University of California Santa Barbara
Operational Effectiveness: Energy Management Initiative

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

by

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UCSB Operational Effectiveness: Energy Management Initiative

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(The faculty advisor may change this statement prior to submitting this report).

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

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

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Abstract

UCSB is currently tasked with meeting the UC Office of the President's 2025 Carbon Neutrality Goal. Meeting this goal becomes even more challenging due to the recent passage of UCSB's Long Range Development Plan, where the campus is expected to grow 1% annually through 2025. Since departments on campus do not directly pay their utility bills, they lack any financial incentive to reduce energy use. Campus utility bills, which are currently around $800,000 every month, will continue to increase as the campus expands. Therefore, UCSB must implement a number of energy reduction strategies to meet this ambitious Carbon Neutrality Goal. The OE: Energy Management Initiative will help reduce campus energy consumption by influencing how occupants interact within their built environment. This will be accomplished through an education and strategic messaging campaign and will reward departments with a financial incentive worth 50% of their annual energy savings. This project experimented with different strategies that addressed both individual behaviors as well as building-wide inefficiencies. Using these different strategies, the group conducted a pilot program in three buildings on campus and observed over a 4% average energy reduction over a five-month time frame. A cost-benefit analysis of a campus wide program indicates that the campus will only need to reduce energy use by 2.5% for this program to be financially beneficial. Based on the success of the pilot program, the group is presenting UCSB Utility and Energy Services with a timeline and framework that can be used to implement a behavior-based energy conservation program campus wide.

Executive Summary

UCSB is currently tasked with meeting the UC Office of the President's 2025 Carbon Neutrality Goal. Meeting this goal becomes even more challenging due to the recent passage of UCSB's Long Range Development Plan, where the campus is expected to grow 1% annually through 2025. Since departments on campus do not directly pay their utility bills, they lack any financial incentive to reduce energy use. Campus utility bills, which are currently around $800,000 every month, will continue to increase as the campus expands. Therefore, UCSB must implement a number of energy reduction strategies to meet this ambitious Carbon Neutrality Goal. The OE: Energy Management Initiative will help reduce campus energy consumption by influencing how occupants interact within their built environment.

This program will target occupant behavior through an educational and strategic messaging campaign and a financial incentive, which will reward departments with a financial payment worth 50% of their annual energy savings. This project experimented with different strategies that addressed both individual behaviors as well as building-wide inefficiencies. Individual behavior strategies included: providing occupants with information on energy use in their building, giving tips on how to save energy, utilizing strategic messages, such as normative and commitment messages, and enabling competitions between building occupants. While engaging building occupants in understanding and reducing their energy use, methods to optimize existing building systems were also identified. These included: adjusting lighting controls, temperature settings and HVAC settings.

Using these different strategies, the group conducted a pilot program in three buildings on campus, the Gevirtz Graduate School of Education (GGSE), Social Science and Media Studies (SSMS), and Physical Science Building North (PSBN). Over five months, each building's average energy reductions were 6.3%, 5.9% and 2.5%, respectively. The results of a cost-benefit analysis of a campus wide program indicated that the campus would only need to reduce energy use by 2.5% for this program to be financially beneficial. Based on the successes of the pilot program, the group is presenting UCSB Utility and Energy Services with a timeline and framework that can be used to implement a behavior-based energy conservation program campus wide.

Introduction

At the University of California, Santa Barbara, sustainability is at the core of campus operations and management. Through a vast number of programs and initiatives, the school has been successful in combating a variety of environmental issues ranging from climate change to water security and waste diversion. As a result of these efforts, UCSB has received national recognition as a leader in sustainability from organizations such as Princeton Review and The Sierra Club. In regards to combating climate change and the reduction of greenhouse gas (GHG) emissions, UCSB has implemented several mitigation strategies from on-site renewable power generation to increasing efficiencies in transportation and buildings. However, UCSB has yet to invest in a behavioral based energy reduction program. The UCSB Operational Effectiveness (OE): Energy Management Initiative was developed to address occupant behavior as it relates to energy and serve as our Master's Thesis Group Project.

The ultimate goal of this project is to reduce energy use at UCSB by developing a comprehensive energy management plan that specifically targets user behavior. Since most departments on campus do not directly pay their utility bills, they lack any financial incentive to reduce energy. The OE: Energy Management Initiative will help reduce campus energy consumption by influencing how occupants interact within their built environment. This will be accomplished through an education and strategic messaging campaign and will reward departments with a financial incentive worth 50% of their annual energy savings. It is important to note that this program specifically focuses on reducing campus electricity consumption; natural gas and water use are not directly included in this study.

In order to determine how to effectively change user behavior, the development of this plan followed three basic research questions: 1) Which behaviors can be changed to reduce energy? 2) Which strategies can effectively influence behavior to reduce energy use? 3) How can strategies be scaled for a campus wide rollout? For this program to be effective, it must be able to be applied to a variety of buildings on campus, which greatly vary by their use and occupant composition. As a result, the group developed a variety of strategies to effectively influence occupant energy use, including education and strategic messages. Our strategic messaging campaign utilized social science research to encourage energy efficient behavior. These messages were tailored for building types (i.e., lab, offices, etc.) and user behaviors, and were disseminated through a variety of channels (posters, e-mails, handouts) to reach as many occupants as possible.

Pilot Buildings

To answer the three research questions above, a pilot project was conducted in three buildings on campus, the Gevirtz Graduate School of Education (GGSE), the Social Sciences and Media Studies (SSMS) building and the Physical Sciences Building North (PSBN). These buildings were chosen by UCSB Utilities and Energy Services for a number of reasons: they had no recent energy efficiency upgrades, were comprised mainly of one department and had sufficient energy metering data to calculate a two-year baseline to compare savings.

GGSE and SSMS were constructed in 2008 and are both LEED Silver certified buildings. The certification signifies their energy efficiency, and a lower potential for energy savings compared to other buildings on campus. As a result of their near identical building design, both GGSE and SSMS are comprised of classrooms on the first floor, faculty and research offices on the second and third floors and a mix of offices and conference rooms on the fourth floor. Occupants in these buildings are a combination of graduate students, faculty and staff. The majority of occupants that we interacted with in GGSE and SSMS were receptive and excited about reducing their energy use and being part of the pilot program.

PSBN was constructed in 1984 and is primarily comprised of teaching labs on the first and second floors and research labs on the third and fourth floors. PSBN hosts the chemistry department, which includes researchers, laboratory staff, teaching assistants, graduate students, and students taking lab-based courses. Overall, the departments and occupants of PSBN were less receptive to the pilot program than individuals we interacted with in the office buildings, and placed much less significance on changing their behavior to reduce energy use.

Objectives

The group's project objectives are as follows:

- Reduce occupant energy consumption in pilot buildings and ultimately in all buildings on campus.
- Develop an Energy Management Initiative utilizing a financial incentive and strategic messaging campaign to target occupant behavior.
- Pilot the messaging campaign to determine which messaging strategies were effective in reducing energy consumption
- Present UCSB Utilities and Energy Services with a timeline and detailed framework of how to administer the program campus wide
    - Apply the results of the pilot to establish messaging strategies for all buildings on campus – determine which strategies are most effective for each type of building:
    - Calculate baseline energy use for each building on campus and determine where energy monitoring and sub-metering needs to be installed for buildings lacking sufficient baseline data.
    - Increase coordination with campus energy groups, such as LabRATS and Power Save UCSB, and determine their role in implementing a campus rollout.

Significance of the Project

Currently, the main UC Santa Barbara (UCSB) campus consumes, on average, over $800,000 in energy utilities every month. At current consumption rates, UCSB's utility costs will continue to rise as the campus expands, student population grows and more advanced research initiatives are implemented. Due to the recent passage of UCSB's Long Range Development Plan (LRDP), housing will be built for 5,000 additional students and 1,600 additional staff to compensate for the yearly 1% growth the campus is expecting through 2025. Although UCSB has many energy efficiency projects that improve building performance, there are no programs in place to incentivize behavior change. In most buildings on campus, the state pays the electricity bill, creating a disconnect between the users of the building and the cost of the electricity. By creating an incentive program where users receive a portion of their energy savings combined with a strategic messaging campaign, we can encourage more energy efficient behavior. The University of California Santa Barbara stands to benefit from this project by significantly reducing the campus' energy consumption, carbon footprint, and utility expenditures, which will help in meeting the 2025 carbon neutral goal set by the University of California Office of the President (UCOP). This energy management plan will provide a framework that can be carried out by UCSB Utility and Energy Services and UCSB Facilities

Management, and can be used as guidance for departments on campus to reduce energy consumption.

Literature Review

Other universities have implemented energy efficiency programs and successful behavior interventions, particularly with regards to energy efficiency, by using monetary incentives and specific messaging strategies that were influential in long-lasting behavior change. These successful programs offered guidance for determining which behaviors can have the greatest influence on energy savings as well as identifying opportunities for the largest energy savings in office and laboratory buildings.

Other University Energy Management Initiatives

Stanford University and University of California Berkeley (UCB) have already adopted successful energy incentive programs. The Stanford Energy Conservation Incentive Program began in the spring of 2004 and incentivized energy savings by setting an energy "budget" (baseline) based on past consumption. Participants that reduced consumption below their baseline received a portion of the value of their unused energy, and if they exceeded their budget, were required to pay the cost of the additional energy (units that share buildings are allocated their budget, in kWh, based on square footage). The first six months of the program acted as a "grace" period, where participants were not penalized for going over their budget. The budgets were set based on a 12-month period and were evaluated at the end of the fiscal year. To ensure users were aware of energy consumption, each unit received a monthly report showing their usage and how they compared with their budgets. By the third year, users saved $830,000 worth of energy.

UCB initiated a similar energy management incentive program in April 2012 that gives operating units a financial incentive to reduce energy consumption. UCB's incentive program works very similarly to Stanford's, where departments received a financial payment of ⅔ of the energy they saved compared to a baseline budget evaluated over the fiscal year. In the second year of program implementation, departments that use more energy than budgeted faced financial penalties. Not surprisingly, the largest users of energy at Berkeley have generally been the largest reducers of total energy. The College of Engineering was able reduce electricity consumption by 1,343,584 kWh in the first year and received a financial incentive payment of $134,400. The other two largest reducers were the VC Research Units (1,232,135 kWh worth $123,200) and the University Libraries (1,168,998 kWh worth $116,900). Since inception, UCB has reported overall energy savings of $2 million. A main goal of the UCSB Energy Management Initiative is to achieve comparable results to the Stanford and Berkeley programs but without the financial penalty.

Along with the incentive program, UCB is implementing several strategies to increase energy efficiency including competitions for fume hoods and plug in loads, power agents (volunteers committed to engaging the campus community in actions that reduce energy use in buildings), stop light stickers to indicate if equipment should be turned off, and online energy dashboards so buildings can see their real-time and historical energy use. Berkeley also increased collaboration with campus student sustainability groups to increase their effectiveness. Many of these strategies, such as stickers for equipment and collaborating with campus sustainability groups, have been included in the scope of the UCSB OE: Energy Management Initiative.

A key takeaway from UC Berkeley's program and other universities' behavior-based energy management programs is the importance of communication and education regarding energy use. Although stickers on lab equipment, fume hood competitions and power agents are all different approaches to reduce energy consumption, they each share the common trait of bringing attention to energy use on campus. Therefore, we sought to incorporate a range of strategies into the pilot program that have been proven successful by other universities in order to achieve the greatest energy savings possible. The specifics of these strategies are discussed in further detail below.

Energy Savings Categories, Behaviors and Strategies

In order to design a program focused on changing user behavior, it was important to identify energy use categories that should be addressed in order to achieve substantial energy savings, as well as evaluate the potential monetary savings for each category. The energy use categories below were targeted specifically because occupants have a direct influence on energy consumption for that category, and energy from that category comprises a significant amount of building wide electricity. Behaviors were identified based on the ease of behavioral change and the potential for energy savings. For this evaluation, we have approximated the cost of electricity at $0.10 per kWh based on an average from 2013-2014 campus energy bills. The actual cost of electricity at UCSB varies depending on the time of day and season, but usually ranges between $0.08 and $0.12 per kWh. However, it is important to note that over the past decade, the campus has seen a low of around $0.06 per kWh and a high of around $0.14 per kWh.

Lighting

Lighting was identified as a significant energy use category to focus on. According to the U.S. Energy Information Administration, lighting accounts for 31% of total electricity use in U.S. colleges and university educational facilities. In addition, the group had circuit sub metering installed in GGSE in order to analyze energy use by floor and by building system (lighting, HVAC and plug load). From June-November 2014, GGSE used an average of 933 kWh per day for lighting, which is approximately $3,472/year. Similarly, according to many Department of Energy (DOE) Labs21 case studies, lighting accounts for 10-15% of total electricity use in laboratory buildings on campus. PSBN averaged 8,880 kWh per day in March 2014. Assuming 12% of total electricity is used for lighting, about 383,610 kWh ($38,361) are used per year.

To save energy on lighting, UCB and DOE Labs21 studies advise occupants to: turn off lights when they aren't needed, use natural lighting when possible, use task lighting instead of overhead lights (can reduce energy use by up to 40%), and switch to CFL or LED light bulbs (last 6-12 times longer and use up to 75% less energy). For the UCSB OE: Energy Management Initiative, some of these energy-saving recommendations have been included as part of the messaging campaign for the pilot program, which is discussed in more detail below.

Plugin Load/Standby Power

Most electronic devices, even when turned off, use between 1-10 watts of electricity, which is known as phantom power (Table 1). Unplugging devices or using a power strip and turning it off when not in use can achieve small savings. These savings are small individually, but can add up to significant amounts of electricity over time. However, it is difficult to influence occupants to unplug devices or use power strips, which makes phantom power a "lower-priority" behavior change. More significant savings can be achieved by making sure that equipment is turned off when not in use. This includes turning off printers, scanners, faxes, computers, monitors, and lab equipment. When determining which behaviors to target in terms of plug load reduction, it is important to ask individuals to change their behavior in a way that only requires them to complete easy and convenient tasks. For standby power, UCB recommendations include: unplug items that aren't used very often, use a power strip and turn it off when not in use, and utilize a Kill-a-watt to assess how much energy a device uses.

Table 1. Average electricity use, phantom power and yearly electricity use of various devices for one year (Source: Lawrence Berkeley National Laboratory).

Device	Average Energy Use	Phantom Power in One Year	If Left on for a Year
Coffee maker		9 kWh ($.90)	
Copier	9.63 W	13 kWh ($1.30)	84 kWh ($8.40)
Fax	6.1 W	47 kWh ($4.70)	55 kWh ($5.50)
Microwave	1433 W	26 kWh ($2.60)	
LCD Monitor	27.61 W	10 kWh ($1.00)	242 kWh ($24.20)
CRT	65.1 W	7 kWh ($.70)	569 kWh ($56.90)
Desktop Computer	73.97 W (Idle)	25 kWh ($2.50)	648 kWh ($64.8) Sleep mode 185 kWh ($18.5)
Laptop Computer	29.48 W	78.84 kWh ($7.88)	258.42 kWh ($25.80) Sleep - 138.1 kWh ($13.81)
Printer inkjet	4.93 W	11 kWh ($1.10)	43 kWh ($4.30)
Printer LaserJet	131.07 W	14 kWh ($1.40)	1148 kWh ($114.8)
Scanner	9.6 W	25 kWh ($2.50)	84 kWh ($8.40)
Computer Speakers	4.12 W	16 kWh ($1.60)	36 kWh ($3.60)
TV (rear projection)	186.09 W	61 kWh ($6.10)	

Computers

According to UCB, computers make up approximately 5-10% of office power usage. According to Griffith University, the average desktop computer and monitor uses 130 watts and the cost of electricity to operate a typical computer and monitor workstation (130 watts at $0.10 per kWh) for 24 hours a day, 7 days a week, 365 days a year, is $114. The same workstation operating only during work hours – 8 hours a day, 5 days a week, for an entire year is $27. Therefore, shutting down computers and monitors rather than leaving them on can save $87 per year per computer. Similarly, substantial power savings (between 50 to 90%) can be realized if computers and printers are put into power saving mode when not in use. UCB identified several strategies to reduce energy consumption with computers such as: set monitors to standby (sleep mode) instead of using screen-savers, turn off monitors and printers when not in use, reduce brightness and increase contrast of monitor (can reduce power usage by up to 50%), enable energy saving features, see if backups and updates could be regularly done on the same day of the week so that computers can be turned off the other days. For the UCSB OE: Energy Management Initiative, many of these energy saving tips have been included in the messaging campaign for the pilot buildings.

Purchasing

For purchasing, UCB recommendations include: buying energy efficient equipment (energy star or EPEAT), choosing a laptop instead of a desktop can save 90% of electricity, upgrading CRT monitors to LCDs saves about 40% electricity, and replacing old refrigerators (new refrigerators use about half the electricity compared to models from the 1990s). This behavior is not being targeted in the UCSB pilot program, as most occupants do not have control over purchasing in their building.

Thermal Comfort

For thermal comfort, UCB recommendations include: close doors and windows when the heat or AC is on, use sunlight wisely by closing or tilting blinds, avoid using space heaters and wear extra layers instead. For the UCSB pilot program, building occupants are advised to contact Utility and Energy Services if the building is consistently too hot or cold. The group is also advising building occupants to use blankets and jackets instead of space heaters.

Fume Hoods

In campus laboratories, a major area of energy savings can be realized from efficient usage of fume hoods. Fume hoods ensure safe work conditions in laboratories by exhausting air to the outdoors. Besides the exhaust fans themselves being energy intensive, fume hoods are directly connected to the buildings heating, ventilation, and air-conditioning (HVAC) system, and greatly increase the energy demand of HVAC systems as a whole. Because air is directly vented from outside, all fresh air must be conditioned to the ambient temperature inside of the lab, thus greatly increasing heating and cooling costs in non-temperate locations. These features account for laboratories being 3-4 times more expensive than average commercial buildings. Astoundingly, a single conventionally sized fume hood (6ft opening) operating at full capacity can consume more than 3 times the energy of an average house annually (Mills, et al. 2006).

There is potential for large energy savings resulting from efficient user behavior depending on the type of fume hoods installed on campus. Variable air volume (VAV) fume hoods are designed so the position of the sash affects the intensity of the exhaust fan and HVAC system as a whole (Mills et al, 2006). In other words, if users lower the height of the fume hood sash, the fume hood uses less energy. Conversely, constant air volume (CAV) fume hoods operate continuously at a set flow speed, irrespective of user operation (Mills et al, 2006). Therefore, changing occupant behavior to lower the height of the fume hood sash will not reduce the amount of energy the fume hood uses. The difference in energy savings potential between these two systems is significant, especially because fume hoods are linked to the overall HVAC system of the building and are usually a major category of energy use in lab buildings.

There have been numerous studies, which sought to identify effective strategies to influence efficient use of VAV fume hoods. To name a few, Harvard, UC Davis, and Duke all have had programs which employed different strategies aimed at increasing user efficiency. At Harvard University, labs that were retrofitted with VAV's had monitors that showed the labs total energy usage, and competitions were implemented between labs to reduce energy use. This mix of informational messaging and competition resulted in a 30% sustained reduction in lab energy use involved in the program (National Wildlife Federation, 2009). UC Davis employed a lab 'reminder' system in the form of vinyl stickers to remind fume hood users to close their sashes when not in use. The stickers resembled a traffic light scheme where a closed sash was associated with a green sticker, and a completely open sash with red (consuming the most energy). These stickers resulted in measurable energy savings from their VAV fume hoods, and also showed a decrease in sash closure rates over time (Department of Energy, 2012). Lab trainings at Duke University showed an increase in sash closures of 30% (Pacific Gas and Electric, 2007).

At $0.10/kWh, individual fume hoods cost $7,600 per year (Pacific Gas and Electric, 2012). The observed potential for 30% energy reductions through lab trainings, competition, and informational stickers indicates a massive area for potential savings. Thus, a system for sash management within labs is an essential element to lab energy efficiency. The UCSB pilot program is currently not employing these strategies, as the pilot building PSBN has CAV fume hoods. However, fume hoods will be a very important component of the campus wide program rollout for the other major science building on campus with VAV fume hoods.

Cold Storage

Within laboratory energy consumption from plug-loads, cold storage is one of the larger factors in overall energy use. Outdated -80°C labs freezers can consume up to 20,000kWh per year, costing Universities $2,000 (at $0.10/kWh) per freezer (Goodcampus.org). There are a number of strategies to ensure maximum energy performance of laboratory cold storage units. Specific recommendations for cold storage include: minimize frost formation of freezers, clean refrigerator and freezer coils, check the door seals and gaskets for leaks, keep items off and away from freezers (3" radius), locate freezers in cooler areas, use chest freezers when possible (more efficient than upright freezers), combine refrigerators and freezers, unplug those that aren't being used, and set temperatures only as low as they need to be. Additionally, lab managers should strive to replace outdated freezers with newer, more efficient models whenever feasible. This behavior is not being targeted in the UCSB pilot program because cold storage is a shared resource, which makes it harder to manage. However, as part of the policy framework for building and department management in an overall campus rollout, cold storage policies will be recommended for building and lab managers.

Behavioral Science and Messaging

With an understanding of different energy consumptive categories and the associated energy saving behaviors, it is important to determine how these behaviors can be changed and sustained over a long period of time within an energy management framework. For a broad-scale program to be successful, there are three critical components necessary; analytics, technology and behavioral science (OPower, 2011). Analytics give consumers specific insights, advice and recommendations about where to focus their attention. Targeted advice ensures that each customer receives the most impactful energy efficiency recommendation based on a number of energy user profile attributes including demographics, characteristics, and energy usage patterns. One component of the UCSB OE: Energy Management Initiative involved analytics, where building occupants were given specific energy savings recommendations based on their own behavior. This was done through an online survey, where occupants received customized recommendations depending on how they responded to various questions regarding their behavior in the building.

Technology enables delivery of this customized content to consumers at a very large scale. For the pilot project, this was achieved through three means: e-mails, interactive surveys and the campus energy management software. Technology can also help accomplish targeted energy measurements. At UCSB, submetering and circuit metering technology will be utilized to facilitate this program. Submetering and circuit metering technologies allow UCSB Utility and Energy Services to analyze electricity usage between floors and sections of buildings, as well as the amount of energy being used by certain building systems such as lighting, plug load and HVAC. A more descriptive metering system allows individuals to better understand how electricity is being used in their building and to pinpoint potential energy savings to focus efforts. For the campus wide rollout, technology can be used to more efficiently process and analyze data for buildings in order to produce monthly energy reports. This can be accomplished using programing languages such as Python to automatically download, process and produce energy report data for all buildings on campus.

Finally, the group analyzed the role of behavioral science and strategic messaging to influence behavioral change. Many studies show humans often resist actions with clear-long term benefits if they tend to be unpleasant in the short run. For example, studies show people fail to take advantage of technologies that would save them money in the long run (better insulation, fuel efficient vehicles, etc.), if there were not immediate benefits (OPower, 2011). However, behavioral science research suggests a more complex view; humans are inclined to act in certain ways and this can be utilized through a variety of strategies to promote behavior change. By utilizing behavioral tendencies and inclinations in messaging, we can more effectively encourage energy efficient behavior.

There are a number of characteristics that energy efficiency programs must exhibit. These characteristics include measurable savings, cost-effectiveness, sustained impact, and customer satisfaction (OPower, 2013). For the purpose of this project, customer satisfaction is not considered as it relates to a homeowner-utility relationship and is not applicable to the goal of changing user behavior in campus buildings. Measurable savings is a pertinent component of implementing a behavioral energy efficiency program and relies on the ability to isolate and measure these savings (OPower, 2013). For this project, savings were measured against an established two-year baseline. For cost-effectiveness, targeted messages distributed in faculty mailboxes, hung up in bathrooms and kitchens, and emailed to building occupants were used to change user behavior with relatively low costs. Printed messages were placed in areas of the building where occupants would have sufficient idle time necessary to read the information such as on the back of bathroom stalls, above the urinals and above the microwave. The most cost-effective approach is usually achieved by targeting the highest energy users to participate; for this project, lab buildings are being included. This was supported by an in-depth cost benefit analysis of the program on a campus wide scale, where significantly larger savings were realized from lab buildings because they use notably more energy than other types of buildings on campus.

An energy efficiency program reliant on user behavior must sustain engagement and behavior change over time. Long-term behavior change can be accomplished through messages that use intrinsic motivators such as social and injunctive norms, identity value, and commitments. Social norms compare behavior of individuals to behavior of those similar to them. Identity value is used to associate an individual with their behavior, and provides them with a unique sense of purpose with the specific behavior being targeted. Lastly, public commitments to a goal compel people to act because this goal becomes linked to their self-image. One extrinsic motivator the group utilized was financial incentives. Although these extrinsic incentives are shown to be less effective in long-term behavior change, they can motivate building managers and department heads to align with an energy efficiency program, adopt energy efficiency building and department policies and make better purchasing decisions in the hopes of energy savings and future earnings.

Social Norms

For this project, we determined how to target energy consumers and strategically generate messages that will inspire them to change their behavior. Normative messaging has been proven effective in motivating sustained behavior change. Injunctive norms typically encompass behaviors or actions that people approve or disapprove, and descriptive norms show what actions people take (Cialdini, 2003). Injunctive norm messages are generally phrased as "people think you should (or should not) do this" whereas descriptive norms are worded as "people do this action". Both types of messages have proven effective in motivating behavior change, as individuals want to do what is popular as well as socially acceptable (Cialdini, 2003). Studies show that using social norms are the most effective messaging strategy at producing energy conserving behaviors (Goldstein, 2010).

One of the most widely known social norm experiments involves messaging individuals in hotel rooms to reuse their towels. People who received a social normative message, such as "75% of the guests participated in our new resource saving program by using their towels more than once. You can join your fellow guests in this program to help save the environment by reusing your towel during your stay", were 20% more likely to reuse their towels compared to guests who received an environmental-only related message. (Goldstein 2010). Furthermore, individuals who received a message expressing greater similarities, such as "75% of the guests who stayed in this room participated in our new resource savings program by using their towels more", were 33% more likely to reuse their towels compared to individuals who receive an environmental-only related message (Goldstein, 2010). To summarize, social norms often contain personalized analysis that show how a consumer's energy use compares to that of average neighbors as well as the most efficient neighbors with similar scenarios. We used social normative messaging in the pilot program by describing behaviors of the occupants in each pilot building in hopes of motivating people who do not currently act that way. Based on the proven influence of social norms, we believe normative messaging will be a key strategy for influencing behavior change, especially in a campus wide rollout.

Identity

Another potentially powerful influence on energy efficient behavior is social identity theory. This psychological phenomenon describes how people strive to maintain a positive self-image through membership in a larger group characterized by similar values. Studies have identified the ability of a common group identity to enhance cooperation and individual performance of group members. Further, common group identities reduce individual uncertainty and provide a basis for evaluating personal behavioral choices (McMakin, et al., 2002). According to McMakin et al., it may be best to combine a variety of motivators, where identity strategies could be incorporated to create a more sustained long-term shift in building use behavior. With more data on building occupants, social identity theory may present an effective strategy when combined with other messaging treatments during a campus wide rollout. The goal of using identity messages in this project is to create an association between being energy efficient in buildings on campus and being a member of a specific department or the entire UCSB community. For example, an identity message might read: "Green Gauchos remember to turn their lights off at the end of the day." Those who identify as a "Green Gaucho" will be more likely to partake in that behavior because they want to maintain a positive image within their group. However, identity messages were not incorporated into the pilot program as data is not available for in-group and outgroup associations for occupants in the pilot buildings.

Commitment

Commitment is another type of messaging strategy that can influence behavior, where individuals make a commitment to act in a certain way or partake in a specific behavior. Since people have a desire to be seen as consistent, it is more likely that individuals who made a public commitment are more likely to follow through with their behavior. Commitments are also likely to be effective when there is good group cohesion because individuals generally care about what others in their group think about them; this strategy tends to be most effective when there is a central leader motivating the commitment. Studies reveal that written commitments tend to be more successful than verbal commitments and public commitments tend to be more effective than private commitments. For example, households that made a public commitment had significantly more energy savings than those that made a private commitment. Finally, commitments can help individuals see themselves as environmentally concerned, and people are more likely to act on environmental issues when they feel a connection to this identity (Baca-Motes, et al., 2013). For this project, different commitment strategies have been utilized, such as using a survey monkey to ask people to commit to change their computer settings or handouts people can place on their door that shows they made a commitment to turn their lights off. These strategies will be discussed in further detail below.

Financial Incentives

As mentioned earlier, both UC Berkeley and Stanford have shown financial incentives to be an effective strategy to achieve increased efficiency from building occupants on campus. These extrinsic motivators can be a main driving force in changing behavior. However, as interest in the reward fades so does the behavior, therefore it is generally insufficient for long-term behavioral change. As a result, the financial component of the program will not be heavily communicated to building occupants, but will be targeted mostly towards building managers and those in charge of purchasing equipment.

Based on the literature, we executed a behavioral science messaging campaign that targeted specific energy-intensive behaviors within an energy management framework. The group applied lessons learned from other universities and utility companies' behavior programs to the UCSB OE: Energy Management Initiative. By utilizing messaging techniques that contain different combinations of social norms, commitment and financial incentives, this energy initiative has the potential to reach large audiences in a meaningful, accessible and cost-effective way.

Technical Approaches

The group focused on three research questions: 1) Which behaviors can be changed to reduce energy? 2) Which strategies can effectively influence behavior to reduce energy use? 3) How can strategies be scaled for a campus wide rollout?

1) Which behaviors can be changed to reduce energy?

First, the group identified the major behaviors in offices and labs that could be changed and would have the greatest potential to reduce energy use. We then quantified how much energy each behavior uses and assessed how easy it would be to change those behaviors. This allowed us to prioritize our efforts based on energy saving impact and feasibility.

Prior to administering our messaging campaign, we designed a survey and walkthrough procedure for two pilot buildings on campus. These captured pre-pilot occupant behaviors that would help us identify behaviors we thought would be most significant to target. The survey provided data on a number of topics, such as occupants keeping their lights on during the day or leaving their computers on at night. We performed walkthroughs (energy audits) to confirm these behaviors by observing offices and labs at various times of the day. We also delivered surveys in person at the same time that walkthroughs were conducted. Additional surveys with other campus researchers and faculty members were conducted to produce our normative messages. Utilizing the surveys, walkthroughs and energy metering data, we determined baseline energy use and energy consumption behavior in the GGSE and PSBN.

By looking at other behavioral energy efficiency programs, our pre-pilot walkthroughs and surveys and building circuit submetering data, we identified significant energy behaviors to target in the categories of lighting (~40% total energy use in GGSE), computers (most prevalently found in offices), and thermal comfort (space heaters are the most energy intensive equipment in individual offices). Within these categories, we identified specific behaviors to target through our strategic messaging initiatives. These behaviors were chosen based on how easily the behavior would be to change and its energy impact (Table 5).

The behaviors identified for lighting are:

- Turning lights off during the day when there is sufficient ambient light
- Turning lights off in rooms that are not in use/at night
- Using task lighting instead of overhead lighting when possible

For computers, the specific behaviors identified are:

- Turning off computers on nights and weekends
- Enabling automatic power saving modes
- Turning off monitors instead of going to a screensaver

For plug loads, the behaviors identified include:

- Turning off equipment on nights and weekends including: printers, scanners, faxes and lab equipment
- Unplugging equipment or using power strips

For thermal comfort, we have identified behaviors such as:

- Using jackets or blankets instead of space heaters
- Contacting facilities personnel when the temperature is uncomfortable or the system is not operating correctly

2) Which strategies can effectively influence behavior to reduce energy use?

In order to determine how to reduce energy use through behavior change, we experimented with both occupant-based and building-based strategies. The occupant-based approaches targeted behaviors at the individual level, with the goal of shifting individual habits toward more efficient usage of energy in buildings. This was primarily accomplished through emailed energy reports, printed energy reports and printed messages. In addition, by engaging occupants in understanding and reducing their energy use, we identified several building system inefficiencies that occupants could not affect with their individual behavior. These inefficiencies were addressed by optimizing existing building systems, without the need for infrastructure improvements. By addressing these building wide inefficiencies, the group found that significant energy savings could be achieved.

For example, in GGSE, we worked with UCSB Utility and Energy Services to reprogram light motion sensors in offices. Through interactions with occupants in GGSE, it was brought to the group's attention that the motion sensors for lights in offices were programed to automatically turn on when an occupant entered the room, even if there was sufficient natural light. This resulted in many offices having overhead lights on even if the office had sufficient natural light because occupants wouldn't take the time to turn their lights off. Often times, many occupants wouldn't even notice their lights were on during the day due to the prevalence of natural light. In October, the group reprogramed the office lights in GGSE so occupants have to manually turn them on and they automatically turn off. Because occupants now have to manually turn their lights on when they enter the room, this increases the chance that they utilize natural lighting. In addition, a GGSE staff member informed the group that the outdoor lighting was on 24 hours a day. Coordinating with Utility and Energy Services, we reprogramed outdoor lighting at GGSE to ensure they are off during daylight hours.

Furthermore, in GGSE we worked with UCSB Utility and Energy Services to adjust heating and cooling settings in classrooms and offices. These readjustments likely had small savings in electricity due to reduced ventilation fan operation, but would have larger energy savings through decreased natural gas and chilled water consumption to heat and cool the building. However, natural gas and chilled water consumption were not included in our project scope.

At PSBN, we are working with Utility and Energy Services, the building manager and faculty to recalibrate fume hood flow rates and increase the nighttime setback schedules for the HVAC system. Once these changes have been made, fume hoods should run at a more efficient ventilation rate (while still ensuring occupant safety) and the number of hours each day that the HVAC system as a whole runs at full capacity will be reduced. These two changes should result in considerable reductions in energy. The group also coordinated with LabRATS, a campus-based group, that conducts sustainability assessments in science labs. The group asked lab managers and Principle Investigators (PIs) in PSBN to sign up for a twenty-minute energy assessment with LabRATS. LabRATS worked with the lab managers and PIs to determine which pieces of equipment could be turned off after use, which needed to stay on at all times, and which shut down automatically. Upon completion of the assessment, the lab received stickers to place on all of the equipment informing lab users of when the various equipment could or could not be shutdown so occupants can better manage energy use (Appendix 1). With the help of LabRATS, all eleven teaching labs on the first and second floors of the building and three research labs on the third and fourth floors signed up for these assessments and placed stickers on equipment in their labs.

In addition to these building wide approaches, we focused a lot of our effort on occupant-based approaches to target individual behaviors. This involved creating a messaging campaign tailored to each building. This campaign included a monthly email energy report, printed energy reports that hung in kitchens and bathrooms, and targeted messages with energy saving tips that hung in kitchens, bathrooms and delivered to faculty and staff mailboxes. Every month, we targeted a specific category (such as lighting) and highlighted specific behaviors (such as keeping lights off during the day and using task lighting).

We used email energy reports for GGSE to explain specific information about the building's energy use. Figure 1 below is an example of an emailed energy report for the month of October and includes information such as:

- An energy reduction goal for that month
- How energy use is broken down in the building

- Electricity use during the pilot program compared to a two year baseline
- Total energy saved over the pilot program
- Tips on energy efficient behaviors for the category targeted that month (Appendix 2)

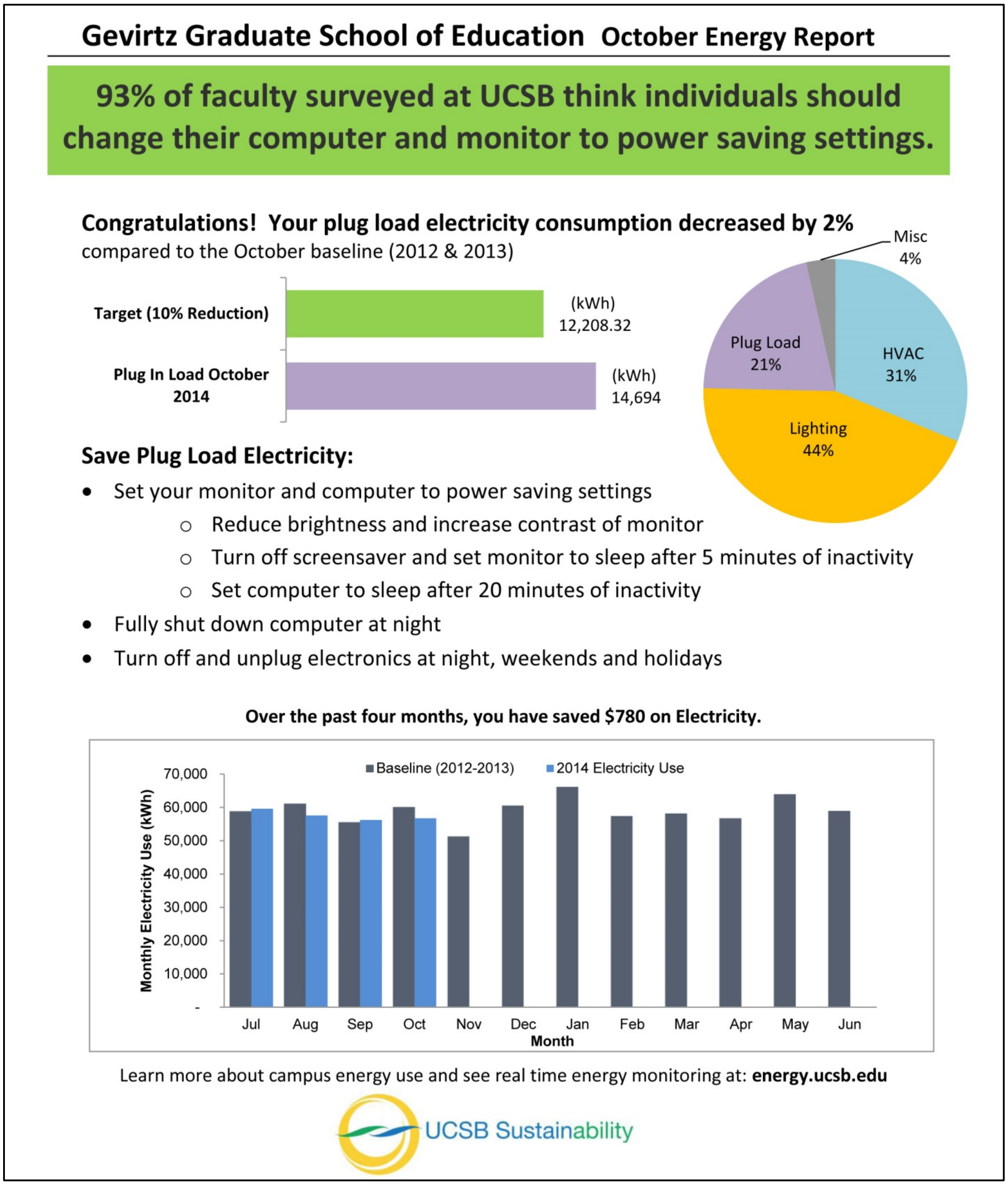

Figure 1: An example of the October monthly energy report that was emailed to building occupants in GGSE.

If building occupants reduced their electricity consumption compared to the baseline, the report also included a "Congratulations!" at the top. The emails were sent with tracking software to observe how many people opened them. Overall, this software allowed the group to determine if messages via e-mail are a viable way to reach a large population and was a way to measure engagement of the building occupants in the program (Table 11).

We distributed printed energy reports with the same graphs from the email report but with some of the wording removed. These printed reports were hung in the kitchens and bathrooms at GGSE and SSMS. All printed materials included the UCSB campus seal, the UCSB sustainability logo and a background of the UCSB campus for continuity and perceived authority of printed materials. These handouts were comprised of a behavioral science or informational message and energy tips and were placed in faculty mailboxes and bathroom stalls.

For GGSE, we experimented with different behavioral science techniques for each floor. For the second floor, we used social normative messages on the handouts and email reports mentioned above (Appendix 3). For the third floor, we used commitment messages on the email reports and experimented with three different commitment strategies to see which were effective and feasible in a campus wide rollout (Appendix 4). In November, we included a link in the email report to a survey monkey where occupants could enter their name to make their commitment to reduce energy. In December, we gave occupants signs to hang on their office doors that showed their commitment to reducing energy. In January, we hung a sign up sheet in the kitchen where occupants could sign their name to make their commitment. Finally, the fourth floor was used as a control and given the monthly energy report with a generic informational message (Appendix 5). Using circuit submetering, we were able to see how energy use increased and decreased for each floor, specifically for the energy category we targeted that month.

Because circuit submetering was installed in GGSE, the group was able to run a competition and observe how much energy each floor was using. In the month of February, we implemented a competition between the second, third and fourth floors of GGSE, and occupants were informed the floor that reduced the most energy would receive a wine and cheese party. Each week, occupants were provided weekly e-mail updates informing them of how much energy each floor had reduced and also included tips on how to conserve energy. Overall, we wanted to observe if engaging occupants in a competition encouraged higher participation in our program and further influenced occupant behavior.

Table 2 shows the overall experimental design and different messages that were applied in GGSE for November, December and January months.

Table 2: Experimental design in GGSE showing messaging type, energy category, and specific message for November, December and January.

GGSE	Messaging Type	Category	Message
November 2nd Floor	Normative	Plug load Computer	"93% of faculty surveyed at UCSB think individuals should change their computer and monitor to power saving settings."
November 3rd Floor	Commitment	Plug Load Computer	"Make the commitment to change your computer and monitor to power saving settings." Used a link in the energy update email to survey monkey commitment.
December 2nd Floor	Normative	Lighting	"85% of occupants in GGSE leave their lights off if there is sufficient ambient lighting."
December 3rd Floor	Commitment	Lighting	"I commit to leave my lights off if there is sufficient natural lighting." Occupants were instructed to post this message on their door to make the commitment.
January 2nd Floor	Normative	Heating	"89% of faculty surveyed at UCSB uses a jacket or blanket instead of a space heater."
January 3rd Floor	Commitment	Heating	"Make a commitment to use a blanket or a jacket instead of a space heater."

In order to test the effectiveness of a financial incentive, we chose to message the Social Sciences and Media Studies (SSMS) building, which has the same layout as GGSE. SSMS was given the same messages as GGSE, but without the financial aspect. Comparing building wide energy metering data from GGSE to SSMS, we were able to see if there was a difference in the effectiveness of our messaging strategies with and without the financial incentive.

In addition to the building-wide approaches mentioned above, we applied the following occupant-based approaches in PSBN as well. In November, the group hung large posters describing the pilot program in common spaces to inform building occupants about the program and financial incentive. The occupants also received monthly energy updates and social normative messages about building energy use that were distributed through e-mail, handouts in mailboxes and posted in restrooms. December messaging focused on turning off lights when leaving an office or lab. January messages encouraged the use of energy intensive equipment in the morning and evenings, when electricity costs are lower. February messaging focused on increasing awareness of the stickers and the LabRATS twenty-minute energy assessments, and reminded lab users to power down lab equipment at night. The specific messages for each month are provided in Table 3.

Table 3: Experimental design in PSBN showing messaging type, energy category, and specific message for November, December and January.

PSBN	Messaging Type	Category	Message
November	Normative	Plug Load Computer	"93% of researchers surveyed at UCSB think individuals should change their computer and monitor to power saving settings."
December	Normative	Lighting	"83% of researchers surveyed at UCSB turn off their lights when they leave the room."
January	Informative	Plug Load Time of Use	"Use energy intensive equipment in the morning or at night to reduce electricity costs by up to 60%."
February	Informative	Plug Load Equipment	"Look for stickers on lab equipment to better manage your energy use in your lab."

After administering the various treatments, we conducted follow up surveys and walkthroughs and analyzed energy metering data. This allowed us to determine how effective different treatments were at changing occupant behavior to decrease energy use. By identifying the most impactful strategies, we will be able to compile an implementation framework that can be utilized for campus wide rollout. This plan has different strategies for different types of buildings such as offices and laboratories. Table 4 shows a summary of energy behavior targeted in the pilot program, strategies for changing that behavior and the method used to measure the behavior change.

Table 4: Energy saving behaviors, how they can be changed, and how to measure the behavior change.

Behavior	How to Change	How to Measure
Lighting		Lighting Submetering
Turn lights off during the day when there is sufficient ambient light	Reprogramming lights, messaging	Surveys, walkthroughs
Turn lights off in rooms that are not in use/at night	Messaging, turn off light stickers	Surveys, walkthroughs
Use task lighting instead of overhead lights when possible	Messaging	Surveys, walkthroughs
Computers		Plug in Submetering
Encourage turning off computers at night and weekends	Consolidate data backup and update schedule, messaging	Surveys, walkthroughs
Enable automatic power saving modes	Messaging	Surveys
Turn off monitors instead of going into screensaver mode	Messaging	Surveys, walkthroughs
Plug in loads		Plug in Submetering
Share equipment	Messaging	Walkthroughs
Turn equipment off on nights and weekends	Messaging	Surveys, walkthroughs
Purchasing		
Buy energy star equipment	Messaging	Surveys
Thermal comfort		
Discourage using space heaters	Messaging	Surveys, walkthroughs
Keep doors/windows closed when heaters/air conditioners are active	Messaging	Surveys, walkthroughs
Contact facilities personnel when the temperature is uncomfortable or the system is not operating correctly.	Messaging, stickers on thermostats with #	Facilities call log

In order to measure behavior change and energy savings, the group calculated a two-year monthly baseline for both PSBN and GGSE. For 2012 and most of 2013, facilities personnel collected metering data manually by reading the building meter at the end of each month. However the meter was usually not read at the same time and day each month. In order to calculate a baseline for these months, we used this monthly read data and divided by the number of days between the reads to get the average daily energy use. We then multiplied the average daily energy use by the number of days in the month to get the adjusted monthly electricity use. In September 2013 in PSBN and December 2013 in GGSE, energy meters were upgraded, and metering data was automatically uploaded to the campus energy management software in 15-minute intervals. This allowed data to easily be aggregated into daily, monthly or yearly totals. This reduced user error associated with manually reading meters and greatly increased the richness of the data set by supplying information on a more granular timescale. We used a combination of the monthly manual read data (from 2012 and 2013) and the automatically uploaded data (2013 and 2014) to calculate a monthly baseline for each building. The baseline for each month was calculated by averaging the monthly metering data for that month from the prior two years. Baselines were established on a monthly basis because we hypothesized that monthly data would be similar across years based on the average temperatures, amount of daylight, amount of workdays/holidays, etc. that would be captured by data from previous years.

In addition to calculating baselines, the group was able to use the data from the electricity meters in each building to run regressions, create building energy models, analyze energy use and assess the effectiveness of different outreach strategies, which will be discussed below. As previously mentioned, circuit submetering equipment in GGSE allowed us to track energy consumption by floor and by type of use (lighting, HVAC, plug load). This range of data allowed the group to compare and analyze messaging techniques across behaviors, groups of occupants (differences between floors), entire buildings (GGSE compared to SSMS), and ultimately provided a deeper understanding of the results.

The group also designed an interactive survey that integrates the information from the individual's responses to provide personalized recommendations for how occupants can most effectively reduce their energy use. We designed the survey utilizing the messaging strategies described above in order to give feedback and recommendations. For instance, if an occupant indicates on the survey that they normally practice energy efficient behavior, but don't use power saving settings on their computer, the feedback will read:

> "Thanks for taking steps to reduce your energy use! Changing your computer and monitor to power saving settings can reduce computer energy use by up to 75%.
> - Reduce brightness and increase contrast of monitor
> - Turn off screen saver and set monitor to sleep after 5 minutes of inactivity
> - Set computer to sleep after 20 minutes of inactivity."

3) How can strategies be scaled for a campus wide rollout?

To implement a campus wide rollout, it was necessary to determine which buildings have sufficient energy data for baseline energy rates, which require further monitoring, and which require installing meters. We created a data sheet of buildings on campus that contains the type, length and quality of energy monitoring data (Appendix 10). The data was obtained from the UCSB energy monitoring software, EEMSuite. Utilizing this information, we determined timelines for when buildings will be ready for campus wide rollout. We will also determine how to strategically message each building during the rollout phase based on the building type and the effectiveness of the messaging during the pilot program.

Messaging Research Design

GGSE

Prior to the rollout of our strategic messaging, GGSE was introduced to the pilot project in July through an email distributed by the assistant Dean and during the first faculty meeting of fall quarter (2014). In both of these instances, occupants were informed of the financial incentive the department would receive if they reduced energy compared to a two-year baseline. Based on the literature, financial incentives are not as effective in promoting long-lasting behavioral changes, so the group decided to focus on other messaging techniques during the pilot program that could prove more effective in sustained behavior change. In addition, because GGSE doesn't use as much electricity as other buildings on campus, there was less potential for savings and therefore a weaker financial incentive.

Due to GGSE's layout, two different types of messages were used: normative and commitment. Floor 1, which is mainly classrooms and common spaces, was not viable to message because many people share these spaces and have little ownership over them. Floor 4 was chosen to be the "control" floor, and Floor 2 and Floor 3 were chosen to test different messaging strategies. The group arbitrarily decided which floor received normative and which received commitment; Floor 2 received normative messaging and Floor 3 received commitment messaging. As mentioned, Floor 4 received the 'control' or informational messages. However, the occupants on this floor (mostly department administration) showed greater enthusiasm for the project (gauged during walkthroughs, department meetings and email opening rates) and were therefore expected to show greater energy reductions. The greater engagement from the fourth floor potentially biased the results since the other two floors were being compared to the fourth floor as a control.

It was determined that messages would be placed in locations that were frequently visited by building occupants but also had a low probability of spillover. Locations were also chosen where occupants would be present for long enough to read the message. In the kitchens on the second and third floors, posters were hung on the cabinets above the microwave and on the refrigerator. For the first two months of messaging, 4x6 handouts were placed in faculty, staff and graduate student mailboxes. We placed posters on the back of bathroom stalls and near urinals. We purposely left messages out of hallways, classrooms and other general areas to reduce spillover between floors.

We chose these two messaging styles after careful consideration of the literature and the makeup of the building. Identity messaging was not used because the majority of the Education building is made up of teachers, graduate students and administrative staff, and there was not a clear identity that would resonate with all occupants. With more in-depth research, it is possible that a common identity could be determined for these building occupants, and identity messaging could be used as another strategy in the future.

SSMS

SSMS was included in this study primarily to test the effectiveness of the financial incentive in GGSE. Both buildings are nearly identical in structural layout and SSMS also had the metering data available to enable monthly baselines of energy use. SSMS received the same messaging campaign as GGSE, without any mention of a financial incentive. For uniformity, the exact same research deign was used: Floor 1 was excluded, Floor 2 received normative messages, Floor 3 received commitment messages, Floor 4 received control messages, and messages were placed in the same locations within the building. However, unlike GGSE, lack of submetering equipment in the building prevented detailed analysis of the effectiveness of each messaging strategy. However, we could still measure the overall building-wide energy consumption and this did not interfere with the comparative analysis between buildings for the financial incentive. Lastly, in addition to analyzing the effectiveness of the financial incentive, SSMS was included in the experimental design to increase the number of subjects tested and the robustness of our results.

PSBN

Prior to the rollout of our strategic messaging in July, the dean sent and email to the staff and faculty describing the program, and the financial incentive and was further discussed at a faculty meeting in September before school started.

Due to the building's layout and occupant make-up, only one type of messaging (normative) was used. Because the first and second floors are mainly teaching labs, while the third and fourth floors are comprised of research labs, the group decided that experimenting with different types of messaging would be more complicated and less straightforward than in GGSE. Furthermore, since PSBN is an older building that has undergone retrofits and changes in the wiring, it was not feasible to install circuit submetering that can break down and monitor energy use by floor. Because it would not be possible to observe changes in energy use by floor, the group decided to choose a single messaging style. We chose to use normative messaging for all four floors in PSBN based on the literature's strong correlation between sustained behavior change and normative messaging.

Similar to GGSE, we decided that messages would be placed in locations that were frequently visited by building occupants. Since we were not experimenting with different messages, there was no concern of spillover and messages were hung in hallways and the elevator. For three of the four months of messaging, we placed 5x7 handouts in faculty, staff and graduate student mailboxes. We also hung posters on the back of bathroom stalls and near urinals.

Results

1) Which behaviors can be changed to reduce energy?

An analysis of our results merits a return to the fundamental question of this behavior-based energy reduction program: which behaviors can be changed to reduce energy? There are a number of ways building occupants on campus can reduce their energy consumption without compromising their ability to work and perform research. The group identified potential areas for increased efficiencies in the categories of lighting, computers, plug load, purchasing and thermal comfort. Table 5 categorizes some of the behaviors that were targeted in the program, lists estimates of energy/monetary savings (on a yearly basis), and the expected degree of difficulty to change each behavior. The table also shows the percentage of people partaking in those behaviors before the pilot program and messaging campaign began. This percentage was based on our pre-surveys and walkthroughs of GGSE conducted prior to the start of the pilot program (Tables 8 and 9). Empty spaces in the electricity and monetary columns were left open due to the difficulty of estimating such behavioral changes. Overall, the group targeted the behaviors that had the greatest potential for energy savings as well as the smallest degree of difficulty to change - these are highlighted in yellow.

Table 5: Targeted behavior with calculated electricity savings per year, the monetary value per year and difficulty level of the behavior change. The highlighted rows are the behaviors specifically targeted in the messaging campaign. We calculated the energy savings from specific behaviors by multiplying the energy use of the behavior by the amount of time associated with that behavior (we assumed that occupants were in their offices for eight hours a day and five days a week). For example, if an office has fluorescent overhead lights that use 120 W of electricity, we calculated the amount of energy required to keep lights on during the day to be: 120W * 8hrs/day *5 days/week * 50 weeks/year = 240 kWh/year. To calculate energy costs, we multiplied this number by the average price of electricity ($0.10/kWh): 240 kWh * $0.10/kWh = $24/year (Electricity use data source: Lawrence Berkeley National Laboratory).

Behavior	Electricity Savings/Year	Monetary Value/Year	Observed/Reported Behaviors	Ease of Changing Behavior
Lighting				
Turning lights off during the day when there is sufficient ambient light	120-480 kWh/Office	$12-48/office	64% of rooms with sufficient natural light had overhead lights on.	Easy
Turning lights off in rooms that are not in use/at night			62.5% of unoccupied rooms had lights on.	Easy
Using task lighting instead of overhead lights when possible (assumed using a CFL bulb for task light).	94-454 kWh per office	$9-45/office	94% of offices were not using task lighting.	Medium
Computers				
Turning off computers at night and weekends	507-1352 kWh per computer	$51-135 per computer	26% of respondents leave their computers on overnight.	Easy
Enabling automatic power saving modes (but not fully shutting down at night and weekends)	362-966 kWh per computer	$36-97 per computer	32% of occupants do not use power saving settings.	Easy
Having monitors turn off instead of going into screensaver mode (not fully shutting down on nights and weekends)	186-440 kWh per monitor	$18-44 per monitor	77% of occupants responded that they use a screensaver.	Easy

Plug in loads				
Unplug electrical devices or use power strips and turn them off	10-100 kWh per device	$1-10 per device	Average percent of plug load items on per office was 45%.	Difficult
Share equipment				Medium
Turn equipment off on nights and weekends			47% of occupants do not turn off printers, scanners or fax machines.	Medium
Purchasing				
Buy energy star equipment				Difficult
Thermal Comfort				
Discourage using space heaters (assumed space heaters are used 4 days a week Nov-Feb)	411-819 kWh per space heater	$41-82 per space heater	55% of occupants would use a space heater if they were cold.	Medium
Contacting facilities personnel when the temperature is uncomfortable or the system is not operating correctly.			80% of occupants were not aware of who was in charge of their thermostat settings.	Medium

The group also looked at how energy was used in the building from energy metering data. Utilizing the circuit submetering, GGSE's energy profile was broken down into relevant types of energy use (Figure 2). Electricity for lighting was the highest proportion of building electricity use and was therefore highlighted as an important behavior to target.

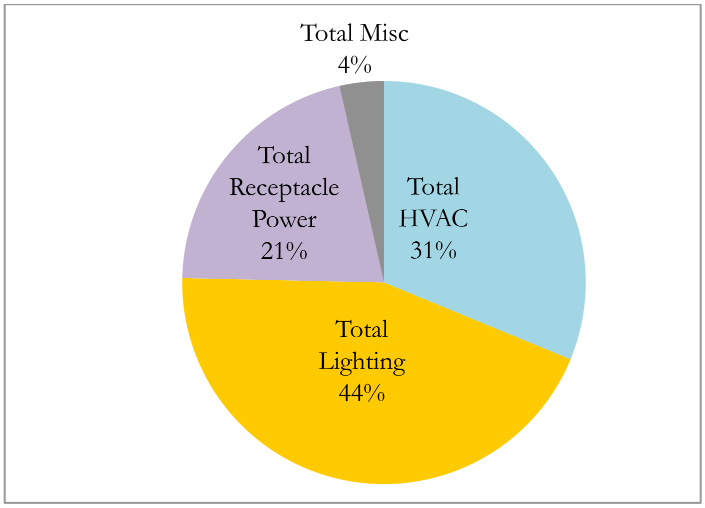

Figure 2: Circuit submetering breakdown of GGSE's energy use for October 2014.

It was not possible to install circuit submetering in PSBN, so to get a better understanding of energy use in this building the group analyzed how energy consumption changed throughout the day. Using a linear regression (Table 6), it was confirmed that HVAC uses a vast majority of electricity in PSBN, and accounts for roughly 80% of the peak energy demand.

Table 6: Regression results for PSBN building energy use for May 2014 on a 15-minute time interval. 'Temp' is ambient dry bulb temperature from the Davidson Library at UCSB. 'Daylight' is a dummy variable that is 1 after sunrise and before sunset and 0 otherwise. 'HVAC' is 1 while HVAC is running at full capacity (7am – 2am) and .5 when running at half capacity (2am-7am). 'Work hours' is a dummy variable to roughly capture occupant energy use during normal work hours (between 8am and 5pm).

PSBN Hourly	Coefficients	Pr (>|t|)
Intercept	18.727	< 2e-16 ***
Temp Above	0.410	8.75e-10 ***
Temp Below	-0.085	5.00e-08 ***
Daylight	4.600	4.02e-07 ***
HVAC	**391.460**	**< 2e-16 *** **
Work hours	37.932	< 2e-16 ***
Weekend	-13.960	2e-16 ***
Holiday	-6.072	0.003 **
Adjusted R-squared:		.0954

Figure 3 shows actual PSBN electricity use compared to modeled electricity use from the regression. The regression models electricity use in the building fairly well, but it does not account for all the smaller variability throughout the day. Daily occupant energy use seems to peak in the middle of the day and taper off in the morning and evening. The largest variability in energy use throughout the day is when the HVAC system drops to half capacity at 2am and goes back up to full capacity at 7am. However, because PSBN has a constant air volume ventilation system, it was ineffective to target HVAC from an occupant approach of having users close their fume hoods. Instead, the group pursued the building approaches of recalibrating fume hood ventilation flow rates and increasing the nightly HVAC setback. Approval of both of these initiatives is in progress and if implemented, should significantly reduce energy use in PSBN.

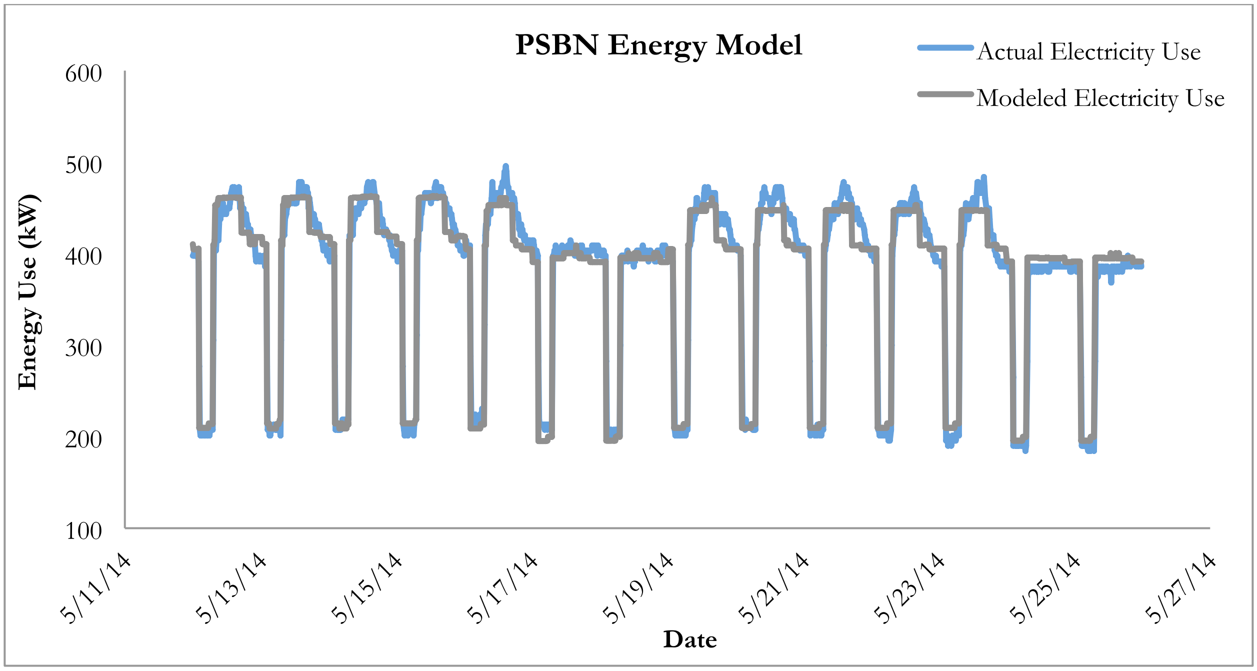

Figure 3: PSBN energy model (gray) compared to the actual (blue) electricity use from May 12 through May 26.

To summarize, based on the information and data from our literature review, circuit submetering, walkthroughs and surveys, we focused our messaging on three specific behaviors in the categories of lighting, computer power saving settings and space heaters. Specifically, we messaged on turning off lights if there is sufficient natural lighting, changing computers to utilize power saving settings, and using blankets or jackets instead of space heaters. We chose these behaviors because they are relatively easy to change and can reduce substantial amounts of energy.

2) Which strategies can effectively influence behavior to reduce energy use?

GGSE

To determine if targeting user behavior was an effective energy reduction strategy, metering data was used to observe building-wide changes in energy use over the span of the pilot program. A basic overview of the monthly metering data shows reductions below the two-year baselines for most months since the pilot began in GGSE (Figure 4). During the months of our strategic initiatives campaign (October-January), GGSE's average reduction in energy use was 6.3%, with a high of 10.2% in October. This is much greater than the average 2.4% reduction during earlier months of the pilot program (July-September). From July to September, the group was not present to implement the strategic initiative component of the pilot program due to summer break. However, once the group returned in October, we were able to implement the various strategic initiatives discussed above. Figure 4 provides an overview of the monthly energy reductions in the building, suggesting the effectiveness of the messaging campaigns and strategic initiatives.

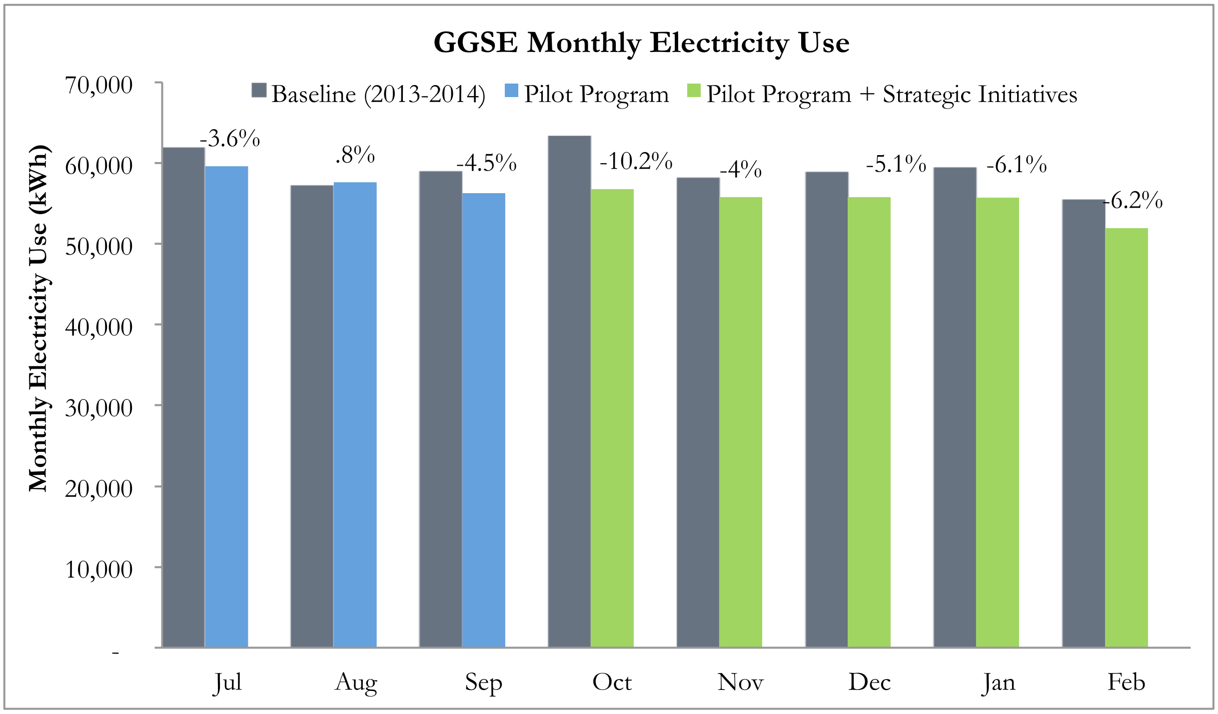

Figure 4: Overall monthly building energy use in GGSE compared to an established two-year baseline. The gray bars represent the two-year baseline energy use, the blue bars represent energy use since the pilot program began and the green bars represent months that the strategic initiatives were implemented.

In order to be confident that the monthly baselines accurately accounted for external factors that affect daily energy use in these buildings, such as, daylight hours, temperature, weekends, holidays, school breaks, the strategic initiatives, and the pilot program in general, the group ran a multivariate linear regression for each of the pilot buildings. Based on the historic data available for GGSE, we ran the regression on a daily time scale from December 2013 to February 2015. This time period correlates with the date that the building meter was updated to track daily energy use data.

From this analysis, we determined that, weekends, holidays and breaks correlated with significantly lower electricity use in GSGE. We also determined that the strategic initiatives were statistically significant ($P < .001$) and had a large effect in the building (Table 7). Overall, the combination of the pilot program, strategic initiatives and messaging were correlated with a 4.7% decrease in daily energy use in GGSE. It is important to note that the pilot program by itself did not significantly reduce energy use in GGSE. This could be due to the earlier months of the program when the group was not available to implement the strategic initiatives and messaging campaign. However, the strategic initiatives and messaging are statistically correlated with lower electricity use, and again highlights the importance of the strategic initiatives in the pilot.

Table 7: GGSE linear regression results from December 2013 to February 2015. 'Average temp' is the average daily temperature from the Davidson library at UCSB. Daylight is the number of daylight hours in the day. 'Light Controls' is the number of daylight hours, multiplied by a dummy variable when the office lighting controls were changed from "automatic on" to "manual on". 'Weekend' is a dummy variable that is 1 on weekends and 0 on weekdays. 'Holiday' is a dummy variable that is 1 on holidays and 0 otherwise. 'Finals' is a dummy variable that is 1 during finals week and 0 otherwise. 'Breaks' is a dummy variable that is 1 during summer, winter and spring breaks and 0 otherwise. "Messaging" and 'Strategic Initiatives' are dummy variables that are 1 during the months that our strategic initiatives were implemented and 0 otherwise. 'Pilot program' is a dummy variable that is 1 during the months of the pilot program and 0 otherwise.

GGSE	**Coefficient**	**PR(>|t|)**
(Intercept)	1940.312	< 2e-16 ***
Averagetemp	0.2803	0.817
Daylight	7.4961	0.0746
Weekend	-367.924	< 2e-16 ***
Holiday	-231.749	3.42e-14 ***
Finals	-20.4501	0.3152
Breaks	-141.679	< 2e-16 ***
Messaging	**-99.738**	1.58e-05 ***
Strategic Initiatives	**-68.607**	0.0101 *
PilotProgram	**76.076**	4.97e-05 ***
R-squared	0.7805	

Using the regression results to model daily energy use in GGSE by summing the days in the month, the modeled energy use coincides well with the actual energy use of the building (Figure 5). For GGSE, September, October and November 2013 were not included in the regression due to a lack of daily energy data. However, using the model to predict the electricity use for those months matches up well with the monthly read meter data for those months, further corroborating the model.

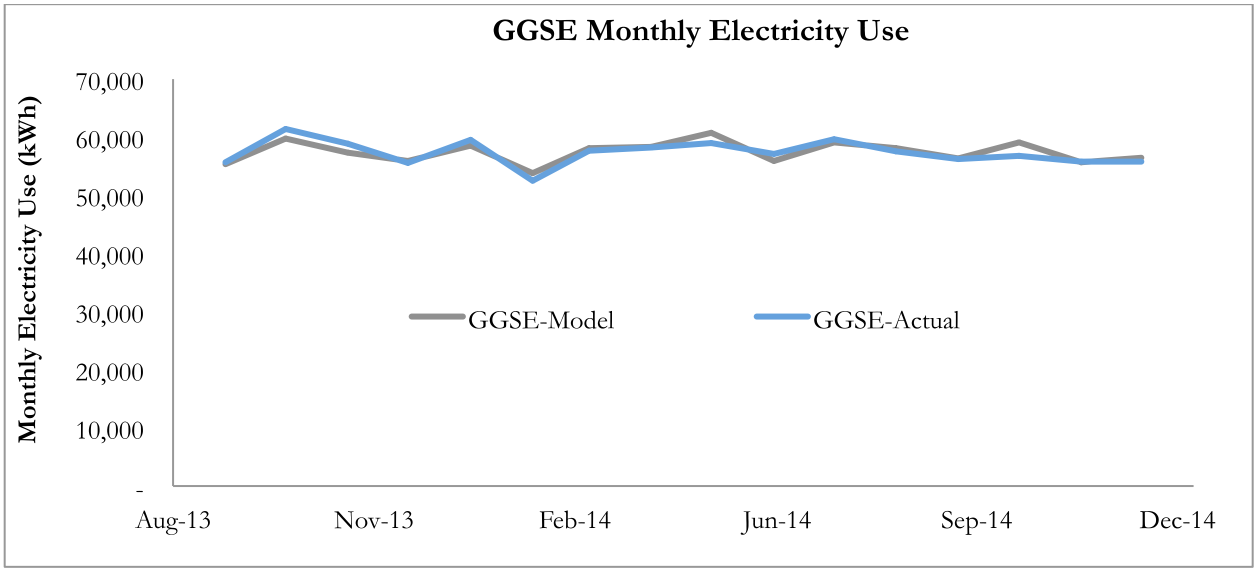

Figure 5: GGSE monthly electricity use from December 2013 to December 2014. The gray line represents the model output of electricity use and the blue line represents actual electricity use from the energy metering data.

These building-wide trends in energy consumption from both the monthly metering data and the linear regression show evidence that the strategic initiatives, including the messaging campaigns, and the pilot program as a whole were effective at reducing electricity use. In addition, a more in-depth analysis was performed to understand which messaging strategies were most impactful. The analysis was only performed for GGSE, as circuit submetering data provided insight into energy use by floor and type of use. The energy data broken down by floor enabled us to measure the energy use between the lighting, HVAC and plug-load systems and track the effectiveness of our messages across different behaviors and types of energy use. Baselines were calculated by multiplying the two-year building monthly baseline by the percentage of building energy use attributed to lighting and plug load. For example, lighting makes up 44% of total building energy use in GGSE so the building-wide monthly baseline was multiplied by .44 to get the monthly baseline for lighting electricity use. Figures 6 and 7 show electricity use from lighting and plug load in GGSE during the months of our strategic messaging campaign. Both figures show marked reductions in lighting and energy use for all months besides November. The lack of energy reduction in November is surprising, considering the lighting system change from “automatic on” to “manual on” in GGSE offices. This discrepancy is likely due to the lower baseline for November, which may have been inaccurately low in November 2012 due to human error when recording the meter read. This type of error associated with the older meters further speaks to the need for newer meters that automatically upload energy data to the UCSB energy management software and reduces the likelihood of error.

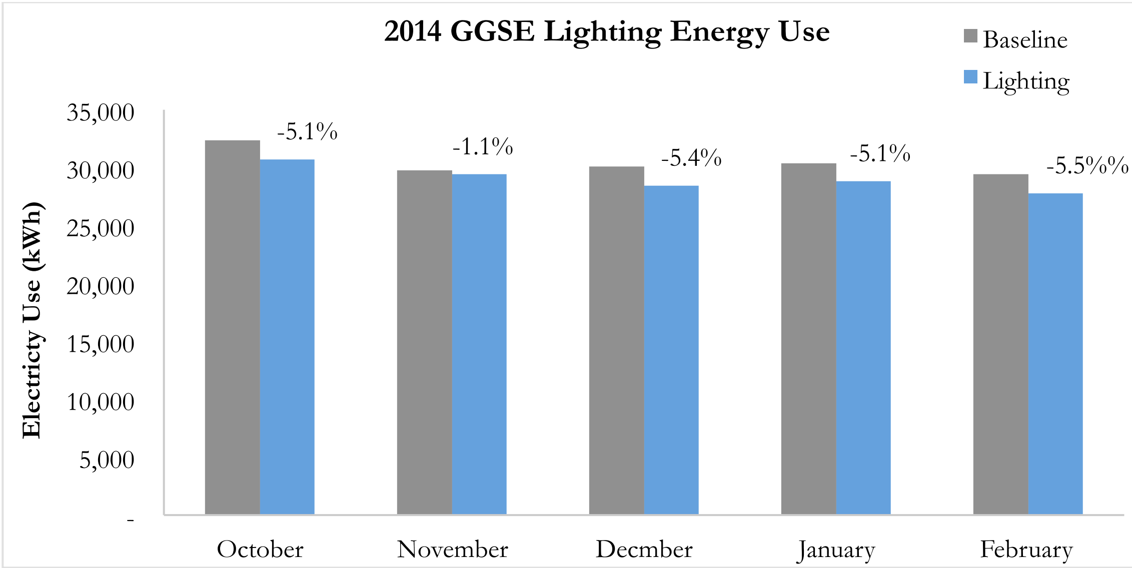

Figure 6: Electricity use for lighting in GGSE (blue) compared to a baseline (gray) between October and January.

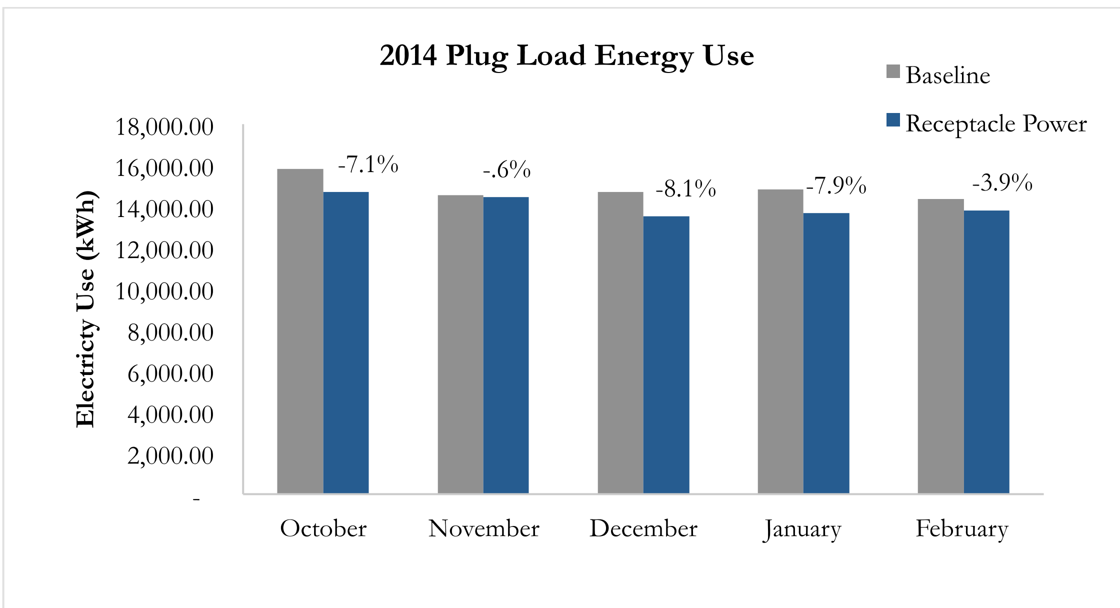

Figure 7: Electricity use for plug load in GGSE (navy) compared to a baseline (gray) between October and January.

Furthermore, Figure 8 shows the changes in energy use for lighting (compared to a baseline) between November, December and January for the three floors in GGSE that received messages. As previously mentioned, building occupants were given plug load messages in November, lighting messages in December and space heater messages in January. For lighting, there were substantial reductions in energy use in both November and December, with performance waning in January.

Figure 8 also indicates slightly different levels of performance between messaging strategies. The normative floor averaged a reduction of 7.2% over the four-month period, and out-performed the commitment floor in November. The commitment floor averaged a reduction of 7.5% across the same period but out-performed the normative group in December and January. The control group on the 4th floor, which received a generic informational message, maintained steady reductions just below the normative and commitment groups in almost all months with an average reduction of 6.4%. These results show that neither messaging strategy was consistently more effective than another at reducing energy use in GGSE. However, these results reveal that providing occupants with information about their energy use in a number of different ways can influence their behavior.

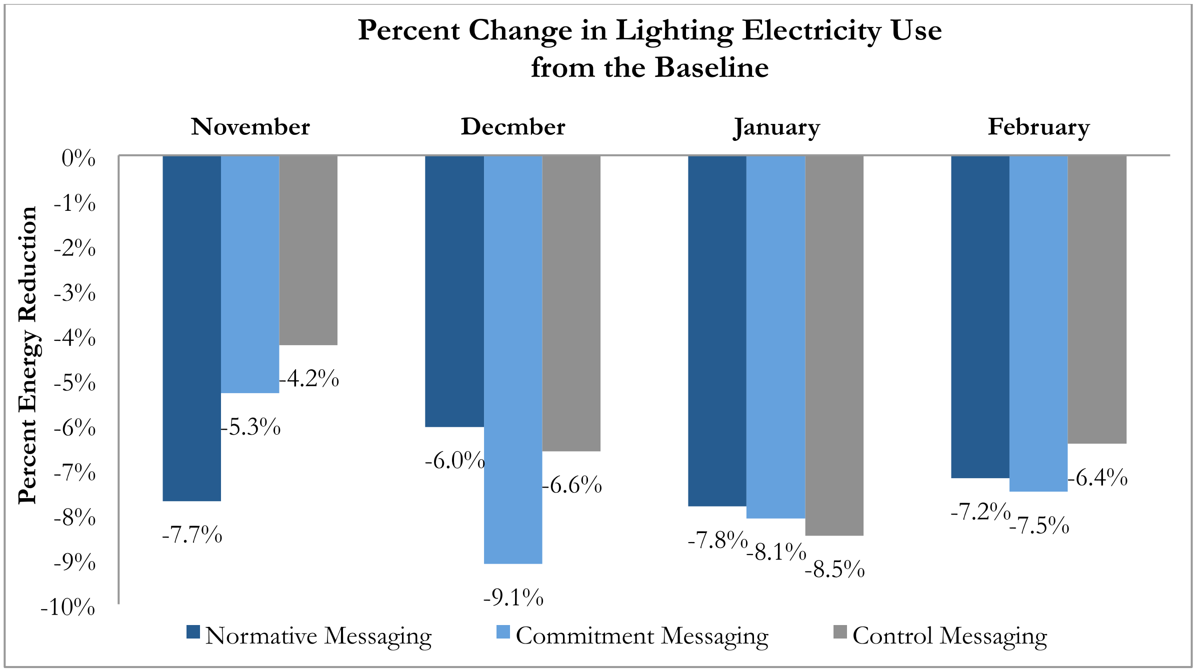

Figure 8: Change in lighting electricity use between the three floors of GGSE for November, December, January and February. Three messaging strategies were tested: normative messaging (navy), commitment messages (blue) and informational messaging or control (gray).

As previously mentioned, office light controls in GGSE were switched from an "automatic-on" system to a "manual-on" system at the end of October, which was expected to significantly reduce the amount of lighting energy use in the building. Although the November messages deliberately focused on plug-load use (the month after the lighting system was changed), lighting energy use further decreased in December (from 5.7% to 7.2%) when the messages specifically focused on lighting. This continued reduction in energy is indicative of the effectiveness of messaging. For December, the commitment message seemed more effective than normative and informational messages at motivating occupants to reduce electricity from lighting.

Plug-load energy use in GGSE does not show consistent results between messaging strategies or the specific behaviors targeted. As shown in Figure 9, the normative floor averaged an energy reduction of 5.5% over the four-month period, outperforming the commitment group in November and January. The commitment group averaged a reduction of 4.5% across the same period and out performed the normative group in December. The control group on the 4th floor again maintained relatively steady reductions below their baseline for an average reduction of 5.2%.

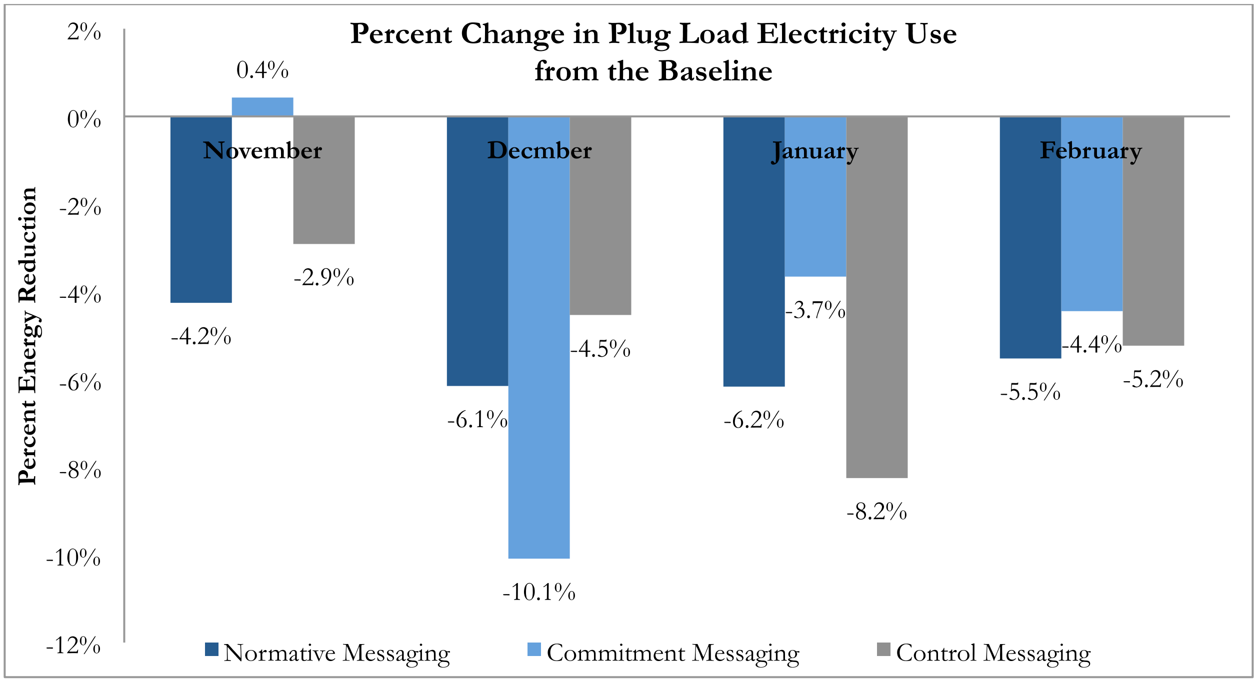

Figure 9: Percent change in plug load electricity use between the three floors of GGSE for November, December, January, and February. Three messaging strategies were tested: normative messaging (navy), commitment messages (blue) and informational messaging or control (gray).

Overall, both normative and commitment messages seemed slightly more effective at reducing total building electricity consumption compared to the control (Table 10). However, the energy reductions observed from all three messaging types reveals that by providing building occupants with a variety of messages regarding energy use within their building, will make them more likely and able to be more energy efficient in their workplace.

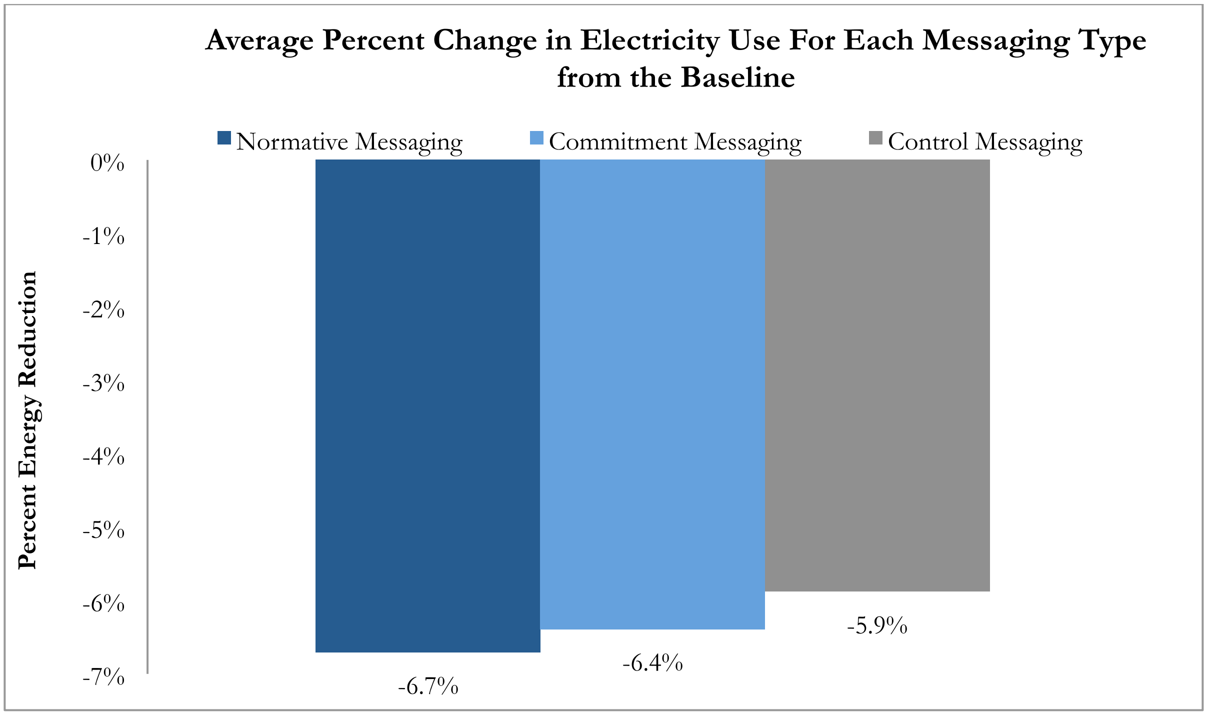

Figure 10: Average percent change in electricity use from the baseline for different strategic messages from November through January. Three messaging strategies were tested: normative messaging (navy), commitment messages (blue) and informational messaging or control (gray).

In order to further evaluate behavior change, the group performed a second set of walkthroughs and administered another survey in order to compare observed and self-reported behavior before the pilot program and six months in. Table 8 shows a comparison of GGSE building-wide behaviors observed during the pre and post walkthroughs, and Table 9 shows the comparison of self reported behaviors between both sets of surveys.

Table 8: Comparison of pre and post walkthrough results in GGSE. Highlighted boxes are the behaviors specifically targeted throughout the messaging campaign. Pre walkthrough n=68, post walkthrough n=48.

Areas of Interest	**Pre Walkthrough**	**Post Walkthrough**
Is there natural light, if so is overhead lighting still being used?	Of the rooms with natural light, 64% had the lights on.	Of the rooms with natural light, 19% had their lights on.
Were the lights on?	70% of the rooms had their lights on. 63% of unoccupied rooms had lights on.	33% of rooms had their lights on. 9% of unoccupied rooms had lights on.
Is task lighting being used instead of overhead lighting?	0% of offices were using task lighting instead of overhead. 4% of rooms were using both.	4% of offices were using task lighting instead of overhead lighting. 2% of the rooms were using both.
Are the lights automatic on?	72% of the rooms had automatic lights.	2% of rooms had automatic lights.
Number of plug load items on?	45% of plug load items were on at the time of the walkthrough.	39% of plug load items were on at the time of the walkthrough.
Number of laptops and desktop computers on?	85% of laptops were on, 62% of desktops 62% were on. No computers were on in unoccupied rooms.	83% of laptops were on and 70% of desktops were on. 6 desktops (14%) were left on in the same unoccupied room.
Is there a space heater?	19% of rooms had a space heater. 20% of space heaters were on at the time of the walkthrough.	25% of rooms had a space heater. None were on at the time of the walkthrough.
Is there a printer on?	In 35% of the offices had a printer on.	27% of the offices had a printer on.
Were the rooms in use at the time of the walkthrough?	65% of the rooms had an occupant in it at the time of the walkthrough.	44% of the rooms had an occupant in it at the time of the walkthrough.

Table 9: Comparison of pre and post survey results in GGSE. Highlighted boxes are the behaviors specifically targeted throughout the messaging campaign. Pre survey n=35, post survey n=23.

Areas of Interest	Pre Survey	Post Survey
How often do you turn on the lights during the day?	53% answered rarely/never and 37% answered daily.	13% answered rarely and 30% answered daily.
Why do you turn on the lights? Check all that apply	72% of people said it would otherwise be dark (inadequate natural light).	39% of people said it would otherwise be dark (inadequate natural light).
Do you use task lighting instead of overhead lighting?	83% of occupants responded they do not use task lighting.	91% of occupants responded they do not use task lighting.
Do you leave your computer on overnight?	63 % answered no.	65% answered no.
Do you use power saving settings on your computer?	68% answered yes.	91% answered yes.
Do you use a screen saver?	77% answered yes.	86% answered yes.
Imagine you are feeling too warm or too cold in your office. What do you do? Check all that apply.	71% of people would alter their dress wear as one option. 56% would use a space heater as one of their options.	96% of people would alter their dress wear as one option. 21% would use a space heater.
Do you know who is in charge of the thermostat settings in your workspace?	80% of people answered no.	82 % of people answered no.
Do you turn off your printers/scanners and fax machines at night?	47% answered no.	39% answered no.
In the past few months did you see/receive messaged about energy efficiency in your workplace?		100% answered yes.
Where did you see these messages?		E-mail: 91% Bathroom: 82% Stairway: 13% Kitchen: 69% Hallway: 34%
Did these messages make you more energy conscious in your work place?		Yes: 43%. No: 52% responded they already thought about energy efficiency prior to seeing the messages. No: 4%

Overall, the results of the GGSE walkthrough and survey comparison reveal an increase in energy efficient behavior in the majority of the areas of interest (Table 8 and Table 9). Furthermore, of the behaviors we strategically messaged in the categories of lighting, computer power saving settings and space heaters, we saw a statistically significant increase in energy efficient behaviors between pre and post behaviors using chi-squared test of proportions. It is important to note that in the second set of walkthroughs, we observed more offices with space heaters (20% to 25%) which is likely a result of pre walkthroughs being conducted in June while post walkthroughs were conducted in January, when space heaters would be used more frequently. Although more space heaters were observed in the post walkthrough, the post survey revealed only 21% of occupants responded that they *would* use a space heater, compared to 56% in the pre survey ($p<.005$). The other two behaviors that were strategically targeted showed an increase in energy efficient behavior. Of the rooms with natural light, only 19% had their overhead lights on during the post walkthrough, compared to 64% in the pre walkthrough ($p< .001$). Lastly, in the pre-survey 32% of respondents stated they did not use power saving settings on their computer, this fell to only 9% in the post-survey ($p<.05$).

The group further analyzed behavior change by comparing walkthroughs and surveys of corresponding rooms and individuals that were included in both the pre and post survey/walkthrough (Appendices 6 and 7). However, it was difficult to reach the same occupants before the pilot and six months later because many did not list their room number on their surveys, resulting in a very low response rate (n=8). Therefore the group chose to analyze building-wide walkthrough and survey comparison data.

To further influence energy efficient behavior, the group administered a competition between the floors of GGSE during the month of February. Weekly competition update emails were sent out to staff and faculty on participating floors. The fourth floor won the competition with a monthly energy savings of 5.2% compared to their baseline (Figure 11). Baselines were calculated by multiplying the February GGSE 2 year average baseline by the average percentage of building energy going to that floor. The fourth floor has a significantly higher baseline than the other floors, due to the computer lab and data servers located there. As previously mentioned, both the administrative staff and IT department that are located on the fourth floor showed enthusiasm for this program from the beginning. The enthusiasm for not just the competition, but also the program in general by the fourth floor (which was the control), may have contributed to the inconclusive results on the effectiveness of the normative and commitment messages.

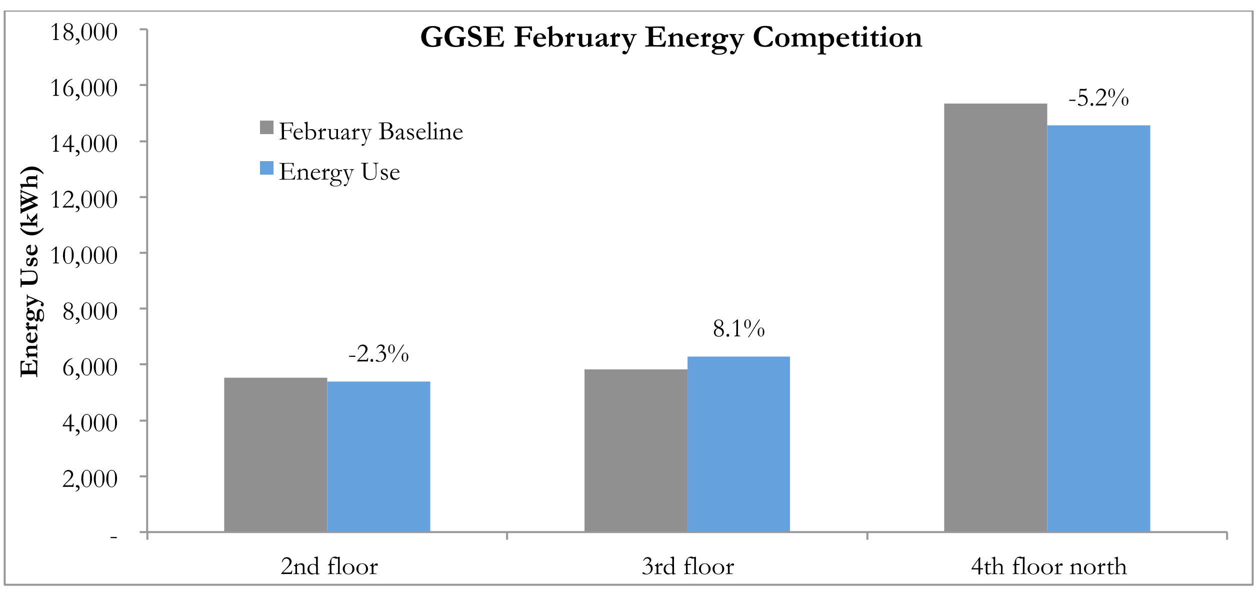

Figure 11: Results of the GGSE February Energy Competition. Gray bars represent the baseline energy use for each floor and the blue lines indicated February energy consumption.

SSMS

Similar to GGSE, metering data was used to observe building-wide changes in monthly energy use over the span of the pilot program in SSMS (Figure 12). Overall, SSMS reduced an average of 5.9% over the months with strategic messaging with the highest reduction of 11.9% in November. In the months leading up to the messaging program, SSMS had an average reduction in energy use of 1.5%. We believe this small energy reduction prior to November is due to the strategic initiatives not being implemented until after the group returned from summer break.

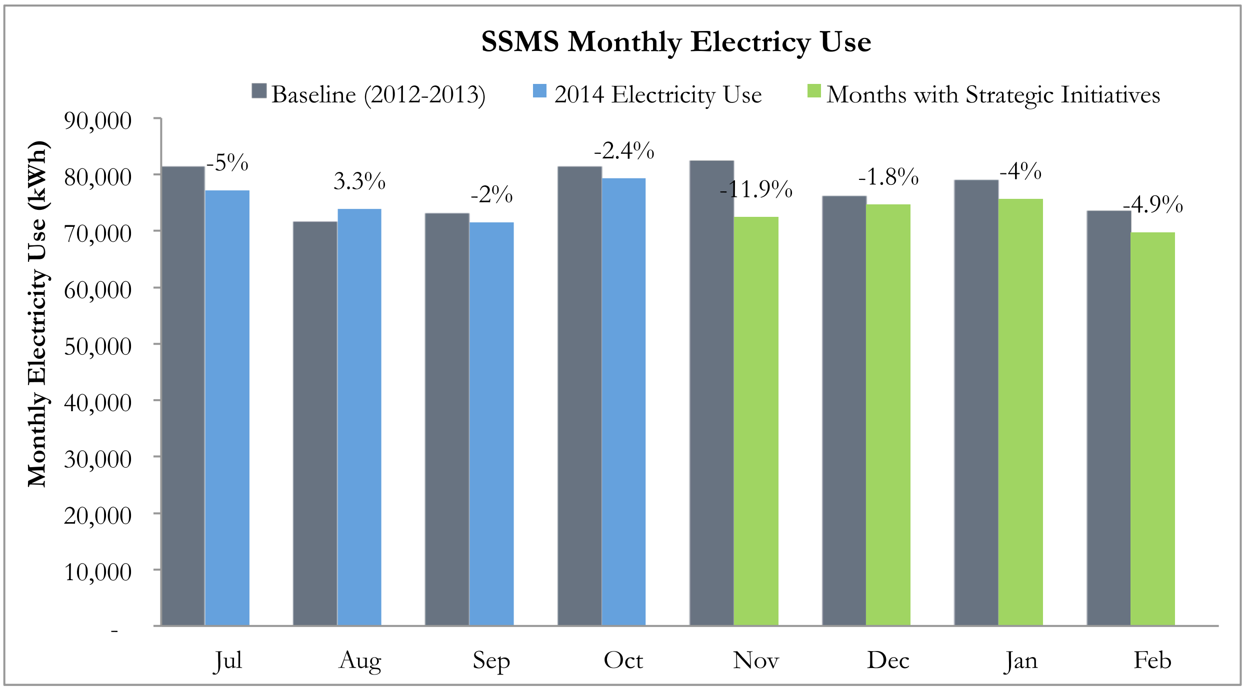

Figure 12: Overall monthly building energy use in SSMS compared to an established two-year baseline. The gray bars represent the two-year baseline energy use, the blue bars represent energy use since the pilot program began and the green bars represent months where strategic initiatives were implemented.

Similar to the other pilot buildings, in order to be confident that the monthly baselines accurately accounted for external factors that affect daily energy use in SSMS, the group ran the same multivariate linear regression using the same daily metering data and external factors. Similar to GGSE, weekends, holidays, breaks and our strategic messaging as statistically significant factors affecting energy use (Table 10). In SSMS, strategic messaging was correlated with a 4.1% decrease in daily energy use.

Table 10: SSMS linear regression results from September 2013 to February 2015. 'Average temp' is the average daily temperature from the Davidson library at UCSB. 'Daylight' is the number of daylight hours in the day. 'Weekend' is a dummy variable that is 1 on weekends and 0 on weekdays. 'Holiday' is a dummy variable that is 1 on holidays and 0 otherwise. 'Finals' is a dummy variable that is 1 during finals week and 0 otherwise. 'Breaks' is a dummy variable that is 1 during summer, winter and spring breaks and 0 otherwise. 'Strategic Messaging' is a dummy variable that is 1 during the months that our strategic messaging was implemented and 0 otherwise.

SSMS	Coefficient	PR(>|t|)
(Intercept)	2764.563	< 2e-16 ***
Averagetemp	-0.4244	0.772
Daylight	0.8946	0.874
Weekend	-554.804	< 2e-16 ***
Holiday	-375.029	< 2e-16 ***
Finals	-47.2172	0.103
Breaks	-189.085	< 2e-16 ***
Strategic Messaging	**-101.317**	**6.03e-07 *** **
Adjusted R-squared:	0.7947	

The regression results were similarly used to model daily energy use in SSMS, which coincided well with the actual energy use of the building (Figures 13).

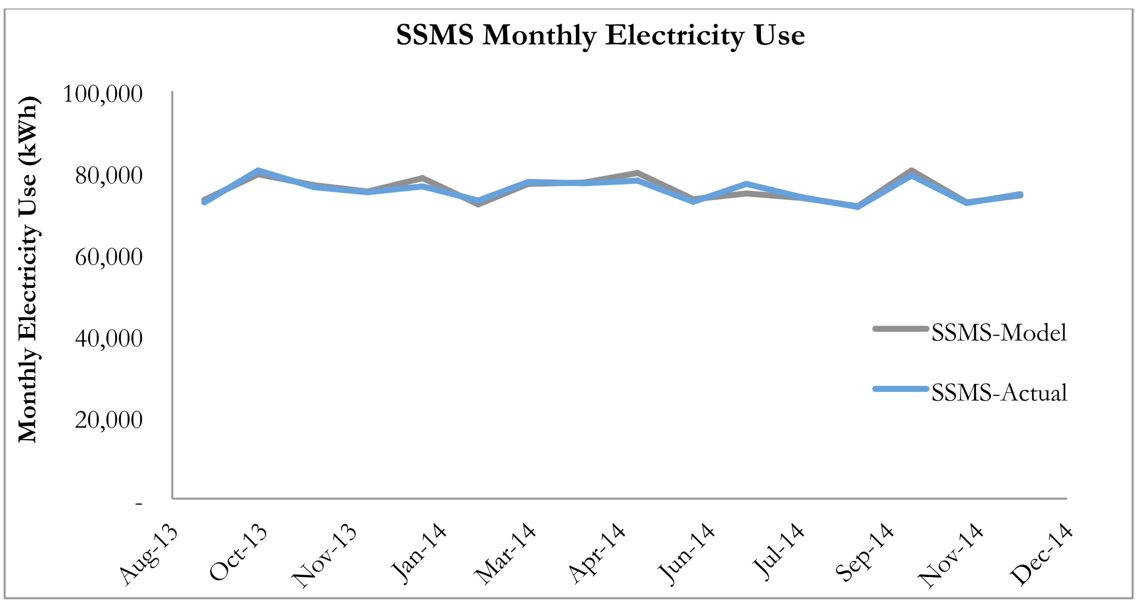

Figure 13: SSMS modeled electricity use compared to actual monthly energy use from September 2013 to January 2014. The gray line represents the model output of electricity use and the blue line represents actual electricity use from the energy metering data.

SSMS was included in the pilot program to analyze the effectiveness of the program's financial incentive in motivating behavior change. SSMS has the same structural layout as GGSE and was given the same monthly messaging (without the occupants being told they were involved in a pilot program with a financial incentive). By comparing how much each building reduced their electricity use compared to their baseline, the group could analyze the significance of the financial incentive. On average, GGSE reduced their electricity usage by 6.3% compared to their baseline over the months strategic initiatives (October-Feb) were implemented while SSMS reduced energy use by 5.9%. As shown in Figure 14, energy reduction in both buildings is similar, and both reduced energy compared to their baseline throughout the three months (four months in GGSE) of strategic messaging. It does not appear that the financial incentive in GGSE resulted in considerably larger energy reductions compared to SSMS. However, even though GGSE showed a smaller reduction in November, they showed a larger reduction in December, January and February. The lack of financial motivation could be due to the fact that individuals in GGSE have not yet received a financial payment for their energy savings, so they are not yet motivated by this reward.

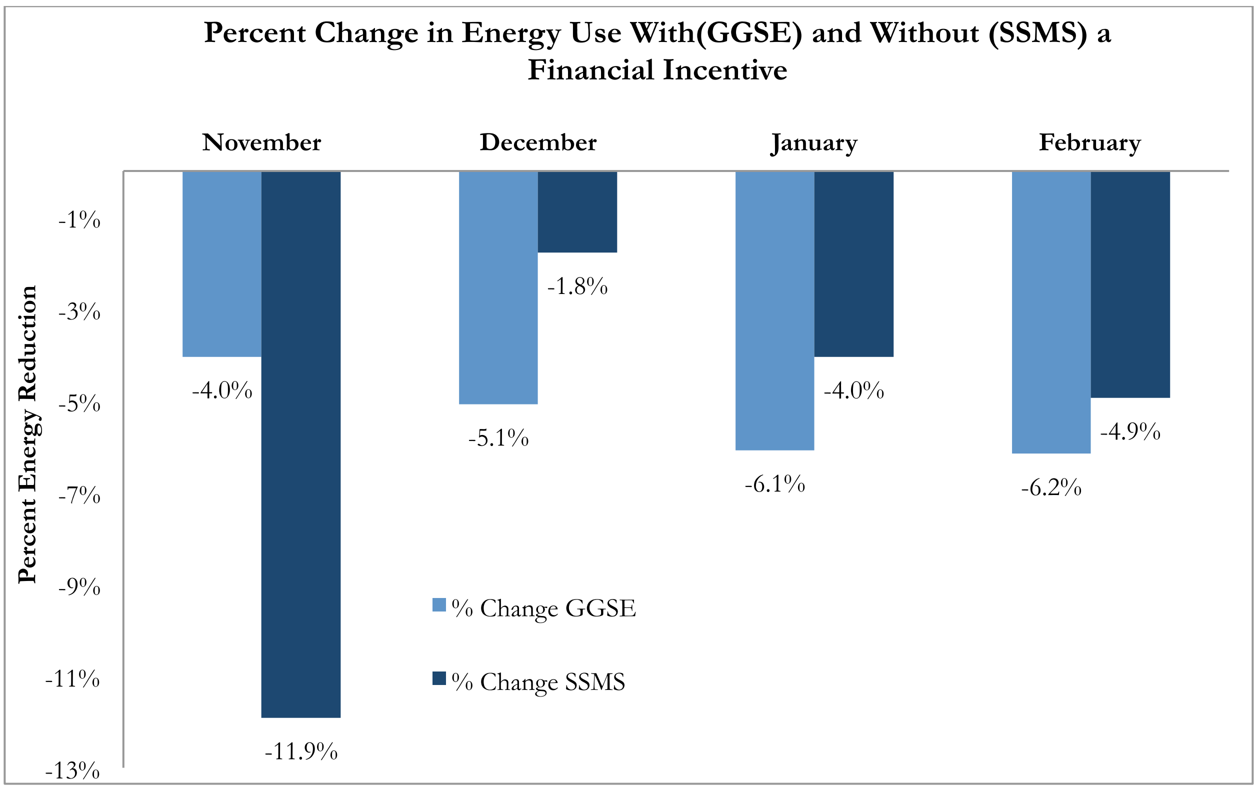

Figure 14: Monthly energy use of GGSE (blue) and SSMS (navy) for November through February compared to an established two-year baseline.

The group also evaluated the percentage of email energy reports opened for each building each month in order to determine if using email is a viable strategy for disseminating information campus wide. Table 11 shows the percentage of emails opened for the second, third and fourth floors of GGSE, the second floor of SSMS, and the faculty and staff for PSBN. The other floors in SSMS were not tracked because the emails were being sent from the business managers of those departments.

Table 11: Percentage of monthly email reports opened for GGSE, the Film department in SSMS and all faculty and staff in PSBN. *The February GGSE Energy Email Reports were sent to the building as whole and not individual floors. Therefore, opening rate percentages represent the building as whole and not individual floors.

	November	December	January	February
Second Floor (GGSE)	83%	71%	88%	44%*
Third Floor (GGSE)	62%	49%	62%	44%*
Fourth Floor (GGSE)	100%	67%	76%	44%*
Second Floor (SSMS)	81%	48%	69%	61%
PSBN	-	26%	49%	26%

The percentage of emails opened in November is higher than the percentage of emails opened in December in GGSE, with more emails opened again in January. This discrepancy in percentage of emails opened could have occurred for a few reasons. First, as building occupants continue to receive the email reports, they may be less likely to open them since they have previously seen the report. Furthermore, December may have seen a decline in emails opened, as individuals tend to be busier during this time due to finals and the holidays. Individuals may be more likely to open emails in January when they have returned from winter break and the new quarter has started. Based on the high percentages of emails opened, emails seem like a viable strategy for disseminating information campus wide. However, given the varying percentages of emails opened as the months progressed, sending emails could be executed less frequently or at strategic times (during months where there are no breaks) could maximize the number of individuals who open the emails. Lastly, it was noticed that PSBN opened far fewer e-mails compared to GGSE and SSMS; this supports the idea that occupants in PSBN were less interested in the program than the other two buildings.

PSBN

Similar to GGSE and SSMS, we needed to determine if targeting user behavior was an effective energy reduction strategy, and building-wide metering data was used to observe building-wide changes in energy use over the span of the pilot program. As shown in Figure 15, PSBN had higher energy use compared to the baseline during August, September and October and reduced energy use in all other months. Overall, energy use was above the baseline for the initial months of the pilot program and below the baseline after the strategic initiatives were implemented, with an average reduction in energy of 2.7%.

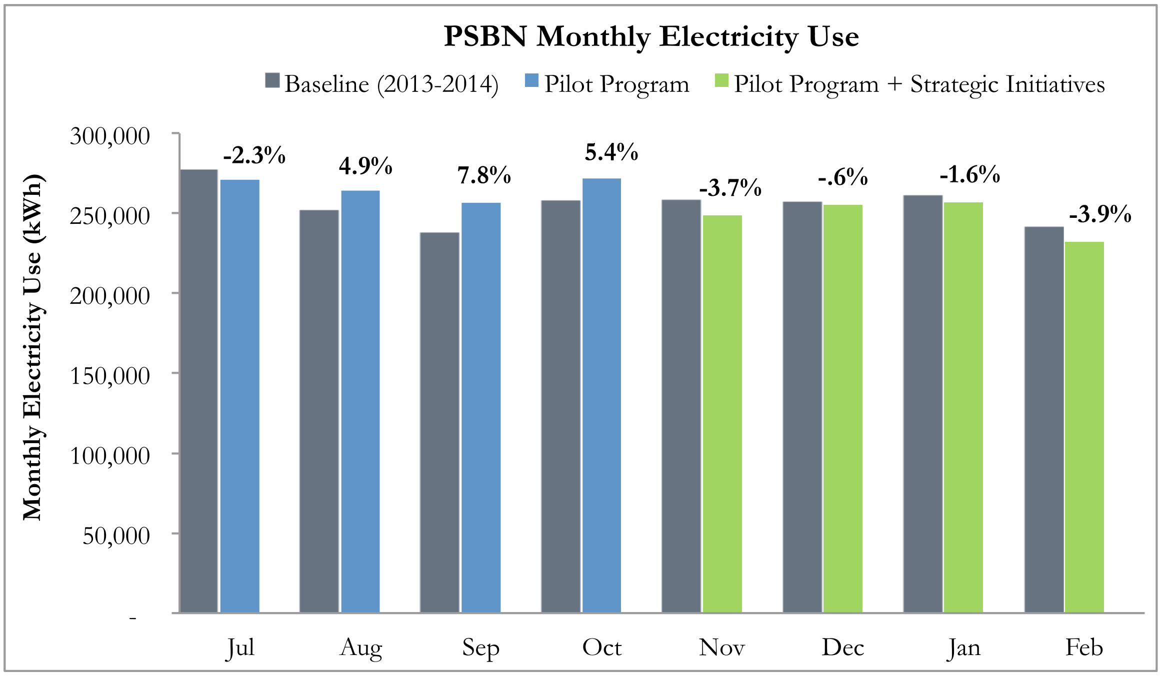

Figure 15: Overall monthly building energy use in PSBN compared to an established two-year baseline. The gray bars represent the two-year baseline energy use, the blue bars represent energy use since the pilot program began and the green bars represent months where strategic initiatives were implemented.

In order to understand how daily building energy use in PSBN is affected by influential factors such as daylight hours, temperature, weekends, holidays, school breaks, the strategic initiatives, and the pilot program in general, the group ran a multivariate linear regression for each of the pilot buildings. Based on the historic data available for PSBN, we ran the regression using daily data from September 2013 to February 2015. This time period correlates with the date that the building meters were updated to track daily energy use data. Daylight was only statistically significant in PSBN, where longer daylight hours correlated with higher daily electricity use. This may be due to people working longer in the lab during the summer.

From this analysis, we determined that weekends, holidays and breaks correlated with significantly lower electricity use. We also determined that the strategic initiatives were statistically significant ($P < .001$) and were correlated with a 2.7% decrease in electricity use (Table 12). Using these regression results to model daily energy use in PSBN by summing the days in the month, the modeled energy use coincides well with the actual energy use of the buildings (Figure 16).

Table 12: PSBN linear regression results from September 2013 to February 2015. 'Average temp' is the average daily temperature from the Davidson library at UCSB. 'Daylight' is the number of daylight hours in the day. 'Weekend' is a dummy variable that is 1 on weekends and 0 on weekdays. 'Holiday' is a dummy variable that is 1 on holidays and 0 otherwise. 'Finals' is a dummy variable that is 1 during finals week and 0 otherwise. 'Breaks' is a dummy variable that is 1 during summer, winter and spring breaks and 0 otherwise. 'Strategic Initiatives' is a dummy variable that is 1 during the months that our strategic initiatives were implemented and 0 otherwise. 'Pilot program' is a dummy variable that is 1 during the months of the pilot program and 0 otherwise.

PSBN	**Coefficient**	**PR(>|t|)**
(Intercept)	7879.711	< 2e-16 ***
Averagetemp	-0.732	0.81
Daylight	93.339	< 2e-16 ***
Weekend	-635.220	< 2e-16 ***
Holiday	-364.062	3.65e-06 ***
Finals	6.601	0.908
Breaks	-203.403	9.70e-11 ***
Strategic Initiatives	**-226.149**	**5.93e-06 *** **
Pilot Program	-49.503	0.193
R-squared	0.654	

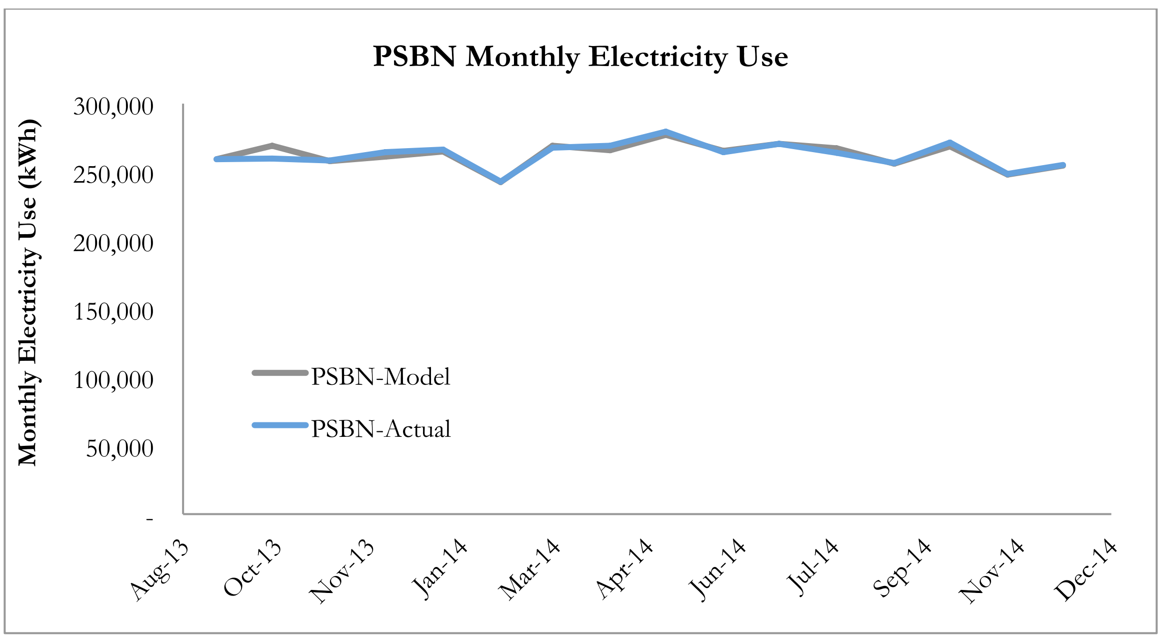

Figure 16: PSBN monthly electricity use from September 2013 to December 2014. The gray line represents the model output of electricity use and the blue line represents that actual electricity use from the energy metering data.

Due to the age of PSBN, Utility and Energy Services was unable to install circuit submetering in the building, therefore we were unable to measure energy use by floor. To further observe behavior change and energy use outside of the monthly metering data and linear regression, a post walkthrough was conducted in PSBN as a follow up to the walkthrough conducted before the pilot began. Table 13 compares the pre and post walkthrough data for unoccupied workspaces in PSBN. The group chose to focus on unoccupied rooms because the behaviors we were targeted largely focused around what an individual does in regards to energy efficiency when they leave the room. Appendix 8 contains the analysis of the building wide pre and post walkthroughs which yielded similar results to Table 13.

Table 13: Comparison of pre and post walkthrough results of unoccupied workspaces in PSBN. Highlighted boxes are the behaviors specifically targeted throughout the messaging campaign. Pre walkthrough n=25, post walkthrough n=20.

Area of Interest	Pre Walkthrough	Post Walkthrough
Are the lights on?	32% of unoccupied rooms had more than the safety lights on (greater than 25% of overhead lights).	In 50% of unoccupied rooms more than the safety lights were on (greater than 25% of overhead lights).
How many unoccupied rooms have all lights on?	In 16% of the rooms 100% of the lights were on.	In 35% of the rooms 100% of the lights were on.
Is there a task lighting option?	0% of the rooms had task lighting.	5% of the rooms had task lighting.
Is the light switch accessible?	88% had an accessible light switch.	88% of rooms had an accessible light switch.
Number of fume hoods? How many are open?	48% of unoccupied labs had fume hoods open.	70% of unoccupied labs had fume hoods open.
What is the average plug load percent on?	On average 35% of plug load items were on in unoccupied rooms.	On average 46% of plug load items were on in unoccupied rooms.
How many unoccupied rooms have computers on?	16% of unoccupied rooms had at least one computer on.	65% of unoccupied rooms had at least one computer on.
How many scales are in the lab? How many are on?	36% of unoccupied labs had at least one scale on.	81% of unoccupied labs had at least one scale on.
How many ovens are in the lab? How many are on?	16% of unoccupied labs had at least one oven on.	30% of unoccupied labs had at least one oven on.

PSBN pre and post walkthrough comparison revealed that almost all of the areas of interest observed showed a decrease in energy efficient behavior. The overall walkthrough results are contradictory to the metering data and regression which both reveal a decrease in overall energy use. The group believes this discrepancy is likely a result of human error and only conducting two overall walkthroughs (pre and post). For example, post-walkthroughs would have ideally been conducted at the same time of day, week and month as the pre-walkthroughs, but given the time frame of the pilot program we were not able to match up the data for each lab. Furthermore, given the complexities of labs, a considerable amount of walkthroughs would need to be conducted in order to get an accurate gauge on occupant behavior.

Moreover, unlike GGSE, a pre-pilot survey was not administered in PSBN because the pre-pilot survey was administered as a hard copy. The group was conducting walkthroughs in empty labs, and could not find enough people to take a hard copy of the survey. We believed it would be easier to reach occupants in a follow up survey six months later because it was administered via email. However, we only received six responses, and we believe this is due to occupants being less receptive to the program. As a result of the low response rates, we chose to focus our analyses on the walkthroughs (PSBN survey results are provided in Appendix 8). Similarly to GGSE, an analysis of matching offices between pre and post walkthroughs were conducted but yielded a smaller sample size and therefore is only provided in Appendix 8 and not discussed within the paper.

Another aspect the group considered for lab buildings was that prices for electricity vary significantly between different times of the day and seasons of the year. In general, the middle of the day has the highest electricity rates, while mornings, nights, and weekends have lower rates. The difference in price is greatest in the summer when rates vary between $.058/kWh (low) and $.1277/kWh (high). In the summer months, utilities incur additional charges based on the peak demand of electricity use over the month. These demand charges can be hundreds of thousands of dollars per month and are a significant portion of summer utility bills. By shifting energy use into the mornings and evenings, there are substantial savings opportunities for UCSB. Ideally, it would be best to test time of use (TOU) energy consumption in the summer, when there is a greater savings associated with shifting energy use away from the middle of the day. However, given our time constraints for the project, we tested TOU energy consumption in January in PSBN. Messages were distributed through an email and printed materials throughout PSBN to encourage using energy intensive equipment in the morning or at night to reduce electricity costs. We then calculated TOU billing for January 2015 and January 2014 based on hourly metering data (Table 14). In addition, the summer rate structure was applied to the January data to test if there were any differences in associated costs. We used January 2014 data as a baseline to test the effectiveness of our messaging. It would have been preferred to use at least two years of data to calculate the TOU baseline for PSBN. However there was only one year of data available with sufficient granularity for this type of analysis.

Overall, electricity use was lower in PSBN in 2015 compared to 2014. Also, there was a slight increase in percentage of total energy consumption during the lower rate hours and a decrease in the percentage during the higher rate hours. However, this shift was relatively small and resulted in a minor reduction in the average cost of electricity for the month. It would be significantly more difficult to implement a financial incentive program based on TOU electricity consumption instead of the average price of electricity that is currently being used. Based on these findings, and the added complexity of TOU billing, it would not be recommended for implementing the financial incentive. However, it would be interesting to try testing TOU messaging again in the summer, when it could have a greater effect on energy bills.

Table 14: Time of Use results for January 2014 and January 2015 in PSBN. Total energy use, percent of electricity used during specific rate hours, total electricity cost and the average price of electricity are given for 2014, 2015 and the percent change from 2014 to 2015.

Time of Use Winter	January 2014	January 2015	% Change
Total Energy Use (kWh)	266,538.24	256,747.68	-3.7%
% Low Rate ($.0645/kWh, 9pm-8am & Weekends)	52.5%	54.2%	1.6%
% Mid Rate ($.0842/kWh, 8am-9pm)	47.5%	45.8%	-1.6%
Total Electricity Cost	$22,562.95	$21,685.65	-3.9%
Average Price of Electricity	$0.0847	$0.0845	-0.2%
Time of Use Summer			
% Low Rate ($.0581/kWh, 11pm-8am & Weekends)	47.9%	49.6%	1.7%
% Mid Rate ($.08008/kWh, 8am-12pm & 6pm-11pm)	30.4%	29.6%	-0.8%
% High Rate ($.1277/kWh, 12pm-6pm)	21.6%	20.8%	-0.9%
Total Cost of Electricity	$36,864.58	$35,525.38	-3.6%
Average Price of Electricity	$0.1384	$0.1383	0.0%

Cost-Benefit Analysis

Based on the findings from the pilot and planning for a campus wide rollout, the group evaluated the cost-effectiveness of this program from the perspective of UCSB Utilities and Energy Services, who will be managing the program and helping the campus realize the benefits of avoided costs from electricity reduction. The group also evaluated the program from the perspective of UCSB as a whole, which includes the benefits to departments that are able to reduce their electricity compared to the baseline. Alternatively, the UCSB as a whole scenario is the same as a program without the financial incentive to departments, where UCSB realizes all of the benefits from reduced electricity consumption from occupant behavior. Utility and Energy Services is determining the logistics of the financial incentive with the UCSB Budget Office, but benefits as a whole to the university remain the same. The group also evaluated the program based on a range of energy savings, ranging from a 3% to a 10% reduction in energy use. The value of carbon emission reductions was also calculated within the analysis.

From the perspective of Utilities and Energy Services, this program has a net present value (NPV) ranging from $170,242 (3% reduction) to $2,478,278 (10% reduction) and a benefit-cost (B/C) Ratio ranging from 1.21 (3% reduction) to 4.03 (10 % reduction) (Table 14). From the perspective of UCSB as a whole and including benefits to departments, this program has a NPV ranging from $1,159,400 (3% reduction in electricity) to $5,775,472 (10% reduction in electricity) (Table 15).

Table 15: Variation in Net Present Value and Benefit Cost Ratios for different percent reductions in electricity use. Three cost-benefit scenarios were analyzed. The first scenario (green) considers only the cost and benefit directly realized by Utilities and Energy Services. The second scenario (gray) considers the costs and benefits directly realized by the campus as a whole, this includes financial incentives given to departments. The third scenario (yellow) shows the same analyses but with the addition of CO_2 offset value.

	Utilities and Energy Services		UCSB including Departments		UCSB w/ CO_2 Offset Value	
%Reduction in Electricity	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**
3%	170,242	1.21	1,159,400	2.42	1,222,274	2.49
5%	829,680	2.01	2,478,278	4.03	2,583,068	4.15
10%	2,478,278	4.03	5,775,472	8.05	5,985,053	8.31

The group also evaluated the minimum electricity reduction to make this program viable. For UCSB Utilities and Energy Services, the program is cost-effective for any energy reduction greater than 2.5%. For UCSB as a whole, the program is cost-effective for any energy reduction greater than 1.3%.

A sensitivity analysis was calculated for different discount rates (Table 16). A 3% discount rate increases the NPV and B/C ratios as future benefits have higher present values. The percent of energy reduction needed for the program to be cost-effective does not change significantly with a 3% discount rate. Similarly, attrition rates for messaging effectiveness were varied to see the effect on NPV and B/C ratios (Table 17). The higher the attrition rate, the lower the NPV and B/C ratios. However, the percent reduction needed for the program to be cost-effective does not change significantly for the range of attrition rates that we tested. Finally, including CO_2 offset values increases NPV and B/C ratios slightly (Table 18). However, due to the uncertainty associated with climate change, the difficulty to capture savings from CO_2 reductions and the fact that the UC carbon neutrality will only take place for the last 5 years of our analysis timeframe, it is not necessary to include the value of these offsets to justify the financial viability.

Table 16. Variation in Net Present Value and Benefit Cost Ratios for three different discount rates using a 5% reduction in electricity use and an attrition rate of 25% per year.

	Utilities and Energy Services		UCSB including Departments		UCSB w/ CO_2 Offset Value	
Discount Rate	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**
3%	1,002,081	2.09	2,927,392	4.17	3,048,566	4.30
5%	829,680	2.01	2,478,278	4.03	2,583,068	4.15
8%	631,860	1.91	1,960,655	3.81	2,046,332	3.94

Table 17: Variation in Net Present Value and Benefit Cost Ratios for three different attrition rates using a 5% discount rate and a 5% reduction in electricity use.

	Utilities and Energy Services		UCSB including Departments		UCSB w/ CO_2 Offset Value	
Attrition Rate	NPV	B/C Ratio	NPV	B/C Ratio	NPV	B/C Ratio
5%	1,193,481	2.46	3,205,879	4.91	3,333,411	5.07
25%	829,680	2.01	2,478,278	4.03	2,583,068	4.15
40%	591,087	1.72	2,001,090	3.44	2,090,952	3.55

Table 18: Total electricity saved (GWh) and the resulting tons of CO_2 reduced at three different campus electricity reduction scenarios. The greater amount of energy saved, the great reduction in CO_2 emissions.

%Reduction in Electricity	Total Electricity Saved (GWh)	CO_2 Reduced (Tons)
3%	16.82	7,877
5%	28.04	13,128
10%	56.07	26,256

For a 4% reduction in electricity use, this program would save over 28 GWh of electricity over the 15 years (Table 18). This averages to 1.9 GWh of electricity per year. Using the PVWatts solar modeling program to take into account local Santa Barbara location and weather profiles, a 2.6 MW solar PV system would be needed to produce an equivalent amount of renewable energy production (1.9 GWh/year). Using an approximate installed solar cost of $2.89/W, this sized system would require an investment of about $7,600,000. Given the estimated savings from this solar generation, this project would have a NPV of -$1,918,000 over a 15-year time frame and would only reach a positive NPV after 22 years. This calculation is a rough estimate and rebate programs would reduce the cost of solar, but it shows how investments in energy efficiency can be much more cost effective than renewable energy investments.

Based on these results, the group concludes that a campus wide behavioral energy efficiency initiative is a cost effective way to reduce energy consumption, utility costs, and CO_2 emissions. When evaluating the program from the perspective of Utilities and Energy Services, the program would have to reduce building energy consumption by at least 2.5% to have a positive NPV. However, if the evaluation included the benefits realized by UCSB as a whole (departments included) or without a financial payment to departments, there would only need to be a 1.3% reduction in electricity consumed to have a positive NPV. Based on the literature review of similar programs, the group expects to have a 3-15% reduction in energy use through this program, which would make this program economically feasible throughout the entire range of expected reduction values.

Discussion

Overall, targeting behavioral change has shown to be an effective way to reduce energy use in buildings on campus. All three buildings in the pilot program saw energy reductions compared to their two year baselines for the months where strategic messaging and initiatives were administered. During these months, GGSE, SSMS and PSBN saw average reductions in electricity use of 6.3%, 5.9% and 2.5%, respectively. Further, our linear regression analysis, which accounted for external factors such as daylight, temperature and number of workdays in the month, indicated statistical significance in energy reductions as a result of our messaging campaigns and initiatives in GGSE, SSMS, and PSBN with 4.7%, 4.1% and 2.7% reductions in electricity use associated with the program, respectively. Based on these results and the characteristics of these pilot buildings, we expect even greater energy reductions in other buildings on campus. For example, GGSE and SSMS are Silver LEED certified buildings so they generally operate more efficiently than other buildings on campus. In addition, we could not address fume hoods in PSBN due to the ventilation system, which accounts for roughly 80% of the building's electricity use. Therefore, we would expect to see greater energy reductions in buildings that do not have these characteristics. Considering the results of the cost-benefit analysis previously discussed, which indicated positive financial returns with an overall campus energy reduction of only 2.5% (only 1.3% without distributing a financial incentive), we would advise UCSB administration to move forward with a structured campus wide rollout of the program.

3) How can strategies be scaled for a campus wide rollout?

The overall effectiveness of this program on a campus wide basis will be dependent on a number of factors including: building baseline energy use, receptiveness of occupants, delivery methods of energy information and messages, messaging strategies, other motivating factors, building efficiencies and physical conditions, and financial incentives.

Determining and Calculating Baselines

In order to implement this program campus wide, accurate energy baselines are needed for each building to assess energy savings in the program, give users accurate feedback and calculate financial incentive payments. From our pilot program, we found that "manual read" data, which was manually recorded by an employee each month, was often associated with user error and was less dependable than the "automatic read" data, which is automatically uploaded to the UCSB energy management software every fifteen minutes. For this reason, we recommend that all buildings incorporated into the campus wide program have at least two years of automatic read data to calculate accurate baselines. Appendix 10 shows which campus wide buildings have at least two years of automated metering data that can be used to create an accurate baseline, which buildings have less than two years automated data, and which buildings need their meters to be updated or fixed. Currently, there are 25 buildings that have at least 2 years of automated read data and could be rolled out in the first year of the program, 22 buildings have automated meters installed and would have sufficient data in year two of a campus rollout and 17 buildings would need automated meters installed or their meter fixed and could be rolled out in year three of the program.

An additional factor that will need to be considered when constructing baselines is the incorporation of building infrastructure energy efficiency upgrades. There are three different ways that energy reductions from building infrastructure upgrades could be factored into the baseline. First, savings can be estimated from the upgrade based on the characteristics of the system. For instance if you replaced outdoor lighting in a building from fluorescent lights to LED lights, you could take the difference in energy use between the two lighting fixtures, multiplied by the amount of fixtures, multiplied by the hours that the lights are on ((200W/fixture-100W/fixture) x 50fixtures x 12hours/day = 60kWh/day). This type of estimation is often preformed when considering an energy infrastructure project and would be readily available for review. It would also be possible to use building analytics to understand energy use of a building system from knowing characteristics of that system. This type of analysis was done for this project in PSBN to isolate the amount of energy going to HVAC. In addition, circuit submetering can be used to measure energy use in certain areas of a building and types of use. This could be utilized to measure the difference in energy use before a project and after.

Receptiveness of Occupants and Relative Strategies

Based on the results of the pilot program, we believe that a program focused on influencing occupant behavior will find differences in performance based on a buildings overall receptiveness to energy efficiency measures. This finding is useful because it allows us to differentiate strategies to maximize the program's effectiveness, and determine where to utilize occupant approaches and building approaches. As previously stated, building strategies, such as, lab management plans and building system settings, are policy or rule-oriented and often require a group or individual to ensure the policy is implemented. A strategy more focused on building approaches would be recommended for buildings where the ability to influence occupant behavior is more challenging. Occupant strategies, such as our targeted messages, informational messages, or lab sticker prompts are more recommended for buildings in which occupants are receptive to changing their behavior to be more energy efficient.

The receptiveness of occupants in a building/department should be evaluated to help estimate the relative effectiveness of a behavioral based energy program. We recommend gauging this through occupant surveys, discussions at department meetings, and interviews with department heads. Receptiveness of occupants will also help determine the timeline for when to incorporate buildings in a campus wide rollout. We recommend rolling out the program in buildings that are more receptive so the campus can realize higher energy and monetary savings earlier in the program. We believe achieving greater savings earlier on may persuade the less receptive departments to participate. Moreover, in order to utilize normative messaging, it would be preferred to start with more receptive buildings, because they would create a higher standard for occupant energy efficiency and apply more social pressure on other buildings to save energy.

Data Collection and Analysis

Once a timeline for campus rollout is established based on sufficient metering data and occupant receptiveness, methods for data collection will need to be established. Much of our data collection and analysis was performed to help determine our project design and gauge the effectiveness of different messaging strategies. In a campus wide rollout, we would expect the intensity of data collection and analysis to be less for subsequent buildings, as the findings of the pilot answered many of our initial questions. However, for a campus wide rollout, significant amounts of data will need to be collected and analyzed to compare building energy use to baselines. Building analytics can offer insights into how energy is being used in a building to better direct occupant energy efficiency strategies. In order to efficiently accomplish this, the methods and approaches we developed in this program could be coded into a program such as

Python, to automatically download energy data from the UCSB energy management software, process the data and return results that could be easily incorporated into monthly energy reports.

Circuit submetering data also helps assess how energy is being used within a building to provide occupants a more detailed understanding of their energy consumption. This data also allows for the implementation of building wide energy competitions and can be used to separate out energy savings between departments in a single building. We recommend that for a campus wide rollout, facilities invest in roughly 50 circuit sub-meters to be used on buildings being incorporated into the program. These meters can then be traded between buildings based on the timeline.

Moreover, our pre-surveys and pre-walkthroughs provided insight on individual energy use and helped identify behaviors to target in the pilot program. Through analyzing the effectiveness of the program as a whole, our post surveys and post walkthroughs indicated changes in specific behaviors. We recommend that interns working for the campus wide program perform periodic walkthroughs to gather updates on program effectiveness, identify new potential targeted behaviors, and elicit relevant information from building occupants. Interactive surveys can also be periodically administered online, where responses could easily be analyzed.

Strategic Messaging

Once data is collected in these buildings, it will be important to determine the different strategic messages that will be distributed. A main objective of our project was to test and identify the effectiveness of different messaging strategies to determine which had the greatest impact on behavioral change. Our results did not definitively indicate that normative or commitment messages were more effective than one another, as each outperformed the other during different months and for different targeted behaviors. Occupants on each floor may have a stronger response to one messaging strategy, and since neither strategy proved to be dominant, we would recommend a mixed use of each in a campus wide rollout. Furthermore, due to the relatively short time frame of the program and the building layouts (number of floors), we were not able to test all of the messaging strategies we wanted to, such as identity and financial-based messaging. Therefore, more research should be done in other buildings on campus to test other strategic messages and their effectiveness.

Although normative and commitment messages produced slightly greater energy reductions overall than the control group, the control generally performed well and maintained greater consistency across the three month period. This result is suggestive evidence that providing occupants with information and feedback on how they are using energy and tips on how to be more energy efficient, regardless of specific messaging type, can influence their behavior to reduce energy. It is important to note that the control group consisted of many administrative members of the department who clearly expressed interest in the program. We hypothesized that this exceeding willingness to engage in energy efficient behavior would result in substantial savings, and our results seem to verify this hypothesis. However, we are still confident that just providing occupants with information on their energy consumption can lead to significant reductions in energy use.

Delivery Methods of Information and Messages

After the specific messaging campaigns are decided, it will be important to determine how the information will be delivered to the building occupants. In the initial months of the pilot program, information was sent as a monthly email to department representatives in GGSE and PSBN who forwarded it to their colleagues. However, this information did not always reach the intended audience and overall energy reductions were relatively low or nonexistent. For this reason, information should be sent directly from the energy program staff to occupants in a campus wide rollout. This also enables emails to be tracked using software to assess how many people are opening them. By monitoring the percentage of emails opened, staff can assess attrition of email messaging effectiveness.

In addition, it was shown that energy reduction significantly increased once printed materials were hung in accessible places throughout the building such as restrooms, kitchens, elevators, hallways and common areas. For a campus wide rollout, poster holder wall mounts should be installed on the back of restroom stalls, above urinals, in kitchens, elevators and entrance ways so printed materials can be displayed in prominent areas, be rotated on a monthly basis and reused. During the first few months that a building is being incorporated into the program, we recommend an intensive printed messaging campaign, including printed monthly reports in addition to more strategic energy efficiency messages. This would help bring greater awareness and engagement to the program. After the first few months, the more generic (non-building specific) energy efficiency messaging will be rotated in and out by program interns. After a three-year cycle, the intensive printed messaging campaign should be used again for a few months, as attrition is likely to take place.

Competitions and Other Motivating Factors

Along with strategic messaging, competitions are another way to effectively motivate occupants to reduce energy consumption. Competitions between floors can be accomplished within buildings with circuit submetering by measuring energy use between different floors and wings of the building. In addition to building wide competitions, campus wide competitions can be implemented between buildings of similar types to further encourage energy savings.

Physical Building Conditions

Once occupant-based approaches have been determined and administered, it will be important to understand how physical building conditions can play a role in the way energy is used in these buildings. Based on the results from the pilot program, we found that building conditions have a significant influence on the effectiveness of this type of program. The largest potential savings for electricity on campus are in laboratory buildings, which are generally more energy intensive. In laboratory buildings, ventilation systems use a majority of the electricity and can only be effectively targeted on an occupant basis through fume hood closure if it is a variable air ventilation (VAV) system. Therefore, this type of program would likely see the largest energy savings in laboratory buildings that have VAV systems in place. However, other building oriented approaches can be applied to buildings with constant air volume (CAV) systems, similar to PSBN. Engaging occupants in PSBN about energy efficiency during the pilot program sparked conversations with researchers, building managers and the department head to develop an initiative to increase the nightly HVAC setback and recalibrate fume hood flow rates. Once implemented, this is expected to lead to large electricity reductions in PSBN.

Moreover, we found that engaging occupants in understanding and improving their energy use can help facilities and building managers better understand and improve existing building systems. For example, in GGSE, the largest use of energy is lighting. During our pre-walkthroughs and surveys, we were informed that a majority of occupants had their office lights on during the day because they automatically turned on and occupants did not go through the extra effort to turn them off. This was due to improper lighting control settings during installation. With a simple adjustment, office lights were changed from "automatic on" to "manual on" which enabled occupants to more easily adopt energy efficient lighting behavior. In addition, building occupants informed us that outdoor lighting was on during the day and that classroom temperature settings were too low. These issues were addressed, and have led to energy savings in the building.

Due to the building specific conditions that can affect behavioral energy efficiency, it is important to analyze each building as it is being incorporated into the campus wide rollout. This can be done through a combination of online surveys, walkthroughs, circuit submetering data and building energy modeling. By understanding building specific conditions, facilities can better compile an effective combination of strategies for each building.

Financial Incentive

The ultimate goal of this program is to reduce campus energy consumption by targeting user behavior and rewarding occupants with a portion of their energy savings. Departments will receive a financial reward on an annual basis based on their energy reductions compared to an established baseline. The addition of SSMS into the pilot program allowed us to analyze the effect of the financial incentive on changing occupant behavior. SSMS, which is structurally identical to GGSE, was given the same exact messaging material (e-mails, posters, handouts, etc.) without any indication of a financial reward associated with reduced energy use. The results showed that GGSE reduced slightly more energy than SSMS with an average reduction of 6.4% compared to an average reduction of 5.9% in SSMS. We expected the financial aspect of the pilot program to have a substantial impact on occupant behavior. However, a difference of 0.5% indicates that this effect is relatively small. There are a few potential reasons for our findings. At this stage of the program, occupants have not yet realized any rewards for their energy efficient behavior. We hypothesize that once occupants actually see improvements in their buildings as a result of their behavior change, there will be a positive feedback scenario where efficiency continues to increase. Therefore, until the rewards are delivered, the influence of the incentive may have little effect. Another issue is the lack of trust or transparency with the deliverance and management of the reward. Again, we would expect this issue to wane as rewards come to fruition and the benefits of efficient behaviors are realized. We think this could happen in other buildings on campus as well during their first year in the pilot program. In order for the financial incentive to stay relevant to occupants, it could potentially be administered biannually instead of on the current annual basis, or occupants can be provided with more information on the amount and use of the money.

The group has also recognized a complication in the administration of the financial incentive because multiple departments occupy some campus buildings. Therefore, the financial incentive will need to be distributed fairly between them. This distribution can be achieved by rewarding departments with their incentive based on the square footage the department occupies. Additionally, if departments occupy different floors, circuit submetering can be used to split the incentive based on how much energy each department reduced.

Implementation Framework and Timeline

The following is a scope of the work to be completed by a program administrator and interns if the UCSB OE: Energy Management Initiative is adopted campus wide. This includes:

- Send interactive survey to buildings on campus to gauge receptiveness and initial behaviors
- Finalize the timeline for campus wide rollout based on metering data and receptiveness of occupants
- Identify strategies for each building with a combination of both building approaches and occupant approaches

- Create targeted messaging strategies for buildings in first phase of roll out (these same messages can be used in the later phases for other buildings adopting the program)
- Manage recruitment and workload for program interns
- Develop a streamlined data collection and processing system to manage energy reports for buildings incorporated into the program
- Manage distribution of information including monthly email reports and printed materials
- Continually evaluate program effectiveness
- Identify and problem solve buildings with low performance

The effectiveness of this program is reliant on many factors. By taking these into consideration and addressing them, the group is confident the program will successfully reduce energy use on campus. Moving forward the group will present UCSB Utility and Energy Services with a comprehensive energy management plan that can be used to roll this program out campus wide.

Setbacks and Limitations

There were setbacks and limitations the group faced throughout the project. First, we were working within a relatively short time frame, and it is difficult to observe sustained behavior change after only four months of consistent messaging. Furthermore, we could have tested more strategies for their effect on sustained behavioral change if more time was available.

Furthermore, this project was developed with the initial understanding that the financial incentive would be funded through the UCSB Budget Office. However, the Budget Office did not agree upon the logistics, and the financial incentive for the project was funded through a grant from The Green Initiative Fund, an organization that funds student run sustainability initiatives on campus. Although funding was secured for the pilot program, the logistics have not been confirmed for funding the financial incentive for the campus wide rollout.

One potential weakness of the project was limited baseline data. More accurate baselines could have been established if we had more than one year of automated metering data. The first year of the metering data used for baseline calculations was not completely accurate due to user read error, and better data would provide a more accurate baseline of past energy use in the pilot buildings. We were also limited by the survey and walkthrough data that was collected before and during the pilot program. Surveys and walkthroughs were conducted in June before the pilot program began in July, and were also conducted as a six-month follow up in January. Although we tried to survey the same individuals and audit the same rooms/lab in January that were completed in June, it was difficult for the group to completely match up the individuals to survey and rooms to audit. Furthermore, there may be a discrepancy in survey response and walkthrough findings due to seasonal differences in June and January.

In addition, the group emailed staff and faculty from the email address ucsbenergy@gmail.com, which is not an official UCSB or Bren email address. This could limit the legitimacy of the emails being sent and individuals may choose to not open emails because it is not an official school email address. Initially, the group did not get as much data as planned during the pre-survey and walkthroughs based on the timing of these assessments (during finals week before summer break). Finally, many participants in PSBN were unreceptive to participating in the pilot program. The group tried a number of different strategies to reach individuals and promote positive behavioral change, however, it was apparent that some people did not want to participate in the program regardless of how we messaged them.

GGSE

During the summer months when the pilot program began (July-September 2014), only one of the three monthly email reports was sent to faculty and staff. This was addressed in October when the group began sending out emails from our own email address (ucsbenergy@gmail.com). In November, the group placed commitment messages in all of the mailboxes on the third flood (there weren't any on the second floor), and did not realize that some of the mailboxes belonged to faculty and staff on the second floor. Message spillover likely occurred here as a result. In December, we noticed a response note hung in one of the kitchens on a previous month's message. The note stated that they felt the use of resources to make these handouts was a waste, particularly for an energy conservation program. We acknowledged this complaint and only placed messages in bathrooms and kitchens the following month (January), and did not distribute messages to faculty and staff mailboxes.

SSMS

In November, the custodial staff removed the program messages from women's restrooms on the second and third floors the day after they were hung. The group re-hung the messages one week later on Wednesday November 12th and found they were removed again the next day. In addition, we were unable to track some emails because we were not given access to two of the department's listervs. Therefore, the group cannot be certain these were sent out. During the month of January, the energy metering system was not working correctly from January 4 to January 21. In order to calculate January energy use, we used an average of the available data to calculate overall monthly energy use for SSMS.

PSBN

During the summer months when the pilot program began (July-September 2014), the group is not certain that the monthly email reports were distributed because we were not sending out the emails during that time. Furthermore, during the month of November, the group did not distribute the messaging and email reports until November 13th because of the time it took to develop a messaging strategy as well as design and create the posters. In December, we attempted to coordinate with LabRATS, lab managers, and PIs for twenty-minute lab assessments that would inform occupants of when certain lab equipment could be turned off. However, the group did not receive confirmation on scheduling from LabRATS until the beginning of January, therefore the twenty-minute assessments did not begin until the end of January.

Other setbacks in PSBN resulted mainly from occupants who were less receptive to the program. As mentioned earlier, a lot of PSBN faculty and staff were uninterested in the mission of the program because they thought it would interfere with their research. This disinterest, coupled with the complexity and sensitivity of work in the research laboratories, created many obstacles in implementing the pilot program. One difficulty was convincing occupants to sign up for the energy assessments with LabRATS. These energy assessments were necessary for the administration of our stickers, which indicated when lab equipment could be turned off. The low signup rate meant that fewer labs were given stickers, and reduced the effectiveness of our February messaging in the building (which focused on sticker awareness).

Perhaps the largest limitation in PSBN was the buildings CAV fume hood type. Since the operation of CAV fume hoods does not influence their energy consumption, energy reductions via behavior change were impossible. Since fume hoods and the HVAC system as a whole constitute the vast majority of energy use in PSBN, the greatest potential for energy savings was unable to be affected. Since fume hoods are so frequently used in most labs, their operation would have been a major focus for behavioral change and targeted messaging.

Conclusion

With a growing campus, increasing utility bills and a carbon neutrality goal on the horizon, UCSB will need to implement a variety of strategies to reduce energy use on campus. Based on energy efficiency and behavioral science literature, there will always be energy reductions possible through targeting user behavior. As our project revealed, even in energy efficient, LEED certified buildings, occupant behavior was able to reduce energy use in the buildings. Furthermore, we have demonstrated through a cost benefit analysis that the campus will only have to reduce electricity consumption by 2.5% (assuming a financial incentive is used) for this program to be cost-effective. Based on the average percent energy reductions observed in the pilot buildings of over 4%, we are confident the campus can achieve at least a 2.5% reduction. Overall, compared to other energy efficiency projects, this behavioral-based strategy has reasonably low initial costs and is relatively inexpensive. This program has shown to reduce energy in campus buildings in a cost-effective and timely manner, and we highly recommend that campus administration consider implementing a campus wide program. If implemented, UCSB will benefit from decreased utility costs, reduced carbon emissions and will move closer to the 2025 Carbon Neutrality Goal. By providing UCSB Utility and Energy Services with the necessary information and framework, we hope to see this program rolled out campus wide to keep UCSB at the forefront of campus sustainability.

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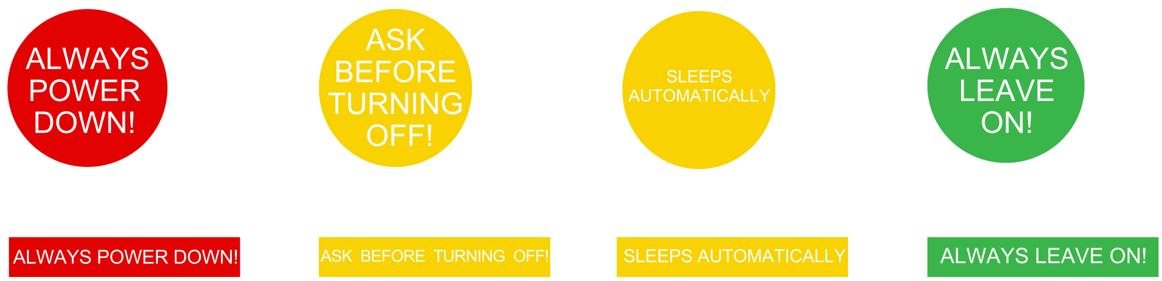
Appendix 1:
Stickers placed on equipment in PSBN labs to establish official shut down procedures

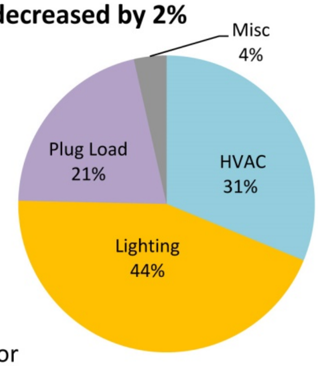


Appendix 2: Example of a Monthly Email Energy Report

Gevirtz Graduate School of Education October Energy Report

93% of faculty surveyed at UCSB think individuals should change their computer and monitor to power saving settings.

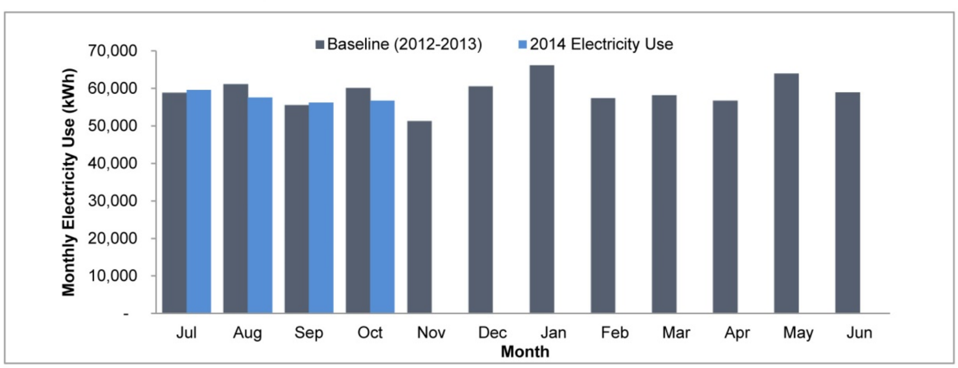
Congratulations! Your plug load electricity consumption decreased by 2% compared to the October baseline (2012 & 2013)



Save Plug Load Electricity:

- Set your monitor and computer to power saving settings
  - Reduce brightness and increase contrast of monitor
  - Turn off screensaver and set monitor to sleep after 5 minutes of inactivity
  - Set computer to sleep after 20 minutes of inactivity
- Fully shut down computer at night
- Turn off and unplug electronics at night, weekends and holidays

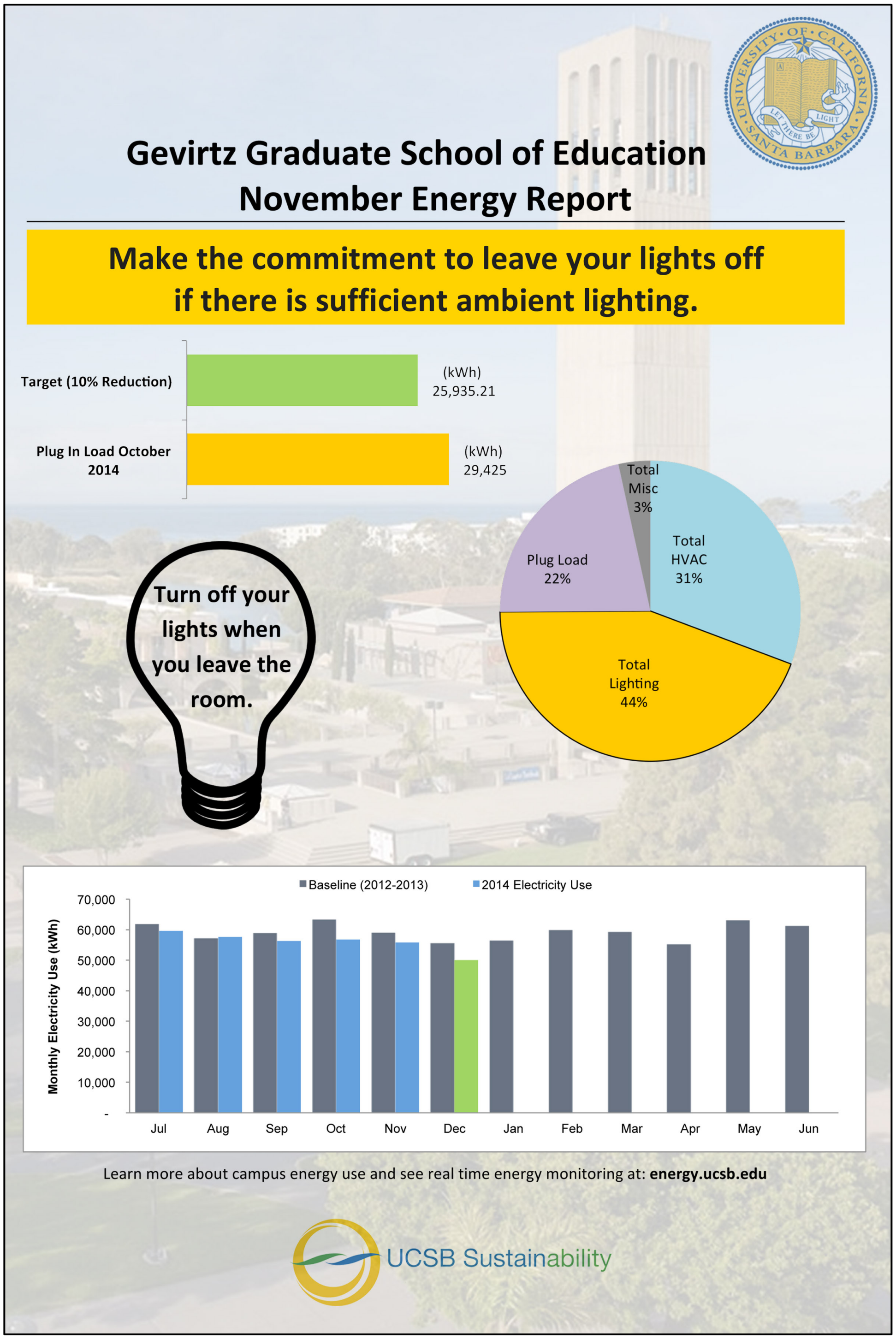
Over the past four months, you have saved $780 on Electricity.

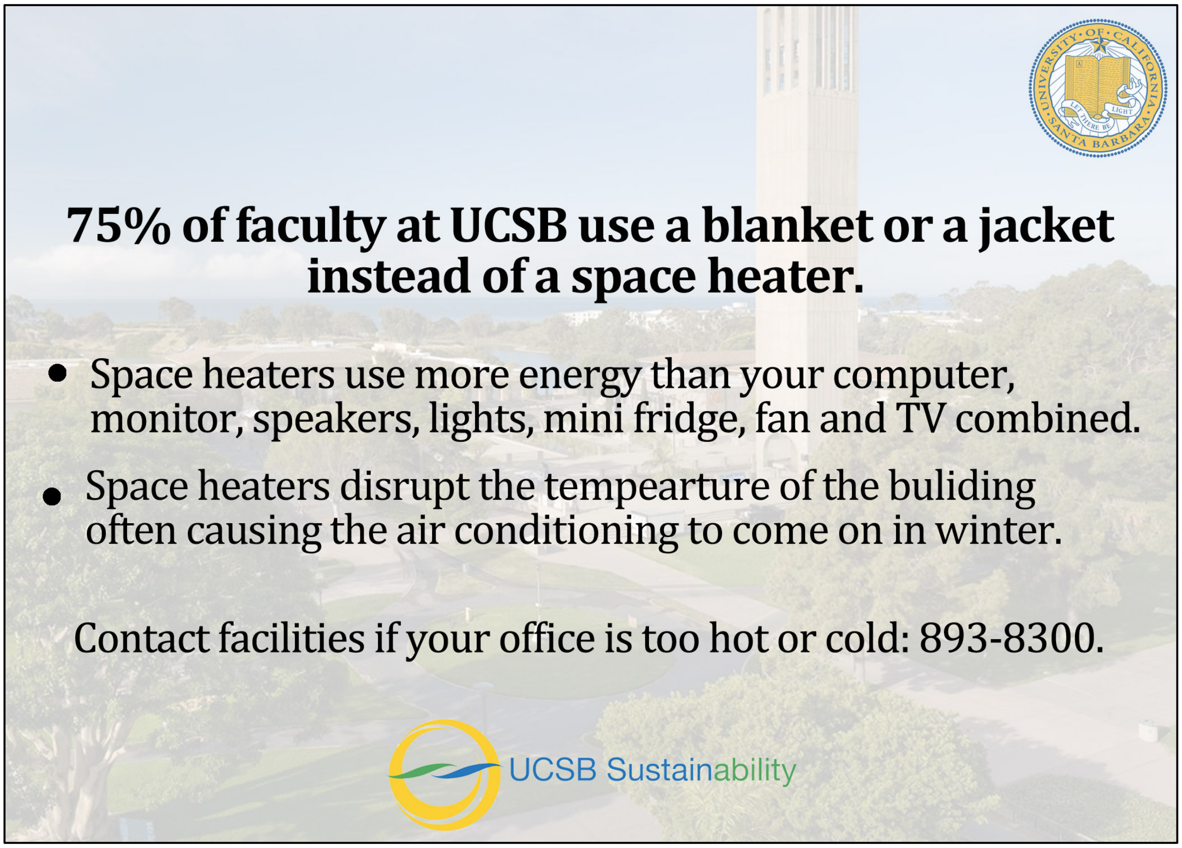


Learn more about campus energy use and see real time energy monitoring at: **energy.ucsb.edu**

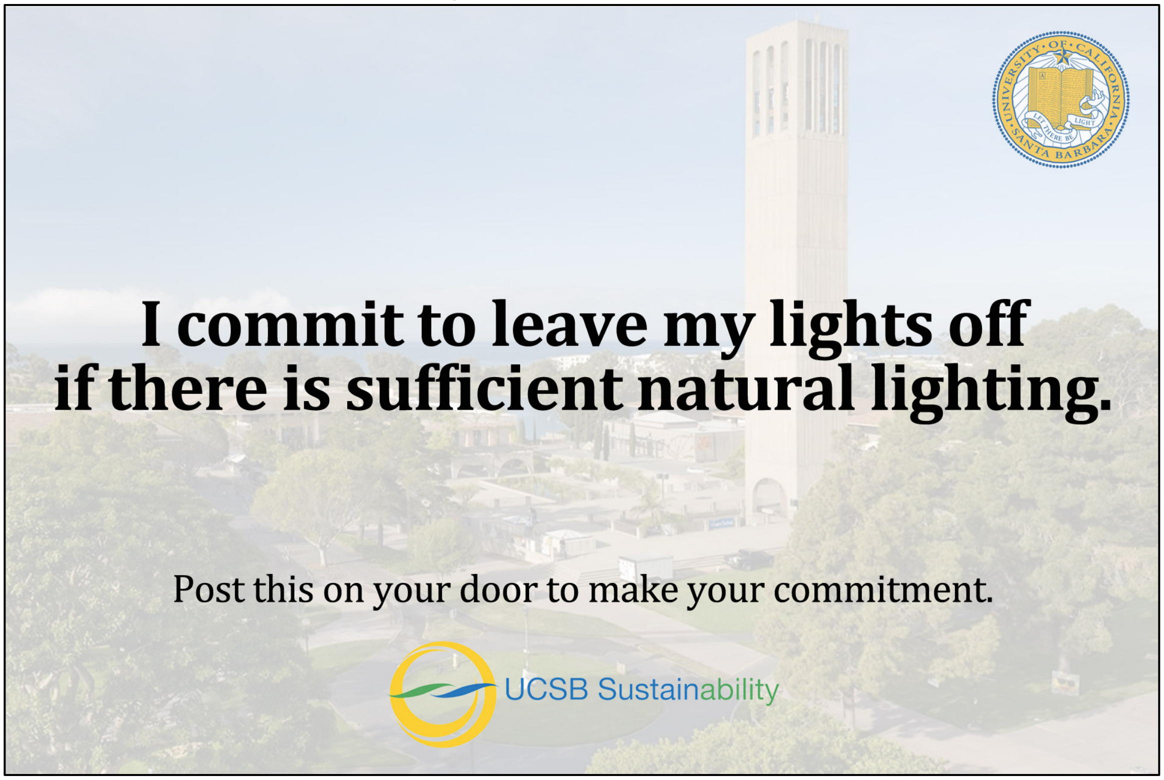
UCSB Sustainability

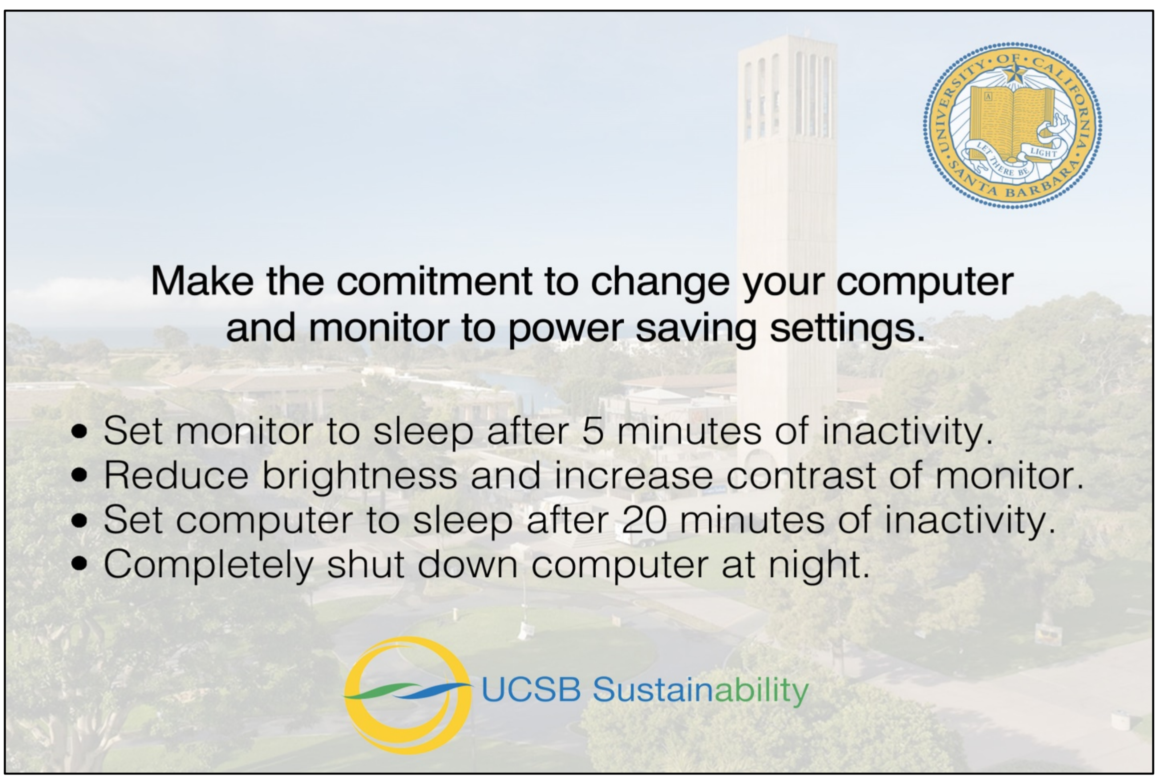
Appendix 3:
Examples of Social Normative Messages Distributed to the Second Floors of GGSE and SSMS



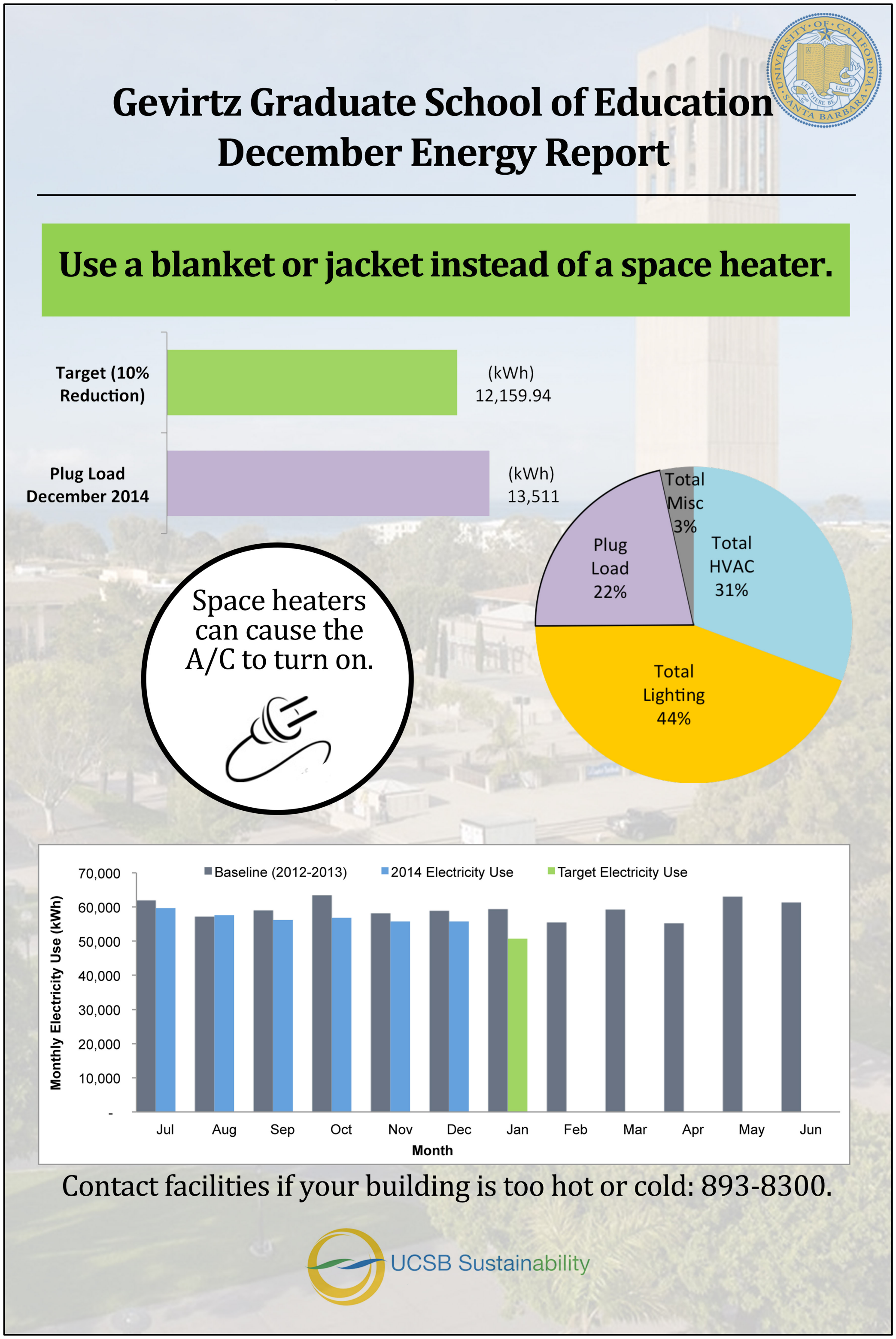

75% of faculty at UCSB use a blanket or a jacket instead of a space heater.
Space heaters use more energy than your computer, monitor, speakers, lights, mini fridge, fan and TV combined.
Space heaters disrupt the tempearture of the buliding often causing the air conditioning to come on in winter.
Contact facilities if your office is too hot or cold: 893-8300.
UCSB Sustainability

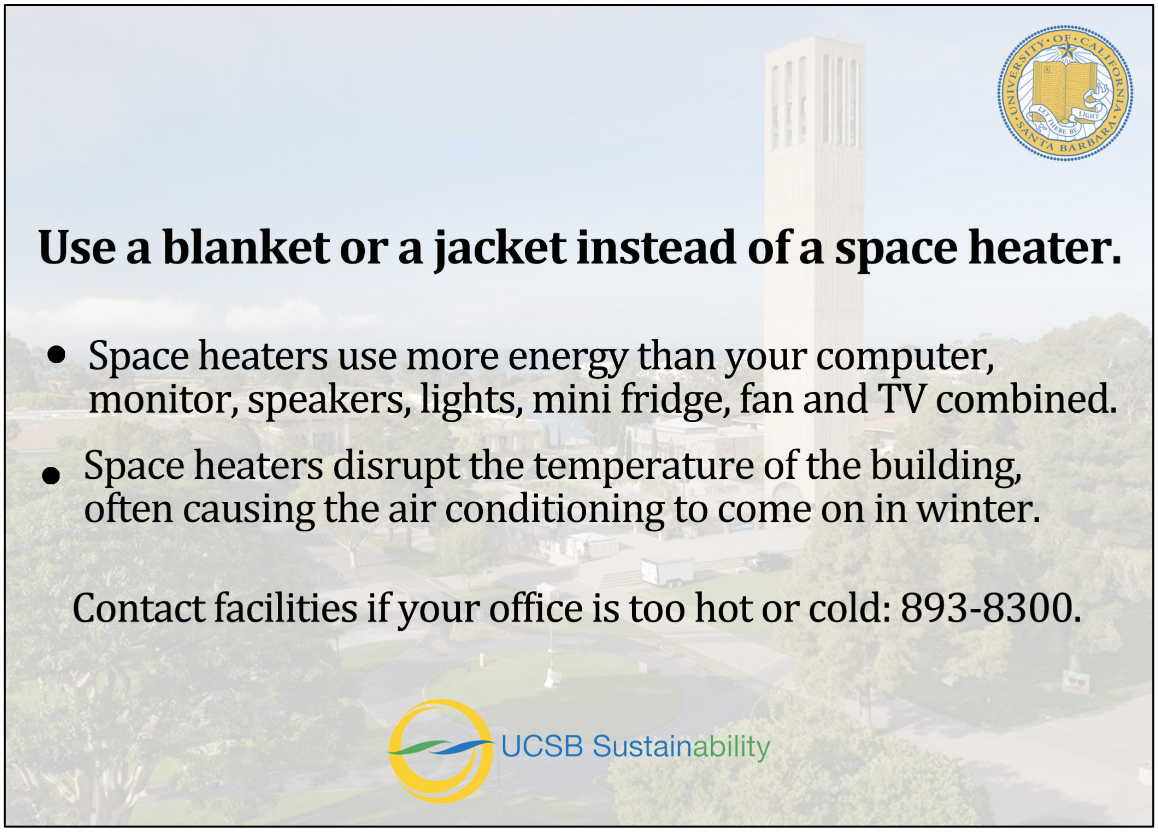
Appendix 4:
Examples of Commitment Messages Distributed to the Third Floors of GGSE and SSMS





Appendix 5:
Examples of Informational Messages Distributed to the Fourth Floors of GGSE and SSMS




Use a blanket or a jacket instead of a space heater.
Space heaters use more energy than your computer, monitor, speakers, lights, mini fridge, fan and TV combined.
Space heaters disrupt the temperature of the building, often causing the air conditioning to come on in winter.
Contact facilities if your office is too hot or cold: 893-8300.
UCSB Sustainability

Appendix 6:
GGSE Pre and Post Survey Comparison of the Same Individuals (n=8).

Critical Question	Pre Response	Post Response
How often do you turn on the lights during the day?	75% answered daily, 25% answered never.	50% answered daily, 0 % answered never.
Why do you turn on the lights? Check all that apply	50% said they're automatic on and don't bother to turn them off/ 25% said it results in a glare, 25% said it would otherwise be dark.	38% of people said they don't turn on the lights/ 38% of people said it would otherwise be dark (inadequate natural light).
Do you use task lighting instead of overhead lighting?	75% answered no.	63% don't have a task lighting option.
Do you leave your computer on overnight?	63% answered no, 25% said occasionally and 12% said yes.	63% answered no, 36% answered occasionally.
Do you use power saving settings on your computer?	100% answered yes.	75% answered yes, 12.5% answered No and I don't know.
Do you use a screen saver?	88% answered yes.	88% answered yes.
Imagine you are feeling too warm or too cold in your office. What do you do? Check all that apply.	63% of people would alter their dress wear OR use a fan/space heater/ 50% would open/close the window.	75% would alter dress wear / 12.5% would use a space heater, 12.5% other.
Do you know who is in charge of the thermostat settings in your workspace?	75% of people answered no.	75% of people answered no.
Do you turn off your printers/scanners and fax machines at night?	75% answered no.	50% answered no, of which half were because they're 'shared'/50% answered occasionally .

Appendix 7:
GGSE Pre and Post Walkthrough Comparison of the Same Rooms (n=38)

Critical Question	Pre Response	Post Response	Messaging / Other Notes
Is there natural light?	Of the rooms with natural light, 53.3% had the lights on	Of the rooms with natural light, 18.18% had the lights on	Normative and commitment: "Keep your lights off if there is sufficient natural light"
Were the lights on?	54.5% of unoccupied rooms had lights on	11% of unoccupied rooms had lights on	
Is task lighting being used instead of overhead lighting?	0% were using task lighting	2.6% were using task lighting	
Are the lights automatic	52.6% of the rooms had automatic lights	0% of the rooms had automatic lights	
Number of plug load items?	Average percent of plug load items on was 46.2%	Average percent of plug load items on was 36.05%	
Number of laptops and desktop computers on?	Laptops 90.4% were on Desktops 57% were on / None of these were on in unoccupied rooms	Laptops 80% were on Desktops 62.8% were on / 0 laptops and 5 desktops were on in unoccupied rooms	Normative and commitment: "Change your computer and monitor to power saving settings"
Is there a space heater?	6 offices, or 15.8% of rooms had a space heater	9 offices, or 23.6% of rooms had a space heater	Normative and commitment: "Use a jacket or blanket instead of a space heater"
Is there a printer on?	In 74.4% of the rooms the printers were on	In 52% of the rooms the printers were on	
Were the rooms in use at the time of the walkthrough?	55.2% of the rooms had an occupant in it at the time of the walkthrough	52.6% of the rooms had an occupant in it at the time of the walkthrough	

Appendix 8:
PSBN Pre and Post Walkthrough Results of the Same Rooms (n=27)

Critical Question	Pre	Post
Are the lights on?	56.8% of the rooms had their lights on/ In 36.3% of unoccupied rooms, more than the safety lights were on (greater than 25% of overhead lights).	88.8% of the rooms had their lights on/ In 52.6% of unoccupied rooms, more than the safety lights were on (greater than 25% of overhead lights).
Percentages of lights on?	In 40.9% of the rooms, 100% of the lights were on/ In 43.2% of rooms, 25% or less of the lights were on (safety lighting is 25%).	In 51.8% of the rooms, 100% of the lights were on/ In 40.7% of rooms, 25% or less of the lights were on (safety lighting is 25%).
Is task lighting being used?	95.3% of the rooms *did not* have task lighting.	96.2% of the rooms *did not* have task lighting.
How many fume hoods are open?	61.36% of rooms in the walkthrough had fume hoods. Average number was 4/ On average 44% of fume hoods were open.	81.4% of rooms in the walkthrough had fume hoods. Average number was 3/ On average 40% of fume hoods were open.
What is the average plug load in each room and the average percent on?	The average number of plug load items was 16. On average 37% of these items were on.	The average number of plug load items was 24. On average 57% of these items were on.
How many computers are on?	33% of computers (laptop and desktops) were on / 49% of computers on were in unoccupied rooms.	56.7% of computers (laptop and desktops) were on / 37.8% of computers on were in unoccupied rooms.
Average number of scales in the lab? How many are on?	Average number of scales in a lab was between 3 and 4. On average 71% were on.	Average number of scales in a lab was between 2 and 3. On average 52% were on.
Average number of ovens in the lab? How many are on?	Average number of ovens in a lab was between 1 and 2. On average 27% were on.	Average number of ovens in a lab was between 1 and 2. On average 54.5% were on.
Were the rooms in use at the time of the walkthrough?	45.5% were occupied.	33.3% were occupied.

PSBN Pre and Post Walkthrough Results Building-Wide (pre n=55, post n=32)

Critical Question	Pre Walkthrough	Post Walkthrough
Are the lights on?	36% of unoccupied rooms had more than the safety lights on (greater than 25% of overhead lights).	48% of unoccupied rooms had more than the safety lights on (greater than 25% of overhead lights).
Percentages of lights on?	In 50% of the rooms 100% of the lights were on.	In 48% of the rooms, 100% of the lights were on.
Is task lighting being used?	94% of the rooms did not have	97% of the rooms did not

	task lighting.	have task lighting.
Is the light switch accessible?	87% of rooms had an accessible light switch.	87% of rooms had an accessible light switch.
Number of fume hoods? How many are open?	In 22.5% of the rooms 100% of the fume hoods were open. Only 13% of the rooms had less then 10% of the fume hoods open.	40% of labs had 100% of their fume hoods open. Only 12 % of labs had less than 10% of the fume hoods open.
What is the average plug load in each room and the average percent on?	The average number of plug load items was 17. On average 40% of these items were on.	The average number of plug load items was 24. On average 54% of these items were on.
How many computers are in the room and how many are on?	On average 37% of computers were on.	On average, 69% of the computers were on. Only 1 laptop was on in an unoccupied room. Of the 22 rooms with PCs, 59% had PCs on while unoccupied.
How many scales are in the lab? How many are on?	Average number of scales in a lab was between 3 and 4. On average 72% were on.	Average number of scales in a lab was between 2 and 3. On average 47% were on.
How many ovens are in the lab? How many are on?	Average number of ovens in a lab was between 1 and 2. On average 31% were on.	Average number of ovens in a lab was between 1 and 2. On average 52% were on.

PSBN Survey Post Messaging (n=6)

Critical Question	Findings /Major Response	Secondary Response
Do you turn the lights off when you leave the room?	56% answered yes always	22% answered occasionally, 22% answered rarely
Why do you turn on the lights? Check all that apply	63% of people said it would otherwise be dark (inadequate natural light)	38% of people said its because they are required to turn on the lights for safety purposes/ 13% said it would result in a computer screen glare /0% of people don't turn on the lights
Do you use task lighting instead of overhead lighting?	33% answered they use both and 33% also answered they do not use task lighting	11% said they use task lighting instead of overhead lighting and 22% of people said they don't have a task lighting option
Do you leave your computer on overnight?	78% answered no	11 % answered yes
Do you use power saving settings on your computer?	56% answered yes	11% answered no, 22% answered I don't know
Do you use a screen saver?	78% answered yes	11% answered no

Do you know who is in charge of the thermostat settings in your workspace?	67% of people answered no	
Imagine you are feeling too warm or too cold in your office. What do you do? Check all that apply.	44% of people would alter their dresswear as one option	22% would open/close the door. 0% would use a space heater
When do you close your fume hood sash?	78% said when they walk away from their fume hood	11% said most of the time but not always/at the end of the day
If you leave lab equipment on, what are the reasons? Check all that apply.	56% of people answered they don't leave lab equipment on	11% answered – someone will be using it / I forget/ it is not my responsibility
At the end of the day do you turn off all lab equipment that should be turned off?	89% answered yes always	11% answered occasionally
Do you turn off your printers/scanners and fax machines at night?	33% answered yes	22% answered no
In the past few months did you see/receive messaged about energy efficiency in your workplace?	100% answered yes	
Where did you see these messages?	E-mail: 78% Bathroom: 78% Stairway: 44% Kitchen: 0% Hallway: 78%	
Did these messages make you more energy conscious in your work place?	56% said no I already thought about energy efficiency prior to seeing the messages	Yes: 33% No: 11%

Appendix 9: Cost Benefit Analysis

Problem Statement and Research Question

The group predicts that this initiative has the potential to reduce total UCSB building energy consumption by 5-15%, which will be measured through metering data and previously established baselines. Based on the timeline developed by the group, Utility and Energy Services will rollout the various messaging strategies to all state funded campus buildings. Ultimately, the group has been tasked with determining how to reduce campus energy use by incentivizing and influencing behavioral change. Therefore, the group seeks to answer the following research question: *Is implementing a behavioral-based energy conservation program with a financial incentive a cost-effective tool to reduce campus energy consumption?*

Project Objectives:

The group's project objectives are as follows:

- Calculate baseline energy use for each building on campus and determine where energy monitoring and submetering needs to be installed for buildings lacking sufficient baseline data.
- Complete messaging strategies in pilot buildings and analyze results.
- Apply the results of the pilot project to establish messaging strategies for all buildings on campus - determine which strategies are most effective for each type of building.
- Increase coordination with campus energy groups, such as LabRATS and PowerSave UCSB, and determine their role in implementing a campus rollout.
- Confirm details of financial incentive with UCSB Budget Office.
- Present UCSB Utility and Energy Services with a detailed framework of how to administer the program campus wide.

Standing

Campus Utilities and Energy Services

The group's primary point of contact is Jordan Sager who works for UCSB's Utility and Energy Services. Utility and Energy Services will be the primary party responsible for funding and administering the program campus wide. The group thinks this will require Utilities to hire at least one full time employee and several student interns to assist with the additional responsibilities.

Building Occupants

Departments will receive a portion of the value of the energy they save to use for building improvements and other departmental expenses. Building Managers and Department Chair's will be the primary point of contact for message and email dissemination as well as information about the program and financial incentive. Faculty, staff, researchers and students also have standing because they will be exposed to the messaging and possibly have their behavior influenced.

Chancellor's Sustainability Committee

The Chancellor's Sustainability Committee is spearheading this initiative alongside Utilities. Other organizations, including The Green Initiative Fund (TGIF), are funding the incentive portion of the program while logistics are figured out with the UCSB Budget Office.

UCSB

In addition to campus organizations and departments taking part in this program, UCSB as a whole needs to take actions to meet the 2025 system-wide carbon neutrality goal. Now that the LRDP has been approved, it is imminent that the campus develops a diverse portfolio of strategies for reducing energy use.

UC System

The UC Office of the President has set a 2025 carbon neutrality goal for the UC System, and this program will help UCSB (and potentially other UC schools) work toward this target and reduce the number of carbon offsets the campus may have to purchase.

Utility company (SCE)

Reduced energy use could increase grid stability for SCE, particularly during peak consumption. This program could also decrease revenues for SCE.

Time Frame

A fifteen-year time frame was chosen for this project based on our client's recommendation. The client assumes that it will take approximately three years to roll out the program campus wide. Following the initial roll out, the messaging campaign will be re-administered every three years in all buildings to ensure effectiveness and combat attrition. New baselines will be calculated for each building based on the previous three years of energy use. The messaging campaign will be adjusted over the course of the project based on the effectiveness of different messages and relevance to each building. Ultimately, the client hopes this program will be a fundamental change in campus operations and will continue indefinitely.

Discount Rate

A 5% discount rate was chosen for this analysis. The UC Regents use a 4.85% interest rate on general revenue bonds. Therefore, it was assumed a 5% discount rate would be an appropriate rate to use for this analysis[1]. Similarly, the National Institute of Standards and Technology provides discount rates (3% real discount rate and 4% nominal discount rate) that the DOE's Office of Energy Efficiency and Renewable Energy uses in their Federal Energy Management Program for projects related to energy conservation, water conservation and renewable energy resources[2]. We concluded a 5% discount rate would be appropriate since this is a state-funded program. Finally, according to the EPA's National Action Plan for Energy Efficiency, evaluating the cost-effectiveness of energy efficiency programs with the Societal Cost Test (SCT) uses a 5% discount rate. Based on this cost-effectiveness test, benefits are spread over the long term and risk is distributed across an entire region, such as a university campus.

Costs

Labor

The scope and timeline of this project will require Utilities to hire a full-time employee to manage and implement the program. The average early career salary of a UCSB employee is $47,000[3]. We rounded this number up to $55,000 due to the knowledge required for an Analyst II position and then included employee benefits bringing the total to $75,000. Campus

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1 The Regents of the University of California General Revenue Bonds (2012. <http://emma.msrb.org/EP598280-EP468150-EP868291.pdf>

2 Department of Energy: Federal Energy Management Plan (2010). *NSIT Updates Discount Rates for Federal Life-Cycle Cost Analyses.* http://www1.eere.energy.gov/femp/news/news_detail.html?news_id=15859

3 Average Salary for University of California - Santa Barbara (UCSB) Alumni (University of California) http://www.payscale.com/research/US/School=University_of_California_-_Santa_Barbara_(UCSB)/Salary

organizations such as Utility and Energy Services and LabRATS will also need to hire five additional interns for five hours a week for forty-five weeks a year at $10/hour based on the workload required.

Poster wall mounts and adhesives

Poster wall mounts will be placed in bathroom stalls, kitchens and elevators in all buildings during the initial roll out period, based on recommendations from University of Colorado personnel[4]. The number of wall mounts and adhesives required for each building were estimated using amounts needed for GGSE and PSBN and were based on the number of bathroom stalls/urinals, kitchens and elevators in each building. Each stall/urinal will have a 5x7 or 8x12 wall mount and each kitchen will have one 18x20 wall mount. The cost of wall mounts and corresponding adhesives in GGSE and PSBN would be $547.81 and $441.19, respectively. Lastly, it was determined that the average wall mount cost of .005 dollars/sqft for GGSE and PSBN, could reasonably be applied to all buildings to determine their individual wall mount and adhesive costs. The group acknowledges that these costs may not directly scale on a square foot basis because building densities vary, but this method was determined to be reasonable for this analysis.

Printing

To determine printing costs for a campus wide roll out, the group calculated the dollars/sqft/month adjusted to reflect the change in print sizes with the use of wall mounts. The change in print sizes will be to replace 5x7 sizes with additional 8x12 sizes. Using this sizing scheme we determined the cost of materials/sqft/month for each building then averaged the two resulting in 0.0010 dollars/sqft/month. This number was then multiplied by each buildings square foot and then doubled to get the cost of printing for the two-month messaging period. Total printing costs for the program were estimated by summing all building printing costs described above.

Stickers

Stickers have a cost of $325 per building based on the group's actual cost of purchasing stickers for PSBN. The group is assuming stickers will be purchased during each 3 year messaging period, and will only be purchased for the fifteen major lab buildings on campus.

Installing metering and submetering

Metering equipment must be installed and functional in every building on campus involved in the program. The majority of buildings on campus currently have automated metering equipment installed and buildings that don't will need equipment to establish baseline energy data. The cost of this metering equipment is roughly $3,000 per building. Circuit submetering, which is estimated to cost around $300 per circuit metered, will be installed on buildings less than 15 years old to gain a better understanding of energy use. To sub-meter all buildings within each rollout year, 50 circuit meters will be purchased for a total of $15,000. Installation costs are roughly $180 (3 hours work from electrician at $60/hour).

Meter Maintenance

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4 18 x 24 Acrylic Poster Frame for Wall Mount, Side Insert - Clear (Displays2go) http://www.displays2go.com/P-149/Wall-Mounted-Sign-Holder-Holds-18-by-24-Poster

The group estimates that it will take one maintenance professional 3 hours at $50 per hour to fix an individual meter.

Tracking software

Software to observe the amount of emails opened costs $120 a year with no limit on usage.

Benefits

Energy savings

The benefits of this analysis can vary significantly depending on program effectiveness and financial incentive logistics. To calculate electricity saving benefits, the group evaluated electricity consumption on an individual building basis to determine average annual electricity use. The group also determined which buildings had metering data to calculate a two-year baseline, and which buildings were lacking this data. This information was used to organize when buildings should be incorporated into the program over the three-year rollout period. Each building's average annual electricity use was then multiplied by the estimated electricity reduction associated with the program to determine the amount of electricity saved per building. Because of the uncertainty in energy reduction from this program, electricity savings were calculated for a range of 1 to 15%. These values were then multiplied by the average annual cost of electricity ($0.11/kWh increasing by 3% annually). The group also considered program attrition rates. Based on research of nationwide energy conservation programs, attrition rates range from 3-39%[5][6]. The group chose an attrition rate of 25% per year after the initial roll out year for each building because of the low turnover rate for faculty and staff but the high turnover rate for students. Therefore, the group expects an annual 25% decrease in efficiency per year after the year of initial rollout until messaging is re-administered (every three years). A sensitivity analysis was conducted for different attrition rates.

The financial component of the program dictates that half of a buildings energy savings will be distributed to the department(s) within the building, and the other half will be realized by UCSB facilities through avoided costs of electricity purchased. The distribution of money to building departments is incorporated into the group's analysis depending on the scenario. Scenarios referring to Utility and Energy Services do not include the 50% of the energy savings financial incentive received by departments. The UCSB campus as a whole scenario does include the 50% energy savings financial incentive received by departments.

GHG emission savings

UCSB may need to purchase carbon offsets as a strategy to reduce CO_2 emissions and meet the 2025 carbon neutrality goal. The value of reduced CO_2 emissions associated with this program was calculated with respect to the price of carbon offsets (carbon emissions per kWh of electricity generated by SCE). The group calculated how much carbon UCSB indirectly emits from its purchase of power from the utility, and SCE claims to emit 3.42×10^{-4} ton of CO_2 per kWh of generated electricity[7]. Further, the price per tonne of CO_2 equivalent in February 2015 in

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[5] The effect of tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents". Journal of Environmental Psychology: Volume 27, Issue 4. 2007 http://ac.els-cdn.com/S0272494407000540/1-s2.0-S0272494407000540-main.pdf?_tid=1fdb94fa-6fac-11e4-ba0c-00000aab0f27&acdnat=1416374758_54500686a624b27bdf84b7ee1bd86b6f

[6] Hunt Alcott. "Social Norms and Energy Conservation". Journal of Public Economics: Volume 95, Issue 9-10. 2011. http://ac.els-cdn.com/S0047272711000478/1-s2.0-S0047272711000478-main.pdf?_tid=e66fa6d2-6fad-11e4-85f6-00000aab0f6c&acdnat=1416375521_19ed0f12db90e1e02a8a57499b150fe2

[7] SCE. 2012 Corporate Responsibility & Sustainability Report. Page 2. https://www.sce.com/wps/wcm/connect/68145014-2eba-40c2-8587-6482ce056977/CRR_08202013.pdf?MOD=AJPERES&ContentCache=NONE

California was $12.38[8]. Using this information, we calculated the maximum possible benefits from CO_2 offsets by multiplying the energy saved by SCE's CO_2 per kWh of generated electricity and the price per ton of CO_2. If UCSB must purchase offsets, this value would be incorporated into the direct benefits of the program.

Results:

The group evaluated the effectiveness of this program from the perspective of UCSB Utilities and Energy Services, who will be managing and implementing the program and to help the campus realize the benefits of avoided costs from electricity reduction. The group also evaluated the program from the perspective of the UCSB as a whole, which includes the benefits to departments that are able to reduce their electricity compared to the baseline. How money is distributed between departments in buildings on campus is still being developed, but benefits as a whole to the university remain the same. The value of carbon emission reductions was also calculated within the analysis. From the perspective of Utilities and Energy Services, this program has a NPV ranging from 170,242 (3% reduction) to $2,478,278 (10% reduction) and a B/C Ratio ranging from 1.21 (3% reduction) to 4.03 (10 % reduction)(Appendix 9C). From the perspective of UCSB as a whole and including benefits to departments, this program has a NPV ranging from $1,159,400 (3% reduction in electricity) to $5,775,472 (10% reduction in electricity) (Appendix 9C).

Looking at how NPV changes for different reductions in energy use, the group evaluated the minimum electricity reduction to make this program viable. For UCSB Utilities and Energy Services, the program has a positive NPV and a B/C cost ratio greater than one for any energy reduction greater than 2.5% (Appendix 9D). For UCSB as a whole, the program has a positive NPV and a B/C cost ratio greater than one, for any energy reduction greater than 1.3% (Appendix 9D).

The group ran a sensitivity analysis on different discount rates (Appendix 9C). Using a 3% discount rate increases the NPV and B/C ratios as future benefits have higher present values. The percent reduction needed for a positive NPV and B/C cost ratio greater than 1 does not change significantly with a 3% discount rate. Similarly, attrition rates for messaging effectiveness were varied to see the effect on NPV and B/C ratios (Appendix 9C). The higher the attrition rate, the lower the NPV and B/C ratios. The percent reduction needed for a positive NPV and B/C cost ratio greater than 1 does not change significantly for the range of attrition rates that we tested. Finally, including CO_2 offset values increases NPV and B/C ratios slightly (Appendix 9C & 9E). However, due to the uncertainty associated with climate change, the difficulty to capture savings from CO_2 reductions and the fact that the UC carbon neutrality will only take place for the last 5 years of our analysis timeframe, it is not necessary to include the value of these offsets to justify the financial viability.

For a 5% reduction in electricity use, this program would save over 28 GWh of electricity over the 15 years (Appendix E). This averages to 1.9 GWh of electricity per year. Using the PVWatts solar modeling program to take into account local Santa Barbara location and weather profiles, a 2.6 MW solar PV system would be needed to produce an equivalent amount of renewable energy production (1.9GWh/year). Using an approximate installed solar cost of $2.89/W, this sized system would require an investment of about $7,600,000. Given the estimated savings from this solar generation, this project would have a NPV of -1,918,000 over a

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[8] Environmental Defense Fund. California Carbon Market Watch: A comprehensive Analysis of the Golden State's Cap-and-Trade Program/ Year One 2012/2013 http://www.edf.org/sites/default/files/CA_Carbon_Market_Watch-Year_One_WebVersion.pdf

15 year time frame and would only reach a positive NPV after 22 years. This calculation is a rough estimate and rebate programs would reduce the cost of solar, but it shows how investments in energy efficiency can be much more cost effective than renewable energy investments.

Conclusion/Recommendations

Based on the results, the group concludes that a campus wide behavioral energy efficiency initiative is a cost effective way to reduce energy consumption, utility costs, and CO_2 emissions. When evaluating the program from the perspective of Utilities and Energy Services, the program would have to reduce building energy consumption by at least 2.5% to have a positive NPV. However, if the evaluation included the benefits realized by UCSB as a whole (departments included), there would only need to be a 1.2% reduction in electricity consumed to have a positive NPV. Based on the literature review of similar programs, the group expects to have a 3-15% reduction in energy use through this program, which would make this program economically feasible throughout the entire range of expected reduction values.

Results from the two pilot buildings will provide further insight into the potential energy savings from a campus wide rollout and allow the group to create a more accurate CBA. In the future, the group can consider how the CBA is affected by the different messaging strategies and the possibility of a more robust campaign. Additionally, an analysis of hourly price fluctuations could lead to messaging strategies that target energy reductions during peak demand hours as this will result in different monetary savings compared to off peak energy reduction. Lastly, the group can conduct a more robust CBA of an equivalent renewable energy project for comparison.

Appendix 9A

Experimental Design of Pilot Program

PSBN and GGSE were chosen by UCSB Utility and Energy Services to participate in this pilot because the buildings had at least two years of historical energy data and have not had recent energy efficiency upgrades.

The following experimental design is being applied to GGSE as well as SSMS, but without the financial incentive in SSMS. These experiments began in November due to the timing of fall quarter and results will be analyzed at the end of January for the project defense in February. For the month of November, the messages focused on plug load. The second floor of GGSE received a social normative message about plug load in the form of handouts in faculty mailboxes, posters in the restrooms and kitchens, and an email report with updates on building energy use. This social normative message was "93% of faculty surveyed at UCSB think individuals should change their computer and monitor to power saving settings". The third floor received a commitment message about plug load in the same mediums as the second floor, and a survey monkey link was included in the email for occupants to specifically "make a commitment" to reduce plug load energy consumption. This commitment message was "Make the commitment to change your computer and monitor to power saving settings". The fourth floor (control) received a generic message about the building's energy consumption through an email report. The emails were sent with tracking software to observe how many people opened the emails, so the group can determine if this is a viable way to reach a large population. For the month of December, the messages will focus on lighting and the same strategies will be applied to each floor as was done in November. The January messages will be a combination of the two strategies and will be determined during December. Circuit submetering has been installed in

GGSE, which breaks down energy use by type (lighting, plug load, HVAC, misc.) and floor, so reductions in energy consumption can be observed on a type and floor-by-floor basis. The goal of this experiment is to see which messaging strategy is most effective in reducing energy consumption in order to apply to the campus wide rollout.

Furthermore, the following experiment design is being applied in PSBN. Large posters describing the pilot program have been hung in common spaces and stairwells to inform building occupants about the program and the financial incentive. The occupants also receive monthly emails about building electricity use. During November, social normative handouts about plug-load (similar message as above) were distributed in faculty mailboxes and hung in the restrooms. The same will be done in December with social normative messages about lighting, and the January messages are to be determined. The group has also been coordinating with LabRATS, a campus-based group that conducts sustainability assessments in sciences labs. The group is asking lab managers and PIs in PSBN to sign up for free energy assessments with LabRATS. Upon completion of the twenty-minute assessment, the lab will receive stickers to place on all of the equipment informing lab users of equipment shutdown procedures to better manage energy use in labs.

Appendix 9B

Major Assumptions

The group's assumptions are as follows:

- Based on the literature, behavioral-based, energy conservation incentive programs have seen results of 3-15% reduction in energy use. Ideally, the UCSB campus could achieve at least a 5% reduction in building energy use through this program with a target of 10%.
- The group determined that a full time position and five interns will be needed to administer this program for its 15 year lifetime. This is based off of the group's own work on this project scaled to a campus wide level.
- The project will take three years to rollout campus wide and messaging will need to be re-administered every three yearly.
- A fifteen-year time frame is the most appropriate scale for the program.
- 25% attrition rate of program effectiveness per year after initial roll-out in each building
- There is always the ability to reduce energy consumption in UCSB buildings through more efficient occupant behavior regardless of the technologies/ building systems in place.
- Opportunity costs of occupants to change to more energy efficient behavior are negligible.
- For simplicity and practicality, we are assuming that our current messaging strategy/campaign and the associated costs will be uniform over the length of the project
- There is no spillover between floors in experimental design in GGSE.
- Printing costs extrapolated from PSBN and GGSE based on square footage are uniform across buildings on campus.
- The benefits associated with GHG emissions reductions was calculated assuming the school would be converting all CO_2 reductions into reduced offsets for all years in the analysis.

Appendix 9C

NPV and B/C ratios for Different Electricity Reduction Scenarios

Variation in Net Present Value and Benefit Cost Ratios for different percent reductions in electricity use. Three cost-benefit scenarios were analyzed. The first scenario (green) considers only the cost and benefit directly realized by Utilities and Energy Services. The second scenario (gray) considers the costs and benefits directly realized by the campus as a whole, this includes financial incentives given to departments. The third scenario (yellow) shows the same analyses but with the addition of $CO_{2\ offset}$ value.

	Utilities and Energy Services		UCSB including Departments		UCSB w/ CO2 Offset Value	
%Reduction in Electricity	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**
3%	170,242	1.21	1,159,400	2.42	1,222,274	2.49
5%	829,680	2.01	2,478,278	4.03	2,583,068	4.15
10%	2,478,278	4.03	5,775,472	8.05	5,985,053	8.31

Variation in Net Present Value and Benefit Cost Ratios for three different discount rates using a 5% reduction in electricity use and an attrition rate of 25% per year.

	Utilities and Energy Services		UCSB including Departments		UCSB w/ CO2 Offset Value	
Discount Rate	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**
3%	1,002,081	2.09	2,927,392	4.17	3,048,566	4.30
5%	829,680	2.01	2,478,278	4.03	2,583,068	4.15
8%	631,860	1.91	1,960,655	3.81	2,046,332	3.94

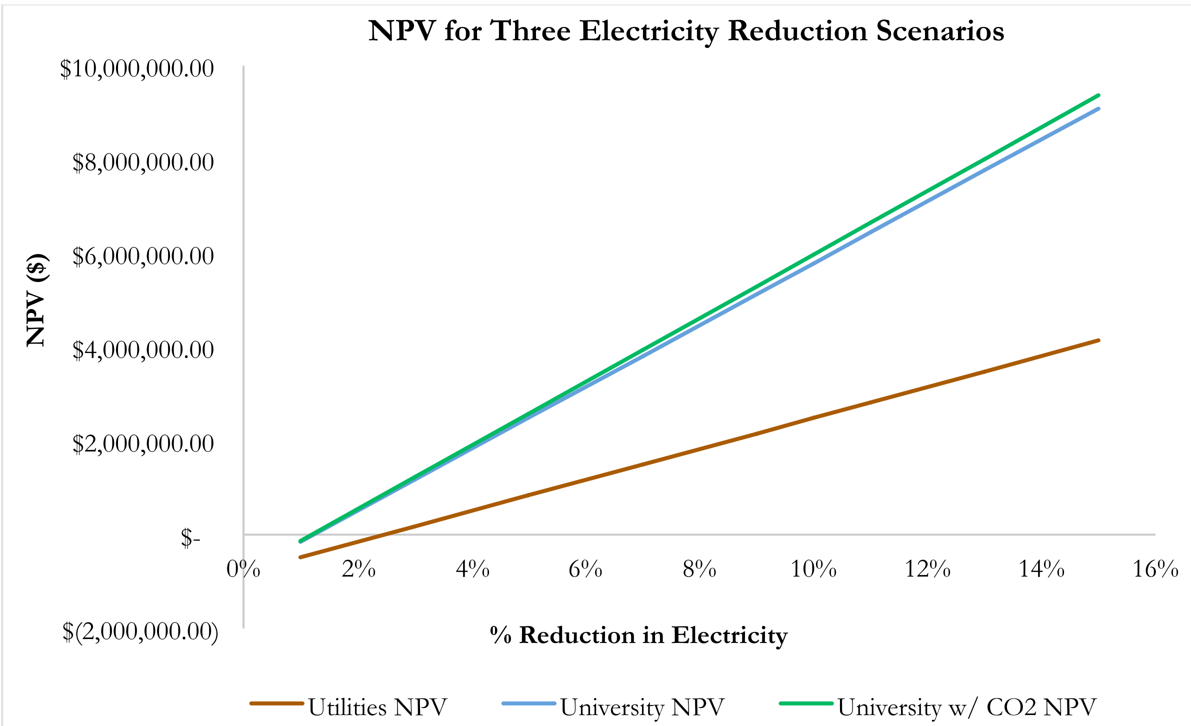
Variation in Net Present Value and Benefit Cost Ratios for three different attrition rates using a 5% discount rate and a 5% reduction in electricity use.

	Utilities and Energy Services		UCSB including Departments		UCSB w/ CO2 Offset Value	
Attrition Rate	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**	**NPV**	**B/C Ratio**
5%	1,193,481	2.46	3,205,879	4.91	3,333,411	5.07

25%	829,680	2.01	2,478,278	4.03	2,583,068	4.15
40%	591,087	1.72	2,001,090	3.44	2,090,952	3.55

Appendix 9D

NPV for Three Electricity Reduction Scenarios



Cost-benefit analyses were performed for four scenarios, two of which only consider our client –Utility and Energy Services – and two consider the UCSB campus as a whole. For each we consider the benefits with and without CO_2 reduction. The scenario considering benefits to the UC campus as a whole, including the carbon reduction yields a positive NPV at the lowest percent energy reduced.

Appendix 9E

Total Electricity Saved (GWh) and CO_2 Reduction for Different Electricity Reduction Scenarios

Total electricity saved (GWh) and the resulting tons of CO_2 reduced at three different campus electricity reduction scenarios. The greater amount of energy saved, the great reduction in CO_2 emissions.

%Reduction in Electricity	Total Electricity Saved (GWh)	CO_2 Reduced (Tons)
3%	16.82	7,877
5%	28.04	13,128
10%	56.07	26,256

Appendix 10: List of Campus Buildings and Metering Data Status

List of all buildings on campus organized into four categories: has at least 2 years of good automated metering data, has automated metering data but needs more monitoring, problem with meter, and needs meter.

Broida	Has at least 2 years of good automated metering data
Buchanan Hall	Has at least 2 years of good automated metering data
Campbell	Has at least 2 years of good automated metering data
Chemistry	Has at least 2 years of good automated metering data
Engineering Science Building	Has at least 2 years of good automated metering data
Environmental Health and Safety	Has at least 2 years of good automated metering data
Harrold Frank Hall	Has at least 2 years of good automated metering data
Humanities and Social Sciences Building	Has at least 2 years of good automated metering data
Intercollegiate Athletics	Has at least 2 years of good automated metering data
Kerr Hall	Has at least 2 years of good automated metering data
Life Sciences Building	Has at least 2 years of good automated metering data
Upper Marine Bio	Has at least 2 years of good automated metering data
Marine Science Research building	Has at least 2 years of good automated metering data
Materials Research Lab	Has at least 2 years of good automated metering data
Mosher Alumni House	Has at least 2 years of good automated metering data
Multi Activity Center	Has at least 2 years of good automated metering data
Nobel hall	Has at least 2 years of good automated metering data
Psychology	Has at least 2 years of good automated metering data
Psychology E	Has at least 2 years of good automated metering data
Public Safety	Has at least 2 years of good automated metering data
Rec Center	Has at least 2 years of good automated metering data
Robertson Gym	Has at least 2 years of good automated metering data
Student Health	Has at least 2 years of good automated metering data
Student Services	Has at least 2 years of good automated metering data
Theater & Dance East	Has at least 2 years of good automated metering data
Arts Upper	Has an automated meter but needs more monitoring
Bren	Has an automated meter but needs more monitoring
Cheadle	Has an automated meter but needs more monitoring
GGSE	Has an automated meter but needs more monitoring
Ellison Hall	Has an automated meter but needs more monitoring
Engineering	Has an automated meter but needs more monitoring
Ocean Science Education Building	Has an automated meter but needs more monitoring
Meter 1	Has an automated meter but needs more monitoring
Meter 2	Has an automated meter but needs more monitoring
Meter 3	Has an automated meter but needs more monitoring
Phelps	Has an automated meter but needs more monitoring
PSBN	Has an automated meter but needs more monitoring

SAASB	Has an automated meter but needs more monitoring
Girvetz	Has an automated meter but needs more monitoring
South Hall Incl. Girvetz	Has an automated meter but needs more monitoring
SSMS	Has an automated meter but needs more monitoring
Student Resource	Has an automated meter but needs more monitoring
EM South	Has an automated meter but needs more monitoring
Data Center 400v Main	Has an automated meter but needs more monitoring
Data Center 480v Main	Has an automated meter but needs more monitoring
Theater & Dance West	Has an automated meter but needs more monitoring
University Center	Has an automated meter but needs more monitoring
Bio Meter 1	Problem with Meter
Bio Meter 2	Problem with Meter
Bio Meter 3	Problem with Meter
Ellings	Problem with Meter
Tipton Meeting	Problem with Meter
Webb	Problem with Meter
Arts Lower	Needs Meter
Bioscience Instruction Facility	Needs Meter
Events Center	Needs Meter
Faculty Club	Needs Meter
Harder office	Needs Meter
Kohn Hall	Needs Meter
MER 1	Needs Meter
MER 2	Needs Meter
Parking Administrative Services	Needs Meter
PSBS	Needs Meter
WC Child Care	Needs Meter