - Occupancy heat gains (Btu/person)
    - Summary of any advanced controls

    - Profiles/schedule
  - Miscellaneous
    - Building infiltration rates
    - Miscellaneous process loads
    - Elevators

- Domestic Hot Water
  - Description of system
  - Efficiency Ratings
  - Storage capacity, if applicable

- HVAC Systems
  - Description of all HVAC system
  - Design Conditions
  - Air Side design conditions:
    - Equipment efficiency
    - Fan power, static pressure
    - Supply air temperatures
    - Description of controls (economizers, DCV, resets, etc.)
  - Water Side design conditions
    - Equipment efficiency
    - Pump configuration and power (including head pressure)
    - Supply temperatures
    - Description of controls (resets, economizers, etc.)
  - Other
    - Description of system
    - Efficiency Ratings
    - Description of controls

Summary of Outputs & Results

The following outputs should be provided as part of the final energy modeling report for all NZE projects.

- Annual end use energy computation: utility units, MBtu, and kBtu/sf
  - Lights
  - Receptacles/misc equipment
  - Elevators
  - Space heating
  - Space cooling
  - Heat rejection
  - Pumps
  - Fans
  - Domestic hot water
  - Exterior lighting
  - Total energy use (gas & electric)
  - Renewable energy generation

- Site Energy Use Intensity (EUI)
  - The project's site EUI shall be calculated based on the energy consumption per square foot. The square footage of the building shall include all spaces including those not regularly occupied (MEP Rooms, IDF rooms, etc.) but does not include shaft space.

- Greenhouse Gas (GHG) emissions
  - This shall be provided in metric tons of equivalent CO_2 emissions (MTE)
  - Provide estimated GHG emission based on E*NERGY STAR Portfolio Manager Greenhouse Gas Emissions* T*echnical Reference* (August 2018) using the following emissions factors. Emissions factors should be updated based on current emissions.
    - Electricity (CAMX): 70.44 kg/MBtu
    - Natural Gas (US): 53.11 kg/MBtu
  - Provide estimated GHG emissions in the year 2045, accounting for CA Senate Bill 100, using the following emissions factors:
    - Electricity (CAMX): 0 kg/MBtu
    - Natural Gas (US): 53.11 kg/MBtu

- Description of energy efficiency measures included in the design

- Any other relevant information, graphs, tables or charts

- Title 24 Form PRF-01-E Certificate of Compliance

12.3 CERTIFICATIONS

The *Green Building Action Plan,* which summarizes the NZE requirements for State entities under the governor's direct executive authority, details the validation process and submittals essential to document NZE performance. A summary of those requirements is as follows:

- Submission and verification of data entries into Energy Star Portfolio Manager
- Annual report submission by March 1st including:
    - Energy usage
    - Individual building square footages
    - Individual building types
    - On-site renewable energy generation and usage
- Submission of GHG emissions to The Climate Registry's CRIS Database

The *Department of General Services* also provides a NZE Calculator for the calculation and submission of pertinent energy consumption characteristics[59]. By these means, it is possible to demonstrate and document NZE performance per the requirements of the State of CA.

There are also third-party certification companies that offer net zero energy certifications that CSULB could choose to pursue. These include:

- *Zero Energy Certification* – International Living Future Institute (Living Building Challenge)
- *Net Zero Certification* – US Green Building Council (LEED)

[59] Zero Net Energy Program, *California Department of General Services,* 2017. Available: *https://www.documents.dgs.ca.gov/os/ZNE/StateofCAZeroNetEnergyCalculator.xlsx*

13. CEMP CONCLUSIONS

The following conclusions and final recommendations should be used by CSULB over the next 5-Year as they work towards 2030 Carbon Neutrality

BUILDING ENERGY EFFICIENCY

CSULB should continue to focus on reducing the energy use in existing buildings as part of their path towards 2030 Carbon Neutrality. This offers one of the largest opportunities for CSULB to reduce its direct environmental impact. It is recommended that CSULB accelerates their investment strategy in EE Projects beyond the current spend rate on campus ($1-1.5 million annually). Specific actions that CSULB can take to reduce building energy use across campus include:

1. Aim to implement all EE projects with a reasonable payback periods prior to 2030.
2. Target an average annual EE investment rate of at least $2.8 million leading up to 2030
3. Prioritize projects with lower paybacks up front and with external financing.
4. Outsource (potentially through CSU CO's Master Energy Agreements)
5. Establish a revolving green fund to measure & verity EE project energy savings and to fund future clean energy projects on campus
6. Combine capital intensive retrofit projects with larger building renewal projects to reduce net project cost for EE project and limit impact to campus operations
7. Establish a campus wide retro-commissioning/control optimization initiative
8. Review building hours of operations and reduce the HVAC hours of operation when buildings are always unoccupied or underutilized
9. Establish a quarterly schedule review process. This should include: Summer Building Shutdown, Friday/Saturday Shutdown, Schedule & Space Optimization, etc.
10. Maintain current ZNE standards for new construction and major renovation projects.

RENEWABLE ENERGY

Renewable Energy can provide significant reductions in the GHG footprint of the campus and be a key component of an integrated strategy to reach the campus carbon neutrality goals. Specific actions that CSULB can take to ecumenically develop additional solar PV projects include:

1. Assess the opportunity to switching the existing 4.8MW solar system to a net energy metered (NEM) contract. Ensure that additional PV can be added under the NEM agreement.
2. Establish a renewed competitive solar PV procurement process
3. Conduct a due diligence assessment of Solar PV proposals to address potential economic challenges on campus (4.8MW No-Export Agreement, New SCE Rate Structure, etc.)
4. Establish self-generation targets based on PPA rates from the competitive procurement process and due diligence assessment

CLEAN ENERGY VEHICLES

While vehicle fuel use accounts for only 0.5% of the overall GHG emissions of the university, transitioning to alternative clean vehicles should be an important part of CSULB's clean energy master plan. Specific actions that CSULB can take to transition to a cleaner fleet of vehicles include:

1. Prioritize purchasing fully electric vehicles long term
2. Establish a clean energy vehicle standard for all replacement vehicles
3. Establish interim electrification targets between now and 2030
4. Prioritize transitioning highly used and older inefficient vehicles
5. Assess using electric shuttle busses in five years when the current third-party provider's contract expires under the competitive RFP process
6. Continue to track and pursue funding opportunities for clean energy vehicles
7. Establish a pilot electric vehicle program immediately
8. Establish an electric grounds equipment pilot program with the facilities department

CARBON OFFSETS

CSULB should continue to follow the carbon management hierarchy and reduce its emissions through owned and operated projects before purchasing offsets. Leading up to 2030, CSULB should take the following action to ensure they establish an impactful carbon offset program:

1. Establish a written CSULB Carbon Management Hierarchy policy.
2. Establish minimum internal requirements for the make-up of carbon offset portfolio
3. Establish minimum requirements for the sources for carbon offset purchase
4. Begin to clearly communication carbon management hierarch with the key stakeholders and the CSULB community

14. APPENDIX

APPENDIX A – ENERGY AUDIT SUMMARY REPORTS

APPENDIX B – ASHRAE LEVEL II ENERGY AUDIT REPORTS

APPENDIX C – SAVI TOOL – BASIC USER MANUAL

APPENDIX D – SAVI TOOL – SUPER USER MANUAL

APPENDIX E – CENTRAL PLANT ELECTRIFICATION

APPENDIX F – SOLAR PV FINANCIAL ASSESSMENT