UNIVERSITY OF CALIFORNIA
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Achieving Carbon Neutrality at UCSB by 2025:
A Critical Analysis of Technological and Financial Strategies

A Group Project submitted in partial satisfaction of the requirements for the degree of Master of Environmental Science and Management
for the
Bren School of Environmental Science & Management

by

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As authors of this Group Project report, we archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

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The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

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Acronym List

AB 32	-	California Assembly Bill 32
ACH	-	Air Changes per Hour
COP 21	-	United Nations Conference of the Parties held in Paris, December 2015
CPUC	-	California Public Utilities Commission
CSG	-	Community Solar Garden
CSU	-	California State University
C&T	-	Cap and Trade
DEEC	-	Deep Energy Efficiency and Cogeneration Study, Findings Report (2014)
DPP	-	Detailed Project Program
ESDVR	-	Exhaust Stack Discharge Velocity Reduction
ESP	-	Energy Service Provider
GHG	-	Greenhouse Gas
GRF	-	Green Revolving Fund
HRS	-	Housing & Residential Services
HVAC	-	Heating, Ventilation, and Air Conditioning
IOU	-	Investor Owned Utilities
LCCA	-	Life Cycle Cost Analysis
LED	-	Light Emitting Diode
LRDP	-	Long Range Development Plan
MBCx	-	Monitoring-Based Commissioning
$MtCO_2e$	-	Metric tons of carbon dioxide equivalent
OGSF50	-	Campus Gross Square Feet + 50% of Outside Area
O&M	-	Operations & Maintenance
PPA	-	Power Purchase Agreement
PV	-	Photovoltaic
REC	-	Renewable Energy Credit
SB 286	-	California Senate Bill 286
SBCAPD	-	Santa Barbara County Air Pollution Control District
SCE	-	Southern California Edison
SEP	-	Statewide Energy Partnership
TCR	-	The Climate Registry
TOU	-	Time of Use
UCOP	-	University of California, Office of the President
UCSB	-	University of California, Santa Barbara
UNFCCC	-	United Nations Framework Convention on Climate Change
VFD	-	Variable Frequency Drive
ZEV	-	Zero Emission Vehicle
ZNE	-	Zero Net Energy

Executive Summary

In 2013, University of California (UC) President Janet Napolitano established the Carbon Neutrality Initiative (CNI), a commitment to eliminate all Scope 1 and Scope 2 emissions by 2025. As one of the first major universities to make a climate commitment of this magnitude, few resources existed to aid the university in accomplishing this complex goal. Recognizing the need to develop plans to achieve the CNI target, UCSB's Chancellor's Sustainability Committee proposed "Optimal Strategies for Achieving Carbon Neutrality at UCSB by 2025" to the Bren School of Environmental Science & Management as a group thesis project, which resulted in a year-long directed research effort aimed at developing a strategy to achieve carbon neutrality at UCSB by 2025.

UCSB has a history of environmental leadership in the UC system, yet maintaining the current emissions trajectory will result in 42,000 $MtCO_2e$ of combined Scope 1 and Scope 2 emissions in 2025. In light of an expanding campus, UCSB must take aggressive actions to pursue energy efficiency retrofits, source renewable electricity, and identify financing strategies that will enable the investments necessary to achieve carbon neutrality and reduce long-term operating costs by 2025. Accordingly, this study aimed to identify the most promising energy efficiency strategies, assess on- and off-site options for the procurement of renewable energy, develop a Life Cycle Cost Analysis (LCCA) tool to enable holistic understanding of economic impacts during project evaluation, and identify barriers and opportunities for financing energy efficiency at UCSB. In this report, we identify attractive and feasible greenhouse gas mitigation strategies that require a total investment of $48.3 million. We project that these measures will result in $6.6 million of annual avoided utility costs and a 60% reduction in UCSB's annual emissions by 2025.

The demand-side strategies we identify include LED & Controls Retrofits, HVAC Retrofits, Laboratory Retrofits, Monitoring-Based Commissioning (MBCx), and the installation of a campus Hot Water Loop (HWL). For the procurement of renewable energy, we recommend that on-campus solar photovoltaic power purchase agreements (PPAs) be pursued to the highest degree feasible, as they have no upfront cost and are projected to reduce utility expenditures over the lifetime of the technology. For additional renewable energy procurement, we identify three off-site options for which there is currently too much price uncertainty to provide a recommendation. We conclude our analysis by proposing a deployment schedule that accounts for barriers related to the availability of funding, logistical challenges, and UCSB's regulatory context.

Using our LCCA tool, we found that UCSB could reduce its 20-year operating cost from $182 million (2016 present value) to $138 million (2016 present value), $44 million lower than our estimated baseline scenario. This $138 million includes total investments necessary for all demand- and supply-side strategies mentioned above, and results in over 500,000 $MtCO_2e$ of emission reduction over 20 years. Based on these results, we find that UCSB is well positioned to achieve carbon neutrality for Scope 1 and Scope 2 emissions by 2025, reduce long-term operating costs, and maintain its reputation as a sustainability leader. We recommend that UCSB focus short-term efforts on energy efficiency projects with quick payback periods and establish a Green Revolving Fund (GRF) to capture and leverage the avoided utility costs and support further energy efficiency projects with longer payback periods. With 2025 quickly approaching, the annual purchase of renewable energy credits (RECs) or carbon offsets to meet the 2025 goal may be necessary in the short term, but we recommend that UCSB prioritize energy efficiency and on-site solar in order to retain value on campus before diverting resources off campus.

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1. Introduction

In 2013, Janet Napolitano was appointed the President of the University of California. Inspired by the University of California's (UC) leadership in climate research and past efforts to reduce environmental impacts, President Napolitano established the Carbon Neutrality Initiative (CNI), which calls for the 10 UC campuses and associated medical centers to reach carbon neutrality for Scope 1 and 2 emissions by 2025.[1] Primarily, Scope 1 includes emissions associated with on-site combustion of natural gas, and Scope 2 includes emissions associated with generation of the electricity purchased by UCSB. In November of 2015, University of California, Santa Barbara (UCSB) Chancellor Henry Yang pledged to support this initiative and put forth the resources necessary to become carbon neutral by 2025, stating: "We recognize the urgent need to act now and avoid irreversible costs to our global community's economic prosperity and public health."[2]

At the 2015 Conference of the Parties (COP21) held in Paris, an agreement was reached between 195 countries aimed at keeping the average global temperature increase below 2°C.[3] As global consensus builds around the concept of anthropogenic climate change, quickly reducing carbon emissions is becoming more important than ever.[4] During COP21, greenhouse gas (GHG) mitigation was identified as one of the crucial steps to attaining this goal. However, mitigating institutional carbon emissions is a challenging endeavor – scientific progress tends to improve the practicality of carbon neutrality by improving technologies and reducing costs, while institutional dynamics, policy constraints, and financial realities tend to pose significant barriers. Despite these challenges, UCSB should take the steps necessary to meet President Napolitano's goal by 2025, as these efforts will decrease UCSB's long-term operating costs, improve campus resiliency, attract positive press, assist in recruiting efforts, and enable compliance with air quality and emissions regulatory mandates.

Through examination of technological and financial strategies, our group has formulated a plan for UCSB to achieve carbon neutrality by 2025. This document details the state of current technologies, potential financing options, and policies that shape the plan recommended by this team, and provides estimates of cost and GHG emission savings derived from the Life Cycle Cost Analysis (LCCA) tool that we developed for UCSB. We will provide the LCCA tool and our Green Revolving Fund (GRF) "spin-up" optimization model to the Chancellor's Sustainability Committee upon completion of this project.

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1 St. Clair, "The University of California's Commitment to Climate Solutions."

2 Yang, "Chancellor Yang Pledges Carbon Neutrality by 2025."

3 United Nations Framework Convention on Climate Change, "Historic Paris Agreement on Climate Change 195 Nations Set Path to Keep Temperature Rise Well Below 2 Degrees Celsius."

4 Victor and Zhou, "Mitigation of Climate Change."

2. Objectives

Prompted by the President Napolitano's CNI and the Chancellor's Sustainability Committee (CSC) at UCSB, this project was formed to investigate strategies for UCSB to achieve carbon neutrality for Scope 1 and Scope 2 emissions by 2025. The objectives of this project are to:

1. Assess the efficacy of GHG mitigation technologies
2. Estimate implementation costs and evaluate financing options
3. Recommend a deployment schedule based on regulatory, financial, and logistical considerations

3. Assessment of the Current State of UCSB

In order to understand the relative impact of our carbon reduction strategies to reduce UCSB's carbon emissions, we performed an assessment to determine the amount of emissions that the university is currently producing annually, also referred to as the baseline condition. This assessment was completed through reviews of university reports and historical carbon reporting. Energy costs, energy efficiency projects, regulations, and energy use trends of the past and present were revealed through this study.

3.1 – UCSB Campus Energy Management and Procurement

According to UCSB's 2015 Utility and Energy Report, UCSB held a SCE electrical account with a bundled service, time of use (TOU) rate, and continued to purchase natural gas from Southern California Gas Company for the entirety of the 2014/2015 fiscal year. Total consumption at UCSB in 2014/2015 was about 3 million therms and 90.3 GWh[5], and the average price paid for natural gas and electricity was about $0.60/therm and $0.11/kWh.[6]

Despite reductions in natural gas and electricity consumption in 2014/2015, UCSB experienced a 0.7% overall increase in utility costs.[7] This growth in utility spending during 2014/2015 was primarily driven by increased electricity expenditures resulting from "substantial increases in seasonal and time dependent demand changes". This led UCSB Utility & Energy Services to prioritize measures that reduce peak demand. For more information, please review UCSB's 2014/2015 Annual Energy & Utility Report.

3.2 – Baseline Emissions

In order to understand what efforts are necessary to reduce UCSB's Scope 1 and 2 emissions to zero, it was essential to project UCSB's future emissions. Creating this baseline scenario provides planners with a starting point from which progress toward carbon neutrality can be measured, aiding in mid-goal project adjustments and planning.

Each year, UCSB reports emissions to The Climate Registry (TCR), a GHG reporting program that assists organizations in measuring, verifying and reporting their operational carbon

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[5] Snavely and Watson, "UCSB_CAP_GHG_Workbook_Emissions_Projection.xlsx."
[6] "UCSB Utility & Energy Report 2015.pdf."
[7] Ibid.

footprints in order to facilitate carbon management and reduction. Reported emissions are broken down into three different scopes, with Scope 1 representing on-campus combustion (natural gas, diesel, gasoline, biodiesel, CNG, propane); Scope 2 representing indirect emissions associated with the generation of our purchased electricity, and Scope 3 representing all other indirect emissions. In the 2014 Climate Action Plan, UCSB reported total emissions of 82,928 $MtCO_2e$.

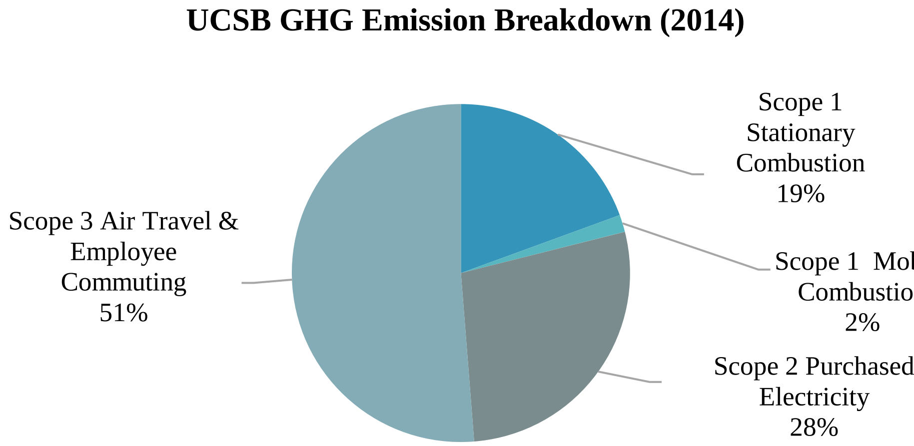

Figure 1. Reported GHG Emissions at UCSB (2014).[8] Total: 82,928 $MtCO_2e$

3.3 – Energy Demand End Use

Energy use at UCSB is primarily a function of heating and cooling systems, lighting, plug load, pumps, fans, and other process loads. While a lack of sub-metering prevents a detailed understanding of each end use, consumption is not proportionately distributed among buildings. Rather, it is concentrated in spaces such as laboratories and server rooms that have a high number of air changes per hour, a high need for space heating/cooling, and a high plug load associated with advanced appliances.

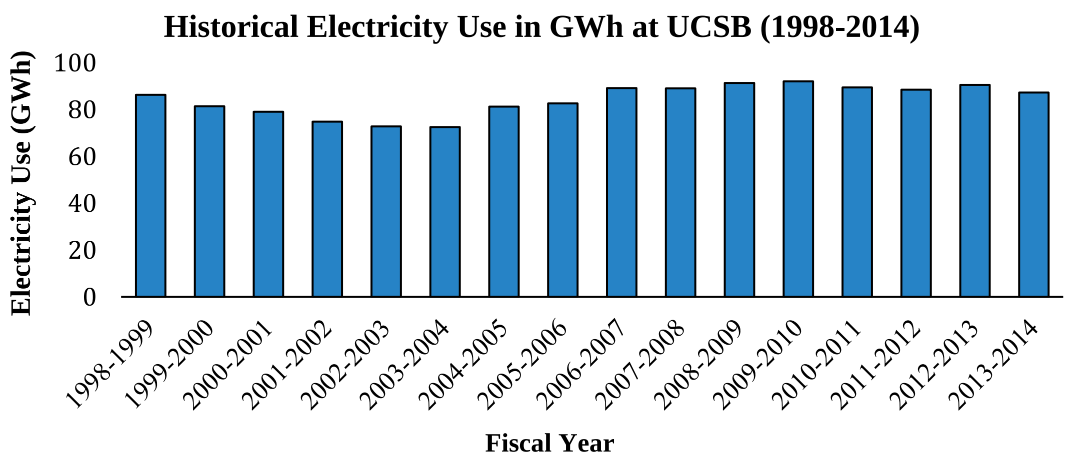

Figure 2. Historical Electricity Use in GWh at UCSB from 1998 to 2014.[9]

[8] "Climate Action Plan (2014)."
[9] "UCSB Utility & Energy Report 2015.pdf."

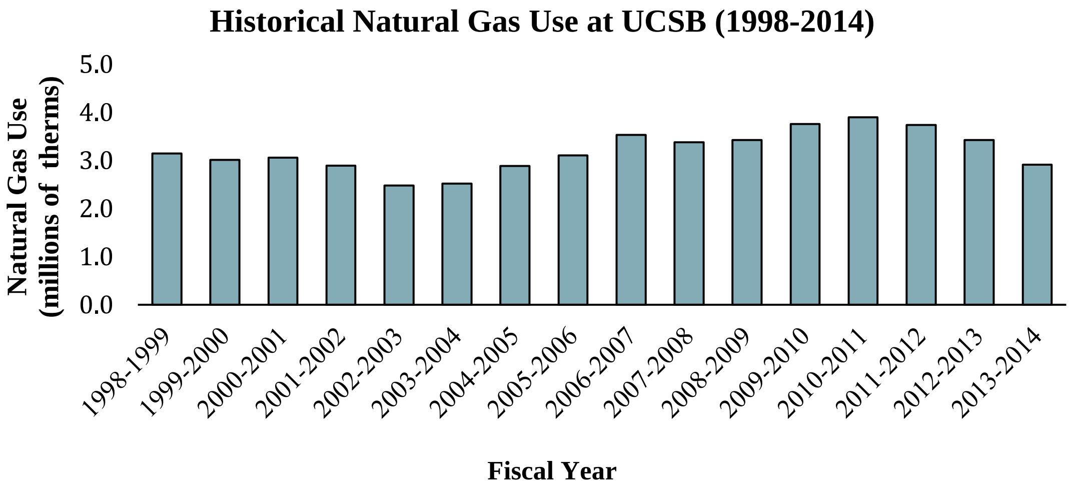

Figure 3. Historical Natural Gas Use in therms at UCSB from 1998 to 2014.[10]

This uneven distribution of energy consumption means that efficiency measures must be prioritized in the spaces with the greatest energy intensity and on projects that work to centralize heating and cooling. High efficiency laboratory equipment should be phased in as older equipment requires replacement, and exhaust stack discharge velocity reduction (ESDVR) retrofits and commissioning must be pursued to reduce the energy intensity of lab spaces while maintaining safety standards. LED & Controls Retrofits must be considered in all spaces. By focusing on these types of projects and prioritizing those with the fastest payback, UCSB can generate short-term utility savings that will translate into buying power for future efficiency projects.

3.4 – Historical Reductions on Campus

UCSB has a record of accomplishment for being a leader in campus sustainability, including projects that reduced energy demand and decarbonized electricity consumption. This section covers the primary energy efficiency measures that UCSB has implemented in recent history.

3.4.1 – Statewide Energy Partnership (SEP)

UCSB has reduced project implementation costs and accelerated investments in energy efficiency on campus by taking advantage of the SEP program, which has provided millions dollars in incentives. From 2009 to 2014, 77 SEP projects occurred at UCSB. Project types have varied, and include investments in interior and exterior lighting, compressed air optimization, chilled water loop optimization, MBCx, and upgrades to HVAC equipment and controls. During this time, total investment after utility incentives has totaled $11,757,146 with an average simple payback of about 8 years.[11] A summary of these projects is displayed below in Table 1.

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[10] Ibid.

[11] Sager, "UCSB SEP Projects 09-14 Summary Excel Workbook."

Table 1. SEP Projects Summary (2009–2014). Total project costs take into account SCE and SCG incentives. Cost assumptions are $0.11/kWh and $0.6/Therm. Source: Jordan Sager, UCSB SEP Projects 09-14 Summary Excel Workbook.

Project Type	Total Project Cost	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (therms)	Annual Cost Savings
LED & Controls Retrofits	$ 1,714,007	926,851	-	$ 101,954
HVAC Retrofits	$ 3,687,629	1,393,158	121,602	$ 238,369
MBCx	$ 1,194,771	4,395,431	40,326	$ 238,369
Hot Water Loop	$ 3,333,649	-	62,396	$ 43,677
Chilled Water Loop	$ 271,666	2,490,307	-	$ 273,934
Other	$1,353,016	1,150,445	99,264	$ 196,034

3.4.2 – Demand Response

UCSB Utility & Energy Services moved forward with the implementation of an automated demand response capability in cooperation with SCE at the end of 2014. This project allows UCSB to reduce electrical demand by over 1 megawatt during times of peak load on the electricity grid. While UCSB experiences relatively low seasonal variability, demand response is most effective between the summer months of June and September. Demand response increases local grid reliability, and expands UCSB's relationship with their primary energy partner, SCE.

3.5 – Total Carbon Reductions to Date

According to campus emissions reporting, overall Scope 1 and Scope 2 emissions at UCSB fell by 18% between 1990 and 2015, while the campus almost doubled in size.[12] This represents an impressive 41% decrease in emissions intensity. This decrease is the result of ongoing investments in energy efficiency, as well as varying emission factors for purchased electricity, which have changed over time due to periodic switching between electricity providers. Figure 4 below is a visual representation of UCSB's historic emissions for both Scope 1 and Scope 2.

[12] Snavely and Watson, "UCSB_CAP_GHG_Workbook_Emissions_Projection.xlsx."

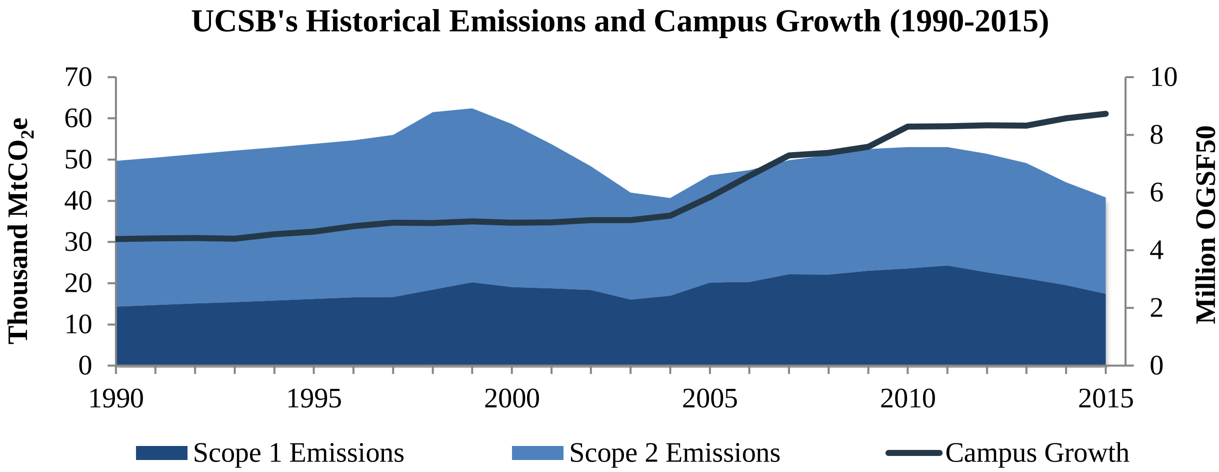

Figure 4. UCSB's Historical Emissions ($MtCO_2e$), 1990-2015.

3.6 – Regulatory Context

Policies at the regional, state, and local level influence UCSB's emissions reductions by providing incentives, establishing rules and regulations, and creating standards for renewable energy portfolios. While energy efficiency and carbon emission reductions are important to decision-makers at UCSB, meeting these regulatory requirements is the highest priority. As new bills are proposed and passed each year, it is important for UCSB to understand the regulatory landscape in order to maintain compliance and take advantage of all available incentives for energy efficiency projects.

3.6.1 – California Assembly Bill 32

The Global Warming Solutions Act of 2006 (AB32), delegates power to the California Air Resources Board (CARB) to reduce GHG emissions. This legislation set a goal for total California GHG emissions to reach 1990 levels by the year 2020, and 80% below 1990 levels by 2050. The 2020 GHG limit for the state is 431 $MtCO_2e$.[13]

AB32 required state agencies to establish GHG emission reporting, verification, monitoring, and enforcement regulations. The first scoping plan was approved in 2008 and outlines how the state should aim to reach GHG reduction goals while "achieving maximum technologically feasible and cost-effective reductions."[14] This plan is required to be updated every 5 years with the latest update approved in May of 2014. A second update to the scoping plan is currently being developed to include Executive Order B-30-15, which aims to reduce GHG emissions 40% below 1990 levels by 2030.[15]

[13] California Air Resources Board, "California 1990 Greenhouse Gas Emission Level and 2020 Limit."
[14] Schwarzenegger, "Climate Change Proposed Scoping Plan Appendices."
[15] "Governor Brown Establishes Most Ambitious Greenhouse Gas Reduction Target in North America."

AB32 also authorized the adoption of market-based compliance strategies, known as the California Cap-and-Trade Program.[16] This program puts a limit on the sources responsible for 85% of the state's emissions, which includes 450 entities. C&T initially covered electricity generators and large industrial facilitates, and in 2015 began to regulate distributors of transportation fuels, natural gas, and other types of fuel. Enforcement began January 1, 2013, and the cap for 2014 was set at 2% below the 2012 expected emissions. Between 2015 and 2020 the cap will be decreased approximately 3 percent annually.[17]

3.6.2 – California Senate Bill 286

Introduced by Senator Robert Hertzberg of District 18, Senate Bill 286 (SB286) would give commercial and industrial customers the opportunity to buy renewable energy on the wholesale market without interfacing through their local utility. In September of 2001, California Public Utilities Commission (CPUC) Decision D.01-090-060 suspended retail end-use customers, excluding community choice aggregation and qualifying DA customers from participating in DA electricity transactions.[18] From December of 2009 – December of 2012, UCSB participated in DA with two 18-month contracts but chose to opt out at the expiration of the second contract in favor of a bundled SCE service contract for rate reasons. Five campuses within the University of California system are participating in DA, utilizing the UCOP as an Energy Service Provider (ESP).

Under the proposed SB 286, retail non-residential electricity consumers would have the option to purchase electricity from either an ESP or a IOU. Under DA, an ESP provides electricity that they either generate themselves or purchase through contracts. Then the electricity is distributed through IOU infrastructure. If UCSB does decide to pursue DA in the future, the university would have the option to choose the power generated by the UC as an ESP. In August 2015, this bill was classified as an appropriations suspense file. This means that the bill has a fiscal impact greater than $150,000 and thus must be voted on by the Appropriations Committee.

3.6.3 – California Senate Bill 350

The Clean Energy and Pollution Reduction Act of 2015 (SB350) increases California's RPS to 50% by the year 2030.[19] This means that by December 31, 2030 50% of the energy provided to retail customers will be procured from renewable sources of energy.

California's first RPS was enacted in 2002 through California Senate Bill 1078, which requires energy procurement from renewable sources to increase by at least 1% per year.[20] The standard has been increased several times since 2002, with the most recent update to the RPS in 2011. Senate Bill X1-2 increased the RPS to 33% by 2020.[21] This regulation will cause SCE's emission factor to decrease, which will decrease UCSB's Scope 2 emissions.

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16 Schwarzenegger, "Climate Change Proposed Scoping Plan Appendices."
17 California Air Resources Board, "California 1990 Greenhouse Gas Emissions Level and 2020 Limit."
18 Hertzberg, *Electricity: Direct Transactions*.
19 de León, Senate Bill No. 350: Clean Energy and Pollution Reduction Act of 2015.
20 Sher, Senate Bill 1078: Renewable Energy: California Renewables Portfolio Standard Program.
21 Simitian, *Senate Bill 2: Renewable Energy Resources*.

3.6.4 – California Assembly Bill 802

Approved by Governor Brown in October 2015, California Assembly Bill 802 (AB 802) focuses on energy efficiency within California and enacts three changes to existing law:

(i) The Energy Commission and CPUC are required to assess the energy industry to develop policies and programs,

(ii) IOUs are required to maintain records of the energy usage of all buildings to which they provide energy, and

(iii) IOUs are required, by September 1st, 2016, to provide incentives to customers for all saving achieved through energy efficiency retrofits, including savings achieved in order to reach Title 24, and IOUs are allowed to recover their costs through rate increases[22]

The last part of this bill—the broadening of the availability of energy efficiency incentives—is most applicable to UCSB, as past policy only permitted IOUs to recover costs (and therefore offer incentives) on savings for energy efficiency that went *beyond* Title 24.[23] This deterred many building owners from pursuing efficiency projects and retrofits within older buildings, hindering the state's ability to meet GHG reduction targets.

3.6.5 – Santa Barbara County Air Pollution Control District Rule 361

Adopted by the SBCAPCD in January of 2008, Rule 361 deals with boilers, steam generators, and process heaters that have a heat capacity between 2 million and 5 million British thermal units.[24] Based on Goss Engineering, Inc.'s February 2016 report, 42 on UCSB's campus boilers come under review due to this regulation. Under previous SBCAPCD rules, these boilers are exempt from compliance, but are now required to be designated as "low-use", retrofitted, or replaced.[25]

To consider the options of low-use designation, retrofits, replacement, and the installation of a HWL, UCSB has contracted Goss Engineering. Regulation required the university to have a comprehensive plan in place and submitted to SBCAPCD by March 15, 2016 and this plan to be executed by January 1, 2020.[26]

3.7 – UCSB's Positioning Within the UC - Achieving Carbon Neutrality

UCSB is well positioned within the University of California to achieve carbon neutrality by 2025. In recent decades, many UC campuses made investments in on-campus "cogeneration" natural gas power generating facilities, which produce electricity by powering a generator with a natural gas burning turbine engine. These types of power plants use relatively clean-burning natural gas and utilize the waste heat that would otherwise be discarded into the environment. As a result, cogeneration facilities are considered to have high thermodynamic efficiency compared

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[22] Williams, *Assembly Bill No. 802: Energy Efficiency*.
[23] "Legislation - Assembly Member Das Williams Representing the 37th California Assembly District."
[24] Santa Barbara County APCD, "Rule 316."
[25] Goss Engineering Inc, "APCD Rule 361 Boiler Study: Draft Report."
[26] Santa Barbara County APCD, "Rule 316."

to other types of fossil power plants. UCSB has not invested a cogeneration facility, which has played out favorably, as there are no cost-effective substitutes for natural gas.

UCSB sits on the edge of the Pacific Ocean along the southern coast of California. Throughout the year, onshore breezes keep temperatures moderate, resulting in warmer winters and cooler summers compared to inland regions. These moderate temperatures explain UCSB's relatively low demand for the heating and cooling of buildings, which drive energy consumption in regions with greater seasonal fluctuations in temperature.

UCSB's history of student driven sustainability efforts, as well as a strong institutional commitment to energy efficiency, contributes to a sense that carbon neutrality could become a reality on campus. Continued efforts by UCSB's Utility & Energy Services department to pursue energy efficiency projects and take advantage of SEP incentives have resulted in considerable in-house knowledge that will be critical to the implementation of future energy efficiency projects in a cost effective manner. Moreover, Chancellor Henry Yang's recent signing of UCSB's commitment to achieving carbon neutrality has provided the administrative signal necessary for making carbon neutrality at UCSB a priority.

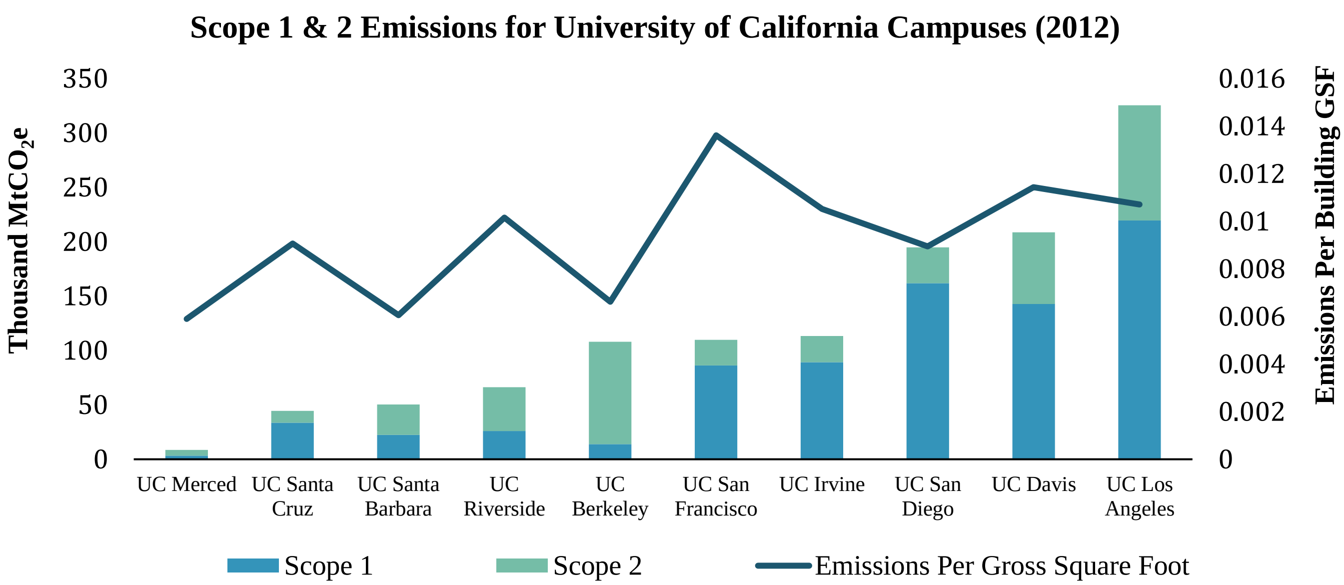

Figure 5. Scope 1 & 2 emissions for University of California campuses (2012).[27]

3.8 – Challenges for UCSB Achieving Carbon Neutrality

The major barrier to achieving carbon neutrality at UCSB is the campus' current inability to accrue additional debt. Efforts to satisfy the fundamental mission of the University of California have led to the expansion of campus infrastructure to accommodate the growing demand for the high quality education UCSB provides. These investments have demanded high levels of capital expenditure, which have caused the university to reach its debt limit, limiting traditional financing strategies in the context of energy efficiency.

[27] "Campus Climate Action | UCOP."

Another challenge to achieving carbon neutrality is that project evaluation at UCSB is based upon a simple payback model, which doesn't take into account the time value of money, escalation rates for electricity and natural gas, differing operating, maintenance, replacement schedules, or variations in the expected life of technologies. By using simple payback, decision makers on campus ultimately fund projects with higher emissions and life cycle costs. To remedy this issue, our group has developed a LCCA tool specific to UCSB.

Finally, the structure of the budgets at UCSB have resulted in the dismissal of projects that make financial sense. According to interviews with Jordan Sager and Dave McHale, projects that would result in considerable savings for the operations and maintenance budget cannot be justified by spending surplus dollars from the utility budget, as the savings from those projects cannot be captured by the utility budget. After considering a number of potential solutions to this situation, we have focused on the implementation of a GRF, which captures and re-invests the avoided utility costs associated with reduced energy consumption.

4. Methodology

Our recommendations for how UCSB can achieve carbon neutrality are broken down into four steps, which categorize our objectives in a logical framework. These four steps include:

(i) Strategies to reduce demand-side energy consumption,
(ii) Opportunities to procure renewable energy,
(iii) Estimates of lifecycle costs and identification of financing options, and
(iv) A deployment schedule based on a 3-phase approach that extends to 2030.

While the UCOP goal is to achieve carbon neutrality for Scope 1 and Scope 2 emissions by 2025, we chose to look past the target date in order to emphasize that demand reduction efforts must continue beyond 2025 in order to minimize reliance of carbon offsets.

STEP 1
Reduce Energy Demand

STEP 2
Procure Renewable Energy

STEP 3
Analyze Cost Implications

STEP 4
Create Deployment Schedule

4.1 – Methodology Overview

Research on carbon neutrality was performed through various strategies, including interviews, literature review, and examination of case studies from other UC campuses. Interviews were conducted with UCSB energy managers, UC sustainability experts, and renewable energy industry professionals. Our literature review covered peer-reviewed papers focused on reducing carbon emissions at the state and national level, reports on technological maturity and levelized costs of energy, and case studies focused on specific energy efficiency projects and meta-analysis' of Statewide Energy Partnership (SEP) projects.

4.2 – Baseline Emissions Methodology

Baseline emissions were calculated by updating existing campus emissions projections from 2012-2013 campus emissions reporting to include campus reporting from 2013-2014 & 2014-2015, campus growth based on the UC 2014-2024 Capital Financial Plan, and projected decreases to the carbon intensity of SCE's grid mix (Appendix D) prompted by California Senate Bill 350.[28]

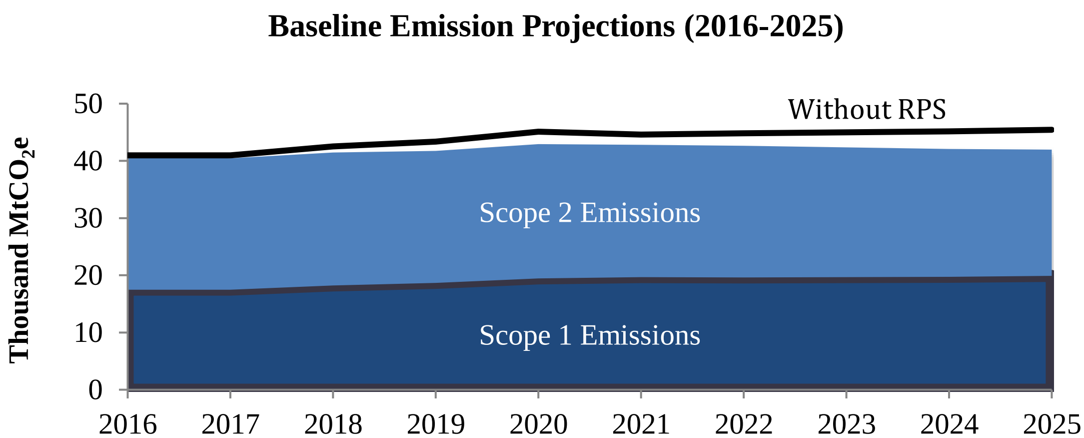

Figure 6. Baseline Emission Projections (2016-2025). Shaded area represents projected emissions in metric tons of carbon dioxide equivalent ($MtCO_2e$) with assumptions that SCE will meet a 50% RPS by 2030, and the black line represents projected emissions assuming that the carbon intensity of purchased electricity stays constant over time.

4.3 – Methodology for GHG Emission Mitigating Strategies

Based on our projection, UCSB's 2025 emissions will total 41,964 $MtCO_2e$, including Scope 1 contributions of 19,885 $MtCO_2e$ and Scope 2 contributions of 22,079 $MtCO_2e$ (Figure 6). To eliminate these 2025 baseline emissions, UCSB must plan for and implement a portfolio of cost effective GHG mitigation strategies.

4.3.1 –Demand Reducing Technology Methodology Overview

To understand the potential GHG abatement associated with each recommended technology, our team assessed the maturity, financial feasibility, capital investment, GHG abatement potential,

[28] The University of California, "University of California, 2014-2024 Capital Financial Plan.pdf."

regulatory implications, and ease of implementation associated with each identified option. While there are a number of additional strategies that may be relevant to UCSB's approach to carbon neutrality, it clear that focusing on several cost-effective technologies with high GHG abatement potential to implement in the near-term would yield the most practical results, given our time constraints. Through our process of interviews and literature review, we identified five primary demand reduction strategies that we believe are necessary to significantly reduce UCSB's energy demand by 2025: (i) LED & Controls Retrofits, (ii) HVAC Retrofits, (iii) Laboratory Retrofits, (iv) MBCx, and (v) the installation of a Hot Water Loop. The following section provides background and methodology for each identified strategy.

4.3.1.a – LED & Controls Retrofits

Light Emitting Diodes (LEDs) are a solid-state lighting technology that in recent years have surpassed conventional lighting technologies in terms of energy efficiency, average rated life, versatility, and color quality. Most importantly, the increasing cost competitiveness of LEDs is driving their adoption in a variety of lighting applications, enabling significant reductions to building energy consumption and operating budgets. The installation of adaptive lighting control technologies can significantly increase the overall savings from lighting retrofits, as these controls automatically adjust light output based on environmental conditions in order to optimize space and building energy performance.[29]

In 2014, UCOP commissioned the Deep Energy Efficiency and Cogeneration Study (DEEC)[30], a report written by ARC Alternatives that identified the potential for retrofits of lighting, laboratories, and HVAC systems for each of the UC campuses. This study found that 50% of energy used for lighting can be reduced through the adoption of LEDs and adaptive lighting control technologies, resulting in estimated savings of 2.7 to 3.1 million kWh/year. Since this report, additional advances in LEDs, control technologies, and commissioning practices have enabled even deeper savings. Accordingly, we conducted our own study of lighting at UCSB in order to estimate this new savings potential.

A wide variety of light fixtures and bulbs currently exist at UCSB. Indoor spaces generally contain linear and compact florescent technologies, while exterior spaces predominantly contain high-pressure sodium, metal halide, and various florescent bulbs.[31] Efforts to upgrade lighting systems to LEDs are already under way on campus, but projects have primarily been implemented in spaces with the highest savings potentials, such as hallways, in order to justify projects financially. As LED and control technologies continue to experience quality improvement and reduced prices, comprehensive building retrofit projects are expected to become more attractive. UCSB has the ability to capitalize on reduced costs achieved from bulk procurement, resulting in faster payback and lower barriers to implementation.

As mentioned above, our group conducted our own study of lighting at UCSB in order to understand how much energy could be through comprehensive retrofit of lighting systems. This study involved the audit of 9 on-campus buildings, including three laboratory, three administrative / academic, and three residential buildings. These building types account for 83%

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[29] Papamichael, Konstantinos, "CLTC, Adaptive Lighting Controls, 2014.pdf."
[30] ARC, "Deep Energy Efficiency and Cogeneration Study Findings Report."
[31] UCSB, "UCSB Exterior Lighting Report."

of campus square footage, while the remaining 17% of campus buildings are parking structures, storage, and small miscellaneous structures (Figure 7).

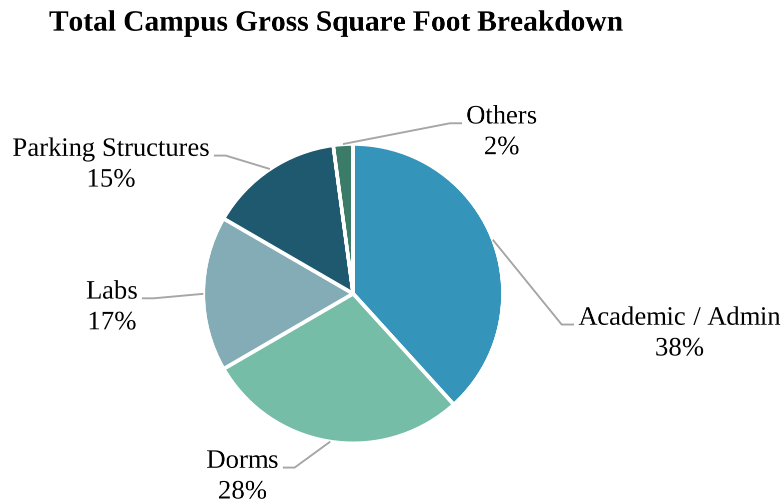

Figure 7. Total Campus Gross Square Foot Breakdown (2016). Total: 8 million ft^2

To conduct this analysis, the related gross square footage (OGSF50) of interior spaces were inventoried into the bins based on expected residual Hours of Use (HOU) (Figure 8), and lamp count and wattage were recorded. We simplified existing lighting systems on campus by expressing lamps in terms of 32W T8 4' fluorescent tubes and 18W CFL bulb equivalents, as we found those bulb-types to be the predominant lighting installed on campus. Our lighting surveys allowed us to estimate baseline power consumption from lighting in each space type, which we then divided by the OGSF50 found for each space type in order to generate metrics in the form of kWh/year/ft^2. Multiplying baseline space type metric by the average existing square footage of each space type by building type yielded metrics for baseline energy consumption by building type in kWh/year/ft^2 (Figure 9).

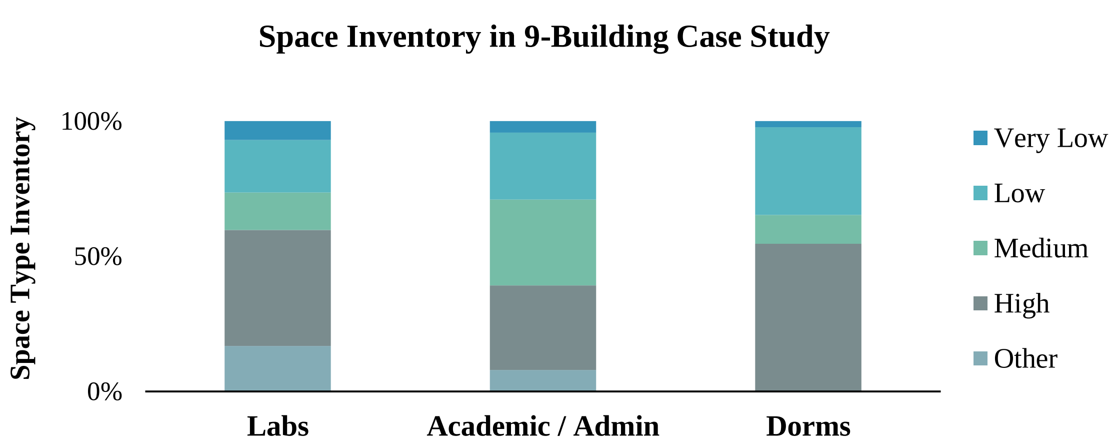

Figure 8. Result from Space Inventory in 9-Building Case Study. Space inventory measured in kWh/ft^2/year. Space-type is broken down by expected post-retrofit energy consumption.

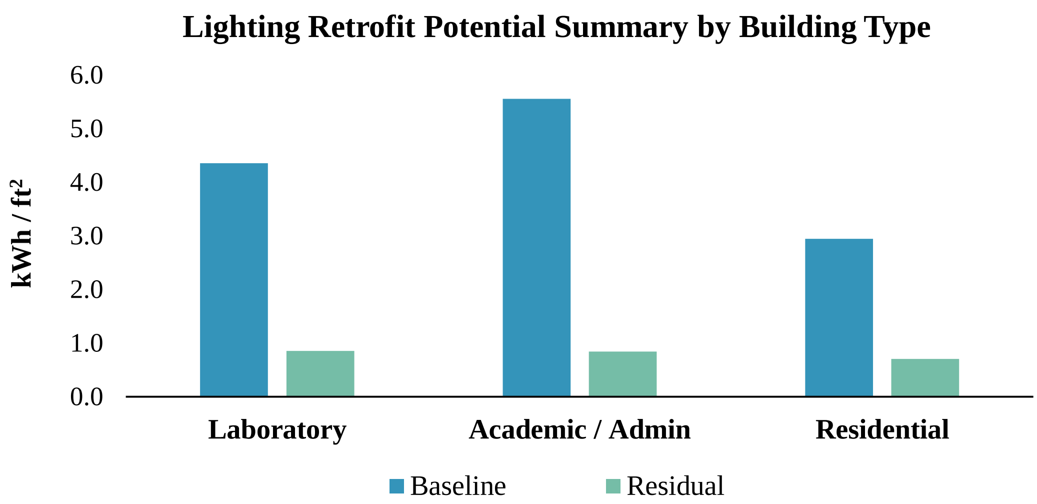

Figure 9. Lighting Energy Intensity by Building Type. Lighting Energy Intensity is normalized to gross floor area in kWh/year/ft^2.

In order to develop building type metrics for residual energy consumption, we assumed that fixtures with 2x32W T8 4' bulbs would be replaced with 1x36W 2'x4' LED Philips Evokit retrofit kit, which would be programmed to operate at 60% output during occupied periods for a functional wattage of 21.6W. We also assumed that 1x18W CFL would be replaced with 1x8.5W LED in a "plug & play" scenario, without integration with adaptive controls. During unoccupied periods under the Philips Evokit scenario, we modeled "Very-Low" spaces to turn off based on the installation of 1-hour twist timers, "Low" and "Medium" spaces to dim to 10%, "High" occupancy spaces turn off based on the installation of an occupancy sensing wall switch, and "Other" spaces to be retrofitted with LED bulbs without dimming. HOU assumptions were determined based on recent best-practice LED projects from other UC campuses, including the 2014 Student Center retrofit at UC Irvine and the Smart Lighting Initiative at UC Davis (Appendix E).

Using these assumptions, we estimated residual power consumption from lighting in each space type, and then divided by the OGSF50 found for each space type in order to generate metrics in the form of kWh/year/ft^2. Multiplying residual space type metric by the average existing square footage of each space type by building type yielded metrics for residual energy consumption by building type in the form of kWh/year/ft^2 (Figure 9). After determining our building type metrics, we then subtracted our residual metrics by building type from our baseline metrics by building type to find savings metrics by building type (kWh/year/ft^2). Finally, we multiplied by the square footage of each building type found at UCSB, and summed the savings in order to estimate total campus energy savings, as shown by the equation below:

$$E_{Savings,campus} = \sum \left[\left(e_{baseline,building\ type} - e_{residula,building\ type} \right) \times Area_{building\ type} \right]$$

4.3.1.b – Heating, Ventilation, and Air Conditioning (HVAC) Retrofits

HVAC equipment is a primary contributor to energy-consumption in buildings. HVAC systems can last for many years, yet become less efficient and more expensive to run over time. It is best practice for UCSB to hire a mechanical engineer to audit and inspect major pieces of mechanical equipment in buildings prior to their replacement, as retrofits may save time and money across campus compared to equipment replacement. HVAC retrofits include the installation of technologies that optimize energy consumption, such as variable frequency drives, zoned temperature controls, occupancy sensors, and integration with building automation systems.

Our group sourced data from DEEC in order to understanding the savings potential of HVAC retrofits at UCSB. The methodology and findings of DEEC were intended to provide information that would be useful at a planning level, and the report therefore provides both low and high estimates for their energy saving and capital cost. In an effort to remain conservative in our estimates, our team used the average between low and high values presented in DEEC. HVAC retrofits in Laboratory spaces are not included in this section because they are integrated into the "Laboratory Retrofit" results, as was done in DEEC. We did not expand the estimated potential of HVAC retrofits, despite the fact that buildings under 40,000 gross square feet were excluded from the DEEC study.

4.3.1.c – Laboratory Retrofits

Laboratories typically consume five to ten times more energy per square foot than office buildings, primarily due of their higher rate of air change per hour (ACH).[32] Building designers commonly derive laboratory ventilation rates from "high-end" ACH values found in design guidelines, which are generalized recommendations not meant to address specific ventilation needs.[33] This practice leads to unnecessary energy consumption, as high volumes of outside air are heated, cooled, humidified, dehumidified, and filtered regardless of laboratory occupancy.[34]

As UCSB looks toward the future, the commissioning of laboratory spaces must be given serious consideration. Exhaust ventilation is another major contributor to the energy intensity of laboratory buildings.[35] Using air at high velocity, these systems ensure that contaminants are well dispersed and do not impact other buildings, pedestrians, and/or facility staff. The velocity of these systems, and therefore the energy demand of the systems, can be reduced without compromising the dispersal of airborne chemicals by utilizing wind monitoring technology, variable frequency drives, and installing stack extensions.

Our results for the retrofit of laboratory spaces are based on cost and energy savings metrics from DEEC. In DEEC, laboratory retrofits represent a holistic approach to reducing energy consumption in laboratory buildings, and include strategies such as upgrading lighting systems and energy efficient equipment, reducing ACH, and reducing the discharge velocity of fume hood exhaust. Our team averaged the high and low cost and energy savings metrics from DEEC,

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[32] Efficiency, "Laboratories for the 21st Century."

[33] Ibid.

[34] UC Irvine, "Smart Laboratories Cut Energy Consumption More Than Half."

[35] Green Building Research Center, "UC Irvine Exhaust Stack Discharge Velocity Reduction."

and then subtract 20%, because we included savings from lighting in laboratory spaces in our LED & Controls Retrofits calculation. Lighting systems typically contribute about 10-15% of total energy consumption by floor space, so we chose to subtract 20% to ensure that our results are conservative.[36] Average DEEC savings metrics from Exhaust Stack Discharge Velocity Reduction (ESDVR) projects were included in our "Laboratory Retrofit" calculations.

4.3.1.d – Monitoring Based Commissioning (MBCx)

MBCx is a measurement-based process of verifying energy performance and correcting deficiencies, and incorporates:

(i) Permanent energy information systems and diagnostic tools at the whole building and sub-system level,
(ii) Retro-commissioning based on the information from these diagnostic tools as opposed to estimates or assumptions, and
(iii) Ongoing commissioning to ensure efficient building operations and measurement-based savings accounting.[37] By taking the time to measure, analyze, and optimize energy use in buildings, MBCx identifies and corrects operational problems associated with HVAC and lighting controls, and verifies the energy savings using whole-building metered data.

The assumptions we used to perform calculations for the cost and energy savings potential of MBCx are based on findings from a 2009 study entitled Monitoring-Based Commissioning: Benchmarking Analysis of 24 SEP Projects in conjunction with anticipated SEP projects identified by UCSB's energy and utility services division. By aggregating costs and energy savings associated with this portfolio of projects, the authors of the 2009 study found energy savings of 10% on average, with a range from 2-25%. The highest savings were achieved in laboratory buildings, and a median simple payback of 5 years was observed for the portfolio of projects.[38] In addition to our literature review, UCSB Energy and Utility Services has compiled a list of proposed projects for the 2016-2018 SEP program, of which MBCx measures are a significant portion, contributing an estimated savings of 2 million kWh and 250,000 therms across 13 buildings.[39]

In order to apply this methodology to UCSB as a campus, our team took the proposed SEP projects and applied the cost and energy savings metrics to other applicable buildings on a per square foot basis. The projection of annual emission reductions associated with MBCx decreases over time as other energy efficiency measures are implemented and the carbon intensity of our purchased electricity falls. For instance, building-specific energy savings calculations were scaled down by 50% - 80% depending on other interacting energy efficiency measures, such as HVAC Retrofits and/or Laboratory Retrofits. This reduction in potential energy savings is intended to prevent double counting. In addition to capital costs, this assessment assumes a

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36 U.S Department of Energy, "2010 U.S. Lighting Market Characterization."
37 Brown, K. & Sahai, R. (2014). Benchmark-based, Whole-Building Energy Performance Targets for UC Buildings. Retrieved July 23, 2015
38 Sager, "UCSB SEP Projects (2015-2018)."
39 Ibid.

$200,000 annual fee for maintaining the energy savings by hiring an on-site engineer to manage the program.

4.3.1.e – Hot Water Loop

A district energy system is a type of HVAC system that produces electricity, hot water, steam and/or chilled water at a central plant, and then distributes heating and cooling to a network of nearby buildings.[40] At UCSB, the second largest contributor to projected 2025 GHG emissions is on-campus stationary combustion from natural gas boilers used for heating.[41] As a result, UCSB Energy and Utility Services has been working with Goss Engineering for several years to assess the feasibility of a hot water loop (HWL) on campus. UCSB took the first steps towards this goal in 2013 by completing construction of a mini-loop for three buildings in the eastern portion of campus.

By installing fewer and larger pieces of equipment at strategic locations on campus, HVAC loads in new and existing buildings can be met more efficiently, and the need for boilers at every building can be eliminated. By integrating the existing chilled water loop into future HWL expansion, UCSB can take advantage of heat recovery, ground sourced heat pumps, and thermal storage opportunities, and significantly reduce Scope 1 emissions. Additional benefits include fewer points of failure and increased compliance with Santa Barbara County Air Pollution Control District's Rule 361.

Data for the HWL was sourced from a Goss Engineering report completed in 2011 which focused on a hot water loop with connection to up to 11 buildings on campus, and explored the potential for either an expansion or duplication of the proposed HWL.[42] Discussions with energy managers from Energy and Utility Services revealed that about $3.3 million was spent on the 2013 HWL, but realized minimal utility savings because the capital investment was primarily spent on trenching for infrastructure. This leaves the remaining scope of the project with a lower capital cost to achieve similar expected savings. Aside from removing the $3.3 million in sunk costs, the information presented in this report was used without manipulation.

4.3.2 – Renewable Energy Procurement Methodology Overview

To address Step 2 of our four-step process, we interviewed campus energy managers and reviewed literature relevant to institutional procurement of renewable energy. In order to identify the potential expansion of on-campus solar PV, our team utilized NREL's PV Watts Calculator tool to estimate the sizes of potential arrays on large, flat rooftops and parking lots around campus. We subtracted 5% of our total estimated capacity from rooftops to account for racking and equipment, and 25% was subtracted from parking lots to account for future development. Once potential aggregate system size was identified, we applied the kWh/kW ratio from the recent 5MW SunPower PPA to estimate the total electricity generation from each system on an annual basis. Results from this study can be found in Appendix H.

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[40] UCSB, "Campus Hot Water Loop Program -- Final Report.pdf."
[41] "UCSB Utility & Energy Report 2015.pdf."
[42] Ibid.

4.4 – Life Cycle Cost Analysis Methodology

To understand the long-term impacts associated with our demand-side strategies, we developed and utilized a Life Cycle Cost Analysis (LCCA) tool. LCCA is used by many institutions to influence decision-making, including Stanford University and the California state government, because it reveals the true value or cost of a project and enables comparison to the cost of the existing infrastructure.[43,44] Stated another way, the tool can be used to analyze the trade-offs between projects with different levels of long-term savings and capital costs. This allows us to determine the most cost-effective option and calculate the expected payback period.[45] Our team worked with UCSB Energy and Utility Services and the Office of Budget and Planning to determine the appropriate assumptions to include in our LCCA model. LCCA is well suited for financial analysis of energy efficiency projects, as energy efficiency projects have characteristically high capital costs and accumulate savings over time, and because additional elements such as air quality improvements and other environmental metrics can be incorporated into the tool.

We developed the LCCA tool by tailoring existing models to fit the needs of the University of California (UC) system. The modifications we made do not compromise the tool's compliance with the *Life Cycle Costing Manual for the Federal Energy Management Program* established by the National Institute of Standards and Technology (NIST).[46] Five assumptions were used in the LCCA model: (i) discount rate, (ii) energy escalation rate, (iii) length of the study life, (iv) residual value, and (v) the GHG emissions factor. A discount rate of 5% is used in our analysis, and is the typical discount rate used by UC for project evaluation despite the fact that the university currently borrows capital at an interest rate closer to 4%. For electricity and natural gas prices an escalation rate of 3% was applied. This rate was selected based on historical price trends, and is currently used in university project evaluations. Material, labor, and other costs are assumed to have no escalation rate in our study, however the tool allows for incorporation of this information in future studies if desired. A study life of 20 years is used in this tool based on interviews with current LCCA practitioners at Harvard University and Stanford University.

4.5 – Deployment Strategy Methodology

Financial constraints, buffer time needed for planning and scheduling, labor availability, ease of implementation, return on investment, regulatory implications, and technological maturity were all considered when to determining the recommended timing each proposed strategy. Our team developed a methodology for scheduling the implementation of our proposed strategies, which is broken into 3-phases, and can be observed below in Table 2, which guided the determination of our deployment schedule (Figure 17).

Table 2. Phase Prioritization Criteria.

43 Davis et al., "Guidelines for Life Cycle Cost Analysis (LCCA)."
44 Department of General Services, State of California, "Life Cycle Cost Assessment Model Fact Sheet."
45 Environmental Building Strategies, "Financial LCCA / GAP Analysis – EBS."
46 Fuller and Petersen, "NIST Handbook 135 Life-Cycle Costing Manual for Federal Energy Management Program."

	Phase 1 (2016 – 2020)	Phase 2 (2020 – 2025)	Phase 3 (2025 – 2030)
Implementation	Easy	Moderate	Difficult
ROI	>15%	5% - 15%	<5%
Regulations	Immediate	Anticipated	Potential
Maturity	Yes	Yes	No

5. Assessment of Future Opportunities for UCSB

Aggressive investments in energy efficiency are necessary if UCSB hopes to achieve carbon neutrality by 2025 without relying heavily on purchases of carbon offsets. The impacts of each GHG mitigating strategy is shown in Figure 14, and are discussed in this section.

5.1 – Energy Demand Reducing Technologies

This portion of the study focuses on the five technologically mature and financially attractive demand-side strategies that are critical to achieving carbon neutrality by 2025. These strategies were chosen because their application at UCSB is feasible in the immediate future. While there are many potential strategies that UCSB can implement to achieve carbon neutrality by 2025, these strategies present the greatest near-term GHG abatement potential while creating positive returns over the technologies' useful life.

5.1.1 – LED & Controls Retrofits

Through the installation of LED lamps and adaptive control technologies, and the utilization of programmed trimming, our model predicts an 82% reduction in total residual energy consumption from lighting (Figure 10). This finding may represent high-end estimates of potential savings from lighting when applied at scale across campus, as proper commissioning and maintenance greatly contribute to overall savings in these systems. However, as CFL's were assumed to be retrofitted with "plug and play" LED options, there remains future energy savings potential for full downlight fixture replacement and integration with occupancy controls.

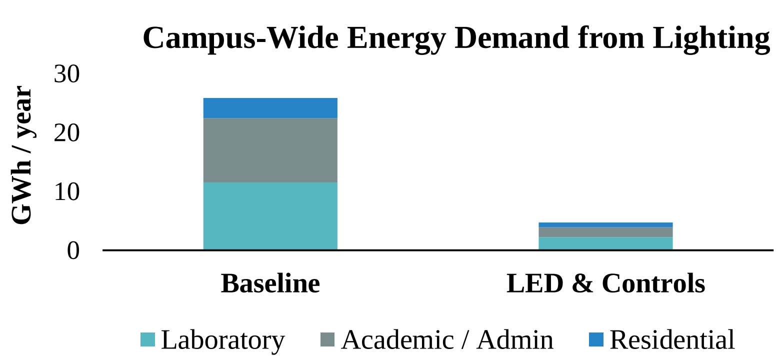

Figure 10. Campus-wide Energy Demand from Lighting (Baseline vs. LED & Controls).

To enhance decision-making at UCSB, three different lighting scenarios were compared to evaluate their long-term cost implications: Fluorescent for baseline, LED retrofit, and LED and Controls retrofit. Required data input to run LCCA is summarized in Appendix F. Realistic cost information and specifications for the Baseline and Retrofit scenarios were gathered from building surveys and interviews with energy managers at UCSB, and are displayed in Table 3. While there is no initial cost under the Baseline scenario, the cost of replacing a standard linear fluorescent bulb is used to calculate non-energy cost in order to compare with the alternatives.

Table 3. Cost Assumptions for LED & Controls Retrofit Projects. Baseline data was gathered from building surveys and maintenance staff, while retrofit data was gathered from a recent LED retrofit project at the SAASB building at UCSB, and from interviews with energy managers at UCSB.

LED & Controls Retrofit Project Costs							
Items	Campus Standard “T8” ($/Lamp)			Campus Standard “CFL” ($/Lamp)			Reference
	Lamp	Control	Labor	Lamp	Control	Labor	
Baseline (Lamp replacement)	$1.8	$0	$10	$2.5	$0	$10	PLC18/CFL & Octron 700
Retrofit (Installation of new lamp & controls)	$110	$60	$110	$20	$0	$20	Phillips EvoKit & InstantFit LED 4-pin

Cost metrics for different building types were developed based on cost assumptions and building audits. A retrofit of LED without controls incorporates lamp and labor costs, while LED and Controls includes lamp and labor costs, plus the additional cost of controls. Total cost for LED and Controls retrofits were calculated by multiplying each of the cost metrics (Figure 11) by the total floor space of relevant built space on campus (Figure 7).

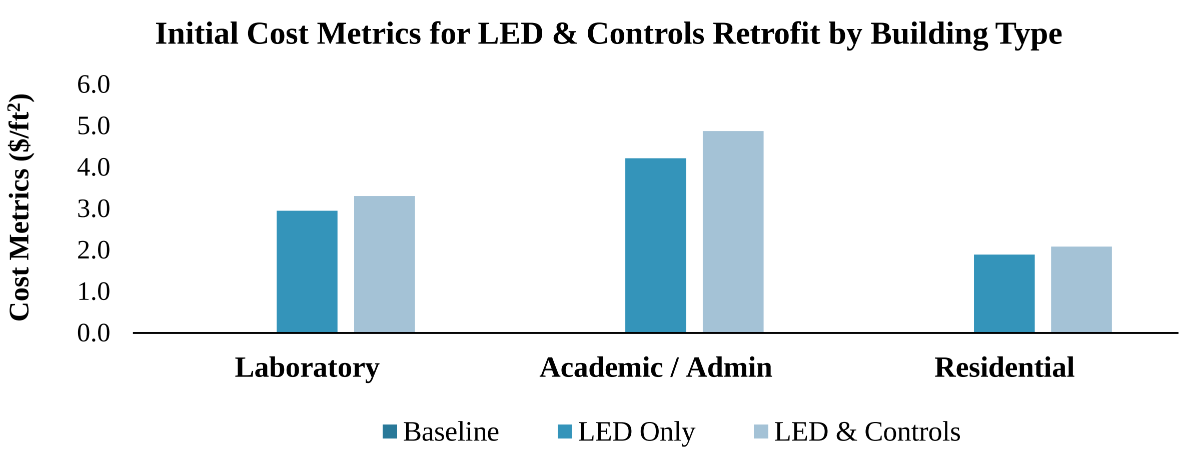

Figure 11. Cost Metrics for LED & Controls Retrofits by Space Types. Building types are listed on the x-axis. The light blue bar represents the initial (Capital) cost metrics for the LED & Controls Retrofit, while the dark blue bar represents LED retrofit without controls. There are no capital costs associated with the Baseline scenario.

The primary non-energy cost for LED & Controls Retrofits is lamp replacement. Useful life of light bulbs varies by bulb type, which results in varying lamp replacement schedules between existing and proposed lighting systems. Linear fluorescent light bulbs averaging approximately 22,000 hours, while LEDs average approximately 66,000. After considering our HOU assumptions, we assume that fluorescent bulbs will need to be replaced every 7 years, while LEDs will need replacement every 25 years. Accordingly, there are no bulb replacement costs associated with LED scenarios. However, we assume that adaptive lighting controls will need to be replaced every 10 years.

LCCA results for the three different scenarios are shown in Figure 12. High energy consumption drives the baseline to be the most expensive option, even without any upfront cost. LED case is the second most expensive option and LED and Controls case is the cheapest. The main costs for LED and Controls scenario are the upfront costs, but due to its energy efficiency, annual energy consumption is significantly lower. This is also the scenario with the lowest GHG emissions. Based on our analysis, we found the LED & Controls scenario to be a very cost-effective GHG mitigating technology.

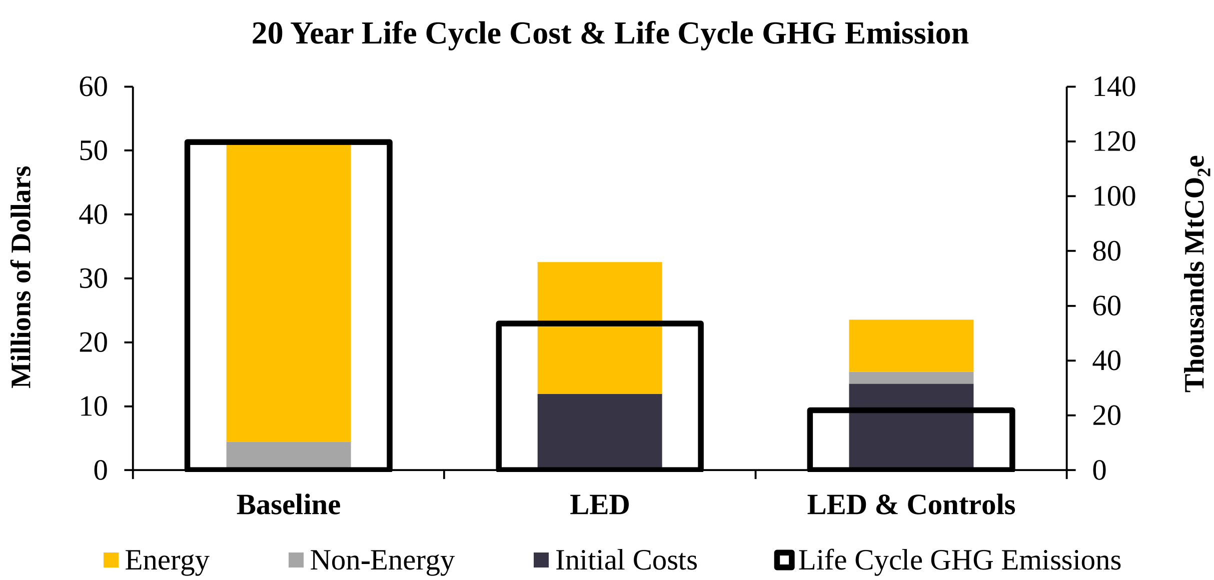

Figure 12. LCCA Result for LED Retrofit Options. Baseline represents fluorescent, LED represents retrofit with LED lamp, LED & Controls represents retrofit with LED and occupancy and lighting sensing. Bar graphs represent 20-year life cycle cost for each option broken into different colors: Initial cost in dark blue, non-energy cost in grey, energy cost in yellow. The outlined black boxes represent 20-year life cycle GHG emissions and correspond to the right y-axis.

Based on the LCCA results, it is clear that the LED & Controls Retrofits is the best choice for UCSB in terms of life-cycle costs and greenhouse gas emissions. While the LED & Controls scenario has the highest up-front capital cost, it represents a total life-cycle cost of only $23.5 million, $27.7 million less than the baseline option. Installing only LEDs is still an attractive option; however, when compared to the LED & Controls scenario, it will cost $10M more and will forego 33.5 $MtCO_2e$ in reduced emissions over the 20-year study period.

5.1.2 – Heating, Ventilation, and Air Conditioning (HVAC) Retrofits

HVAC retrofits at UCSB should be considered as part of a comprehensive approach to addressing aging HVAC equipment. HVAC retrofits can be delivered as a pure retrofit project, but may also be delivered in conjunction with MBCx to ensure optimal operation. Integration of large HVAC systems with UCSB's future hot/chilled water loop infrastructure present additional opportunities for energy savings. Information regarding estimated cost and savings for HVAC projects at UCSB were sourced from DEEC. As we did for energy savings, we took the average of the high and low cost estimates, and can be found in Appendix H.

5.1.3 – Laboratory Retrofits

Laboratory buildings are the most energy intensive buildings at UCSB, and therefore are a prime target for the reduction of energy consumption and emissions. Although payback times for these comprehensive projects are longer than those associated with our other identified demand-reduction strategies, they cannot be ignored to due to their vast potential for energy savings. Identified reduction potential of Laboratory Retrofits at UCSB can be seen above in Appendix G.

5.1.4 – Monitoring Based Commissioning (MBCx)

Working to minimize energy consumption will significantly reduce the long-term operating cost of UCSB's facilities, allow for greater flexibility under air quality and GHG emissions regulation, and contribute to fiscal fortitude at UCSB. MBCx is a highly cost-effective strategy for obtaining significant energy savings across a variety of building types, and therefore should be approached as a high-priority demand management strategy. Identified reduction potential of MBCx at UCSB can be seen in Table 4.

5.1.5 – Hot Water Loop (HWL)

The proposed HWL design adds more electricity consumption to the system, but greatly reduces natural gas consumption. Increased electricity consumption will result from added heat pumps and distribution pump, while natural gas reduction occurs due to the efficiency gains of district energy systems, the elimination of simultaneous heating and cooling, and waste heat capture. Identified reduction potential of a HWL at UCSB can be seen in Table 4.

Appendix G shows a summary of the construction costs for the proposed base case hot water loop including alternatives 1, 2, and 3. The base case hot water loop proposal includes the Life Sciences, Engineering 2, Davidson Library, Biological Science, and Broida Hall buildings. Alternatives 1, 2, and 3 allow the Chemistry, Physical Sciences North Building, Engineering Science Building, and CNSI/Elings Hall to also be connected to the loop. Included in the proposal are a central plant (building, 600-ton heat pump, new heating hot water distribution loop serving 7 existing buildings on campus, and future buildings, conversion of constant volume pumping systems to variable volume pumping systems for three existing buildings.

It is important to note that the HWL will add electricity demand but this will be more than offset by the natural gas savings. Specifically, assuming the cost of \$0.11/KWh, and \$0.60 per therm, the HWL will save \$557,776 annually due to natural gas savings alone, and add the cost of \$452,767 due to additional electricity demand. Following our assumptions for the greening of the electricity grid and the RPS, the therm reduction will save 4,037 MtCO_2e.

While we were unable to calculate the potential costs and benefits of a hot water loop expansion beyond Phase 1, this project represents a major opportunity for UCSB to re-design how energy is shared and efficiency is maximized on campus. District energy systems have been successfully implemented to reduce HVAC emissions at Stanford University and the University of British Columbia.

5.2 – Renewable Energy Procurement

UCSB has a several options for expanding its use of renewable energy. Increases in the efficiency of solar panels and reductions in the price have made solar cost competitive with other energy sources. New innovative designs for procuring and financing solar energy are continuing to develop as individuals, companies and organizations place larger importance on carbon free energy. We have identified both on-site and off-site options for expanding solar energy at UCSB: expanding on-site solar generation through Power Purchase Agreements (PPAs), and obtaining off-site renewable energy through Direct Access (DA), community solar gardens (CSG), or the purchase of green power from the utility. Although we have identified these options, it was difficult to evaluate them without knowing more about SCE's plans for green power purchasing, UCOP's plans to pursue DA and virtual power purchase agreements, and the status of legislation regulating each option.

5.2.1 – Power Purchase Agreements

PPAs increase reliability in the budgetary planning on campus; the fixed rate reduces risk, blocking exposure of UCSB to increases in the cost of energy. Additionally, UCSB is able to generate solar electricity without having to buy solar panels that may break or soon become outdated, reducing the risk to the university without the necessity to take on additional debt.

UCSB currently owns solar panels that annually generate 673 kW DC of electricity. The university is entering into a multi-site solar PV PPA with SunPower to expand solar electricity another 5,320 kW DC (9,546,186kWh annually) in 2016. In this agreement, SunPower installs, and operates solar PV at six sites on campus and UCSB pays a fixed and agreed upon rate for the energy that it produces. The costs for maintaining and operating the panels are built into the rate. Together, the current solar on campus and the planned SunPower PPA compose 10% of the total electricity demanded.

If UCSB invests in the five primary energy efficiency strategies explained in 5.1, the projected power needs in 2025 will be 103 GWh of electricity. With this projection as the baseline, Figure 13 below visually displays how the currently installed arrays, SunPower PPA, and potential solar expansion compare to the total electricity needs of the campus as well as the remaining, or residual, electricity consumption. The remaining needs can be met through green rate structure with SCE, community solar arrays, or other off-site renewable energy options. Results from this assessment can be found in Appendix H.

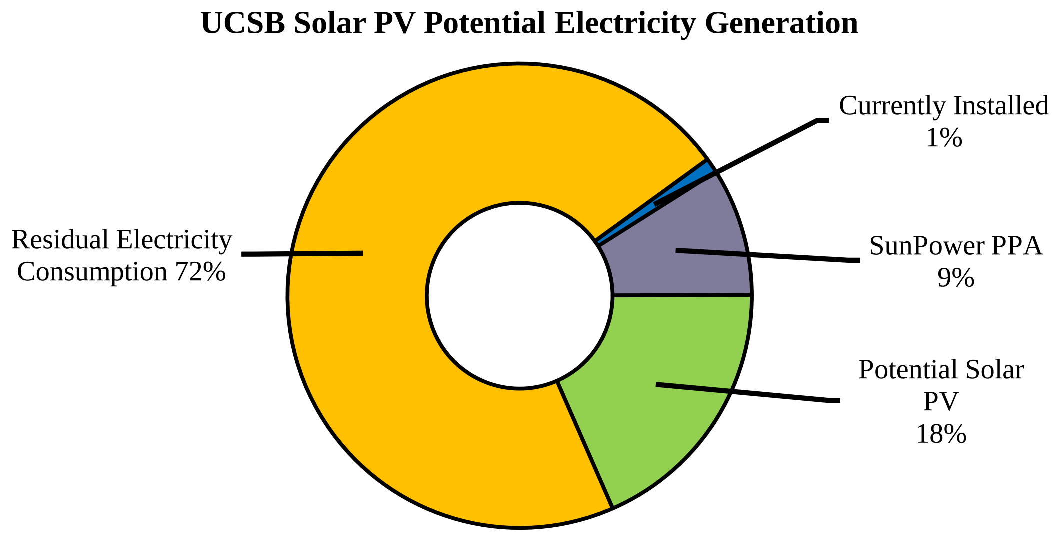

Figure 13. UCSB's Solar PV Electricity Generation. This figure uses 2025 projected electricity consumption as a baseline, not including the demand-reduction strategies proposed in 5.1. The potential solar PV expansion is shown in green, the 5MW SunPower PPA is in lavender, and currently installed solar arrays in blue. Remaining electricity needs are represented by orange.

Rather than borrowing money to invest in assets must be maintained over time, UCSB should enter into PPAs to install solar panels on campus at zero cost. Through PPAs, third-party contractors install, own, and maintain solar panels on campus, and sell renewable energy to the university for a pre-determined price. This delivery mechanism provides benefits for all parties, as UCSB acquires renewable energy at a competitive rate, the third-party contractor is able to take advantage of incentives that are unavailable to UCSB, and emissions are reduced.

5.2.2 – Direct Access

Theoretically, DA expands the supply of renewable energy and consequently lowers the price of clean electricity. Under DA, individuals or companies can sell electricity directly to customers as third party ESPs in a competitive market.[47] Senate Bill 286 proposes California adopt DA on these grounds. Per the CPUC Decision (D.) 12-12-026 dated December 20, 2012, IOUs hold an "annual DA lottery" to establish wait lists for customers who wish to transfer to DA service.

When UCSB is eligible for DA, the university can sign an energy supply agreement (ESA) with the ESP for the entire electric supply. ESAs also offer flexibility to negotiate pricing terms and structure, risk allocation, and the term of years. This flexibility is greater than what would be available from SCE, which offers a single "tariff" rate to all similarly situated customers. The legal process to acquire DA seems feasible and relatively straightforward for UCSB, but cost implications of this option remain unknown.

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[47] Bedard, "Senate Bill 286: Electricity Choice."

5.2.3 – Community Solar

Community solar (CSG), or shared solar array, offers cost-effective renewable energy solutions to consumers who may not have access to rooftop space or the financing options to make an onsite solar array a reality. CSGs generates local benefits by creating jobs and increasing electric reliability through dispersed generation. Due to the scalability of community solar, subscribers are able to select the option that suits their electricity needs. These options range from purchasing a single community solar panel to subscribing at a level large enough to offset their building's entire electricity budget.

CSGs are attractive because UCSB wouldn't be responsible for managing operations and maintenance. Subscription/membership fees are designed to cover installation and O&M costs, while rates are structured to be at or below retail price. As UCSB's rooftop space is limited, working with SCE or collaborating with local entities to develop CSGs in the Santa Barbara region, offers various benefits. By aggregating customer demand and dividing the cost of installation, CSGs can reduce the financial and technical barriers to going solar by meeting the budget of its members.

5.2.4 – Southern California Edison (SCE) Green Power

SCE recently announced the opportunity for commercial customers to purchase 100% renewable energy.[48] Price premiums are not expected to be competitive with other opportunities for renewable procurement, but as the program evolves over time, this may be an opportunity to easily offset Scope 2 emissions.

5.3 – Implementation Costs, Offset, and Financing

This section looks at the implementation costs of all demand- and supply-side technologies that are covered in this report. While each measure has unique characteristics with a wide range of paybacks, the cumulative numbers show that if all six of the proposed strategies are implemented, UCSB can recover the costs within approximately 7 years. While it is in the best interest of the university to move away from simple payback decision-making, these metrics are presented in order to provide a familiar context for current campus decision makers.

In addition to implementation costs, this section covers some of the offset options as well as the financing mechanisms that this study uncovered. Carbon offsets are a viable option for achieving carbon neutrality, however; prices are extremely volatile and future costs of carbon offsets or Renewable Energy Credits are uncertain.

5.3.1 – Strategy Implementation Costs

Below is a summary table highlighting the initial capital costs, energy savings, and simple payback for the GHG mitigation strategies that were the focus of this study. With $48.3 million in capital expenditures, we calculate that UCSB can save 65.5 GWh and 2 million therms annually, and generating roughly $6.6 million in annual avoided utility expenditure. Simple payback is included in Table 4 in order to provide a familiar metric for campus planners, despite the drawbacks of this project evaluation method.

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[48] SCE Website, "SCE Green Rate."

Table 4. Initial Costs, Energy Savings, and Simple Payback for GHG Mitigation Strategies.

Project Type	Initial Costs	Energy Savings			Simple Payback
	Million $	kWh	therms	Million $	years
LED & Controls Retrofits	15.55	26,569,883	0	2.32	6.42
HVAC Retrofits	6.89	5,742,505	326,364	0.83	7.75
Laboratory Retrofits	17.60	12,786,676	404,271	1.65	10.05
Monitoring-Based Commissioning (MBCx)	3.33	3,374,929	405,060	0.61	7.03
Hot Water Loop	4.87	-4,116,061	929,627	0.11	25.64
On-Site Solar PV	0	26,569,883	0	1.06	-
Total	**48.3**	**65,503,671**	**2,065,322**	**6.6**	**6.98**

5.3.2 – Offset Purchasing

Carbon offsets are likely to be part of UCSB's 2025-2030 carbon neutrality strategy, but efforts should be taken to reduce reliance on them as much as possible. Based on conversations with Todd Lee, Vice Chancellor of the Office of Budget and Planning, and Chuck Haines, Director of Capital Development, we learned that measures that retain value on campus, such as energy efficiency, are preferable to measures that send value off-campus, such as purchasing offsets.

Carbon offsets can be purchased in compliance and voluntary markets. The California cap-and-trade market is a compliance market within which the University is already operating, but there are various other markets throughout the world. Voluntary offsets occur worldwide typically in the form of energy efficiency or land conservation projects.

Offset purchasing for the University of California is coordinated by UCOP. Currently, a taskforce composed of representatives from various campuses is charged with purchasing offsets in the compliance market for the ten campuses. In late 2015, a voluntary offset purchasing taskforce was in development. Due to the uncertainty in the prices of offsets and RECs, and the fact that they will not be purchased until 2025, we are unable to offer a recommendation, and advise that this topic be revisited in the coming years in coordination with UCOP leadership.

5.3.2.a – Compliance Markets

Currently, the price to offset a metric ton of CO_2 tends to be more expensive in a compliance market than in a voluntary market. Moreover, the California cap-and-trade market is one of the more expensive markets, with prices averaging around $12.50/metric ton in 2016.[49] While UCSB has opted-into the California cap-and-trade market to satisfy AB32, the university could buy additional offsets from this market in the future to achieve carbon neutrality. The California ARB has a list of approved offsets that are associated with projects related U.S. forests, urban forests, livestock, ozone depleting substances, methane capture, and rice cultivation.[50]

5.3.2.b – Voluntary Markets

The price of voluntary offsets hit an all-time low in 2014, with the average price falling to $3.80/metric ton.[51] The voluntary offset market has been criticized in the past for having less stringent standards to insure the "additionality" of offsets. Due to this skepticism, four organizations have been created to certify offsets: The Verified Carbon Standard, The Gold Standard (GS), American Carbon Registry (ACR), and the Climate Action Reserve. Voluntary offsets take the form of many different types of projects, the most common project types include: (i) avoided deforestation, (ii) wind power, (iii) landfill methane, (vi) reforestation, (v) hydropower, and (vi) clean cook stoves.[52]

5.3.3 - Financing Options

Energy efficiency is commonly under-utilized in public universities, as fierce competition for limited financial resources prevents investments at levels that dramatically reduce long-term operating costs and increase resiliency. Despite these challenges, UCSB has invested modestly in energy efficiency over the past decade by utilizing varying combinations of debt financing, utility budget surpluses, and incentives provided by the SEP program whenever possible. In light of UC President Napolitano's CNI, the need for project financing and UCSB's current inability to procure funding through debt financing, creative financing instruments must be pursued. After careful consideration, our group recommends that UCSB establish a GRF in order to capture avoided utility costs and leverage them for future investments in energy efficiency. We will now discuss various barriers and opportunities that affect the implementation of energy efficiency at UCSB.

5.3.3.a – Green Revolving Fund (GRF)

A Green Revolving Fund (GRF) is an account that receives external "seed" funding, provides capital for various energy efficiency projects, and then captures and leverages the avoided utility costs to enable future energy efficiency investments. By taking advantage of the relatively high median ROI of energy efficiency retrofit projects, GRFs reduce the magnitude of funding that must be sourced from outside the university to a significant degree. A 2012 report from the Sustainable Endowment Institute reported that GRFs have a median annual ROI of 28%.[53]

At UCSB, the Utility and Energy Services department is permitted to invest utility budget surpluses on energy efficiency in the following year. Since this allows energy efficiency projects

49 Climate Policy Initiative, "California Carbon Dashboard."
50 California Air Resources Board, "Compliance Offset Program."
51 Forest Trends' Ecosystem Marketplace, "Ahead of the Curve: State of the Voluntary Carbon Markets 2015."
52 Ibid.
53 Sustainable Endowments Institute, "Greening the Bottom Line."

to be funded without debt financing, and since these energy efficiency projects ultimately reduce UCSB's utility expenditures, it appears that an informal version of a GRF already exists on campus. Our recommendation is that UCSB formalize this process so that avoided utility cost streams are captured and reinvested exclusively in energy efficiency projects, therefore further reducing utility expenditures and increasing future capacity for energy efficiency investments.

Formalizing a GRF on campus promotes the tracking of energy savings from the baseline utility budget, enables the university to make informed, quantitative statements about their progress on energy efficiency, and provides a location where green funds can "spin-up" without being redirected for other uses. As a result, UCSB can publicize its commitments to dramatically reducing its operating emissions, provide confidence to "green donors" that their gifts will be used in the manner desired, and further attract sustainably minded students and faculty to UCSB. In addition to GRF "seed" funding sourced from utility budget surpluses and green donors, funds to jumpstart a GRF on campus could be sourced from the sale of surplus AB32 allowances, student fees, and other funding sources such as the potential allocation of Cap-and-Trade money in Governor Brown's proposed budget for 2016-2017.

We performed optimization analysis by using Solver in Microsoft Excel to identify investment schedules where capital expenditures are minimized. The results show UCSB can fund $48.3M of our identified energy efficiency projects with only $15.7M of "seed" funding. Figure 14 shows the investment scenario for each year. This scenario can be changed to incorporate varying constraints, such as limitations on initial "seed" funding.

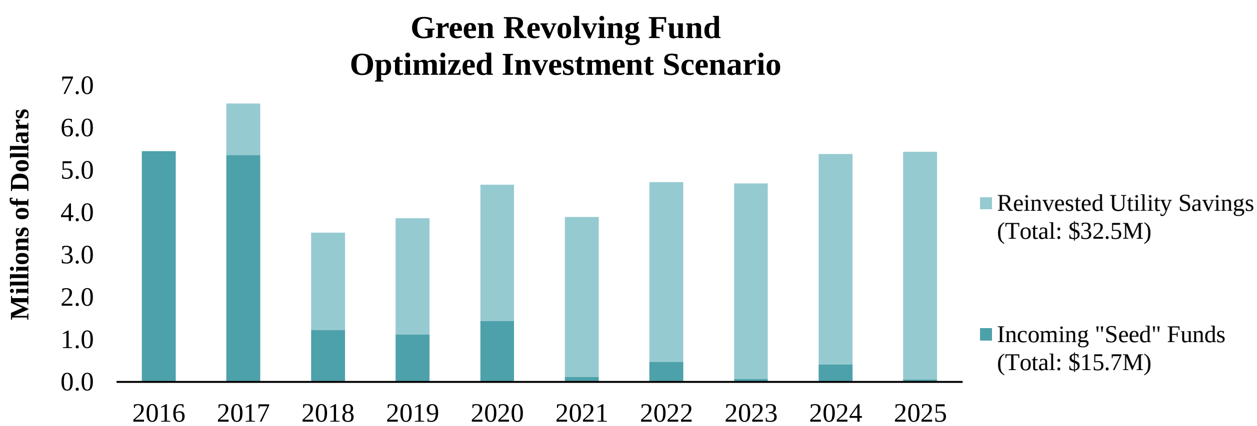

Figure 14. Green Revolving Fund Investment Scenario (2016-2025). This investment scenario is generated using Solver in Microsoft Excel. Incoming "seed" funding was minimized as a parameter. Total investment for the GHG Mitigation Strategies identified in this study is $48.3M.

5.3.3.b – Sale of AB32 Allowances

According to Nick Balistreri from UCOP, each campus is permitted to sell unused AB32 emission allowances. While the current allowance program is tied to AB32 which ends in 2020, it is expected that this program will be renewed. This would create additional incentive to frontload energy efficiency investments, so revenue generated from unused allowances can be generated to further reduce the magnitude of "seed" funding required to reach the necessary levels of investment with a GRF.

5.3.3.c – Building Planning

If energy efficiency measures are to be included in new buildings, they must be brought into consideration during the programming phase when the Detailed Project Program (DPP), which outlines the functional interior and exterior requirements of a building, is established. At this point, building planners can consider how energy efficiency measures impact the total cost of ownership of the building, and how to incorporate these measures before project budgets are finalized. When energy efficiency is not mandated in these early stages, "value engineering" often leads to efficiency features being dropped in order to minimize capital expenditures. To solve this issue, the university can allow equal bidding between contractors and put forth a set of guidelines that the project proposals must follow. Subsequently, the DPP will be established based on these quality cost points, and a call for bids can occur based on the desired project specifications which incentivize contractors to incorporate energy efficiency measures into their building proposals. UCSB should utilize LCCA during the building delivery process to estimate the lifetime energy costs of the project, regulate the extent to which contractors and manufacturers can alter their plans, and provide incentives for achieving stretch goals that lower operating costs over time.

5.3.3.d – Internal Financing

Historically, variable commodity prices have caused unpredictable cycles of surplus and deficit in the utility budget. For this reason, the UCSB Office of Budget and Planning (OB&P) has a described the utility budget as being encased by a "firewall" in order to provide a cushion for year-to-year fluctuation. Managers of the utility budget currently allow surplus funds to be used for "one time" capital investments in energy efficiency projects, but are wary of assuming an annual surplus in the utility budget and obligating it as a recurring source of energy efficiency financing. To account for these concerns, guidelines should be established to allow for a reasonable buffer to accrue in the utility account before energy efficiency projects are pursued, and projects with quick paybacks could be prioritized. While this may delay investments in energy efficiency projects, it may be a necessary component to gain approval from campus decision makers. Avenues of internal financing for energy efficiency other than utility budget surplus are not expected to be available in the near future.

5.3.3.e – Statewide Energy Partnership (SEP)

The SEP program has successfully accelerated the implementation of energy efficiency and the installation renewable energy systems at higher education institutions throughout California by providing savings incentives of $0.24 / kWh and $1.00 / therm. Despite the success of the SEP program, certain aspects of the program have arisen that act as barriers to even greater energy savings and renewable energy procurement. For example, campus energy managers have historically been required to submit detailed project proposals to the IOUs before submitting applications for debt financing, a procedure that provided assurance to UCOP that benefit streams would be generated for debt service but also slowed the rate of project proposal and implementation. Further, IOUs are required to use conservative assumptions in savings calculations that likely underestimate the actual savings that can be achieved from energy efficiency projects, and were not permitted to provide incentives for energy efficiency unless the savings were achieved beyond code.

Fortunately, these issues are being addressed. The California Energy Commission (CEC) is now required by AB 802 to authorize IOUs "by September 1, 2016… to provide financial incentives… to their customers to increase the energy efficiency of existing buildings based on all estimated energy savings… [including] energy usage reductions resulting from the adoption of a measure or installation of equipment required for modifications to existing buildings to bring them into conformity with, or exceed, the requirements of Title 24 of the California Code of Regulations... [and] to recover in rates the reasonable costs of these programs." [54] Prior to the passage of AB 802, UCOP began creating its own path for due diligence on loan applications independent from utility incentives, as not all energy efficiency projects are eligible for incentives through the SEP program.

5.3.3.f – Revenue Bonds

State loans in the form of revenue bonds offer UC a familiar opportunity to source funding for various capital needs. General Revenue Bonds (GRBs) are commonly used to finance a variety of projects that are integral to the university's core mission, and obligate UC's general revenues for loan repayment. Limited Project Revenue Bonds (LPRBs) are similar to GRBs, but are only used to finance specific projects such as student housing or parking, and only obligate the revenues generated from these specific projects for debt service. As mentioned above, borrowing related to long-term campus development has limited additional debt financing, which inhibits investments in energy efficiency.

5.3.3.g – AB32 Governor's 2016-2017 Budget Allocation

Another component influencing energy efficiency financing within UC is the *potential* allocation of funding from AB32 Cap-and-Trade dollars currently present in Governor Jerry Brown's 2016-2017 proposed budget. Similar to utility incentives, Cap-and-Trade dollars could be used to buy down the payback on certain qualifying projects, or provide "seed" funding for a GRF. This funding allocation is pending legislative approval, but may result in $25 million of one-time funding for energy efficiency within the UC system. Each UC campus and medical center is expected to receive $1 million, which would leave an additional $10 million available for distribution based on competitive project proposals. It is possible that applications for energy efficiency funding from campuses that implement a GRF will be prioritized.

5.4 – Results for GHG Mitigating Technologies

This section covers the results from this study in regard to the six identified GHG mitigation technologies. Each technology was considered for its GHG mitigation potential, capital cost, energy savings, utility savings, and avoided cost of carbon offsets. Figure 15 shows the summary GHG mitigation potential for all six of the proposed strategies from Step 1 and Step 2.

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[54] Williams, *Assembly Bill No. 802: Energy Efficiency*.

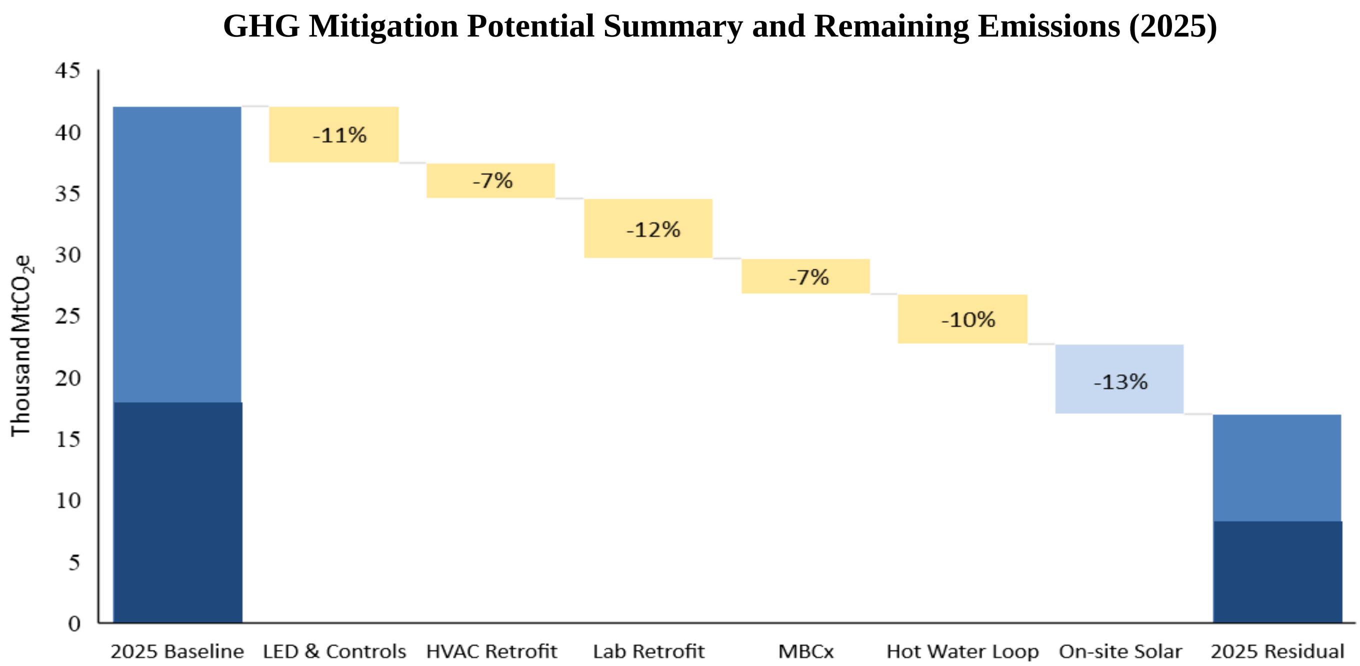

Figure 15. GHG Mitigation Potential Summary and Remaining Emissions (2025).

Overall LCCA result are presented below in Figure 16. All assumptions made to calculate Figure 16 can be found in Appendix F. We find that by implementing the measures we discuss above, UCSB can reduce its 20-year operating costs from $182 million (2016 present value) to $138 million (2016 present value). This represents savings of $44 million compared to our estimated baseline scenario, and results in emission reductions from 744,000 $MtCO_2e$ under the baseline scenario to 215,000 $MtCO_2e$.

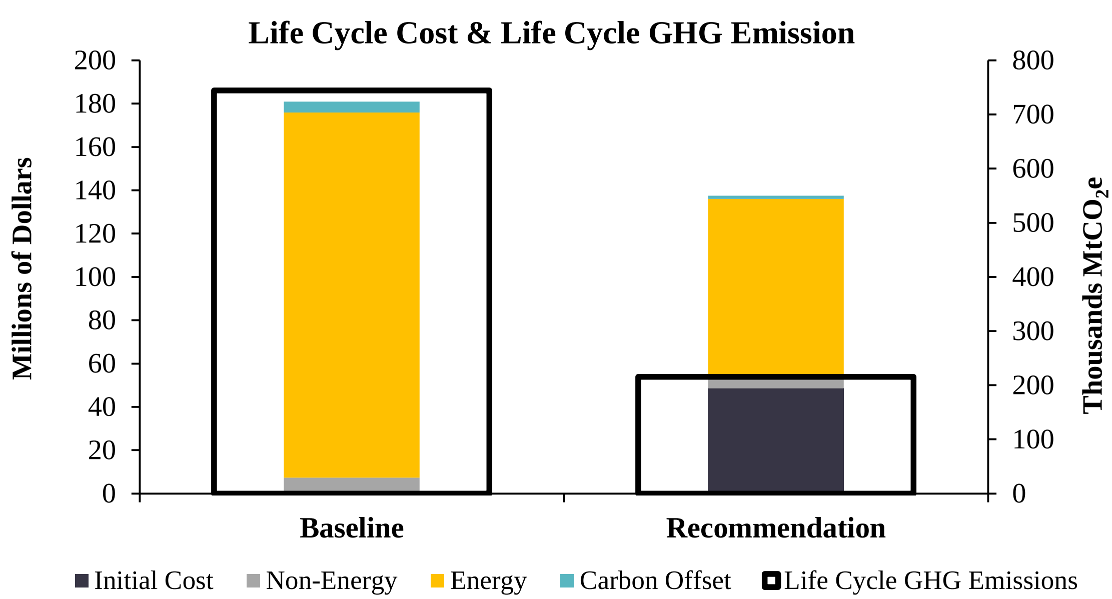

Figure 16. LCCA result for Baseline Scenario and Recommended Scenario. Bar graphs represent 20-year life cycle cost for each option broken into different colors: Initial cost in blue, non-energy cost in grey, energy cost in yellow. The outlined black boxes represent 20-years.

5.5 – Interactions and Uncertainty

The results in this report are intended for use at a planning scale. Savings from measures such as MBCx, HVAC retrofits, and the HWL are likely to have some interactions and overlap which we were unable to quantify. Despite these uncertainties, we believe our analysis provides a useful first step toward understanding the magnitude of investments necessary to achieve carbon neutrality at UCSB and that the need for external "seed" funding can be dramatically reduced by implementing a GRF.

6. Conclusions & Recommendations

The results of this study show that UCSB can achieve carbon neutrality by 2025. While this effort will require large capital investments and considerable ongoing efforts, there are viable demand- and supply-side GHG mitigation strategies available today that can help reduce emissions by 60% and viable carbon offset options to reduce the remaining 40% to zero. UCSB is well positioned to provide leadership on climate mitigation and doing so will promote the recruitment of high quality students and faculty, as well as improve campus resiliency.

In order to meet the goals of President Napolitano's CNI by 2025, our team recommends that UCSB rapidly pursue demand-reduction strategies including (i) LED & Controls Retrofits, (ii) HVAC retrofits, (iii) Lab retrofits, (iv) MBCx, and (v) the installation of a campus Water Loop. Additionally, we recommend that UCSB pursue on-campus solar PPAs and switch from the simple payback method to LCCA when evaluating projects. A Green Revolving Fund can speed energy efficiency and renewable energy project implementation and increase the tracking and monitoring of energy efficiency projects. Further, implementation of a GRF can reduce the "seed" funding needed for these recommendations from $48.3M to $15.7M. If the recommendations in this report are pursued, long-term operating costs and campus emissions will decline over the next decade and value will be retained on-campus.

Despite the clear benefits of achieving carbon neutrality, there are considerable challenges to achieving this goal by 2025. The largest barrier at this time is UCSBs inability to accrue additional debt, which has resulted from the rapid expansion of campus infrastructure. For these reasons, alternative strategies for funding energy efficiency, such as the GRF, must be seriously considered.

6.1 – Deployment Schedule and Reduction Wedge Analysis

Taking into account the required capital investment, buffer time for planning and scheduling, policy context, and labor availability, Figure 17 represents our recommended deployment schedule for each demand and supply side technology discussed in this report.

Due to local air quality mandates, UCSB should invest in the hot water loop as soon as possible to capture energy savings and comply with Rule 361 requirements. Each technology is scheduled to be implemented based on its unique characteristics, the surrounding regulatory environment, and their up-front capital investment.

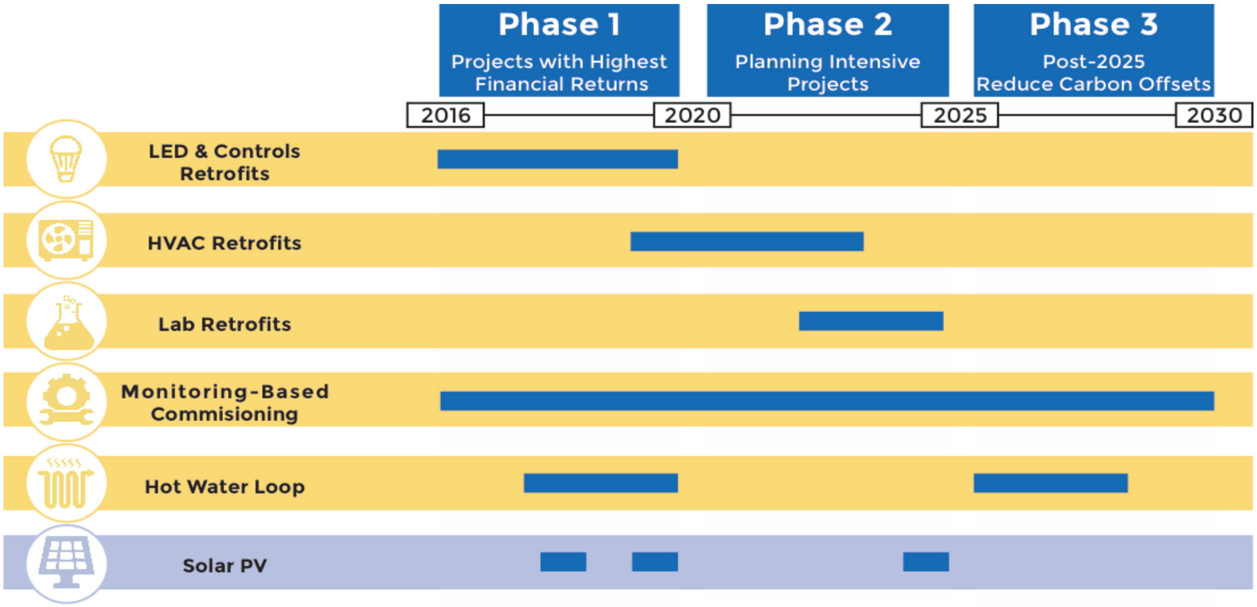

Figure 17. Three-Phase Implementation Schedule. Each mitigation strategy is phased in over the next 15 years, identified by the yellow bar for demand-reducing strategies and the blue bar for renewable energy. Projects that include mature technologies and quick payback are recommended for Phase 1. Additional energy efficiency measures and renewable energy procurement should be pursued in Phases 2 and 3, or as funds become available from avoided utility costs, green donors, AB 32 allowance sales, or other sources.

Below is a visual repesentation of the greenhouse gas emissions reductions for each of the suggested measures in this report. Each technology is phased in according to the potential energy savings, up-front capital costs, and policy requirements.

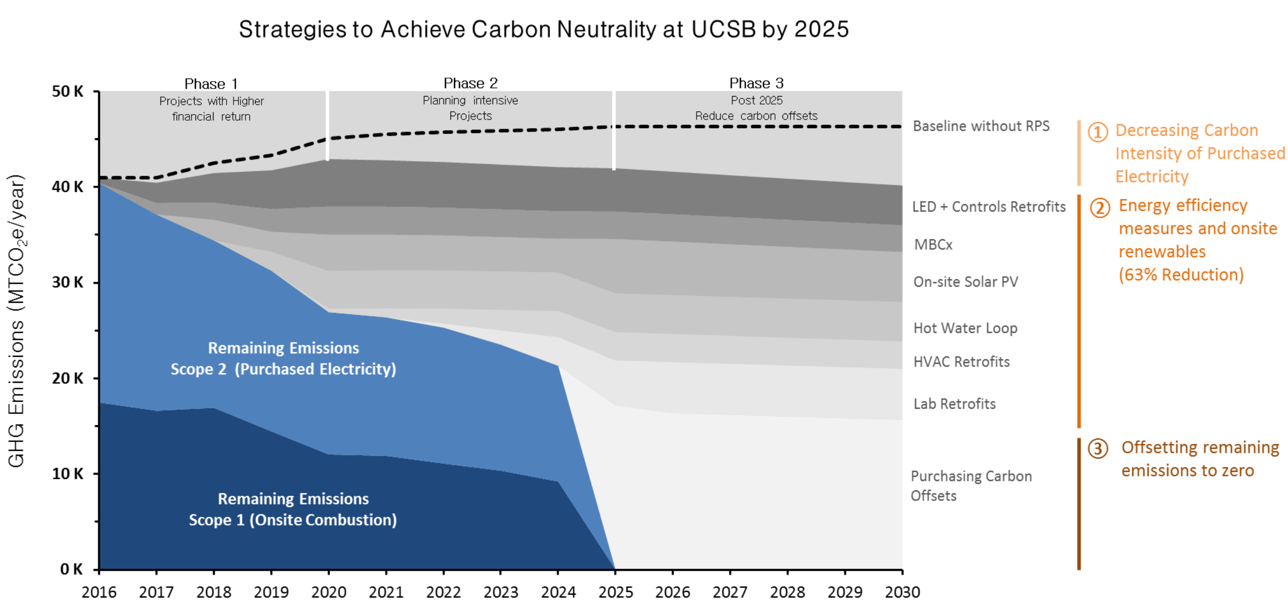

Figure 18. UCSB Greenhouse Gas Abatement Wedge. Baseline emissions (Dotted Line) represents UCSB's carbon footprint if the RPS does not succeed. Scope 1 (Dark Blue) and Scope 2 (Light Blue) emissions encompass all 42,000 $MtCO_2e$ in 2016, while each energy conservation measure (Grey) represents the respective GHG abatement potential.

Each of the energy conservation measures suggested in this report is represented by its own wedge, equivalent to the greenhouse gas abatement potential in metric tons of carbon dioxide equivalent. Together, these energy conservation measures can help save UCSB $6.6 million in utility savings and approximately 25,000 $MtCO_2e$. While there are additional measures that UCSB may employ for further GHG abatement, the measures represented in the wedge graph above account for the most promising measures identified within the timeframe of this report. We recommend that UCSB pursue investigation of further measures, such as an expansion of the hot water loop, server room efficiency, and some of the other measures identified in Appendix A below.

6.2 – Summary of Findings

The results in this report are intended for use at a planning scale. Measures such as MBCx, HVAC retrofits, and the HWL are likely to have some interactions and overlap which we were unable to quantify. Despite these uncertainties, we believe our analysis provides a useful first step toward understanding the magnitude of investments necessary to achieve carbon neutrality at UCSB by 2025 and highlights GRFs as a way external funding can be dramatically.

Table 5. Energy Savings and GHG Abatement Potential for GHG Mitigation Technologies.

Project Type	**Capital Cost**	**Annual Potential Energy Savings**		**Annual Potential GHG Mitigation**	
	Million $	kWh	therms	$MtCO_2e$	% Reduction from Baseline
1. LED & Controls Retrofits	15.55	21,145,741	-	4,529	10.8%
2. HVAC Retrofits	6.89	5,742,505	326,364	2,957	7.0%
3. Laboratory Retrofits	17.61	12,786,676	404,271	4,878	11.6%
4. Monitoring-Based Commissioning	3.33	3,374,929	405,060	2,866	6.8%
5. Hot Water Loop	4.86	-4,116,061	929,627	4,037	9.6%
6. On-Site Solar PPA	0	26,569,883	-	5,691	13.6%
TOTAL	**48.26**	**65,503,671**	**2,127,718**	**24,959**	**59.5%**

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Appendix A: Measures Identified for Future Research

Behavioral Programs and Strategic Messaging

A 2015 Bren group project experimented with behavioral programs and strategic messaging, and conducted a pilot program in three buildings on campus. Results from their study show that energy reductions over a five-month timeframe surpassed a 4% reduction in total energy use.[55] If UCSB is able to reduce campus energy consumption by 4%, it could save over 20 GWh of electricity in a 15 year project horizon. Energy competitions, pecuniary rewards, and a clear messaging strategy would provide efficient incentives for departments to feel the need to engage in energy conservation methods within their buildings and across campus. In addition, a cost-benefit analysis was performed to calculate the financial feasibility of this type of program and and showed that the campus would need to achieve a 2.5% reduction in emissions to make the project viable.[56]

Based on the success of the pilot program, it is clear that there are significant savings available through behavioral programs that are likely unachievable through technological advancements. As stated by the project team, the overall effectiveness of this program will be dependent on various factors including, but not limited to: building baseline energy use, occupant receptiveness, delivery methods, messaging strategies, motivating factors, building efficiency, physical conditions, and financial incentives.[57] As opposed to SEP and Deep Energy Efficiency projects that have high upfront capital costs, a behavioral program has reasonably low initial costs and is relatively inexpensive to operate. This strategy has proven to reduce energy consumption at other campuses and will benefit UCSB from reduced utility costs, a lower carbon footprint, and increased responsibility for each department on campus. For a behavioral program to be effective, it must be bold and widespread in order to collectively trend with other campus-wide energy efficiency and conservation efforts.

Zero Net Energy Buildings

As the name suggests, a zero net energy (ZNE) building is a building with zero net energy consumption. This means that the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site. Consequently, these buildings do not increase the amount of greenhouse gases in the atmosphere. They do at times consume non-renewable energy and produce greenhouse gases, but at other times they reduce energy consumption and greenhouse gas production elsewhere by the same amount.

ZNE buildings have unprecedented potential to transform the way buildings use energy. This ultra-efficiency goal is one that owners can define, design teams can reach for, and occupants desire. An increasing number of buildings are meeting this standard, raising confidence that a ZNE goal is realistic given current building technologies and design approaches. As California's

55 Campbell et al., "Operational Effectiveness."
56 Ibid.
57 Ibid.

building code continues to move toward increased stringency, developing a ZNE building approach will greatly benefit UCSB in the future.

The implementation of zero net energy buildings can and should start as soon as planning and developmental discussions begin for the next buildings coming on-site. By reviewing at the LRDP UCSB (2025) it becomes clear which projects to align ZNE goals with. If the university is successful in implementing a ZNE standard for new buildings on campus, either through on-site or off-site renewable energy projects, it is possible to limit or even eliminate all future GHG emissions due to the LRDP.

Carbon Pricing

Carbon Pricing internalizes the externalities of energy production by holding consumers responsible for the emissions associated with their use of energy and gas. Programs for the university can be approached as a carbon tax or carbon cap and trade program, but a recent report finds that perhaps a combination of the two will work best for the University. A 2015 report by Max Stiefel, a UC Carbon Neutrality Initiative Fellow, found that a carbon-pricing program would likely take 2-5 years to design and launch.[58]

Vehicle Fleet

The UCSB-owned vehicle fleet is crucial for the operation of campus, utilized by a wide range of users including gardeners, facilities, and department operations. Today, 1,422 MT CO2e of the university's total emissions are associated with mobile combustion. Zero-emission vehicles (ZEV) can be phased in to reduce these emissions. Where electric vehicles are infeasible replacements for vehicles that need beds or cargo space—hybrid engines are available.

Server Rooms

30-70% of building electricity is associated with powering and cooling server rooms. As the need for data hosting and management grows within UCSB, the potential for emissions savings derived from changes in the ways these rooms are powered and cooled will increase. A 2015 report by Claire Dooley, a UC Carbon Neutrality Initiative Fellow, found that "potential solutions include server room consolidation, virtualization, and HVAC system and room configuration optimization." [59]

Methane Seeps

In 2002, a UCSB Bren School of Environmental Science and Management Group Project evaluated the feasibility of capturing the hydrocarbon seeped off of Coal Oil Point. Under a "most likely Scenario" the team concluded that the project would entail capital cost of $7.5 million and result in a total project loss of $3.1 million over a 20 year study period.[60] The results also show that if carbon reduction credits could be issued, the project would become attractive

[58] Stiefel, "Best Practices for Carbon Neutrality: University of California, Santa Barbara."
[59] Dooley, "UCSB Carbon Neutrality Initatie Fellow Report."
[60] Ger et al., "Marine Hydrocarbon Seep Capture."

economically. Taking political, environmental, and economic aspects into consideration, they concluded that the costs to achieve the health benefits of ozone reduction do not justify capturing the seeps.

Fuel Cells

Solid Oxide Fuel Cells convert natural gas into electricity through an electrochemical process that does not involve combustion. UCSB currently has a fuel cell on campus—a 200 kw Bloom Fuel Cell that was installed in August 2012. [61] The existing Bloom Fuel Cell Utilizing is a collaboration between UCSB and SCE, and has very high efficiency, as it reduces carbon emissions approximately 30%, almost eliminates SOx and NOx emissions, and uses 99.9% less water for electricity production than the average power plant.[62] Utilizing biogas as a fuel source for a solid oxide fuel cell would make this a source of renewable energy.

Anaerobic Digestion

Anaerobic digesters create biogas through a process where microorganisms break down organic material in oxygen-deprived containers. [63] In 2014, UC Davis installed an anaerobic digester which can convert 50 ton of waste into 12,000 kWh of electricity each day. [64] While it may be possible for UCSB to also utilize anaerobic digestion in order to create biogas, funding, siting, and creating sufficient feedstock represent three barriers to this project. [65]

Ocean Water Cooling

Recently, some coastal buildings have begun utilizing ocean water to reduce the energy needed for HVAC systems through heat exchangers. Southern Maine Community College implemented an ocean HVAC heat exchange system in 2011 and saw reductions in both energy use and emissions; [66] they found that the heat exchange system had coefficients of performance about four times greater for both heating and cooling in this way than their conventional HVAC system. [67] As UCSB is sited on the coast, this could potentially be a way to reduce energy demand and emissions.

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[61] University of California, Santa Barbara Utility & Energy Services, “Fuel Cell Demonstration Project.”
[62] Ibid.
[63] American Biogas Council, “What Is Anaerobic Digestion?”
[64] Kerlin, “Biodigester Turns Campus Waste Into Campus Energy.”
[65] Dooley, “UCSB Carbon Neutrality Initiative Fellow Report.”
[66] Beatty, Klinedinst, and Reinheimer, “Harnessing Seawater: An Innovative Thermal Exchange HVAC System.”
[67] Southern Maine Community College, “Southern Maine Community College Sea Water System.”

Appendix B: LCCA Tool Description & User Guide

Our Microsoft Excel based LCCA tool allows users an apples-to-apples comparison for total costs of projects that have different cost stream and different equipment lives. LCCA provides effective decision-making criteria for both finance and GHG mitigation potential. In addition to conventional financial impacts of energy and operation, the tool also includes cost implications of purchasing carbon offsets and purchasing 100% renewable energy to allow a more complete picture of carbon neutrality.

The tool provides three important aspects: consistency, flexibility, and transparency. In order to maintain consistency across the different project evaluations, our team established default assumptions to apply project evaluations at UCSB. However, to adapt to future changes and increase flexibility, the user can easily change the assumptions by simply inputting the new data. The tool consists of three input sheets and two reference sheets: Project Information, Assumptions, Data Input and Result, Calculation, and GHG Emission Factor. The project information sheet includes basic project information such as building name, date, and contact information for the project team; and utility price with associated GHG emission factor.

The assumptions sheet includes financial assumptions as well as study life period. Financial assumptions include a discount rate and escalation rates for utilities, carbon price, and REC. The analysis uses these numbers to calculate the total costs and life cycle GHG emissions. The Data Input and Result sheet allows users to input project specific information: capital cost, incentives, annual & non-annual operation and maintenance costs, equipment life, and utility consumptions. Once the user plugs in the data, the tool shows the year-to-year cost stream broken down into energy, non-energy, water, and total costs. The analysis generates the result in both numeric and graphic to provide robust and instant understandings for users. The Calculation sheet shows the year-by- year calculation process for each item.

Definitions of terms and equations explained in the Instruction sheet below:

Life Cycle Cost Calculation

Life Cycle Cost (LCC)	Total Life cycle cost in present-value (PV) dollars of a given design for a study life.
	LCC = I + Repl +- Res + E + W + OM&R + O
Net Savings (NS)	This is the total savings, in present dollars, for the Alternate as compared to the Baseline. If this is positive, the Alternate is less expensive to own when compared to the Baseline. If this is negative, the Alternate is more expensive to own than that Baseline.
	$LCC_{Baseline} - LCC_{Alternative}$
First Year Utility Savings	The sum of the costs of each utility consumed by the Baseline minus the sum of the costs of each utility consumed by the Alternate in a single year. The figure displayed represents the savings in Year 1.
	$\text{First Year Utility Cost}_{Baseline} - \text{First Year Utility Cost}_{Alternative}$
Simple Payback (Years)	Tt does not include the time-value of money.
	((ALT Initial Investment) - (BASE Initial Investment)) / First Yeat Utility Savings
Savings to Investment Ratio (SIR)	A dimensionless measure of performance (i.e., it has no units). In general, as long as the SIR of an alternative compared with a base case is greater than 1.0, the alternative is considered cost effective.
	Savings over study life / ((ALT Initial Investment) - (BASE Initial Investment))
Discounted Payback (Years)	The discounted payback period is the latest year that the line crosses the x-axis on the "Net Savings Over Time" graph. For projects that include a Baseline and Alternate case with ongoing material or labor expenses (i.e. many projects), the metric refers you to the "Net Savings Over Time" graph. The reason for this is that there may not be a single period in which the project becomes cost neutral, since material or labor expenses in later years may cause the Alternate to become NS negative more often than once.
Adjusted Internal Rate of Return (AIRR)	A Discount Rate at which the Alternative is revenue neutral compared to the Baseline. It examines the net escalated but undiscounted cash flows resulting from comparing the Baseline and Alternate cases for each year. As this measure compares the undiscounted cash flow, if the IRR is higher than the Discount Rate, the project is NS positive.
	IRR(Year 0 Through Study life Undiscounted Cash Flow of (BASE All Costs - ALT All Costs))
First Year GHG Savings	This is the difference between the Baseline and Alternate emissions stemming from utility consumption presented in Metric Tons of Carbon Dioxide Equivalent (MTCDE). The emission factors should be found for site specific utility data. MA average can also be found on the "lbe conversion ghg" tab. Emissions factors are assumed constant over the study period and are not escalated or discounted in any form.
	(BASE Sum of Annual Utility GHG Emissions) - (ALT Sum of Annual Utility GHG Emissions)
GHG Savings for the study life	The emissions savings over the full study period.
	Annual GHG Savings * Study life
Investment Cost/ GHG Savings	This is the total capital expenditure of the Alternate less that of the Baseline divided by the total anticipated GHG savings, or more simply, the total investement cost per MTCDE saved over the study period. This metric is most useful in comparing the relative cost per GHG reduction among multiple energy conservation measures that may not otherwise be viable from a purely economic sense (i.e. comparing NS negative projects).
	((ALT Initial Investment) - (BASE Initial Investment)) / Study Life GHG Savings
Net Savings/ GHG Savings	This metric divides the total savings of the Alternate and divides that by the total GHG savings earned, showing the amount of money saved per GHG saved. This is useful for analyzing ECMs with similarly positive economic performance.
	ALT Net Savings over study life / Study Life GHG Savings

The blue-shaded cells require data inputs, and the rest is calculated automatically.

Project Information

CARBNEWT

Site Information	
Audit Date	
Building Key	117
Building Name	Bren Hall
Official/Long Name	Bren Hall
Abbrev/Short	Bren Hall
Basic Gross	82972
Outside Gross	94443
Related Gross	88708
FDX Code	BREN
Facility Code	521
Region	MAIN
UBC Code	3 - Ordinary Masonry
Planning	P - Permanent
Condition	2 - Good
Address	CORE CAMPUS
Floors	5
Footprint	32900
Constructed	37257

Note

Site Contact	
Name	
Title	
#	
Email	
Auditor	
Prime	
Sub	
Name	
Title	
#	
Email	

Utility	Rate ($ per unit)	GHG Emission (MTCDE)
Electricity, [per kWh]	**0.11**	**0.000270**
Electricity, Renewable [per kWh]		
Fuel Oil, (No. 2) [per Gallon]		**0.010278**
Fuel Oil, (No. 4) [Gallon]		**0.010617**
Fuel Oil, (No. 5 & 6) [Gallon]		**0.011303**
Natural Gas, [Therm]		**0.005311**
Other, [MMBTU]		
Propane, [per Gallon]		**0.005847**
Steam, [Pound]		
Water, [Gallon]	**0.01**	

Go to GHG Emission Factor Table

This sheet provides basic project information and utility prices. Utility prices and emission factor for the electricity are subject to change over time and should be updated annually or as needed. GHG emissions factors and references are listed in the GHG Emission Factor sheet and can be directed by clicking the blue box on the bottom.

Restore Defaults

Assumptions

Last updated *8/20/2015*

	Real Rate	
Discount Rate	5.0%	
Escalation Rate		
Electricity	3.0%	
Natural Gas	3.0%	
Water	0.0%	
Steam	0.0%	
Fuel Oils	3.0%	
Materials	0.0%	
Others	0.0%	
Carbon Cost	0.0%	
RECs	0.0%	
Study Period	20	years
Price of Carbon		$/MTCDE
Price of RECs		$/MWh

Assumption Notes

Note: Edits to the fields will affect the results, but all DCAMM projects must use the default rates, price, and study period, otherwise explain here.

Reference

The Assumptions sheet lists all the financial assumptions and study period. These assumptions should be updated on a regular basis. Default assumptions can be recovered by clicking “Restore Default” box on the top.

	Baseline		LED+ Control		

Costs

Initial Costs					
Total Cost		Total Cost	$ 19,432,452	Total Cost	
Expected life (years)	7	Expected life (years)	27	Expected life (years)	
Incentives		Incentives	$ 4,858,113	Incentives	
Net Costs	$ -	**Net Costs**	**$ 14,574,339**	**Net Costs**	$ -
End yr Equip. Residual Value	$ -	**End yr Equip. Residual Value**	**$ 5,038,043**	**End yr Equip. Residual Value**	$ -

Non Energy Cost								
One Time OM&R			**One Time OM&R**			**One Time OM&R**		
Description	**Year**	**Cost**	**Description**	**Year**	**Cost**	**Description**	**Year**	**Cost**
Bulb replacement	3	$ 2,318,103	Control System Repair	10	$ 3,191,725			
Bulb replacement	10	$ 2,318,103						
Bulb replacement	17	$ 2,318,103						
Annual O&M Cost			**Annual O&M Cost**			**Annual O&M Cost**		

Annual Energy & Water Consumption					
Electricity (kWh)	26,990,681	**Electricity (kWh)**	2,999,405	**Electricity (kWh)**	
Renewable Electricity (kWh)		**Renewable Electricity (kWh)**		**Renewable Electricity (kWh)**	
#2 Fuel Oil (Gallons)		**#2 Fuel Oil (Gallons)**		**#2 Fuel Oil (Gallons)**	
#4 Fuel Oil (Gallons)		**#4 Fuel Oil (Gallons)**		**#4 Fuel Oil (Gallons)**	
#5 &6 Fuel Oil (Gallons)		**#5 &6 Fuel Oil (Gallons)**		**#5 &6 Fuel Oil (Gallons)**	
Natural Gas (Therms)		**Natural Gas (Therms)**		**Natural Gas (Therms)**	
Other (MMBtu)		**Other (MMBtu)**		**Other (MMBtu)**	
Propane Gas (Gallons)		**Propane Gas (Gallons)**		**Propane Gas (Gallons)**	
Steam (Pound)		**Steam (Pound)**		**Steam (Pound)**	
Water/Sewer (Ccf)		**Water/Sewer (Ccf)**		**Water/Sewer (Ccf)**	

Revenues from RECs

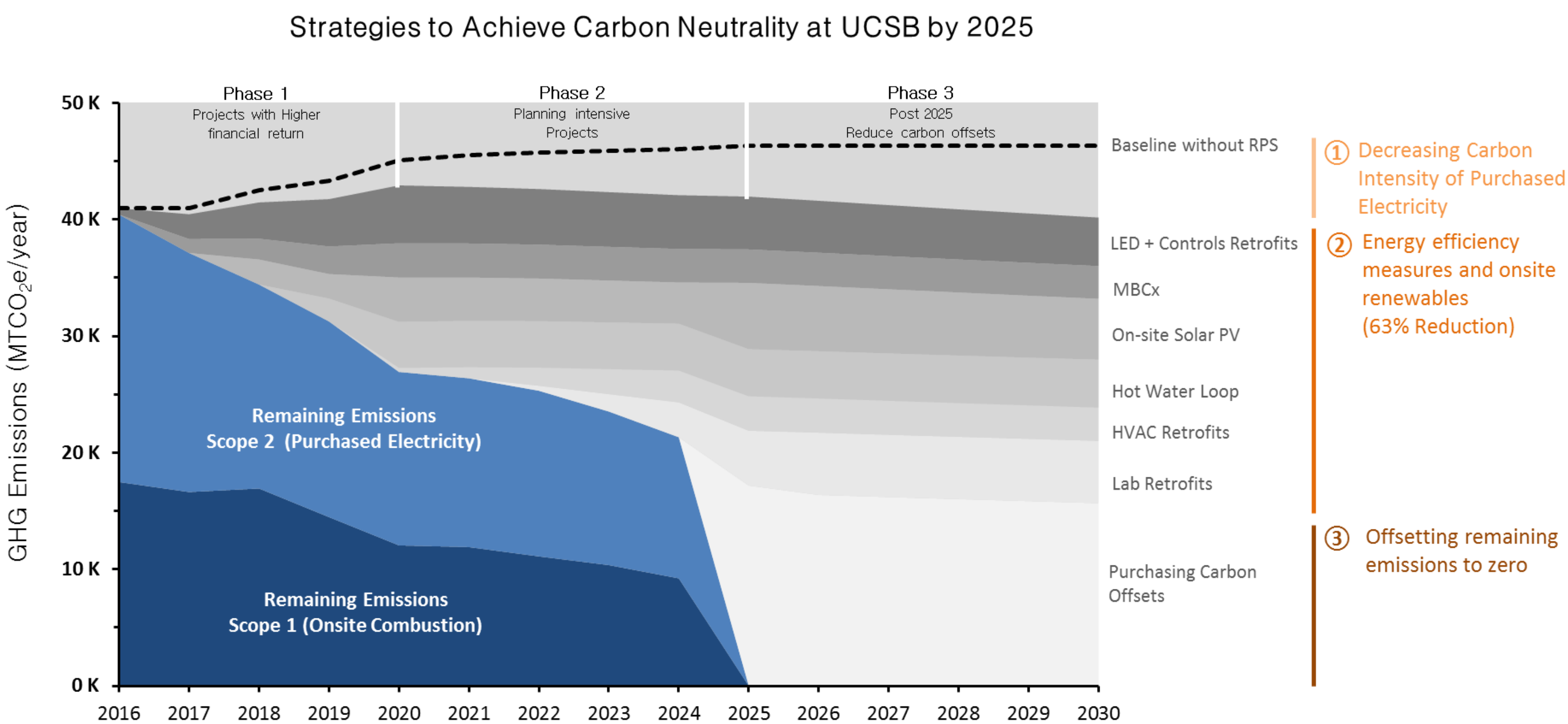
Renewable Energy Generation					
Electricity (MWh)		**Electricity (MWh)**		**Electricity (MWh)**	

Up to four options can be compared at once including baseline. The first option should be always a baseline scenario, because Net Savings refers to baseline cost and calculate the differences. Two cost input sections includes initial costs and non-energy costs. Initial cost and incentives balance out to the net costs. Equipment life is important when it is shorter than the study life. It will add replacement cost at the end of equipment life automatically. Non-energy costs includes one-time OM&R costs and annual O&M costs. One-time costs require the time of occurrence and description. Up to four non-reoccurring costs can be considered for each option. For utility, consumptions for each item are required. Conventionally annual fuel savings are presented in $ savings. Utilizing consumption data will allow easy manipulation or sensitivity testing of assumptions (e.g. escalation rate and utility price). After data input, the tool provides year-to-year calculations and results.

Appendix C: Wedge Graph Description & User Guide

UCSB Greenhouse Gas Abatement Wedge. Baseline emissions (Dotted Line) represents UCSB's carbon footprint if the RPS does not succeed. Scope 1 (Blue) and Scope 2 (Orange) emissions represent the entire graph in 2016, while each energy conservation measure (Grey) represents the respective GHG abatement potential. Offsets (Red) represent the remaining emissions left over after 2025.

The left and right axis represents the greenhouse gas emissions associated to UCSB's annual operations. The horizontal axis represents each year from 2016 to 2030. Through our assessment, we estimated that UCSB will emit just over 40,000 $MtCO_2e$ in 2016. Each wedge represents the abatement potential for each energy conservation measure recommended, while the red section shows the carbon offsets needed if further energy efficiency or renewable energy options are not pursued beyond what is presented in this report.



Wedge Graph User Guide

In order to manipulate or add additional energy conservation measures to the wedge graph, we have provided our Reduction Wedge Calculator as an accompanying deliverable to this report. The first worksheet shows each measure, its implementation date, utility savings, and greenhouse gas abatement potential. Each measure references its own individual worksheet in the excel document. The (Energy Conservation Measure) "ECM Investments" sheet is used to manipulate the costs and savings metrics for each measure, which speaks directly to the wedge on the first sheet. This sheet also includes the LED lighting project broken down by space type and the three rounds of solar PV expansions, including the ~5MW SunPower PPA which is expected to be installed on campus in 2016.

In the first sheet, titled "Wedge", there is Scope 1 and Scope 2 calculations used for each year. These numbers reflect the projected reduction in carbon intensity from the utility grid that will be achieved in California as the state renewable portfolio standard drives for 50% renewable grid mix by 2030. Each measure is deducted from the previous year's residual carbon emissions depending on when the strategy is deployed. If ECM's are to be added, first make a row in the ECM Investments sheet, then add rows in the Scope 1 and/or Scope 2 sections as well as the capital cost impacts and utility savings section. Follow the formulas for the other ECMs in order to maintain consistency and accuracy. The offsets portion is calculated by the residual carbon emissions left over after employing all of the ECMs in the worksheet. As new projects are added, this section will naturally decrease.

Appendix D: Southern California Edison Emissions Factors

Projected Emission Factors for Electricity and Natural Gas. The carbon intensity was calculated assuming a linear intensity decrease that would result in a 50% renewable grid mix by 2030.

	Electricity	Natural Gas
Year	[MtCO_2e/MWh)	[MtCO_2e/therm)
2016	0.25639	0.00529
2017	0.25075	0.00529
2018	0.24524	0.00529
2019	0.23984	0.00529
2020	0.23456	0.00529
2021	0.22940	0.00529
2022	0.22550	0.00529
2023	0.22167	0.00529
2024	0.21790	0.00529
2025	0.21420	0.00529
2026	0.21056	0.00529
2027	0.20698	0.00529
2028	0.20346	0.00529
2029	0.20000	0.00529
2030	0.19660	0.00529

Appendix E: LED & Controls Retrofits Supporting Tables

Annual Hours of Use (HOU) of Various Space-Types.

	Annual Hours of Use (HOU)				
	"Very-Low"	"Low"	"Medium"	"High"	"Other"
	Mechanical, Electrical, Janitorial, & Storage	Corridors, Hallways, & Bathrooms	Open Spaces, Labs, Lecture Rooms, & Shared Offices	Single-Occupancy Offices, & Bedrooms	Covered, Balconies, & Decks
Baseline	4000	7000	4400	3600	4200
Residual	1200	2000	2400	2800	4200
Savings	2800	5000	2000	800	0

Appendix F: LCCA Supporting Documentation

LCCA assumptions by Scenario.

		Baseline Scenario	Recommended Scenario
Initial Costs		$0	$ 48.3 M
Non-Energy Costs		$ 2 M for lamp replacement (year 2, 10, 17) $3 M for boiler replacement (year 1)	$ 0.2 M for MBCx (annual) $ 3 M for LED & Controls replacement (year 10)
Energy Consumption		91.6 GWh (SCE)	26 GWh (SCE) 26.6 GWh (Solar PPA)
		3.0 M therms	0.9 M therms

Carbon Price: $10/MtCO_2e$

Carbon Price Escalation Rate: 3%

LCCA Input Data for 3 Lighting Scenarios.

	Fluorescent	LED Retrofit	LED & Controls Retrofit
Initial Costs	-	$ 13.7 M	$ 15.6 M
Non-Energy Costs	$ 2 M (at year 2, 10, 17)	-	$ 3 M (at year 10)
Energy Consumption	25.9 GWh	11.6 GWh	4.7 GWh

Appendix G: Detailed Cost Information

1. Initial Cost and Associated Energy Reduction for Lab Retrofits.

BUILDING_NAME	BASIC_GROSS_AREA	Estimated kWh reduction for Applicable gsf			Estimated Therm Reduction for Applicable gsf			Estimated Project Cost for Applicable gsf			Estimated Utility Savings		
		Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
ENG SCI	84,162	966134	1307587	1136860.5	29206	38703	33954.5	1208311	1824652	1516481.5	123798.34	167056.37	145427.355
LIFESCI	78,295	830390	1123868	977129	12551	16633	14592	1038540	1568284	1303412	98873.5	133605.28	116239.39
ELINGS HALL	116,999	818848	1118064	968456	39045	51740	45392.5	1322042	2117237	1719639.5	113500.28	154031.04	133765.66
ENGR 2	127,751	1555173	2104805	1829989	47013	62300	54656.5	1945002	2937118	2441060	199276.83	268908.55	234092.69
MAR SCI BLDG	59,141	472401	639359	555880	14281	18924	16602.5	590816	892183	741499.5	60532.71	81683.89	71108.3
BREN	82,858	141,122	188067	164594.5	0	0	0	87556	96144	91850	15523.42	20687.37	18105.395
NOBLE HALL	44,536	287976	389753	338864.5	12188	16151	14169.5	360162	543875	452018.5	38990.16	52563.43	45776.795
PSYCHOLOGY	48,027	535536	724806	630171	16189	21453	18821	669776	1011420	840598	68622.36	92600.46	80611.41
HAROLD FRANK (ENG I)	98,212	733032	992102	862567	9695	12847	11271	916779	1384413	1150596	86450.52	116839.42	101644.97
CHEMISTRY	98,632	1230797	1665790	1448293.5	37207	49305	43256	1539317	2324500	1931908.5	157711.87	212819.9	185265.885
BIOLOGY 2	127,949	1782983	2413131	2098057	53900	71426	62663	2229917	3367364	2798640.5	228468.13	308300.01	268384.07
BROIDA HALL	139,440	817470	1106382	961926	19770	26198	22984	1022381	1543883	1283132	101783.7	137420.82	119602.26
PSB NORTH	93,045	1163493	1574698	1369095.5	35173	46609	40891	1455141	2197386	1826263.5	149088.03	201182.18	175135.105
ENG RSH LAB	56,596	711831	963409	837620	21519	28516	25017.5	890263	1344372	1117317.5	91212.81	123084.59	107148.7
Totals	1,255,643	12,047,186	16,311,821	14,179,504	347,737	460,805	404,271	15,276,003	23,152,831	19,214,417	1,533,833	2,070,783	1,802,308

[68] ARC, "Deep Energy Efficiency and Cogeneration Study Findings Report."

2. 2015 MBCx Projects and 2016-2018 Proposed MBCx Projects for SEP program at UCSB.

Building Name	Cost	Annual KWh Savings	Annual Therm Savings
MRL MBCx	$20,000	80000	5000
Kerr MBCx	$22,000	100000	20000
Snidecor MBCx	$34,000	100000	20000
ESB MBCx	$44,000	300000	20000
Psychology MBCx	$48,000	120000	20000
Girvetz MBCx (WPT)	$51,000	50000	8000
CNSI MBCx	$56,000	150000	20000
North Hall MBCx (WPT)	$66,000	80000	5000
PSB North MBCx (WPT)	$93,000	500000	50000
ESSB MBCx	$100,000	157774	2693
Ellison MBCx (WPT)	$114,000	100000	15000
South Hall MBCx (WPT)	$132,000	100000	15000
Phelps MBCx (WPT)	$135,000	100000	15000
Engineering 2 MBCx (WPT)	$145,000	75000	7500
Library MBCx (WPT)	$338,000	100000	15000
Total	$1,398,000	2,112,774	238,193

3. Initial Cost for Hot Water Loop.

Item	Cost
Architecture	$126,926.00
Landscape Put-Back	$177,218.00
Structure	$323,440.00
Civil	$1,886,950.00
Mechanical Central Plant	$616,080.00
Mechanical Building Modifications	$1,169,135.00
Electrical	$823,286.00
General Requirements	$200,000.00
Sub-Total	$5,323,036.00
Contingency (20%)	$1,064,607.00
Sub-Total	$6,387,643.00
Insurance and bonds	$191,629.00
Sub-Total	$6,579,272.00
Soft Costs (12%)	$789,513.00
Owner Furnished Equipment	$830,850.00
Installed Infrastructure (as of 1/1/2016)	-$3,333,649
Total Estimated Costs	$4,866,351

4. Initial Cost and Associated Energy Reduction for HVAC Retrofits.

Building Name	Basic Gross Area (ft^2)	Estimated kWh reduction for Applicable gsf			Estimated Therm Reduction for Applicable gsf			Estimated Project Cost for Applicable gsf			Estimated Utility Savings		
		Low	High	Average	Low	High	Average	Low	High	Average	Low	High	Average
BROIDA HALL	139,440	50,274	65,739	58,007	3,194	4,760	3,977	$57,662	$81,652	$69,657	7446.54	10087.29	8766.915
MAC	53,197	79,418	103,848	91,633	2,523	3,759	3,141	$91,090	$128,986	$110,038	10249.78	13678.68	11964.23
HAROLD FRANK (ENG I)	98,212	93,007	121,616	107,312	3,232	4,815	4,024	$106,675	$151,056	$128,866	12169.97	16266.76	14218.365
ELINGS HALL	116,999	99,863	130,582	115,223	7,931	11,818	9,875	$114,539	$162,192	$138,366	15743.53	21454.82	18599.175
GIRVETZ HALL	50,924	106,435	139,175	122,805	6,038	8,997	7,518	$122,077	$172,865	$147,471	15330.65	20707.45	18019.05
ARTS	82,271	122,823	160,605	141,714	5,853	8,721	7,287	$140,873	$199,481	$170,177	17022.33	22899.15	19960.74
KERR HALL	43,548	130,026	170,024	150,025	10,327	15,388	12,858	$149,135	$211,181	$180,158	20499.06	27935.44	24217.25
ICA	43,742	130,605	170,781	150,693	10,373	15,456	12,915	$149,799	$212,121	$180,960	20590.35	28059.51	24324.93
MUSIC	90,428	135,001	176,528	155,765	10,722	15,976	13,349	$154,841	$219,260	$187,051	21283.31	29003.68	25143.495
DAVIDSON LIB	339,447	82,813	238,699	160,756	16,099	23,989	20,044	$94,984	$296,480	$195,732	18768.83	40650.29	29709.56
ROBERTSN GYM	79,276	189,363	247,613	218,488	15,039	22,410	18,725	$217,192	$307,551	$262,372	29853.33	40683.43	35268.38
EVENTS CNTR	64,197	191,680	250,643	221,162	7,612	11,342	9,477	$219,850	$311,315	$265,583	25652	34375.93	30013.965
RECCEN	66,130	197,452	258,190	227,821	15,682	23,367	19,525	$226,470	$320,689	$273,580	31128.92	42421.1	36775.01
CHEADLE HALL	68,242	203,758	266,436	235,097	8,091	12,057	10,074	$233,703	$330,931	$282,317	27267.98	36542.16	31905.07
SRB	69,143	206,448	269,954	238,201	3,279	4,886	4,083	$236,788	$335,300	$286,044	24676.68	32626.54	28651.61
SAASB	77,755	232,162	303,577	267,870	5,532	8,242	6,887	$266,281	$377,063	$321,672	28857.02	38338.67	33597.845
PHELPS HALL	134,419	280,945	367,367	324,156	22,313	33,248	27,781	$322,233	$456,294	$389,264	44291.75	60359.17	52325.46
ELLISON HALL	113,304	338,305	442,371	390,338	13,434	20,018	16,726	$388,023	$549,453	$468,738	45273.95	60671.61	52972.78
SOUTH HALL	131,496	392,622	513,397	453,010	15,591	23,232	19,412	$450,323	$637,673	$543,998	52543.02	70412.87	61477.945
UNIV CENTER	148,936	444,695	581,488	513,092	17,659	26,313	21,986	$510,048	$722,246	$616,147	59511.85	79751.48	69631.665
HSSB	155,089	463,067	605,511	534,289	11,033	16,440	13,737	$531,120	$752,085	$641,603	57557.17	76470.21	67013.69
SANTA CATALI	251,100	749,738	980,365	865,052	48,378	77,559	62,969	$859,921	$1,217,678	$1,038,800	111497.98	154375.55	132936.765
Total	**2,417,295**	**4,920,500**	**6,564,509**	**5,742,505**	**259,935**	**392,793**	**326,364**	**$5,643,627**	**$8,153,552**	**$6,898,590**	**$697,216**	**$957,772**	**$827,494**

Appendix H: UCSB Solar PV Results Table

UCSB Solar PV Results Table (Current and Proposed Projects)				
	kW DC	**kW Cumulative**	**MW Cumulative**	**Cumulative kWh Estimated (95% conversion)**
Current Projects (Based on actual readings)				
Bren, Harder Stadium, Carillo DC, East Gate, Rec Cen 2	247	247	0.25	364,122
Parking lot 22	426	673	0.67	992,122
SunPower PPA (Based on SunPower expected 1608 kWh/kW DC Multiplier)				
parking lot 38	2,010	2,683	2.683	4,314,264
san clemente parking structure lot 50	722	3,405	3.405	5,475,240
thunder dome (events center)	513	3,918	3.918	6,300,144
rob gym	494	4,412	4.412	7,094,496
mesa parking structure lot 18	970	5,382	5.382	8,654,256
parking structure II lot 10	613	5,995	5.995	9,639,960
Carbon Neutrality Proposed Projects (Based on SunPower PPA Multiplier)				
Davidson Library	825	6,820	6.82	10,966,560
Phelps Hall	780	7,600	7.6	12,220,800
Harold Frank Hall	180	7,780	7.78	12,510,240
Lotte Lehman Hall	175	7,955	7.955	12,791,640
University Center	675	8,630	8.63	13,877,040
Arts	250	8,880	8.88	14,279,040
Theater & Dance West	200	9,080	9.08	14,600,640
Student Health	465	9,545	9.545	15,348,360
SRB	200	9,745	9.745	15,669,960
Intercollegiate Athletics	275	10,020	10.02	16,112,160
Rec Cen 1+3	485	10,505	10.505	16,892,040
Cheadle Hall	300	10,805	10.805	17,374,440
Potential Parking Lot Projects (Based on SunPower PPA Multiplier with 75% Capacity)				
Parking Lot 12	1050	11,855	11.86	19,062,840
Parking Lot 14	1100	12,955	12.955	20,831,640
Parking Lot 16	1200	14,155	14	22,761,240
Parking Lot 23	800	14,955	14.955	24,047,640