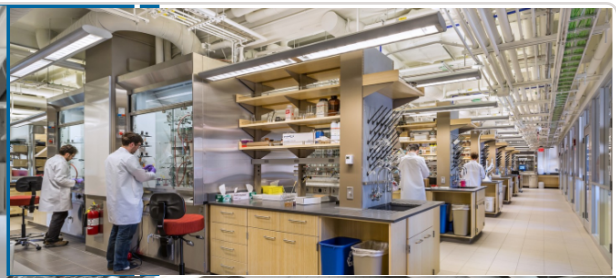

Reducing Laboratory Energy through Financial Incentives

A Pilot Study at the Harvard University Faculty of Arts & Sciences

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Abstract

The Harvard Faculty of Arts & Sciences (FAS) conducted a pilot program to understand the efficacy of providing a financial incentive to lab groups for saving energy over a one-year period to reduce energy consumption and greenhouse gas emissions. Six labs were chosen based on the availability of sub-metering; three chemistry labs and three biology labs. The pilot resulted in saving 22 MTCDE; the chemistry labs achieved all of the savings, thereby receiving a total incentive of $8,647. While it could be said that the chemistry labs had an unfair advantage in the pilot due to their numerous opportunities to shut fume hood sashes, the hypothesis was that the biology labs would be able to achieve an incentive of $1,000-$10,000 from reducing energy and emissions. Further study is needed before meaningful assumptions can be made.

Introduction

Laboratories are generally very high consumers of energy. This can be attributed to a number of factors, including high ventilation rates, plug load, and lighting requirements. The Energy Use Intensity (EUI) of a building is the generally accepted method of benchmarking building energy use for the United States and is defined in terms of British Thermal Units per square foot per year (kBTU/ft2/yr). To provide perspective, the EPA estimates the median site EUI for a dormitory as 115 and for an office as 148, while the 2014 Boston Green Ribbon Commission Laboratory Benchmarking Study found the average site EUI for biology labs was 317, and the average for a chemistry lab was 369.

Research universities have been implementing energy conservation measures (ECMs) to reduce energy consumption in the labs. At Harvard, the FAS usually treats ECMs as proactive building upgrades with less than 10 years simple payback, and do not fall into the categories of facility maintenance or capital projects. In addition to ECMs, Harvard also commits resources to occupant engagement and behavior change programs, such as competitions for shutting off lights and for closing fume hood sashes, with recognition and rewards for both individuals and lab groups. These motivators are important because of the way federally funded grants are processed; the principal investigators do not pay their energy bills directly, and therefore have no direct incentive to conserve energy.

There is little data available that can be used to estimate how much a lab group can save by simply being conscious and thoughtful of their energy use. Some general assumptions can be made regarding how energy is used in different categories of labs, but each lab group can be variable in number of researchers, types of equipment, and hours per day of occupancy. Based on some data available regarding best practices for labs, it was hypothesized that a given lab could save between $1,000 and $10,000 per year.

Given that there are roughly 500 labs groups at Harvard, hypothetically Harvard could save between $500,000 and $5,000,000 each year if labs were properly motivated to conserve energy. It was decided to test this hypothesis on six labs, where a financial incentive would be provided for energy saved over a one-year period.

Background

Financial incentives for efficient behavior can be found in everyday life. At home, many people turn off the lights and other appliances when leaving for the day to reduce their utility bills or they might purchase energy efficient automobiles to save money on gasoline. When it comes to academic research laboratories, principal investigators (PIs) pay a general overhead rate for their space. Because energy use is difficult to allocate and is a small component of their overall costs, regardless of how efficiently they run their operations, they essentially pay the same rent. This creates a fundamental disconnect between efficient use of the space and the positive reinforcement of a financial incentive. Though many people would like to do the right thing for its own sake, it does take effort and forethought, and this disconnect is a lost opportunity to incentivize and reward energy savings. The result is higher energy costs for the research institutions and the creation of unnecessary greenhouse gas emissions.

Many research universities attempt to combat this disconnect with occupant engagement programs and signage. One example of such a program is the Shut the Sash Competition at Harvard University in the Department of Chemistry & Chemical Biology (CCB). Being one of the longest-running occupant engagement programs at Harvard, Shut the Sash saves energy by encouraging groups to close their fume hood sashes, reducing ventilation needs. Goals are set, energy consumption is measured, and winners receive monthly prizes and celebrations for their efforts.

To help researchers see their impact, Shut the Sash provides real-time information through a display mounted by the entrance to each lab showing the number of cubic feet of air per minute (CFM) being exhausted through the fume hoods. CFM is then translated to energy, cost, and greenhouse gas emissions. Researchers know what numbers to expect when the hoods are open and closed, and can easily identify when someone left a fume hood open based on the number on the display. The effect of the competition yields significant annual savings. As of 2016, the competition was confirmed to have prevented at least $200,000 worth of energy consumption and 300 MTCDE on an annual basis.

Shut the Sash is one many programs that institutions use to incentivize efficient behavior. Harvard also engages labs in similar programs around lighting and ultra-low temperature freezer management. Competitions have been shown to be effective in the lab setting, but tend to have a specific duration, and concerns around sustained behavior change have cast some doubts on the long-term effectiveness. Some data suggests that competition can drive energy consumption to levels below what is sustainable in the long-term, but can still have a lasting impact compared to baseline behavior. While there are numerous examples and schools of thought to consider when exploring a potential occupant engagement opportunity, it is still a relatively new and evolving approach for achieving energy and emissions reductions in laboratories.

Methods

Before testing the efficacy of a financial incentive to improve researcher behavior in labs, the initial proposal went through a rigorous feasibility review. This included a review of the scope of the project with several administrative stakeholders, a survey of the technical & infrastructure needs, and the setup of a funding framework.

Before the study began, we acknowledged two primary efforts that had underpinned our study. Firstly, Harvard had already invested significantly into climate change mitigation by improving building efficiency and driving behavior change. It was estimated that by improving researcher engagement, an additional 8,200 MTCDE could be saved annually. Secondly, The Harvard Office for Sustainability had expressed interest in studying the feasibility of changing the way federal grant procurement pays for energy consumption, so that all federally-funded university-based research groups would have an incentive to conserve. Below are the major steps of the project, which also serve as a general timeline.

Step 1: Determine the goals of the study. Seth Hoedl, Fellow at the Emmett Environmental Law and Policy Clinic at Harvard Law School and Quentin Gilly of OFS worked together to create a proposal for all stakeholders involved.

Step 2: Develop a funding model. Under this proposal, both the FAS Office of Physical Resources and Planning (OPRP) and the individual lab groups could receive a financial benefit from reduced energy consumption. With OPRP paying the utility bills for the labs, it was determined that 65% of the savings during the pilot would go back to the labs.

Step 3: Identify spaces where energy consumption could be measured at the lab level. It was found that only newly renovated lab spaces had any energy data at the lab or floor level. As of spring 2015 there were very few spaces on campus with the metering infrastructure available to conduct this occupant engagement program. Ultimately six labs were chosen for the pilot, comprised of three chemistry labs, and three biology labs. These spaces had been occupied and metered long enough to establish a baseline for energy consumption.

Step 4: Collect baseline data and check for accuracy. For the chemistry labs, this was done by working with facility operators and Siemens engineers. We walked the spaces and confirmed which rooms and panels were reporting to which sub-meter. Some sub-meters were found to not be useful for the study and were excluded. For the biology labs this was done similarly, as we walked through the building and confirmed what each electrical panel served. We set up 30-minute trends on those panels, and they were programmed to automatically send OFS a report at the beginning of the month. Historical trends on these spaces was found on the Harvard Apogee Consolidated Server. This provided 10-12 months of energy data usage in these spaces before any intervention was announced.

Step 5: Run the pilot program for one year, and reassess for a longer pilot. Each of the six lab groups were introduced to the project in a separate meeting. All lab groups that were approached agreed to be involved in the study. Each lab manager was also provided with a list of energy saving opportunities, such as shutting down of refrigerated centrifuges and thermal cyclers at night, shutting off water baths and heat blocks, and warming up the ultra-low freezers from -80° C to -70° C.

One additional component of the study was to attempt to understand how energy needs change over time. Labs can vary temporarily in number of researchers, and types of research being conducted. All labs were encouraged to report any significant changes along the way and each lab received an update every three months with their energy performance.

The pilot program was officially launched on October 1, 2015 and ran through September 30, 2016. Total energy use was calculated for each of the labs, and a summary of the findings was drafted in November 2016.

Findings

The results of the study were mixed, with half of the labs showing energy savings and the other half showing a slight increase in energy use. The split was largely along departmental lines, with all of the chemistry labs showing energy savings, and the biology labs showing a slight net energy increase. A summary of the results can be found in Figure 1.

Discussion

A significant portion of the energy savings from this project came from the lighting systems. The participating chemistry labs have been engaged in annual three-week Lighting Competitions since the spring of 2015, and sustained behavior improvement has been seen throughout the year. With the goal being to understand the potential savings from a financial incentive and normalize the effect of the lighting competition, it was decided to use the original baseline that was established before the very first lighting competition.

The first major difference between the biology and the chemistry labs is that the lighting systems in biology were mostly operated through occupancy sensors, meaning that they could save less energy by proactively shutting off lights. The chemistry lab lighting systems are completely manual, only shutting off when the occupants flip a switch. The total savings from the labs lighting system can be seen in Figure 2.

The second major difference between the biology labs and chemistry labs is the fume hoods. Both operate on a variable air volume (VAV) system, but the fume hoods in biology have automatic sash closers. These operate by automatically closing if they are left open for more than five minutes if no movement is detected. The chemistry fume hoods are much more numerous per lab group, and are completely manual, requiring the user to make the conscious decision to save energy. In this case, the Shut the Sash Competition has served as a long-term motivator with the selected groups having already performed exceptionally well for several years. It was decided that the baseline for chemistry fume hoods should not include the historical baseline, but instead use the average of the last six months fume hood exhaust averages for each participating lab. This would help provide better understanding of whether a financial motivator provided is more effective in getting people to close fume hoods sashes than with competition and and monthly celebrations.

As can be seen in Figure 1, the HVAC savings were minimal, and were within the noise of normal lab operations. For example, Chemistry Lab 1 has a maximum CFM of 43,833 if all hoods are open, and a minimum of 8,548 CFM, meaning that savings of 75.5 average CFM represents less than a 1% change. Chemistry Lab 2 also has a similar min/max, but exceeded their average by 69.6 CFM. With all three chemistry labs being good performers in the competition, it is fair to say that the current occupant engagement strategy (Shut the Sash Competition) with fume hoods in these labs yields equal results as a financial incentive, with minimal costs.

As stated in the Methods section, each lab group was encouraged to report changes in occupancy and research over the year. Only one lab group reported any changes during this period. One of the fume hoods in that lab needed to be set at a higher flow rate, and the facility manager confirmed the exact CFM change that would affect their numbers. At the end of the study when results were announced, two lab groups retroactively reported major changes in staffing over the study period. Since they did not report the changes in a timely fashion, or produce accurate numbers retroactively, these changes were not included in the figures or analysis. If a second study is warranted, it is suggested to have each lab manager report the exact number of researchers at the beginning of each month, as part of filling out a simple questionnaire, so that these changes can be studied.

The final category for energy incentives was plug load. Plug load was originally proposed as the primary area where labs could influence energy consumption. The results indicated that 67% of the total energy saved during the pilot program came from plug load, saving just over 63,000 kWh. For the biology labs, plug load was the primary category where they could receive a financial incentive. With the numerous freezers, centrifuges, water baths, and other equipment found in the biology labs, they were expected to have ample opportunity to save energy. Simple actions like setting ultra-low temperature freezers to -70° C from -80° C can have a significant impact, as can turning off equipment like thermal cyclers and water baths at night. As indicated in the Findings section, the biology labs used slightly more energy than during the baseline, and it was confirmed through discussion with the lab managers that many of these efforts were not undertaken. The lab managers in biology claimed that everyone tried their best to save energy, but it is unclear exactly what measures were taken. The chemistry labs had mixed results, with two labs showing significant reductions in plug load energy consumption, and one lab consuming about the same. It is interesting to note that the chemistry lab who had a set-up most similar to the three biology labs had little plug load savings. The energy use of the three chemistry labs over time can be seen in Figure 3.

Conclusion

The results of the pilot study were mixed but warrants further investigation to develop more meaningful assumptions around energy use in labs. It appears that some lab groups can be motivated to reduce energy use through a financial incentive. Given the split in results between chemistry and biology, a larger sample size is warranted to better understand these differences, and if there is indeed greater opportunity for chemistry labs to reduce energy consumption than biology labs.

Figures

Figure 1. Energy Savings by Group and Category

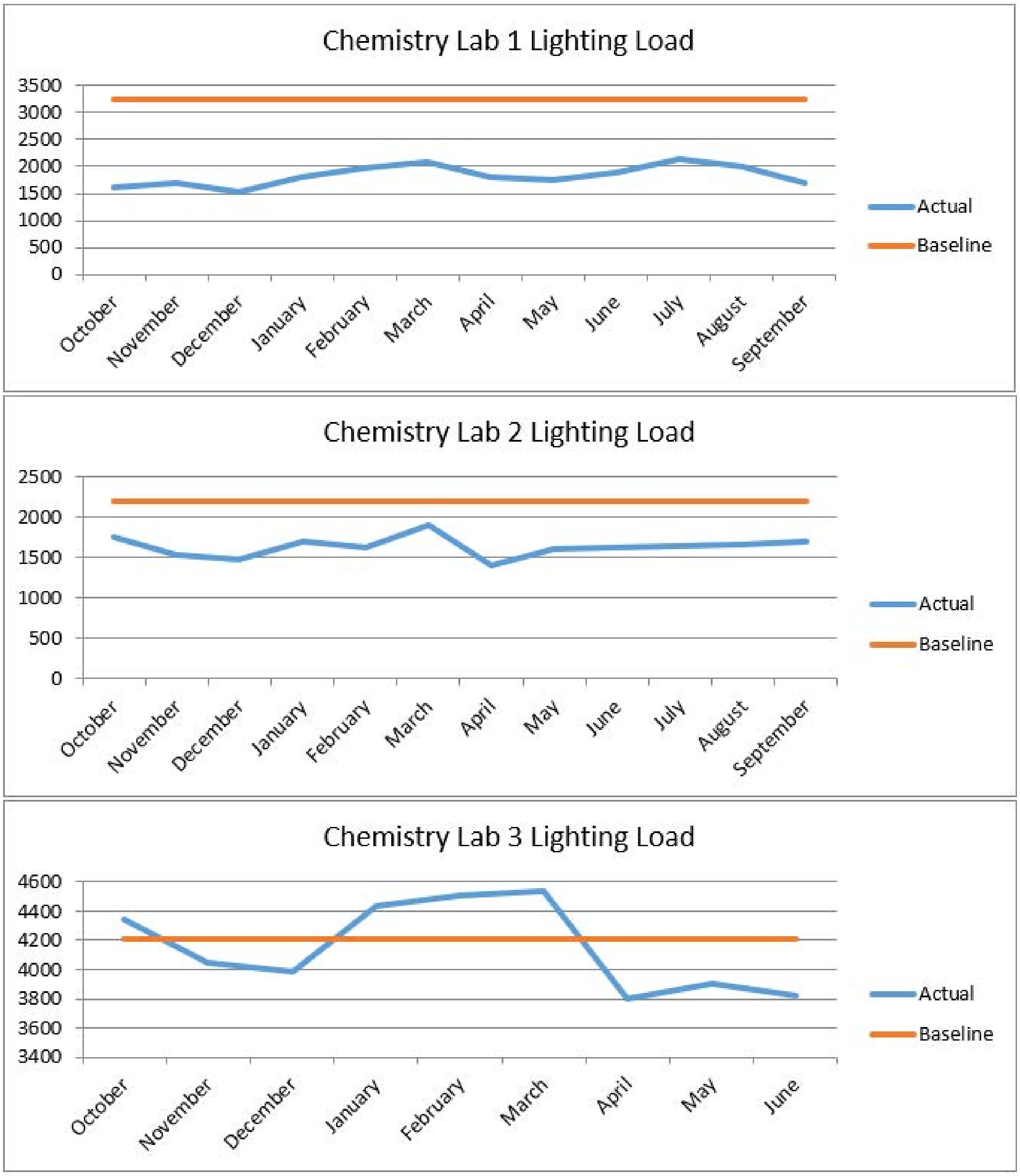
Lab	Financial Savings Year-1 of pilot to FAS	Financial Incentive Rewarded to each group	kWh Savings	HVAC Savings (CFM) exhaust	MTCDE
Chemistry Lab 1	$7,463.85	$5,051.50	33,413.05	75.50	11.03
Chemistry Lab 2	$3,107.88	$2,220.12	25,420.28	(69.65)	8.52
Chemistry Lab 3	$1,115.99	$925.39	8,955.59	3.18	2.77
Three Biology Labs	($461.15)	$450.00	(3,689.16)	N/A	N/A
Total	$11,687.72	$8,647.02	67,788.93	9.03	22.32

*Labs that come in under budget get receive a social event at $150 each.

*The three biology lab groups were summarized together as they shared overlapping space and equipment.

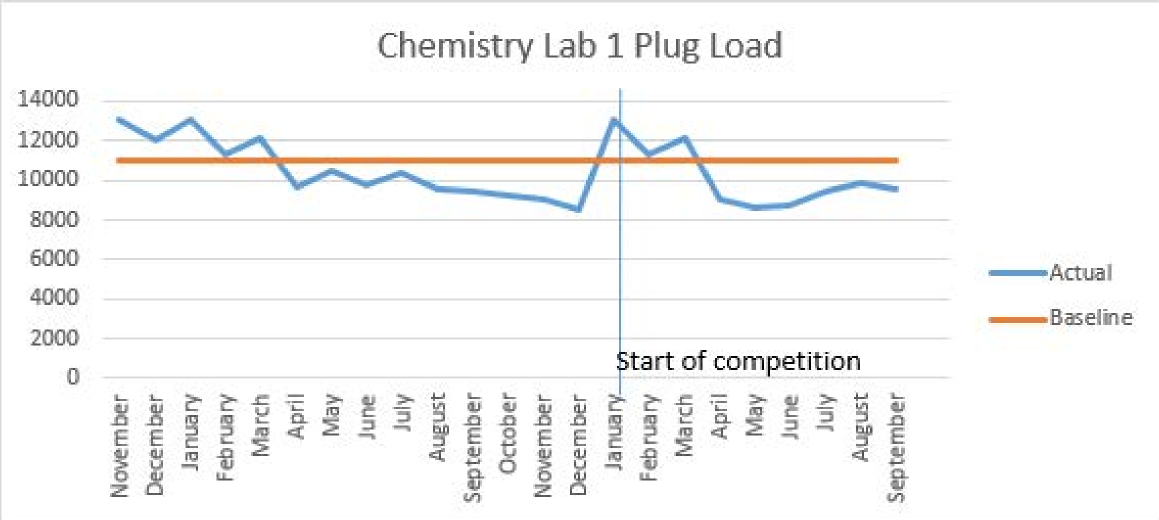
Figure 2. Total Savings from Lighting. Orange line indicates baseline average, and blue line indicates changes in consumption over time.

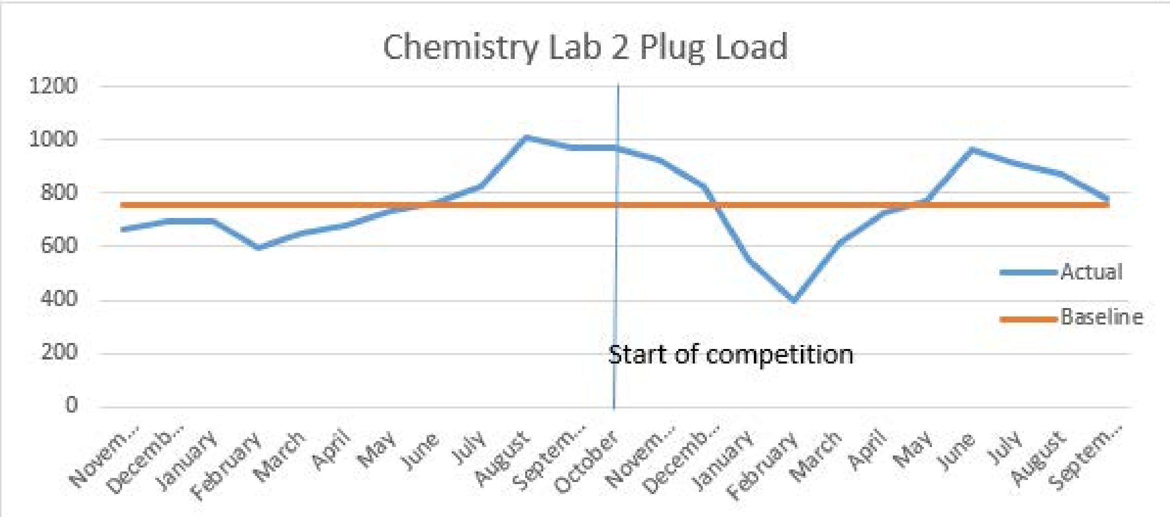
Total Savings from Lighting	kWh	Cost
	30,984	$3,872.97

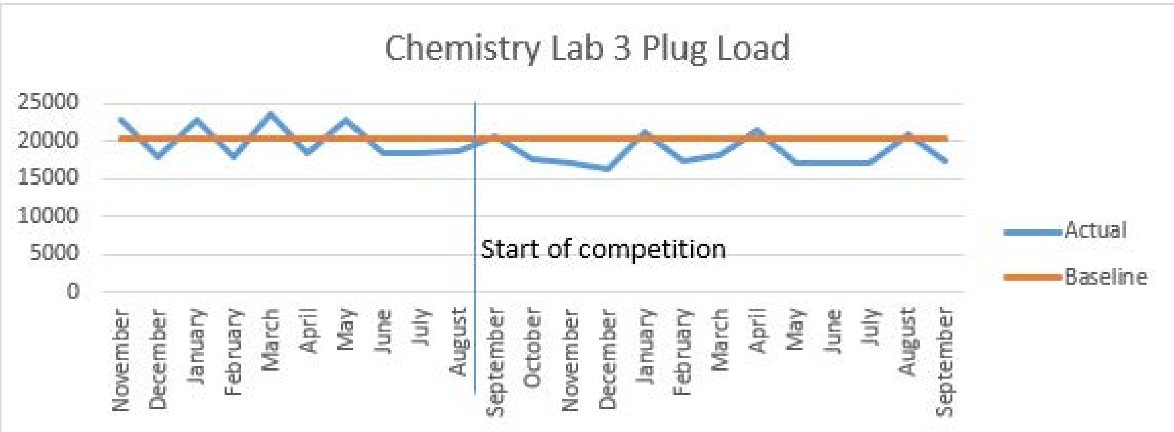


Figures

Figure 3. Total Savings from plug load. The orange line indicates baseline average, and blue line indicates changes in consumption over time.







Figures

Figure 4. Total Savings from plug load. The orange line indicates baseline average, and blue line indicates changes in consumption over time.