GoldenEnergTech

Better Buildings Case Competition 2014

Golden EnergTech Proposal

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EXECUTIVE SUMMARY

Objective:
Laboratories are tasked with the lofty goal of expanding the realm of human knowledge. In the pursuit of their mandate, research laboratories-with their specialized equipment and ventilation systems- grow their energy demands year after year which accounts for as much as two-thirds of a university campus energy consumption. In the past, the belief might have been that laboratories were too complicated to make sustainable without imposing on researcher safety or research results.

Observations:
Few incentives exist to encourage researchers to implement efficiency measures in their labs. Such issue spans a number of parties involved from grant-making agencies to the laboratory personnel and universities themselves.

Recommendation and Analysis:
Due to this delicate multi-faceted problem, we understand that not only does this proposal require several measures for universities to approach building their efficiency but also be an explicitly scalable model. Consequently, we have proposed a corresponding multi-pronged approach identifying and targeting four major areas of energy efficient savings: policy, technology, grants, education, and federal agencies. Each element is crucial to develop the needed responsive and self-sustaining system with the ability to save time for researcher, reduce costs for laboratories, identifying needed resources, improving communications while supporting laboratories in the pursuit of high quality research. As such, we were careful to holistically develop recommendations that meet both research and sustainability objectives via university policy modification, adaptation of newer more energy efficient technology, grant policy restructuring, and energy education of researcher and staff.

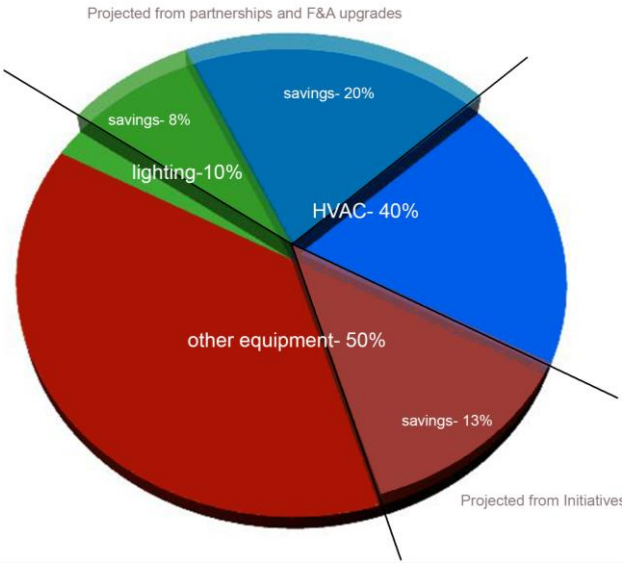
With respect to university policy, we recommend implementing a campus wide metering system for monitoring and analyzing of the campus energy output thus allowing each university to quickly identify possible savings and base load anomalies while also implementing a campus-wide energy incentive program with high returns. This will return an estimated energy consumption cut of 15% in 20 years. We also aim to consolidate the current decentralized campus procurement for the purposes of transparency, accountability, and encourage procurement of energy efficient equipment.

From a technological standpoint, possible avenues to minimizing various energy consumption are accessible through upgrades and retrofits. After costs-benefit calculations and case study analyses, we estimate HVAC system and lighting have the highest returns in the shortest payback periods, with respective savings of 50-60% and 81%. Also, we addressed the importance of preventative maintenance implementation on multiple university campuses. Given previous results and scalability, this practice will improve equipment life cycle and ensure the consistency of their energy efficiency.

Regarding grant modification, we suggest expanding or modifying the current F&A guidelines to include additional allowances for choosing more energy saving measures. These measures will return the higher costs difference within the span of the grant and the introduction of such clauses in the initial grant will reward achieving certain benchmarks in energy saving behavior. As the middleman between the P.I. (private investigator) and grant agencies, the university becomes responsible for ensuring compliance of the labs and negotiating with the agencies for the funds.

Installing energy-efficient retrofits, purchasing energy start equipment and modifying grant clauses are certainly immediately effective in our goal to greener buildings but ultimately the human element is

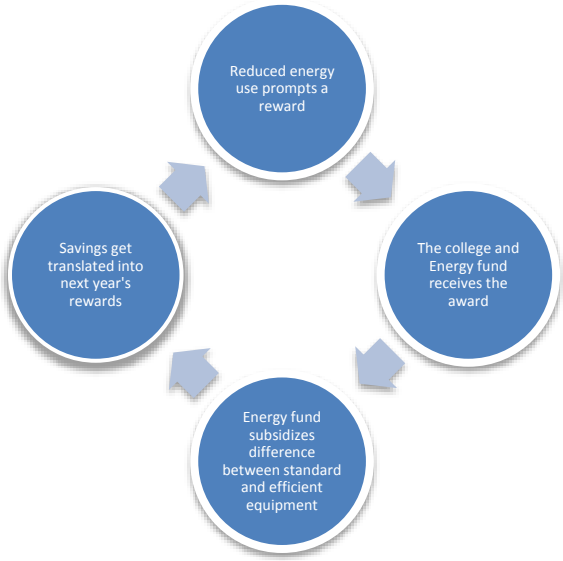
crucial in our effort of energy savings and efficiency. Educating, encouraging and collaborating with researchers to make recycling, conservation and reuse a part of lab culture is both the biggest challenge and, quite potentially, the highest payoff. Our proposed measures in education has the ability to produce considerable amount of savings by educating future generations about energy efficient practices. Laboratories walkthrough and sticker reminder will also be implemented as an effort to understand each laboratories circumstances and ongoing research and identify various energy saving measures that can be tailored to each specific lab.



Analysis on Average energy use in buildings, with savings projected 20 years

"This chart best summaries our analysis in each major category of energy consumption. In total we expect a 40% savings in 20 years."

Incentive Program Savings Cycle



We intend to reduce energy usage in laboratory buildings using two approaches; the first approach is the creation of a self-sustaining energy program called the "Energy Incentive Program" which uses the previous year's savings to fund the next year's round of efficient equipment purchases. If the university and the grant agency have an agreement that a certain level of energy compliance in a lab results in a post-grant award, there would be an additional stream of income for this program. The second prong relies on a rule change in the F&A requirements that allow the funds to be used for building upgrades provided that the upgrades break even before the conclusion of the grant. This loosening of restrictions combined with partnerships with private energy entities/ utilities can allow for the large, expensive building upgrades to happen without incurring heavy up-front expenses from the University.

By the end of 20 years, we expect the Incentive Program to save 12 percent of a building's energy use, and the large infrastructural upgrades to save an additional 28% of the building's energy usage. Combined, the two approaches will reduce the laboratory building's usage by 40% by 2034.

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INTRODUCTION

Research universities are heavily invested in their laboratories. Not only do the laboratories devote millions of external funding to support university research but also they provide the university with a mission and identity. As important as the research is for the university, we must be mindful of the context that the laboratories exist in. In the last decade, it has been increasingly clear that a looming energy crisis and a changing climate is due to our wasteful use of energy and natural resources. Not only that, the balance of economics is shifting in order to justify changing the methods of operation. A university, as an entity that houses research laboratories, now has a financial responsibility to participate in this paradigm shift.

As an energy manager, we propose several approaches to tackle energy usage in the sectors we discussed in the executive summary. Regarding policy implements our first plan of action acknowledges that computerization is the key to streamlining many older systems that were optimized for pen and paper. Therefore, we propose streamlining the procurement system to a more efficient central-university wide system to that can easily monitor and recommend energy efficient purchases throughout the university. Although it is impossible to generalize the building stock of a generic university, many of the buildings are likely historic or simply out of date. Many are in dire need of retrofits and the implementation of new monitoring and control technology. In this proposal we outlined the changes on how we implement with maintenance, HVAC system, and lighting. On the research grant front, we would like to propose a modification on the F&A policy to broaden its scope to include upgrades. In addition to the current allow the usage of such funds to invest in energy saving measures would provide the university another source of funds to save energy. Lastly, we aim to promote energy education. This will be done through educational campaigns, policy implements to energy holiday curtailment and laboratory specific recommendation between laboratory managers and the university's energy office.

POLICY

Streamlining the System

I. Recommendations for Energy Management

Few motivations exist for university departments to reduce consumption since the utility bill is paid by central campus. Furthermore, energy consumption is not systematically measured and managed across campus. Therefore, we propose that universities establish an incentive system to reward reduced energy consumption and refocus energy management resources to increase departmental accountability. Financial reward compensation should be based on variable energy output saved following building energy baseline standards. The incentive program and other recommendations require the creation of an Energy Office, to oversee and implement the proposal, if the university does not already have an equivalent. With millions of possible savings, an effective office could be a financial windfall for the university

II. Metering Implements and Monitoring

In 2012, researchers in the Energy and Resources group based in Barrows Hall reported a large increase in building 'base load' demand on the recently implemented Pulse, Berkeley's energy dashboard. After informing the Berkeley Energy Office, which researched the observation, building managers found that some equipment were turned on due to construction and were not turned off at night when it was not being used. This oversight could have cost as much as $45,000 in a year if it had continued undetected. Instead action was taken and the equipment setting was changed and Barrows' electricity immediately dropped. This is one of many cases (other example is shown on Appendix A.1) that reinforces a general university campus initiative to install metering systems in order to accurately measure energy consumption in buildings, check anomalies in building 'base load' demands by utilizing simplified diagnostic reports compiled yearly with data aggregated and consolidated monthly, encourage savings, and increase easability in viewing usage. Compare this to the current system where universities

infrequently perform this analysis due to the high costs of external consulting firms. This will be consolidated on a platform thereby developing standards for application development, support services and IT procurement.

III. Campus-wide Energy Incentive Program

We assume the university takes 50% of incoming grant money to cover internal costs of running the laboratory facilities (Facilities and Administrative Costs, F&A). F&A goes to covering the electric bill and any overhead costs for laboratory facility operations. Each lab consists of dozens of unique items with their own pattern of usage and consumption. It is difficult for the university to legislate how to best optimize equipment use. Consequently, we believe energy saving methods are best decided by individual labs. We believe that an incentive program will be the strongest way to promote a change in habits. For example, Berkeley has the "Energy Incentive Program" (EIP) which evaluates each building to establish an energy use baseline and rewards energy savings with a 10 cents per kilowatt refund. Increases in usage are penalized with a fine. Each year, the baseline is recalibrated based on the building's performance and the cycle starts anew. All the buildings in a particular college are aggregated and the award is sent to the specific college's office of the dean who usually uses the money in a discretionary manner. This system costs the university almost nothing in its current form because the savings are passed from the university to the colleges.

This program has been effective in rewarding energy savings throughout campus. In its first year, the program rewarded 3% in terms of energy savings which amounted to approximately $900,000. The savings typically came through better energy practices versus infrastructural improvements. This implies a limit as energy practices can only go so far if the money is not being reinvested in better equipment. This program is projected to save 15% of energy in the next 20 years without any additional initiatives. (Appendix A.2) We recommend stipulating a matching portion of the incentives go to equipment and facilities upgrades to increase the potential of the program. In addition to the 10 cents per kWh that goes to the each specific college, an equivalent or greater amount would enter an Efficiency Fund managed by the Energy Office for use on physical upgrades. The fund will be tapped to pay the difference between energy star and standard lab equipment, and ensure efficient equipment purchases without additional research costs. Although our proposal changes the program from money neutral to money negative in the first years, we feel that the annual energy decrease, combined with the new structure to reinvest savings will create a sustainable EIP thus saving even more money in the long run.

As effective as the program can be, there is room for improvement. In the scenario above, research programs are excluded and not penalized for expansion because labs need the flexibility to grow and expand without worry of punishments. However, there is a failure of this initiative to adjust the baseline to increasing equipment counts. Without fixing this exception, burgeoning labs have no incentive to save energy. We need to add flexibility to the concept of the baseline to accommodate growing labs in ways that will not harm research. To accommodate growing labs without harming research, we recommend calculating the baseline for labs based on historical data combined with an inventory of devices and a lab personnel count (this requires an analysis to determine how the factors contribute to baseline growth). The adjustment allows the baseline to match growth and thus reward more efficient practices even as the equipment and personnel count increases. It is with this system that buildings with growing labs can compete in energy saving measures instead of being passed by from the program. Although this proposed program is good at promoting more efficient practices with existing equipment, the weakness of the growing baseline is that it adapts to each purchase without guiding those decisions. To supplement the incentive program, we also need an additional system that controls the efficiency and quantity of new units. The university, via its procurement program and the Energy Office should be able to suggest efficient equipment if internal calculations show it can pay for itself over its lifetime. The Energy Office will have data and conduct its own research, and issue its recommendations accordingly. One effect of this program would be to phase out older models of equipment, while bringing in new devices calculated to be economical for their service lives. One thing that is sacrosanct is the preservation

of research, so different models should never be introduced into the middle of a research project. Instead, new projects receive the newer equipment, and the old equipment gets phased out as the research ends. Ultimately, these two programs need to work in tandem to accommodate each other's short fallings. The EIP rewards efficient use of equipment but cannot encourage efficient buying because it grows with each purchase. This change in the EIP system will increase projected savings to an estimated of 25% over 20 years (Appendix A.2).

IV. Procurement and Procedures- A Two Tiered E-Commerce Approach

A UC Berkeley study (2008-09) showed that of the $410M spent on procurement, only $35-175M is 'managed' (expenditure managed under campus contracts and plus expenditure covered by UCB department-level negotiations); The most expensive component of procurement is IT followed by lab equipment. Large organizations, particularly Universities, have numerous cataloging and purchasing systems, vendors, customers, and processes that must be efficiently managed. Consequently individual purchases due to larger, more complicated or obscure purchase orders create inefficiencies and incur administrative overhead as well as opportunity loss from potential University strategic 'discount' contracts.

In order to encourage the purchasing of energy efficient equipment and streamline the procurement system in general, we propose a two tiered online purchasing approach to more efficiently complete and document procurement. Not only will this centralize several coexisting and competing systems, but also allow the university to increase its focus on strategic sourcing rather than performing multiple transactions between the university, the PI, and the Vendor. By simplifying the procedures for lower value items, we allow sourcing staff to develop methodology to quantify procurement savings and more importantly, identify categories based on complicated orders, higher costs, and other anomalies from the usual, more standardized purchase orders. The organization of the new system should be tiered into two possible systems- one that focuses on transactional buying for less expensive equipment (an extension of current Berkeley "BearBuy program," a university procurement website for purchases not exceed $4999.00) and another system that would account for a heavier investment in technology which requires higher end systems support (eg. PeopleSoft or SciQuest). Because the more expensive equipment is usually larger and consumes more energy, the energy office could add an additional layer of screening and propose alternatives, either by suggesting more efficient equivalents (backed by the Efficiency fund) or recommending using underutilized equipment within the university. By differentiating the two tiers and increasing departmental visibility, the university will be able to evaluate the efficiency of their P2P (Purchase-to-pay) process much more easily thus providing consistent comprehensive insights into the cash flow and financial commitments for each department. Therefore, financial officers can better manage the research related grant funding for each department. As such, energy efficient savings in equipment can be measured and rewarded to the department.

V. Managed Online Laboratory Equipment Catalogue

With a centralized system, universities can implement a research equipment catalogue service, something currently required by the UK Research Council for all British Universities. Through the standardized procurement system (all of which large equipment will be purchased), creating a web-based catalogue will support research grant applications, help maximize equipment usage and promote collaboration within the University and beyond. As shown through University College of London (UCL) Department for Finance's results after implementing this system, "UCL has incorporated the equipment catalogue into the grant application process. Researchers submitting funding bids must now verify that existing assets were unavailable. In satisfying [the] Research Council requirements, this helps ensure UCL attract research funding." Additionally, the catalogue will serve as a surrogate for the central insurance register thus cutting administrative costs by reducing the need for departments to submit annual spreadsheet returns. This prevents the unnecessary double purchasing of items as well as controlling the availability and visibility restrictions for each items. Hindrances to normal teaching schedules and research projects are prevented and the process by which users request the use of equipment is greatly

expedited and accelerated. By enabling public visibility for a host of items, the University provides a potential to generate money for the laboratories and enhance possibilities for collaborative research and development, ensuring each laboratory item works to its utmost efficient and effective potential. This system is easily adaptable and customizable via current open source licenses like Kit Catalogue.

VI. Campus Server Farms Management Observations and Potential Opportunities

Server farms on campus are highly decentralized with over 900 servers located in 50 + buildings. As shown in the diagram of Appendix A.3, 35% of servers outside a central data center lack proper HVAC ventilation. The 95% of servers outside the central data center that do possess HVAC consumes excessive energy due to the sub-optimal distributed system. On a broader scale, as the National Resource Defense Council's (NRDC) research indicates, 30-70% of electricity use for the servers come from cooling servers running 24 hours a day. The average U.S. server operates at only a 5 to 15% utilization level while consuming 60-90% of its maximum system power, according to an EPA report to Congress in 2007. On university properties, server farms are usually dispersed and efforts should be made to consolidate such machines since servers are often underutilized (Appendix A.4).
Consequently, we recommend proven, cost-effective solutions to reduce the energy footprint of a typical research university's servers including consolidating servers into a central data center and virtualizing servers where possible. (Virtualizing is a way of dividing a physical server into multiple servers in virtual environments, often running on multiple operating systems.) Possible designs for a large, flexible space to house the server include developing a robust rack systems to provide significant expansion capability for future supercomputing needs and a raised floor to deliver efficient cooling. Consolidating servers will save electricity on many fronts-- optimizing the efficiency of cooling, power distribution, lighting and other electrical loads that are necessary to run the data center.

VII. University Partnership with External Organizations

We propose the university seek out private-public partnerships to bring in outside financial structures and projects that can align with each university's energy goals. Building upgrades are expensive, and finding funding to perform them is difficult in a time where endowments and budgets are shrinking. There are several innovative businesses that offer low-risk methods of performing building upgrades. In UC Berkeley's case, PG&E worked with the university leadership to develop the SEP (Strategic Energy Plan) in a successful example of university partnership with a local utility. Since its launch in 2009, the combined efforts of identifying and addressing potential energy efficiency retrofit projects (VFD and other upgrades) at campus buildings have resulted in an annual cost savings of over $2.5M. The projects are funded through debt financing and rebates from PG&E. Previous optimization projects with calculated project costs, annual utility cost savings, and project payback times based on two Berkeley on campus buildings (Appendix A.5). We recommend other universities partner with local utility companies and devise energy strategies such as cheaper rates per kilowatt hour saved and campus project retrofits. Other partnership options include working with private entities like SolarCity, which installs and maintains solar panel installations for no down payment also provide cheaper energy than utilities usually provide. Because funding may still be a limiting factor in many of these projects, we would propose using our position in the consortium to recommend that the scope of what F&A funds can be used for to include building energy upgrades via such partnerships, provided that they pay for themselves within the time period of the agreement.

TECHNOLOGY

I. Maintenance, Repairs, and Investments

University facilities services are often pressed for multiple repair and high-priority requests, causing them to neglect maintenance tasks. As a result, non-emergency problems are left in the background and eventually evolve into much larger and costly issues to fix. The University of California Berkeley, for instance, has suffered years of meager state funding and lacks substantial endowments

despite its acclaim as the top public research university. As a result, the university facilities are in a reactive mode-only able to respond to immediate concerns rather than address chronic non-debilitating issues.

In order to effectively mitigate costly maintenance repairs, we propose creating a Preventative Maintenance (PM) team dedicated to the upkeep of facilities, equipment, and building infrastructure. This way, the engineering team consists of two subcategories, one solely in charge of repairs, and one in maintenance. For those universities that currently lack the funds to manage a PM team, the capital cost is a worthy investment. The evidence overwhelmingly favors this subteam, according to a case study conducted by Jones Lang LaSalle, LLC. This study analyzed the economic value preventative maintenance on a telecommunications firm, and finds that the investment not only pays for itself, but also incurs greater savings further on.

In a study where 14 million square feet of facility types were evaluated, equipment quantity, size, age, and type were detailed. Two scenarios were considered, differing in the amount of money spent on preventative maintenance: industry standard and none at all. Assuming an air compressor is maintained at industry standard, the equipment will last its full lifetime and its energy performance does not degrade with time. Without PM, it will need to be replaced sooner. Considering the time value of money, if the expense of replacing an equipment can be delayed, it is more profitable to do so. Avoiding this expense will result in a greater return on investment. The net present value of PM was determined by comparing the repair, energy and replacement costs. In this analysis, the return on investment was as high as 545%. This comes mainly from the equipment's useful lifetime; energy savings also make up 7%. Even if a university may lack appropriate funds, the initial investment will actually generate a net profit.

The Preventative Maintenance Team will ensure the benefits of this investment. By focusing on PM, universities can maximize energy efficiency of equipment and building infrastructure. This will reduce overall expenditures and F&A costs. Many problems that require costly replacements could be offset if PM was enacted. The expenses, although hefty, will be incrementally paid back each year. Additionally, the cost is spread over a large time period, not requiring a large upfront cost aside from the alteration of the engineering team. The savings that are gained can then be funneled into more energy saving measures that will result in more savings.

II. HVAC System Investments Savings

Although projects that keep energy efficiency in mind are generally more costly than conventional solutions, it is important to note that this initial capital cost is necessary in order to produce returns and eventually profit. On the other hand, using inefficient equipment will result in a net cost. For instance, HVAC systems are one of the greatest energy consumers on university campuses, particularly those in research laboratories.

Current HVAC Building and Laboratory Regulations and Guidelines

In any building and specifically laboratory building, majority of energy consumption comes from the heating, ventilation, and air conditioning (HVAC) loads. Specifically in wet laboratory buildings, the energy consumption is further increased due to the specific requirements set by Uniform Building Code (UBC) H-6 Occupancy--exhaust ventilation for laboratory space has to be at least one cubic foot per minute per square foot of floor area (UBC section 1202.25, 1997). Additionally, laboratory spaces are required to only have a once-through air flow without any recirculation to meet with the regulation for employee safety and health.

Factors of HVAC Consumption

The energy usage of a building varies depending on building region location (moderate climate region vs. fluctuating climate region). In regions whereupon temperature changes drastically annually, the cost of heating and cooling the air flow consequently increases. Because the HVAC system could take an upward of 40% of energy demand of a laboratory building (Appendix B.1), we extensively researched HVAC optimization due to the high potential for saving costs.

Efficient HVAC Technologies and Subsequent Savings

Each HVAC system needs to be tailored to its building. A significant annual savings is determined by considering factors such as cooling, heating, process (air flow & water), and electrical loads that the building requires in the design of the HVAC system. Specifically, correctly sizing premium efficiency equipment, optimizing system and operations sequence run time, and control system optimizations of the HVAC system will offset the higher initial cost paid for the premium efficiency equipment. Further savings can be obtained through reduced mechanical equipment size, reduced cost in electricity, maintenance, water, and natural gas-- thus significantly reducing overall lifecycle costs.

The challenge for designing an energy efficient HVAC system is to also satisfy the needs of the occupants and facility by requiring the design team to know and forecast the energy consumption baseline in order to meet the facility's basic requirement. Thus, designers not only need to apply the appropriate accounting and analysis method to predict future usage but also understand how their energy efficient designs can improve building performance. In this proposal, we are suggesting several improvements that should be implemented in energy efficient building: variable-frequency-drives (VFD) for fans and pumps, chilled beams for air conditioning, heat recovery system, variable-air-volume (VAV) exhaust, and energy control and monitoring center (ECMC) amongst other things.

Variable Frequency Drives (VFD)

We propose the use of VFD over inlet vanes for all major fans in laboratory building. Adoption of VFD allows fans to operate at lower or higher speeds depending on the individual building needs, resulting in reduction in energy consumption when maximum airflow is not needed. This would potentially reduce the energy usage around 50%-60% compared to inlet vanes, which only lowers available airflow instead of slowing down fans. Additionally, the use of VFD can also be implemented to water pump system in the building. This will allow the facility to pump only what is required to meet the system needs. By changing the airflow and water supply from constant supply to variable-volume and demand based, energy reduction can be maximized.

Chilled Beams Retrofit

The second energy saving technology is by installing chilled beams to support traditional air conditioning system. Chilled beams utilize the fact that water has a significantly higher heat capacity compared to air. A unit volume of water could carry up to 445 times more energy compared to a unit volume of air. Thus, a retrofitted chilled beams system employs fins to enhance the heat transfer rate and utilizes natural convection as method of cooling air and forced convection by driving fans as method of heating air. This system has been proven to be energy efficient based on previous successful Australia and Europe building case studies. However, this rate is highly dependent on the type and structure of building it is implemented in.

Heat Pipe Energy Recovery System

Exhaust ventilation for laboratory spaces has to be at least one cubic foot per minute per square foot of floor area. When combined with the requirement to have a "once-through air," laboratory spaces utilize significant amounts of energy in exhausting an energy expensive conditioned air. Therefore, the single and (probably most important) savings that a laboratory building can recover from energy savings is derived from exhaust air flow. The importance of this recovery should be stressed even more in large laboratory spaces due to the large amount energy required to filter, heat or cool the air. An energy recovery system should be used to recover much of the energy left in the exhausted air and transferred it to incoming supply air. Heat pipe heat exchanger is the method of energy recovery that has an average effectiveness range of heat transfer an upward of 50% (American Society of heating, refrigerating, and Air Conditioning Engineers, Inc., 2000 ASHRAE Handbook – HVAC System & Equipment, 44.16). Technical explanation on system can be seen on Appendix B.2.

VAV-Type Fume Hoods with Partial Bypass

The VAV-type fume hoods with partial bypass is designed to provide a set airflow velocity at any sash position. The partial bypass feature allows air to enter from both the hood under the airfoil bottom sill and through an opening above the sash. The airflow, while minimized under a closed sash position, will continue to capture fumes even when the sash is closed. These fume hoods are also equipped with a user interface panel (that indicates the airflow velocity per minute), a motion sensor, and automatic closing mechanism. The motion sensor detects when a fume hood is not being used and sends a signal for the sash to close automatically. Thus reducing the energy consumption since an open sash will exhaust more conditioned air than a closed sash. Furthermore, this feature increases the general safety of the fume hoods. The operation of these fume hoods will be monitored through ECMC and be used to calculate the total exhaust flow that is required by a laboratory and adjust the make up and exhaust flow accordingly.

Central ECMC

A centralized ECMC provides a central computing and control station that connects all data gathered from the exhaust fans, fume hoods, water systems, pump, heat exchangers, room temperature, make up air units, and air handling units. The ECMC presents the entire building energy consumption (and other related data) through user graphic interface and enables manual and automatic control over all units in the building. Equipped with alarms, ECMC will send maintenance reminders to ease the monitoring of the building's equipment and system. Also responsible for the monitoring and managing of air flow throughout the building systems, ECMC will confirm building and occupancy requirements. Furthermore, ECMC will ensure that fume hoods will always maintain a negative pressure at all times relative to the laboratory space. The laboratory space will always maintain a negative pressure relative to the office spaces, while office and common spaces will maintain a positive pressure relative to the outside pressure in order to keep dirt and dust from flowing in. These entire variables is controlled by the ECMC and maintained to minimize the energy consumption as low as possible.

Cost-Benefit Analysis

Installation or an upgrade to the technology mentioned above will undoubtedly increase the initial cost of the project. However, these costs will be repaid in long term savings and reduction in the payback time. On a simulation based on a 150,000 ft^2 laboratory building, installment of VFD will increase the initial cost by around $100,000. However, it is able to save around 1,000,000 kWh/year. From these energy savings, VFD that has an expected life of 10 years will be paid back in 2 years. Another simulation done through ASPEN on the installment of heat pipe heat exchangers showed that while there is an increase in initial cost by around $350,000, the system is able to save around 3,000,000 kWh/yr from electricity and natural gas. From these energy savings, heat pipe heat exchangers that has an expected life of 25 years will be paid back in 10 years.

III. Lighting Investments

There are other small changes that add up to large savings that do not have to be costly. By simply scheduling the usage to more closely match building occupancy, as did the Haas School of Business at UC Berkeley, the result was more than $2,000 in savings per year. This is especially attractive for liberal arts schools. For large research universities, these changes may not be easily implemented in laboratory buildings due to higher demands from experimental sensitivity. However, the university can still utilize these changes on other areas on campus, especially classroom-style buildings.

Another area of exploration are retrofits to the lighting system. Lighting changes are one of the cheaper energy-saving alterations and have relatively short payback periods. By retrofitting 1000 outdoor post lamps with LED lights, the University of California, Berkeley, the campus saved 774,600 kWh per year, a 81% reduction in original power consumption. It is worth noting that LEDs require little to no maintenance cost, whereas metal halides and incandescent require maintenance and replacement over a 10-year period, or 50,000 hours, the rated lifetime of an LED bulb. For the university, which pays $0.11 per kWh, this results in over $80,000 in savings per year. For other colleges and universities that incur a

higher cost of electricity, the monetary savings are even greater. Occupancy sensors can also be utilized in tandem with lighting retrofits to avoid unnecessary use of energy. A special low-cost Image Processing Occupancy sensor has proven to save an average of 18% of a building's energy use when used to control lighting and airflow.

All of these retrofits collectively add up to substantial energy savings. Noting the relatively short payback period in the life cycle cost (LCC) analysis for many energy-efficient technologies, the university should utilize these savings from retrofits that result after the payback period to invest in more energy-saving implementations. Doing so will ensure that the university is continuously paying itself back and is not spending excess money to initiate such changes. This positive feedback mechanism is sustainable and results in both financial benefits and improved campus climate.

GRANTS

I. Reconfiguring the Grant Process

We will be using UC Berkeley as a representative large, heavily research oriented school. Every year it receives 700 million grant dollars (50% of that is federal, 30% are nonprofit, and the rest is from industry). The Department of Health and the NSF each contributes to 1/3 of the total federal funding.

In this case, federal funding is the most important player not only because of its sheer volume, but also because there is a possible impetus for federal money to support environmentally sustainable measures. This Executive Order 13514 encourages all federal agencies to "reduce greenhouse emissions through all direct and indirect activities". The research performed with federal grants would most certainly fall under this category. Although there are clauses stipulating that grant giving cannot be ruled by environmental concerns, agencies can give post-awards for energy efficiency results.

Currently, there are recommendation flaws in having federal grant-making organizations suggest preferences for environmental efficiency in their requirements. Federal agencies have little means to guarantee compliance or enforce regulations and at the university level, administrators are wary of measures that may jeopardize funding for research. Thus, attaching environmental conditions to research grants' clauses with punishments would affect research quality if researchers are fraught with the thought of losing funding for bad energy compliance.

The university is in the position to enforce its sustainability standards that if so desired, could be partially written or suggested by the grant-making agencies. Framed as a research supportive university environment, the emphasis here should provide an incentive for researchers to change. The appropriate time to involve the grant making agencies in the very beginning of the process, when the money allocation is being decided. It is then that the university or the grant writer can request an differential sum of money to buy efficient equipment vs the normal variety and help the federal agency satisfy Executive Order 13514. The university would be held accountable for ensuring the money is spent as intended.

II. Facilities and Administrative Rates (F&A)

The F&A rate covers the general running of the building that is hard to tie into the actual costs of the research. This is fully under the control of the university and not the research group. If the laboratory containing buildings lower their costs of running its facilities, the F&A rate would decrease as well. This means that upgrades that the buildings make won't necessarily recoup savings- every few years the F&A rate goes down and the more efficient building will simply receive less money. Building efficiency improvements cannot be looked at from a financial standpoint. Instead, this needs to be approached from the attractability standpoint. Grant making agencies likes energy efficient buildings because it means more of their dollar is going towards research. Building upgrades that decrease the F&A rate can come from outside sources if the university is unable to provide the down-payment from private-public partnerships like SolarCity.

III. Agreements between University and Grant makers

When the grant organization awards a grant for the university, adherence to environmental standards should be encouraged but not punished. Under our proposal, the university has internal processes to encourage labs to use energy star equipment. What the university may need is some guidance as to what best methods and standards are. If each grant agency notifies the university what their laboratory energy policies are, the universities have a clear roadmap to follow.

EDUCATION

Low-cost measures that colleges and universities can implement for further energy savings by educating students, staff, and researchers about how behavior affect energy use on campus.

I. Holiday Curtailment & Checklists

During periods of campus vacations and low activity, universities can extensively shut down or curtail their services to buildings. A successful example of this action occurred in 2012 when UC Berkeley's Energy Office included significantly more buildings in this program (the first time modern research facilities voluntarily participated). The program also expanded their outreach to include a Curtailment Checklist that made it easier for the last person in a building to prepare for the break. Due to these other efforts, the campus used $110,470 less energy, almost double the savings achieved during 2011's curtailment. A scalable method, energy managers should encourage policy implementations and create curtailment checklists (Appendix C.1).

II. Behavioral Modification via Educational Campaigns

Educational campaigns can be done alongside safety campaign, especially for wet laboratory. This would be an efficient method since every researcher need to pass the safety education and certification program before they are allowed to work in the lab. By adding an energy saving component to this training program, we would undoubtedly able to reach every single researcher on campus. Additionally, educating researchers on new energy-saving equipment could alleviate some of their hesitations about performance. For instance, conventional metal halide lamps that are used for research-grade microscopes contain mercury, are unstable as a light source, have long warm-up times, and only last 2000 hours on average. LEDs, though more expensive, eliminate all of these issues.

III. Laboratory Walkthrough

A laboratory walkthrough is a necessary initial steps to understand the regular activity in laboratory. A walkthrough of the laboratory is guided by someone that works in that lab, will give us a more information about the lab activity and allows for further analysis on how savings can be done in the lab. After the initial analysis is completed, we propose further steps taken in order to promote overall campus awareness via active student involvement. A pilot program for the Energy Management Initiative, which included follow-up involvement after the walkthrough, identified and labeled equipment that would be turned off at certain times. The myPower team (spearheaded by a funded student organization) worked with the building's lab manager to place specially-designed stickers--which were a combination of labels and reminders-- on over 50 pieces of equipment including incubators, centrifuges, water baths, and shakers. Of this number, 80% reminded users to turn off the equipment, only ones identified by the lab manager, when not in use. The results were promising. Not only did this foster a collaborative environment between energy managers, energy-championing students, and lab personnel but also facilitated more lab specific recommendations such as checking gaskets and seals on freezers and regularly defrosting freezers to prevent ice from building up to more than ¼ inch thick. Building metrics reflected that energy use savings in the first two months after the equipment stickers were applied went down slightly (1000-2000 kWh per month).

IV. The Importance of Energy Education

Through the development and structuring in energy education programs, increased consumer awareness on the importance of energy efficiency becomes intrinsic into developing a suitable framework to encourage future projects on energy savings and energy awareness. Unfortunately, according to UC Berkeley's Energy Management Communications Specialist, this vision requires enormous effort and diligence to implement with little to no means of accountable effective measurement. However frustrating, it is always most important to remember that the impartation of energy conservation education is crucial towards achieving the goal of motivating the entire cross section of society to take action. In so doing, the future consumers and decision makers will be knowledgeable to play a meaningful role in energy conservation and efficiency through their better habits and behavior.

RECOMMENDATIONS FOR FEDERAL AGENCIES

I. Energy Dashboard

To accurately and systematically measure and compare data, we propose an Energy dashboard that displays simple metrics such as energy consumption per sq. foot (and time frame), energy intensity during the day, building comparisons, interactive map, etc. Furthermore, this dashboard should be an accessible tool for all schools. Consequently we propose that the Department of Energy combine tracking energy metrics dashboard s (based on universities and current web applications that have already developed a similar interactive tool) and create a standardized platform of which schools can utilize and upload their data into. Not only will this promote and accelerate energy infrastructure improvement projects (metering and reporting systems) but also reduce the costs for universities who are unable to find funding to build an intricate system (or hire external consultants) and monitor a centralized data set. From there, the Department of Energy can assist with setting reachable and achievable energy saving goals.

CONCLUSION

Increasing energy efficiency on university campus research laboratories require changes on all fronts administrative and technical. This problem does not solely exist in laboratory equipment, but also in the buildings themselves and even the regulatory environment in which the laboratories exist. With university policy, we can modify procedures to more efficiently manage and allocate finances as well as leverage the F&A grant money to reward efforts that save money. Pooling these money-making measures into investments in various technological retrofits, installment of a preventative maintenance team, and educational campaigns, further savings can be accrued. By further investing in energy saving implementations, we generate a self-sustaining cycle that pays for itself. And by increasing the scope of F&A funds to include upgrades, we open up funding sources that the university could not consider before.

APPENDIX

APPENDIX A: POLICY

A.1 Metering Monitoring Case Study Evans Hall

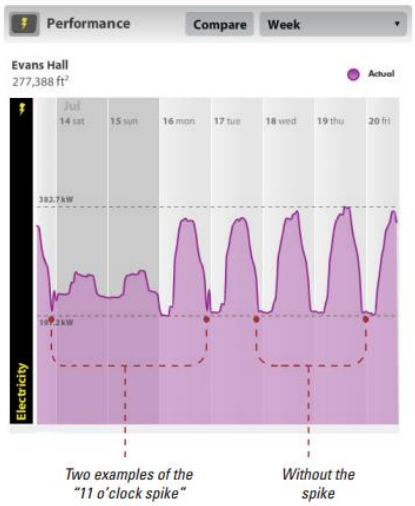


Figure 1: Evans Hall Metering Anomaly, identified by Mathematics Professor

Evans Hall (Home of the Mathematics Department)'s electricity use, posted publicly on the myPower dashboard, reported a building electricity use irregularity in the form of a consistent increase in electrical demand each weeknight. The spike at around 11:00 pm that is visible in the graph occurred most weeknights and didn't have an obvious explanation. A professor noticed the anomaly and emailed the Energy Office who invested the situation and found that one of the building's supply fans had been running on a legacy operating schedule (inherited when the Hall was used as a surge building to house occupants of adjacent buildings under renovation). Because of the public access to a well-developed online metering system, not only was the schedule for the fan has restored to its original intended runtime, without sacrificing occupant comfort but also the estimated annual savings totaled $2,000.

A.2 Incentive Varieties (Energy Incentive Program)

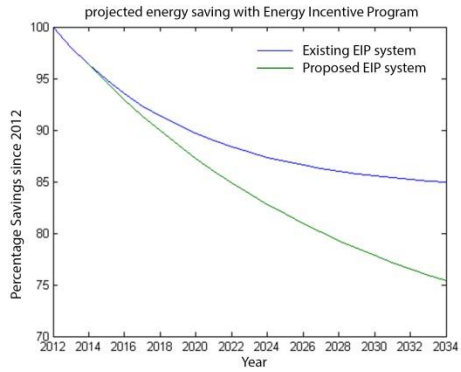


Figure 2: Projected Percentage of Energy Savings from the current and proposed EIP

The current EIP rewards the colleges directly with no stipulation that the money be reinvested into further money saving measures. That means absent of any other initiatives or factors, there is no prompted physical reinvestment in the system. Better equipment sharing and lab practices can cut laboratory use by 15% over 20 years. The proposed system has a mechanism to reinvest savings in energy star appliances and by doing so, reduce energy use by an additional 10% and assumes a 100% energy star compliance by the end of 2034.

A.3 Optimizing Infrastructure via consolidating on-campus Server Farms

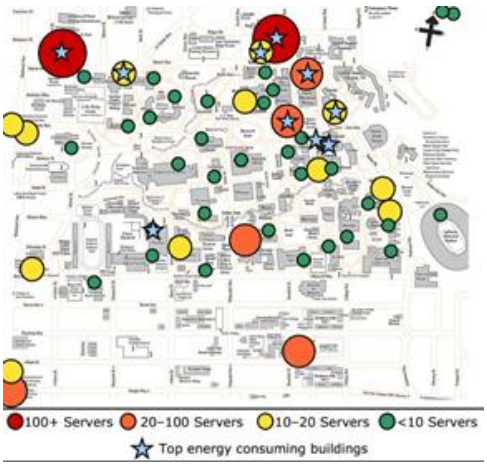


Figure 3: Server Distribution at UC Berkeley

GoldenEnergTech

As part of UC Berkeley's Operational Excellence Program Final Diagnostic Report in conjunction with Bain & Company April 2010, server management is highly decentralized on the UC Berkeley campus map. The following only include servers over $5K. 35% of units with servers that are not in the central data center do not have HVAC controlled machine rooms. Bubble size corresponds to the number of servers. "Top energy consuming buildings" are those in the top 10 energy consumption in 2008-09. Potential opportunities include consolidation into a central data center as well as virtualizing servers where possible.

A.4 Underutilized servers on UC Berkeley camp

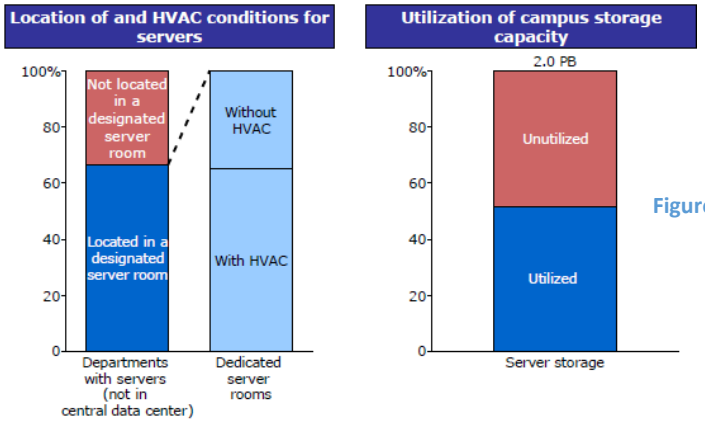


Figure 4: 2009 Report on UC Berkeley Server Space

On research-based campuses, where petabytes of storage (a unit of digital storage equal to 1M gigabytes) is prevalent, there comes a point when there may be too much storage available and actions should be taken to consolidate. The visual on the left notes that the reported storage data isn't comprehensive in the sense that total capacity is likely much higher. The number of departments reporting servers totaled 54 and the number of dedicated server rooms reported by these departments equaled 75.

A.5 Incentive-based Partnership with External Organizations

Latimer Hall HVAC Optimization (2009)

Project Cost	310,000
PG&E Rebate	146,000
Net Cost to University	164,000
Annual Utility Cost Savings	93,000
Project Payback Time	1.8 years
Annual electricity energy savings	377,000 kWh
Annual gas savings	55,000 therms

Retrofit project in Chemistry lab building: optimized heating hot water, chilled water, and cooling water systems with the addition of integrated DDC controls and variable frequency drives

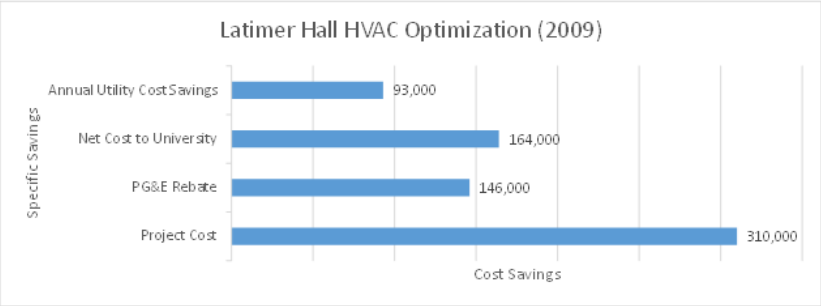


Figure 5: Latimer Hall HVAC Optimization

The climate action partnership (CALCAP), formed in 2006, is a collaboration of faculty, administration, staff, and students working to reduce greenhouse gas (GHG) emissions at UC Berkeley. The following data taken from Latimer Hall, a chemistry lab building on the Berkeley campus, was retrofitted 5 years ago with measurable considerable systems in subsequent years. Generally speaking an average of 2 years payback time is typical of similar building retrofits, however this project payback time was 1.8 years.

Wurster Hall HVAC Optimization (2009)

Project Cost	90,000	Retrofit project in architecture building: upgraded existing rooftop air supply and exhaust systems by adding avariable frequency drives and controls to optimize airflow
PG&E Rebate	50,000	
Net Cost to University	40,000	
Annual Utility Cost Savings	22,000	
Project Payback Time	1.8 years	
Annual electricity energy savings	205,000 kWh	
Annual gas savings	1,800 therms	

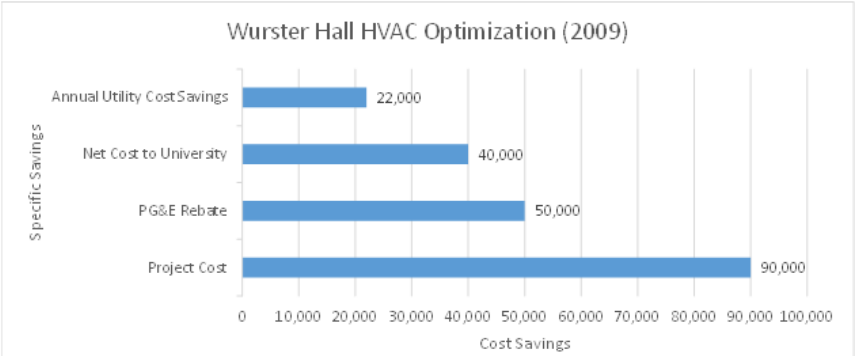


Figure 6: Wurster hall HVAC Optimization

Wurster Hall was another recent case study CALCAP documented in its efforts to reduce its greenhouse emissions by 50% of its 1/3 target in the 2009-2012 Strategic Energy plan. As you can see, the payback time for the HVAC optimization lasted 1.8 years and utility savings are substantial savings.

APPENDIX B: TECHNOLOGY

B.1 Energy Usage of Laboratories

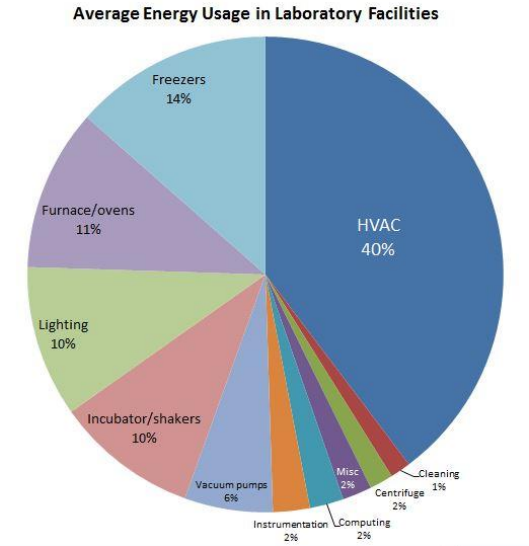


Figure 7: Distribution of Energy Consumption in Wet Laboratories

This chart shows the distributions of energy consumption in an average wet laboratories facility and provides us an insight of the prioritization of retrofit and upgrade that needs to be done. We see that HVAC consumes most of the energy supply and thus needs to be prioritized. Second priority would be an upgrade of ovens and freezers to a premium or energy star efficiency. Another priority would be lighting which takes up to 10% of the energy consumption. We believe a technological upgrade to these areas could amount to a significant energy reduction.

B.2 Heat Pipe Heat Exchangers Mechanism

The heat pipe heat exchangers transfer heat between two airstreams using a counter-flow configuration to maximize heat transfer and minimize pressure drop. The heat pipes are made out of rows of copper tubes with aluminum fins, which are partially filled with refrigerant and permanently sealed to create a close loop system. Hot air flowing over the evaporator end of the heat pipe vaporizes the refrigerant and creates a pressure drop. The vapor pressure gradient drives the pressure to condense at the condensator end of the pipe, releasing the latent heat of vaporization of the refrigerant. The condensed refrigerant then flows back to the evaporator end and the cycle continues. This process is a closed loop process and will continue to operate as long as there is enough temperature gradient difference between the two airstreams to drive the process. This mechanism allows a much faster heat transfer rate along the heat pipe, up to 1000 times faster compared to heat transfer through copper, which makes it has a high energy transfer rate.

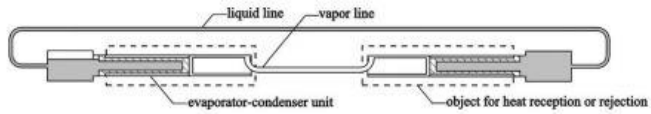


Figure 8: Closed Loop mechanism of heat pipe heat exchanger

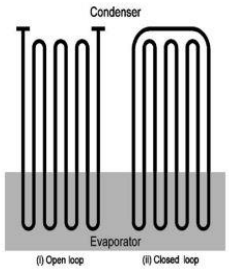


Figure 9: Difference between open and closed loop heat exchangers

APPENDIX C: EDUCATION

C.1 Holiday Curtailment Checklists

Each year between semesters and around the winter holidays, activity on campus slows down. In 2011, curtailment saved 300,000 kilowatt-hours of electricity and 3,400 therms of steam, for costs savings of about $59,000. Between December 24, 2013 and January 1, 2014 in order to conserve energy, most campus buildings will be closed and heat to those buildings will be turned off. A list of the buildings scheduled to be without heat for the curtailment period is decided beforehand and a link to a form that can be submitted to request that a building be exempt from energy curtailment which is sent directly to the Campus Energy Manager. Winter HVAC energy curtailment attachment sent out to all building managers and can also be found on the physical plant website. Additionally, emails and online news article published encourage faculty and staff to stay away from campus for the duration. Employees are asked to make these preparations:

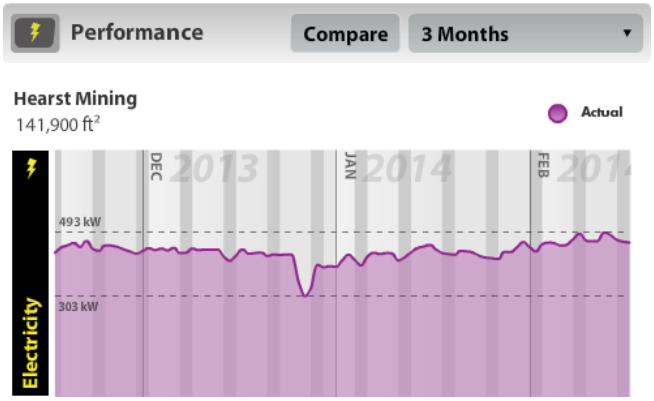
-Turn off hand-operated radiator valves in work areas.

-Turn off lights, including in public areas, since lighting can account for up to half of a building's energy use.

-Turn off all monitors, printers, copying machines, typewriters, coffee pots, and other appliances. Check with your support unit before turning off your computer.

-Make sure all windows are closed tightly.

-For those who need to be on campus during curtailment, the use of electric space heaters is strongly discouraged.



The figure shows Hearst Mining's dip in energy use during December break. Hearst Mining is home to laboratories dedicated to experiments in computation, ceramic, metals and polymers, as well as facilities to develop nano-scale and superconducting materials.

Figure 10: Hearst Mining Building Winter Curtailment Energy Savings

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