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REDUCING ENERGY USE IN LABORATORIES ON UNIVERSITY CAMPUSES

Executive Summary

Laboratories present unique opportunities in energy conservation due to their high intensity of energy consumption. However, the potential savings at many universities are largely untapped due to the complexity and sensitivity of lab environments and the lack of appropriate incentives for the major decision makers to prioritize energy efficiency. The purpose of this proposal is twofold – to advise federal grant-making agencies on how to create incentives for energy efficient research, and to outline a strategy for large research institutions to manage energy consumption within their wet and dry laboratory portfolios.

Recommendations for Federal Action

Today federal agencies spend billions of dollars subsidizing research in universities, but millions are spent on wasted energy. In order to reduce this amount, we recommend three approaches:

1. Institute **efficiency standards** for the most energy intensive lab equipment, including fume hoods and Ultra Low Temperature freezers. Equipment not meeting these standards would not be eligible for grant funding.
2. Change the F&A calculation to reduce the amount of energy expenses that are recoverable, while simultaneously providing **new funds for energy conservation**. This recommendation restores economic justification to universities for energy efficiency.
3. Mandate that a **best energy practices training** be required of all lab staff, to inform them of simple everyday changes they could make and how much energy they would save.

Laboratory Energy Management Program Recommendations

Truly prioritizing energy efficiency on a large campus requires sustained and visible commitment at all levels of the organization, as well as institution-specific plans for identifying and overcoming barriers to efficient actions among critical decision-makers.

Therefore, our three high level recommendations for energy management within universities are:

1. Publicize **university commitment** to policies for new construction and building operation that enable energy efficiency to be prioritized. These policies should address strategic means of financing energy efficiency as well as community involvement in goal-setting and implementation.
2. Leverage commitment to enable facilities teams to devote more attention and financial resources to **a laboratory energy management plan**. Financing could include revolving loan funds, performance contracting, state funding, reinvestment of savings, and more.
3. Use incentive systems and recognition programs to **capitalize on the expertise of both research staff and safety staff** in all stages of decision-making, from new laboratory design to building operations, and from equipment procurement to efficient day-to-day practices. Lab researchers learn best from their peers, so strategically engaging researchers who are passionate about sustainability can accelerate behavior change.

No single solution will work in every lab type, every climate zone, and every type of organization, but applying the principles above will enable any university to effectively address a wide range of lab-related energy challenges.

Introduction

Understanding the barriers to sustainable behaviors is the critical first step in determining strategies to reduce energy consumption in labs. We believe that there is great variation in the culture of research institutions across the country, but that certain attributes inhibiting energy efficiency are common - the primacy of research over all objectives except safety, financial accounting that does not directly charge researchers for their energy consumption, overstretched building managers who have numerous requirements beyond energy management, a culture of uneasiness with changes to the status quo, and the lack of an effective recognition system for community members who innovate for sustainability.

As a result, few researchers know what equipment is most efficient and what energy-conscious behaviors are most important. Those who have the knowledge have little incentive to change practices because of the financial structure and lack of prioritization from leadership.

On the facilities side, similar problems emerge. Facilities managers do not often recoup their savings so they cannot financially justify their energy-saving projects. They have little incentive to implement projects that change the status quo because they fear it will bring negative attention, even if the projects are objectively benign to research.

However, we believe that substantial numbers of researchers and facilities staff alike are motivated by "soft" psychological factors such as a desire to fit in and a desire to do the right thing. Much evidence exists to support the effectiveness of a Community Based Social Marketing (CBSM) approach – for instance, building managers at Harvard have become increasingly eager to implement energy conservation projects as they have seen more of their peers getting recognized for leadership in this area. Similarly, once the majority of lab members begin shutting their fume hoods, those that don't shut them subconsciously feel that they are outliers and adapt their behavior to the tacit social pressure.

Taking advantage of these inherent human desires, our proposal addresses the critical barriers outlined above. Our recommendations for federal action seek to properly align financial incentives and address the knowledge gap at universities. Our recommendations for the university seek to make energy-conscious behaviors highly visible and to create a culture that rewards creative and collaborative processes to achieve efficiency.

The Role of the Federal Government in Facilitating Efficiency

The federal government has several potential tools to influence energy efficiency within research laboratories. In addition to changing the way the F&A rate is calculated, the government can create educational material, provide information that helps labs make efficient decisions, and even use its clout to push manufacturers of critical energy-consuming equipment to meet efficiency standards. The Federal Government can also create and support forums where best practices are exchanged and can support efforts to create guidelines and standards to be adopted by institutions accepting grant monies.

Federal Recommendation 1: Implementing Equipment Efficiency Standards

The federal government should implement performance standards for **fume hoods** and Ultra Low Temperature **freezers** (ULTs), which are the most common energy intensive appliances in

many labs. Performance standards should include not just exhaust air and energy, but also reliability, functionality, and safety. The process should involve EH&S experts, facilities engineers, and PIs from a wide range of experimental fields. If specific equipment does not achieve the standards by the target date, researchers would still be able purchase it with their own funds, *but it could not be funded through a federal grant*. Standards should be lenient at first but become more stringent with time. The timeline will vary with type of equipment.

When setting these standards, we recommend that policy-makers take advantage of the wealth of energy certification expertise that the Energy Star program has accumulated over the past 20 years. An analysis of feasibility of the targets, practicality, and financial impacts on users should be conducted. Testing should determine **as-used energy consumption**, not just manufacturer specifications. In order to determine feasibility of proposed standards, it is also important to include manufacturers in the process.

In the case of ULTs, the efforts of the Energy Star study and the NIH sustainable procurement guidelines should determine the cutoff. In order to prevent monopoly power and in order to insure there are enough choices on the market, because restricting choices too much could harm research, there must be a provision insuring that multiple manufacturers qualify. This provision would need to take freezer volume into account, and allow for different standards. In the case of hoods, the standards should be based around containment effectiveness at low airflow.

Properly designed standards would give Principal Investigators (PIs) an incentive to pick efficient models *without restricting their choices.* As shown in Appendix 1, the requirement of using freezers that cut energy consumption by approximately 50% from typical levels today could save on the order of 370 million kWh over 5 years, averting 260,000 metric tons of CO2 emissions. Similarly, by making new hoods meet containment standards at 80fpm, 2.7 million metric tons of CO2 emissions could be saved (Appendix 2).

Federal Recommendation 2: Changing Energy Cost Recovery in F&A Rate Calculation

The federal government should limit its expenditures on types of consumption that it does not want to encourage (e.g. energy) and provide funding for activities that it does want to encourage. Because energy costs are recoverable F&A expenses, the university has a greatly reduced financial incentive to reduce energy consumption[1]. Therefore, we recommend that the government change the way energy costs are considered within the F&A rate.

As a prerequisite for including energy expenses in their F&A calculation, we suggest that granting agencies require all universities to draw up an energy management plan. More details on an ideal plan will be included in our recommendations for the university in the section **University Sustainability Commitments - Content**, but the role of the agency would be minimal - reviewing a short submission by each university from a template to ensure that the university had goals, timelines for internal reporting and assessment, and a funding and training strategy. It would be necessary to allow universities a few years before the policy goes into effect, since writing such plans takes time.

[1] Since most universities do not sub-meter individual labs, energy conservation in non-lab parts of the building is also dis-incentivized since energy cost recovery is often based upon a square footage allocation.

In addition, we suggest that the percentage of energy expenses recoverable through F&A be decreased over time. The money saved should be put aside for the university to fund energy conservation measures (ECMs). Figure 1a shows our suggested change: removing a certain percent of energy costs before dividing by total costs. As shown in Figure 1b, this removed cost will be set aside by the granting agency, but will not be recovered immediately in the F&A rate. These funds will be put into a pool, managed by the DOE. To recoup this money, the university would be required to submit ECM project proposals, including cost analysis and estimated payback period. We recommend that in the next F&A allocation cycle, the DOE should verify ECM implementation and actual energy savings.

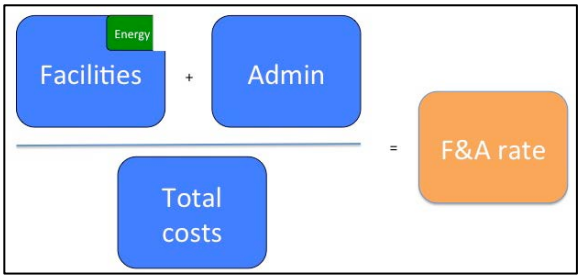

Figure 1a: F&A to be received upfront

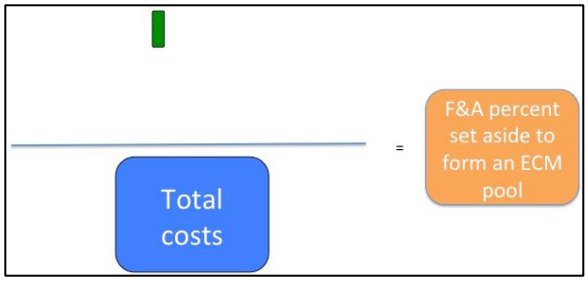

Figure 1b: ECM carve-out available on application

Further studies should be undertaken to determine the optimal percentage to allocate to this new ECM pool. It should not be so large that it hurts universities financially or so small that it cannot fund meaningful ECMs. By our analysis, devoting 2.5% of utility expenses to 3-year payback ECMs could cut annual university energy expenses by 14% in 20 years. Furthermore, with 3-year payback ECMs, the 20-year net present value of savings for the granting agency on F&A costs for a university with annual $10M utility budget is over $4.1M at a cost to the university of less than $800k (see Appendix 3). Granting agencies should share savings to ensure universities would not be adversely affected.

Further Considerations

Since F&A funds come at disparate points in time throughout the year, this pool should have an automatic rollover of one year – the funds should be available for ECMs for a year after the year in which a grant is awarded to the university. To expand the range of projects that can be funded through the new ECM pool, a university could apply for additional rollover time allowing it to pool its allowed ECM money over multiple years and implement large-scale energy projects that exceed its single year allowance. However, we anticipate that carving out 2.5% of energy expenditures for ECMs should be enough to fund the vast majority of individual ECMs.

This scheme should be implemented in a way that minimizes additional administrative burden, both at the university and in the federal government. From the university's side, additional person-hours should be minimal, since they are already reporting energy expenditures through the F&A submission process, and a system can be set up to do it automatically, such as through their CRIS software, which is already set up for similar purposes. Furthermore, the information needed to vet the projects is information that the university's energy manager would already be compiling. On the federal side, some office will need to vet projects, send approval, and then reimburse expenses that are incurred. Since all states have utility rebate programs that offer incentives, a simple way for the government to do this without getting into all the details of each

proposal would simply be to require the energy manager vouch that the project has gained approval through the local incentive programs. Moreover, the money saved by granting institutions when universities don't spend all of their ECM funds would pay for the administrative burden on the federal side.

Since these ECMs will bring down energy costs (and result in lower F&A expenses), granting agencies should establish a methodology to share these savings with the universities. In addition, a provision should be installed such that when a university can prove that there are no longer any economically viable ECMs for it to invest in, the university will again be able to recover all its energy expenses through F&A.

Federal Recommendation 3: Required Energy Conservation Training
Another simple solution would be to require that all lab users receive energy conservation training, in the same manner that the U.S. Department of Health and Human Services requires that all researchers working on human subjects (for example psychological studies) follow a training to make sure that no harm is done to the subjects. A best energy practices training is already implemented in several universities across the country (Harvard and Northeastern are examples) so the program would not have to be built from scratch.

The Role of the University

University Recommendation 1: Publicize University Commitment to Sustainability
To create a culture of sustainability within research laboratories, universities must create a context in which there is **both social pressure and proper incentives** for all stakeholders to make sustainable decisions. Universities can do this by setting public goals, by creating a culture of recognition of individuals who help the organization progress towards these goals, and by setting policies and procedures that will make energy efficient decisions the default. In cases where the university already has very tangible and aggressive goals, more effort should be devoted to publicizing the goals, providing frequent opportunities for high-level leadership to reaffirm support, and providing accountability through regular progress reports.

University Sustainability Commitments – Content
We recommend that the university produce an overarching plan (which we propose would be a prerequisite for recovery of energy costs through F&A) that includes:

- Tangible and specific goals by which the university can assess progress on key sustainability metrics such as power consumption, greenhouse gas emissions, waste, power generation, and others. These should ideally follow the principles of "SMART" goals - meaning that goals are specific, measurable, attainable, realistic, and time-based. For example, Yale University sets 3 year plans across every aspect of sustainability - from energy usage and greenhouse gas emissions to waste management and food waste (Sustainability Strategic Plan 2013-2016). The plan includes goals such as:
    - *"the reduction of energy usage by 5% below the university's 2013 baseline by June 2016"*, and
    - *"the reduction of greenhouse gas emissions from fleet vehicles by 80 tons of CO2 equivalent per year below 2013 levels by June 2016"*
- Broader sustainability principles that define a qualitative vision of sustainability. For example, Harvard University has adopted sustainability principles such as:

    - *"Promoting health, productivity, and safety of the University community through design and maintenance of the built environment"*
- Sustainable procedures in building management that define what actions will be needed to achieve energy efficiency. These can include:
    - lifecycle cost analysis for evaluating new buildings, renovations, or ECMs,
    - a campus-wide temperature policy,
    - green building standards and targets to achieve high LEED ratings in all projects
    - and other procedures as described below in **University Recommendation 2**
- Behavioral elements that define the "soft" actions needed to achieve energy efficiency gains. These can include actions as simple as shutting fume hoods and turning off lab equipment, computers and lights when possible in labs.

University Sustainability Commitments - Development Process & Approach
Plans should be developed collaboratively with representatives from all major stakeholder groups across all departments and administrative levels (including PIs, lab staff, students, safety professionals, facilities, finance, and lab directors). A bottom-up collaborative process such as this would help build university engagement and support from the beginning. Once the plan is generally agreed upon, the implementation should follow these principles:

1) Ongoing stakeholder involvement: To maintain support, stakeholders must continuously be involved in designing any initiative that involves changing the status quo. Cross-functional working groups should conduct safe, small-scale pilot projects to test (and hopefully debunk) the assumptions that underlie resistance to change. These working groups should evaluate and refine effective pilot projects for larger-scale implementation.
2) Incentive alignment: Policies should align incentives with desired, socially beneficial actions. In designing new incentives, the university should adapt to concerns and entrenched interests that key stakeholders have. For example, PIs may feel their independence threatened by additional policies. To balance against these perceived threats, the university should ideally be able to "trade" a policy for a benefit.
3) Cultural embedding: Ultimately, the university should embed sustainability into its organizational culture, by celebrating sustainability achievements, small and large.

To embed sustainability in the culture, non-financial incentives can motivate individuals to take lab energy efficiency opportunities seriously. These incentives should use the concept of "social proof" to persuade compliance with sustainability goals. By social proof, we mean that individuals respond strongly to peer affirmation and peer pressure. Ideas for creating social incentives could vary widely, and should conform to principles of CBSM. For example:

- profiling energy saving labs or energy saving "success stories" through hallway posters, web features, social media, newsletters, and magazine articles, seeking to portray sustainable actions as a behavioral norm
- offering the most energy-saving labs small prizes or parties to celebrate success

The approach outlined above will create an environment that will facilitate the development of many innovative and effective programs to handle lab renovations, equipment procurement, and day-to-day lab operations in an energy efficient manner.

University Recommendation 2: Implement Laboratory Energy Management Plans

In an environment as described above, in which granting agencies share energy savings with universities but do not allow 100% of expenses to be recovered through F&A, all universities will have financial incentives for improving energy efficiency in grant-funded environments. The combination of high-level policy directives from the top (the goals and standards outlined above) and new financial justification will enable facilities teams to properly evaluate and plan the complex projects necessary to save energy across their lab portfolios. In this context, universities should implement Lab Energy Management Plans that involve the broadest possible array of stakeholders in identifying, prioritizing, and implementing energy-saving projects, both in existing buildings and new lab design. These Plans should create implementation capacity by including adequate training opportunities for building managers and facilities personnel.

Facilities – Stakeholder Involvement in ECM Prioritization

In a portfolio of lab buildings, the number of ECMs available to be implemented can overwhelm both the implementation capacity of facilities staff and the financial resources available to fund them. Therefore, prioritization is a key component of an effective plan. A central office should be charged with constantly inventorying possible ECMs and ranking them based on savings to investment ratios (SIRs). A committee should be established that includes representation from all stakeholders to map out the barriers to specific changes to the status quo and weigh the costs and benefits. Particularly important will be the inclusion of EH&S representatives, lab members, local building managers, and the central facilities team[2].

Early involvement of EH&S and lab researchers in the planning of ECMs is the best strategy. EH&S may feel most comfortable with status quo operations because they have not had major safety issues. If they are brought in during the late stages of ECM development, they are more likely to be hesitant and may ask for further study or changes that can delay or prevent implementation. When brought in at project inception EH&S and researchers can be leading supporters of the efforts. For instance, EH&S experts have become more receptive to night temperature and ventilation setbacks in recent years, and their comfort stems from their early involvement in discussions, and their ability to bridge the gap between facilities offices and lab occupants (M. Labosky, personal communication, December 12, 2013).

By using the committee to develop projects with the highest SIR first, the university can quantify its savings and reinvest them in projects with longer paybacks and thereby maximize the overall net present value of its ECMs overall. In addition to prioritizing ECMs, the Plan should include continuous commissioning in all large lab buildings, regardless of how new they are. At MIT, the facilities team has taken advantage of relationships with recent graduates of its academic programs, who have developed low cost and time-efficient ways of implementing continuous commissioning in sophisticated buildings. Their solution allows facilities managers to focus on

[2] However, primary *implementation* responsibility should reside with the central utility team due to economies of scale and economies of expertise (P. Cooper, personal communication, February 4, 2014). For example, if the university wants to retro-commission or energy audit a large number of facilities, it can get lower pricing based on volume of projects, which is the way that ASHRAE Level II audits were performed at Harvard in the time period of 2008-2010. Furthermore, one central entity can better manage prioritization in the face of limited time and resources.

the major opportunities[3]. At Harvard, reprograming of the LISE clean room in 2009 was facilitated by sharing building automation data between the primary air system and the recirculation air, as well as the re-evaluation of static pressure resets. The team reduced energy cost 46%, saving $485,000/year (J. Hehlo, personal communication, February 3, 2014).

ECMs, audits, and commissioning all involve upfront costs and have been underutilized at many institutions. The ECM pool created by granting institutions will reduce this barrier, but the university may wish to have a strategy to devote more financial resources. Numerous financial strategies have been applied in the institutions we interviewed, and each has its own set of benefits - a revolving loan fund, a dedicated fund created out of utility savings from periods of low energy prices and/or consumption, ESCO financing, aggressive partnerships with progressive local utilities, and more. The specific strategy matters less than the commitment of the university to maintain adequate funding, even in difficult financial years[4].

Facilities – Researcher Involvement in New Lab Design

Too often, lab spaces are designed without involvement from adequately informed researchers. The lab design process can span months to years, and faculty members have many other priorities commanding their attention during this time. Researchers rarely come to understand the energy implications of small changes to lab design. Harvard University, through the initiative of its EH&S, its Green Building Services group and its Green Labs Program, increased the involvement of lab researchers in the renovation and fit-out of their labs in the following ways.

- Including PIs and EH&S in charrettes and project meetings from earliest project design
- Educating PIs about university emissions reductions goals
- Hosting lab sustainability orientations when the space was ready for occupancy to:
    - Educate all lab members about their HVAC, lighting, and hood systems,
    - Inform them of ways to procure energy efficient equipment and implement green lab practices identified by their peer researchers around the university, and
    - Ensure that they all knew how to get in touch with facilities promptly when something did not seem right about HVAC or energy consuming equipment.

In this way, numerous LEED projects implemented night-time ventilation and temperature setbacks with full EH&S endorsement. Occupancy sensors were used not only for lighting, but also for reducing supply and exhaust air; occupants were made aware of the status of the lab's HVAC system through simple displays. Occupants are educated about the reasons for lower space temperatures in the summer[5].

In summary, if the Plan fails to include proper prioritization and adequate stakeholder communication, opportunities will be lost as ECMs are implemented in a piecemeal manner.

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[3] Through the continuous commissioning process, MIT estimates that it has saved over $800,000 per year in *just four lab buildings*, and significant additional opportunities remain in those buildings. As an unexpected benefit, they were able to repair collapsed ductwork under warranty in one biological lab (P. Cooper and L. Glicksman, personal communication, February 4, 2014).

4 The budget pressure related to the 2008 recession helped heighten Harvard University's awareness to low cost and no cost efficiency measures and resulted in significant energy savings across the lab portfolio. Many of these savings were maintained as the lack of complaints related to many of these setbacks allowed the building managers to adopt a new status quo (J. Connors, personal communication, August 2010).

[5] Prior to education, researchers more commonly complained about low summer temperature setpoints because they believed it was wasting energy, when in fact the university was saving reheat energy.

University Recommendation 3: Create Peer-Learning Opportunities for Researchers

Identifying Energy Efficient Practices through a Researcher Outreach Program

Strategies for achieving efficiency in university lab environments must be tailored to the type of research that is dominant at that university. Without listening to researchers, it can be nearly impossible to identify the *appropriate and feasible* energy efficient practices to encourage at a specific university. Many universities have not yet invested heavily enough in listening to their researchers because they have an overstretched sustainability office (or do not have one at all), and it is not clear which other offices should be responsible for gathering researcher input. However, this barrier can be surmounted if top leadership in EH&S or in facilities realizes the additional value that can be obtained through increased two-way communication with researchers. Allocating a small amount of an EH&S representative's time to interfacing with researchers and holistically brainstorming sustainability and safety improvements can help EH&S staff understand researcher psychology, which benefits the EH&S department's mission. At Harvard, the sustainability office and the EH&S office collaborate closely, each seeing the other as additional eyes on the ground and each taking the opportunity to reinforce the other's mission. For instance, Harvard's Radiation Protection group had technicians flag sustainability improvements in addition to safety improvements during their walkthroughs.

For those universities willing to commit some staff time to listening to their researchers, a good way to start is to implement a lab sustainability representative program. UC Santa Barbara's LabRATS pioneered this technique, hiring part time student employees to interview researchers and perform sustainability assessments on their labs. A crucial factor in the success of this program and others like it is the hiring of students who are already working within labs at that institution, and the focus on gaining ideas from the researchers and helping them *choose their own goals*. Taking advantage of the networks within the research community, universities can gain credibility for sustainability initiatives by highlighting their origin among researchers, and can have a low cost way of motivating behavior change. Lab members, who are primarily hungry graduate students, can be motivated to change their practices by a potential pizza and beer party. These recognition events build momentum, as researchers who are pleased about their sustainability accomplishments brainstorm new ideas.

For illustrative purposes, below we enumerate practices that can be implemented based on lab researcher input in a university more focused on chemical and biological research, which tend to result in the highest energy consumption per square foot. The most significant energy consumers in these fields are fume hoods and ultra-low temperature freezers.

Fume Hoods

Reducing air volume through a fume hood dramatically reduces energy consumption from exhaust and supply fans and the heating and cooling of make-up air, even in the most temperate climates. Sometimes researchers can identify hoods that are not currently needed; programs can be implemented to decommission them temporarily, with the option of turning them back on later (P. Greenley, personal communication, February 11, 2014). Pending containment tests, many EH&S professionals are now comfortable with face velocities of 80fpm as opposed to traditional face velocities in excess of 100fpm. Additionally, closing a variable air volume (VAV) fume hood can reduce airflow through the hood by over 80% (assuming 200CFM min and 1200CFM max).

As a result, keeping VAV hoods closed when not in use is one of the most important lab energy conservation behaviors. Two major options exist for reducing VAV hood energy consumption:

1. Automatic **sash closing devices**
2. An **education program** coupled with incentives for labs that keep their fume hoods closed when possible, such as Harvard's Shut the Sash competition.

Depending on researcher attitude, one of these options should be chosen. Automatic sash closers have long been faced with skepticism from researchers and come with a non-trivial upfront cost, but recent advances in technology including better sensors to prevent sashes from knocking over sensitive equipment, multiple modes that can prevent unintentional sash opening, and hands-free operation can alleviate much of this skepticism. The benefit of automatic sash closers is that if properly maintained, they represent a permanent solution and do not depend on researcher habits.

However, a significant benefit of choosing an education program with small incentives is that it can serve to create an ongoing communication channel between research staff and the entity administering the fume hood education program. Additionally, researchers who move between institutions can educate their new peers and spread the practice. Conversations between lab researchers and sustainability staff at recognition events for Shut the Sash competitions at Harvard let to the implementation of several new sustainability initiatives developed by the researchers themselves, such as the installation of plug timers on many types of formerly 24/7 energy consuming devices such as drying ovens, hot plates, and more.

Despite the well-known energy benefits of initiatives to reduce airflow through fume hoods, not enough universities are implementing programs to keep unattended hoods closed, which also has important safety benefits. The creation of a fume hood competition requires only a small amount of an administrator's time, building automation controls that are relatively ubiquitous, and support from PIs and graduate student leaders like lab safety officers. For an estimate of the cost of running a fume hood competition, see Appendix 4. Lab members can assist with program design to ensure that it is well targeted to researchers' attitudes.

Freezers

ULTs are some of the most energy intensive lab appliances. At any large institution, there may be hundreds of ULTs, each using 15-25 kWh/day. Typically set to -80˚C, these appliances are the life-line of biological researchers – if a freezer malfunctions and samples thaw, decades of work can be lost. Therefore, ULTs are a sensitive and challenging opportunity for institutions to cut energy consumption, and should be a critical focus in any Lab Energy Management Plan.

At Harvard, researchers have been intimately involved in the university's efforts to come up with strategies to manage the energy consumption of its cold storage needs. Researchers have pilot-tested room temperature storage technologies that enable RNA, DNA, and blood to be stored in dry form without freezers. They have also consulted on the best ways to get researchers to perform preventative maintenance on their equipment, and they have volunteered their freezers for energy performance measurement. As a result the University is implementing a new Freezer Management Program that involves Preventative Maintenance (PM), incentives for replacing worst-performing units with high efficiency models, and education for freezer users.

Freezers present an excellent opportunity for lab users to learn from each other. If a spokesperson who is herself a researcher at the same university met with a lab to share ideas related to freezer maintenance, the following best practices could be explored:

- Using the freezer at a less cold setpoint, reducing load on the appliance, cutting energy costs, and extending equipment life. Some types of research may require the default setpoint of -80˚C, but many other types could use setpoints of -70 or -60˚C.
- Using a barcode system or inventory system to reduce sample search time with freezer doors open. Some labs have even created freezer maps to post on the door of the freezer. Reducing search time saves energy, lets less cold air escape the freezer, and guarantees more stable temperatures for the valuable samples inside the freezer.
- Regularly cleaning out outdated samples from previous researchers saves space and makes currently used samples easier to locate.
- Enrolling in a freezer PM program to ensure that filters and coils are cleaned frequently.

Researchers at UC Davis and CU Boulder recommended these actions to sustainability professionals at their schools. These professionals then started the Store Smart Lab Freezer Competition in 2011, through which many labs took these actions and even decommissioned several old freezers (“CU-Boulder Labs Wins”, “StoreSmart Lab Freezer”).

Without researchers as the spokespeople for these strategies, the university administration stands almost no chance of convincing labs to adopt any of these practices on a widespread basis, even though several of these practices have the potential to improve the research experience in addition to saving energy. Yet, researchers who have piloted the technique can vouch for the benefits - less wear and tear on compressors (from running at a higher setpoint), more advance warning if a freezer is about to fail (from refrigeration monitoring that could be implemented with a freezer PM program), and more stable freezer temperatures (from freezer inventories and maps that can reduce sample search time with the door open).

The energy savings possible from involving researchers in the search for waste have been clearly demonstrated by fume hood competitions and freezer management strategies on many campuses. Though not discussed in this short report, many other opportunities exist. Simply by listening to the right knowledgeable people in the researcher community, universities can develop pilot projects, leading to innovative, researcher-backed sustainability initiatives.

Concluding Remarks

As with any recommendations, significant customization will be required to maximize sustainability benefits across a diverse range of research types, climate zones, and institutional cultures. Our recommendations for federal action create an environment that will provide individual universities adequate incentives to further develop their energy management priorities within research labs. For campuses, we believe it is critical to engage research staff and safety staff early and often in order to gain from their ideas, their understanding of the barriers, and their desire to make their research organization the best it can be. A campus with visible and aggressive efficiency commitments, high quality energy management plans and policies, and clever mechanisms of engagement will achieve a culture where sustainable actions are a behavioral norm for researchers and staff alike, and where efficiency projects are continuously and prudently implemented without adversely affecting research.

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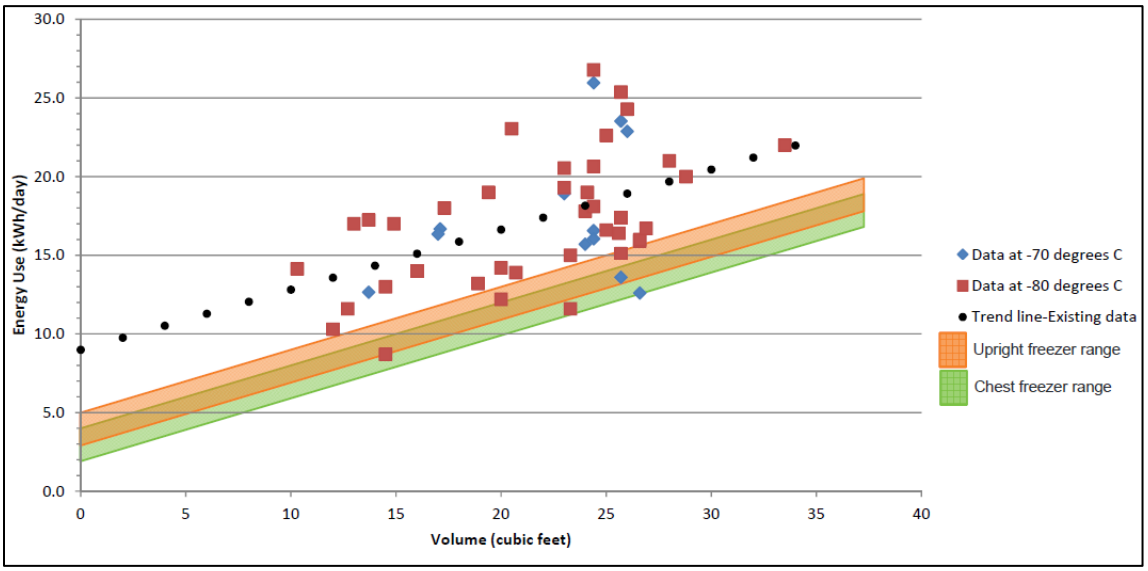
Appendix 1: Freezer Standards

Test data sourced from the Labs 21 wiki for 27.5 ft^3 ULT freezers shows that they perform within the range of 15-25 kWh/day when set to -80C. The DOE has modeled the consumption of freezers of that volume as approximately 20 kWh/day (Figure 1). Current technology exists that can reduce the consumption of a 27.5 ft^3 freezer to about 11 kWh/day (from Stirling Ultracold, independently tested at UC Davis).

We do not recommend a specific value for the efficiency standard for each size class, since we would defer to the testing currently being done for the Energy Star process. However, we attempt to show the potential impacts of making only those 27.5 ft^3 units that reach 11 kWh/day eligible for purchase under federal grants, since we know this is already technologically achievable.

Figure 1: DOE EERE draft specifications based on actual freezer energy consumption data.



Payback Analysis

According to Stirling Ultracold, its most efficient 27.5 ft^3 freezers are priced around $13,500, which we compare to about $11,000 for a competitor freezer of that size. This represents the maximum price differential one would expect if an efficiency standard required manufacturers to reach 11 kWh/day. Given that direct electricity savings for each freezer would be in the range of $330 to $530 per year and that HVAC savings could double that value, we calculate a simple payback period of 2.4 to 3.8 years from purchasing these units. With increased competition, we expect that in a few years, the cost premium and the resulting payback period would be even smaller.

Potential Savings

According to a DOE study, 10,000 ULTs are purchased every year. By only allowing ULTs that meet the efficiency standard to be eligible expenses on federal grants, the granting agency could expect a very high percentage of future purchases would meet the standard. If 90% of the ULTs purchased over 5 years met the 11 kWh/day standard, the direct electricity savings over 5 years could amount to 370 million kWh, excluding lab HVAC savings. Calculations are provided below.

Single 27.5 cu.ft. freezer:

	kWh/Day			Savings/year		
Energy cost	As efficient as today's efficiency leader (Stirling)	Typical cascade freezers	Savings	Energy (kWh)	$	CO2 (metric tons)
$0.10	11.0	20.0	9.0	3,285	$329	2.3
$0.12	11.0	20.0	9.0	3,285	$394	2.3
$0.14	11.0	20.0	9.0	3,285	$460	2.3
$0.16	11.0	20.0	9.0	3,285	$526	2.3

Nationwide:

Assume 10,000 freezers purchased per year (DOE study). Assume 90% of new freezers meet the new standard:

	New savings each year			5-year total savings		
Energy cost	Energy (kWh)	$	CO2 (metric tons)	Energy (kWh)	$	CO2 (metric tons)
$0.10	29,565,000	2,956,500	20,860	369,562,500	$36,956,250	260,745
$0.12	29,565,000	3,547,800	20,860	369,562,500	$44,347,500	260,745
$0.14	29,565,000	4,139,100	20,860	369,562,500	$51,738,750	260,745
$0.16	29,565,000	4,730,400	20,860	369,562,500	$59,130,000	260,745

Note on all savings calculations: Calculations do not include the sizeable energy savings associated with reduced HVAC load. In much of the country, the savings will be doubled by reducing the amount of space cooling required.
Note on 5-year savings: each year with the purchase of 9,000 new and energy efficient ULTs, we see additional annual savings that persist for the lifetime of the freeer. Therefore, the 5-year savings is not simply five times the annual savings.
Assumptions from EPA (http://www.epa.gov/cleanenergy/energy-resources/refs.html):
National average marginal CO2/kWh: 7.06E-04

Appendix 2: Fume Hood Standards

A fume hood standard should be set such that all hoods that qualify for grant spending must be able to pass third-party validated ASHRAE containment tests at 60 feet per minute. Many manufacturers have already been able to design hoods with streamlined airflow that reduces turbulence and pass containment tests at this face velocity, so this standard would simply reward fume hood manufacturers for using existing technology to optimize the performance of their hoods, and it would ensure that more of these hoods are used in new renovations. Even hoods that are not marketed as “low flow” may actually already meet this criteria, based on as-used testing at universities and research institutions.

Given proof of containment at 60fpm in a range of as-used tests on campus, building managers would be much more likely to run their hoods below 100fpm, perhaps at 80fpm (as some universities already do for *some* of their hoods, including Harvard and MIT). Assuming the average fume hood in the country is actually running at 100fpm now, facilities managers could save a significant percentage of their energy costs under the new standard, even if they did not opt to run them at the 60fpm standard. Feedback from EH&S officials would be critical in the setting up of any fume hoods, regardless of whether they were low flow.

From the Lawrence Berkley Labs (LBL) Fume Hood Calculator, using energy prices typical of the **northeast US** and an average sash height of 12 inches, a 5-foot hood could save about $800/year, and 3.6 metric tons of CO2, being run at 80fpm instead of 100fpm. Extrapolated across the 750,000 hoods in use in the United States (Halber, Deborah), nearly 2.7 million tons of CO2 could be saved per year, with little cost since many manufacturers already provide hoods that perform well at face velocities of 60fpm.

Location Boston, Massachusetts, United States | Boston, Massachusetts, United States

ASSUMPTIONS	Hood 1	Hood 2	
Energy Prices [1]			
Electricity	0.15	.15	$/kWh
Electricity Demand	170	170	$/kW-yr
Fuel	9	9	$/million BTU
Operation [2]	24	24	hr/day
Hood Opening (Horizontal)	62	62	inches
Hood Opening (Vertical)	12	12	inches
Face Velocity	100	80	ft/min
Fan Power (supply/exhaust) [3]	1.80	1.80	W/CFM
Cooling Plant Efficiency	1.00	1.00	kW/ton
Heating System Efficiency	70	70	percent
HVAC Supply Air Setpoints			
Heating	55	55	°F
Cooling	45	45	°F
Reheat Energy [4]			
Delivery Air Temp.	65	65	°F
Energy Type	Fuel	Fuel	

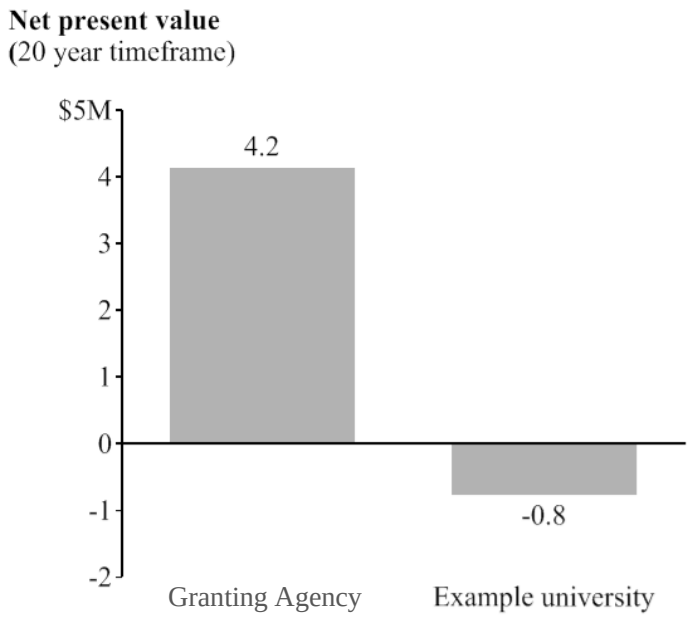
RE-CALCULATE RESET

ANALYSIS	Hood 1	Hood 2	Difference
Flow Rate	517	413	103 CFM
Cooling & Air-handling			
Chiller Energy [5]	7,146	5,716	1,429 kWh/year
Fan Energy	8,147	6,517	1,629 kWh/year
Total	15,292	12,234	3,058 kWh/year
Total Power	2.8	2.2	0.6 kW/hood
of which Fan	0.9	0.7	0.2 kW/hood
of which Chiller	1.9	1.5	0.4 kW/hood
Heating			
Supply Load [5]	47	38	9 million BTU
Reheat Load	48	39	9 million BTU
Total Load	96	77	19 million BTU
Energy (fuel)	137	110	27 million BTU
Energy (electric)	0	0	0 kWh
Average Reheat Power	0.0	0.0	0.0 kW
Total Per-Hood Costs	**4,008**	**3,206**	**802 $/year**
Cost Per CFM	7.76	7.76	-0.00 $

Using output from LBL fume hood calculator:						
Annual savings from a single hood				**Annual avings from all 750,000 hoods in the US**		
Energy		CO2 (metric tons)		Energy		CO2 (metric tons)
3058	kWh	2.2		2,293,500,000	kWh	1,618,179
270	therms	1.4		202,500,000	therms	1,074,465
Total CO2 savings:		3.6		Total CO2 savings:		2,692,644
Assumptions from EPA (http://www.epa.gov/cleanenergy/energy-resources/refs.html):						
National average marginal CO2/kWh						
7.06E-04						
CO2/therm of gas						
0.005306						

Appendix 3: Financial Analysis of F&A Rate Calculation Change

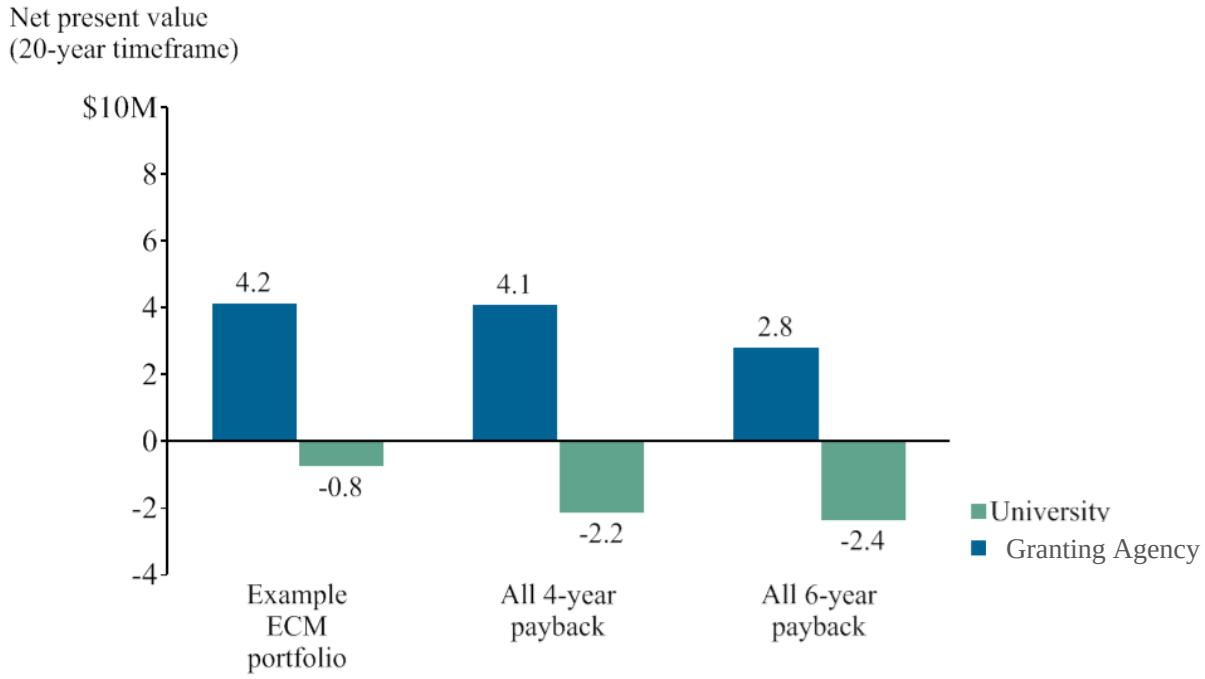
ECM funding pool is financially viable



ASSUMPTIONS

- *University*:
  - $10M annual lab energy spend
  - Constant level of grant spending
  - No baseline growth in energy usage
  - 5-year F&A recalculation cycle
  - Discount rate of 7%
- *ECMs*:
  - Based on actual ECM list for an example research university
  - Excludes projects with paybacks >5 years, and projects with negligible upfront costs (i.e. control changes or setbacks)
- *Overall timing*:
  - 1st year: No activity as initial funds are accrued
  - 2nd year: ECM reimbursement begins
  - 3rd+ year: Savings begin to be realized, ECM reimbursements continue

Even with a less attractive ECM portfolio, ECM funding pool unlocks significant value



Note: Net present value calculations use conservative assumption that ECMs take one year to implement before savings are realized. In reality, ECM savings can often be realized more quickly, improving the financial viability of the ECM funding pool.

Appendix 4: Benefits and Costs of Fume Hood Competitions

If little outreach has been done to fume hood users, it is likely that there are significant opportunities to save energy through a little education. At Harvard's Shut the Sash competition, a competition among roughly 20 labs with nearly 200 hoods achieved annual savings of $180,000 per year, and 300 metric tons of CO2 emissions, by achieving an average reduction in airflow of 30%. These savings are **roughly 20 times the expected annual cost** of administering a similar program (estimates are from personal experience). Even though costs may vary significantly depending on building automation system provider or other variables, the payback on implementing such a program will be extremely fast.

Costs to develop a fume hood competition:

Assumptions

Twenty labs with a total of 200 VAV hoods are enrolled in a competition.
Building automation system already tracks the airflow through VAV hoods.
Optional enhancements could add a few thousand dollars, including real time monitors summing airflow of all hoods in each lab.

Scenario 1: Competition done by employee of the university, paid $50,000/year with 40% fringe

Item	One-time costs	One-time time (hrs)	Monthly Cost	Monthly Time (hrs)	Annualized Cost
Setting up automatic reports from BAS for analysis by staff	$1,000				$1,000
Analyzing data (baselines and performance), setting monthly goals				4	$1,714
Distributing reminder prompts like fume hood magnets or stickers	$200	10			$557
Reaching out to labs to inform them of their goals and progress				2	$857
Hiring a computer science student to create an online tool to track real-time performance outside of the BAS	$200				$200
Hosting parties for the winning labs				6	$2,571
Posting feedback on results twice per month				1	$429
Pizza and beer for a 20 member lab			$120		$1,440
Competition-wide celebrations twice per year			$42		$500
Totals	$1,400	10	$162	13	**$9,269**

Scenario 2: Competition done by student employee of the university, paid $12/hour

Item	One-time costs	One-time time (hrs)	Monthly Cost	Monthly Time (hrs)	Annualized Cost
Setting up automatic reports from BAS for analysis by staff	$1,000				$1,000
Analyzing data (baselines and performance), setting monthly goals				4	$576
Distributing reminder prompts like fume hood magnets or stickers	$200	10			$320
Reaching out to labs to inform them of their goals and progress				2	$288
Hiring a computer science student to create an online tool to track real-time performance outside of the BAS	$200				$200
Hosting parties for the winning labs				6	$864
Posting feedback on results twice per month				1	$144
Pizza and beer for a 20 member lab			$120		$1,440
Competition-wide celebrations twice per year			$42		$500
Totals	$1,400	10	$162	13	**$5,332**