Energy Efficiency in Campus Buildings

Recommendations of the Spring 2010 CalCAP course

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About the CalCAP class:

The Spring 2010 CalCAP class was a group of 8 graduate students from departments across campus, including engineering, architecture, building science, business, and policy. The students spent the semester talking to researchers and facilities staff at Berkeley about a variety of campus sustainability issues. They also pursued individual research topics in more depth, investigating potential costs and savings from different possible sustainability measures and looking into case studies from other universities. This report is the work of a subset of students whose research focused on energy efficiency in campus buildings.

Chapter 1. Introduction

Under the Cal Climate Action Partnership (CalCAP), UC Berkeley has established its goal of reducing greenhouse gas emissions to 1990 levels by 2014, just four years away. Emissions have started to decline, but significant reductions are still necessary to reach this goal. In 1990, total campus emissions were 166,000 tons of carbon dioxide equivalent (CO2e), and in 2009 campus emissions were 199,000 tons. Thus, the campus needs to reduce its emissions by 16% over current levels in order to meet the 2014 CalCAP target. In total, the planned reductions outlined in Berkeley's 2009 Climate Action Plan will lead to emissions reductions of 30,000 tons of CO2e. The necessary emissions reduction in 2014 (relative to an estimated business as usual scenario that takes into consideration planned growth) is approximately 55,000 tons of CO2e. Last year building energy use accounted for 78% of greenhouse gas (GHG) emissions at UC Berkeley through purchased electricity, steam and natural gas (see Figure 1). UC Berkeley spent about 22 million dollars on electricity in buildings for 218,800,000 kWh. Thus, a large portion of the decrease in emissions necessary to reach our 2014 CalCAP goal will need to be related to energy efficiency and conservation in buildings. Although this report does not discuss new buildings, addressing energy consumption in new buildings will also be key to meeting our CalCAP goals. As Figure 2 shows, the decline in electricity consumption per square foot has been overwhelmed by the growth in square footage of building space.

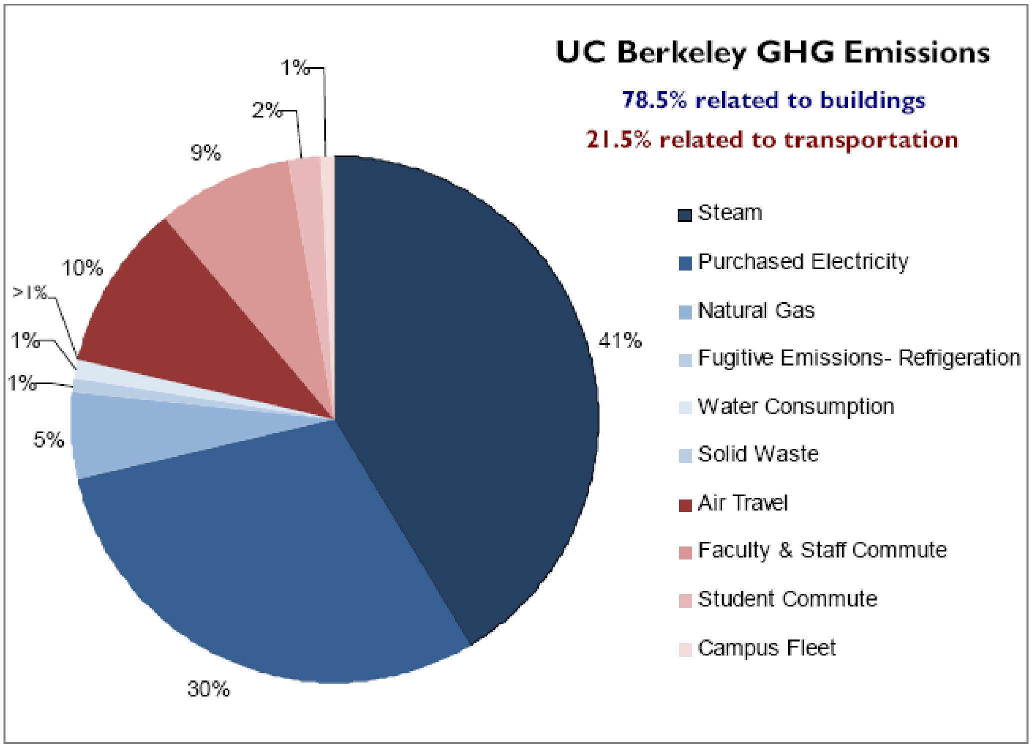


Figure 1. Breakdown of 2008 greenhouse gas emissions by sector. Source: 2009 Climate Action Plan

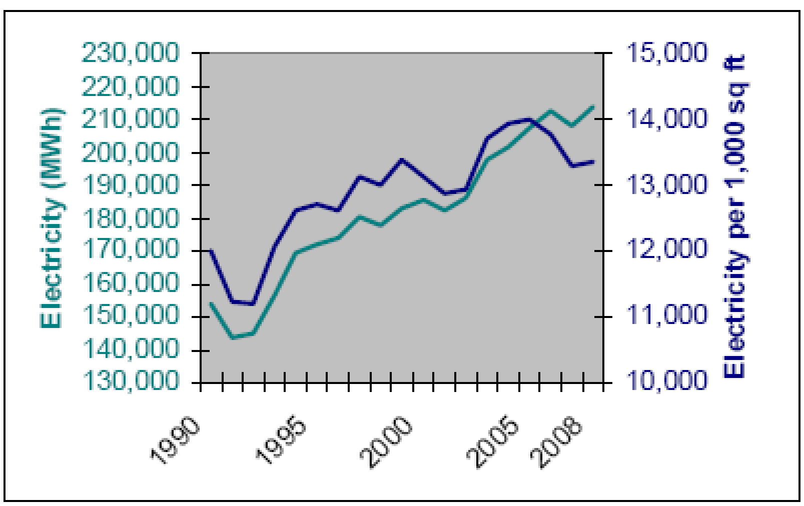


Figure 2. Electricity consumption (green) and electricity consumption per thousand square feet (blue).

Berkeley's main efforts to reduce energy consumption in campus buildings fall under the Strategic Energy Plan (SEP). This program, which addresses energy consumption in buildings over 50,000 square feet, is funded in large part by a partnership between UC, California State University, and the investor-owned utilities (IOUs). Buildings in the SEP account for about 74% of campus electricity consumption. The SEP covers retro-commissioning, heating/ventilation/air conditioning (HVAC) improvements, and lighting improvements of campus buildings. As buildings undergo SEP retrofits, real-time electricity metering is installed; however, the data is not currently used on a regular basis for continuous commissioning. Notably, the Strategic Energy Plan leaves out plug loads (including laboratory plug loads) and focuses on projects with persistent savings in order to avoid the need for continuous commissioning. Thus far, about 2/5 of the buildings covered by the SEP have been commissioned, with energy savings of roughly 10-15% per building. Planned future work under the SEP will save an estimated 23,000 tons of CO2e.

The CalCAP Steering Committee has stated its desire to meet the 2014 goal by investing in on-campus emissions reductions as opposed to purchasing offsets. We strongly support this goal; our research suggests that a combination of technical and institutional changes can allow us to achieve deeper levels of energy savings in campus buildings. For example, combining energy management software with incentives for Facilities staff and behavioral incentives to unlock the knowledge of building managers and building occupants about building energy use will likely lead to large opportunities for new savings.

UC Berkeley has recognized at the highest levels the need for improvements in energy conservation. The Operational Excellence report, released in April 2010, highlights the financial opportunity for improving energy management and specifically recommends: accelerating deployment of energy metering and reporting, establishing an incentive program to reward energy conservation, and increasing staff accountability for energy consumption. In this report, produced through a completely independent process, we have arrived at many of the same recommendations. We have investigated areas where we saw the possibility for large savings – in laboratory buildings which are the most energy intensive buildings on campus, in better management of energy data for continuous commissioning of buildings, and in behavioral changes and incentives. We have also looked to other universities for guidance; by using a broad sampling of case studies from schools from coast to coast, and both private and public, we offer a number of recommendations which will lower the University's energy usage, and subsequently decrease energy spending. Our recommendations are summarized in the final chapter. The Appendix also suggests areas for future research.

Chapter 2. Laboratory Ventilation

2.1 Background

Laboratory buildings are some of the largest energy consumers on campus. In general, laboratory buildings consume many times more energy per square foot than typical office buildings, and this relationship appears to hold true of campus buildings as well. As of 2009, the average energy consumption per square foot in Koshland Hall is 54.5 kWh/gsf, Silver Lab Addition is 39.5 kWh/gsf, and the Life Sciences Annex is 42.7 kWh/gsf. Non-laboratory buildings have much lower energy consumption per square foot; for example, Wurster Hall in 2009 used 9.2 kWh/gsf, Barrows Hall in 2005 used 9.5 kWh/gsf, and the Haas Business School in 2005 used 15.9 kWh/gsf. A study of laboratory buildings at UCLA, Berkeley, UCSD, UC Irvine, and UCSF found that laboratory buildings occupy 25% of total floor area but are responsible for 55-60% of energy use.

One of the major reasons for high energy consumption in laboratories is the need for high ventilation rates. At UC Berkeley, laboratories must meet a minimum air flow standard of 1 cfm (cubic feet per minute) per square foot of space; depending on ceiling height, this typically works out to five or six air changes per hour (5-6 ACH). Fume hoods may increase ventilation rates above this amount by increasing the air flow through the building. Fume hoods are designed to keep hazardous chemical fumes away from users, and they work by sucking air through the hood and exhausting the fumes outside the building. The amount of energy consumed by a fume hood depends on whether it is constant air volume (CAV) or variable air volume (VAV). All hoods have a sash which the user can close when the hood is not in use; however, CAV hoods maintain a constant volume of air flow through the hood, meaning that the velocity of air through the hood is faster when the sash is lower (the hoods also have a bypass that sucks air through the hood to maintain constant volume when the sash is completely shut). Variable air volume (VAV) hoods, on the other hand, maintain a constant velocity of air into the hood ("face velocity") so that the volume of air through the hood is reduced as the sash is lowered.

There are currently 1248 fume hoods on campus, each of which requires approximately the same amount of energy as 3 average homes. Only about 180 hoods on campus are VAV; these are in Tan Hall, Latimer Hall, GPBB, and Birge Hall. Fume hood energy use needs to be considered in the context of the whole building's ventilation system. In buildings with a low density of fume hoods, there is less potential to reduce energy consumption from fume hoods because fume hoods are the only source of exhaust in the laboratory; in order to maintain adequate ventilation, the hoods must exhaust a certain amount of air. Table 1 shows the number of fume hoods by building on campus; this information was obtained from the Office of Environment Health and Safety (EH&S). EH&S checks each hood annually to make sure that the face velocity is in the acceptable range of 100-150 feet per minute.

Building	# hoods
2251 College	1
Barker	24
Birge	12
Calvin	14
Cory	15
Davis	14
Etcheverry	16
FSBR	1

Giannini	2
Giauque	2
Gilman	7
GPBB	11
Hearst	33
Hesse	4
Hildebrand	56
Hilgard	45
HMF	4
Koshland	74
Kroeber	5
Latimer - 1st floor	102
Latimer - 2nd floor	100
Latimer - 3rd floor	120
Morgan	31
LeConte	5
Lewis	39
LHS	3
LSA	66
Marchant	8
McCone	28
Minor	7
Mulford	10
NAF	14
O'Brien	6
Oxford Tract	13
Pimentel	1
RFS	27
Space Science	10
Stanley	98
Tan Hall	107
Tang Center	1
VLSB	98
Wellman	14

Table 1. Number of fume hoods by building (source: Office of Environmental Health & Safety)

2.2 Case Studies

The Laboratory Research and Technical Staff (LabRATS) at UC Santa Barbara instigated an effort to turn off fume hoods that were not used. They consulted the Environmental Health and Safety (EH&S) office and determined that fume hoods could be turned off if each of three conditions were met: a negative air balance is maintained (this is to eliminate the chance of air from the lab migrating to the hall or other parts of the building), the hood is not used for storing chemicals, and the users of the lab are well informed of the decommissioned status of the fume hood. Another interesting finding from LabRATS is that they attribute much of their success to the fact that the people making the suggestions and changes also were the people who work in the labs; the LabRATS program was initiated and run by laboratory researchers. This brings up the very important point that it is crucial to work with the building occupants to find out their priorities and behavioral patterns.

Lawrence Berkeley National Laboratory (LBNL) completed a retrofit in 1995 that included replacing constant air volume (CAV) hoods with VAV hoods and achieved a payback period of less than 5 years. The retrofit also included putting variable speed drives on fans and pumps, installing more efficient motors and HVAC equipment, and lighting retrofits (T-8/electronic ballasts, occupancy sensors, LED exit signs, and CFLs). This comprehensive laboratory retrofit achieved savings of 41% in overall energy use. While the data is not very clear because the project was a comprehensive retrofit, it is apparent that VAV hoods have real potential to save energy.

Along with replacing CAV hoods with VAV hoods during a renovation of the Darwin Hall laboratory building, Sonoma State University was successful in convincing safety officials that it was acceptable to reduce ventilation from six air changes per hour to four air changes per hour in Darwin Hall when lights were off and the buidling was unoccupied (verified by occupancy sensors). Note that because fan power scales as the cube of air speed, reducing the building's ventilation by 1/3 reduces fan power by close to 70%. According to the engineering analysis of Darwin Hall, the small time required to ramp up ventilation rates when the space is re-occupied is not significant. The projected savings just from implementing nighttime setback were estimated at over 150,000 kWh and 10,000 therms per year with a payback of 0.8 years, although it is not clear that these savings have been achieved. Overall, the retrofit reduced the building's energy consumption to less than 20 kWh/gsf, significantly less than the energy consumption per square foot of laboratory buildings on Berkeley's campus.

At Berkeley, a CAV to VAV fume hood retrofit was recently done in the Genetics and Plant Biology Building. Eleven fume hoods were converted to variable air volume in the teaching laboratories. The total project cost was about $230,000, with a payback of 10 years (well within the Strategic Energy Plan's suggested payback of less than 15 years).[1] Because the fume hoods were the only source of exhaust in the laboratories, stops had to be placed on the hoods to prevent the sashes from being fully closed (and thereby blocking all exhaust from the laboratories). This means that the sash height, or work opening, can only be adjusted between 12 and 18 inches. There is still potential for additional savings from this project:

- Reducing the face velocity on the hoods. The VAV retrofit was done with the goal of having the face velocity on the hoods set at 105 feet per minute. However, due to a complaint about a chemical fume in the laboratory, air flow was increased to 120 feet per minute. Obviously it is not acceptable to expose laboratory researchers to hazardous fumes, but one could imagine that face

[1] Personal communication, Patrick MacArdle (Capital Projects), April 21, 2010.

velocities could be reduced when that chemical is not being used or that the fume smell was due to improper handling of the chemical. If the air flow could be reduced back to 105 feet per minute for the majority of the time, the savings per hood could be 2200-3300 kWh/year and 13-19 million BTU, depending on the sash height.[2] For all the hoods in GPBB, this represents savings of $3,500-$5,200 and 15-22 tons CO2e.[3]

- Changing temperature setpoint: Because of their high ventilation rates, changing the thermostat in a lab has a larger impact than changing it in any other room. Although data on the current heating setpoint in GPBB could not be obtained, as a hypothetical case one could consider the potential savings from changing the heating setpoint from 55F to 65F (in Koshland Hall, the heating setpoint is 57F all year, so this may represent a reasonable change to consider for GPBB if it has a similar setpoint). According to Lawrence Berkeley National Laboratory's fume hood calculator (http://fumehoodcalculator.lbl.gov), this would save 20-30 million BTU per hood per year, depending on the sash height and assuming a face velocity of 105 feet per minute. For all of GPBB, this would be a savings of 12 - 17 tons CO2e. While this savings may not be achievable depending on the current temperature setpoint, it is merely meant to illustrate the potential savings from changing temperature setpoints in a laboratory building.

2.3 Findings and Recommendations

[2] This calculation was done using http://fumehoodcalculator.lbl.gov. The hoods in GPBB are 62'' wide and 12-18'' tall. It was assumed that the fan power in GPBB is the same as in neighboring Koshland Hall, namely 2.9 W/cfm (Quantum Energy Services and Technologies, 2007).

[3] This is based on 2009 emissions factors of 0.3 kg CO2e/kWh and 5.295 kg CO2e/therm and utility costs of $0.10/kWh and $0.77/therm.

Given the high demand of energy, fume hoods have been the target of many ideas aimed at creating greener labs. Ideas that hold potential for Berkeley's campus include:

- Turn off fume hoods that are not in use. It has been estimated that this strategy would save approximately 15 tons of CO2e per decommissioned hood per year.[4]

- As discussed above, changing the temperature setpoints in labs can lead to significant energy savings because of the large volume of air required to be conditioned. Changing the heating temperature set point from 55F to 65F would save 33 MMBTU/year/hood. For all 1248 hoods on campus, this works out to a savings of roughly 2,200 tons CO2e/year.[5]

- Install variable speed drives on the motors for exhaust and supply fans, allowing for the possibility of reducing the ventilation below the required 1 cfm per square foot of lab space (5-6 ACH) when the lab is not being occupied. This strategy would be most suitable in teaching labs which are unoccupied at night and on the weekends.

- Convert constant air volume to variable air volume hoods so that energy savings can be achieved by lowering the sashes on the hoods. This option would generate more savings in laboratories with a high density of hoods where it is not necessary to keep all of the sashes open to maintain adequate laboratory ventilation. Based on Table 1, it appears that Latimer Hall, Stanley Hall, and VLSB may be good

[4] Assuming that the average decommissioned hood is 62'' by 17'' and operates with a face velocity of 120 feet per minute, and assuming fan power of 2.9 W/cfm switching off the hood would save 24,500 kWh/year in electricity and 150 MMBTU/year, according to http://fumehoodcalculator.lbl.gov. .

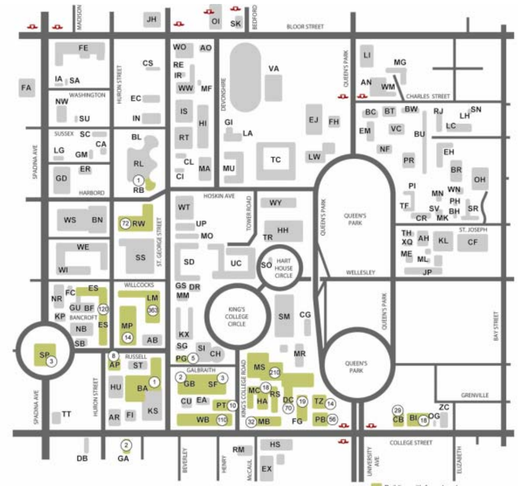
[5] Again, this calculation is based on http://fumehoodcalculator.lbl.gov, assuming that the average hood is 62'' by 17'' and operates with a face velocity of 120 feet per minute.

candidates. However, even in a building like Genetics and Plant Biology, where the fume hoods were the only source of laboratory ventilation, a VAV retrofit still achieved a payback of 10 years.

- Maintain face velocity of VAV hoods close to 100 feet per minute. The potential savings from reducing face velocity from 120 to 105 feet per minute on a VAV hood is 15-22 tons CO_2e, as described above. With 180 VAV hoods on campus, this represents potential savings up to 4,000 tons CO_2e. Because EH&S inspects fume hoods only once per year, maintaining face velocities at 105 fpm would require educating laboratory researchers about the energy savings from this measure so that they understand why face velocities should be maintained at this level unless a particular safety concern requires otherwise. Obviously protecting researchers from hazardous fumes is of paramount concern, so exceptions would have to be made when EH&S deems necessary.

Each of these strategies makes sense in certain situations, and should be implemented only after careful study and thorough understanding of how such a change will affect various aspects of the laboratory and the building as a whole.

Before any projects are proposed it is necessary to know more details about the density of hoods in laboratory buildings and how the hoods are used. It is therefore the recommendation of these authors to create a map similar to that of the University of Toronto, on the following page, showing the number of hoods per laboratory building. Further, it is recommended that the UC Berkeley map include an indication of whether the labs are used (research or teaching), the density of hoods, and whether the fume hoods are the only form of exhaust for the area, as this complicates several of the options.



Location of Fume Hoods (2008)
University of Toronto — St. George Campus

Once it is understood which of the buildings are appropriate candidates for some sort of project, it is crucial that the EH&S office and Physical Plant are included in any decision-making process before implementation. Regarding actual projects, it makes the most sense to start with the least capital intensive methods of saving, such as determining which if any hoods can be turned off, and raising heating setpoints, in the labs. In labs that are highly over-ventilated or that are unoccupied for long periods of time, it might make sense to replace CAV hoods with VAV hoods and reduce ventilation periodically.

We recommend that the CalCAP Committee establish a sub-committee that can further investigate different options for energy savings from laboratory ventilation systems, including the options detailed above: shutting off unused fume hoods, changing temperature set points, instituting nighttime setbacks, educating laboratory researchers about face velocity setpoints, and installing VAVs. This process would require consultation with laboratory researchers to find out how hoods are currently being used and occupancy patterns of laboratory spaces. The sub-committee should also author fume hood standards for new construction, which do not currently exist.

Chapter 3. Energy Information Systems

3.1 Introduction

UC Berkeley lacks detailed data on patterns of energy use by building, which is a serious limitation to trying to understand the energy conservation and efficiency potential for different buildings. Real-time electricity metering data is available for fewer than 30 buildings. UC Berkeley needs to reevaluate the way energy information is analyzed, monitored, and viewed. The campus needs to be able to set building-by-building energy and GHG targets, in order to reach 1990 GHG levels by 2014, and to actively track in real-time whether current energy use in relation to energy goals. UC Berkeley also needs to be able to view historic baseline information building-by-building and see improvements in energy usage year by year.

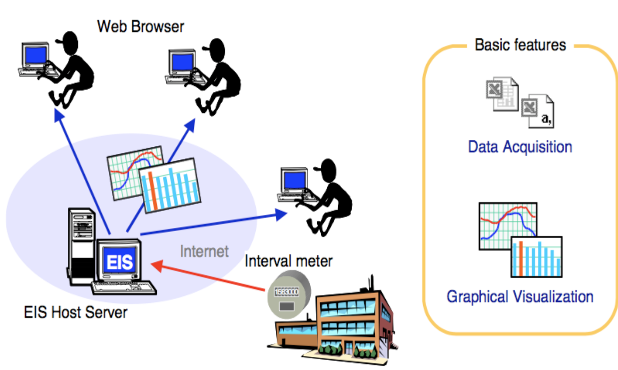


Figure 3. Energy Information System (Source: LBNL)

The tool that will help UC Berkeley analyze energy information is generally referred to as an Energy Information System, or EIS. An EIS combines software, real-time meters, data acquisition, communication systems, and visualization to collect and display energy information in order to decrease energy use. An EIS displays actionable energy information that facilities managers, other decision makers, students and staff, can make better energy saving decisions.

Currently, UC Berkeley views energy use while buildings are being re-commissioned using data software called Obvius. Once a building is re-commissioned, the University tends to stop tracking a building's energy use. While re-commissioning is critical to decreasing energy use, building systems can fall out of tune by as much as 20% after only two or three years post commissioning. The Obvius system has no way of tracking baselines when re-commissioning finishes, and no way of setting targets. UC Berkeley needs to move toward continuous commissioning of buildings by upgrading EIS software and integrating EIS into campus Physical Plant operations to not only track current energy use, but identify new opportunities for energy savings.

Figure 4. Energy Visualization Dashboard (Source: Small Energy Group)

3.2 Case Studies

While UC Berkeley has not actively used an EIS at the campus-wide level, students in the architecture department have used energy visualization to identify energy saving opportunities at Wurster Hall. Students, along with some professors and building management staff, identified excessive ventilation and lighting use by viewing energy data on the Berkeley Dashboard (see Figure 5). The Berkeley Dashboard, a student project funded by The Green Initiative Fund (TGIF), is a user interface tied into the Obvius data logger. As a result of excessive energy use identified at Wurster, ventilation fan running times were reduced, variable speed fans were installed, and more efficient lighting with occupant sensors was put in place, decreasing energy use by 30%. While about half of those savings could fall into the category of re-commissioning, the other half came from simply fine tuning existing systems at very little additional cost. Students and staff at Wurster continue to view progress by comparing current energy use to last year's energy use with the Berkeley Dashboard.

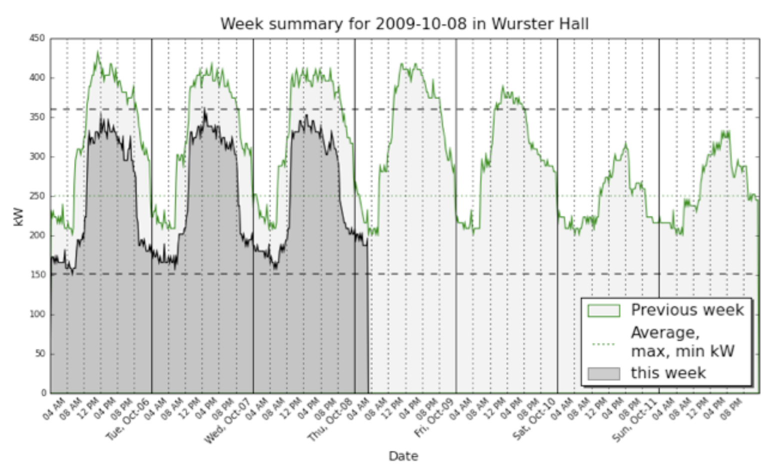


Figure 5. Wurster Hall Energy Use, Week in October (Source: Berkeley Dashboard)

At the University of British Columbia in Canada, an EIS helped facilities managers identify excessive airflow at the Buchanan Tower, one of the largest buildings on campus, leading to building controls adjustments and energy savings of around 12%. The university estimates annual campus-wide savings at about $600,000. The EIS visualization tool was also installed in kiosks and available online for students and staff to view. In a campus survey, 50% of building users said that they decreased their energy use after viewing the energy use information.

3.3 Findings and Recommendations

Integration of an EIS into campus wide energy management can lead to electricity savings at UC Berkeley of around 10% largely based on fine tuning building controls, such as decreasing fan airflow rates. An EIS, as a continuous commissioning tool, would also help maintain those energy savings already achieved from re-commissioning. A 10% decrease in electricity use translates to a decrease of 6,500 tons CO2e, or as much as 20% of the decrease needed to reach 1990 GHG levels from current levels. A 10% decrease in electricity use from implementing EIS would mean a decrease of 21 million kWh/year and a total cost savings of 2 million dollars. This is not including additional savings from decreased steam resulting from shorter HVAC run times. The 6,500 predicted savings from an EIS compares to estimated savings from monitoring-based commissioning of 7,000 tons CO2e on 20 buildings.

Achieving a 6,500 ton drop in GHG emissions does not come with only an upgrade in EIS software. The costs of campus-wide software from a major vendor are estimated at around $140,000 per year for software and technical support, in addition to one-time metering costs of $390,000.[6] Much of the infrastructure is already underway for re-commissioning efforts, but these efforts will need to be expedited. Currently there are about 25 buildings on campus with real-time metering. The campus should expand to around 60 buildings in the next year, starting with the largest buildings.

Besides technology upgrades, the campus will need to make organizational and behavioral changes. An EIS can be used to identify two primary sources of energy reductions. The greatest opportunity is in identifying building controls related reductions, while the second opportunity is in occupant behavior-related reductions, which will be discussed in more detail in the next chapter. An EIS does not automatically adjust building controls, nor does it automatically lead to behavior changes, but it can facilitate identifying energy savings opportunities. An EIS interface can set up a series of triggers in relation to baselines, so that when energy use exceeds or drops a certain amount in relation to the norm, an email could go out to a building manager to check controls for operations. An EIS needs to be integrated into the correct decision-making framework, therefore we recommend a full time staff person to be assigned to managing the use of the EIS. This new energy manager should be located within Physical Plant and actively coordinate with re-commissioning efforts at Capital Projects, with other Physical Plant staff, and with individual departments and building managers. Energy savings opportunities will need to be relayed from the energy manager to staff maintaining building controls. Department building managers, who have greater knowledge of their particular buildings, should also be able to view EIS and override building controls

[6] This assumes that metering is needed for 35 additional buildings and the EIS software is installed in 60 buildings.

settings with the energy manager's approval. Also, as discussions are underway for department-related incentives for behavioral changes such as turning off lights and computers to decrease energy use, departments and students will need to be able to view their progress in relation to established historic baseline energy use with easily accessible visualization tools.

As a result of recommendations from Operational Excellence, Physical Plant is already considering purchasing an EIS and establishing a staff member to manage its use. Physical Plant is ready to take on the opportunity to manage energy use in real-time with an EIS. As creating energy savings by visualizing energy information largely depends on dedicated staff, UC Berkeley is well prepared. While energy visualization depends on the right decision-making framework, an EIS will actively help organize the energy saving process by serving as the center of energy information distribution. The CalCap Steering Committee should continue to coordinate with Physical Plant to make sure that big picture GHG targets are integrated with energy management. We suggest that implementation will be most successful by first integrating into facilities level building controls decisions, then distributing to department building managers, and then to other staff and students. This way building historic baselines and future targets can be understood and campus-wide energy feedback will be more informative at the building-by building scale. The campus should set step-by-step goals for integrating an EIS into campus decisions in order to pick the correct software and integrate it successfully into the campus energy management system.

Chapter 4. Behavioral and Institutional Changes

4.1 Background

While the Strategic Energy Plan focuses on retro-commissioning building equipment, less attention has been devoted to engaging building managers and building occupants in energy conservation. Although there are many student groups at Berkeley that have been working on behavioral changes, there has been less work in this area at the institutional level. As mentioned in the previous chapter, the introduction of an Energy Information System (EIS) offers an increased potential for energy conservation behavioral changes – both by providing feedback to building occupants and by allowing the opportunity to financially incentivize conservation at the departmental level. In this chapter, we begin with some case studies from other universities that highlight the potential for increasing education and awareness around energy conservation. We then move on to discuss two specific proposals in greater detail: providing increased support to building managers for energy conservation and establishing an energy conservation incentive program.

4.2 Case studies

One of the key elements in the efforts of the University of Illinois' main campus is the promotion of personal and unit level responsibility for energy conservation. The University introduced an Energy Liaison Program which creates teams from across campus, both functionally and physically. These teams, from different colleges and departments, promote energy conservation, share ideas, and create obtainable goals to reduce energy. But the key to this program is that each department has to report energy usage to the Chancellor. By introducing these as well as a number of other initiatives, the campus has been able to reduce energy by 9%, thereby saving more than $5 million dollars in a fiscal year[7].

The University of Michigan has one of the most comprehensive and far reaching energy programs in the country. With more than 30 million square feet on buildings on campus, and an energy bill of more than $110 million a year, energy conservation and efficiency is extremely important on campus[8]. With active support from the University President, the campus rolled out Planet Blue, which is a campus wide educational and outreach program[9]. One of the main elements of the program is to create cross functional teams from varying perspectives on campus, including building managers, facilities operators, and building representatives. These teams, utilizing a seven step process, identify and implement retrofit opportunities in buildings across the campus. Once the retrofits have taken place, there are marketing materials created to educate the building occupants, and regular Open Houses to demonstrate the inner workings of the building. This enables the end users to understand and appreciate how much their actions directly result in energy savings. In fact, energy managers have quantified how much each % of energy reduction translates into savings for the University (i.e. a 1% reduction means annual savings of $1 million for the University). Because they have automatic building controls in more than 140 buildings on campus, and a campus wide Energy Management System, anyone can find their building and determine energy usage by looking at simple charts and graphs with pertinent information. To increase the knowledge sharing, and to

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[7] http://news.illinois.edu/II/09/0618/energy.html
[8] http://blog.mlive.com/annarbornews/2008/09/university_of_michigan_aims_to.html
[9] http://planetblue.umich.edu/about.php

ensure the dissemination of information, there is a comprehensive website dedicated to Planet Blue, and it has case studies, an annual report, and resources to educate users, and a feature for individuals to make a public commitment to energy conservation.

The University of Iowa created a campus wide Energy Conservation Advisory Council to encourage conservation. The school also participates in an energy curtailment program with the local utility for favorable pricing. Furthermore, it is one of five public schools to belong to the Chicago Climate Exchange (CCX). This self regulated exchange for greenhouse gas emission reduction and trading, imposes voluntary, but legally binding commitments to reduce greenhouse gases on its members[10]. Another initiative which may have significant effect in reducing energy usage in the 17 million square feet of buildings on campus is the recently installed Energy Control Center. This system, designed by Rockwell Automation, centrally monitors all the buildings across the campus, and interacts with more than 100,000 measurement points. There are dashboards with live displays in both the buildings and the control center, and although it has been operational since January 2010, it was only formally introduced in April[11].

4.3 Increasing support to building managers in LEED EBOM and retro-commissioning processes

4.3.1 Background

Some of the larger buildings on campus, including most laboratories, have their own building managers, hired by departments or colleges. These building managers have detailed knowledge about building energy consumption. As the university moves

[10] http://www.uiowa.edu/~fyi/issues/issues2004_v42/03042005/conservation.html
[11] http://www.facilities.uiowa.edu/sustainable-initiatives/?submenuheader=4

forward with more ambitious plans for building energy conservation, as well as certifying existing buildings under the LEED for Existing Buildings: Operation and Maintenance (LEED EBOM) program, there is significant potential to use the knowledge of these building managers and increase their incentives to pursue energy conservation goals.

4.3.2 Case study: Wurster Hall

Wurster Hall is located in the southeast corner of the campus. Its floor area is approximately 220,000 square feet. The building has a library, studios, offices and many workshop areas (e.g. woodshop, pottery area, etc.). Eliahu Perszyk is Wurster's building manager. He is a very positive and active person, interested in energy efficiency and sustainable management of buildings. He has been pushing sustainable management and he has been working with students and physical plant operators to make Wurster's Hall energy performance the best possible.

The Wurster building manager, as well as professors and students, were heavily involved in the monitoring-based commissioning process at Wurster. The commissioning process gave insight into how the building was performing, which is a fundamental step for setting future goals and being able to analyze, modify, improve, and learn. Some management adjustments (such as changes to fan schedules) were then simple to make through the energy management system (EMS) and these measures resulted in energy savings. In parallel students worked on how to make what was going on in the machine rooms of the building visible to the public. They made an online dashboard, the Berkeley Dashboard, which shows Wurster's energy consumption on a daily, weekly and monthly base, based on information from the campus' energy management system (Obvius).

After the commissioning of Wuster, the building manager, with the help of some students, decided to start going through the LEED process for existing buildings. The College of Environmental Design, which is housed in Wurster, decided to use the LEED-EBOM rating system as a blueprint for Wurster's sustainability plan. What does it take to manage the LEED-EBOM certification process? Beyond LEED-EBOM's prerequisites, the US Green Building Council (USGBC) does not dictate which credits a project team has to achieve. The selection of the credits and points to target, therefore, depends upon the particular goals and motivations driving the pursuit of LEED-EBOM certification in the first place and upon budgetary constraints. The first step in any LEED-EBOM effort is to audit a building's current energy performance and operations by collecting information required to demonstrate compliance with the rating system's prerequisites and credits, and in Wurster Hall that had already been done with the monitoring-based commissioning.

Because Wurster is the first building on campus to go through the LEED EBOM process, the certification process is generating new knowledge that should not be lost. Eliahu says: "For the LEED process, Physical Plant has committed resources, so I am not alone, but there could be more resources put towards LEED certification and going beyond it to make the campus a model of cutting edge sustainable practices". There is no formal network for sharing knowledge about LEED EBOM to other building managers. More generally, in his attempts to manage Wurster more sustainably, Eliahu has had difficulty in finding answers to difficulties he encounters during this process and he feels that more resources devoted to supporting building managers would be helpful.

4.3.3 Findings and Recommendations

Much of the energy conservation work in Wurster Hall has been done on a voluntary basis: staff (Eliahu Perszyk), faculty (such as Professor Charles C. Benton in CED) and students with a passion for energy and sustainability are spending time and energy in Wurster Hall and in many other buildings on campus. But the lack of communication of the experience gained in Wurster is not making these efforts public and as strong as they could be. Specifically, we recommend that the administration facilitate increased collaboration amongst building managers and between building managers and Physical Plant. This should include establishing a centralized set of resources for building managers to help them through the LEED EBOM certification process, as well as experiences of energy efficient building management techniques. This could involve creation of a new staff position (e.g. a Green Consultant for building energy efficiency) or devoting existing staff time to this role.

4.4 Energy Conservation Incentive Program

4.4.1 Background

Currently, most of UC Berkeley's energy consumption is paid for by the central campus administration. With the exception of a few buildings, including the Recreational Sports Facility, Tang Health Center, and others that pay for their own electricity bills, most buildings on campus (including all academic departments) do not see their energy consumption or resultant bills. The University currently pays about $35 million in annual utility costs; every year, this exceeds the University's energy budget by several million dollars, which must be made up through the Chancellor's discretionary funding. Under an Energy Incentive Program, departments would be given feedback on their energy consumption and financial incentives to conserve. Departments could either be asked to pay their entire energy bills, or they could be rewarded with the monetary savings of reducing their energy consumption below a historical baseline (and possibly punished for exceeding their baseline).

4.4.2 Case studies

The SUNY- University of Buffalo campus has a very active Energy Officer, and from 1993-1997, worked with an energy services company (ESCO) to save the $17 million of upfront energy efficient capital costs, and consequently saves $3 million a year on energy costs. Additionally, the campus instituted an energy conservation program, but it was eventually disbanded because of inherent implementation problems. One of the biggest problems with the program was that disincentives for energy conservation existed throughout the SUNY system. The most egregious disincentive was caused by the fact that when a school conserved energy, their energy budget was subsequently reduced the following year. One of the lessons from this experience is that the savings (or at least a portion of them) should be given back to the school or department to incent them to continue to save. Furthermore, incentives need to be considered for rented spaces, including for research institutes, vending machine operators, and auxiliary services like food services[12].

Washington State also initiated an Energy Conservation Incentive Program (ECIP), and terminated it after only two semesters. Although the campus sustainability office would like to implement a similar program again, there were structural issues which need to be overcome before a new program would be successful. The program, which was instituted in the Fall of 2002, involved monitoring energy usage on 60

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[12] http://www.aashe.org/blog/campus-energy-conservation-job-1

buildings on campus. Each month, if the occupants of a building reduced their energy consumption they could split the savings. However, there were some key issues which caused the program to be virtually ineffective. First, most of the buildings under scrutiny had archaic, manually read meters. Thus, there was not sufficient opportunity to measure energy on a timely basis. Second, the Energy Group consisted of only two people, and thus there was insufficient manpower to effectively monitor energy and address incentives within specific departments. These issues, along with the difficulty in allocating savings in shared buildings, led to the conclusion of the trial period. However, the head of the Energy Group expects to reinstate the program once more "smart" meters and energy management systems are installed.[13]

The school which has implemented the most comprehensive Energy Conservation Incentive Program (ECIP) is Stanford University. Besides a number of retrofit programs which will save the University more than $4 million a year, a campus regeneration program, and an annual winter energy curtailment program, one of the campus' best practices is the ECIP[14]. This program, which was established in 2004, gives a financial incentive to academic departments to reduce energy usage. For many years the campus' energy was paid for centrally by the University's Budget Office. However, now the energy is paid for by 21 distinct Budget Units, which might be an academic department, a non-academic department (i.e. Alumni Association), or a staff office (i.e. the Office of Public Affairs). A budget for each unit is set based on the previous five years worth of consumption. This baseline can be revised with the expansion of facilities or research based programs, additional renovations, or program changes. The first six months of

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[13] Personal communication, Terry Ryan, WSU Facilities Operations Department, April 29, 2010
[14] http://sustainablestanford.stanford.edu/

rollout is considered a trial period- if the unit saves energy the department gets to keep the savings. If the unit goes over, the Central Office pays the difference. However, after the six month trial period each unit pays its own energy bills, and thus departments are incentivized to reduce energy costs[15].

There are, of course, potential challenges with a program like this. One challenge is what to do with shared buildings. At Stanford, shared buildings are split based on space allocation, and in fact, as a corollary, some schools have to pay for underutilized space. Another potential problem is what to do with new departments or buildings, as well as program changes. To address this, all new buildings are paid for by the Central Office for three years to establish an historic baseline. Additionally, baselines are adjusted each year to allocate more efficiently, and based on changed space assignments. This necessitates enough personnel resources to manage the process. And to that end, Stanford's Sustainability and Energy Management Department has 85 full time staff members, 13 of which are dedicated solely to sustainability. This Conservation Incentive Program has reduced energy consumption a further 3% on top of the numerous other efforts on campus, and remains the best example of a comprehensive energy incentive program.

4.4.3 Findings and Recommendations

Anecdotal evidence suggests that in buildings where building occupants and building managers are more invested in energy conservation, more savings can be achieved through the retro-commissioning process. This appears to be the case from the commissioning of Wurster Hall and Cory Hall (where there was an unusual degree of

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[15] http://lbre.stanford.edu/sem/ECIP

interest from students, faculty and the building manager) and Tang Health Center (which pays for its own electricity). Commissioning in Cory Hall reduced electricity consumption by 25% (although part of this reduction can also be attributed to a decline in usage of a semiconductor wafer fabrication laboratory). According to data on the Obvius system, commissioning of Tang Health Center reduced the baseload electricity consumption by about two-thirds (note that this does not imply a 2/3 reduction in building electricity use); these savings were partially driven by the fact that Tang Health Center pays for its energy consumption and the building manager was therefore more engaged in the commissioning process.

We recommend that UC Berkeley adopt an energy conservation incentive program like Stanford has done. Their program has been very successful in reducing an additional 3% of energy on top of all the other conservation efforts on campus. By understanding the best practices from Stanford, and learning from what did not work at Washington State and SUNY-Buffalo, UC Berkeley should be able to implement a system that will save a significant amount of energy. Campus leadership needs to be cognizant of disincentives (i.e. lowering a school's budget after energy is reduced), the challenges of shared spaces, and the need for management of the system (one of the downfalls of the Washington State program). Thus, we suggest accelerating the roll-out of real-time metering on campus before beginning an energy incentive program. For situations where there are multiple departments per building, a partitioning of energy use based on square footage could be used as long as the departments do not have radically different energy needs (e.g. laboratory versus non-laboratory). Finally, we suggest that the program, at least in its initial phases include only positive incentives, i.e. rewarding departments for consuming below their historical baseline. After departments have more experience with the program, a penalty could be imposed for departments that increase consumption above their baseline.

Chapter 5. Conclusions and Recommendations

UC Berkeley needs to aggressively pursue energy efficiency measures in campus buildings in order to meet its 2014 CalCAP goal. The Strategic Energy Plan is Berkeley's main mechanism for addressing energy efficiency in buildings, and SEP projects have contributed significantly to achieving the CalCAP goal. Some of the themes that have emerged from our research include the energy saving opportunities available from engaging building occupants, changing incentive structures, and investing in better quality data and information management systems. After meeting with administrators, researchers, and staff members from across the campus, we have come to the conclusion that the primary barriers to achieving energy efficiency on campus are not technical, but organizational and institutional. For example, the office with primary responsibility for meeting our CalCAP goals (the Office of Sustainability) has no direct influence on energy management in campus buildings; staff responsible for building management have incentives to maintain the status quo and avoid complaints rather than pursue energy-saving changes; and academic departments that consume the majority of energy on campus have no incentive to conserve or to be engaged in the building commissioning process. Moreover, there are building managers and students across campus whose knowledge of building energy consumption is not being used to its full potential. There are many opportunities to address these issues, and the following is a summary of our recommendations:

Laboratory Ventilation

- We recommend that the CalCAP Committee establish a sub-committee that can to gather additional data on the status of existing fume hoods and further investigate different options for energy savings from laboratory ventilation systems, including: shutting off unused fume hoods, changing temperature set points, instituting nighttime setbacks, and installing variable air volume hoods. This process would require consultation with laboratory researchers to find out how hoods are currently being used and occupancy patterns of laboratory spaces and to address concerns about health impacts of changing ventilation rates. The sub-committee should also author fume hood standards for new construction, which do not currently exist.

Energy Information Systems

- UC Berkeley should move forward with installing an Energy Information System. This will also require accelerating the roll-out of real-time electricity metering of major buildings on campus. Currently there are about 25 buildings on campus with real-time metering. The campus should expand to around 60 buildings in the next year, starting with the largest buildings.

- A full time staff person should be hired to manage the use of the EIS for continuous commissioning of campus buildings. This new energy manager should be located within the Physical Plant and actively coordinate with re-commissioning efforts at Capital Projects, with other Physical Plant staff, and with individual departments and building managers. Energy savings opportunities will need to be relayed from the energy manager to staff maintaining building controls. Department building managers, who have greater knowledge of their particular buildings, should also be able to view EIS and override building controls settings with the energy manager's approval.

- Departments and students should have easy access to visualization tools in order to view their building's energy use and progress towards meeting energy conservation goals.

Behavioral and Institutional Changes

- The University should facilitate increased collaboration amongst building managers and between building managers and Physical Plant. This should include establishing a centralized set of resources for building managers to help them through the LEED EBOM certification process, as well as best practices of energy efficient building management techniques. This could involve creation of a new staff position (e.g. a Green Consultant for building energy efficiency) or devoting existing staff time to this role.
- UC Berkeley should adopt an energy conservation incentive program that provides financial incentives to departments to conserve energy, based on their baseline energy use.
- Existing staff should be incentivized for energy conservation activities. Most energy efficiency projects on campus appear to be more constrained by staffing than by funding. Hiring additional staff devoted to building energy efficiency would be very useful, but the university could also do more to incentivize existing staff by integrating energy performance into performance review criteria and

bonus criteria. Staff could potentially be hired on a shorter term basis using UC/CSU/IOU partnership funding.

In short, there are many opportunities for increasing the energy efficiency of our existing buildings. By vigorously pursuing these strategies, which often do not have high upfront costs, UC Berkeley should be able to meet its CalCAP goal in 2014 without having to resort to purchasing offsets.

Appendix

In the course of our class discussions, several issues emerged which would be useful topics for research in future CalCAP classes. These include:

- Energy consumption by servers: The electricity and heating load from computer servers and data centers is rapidly increasing. Because servers are often purchased by individual researchers and not stored centrally, there is very little data on servers, including such basic information as how many servers we have and where they are located. Gathering this information and making recommendations for how to better consolidate and use servers more efficiently would help the University with this emerging concern.

- Steam system: The University's contract with Delta Cogeneration, which provides steam for the campus, will expire in 2017. The options currently available to the University include: enter into another lease agreement with a third party operator, replace with another steam plant, or replace with another source of heating (such as geothermal or solar thermal). An analysis of renewable energy alternatives to the current steam plant could be a valuable contribution to the debate over how to meet our steam needs post-2017.

- Behavior: Engaging building occupants in energy conservation could be an important step towards achieving our CalCAP goal. A review of behavioral economics and social psychology to apply what we know about the effectiveness of different strategies (competitions, feedback, goal-setting, and changing social norms) to the campus setting could be helpful in prioritizing behavioral strategies.

- Laboratory plug loads: Laboratory equipment is not included in the Strategic Energy Plan, and purchase of laboratory equipment is decentralized. More research is needed to work with laboratory researchers on finding the best ways to reduce energy consumption from plug loads and to encourage purchase of the most efficient equipment (since equipment purchasing is typically covered by overhead on grants and electricity bills are not paid by researchers, there is a financial incentive to purchase less expensive and less energy efficient equipment).

- Energy performance criteria for new construction: Currently there are no standards in place for energy performance for new buildings. Although the University policy is to meet LEED Silver standards, the flexibility of LEED means that a wide variety of energy performance targets are acceptable under the LEED program. More research is necessary to determine reasonable standards for the diversity of buildings that are constructed on campus (laboratories, classroom buildings, office buildings, etc).

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