Climate Action Course Final Report

December 10, 2007

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Acknowledgements

With special thanks to ERG Professor Dan Kammen for sponsoring the course and Fahmida Ahmed - CalCAP Project Manager, Karl Brown - Deputy Director CIEE, Judy Chess - Capital Projects, and Raul Abesamis - Energy Engineer for their sustained and multifaceted support during the course of the semester.

We'd also like to thank the following guest speakers, who took valuable time out of their schedules to share their ideas and wisdom with us: Cathy Koshland - Vice Provost and CalCAP Chair, Nathan Brostrom - Vice Chancellor, Ed Denton - Vice Chancellor, Matt St. Clair - UCOP, Julian Dautremont-Smith - AASHE, Arpad Horvath - Professor Civil Engineering, Chris Jones - BIE, Scott Zimmermann - ERG/Boalt, Gail Brager - CBE, Ed Arens - CBE, Paul Black - Facilities (Retired), Charlie Huizenga - CBE, Chris Marnay - LBL, Daniel Prull - ERG/ME, Paul Matthew - LBL, Kameron Kitajima - Green Intern, Michael Murray - Lucid Design Group.

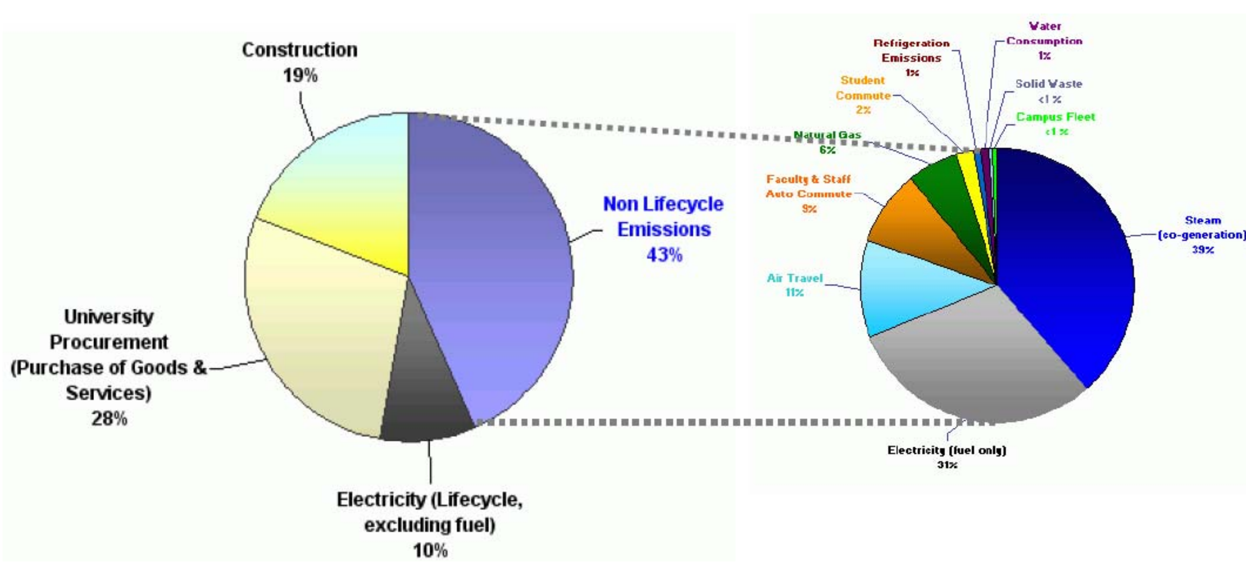
Section 1: Vision and Recommendations

1.1 Background & Vision

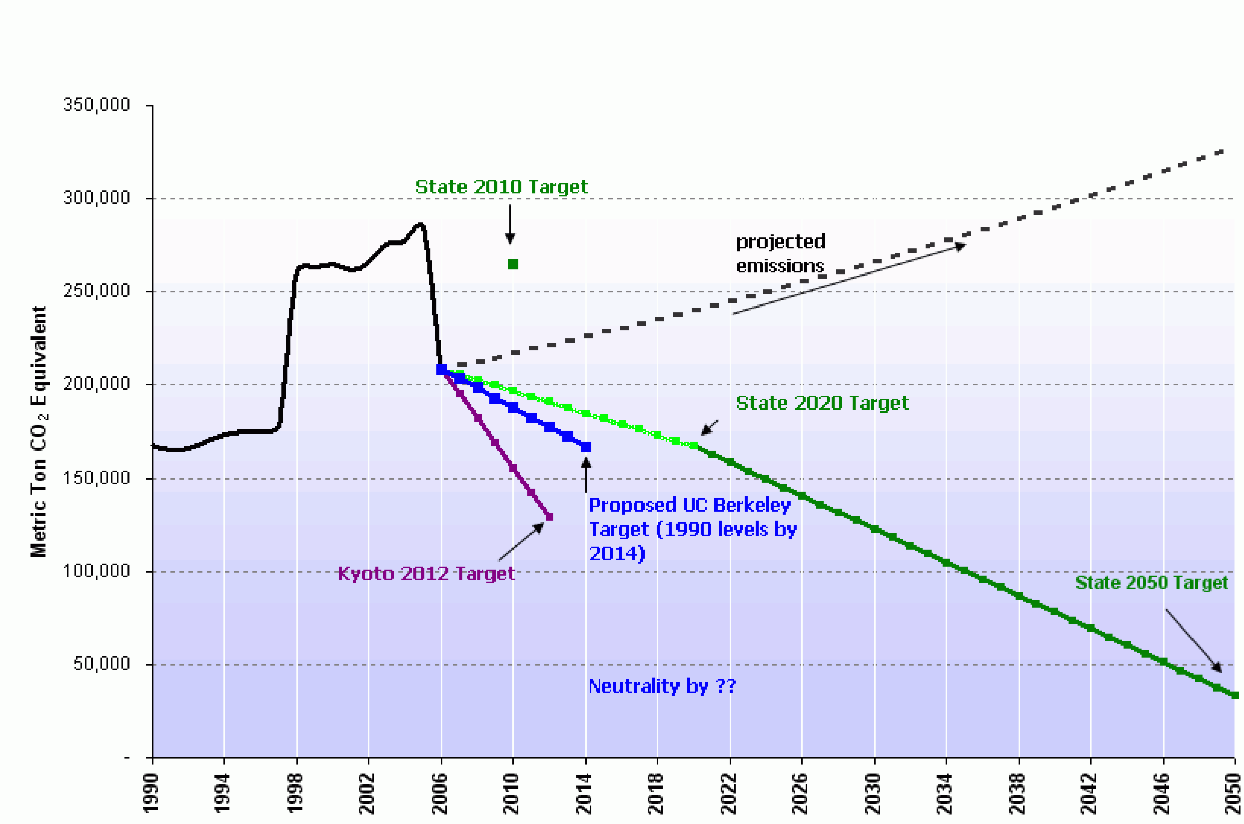
By committing UC Berkeley to the goal of returning to 1990 levels of greenhouse gas emissions by 2014, Chancellor Robert Birgeneau further cemented UC Berkeley's reputation for leadership on issues of campus sustainability. Although the goal is laudable and the supporting research was groundbreaking, questions remain about how best to achieve the 2014 goals. In fact, the process of goal setting itself has revealed many of these questions. There are several possible approaches, each with its own costs, benefits, and risk profile. For example, some ideas and opportunities for projects have benefits for the campus and environment that extend well beyond carbon mitigation, while other projects and offset programs focus narrowly on CO_2 mitigation. Even the calculations of emissions and the measurement of mitigation have been shown to be more complex and subtle than they originally appeared. In the end, all of these issues must be considered with the knowledge that the cost and feasibility of more ambitious goals (post 2014), including climate neutrality, will likely be influenced by actions taken now.

The student initiated Climate Action Course focused on understanding the nature of a potential commitment to climate neutrality and its underlying motivations. We sought compelling strategies that stand to enrich academic life, further the cause of research into climate solutions, and make economic sense for the school. Weekly class meetings have included guest appearances by CalCAP members, student leaders, academic faculty, administrators, and business leaders on the cutting edge of sustainable practices, policies, and technologies. Through class conversations, readings, and independent research, tantalizing opportunities for achieving and surpassing the CalCAP goals have begun to emerge. By coupling foresight and strategic planning with a sustained effort to fund, staff, and implement promising projects, UC Berkeley can exceed the CalCAP targets while saving money and enhancing its educational mission.

To set some context, the CalCAP Feasibility Study found that current lifecycle emissions are 482,000 Mt CO2e, and non-life cycle emissions are 210,000 Mt CO2e.



Reaching 1990 levels for non-life cycle emissions by 2014, which is what we are currently tracking and what the California registry counts, requires a 20% reduction from today's emissions or a 26% reduction from the business as usual projection for 2014.[1] However, serious thought should also be given to fully integrating a life cycle cost analysis into our climate change mitigation planning.



Source: CalCAP Feasibility Study

1.2 Call to Action

UC Berkeley has already begun several projects that work towards the Chancellor's CalCAP goal of a return to 1990 levels of emissions by 2014. However, we have not yet planned work at a scale that will enable us to meet or exceed this goal. Existing work is proceeding slowly and constrained by limited funding and staff time. During the 2006-2008 PG&E/UC/CSU Partnership funding period we received support for monitoring-based commissioning in four buildings on campus, and lighting retrofits in 15 buildings. With approximately 200 major buildings on campus that contain over 13 million gross sq ft, **at our current rate it will take us over 60 years to commission all the buildings and over 40 years to upgrade all the lighting.**[2] The campus also lacks vision in the area of renewables; the largest existing source of renewable energy on campus was planned and funded by students. We can reach our 2014 emissions target **without resorting to emissions credits** while saving money and enriching campus life, but to do so will require a long term, campus-wide plan for mobilizing the resources needed for implementation.

[1] See Appendix 6.1.2

[2] See Appendix 6.1.2

In addition to it being the right thing to do for the environment, future generations, and our own policy goals, these projects pay for themselves. According to a recent UC-wide study of the PG&E/UC/CSU Partnership program, commissioning projects saved an average of 11% of the site energy, and pencil out with an average payback of 2.3 year – after that savings go directly to the University's bottom line.[3] Lighting, which currently accounts for 30% of campus electricity use and 9.3% of our GHG emissions, is also an attractive potential source of savings.[4] Lighting upgrades can save 35-60% of electricity use depending on the technology and usually pay back between 1 and 3 years.

These types of savings, and the benefits that come with decreased energy use, should be enough to motivate serious action. UC Berkeley has further reason to act now due to an incentive program through PG&E that will fund up to 80% of the costs of energy efficiency projects. These funds come from a surcharge on utility bills to support energy efficiency and renewables in California. Berkeley has participated in this incentive program for the last four years and has used all of the funds allocated to us each year. **The exciting part is that the funding is likely to increase drastically, from about $800,000 per year today, to an estimated $5 million per year for 2009-2014**.[5] This means that for 2009-2014 Berkeley may have $30 million in incentives which would be matched by $20 million in internal funds.

This is an **enormous change in magnitude of the energy efficiency work on campus**, and will require a significant investment of time, financial resources, and human resources to make sure that we make full use of this opportunity. In October, Paul Black, who was Berkeley's Utilities Engineering Manager and a driving force behind efficiency on campus, retired after 29 years of service. His departure further increased the pressure on the other staff members managing energy efficiency projects. Paul's group was already stretched very thin before his departure. Given the planned increase in partnership funding and the fact that the money will only be awarded to projects completed before 2014, there will need to be a corresponding increase in campus energy efficiency and conservation staff. T**he likely value of projects supported by the funding from PG&E and matching funds for 2009-2014 is more than 6 times what we are currently doing. We can therefore expect about a six fold increase in the demands on staff time.**

This is not an opportunity we can afford to miss. If we are able to reduce our energy use (including both steam and electricity) by 30%, which is a goal that has been attained by other campuses, we would reduce our non-life cycle GHG emissions by 21%, beat our 2014 CalCAP goal![6]

This work would also contribute directly to funding the University's primary goal of education. Last year, we exceeded our energy budget by $6.6 million, which came out of the campus' discretionary funds. **If energy costs decreased by 30%, discretionary funds would increase by 34%**, freeing funds to pay for our highest priority needs on campus.[7] Investing in emission reductions, especially through energy efficiency, has an impressive financial return. According to a back-of-the-envelope

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[3] Brown, K., J. Harris, and M. Anderson. 2006. "How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings" Proceedings of the 2006 ACEEE Summer Study of Energy Efficiency in Buildings. 3:27-40. Washington D.C.: American Council for an Energy-Efficient Economy.
[4] See Appendix 6.1.2
[5] See Appendix 6.1.2
[6] See Appendix 6.1.2
[7] See Appendix 6.1.2

calculation, if we invest a total of $50 million and use loans to pay our matching portion of the project costs of $20 million, the net present value of our investment is approximately $41 million.[8] We need to align our resources and marshal campus expertise to do this work on a large scale. Where we do not have resources, we need to fill the gap. **The time to act is now.**

1.3 Recommendations

- **Develop, staff, and fund a long range energy program that is harmonized with other campus planning and targets 30% or more in total energy savings.**
  - Use PG&E funding as a springboard for ongoing future work.
  - Establish a permanent organizational group focused on saving energy through efficiency, retrofits, commissioning, outreach and education and fund the group with a fraction of the money saved through their efforts.
  - Commit to an efficiency program that will touch all buildings on campus, starting with high resolution energy monitoring to set a baseline.

- **Develop more aggressive and binding standards for new and existing building energy performance that includes specific attention to fume hoods, refrigerators, other lab equipment, computers, and miscellaneous plug loads.**
  - Commit to LEED certification or beyond for all new construction and renovations on campus.
  - Require justification of excessive glazing and air conditioning in our sunny and mild climate.
  - Develop an upcoming building project into an example of cutting edge high performance building design, construction, and operation with a goal of net-zero emissions.

- **Use campus emissions reductions as an opportunity to develop academic research programs focused on climate mitigation.**
  - Begin to use the campus as a laboratory for learning about renewable energy and microgrids.
  - Start with solar thermal and photovoltaic panels on the roofs of campus buildings, and potential investments in wind, wave, and biogas energy for campus use.
  - Study the potential and effects of education and behavior change on campus energy use through an education and outreach program backed by real time campus energy consumption data.

Details and additional project specific recommendations can be found in the sub-sections below.

[8] See Appendix 6.1.2

Section 2: Case Studies

One of the best ways to evaluate Cal’s options for moving forward is to take a look around at what other campuses have been doing. This section is dedicated to case studies of successful mitigation programs at other schools with a focus on adapting their experiences to Cal’s specific circumstances.

2.1 UC Santa Barbara

UCSB serves as a great case study for Cal as the two campuses share many of the same challenges, constraints and opportunities. UCSB has a strong culture of pursuing sustainability, and as a member of the California Climate Action Registry, has set stringent energy reduction goals. The campus faces the needs of a growing enrollment and the maintenance and expansion of state-of-the-art science and research facilities with high energy loads. Through strategic planning and use of partnership funding, UCSB has demonstrated that “managing energy and upholding academic excellence can be complementary goals”[19] as evidenced by awards from the CPUC, the National Wildlife Federation, and Southern California Edison in recognition of their climate action and efficiency measures.[2]

2.1.1. Impact of Program

The University has undertaken an ambitious program of energy efficiency work using partnership funding. It has just completed the first phase and is embarking upon the second phase. The Total cost of phases 1 and 2 is $3,946,766. Of this amount, $1,522,843 has been or will be funded through grants. The average IRR of these projects is 33% and they save 5,569,659 KWH/yr of electricity, 127,172 therms/yr of natural gas and 8,609,446 lb CO_2/yr.[3]

Phase 1,2006-7

- Installed two-position dimming switches in 150 stairwells. The project cost $35,250, saving 49,631 KWH/yr and 63,528 lbs CO_2/yr.
- Initiated HVAC retrofit projects, specifically installing low pressure drop, long life filters on 28 air handlers. Costs were $404,395 with an associated 1,350,000 KWH/yr and 1,728,000 lbs CO_2/yr savings.
- Implemented monitoring based commissioning for three buildings: Engineering 2, Life Science, and Marine Science. Costs were $160,000, $160,000, and $145,000 respectively. Savings for Engineering 2 were 369,384 KWH/yr, 36,709 Therms/yr of natural gas, and 900,104 lbs CO_2/yr. The other buildings had similar results.

Phase 2 projects include an aggressive lighting systems upgrade on ten campus buildings, the replacement of eighteen V-belt fans with direct drive fans, the commissioning of Bren, and the constant volume air handler reset program at several buildings.

1 Jim Dewey, Former Energy Manager UCSB
2 UCSB Energy Website http://energy.ucsb.edu/
3 All data was computed by the UCSB energy team. Personal Correspondence with Ryan Schauland Energy and Sustainability Coordinator UCSB

2.1.2 Funding Sources

The total cost of phase of 1 and 2 is $3,946,766. USCB has been able to fund $1,522,843 of the projects through grants from the California Public Utilities Commission. The remainder has been funded through loans from the UC/CSU/IOU partnership. The average IRR of these projects is 33%.

2.1.3 Human Resources

UCSB considers one of their primary constraints to be human resources. Yet, they have been able to organize an Energy Team to identify and execute projects. The energy efficiency program has been undertaken by the UCSB Energy Team which consists of:

- Associate Director/ Utility and Energy Manager
- Campus Sustainability Manager
- Energy and Sustainability Coordinator
- Four Engineers

In general, these projects are scoped by one of the teams of engineers, who then secure grants, rebates, and other funding as well as hire contractors to do the physical retrofit and/or repairs. That engineer will project manage those contractors. There is wide variation in the amount of time involved in project scoping. It could be minimal, or as is the case with a project like monitoring-based commissioning, staff do most of the work and only contract out for the repairs.

The two staff most involved in these projects are mechanical engineers. They also receive support from the rest of the staff (electrical and civil engineers, electricians, HVAC mechanics, etc.) and from the campus sustainability manager and the energy and sustainability coordinator, who are not engineers but have some experience in the field.

2.2 University of British Columbia

The University of British Columbia's sustainability program is an excellent model for Berkeley to follow. UBC's campus in urban Vancouver with 43,000 students and 10,000 staff and faculty is a comparable size and location to Berkeley. Since opening their sustainability office in 1998, UBC has greatly expanded the programs and their impact. The office is entirely funded by the savings it creates. A major strength of their program is that they hired a professional staff that places an emphasis on measuring and reporting the impact of their programs. The sustainability office website[10] includes their annual progress reports and a "real time" calculator of the savings of water, paper, electricity, greenhouse gas emissions, and money that are a result of their programs. They also completed an "Ecotrek" project in 2006 that renovated and upgraded 6.8 million gross square feet of space in 280 buildings using performance contracting to guarantee savings. The Ecotrek project reduced energy use by 27% and carbon emissions by 26% over the 2002-2003 baseline.[11]

2.2.1 Impact of Program

[10] UBC website with savings calculator and annual reports: http://www.sustain.ubc.ca/ (accessed 11/18/07)
[11] Personal correspondence with Jorge Marques, former director of the UBC Sustainability Office (11/23/07)

UBC program impacts include reducing electricity use by 160,000,000 kWh, greenhouse gas emissions by 60,000 tonnes, and water use by 11 billion litres since 1999 at a savings of $22 million Canadian (CAD). The sustainability office runs a range of initiatives that promote sustainable practices. The results include:

- Installing a geo-exchange heating and cooling system using groundwater as an energy source, which will save more than $100,000 and almost 2,000 tonnes of carbon dioxide annually.
- A project called Sustainability Street that is the world's first closed-loop system integrating storm water management, wastewater treatment, and ground source heat pumps.
- A pilot with UBC's custodial services to test the use of certified green cleaning products in campus buildings.
- A reduction in the use of virgin white, recycled white paper, and recycled colored paper by 19 % in absolute numbers and 37 % on a per capita basis since 1999.
- A new initiative designed to save money for researchers while salvaging chemicals that would have normally been thrown out. Researchers are now encouraged to donate their surplus chemicals to western Canada's first university central depository.
- The diversion of more than 2,000 tonnes of garbage from the landfill in 2006, a 42 % diversion rate.
- Installation of an in-vessel composter in 2005 that has digested 130 tonnes of waste collected from more than 30 sites on campus.

In addition, UBC's Ecotrek project is interesting as a case study for what is possible at UC Berkeley for reducing the use of energy and resources. Through building and systems upgrades and retrofits, Ecotrek aimed: "to reduce the consumption of electrical, steam, natural gas and water on campus; to renew and enhance air conditioning, heating, ventilation, lighting and water-use facilities; to increase occupant comfort and decrease complaints; to reduce greenhouse gas emissions; and to provide design, technology and training solutions to realize continued utility cost savings."[12] The results from this massive project are impressive:

- Annually reduced electricity use by 16.2 GWh, steam consumption by 154.5 million lbs, and natural gas by 111,510 GJ for a total of 400,000 GJ of energy in savings which represents a 27% reduction in energy use for the academic & administration buildings from the 2002-2003 baseline
- The GHG reductions are 17,000 tonnes per year, which is a reduction of 26% of the GHG emissions from energy used in academic & administration buildings
- Reduced water use by 1.5 million cubic meters each year, which is 41% below the 2002-2003 consumption for academic & administration buildings[13]

It took 2 years to develop the project, including issuing an RFP, selecting the firm, doing a full audit, finalizing the scope, and negotiating the contract. The work included in the original scope took 3 years, and additional work identified in the process will end in January 2008.

2.2.2 Funding Sources

[12] Ecotrek website: http://www.ecotrek.ubc.ca/ (accessed 10/15/07)

[13] Personal correspondence with Jorge Marques, former director of the UBC Sustainability Office (11/23/07). Note these performance numbers will not be found on the Ecotrek or Sustainability Office websites, Jorge calculated these based on the most recent project data from the 2002-2003 baseline.

The UBC sustainability office has always been funded by the saving from its energy saving programs. The savings from the Ecotrek project were $2.6 million CAD annually at the end of 2006 (this is now projected to be $4.2 million annually with an expansion of the project and increased utility rates), though all the Ecotrek savings now go towards repaying the project costs.

The Ecotrek project value was $35 million CAD plus $3.8 million for internal UBC costs for project management and building shut-downs. The project was funded with an internal loan through the UBC Treasury. MCW Custom Energy Solutions, an engineering firm, designed, installed, and managed upgrades to UBC buildings and systems, substantially reducing their energy consumption and operating costs. There were also funds for training in the project budget that were used to train building operators and trades workers to operate and maintain the facilities.

All capital costs associated with the program will be paid back from energy savings, and MCW's guarantee of performance ensures transfer of performance risk from UBC. The contract between UBC and MCW is structured so that performance is guaranteed, and any shortfall in savings must be made up by MCW. According to a lead staff person working on this project, the project was "sold" to UBC as a way to "upgrade campus facilities and address deferred maintenance at no net cost to the University," not as a project to save energy.[14]

2.2.3 Human Resources

The UBC sustainability office has seven professional staff members[15] (four full-time and three part-time) and 4 student staff members. There is also a UBC Sustainability Advisory Committee, which is a select group of faculty, staff, and student representatives, similar to the CalCAP committee. This group "identifies strategic opportunities for sustainability initiatives, helps establish and maintain sustainability as a high-priority focus throughout UBC, and facilitates consultation with the university community."[16] In addition to the sustainability-focused staff there is also a lot of support given by the UBC Land & Building Services department, the faculty and students on campus, and the contracted engineering firms who do much of the retrofitting work.

The following staff was required to manage the Ecotrek program:[17]

- Energy Manager from the UBC Sustainability Office (1/3 time)
- Project Manager (Full-time) and Project Coordinator (Full-time) from the UBC Land & Building Services department
- Project Manager (halftime), Construction Manager (Full-time) and Project Coordinator (Full-time) from MCW Custom Energy Solutions

To actually implement the measures additional staffing resources were required. These included UBC staff to shut-down building systems, MCW engineering staff for design, and subcontractors to install equipment and systems.

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[14] Personal correspondence with Jorge Marques, former director of the UBC Sustainability Office (11/23/07)
[15] Staff bios can be found here and are included in the "Notes to Future Students" section: http://www.sustain.ubc.ca/about.html (accessed 11/18/07)
[16] AASHE profile on UBC: http://www.aashe.org/resources/profiles/ubritishcolumbia2006.php (accessed 11/18/07)
[17] Personal correspondence with Jorge Marques, former director of the UBC Sustainability Office (11/23/07)

UBC sustainability office also runs a Sustainability Coordinators program to engage faculty and staff in encouraging others to saving energy and resources. The sustainability office provides training and support for these volunteers. In 2006 UBC's 145 faculty and staff Sustainability Coordinators saved the university $75,000 worth of electricity.

2.3 Texas A&M

Texas A&M is a leader in energy efficiency, and has tapped into campus researchers to develop a strong program for reducing its environmental impact. They have saved more than $50 million since 1996 through their campus-wide metering, retrofits, and continuous commissioning program.[18] Their campus master plan includes the goal to "promote sustainability by teaching, planning, and acting in an environmentally sustainable manner."[19] Their campus size is comparable to Berkeley with 46,000 students and 2,500 faculty members. Texas A&M has a campus Office of Energy Management (OEM), which was established in 1991 as a part of the Physical Plant Utilities Division. OEM has worked closely with the Energy Systems Laboratory (ESL), a research facility that is part of the Texas A&M system, to commission 150 buildings, 5 central utility plants, and the distribution infrastructure.

2.3.1 Impact of Program

Texas A&M has reduced its campus energy consumption per square foot by 33% over the last ten years, at a savings of $50 million. This work has included:

- An active and ongoing building retrofit and commissioning program. Texas A&M is constantly commissioning its buildings a rate of 12 to 18 per year.
- All new buildings are required to have meters and metering has been installed in much of the existing building stock. So far, they have installed 1000 meters to measure energy consumption, which transfers information to a centralized server to monitor performance and quickly identify problems; this information is also made available online to building users so they can monitor their consumption and energy costs.
- Review of plans and specifications for all new buildings and major renovations by the OEM, which provides specific recommendations and specifications to project managers and engineering design firms to improve the design, construction, and commissioning of major building projects.
- Energy conservation programs such the Residence Hall Energy Challenge, Care Pledge Campaign, website posting of charts and information, and a program to reduce energy consumption during holidays, nights and weekends.

In addition, Texas A&M also recently signed a contract with TXU Energy to purchase more than 176 million kWh of energy from Texas wind farms over the next four years.

2.3.2 Funding Sources

[18] Info from the Office of Energy Management website: http://energy.tamu.edu/index.php?option=com_content&task=view&id=34&Itemid=69 (Accessed 11/23/07)

[19] Texas A&M 2004 Campus Master Plan: http://www.tamu.edu/campusplan/pdf/Final%20Master%20Plan%20book%20file.pdf (Accessed 11/23/07)

The work of the OEM is funded through the annual budgeting process. There is an operating budget that covers regular expenses such as staff time and ongoing maintenance and commissioning, and a capital budget that covers one-time expenses such as lighting retrofits, and other large projects. In addition to internal funding they have borrowed from the Texas Loan Star program, a state-created entity that offers low interest rates to schools and state agencies.[20]

2.3.3 Human Resources

Several groups work together at Texas A&M to implement their programs. The OEM is the lead group on campus with responsibilities that include: "reporting on the Energy Management Program, managing energy consumption, preparing projections and reporting actual versus projected quantities, actively promoting energy conservation, implementing energy conservation measures, maintaining and upgrading the campus building automation systems, installing and maintaining meters to accurately measure consumption, maintaining, and creating invoices to bill utility commodities such as electricity, domestic water, chilled water, heating hot water, domestic hot water, steam, solid waste collection, sanitary sewer and storm drainage."[21] OEM staff also guest lecture in classrooms, give tours, and provide utility data for classroom education. The OEM staff includes 12 full staff, 9 contract employees, and 2 students: 1 energy manager, 1 energy coordinator, 2 staff and 1 student performing IT support, 2 database administrators, 2 staff and 1 student in billing analysis, 1 staff HVAC technician, 1 contract HVAC technician, 1 staff electrician, 2 contract electricians, 2 control systems/metering staff, 4 contract HVAC controls technicians (Siemens), and 2 contract welders.[22]

There are other groups that OEM collaborates with for campus work. Facilities Maintenance provides preventative maintenance support and makes HVAC repairs. The Energy Systems Lab (ESL), a research lab on campus with 120 professional staff members and 50 student employees, provides engineering support with commissioning and retrofit work. OEM contracts with ESL at a cost of $750,000 annually. Texas A&M also founded a University Committee on Energy Conservation in 2001 with the charge of determining methods for reducing energy consumption and thus energy costs on campus.

2.4 Los Angeles Community College District

The Los Angeles Community College District (LACCD), serving over 185,000 students, is currently undertaking the largest public sector sustainable building effort in the United States, funded by its voter-approved $2.2 billion Proposition A/AA Bond Program.[1] All 9 campuses are undergoing extensive construction projects, and the District is committed to doing everything in the most sustainable way possible, including new Leadership in Energy and Environmental Design (LEED) certified buildings, water efficient landscaping, flexible renewable generation systems, and "green" curriculum.

2.4.1 Impact of the Program

[20] Personal communication with Charlie Shear (11/29/07)
[21] Info from the Office of Energy Management website: http://energy.tamu.edu/index.php?option=com_content&task=view&id=34&Itemid=69 (Accessed 11/23/07)
[22] Personal correspondence with Charles Shear, Coordinator for the Office of Energy Management (11/20/07)

The program is based around a huge building plan which is just beginning. Projects which are currently being undertaken include:

- 44 LEED Silver buildings in planning, design, and construction. One has already been built and construction has begun on nine others.
- Each campus is in the process of either planning for or building a 1 megawatt photovoltaic system.[23]

Future projected projects:

- The LACCD has proposed to build and operate a "Renewable Energy Central Plant"
- Extensive energy efficiency measures.[24]

2.4.2 Funding Sources

The new construction is being funded through two bond measures, Prop A and Prop AA, which amounts to 2.2 billion dollars. Money from the statewide Prop 1D bond will also be used to fund sustainability measures. The district has made a commitment that all buildings that are at least 50% funded by bond money will be LEED-certified. Additional funding sources include the following:

- The "Renewable Energy Central Plants" will be funded through third parties dependent upon loans.
- Energy efficiency work will be financed through a combination of CPUC funding and private sector financing.
- The LACCD plans to take advantage of solar/pv incentives through their IOU and CPUC.
- The LAACD has been designated as a pilot program by and will be receiving support from the Clinton Climate Initiative, however the details are not yet public.[2]

2.4.3 Human Resources

The LAACD has extremely limited staff and proposes to do energy retrofitting and renewable energy installation using third parties who will be hired through competitive bidding.

2.5 Harvard University

The Harvard Green Campus Initiative (HGCI) offers a powerful example of program growth for Berkeley to follow. When the HGCI began in 2000, the program was small (one person and a $70,000 budget).[25] Yet, over the years, the HGCI has grown to be a leader in achieving ambitious campus sustainability efforts. Today, the HGCI office includes 19 professional staff and 38 part-time students. In addition, they have developed in-house expertise. As the HGCI website observes, the staff "have been trained and managed to work on building upgrades, building construction and design, behavioral change, procurement practice, renewable energy, staff training, waste reduction, ongoing environmental education, recycling and more."

While Harvard may be a private university with a set of funding mechanisms that are different from those of a public university like Berkeley, the HGCI experience nevertheless highlights the

[23]LAACD Builds Green Site http://www.laccdbuildsgreen.org/building_green_laccd_is_building_green.php
[24] Personal communication with Dr Woodrow Clark Energy Director LAACD
[25] About Us. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/about/funding.php

importance of securing additional staff support for long-term program development, growth, and success.

2.5.1 Impact of Program

The Harvard Green Campus Initiative (HGCI) has generated annual savings that exceed program costs. In fact, every distinct HGCI program must generate financial returns that exceed the annual cost of the program in order for it to be approved.[26] As of Nov. 2007, the overall impact from HGCI's projects included the following:

- Over $7 million in annual savings[27]
- The most (3) LEED registered and certified buildings of any university
- One of the top 10 universities purchasers of renewable energy
- Reduced campus annual greenhouse gas emissions by over 70 million pounds per year.
- Saved over 15 million gallons of water[28]
- Reduced wasted by 200,000 lbs

At the heart of the HGCI success has been its investment in the development of a revolving loan fund program, the Green Campus Loan Fund (GCLF), which provides capital for conservation projects. More than $8,000,000 has been invested in 140+ GCLF projects with an average ROI of over 30% and with impressive GHG reduction savings.[29] See tables below for a project summary.[30]

26 Funding (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/about/funding.php
27 Harvard Green Campus Initiative Business Plan FY08 Retrieved December 13, 2007 from http://www.greencampus.harvard.edu/about/documents/FY08BusinessPlan.pdf
28 Loan Fund Achievements. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/gclf/achievements.php
29 Harvard Green Campus Initiative Business Plan FY08 Retrieved December 13, 2007 from http://www.greencampus.harvard.edu/about/documents/FY08BusinessPlan.pdf
30 Loan Fund Achievements. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/gclf/achievements.php

Department	Number of Projects	Total Loans	% Total Fund Utilization
Harvard Medical School	22	$2,322,768.88	19%
Harvard Business School	18	$1,718,877.69	14%
Harvard Faculty of Arts and Sciences	32	$1,687,923.18	14%
Harvard School of Public Health	10	$964,067.10	8%
Harvard Real Estate Services	14	$853,429.95	7%
Harvard Athletics	7	$1,034,083	8%
Harvard University Dining Services	14	$634,146.32	5%
Harvard Radcliffe Institute	6	$612,405.00	5%
Harvard Arboretum	2	$544,770.00	4%
Harvard Graduate School of Education	2	$452,549.00	4%
Harvard University Operations Services	6	$407,599.70	3%
Harvard Kennedy School of Government	5	$361,667.24	3%
Harvard Forest	1	$96,650.00	1%
Harvard Museums	1	$81,066.00	1%
Harvard University Library	1	$79,572.00	1%
Harvard Divinity School	3	$192,674.00	2%
HSPH/HMS	1	$74,340.00	1%
Harvard University Art Museums	1	$33,864.00	0.30%
Harvard Division of Continuing Education	1	$18,292.00	0.20%
Total	**147**	**$12,212,146.06**	**100%**

Project Category	# of Projects	Amount of Fund Allocation	% Total Fund Allocation
Lighting	72	$5,231,027	49%
Heating, Ventilation, Air Conditioning (HVAC)	32	$2,650,004	22%
Ground Source Heat Pump	2	$1,000,000	1%
Behavior	8	$955,435	6%
Kitchen Renovation	10	$563,257	7%
Co-generation	2	$464,222	1%
Photovoltaic power generation (PV)	3	$334,591	2%
Controls	4	$286,517	3%
Irrigation	2	$252,150	2%
Insulation	3	$92,336	2%
Construction Soft Costs	1	$69,724	1%
Metering	2	$67,432	1%
Process Load	1	$53,460	1%
Recycling Enhancement	1	$38,000	1%
Transportation	2	$9,868	1%
Feasibility	1	$29,000	1%
Renovation	1	$115,122	1%
Total	**147**	**$12,212,146.06**	**100%**

In the beginning, undertaking projects with more immediate cost savings was a primary focus and critically important to the HGCI's success. As the HGCI has developed over the years, however, their scope is also expanding to cover projects that may have a less clear and immediate payback, such as in sustainable food.[31]

2.5.2 Funding Sources

It's rather remarkable that from their original $70,000 budget, the HGCI has grown to a fiscal year 2008 operating budget of $1.8 million.[32] Each year, the HGCI completes an annual business plan that outlines their full budget and financial forecast. Approximately 20% of HGCI's funding comes from Harvard University's central funding.[33] In order to cover the additional 80% of funding, the HGCI collaborates with various Harvard University departments and schools on fee-for-service partnerships. The HGCI has provided expertise on a range of projects, such as building operations, building design, procurement, behavioral change and energy conservation projects. While such partnerships were initially handled on an annual basis, the HGCI has evolved its business model to also offer services on an hourly basis, such as for LEED engagement work.[34] Hourly fees vary, depending of the specific service. For example, green building support services might be in the range of $75 - $100 per hour.[35] The HGCI has witnessed significant growth in the service area over the yeards. "The volume of HGCI business funded by the schools and departments has grown from nothing in FY01 to over $1.3 million in FY08," according to the Harvard Green Campus Initiative Business Plan FY08.[36]

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31 Jaclyn Olsen, HGCI Assistant Director. Phone Interview. (December 13, 2007).
32 Funding (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/about/funding.php
33 Funding (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/about/funding.php
34 Jaclyn Olsen, HGCI Assistant Director. Phone Interview. (December 13, 2007).
35 Christine Benoit, HGCI Manager of Communications & Business Organization. Phone Interview. (December 13, 2007).
36 Harvard Green Campus Initiative Business Plan FY08 Retrieved December 13, 2007 from http://www.greencampus.harvard.edu/about/documents/FY08BusinessPlan.pdf

Green Campus Loan Fund

The HGCI also helped to establish and manage the Green Campus Loan Fund (GCLF), a $12 million, revolving loan fund made available for conservation projects. That said, the GCLF is independently evaluated and advised by a cross-faculty/department Advisory Committee, which includes members with expertise in and responsibility for engineering and utilities, environmental impact, health and safety, operations, finance and administration, and maintenance.[37]

The GCLF provides up-front capital for projects that will reduce the University's environmental impacts and have a payback period of 5-10 years or less.[38] As a resolving loan fund, GCLF will provide this capital to the departments, who it turn agree to repay the fund via savings achieved by project-related cost savings. For example, GCLF approved projects may help to reduce utility consumption, waste removal, or operating costs, and these savings can then be used to repay the GCLF. The advantage of the revolving loan fund model is that it allows departments to upgrade the efficiency, comfort, and functionality of their facilities without incurring any capital costs, as noted by the GCLG website.[39]

Former Harvard University President Larry Summers, praised the Green Campus Loan Fund for its sound economics, remarking that, "The best investment in the University is not the endowment but the Green Loan Fund." And given that Harvard University has doubled the GCLF from $6 Million to $12 Million dollars during his tenure, the University truly is investing in the expansion of a program that it has deemed both environmentally and financially sound.

It is important to note that a revolving loan fund functioned especially well because of the decentralized approach to budgeting for the various departments and schools within Harvard University. "This model worked really well at Harvard University because everyone has control over their own budget," noted Jaclyn Olsen, HGCI Assistant Director.[40] No big institutional changes to accounting were required to implement the GCLF: from the outset, the schools would be able to see the savings themselves.

To-date, donor money has not been a significant part of the HGCI's funding mechanism.[41] While the HGCI staff said that they may investigate donor funds in the future for projects with a longer payback (such as in renewable energy), they also noted that there are often political issues and another set of protocols that go along with soliciting donor funding for projects.

2.5.3 Human Resources

Today, the HGCI office has 19 professional staff, including the following positions (listed below by focus area):[42]

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37 Who Runs It? (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/gclf/team.php

38 The Green Campus Loan Fund. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/gclf/index.php

39 The Green Campus Loan Fund. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/gclf/index.php

40 Jaclyn Olsen, HGCI Assistant Director. Phone Interview. (December 13, 2007).

41 Ibid.

42 Harvard Green Campus Initiative Business Plan FY08. Retrieved December 13, 2007 from http://www.greencampus.harvard.edu/about/documents/FY08BusinessPlan.pdf

Core

- Director, HGCI – Full-time
- Assistant Director, HGCI - Full-time (New in FY08)
- Manager, Finance - Full-time
- Manager, Renewable & Special Projects - Full-time (New in FY07)
- Web Coordinator - Full-time (New in FY07)

Campus Energy Reduction Programs (FAS and Longwood)

- Coordinator, FAS Campus Energy Reduction Program – Full-time
- Coordinator, Longwood Green Campus Initiative– Full-time

High Performance Building Service - Existing Buildings

- Manager, HPBS – Full-time
- Manager, HPBS – Full-time (New in FY08)
- Coordinator, HPBS – Full-time
- Coordinator, HPBS – Full-time

High Performance Building Service - New Construction

- Manager, HPBS – Full-time
- Manager, HPBS – Full-time (New in FY08)
- Coordinator, HPBS – Full-time (New in FY07)
- Coordinator, HPBS – Full-time (New in FY07)

High Performance Building Resource

- Coordinator, High Performance Building Resource, HPBS – Full-time

Green Living Programs (Undergraduate and Graduate)

- Manager, Green Living Programs – Full-time
- Coordinator, FAS Resource Efficiency Program – Full-time
- 19 REP students (2 at 10 hours and 17 at 4 hours per week)
- Coordinator, Graduate Green Living Program – Full-time
- 18 GGL student/spouse residents

Renewable Energy

- Coordinator, Renewable – Full-time (New in FY07)

Interestingly, though, the HGCI began as one staff person and a limited budget, but quickly set out to expand its vision and support across the University. After spending fifteen months between March 2000 to June 2001 to plan extensively and build internal support, Director Leith Sharp and Co-Chairs Tom Vautin and Jack Spengler met with the President and Provost to request five years of funding at $150,000 a year to further establish the HGCI.[43] Moreover, they also requested $3 million to develop a Green Campus Loan Fund, a revolving loan fund. When their proposal was approved, HGCI got its official start.

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[43] Start-Up Story. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/about/startup.php

Building the case for schools and departments to support HGCI was a top priority from the program outset. In the first year, Director Leith Sharp developed new programs that served various Schools and Departments across the Harvard University campus.[44] Sharp's attention to and investment in outreach helped build credibility among schools and departments for the HGCI's fee-for-service model, especially after the successful completion of a few, initial projects.[45] Since then, regular meetings with the Advisory Group, whose members include representatives from each school and department, has helped build further momentum for HGCI.[46] These meetings are a primary vehicle for communication among the Facilities/ Energy Directors and provide a forum for sharing across the University.

Staff development has played an important role in building up capacity and internal expertise, especially with their fee-for-service model. As the HGCI website observed, the majority of successful loan funded projects benefited from one or more of HGCI support services. Even today, project management and implementation is one of the most important services – such as contacting companies on behalf of University Schools and Departments for lighting retrofits. Having additional staff to help provide these support services is key for the overall, long-term program success. As the HGCI website observed, "It is worth noting that preserving the Director's function as program development (figuring out funding, project definition, staff training and management) rather than project management (staffing the actual project implementation itself), is essential for creating a wide reaching green campus effort."[47]

2.6 Yale University

Yale's experience in creating its Office of Sustainability offers another aspirational example of administrative support for campus sustainability and underscores the need for institutionalizing resources as part of a campus commitment to go green.

2.6.1 Impact of Program

One of the main initiatives has been Yale's greenhouse gas reduction project. Though Yale was neither the first nor the boldest with its carbon reduction target, it has captured international headlines due to a misquote of a statement by Yale President Richard Levin at the Davos World Economic Forum in January 2007. At Davos, Levin commented, "Large organizations with the power to act independently should take matters into their own hands and begin to reduce green-house gas emissions now."[48] The resulting misquotes, however, included headlines like that of *Newsweek* which declared, "Yale President Richard Levin Explains His Plan to Make University the Greenest in the United States." While Levin denies using this phrase, ironically, the misquote helped galvanize internal campus attention towards a carbon reduction plan. That said, Levin has demurred from signing the American College and University Presidents Climate Commitment, citing a lack of specifics that does not provide a meaningful commitment.

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44 Start-Up Story. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/about/startup.php

45 Jaclyn Olsen, HGCI Assistant Director. Phone Interview. (December 13, 2007).

46 Jaclyn Olsen, HGCI Assistant Director. Phone Interview. (December 13, 2007).

47 Start-Up Story. (n.d.) Harvard Green Campus Initiative. Retrieved November 9, 2007 from: http://www.greencampus.harvard.edu/about/startup.php

48 Baas, Carole. "Yale's big green experiment." *Yale Alumni Magazine*. November/December 2007, Vol. 81: 2. p. 34- 47, p. 43.

In an October 2005 letter from President Richard C. Levin, Provost Andrew D. Hamilton, and Vice President for Finance and Administration John E. Pepper, Yale committed to adopting a greenhouse gas reduction strategy through 2020, making it one of the first U.S. universities to commit to a fifteen-year strategic energy plan.[49] Developed by the Energy Task Force, the plan advocates a combination of an energy conservation program, alternative energy investments, Renewable Energy Certificates (RECs) purchases, and implementation of on-site renewable and clean energy demonstration projects.

The campus goal is to reduce greenhouse gas emissions to 10% below 1990 levels by the year 2020, which represents a 43% reduction from 2005 levels, according to the August 2007 report on Yale's Greenhouse Gas Reduction Strategy.[50] Interestingly, this report notes that while the Kyoto Protocol prescribes a reduction to 7% below 1990 levels by 2012, Yale opted to adopt targets that are consistent with the Climate Change Action Plan adopted by the New England Governors and Eastern Canadian Premiers.

To date, Yale has made progress in achieving 21% of their 2020 goal for a 203,000 MTCE reduction, including the following:[51]

- Conservation (e.g.: existing buildings, more efficient on campus production and distribution of energy) has resulted in 42,607 MTCE reduction
- Sustainable construction of new buildings has resulted in 932 MTCE reduction
- Renewable energy has resulted in 635 MTCE reduction

Yale's Greenhouse Gas Reduction Strategy has four main tenets that include the following: 1) Conservation & Community Engagement, 2) Sustainable Design & Construction, 3) Campus Energy Production & Distribution, and 4) Renewable Energy & Alternative Fuels.[52] However, the University carbon reduction plan has not yet incorporated transportation or travel. To address this gap, the University recently created a new position for a director of sustainable transportation that was filled by Holly Parker in April 2007. For 2008, they will be conducting a quantitative analysis to understand how much employee commutes contribute to the overall carbon footprint of the University.

2.6.2 Funding Sources

According to the August 2007 Yale's Greenhouse Gas Reduction Strategy report, "Energy conservation and alternative energy projects requiring significant capital investment by the University are evaluated on the basis of 'resulting carbon reduction per operating dollar incurred.' Projects yielding the largest return are undertaken first so that emission reductions can be achieved as quickly as possible."[53]

2.6.3 Human Resources

49 Yale commits to long-term Greenhouse Gas Reduction and Renewable Energy Strategy. (October 2005). Yale Office of Sustainability. Retrieved November 9, 2007 from http://www.yale.edu/sustainability/yaleCommits.htm

50 Yale Sustainability Strategy. (n.d.) Yale Office of Sustainability. Retrieved online November 19, 2007 from http://www.yale.edu/sustainability/strategy.htm, p.2

51 Yale Sustainability Strategy, p. 2.

52 *Ibid,* p. 2

53 *Ibid,* p. 3.

In 2004, Yale created the new position of Sustainability Director, a role that was filled by Julie Newman. "A new directorship may sound like merely an additional layer of bureaucracy, but in most bureaucracies, nothing new happens until someone is put in charge of making it happen," observed Carole Bass, in her November 2007 article, "Yale's big green experiment."[54] Indeed, Sustainability Director Julie Newman appeared to bring the very energy that the University had hoped for to formalize the long-standing, grassroots activities on campus around sustainability. After one year, Newman's efforts had sufficiently encouraged the provost, vice president of finance, and administration to create a formal Office of Sustainability, which reports jointly to the Office of Facilities and the Office of the Provost.

Today, under the direction of Julie Newman, the Office of Sustainability now has four staffers and about a dozen student research assistants. The roles include the following:

- Director
- Education and Outreach Manager
- Administrative Assistant
- Project Coordinator - To be hired
- Research Assistants – approximately 12 students

During its first year, the Office of Sustainability focused on Energy, Transportation, and Waste management. The goal was to develop a baseline of information, establish short and long term goals, and create an implementation plan to achieve those goals.[55] As a result, several committees were created, including the Energy Task Force, Transportation Policy Committee, and Integrated Waste Management Committee. In fiscal year '06, these committees continued their work and a new committee was established on Sustainable Building Design and Construction. With the help of students and with staff support, a Marketing and Communication Committee was created to manage the development of the Office of Sustainability web site and to help advise community outreach efforts. Finally, the long standing Advisory Committee on Environmental Management (ACEM) has continued its work in managing the distribution of the Green Fund as well as recommending a set of long-term sustainability targets.

The Office of Sustainability is also developing overall sustainability metrics. The objective is to establish a baseline from which to establish goals and measure progress in meeting targets. Through its committees, they are working to develop very specific short and long term goals as well as quantitative targets. These recommendations will be paired with proposed implementation tactics that will consider policy changes, new investments, and potentially new ways of approaching old issues (e.g.: parking, waste disposal, energy use) to successfully meeting their targets.

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54 Baas, Carole. "Yale's big green experiment." *Yale Alumni Magazine*. November/December 2007, Vol. 81: 2. p. 34- 47, p. 39.
55 Yale Sustainability Strategy. (n.d.) Yale Office of Sustainability. Retrieved online November 19, 2007 from http://www.yale.edu/sustainability/strategy.htm

Section 3: Project Potential

In this section we detail the Greenhouse Gas mitigation potential of various retrofit projects, commissioning, changes in energy use behavior, and on campus generation of renewable energy. In sum, the solutions detailed below represent potential mitigation well beyond the 2014 CalCAP target and begin to suggest the form of workable solutions for approaching climate neutrality.

3.1 Energy Efficiency

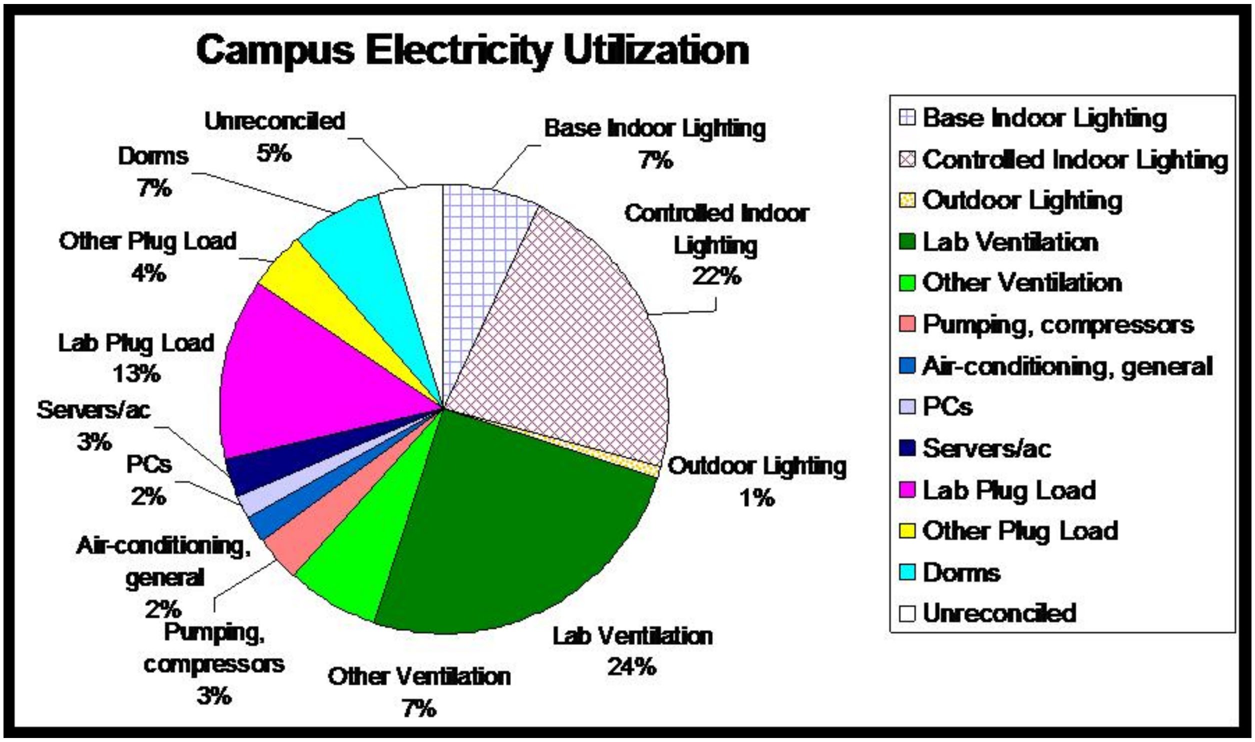
More efficient use of energy is the single largest potential source of greenhouse gas mitigation on campus that pays for itself. In addition, the PG&E/UC/CSU Partnership money is only available to support projects that reduce energy use. These two facts taken together make efficiency projects the logical first place to look for mitigation potential at Cal. Our research has shown that such projects do stand to significantly reduce campus emissions, especially if they are carried out across the entire campus. We have become convinced that efficiency projects alone are capable of achieving the CalCAP goals in their entirety by 2014.

3.1.1 Lighting Retrofits

While the campus is currently conducting a limited number of retrofits with help from the PG&E partnership, there needs to be a larger focus on these projects as they can reliably result in huge monetary savings as well as in significant emission reductions in the near future.

3.1.1.1 Summary

The electricity consumption on campus in 2006 was 212,800,000 kWh, which amounts to approximately 31% of total campus GHG emissions. The biggest contributors to campus electricity use are indoor lighting and lab ventilation. Indoor lighting, which includes base indoor and controlled indoor, is responsible for 29% of the campus electricity use (see figure below). Lighting retrofits are one of the easiest tasks that the campus can take advantage of to save money and reduce greenhouse gas emissions. Currently, all purchased electricity accounts for 65,000 tons of CO_2e emissions a year. Note that when doing a life-cycle analysis approach, this number increases to 110,000 tons of CO_2e. In order to reduce the university's greenhouse gas emissions, campus wide lighting retrofits including the conversion from T12 to T8 or T5 lamps, Integrated Classroom Lighting System (ICLS), bi-level stairwell fixtures, and automated light controls should be considered.



3.1.1.2 Problem Statement

The potential for lighting retrofits is great on the UCB campus. Many buildings on campus still use T12 lamps with magnetic ballasts, which are highly inefficient. Additionally, many buildings lack proper lighting controls to switch lights off when not in use. Consequently, a large amount of energy is wasted on unnecessary and inefficient illumination. Retrofits with improved technology are cost effective approaches to addressing this problem.

The campus is currently conducting a limited number of retrofits with help from the PG&E partnership. However, these projects could be accelerated and expanded to predictably achieve significant monetary savings and emissions reductions in the near future. The partnership funding will allow us to retrofit 20 buildings by 2008. This number accounts for less than five percent of the buildings on campus. A shift in paradigm is needed from the administration which incorporates retrofits and energy efficiency projects as part of a comprehensive building management plan. Additionally, this process needs to be continuous to keep up with technological advances.

3.1.1.3 Research/Current Situation

Below is a list of some of the key lighting retrofits that can be done on campus:

T8 Fluorescent lamps

Lighting systems are responsible for 35% of electricity costs in a typical commercial building. Until recently, T12 fluorescent lamps with magnetic ballasts were most often used for both general ambient and specific task lighting. Fluorescent lamps consist of a glass tube that contains a gas made of argon and mercury vapor with electrodes on either end. Electrons flow at high voltage through the ionized gas from one electrode to another. The collision of electrons with mercury atoms causes them to give off UV photons, which hit a phosphor coating inside the fluorescent tube, creating visible light photons. Steady improvements in ballast and lamp technologies have improved the efficiency of this process over time. T8 lamps and electronic ballasts provide the same levels of illumination much more efficiently.

The conversion from T12 to T8 results in higher efficacy (fewer watts/lumen) and has other benefits. T8s last longer which requires less maintenance over the useful life of the lamp as well as less waste in local landfills. Since their light quality is better, fewer fixtures/square foot are needed. Furthermore, fewer watts/fixture along with fewer fixtures/square foot results in lower cooling loads which reduces cooling costs as well. Typically, lighting retrofits can pay themselves off in a short period of time and are low-risk investments.

Super T8 Lamp Systems

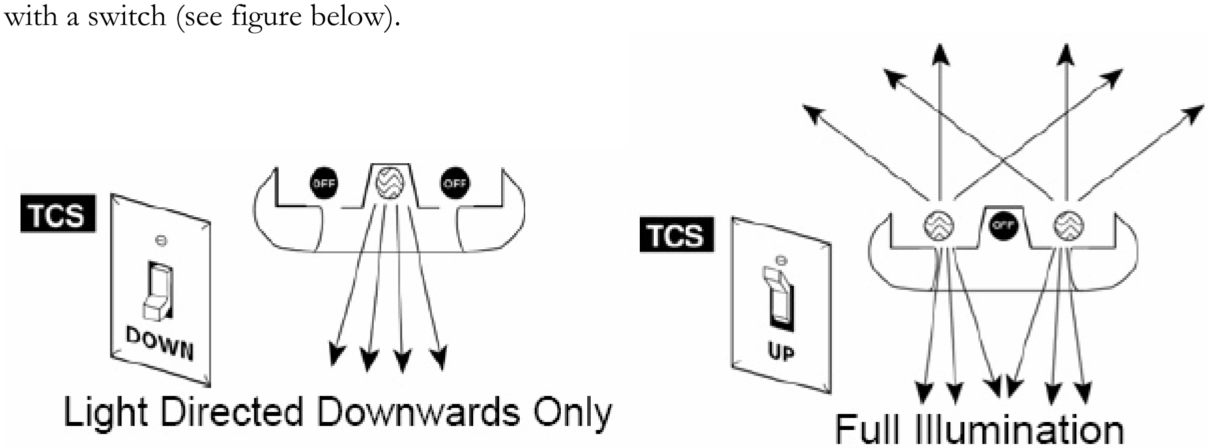
In addition to changing lamps from T12 to T8, a more efficient route to take is to install super T8 lamps instead of the standard T8s. Super T8 and reduced-power ballasts decrease energy use by 15-20%. A typical two-lamp fixture, the super T8 saves approximately 37kWh/year and for a four-lamp fixture the system saves 66kWh/year [assumes 3,650 hours/year operation based on daily lighting energy use in offices of 10 hours].

Integrated Classroom Lighting System (ICLS)

This lighting system is well suited for classrooms and can result in energy savings as high as 60%. The ICLS is a high-performance lighting system with automated sensors and controls for classrooms and training facilities.

It uses 3100 lumen T8 lamps with 1.18 BF (ballast factor) IS electronic ballasts. A typical system, which includes two rows of lamps (14 ft. long), can light a 32ft. wide classroom. An example of this can be seen in Wheeler Hall. The current ASHRAE 90.1 standard for classroom lighting is 1.6W/ ft^2, however the ICLS keeps power to 0.95W/ ft^2.

The lamps are oriented perpendicular to the chalkboard or the front of the room in order to minimize glare and eyestrain for teachers and students. The system also keeps faces lit along with vertical wall surfaces. Another advantage to the ICLS is its application in different situations like viewing audio/video presentations. The system can be equipped with an A/V mode (control on the wall switch), which gets rid of veiling reflections for better presentation lighting. A/V mode uses 1 lamp which reduces reflections off walls and general mode uses all three lamps but can me dimmed with a switch (see figure below).



Note: TCS is Teacher Control Switch.

Bi-level Stairwell Fixtures
Lights in stairwells are usually lit 24 hours per day even if they are not occupied. Most buildings on campus have T12 or T8 fixtures which can result in a significant amount of electricity that is wasted. Systems such as the bi-level stairwell fixture can reduce the amount of energy used by 50 to 80 percent. The fixtures have ultra-sonic motion sensors which can dim the lamps to as little as eight watts using a one-light 25W T8 fixture. Bi-level fixtures can be stepped-down to 5, 10 or 33 percent of full light output. For instance, two 4ft. T8s with step down to 10 percent reduces power from 62 Watts at full power to 13 Watts at standby. The full and standby light levels provide the proper amount of light based on local and national codes.

The Public Interest Energy Research (PIER) project has done a study with these fixtures in Evans Hall on campus. Their results showed that the stairwells in the building were occupied 32 percent of the time and on standby for 68 percent of the time. By using these fixtures they were able to save 63 percent on electricity usage.

Automated light controls: Adura Tech
Lighting switches in buildings are usually inadequate and inflexible which can result in significant energy waste. Switches are often located in inconvenient spots and do not necessarily work with daylight patterns. Most buildings lack adequate light controls, but this system offers wireless controls which can reduce a building's electricity bill by 40%. Charlie Huizenga, who is a researcher at the Center for Built Environment (CBE) in the Department of Architecture at UCB, helped to develop and commercialize this technology.

This system takes advantage of a mote, which is a microprocessor that is attached to the ballast of the lighting fixture. A light and motion sensor is placed near a desk which can send signals to the mote. The mote can also relay information between remote locations without additional wiring. Additionally a wireless control can be used to turn the lights on and off manually. The whole system is tied together by software which can be managed through the internet. The installation process is also simple as it requires no tools and takes about five minutes per fixture.

This system has been installed in Moffitt Library and has resulted in a 45 MWh/year savings with a two year payback. The system will be installed in the North Reading Room of Doe Library where similar savings are projected with a nine month payback.

3.1.1.4 Solution and Proposal
Electricity consumption on campus is mostly attributed to indoor lighting and HVAC systems. In order to reduce the impact of lights inside buildings, several lighting retrofits can be done. The retrofits include conversion from T12 to T8 or T5 lamps, changing classrooms lighting to the ICLS, installing bi-level stairwell fixtures and automated light controls. Lighting retrofits are attractive projects because they usually feature extremely predictable and reliable savings and have short payback periods that range from a few months to five years.

The Energy Efficiency Partnership with PG&E and the university can help fund these projects. Under the partnership, PG&E will pay $0.24/kWh saved for electric retrofits and $0.08/therm for heat and natural gas retrofits. The first step to achieve this funding is to commission all of the buildings on campus in order to realize potential problems and projects. Currently, the plant facilities are conducting some of these retrofits and have a goal to get these projects completed by the end of 2008. Due to the limited personnel in the facilities department, these projects are not being implemented as fast as they can be. To achieve significant savings on the campus energy bill, a greater focus is needed on retrofits and commissioning in the near future. Furthermore, there is an even greater potential to undertake new projects during the next phase of the partnership (2009-2014) due to the availability of more funds.

3.1.1.5 Impact and Significance

ICLS

Simple calculation of savings from the ICLS in Wheeler Hall

	Current Lighting System	ICLS
Input Watts/Room	1440	800
Hours of Operation/Year	2550	2550
Energy Consumption/Year (kWh)	3672	2040
Energy Savings/Year		**1632**
Utility Cost/kWh	$0.10	$0.10
Energy Savings/Year ($)		$163.20
Number of classrooms retrofitted	30	30
Total Energy Savings/Year ($)		**$4,896.00**
Carbon Emissions (g/kWh)	301	301
Carbon Emissions per room (t/Year)	1.11	0.61
Carbon Emissions Saved (t/Year)		**0.49**

Assumptions:

- Input Watts/Room
    - Existing: Assume each room has T12 fixtures where each fixture uses 120W
    - ICLS: Assume a 45% reduction in wattage from T12
- Hours of Operation – obtained from plant manager

The chart below shows the energy, dollar and emissions savings that can be achieved per year by switching to the ICLS system in 15 buildings on campus.

Building	kWh (from 2005)	% Classrooms	kWh in Classrooms	kWh in Classrooms Saved	$ Saved	CO2te Saved
Koshland	9,555,661	20	1911132	1051123	105112	316
McCone	6,499,351	30	1949805	1072393	107239	323
Hildebrand	5,674,532	30	1702360	936298	93630	282
Barker	3,661,973	30	1098592	604226	60423	182
Cory	8,540,422	30	2562127	1409170	140917	424
LSA	8,317,660	20	1663532	914943	91494	275
Soda	4,398,062	30	1319419	725680	72568	218
Tan	3,844,407	30	1153322	634327	63433	191
VLSB	11,764,563	20	2352913	1294102	129410	390
Latimer	6,030,561	30	1809168	995043	99504	300
Evans	3,650,178	30	1095053	602279	60228	181
Barrows	1,839,584	30	551875	303531	30353	91
Tolman	1,848,285	40	739314	406623	40662	122
Kroeber	839,654	20	167931	92362	9236	28
Etcheverry	4,374,402	30	1312321	721776	72178	217
Total	**80,839,295**		21,388,863	**11,763,875**	**$1,176,387**	**3541**

Assumption:

- The amount of classrooms per building was roughly estimated.
- 0.301kg CO_2/kWh
- Energy use of lights is roughly the same percentage of the total in every building. Note that this may not be true for some of the lab buildings featured and would cause these estimates to be revised lower.

Bi-Level Stairwell Fixtures calculations.

Energy Use Comparison Between Retrofits (Evans Hall)

	Percent Full	Percent Standby	Number of Fixtures	Watts Full (W)	Watts Standby (W)	Energy Use (kWh/yr)	Energy Savings (kWh/yr)	Energy Savings (%)
No Retrofit	100%	0%	23	80	n/a	16,120	--	0%
Standard Retrofit (T12-T8)	100%	0%	23	64	n/a	12,890	3230	20%
Bi-Level Retrofit	32%	68%	23	64	13	5,910	**10210**	**63%**

Source: www.energy.ca.gov/pier

3.1.2 Campus Steam System

The campus steam system provides space and process heat to most building on campus through a system that contains miles of underground steam pipes. Perhaps because it is largely invisible or because it still delivers heat even when parts of it are damaged, leaky, or otherwise operating inefficiently, it has accumulated a large amount of deferred maintenance over the years. Recently, partnership money has been available to subsidize upgrades to the system that improve operating efficiency. The program to find and replace malfunctioning steam traps is a good example of putting partnership money to use in the steam system and suggests that efficiency and retrofit programs have a high likelihood of attracting new funding to perform deferred maintenance while lowering campus emissions and saving energy and money in the process.

3.1.2.1 Summary

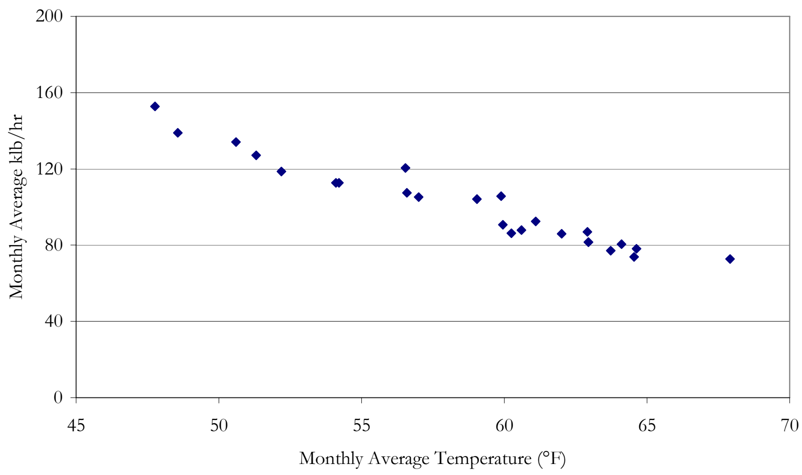
About 40% of the Berkeley Campus' CO_2 emissions are from the generation of steam for use in campus buildings, according to the CalCAP report. Steam is generated in a cogeneration facility that also produces electricity. Because they focus on the energy content of the steam without accounting for its origin as waste heat from electricity generation, the accounting methods overestimate CO_2 emissions from cogeneration. However, steam demand is often high enough to require the use of auxiliary systems that do not produce electricity. Even when these accounting issues are corrected, steam generation is still responsible for a significant portion of campus emissions. Maintenance of the steam system, such as a current program to replace broken steam traps and a potential project to fix leaking heat exchangers will help reduce system demand due to waste, but there is likely more that can be done. Analysis of monthly steam usage compared to temperature shows that the campus uses a great deal of steam even in the warm summer months when heating loads are low, indicating that better regulation of steam may go a long way towards improving efficiency. Looking towards the future, carbon emissions attributable to the steam system will remain until the university can end its use of natural gas for steam production by implementing fuel alternatives such as landfill gas or sewage-derived bio-fuel and by supplementing heating supply with solar water heaters.

3.1.2.2 Problem Statement

UC-Berkeley is responsible for the CO_2 emissions from natural gas combusted to produce steam. Since electricity is produced along with steam through cogeneration, assigning numbers to the amount of CO_2 released by steam production is not an exact science. The CalCAP Report credits 38.8% of the UC-Berkeley CO_2 emissions to steam generation, but this number is misleadingly high. The CalCAP calculations were done according to the California Climate Action Registry's General Reporting Protocol, which requires that the "'share' of the total emissions is a result of electricity and heat by using a ratio based on the Btu content of heat and/or electricity relative to the cogeneration plant's total output."[56] The downside of this reporting method is that it ignores the fact that much of the heat used to make the steam would otherwise be wasted if electricity was generated without cogeneration. Because of this, the generated electricity is credited with a smaller amount of greenhouse gas emissions than if it were produced without cogeneration. Unfortunately, UC Berkeley does not realize the CO_2 savings associated with the cogenerated electricity, as the electricity is sold by Delta Power to PG&E. As a result of this reporting requirement, efficiently cogenerated steam is credited with generating more kg CO_2/Btu of steam than steam produced in the less efficient auxiliary boiler system.

Analysis of monthly steam usage as seen in Figure Steam1 shows that even in warm summer months, the campus often requires steam in excess of the cogeneration plant's most efficient operating point of 80,000 lb/hr. Ideally, the campus would efficiently utilize exactly as much steam as the cogeneration plant produces when generating electricity. In practice, this is not the case. When demand surpasses this amount, the auxiliary systems must burn more gas to create extra steam, creating additional carbon dioxide emissions without the accompanying efficient generation of electricity from cogeneration. In summer months, the campus can require as low as 50,000 lb/hr[57], but even in these summer months when average outdoor temperatures are over 60° F, analysis of auxiliary steam generation data shows that demand sometimes requires that the auxiliary systems be used. Some projects are underway to reduce demand to promote overall efficiency, but the amount of steam used even in the summer indicates that there is likely still much room for improvement.

Figure Steam1: Dependence of Campus Steam Demand on Temperature, 2004-2005



[56] California Climate Action Registry: General Reporting Protocol, Version 2.2, March 2007: 48 http://www.climateregistry.org/docs/PROTOCOLS/GRP%20V2-March2007_web.pdf

[57] Communication with UC-Berkeley steam engineer Wayne Jin, 11/27/07

No matter how efficiently natural gas is utilized, it is still a non-renewable resource with a detrimental net contribution to the greenhouse effect. For lack of better alternatives, natural gas use will continue in the short term. In the long term, however, it behooves UC Berkeley to consider a replacement to fossil fuel combustion as the main source of the University's building energy.

3.1.2.3 Research/Current Situation

Overview of generation and usage of steam on campus

Steam is generated by burning natural gas in a process called cogeneration that also produces electricity. The natural gas runs a General Electric LM2500 gas turbine that generates electricity, and the hot turbine exhaust gas heats water to create steam. This steam then runs through a steam turbine generator that generates extra electricity as steam pressure is decreased from 600 psi to the campus distribution pressure of 125 psi. Under the normal condition, electricity generating operational mode, the turbine exhaust can create 80,000 lb/hr of steam. If this is insufficient, auxiliary duct burners make more steam by burning additional gas. These burners can produce an additional 90,000 lb/hr. The plant itself requires 20,000 lb/hr to control NO_x emissions and 12,000 lb/hr to run auxiliary equipment, so the combined steam capacity of the cogeneration process and the duct burners is approximately 140,000 lb/hr. Peak campus demand exceeds 200,000 lb/hr, so auxiliary boilers that do not generate any electricity satisfy steam demand in excess of 140,000 lb/hr. The boilers must be ready to produce steam as soon as demand exceeds 140,000 lb/hr, so they are warmed up when demand approaches the 140,000 lb/hr threshold, burning natural gas without generating any steam that the campus uses. When campus steam demand is less than 80,000 lb/hr, the gas turbine is throttled back, reducing production of electricity and steam.

Steam flows through underground pipes at 125 psi where valves called steam traps regulate the flow of steam so that it is used when needed. The main use of steam on campus is heating. In some buildings, steam is utilized directly in steam radiators or steam coils to heat air and in heat exchangers to heat domestic hot water. In newer buildings, steam is run through heat exchangers to heat a separate loop of water which is then used to heat domestic hot water and to warm air. In a few buildings, including newly renovated Stanley Hall, an absorption chiller uses the steam energy to cool the building's air. In a lower capacity, steam also powers autoclaves, sterilizers, cage washers, laundry, cooking, dishwashing, and humidification on campus. A central source for campus energy eliminates the need to have staff maintain boilers in each building.

Investigation of CalCAP numbers for carbon impact of steam

Further investigation of the numbers going into the CalCAP calculation of the carbon impact of steam gives insight into how the actual carbon impact of cogenerated steam may be lower than reported.

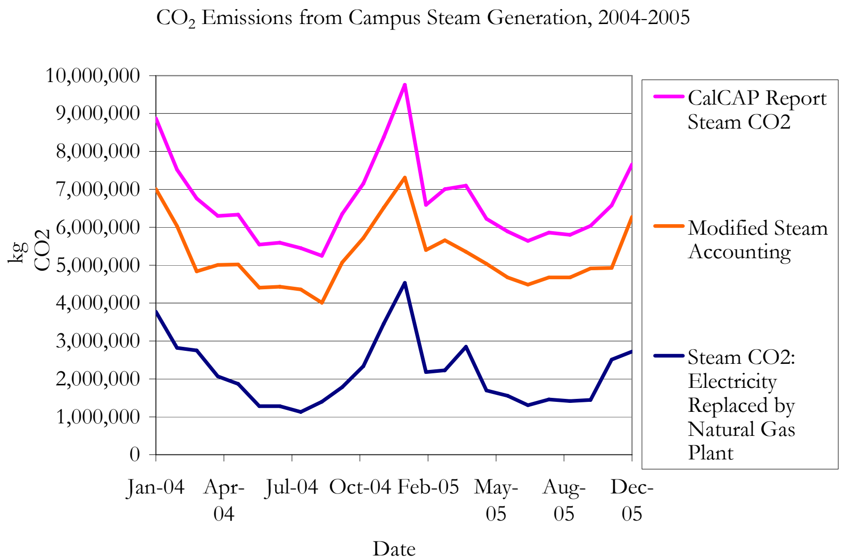
An alternate way to consider the steam's share of emissions is to look at the overall CO_2 emissions of the cogeneration plant and auxiliary steam system and then subtract the amount of CO_2 that would have been produced if an equivalent quantity of electricity was generated by a standard natural gas power plant, which generates 2.497 kg CO_2/kWh of electricity.[58] In 2004 and 2005 combined, 270,130,000 kg CO_2 were released by burning natural gas to generate 423,068,459 kWh of electricity and all of the campus' steam needs. Applying the EPA emission factor for electricity generated by natural gas reveals that 218,265,000 kg CO_2 would have been released to generate this electricity in a regular natural gas plant, meaning that only 51,865,000 additional kg CO_2 were

[58] http://www.epa.gov/solar/natgas.htm

released due to steam generation. Since CalCAP attributes 159,640,000 kg CO_2 to steam generation during this period, this change of calculation methods changes steam's share of total campus emissions from 38.8% to 17.1%.

The previous calculation method assumes that the electricity produced through cogeneration can only be replaced by natural gas electricity generation and does not fall within the guidelines required by the California Climate Action Registry's General Reporting Protocol. Steam's share of cogeneration CO_2 emissions can be reduced from CalCAP while staying within the protocol, however. When calculating the share of energy going towards the university's steam, the CalCAP report does not consider that 32,000 lb/hr of steam created through cogeneration go towards running plant equipment and pollution controls. Additionally, the report counts the steam enthalpy without considering the initial enthalpy of the water in the steam system. Assuming that water comes in at ambient outdoor temperatures and taking the campus steam energy share as a fraction of the electricity, campus steam, and the steam used in the plant suggests that 125,804,000 kg CO_2 were created from 2004 to 2005 for steam generation. This change of calculation methods from CalCAP changes steam's share of total campus emissions from 38.8% to 33.3% of overall campus emissions. The CO_2 attributable to steam from the previous two reporting methods and the CalCAP report can be seen in Figure Steam2.

Figure Steam2: CO_2 Emissions from Campus Steam Generation, 2004-2005



Steam Demand Reduction

A project is currently underway to reduce steam demand by replacing steam traps. Of the 1284 traps tested, 111 were found to be faulty and are currently being replaced. Energy will be saved by replacing 47 traps that were found to be stuck in the "open position" such that they allowed a constant flow of steam even when unneeded. Completion of this replacement project is scheduled for the end of 2007. The total estimated project cost is $342,000 with an estimated annual energy savings of $56,000. This project, with a simple payback of 6 years, projects to reduce greenhouse gases by 632 metric tons CO_2/yr.[59]

The steam trap survey also revealed that heat exchangers in University Hall, Tolman Hall, and Cesar Chavez Student Center have leaks that allow water from the closed heating loop to mix with the steam condensate. This water contaminates the steam condensate, rendering it unfit for return to the cogeneration facility. Though the heat exchangers still function, there are several sources of waste associated with this problem. First of all, there is the need to replace the water in both the closed heating loops and in the steam loop with city water. The replacement water in the steam system must be filtered to remove suspended solids and also chemically treated to remove hardness before it can be used in the steam system. City water does not enter at as high a temperature as return condensate from the steam system, so more natural gas must be burned to heat 50° F water into steam than would be necessary if the 120° F condensate was returned from the heat exchanger. Delta Power factors the water shortage into the amount of steam that it bills the university. Currently, these losses are simply accepted because a feasibility study has not been conducted to determine the cost-effectiveness of repairing the heat exchangers.

Comparison of steam demand data in summer and winter shows potential to decrease steam usage by improving the control of steam use in the buildings. Summer usage should be lower than in winter, but as Figure Steam 1 showed, the campus still requires a large amount of steam even in warmer months. Live data from Soda Hall, a building primarily consisting of computer labs, offices, and classrooms, shows that winter steam usage was actually lower than summer usage. The building

[59] Communication with Raul Abesamis, Physical Plant Campus Services, UC-Berkeley 12/6/07

does not utilize absorption chilling, so it is likely that usage is driven by some system problem instead of actual demand. Live data from Tan Hall indicates that steam use never drops below a plateau of about 2300 lb/hr. Though it is possible that there are times that the building requires less than 2300 lb/hr of steam energy, for some reason the building uses this much at all times. If control can be restored in these and other buildings with similar issues, then it is likely that significant savings will be realized.

Figure Steam3: Comparison of Soda Hall Steam Usage, February and July 2007[60]

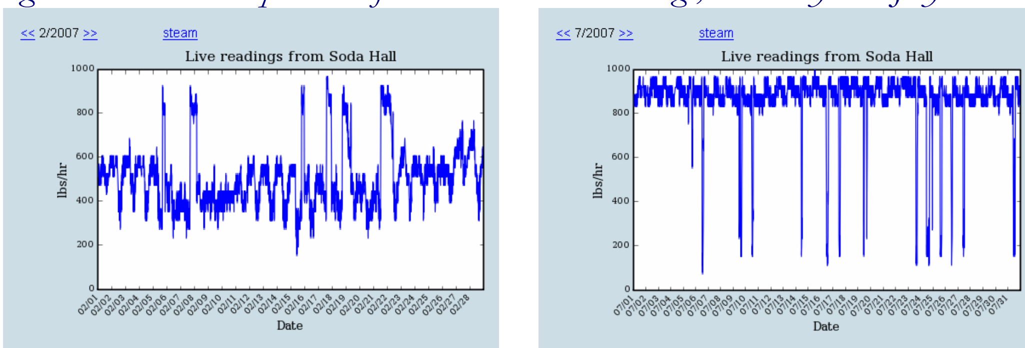
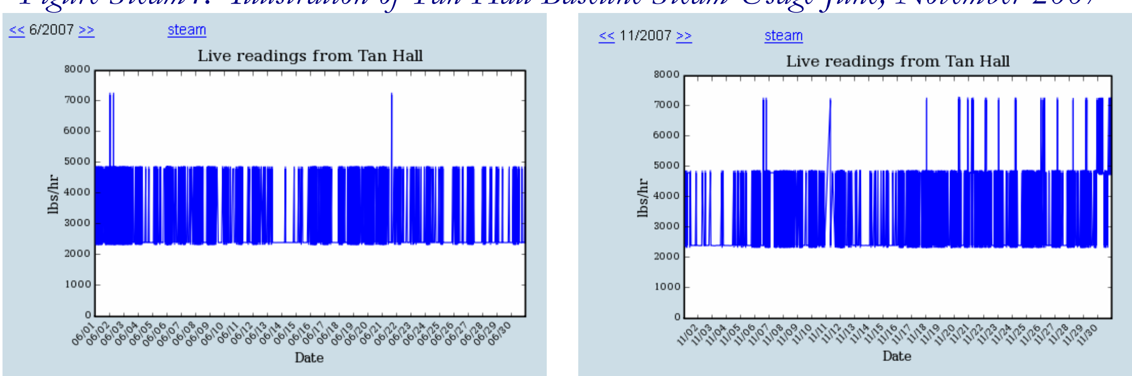


Figure Steam4: Illustration of Tan Hall Baseline Steam Usage June, November 2007[61]



Renewable Technology in the Steam System

As technology improves, options will arise that may allow the university to eventually shift away from using natural gas for all of its cogeneration needs. This past August, The University of New Hampshire implemented a project called EcoLine, which will use locally collected landfill gas in its on-campus cogeneration power plant that currently runs on natural gas. The gas will be collected 12.7 miles away at a facility in Rochester, N.H., where it will be purified into methane and pumped through an underground pipeline to the university. Officials speculate that the landfill gas will replace 80 to 85% of the natural gas currently used on the campus. The project, which costs $45 million upfront, should pay for itself in ten years due to natural gas savings. The project will reduce the school's net greenhouse gas emissions by 67% below 2005 levels and 57% below 1990 levels.[62] The project will benefit the school in the long term, as it will pay for itself in just ten years while

60 http://www.demandless.org/building/
61 http://www.demandless.org/building/
62 Geiselman, Bruce. "It's a gas; N.H. university to launch major LFG project." Waste News 20 Aug. 2007. Retrieved from LexisNexis Academic.

reducing the campus' net greenhouse gas emissions and shielding the campus from increases in natural gas prices.

If there is not a suitable landfill near campus for Berkeley to use, there are other options. First, as bio-fuel technology improves, Berkeley could explore the processing of sewage from campus restrooms and food waste from campus dining to generate gas to run the cogeneration facility. Other options, such as solar water heaters on building roofs, could help to reduce campus steam demand in a renewable, carbon neutral way. Though they have the potential to decrease demand, solar heaters cannot be relied upon to replace the steam generation system, as their output will be limited on cloudy, cold days when heating is needed most.

3.1.2.4 Solution and Proposal

Efforts should continue to reduce waste and improve efficiency in the steam system so that steam demand will not require the use of the auxiliary burner system. The steam trap project will be completed soon, but the traps should not be forgotten. The system is old, and audits should be done regularly on the system to ensure that when valves fail, they do not stay broken for long. Steam and condensate pipes, heat exchangers, and steam traps must all be maintained to minimize inefficiencies that inflate steam demand. Appendix 6.5.2 contains an example of how a feasibility study should be conducted to determine the payback period associated with repair of the leaky heat exchangers in University Hall, Tolman Hall, and Cesar Chavez Center that dump contaminated condensate down the drain instead of returning it to the cogeneration facility. Repair of system equipment will help to reduce steam usage, but additional effort should go towards investigating how steam is used in buildings. The case of Soda Hall shows that demand is not necessarily always driven by need and that proper controls may reduce steam use at certain times. Modifications such as simply changing hot water heater and heat exchanger settings will cut some waste out of the demand. Analysis of building steam use should be done so that they can be set to only use steam when its energy is actually needed.

3.1.2.5 Impact and Significance

This analysis does not include many specific calculations regarding the carbon impact of changes to the steam system, but the general idea is that efforts should be made to maintain the system at the cogeneration plant's capacity so that maximum overall energy efficiency can be achieved. The steam trap replacement project shows projects to pay back in six years. Assuming that these steam trap repairs last six years or more means that the cost per ton of carbon saved is zero. The main cost of modifying building controls to reduce baseline usage and to ensure that demand is driven by need may lie in commissioning costs, but as section 3.1.3 will show, commissioning can be both beneficial and cost effective. Reduction of the CalCAP accounting numbers for steam emissions will cause actual reductions in steam consumptions to count for a smaller but more accurate share of total campus emissions.

3.1.2.6 Recommendations

Though steam generation may not actually represent as large of a fraction of the campus' emissions as appears in the CalCAP report, measures to cut system waste and efficiently utilize steam will go a long way towards reducing the overall campus CO_2 emissions profile. As the campus expands throughout the next century, the future adequacy and optimality of the current cogeneration system should be considered. When steam demand continues to consistently exceed the optimal 80,000 lb/hr that the gas turbine produces, it may be worthwhile to consider adding cogeneration capacity so that electricity can be generated along with the steam. Though this may prove to be an environmentally friendly option, the CO_2 accounting problems associated with cogenerated steam that were mentioned earlier could cause such an investment to look worse for the campus CO_2 goals than simply using the auxiliary boilers to produce steam. Renewable fuels should be a focus of future analysis of the steam system. Investments in technologies such as landfill gas recovery, sewage gas recovery, and solar water heating will help the university achieve a truly sustainable future.

3.1.3 Fumehoods

Because UC Berkeley has robust programs in research science, there are many lab buildings on campus. With some lab buildings using over $1M a year in energy, they dominate the list of campus energy hogs. While there are many types and pieces of lab equipment with high energy use, fume hoods stand out as the most common and obvious targets for energy savings. Their fans directly use large amounts of electricity, and the process of conditioning and circulating the air that replaces what they exhaust uses even more energy from both electricity and natural gas. The replacement of hoods that always operate at full speed with variable speed hoods is likely to save 50% of their energy use. Examination and elimination of over ventilation could save even more energy on top of that.

3.1.3.1 Summary

Lab buildings are the largest consumers of energy on campus, using on the order of 5-6 times more energy per square foot than standard buildings. On UCB campus labs contribute as much as 43% of entire campus electricity use of over 200 million kilowatts a year. The main reasons for such high consumption are labs (HVAC) systems and their ability to support energy intensive lab equipment. In labs like VLSB they are still running on the same standards from its remodel in 1995. In order to realize energy savings for campus labs two things must happen for existing and future buildings. Commissioning must become a binding standard with the implementation of new and retrofit systems to create greater overall efficiency in labs.

3.1.3.2 Problem Statement

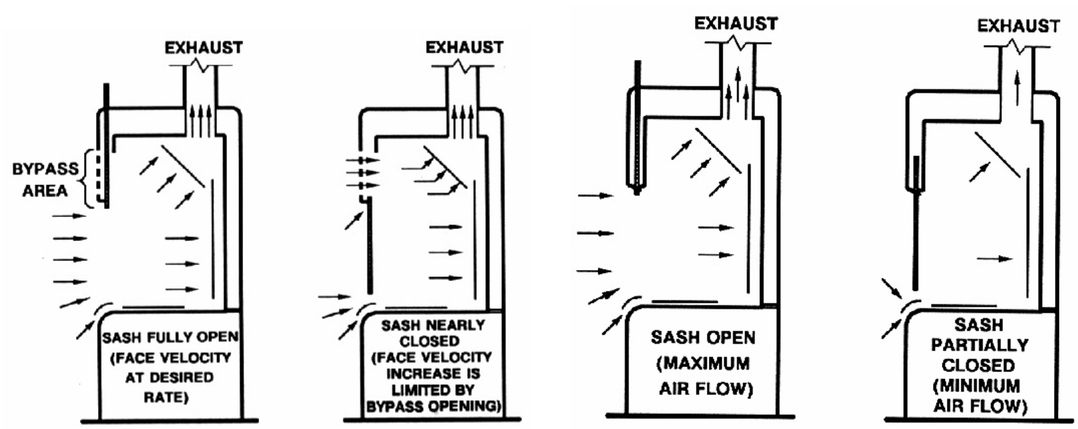
Fume hoods play an integral role in lab heating, ventilation, air conditioning, cooling (HVAC) systems, each hood using as much energy as 3.5 homes. In a lab like VLSB with 78 fume hoods, that is the same energy consumed by a small neighborhood. The reason for such high energy demand from fume hoods is their high exhaust rates as they contain and draw out harmful vapors from lab environments to preserve user health.

To maintain healthy conditions labs require Air Change Rates (ACR) of 6-20 times an hour. One room Air Change is when the total volume of a room has been exhausted and replaced. Fume hoods air flow rates multiplied by the cross sectional area of their intake determine the number of air changes per hour. Consequently, the energy used by hoods can be moderated by either reducing their air flow rates or decreasing the area of their intakes (or both).

California air flow standards are set at 100 ft/min (fpm). Although, the actual flow rates of campus hoods are seldom measured, hoods in UCB labs are set from 100-200 fpm, which is much higher than necessary. This phenomenon is called over ventilation and it should be possible to work with EH&S to reduce air flow rates with no impact on safety.

So called Variable Air Volume (VAV) hoods have sashes that can be pulled down to reduce the cross sectional area of hood intakes when they are not in use. Because they can maintain steady air flow rates, the volume of air exhausted by VAV hoods can be substantially lower than their fixed counterparts. A new (non-commercial) fume hood technology developed by LBNL has been measured at 75% savings over older models. With a more efficient design they use only 60 fpm without compromising user health. Because they are directly connected to (HVAC), if fume hoods are working at higher rates, the entire system is using greater amounts of energy. By implementing VAV technologies in new buildings and replacing existing fume hoods in older labs we can tap a great potential for energy savings and emissions reduction.

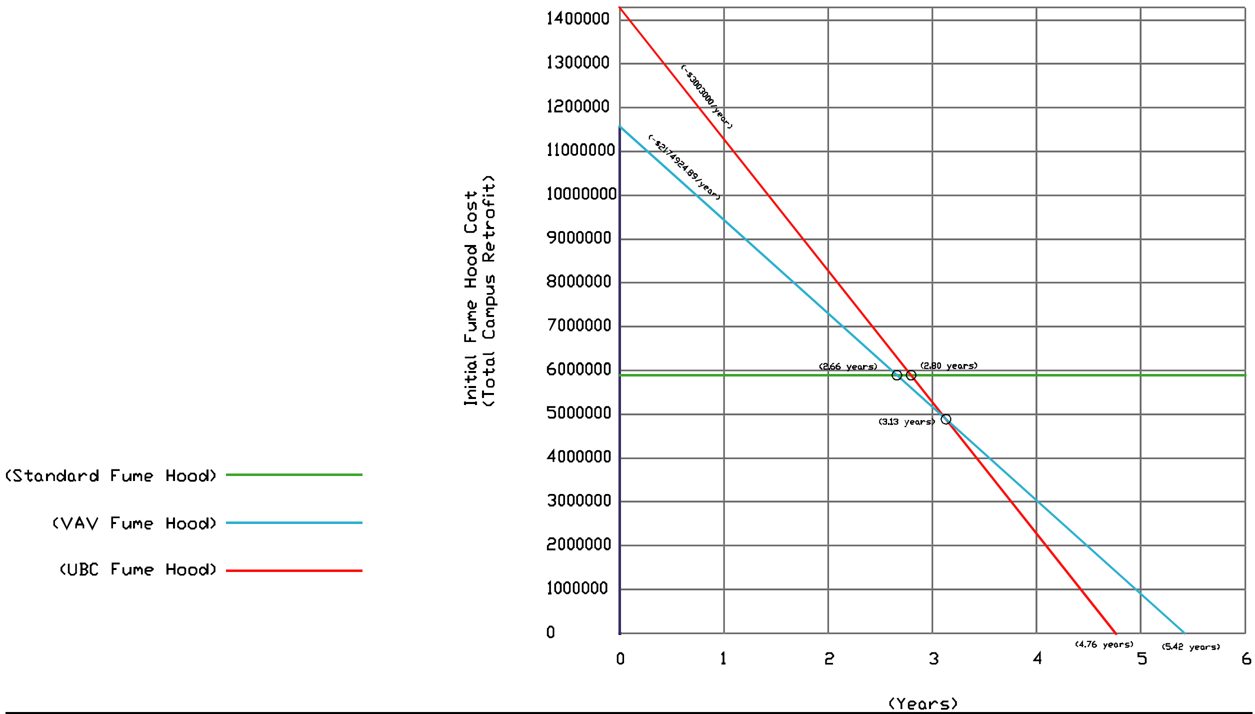
Using VAV to replace older Constant Air Volume (CAV) fume hoods systems creates greater energy savings. With (VAV) fume hood air is regulated by how much the sash is open while (CAV) models pull in the same open or shut. Currently only two labs Tan and Stanley Halls are using VAV systems. As a comparison two chemistry labs Tan Hall uses 33.77 kilowatt/sq.ft while Koshland Hall uses 62.17 kilowatt/sq.ft. With a savings of almost 50% it is crucial we make these systems a standard in every lab building.



(CAV) Fume Hood Models **(VAV) Fume Hood Models)**

In most cases lab (HVAC) system are oversized. Ventilation alone is 44% of a typical lab's energy use but it also effects cooling systems, which comprise 22% of energy use in lab environments. By making commissioning a priority we can begin replacing older fume hoods with more efficient models and using this as a basis for right sizing new labs with smaller more efficient (HVAC) systems.

3.1.3.3 Project Calculations



Calculations:

Total Annual Lab Kilowatt Usage- 207,649,510 kilowatts (.43)= 89,289,289 kWh

Total Campus Annual Lab Energy Cost- 89,289,289 (.08)= $7,143,143

(Standard) Single Annual Fume Hood Usage 29,326 kWh and 223 MMBtu

(VAV) Single Annual Fume Hood Usage- 14,663 kWh and 112 MMBtu

Annual CAV Operation Cost- 29,326 kWh ($0.08) + 112 MMBtu ($10)= $4,576

Annual VAV Operation Cost- $4,576 (0.5) = $2,288 (with a $2,288 energy savings per year)

# of Campus Fume Hoods- 1300 Fume Hoods

Total Annual Operating Cost for Campus Fume Hoods- 1300 ($4,576)= $5,948,904

Potential Annual Savings from 100% replacement with VAV - $5,948,904 (0.5) = $2,974,452

(CAV) Total Estimated Campus Fume Hood Energy Usage = 38,123,800 kWh and 289,900 MMBtu

(VAV) Total Energy (50% reduction) = 19,061,900 kWh and 44,950 MMBtu

(Berkeley Hood) Total Energy (75% reduction) = 9,530,950 kWh and 72,475 MMBtu

(Standard)Fume Hood Cost (Total Campus Fume Hoods)- $4540 (1300)= $5,902,897

(VAV) Fume Hood Cost (# of Campus Hoods)- $9,081 (1300)= $11,805,794

(UCB) Fume Hood Cost unknown…

(VAV) Fume Hood Payback Period- $11,805,794 (first cost)/ ($2,974,452/year)= 4 years

UCB Lab CO2 Emissions

kg CO_2 / yr from electricity demand (per hood) = 8,827

kg CO_2 / yr from heat = 15,476

total kg CO_2/yr per hood = 24,303

total CO_2 per year from 1300 hoods = 31,594 tCO_2e

CalCAP official emissions from electricity = 65,000 tCO_2e

CalCAP official emissions from steam = 82,000 tCO_2e

% total steam emissions from hoods = 24.5%

% total electricity emissions from hoods = 17.7%

% total energy emission from hoods = 21.5%

Potential total energy emissions savings with VAV hoods = 10% or 15,000 tCO_2e/yr

3.1.3.4 Conclusions

Commissioning is an important part of a buildings life cycle. Buildings are constantly changing with the needs of users. With labs (HVAC) systems so heavily utilized, small adjustments over time can add up to big energy use changes. This makes it very important to have a regular lab building analysis in place to keep them working at their best. By implementing energy metering in every building we can become more aware and know when old systems need replacing and make commissioning for buildings a smoother process.

Labs at UCB contribute as much as 43% of overall campus energy usage as result of (HVAC) systems and their ability to maintain controlled in lab environments for users and equipment. Ventilation in itself is responsible for 44% of an entire labs energy use. Fume hoods work with this system and contribute 25% of the energy required to run (HVAC) and maintaining a healthy in lab environment for users. By using more efficient fume hood models UCB has the potential to save 19,061,900 kWh and 44,950 MMBtu a year while saving $2,974,452 and mitigating 15,000 tCO_2e. Until energy metering becomes a standard for every building however, these solutions for creating greater overall energy efficiency will be difficult to accurately measure and monitor.

3.1.4 Commissioning and Ongoing Maintenance

After a typical building is built, little attention is paid to the specifics of its energy consumption. The reasons for this can include a general lack of awareness of potential savings, a lack of available staff, inaccessible or low resolution data on building performance, or a lack of interest due the low price of energy. In many ways, UC Berkeley has been doing a better than typical job of staying on top of these issues. The university benefits from smart and dedicated staff, and since 2004 has been involved in a joint project called "the Partnership" that allocates utility funding (originating from the CPUC) and expertise to energy efficiency projects on UC and CSU campuses throughout the state. Partnership projects have generally come in on or under budget and have consistently beaten their energy savings estimates.[63] However, a variety of pressures have resulted in the accumulation of a great deal of deferred maintenance on campus and the steady erosion of facilities staff positions. The result is that we know that there are large building energy savings out there waiting to be discovered, and thanks to the Partnership program with PG&E, we now have a well documented track record of being able to predict and deliver them.

3.1.4.1 Summary

The operational energy use of building on campus account for a large share of campus greenhouse gas emissions (70% of the official UC Berkeley emissions inventory comes from building steam and electricity use alone). At the same time, energy costs run upwards of $26M a year, and consistently exceed budgeted amounts by $6M annually. Consequently, there exists a very large potential for GHG mitigation with a highly attractive ROI followed by ongoing payback in UC Berkeley's campus buildings. Energy efficiency and commissioning (Cx) projects to date have exceeded their aggressive savings and efficiency targets and have paid off over short time periods, but have been restricted to relatively few buildings due to budgetary and staffing constraints.

Given the CalCAP commitments to GHG emissions reductions, the scale of campus building energy use, the proven savings from existing projects (averaging well over 10% of building energy with simple paybacks averaging under 2.5 years[64]), and the approximately $30M of utility "Partnership" money predicted to be available to UC Berkeley between 2009 and 2014, it is time to scale up the energy and efficiency and commissioning projects on campus. Our goal should be to complete energy efficiency and commissioning work in *all* campus building by 2014. Several case studies we've looked at, particularly similar projects already completed at Texas A&M[65] and University of British Columbia[66], both of which averaged over 20% energy savings, indicate that this is indeed possible. All indicators are that the finances would be favorable without subsidies, and with partnership funding these projects will be dramatically cost effective with ongoing returns well after they have been paid off. Commissioning efforts alone stand to take a huge bite out of our annual energy bill, substantially contribute a large fraction (or possibly even all) of the emissions mitigation

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[63] Brown, K. 2006. "Enhanced O&M through Building Performance Monitoring and Benchmarking." Presented at the 2006 National Symposium on Market Transformation. Washington D.C.: ACEEE.

[64] Brown, K., J. Harris, and M. Anderson. 2006. "How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings" Proceedings of the 2006 ACEEE Summer Study of Energy Efficiency in Buildings. 3:27-40. Washington D.C.: American Council for an Energy-Efficient Economy. http://ciee.ucop.edu/mbcx/documents/MBCx_ACEEE_2006_revised_9jan07.pdf

[65] http://txspace.tamu.edu/handle/1969.1/5346

[66] http://www.ecotrek.ubc.ca/

promised by the CalCAP commitment, and substantially bolster UC Berkeley's sustainability credentials.

3.1.4.2 Problem Statement

According to the official UC Berkeley emissions inventory, buildings on campus (largely through steam and electricity consumption) account for over 70% of our GHG emissions. The campus budgets around $20M a year for energy, but winds up spending $26M. The difference is made up using discretionary funds that might be spent on academic programs or other initiatives that give back to the campus community. Buildings represent the single largest source of cost effective GHG mitigation opportunities on campus and are also a major drain on discretionary funding. Despite a promising round of initial projects, budgetary, staffing, and informational barriers have prevented a large scale commitment to building energy efficiency and commissioning from taking shape. However, there are many signs that the time is right to commit to more aggressive programs.

3.1.4.3 Research/Current Situation

Commissioning is a process that involves measuring building energy performance and tracking down and fixing sources of underperformance. These sources fall into roughly three separate categories and each category requires its own type of fix:

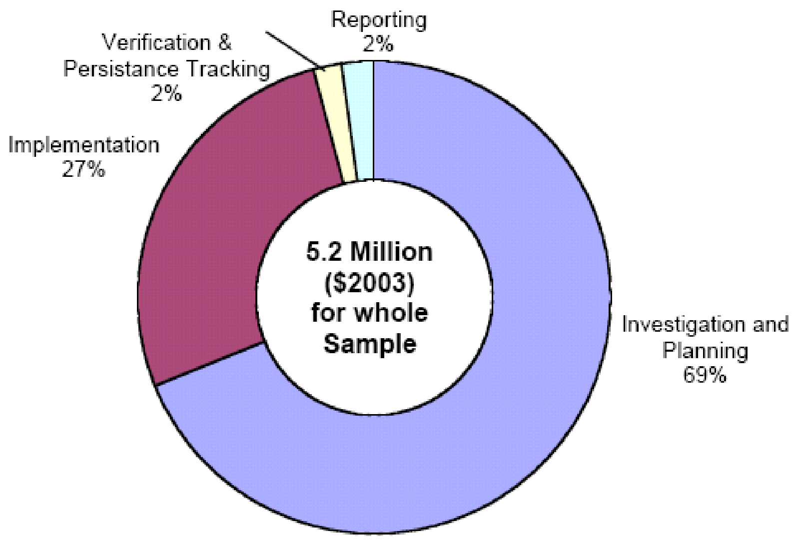
1. Improperly installed equipment is re-installed correctly
2. Broken or damaged equipment is replaced or repaired
3. Mis-configured equipment or control systems are re-configured or re-programmed

As should be clear, the actual actions required by commissioning are fairly simple and usually quite cost effective (1 and 3 involve no new purchases and only short term commitments of building engineering resources). It should also be clear that 1 will not repeat, but 2 and 3 will naturally recur over time as the equipment ages, and the building controls are overridden for special events, occupant complaints, or the convenience of building operators. This means that commissioning is not a one time event. A rule of thumb is that a commissioned building should be re-commissioned after approximately 4 years. For example, a LBL study on 8 commercial buildings retro-commissioned under a SMUD incentive program found that only 65% of the peak energy savings remained after 4 years[67].

Another key characteristic of commissioning is that it is quite labor intensive. As the figure below indicates graphically, the expertise, labor, and time required to diagnose building performance issues represent the vast majority of commissioning costs.

[67] Bourassa, N. J., Piette, M.A., Motegi, N. (2004). Evaluation of Retrocommissioning Persistence in Large Commercial Buildings. National Conference on Building Commissioning.

Fig 13. Commissioning Cost Allocation (Existing Buildings, N=55)



Source: Mills 2004

This simple fact has two simple and logical consequences:

1. Professional expertise and familiarity with the building can dramatically reduce the time and costs associated with commissioning
2. Although it is often still a good investment, it is always more expensive to pay outside contractors to commission buildings: because they take the knowledge of your building with them, you "lose" that part of your investment and you will always pay a premium on their labor rates compared to fulltime staff

While there may be other compelling reasons to contract out Cx work, it is important that such decisions are made with the knowledge that there are substantial economic and performance benefits from involving trained staff members who retain institutional knowledge about building systems and who cost less on an hourly basis in these efforts.

Case Studies

Studies of real world results show that properly commissioned new buildings (or retro-commissioned existing buildings) have substantial financial and energy savings. The examples of Texas A&M's continuous commissioning program on their campus and University of British Columbia's Ecotrek program are particularly compelling and relevant. The Texas A&M program includes high resolution monitoring data from 150 buildings integrated into a single data acquisition and control system and as the name implies, they are now able to continuously monitor their building for issues and to search for new savings opportunities. The continuous commissioning program is an outgrowth of the process developed by the Energy Systems Laboratory in their Mechanical Engineering department and continues to benefit from academic involvement. Their example suggests the potential academic benefits from developing such a program on the Berkeley campus.

UBC's Ecotrek is highlighted in another of our case studies, but the commissioning scope of their program is worth highlighting here as well. The whole program was executed under performance contracts and took two years to plan and three years to complete. In the process they updated or renewed the infrastructure in nearly 300 buildings comprising nearly 6.8 million square feet of building space. Their Building Management System (BMS) now automates approximately 90% of the academic campus. They have realized improved comfort for building occupants and managed to reduce core campus energy use by over 27%, and water use by 41%. It is also estimated to have reduced energy related GHG emissions by 27% from the 2002-2003 baseline. They expect the program to pay for its $39M price tag through projected savings of $4.2M a year.

The 5 year payback period for the UBC project is in part due to the fact that they pursued a comprehensive program that included a complete renewal of their steam system, some PV installation, a staff training program, a major modification of their central steam plant, and plumbing retrofits in 250 buildings, strict Cx work tends to have much more aggressive payback periods.

3.1.4.4 Academic Literature

A recent meta-study of commissioning in 224 buildings found a median payback time of 8.5 months, and an average energy savings of 18% for existing buildings[68]. At just under 5 years, median payback times for new buildings were longer, but still attractive. The study also showed that for certain types of buildings, like labs and university buildings, the payback and energy savings are often even higher. These are compelling numbers, and they have not even accounted for the additional economic savings from the fact that commissioned mechanical systems tend to last longer before wearing out and contribute to the improved comfort of building occupants.

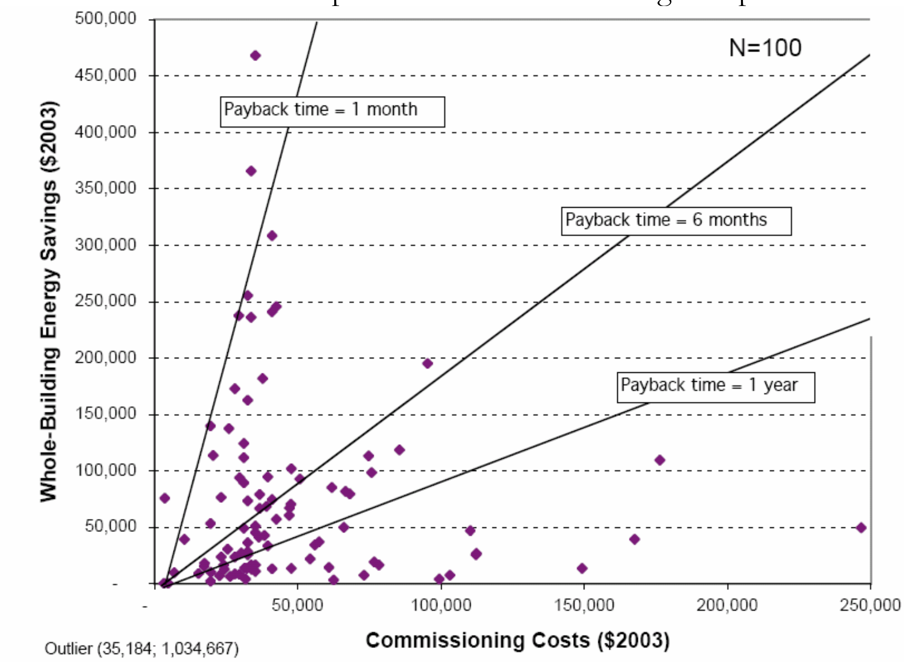


Figure: Existing building costs and savings. Source: Mills 2004

68 Mills, E., et. al (2004). The Cost-Effectiveness of Commercial-Buildings Commissioning, LBNL: 60.

Given such attractive attributes, one might expect that commissioning is a high priority among building owners and managers. Yet it is estimated that less that 5% of new building are commissioned, and less that 0.03% of existing buildings are commissioned each year[69].

In the building engineering and management world, it has long been known, at least anecdotally, that retro-Cx measures are highly cost-effective. After all, it is not uncommon to find ducts installed backwards or not properly sealed, control systems not hooked up or turned on, or any number of thousands of other little things that add up into big performance issues. Once identified, many of these issues are relatively quick and easy to resolve. However, the lack of industry standard data on the typical costs and benefits of retro-Cx coupled with confounding conditions like the assumption that any given building is working fairly well and is therefore not going to have major operational flaws, has created general uncertainty about the benefits of retro-Cx among key building decision makers. An American Council for an Energy Efficient Economy study specifically identified the following barriers to undertaking retro-Cx[70]:

- Lack of awareness of benefits of retro-Cx
- Difficulty in identifying qualified retro-Cx providers
- Perception that it is expensive and has a long payback
- Lack of confidence in anticipated results – "too good to be true"
- Misunderstanding of the types of building performance problems retro-Cx can address
- Internal accounting practices that do not return the savings to those who fund the improvements

What is interesting about this list is that most of the issues relate to the availability or accuracy of information and in principle are easily addressed. It suggests that efforts to provide trusted and accurate information about retro-Cx stand to resolve many of the doubts and uncertainties that sometimes prevent it from happening. A 2004 LBL evaluation of retro-Cx persistence found that payback estimates are generally accurate and even underestimated[71] and that actual paybacks are largely determined by the scope of the investigation of building performance and the list of fixes undertaken. Such information should help dispel misinformation and confusion about the outcome and payback of Cx work for building owners and managers and campus decision makers alike.

3.1.4.5 Our Own Experience

Karl Brown, Deputy Director of the CIEE (California Institute for Energy and the Environment), has been tracking the performance of Partnership campus efficiency projects throughout the UC and CSU system. He has published[72] several[73] studies[74] that document the savings achieved.

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69 PECI (1998). National Strategy for Building Commissioning, Portland Energy Conservation, Inc

70 Thorne, J., Nadel, Steven (2003). Retrocommissioning: Program Strategies to Capture Energy Savings in Existing Buildings. Washington D.C., ACEEE

71 Bourassa, N. J., Piette, M.A., Motegi, N. (2004). Evaluation of Retrocommissioning Persistence in Large Commercial Buildings. National Conference on Building Commissioning.

72 Brown, K., J. Harris, and M. Anderson. 2006. "How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings" Proceedings of the 2006 ACEEE Summer Study of Energy Efficiency in Buildings. 3:27-40. Washington D.C.: American Council for an Energy-Efficient Economy.

73 Brown, K., and M. Anderson. 2006. "Monitoring-Based Commissioning: Early Results from a Portfolio of University Campus Projects." Submitted for publication in Proceedings of the 13th National Conference on Building Commissioning. Portland, Ore.: PECI.

74 Brown, K. 2006. "Enhanced O&M through Building Performance Monitoring and Benchmarking." Presented at the 2006 National Symposium on Market Transformation. Washington D.C.: ACEEE.

The 2004-05 Program included 37 building projects (half labs) and 9 plant projects on 25 campuses and received $5.2 million funding. They set portfolio targets of reducing demand by 1.0 MW, saving 9,300,000 kWh/yr and 580,000 therms/yr all with a 3.6 year simple payback period.

At the time of the most recent report, commissioning projects had achieved 138% of targets (34% of funding produced 47% of targeted savings) with a 10% average energy use reduction (cost basis) from initial commissioning and clearly identified potential for program improvement (e.g. better project design). The table below summarizes the results of 2004-2005 partnership projects notice the money spent and the payback times in the right most columns.

Table 1: UC/CSU/IOU Partnership MBCx Project Results Summary (1)

Project ID	Reduction in Energy Use: Total Electricity (kWh/year)	Peak Electricity (kWh/year) (2)	Demand (kW) (2)	Natural Gas (therms/year)	Annual Cost Savings (3)	Total Project Funding (4)	Simple Payback on Funding (years)
Results for Complete Building MBCx Projects Reporting To-Date							
2005.01	197,679	13,743	23	40,591	$62,420	$67,500	1.1
2005.02	496,619	11,262	18	43,497	$94,848	$114,140	1.2
2005.03	454,586	23,751	39	0	$49,021	$83,500	1.7
2005.04	720,038	50,899	84	76,987	$156,626	$270,000	1.7
2005.06	36,754	2,555	4	9,406	$13,465	$25,500	1.9
2005.08	302,529	18,013	30	15,836	$48,796	$110,000	2.3
2005.13	714,430	25,274	42	0	$75,234	$184,900	2.5
2005.10	758,644	75,864	125	11,787	$99,031	$244,950	2.5
2005.15	343,412	44,726	73	11,221	$52,271	$192,163	3.7
2005.12	250,009	17,010	28	5,233	$32,785	$152,601	4.7
2005.16	76,670	7,806	13	661	$9,499	$49,300	5.2
2005.14	129,394	6,182	10	11,186	$25,053	$143,000	5.7
2005.17	4,354	343	1	3,587	$4,074	$27,700	6.8
Subtotal	**4,485,168**	**297,428**	**488**	**229,992**	**$723,123**	**$1,665,254**	**2.3**
	48% of Portfolio Target 61% of Program Target		**48% of Portfolio Target** 53% of Program Target	**40% of Portfolio Target** 76% of Program Target	**46% of Portfolio Target** 66% of Program Target	**32% of Funding**	
Results for All Projects Reporting To-Date							
Total	**6,262,973**		**643**	**364,346**	**$1,044,673**	**$2,572,904**	**2.5**
	67% of Portfolio Target 85% of Program Target		**63% of Portfolio Target** 70% of Program Target	**63% of Portfolio Target** 120% of Program Target	**66% of Portfolio Target** 95% of Program Target	**49% of Funding**	

Source: Brown 2006 at ACEEE

3.1.4.6 Solution and Proposal

UC Berkeley is in the enviable position of being offered a substantial amount of money through utility incentive programs to subsidize work that would have been cost effective anyway. The University should take steps now to prepare to maximize the value it derives from the next round of Partnership funding. It should embark on a program to retrofit and retro-commission *every* building on campus by 2014 and to reap multiple benefits from each step along the way. As documented in the academic literature and confirmed in our case studies, a portfolio approach that touches all buildings can provide substantial and predictable energy savings. Our next steps should include:

- Start working to identify the range of projects that could be completed using the estimated $30M of utility money between 2009 and 2014. The more we know about our options, the more likely we are to maximize our return on investment.
- Take steps to ensure that the non-subsidized portion of the projects (usually 20-40% of costs) can be covered by the university (Note that it is expected that the UCOP will extend favorable loans for this purpose)
- Increase capacity for identifying and managing efficiency and commissioning projects through strategic staff hiring and internal reallocation of work responsibilities.
    - Start by filling Paul Black's position with someone at least as capable (hard to do!)
    - Plan for ongoing attention paid to the upkeep and continuous improvement of building operations after the Partnership funding has run its course. This could easily be paid for by a fraction of the energy savings from the program.
- Invest in measurement and monitoring infrastructure in every campus building prior to the allocation of 2009-2014 project budgets. The hardware side of this can be done for approximately $2000 per building (see the discussion of monitoring in another section). This infrastructure can be used to
    - Identify future projects
    - Support commissioning work and subsequent maintenance
    - Raise awareness of energy consumption on campus and support behavior changes
    - Establish a high resolution baseline against which to the measure eventual savings
    - Provide data to various campus research activities
- Cultivate academic interest in the project by seeking input from departments such as:
    - The Energy and Resources Group
    - The Center for the Built Environment
    - Computer Science (particularly for information visualization and automated data gathering)
    - Mechanical Engineering (perhaps through CITRIS)
    - Psychology and Sociology (particularly for input on the potential for and motivations behind changing patterns of discretionary energy use)

3.1.4.7 Impact and Significance

Although commissioning savings are typically highest in colder climates, it is no exaggeration to say that a campus wide program focused on just commissioning work could save the campus as a whole 15% or more of its energy costs with a very aggressive payback schedule. Furthermore, an integrated approach that makes use of the high resolution data gathering infrastructure required to identify and maintain Cx work in support of academic research and campus education and behavior change could produce enough benefits to be considered cash flow positive from the start. While not all benefits from such an arrangement could be quantified or guaranteed, those that can reasonably be expected to materialize are compelling enough to justify the program, particularly at an institution like UC Berkeley that ought to take a long view towards infrastructure planning. When the

Partnership money, likely to total around $30M and cover the time period from 2009-2014, is taken into account, a program to aggressively retrofit and retro-commission every building on campus becomes so attractive that it would be a big mistake not to do it. Once the upfront investment is paid off, such a project would return on the order of $2-3M a year into the general fund, and could deliver the lion's share of the CalCAP GHG mitigation commitment before even looking at fume hoods, lighting retrofits, refrigeration replacement, and a whole host of other extremely attractive energy saving ideas.

3.1.4.8 Costs and Carbon

The Mills 2004 study found median commissioning costs (for existing buildings) of $0.27 per square foot producing whole-building energy savings of 15% with payback times of 0.7 years (roughly 8.5 months). The total GSF for the roughly 200 buildings on campus[75] is about 13M, so an investment with similar characteristics would cost:
$0.27 x 13M = $3,500,000
Again, if the number Mills used are accurate, this investment would save 15% of our $26M annual energy budget or $3.9M/yr every year. Even if we don't save quite this much, this is a truly attractive financial proposition.

We do have some real world data from commissioning Soda and Tan Halls to add to the picture.

Soda Hall
The Soda Hall retro-Cx project cost $99,784 applied over 109,000 sqft or $0.92/sqft. This is roughly triple the cost that Mills found on average.

Against a 4,898,445 kWh/yr baseline, the project is saving 462,472 kWh/yr or **9.44% of the building's total electricity use**.

Against a 6,072 MBtu steam energy baseline, the project is saving 854 Mbtu or **14% of its total steam usage**.

Tan Hall
The Tan Hall retro-Cx project cost $90,873 applied over 106,000 sqft or $0.86/sqft. This is roughly triple the cost that Mills found on average.

Against a 4,842,840 kWh baseline, the project is saving 663,184 kWh/yr or **14% of the building's total electricity use**.

Against a 27,512 Mbtu steam energy baseline, the project is saving 5,246 Mbtu or **19% of its total steam usage**.

Note that all costs include payments to contractors, staff time, and monitoring hardware and that no lab equipment was changes by the process. By far the largest expense on both projects was for work that was contracted out ($84k for Soda and $63k for Tan). We can conclude that some portion of

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[75] In most cases, we are using the subset of campus buildings found in the facilities metering database as supplied by Paul Black (about 214 buildings). However, the number of buildings and their floor space is rather subjective depending on your spatial and ownership criteria. See the Facilities Inventory System (FDX) http://fdx.vcbf.berkeley.edu/ for a query-based interface to campus building data on over 700 buildings!

the price difference between the Cx costs the Mills study found and the costs of Soda and Tan should be chalked up to the price premium paid to outsource the work. However, it is not likely that this alone explains the difference. The rest of the difference implies that either:
1) Labs in general cost more to commission
2) Berkeley could find less expensive commissioning methods
3) We could expect that a larger sample size would average out to a lower cost (N=2 doesn't tell us much)

However, even at $0.90/sqft, which is about what we paid for Tan and Soda, a retro-Cx project for all of campus would cost just under $12M, producing a 3 year simple payback assuming it delivers 15% savings off our $26M energy budget. The retro-Cx projects to date have easily beaten their 3.6 year payback goals, so this calculation can be considered representative.

According to the official CalCAP report, Berkeley's campus emissions totaled 209,000 tons of CO_2 equivalent (TCO2e). Of the total, 82,000 TCO2e were associated with steam and 65,000 with purchased electricity.

Assuming that 13% campus wide energy savings, split evenly between steam and electricity, could be achieved, Cx work alone could save the campus 19,100 TCO2e/year, which is over 9% of total emissions. Now assuming that the savings will persist for five years with maintenance costing only pennies on the dollar, we find (key inputs highlighted in green) a negative cost of conserved carbon:

Campus wide Cx program (conservative)	
total annual tons CO2 emitted	209,000
tons CO2 from electricity and steam	147,000
% elec. And steam savings from Cx work	13%
annual saved tons CO2	19,110
% of total emissions saved	9.14%
$/sqft for Cx	$0.90
Total sqft Cx'd	13,000,000
total first cost	$11,700,000
annual utility bill	$26,000,000
annual $ saved by Cx work	$3,380,000
percentage of first cost applied to maintenance	5%
cost of maintenance per year	$585,000
years of sustained Cx savings	5
total project expenditures	$14,625,000
total project savings	$16,900,000
net project cost	-$2,275,000
total saved CO2	95550
cost of conserved carbon ($/ton)	**-$23.81**

While this estimate matches observed savings from Tan and Soda Halls, and is conservative when compared to results from the Mills 2004 study, it should be noted that it is very sensitive to the cost of commissioning per square feet, the energy savings achieved, and the number of years over which the savings are sustained. We expect that maintaining energy savings will require a re-investment of a small fraction of the utility budget saved back into staff salaries to support re-commission buildings on a regular schedule. However, it is also expected that having staff commission buildings in the first place will save a substantial portion of the first cost. The above calculation produces a simple payback in just over 4 years, without increases to energy prices, but the average observed average Partnership payback to date has been less than 3 years. Soda and Tan Hall in isolation paid back in 3.7 years. Per the experience at Texas A&M and elsewhere, there is no reason to assume that properly maintained buildings couldn't retain their form well beyond 5 years.

Note that these cost calculations do not include retrofits or other expenditures that could also be classified as energy efficiency work. Also, we know that we can apply partnership money to projects averaging under 5 years simple payback. This means that we could spend more than the $0.90/ft^2 from the Soda/Tan model and squeeze additional performance out of the buildings. In other words, we could expect to save more energy by spending more money on retro-Cx and still meet the Partnership criteria of sub 5 year paybacks.

Despite the highly attractive financial picture, this program's biggest benefit to campus could be the effect it has on the overall "energy literacy" of the campus community. As warnings about the likely impacts of climate change get increasingly dire and the search for solutions gain momentum, it will be critical that academic institutions produce professionals and leaders capable of imagining, and realizing a world whose patterns of energy use are dramatically different from those today. This project has the potential to capture the imagination of students, faculty, staff, and administrators alike as well as to give us both a target to aim for and some of the necessary tools for measuring our progress along the way. It is easy to imagine that a site that starts out providing real-time campus energy use information could evolve into a pioneering platform for studying and documenting the range of potential programs for mitigating green house gas emissions.

3.1.5 Feedback and Behavior Change

In aggregate, much of the energy used on campus is the result of millions of individual consumption decisions that take place every day on campus. From shutting the sash on VAV fume hoods, to putting computers to sleep and turning out lights, end users control a substantial fraction of total campus energy use. A campaign to create greater awareness of energy use on campus that includes greater feedback to occupants on the consequences of their energy choices is likely to substantially impact total campus energy use.

3.1.5.1 Summary

Feedback-based behavior change programs have already been shown to reduce energy consumption significantly across many building types: dormitories, office buildings and residences. However, Berkeley is not using feedback-based methods to encourage the adoption of energy efficient behaviors. We examined current programs on campus that focus on behavior change and programs elsewhere that integrate feedback into their behavior change programs and we have made suggestions for how Berkeley can incorporate feedback into current programs.

3.1.5.2 Problem Statement

Building occupants can play an important role in reducing energy consumption on campus. They could more aggressively turn off lights, shut down their computers at the end of the day, and/or report building problems that lead to over-consumption like heating and ventilation problems. Dorm room occupants, who have great control over the items they plug into outlets, could more actively manage their consumption.

These are all things building occupants *could* do. Yet very few do so now. All of these actions require a change in behavior, and behavior change is unlikely to occur if occupants do not have *feedback* concerning the effects of their behavior so they can adequately react and continue or modify their actions. In this context, feedback means conveying energy usage to building occupants in some form. To be concrete, here are some feedback possibilities:

- Comparisons to:
    - Previous performance ("Your building used 10% less energy compared to the same period last year."
    - Other users ("Your building has saved more energy than building X.")
- Converting usage to understandable units, such as:
    - Monetary units in the form of bills, where usage is converted to a cost (bills not only offer feedback but a clear incentive to change behaviors as those billed are paying the cost)
    - Environmental units ("Your building's savings reduced CO_2 output into the atmosphere by 10 megatons.")
    - Cultural units ("Your building consumed the equivalent of one million hamburgers last year. This year it's only nine hundred thousand. Good work!")

Unfortunately, on the Berkeley campus, most students, faculty, and staff have never received **any** feedback on their energy consumption behaviors. As a result, they are unlikely to enact energy saving behavior or to know what those behaviors might be. Yet, the success of using feedback to reduce energy consumption in office environments (Siero, Bakker, Dekker, & Van Den Burg, 1996), dormitory environments (Petersen, Shunturov, Janda, Platt, & Weinberger, 2007) and residential environments (Darby, 2006) strongly suggests that we should pursue feedback-based behavior change initiatives.

Campus Behavior Change Initiatives: Education and Incentives, But Little Feedback

The Green Campus program (see http://www.ocf.berkeley.edu/~saekow/greencampus/) runs two behavior change initiatives on campus: Resident Hall Blackout Battles and the Shut the Sash campaign. Each aims to reduce energy consumption on campus. Both are primarily education and incentive based – they do provide some feedback, though it is sparse.

Blackout Battles

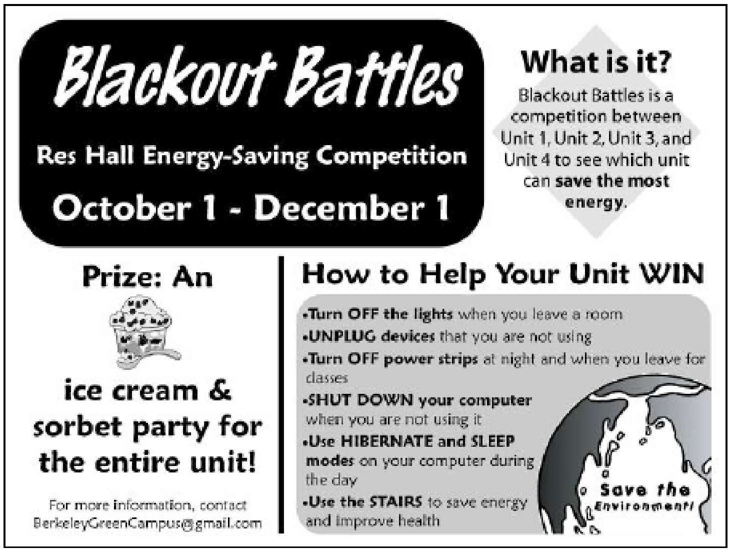

Figure 1: A poster placed in participating dormitories advertising the Blackout Battles competition (Blackout Battles, 2007)

Since spring 2005, the Green Campus program at Berkeley has run a competition between residence halls where residents compete to see which hall can most reduce its energy consumption over a one to two month period.[76] A poster advertising Blackout Battles is shown in Figure 1. Incentives are prominently featured: the best residence will "WIN" an ice cream and sorbet party for the entire unit. To win, the participants need to know what to do, and the posters provide some educational content regarding winning behaviors: switching off lights, unplugging devices, shutting down the computer, etc. To date, the Blackout Battles, over 3 years, have reduced energy consumption in resident halls by an average of 7.95% when compared to baseline levels.[77]

However, residents don't necessarily receive feedback concerning their performance. Instead, resident advisors, midway through the competition, get an update on the performance of their unit. It is unclear how this small amount of feedback is used to encourage individual residents. However, it is known that more detailed feedback can help save even greater amounts of energy, as witnessed at Oberlin College (discussed below).

Shut the Sash!

Fume hoods are one of the largest energy consumers in labs. In one year, a fume hood can consume as much energy as three and a half American households. For Variable Air Volume fume hoods, there is a simple behavior that lab occupants can execute to reduce energy consumption: shut the fume hood sash.

[76] Green Campus. (2007). *Blackout Battles*. Retrieved November 21, 2007 from http://www.ocf.berkeley.edu/~saekow/greencampus/current-projects/blackout-battles/
[77] Ibid.

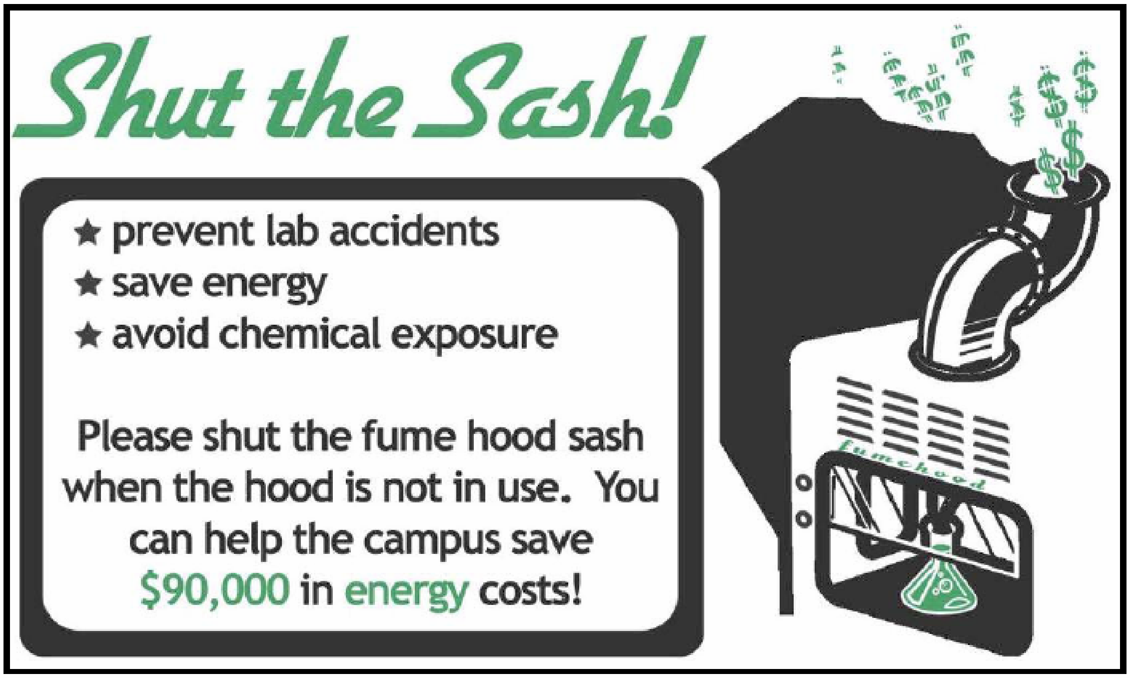

Figure 2: A label placed on all fume hoods in the "Shut the Sash!" program[78]

The sticker in Figure 2, placed on appropriate fume hood sashes, implores users to shut the sash. It explains why this is a beneficial action, from a safety and energy consumption perspective. Furthermore, the lab that is most effective at shutting their sashes wins a fruit and cheese party.

3.1.5.3 Feedback-based Behavior Change Initiatives

Incorporating feedback into behavior change programs can lead to significant energy savings, as witnessed in dormitory, office and residential settings at other institutions. This section highlights the results of published studies on the effects of feedback on consumption.

Dormitory Energy Competition at Oberlin College

On the Oberlin campus in 2005, an energy saving competition was run between dormitories.[79] Different dormitories received either high-resolution metering feedback of their electricity usage (readings available in real-time, every few minutes), or low-resolution feedback (weekly updates). The high-resolution group could monitor their dormitory's usage on the Internet (see Figure 3 below for a particular residence, Kade Hall), or on an interactive display in the lobby of the building, whereas low-resolution dormitories simply received a total energy consumption number each week. The competition succeeded at reducing energy consumption, but high-resolution dormitories were more effective: these dormitories reduced their consumption on average by 55%, whereas low-resolution dormitories reduced their consumption by 31%. While it is difficult to compare these absolute numbers to Berkeley's numbers, as baselines could have been computed differently, there is

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[78] Green Campus. (2007). *Shut the Sash Campaign*. Retrieved November 21, 2007 from http://www.ocf.berkeley.edu/~saekow/greencampus/current-projects/fume-hood-pilot/

[79] Petersen, J. E., Shunturov, V., Janda, K., Platt, G., & Weinberger, K. (2007). Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. International Journal of Sustainability in Higher Education, 8(1), 16-33.

no doubt that detailed feedback can greatly increase energy savings. Both cases featured feedback that is not currently available at Berkeley today.

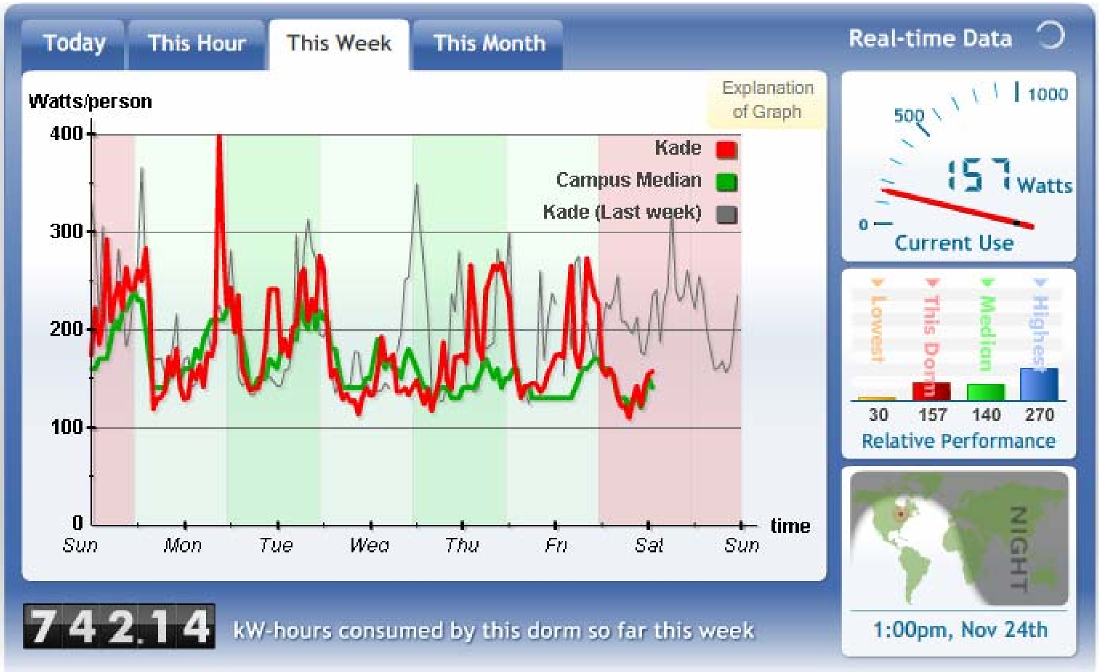

Figure 3: Interactive visualization of consumption data available to Oberlin residents in high resolution dormitories. This picture depicts Kade Hall.[80]

Office Building Feedback-based Energy Savings

In a 1996 study, researchers in the Netherlands found that providing education and constant feedback on energy usage to employees significantly reduced energy wasting behaviors, with a comparative feedback mechanism performing most effectively (i.e. receiving feedback not only about your group's performance, but also the other group's performance).[81] At the time, detailed monitoring equipment was not available, so the researchers had to develop customized mechanisms for tracking what they deemed wasteful energy consumption. Today, such a program could be implemented much more easily because equipment to track energy consumption at individual plugs or entire rooms is more readily available.

Residential Feedback-based Energy Savings

Home residences are different than campus-based buildings because individual occupants pay the energy bill. Based on an extensive review of the residential energy feedback literature, researcher Sarah Darby concluded that:

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[80] Lucid Design Group, LLC and Oberlin College. (2007). *Oberlin College Campus Resource Monitoring System.* Retrieved November 21, 2007 from http://www.oberlin.edu/dormenergy/series.htm#dorms

[81] Siero, F., Bakker, A., Dekker, G., & Van Den Burg, M. (1996). Changing organizational energy consumption behaviour through comparative feedback. Journal of Environmental Psychology, 16(3), 235-246.

> Direct displays [of energy usage] in combination with improved billing show promise for early energy and carbon savings, at relatively low cost. They also lay the foundations for further savings through improved energy literacy.[82]

For example, in a large pilot study of the effect of feedback on energy consumption in homes, Hydro One, a utility in Ontario, Canada, provided real-time monitors to hundreds of households over a two and a half year period. Compared to previous years, the researchers found households reduced energy consumption by an average of 6.5%.[83]

3.1.5.4 Proposed Solutions

Feedback-based Blackout Battles

The overwhelming success of the dormitory energy competitions at Oberlin College suggests that by providing additional feedback, the Blackout Battles further reduce consumption, and increase energy consumption literacy. To achieve this level of feedback, in addition to the education and incentives the Blackout Battles are providing now, Berkeley must:

- install high resolution monitors to gather data for feedback
- provide interactive visualizations of this data on the web and in the lobbies or other high visibility areas of residence halls

High Resolution Monitors

Currently, the Blackout Battles involve units 1, 2 and 3, and unit 4, which consists of Stern, Foothill and Bowles. All six of these buildings would need high resolution meters installed and connected to the Internet so the data can be efficiently logged.

Interactive Visualizations of Consumption Data

The easiest route to developing interactive visualizations of this data would be to contract with a company similar to the Lucid Design Group, a company formed by researchers in the Oberlin study that now provides interactive displays for dozens of buildings around the country. We could install a basic display, like that used at Oberlin College, with little customization.

Estimates

Based on Table 1, even a conservative estimate of savings (14% compared to the baseline) would offer a payback on the equipment in less than four years. Furthermore, this number is quite conservative given that in some semesters dormitories have averaged around 11% savings (7% was chosen based on data from the most recent 2007 Blackout Battle). We also include estimates based on the Oberlin College study. If we implement high resolution feedback, we can likely achieve results at least similar to Oberlin's low resolution condition, which implies payback in less than 2 years.

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[82] Darby, S. (2006). The effectiveness of feedback on energy consumption. A review for DEFRA of the literature on metering, billing and direct displays, page 4.
[83] Mountain, D. (2006). The impact of real-time feedback on residential electricity consumption: the Hydro One pilot. Mountain Economic Consulting and Associates Inc., Ontario.

Cost of Implementing Feedback-based, High Resolution, Blackout Battles

Item	# Units	Cost/Unit	Total Cost
High Resolution Metering	6	$2,000	$12,000
Lobby Kiosk Display and Web-based Display	6	$10,000	$60,000
TOTAL			$72,000

Energy Savings per Year (estimates linearly scaled from current numbers)

Method (Estimate Type)	Percent	in Dollars
Current Blackout Battles (based on Green Campus comparison to baseline)	7%	$10,000
Feedback Blackout Battles **(Conservative)**	14%	$20,000
Feedback Blackout Battles **(Oberlin - low resolution weekly feedback)**	31%	$44,286
Feedback Blackout Battles **(Oberlin - high resolution minute-level feedback)**	55%	$78,571

Payback Period of Feedback-based Blackout Battles

Estimate Type	# Years
Conservative	< 4
Oberlin - low resolution	< 2
Oberlin - high resolution	< 1

Table 1: Cost and payback estimates for implementing feedback-based Blackout Battles. Item cost estimates are based on quotes from a company providing high resolution metering solutions, and Lucid Design, which creates the interactive visualizations

Beyond the monetary payback, feedback mechanisms provide greater understanding and education concerning energy usage and efficiency. Improvement of the energy literacy of the Berkeley student population will produce further benefits in the future as these students become community leaders.

Feedback Mechanisms for Office and Lab Buildings

Enacting environmentally responsible behaviors in office and lab buildings is more difficult than in residence halls because office occupants often do not have as much control over the working environment. Indeed, in many office buildings residents do not even know how to control the lights.

Yet, on the Berkeley campus today, six buildings are metered at a high resolution. There has been only a small amount of research on using such high-resolution data to provide feedback to office occupants.[84] The "Shut the Sash!" program shows that there is great potential in office/lab buildings. The data from existing high resolution buildings should be used to identify useful and compelling visualizations and statistics for promoting greater conservation.

3.1.6 Multiple Benefits of Good Energy Data from Buildings

During the course of our research on emissions accounting, retro-commissioning, and energy behavior change, we noticed that they all benefit from or require high resolution building energy data, preferably in real time. This section explores the benefits of capturing high resolution building

[84] Holmes, T. G. (2007). Eco-visualization: combining art and technology to reduce energy consumption. Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition, 153-162.

energy data and presents some scenarios for how monitoring infrastructure might be introduced and taken advantage of on campus.

3.1.6.1 Benefits of a Comprehensive Monitoring System

Measurement and Verification

Central to every greenhouse gas mitigation effort is the assumption that current emissions are known and that future emissions will be measured accurately. However, in most cases, these assumptions are baseless until proactive steps are taken to ensure the quality of such data. A system designed to monitor energy use on campus with high resolution and in real time could provide a detailed energy baseline against which mitigation could be measured. It would also provide timely evaluation of specific mitigation efforts to verify their performance. It is not uncommon for the output of different sensors to vary by nearly as much as the CalCAP goals themselves. Ideally, verification would be performed using the same equipment that had been used to set the baseline to ensure consistency.

Commissioning

There are currently only six buildings on campus with high resolution networked meters in them: Koshland Hall, Cory Hall, Life Science Addition, Silver Lab Addition, Tan Hall, and Soda Hall. Each of those meters is the legacy of a Partnership funded retro-commissioning project. To support commissioning work in a given building, high resolution energy consumption data must be available to establish an energy baseline at the outset of the project as well as to provide commissioning agents feedback on how the building is operating and the potential impacts of various adjustments. In Tan Hall, the monitoring system has already contributed to substantial energy savings. At the end of last year, Tan Hall's control system had been accidentally left in a test mode by a technician servicing and testing air conditioning equipment. The system was actually attempting to run a chiller in the middle of winter! It would turn on, detect that the temperature was too low for AC and turn off in rapid succession over and over again. Simply looking at the data shown in the figure below revealed to building operations staff that something was wrong. They fixed the control system with the press of a few buttons and that change alone is saving on the order of $100,000 a year! It probably would have been discovered eventually, but it certainly would not have been detected through once a month meter readings alone.

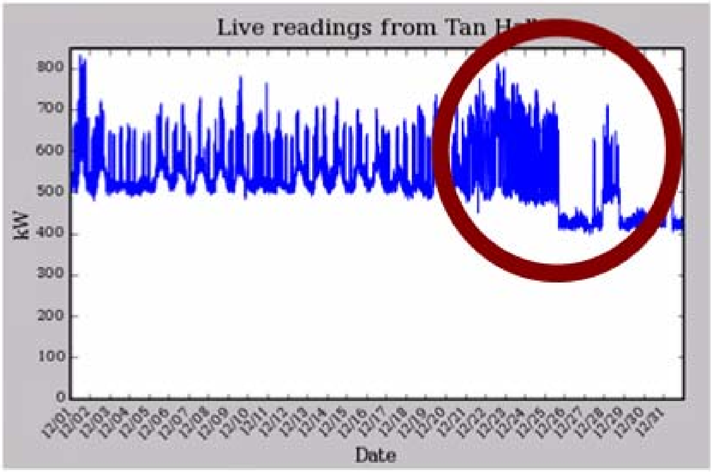
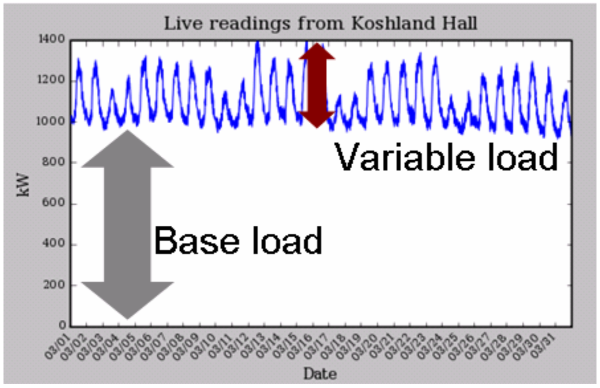


Figure: Tan Hall equipment configuration fix.

Education and Behavior Change

But the commissioning energy savings are only part of the story. Such real time systems can educate building occupants and inform researchers studying building energy performance, occupant behavior, control systems, human-computer interactions, and a whole host of other topics. Look at the figures below and think about the insights gained and questions raised by just getting a qualitative understanding of their similarities and difference.



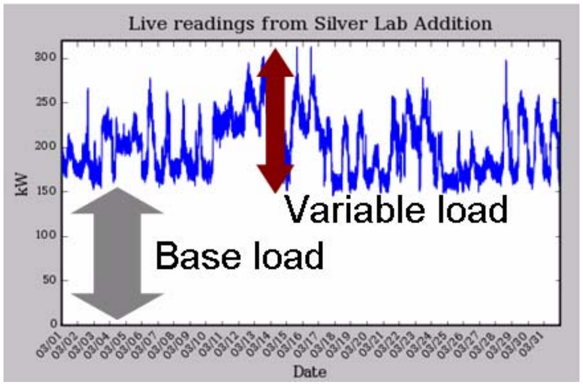


Figure: Koshland compared to Silver Lab.

At a glance we can see the steady base load and the variable loads. We can see daily and weekly cycles, and we start to notice the "personality" of each building. Readers of these graphs might immediately wonder "What is that high period in Silver Lab? Was lab equipment running for an experiment for several days?" By making the data visible we open it up to a host of questions from both experts and the general public and we help people become more "energy literate" as they develop a more sophisticated understanding of the dynamics of energy use.

Building data helps occupants develop intuition about their contribution to campus resource use and monitor the effects of various strategies to reduce use. A networked system could be used to show live data to occupants about their energy use. They will notice the difference between night and day; weekdays and weekends. It will help them become mindful of their consumption, in the same way feedback systems in household residences and dormitories have helped those occupants become mindful. The figure below illustrates how a campus feedback system might work.

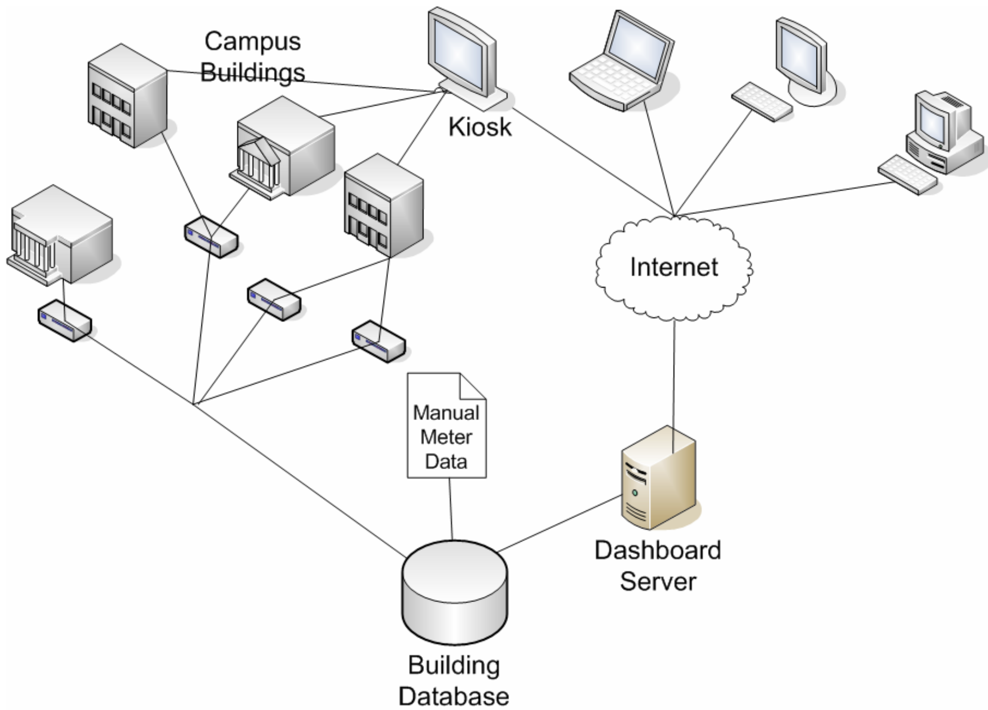


Figure: Schematic drawing of building energy monitoring and feedback network on campus.

Research
In addition, the availability of data from a variety of buildings helps researchers understand correlations between building types and resource use, and to look for useful metrics for spotting potential savings. Perhaps variation in load represents the potential for demand controlled by occupant decisions and the maximum achievable savings through changing occupant behavior. Perhaps a certain type of cyclical behavior indicates an equipment malfunction. Researchers are beginning to ask whether these conditions can be automatically detected. Making the data available to the Berkeley research community will help answer such questions and could support the development of the next generation of building control and diagnostic tools.

The Cost of Metering
Many of the major controls hardware vendors are increasingly offering Energy Information Systems (EIS) that provide access to high resolution building energy data and tools to analyze it. At the same time, new companies like Lucid Design Group and Obvius are developing less costly systems with specific attention paid to visualizing consumption data to support behavior change and taking advantage of modern electronics and wireless communication to cut the costs of monitoring.

Budget
By utilizing component hardware and radio mesh networks, it should be possible to install net electricity monitoring in all200 or so campus buildings for around $1800/building (see more details in the cost calculations section below), or just under $400K.

Monitoring and recording would cost $20/month per data point (per building), or $4,000/month unless we developed a system to store the data locally, in which case, this latter expense could be saved.

We estimate that for an additional investment of $200-300K and possibly much less, a highly usable web and kiosk based system could be put in place for visualizing and communicating all this data in a way that we'd expect to noticeably change energy use behavior on campus, and would support research and management needs as well. Considering the potential benefits mentioned above and that we spend over $70,000 per year paying people to read meters alone (see calculation below), these costs seem well worth it.

Savings: Less money spent reading meters
The utilities engineering group estimates that they spend 12 hours per month per staff for a total of 720 hours per year reading meters and entering the data. The recharge rate for Engineering Services is $105/hr so this task "costs" almost $74,000/yr in engineering time that could be spent more productively. (NOTE: to actually save this amount, all metered utilities would need to be included in the system.)

Spotting fluke building behaviors
While it would be impossible to accurately quantify, the experience with Tan hall detailed above shows that the energy savings potential from early detection of bad building energy behavior is quite substantial. With 200 or so buildings being carefully monitored, we could probably expect at least tens of dollars a year in energy savings from early detection of problems.

3.1.6.2 Cost Calculations

Meter itself...per data point (more for extra data points).
$750-$1000

Steam and water get more expensive
Breaking pipe, draining systems, etc.
They are $300-$8000 per meter depending on lots of things.

The electricity meters are 2hrs to install ($150?). They are split core, which means they snap around the wires and don't require an electrician.

Wireless communication $500 vs. potentially more for running a wire. 900MHz spread spectrum radio module mesh network.

For 200 buildings, you'd have few different logging devices since you can get 30 or 40 building on a single device.

$1500 per logger per 30-40 buildings.

$/meter	$1,000
$/sub-metered electricity @ $750	$0
$/steam or water meter @ $300-8000	$0
$/installation (labor) 2hrs	$200
wireless communications package	$500
$/logger (each can handle 30-40 buildings)	$1,500
$/building	$1,738
# of buildings	200
$ for all hardware	**$347,600**

data storage service per data point $/yr	$240.00
data costs per year	**$48,000.00**

3.2 Renewable Energy at the Richmond Field Station

Renewable energy projects on campus represent a significant opportunity for the University to reduce greenhouse gas emissions through the reduced usage of electricity generated from fossil fuel combustion. In addition, such systems will allow the university to avoid purchasing electricity at peak rates, thereby hedging against future increases in electricity prices. In 2005, UC Berkeley completed the installation of its first on-campus solar system. The array – on top of the rooftop of the Martin Luther King Jr. Student Union building – was installed in two phases, starting in 2003, and was provided by PowerLight Solar Electric Systems, which has since merged with SunPower Corporation.

The first phase of the MLK project resulted in the installation of a 59.3 kW system that measures approximately 4,250 ft^2. The array is expected to generate approximately 77,590 kWh of electricity per year. In phase 2 of the project, an extension of 36.5 kW was installed that is expected to generate another 46,580 kWh of electricity per year. In total, the 95.8 kW system is now capable of generating approximately 124,170 kWh of electricity annually. Actual electricity generation can be monitored using an online feedback system installed by the company.

Students funded the project by voting to allocate portions of the Associated Students of the University of California (ASUC) and Graduate Assembly (GA) budgets to pay for the system's purchase and installation. On top of that, the system qualified for a grant from the California Public Utilities Commission's "Self-Generation Incentive Program." The following table summarizes the costs and cost-savings associated with the project.

	Phase I	**Phase II**	**Total**
Turnkey System Size (in kW)	$59.3	$36.5	$95.8
Expected Annual Output (in kWh)	77,590.0	46,580.0	124,170.0
Turnkey System Price	$507,542.0	$290,746.0	$798,288.0
CPUC Incentive	237,358.0	145,373.0	382,731.0
Price Net Incentive	$270,184.0	$145,373.0	$415,557.0
Incentive as a % of System Price	*46.8%*	*50.0%*	*47.9%*
Total Cost Savings (over 25 years)	$468,451.0	$270,673.0	$739,124.0
Average Annual Cost Savings	18,738.0	10,826.9	29,565.0
Internal Rate of Return	4.0%	5%	n.a.
Payback Term in years	17	n.a.	n.a.

Opportunities to install renewable energy onto other facilities on campus are currently being evaluated, and they may be able to contribute in large part to the campus' commitment to reducing greenhouse gas emissions as part of the Cal Climate Action Partnership.

3.2.1 Summary

The Richmond Field Station ("RFS") is an off-site research facility where renewable energy prospects are promising. The facility's administrators are excited about the possibility of a solar array, particularly on the library building B400. As such, the following discussion outlines the opportunities that exist, and provides an overview of the renewable energy solutions which appear feasible given our assumptions on solar insolation, system size and type, and available incentives.

Overall, we believe the building would be suitable for a 200 – 300 kW system, which could generate over 300,000 kWh annually, reducing greenhouse gas emissions by 260 t CO_2e per year.

3.2.2 Problem Statement

Depending on the scope of analysis, electricity use accounts for approximately 10 to 31 % of UC Berkeley's carbon footprint. Any comprehensive effort to reduce Berkeley's greenhouse gas emissions will include a "greening" of the electricity supply, either through the direct consumption of a greater proportion of electricity generated from renewable sources or through the purchase of Renewable Energy Credits (RECs). Given the availability of renewable energy resources in the Bay Area, there is significant potential for the University to meet a share of its emissions reduction goals through on-campus generation and use of renewable energy.

We hypothesize that installing an array of distributed photovoltaic and wind energy generators can displace a substantial quantity of grid electricity consumption, an outcome that will in turn have a significant and positive impact on UC Berkeley's carbon footprint. In order to gauge the technical feasibility, economic viability, and environmental sustainability of local, renewable energy generation, we used the UC Northern Regional Library Facility (located in building B400 of the Richmond Field Station) as a case study in designing and optimizing a renewable, building-based distributed generation scheme for campus use. In addition to calculating the costs, benefits, and limitations of such a system in the specific instance of the library facility, we have attempted to provide a model of procedure and analysis, as well as set of considerations and contact points for future student-led efforts to install renewable energy generators at Berkeley.

3.2.3 Research/Current Situation

1) The Richmond Field Station Site:

The website for the Richmond Field Station describes the facility as an "an academic teaching and research off-site facility located 6 miles northwest of the UC Berkeley Central Campus on the San Francisco Bay that has been used primarily for large-scale engineering research since 1950. The 152-acre property consists of 100-acres of uplands with the remainder being marsh or bay lands."

The Richmond Field Station is owned by the Regents of the University of California system, managed by the University of California at Berkeley, and operated by UC Berkeley's College of Engineering. The RFS is host to a range of private and university research programs, and is the site of a regional laboratory of the U.S. Environmental Protection Agency. It also provides critical habitat to different fauna and flora, including now-rare native coastal grasses, and thus provides important research opportunities.

The RFS is also the home of the Northern Regional Library Facility, which stores 7.7 million volumes for the four northern campuses of the UC system. The NRLF has two chilling units to manage thermal and humidity conditions within a precise range for preserving and protecting these volumes. Facilities managers, administrators, and faculty had discussed the possibility of using renewable energy systems to meet some of the NRLF's high electricity loads. This study explores the feasible options for using photovoltaics and/or wind generation to meet some of the NRLF's loads onsite.

The NRLF is housed in building B400 on the northern edge of the RFS campus. B400 has been constructed in three phases, as the need for additional storage capacity has expanded. Three more phases (additions) are projected to take place within the next 15 to 20 years. For roof-mounted photovoltaic systems, we limited our study for rooftop photovoltaics to Roofs 1 and 2 of B400. Roof 3 has extensive piping for the chiller system and other mechanicals that would limit its amount of usable roof space (though facilities managers might decide at a later point that the benefits of adding solar panels there outweigh maintenance and installation challenges). Roofs 1 and 2 are mostly open, with a durable tar-gravel covering, and slightly sloping toward the edges along the north-south axis. This slope should not significantly affect either the PV installation or output.

There are two important constraints on rooftop installations on Roofs 1 and 2 of B400. The first is related to the roof structure: according to Dominic Campi of Rutherford & Chekene, the structural engineer for the NRLF facility, these two roofs are "constructed with concrete fill over steel deck, supported by steel framing and should be capable of supporting panels of modest weight." However, the unique function of the B400 building – storing and chilling library books – creates an important constraint on any PV rooftop installation: the mounting system ideally would not penetrate the roof, in order to eliminate risks of leaking that could damage the volumes. This limits the rooftop mounting options to special non-penetrating designs, which in turn limit the steepness of the tilt angle of the PV modules to at most 15 degrees. According to Campi, Roofs 1 and 2 are not designed to support the weight of a heavier, ballasted PV mounting system, which a non-penetrating installation would require. For the purposes of demonstrating the methodology of the assessment, we are assuming a system covering the rough area of Roofs 1 and 2; perhaps a minimal-risk strategy will be identified for securing a standard, more lightweight mounting system to these roofs.

The building is roughly oriented on the north-south axis, so PV modules can placed perpendicular to the building outline to be due south-facing. To the immediate south across the access road is a row of tall trees; a visual assessment on a site visit suggested that they would not cause significant shading, but the installing vendor will provide a thorough shading analysis to determine potential losses.

An analysis of the B400 roof blueprints determined that the useable space was approximately 160 ft by 124 ft on Roof 1, and 156 ft by 100 ft on Roof 2. This constituted a total available roof space area of 35,440 square feet, to which we applied a 75% factor, an industry standard coefficient for a fixed, 10 to 20 degrees tilt system, to account for spacing between panels, maintenance and walkway access, and space from roof edges. Multiplying by 0.75 yields 26,580 square feet of potential area for coverage by PV modules.

An open field to the immediate north of B400 offers a potentially good site for wind turbines and/or a ground-mounted photovoltaic system. Part of the field is designated as open habitat, but roughly 20000 square feet are available for use. The close proximity to the San Francisco Bay suggested to facilities managers that a good wind resource might be available at the RFS. The rule of thumb in siting wind turbines requires that the hub height of the generator be at least 30 feet above any surrounding obstruction or feature (tree, roofline, etc.) in order to limit turbulence. Also, the turbine should be situated at a distance from any surrounding structure or frequently used space (road, parking lot) that is greater than its height.

Photovoltaics installed in this field could be ground-mounted at any angle, and if parts of the field are opened up to use at a later date there is potential to add panels to create a much larger system.

Google Earth image of B400 building housing the Northern Regional Library Facility at the Richmond Field Station. Roofs 1 and 2 are the darker structures in the lower center; Roof 3 is the white surface at upper left. The field available for a system is immediately to the left of Roof 1.

Incentives:

UC-Berkeley would qualify for the performance-based incentives offered by the California Public Utilities Commission through its California Solar Initiative. Qualifying systems must be grid-tied and installed by licensed California solar contractors. The RFS system would be larger than 100 kW capacity, and so would qualify for $0.50/kWh for the first five years as a nonprofit entity. Incentives are paid monthly based on the actual amount of energy produced, and the program is managed by the Pacific Gas and Electric Company (PG&E).

Under a third-party ownership model such as the ones offered by MMA Renewable Ventures and SunEdison, the vendor qualifies for the Federal Business Energy Tax Credit of 30% of expenditures of equipment placed in service. These companies can then pass the savings along to their clients in the cost per kilowatt-hour they charge.

Building Load:

The UC Northern Regional Library Facility (NRLF) serves as a repository for valuable and/or infrequently used materials from the libraries of the University of California's Berkeley, Davis, Merced, San Francisco, and Santa Cruz campuses, as well as the California State Library. After the addition in 2005 of a third module that increased the building footprint to more than 250,000 square feet, the facility reached a capacity to house a total of 7.4 million volumes. (Currently, 4.7 million items are being held.) In order to maintain optimum environmental conditions for book storage, the facility operates a climate control system of chillers, boilers, and fans to keep the stacks at a constant 60 °F and relative humidity of 50%.

Affectionately described by one administrator as the Field Station's "energy hog," NRLF consumes a considerable amount of electricity and fuel. Owing to recent difficulties in tracking and recording building-specific energy use at RFS, however, there is a lack of complete and detailed information quantifying the building load on an hourly, daily, or monthly basis, all of which are required for a more accurate assessment of the scale and economic viability of renewable energy generation. The calculations of this report are based on monthly electricity use data from July, August, and September 2007:

Month	Total electricity use (MWh)	Average electricity use (kWh/day)
July	69	2200
August	213	7100
September	140	4700

Based on this data and on energy load patterns for buildings of similar character, conservative hourly load profiles were generated for the months of August and March and used as inputs for the HOMER model. (See B400 Load Model)

2) HOMER Model

To look at the potential for solar and/or wind at the B400 site, we used HOMER. HOMER is a micropower optimization model created and offered for public use by the National Renewable Energy Laboratory (NREL), which simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. When designing a power system, one must make many decisions about the configuration of the system: What components does it make sense to include in the system design? How many and what size of each component should you use? The large number of technology options and the variation in technology costs and availability of energy resources can make these decisions difficult. HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations.

To use HOMER, you provide the model with inputs, which describe technology options, component costs, and resource availability. HOMER uses these inputs to simulate different system configurations, or combinations of components, and generates results that you can view as a list of feasible configurations sorted by net present cost.

HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system.

HOMER performs these energy balance calculations for each system configuration that you want to consider. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the conditions that you specify, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest.

The following sections outline the specific data used in the RFS HOMER model and assumptions made in order reflect the true costs and local resources available.

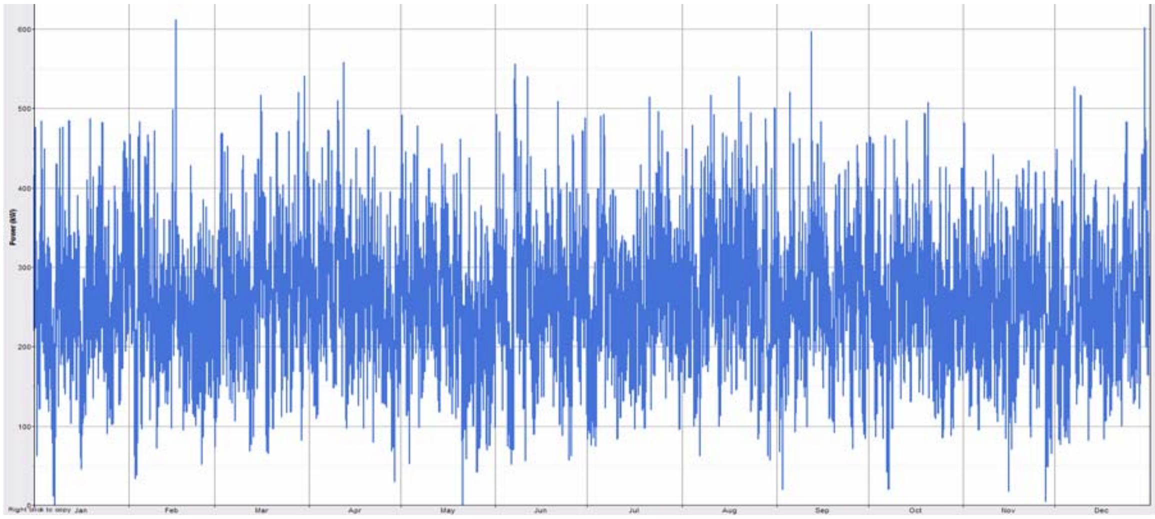
B400 Load Model

The electrical demand of the library was modeled using data recorded on the site. We entered mean hourly load profiles for an average day during two months (August, the month of peak energy usage and March).

Here are the loads entered in HOMER:

Hour	**Average load (kW)**	**Hour**	**Average load (kW)**	**Hour**	**Average load(kW)**	**Hour**	**Average load (kW)**
1	219	7	263	13	315	19	254
2	219	8	263	14	302	20	245
3	228	9	276	15	289	21	236
4	236	10	302	16	276	22	228
5	245	11	315	17	263	23	219
6	254	12	328	18	263	24	219

The simulated library load profile for one year is shown in the figure below.



B400 library electric demand over 1 year

<u>2.2 Electric Grid Model</u>

The benefits of installing a solar photovoltaic array or wind turbine at any grid connected site are dependent on the local electricity rate structure. The Richmond Field Station is located within Pacific Gas and Electric Company (PG&E) service territory. PG&E is a large investor owned utility (IOU) that provides natural gas and electric service to approximately 15 million people throughout a 70,000-square-mile service area in northern and central California.

We assume here that the B400 library is eligible for service under the schedule E-20 rates. A commercial or industrial customer is eligible for the E-20 rate if their maximum demand exceeds 999 kW over a consecutive three-month period. The E-20 is a time-of-use (TOU) rate structure with electricity prices varying by time of day, week and season. These prices differ depending on how the electricity is physically brought to the customer. Customers can get power from PG&E through three standard service voltages:

- Primary (voltage class if customer is served from a "single customer substation" or without transformation from PG&E's distribution system)
- Secondary (voltage class for service voltages less than 2,400V)
- Transmission (voltage class if the customer is served without transformation at one of the standard transmission voltages)

For this study, it was assumed that the Richmond Field station would obtain power from PG&E at a primary service voltage. The current schedule E-20 primary voltage rates are given below.

Time-Of-Use	**Total Rates**	
	Energy Rates ($/kWh)	**Demand Rates ($/kW)**
Peak-Summer	0.12385	11.88
Part-peak Summer	0.09183	2.72
Off-peak Summer	0.06527	5.04
Part-peak Winter	0.08266	0.80
Off-peak Winter	0.06832	5.04

PG&E defines their time-of use categories as follows:

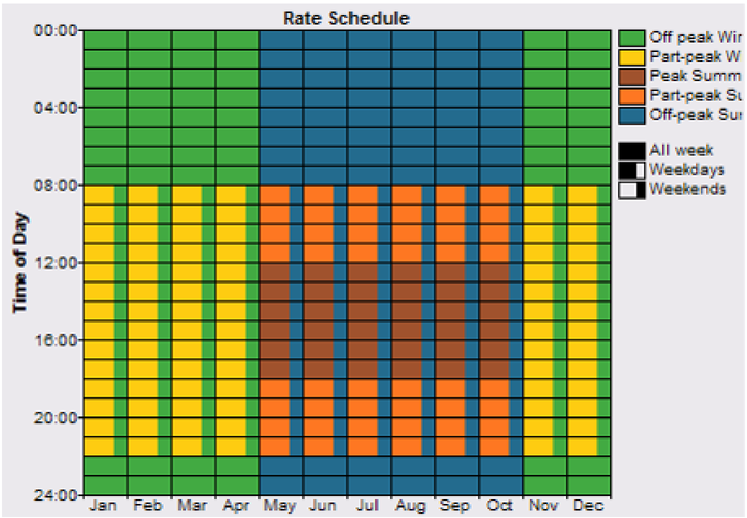
Summer: May 1st through October 31st

- Peak summer: 12:00 pm to 6:00 pm, Monday through Friday
- Part-peak summer: 8:30 am to 12:00 pm and 6:00 pm to 9:30 pm, Monday through Friday
- Off-peak summer: 9:30 pm to 8:30 am, Monday through Friday and all weekend

Winter: November 1st through April 30th

- Part-peak winter: 8:30 am to 9:30 pm, Monday through Friday
- Off-peak winter: 9:30 pm to 8:30 am, Monday through Friday and all weekend

Below is a screenshot of the HOMER model created to reflect the PG&E E-20 electric rate schedule.



2.3 Emission Model

Power supplied from the local grid to the B400 library will result in the emission of various greenhouse gases (GHG). The relative amount of each GHG emitted per kWh of electricity supplied is a function of the local utility's electricity mix as well as transmission distances and plant power factor.

The Emissions & Generation Resource Integrated Database (eGRID) compiled by the U.S. Environmental Protection Agency was used to estimate emissions from the PG&E grid. There are mainly three GHG to take into account: Carbon Dioxide (CO_2), Sulfur Dioxide (SO_2) and Nitrogen Oxides (NOx).

Each of these three greenhouse gases contributes to global warming to a different degree. An internationally accepted measure of a greenhouse gas' contribution to global warming is its GWP (Global Warming Potential). The GWP is a relative scale which compares each gas to an equivalent mass of carbon dioxide (CO_2).

The GWP of the three pollutants above over a 100 year time horizon is estimated as:

Pollutant	GWP (over 100 years)
CO_2	1
SO_2	0.075
NO_x	310

Thus, a kilogram (kg) of SO_2 released into the atmosphere has the same effect over the next 100 years as 0.075 kg CO_2.

The carbon dioxide equivalent (CO_2e) of a pollutant is calculated using the GWP as:

$$CO_2e = \text{mass of each gas released} \times \text{GWP of that gas}$$

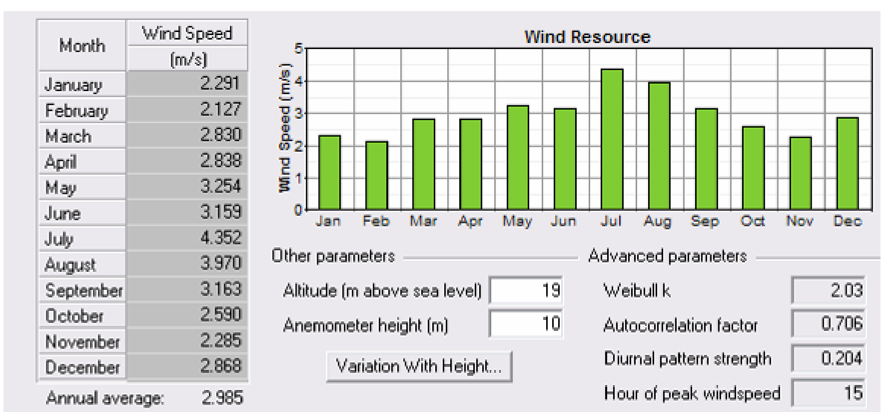
The CO_2, SO_2 and NO_x emissions from eGRID 2006 v2.1 for PG&E are given below with the calculated CO_2e.

Pollutant	Emissions of PG&E (g/kWh)
CO_2	636.49
SO_2	0.019051
NO_x	0.715769

$$CO_2e = 636.49 + 0.019051 \times 0.075 + 0.715769 \times 310 = 858.379 \text{ g/kWh}$$

2.4 Wind Resource

The wind resource in the RFS was estimated using data compiled by the Weather Station. We obtained hourly collected data for the year 2005. We entered these 8,760 values in HOMER to create a wind model:



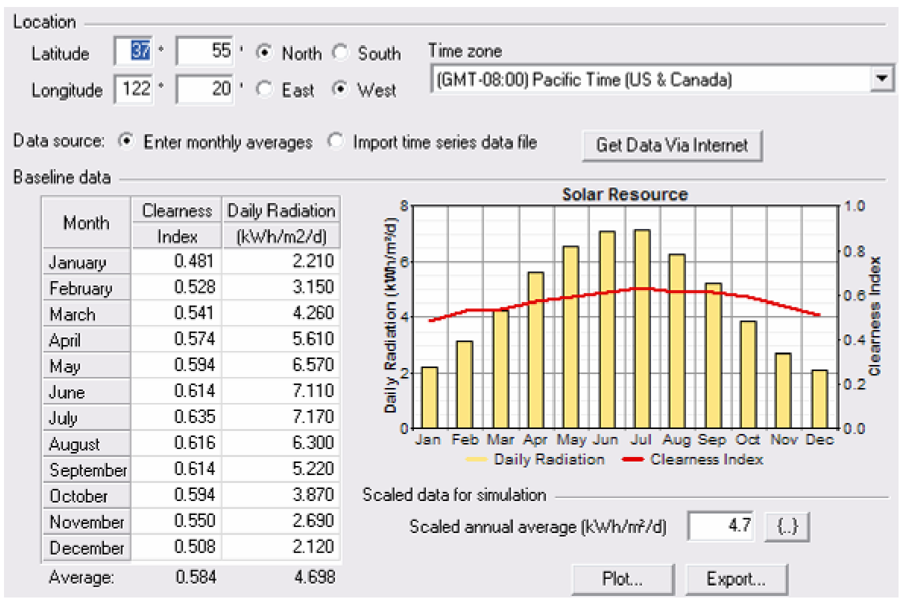
2.5 Solar Resource

The solar resource was estimated using NASA's Surface Solar Energy Data Set. This site provides monthly average solar radiation data as well as an estimated clearness index for everywhere on earth.

HOMER defines these quantities as follows:

- The clearness index is a measure of the clearness of the atmosphere. It is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the Earth. It is a dimensionless number between 0 and 1, defined as the surface radiation divided by the extraterrestrial radiation. The clearness index has a high value under clear, sunny conditions, and a low value under cloudy conditions.
- The daily radiation represents the average global solar radiation incident on a horizontal surface, expressed in kWh/m², for each hour of the year.

With these data, the performance of a photovoltaic array can be calculated within HOMER. The HOMER solar resource model is shown below.



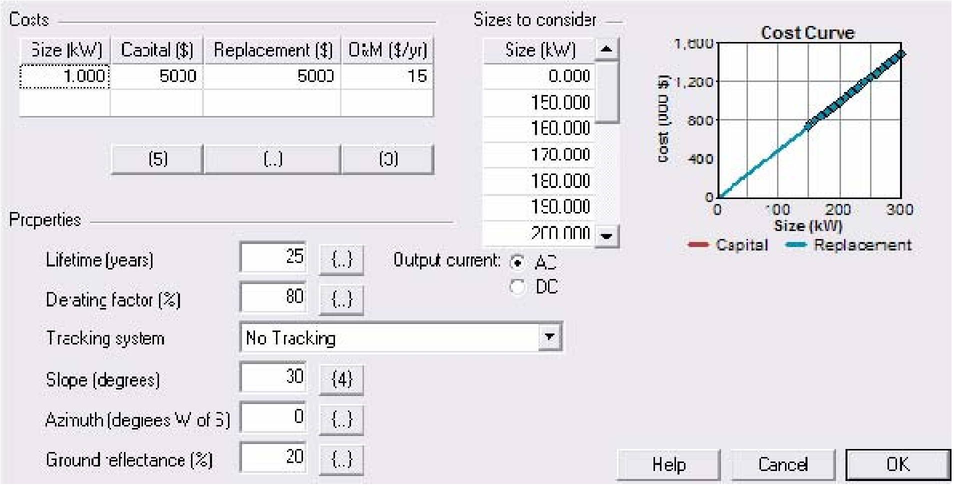
<u>2.5 PV System</u>

The profitability of a solar photovoltaic (PV) system depends on the solar resource described above as well as the assumed costs (capital cost, O&M cost and replacement cost), efficiency and size of the installed system. We assume a project lifetime of 25 years.

For the present study, an installed capital cost range from \$5.00 to \$8.00/W was assumed. A panel replacement cost of \$5.00/W was also assumed. All systems were assumed to be ground-mounted. The PV modules were also assumed to be fixed-tilt rather than tracking devices. A major benefit that PV has over wind power is the near-zero O&M cost for the fixed-mount design. An O&M cost range from \$15 to \$120/kW/yr was assumed for this study.

The derate factor reflects system losses due to DC-AC conversion, impedance mismatch, DC wiring, shading, soiling and age. A total derate factor of 80% was assumed because of the shading due to the trees. The ground reflectance is the fraction of solar radiation incident on the ground that is reflected. A ground reflectance of 20% was used (usual value for dirt and grassland areas).

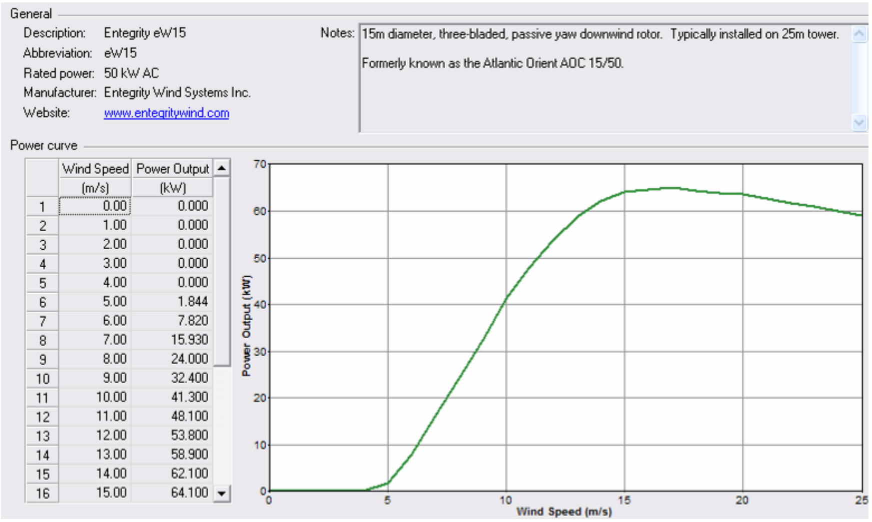
Each PV system was assumed to be mounted facing south at a tilt angle that we made vary in order to maximize production throughout the year. All of the above assumptions are summarized in the HOMER PV system model screenshot shown below.



2.7 Wind Turbines

For this study, one or several 50 kW machine(s) was considered the most applicable, given the space available.

The turbine modeled for this study is the Entegrity eW15. The power curve of this turbine (as well as a few key statistics) is shown below.



For this study, and installed cost range of $4.00 to $5.60/W was assumed.

Replacement costs will be on the order of 2/3 of the original capital costs, as some of the major components of the installation (e.g. concrete work) do not need to be replaced. In addition, O&M were assumed to be about $0.10/W.

3.2.4 Solution and Proposal

Based on the PV system design modeled from input parameters and the requirements and preferences of Field Station shareholders, we found that a stationary, 200-kW with a 15-degree tilt would optimally balance electricity production, capital costs, and payback time. See the table below for key cost and production values for this system:

Power (kW peak)	200
Renewable System Capital Cost ($)	1,400,000
Renewable System Power Generated (kWh/yr)	301,188
Cost of Avoided Energy from Grid ($/yr)	37,716
Annual System O&M Cost ($/yr)	3,000
Renewable Energy Credit From CSI ($0.5/kWh for 5 years)	150,594
Annual System Savings	34,716
Cost of Energy from PV ($/kWh)	0.0959

Assumptions: System cost = $7/W; O&M cost = $15/kW (industry standard)

	Without subsidies	With subsidies
IRR	-3.38%	1.88%
Simple Payback time (years)	40	19
NPV	-$956,213	-$321,856

Because of the potential barriers to the installation of a rooftop PV array, a second set of scenarios was run to find the optimal size for an ground-mounted system located in a field adjacent to the west side of B400. We found that a 200-kW system with a 38-degree tilt and horizontal, single-axis tracking system provided the best balance of price and productivity. See the table below for key cost and production value for this system:

Power (kW peak)	200
Renewable System Capital Cost ($)	1,600,000
Renewable System Power Generated (kWh/yr)	338,836
Cost of Avoided Energy from Grid ($/yr)	40,931
Annual System O&M Cost ($/yr)	4,000
Renewable Energy Credit From CSI ($0.5/kWh for 5 years)	169,418
Annual System Savings	36,931
Cost of Energy from PV ($/kWh)	0.1007

Assumptions: System cost = $8/W; O&M cost = $20/kW (industry standard)

	Without subsidies	With subsidies
IRR	/	1.29%
Simple Payback time (years)	43	20
NPV	-$1,127,898	-$414,248

We recommend that, if feasible, the 200-kW rooftop system be the primary option for the installation of a PV system on B400. Should the roof be unavailable for installation, the 200-kW ground-mounted system is the next-best choice.

3.2.5 Impact and Significance

Using the projected annual electricity generation from the optimal HOMER model and the grid greenhouse gas signature values as determined by eGRID, the total reduction in greenhouse gas emissions (in t CO2e/yr) is calculated by the following method:

Greenhouse gas emissions reduction = Projected renewable electricity generator (kWh/yr) x 858.379 g CO2e/kWh x 1 t CO_2e/ 1,000,000 g CO_2e

Inputting the projected energy generation from the optimal HOMER scenario (301,188 kWh/yr), we find that the proposed design with offset approximately 12% of the building's electricity demand and 260 t CO_2e/yr over the lifetime of the system. The 2007 CalCAP report found that, in 2006, purchased electricity accounted for 65,000 t CO_2e in campus emissions. Installing the recommended renewable generation system at the NRLF would then reduce the campus electricity carbon footprint by 0.4%. In the context of overall campus carbon footprint, the offset 260 t CO_2e/yr would amount to a 0.05 to 0.12% reduction in impact.

The worth of an installed PV system at B400 cannot be entirely captured by electricity costs and abated carbon values. Renewable energy systems in general, and solar panels in particular, have a cachet and iconic value that is not easily quantifiable, yet is nonetheless beneficial to system owners. The installation of these panels will improve public perception of the Richmond Field Station, and will serve as an important step in its further establishment as a hub for energy and environmental research and development. Furthermore, a highly visible and sizeable photovoltaic system at RFS would be a concrete, if incremental, step toward reducing campus emissions that carries a symbolic and educational value beyond its strict carbon mitigation impact; this kind of project signals UC Berkeley's strong, ongoing commitment to finding practical and creative solutions to our climate impact, and helps reinforce public recognition for the University's leadership, in terms of both research and action, on energy and climate issues.

3.2.6 Recommendations

In our meetings with John Felling, Facilities Manager at RFS and Scott Shackleton, Assistant Dean, Facilities and Capital Projects, we discussed the potential for future investment and deployment of renewable energy systems at RFS. Dean Shackleton emphasized that a master planning process is beginning for the RFS campus; many structures are likely to be replaced, and a comprehensive approach to energy generation, delivery and management will need to be developed. The RFS might soon host a hydrogen fueling station for new vehicle prototypes being tested by researchers and local municipalities, among other energy-related initiatives. In this emerging context, there will be many opportunities for implementing more energy-efficient technologies, expanding onsite power generation, and building a platform for innovative hands-on energy research by UC faculty and students. There will also be a significant public educational value in moving RFS in this direction, as positioning the research campus as a leading model/practitioner in the emerging "clean technology" arena will signal UC Berkeley's leadership role in driving innovation and addressing the environmental impacts of energy use.

Some strategies that merit further examination for possible implementation at RFS might include:

- Natural gas-powered microturbines for onsite generation in larger, energy-intensive RFS facilities.
- A high-efficiency cogeneration plant, sized to anticipate future expansion at RFS, that can use waste heat for district heating applications on densely occupied parts of the campus.
- Collaboration with researchers at Lawrence Berkeley National Laboratories, who are developing and testing micro-grid systems with innovative power control strategies. RFS would be an ideal scale application for one or more micro-grids, powered by a mix of renewables and reciprocating engines, and even fuel cells. For example a micro-grid could have a fuel cell alternatively charged by photovoltaics and building-mounted vertical-axis wind generators. Micro-grids could also incorporate microturbines or biodiesel-powered generators. These systems offer reliability and local recovery and use of waste heat for onsite applications. Operating such a system would not only provide power for some RFS buildings but also offer a valuable research opportunity for UC Berkeley engineering faculty and students on important emerging technologies.
- Alternative, highly efficient chilling systems utilizing passive thermal strategies (for example, designs based on Trombe wall thermal mass principles, or solar desiccant cooling systems) for future phases of the NRLF expansion.
- Testing of new photovoltaic products, such as thin film cells built into building siding and roofing tiles. Again, valuable power production could happen simultaneously with valuable testing, data collection and research.
- The Renewable and Appropriate Energy Laboratory (RAEL), directed by Professor Dan Kammen at UC Berkeley, has a facility at the RFS that is initiating a small wind turbine testing operation, and a solar cell testing project, among other renewable energy projects. RAEL could be a source of expertise and student involvement in designing, implementing and testing future energy systems at RFS.
- Engaging tenants in collaborative, innovative energy system development. For example, Schlumberger is a prominent corporation that develops oil and gas exploration technology, and it has leased space on the RFS campus for several years. According to Dean Shackleton, Schlumberger is interested in a long-term presence at RFS. It also has a stated commitment to "develop global energy systems with lower greenhouse gases"; it is one of four corporate partners providing $225 million of funding over the next decade to the Global Climate and Energy Program at Stanford University. The master planning process at RFS could involve tenants such as Schlumberger and the EPA to secure financial support for the deployment

Section 4: Overcoming Barriers

4.1 Regional Context

4.1.1 Summary

With the advent of AB 32, the *California Global Warming Solutions Act*, the regions of California are beginning to team up to take action against climate change and make a global statement. It is now the responsibility of players such as UC Berkeley to engage at both the regional level and with the greater community on this shared environmental issue.

The authors recommend that UC Berkeley engage on Regional Level with CARB and Bay Area Politics. This means:

- Engage in high-level policy and partnership discussions with other regional bodies.
- Consider regional impacts of climate chance, sea rise and temperature increase on campus facilities and work with regional bodies on solutions.
- Look for tangential avenues on the periphery to learn and share techniques and best management practices.

4.1.2 Activity in the Bay Area Region

In 2007, California passed AB32, *California Global Warming Solutions Act*, setting in place a legally binding target to reduce California's GHG emissions to 1990 levels by 2020. This is equivalent to a 25% reduction from projected levels on business-as-usual emissions. The legislation was the first of its kind – the first legally binding emissions cap in the world, giving California a platform for addressing some of the goals set forth in the 1997 Kyoto agreement which the United States signed but failed to ratify as a nation. The goal of the Kyoto agreement was to work toward the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

AB32 introduces a state-wide program of regulatory and market mechanisms to achieve real, quantifiable, cost-effective reductions of Green House Gas (GHG) emissions. By January 2008, the California Air Resources Board (CARB) must establish what the 1990 emissions levels were, along with a "Scoping Plan" for achieving the maximum technologically feasible and cost-effective reductions in GHGs from sources or categories of sources by 2020. This plan will identify significant sources of GHGs within the state and create regulations for establishing a mandatory monitoring and reporting system for these sources.

This puts the Bay Area region in an exceptional position as it is one of the few urban areas in California with both a significant climate footprint and a Regional Air Quality Board in charge of monitoring federal and state criteria emissions. The Bay Area Air Quality Management District (BAAQMD) is the local board charged with backing up the standards set by CARB, and according to Jean Roggenkamp,[85] they are leading the way in addressing climate change on a regional level. On June 1, 2005, the region adopted a climate protection program. It is anticipated that the BAAQMD

[85] Personal Interview, October 2007.

will eventually have regulatory oversight of emission levels and offsets upon finalized scoping by CARB.

More recently, this has materialized in a Joint Policy Committee (JPC), as state mandated collaboration of the regional Council of Governments (COGs) with the air quality districts. In the Bay Area, this involves the Metropolitan Transportation Commission (MTC), the Association of Bay Area Governments (ABAG), and, with some limitations, the Bay Conservation and Development District (BCDC). Although this is not unlike other areas of the country, such as the regional initiative formed by the Northeastern and Mid-Atlantic states called Regional Greenhouse Gas Initiative (RGGI), the backing of AB32 targets give it special credence.

4.1.3 Current Situation

Currently UC Berkeley, although a regional stakeholder, does not have a seat at the table in these regional efforts to reduce climate emissions. This JPC has been able to assemble the representatives from all cities and counties region-wide to address these regionally-unifying and cross disciplinary issues. Their May 2007 *Bay Area Regional Agency Climate Protection Program* has set regional priorities and goals that are both important and highly significant to the University of California within the region. They have cooperated in an ad-hoc manner that has put prior debate of regional politics to rest, working to create a new regional plan, with regional goals for particulate matter and for climate change, pricing schemes, and land use scenarios.

Some of the immediate action items for the Joint Policy committee include forming teams to address how climate chance should be factored into the regional California Environmental Quality Act (CEQA) documents and what the immediate impact of the anticipated 1 meter of sea rise will mean to the Bay Area in coming years. These discussions are highly relevant based on the future strategic investment for the University system. In an October 5, 2007 memo to the BCDC commissions and alternatives, Executive Director Will Travis, estimated that "continued sea level rise from global warming will have profound impacts in the San Francisco Bay region, largely because over 200 square miles of low-lying filled land borders the Bay." These impacts could have profound implications on locations such as those in Richmond (see graphic below), and based on those involved from regional organizations, these policy-based discussions should be entered into at the highest possible level (provost or vice-provost).

Source: BCDC, 2007

4.1.4 Recommendations and Potential Impact

We recommend that UC Berkeley's leadership, at the provost or vice-provost level, engage with CARB and Bay area leaders to determine how best to connect UC Berkeley's climate initiatives with regional climate initiatives. Activities would include:

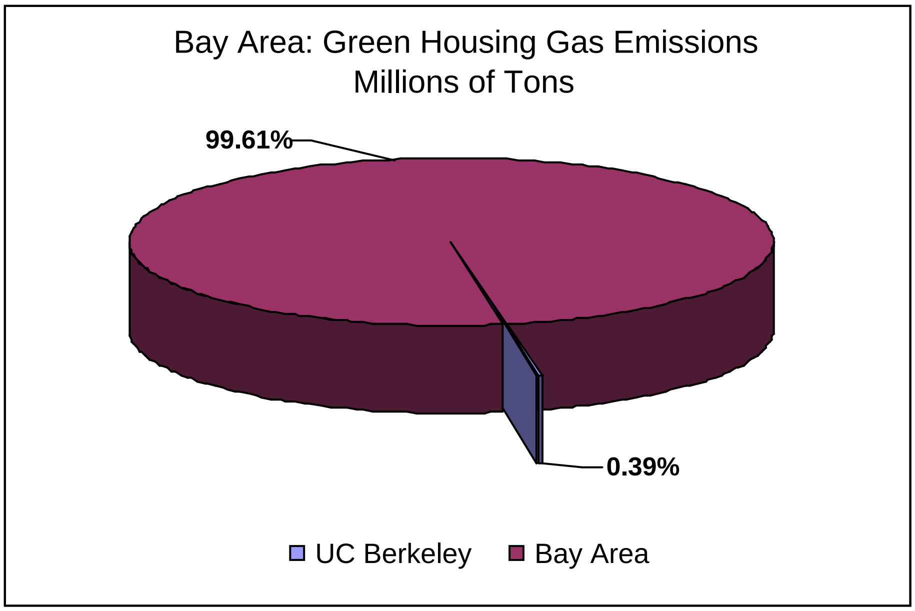
- Engage in high-level policy and partnership discussions with other regional bodies.
- Consider regional impacts of climate change, sea rise and temperature increase on campus facilities and work with regional bodies on solutions.
- Look for tangential avenues to learn and share techniques and best management practices.

For UC Berkeley this means the opportunity:

(1) To engage in making regional strides to reduce GHG emissions;
(2) To form partnerships and assume a role in climate action efforts in the region (How the university can better help and what specific role(s) it can play.);

(3) To give attention to the positive strides UC Berkeley is making to reduce its GHG emissions, and;
(4) Provide a broader global context to UC Berkeley's current initiatives, by showing that the University fits into the regional community initiative as a larger piece of reducing the impact on the climate.

For the Bay Area region this means that the efforts of UC Berkeley would be included within the regional context. The region has approximately 54 million tons of emissions to grapple with, of which UC Berkeley's regional share is less that 1%.



The region stands to gain:

(1) Access to UC Berkeley and furthered platforms for sharing best practices;
(2) Access to information on other UC Berkeley efforts on climate change including community, transportation, and how the university is documenting our emissions;
(3) Increased marketability of the entire region to the larger global forum and creation of a policy window for others to emulate. As the region gains national and even global political share, the opportunity for impacting change and global paradigm shift increases.

4.2 UC Berkeley's Building Process

4.2.1. Summary

UC Berkeley currently utilizes a detailed process for planning and executing capital projects, beginning with concept approval and budget development and proceeding into schematic and design development. While some stages in this process already serve as potential touch points to ensure efficiency and sustainability in building projects, there are several areas which could be improved.

The authors recommend the following to improve UC Berkeley's building design roadmap:

- The Capital Projects Division and CalCAP should work together to divvy up responsibility for all the actions necessary to make buildings more sustainable, including: *Whose job is it to educate users about sustainability? Who needs to make what policy changes and whose job is it to push for them? Etc.*
- Explicitly make long term University carbon goals a part of the process by which buildings are designed and evaluated.
- Make specific tweaks to the building design "roadmap" to ensure that knowledge of green building features, knowledge of green funding sources, and knowledge of University carbon goals are included.

4.2.2. Problem Statement

Over the last several years, the capital projects and building processes at UC Berkeley have improved to better incorporate green, high-performance building practices. However, additional work must be done to improve integration of green building practices and to ensure that building goals are explicitly linked to campus climate goals from the beginning of each project.

4.2.3. The Current Campus Building Process

In order to think clearly about ways to make campus buildings greener, it's important to note that many former barriers to green building have *already* been reduced or removed. The campus has made great strides over the past few years in incorporating green building principles and energy efficiency into building design.

In 2004, the UCOP issued its *Policy on Green Building Design And Clean Energy Standards*, outlining UC's commitment to build more sustainable buildings and procure more clean energy. The most important building-related provisions in this document are:

- **New buildings 20% above Title 24** - All new buildings (except acute care facilities) must exceed the California Energy Code (Title 24) energy efficiency standards by at least 20%
- **New buildings must achieve LEED Certified equivalency** - All new buildings (except acute care and lab facilities) must be built to a minimum standard of LEED 2.1 Certified

- **New buildings should strive for LEED Silver equivalency** – UC campuses will strive to achieve a standard equivalent to LEED Silver, if possible within program needs and the standard budget constraints
- **Special consideration of labs and acute care facilities** - All new lab facilities must be built to the standards of LEED 2.1 Certified rating and the *Labs 21 Environmental Performance Criteria*. Also, further study will be conducted to determine a standard for acute care facilities
- **Sustainability in renovations** - Any significant renovations to existing buildings must also apply sustainability principles to the section being renovated
- **Adopt lifecycle costing** - University planning and design practices will include explicit consideration of lifecycle costs.
- **Train facilities personnel to utilize these policies** - The Green Building Design Policy will be incorporated into existing facilities-related training programs

These policies have worked their way into the official contract requirements for UC Berkeley building projects. One of the most important documents is the *Executive Design Professional Agreement*, which is the contract between the UC Regents and the Executive Architect or Engineer in charge of a project. One part of this agreement restates verbatim the same policy points listed in the UC Green Building Policy. (See Exhibit C 1.5 "Energy Analysis" in the *Executive Design Professional Agreement (EDPA), Version A, Exhibits*).

A third important document is the capital project process "roadmap" at UC Berkeley consists of eight phases, beginning with the creation and review of the initial building concept and concluding with construction of the final building. (See Appendix 4.1 Capital Projects Roadmap, or the "Project Approval Process" web page hosted by the UC Berkeley Capital Projects Division, for a detailed explanation of the process.) An overview of the eight phases are listed below.

Overview

- Phase 1 - Concept review
- Phase 2 - Feasibility analysis
- Phase 3 - Program development
- Phase 4 - Schematic design
- Phase 5 - Design development
- Phase 6 - Working drawings
- Phase 7 - Bid and award
- Phase 8 - Construction

Of these, Phases 1, 2, and 3 are the most important to the sustainability of a building, since they set the direction of the project and the criteria by which it will be evaluated.

The fourth important set of documents that implement UC Berkeley's sustainability commitments is the Sustainability and Green Building Baseline, which is part of the Construction Design Standards set by the Capital Projects Division. These documents define the "standard" campus practices for building design as being equivalent to LEED Certified. Any project which follows standard campus practices will, by definition, meet these requirements.

The Green Building Baseline is almost an exact copy of LEED, utilizing a credit system and focus areas such as Sustainable Sites, Water Efficiency, and Energy & Atmosphere. Each focus area has prerequisites that must be met, required measures for which credits are awarded, and optional measures which may be implemented for additional credits. The *Campus Green Building Baseline Substantiation* document provides a clear description of each credit, including the documentation requirements, verification procedures, and a reference to the original LEED credit from which it was derived.

One important point to note is that the campus Green Building Baseline requirements have been *interpreted* from the original LEED requirements. Some building practices deemed "equivalent in intent" to the original LEED credit may not actually meet the formal LEED requirements for the credit (*Campus Green Building Baseline Substantiation*, p.ii). However, in practice it is unclear whether or not this makes much of a difference in the final delivered sustainability of a particular building project.

Finally, the Green Building Baseline document even contains a description of how to incorporate pursuit of sustainability credits into each phase of the capital project roadmap – Concept Phase, Feasibility Phase, etc. (*Campus Green Building Baseline Substantiation*, p.iii).

4.2.4. Recommendations – Ways to Improve the Building Design Process

The primary recommendation is for CalCAP to work with the Capital Projects Division to make building sustainability an integrated part of UC Berkeley's carbon reduction strategy.

A key part of this process will be clearly delineating responsibilities for the key actions needed to make buildings more sustainable. Based on interviews with various parties and the general sense of this section's authors, the following paragraphs and sample quotes may best describe the situation:

- **Capital Projects** feels that they are primarily responsible for executing a building design, not creating one. While Capital Projects has some leeway to advocate for green building features, it's the user's responsibility to specify a sustainable building if they really want one.

  Our main responsibility is to execute the building plan that the users ask for. We push for sustainability when we can, but we can't force it upon the user. The users should be the ones requesting more sustainable buildings.

- **Project sponsors** (such as the dean of a college which needs a new building) feel beholden to the wishes of the building occupants – faculty and students. Sustainability is nice, but if faculty demand air conditioning and students are apathetic, green building will not be a priority.

  I want sustainable buildings as much as anyone else, but I am completely beholden to the building occupants – the faculty and the students. If star faculty members demand air conditioning rather than passive cooling, I can't refuse them. Plus, I have to stay in budget.

- **Building occupants and students** feel that it's not their responsibility to know all the complexities of green building. They also don't often don't understand how, when, and to whom to express their preferences for campus buildings.

Why don't University administrators be responsible and make the buildings sustainable? I'd support that. I think I remember hearing that there was some building committee meeting last week, but I had an exam. My teacher had two research proposals due on Friday, so I don't think she went either.

All three of these viewpoints are quite valid and understandable. However, each of these viewpoints also creates a circular "passing the buck" effect. The challenge is for CalCAP, the Facilities Division, and other sustainability advocates on campus to work together to explicitly agree on whose job it should be to address which issues within the process and among project sponsors, building occupants, faculty, and students. In particular, educating building users to gain broad acceptance of sustainability features, and to encourage them to express their views to the department heads who often make the decisions, are critical tasks.

In the meantime, there are things that can be done immediately to better integrate CalCAP goals into the building process and to maximize the sustainability features in each building project. The list below describes various stages of the capital project approval process and explains possible improvements. The phases referenced below are the eight phases (and respective sub-phases) of the road map.

Phase 1.3 – *Sponsor, in consultation with planner, prepares Abstract of proposal: project objectives, justification, alternate solutions to consider, and proposed source(s) of funds.*

Recommendation: Briefly acquaint sponsor and assigned campus planner with green building options, possible funding sources for building sustainability features, and the way in which buildings fit into progress toward CalCAP targets.

This is earliest opportunity for the sponsor and planner to identify project objectives and sources of funding, so it's the place to get sustainability in on the ground floor. The discussion of green options and opportunities should be very brief at this preliminary stage – just enough to get the sponsor and planner thinking.

The green building steps needed in Phase 1 "Concept", according to the Green Building Baseline may be sufficient to introduce green. (See *Campus Green Building Baseline Substantiation*, p.iii) CalCAP should ensure that this is the case. The Baseline document does *not* say anything about UC Berkeley-wide carbon targets, so this definitely needs to be added.

Phase 1.4 – *Campus planner manages Policy Review, including conformance with 2020 LRDP, and consults with VCs for Administration and University Relations on funding strategy.*

Recommendation: Evaluate the building for conformance with CalCAP, just as it is evaluated for conformance with LRDP. Also, make sure that VCs for Administration and University Relations, who handle funding, are tuned in to any particular needs or opportunities for sustainability measure funding.

In particular, this might be a good place to present more details regarding creative financing strategies proposed in section 4.4 of this document.

Phase 2.1 *– Facilities Services prepares work plan for Phase 2: scope, timeline, staff budget and, if required, consultant services and budget.*

Recommendation: Ensure that budget and timeline allocates the necessary resources (money and *planning time*) to do a good job of evaluating sustainability features for the project and making sure that the building design contributes to CalCAP carbon goals.

A key part of this planning might be developing a strategy for the "user education" necessary to generate buy-in for sustainability features with project sponsor and the building occupants he/she represents. While the Capital Projects Division has some discretion to advocate for sustainable building design, they are essentially charged with executing the building plan ultimately decided by the sponsor. Therefore, educating building project sponsors is essential.

Phase 2.2 *– Sponsor (VC, VPAPF) may appoint Preprogram or Working Committee.*

Recommendation: Ensure that the working committee has the resources to understand (a) green building options, (b) options for funding sustainability features in buildings, and (c) the University's carbon goals.

The building process may already include someone on the committee from Capital Projects who would have sufficient knowledge of green building and possibly knowledge of funding options. It is important to add familiarity with specific carbon goals, either by adding a CalCAP-appointed committee member or specifically educating an existing member.

Phase 3.6 *– As concept plans develop, Facilities Services reviews project for conformance with design guidelines, sustainability policies, regulatory requirements and other commitments.*

Recommendation: Ensure that CalCAP carbon targets are explicitly considered in addition to the other sustainability policies. It may be worthwhile for the resulting project plan to include *in writing* a paragraph describing how the building will fit into University carbon objectives.

If and when such changes are made, the website on the design process should be updated to make explicit to those reading it during which stages sustainability needs to be considered.

4.2.5. Potential Impacts

Firmly incorporating CalCAP's carbon reduction goals into the capital project approval process will allow CalCAP to more easily track and manage building-related carbon emissions. It will also give green building advocates in the Capital Projects Division more leverage to influence project sponsors toward more efficiency building practices.

Divvying up the responsibility for getting the various groups of project sponsors and building users to be more accepting of sustainable building features will help UC Berkeley staff better coordinate their efforts to reduce the carbon footprint from buildings on campus. Staff time is one of the University's most important resources, and so using it effectively is essential.

Making the proposed changes o the capital projects approval process will help ensure that project sponsors are engaged in making buildings more sustainable and aware of both the technical and funding opportunities.

It is difficult to quantify directly the carbon impact from these recommendations. If we posit that all these recommendations result in a modest 2% reduction in campus electricity use, that's a reduction of about 1300 metric tons CO_2e per year or about 0.6% of total University emissions, but over time the impacts of strategic changes to campus building procedures could be far greater. LEED Gold and Platinum buildings routinely approach 50% reductions in energy use.

4.3 Externally Verified Standards for Green Buildings

4.3.1. Summary

The University currently uses an internal "LEED equivalent" standard for the energy and environmental performance of its building projects. However, an external standard has many benefits, both in terms of the campus itself and in terms of integrating into regional carbon-reduction initiatives.

The authors recommend that the campus pursue some sort of externally validated standard for green buildings on campus, including the following steps:

- Adopt LEED with an emphasis on energy and carbons efficiency to limit "point chasing."
- Evaluate other standards and recognize a constantly shifting market that may need re-evaluation in the future as the region and nation experience a political paradigm shifts.
- Reassess policies per policy memo within 2-3 years and continue to promote active and livable communities.

4.3.2. Problem Statement

The current campus practice of "LEED equivalence" helps make UC Berkeley's buildings more sustainable, but fails to achieve many of the other benefits of actual certification via an external green building standard.

4.3.3. Current situation

As mentioned earlier, the campus requires that all new buildings adhere to an internal Green Building Baseline which is roughly equivalent to LEED Certified. In addition, campus encourages all buildings to strive for sustainability performance equivalent to LEED Silver, when feasible.

Institution	Certifed	Registered	Referenced elsewhere	Total	Source
Harvard	3	1	3	7	1,2,3
Radcliffe	1			1	1,2
Yale	2	1		3	1,2
Duke	4	3		7	1,2,4
UC Berkeley	0			0	1,2
Columbia	0	2	3	5	1,2,6,7
MIT	0		4	4	1,2,8
University of Pennsylvania	0		1	1	1,2,5
California Institute of Technology	0	1		1	1,2
Princeton	0			0	1,2
Stanford	0			0	1,2
UC Office of the president	1			1	1,2
UC Santa Barbara	1	23		24	1,2
UC Merced	2	1		3	1,2
UC Irivine	1	1		2	1,2

Notes

The "Certified" column indicates number of buildings at each institution which appear in LEED's online database of certified buildings. The "Registered" column is for non-certified buildings registered in LEED's project database.

The "Referenced elsewhere" column indicates buildings which could not be found in LEED's databases but which are (a) described in other sources as LEED certified, or (b) described in outher sources ass planning to seek certification.

Sources

[1] LEED certified projects directory at <http://www.usgbc.org/LEED/Project/CertifiedProjectList.aspx>

[2] LEED registered projects directory at <http://www.usgbc.org/LEED/Project/RegisteredProjectList.aspx>

[3] "Update on Harvard Green building Projects" at <http://www.greencampus.harvard.edu/newsletter/archives/2005/05/update_on_harva.php>

[4] "Duke's Green building Efforts Make Front Page News" at <http://www.duke.edu/sustainability/2007-07-16GreenBuilding.html>

[5] "How Green is Our Center" at <http://www.upenn.edu/gazette/0707/gaz10.html>

[6] "LDEO Building Seeks LEED Certification" at <http://www.environment.columbia.edu/news/Geochembldg/index.html>

[7] "Columbia and the Environment." 16 Apr 2007. The Record. At <http://www.columbia.edu/cu/record/archives/3211A.pdf>

[8] "Green Building Task Force (GBTF)" at <http://web.mit.edu/ENVIRONMENT/commitment/gbtf.html>

Currently, our campus has no LEED certified buildings, nor buildings certified as sustainable by any other external standard. We lag significantly behind many of our most important peers by not having an external certification for our green buildings.

To best consider the different options for external certification of buildings, it is important to understand some common critiques of LEED. First, LEED has been criticized for encouraging "point mongering," in which projects implement cheap, but meaningless, sustainability measures in order to accumulate enough credits for certification. The following quote sums this up nicely.

> In a recent building, we received one point for spending an extra $1.3 million for a heat-recovery system that will save about $500,000 in energy costs per year. We also got one point for installing a $395 bicycle rack. This must be corrected.
>
> *---quote from Green Building Alliance survey on LEED, quoted in Oct 2005 Grist article by Schendler and Udall*

Between the time of the quote and the present, LEED has continued to evolve its credits to reduce opportunities for and impacts of point mongering. However, users of LEED should be cautious. (In the following section, we recommend that rigorous internal standards at UC be combined with the LEED guidelines to avoid this.)

Another common criticism of LEED is the cost of certification. To avoid confusion, it is helpful to understand that the costs of LEED generally fall into two categories. The first category is the incremental construction cost of a more sustainable building. The remaining costs are sometimes referred to as "soft costs," and include the cost of extra design work, commissioning, documentation, energy modeling, LEED registration, and final certification (Northbridge 2003).

<u>Incremental construction costs</u>
The additional construction cost involved in building a greener building than would have been built otherwise. These costs come from the premiums paid for more efficient lights and HVAC equipment, better insulation, improved controls, etc.

<u>Incremental design costs</u>
These costs account for the additional time and effort it takes for architects and engineers to design a more sustainable building.

<u>Commissioning</u>
Commissioning ensures that building systems perform as designed. Building commissioning is one of the most cost-effective ways of improving the energy efficiency of buildings (Mills et al 2004, p.58). Even critics of LEED admit that building commissioning (which LEED requires) *should* be a part of an organization's standard building practice (Schendler and Udall 2005).

<u>Documentation</u>
There are substantial costs associated with documenting that sustainability features in a building have actually been implemented.

<u>Energy modeling</u>
Energy modeling is another requirement for LEED certification. This step involves simulating the performance of the building's "business as usual" design vs the performance of the more efficient design seeking certification.

<u>Registration costs</u>

There is a fee to register buildings with the LEED program. For non-USGBC members, this fee is $600 for all buildings (USGBC 2007).

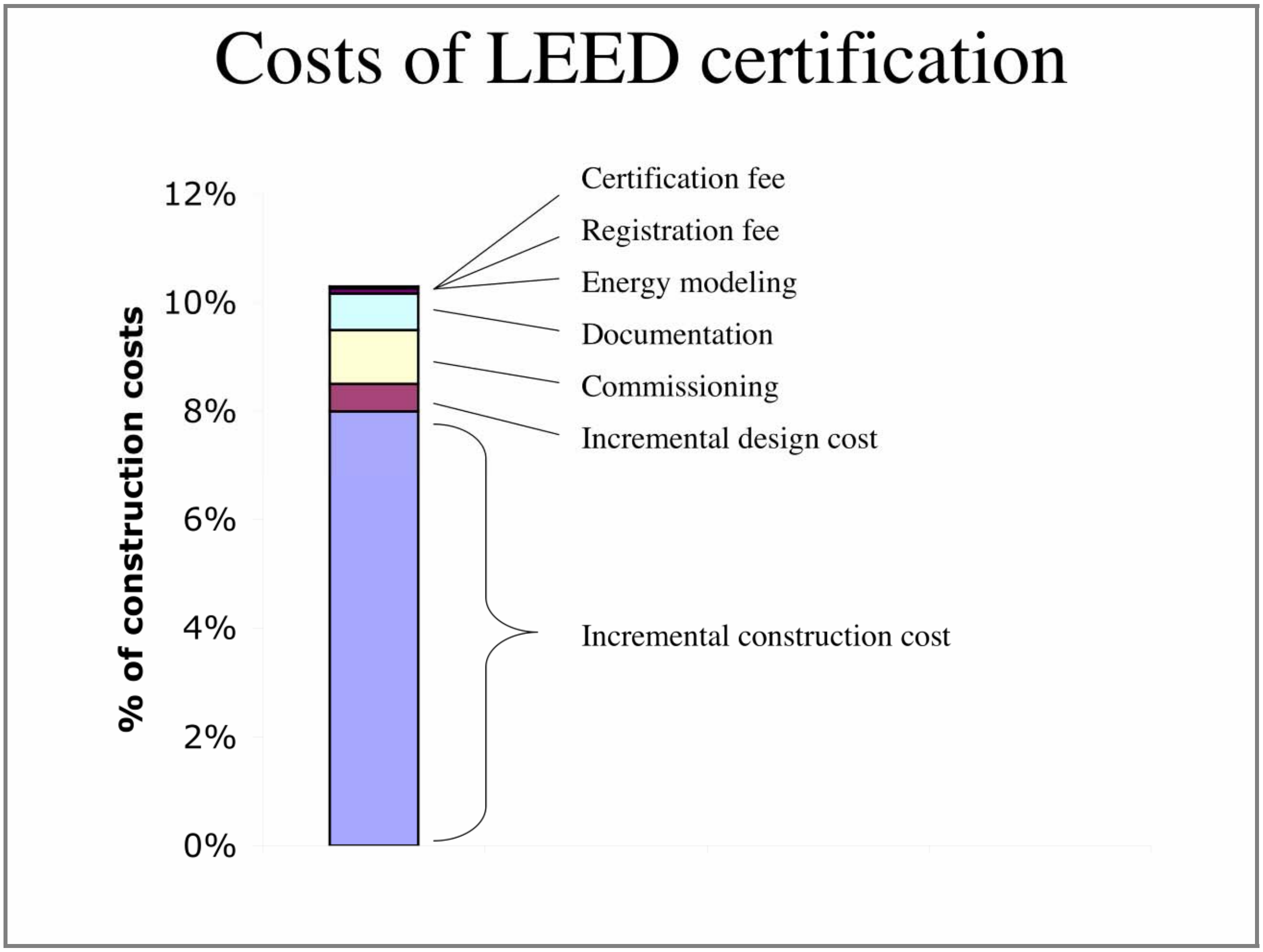
Certification costs
This is the fee paid to the LEED program for final certification of a building. This cost varies by square footage from a minimum of $2,250 for buildings 50,000 sq ft and less, up to a maximum of $22,500 for buildings of 500,000 sq ft or more (USGBC 2007). (Again, this cost is for non-USGBC members.)

The table and graph below show the estimated magnitude of the costs for LEED certification. Alternate external green building standards (such as Green Globes) may have slightly different costs, but the structure is likely very similar.

Estimated incremental costs of LEED buildings

	Point estimate [2]	Range	$ estimate [3]
	%	%	$
Incremental design costs	0.5%	0.4 - 0.6%	$75,000
Commissioning	1.0%	0.5 - 1.5%	$150,000
Documentation	0.7%	0.5 - 0.9%	$99,900
Energy modelling	0.1%	0.1%	$15,000
Registration fee	~0%	~0%	$600
Certification fee	~0%	~0%	$4,500
Total soft costs	2.3%	1.5 - 3.1%	$345,000
Incremental construction costs [4]	8.0%		$1,200,000
Grand total additional cost	**10.3%**		**$1,545,000**

Notes
[1] Source: (2003). Northbridge Environmental Management Consultants. Analyzing the Cost of Obtaining LEED Certification. P.6
[2] Incremental costs expressed as a % of contruction costs
[3] Dollar estimate assumes a 100,000 sq ft building project at $150 / sq ft
[4] Incremental construction costs assumed to be 8%. Source in [1] above states that green building can add around 4-11% to a projects construction costs, more than half of which is for green building features. (p.2)



It is also important to note that LEED is not the only external standard. There are other standards that could be used as external validation as well. The table below lists some of these other standards with a few of their pros and cons.

Rating Body	Website	Pros	Cons
Build it Green	http://www.builditgreen.org/		▪ Focus mainly on homes. ▪ Mainly local recognition and brand
Energy Star	http://www.e-star.com/index.html	▪ Nationally recognition ▪ Well-branded.	▪ Focus mainly on homes.
Green Globes: The Green Building Initiative	http://www.thegbi.org	▪ Specifically focused on climate change using the Athena EcoCalculator for Life-Cycle Analysis ▪ Flexible and verified by a third party.	▪ Worldwide Recognition ▪ Increasing brand recognition and market share ▪ Average of $4,000 to project costs. ▪ All online and require no special certification
Leadership in Energy and Environmental Design: The US Green Building Council	http://www.usgbc.org	▪ Worldwide Recognition ▪ Strong brand	▪ Average 2 to 3 percent of the total building cost. ▪ Inflexible system ▪ No onsite verification.
One World Standards	http://www.oneworldstandards.com/	▪ Worldwide Recognition	▪ In development.

4.3.4. Recommendations

We recommend that the university move from "LEED equivalence" to actual LEED certification, with an additional internal standard to ensure that LEED credits are pursued for genuine sustainability impact. In addition, internal campus standards should be used for factors not addressed by LEED (such as plug loads). This would mean that all new campus buildings would be required to be LEED Certified, all new buildings should strive to be *certified* LEED Silver.

Further, the university should target an upcoming project as a high performance building that will attempt to achieve the LEED Gold or Platinum, or a similar high bar for performance, serve as a case study in campus green building performance, and act as a pilot project in the evaluation of the cost and potential of aggressive green building projects. See Stanford's Global Ecology Center, UCSB's Bren Center, Evergreen College's Seminar II building, or Oberlin's Adam Joseph Lewis Center as examples.

To avoid the problem of "point chasing," the CalCAP steering committee, the Capital Projects Division, the Center for the Built Environment, and other relevant bodies on campus should come together to identify *additional internal* rules the campus might adopt to ensure that meaningful LEED credits are selected as building projects pursue certification.

Also, the University might consider waiving the requirement for actual LEED certification for small buildings (and allowing them to fall back to the current practice of LEED-equivalence). Some of the costs associated with LEED remain relatively fixed regardless of building size, so for smaller buildings the cost of LEED certification could become relatively more burdensome.

4.3.5. Potential Impacts

There are many benefits to seeking actual LEED certification for green building on campus.

First, using external verification rather than internal verification demonstrates to project sponsors that the University is serious about meeting its green building goals, and that a minimal level of sustainable building is not discretionary (Judy Chess interview).

Second, LEED adds prestige to UC Berkeley, adding the high market recognition of the US Green Building Council as a level of external validation and credibility that Berkeley is taking great measures to reduce climate impacts. Many of Berkeley's peer institutions (Harvard, Yale, Duke) already have LEED certified buildings.

Third, such a standard would raise awareness on-campus, creating a more educated user and on-campus stakeholder, informing the quality of future project submissions.

Fourth, externally-validated standards have a level transparency to the buildings process at Berkeley.

Fifth, the common language of an external standard allows regional climate initiatives such as the JPC and CARB to more easily understand what UC Berkeley is doing and to integrate our University's accomplishments into their regional plans. Compare the following two statements that leaders of a regional carbon initiative might make at a press conference:

> *We've got over 40 LEED certified buildings in the Bay Area, and UC Berkeley accounts for 5 of those.*

vs

> *Some places in the Bay do LEED, others in the Bay have their own definitions of green buildings, and UC Berkeley has its own standard which is sort of like LEED but better in some ways and maybe worse in others.*

Sixth, pursuing actual LEED certification might open up avenues for receiving funding to hire external parties to do the documentation and verification of sustainability features. Currently, these functions are handled by over-taxed Facilities staff.

Finally, the additional costs incurred by pursuing actual LEED certification are likely to be relatively small. As shown in the figures above, about 75% of the total cost of LEED certification is in the increased construction cost of a green building. UC Berkeley is *already* paying this cost, since the campus already has a LEED equivalence policy. The incremental design costs are already paid as well. (Note that this 75% is based on the assumption that the premium for green building is +8% to construction costs. If the extra construction cost is greater, it means that the extra "soft costs" incurred by pursuing actual LEED certification matter *less* than stated here.)

Two other substantial costs to LEED certification are those for documentation of green building features and building commissioning. The University is already paying most of these costs as well, since the LEED equivalence policy on campus includes these procedures. In fairness, the LEED documentation and commissioning procedures are almost certainly more expensive than the procedures currently used by UC Berkeley, but it's hard to imagine that these additional costs would be significant compared to what's already being paid. Also, there may be substantial benefit to following the more stringent LEED procedures. For example, *if* our documentation and commissioning procedures are cheaper because they're materially *weaker* than LEED's, then the University's buildings will be improved by adhering to the more rigorous standards.

Another cost of LEED certification is energy modeling. However, this cost is small, and the University may already be paying for energy modeling as part of its participation in the Savings by Design program.

Finally, the registration and certification fees paid to LEED are quite small relative to the other costs. If the University is already doing almost everything required for LEED certification anyway, it is well worth paying these tiny costs to "get the plaque" and the prestige that comes with it.

It is difficult to quantify directly the carbon impact from moving to a true LEED standard plus "no point chasing" provision. A recent New Buildings Institute study of over 140 LEED buildings found that the median energy use of LEED buildings was more 20% less than the average energy use of buildings in general measured by the DOE. Furthermore, it found that the higher the level of certification, the greater the energy savings were. Clearly the effects of any changes to policies that relate to new buildings will accumulate over time. If we posit that all these recommendations result in a modest 2% reduction in campus electricity use overall by 2014, that's a reduction of about 1300 metric tons CO_2e per year or about 0.6% of total University emissions.

4.4 Funding Options

4.4.1. Summary

To reach its CalCAP goals, UC Berkeley will need to identify and complete large-scale projects with great speed. It is unlikely that all of the improvements on campus, especially at a larger scale, will be funded through the existing capital budgets. The good news, however, is that UC Berkeley is eligible to apply for many pools of funding available for financing energy efficiency projects and/or renewable energy projects. As we learned from our case studies of other universities, financing may include a broad range of options, including but not limited to loans, grants, performance contracting, and bonds. Through our research, we have developed recommendations for the long-term financing of the CalCAP program.

4.4.2. Problem Statement

Given the magnitude and scale of projects that will need to be undertaken to meet our CalCAP goals as well as the tremendous opportunity to tap into available sources of external funding for these projects, both the appropriate human resources and a clear priority among project options are needed.

4.4.3. Current Situation

There are three broad categories of potential funding available for CalCAP projects: University funds, external funds, and donor funds. First, University funds, such as the $3.18 million in capital budget for FY06 to FY08, are a key part of CalCAP support. In addition, UC Berkeley is creating a revolving loan fund of $10 -15 million as part of the Capital Bank on campus. While this fund will not be restricted to energy-efficient projects, such projects would qualify for loans, and the energy savings they generate could be used to repay the fund.[86] Finally, the University may consider an energy efficiency bond to match PG&E partnership money. In general, UC schools do not have the political authority to issue a bond individually; approval from UC Regents will be required. The Vice Chancellor's Office, however, has been pushing the Office of the President to issue a system-wide "energy efficiency bond" that would fund Berkeley's portion of the PG&E Partnership projects and would be repaid from energy savings.[87]

Second, the University can also access external funds. From FY09 to FY14, UC Berkeley could apply for up to $50 million of PG&E Partnership money (see further explanation below in section 4.4.4.). Through the California Energy Commission's (CEC) Energy Efficiency Financing Program, Berkeley could also apply for a low-interest loan of up to $3million to cover feasibility studies and the installation of energy-saving measures.[88] Finally, Clean Renewable Energy Bonds (CREBs) are a financing option available for public sector renewable energy projects, and offer a 0% interest rate (the borrower pays back only the principal of the bond and the bondholder receives federal tax credits in lieu of the traditional bond interest).[89] As stated earlier, UC Berkeley must go through UC Regents in order to apply for a bond like the CREB.

Third, donor funds may help to cover important sustainability work that might not be otherwise funded. Case in point: consider the recent example of The Green Initiative Fund (TGIF). Last spring, a group of graduate and undergraduate students led TGIF, a student fee referendum for environmental sustainability that passed with 69% of voting student support.[90] By implementing a fee of $5 per student per semester, TGIF raises money (approximately $200,000 per year) with which to make grants for projects to improve campus environmental sustainability.[91] TGIF has raised $170,000 for FY07 – FY08, and they are working with CalCAP to ensure alignment in funding priority for initiatives that would also help to meet the CalCAP emission reduction targets. Beyond student donations, the CalCAP team has also been investigating the possibility of creating a CalCAP Donor Fund for alumni.

4.4.4. UC/CSU/PG&E Partnership Funding

Since 2004 UC Berkeley has been a member of a partnership with PG&E that gives UC Berkeley access to energy efficiency incentives, funded through the state public goods surcharge on electricity. These incentives are currently $0.24/ kWh and $1/therm, which are higher than the standard incentive rates. These funds have been used to support projects that have direct, measurable savings such as building retrofits, steam trap repair, and monitoring-based commissioning. Funds have also

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86 Personal correspondence with Nathan Brostrom, Vice Chancellor, Administration (12/03/07)
87 Personal correspondence with Nathan Brostrom, Vice Chancellor, Administration (12/03/07)
88 For more information on CEC funding, visit http://www.energy.ca.gov/efficiency/financing/index.html
89 For more information on CREBs, contact Tina Hill at the Internal Revenue Service at 202-283-9774.
90 The Green Campus Initiative. (n.d.) Retrieved from http://bigideas.berkeley.edu/node/34
91 *Ibid.*

gone to support training and education, and 2000 person days of training have been logged so far.[92] It is important to note that these funds can be used to find the salaries of the staff required to implement these projects.

In the 2006-2008 funding cycle UC Berkeley has used $2.5 million in project funding for a range of improvements on campus. Discussions are now going on to have the next funding cycle of 2009-2014 make $30 million available to Berkeley (though the per kWh/therm incentives may be lower), which would be matched by $20 million from the University. The program details are expected to be announced in Spring 2008 by PG&E.

UCOP is also in the process of working on putting together a low interest revolving loan fund to help the UC campuses pay for the 20-40% of project costs that the Partnership money does not cover. At UC Berkeley, this part of project funding must be approved by the Special Projects committee. Access to this UC-wide loan fund may potentially speed up the project funding process and lower the cost of capital. The details on the loan fund are forthcoming.

4.4.5. Donor funding

While UCOP may have additional funds to help cover the Human Resources needs for large-scale energy efficiency projects (especially those needed to take advantage of the PG&E partnership funds), renewable energy projects and/or other projects like behavior change still require funding. These areas are excellent candidates for donor funds.

CalCAP is investigating the option to create an alumni, Climate Action Donor Fund through the Development Office. Our concern, however, is that the resources necessary to manage a successful donor drive and the additional restrictions requested by donors may prove to be a distraction, especially at a time where there are some large buckets of money available for CalCAP application. Throughout our case study research, we were curious to see if other schools may have avoided the donor funding route for similar reasons. The perspective offered by staff at the Harvard Green Campus Initiative (HGCI) is insightful. To-date, donor money has not been a significant part of the HGCI's funding mechanism.[93] While the HGCI staff said that they may investigate donor funds in the future for projects with a longer payback (such as in renewable energy), they also noted that there are often political issues and another set of protocols that go along with soliciting donor funding for projects.[94] For these reasons, we strongly recommend that CalCAP focus first on managing the PG&E Partnership funding and applying for loans from the campus Capital Bank revolving loan fund that is being created.

4.4.6. Energy Service Companies (ESCOs)

Some businesses and institutions use ESCOs to do the energy efficiency retrofitting work. ESCOs usually offer performance based contracts, where they guarantee the savings and often finance the upfront costs of the project. When an ESCO is used to finance a project, they get paid back as the savings are realized over time. Often the ESCO's return increases if the project exceeds the savings targets in order to incentivize high quality work. ESCOs also offer performance guarantees without financing. In the case of the University of British Columbia, project costs were paid with an internal

[92] Andrew Meiman at Newcomb, Anderson & McCormick, personal communication.
[93] Ibid.
[94] Jaclyn Olsen, HGCI Assistant Director. Phone Interview. (December 13, 2007).

loan with an ESCO used only to guarantee savings (i.e. if the savings were less than expected, the ESCO would compensate UBC).

Some problems have been experienced with ESCOs taking advantage of clients if the contract is not written carefully, and the company is not closely monitored, so ESCOs require in-house staff with time to monitor the ESCO's performance. Some projects are also extremely difficult to monitor and do not fit well with an ESCO model. For example, this can be true of commissioning. Other projects, such as lighting and HVAC replacement, have more definable savings and lend themselves to easy monitoring. The main advantage that ESCOs have over normal contractors is that a performance based contract can increase the incentives for the company to do quality work.

Currently, contracts with ESCOs are not allowed within the UC system. However, UCOP staff is now in the process of getting the use of ESCOs approved, though with restrictions that UCOP staff believes will avoid contract manipulation on the part of ESCOs.

4.5 Staffing and Execution

One of the major problems Berkeley faces, if not **the** major problem, to implementing emissions reductions programs on a large scale is the lack of available staff to identify, implement, and maintain projects. All of the other campuses we have identified with successful programs have significantly larger staff (both fulltime and contract staff) to actively push energy and sustainability projects forward. We will have the benefit of UCOP organizing an assessment of campus projects in 2008, but this will not be sufficient to do the day-to-day work of project implementation and management. Berkeley needs to develop a strategic plan for the work we intend to accomplish and a sufficient staffing plan to carry out the work.

4.5.1 Current Situation

UC Berkeley is not prioritizing the hiring of staff to address our potential for cost-effective energy savings, and in the past positions have sometimes not been rehired due to budget constraints. In October we lost our Utilities Engineering Manager, Paul Black, who was an effective and visionary contributor to the University. So far he has not been replaced, further increasing the pressure on the other Utilities Engineering group members. Before Paul left, he also had more work than he could handle, so simply replacing Paul Black may not be enough to even maintain our current level of energy project work.

Another group on campus that needs attention is the department that installs and maintains the utility meters for electricity, water, and steam on campus. This department has been mentioned by several UC Berkeley staff as a significant bottleneck to implementing additional projects. For most building retrofit projects, this group must provide extensive utility data. This group should be expanded to meet the growing demand for the energy data analysis needed for projects.

Additionally, Berkeley will need to use outside contracted engineering firms to do much of the initial energy project work. Currently the campus uses several contractors for project work, including Quantum Energy Services and Technologies for commissioning, DayStar Energy for lighting retrofits, and Federspiel Controls for HVAC retrofits.

Another important resource is the UC Office of the President (UCOP) initiative to jumpstart an energy strategic planning process that will put Berkeley in a better position to take advantage of the emissions reduction projects on campus. The project will include a detailed analysis of the current building stock and an assessment of all energy efficiency projects that can be done with a payback of 10 years or less.[95] According to the Request for Qualification issued by UCOP, this process will run from January to June 2008 and have a projected cost of $1.2 to $1.8 million. This contract was recently awarded to Newcomb Anderson McCormick, the same firm that is coordinating the Partnership.

4.5.2 Recommendations

As mentioned in the introduction, with approximately 200 buildings on campus and over 13 million gross sq ft, it will take us over 60 years to commission all the buildings and over 40 years to upgrade all the lights at our current rate. If we get access to $50 million for projects supported by Partnership funding for 2009-2014 this will be more than 6 times what we are currently doing – this will require a similar step up in staffing.

We believe that UC Berkeley needs to take a step back from the implementation of one-off projects and create a plan for implementing energy projects on campus at a large scale. A major part of the plan should be how to hire or contract the appropriate staff to get this work done. Incremental staffing is not enough – we need to have a strategic plan for a change on this scale.

There are some examples of core staffing that we have highlighted from other universities, such as:

University of British Columbia

- Sustainability Office has 7 professional staff, 4 student staff members, 145 volunteers

Harvard University

- Green Campus Initiative has 19 professional staff, 38 part-time students

Texas A&M

- Energy Office staff includes 12 full time staff, 9 contract employees, 2 students, plus support from the campus Energy Systems Lab

Our implementation plan will be unique to Berkeley. We imagine that elements of this plan will include:

- Replacing Paul Black and making the Energy Manager two jobs
- Hiring at least three managers for next stage of partnership funding (with a plan to hire more as projects ramp up)
- Designating campus energy projects as a major part of the Sustainability Director's job
- Funding the full "Green Team," one or two Sustainability Office staff are not enough
- Strategically hire outside contractors, but make sure we have the internal staff to oversee them who will retain the knowledge gained from the project implementation process
- Expanding the utility meter group to meet the data demands of increase energy projects

[95] More details can be found in Appendix 4.5

Section 5: Conclusion

The most important result of our study is that the CalCAP greenhouse gas emission reduction goals can be reached via a cost effective program that would eventually return millions of dollars a year in saved energy costs to the university's discretionary spending budget without the need to purchase offsets or RECS of any type. Case studies from other institutions and knowledge gleaned from our own experience indicate that comprehensive efficiency programs and imaginative approaches to long term planning can substantially reducing our campus footprint. By cultivating the expertise of current students, faculty, and staff and taking strategic advantage of the Partnership funding and other incentive programs, the university can exceed its goals.

The major barrier to the successful implementation of such a program is not funding. It is allocating the necessary resources, including hiring the in-house and contracted staff, to identify, implement, and maintain an emissions reduction program. There is more than one approach that could meet or exceed university targets, so we must choose the one that best serves our long term interests. In addition to hitting emissions targets, the optimal approach should enrich academic life while laying the foundation for more aggressive future programs. This will require active coordination between departments on campus, and the commitment of staff time to create and oversee the strategic plan. This plan should include efficiency retrofits of all major buildings by 2014, binding green building standards for new construction, the involvement of the entire campus community, connections to academic programs, and renewable energy targets.

Cal has a history of and commitment to serving the public interest. As the world grapples with environmental issues of unprecedented scope and urgency, we are compelled to apply the best of our talents to the search for solutions. It is time to commit focused attention and resources to beating our 2014 emissions goal and setting the stage for a sustained push towards the elimination of campus emissions.

Section 6: Appendix – Information for Future Students

Note: This section numbering mirrors the section the information refers to, with a "6" in front of the section number from above.

6.1.2 Call to Action

Calculation A

Current funding: $2.5 million for 2006-2008 (3 years) is $833,333 per year
Potential funding: $30 million for 2009-2014 (6 years) is $5 million per year

Information on current funding is from personal communications with Andrew Meiman at Newcomb, Anderson & McCormick, which is the coordinator of the PG&E/UC/CSU Partnership.

Calculation B

With the matching funds, we have done a total of $3.5 million ($2.2 million from PG&E) over 2006-2008, so ~$1.17 million a year. This has been done with approximately 1.5 staff people plus contractors.

The 2009-2014 funding is about $50 million with our contribution of $20 million, or $8 million a year. This is $8/$1.17 = more than 6times more $ volume!

Calculation C

Electricity and Steam account for 31% and 39% of our non-lifecycle cost emissions respectively (see Figure B). Reducing each by 30% each would be a reduction of 21% of our total emissions.

Calculation D

Berkeley's current discretionary budget is $23 million (from personal communication with Nathan Brostrom, Vice Chancellor)
Berkeley's current central campus expenditure on energy is $26.2 million (from personal communication with Paul Jenny, Associate Vice Chancellor, Budget and Resource Planning)

Decreasing energy use by 30% would reduce energy expenses approximately $26.2*30% = $7.86 million

This would increase the discretionary spending budget by $7.86m/$23m = 34%

Calculation E

Project Cost	$50	million
Paid by UCB	$20	million
Simple Payback	5	years (average payback for Partnership funding)
Energy Price Increase	2%	per year
Average Project Life	10	years
UCB's Cost of Debt	4.75%	Assume loan amt of 2/5 the project cost
Term of Loan	10	years
UCB's Discount Rate	6.00%	Hurdle rate for investments, this is used for discounting back cash flows

Cash Flows (millions)	0	1	2	3	4	5	6	7	8	9	10
Project Cost	$ (50)										
Savings		$ 10.00	$ 10.20	$ 10.40	$ 10.61	$ 10.82	$ 11.04	$ 11.26	$ 11.49	$ 11.72	$ 11.95
Loan Payments		$ (2.56)	$ (2.56)	$ (2.56)	$ (2.56)	$ (2.56)	$ (2.56)	$ (2.56)	$ (2.56)	$ (2.56)	$ (2.56)
TOTAL	**$ (50)**	**$ 7.44**	**$ 7.64**	**$ 7.85**	**$ 8.05**	**$ 8.27**	**$ 8.48**	**$ 8.70**	**$ 8.93**	**$ 9.16**	**$ 9.39**

NPV for investment of $50m = $ 11 million
NPV for campus cont of $20m = $ 41 million

Calculation F

Rate of Comissioning

Key buildings	200	
Gross Square Feet	13000000	million
Approved 2004-2005	Square Feet	
Soda	111,077	
Tan	118,376	
Sq Feet per year	**114,727**	
Approved 2006-2008	Square Feet	
Cory	206,154	
Koshland	153,700	
LSB Addition	203,787	
Silver lab Addition	43252	
Sq Feet per year	**202,298**	
Years given 2006-2008 Rate	**64**	based on sq ft
Years given 2004-2005 Rate	**113**	based on sq ft
Lighting Retrofits 2006-2008	**5**	buildings per year
Years at this rate	**40**	based on # buildings

Calculation G

Fiscal Year	UCB Package Net Emissions (MT eCO2)
1990	167,463
1991	165,439
1992	165,821
1993	170,158

1994	173,675
1995	174,872
1996	174,923
1997	178,162
1998	260,969
1999	263,597
2000	265,316
2001	262,064
2002	265,477
2003	275,318
2004	277,609
2005	281,656
2006	209,084
2007	211,122 projected BAU
2008	212,546 projected BAU
2009	214,716 projected BAU
2010	217,630 projected BAU
2011	219,830 projected BAU
2012	222,046 projected BAU
2013	224,277 projected BAU
2014	226,525 projected BAU

1990 target is (210,000-167,463)/210,000 = 20% less than today's emissions!
1990 target is (226,525-167,463)/226,525 = 26% less than 2014 BAU emissions

6.2.2 University of British Columbia

Main Contact: Jorge Marques, former Sustainability Office Director, jorge.marques@royalroads.ca

UBC Sustainability Office Staff Profiles

Charlene Easton, Director, Sustainability
Charlene has a 25-year history in sustainability innovation and leadership in Canada and around the world. She has applied sustainability projects across a broad range of sectors including municipalities, corporations, communities, small businesses and educational institutions. Charlene graduated from York University's Masters in Environmental Studies Program, after completing a three-year CIDA scholarship.

Ruth Abramson, Manager, Marketing and Communications
Ruth's job is to communicate the message of sustainability at UBC and beyond. Ruth earned her Bachelor of Arts from Concordia and her Master's degree in Environmental Studies from Toronto's York University. Before joining the Sustainability Office, she worked as a journalist reporting on environmental and social issues for a variety of publications, including Maclean's magazine, TIME, and The Vancouver Sun.

Heather Scholefield, Manager, Sustainability Strategy

Heather works on Canada's first comprehensive Sustainability Strategy with targets and action plans. Heather has a BA Honours in Political Science from Queen's University and a Masters of Business Administration from UBC. She has worked for the provincial government to help local firms develop marketing strategies, to assist with third party forestry certifications and on industry development for BC's green building sector.

Brenda Sawada, Manager, UBC SEEDS Program
Brenda is the founder and coordinator of UBC SEEDS (Social, Ecological, Economic, Development Studies), Canada's only campus initiative bringing together students, staff and faculty to specifically address sustainability issues. Before joining UBC, Brenda co-founded the Sage Foundation in Vancouver to raise awareness about sustainability.

Brigid Macaulay, Coordinator, Programs and Administration
Brigid manages the Sustainability Coordinator program. She earned her Honours BA from the University of Toronto.

Alison Aloisio, Advisor, Sustainable Buildings
Alison encourages green building on campus and manages UBC's Residential Environmental Assessment Program (REAP). She earned her MSc from UBC's School of Community and Regional Planning and her LEED Accredited Professional status from the Canada Green Building Council. Before joining the SO, Alison researched municipal green building policies and helped write the REAP guidelines.

Liz Ferris, Student Development Officer, Sustainability
Liz manages student outreach and engagement programs, including the Climate Action Partnership. She has a Bachelor of Science in Sustainable Community Development from UBC's Global Resource Systems program.

6.2.3 Texas A&M

Main Contact: Charles Shear, Coordinator for the Office of Energy Management, cshear@ppgw.tamu.edu, 979-458-4614

6.2.5 Harvard University

Leith Spear, Director for Harvard Green Campus Initiative, leith_sharp@greencampus.harvard.edu

Christine Benoit, Manager of Communications & Business Organization, christine_benoit@harvard.edu, 617-496-1278

6.2.6 Yale University

Patricia Cucinotta, patricia.cucinotta@yale.edu

6.3.1.1 Lighting

Work on lighting retrofits can be improved by future students who are interested in this topic. There are many key people to keep in mind who can be of great assistance when gathering data and other pertinent information. Below is a list of a few of them:

Raul Abesamis	Physical Plant-Campus Services
Fahmida Ahmed	Project Manager, Cal Climate Action Partnership (CalCAP)
Charlie Huizenga	Research Specialist, Center for Built Environment (CBE)
	Adura Tech: Automated Lighting Controls
Chris Jones	Berkeley Institute of the Environment
Paul Matthew	Energy Analysis Department, Lawrence Berkeley Laboratory

There is also a great amount of literature and information online. Some of these sources can be found in the bibliography. Half of the projects recommended in this section are done through the Public Interest Energy Research (PIER) program. It is worth looking at their website for information on different technologies that they are working on (www.energy.ca.gov/pier).

6.3.1.2 Steam

More careful examination should go towards finding out how steam is actually used in buildings. Calculations done on the actual usable energy content delivered to buildings by steam and what the buildings actually require would help to figure out whether the steam is being properly utilized. Better investigation of the live data may reveal that there is steam being run through systems even when it is not necessary. Further investigation into the use of renewables in the steam system could turn out to be a very worthwhile venture as well. The campus contact for the steam system is Wayne Jin. He can be reached at 510-642-8009. His e-mail address is wjin@berkeley.edu. He is very helpful at answering questions.

Steam Usage Calculations

Solving For Steam CO_2 within General Reporting Protocol

	Avg Temp. (°F)	hrs/ month	Co-Gen Natural Gas (MMBtu)	Co-Gen kg CO2	Aux Natural Gas (MMBtu)	Aux kg CO2	Electricity total (MMBtu)	Campus use of Cogen Steam energy (MMBtu)	Initial Water energy (MMBtu)	Steam used by cogen plant (MMBtu)	Overall Cogen energy (MMBtu)	Steam Share (%)	Cogen use emissions new method kg CO2	Total Steam CO2 new method (kg CO2)
Jan-04	48.56	744	244344	12898920	12739	672492	64818	112416	1560	28403	204077	0.543	7006780	7,679,272
Feb-04	51.31	696	213861	11289722	7642	403421	58688	99340	1608	26570	182991	0.534	6029635	6,433,056
Mar-04	59.89	744	185406	9787583	14895	786307	51730	80298	1877	28403	158554	0.495	4840968	5,627,275
Apr-04	59.04	696	190008	10030522	4467	235813	54238	82379	1867	26570	161320	0.499	5006046	5,241,858
May-04	61.1	744	204998	10821844	3650	192684	60486	78829	1923	28403	165795	0.464	5019829	5,212,513
Jun-04	64.11	720	194399	10262323	1679	88634	60000	67662	1821	27487	153328	0.429	4406778	4,495,412
Jul-04	63.73	744	200502	10584501	1604	84675	62105	67064	1784	28403	155788	0.419	4435274	4,519,949
Aug-04	64.55	744	202133	10670601	393	20746	63268	65180	1778	28403	155072	0.409	4362686	4,383,432
Sep-04	67.91	720	187888	9918608	3697	195165	57653	59513	1791	27487	142862	0.404	4007489	4,202,654
Oct-04	59.95	744	212054	11194331	3098	163543	63322	77819	1823	28403	167721	0.453	5072279	5,235,822
Nov-04	54.1	720	214978	11348689	6325	333897	61809	92277	1709	27487	179863	0.504	5714494	6,048,391
Dec-04	50.6	744	228383	12056339	12946	683419	61417	107257	1672	28403	195404	0.540	6514503	7,197,922
Jan-05	47.76	744	246900	13033851	23687	1250437	64492	120118	1587	28403	211426	0.561	7307150	8,557,586
Feb-05	54.21	672	199816	10548287	2804	148023	56329	87651	1632	25654	168003	0.512	5400832	5,548,855
Mar-05	56.59	744	214599	11328681	3940	207993	61591	91711	1890	28403	179814	0.500	5658873	5,866,866
Apr-05	56.54	672	196326	10364050	13156	694505	54322	87208	1794	25654	165391	0.516	5352406	6,046,911
May-05	60.6	744	212216	11202883	1319	69630	63344	76715	1839	28403	166622	0.449	5034276	5,103,906
Jun-05	62.91	720	199289	10520466	2677	141319	60236	72167	1870	27487	158019	0.445	4680178	4,821,497
Jul-05	64.63	744	202063	10666906	1363	71953	62388	67718	1852	28403	156657	0.420	4484862	4,556,815
Aug-05	62.95	744	205326	10839160	1561	82405	62591	70956	1841	28403	160109	0.432	4679003	4,761,408
Sep-05	62.01	720	198663	10487420	1125	59389	60412	72687	1828	27487	158757	0.446	4680889	4,740,278
Oct-05	60.25	744	207745	10966859	546	28823	63179	76042	1801	28403	165823	0.448	4909999	4,938,822
Nov-05	57	720	187803	9914120	10472	552817	52628	80910	1696	27487	159330	0.497	4929051	5,481,868
Dec-05	52.19	744	227296	11998956	4286	226258	62882	101629	1720	28403	191194	0.523	6270110	6,496,368

Solving for Steam CO_2 Assuming Electricity can be replaced with Natural Gas Plant

	Co-Gen Natural Gas (MMBtu)	Aux Natural Gas (MMBtu)	Co-Gen KG CO2	Aux kg CO2	Electricity total (MMBtu)	kg CO2 generated by equiv. Nat Gas Electricity	kg CO2 generated by cogen elec by PGE emission factor	overall kgCO2 generated by cogen + Aux	kg CO2 attributable to steam	CO_2 reported in CalCAP	Cogen Steam CO_2 reported in CalCAP	Kg CO2 from using co-gen for power + steam
						kg	kg	kg	kg	kg CO2	kg CO2	kg
Jan-04	244344	12739	12898920	672491.8	64818.01	9,797,928	5,716,465	13,571,412	3,773,483	8,878,333	8,203,984	7,854,946
Feb-04	213861	7642	11289722	403421.2	58688.2	8,871,343	5,175,862	11,693,143	2,821,800	7,520,955	7,116,435	6,517,281
Mar-04	185406	14895	9787583	786307.1	51729.69	7,819,491	4,562,174	10,573,890	2,754,399	6,757,527	5,969,059	6,011,716
Apr-04	190008	4467	10030522	235812.9	54237.8	8,198,618	4,783,370	10,266,335	2,067,717	6,301,399	6,064,930	5,482,965
May-04	204998	3650	10821844	192683.5	60486.33	9,143,149	5,334,443	11,014,528	1,871,379	6,333,316	6,140,126	5,680,085
Jun-04	194399	1679	10262323	88634.41	60000.14	9,069,657	5,291,565	10,350,958	1,281,301	5,542,940	5,454,044	5,059,392
Jul-04	200502	1604	10584501	84675.16	62104.75	9,387,791	5,477,176	10,669,176	1,281,385	5,595,414	5,510,532	5,191,999
Aug-04	202133	393	10670601	20746.47	63267.5	9,563,553	5,579,722	10,691,348	1,127,795	5,450,402	5,429,574	5,111,625
Sep-04	187888	3697	9918608	195164.6	57653.43	8,714,927	5,084,603	10,113,772	1,398,845	5,247,502	5,051,824	5,029,169
Oct-04	212054	3098	11194331	163543.4	63321.65	9,571,738	5,584,498	11,357,874	1,786,136	6,353,005	6,189,026	5,773,376
Nov-04	214978	6325	11348689	333896.8	61808.57	9,343,019	5,451,055	11,682,585	2,339,566	7,149,842	6,815,028	6,231,530
Dec-04	228383	12946	12056339	683419.3	61416.9	9,283,815	5,416,513	12,739,758	3,455,943	8,372,752	7,687,454	7,323,245
Jan-05	246900	23687	13033851	1250437	64491.69	9,748,602	5,687,686	14,284,288	4,535,686	9,757,751	8,503,872	8,596,601
Feb-05	199816	2804	10548287	148023.2	56329.31	8,514,772	4,967,825	10,696,310	2,181,538	6,587,509	6,439,102	5,728,484
Mar-05	214599	3940	11328681	207992.6	61590.96	9,310,126	5,431,864	11,536,674	2,226,547	7,004,382	6,795,826	6,104,810
Apr-05	196326	13156	10364050	694505.2	54322.22	8,211,379	4,790,815	11,058,555	2,847,176	7,100,051	6,403,641	6,267,740
May-05	212216	1319	11202883	69630.01	63343.72	9,575,075	5,586,444	11,272,513	1,697,438	6,222,864	6,153,026	5,686,068
Jun-05	199289	2677	10520466	141318.8	60235.5	9,105,234	5,312,323	10,661,785	1,556,551	5,891,691	5,749,989	5,349,463
Jul-05	202063	1363	10666906	71952.77	62388.47	9,430,678	5,502,198	10,738,859	1,308,180	5,639,296	5,567,165	5,236,660
Aug-05	205326	1561	10839160	82405.19	62590.97	9,461,287	5,520,057	10,921,565	1,460,277	5,857,485	5,774,848	5,401,508
Sep-05	198663	1125	10487420	59388.75	60411.74	9,131,874	5,327,865	10,546,809	1,414,935	5,802,566	5,743,034	5,218,944
Oct-05	207745	546	10966859	28823.34	63179.22	9,550,208	5,571,937	10,995,682	1,445,474	6,035,385	6,006,473	5,423,745
Nov-05	187803	10472	9914120	552816.9	52628.48	7,955,353	4,641,440	10,466,937	2,511,585	6,577,729	6,023,386	5,825,497
Dec-05	227296	4286	11998956	226257.9	62881.78	9,505,247	5,545,705	12,225,214	2,719,966	7,659,752	7,432,878	6,679,509
					Total	218,264,864	127,343,606	270,129,967	51,865,103	159,639,848	152,225,256	142,786,361

Project Summary for Heat Exchanger Repair Feasibility

The analysis of the feasibility of replacing leaking heat exchangers would determine the water, natural gas, and carbon dioxide savings that could be expected if the leaking heat exchangers in University Hall, Tolman Hall, and Cesar Chavez Center were repaired. The analysis would require measurements of the amount of condensate discharge from the heat exchangers at a range of outdoor temperature conditions. This would give an idea of how much water is being wasted at the various operating conditions of the buildings. Delta Power would need to be contacted to determine the cost of purchasing, treating, and heating the water that replaces the rejected condensate in the steam system. Additionally, the steam cost of heating the city water that is introduced to replace the lost closed loop heating water should be determined. From here, the savings that the University could realize from fixing the system could be compared to the cost of the repairs and a payback period could be determined. A net carbon impact could be determined by applying an emissions factor to the amounts of steam and water saved and by calculating how much energy is saved by eliminating the need to heat and treat new water in the system. Regular maintenance such as this will help the campus eliminate unnecessary emissions.

6.3.1.3 Fumehoods

Contact Desirae Early for fume hood user habits, as well as green interns. Also EH&S has information on lab energy and fume hood management on campus. They are located on Oxford. Paul Matthew is another good contact for Lab 21 information and energy efficient labs.

Information data on energy metering for lab buildings on campus- There is real-time metering on Tan, Soda, Silver Addition, McCone, LSA, Koshland, Corey, and the Physical Plant building. About half of these were added in the last year (and the rest are less than five years old), so the historical data is in monthly increments.
The rest of the energy metering is done by PPCS and collected on a monthly basis.
Labs using (VAV) systems- All of the labs we are working on in Tan Hall (104 hoods) have VAV, there are 4 VAV hoods in two labs in Birge, and ~20 in Lewis. All the rest are CAV.

6.3.1.4 Commissioning and Maintenance

The argument at Cal should be that commissioning buildings both new and old is cost effective and compelling as a potential source of energy savings. We should be skeptical of our current self policed Cx program for new buildings and should be much more aggressive with our retro-Cx program in existing buildings. It stands to resolve many deferred maintenance issues in a cost effective manner and would put us in a great position to begin learning about and looking for additional sources of savings. Finally, Cx work should be treated as an ongoing concern, not just something that needs to be done in a single pass and then checked off a list. Since we expect to carry our emissions reduction program well beyond 2014, Cx should be viewed as a part of a process of continual improvement.

All of this implies that future Cx work will require a more coherent management plan, and increased staffing. Given that both these requirements will tend to increase the size and budgets of the bureaucratic system, it is important to look for opportunities to re-allocation staff time and priorities to better align existing programs with mitigation goals rather than bolting on new ones. **However, the best way to measure any institution's commitments to change are the staff and financial resources it allocates to new programs. If the projects aren't adequately funded and staffed, then the commitment hasn't been supported, no matter what has been said.**

It is also important to look at what Cx does not do. Technically it is the process of aligning system performance with the expected performance based on the existing design. Cx does not call into question the design itself and it does not call into question the nature of the service demands the building systems are meeting. Finally, it does not address plug loads within a building, even as such loads represent an ever increasing fraction of total energy demands.

As should be clear, a Cx program should be one piece of an overall building energy strategy that addresses all of the above concerns. Just as suburban homes are getting larger and larger while family sizes stay the same, our campus floor space is growing faster than our population. We must question the need for additional building space on campus and the total floor space required for specific activities. We must also question the designed energy consumption of our new buildings and the services that they provide. Air conditioning demands in particular should be engineered out of most of all new campus buildings and there is no excuse for not employing the state of the art in passive and active energy saving technologies in buildings designed to last for generations. Finally, the university needs to get a handle on the energy used by lab equipment and in the ubiquitous computers and other plug loads that are the rule in offices, classrooms, and research areas.

Specific Cx Resources

There are a lot of studies on the economics and impacts of commissioning work. What follows are the highlights from our research that did not make it into the body of the report with references to the source materials.

An excellent overview of commissioning in general with an extensive meta analysis of the results of commissioning is found in Mills, E., et. al (2004). The Cost-Effectiveness of Commercial-Buildings Commissioning, LBNL: 60. It is easily located with a web search for its title. This report has been criticized for aggregating data that was not vetted through a pier review process, but it still represents some of the best information available. It is a perfect place to start if you wish to familiarize yourself with the nature and potential benefits of Cx.

UC / CSU / IOU Statewide Energy Efficiency Partnership Overview
MBCx
2004-2005:
Total of 60 projects at 10 UC and 19 CSU campuses
Total cost $15 million
Savings exceeded projected goals by over 20%
3,520 kW
23,496,192 kWh
1,116,948 th
Projects delivered within budget

source: John Newcomb, Newcomb Anderson McCormick
http://ciee.ucop.edu/mbcx/documents/ee_prtnrshp_jnewcomb.ppt

Enhanced O&M through Building Performance Monitoring and Benchmarking
2004-2005 program
$5 Million Total Funding
Project Size $20k -$290k
$0.21 -$1.54 per gross square foot for buildings

Savings Targets (Conservative for Pilot Program)
1 MW peak demand
9,000,000 kWh per year
500,000 therms per year

$0.21 -$1.54 per gross square foot for buildings

source: Karl Brown http://aceee.org/conf/mt06/c3-brown.pdf

CIEE MBCx Program Summary Description (Karl Brown)

2004-05 Program Scope: 37 building projects (half labs) and 9 plant projects on 25 campuses
$5.2 million funding
Portfolio targets of 1.0 MW, 9.3 million kWh/year, 580,000 therms/year
3.6 year simple payback period on funding @ $0.093/kWh & $1.00/therm

2004-05 Program Results: Projects reporting to-date on initial commissioning achieved 138% of targets (34% of funding produced 47% of targeted savings)
10% average energy use reduction (cost basis) from initial commissioning
Identified potential for program improvement (e.g. better project design)

source: http://ciee.ucop.edu/mbcx/documents/mbcx_sum040306.pdf

Brown, K., J. Harris, and M. Anderson. 2006. **"How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings"** Proceedings of the 2006 ACEEE Summer Study of Energy Efficiency in Buildings. 3:27-40. Washington D.C.: American Council for an Energy-Efficient Economy.

Very good summary from Karl Brown on MCBx
http://ciee.ucop.edu/mbcx/documents/MBCx_ACEEE_2006_revised_9jan07.pdf

"Background for Monitoring-Based Commissioning" Mary Ann Piette

UCSB Campus achieved significant savings (25%) by combination efforts of capital investments and O&M.
EIS (Energy Information System) helped to find O&M energy savings.
EIS helped to quantify each saving opportunity in capital investment or O&M.
EIS reduced time-consuming work.
If the facility did not have someone proactive to analyze the data, the EIS would be useless.

source: http://ciee.ucop.edu/mbcx/documents/bkgrnd_mbcx_mapiette.ppt

An Evaluation of Savings and Measure Persistence from Retrocommissioning of Large Commercial Buildings (for SMUD projects)

Documents the decline in energy savings from RCx over time in a handful of building. Core finding: approximately 80% of savings still present after 4 year, but some buildings had completely reverted in that time.
source: http://gaia.lbl.gov/btech/papers/54986.pdf

Jim Dewey as model for energy efficiency projects at UCSB
http://energy.ucsb.edu/default.htm
Including realtime energy
http://energy.ucsb.edu/ASP-HTM.asp

Texas A&M program of continiuous Cx

"Based on Continuous Commissioning® results from more than 300 buildings, the average measured utility savings are about 20%, with simple paybacks typically occurring in less than two years. Continuous Commissioning® maintains long-term savings using ongoing monitoring of energy consumption with follow-up commissioning, as needed. It also improves system reliability and building comfort by optimizing system operation and control schedules based on actual building conditions, upgrades the operating staff's skills by allowing direct participation in the CC® process, and reduces O&M costs."
http://esl.eslwin.tamu.edu/continuous-commissioning-.html

A Ten-Year, $7 Million Energy Initiative Marching on: Texas A&M University Campus Energy Systems
Author: Deng, S.; Claridge, D. E.; Turner, W. D.; Bruner, H. L.; Williams, L.; Riley, J. G.
Abstract: The $35 million in measured savings for the ten-year, $7 million continuous commissioning (CC) program at the Texas A&M University (TAMU) makes the decision to continue easy. In today's energy environment and with the volatilities and uncertainties of the utilities market, successfully managing a dynamic energy management initiative is an instrumental and challenging priority on any campus. The TAMU project closely involves continuous commissioning of one hundred and fifty (150) major campus buildings, five (5) central, five (5) central utility plants [including one (1) Combined Heat and Power (CHP) plant] and their distribution infrastructure. All levels of energy consumption metering, data management, savings determination, retrofit projects, and M&V (Measurement and Verification) functions are integrated. This paper presents our philosophy, the work scope, structure, approaches, and accomplishments of this on-going process. It also discusses lessons learned and strategies refined. TAMU's one-of-a-kind BAC (Building Automatic Controls) network will also be covered for its role and value in the CC.

Source: http://txspace.tamu.edu/handle/1969.1/5346

UCB Ecotrek informational website
http://www.ecotrekenergyinfo.com/
http://www.ecotrek.ubc.ca/success.htm

ACEE/Stanford 2007 conference on behavior, energy and climate change
http://piee.stanford.edu/cgi-bin/htm/research_behavior_conferences.php?ref=nav4

CIEE (California Institute for Energy and Environment) MBCx information

http://ciee.ucop.edu/mbcx/welcome.html

Southern California RCx program
http://www.sce-rcx.com/

Portland Energy Conservation, Inc. Cx information (a great web resource from some Cx pioneers)
http://www.peci.org/commissioning.htm

Stanford's ECIP program to make departments financially responsible for their energy expenditures and reward savings.
http://news-service.stanford.edu/news/2004/march17/electric-317.html

Stanford energy program overview
http://facilities.stanford.edu/conservation/energy.htm

UC San Diego Success Story
"Since the 1990s, the university has invested approximately $58 million in energy-management-related projects. Even more jaw-dropping than the payout is the payback: These projects, strategies, and equipment are yielding a whopping $11 million in annual energy savings."

"With support from the highest levels of campus leadership, the team proceeded to implement only the big behind-the-scenes projects that would offer the best returns either campus-wide or in individual facilities. The impact was immediate, and not only was efficiency up and utility costs down, but another benefit was revealed: "The most important long-term result of having a campus energy-management program is improved reliability and performance of the central plant and HVAC and lighting systems," Dilliott says."

"One of the most important tools used by the team at UC San Diego is its energy-management system (EMS). In the mid-1990s, the campus upgraded to a centralized direct digital system. With centralized control of mechanical systems, monitoring and advance programming is easier. According to UC San Diego, the EMS facilitates

* Reduction in peak-time energy demand.
* Management of heating and cooling setpoints.
* Maximum conservation through night and weekend programming.
* Long-term trending and comparative analysis."

http://www.buildings.com/articles/detail.aspx?ContentID=3572

6.3.2 Renewable Energy at the Richmond Field Station

The Richmond Field Station has great potential for future renewable energy research and applications. The facilities manager, John Felling, is very accessible, enthusiastic about renewable energy, and open to student ideas and collaboration. Scott Shackleton, Assistant Dean of Facilities and Capital Projects, is also quite open to meeting with students and looking at ideas to increase energy efficiency and onsite generation on the Berkeley campus. He is particularly interested in incorporating these approaches in the upcoming master planning process for the development of the RFS campus.

In addition, a number of staff, faculty and students are working on projects that may be applicable to future development of the RFS campus and synergistic research initiatives.

- Professor Dan Kammen, Energy and Resources Group, Director of the Renewable and Appropriate Energy Laboratory, which has a workspace at RFS. Prof. Kammen is an expert on renewable energy technologies and policy, and can offer very valuable advice planning for future on-campus projects at every stage of the process.
- Dan Prull, PhD student in Mechanical Engineering. Manager of RAEL, Dan is working on small-scale microgrids using wind and solar power. He and Christian Casillas, M.S. student in ERG, are setting up a small wind turbine testing site at RFS. Dan also has a wealth of experience with using the HOMER model.
- Kat Saad, an undergraduate student in Mechanical Engineering, is setting up a project through RAEL at RFS to compare degradation and energy yield of different solar panel types, and is exploring an agreement with solar-manufacturing companies to test cell prototypes. Her work might overlap with RFS managers' stated interest in "beta testing" new PV products at RFS and using the power they generate to offset building loads.
- Susanne Zechiel, Director of Business Development at MMA Renewable Ventures. MMA installs PV systems for institutional clients and offers a third-party ownership system, whereby MMA owns the system installed on the client's property and the client pays a fixed rate per kWh generated. 415-229-8863
- Claire Broido, Vice President of SunEdison, LLC, a company with offices in McClellan, CA. SunEdison also operates as a third-party owner and installer of large PV systems and has supplied a quote for the RFS system.
- SunPower is a local solar company that specializes in rooftop PV, and was part of the installation on the MLK Jr. Student Center roof.

HOMER is an excellent resource, and should prove useful in any future renewables system modeling. (Future teams might consider using the RETScreen tool, as well.) It is, however, better suited as a technical, rather than economic, modeler. Levelized energy cost calculations, etc., are more readily accomplished with other means (such as pencil and paper) in the manner seen in our report.

6.4.2 UC Berkeley's Building Process

Capital Projects Roadmap

Source:
This description of the capital project approval process was taken verbatim from the "Project Approval Process" website at <http://www.cp.berkeley.edu/FS_Info/pa-betaweb/main.htm>. This information is current as of mid-Oct 2007.

Overview

- Phase 1 - Concept review
- Phase 2 - Feasibility analysis
- Phase 3 - Program development
- Phase 4 - Schematic design
- Phase 5 - Design development
- Phase 6 - Working drawings
- Phase 7 - Bid and award
- Phase 8 – Construction

Phase 1 - Concept review

Concept Review is the formal introduction of a project idea to the campus leadership. The concept is presented to the Executive Campus Planning Committee (ECPC), which recommends action to the Chancellor.

No funds are required from the project sponsor for Concept Review.

The PEP staff report to the ECPC describes the objectives, key issues, and proposed funding for the concept, and includes an assessment of whether or not the concept aligns with the strategic goals, policies, guidelines and initiatives in the 2020 Long Range Development Plan (2020 LRDP).

Concept Review is NOT project approval: approval by the Chancellor only means the concept may be taken forward to the next phase, Feasibility Analysis.

Projects with budgets under $5 million may be delegated to the Vice Chancellors Administrative Council (VCAC) following Concept Review approval.

Detailed sequence of events in Phase 1

Planners lead Policy Review, Options Analysis and Campus Review

1.1 Sponsor submits proposal with Vice Chancellor signature to AVC for Physical and Environmental Planning.

1.2 AVC meets with Sponsor to explain process and assigns campus planner to project.

1.3 Sponsor, in consultation with planner, prepares Abstract of proposal: project objectives, justification, alternate solutions to consider, and proposed source(s) of funds.

1.4 Campus planner manages Policy Review, including conformance with 2020 LRDP, and consults with VCs for Administration and University Relations on funding strategy.

1.5 Campus planner prepares Concept Analysis, writes ECPC item and recommends ECPC action.

1.6 VC Facilities Services reviews analysis, confirms recommendation.

1.7 Campus planner reviews draft ECPC item with Sponsor.

1.8 Sponsor reviews draft item with relevant VC. VC must sponsor the item at ECPC.

1.9 ECPC considers concept and recommends action to Chancellor. (Projects under $5 million may be delegated to Vice Chancellors Administrative Council for subsequent reviews and approvals)

1.10 Chancellor's approval of Concept Review is NOT project approval, but only authorizes the project to move forward to the next phase, Feasibility Analysis.

1.11 Sponsor must transfer funds to cover next phase before work begins.

Phase 2 - Feasibility analysis

During Feasibility Analysis, the focus is on identifying options and defining the project. Options may include renovation, expansion, new construction and, if relevant, non capital solutions such as physical reorganization. Options may also include alternate models for project delivery such as public-private partnerships.

Funds are required from the sponsor to cover the cost of campus staff and consultants.

The scope of Feasibility Analysis varies, and can include program and design concepts as well as technical investigations such as site and building condition surveys, code and life safety evaluations, historic and environmental studies, and budget estimates.

Based on the findings of the Feasibility Analysis, the sponsor and PEP identify a preferred option for campus review. PEP manages this review, in which the preferred option is presented to committees including the Design Review Committee (DRC), Space Assignment and Capital Improvements Committee (SACI), the Committee on Academic Planning and Resource Allocation (CAPRA), and then ECPC.

ECPC then recommends to the Chancellor whether the project may be taken forward into the next phase, and may also recommend conditions, such as project features to consider, revise, or eliminate.

<u>Detailed sequence of events in Phase 2</u>

Planners lead Policy Review, Options Analysis and Campus Review

2.1 Facilities Services prepares workplan for Phase 2: scope, timeline, staff budget and, if required, consultant services and budget.

2.2 Sponsor (VC, VPAPF) may appoint Preprogram or Working Committee.

2.3 If not 100% state-funded, Sponsor and/or Preprogram or Working Committee work with Administration and University Relations to develop funding strategy.

2.4 Facilities Services and consultant (if required), working with Sponsor or appointed committee, develop preliminary space program, diagrams and evaluation criteria.

2.5 Facilities Services and consultant (if required) identify options, to include alternate solutions plus “no action”, and conduct Options Analysis.

2.6 Facilities Services develops project specific design guidelines in conformance with 2020 LRDP.

2.7 Design Review Committee: reviews design guidelines, concept ideas and design proposition. Chair reports conclusions to ECPC.

2.8 Space Management & Capital Improvements Committee: reviews and approves space and/or land use assignment. Chair reports conclusions to ECPC.

2.9 Committee on Academic Planning & Resource Allocation: reviews academic concept and impacts. Chair reports conclusions to ECPC.

2.10 Sponsor and Preprogram or Working Committee, with Facilities Services, selects preferred option based on evaluation and review described in earlier steps.

2.11 Facilities Services prepares initial study based on preferred option.

2.12 Facilities Services prepares draft ECPC item, including recommendation, and reviews with VC Facilities Services and Sponsor.

2.13 ECPC considers feasibility of project and makes recommendation to Chancellor to go forward, to conduct further study, or to deny.

Phase 3 - Program development

Programming and Schematic Design are the start of the formal design process. Facilities Services appoints a project manager and conducts the selection of the project architect. The EVC-Provost designates a Program Committee which includes sponsors, stakeholders and other campus representatives (including students).

Under the direction of the project manager, the project architect works with the Program Committee to develop a program and design concept. Based on this concept, PEP begins environmental review, and surge space requirements begin to be defined.

Detailed sequence of events in Phase 3

3.1 Facilities Services prepares workplan for Phase 3: scope, timeline, staff and consultant budget.

3.2 EVC/Provost appoints Program Committee.

3.3 VPAPF, Project Sponsor and/or Program Committee representatives and Facilities Services select architect for project.

3.4 Architect, Program Committee and Facilities Services prepare program and design concept: space program, conceptual site plan, conceptual floor plans, conceptual massing, proposed budge and schedule.

3.5 For projects not 100% state-funded, Sponsor, Administration, and University Relations develop funding strategy.

3.6 As concept plans develop, Facilities Services reviews project for conformance with design guidelines, sustainability policies, regulatory requirements and other commitments.

3.7 Facilities Services continues environmental review based on initial study. Environmental Review must be completed prior to start of construction documents.

3.8 Facilities Services and Space Management & Capital Programs prepare surge analysis in collaboration with VPAPF.

3.9 Design Review Committee: reviews program and design concept. Chair reports conclusions to ECPC.

3.10 Space Assignments & Capital Improvements: reviews program and design concept. Chair reports conclusions to ECPC.

3.11 Committee on Academic Planning & Resource Allocation: reviews program and design concept. Chair reports conclusions to ECPC.

3.12 Facilities Services prepares draft ECPC item, including recommendation and reviews with VC Facilities Services and Sponsor.

3.13 ECPC considers the project and makes a recommendation to the Chancellor to approve or to consider further.

3.14 At the end of this phase, UCOP or Regents (depending on project value) must approve budget and program (PPG) for the project.

Phase 4 - Schematic design

In Schematic Design, the architect prepares scaled drawings of the design concept, begins to select materials, and begins to plan the project infrastructure. Although conceptual budgets may be prepared in earlier phases, the cost estimate prepared at the conclusion of Schematic Design is the basis of the first formal project budget based on architectural interpretation of the project program.

DRC and ECPC typically review the project for the last time at Schematic Design, assuming no further changes of significance to scope, budget and design. Technical reviewers including the Fire Marshal, the Seismic Review Committee (SRC), and the Committee for Removal of Architectural Barriers (CRAB) continue to monitor the project as design details are developed.

Phase 5 - Design development

[No info provided on this phase]

Phase 6 - Working drawings

In Design Development, the Architect prepares more detailed drawings for the design developed in the schematic phase, incorporating more detailed technical analyses of the program and the infrastructural systems. The Working Drawings phase, also known as "construction documents", entails the documentation of design intent (scope, quality, and detail) for the purposes of public bidding for construction.

Committee reviews in these phases are typically required only when there is a change to the project. 100% of the funds required to complete the project must be in place before the construction contract is advertised for public bidding.

Phase 7 - Bid and award

Once the contract is awarded, future budget augmentations must be reviewed by VCAC and approved by the Chancellor.

Phase 8 - Construction

[No info provided on this phase]

6.4.5 Staffing and Execution

UCOP Strategic Energy Plans

A promising source of information for identifying the opportunities for campus-wide energy savings and renewable energy potential are the Strategic Energy Plans being commission by UCOP for the entire UC system.[96] This work will start in January of 2008 and should conclude in June of 2008, with a projected cost of $1.2 to 1.5 million. According to the Request for Qualification, these plans will include at a minimum:

[96] Regents of the University of California's RFQ for Strategic Energy Plans (UCOP-SEP08), Issued September 26, 2007.

For campuses:

- Total square feet including State-funded, Program and Auxiliary buildings
- Energy use and charges, including time-of-use components
- Applicable utility tariff(s)
- Utility or energy service provider
- Energy project inventory – current and proposed
- Funding sources
- Renewable energy potential
- Central plant or distributed HVAC
- Project cost estimates

For buildings > 50,000 square feet size:

- Complex (buildings containing labs) or non-Complex
- Building age or when last renovated
- Energy use and charges (if metered)
- Extrapolated or modeled usages and charges (if un-metered)
- Thermal requirements if served from Central plant
- Energy project(s) – underway & proposed
- Building management system(s)
- HVAC infrastructure
- Lighting system(s)
- Metering or monitoring system(s)

The Strategic Energy Plans will also include:

- Annual energy usage and total charges for whole campus and targeted buildings
- 1990 and 2000 Energy use baseline
- Most recent calendar year carbon footprint
- Description of buildings included in scope
- Electric and gas utility service description and applicable tariffs
- Electric service reliability and power quality analysis
- Energy procurement options
- On-site generation – existing and potential
- Pie chart showing all sources, including on site generated and procured, of energy used
- Current and potential renewable energy sources
- Identification and ranking of energy efficiency projects with a simple payback of 10 years or less, including;
    - Projected energy savings
    - Estimated project cost
    - Simple payback
- Financing sources - internal and external
- Incorporation of recent energy and climate change studies
- Graph and data showing campus