GREEN LAB ACTION PLAN 2019

UC SANTA BARBARA
Sustainability

EXECUTIVE SUMMARY

The University of California has committed to carbon neutrality in scope one (direct emissions from owned or controlled sources) and two emissions (indirect emissions related to the generation of purchased energy) by 2025, zero waste by 2020[1], and a water reduction of 20% compared to each campus' baseline by 2020, and 36% by 2025.

In 2017, UC added a new goal to the UC Policy on Sustainable Practices[2], that "All locations shall complete a UC Green Laboratories Action Plan to determine strengths and areas for improvement within the operations of research laboratories in respect to sustainability and carbon neutrality." The UCSB Green Laboratories Action Plan builds on existing UCSB and UC-wide plans, policies, and standard practices including the Climate Action Plan, Water Action Plan, Waste Diversion Plan, Campus Sustainability Plan, and the UC-wide Lab Safety Design Manual. This plan creates a comprehensive vision for sustainable laboratory operations and additional implementation strategies needed to achieve the UC-wide sustainability goals. Though UC policy only requires inclusion of research laboratories, UCSB has included the operations of STEM teaching laboratories as well.

Just over 50% of campus electricity and 30% of gas is used, and 30% of waste is created in campus laboratories. If UCSB is to achieve these systemwide goals, the campus must consider ways to reduce the consumption of resources in laboratory spaces, research or the safety of our researchers.

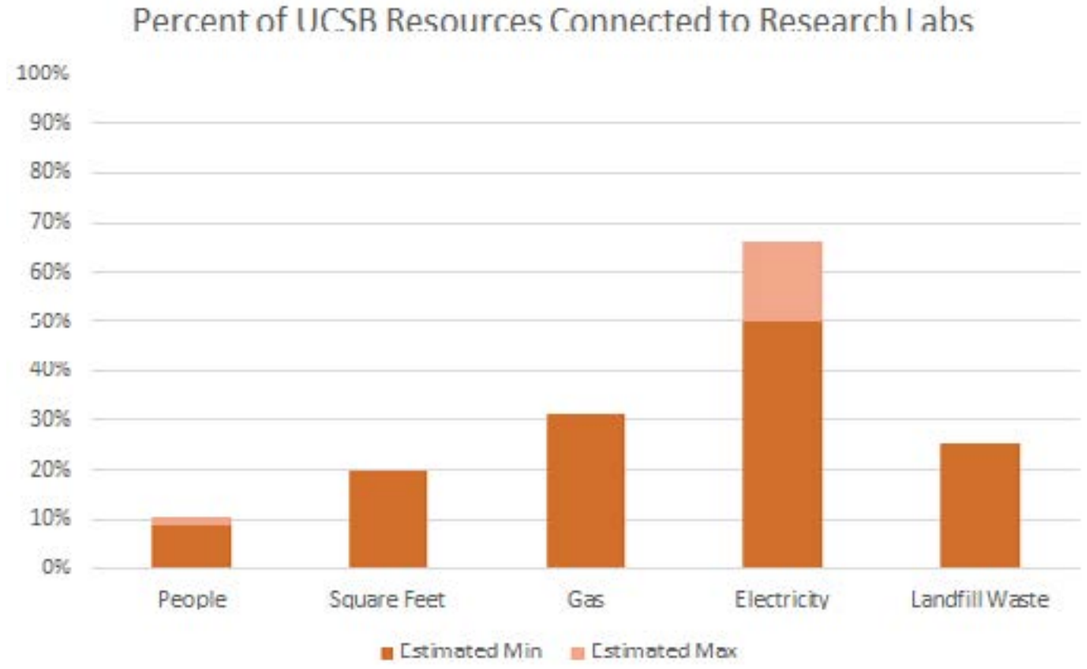
UCSB is already leading the way in sustainable operations of laboratories. 47.1% of academic departments, centers, and institutes which employ researchers include at least one person whose research relates to sustainability. With this broad base of expertise, it is no surprise that many of our researchers are already seeking ways to implement sustainable research practices. UCSB built the first LEED Platinum Laboratory building, Bren Hall, in 2002 and in 2017-2018 completed its second LEED Platinum Laboratory building, BioEngineering. 19.7% of principal investigators on campus have completed a green laboratory assessment (LabSYNC) through the UCSB LabRATS program. LabSYNC assessments identify sustainable research practices already in use and additional practices that can be implemented. Through LabSYNC, researchers can also learn about resources, expertise, and funding opportunities that can support them in implementing green lab practices. Financial savings estimates due to LabSYNC can be found on page 6. More details about LabSYNC operations can also be found on page 36.

The plan below details a brief history of UCSB's work in this area, current programs, benchmarks, best practices, areas of improvement, and implementation strategies.

Reducing environmental impacts in the laboratory environment will require employing a wide variety of strategies that match the broad diversity of research operations at UCSB. Each new strategy proposed will need to be considered in light of the research needs of individual research groups. Given this level of adaptation, it is unlikely that there is one or a small number of golden solutions to address the environmental impact of the research environment. Instead, this plan presents an integrated and multi-faceted set of solutions.

1 The university has defined zero waste as over 90% of the non-hazardous waste on campus is composting, recycled, or reused rather than landfilled. This goal does not include chemical waste or autoclave waste.

2 https://ucop.edu/sustainability/policy-areas/index.html



The graph portrays estimated fractions of users, square footage, gas, electricity, and waste associated with lab buildings and operations at UCSB. Lab users are the fraction of campus occupants (sum of undergrads, grads, and personnel) who are registered in the campus' Lab Hazard Assessment Tracking database, with the 'estimated max' including an additional estimate of personnel supporting labs and lab departments. Square footage is the fraction of total assignable square footage in the Facilities Link database designated as a Lab space. Gas and Electric numbers are per Energy Services reports for 2017-18, for the 13 largest laboratory-focused buildings on campus as a fraction of campus total use. Waste estimates are for the fraction of campus landfill-bound waste that were waste-hauler's Labs-only circuit prior to the Red-Lidded Toter Program, which eliminated this circuit.

A key concept behind the overall strategy for developing sustainable laboratory practices, is borrowed from the field of environmental education. At the Intergovernmental Conference on Environmental Education (UNESCO, 1977), the Tbilisi Declaration[3] was drafted. This declaration identified the following objectives for environmental education: (a) awareness (b) knowledge, (c) attitudes (d) skills and (e) participation. In working with researchers, these steps towards an environmentally aware and engaged community can also be helpful. UCSB has taken this one step further to add leadership, where a researcher from our community goes beyond participation through their own lab, and presents a paper, talk, or offers a toolkit to other laboratories.

The following is a list of the highest priority implementation strategies. Additional details on these strategies as well as medium priority strategies can be found in the sections below. Lower priority strategies appear in the appendix.

3 http://www.gdrc.org/uem/ee/tbilisi.html

HVAC

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	COST
Recalibration of constant air volume (CAV) fume hoods across campus		Facilities Management, Lab Ventilation Working Group	
Publication of a Chemical Fume Hood Guide	This step adds longevity to recently piloted efforts.	Lab Ventilation Working Group	Use of existing staff time
Establish a road map for maintaining optimized ventilation rates in remaining major campus lab buildings	This step adds longevity to recently piloted efforts.	Lab Ventilation Working Group	Use of existing staff time

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	COST
Identify new funding mechanisms to incentivize the purchase of more energy efficient lab equipment	Energy efficient ULT freezers can run at 50% of the kWh/day that traditional ULTs do. For fly incubators, 86% of the energy can be saved. These are a few examples of what is possible.	TGIF manages the current program; Further exploration needs to be done to find alternative funding	Scalable, please see the financial assessment section that is next in the Executive Summary.

Water

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	COST
Retrofit autoclaves where possible with water saving technology, develop a plan to address remaining autoclaves.	Potentially saving 8.5 million gal./yr. retrofitting 50% of existing autoclave	LabRATS working with Building Managers and Principal Investigators	$30,000- $75,000 Variable by autoclave models
Eliminate Single Pass Cooling in Soft Plumbed Systems	Saving 6.1 million gal./yr. for eliminating 127 units[1]	LabRATS engaging researchers	$43,891 (already allocated). Please see cost savings in the next section.

1 Single pass cooling calculation assumes 50 weeks of operation/yr.

Waste

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	COST
Develop a strategy to address plastics #3-7 and other unique laboratory plastics.	Approximately 9,168 lbs/year. This waste stream is no longer recyclable through our local hauler.	LabRATS collaborating with lab supply vendors, researchers, and campus waste management manager	TBD. This will likely be broken down into several separate projects. Changes to recycling laws went into effect in late 2018 so new feasibility assessments are needed.

Engagement

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	COST
Enable 30% of laboratory groups at UCSB to have a LabSYNC assessment.	Could reach over 525 researchers in an in-depth program.	LabRATS and researchers	$7,536 in student internship funding already allocated through existing sources and some use of existing professional staff.

Financial Assessment

There is no current central and ongoing funding allocated for reducing the environmental impacts of laboratories comprehensively. There are several departments such as Environmental Health and Safety and Facilities Management that regularly implement programs that reduce the impacts of laboratory spaces as part of their core operations. LabRATS at UCSB has also been successful in securing internal and external grants to support a variety of green laboratory efforts. In the past few years, a small sustainability fund was also built into statewide procurement contracts for some of the laboratory supply vendors. In 2018-2019, this fund allocated $4,000 in student fellowship funding at a few of the campuses including UCSB. The high priority goals within this plan are achievable with existing staff, scalable over time as resources are available, and/or fundable by securable with grant funding.

This plan represents a blending of policy, planning, education, and direct implementation efforts. Some of the goals described will set the stage for future implementation efforts, but will not have a direct and easily quantifiable resource savings. Several of the implementation strategies identified in this plan will also need further feasibility analysis and cost assessment before a financial analysis can be completed. With these caveats, the following table highlights some of the projects where a full cost benefit analysis could be calculated at this time.

IMPLEMENTATION STRATEGY	RESOURCE SAVINGS	COST SAVINGS	COST	RETURN ON INVESTMENT	% OF UCSB USE[1] [2]
HVAC efforts in PSBN, applicable to similar campus lab buildings	900k kWh (10% of building total) and 50k Therms (20% of building total) per year	$130k/yr	$548k	2 yrs. and 1 mth	3% of campus electricity use.
Equipment Rebate Program[3]	2,850 kWh/yr. - 4,430 kWh/yr.	$314- $490/yr per piece of equipment	$1,000 per incentive; True cost difference is $3,900 to $5,500	2 - 3.2 yrs with $1,000 incentive; 11 - 12.6 yrs with full cost	0.1% of campus electricity use if 222 units were replaced with a cost of $222k
Warm up 25% of -80°C ULT Freezers to -70°C	1,100 kWh per year per chilled-up ULT	$121 per unit per year in electrical, plus increased avg. instrument lifetime and decreased repair requirements	$0	Immediate	<0.1% of campus electricity use
Eliminate Single Pass Cooling in Soft Plumbed Systems	6.1 million gal./yr. for 127 units	$67,356	$43,891 (already allocated)	<8 months	2.7% of campus potable water use.
Retrofit 50% of autoclaves (approx. 15) to be more water efficient	8.5 million gallon/year for 50% of campus autoclaves	$93,857	$30,000-$75,000 Though could range by autoclave	<1 year at high end of costs	3.8% of campus potable water use.

1 Total campus potable water use in 2017-2018 was 224.5 million gallons
2 Total campus electricity use in 2017 was 89,280,270 kWh
3 Based on the TGIF Equipment Rebate Program. Using examples of two freezer replacements.

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CAMPUS AND GREEN LABS HISTORY

UCSB was founded as a campus in 1944, and has been a world-renowned research institution where six nobel laureates made great discoveries. The campus' laboratory footprint has grown substantially to keep up with the demands of our researchers in natural sciences and in engineering.

Concern for the environment is considerable within the research culture: 47.1% of research departments include at least one researcher whose focus of inquiry involves a sustainability-related topic. In assessing the operations of the research labs, that lens of sustainability has been a powerful aspect of UCSB's research environment.

UCSB's green labs efforts manifest primarily in two campus programs: LabRATS and Lab Ventilation Working Group.

GREEN LAB OPERATIONS AND GREEN LABS INTERNS: THE LABRATS PROGRAM

In the 2005-2006 academic year, UCSB hosted a workshop series geared towards the creation of the first UCSB campus-wide sustainability plan. Through these events, a cohort of Change Agents was formed. Among them were a small group of individuals interested in exploring ways to improve the environmental impacts of research and teaching laboratories. This group was referred to as the Labs, Shops, and Studios team, formed to address the unique needs of laboratories; machine, wood, and glass shops; and art studios.

The Laboratory Resources, Advocates, and Teamwork for Sustainability (LabRATS) Program was also launched in the 2005-2006 academic year, inspired in part by the sustainability plan workshop series. The original founders included Researcher, Allen Doyle; Building Manager, Jeff Kirby; Student Interns, Karly Burch and Colin Dowling; and Sustainability Coordinator, Katie Maynard. In 2008, Amorette Getty, a graduate student at the time, joined the program. Upon completion of her PhD in 2009, Dr. Getty studied energy-efficient operations of cleanroom facilities in a post-doctoral research position with UCSB's Institute for Energy Efficiency (IEE). Shortly after, she became LabRATS program Co-Advisor with Katie Maynard.

Amorette Getty and Katie Maynard continue to co-advise the LabRATS program, annually advising a cohort of paid undergraduate interns. Over 20 interns have participated in the LabRATS program to date, averaging 2-3 each year depending on funding. Additionally, LabRATS has engaged in many wide-ranging collaborations with individual campus researchers, whole laboratories, and departments. These collaborative programs, and the involved parties, are outlined thoroughly in the Best Practices section of this document.

GREEN LAB BUILDINGS AND THE LAB VENTILATION WORKING GROUP

The UCSB campus has a long history of prioritizing energy-efficient and sustainable design in its laboratory buildings. The triple-Platinum-LEED-certified Bren Hall has remained a highlight of the campus' commitment to green laboratory design since its construction in 2002. The newly opened BioEngineering building also received a LEED Platinum rating for its design.

In 2013, the IEE began the design process for Henley Hall (currently under construction), with an exploration into what innovative and cutting-edge ventilation designs would be viable in a UCSB laboratory building. Designers requested that the campus convene a group to discuss what may or may not be feasible from the interdependent perspectives of energy efficiency, building code acceptability, human safety, and long-term maintenance. A committee of stakeholders from Environmental Health and Safety, Facilities Management, the campus Fire Marshal, and Sustainability formed the Laboratory Ventilation Working Group. The committee gained a holistic understanding of the present practices on the campus and identified potential improvements to future designs and operations. In addition to providing design guidelines, the findings revealed that the existing laboratory building stock ranged widely in terms of age and HVAC technology. Thus, significant improvements could be made both in the existing buildings and in documentation and communication processes between the stakeholders designing, maintaining and occupying ventilated lab spaces.

Since its creation, the Laboratory Ventilation Working Group has continued to develop documentation, strengthen communication processes, and identify and collaborate on building renovations which improve safety and ventilation operation and optimize energy use in campus laboratory buildings.

UCSB CAMPUS STATISTICS

BASIC STATISTICS	TOTAL NUMBER	NUMBER RELATED TO WET LABS
# of Faculty	1,102	292
# of Undergraduate Students	21,574[1]	10,955 in STEM fields
# of Graduate Students	2,772	1,590 in STEM fields
Assignable Square footage (ft^2)[2]	5,248,262	959,078
# of Buildings	427	43 Buildings with Research Labs, 19 Buildings with Labs 19 Buildings with classroom Labs[3]
# of Designated Lab Spaces	N/A	313 "Labs" where a lab is defined as a set of spaces managed by one PI; 939 separate lab rooms/spaces

1 http://bap.ucsb.edu/institutional.research/campus.profiles/campus.profiles.2016.17.pdf
2 https://ucsb.metabim.com/bldg/SquareFeet2.htm
3 Information from Environmental Health and Safety's LHAT records for registered lab users and spaces.

PROFILE OF CURRENT PROGRAMS

Laboratory Resources, Advocates, and Teamwork for Sustainability (LabRATS)

Program Description: The LabRATS Program works directly with the occupants of individual laboratories to assess and reduce their environmental impact, improve safety practices, and broadly increase the efficiency of their resource use, as well as to promote collaboration, sharing, and vibrancy within the UCSB lab research community. LabRATS maintains connections with many supportive operational units on campus and works to develop new programs in response to sustainability-related needs identified.

LabRATS takes on the following roles:

- Provide individualized green labs assessments;
- Developing short-term or permanent programs addressing specific issues identified as common in the operations of multiple labs;
- Staying apprised of developing technologies and methodologies which support green labs operations on other research campuses; and
- Document and share our campus' best practices with national and international communities.

Program Membership: LabRATS' primary workforce has consisted of campus staff and paid undergraduate interns. Two campus staff members presently co-advise the LabRATS program, and supervise two to three interns each academic year, typically working 10-15 hours per week.

Location in Campus Operational Structure: LabRATS operates as one of several Sustainability Internship Programs on campus. It is based in the Department of Geography, as part of the UCSB Sustainability Program's academic arm.

Funding Mechanisms: For several years, all funding for LabRATS staff and internship time as well as program expenses was sought through annual or one-time grants. LabRATS continues to seek grants for specific programs, but paid internships and some staff support are now included in the UCSB Sustainability Program budget.

Collaborative Relationships:

- Campus Laboratory Occupants
- Departments with Wet Labs, Shops, or Studios
- Environmental Health and Safety
- Chancellor's Sustainability Committee
- Office of Research
- Energy and Engineering Services, Facilities Management
- Waste and Water Management, Facilities Management
- Associated Students Recycling

Laboratory Ventilation Working Group

Description: The multi-stakeholder committee meets to discuss all issues related to the safe and efficient ventilation of laboratory spaces on campus. Roles include:

- Review of current practices in campus lab ventilation;
- Review of relevant codes and standards for lab building ventilation;
- Designated by UCOP as a design champion and reviewer of the UCOP 2016 Lab Safety Design Manual update;
- Consultation with building committees and design staff on ventilation in new lab construction;
- Review and identification of existing opportunities for ventilation improvements in campus lab buildings;
- Review of current lab building renovation and design standards and development of recommendations for campus on potential improvements. This is done in partnership with all members of the LVWG to ensure that safety, efficiency, and code compliance needs are addressed.; and
- Creation of documentation processes to support ventilation improvements.

Core Membership:

- Amorette Getty, Working Group Chair
- Jordan Sager, Campus Energy Manager
- Richard Dewey, FM Energy and Engineering
- Sandro Sanchez, FM Energy and Engineering
- David Vandenberg (now retired), Environmental Health and Safety
- Alessandro Moretto, Environmental Health and Safety
- Jesse Bickley, Environmental Health and Safety
- Hector Acuna, Environmental Health and Safety
- Joe Bickley, Campus Fire Marshal
- Jim White, Deputy Campus Fire Marshal

Location in Campus Operational Structure: The Lab Ventilation Working Group reports to the Built Environment Change Agent Team, which in turn reports to the Chancellor's Campus Sustainability Committee.

Funding Mechanisms: The Working Group operates as a volunteer committee without a cost structure.

Primary Collaborative Relationships:

- Environmental Health and Safety
- Energy and Engineering Services, Facilities Management
- Lab Building Design Teams
- UCOP's Lab Safety Design Manual team
- LabRATS

BENCHMARKS

Cost Assumptions

RESOURCES	COST
Water	$8,26/HCF
Electricity	$0.11/kWh

Outreach and Engagement Impacts

BENCHMARK	NUMBER	PERCENT OF TOTAL CAMPUS WET LABS
# of laboratories assessed to date	59	19.7%
# of researchers directly engaged to date[1]	500	17%
# of researchers LabRATS has presented to[2]	150	5%
# of researchers indirectly engaged in the past year (includes email, flyers, tabling, etc.)	2700	90%
# of undergraduate students presented to or engaged in past year[3]	525	5%

The number of researchers directly and indirectly engaged are estimates based on the best of our knowledge. The number of researchers directly engaged includes the full-time and part-time researchers working in laboratories that LabRATS has assessed.

1 Researchers that we assessed the lab of (est ~6 per lab*65); researchers in freezer study (10) and freezer challenge; labs that participated in single pass cooling replacement program (2ppl*~21 labs); labs who participated in IBIS (much of Bio II)(rough est. ~40);
2 Incoming grad class for Chemistry each year (~30*5yrs, started 2014)
3 Mechanical engineering students that Amorette presents to (7 years (since 2012)*~75 per year); interns

Documented Energy Impacts

ENERGY RENOVATION OF PHYSICAL SCIENCES BUILDING NORTH Return on Investment: 25 months anticipated, early post-project data suggests a shorter time			
TIME FRAME	**ELECTRICAL**	**GAS**	**BTU/SQFT**
Sept 2017 (Prior to Renovation)	240,227 kWh	10,198 therms	28,886
Sept 2018	180,910 kWh	6,116 therms	19,299

Preliminary electrical energy savings data for PSBN. Extrapolating first 2.5 months of savings to an annual sum gives $144k/yr in electrical energy savings, exceeding anticipated ROI.

Estimated Savings in Bren Building due to HVAC Alternate Means

	CUBIC FEET PER MINUTE (CFM) OF EXHAUST AIR	ENERGY SAVINGS
Before Rebalance/Aircuity	20,000	N/A
After Rebalance/Aircuity	10,000	$25,000/yr

Square Footage of Laboratory Buildings Undergoing Ventilation Optimization Retrofits

	SQUARE FOOTAGE	PERCENTAGE
Total Laboratory Buildlings	452,232	100
Total Undergone Renovation[1]	39,882	8.8

Documented Water Impacts

WATER SAVING MEASURES	
# of Single Pass Cooling Units Replaced	127
Estimated Gallons of Water Saved through Replacing Single Pass Cooling (*Please see the Best Practices, Water section of this manual for methodology and assumptions in our water calculations) (at 16hrs/week, 1gpm, 127 condenser setups)	6.1+ million gallons/year

1 Bren Hall and Physical Science Building North

Documented Waste Impacts

LANDFILL DIVERSION FROM RED-LIDDED TOTER PROGRAM	
Estimated diversion from landfill per year due to program	260 tons
Estimated diversion since program implementation	1,560 tons

Documented Hazardous Waste Impacts

ELIMINATION OF MERCURY-CONTAINING GLASS EQUIPMENT	
Number of mercury-containing thermometers replaced	898
Number of mercury-containing microscope bulbs replaced with LED systems to date	4
Estimated cost of cleanup per mercury spill	$69

Additional Quantifiable Impacts

ESTIMATED FINANCIAL SAVINGS DUE TO LABSYNC ASSESSMENTS

Through the LabSYNC assessment program, LabRATS has assessed over 60 laboratories, saving an average of 9,921 kWh/yr per lab. As a result, the University has saved nearly $900 per lab per year. These totals come out to over 500,000 kWh/yr, or over $50,000 saved.

Other efforts include the replacement of old and inefficient ULT freezers, which, when replaced, can save over $800 a year, or well over 8,000 kWh/yr. Furthermore, replacement of other inefficient lab equipment, such as fly incubators, can net over $2,000 a year in reduced energy costs. Smaller-scale impacts such as these have been documented in some Best Practices sections describing completed programs or pilots

BEST PRACTICES AND LESSONS LEARNED

UC Santa Barbara has a long-standing Green Labs Program, with history and experience in all areas included in this report. The Best Practices section summarizes our current knowledge regarding demonstrated best practices specific to our campus.

- **Completed Efforts/Programs** indicate a practice that was undertaken in a project or program at some point in the past. The completion of the work described indicates that no further attention is required in that specific area.
- **Successful Pilots** are practices where initial steps or a concrete and finished pilot project has been undertaken, but there is more work to be to accomplish in this area.
- **Present Efforts** are practices where there is a program presently underway which is developing our campus' strategy surrounding the issue.
- **Ongoing Efforts** indicate that UCSB has developed a maintainable, ongoing program incorporating this practice

Plug Load

Measurement of plug loads has considerable utility in guiding green lab efforts. The collection of accurate timely data on device energy consumption can streamline user behavior, make comparisons between models for purchasing guides, and estimate the health of aging instruments. Below are ways collected data were used:

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Short-term Plug Load Measurements and Data Collection	Energy savings range by the piece of equipment	LabRATS and researchers of labs in assessment process	Ongoing through the LabSYNC assessment process
Long-term Monitoring Pilot	LabRATS identified several malfunctioning freezers using as much as 50% more energy and putting samples at risk. Better understanding of several pieces of equipment was also gained.	LabRATS, PIs, and lab building managers	Completed pilot, area for improvement with expansion on hold
Assessment and Management of Power-down Procedures	Energy savings range by the piece of equipment	LabRATS and researchers of labs in assessment process	Ongoing through LabRATS LabSYNC
Identifying Target Instruments for Replacement	Energy efficient ULT freezers can run at 50% of the kWh/day that traditional ULTs do. For fly incubators, 86% of the energy can be saved. These are a few examples of what is possible.	Purchasing, LabRATS, and researchers	Pilots completed for drosophila incubators and ULT freezers. Overall effort ongoing.

SHORT-TERM PLUG LOAD MEASUREMENTS AND DATA COLLECTION

Status: Ongoing through the LabSYNC assessment process

Description: As part of LabSYNC assessments, target instruments, whose power consumption may be significant or unexpected, have been identified. Temporary meters are utilized to collect 1 to 2 weeks of power data which is then shared with the laboratory owning the instrument and added to the LabRATS collection of such data.

LONG-TERM MONITORING PILOT

Status: Completed pilot, area for improvement with expansion on hold

Description: In Fall 2016, LabRATS and UCSB's Facilities Management launched a pilot with an energy management company, to extensively meter scientific equipment in a large life science research building on campus. The plug-level wireless energy meters collected power consumption data every minute and uploaded that information to an online interface that can be accessed by sustainability staff, researchers, and other entities. 134 meters were installed on equipment that included ultra-low temperature freezers, biosafety cabinets, centrifuges, water baths, and other common lab equipments Data was collected for 8 to 10 months on most instruments.

Information from the pilot has been helpful in creating procurement recommendations that incorporate both energy consumption and common long-term usage patterns. For instance, a 4 ft biosafety cabinet would need to be in use for more than 33 hours each week for a high-efficiency (HE) model to be preferable to a standard unit, even though many labs are using their HE units far less frequently. Additionally, LabRATS has been able to identify malfunctioning freezers based on erratic or non-existent compressor cycling. Moreover, this long-term monitoring is a way to preemptively identify cold storage units before they fail and compromise sample quality.

The pilot program was discontinued due to concerns regarding the reliability of the meters and potential for power to be cut off from critical equipment unexpectedly. Next steps to this pilot and associated data collected are discussed in the Plug Load subsection of Area of Improvement.

ASSESSMENT AND MANAGEMENT OF POWER-DOWN PROCEDURES

Status: Ongoing through LabRATS LabSYNC

Description: When assessing labs through LabSYNC, LabRATS requires as a prerequisite for certification that every instrument have some kind of established shut-down practice, unless there is a specific reason the device must be left powered on on a continuous basis.

Some devices can have their start-up and shut-down automated with timers, such as glassware drying ovens, ensuring that equipment running after hours, or equipment whose cycle is longer

than someone will be present for, will shut down following the timer's ending, and automatically start up again in time for the following research day.

Other devices can be labeled with color-coded red, green, and yellow stickers, to indicate to all lab users whether this device can (and should) be easily powered off after use, whether there is a shut-down procedure that must be followed, or whether the device will automatically enter an energy-saving or 'sleep' mode.

IDENTIFYING TARGET INSTRUMENTS FOR REPLACEMENT

Drosophila Incubator Replacement

Status: Successful Pilot

Description: In 2016, LabRATS obtained funding to purchase one drosophila incubator that utilizes thermoelectric, or Peltier, cooling instead of traditional compressor-based refrigeration. This unit replaced an upright 20 ft^3 incubator that consumed almost as much energy as a ULT freezer. The newer model uses 86% less energy than the previous unit, saving 24,980 kWh/yr, and perfored above satisfaction levels.

Upon successful replacement of one of the six such incubators in the campus' main drosophila facility, the laboratory itself has sought funding to replace the remaining five such incubators.

In addition to drosophila incubation, tissue and cell culture incubators continue to be a large consumer and will be a focus going forward.

Efficient ULT Incentive Program

Status: Completed Pilot

Description: Under a grant from The Green Initiative Fund (TGIF), UCSB offered a $3,000 incentive to laboratories on campus to replace old ultra-low temperature (ULT) freezers with new, energy efficient models. Newer freezers consume 9 kWh/day on average, half of traditional freezers consumption. Additionally, the performance of older ULT units decline over time consuming up to 30 kWh/day. Directly reducing plug and heat load in the building space by replacing oldest freezers can mitigate impact and save money on electricity.

In a number of cases, the $3000 incentive did not appear adequate to motivate a researcher to replace an older freezer if it still functioned. However, the LabRATS program identified several researchers who are in the market for new freezers. Since the closure of the pilot, inquiries have trickled in from researchers asking if the fundings were still available. TGIF has recently launched an equipment rebate program[1] which supports future investments in energy efficient freezers. Additional ideas for funding and structural support for the purchase of new equipment are discussed in the Areas of Improvement.

OTHER BEST PRACTICES CROSS-REFERENCE

- Topics in the sections below also contribute to improved plug load in laboratories:
- Lighting: Targeting fluorescence microscopy and other specialty lighting
- Storage and Sample Management: Room Temp DNA Storage
- Storage and Sample Management: Ultra-Cold Sample Longevity Study
- Communications: Procurement Guidelines

1 http://www.sustainability.ucsb.edu/tgif-equipment-rebate-program/

Lighting

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Promoting Best Practices in General Room Lighting	Varies by practice	Facilities Management, Researchers, and LabRATS	Ongoing
Targeting Fluorescence Microscopy and Other Specialty Lighting	Saves $69 from a prevented mercury spill as well as modest energy savings.	Researchers and LabRATS	Successful Pilot, future Area of Improvement

PROMOTING BEST PRACTICES IN GENERAL ROOM LIGHTING

Status: Ongoing

Description: As part of the LabSYNC assessment processes, all aspects of room and task lighting are examined within the laboratory spaces. LabRATS assessment interns:

- Encourage task lighting and overhead lighting to be used in conjunction with daylighting. LabSYNC promotes task lighting where appropriate as it concentrates light onto certain areas of the laboratory being used, reducing the need for excessive overhead lighting.
- Promote the use of daylight where possible.
- Encourage laboratories to voluntarily remove fluorescent tubes in overhead lighting (called "delamping") or refrain from ordering new tubes when existing ones burn out if they do not feel the lighting is needed. When delamping, the use of a light meter is recommended to determine lighting levels and to compare with common lab standards. The campus energy manager should be consulted to review the meter readings and recommendations for delamping before making a final decision and requesting work from FM.
- Encourage labs to label switches if more than one light switch is in a panel. When an occupant is not sure which switch goes to which light, some occupants have a tendency to turn on all of the switches. LabRATS also recommends shutting lights off when the lab is vacated for the night.
- Conduct metering of lighting in laboratory spaces as part of the assessment process. This data helps LabRATS in reporting on occupant behavior regarding turning lights off and in considering overall lighting levels in the lab.
- Assist labs with reporting problems with their lighting systems for repair.
- Promote the use of LED lighting for laboratories and instrumentation where feasible.

TARGETING FLUORESCENCE MICROSCOPY AND OTHER SPECIALTY LIGHTING

Status: Successful Pilot, future Area of Improvement

Description: Fluorescence microscopy typically uses mercury vapor bulbs to provide illumination at the correct wavelengths. New LED light sources for fluorescent microscopy decrease heat generation, require no warm-up or cool-down time, provide higher intensity light at the relevant wavelengths, eliminate mercury health hazard, and make disposal easier. UCSB worked with our NRI Microscopy Lab in the Bio II building to trial the use of the LED option in two microscopes with funding from TGIF. The LEDs were strongly

preferred by researchers for all of the above reasons. That said, higher up-front cost and lack of energy-savings in earlier models (circa 2014) created barriers for wholesale transition of our facilities. Moving forward, LabRATS should partner with Environmental Health & Safety to address the use of mercury in lighting. Though the energy savings are not substantial, LEDs have a significantly lower cost of ownership, and their energy profiles have improved since the completion of this trial. The cost savings from avoiding the clean-up of broken mercury bulbs (estimated $69/spill) and the avoidance of detrimental health impacts are powerful arguments for this work.

Heating, Ventilation, and Air Conditioning (HVAC)

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Campus Ventilation Survey and Lab Building Dossier	Supports streamlined identification and orchestration of high-ROI lab ventilation projects.	Lab Ventilation Working Group	Successful Pilot, Ongoing through LabRATS and Facilities Management
Documenting Alternate Means of Code Compliance	Allows code-permitted diminished ventilation rates while protecting campus from liability.	Lab Ventilation Working Group	Successful Pilot, Ongoing Practice with Fire Marshal
Assessing and Documenting Laboratory Benchtop Risks	Protects human safety and allows code-permitted diminished ventilation rates while protecting campus from liability.	Lab Ventilation Working Group	Successful Pilot, Ongoing practice with EH&S
Fume Hood Sash Stickers	Continuously raising awareness of behavioral impact, increasing safety and in some cases reducing ventilation-related energy use.	LabRATS	Completed Program
Fume Hood Sash Training	Increased impact on lab culture, increasing safety and in some cases reducing ventilation-related energy use.	EH&S and LabRATS	Ongoing through LabRATS' LabSYNC, EH&S Safety Training, and other lectures
Established Standards for Fume Hood Calibration	PSBN decreased ventilation-related power consumption by 30% through fume hood recalibration.	Lab Ventilation Working Group	Ongoing Practice in Facilities Management and EH&S
Publication of a UCSB-specific Chemical Fume Hood Guide	Consistent implementation of established best practices for campus lab design per energy and safety concerns.	Lab Ventilation Working Group	Present Effort of EH&S

CAMPUS VENTILATION SURVEY AND LAB BUILDING DOSSIER

Status: Successful Pilot, Ongoing through LabRATS and Facilities Management

Description: In 2013,when the Lab Ventilation Working Group was formed, all major laboratory buildings on campus were briefly assessed and documented for the number and type of laboratories therein; ventilation systems serving the building, age, known needed retrofits, etc. to facilitate analysis and prioritization of action as funds become available for retrofit and monitoring-based commissioning (MBCx) projects. That documentation serves the working group in identifying and guiding renovation projects, and is used by the LabRATS program to identify outreach opportunities.

HVAC DOCUMENTATION PROCEDURES

In order to safely optimize ventilation in laboratory spaces, appropriate oversight and documentation of safety measures are necessary.

DOCUMENTING ALTERNATE MEANS OF CODE COMPLIANCE

Status: Successful Pilot, Ongoing Practice with Fire Marshal

Description: California Fire, Building, and Mechanical Codes prescriptively mandate that laboratory spaces constructed between 1988 and 2007 must generally have 1 cubic foot per minute per square foot (1 cfm/ft^2) of exhaust ventilation at all times, for fire and human safety purposes. This code language disallows energy-saving measures such as night-time or un-occupied ventilation setbacks, unless an 'alternate means of protection' is in place to provide equivalent safety to materials and occupants. In 2015, the Lab Ventilation working group identified that there was no existing procedure for documenting such alternate means for campus construction, leaving the campus open to liability concerns. In consultation with the working group, the Campus Fire Marshal created a procedure for formally documenting cases where an 'alternate means of protection' is employed to meet ventilation code requirements for fire safety.

UCSB's Bren Building has been rated LEED Platinum once for new construction and twice for ongoing operations and maintenance. The building contains both administrative spaces and laboratories. One of the principal features of energy-savings within the building is a demand-controlled ventilation system that tracks the presence of detectable contaminants in the laboratory spaces and responsively varies the ventilation rate to provide adequate removal of effluents at a lower base air-flow level. During normal operations this takes the system below the 1 cfm/ft^2 minimum. The Bren Building acted as the test case for the new documentation procedure, and is now formally on file with the Fire Marshal as operating with an approved alternate means in compliance with California Code.

ASSESSING AND DOCUMENTING LABORATORY BENCHTOP RISKS

Status: Successful Pilot, Ongoing practice with EH&S.

In order to ensure that the ventilation system described above would provide adequate protection to laboratory occupants at the reduced levels permitted by the monitoring system in the Bren building, the inventory of chemicals and processes used in each laboratory underwent additional scrutiny using a new Benchtop Risk Assessment process designed by EH&S. The Assessment process was based on a

similar program at UC Irvine.

This type of assessment and lab-by-lab qualification could be instrumental in allowing additional ventilation-optimizing measures across the campus; however, personnel limitations prevent all 900+ laboratory spaces on the campus from being assessed. Nonetheless, this is a valuable tool for the campus to have when looking to implement similar measures in other building spaces on a case-by-case basis, and increases in funding for EH&S personnel could allow more aggressive implementation of such optimizations in the future.

FUME HOOD SASH MANAGEMENT

Fume hoods play a key role in regulating laboratory air circulation, and are also among the largest energy consumers inside a lab, using an estimated 30,000 kWh/yr per hood in fan and cooling energy[1]. Diminishing the air flow through the sash opening can directly decrease that energy cost in many cases, and leads to increased safety for lab users. Please see below for several programs which address sash management.

FUME HOOD SASH STICKERS

Status: Completed Program

Description: At UCSB, traditional fume hood stickers indicating sash position for a vertically-moving sash have had a singular set of red arrows pointing to the maximum sash opening allowable for safety purposes. Many researchers have acted under the impression that this height is either the safest or most energy-efficient height, which was not the intention of the original sticker. Early in the UCSB LabRATS program, a new colorful vertical stripe sticker was developed, which ran along the edge of a hood's sash area to indicate that heights above the 18" mark are dangerous (red) and anything lower than that is progressively safer and more efficient (yellow fading to green). The sticker clearly communicates that the optimal sash position is fully closed unless the hood is in active use. Although a closed sash position is safer in all hoods, these stickers have been applied only on variable air volume hoods, where energy savings may also result from good practices. These sash stickers have been installed on the bulk of UCSB campus' stock of variable air volume fume hoods with vertical sashes.

At the time of sticker installation in the Engineering Sciences Building, data was collected to assess the efficacy of the stickers in altering fume hood sash behavior. The graph on the next page shows the results from the report on that data.

FUME HOOD SASH TRAINING

Status: Ongoing through LabRATS' LabSYNC, EH&S Safety Training, and other lectures

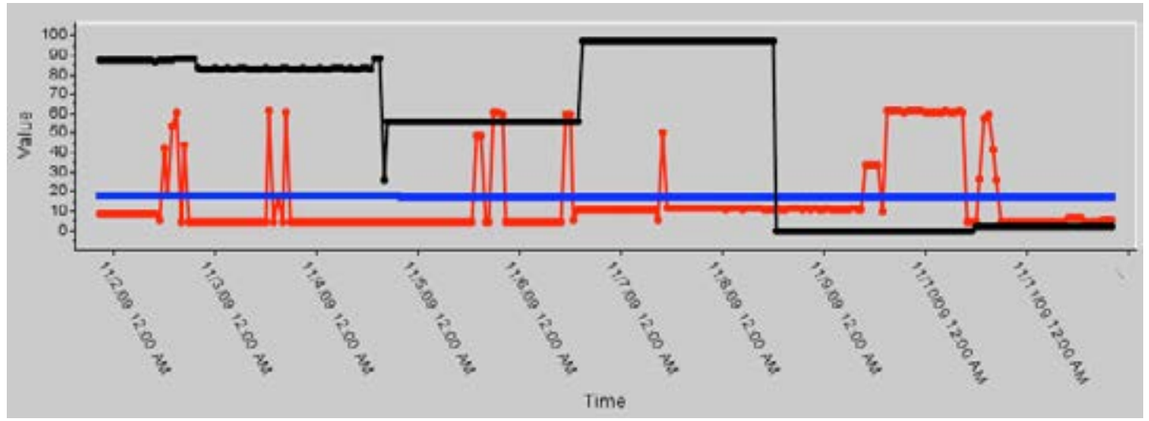
Description: Fume hood sash training is crucial for lab occupants to understand the safety and energy impacts of proper hood use. Through questions in the LAbSYNC assessment process, and slides in both the EH&S Lab Safety Training and in Green Labs-related lectures given to departments throughout the year, lab occupants consistently and repeatedly receive the message that proper sash-closing practices are necessary for their protection, and to minimizing environmental impact.

ESTABLISHED STANDARDS FOR FUME HOOD CALIBRATION

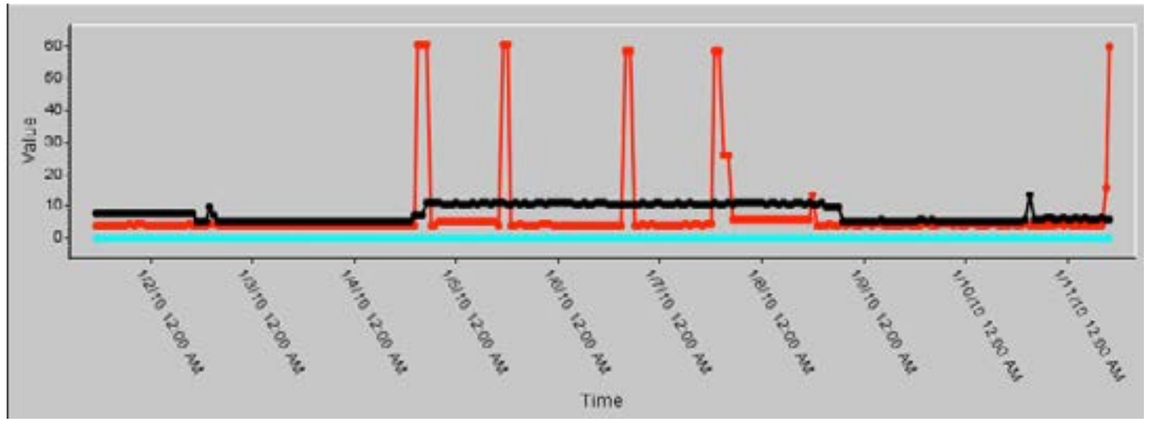
Status: Ongoing Practice in Facilities Management and EH&S

Description: The Laboratory Ventilation Working Group identified that by long-standing practice, Environmental Health and Safety had been certifying constant-volume fume hoods at the CalOSHA-required 100 linear feet per minute (lfm) at a fully-open sash position. Fume hoods do not operate safely with the sash open more than 18 inches. After conferring with other campuses and conducting an analysis of the relevant safety and operational concerns, campus maintenance and safety staff agreed on a new policy in certifying fume hoods at 100 lfm at an 18 inch sash height. The Physical Sciences Building North has been re-balanced according to the new practice, decreasing ventilation-related power consumption, dropping average electrical

1 https://en.wikipedia.org/wiki/Fume_hood#Energy_consumption, Mills and Sartor, https://web.archive.org/web/20160304032406/http://evanmills.lbl.gov/pubs/pdf/fh_energy_full_report.pdf



Fume hood sash position (% open) for three hoods in Engineering Sciences prior to installation of sash stickers. Note multiple overnight periods with sashes left open. Bottom: Positions of same three sashes two months after sticker installation. Note significant improvements in behavior in two of the three labs, as well as longevity of behavior change.



consumption from close to 400 kW to around 260 kW, 30% drop. Additional buildings will be brought in line with this new standard when undergoing ventilation-related updates.

PUBLICATION OF A UCSB-SPECIFIC CHEMICAL FUME HOOD GUIDE

Status: Present Effort of EH&S

Description: UCOP's Laboratory Safety Design Manual provides a compendium of all relevant codes, standards, and policies for laboratory construction on UC campuses. UCSB EH&S is finalizing an addendum to this UC document with specific clarifications for practices and requirements on our campus. In its final form, this document should serve as a guide for laboratory designers working with the campus, as well as the wide range of campus professionals involved in design, construction, and maintenance projects which incorporate fume hoods and other specialized laboratory ventilation systems.

HVAC BEST PRACTICE CROSS-REFERENCE

The following additional practices in other sections of this document have an impact on HVAC-related efficiency:

- Equipment sharing - to minimize redundancy of heat-generating instrumentation.
- Freezer inventory management and maintenance, and freezer sharing - to optimize the number of freezers in operation in a building while reducing the

number of heat-generating pieces of equipment.

- Operation of Shared and Open Access Facilities - to optimize per capita researcher footprint within buildings, minimizing the areas requiring high ventilation volumes.
- Outreach to New Faculty - to impart good levels of ventilation in newly renovated labs which will remain in effect for long spans of time after occupation of the space.

Storage and Sample Management

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Room Temperature Sample Storage	An average traditional ULT freezer uses 6,205 kWh/yr. An energy efficient one uses on average 3,233 kWh/year[1].	Researchers	Successful Pilot, Ongoing Promotion through LabRATS and LabSYNC
Shared Instrumentation Database	47 shared-access facilities housing more than 300 instruments are cataloged in the database	Office of Research (with support from LabRATS on the launch)	Ongoing Program
Freezer Inventory Management and Maintenance	Older labs have a tendency to amass clutter in their cold storage. This can include samples that are no longer needed or damaged as well as personal items from past researchers.	Researchers with support from LabRATS	Ongoing Practice through LabSYNC, Completed Pilots during the National Freezer Challenge, Area of Improvement for ongoing adoption and technology development

1 "UCR Office of Sustainability Ultra-LowTemperature Freezer Performance and Energy Use Tests" https://www.colorado.edu/ecenter/sites/default/files/attached-files/ucr_ult_tests_report_-_2016_final_df1.pdf

ROOM TEMPERATURE SAMPLE STORAGE

Status: Successful Pilot, Ongoing Promotion through LabRATS LabSYNC

Description: In an effort to reduce the amount of cold storage units such as ULTs, LabRATS is encouraging the practice of keeping DNA stored at room temperature where possible. In 2009-2010, Mary Toothman of the Briggs Lab, the Oakley Lab, and LabRATS performed a study on the effectiveness of room temperature DNA Storage. It was found that DNA stored at room temperature performed as well as DNA that was frozen at -20°C among the samples tested. This experiment was a short-term trial that allowed just enough time for the full process to take place. Biomatrica, one of the companies that sold room temperature DNA storage solution and equipment, completed industry research where they stored samples for 26 months at 60°C, which should have a similar impact to 30 years at room temperature. They found better sample integrity with the sample at 60°C with the Biomatrica technology compared to the one stored at -20°C. Several campuses have found that they can avoid the purchase of new cold storage units by using room temperature DNA storage as an alternative. Stanford is the most notable example of this.

DNA-stable technology has been developed based on the natural principles of anhydrobiosis and synthetic chemistry that allows for the dry storage of materials at ambient temperatures. Samples are protected from degradation due to the unique thermo-stable barrier that forms during drying. The matrix completely dissolves within minutes upon rehydration.

The Briggs Lab has continued to use room temperature DNA storage, and encouraged other laboratories to use the same methods. Similarly, LabRATS actively encourages laboratories to consider whether this method is viable for their research and promote it through LabSYNC sustainability assessments. Through future advancement, the types of samples applicable may expand to be more accessible to researchers.

SHARED INSTRUMENTATION DATABASE

Status: Ongoing Program through the Office of Research

Description: The campus has a wide range of open-access research facilities supported by academic departments and scientific programs. Sharing facilities and instrumentation helps minimize the redundant purchases of instrumentation, it increases networking possibilities among researchers with similar needs, facilitate faster training for new users, and support broad sharing of expertise, parts, and measurement techniques.

While these facilities and other instruments are advertised on departmental websites and by word of mouth, LabRATS and the Office of Research also created a campus-wide Shared Instrumentation database[1]. Presently, 47 shared-access facilities, housing more than 300 instruments, are cataloged in the database, with tags indicating their access levels for campus-wide users, other academic or government researchers, and industry partners.

The Shared Instrumentation site also helps to strengthen our relationship with local industry. It increases technology transfer through enhanced interaction between researchers and industry partners who visit campus to collaborate or use facilities. This program also creates recharge revenue from external users which often help support expert technical staff who can see to instrument maintenance and training for new researchers.

FREEZER INVENTORY MANAGEMENT AND MAINTENANCE

Status: Ongoing Practice through LabSYNC, Completed Pilots during the National Freezer Challenge, Area of Improvement for ongoing adoption and technology development

Description: Freezer clean-outs conducted in labs at UC Davis and the CDC indicate that 10-30% of items stored in refrigeration units are no longer needed or viable. Researchers in some laboratories on campus have estimated that the

1 http://www.sharedinstrumentation.ucsb.edu

number could be as high as 50% in their units. Significant time and energy can be spent looking for a poorly-labeled sample in a large freezer, necessitating a longer period to cool it back down after door-opening, and imposing risk on the other stored samples due to temperature fluxuations. Given that many freezers can use upwards of 10 kWh per day, all of these factors are strong indicators of the value of regular sample inventorying practices.

The LabSYNC assessment program, as well as periodic targeted campaigns associated with the National Freezer Challenge, have promoted a range of good sample-management, freezer-cleanout, and inventory practices. LabRATS encourages yearly lab-wide freezer cleanouts, removal of frost, active electronic inventorying, and sharing technologies toward these ends between labs. Frost removal tools and cold-resistant gloves have been offered as giveaways to promote these practices.

SAMPLE MANAGEMENT BEST PRACTICES CROSS-REFERENCE

- For information on chemical supply purchase, storage, management, and waste diversion please see the section on "Hazardous Waste and Green Chemistry."

Waste Management

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Lab Plastic and Empty Chemical Container Recycling	Discontinued due to change in recycling options	MarBorg	Ongoing
Red-Lidded Toter Program	Enabled UCSB to process trash dumpsters from lab buildings through a Materials Reclamation Facility	EH&S, Facilities Management, and MarBorg	Ongoing through EH&S and Waste Hauler
Laboratory Building Waste Assessments	Increased understanding of laboratory waste streams	LabRATS (under EH&S' and Facilities Management guidance)	Multiple completed programs
Surplus Inventory Program	This program isn't viable without a paired storage solution.	Future iterations of this would need to have a strong partnership with Central Stores	Discontinued program
User Waste Education	Varies by specific practice	LabRATS	Ongoing through LabRATS and LabSYNC Program

LAB PLASTIC AND EMPTY CHEMICAL CONTAINER RECYCLING

Status: Ongoing

Description: Up until 2018, LabRATS was able to recycle 1-7 plastics, fluorinated ethylene propylene (FEP), and perfluoroalkoxy copolymer resin (PFA) through our local waste hauler. The waste hauler agreed to mix the more unusual laboratory plastics in with high numbered hard plastics (mostly #7 plastic). As this was previously promoted, the laboratories were already following good safety procedures for what could be thrown away and what had to be sorted separately as hazardous waste or autoclaved. LabRATS started a campaign of "If it is safe to put in a regular trash bin (and did not require autoclaving), it is safe to recycle." Due to changes in the recycling market at the end of 2018, the containers that are recyclable are now only #1, #2, and #5 plastics. LabRATS also developed a protocol for empty chemical container recycling which addressed the safety issues.

RED-LIDDED TOTER PROGRAM

Status: Ongoing through EH&S and Waste Hauler

Description: UCSB began using a materials reclamation facility (MRF) for our trash dumpsters in an attempt to reclaim recyclable material. This was challenging in laboratory buildings where autoclaved waste was allowed to be put into dumpsters. UCSB also received some concerns from the local landfill about needles and other hazards that could affect their workers handling dumpster trash. Due to these areas of concern, Facilities Management, Environmental Health & Safety and LabRATS developed the Red-Lidded Toter Program. In this program, researchers place their lab glass, broken glass boxes, and post-autoclaved waste into a locked red-lidded waste toter. These toters are picked up by a special waste truck for proper disposal. All laboratories can request a key for access to these toters. LabRATS frequently provides keys to the laboratories that the program works with. This new program has given the campus a greater ability to recover recycling from trash dumpsters and improved safety for MRF and landfill workers.

LABORATORY BUILDING WASTE ASSESSMENTS

Status: Multiple completed programs

Description: Since LabRATS started in the 2005-2006 school year, the program has completed several waste audits of laboratory buildings. Data from these audits helped to inform future recycling and waste management efforts. The protocol for laboratory waste audits was developed in partnership between Environmental Health & Safety and LabRATS. Audits are completed by students under close supervision of professional staff. All participants in the waste audit are required to have safety training in advance of the audit. Post-autoclave waste bags and restroom trash are weighed but not opened or sorted. Waste materials are typically cleared from the building the night before collection starts (usually a Tuesday), collected for two weekdays (usually Wednesday and Thursday) and a sort if performed on the third day (usually a Friday).

SURPLUS INVENTORY PROGRAM

Status: Discontinued program, First developed in partnership between LabRATS, Business Services, Central Stores, the campus Materiel Manager, Environmental Health and Safety, and the Campus Change Agent Team on Sustainable Purchasing.

Description: The Surplus Inventory Program was designed to allow users to give away or find equipment, supplies, and furniture from the laboratory or office. All items posted there are free to UCSB staff, faculty, and students for use on campus.

LabRATS designed a built-in approval system to help users navigate the steps to properly exchange equipment. Participants interested in posting an item for exchange filled out a simple form providing the necessary information. Once the posting was submitted, a chain of automatic notification emails was initiated.

The website itself was well designed and helped users more easily navigate the process of donating equipment to other laboratories on campus. It can also be noted that LabRATS

shared access to the website with several other campuses and as a result, some campuses have successfully developed websites similar to ours and/or based their site design on our code. In the end the model had issues that could not be dissolved, so this program was discontinued on our campus. The website was designed with the concept that laboratories would post items to the site and then be willing to store the equipment until another lab requested that item. In the end, LabRATS found that it was rare for a laboratory to be willing to hold onto a piece of equipment for more than 48 hours before they wanted the item to be removed from their lab and often times a lab would only want to hold onto the equipment for another 24hrs. LabRATS also had difficulty maintaining the site. To develop a site that was easily searchable, had the built-in notifications, could keep track of inventory, etc. required developing a fairly sophisticated site design which had to be maintained by a professional website manager. This required significant ongoing costs. Please see the section on areas of improvement for more information on our current approaches.

USER WASTE EDUCATION

Status: Ongoing through LabRATS LabSYNC Program

Description: Through the LabSYNC assessment process, LabRATS helps individual labs identify and reduce their waste streams. This is very important in the laboratory environment, because of the broad variety of waste materials coming out of laboratories and the unique concerns regarding contamination in each laboratory. One example of this is where LabRATS was able to assist one laboratory with downcycling their plastics into a second laboratory. The first laboratory was very sensitive to small levels of potential contaminants. The second laboratory was doing experiments that did not require a high level of sterility and so could accept reused plastics that had been cleaned with a simple soap and water solution. This reduced the need for the second lab to purchase new plastic vials.

WASTE MANAGEMENT BEST PRACTICE CROSS-REFERENCE

- The Surplus Chemical Program addresses waste by repurposing unwanted but still-useable chemicals.
- Many Travel and Fieldwork questions in the LabSYNC interview are related to minimizing waste generation and ensuring proper disposal of waste generated in the field.

Hazardous Waste and Green Chemistry

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Chemical Inventory Maintenance	Meets core campus, state, and federal requirements	EH&S	Ongoing Practice by EH&S
UC Chemical App and Surplus Chemicals	Improved process for both sharing and inventorying chemicals	EH&S (with LabRATS helping with promotion)	Successful pilot and gearing up for expansion
Green Chemistry Review in LabSYNC Assessments	Varies by chemical	LabRATS	Ongoing through LabRATS and LabSYNC
Reduce use and dependency on organic solvents in undergraduate chemistry lab courses	Reduces large waste generation	LabRATS and Chemistry Department	Exploratory phase

CHEMICAL MANAGEMENT

Chemicals required in research and teaching laboratories often pose hazards to human health or the environment if used in quantity or when stored, dispensed or disposed of incorrectly. Solutions that maximize efficient use of chemicals, minimize quantities, and select less deleterious alternatives are essential to a robust green labs program.

CHEMICAL INVENTORY MAINTENANCE

Status: Ongoing Practice by EH&S

Description: Environmental Health and Safety requires that all laboratories provide an updated inventory of chemicals stored in the lab on an annual basis. In addition to safety benefits, up-to-date inventories help prevent the purchase of chemicals that are already in stock.

UC CHEMICAL APP AND SURPLUS CHEMICALS

Status: Successful pilot and gearing up for expansion

Description: Environmental Health & Safety at UCSB is currently piloting the UC Chemical app, a program in which laboratories are able to document, categorize, and barcode scan their chemicals, giving the researchers a comprehensive view of what's available for use in their laboratory. The UC Chemical App can also be viewed through a phone, allowing emergency response staff such as the fire marshall to view what is burning in a laboratory before sending someone into a potentially hazardous situation. LabRATS is in conversation with EH & S about how this program can be

expanded from the initial pilot laboratories to all laboratories on campus. Currently, EH&S is identifying funding for the expansion and maintenance. Once EH&S has the resources to expand, LabRATS will be able to help in the marketing and promotion of the platform.

Currently, UCSB also maintains a surplus chemical program which allows researchers to post and request chemicals that are no longer needed by other researchers through a website. This has been key in reducing waste and preventing the purchase of excess chemicals, as laboratories now have access to a comprehensive database that helps them find chemicals they can share with other laboratories rather than buying new chemicals. Chemicals are screened and logged by EH&S. By using surplus chemicals, significant energy consumption and greenhouse gas emissions from chemical manufacturing are averted.

The new UC Chemical app also has a chemical sharing feature whose intent is also to reduce chemical purchase and subsequent waste generation. Principal Investigators will be able to choose colleagues they trust to have read access to their inventories and the ability to make a request to borrow chemicals. This program may replace the need for the Surplus Chemical Program.

GREEN CHEMISTRY REVIEW IN LABSYNC ASSESSMENTS

Status: Ongoing with LabRATS LabSYNC

Description: LabRATS encourages researchers to only buy the chemicals they will use, apply first in/first out methodologies, and to substitute potentially hazardous or dangerous chemicals for those that pose less of a threat to researchers and the environment.

REDUCE THE USE AND DEPENDENCY ON ORGANIC SOLVENTS IN UNDERGRADUATE CHEMISTRY LAB COURSES

Status: Exploratory phase

Description: LabRATS is exploring the feasibility of reducing the use and dependency of organic solvents. Organic solvents account for a large amount of the waste generated in lab courses and it is believed that there are potential replacements.

HAZARDOUS WASTE AND GREEN CHEMISTRY BEST PRACTICE CROSS-REFERENCES

- There is significant overlap between Green Chemistry, Hazardous Waste, Water, and more general Waste Management in terms of practices and impacts.

Travel and Field Work

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Fieldwork Recommendations in LabSYNC Assessments	Varies by recommendation	LabRATS	Ongoing through LabRATS LabSYNC

FIELDWORK RECOMMENDATIONS IN LABSYNC ASSESSMENTS

Status: Ongoing through LabRATS LabSYNC

Description: LabRATS has developed several recommendations regarding field work which are promoted through their lab assessment process:

- Only travel when necessary and maximize the use of teleconferencing and other alternatives to travel when appropriate.
- Consider purchasing carbon offsets for travel.
- Commit to zero waste field work practices such as picking up all flags or other markers that have been used to outline a specific area. LabRATS also promote the use of reusable or compostable materials wherever possible.
- Preferably, any field work done uses electronic data collection as opposed to paper data collection, further reducing the carbon footprint created in the field.

Communications, Engagement, and Design

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Laboratory Sustainability and Networking Certification (LabSYNC)	59 labs assessed or 19.7% of the labs on campus.	LabRATS	Ongoing Program
Orientations and Class Presentations	525 students impacted in the past year	LabRATS and Dept. Chairs and Student Advisors	Ongoing Practice and Area for Improvement
Outreach to New Faculty	Opportunity to engage faculty in the critical decisions made when a lab is first designed/ renovated.	LabRATS	Current and Developing Efforts
Sustainability Representation on Lab Building Design Committees	Opportunity to affect the initial design of a building. Those design decisions often last the life of the building.	Design and Construction Services, Budget and Planning, and LabRATS	Ongoing Practice
Procurement Guidelines/Sheets	Tool to support many researchers and departments in making decisions presently and also moving forward.	Procurement and LabRATS	Ongoing Effort
Department Support of Shared and Open Access Laboratory Facilities	Reduction in the need to purchase new equipment/expand existing facilities.	Office of Research; LabRATS assisted with launch	Ongoing Programs in multiple departments
Best Practice Sharing Across Institutions	Ability to be the model for peer institutions and expand the impact beyond UCSB.	LabRATS	Ongoing Practice

LABORATORY SUSTAINABILITY AND NETWORKING CERTIFICATION (LABSYNC)

Status: Ongoing Program

Description: LabSYNC Assessments are the backbone of the LabRATS program, and crucial to the campus' efforts toward sustainable laboratory operations and environmental awareness on the part of researchers. The assessment process consists of a one-hour interview and tour of the laboratory space, utilizing a comprehensive questionnaire, typically conducted by a staff member knowledgeable in lab sustainability along with an undergraduate intern from the LabRATS Program. Data is collected about instrumentation, lighting, and other aspects of the laboratory, and all information is collated into a scorecard, report, and slidedeck for the researchers. The rating system is adaptable for the specific needs and constraints of each lab. The lab receives a LabSYNC ranking with levels based on the visible light spectrum. Lab occupants then have the opportunity to follow up and increase their ranking in the system. Thus far, just under 20% of the campus' 300 labs have undergone assessment in either LabSYNC, or it's predecessor assessment system, Laboratory Assessment for Research Sustainability (LARS).

While some campuses have opted for a self-assessment approach where the researcher fills out a checklist independently, UCSB has opted for a more hands-on approach. LabRATS starts the assessment with an in person walk through of the lab and the LabRATS team takes the lead in filling out the assessment checklist based on feedback from the lab (saving the lab time). LabRATS also includes metering into most of our assessments. The system at UCSB allows us to build a relationship with researchers, adapt recommendations to specific labs and incorporate education at each step of the process..

ORIENTATIONS AND CLASS PRESENTATIONS

Status: Ongoing Practice and Area for Improvement

Description: On a university campus, incoming and developing scientists need to be introduced on a consistent basis to the campus' strong sustainability culture, to establish their expectations and good practices as growing contributors. To help communicate this culture and the core best practices, our program advocates, as well as to familiarize researchers with the broad range of campus programs and resources designed to aid them in their research endeavors, the LabRATS programs conducts orientations for new graduate student cohorts and lectures in upper division undergraduate classes annually. LabRATS currently offers this to mechanical engineering undergraduates and incoming chemistry graduate students. In future years, LabRATS would like to expand this to other majors in the sciences as well.

OUTREACH TO NEW FACULTY

Status: Current and Developing Efforts

Description: Incoming faculty can benefit from an introduction to campus sustainability goals and policies, resources that can aid them in designing an energy efficient and sustainable laboratory space, and guidance on sustainable lab purchasing. With these tools, faculty are better prepared to make choices that will have a long-term impact on their lab.

A video highlighting the benefit of these timely connections was filmed and presented at a town hall meeting held by the Vice Chancellor of Administrative Affairs. New-faculty-focused welcome handouts have been designed for inclusion in departmental welcome packets, and ties with Design and Construction Services have been strengthened to help facilitate these efforts. The Laboratory Ventilation Working Group is also striving to provide timely feedback on small lab renovation plans with ventilation elements.

SUSTAINABILITY REPRESENTATION ON LAB BUILDING DESIGN COMMITTEES

Status: Ongoing Practice

Description: Per UCSB Sustainable Practices Policy, a sustainability representative is mandated on the committee for all buildings on campus. When that building plan involves laboratory spaces, LabRATS often holds a seat, and a LabRATS representative assists in the review of design and construction documents to ensure sustainability features are incorporated as deeply as possible.

PROCUREMENT GUIDELINES/SHEETS

Status: Ongoing Effort, Procurement and LabRATS

Description: LabRATS and campus procurement staff have collaborated to create purchasing guides available on the UCSB Procurement website[1]. These guides allow purchasing officials and researchers to more easily identify purchase orders which may be specifying inefficient laboratory equipment and allow them to offer comparable alternatives that are known to be more energy efficient and/or more sustainable in other attributes. Where possible, each guide includes the base cost of several efficient units and an analysis of their lifetime energy consumptions. These can then be compared to any other unit that a lab is planning on purchasing. Our goal is to allow procurement

1 https://www.bfs.ucsb.edu/procurement/department-buyers/your-lab

staff to review orders based on lifetime cost to the university; incorporating both base cost and energy consumption over time. To date, LabRATS has created guides for ultra-low temperature freezers, biosafety cabinets, and drosophila incubators, and promote use of the newly-launched ACT label for product comparison.

DEPARTMENT SUPPORT OF SHARED AND OPEN ACCESS LABORATORY FACILITIES

Status: Ongoing Programs in multiple departments

Description: There are 47 different research facilities on the UCSB campus that have contributed to the campus-wide shared instrumentation website. Many of these shared facilities are wholly or partially supported by the academic programs which house them, are managed by professional technical staff, and leveraged departmental resources by providing research spaces accessible to many researchers and faculty members across the university. These spaces have been shown in some studies[2] to maximize efficient use of funding dollars and square footage of costly laboratory space. These benchmarks closely correlate to ventilation, water, and waste generation per capita.

BEST PRACTICE SHARING ACROSS INSTITUTIONS

As early leaders in the area of laboratory-focused sustainability, representatives from LabRATS began attending the Laboratories for the 21st Century (Labs21) conference to share their work and learn about other campus' best practices. LabRATS representatives have given conference presentations at multiple conference venues:

- International Institute for Sustainable Laboratories (I2SL) - *1-3 presentations annually since 2010*
- California Higher Education Sustainability Conference (CHESC) - *2-5 presentations annually since 2010*
- American Chemical Society (ACS) - *presented in 2010*

as well as invited presentations at universities in the United Kingdom and various educational webinars online. The campus has active representation on several national committees related to lab waste management and the greening of scientific research grants through I2SL.

UC Davis and UCSB LabRATS co-founded the Green Labs Planning community in 2010, which supports collaboration among 321 members, more than 60 Universities, National Labs, as well as other locations.

COMMUNICATIONS BEST PRACTICE CROSS-REFERENCE

- The Shared Instrumentation online database is an excellent exemplar of modern communication tools being leveraged for an increased sustainable lab environment.

2 https://www.colorado.edu/ecenter/greenlabs/case-study-biochemistry-cell-culture-facility

Water

PRACTICE	IMPACT	LEAD STAKEHOLDERS	STATUS
Single-pass Water-cooled Benchtop Condenser Replacement Program	4.3 mil. gal./yr saved since replacing 60 single-pass cooling.	LabRATS with funding from Be Smart About Safety and TGIF	Successful Pilot, Present Effort
Autoclave Inventory and Profiling	Potential for 8,500,000 gallon/year savings based on retrofit of 50% of autoclaves	LabRATS and Building Managers	Present Effort and Area of Improvement
Glassware and Sample Washing Practices	Depends on the amount of glassware and process of each lab.	LabRATS	Ongoing Effort through LabSYNC
Elimination for Water Purification Through Distillation		LabRATS	Ongoing Effort Through LabSYNC and LabRATS
Laboratory Faucet Modification: Aerators and Water Misers		Facilities Management and LabRATS	Ongoing Effort Through LabSYNC and LabRATS
Education Around Water Purification	Reverse Osmosis wastes about 4 gallons per each gallon purified. LabRATS encourages researchers to use only the level of purification needed.	LabRATS	Ongoing Effort Through LabSYNC and LabRATS
Green Labs Integration with Campus Water Action Plan	Strategic goal alignment	Campus Water Manager, Facilities Management, and LabRATS	Established integration, ongoing collaboration

EDUCATION EFFORTS TOWARD WATER SAVINGS

Status: Ongoing Efforts through LabRATS and EH&S

Description: Conscientious and conservative laboratory water use must be taught and reinforced in lab culture. UCSB has taken several steps in the direction of this educational effort.

- Through the LabSYNC assessment, part of the overall score takes into account the lab's water usage, such as eliminating single pass cooling, enforcing equipment washing protocols, and determining appropriate water quality.
- In collaboration with EH&S, stickers were placed on fume hoods where soft-plumbed single pass cooling setups are often used by researchers.
- Water topics are included in flyers distributed to incoming researchers and new faculty.
- Several slides on the EH&S Safety Training presentation now include bullet points about water usage and conservation in laboratory settings, as described in the other Water Best Practices in this section.

ELIMINATION OR REDUCTION OF SINGLE PASS COOLING

Single pass cooling in laboratories is a major source of water consumption on many campuses, and reduction/elimination efforts are mandated by the UC Office of the President. However, replacing once-through cooling units with closed-loop or air-cooled systems is not just a sustainability issue. With several significant flooding incidents in our recent past, the need to replace single pass cooling units has become evident.

With recent grants secured from Be Smart About Safety and TGIF, LabRATS expects to eliminate soft plumbed single pass cooling units in the 2018-2019 academic year. Please also see the section on "Autoclave Inventory and Profiling" below for one of the next major targets in this area.

SINGLE-PASS WATER-COOLED BENCHTOP CONDENSER REPLACEMENT PROGRAM

Status: Successful Pilot, Present Effort

Description: UCSB has put major efforts into eliminating soft-plumbed single-pass condenser cooling, with very significant water savings demonstrated. By the end of the 2018-2019 academic year, UCSB is expected to eliminate soft-plumbed single-pass benchtop processes from the campus.

In 2016, LabRATS to funded 60 replacement units to single-pass cooling setups in laboratories. These replacements included waterless air condensers, simple recirculating pumps, and recirculating pumps plumbed into the building's chilled-water loops. LabRATS estimates this replacement effort to have saved roughly 86,000 gallons of water per week since installation, using a flow rate of 0.5 gal/minute and 48 hours/week of use for each setup replaced. To identify remaining labs that are still using single-pass cooling setups, a survey on water-cooling was recently sent out through EH&S; from this, LabRATS was able to identified at least 20 more replaceable setups save water and reduce flood risk.

Savings Calculations from Condenser Replacements

In order to document the potential water savings, an equation was developed:

gallons per minute (gpm) per condenser x fraction of time condenser is in use x number of condensers on campus = total gallons of water per year

Based on measurements conducted in a typical chemistry lab, condenser set-ups consume 1 - 2 gpm. According to rough estimations by the building manager of the Chemistry Department at the time this project initiated, an average graduate student uses a condenser between 48 to 60 hours per week. More conservative estimates from other university campuses put the number at 16 hours per week, so actual savings may fall over a range illustrated in the tables.

USAGE RATE:	0.25 GPM	0.5 GPM	1 GPM	2 GPM
16 HRS/WEEK	240	480	960	1,920
48 HRS/WEEK	720	1,440	2,880	5,760
60 HRS/WEEK	900	1,800	3,600	7,200
72 HRS/WEEK	1,080	2,160	4,320	8,640

Gallons of water consumed by a single condenser over one week of use depending on flow conditions and usage time.

USAGE RATE:	0.25 GPM	0.5 GPM	1 GPM	2 GPM
16 HRS/WEEK	2,400,000 (1.1%)	4,800,000 (2.2%)	9,600,000 (4.4%)	19,200,000 (8.8%)
48 HRS/WEEK	7,200,000 (3.3%)	14,400,000 (6.6%)	28.800,000 (13.2%)	57,600,000 (26.4%)
60 HRS/WEEK	9,000,000 (4.1%)	18,000,000 (8.3%)	36,000,000 (16.5%)	72,000,000 (33%)
72 HRS/WEEK	10,800,000 (5%)	21,600,000 (9.9%)	43,200,000 (19.8%)	86,400,000 (39.6%)

Annual Usage for weekly estimates, in gallons, 200 users, 50 weeks per year. The percent noted below are the percent of the total potable water usage for UCSB in the performance year of last STARS report: 217,943,205 Gal.

As reported in the Benchmarks section, 127 single-pass condenser setups have now been retired, saving the campus around 6.1 million gallons of water per year.

AUTOCLAVE INVENTORY AND PROFILING

Status: Present Effort and Area of Improvement

Description: Our campus currently operates 32 autoclaves, the majority of which are located in life science research buildings. Although no extensive replacement efforts are planned, the biology department's maintenance staff have been able to reduce autoclave water usage by up to 40% through augmentations to the steam traps on their consolidated autoclaves. Steam lock release (SLR) traps are fitted with a hole that is constantly bleeding water throughout the day, but the biology department has found that standard release traps with no hole can be substituted without affecting performance. An example of this is seen in comparing two Tunstall autoclaves on our campus. An SLR autoclave was found to use 1.35 gallons per hour (GPH) resulting in 32.22 gallons per day (GPD.) In contrast, a standard release autoclave used .951 GPH which resulted in 22.82 GPD. This has been successful in many other autoclaves and can be done at very low cost relative to other retrofit options.

For other autoclave brands where this steam trap option is not viable, LabRATS is continuing to look into retrofits that could support water and energy savings. Effluent cooling tanks are an affordable and simple technology that eliminates 90% or more of the water wasted at low cost, as long as there is enough of a footprint beneath or beside the existing autoclave for installation.

GLASSWARE AND SAMPLE WASHING

Status: Ongoing Effort through LabSYNC

Description: Glassware is a major reusable material in laboratories, and while this is important in terms of how sustainable the laboratory is, it may still come with an unnecessary environmental cost if the glassware is washed in an inefficient manner.

Some lab users wash contaminated containers or samples by running a steady flow of water into an already overflowing piece of glassware. This method has been shown quantitatively to be ineffective at making glassware or samples clean. It is extremely wasteful because the user is not controlling the outflow of water. LabRATS recommends that users refill and dump out rinse water several times, removing remaining soluble contaminants while also reducing the total amount of water used to rinse the glassware.

These are points are checked for on the LabSYNC assessment: establishing protocols for washing lab supplies that take into account water efficiency practices and limiting and controlling faucet flow through the use of aerators of water misers.

ELIMINATION OF DISTILLATION FOR WATER PURIFICATION

Status: Ongoing Effort Through LabSYNC and LabRATS

Description: Distillation, by which impure liquids are vaporized and the condensed vapor is collected, freer of impurities than its source pool, has historically been one reliable technique for purifying water for experimental purposes. However, this technology is both water intensive and energy intensive, and more modern water purification methods typically provide a comparable or better product at a fraction of the resource cost. No lab that has undergone LabSYNC assessment contains an operating still.

LABORATORY FAUCET MODIFICATION: AERATORS AND WATER MISERS

Status: Ongoing Effort Through LabSYNC and LabRATS

Description: Modifying a lab's faucet is a small but noticeable change. Faucets are used everyday to clean equipment and provide water to experiments, thereby discreetly adding significant amounts to how much water is used. Most lab faucets, by default, have a soft-plumb hose-fitting at their end, rather than an aerator. Most lab occupants do not need that type of fitting, given current technologies and laboratory practices; the sink is used for hand-washing and glassware washing the vast majority of the time, for which an aerator is actually more comfortable and effective. By installing an aerator, water miser or any flow control device onto the faucet, the lab is passively and permanently able to diminish its water usage.

Older labs can contact their respective building manager or a LabRATS representative to install aerators. However, new labs on campus will have faucets with flow control valves installed. As an incentive, the LabSYNC assessment awards this practice with one point per faucet.

EDUCATION AROUND WATER PURIFICATION

Status: Ongoing Effort Through LabSYNC and LabRATS

Description: Water purification processes other than distillation still have environmental impacts, in energy use, invisible streams of reject water, and waste generation of filter material. Through similar means as other water-related educational efforts, the conservation of purified water is promoted throughout the campus on an ongoing basis.

GREEN LABS INTEGRATION WITH CAMPUS WATER ACTION PLAN

Status: Established Integration, Ongoing Collaboration

In collaboration with students from the Donald Bren School of Environmental Science & Management (Bren School), LabRATS created the Water Action Plan.

The fundamental purpose of the Water Action Plan (WAP) is to identify future water reduction strategies at the University in accordance with objectives outlined by the UCOP. Goals in the WAP focus on implementing multiple conservation and efficiency strategies and substituting recycled water for potable water. This includes increasing the installation of low aerators, shower heads, and toilets in academic and housing buildings, improving the quality of recycled water used in irrigation and non-potable applications, expanding overall administrative actions such as installing real time meters in existing buildings, and implementing a campus wide outreach and awareness education program to encourage water conservation. Most goals in the WAP have an economic payback of one to four years.

Water usage data was analyzed in order to provide recommendations that will maximize water use efficiency at UCSB. Updates to the WAP are done when data shows that water use efficiency can be improved.

AREAS OF IMPROVEMENT AND IMPLEMENTATION STRATEGIES

Plug Load

OVERARCHING GOALS

- Provide information and incentives to facilitate selection of energy-efficient instrumentation at the time of first purchase.
- Highlight best practices in management of existing high-plug-load devices.
- Monitor major sources of plug-load power draw and analyze data to uncover energy savings opportunities.
- Encourage instrument manufacturers to prioritize energy efficiency in their product design.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Identify new funding mechanisms to incentivize the purchase of more energy efficient lab equipment.	Energy efficient ULT freezers can run at 50% of the kWh/day that traditional ULTs do. For fly incubators, 86% of the energy can be saved. These are a few examples of what is possible.	TGIF manages the current program; Further exploration needs to be done to find alternative funding	High
Plug Load Data Management and Follow-up	Actionable information to multiple parties guide plug-load related decisions during purchasing, operation, and repair/replacement of large biological instrumentation	LabRATS, impacting lab staff/occupants and Procurement	Medium
Equipment Purchasing Guidelines	Savings of up to 1 kW/hour or more for selecting certain large instruments with energy savings as a preference.	Procurement and LabRATS	Medium
Establish Mechanisms for Identifying Key Purchases	Larger fraction of major purchases impacted as described in previous strategy	Procurement and LabRATS	Medium

**Please note low priority strategies have been moved to the appendix.*

PLUG LOAD DATA MANAGEMENT AND FOLLOW-UP

The semi-permanent metering pilot was key in gaining insight to many power-usage phenomena associated with laboratory equipment. Data collected in these areas requires further analysis, sharing, and publication, all of which are an ongoing effort of the program.

It was also hoped that the system would provide real-time notification of a failed cold storage device as well as advanced warning of equipment failure. The data analysis and cloud notification systems available on the platform did not meet those needs, but LabRATS intends to monitor the development of this type of technology in the future.

In use of a system such as this, the risk of accidental power cuts constitutes the most crucial area of improvement. The reported pilot ended after multiple incidents where either user error or device malfunction caused an equipment outage with consequences for the laboratory. Any in-situ energy-monitoring system must eliminate this type of risk for laboratory users.

EQUIPMENT PURCHASING GUIDELINES

Purchases of major scientific equipment are a rare event for any given laboratory, and constitute a significant opportunity for long-term energy savings if the researchers are well-informed when they are in the market for new equipment. Else, it will be years or likely decades before an opportunity to improve the energy profile of the lab in that area will present itself.

In collaboration, LabRATS and the Procurement Office continue to find ways to identify and act within these time frames, to provide feedback and incentive for purchasers to select instruments that optimize energy and water use, or minimize the generation of ongoing waste streams. Opportunities to forge ties with incoming faculty will facilitate this endeavor, as well as flagging of certain types of purchases within the Gateway system, or through other means.

For many pieces of laboratory equipment though, the cost premium for an energy efficient model is well over $1,000, the energy savings potential is much greater. A robust incentive program would give financial and social capital to more buildings and departments that use energy-intensive devices such as vacuum pumps and cold storage.

ESTABLISH MECHANISMS FOR IDENTIFYING KEY PURCHASES

The Procurement Office, the LabRATS program, campus facilities, scientific departments, and other collaborators will continue to develop mechanisms to identify the time-periods when major purchases of instrumentation with high plug load are occurring, to allow opportunities for feedback to the purchaser, recommending energy-saving features or model selection where possible. Key targets for these strategies are bio-safety cabinets, cold storage, autoclaves, incubators, and vacuum pumps.

IDENTIFY NEW FUNDING MECHANISMS TO INCENTIVIZE THE PURCHASE OF MORE ENERGY EFFICIENT LAB EQUIPMENT.

XX have collaborated toward the development of a more permanently funded incentive program for the purchase of energy-efficient equipment options. In past years, LabRATS has been able to assemble funding for similar small, targeted programs; however, an ongoing source of funding for broad application of this type of incentive is strongly needed.

Most recently, TGIF has recently launched an equipment rebate program[1] supporting future investments in efficient equipment. Through this program, a researcher or department can receive support, up to a maximum of $1,000. Since its launch several interested researchers have reached out to TGIF.

Proposals for a broader utilities-savings-based fund which can be applied to assist in the purchase of energy-saving laboratory equipment are under consideration with the campus' Office of Budget and Planning.

1 http://www.sustainability.ucsb.edu/tgif-equipment-rebate-program/

Lighting

OVERARCHING GOALS:

- Expand the use of LED-based general lighting throughout laboratory spaces.
- Look for opportunities to retrofit older instruments with LED lighting options, and other benefits with a suitable return on investment.
- Encourage new instrument purchases to include LED lighting options.
- Encourage instrument manufacturers to offer LED features where they have not been provided.

UPGRADE OF ALL LAB SPACES TO LED LIGHTING

Campus-wide, there has been an endeavor to upgrade all indoor and outdoor spaces to LED lighting over traditional incandescent or fluorescent bulbs. In laboratories, this change is not yet complete. The switch is primarily motivated by the 40-50% energy savings seen between LED and T8 incandescent lights, as well as the significantly longer lifetime and decreased maintenance. Most laboratories on campus continue to be lit via fluorescent bulbs; around 5% have been retrofit to LEDs during recent renovation projects. Through the following years, LabRATS hopes to address the remaining spaces with comprehensive use of LED lighting.

IDENTIFY AND ADD LED RECOMMENDATIONS TO RELEVANT PURCHASING SHEETS

Our program will identify which products have new modifications in their current offerings regarding LED light sources for technical and general purposes, and update our purchasing recommendations to reflect this.

In LabSYNC assessments and consultations with new faculty, opportunities will continue to arise with new products and old which have not seen updating, or for which the updates or upgrades exist, but are not widely known. The LabRATS program will continue to research and publicize such new offerings, and where necessary, seek out other paths for retrofits or pressure manufacturers to add these to their offerings.

TRACK DEVELOPING TECH

Track developing tech and encourage requests to instrument manufacturers for LED retrofits and standardized LED lighting in new models.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Upgrade of all Lab Spaces to LED Lighting	Remaining 95% of campus lab ASF at 0.5 W/SF savings, 4000 hrs/yr operation = 1.8 million kWh/year of savings	Facilities Management	Medium
Identify and Add LED Recommendations to Relevant Purchasing Sheets	Savings of up to 0.5 - 5 kW/day per affected instrument.	Procurement and LabRATS	Medium
Track developing tech	Larger fraction of instruments affected as in previous strategy.	Procurement and LabRATS	Medium

Heating, Ventilation, and Air Conditioning (HVAC)

OVERARCHING GOALS:

- Adjust fume hood flow rates, exhaust ventilation rates, and strategies to safe and efficient levels.
- Approach to laboratory ventilation through a lab ventilation management plan or equivalent documents.
- Establish a road map for optimizing ventilation rates in remaining major campus lab buildings.
- Integrate existing and new guidelines, such as the UC Lab Safety Design Manual and UCSB Chemical Fume Hood Guide, into request for proposals for design and construction projects in lab buildings.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Fume hood 18" Sash Height Recalibration	PSBN decreased ventilation-related energy consumption by 30% through fume hood recalibration. Similar results expected in other CAV buildings.	Lab Ventilation Working Group	Medium
Optimize Ventilation, especially in Low-Chemical-Load Buildings	Cost in fan, heating, and cooling reduced by $2.50 or more per cfm	Lab Ventilation Working Group	Medium
Development of a Laboratory Ventilation Management Plan (LVMP) or Equivalent	Institutionalization of best practices	Lab Ventilation Working Group	High
Publication of a Chemical Fume Hood Guide	Information sharing to spread the best practice	Lab Ventilation Working Group	High
Establish a road map for maintaining optimized ventilation rates in remaining major campus lab buildings.	This step adds longevity to energy efficiency efforts and is also critical to thinking through safety as the type of research happening in labs changes.	Lab Ventilation Working Group	High
Design and Construction Services Continuing Education	Impact on critical design choices that affect the building throughout its useful life	Design and Construction Services and LabRATS	Medium

**Please note low priority strategies have been moved to the appendix.*

SAFELY DECREASING FUME HOOD FLOW RATES

Fume hood 18" Sash Height Recertification

Fume hoods in Physical Sciences Building North have been in the process of being recertified under new criteria set by the Lab Ventilation Working Group. As a result, the campus has changed sash heights from a certification of 100 linear feet per minute with the sash fully open at 23 inches, to a certification with the sash set to its 18 inch maximum operating height, decreasing ventilation cubic feet per minute by more than 20% per hood.

Hoods in other constant-air-volume spaces across campus should also be recertified to this new standard, through on-going work that requires funding and project scoping, yet to established.

OPTIMIZE VENTILATION, ESPECIALLY IN LOW-CHEMICAL-LOAD BUILDINGS

The triple-LEED-Platinum Certified Bren Building, contains a ventilation-management system that constantly samples laboratory air for contaminants, and actively controls ventilation rates based on detected data. Such systems require administrative oversight (to ensure that all possible airborne contaminants will be detectable by the system's sensors) as well as continuous maintenance.

The campus will continue to look for areas where active engineering technologies in applicable in safely decreasing necessary ventilation settings without compromising user or fire safety. Research labs with low chemical loads, such as physics or geology buildings, are potential strong candidates for this type of system. Personnel resources at Environmental Health and Safety, are necessary to maintain administrative measures which complement and support this efficiency measure.

DEVELOPMENT OF A LABORATORY VENTILATION MANAGEMENT PLAN (LVMP) OR EQUIVALENT

The types of measures described above should be incorporated into a Laboratory Ventilation Management Plan, which documents the campus' approach to lab ventilation practice and policy, describes the roles and responsibilities of all stakeholders, and outlines the administrative structures which will support the operation and ongoing redefinition of the plan over time. The Chemical Fume Hood Guide currently under development at EH&S may serve to fill the role of much this document. Coupled with a road map for optimization and ongoing maintenance/improvement of existing buildings, the recommendations of the ANSI Z9.5 and Z10 standards could be properly met.

PUBLICATION OF A CHEMICAL FUME HOOD GUIDE

A new Chemical Fume Hood Guide will be published by EH&S with review and feedback from the Lab Ventilation Working Group. The intention is to integrate this guide into Design and Construction Services documentation resources for sharing with design teams, UCOP's Laboratory Safety Design Manual, and an EH&S Design Plan Review Document. This will allow improved tracking of design elements which motivate specific safety concerns in new construction and renovation projects.

Establish a road map for maintaining optimized ventilation rates in remaining major campus lab buildings.

The Laboratory Ventilation Working Group is beginning discussions of the next laboratory buildings to target for energy- and cost-saving renovation through optimizing safe ventilation practices.

DESIGN AND CONSTRUCTION SERVICES CONTINUING EDUCATION

In recent presentations to DCS, project managers appreciated receiving campus-specific and up-to-date information regarding recently established practices for sustainability, energy management, and researcher support in laboratory design and renovation projects. Further presentations to design staff by the Lab Ventilation Working Group and LabRATS will help DCS stay apprised of developing best practices in lab design and of feedback received from researchers based on the changing needs of research environment.

Storage and Sample Management

OVERARCHING GOALS:

- Improve freezer management and only set freezers as cold as they need to be.
- Develop systems to better track lab samples and chemicals.
- Reduce clutter and space demands by making it easier for researchers to donate equipment.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Campus Engagement in Freezer Inventory and Maintenance	Reduced need for freezers.	LabRATS and Researchers	Medium
Improved Chemical and Inventory Sharing	Reduced storage of chemicals.	EH&S with promotional support from LabRATS	Medium
Ultra-Cold Sample Longevity Study	Demonstrate scientifically whether storing samples at -700C impacts sample integrity. If no negative impacts, this study would empower more researchers to follow the practice.	Dr. Hodges, Dr. Montell, and LabRATS	Medium

**Please note low priority strategies have been moved to the appendix.*

CAMPUS ENGAGEMENT IN FREEZER INVENTORY AND MAINTENANCE

While LabSYNC helps increase the engagement slowly on a wide range of issues, the environmental footprint of Freezers behooves us to place extra emphasis in this area. It has been several years since a major push was made to assist labs in optimizing their freezer usage and making the transition to new electronic inventorying technologies. Greater efforts in this area as part of the National Freezer challenge may motivate researchers though community spirit, potential rewards and prizes, and national recognition of the university.

IMPROVED CHEMICAL AND INVENTORY SHARING

Other campuses are known to have more organized chemical inventory management systems in place, which decreases waste, maximizes sharing, allows for efficient purchasing, and ensures that materials are used in a timely fashion.

UCSB has been piloting a mobile app for chemical inventory management, called UC Chemical, which has met with good results in the lab groups who have adopted it for testing. This app, with additional features to integrate the campus' Surplus Chemical Program, and possibly to allow for other types of materiel management in the laboratory setting, would permit more facile sharing and chemical management across the campus, ultimately reducing waste by giving researchers another facet to obtain chemicals used in the workplace.

ULTRA-COLD SAMPLE LONGEVITY STUDY

Typically, ULT freezers are set to -86°C or -80°C. This set point that was created in order to match the temperature of dry ice and not in response to any scientific study on sample quality. Setting

older freezers -70°C can decrease their energy consumption by up to 40% in some cases. Additionally, decreasing load on the compressors likely prolongs freezer life.

There is presently a lack of scientific data on safe sample-storage temperatures. Researchers cannot afford to risk precious samples, and there is no quantitative, peer-reviewed data demonstrating sample longevity at -70°C as opposed to the more traditional -80°C. However, an increase of setpoint from -80° to -70° would decrease kilowatt hours per month by approximately 100-150, decreasing costs by $50-$100 per year[2]. In addition to energy savings from the temperature change, freezers can last longer at the higher temperature, as compressors undergo fewer, shorter cycles hence stress.

The campus is presently running a rigorous study in hopes of better-documenting the safety, feasibility, and practicality of storing samples at lower temperatures. Western blots, gel electrophoresis, and other analysis techniques will compare samples stored at the two different temperatures over the course of six months and one year. LabRATS hopes to demonstrate that this can save costs and reduce risks to samples related to freezer replacement and maintenance. It is intended that the results of this study will be published in a peer-reviewed journal.

2 https://www.med.upenn.edu/spo/documents/FreezerRecommendations8.5x11_Penn-5.pdf

Waste Management

OVERARCHING GOALS:

- Develop a strategy for addressing our inability to recycle plastics #3-7 and other unique laboratory plastics.
- Include an impactful education campaign that emphasizes recycling changes.
- Explore opportunities to work with manufacturers and suppliers that can take back laboratory waste.
- Expand laboratory composting.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Plastics 3-7 and Lab Plastics	9,168 lbs per year if all Plastics 3-7 were eliminated from laboratories. This is infeasible, but presents a sense of scale. The percentage of that amount that could be eliminated is unknown at this time.	Researchers, LabRATS, and Facilities Management	High
Lowering Equipment Transfer and Donation Barriers	Exact estimates are not available at this time.	Procurement and LabRATS	Medium
Waste reduction through Reuse	This could potentially help with the 9,168 lbs per year of plastics 3-7.	Researchers and LabRATS	Medium
Lab Coats	250 Lbs. per year based on lessons learned from the pilot	Chemical Storeroom, faculty of lab classes, UCSB Bookstore, and LabRATS	Medium (Almost completed pilot)
Fly Vials	3,600 lbs per year	Principal Investigator and Lab Manager of Drosophila raising labs. LabRATS to help in researching options.	Medium
Styrofoam	Very lightweight material and so the lbs are unlikely to be significant. The larger impact will be from reduced styrofoam pollution and the volume of dumpsters filled.	Researchers, Procurement (for upstream solutions), and LabRATS	Medium
Take Back Programs	This could potentially help with the 9,168 lbs per year of plastics 3-7.	Researchers, Procurement (for upstream solutions), and LabRATS	Medium

**Please note low priority strategies have been moved to the appendix.*

PLASTICS #3-7 AND LAB PLASTICS

With changes to overseas recycling disposal options, many types of plastic can no longer be easily recycled. If new sources are not found for the sale of these materials, there may be difficulties with disposal of an increasing range of previously recyclable lab materials.

LOWERING BARRIERS FOR EQUIPMENT TRANSFER AND DONATION

Many laboratories have been "collecting" equipment over their time at UCSB. As a result, labs run out of space and come to us with what options they have regarding their equipment management. Moving equipment within the campus from one lab group to another is fairly straightforward and LabRATS has been able to facilitate that. Though it has been challenging to donate off-campus (such as to the science program of a local school or STEM based non-profit). This was what prompted the beginning of our efforts toward creation of an effective equipment donation program.

Currently there is a group of procurement, asset management, and sustainability professionals from several UC campuses that are working together to develop a clear and easy to follow protocol for donating equipment external to the university. Currently the guidelines within BUS 38, one of the main UC policies which addresses donations, presents challenges for researchers wanting to donate their equipment. In particular, it is unclear how to demonstrate de minimus value without investing more staff time than the item to be donated is worth. The staff time for a researcher to navigate the donation process can also be a barrier.

WASTE REDUCTION THROUGH REUSE

With materials that used to be recyclable no longer able to be recycled, it is ever more important to reduce and reuse. This will have to be carefully considered by each lab with consideration for contamination issues and impacts on research.

SPECIALTY WASTE STREAMS

Laboratory waste streams are filled with unusual and specific waste streams, difficult to divert from the landfill. Continued work is necessary to address these special sources of waste and wherever possible, such as changing either what is procured and used in the lab, or where and how items are disposed of. This becomes especially imperative in light of UC and State of California waste diversion goals.

LAB COATS

While research labs make use of cleaning services and reuse lab coats through the campuswide PPE program, campus teaching labs require that students procure their own lab coats, which are then disposed of when the student reaches the end of their learning-lab career. The UCSB Bookstore and LabRATS have been conducting a pilot to try to eliminate this waste stream through collecting unwanted coats, laundering them, and selling them used in the campus bookstore. The initial pilot will be completed at the end of Winter 2018 and at that point, LabRATS will assess whether it makes sense to continue the program.

FLY VIALS

Drosophila breeding programs in the campus' fruit fly laboratories generate a very significant quantity of waste in the form of sterilized fly vials, which contain fly waste and food remains. The presence of the remaining organic material makes this waste stream difficult to divert to recycling. Alternative vial materials and methods for removing the organics are being examined in an effort to divert this specific source of waste.

STYROFOAM

Styrofoam is typically seen in lab spaces in the form of packing peanuts and coolers. Packing peanuts can be used on site for future shipping needs. Also many companies are beginning to move away from styrofoam peanuts as there are several more sustainable alternatives. Similar to the pipette take-back programs, there are take-back programs for coolers, especially those used for shipping lab materials and samples.

TAKE BACK PROGRAMS

A way to deal with the changing recycling options is to implement take-back programs, where the company who produces an item is willing to take that material back at the end of life and typically remanufacture the material into their product line. In other models of take-back programs, the collected material may be downcycled into another product.

Typically made of #5 plastic, pipette tip boxes are rarely accepted by curbside recycling programs and have become part of a significant waste stream to landfills and incinerators. One program is the Pipette Tip Box Recycling Program from TerraCycle. This program provides a complete waste collection, shipment, and recycling solution for used pipette tip boxes. All brands of plastic pipette tip boxes are accepted. The plastic waste is ground, melted, and formed into pellets through extrusion by TerraCycle to create recycled resin. The resin is then combined with other recycled plastics to make other products, such as park benches.[34]

Hazardous Waste and Green Chemistry

OVERARCHING GOALS:

- Use less toxic chemicals where possible and where these alternatives would not compromise the research goals.
- Partner with honors classes to test alternatives for teaching labs.
- Promote technologies for improved chemical inventory management and chemical sharing.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Promotion of the UC Chemical Application	Better sharing of chemicals; potential reduction in unneeded chemicals due to better inventory management	EH&S	High
Green Chemistry Modules in Teaching Labs	Educating new scientists	Faculty with expertise in green chemistry; Faculty of teaching labs	Medium
Ethidium Bromide Alternatives	Reduction in toxins on campus and reduced need for hazardous waste processing	Principal Investigators and Lab Managers of labs that use Ethidium Bromide	Medium

**Please note low priority strategies have been moved to the appendix.*

3 https://us.vwr.com/store/product/9227627/pipet-tip-box-recycling-program-terracycle

4 http://www.labconscious.com/green-lab-tips/2017/11/16/how-to-recycle-pipette-tips

PROMOTION OF THE UC CHEMICAL APPLICATION

The UC Chemical Application has taken time to pass through the development and pilot stages to enter the campus's market, however as that day approaches, increased efforts to engage researchers in implementation of the platform will be important for the program to be successful. LabRATS will make efforts to build engagement that will be necessary for the campus-wide shift in perspective on chemical usage and decrease in chemical waste production. If the program takes hold, LabRATS expects a significant, reduction in purchasing and waste streams.

GREEN CHEMISTRY MODULES IN TEACHING LABS

When LabRATS first started, the program partnered with a chemistry faculty member who was using a toxic chemical in one of their courses. Using the MIT Green Purchasing Wizard, LabRATS identified a potential alternative to the chemical. A pilot was designed where the honors section would test out the less toxic alternative and the regular class would be the control group. The honors class found that the alternative did not work well within the experiment they were focusing on in the class and so a change was not made. That said, the honors students learned a lot and reported positively on the experience. The Chemistry Department also gained valuable knowledge that the initial recommendation would not be successful and other alternatives would need to be pursued. This model could be used in future situations where an alternative chemical is being considered for a teaching lab.

ETHIDIUM BROMIDE ALTERNATIVES

Ethidium bromide (EtBr) is a ubiquitous non-radioactive DNA stain to identify and visualize nucleic acid bands in electrophoresis and perform other methods of nucleic acid separation.

EtBr is a flat molecule that fits between adjacent base pairs in the DNA double helix. It's used in DNA-staining (gel electrophoresis). Due to it fitting between DNA, it is thought to act as a mutagen. As such, researching alternatives is in our best interest.

In the Ames test[5], 90 micrograms of ethidium bromide is as mutagenic as the smoke from one cigarette.

Alternatives to EtBr include methylene blue, crystal violet, SYBR safe and Gel Red. Of these alternatives, methylene blue is non-mutagenic; however, the other DNA stains are less mutagenic than EtBr. While methylene blue is non-mutagenic it is less sensitive than EtBr and the other alternatives.

SYBR safe and Gel Red do not have to be disposed of as hazardous waste. LabRATS would like to identify labs using ethidium bromide and identify if a replacement would be viable in their research.

5 a test to determine the mutagenic activity of chemicals by observing whether they cause mutations in sample bacteria

Travel and Field Work

OVERARCHING GOALS:

- Encourage the use of "leave no trace" principles when doing fieldwork to the extent possible while still achieving research goals.
- Reduce the impact of research related travel through procurement of carbon offsets.
- Look for opportunities to collaborate electronically rather than traveling.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Leave No Trace Principles in Fieldwork	Varies by the type of research and field study design	Researchers w/ LabRATS support	Medium
Travel Impacts	Benchmarking not well defined for research travel yet. Likely to be a substantial portion of our GHG emissions.	Researchers w/ LabRATS support	Medium

**Please note low priority strategies have been moved to the appendix.*

LEAVE NO TRACE PRINCIPLES IN FIELDWORK

LabRATS encourages researchers to reduce their impact on field sites where possible given the research goals. This could include ensuring materials such as flags or other markers are removed from field sites at the end of the research.

TRAVEL IMPACTS

Researchers can reduce their travel-related greenhouse gas emissions through using teleconferencing and other electronic communication means for some visits. In addition to this, LabRATS recommends considering the purchase of carbon offsets when travel is needed.

Communications, Engagement, and Design

OVERARCHING GOALS:

- Establish campus culture of lab sustainability with all incoming researchers.
- Provide relevant feedback on all lab-related construction projects.
- Strengthen and streamline collaborative opportunities and resource sharing between labs, researchers, departments, and technical staff.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Enable 30% of laboratory groups at UCSB to have a LabSYNC assessment.	Could reach over 525 researchers in an in depth program.	LabRATS and researchers	High
Establish campus culture of lab sustainability with all incoming natural and physical science graduate students.	Could reach over 960 graduate students, a little less than a third of the researchers on the campus	LabRATS with support of Graduate Student Advisors, Chairs, and Department Heads	High
Provide More Comprehensive Orientations for Incoming Faculty	Set the standard when faculty first arrive on campus	LabRATS, department chairs, and AMPs	Medium
Increase Design Review for Small-scale Renovations	Implementing changes at the design level can affect resource use over the lifetime of a building or space	Design and Construction Services and LabRATS	Medium

**Please note low priority strategies have been moved to the appendix.*

ENABLE 30% OF LABORATORY GROUPS AT UCSB TO HAVE A LABSYNC ASSESSMENT

The LabSYNC assessment process is the best way for a research or teaching laboratory to receive a complete analysis of their current practices. Through the assessment, researchers can learn about ways to save water and energy, as well as reduce waste.

ESTABLISH CAMPUS CULTURE OF LAB SUSTAINABILITY WITH ALL INCOMING NATURAL AND PHYSICAL SCIENCE GRADUATE STUDENTS.

Currently, outreach efforts are made for the incoming researcher cohorts in the Chemistry department, and for new faculty in some areas of campus. Expanding the trainings and outreach efforts to include additional cohorts of incoming graduates, and developing strategies to outreach and connect with incoming post-doctoral researchers, are the necessary steps in helping to further embed the culture of ongoing laboratory sustainability into the campus' research fabric. More departments must be enrolled, and information received from various sources --department welcome materials, orientations, safety trainings, etc., should be complementary and reinforce overlapping messages.

PROVIDE MORE COMPREHENSIVE ORIENTATIONS FOR INCOMING FACULTY

LabRATS is actively working on developing the departmental connections needed to make early touch with new faculty members and offer assistance in lab design and instrument selection.

INCREASE DESIGN REVIEW FOR SMALL-SCALE RENOVATIONS

Implementation of sustainable practices is often easiest when a new laboratory is being designed and renovated for updated use.Often new instrumentation is selected at these times as well. Currently, there is no formal mechanism for sustainable design review in small scale lab renovations, but increased ties with Design and Construction Services and campus administrative departments are facilitating LabRATS' opportunities to influence how laboratories are initially designed.

By contacting new faculty as they begin to create their physical lab space, new faculty and LabRATS could work together as a team to create a sustainable space with energy efficient appliances from the start.

Water

OVERARCHING GOALS:

- Eliminate Single Pass Cooling in Campus Labs.
- Identify and disseminate best practices for washing methodologies.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Retrofit autoclaves where possible on campus with water saving technology, develop a plan for addressing remaining autoclaves.	Potential for 8,500,000 gallon/year savings based on retrofit of 50% of autoclaves	LabRATS working with Building Managers and Principal Investigators	High
Eliminate Single Pass Cooling in Soft Plumbed Systems	86,000 gallons of water saved per week since installation of 60 replacements to single pass cooling.	LabRATS engaging researchers	High

**Please note low priority strategies have been moved to the appendix.*

RETROFIT AUTOCLAVES WHERE POSSIBLE ON CAMPUS WITH WATER SAVING TECHNOLOGY, DEVELOP A PLAN FOR ADDRESSING REMAINING AUTOCLAVES.

Please see the "Autoclave Inventory and Profiling" under best practices for details on some areas where UCSB has been able to modify existing autoclaves. Moving forward, LabRATS hopes to retrofit the existing autoclaves that have not yet been adapted for water efficiency measures. Retrofit packages have been found for three of UCSB's current autoclaves and LabRATS is in the process of identifying similar options for the remaining units. When future autoclaves are purchased, units with the latest water efficient technologies should be purchased.

ELIMINATE SINGLE PASS COOLING IN SOFT PLUMBED SYSTEMS

UCSB is expected to eliminate soft plumbed single pass cooling systems by June 2019. LabRATS has led several communications campaigns to identify and replace single pass cooling systems. In 2018-2019, a new campaign themed around old western "Wanted" Posters is being launched to remind researchers of the policy to eliminate single pass cooling. This is the last year in which LabRATS expects to need to purchase replacements to single pass in order to incentivize labs not to use soft plumbed single pass cooling systems.

CONCLUSION

UC Santa Barbara has piloted or established a thorough and comprehensive range of programs addressing nearly every aspect of laboratory research sustainability. In many cases, successful small-scale pilots would strongly benefit from more wide-spread or ongoing implementation throughout research departments. In particular, educational efforts directed toward the campus' continually revolving cohort of graduate and post-doctoral researchers. Broadening awareness and engagement is a major overarching goal for the campus' green labs program.

Sustainable laboratory practices need to be integrated into the established operational/ administrative workflows and research protocols used on campus. Procurement decisions are made quickly, and without integration into the existing processes, the campus can miss key opportunities to affect change. Multi-stakeholder collaborations are also critical to ensuring that UCSB is appropriately tapping into the expertise of our faculty, researchers, and staff. Instances of fruitful on-going endeavors are among programs adopted by collaborating departments, such as Procurement, Environmental Health and Safety, the Office of Research, or specific labs or shops on campus. The UCSB Sustainability Program can help launch initiatives, but has limited resources for long-term stable support for ongoing efforts. Most of the projects LabRATS has launched have now found their home in other departments.

Finally, UCSB must keep apprised of changes in the research operational landscape to continually develop cutting-edge practices and technology. UCSB's green labs must continue to collaborate and share with other institutions, and advocate for improvement on qualities of long-term instrumentation and short-term consumables on environmentally-conscious basis to suppliers and manufactures.

Recognized in articles and conference publications, UCSB is at the forefront of Green Labs Programs nationwide. UCSB must remain active, both on its campus, and within the broader green labs community, to maintain its place of wide recognition and impact in this sphere.

REPORTING

This plan will be updated every two years. UCSB LabRATS will be the project manager of the plan writing and updating, but will consult with faculty, staff, and students across the campus to ensure the plan represents the campus as a whole.

The plan will be submitted to the UC Systemwide Green Operations and Sustainable Laboratory Working Group and the UC Sustainability Steering Committee, who oversees the UC Policy on Sustainable Practices.

SUMMARY OF HIGH AND MEDIUM IMPLEMENTATION STRATEGIES

Plug load

OVERARCHING GOALS:

- Provide information and incentives to facilitate selection of energy-efficient instrumentation at the time of first purchase.
- Highlight best practices in management of existing high-plug-load devices.
- Monitor major sources of plug-load power draw and analyze data to uncover energy savings opportunities.
- Encourage instrument manufacturers to prioritize energy efficiency in their product design.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Identify new funding mechanisms to incentivize the purchase of more energy efficient lab equipment.	Energy efficient ULT freezers can run at 50% of the kWh/day that traditional ULTs do. For fly incubators, 86% of the energy can be saved. These are a few examples of what is possible.	TGIF manages the current program; Further exploration needs to be done to find alternative funding	High
Plug Load Data Management and Follow-up		LabRATS	Medium
Equipment Purchasing Guidelines		Procurement and LabRATS	Medium
Establish Mechanisms for Identifying Key Purchases		Procurement and LabRATS	Medium

Lighting

OVERARCHING GOALS:

- Expand the use of LED-based general lighting throughout laboratory spaces.
- Look for opportunities to retrofit older instruments with LED lighting options where possible, and where the efficiency improvements or other benefits have a suitable return on investment.
- Encourage new instrument purchases to include LED lighting options wherever available.
- Encourage instrument manufacturers to offer LED features where they have not been provided.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Upgrade of all Lab Spaces to LED Lighting		Facilities Management	Medium
Identify and Add LED Recommendations to Relevant Purchasing Sheets		Procurement and LabRATS	Medium
Track developing tech and encourage requests to instrument manufacturers for LED retrofits and standardized LED lighting in new models		Procurement and LabRATS	Medium

Heating, Ventilation, and Air Conditioning

OVERARCHING GOALS:

- Adjust fume hood flow rates and exhaust ventilation rates and strategies to levels which achieve both safety and energy efficiency goals.
- Develop the campus' strategic approaches to laboratory ventilation through the development of a lab ventilation management plan or equivalent documents.
- Establish a road map for optimizing ventilation rates in remaining major campus lab buildings.
- Integrate existing and new guidelines, such as the UC Lab Safety Design Manual and UCSB Chemical Fume Hood Guide into request for proposals for design and construction projects in lab buildings

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Fume hood 18" Sash Height Recalibration	PSBN decreased ventilation-related power consumption by 30% through fume hood recalibration.	Lab Ventilation Working Group	Medium
Optimize Ventilation, especially in Low-Chemical-Load Buildings		Lab Ventilation Working Group	Medium
Development of a Laboratory Ventilation Management Plan (LVMP) or Equivalent	Institutionalization of best practices	Lab Ventilation Working Group	High
Publication of a Chemical Fume Hood Guide	Information sharing to spread the best practice	Lab Ventilation Working Group	High
Establish a road map for maintaining optimized ventilation rates in remaining major campus lab buildings.	This step adds longevity to energy efficiency efforts and is also critical to thinking through safety as the type of research happening in labs changes.	Lab Ventilation Working Group	High
This step adds longevity to energy efficiency efforts and is also critical to thinking through safety as the type of research happening in labs changes.	Impact on critical design choices that affect the building throughout its useful life	Design and Construction Services and LabRATS	Medium

Storage and Sample Management

OVERARCHING GOALS:

- Improve freezer management and only set freezers as cold as they need to be.
- Develop systems to better track lab samples and chemicals.
- Reduce clutter and reduce space demands by making it easier for researchers to donate equipment.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Campus Engagement in Freezer Inventory and Maintenance	Reduced need for freezers.	LabRATS and Researchers	Medium
Improved Chemical and Inventory Sharing	Reduced storage of chemicals.	EH&S with promotional support from LabRATS	Medium
Ultra-Cold Sample Longevity Study	Demonstrate scientifically whether storing samples at -700C impacts sample integrity. If no negative impacts, this study would empower more researchers to follow the practice.	Dr. Hodges, Dr. Montell, and LabRATS	Medium
Publication of a Chemical Fume Hood Guide	Information sharing to spread the best practice	Lab Ventilation Working Group	High

Waste Management

OVERARCHING GOALS:

- Develop a strategy for addressing the reduction in our ability to recycle plastics #3-7 and other unique laboratory plastics. Include an impactful education campaign that emphasizes the changes.
- Explore opportunities to work with manufacturers and suppliers that can take back laboratory waste.
- Expand laboratory composting.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Plastics 3-7 and Lab Plastics	9,168 lbs per year if all Plastics 3-7 were eliminated from laboratories. This is infeasible, but presents a sense of scale. The percentage of that amount that could be eliminated is unknown at this time.	Researchers, LabRATS, and Facilities Management	High
Lowering Equipment Transfer and Donation Barriers	Exact estimates are not available at this time.	Procurement and LabRATS	Medium
Waste reduction through Reuse	This could potentially help with the 9,168 lbs per year of plastics 3-7.	Researchers and LabRATS	Medium
Lab Coats	250 Lbs. per year based on lessons learned from the pilot	Chemical Storeroom, faculty of lab classes, UCSB Bookstore, and LabRATS.	Medium (Almost completed pilot)
Fly Vials	3,600 lbs per year	Principal Investigator and Lab Manager of Drosophila raising labs. LabRATS to help in researching options.	Medium
Styrofoam	Very lightweight material and so the lbs are unlikely to be significant. The larger impact will be from reduced styrofoam pollution and the volume of dumpsters filled.	Researchers, Procurement (for upstream solutions), and LabRATS	Medium
Take Back Programs	This could potentially help with the 9,168 lbs per year of plastics 3-7.	Researchers, Procurement (for upstream solutions), and LabRATS	Medium

Hazardous Waste and Green Chemistry

OVERARCHING GOALS:

- Use less toxic chemicals where possible and where an alternative would not compromise the research goals.
- Partner with honors classes to test alternatives for teaching labs.
- Promote technologies for improved chemical inventory management and chemical sharing.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Promotion of the UC Chemical Application	Better sharing of chemicals; potential reduction in unneeded chemicals due to better inventory management	EHS	High
Green Chemistry Modules in Teaching Labs	Educating new scientists	Faculty with expertise in green chemistry; Faculty of teaching labs	Medium
Ethidium Bromide Alternatives	Reduction in toxins on campus and reduced need for hazardous waste processing	Principal Investigators and Lab Managers of labs that use Ethidium Bromide	Medium

Travel and Field Work

OVERARCHING GOALS:

- Encourage the use of "leave no trace" principles when doing fieldwork to the extent possible while still achieving research goals.
- Reduce the impact of research related travel through procurement of carbon offsets.
- Look for opportunities to collaborate electronically rather than traveling.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Leave No Trace Principles in Fieldwork	Varies by the type of research and field study design	Researchers w/ LabRATS support	Medium
Travel Impacts	Benchmarking not well defined for research travel yet. Likely to be a substantial portion of our GHG emissions.	Researchers w/ LabRATS support	Medium

Communications, Engagement, and Design

OVERARCHING GOALS:

- Establish campus culture of lab sustainability with all incoming researchers.
- Provide relevant feedback on all lab-related construction projects.
- Strengthen and streamline collaborative opportunities and resource sharing between labs, researchers, departments, and technical staff.

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Enable 30% of laboratory groups at UCSB to have a LabSYNC assessment.	Could reach over 525 researchers in an in depth program.	LabRATS and researchers	High
Establish campus culture of lab sustainability with all incoming natural and physical science graduate students.	Could reach over 960 graduate students, a little less than a third of the researchers on the campus	LabRATS with support of Graduate Student Advisors, Chairs, and Department Heads	High
Provide More Comprehensive Incoming Faculty Orientations	Set the standard when faculty first arrive on campus	LabRATS, department chairs, and AMPs	Medium

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Increase Design Review for Small-scale Renovations	Implementing changes at the design level can affect resource use over the lifetime of a building or space	Design and Construction Services and LabRATS	Medium

Water

OVERARCHING GOALS:

- Eliminate Single Pass Cooling in Campus Labs
- Identify and disseminate best practices for washing methodologies

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Retrofit autoclaves where possible on campus with water saving technology, develop a plan for addressing remaining autoclaves.	Potential for 8,500,000 gallon/year savings based on retrofit of 50% of autoclaves	LabRATS working with Building Managers and Principal Investigators	High
Eliminate Single Pass Cooling in Soft Plumbed Systems	86,000 gallons of water saved per week since installation of 60 replacements to single pass cooling.	LabRATS engaging researchers	High

THE BACK BURNER

The following projects are ones that are low priority due to one or more of the following reasons:

- Limited impact in comparison with other goals
- Requires funding, time, or other resources that are not yet available
- Not feasible given current physical, temporal, legal, or policy limitations
- Negative consequences could be triggered which cannot be mitigated at this time

These ideas have been conserved in this appendix so that they can be reconsidered at such a time when one of the conditions above may change.

Lighting

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Additional Specialty Lab Lighting Applications	Overall kWh impact modest; Additional impacts in mercury spill reduction	LabRATS and researchers	Low

ADDITIONAL SPECIALTY LAB LIGHTING APPLICATIONS

Many pieces of research equipment, from bio-safety cabinets to incubators to a range of microscopes, make use of lighting as part of their operation. In many of these cases, instrument manufacturers have not fully made the transition to installing LED lighting by default, decreasing heat load. Additionally, historically purchased instruments stay in operation with the lights they were outfitted when manufactured.

HVAC

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Fume Hood Sash Sticker Redesign for CAV hoods	Increased education around value of sash closures. No energy savings on CAV hoods, however there are safety benefits.	EHS, Facilities, and LabRATS	Low. Though this is low priority, LabRATS is still completing this in the 2018-2019 school year.
Pursuit of CalOSHA Variance for Sash Velocity	Significant impact at the statewide level as this would make it easier for UCSB and other campuses to calibrate sash velocity to the specific needs of the space.	EHS, LabRATS, and peers at other UC campuses	Low

FUME HOOD SASH STICKER REDESIGN

Environmental Health and Safety has requested an update to the vertical sash sticker UCSB first designed in 2009. This sticker is present on all campus Variable Air Volume (VAV) labs. To allow the sticker to be accurately placed on Constant Air Volume (CAV) fume hoods, the sticker will need to be updated to focus on safety and to remove references to saving energy. In a CAV hood, closing the sash will not save energy but will improve safety. LabRATS interns developed a new design and will post those by the end of the 2018-2019 academic year.

PURSUIT OF CALOSHA VARIANCE OR RE-DEFINITION OF FUME HOOD FACE VELOCITY STANDARD

A UC system-wide initiative to reduce the 100 lfm standard to 80 lfm would be a desirable effort to pursue, with support of industrial hygienists and ventilation experts. This standard is relatively common in other states, yet CalOSHA has resisted adopting this standard for qualifying hoods, even though it would further lower occupied hood air flow, and be especially relevant in organic chemistry labs and instructional settings with high abundance of open hoods during working hours. UCSB would join other campuses in this initiative, but does not have the personnel capacity to take the lead on such an effort at this time.

Storage and Sample Management

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
National Freezer Challenge	UCSD saved 500,000 kWh/yr as a result of their participation in the freeze r challenge in 2016-2017. 200 researchers were engaged.	Researchers	Low

NATIONAL FREEZER CHALLENGE

The National Freezer Challenge promotes sample accessibility, cost reduction, and energy efficiency through improved freezer use and maintenance. Laboratories seek efficient, effective sample storage and remove unneeded or unviable samples from refrigeration units. As a result, this reduces the cost associated with maintaining more refrigeration units than deemed necessary. The Freezer Challenge works on a point scale system and laboratories are allowed to work over a five-month period at their own pace for comfort. Any optimal cold storage unit is acceptable and scorecards are then ranked against other institutions around the world.

Incentives implemented by other campuses are luncheons for all those participating to encourage networking amongst different labs on campus, cash incentives to help pay for new energy efficient laboratory equipment, or raffles for prizes such as a coffee maker.

Waste

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Lab Gloves	Kimberly Clark's glove recycling program is the closest to being viable, but still has some challenges. In 2016, UCSB purchased 443 boxes.	Researchers, Store rooms, and LabRATS	Low
Animal Bedding and Other Compostable Lab Materials	Currently the labs that this could work for have inconsistent waste streams that can be significant but are spotty in flow. One potential to explore further would be composting in teaching labs with dissections.	Researchers; TAs and Faculty of laboratory courses with dissections; and LabRATS	Low
Reuse of Lab Safety Glasses	Not yet quantified	LabRATS	Low

Lab Gloves

A large chunk of the typical laboratory waste stream consists of used lab gloves, which are disposed of at a high rate in many labs. There are a few commercial options for lab glove recycling, and UCSB continues to examine whether any of them are cost-effective and logistically feasible. Some glove manufacturers will accept the return of their gloves, but will not allow gloves from other manufacturers to be included in the returned material. Shipping costs and storage of gloves before shipping also need to considered. Some labs have expressed interest in addressing this waste stream, so it is hoped a pilot will be launched in the future.

Animal Bedding and Other Compostable Lab Materials

Most animal bedding collected at UCSB is now being collected for compost. There are several other potential composting streams such as compost from lab classes where they are working with plants or animal dissections. In these cases, there is enough waste to make a pick up worthwhile, however, a plan for how to address the intermittent nature of when that compost is available for pick-up would need to be developed. Similarly, some laboratories have identified potential compost streams from their research, but LabRATS is still developing strategies to address the intermittent flow of the waste streams.

Reuse of Lab Safety Glasses

The concept to reuse lab safety glasses was suggested during the development of this green lab action plan. The project hasn't been researched very much yet, however, this concept should be explored in future years.

Hazardous Waste and Green Chemistry

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Update the MIT Green Purchasing Wizard	TBD	Faculty interested in Green Chemistry	Low
Solvent Recycling and other Re-Use Technologies	TBD; Likely applicable to a small number of campus labs	Researchers, EHS and LabRATS	Low

Update the MIT Green Purchasing Wizard

To further our efforts in hazardous waste management and green chemistry, LabRATS hopes to find several graduate students to work on an application that would rival MIT's Green Chemistry Alternatives Purchasing Wizard[1]. Although this site allows researchers using potentially harmful chemicals to find less hazardous alternatives, the site does not appear to be updated in many years. Doing so would require securing a significant grant and identifying a faculty lead for the project.

Solvent Recycling and other Re-Use Technologies

A number of labs have been identified that use large volumes of acetone in the course of their experiments. Recycling systems exist to re-purify used solvents such as this, and could be incorporated into the operations of those labs to significantly diminish the hazardous waste stream processed by EH&S. Recycled acetone is no longer solvent grade but can be used to clean stuff.

Products, such as automated pipette tip washer, recently launched to market also have potential to eliminate other single-use materials from the waste stream and should be assessed for cost-effectiveness and viability for single labs, groups of labs, or building-level installations.

1 (http://ehs.mit.edu/greenchem/)

Communications, Engagement, and Design

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Developing and Strengthening the Lab Managers Network	Potential for a substantial impact through increased collaboration, but attendance was low at early events. University of Colorado has had success with this model.	Lab Managers and De Facto Lab Managers	Low
Establish Uniform Campus Lab Instrumentation Platform	Increased ease in sharing equipment.	Facility and Equipment Managers	Low

DEVELOPING AND STRENGTHENING THE LAB MANAGERS NETWORK

An area worthy of additional focus is widening the social and communications network of campus lab managers and technical staff, especially those operating the increasing number of shared-access and core facilities. These technical staff retain valuable field-specific and operational knowledge which can be best shared working collaboratively with their peers. Some departments have active collaborative email lists specific to their research labs. Recently a more general Lab Network mailing list was created with intentions for it to be inclusive to shared labs at the campus level, but it requires further adoption to become an active and useful tool.

Additionally, a Lab Manager's tea time or quarterly lunch meeting would allow for facility managers across from various departments to meet face-to-face once a quarter to talk about what is currently going on in their labs and to share ideas that are currently being implemented in their work. LabRATS and the Office of Research have discussed the launch of such an event.

ESTABLISH UNIFORM CAMPUS LAB INSTRUMENTATION PLATFORM

The Shared Instrumentation Website brings together information from many different departments, core facilities, and shared-access labs. Many of these facilities are under the management of technical staff, and utilize software platforms for equipment reservation, safety and training, and, in many cases, recharge and billing. These platforms vary from department to department, and some require significant time overhead to process financial and record data and move it from one platform to another for monthly reconciliation and invoicing to external parties. Many of these departments including the Office of Research and LabRATS, hope to identify an opportunity to move to a single, integrated software solution to allow enhanced cross-over in access for researchers and more streamlined billing through the campus' financial systems.

Water

IMPLEMENTATION STRATEGY	IMPACT	LEAD STAKEHOLDERS	PRIORITY
Review of Washing Methodologies in Peer Reviewed Literature	Exact impact TBD; Estimated to be modest.	LabRATS and researchers	Low
Consolidate Eye-washing Stations Where Possible	Exact impact TBD	EHS and LabRATS	Low

REVIEW OF WASHING METHODOLOGIES IN PEER REVIEWED LITERATURE

LabRATS has not in recent years conducted a study of appropriate washing methodologies for glassware or sample as the subject matter appears in peer-reviewed literature. This is an area which may be due to increased scrutiny in the coming period of time.

CONSOLIDATE EYE-WASHING STATIONS AND SAFETY SHOWERS WHERE POSSIBLE

Eye washing stations and safety showers must be tested on a regular basis to ensure that they are fully operational using a significant amount of water. Locations of current eye washing stations and safety showers should be assessed to determine whether all stations are required for safety. In some specific cases, the campus may be able to consolidate to a smaller number of eye washing stations and safety showers without impacting safety. This would have to be done in close coordination with Environmental Health and Safety and would only be pursued if it did not have an impact on safety.

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