SWATeam Recommendation

Name of SWATeam: Energy Conservation and Building Standards

SWATeam Chair: Marian Huhman Date Submitted to iSEE: November 29, 2016

Specific Actions/Policy Recommended (a few sentences):

The ECBS SWATeam recommends funding a full-time Green Labs Coordinator position. The coordinator would implement, with the help of students, a Green Labs Program. Major components of the program would include energy conservation through analysis of fume hood usage (needs and possible consolidation), a Shut the Sash fume hood initiative, freezer and refrigerator management, space efficiency and utilization, water conservation, recycling (e.g., batteries, Styrofoam) and collaboration and education of effective energy efficiency and sustainable methods for management of lab chemicals and hazardous waste disposal.

Rationale for Recommendation (a few sentences):

Of the 175 most energy-consuming buildings on campus, 9 of the top 10 are lab-related and account for ~23% of the energy usage among the 175. In the ~ 43 lab-related buildings are approx 1700 fume hoods. Depending upon system type and fume hood size, each fume hood costs approx. $3000- $5000 a year to operate. A pilot project done in spring 2015 in Madigan Lab showed that lab personnel often do not close the sash on fume hoods allowing conditioned room air to escape through the fume hood. Lab users responded positively to a subsequent Shut the Sash-type of program that reminded, reinforced and rewarded lab personnel to shut the sash on the fume hood. A Green Labs program at Harvard showed that their Shut the Sash program resulted in utility savings estimated at $200K - $250K per year with a greenhouse gas emissions savings at 300-350 metric tons of carbon dioxide equivalent. Recent audits of fume hood usage have shown that many fume hoods are not being used regularly and could possibly be taken out of service. Fume hoods could be consolidated in certain areas. Recent audits of lab freezers and refrigerators in some buildings showed that many freezers are still set at -80 degrees C, instead of the recommended -70 degrees C, and that lab personnel often do not know what is in the freezers or even which researchers are using certain freezers. Again, the Harvard program found that tuning of temperatures on freezers is saving them $300-$400/yr. per freezer. Removal of unneeded fume hoods and freezers/refrigerators could also enhance efforts at space efficiency that are underway at UIUC. In response to these problems which are common at other universities, many universities (e.g., UT Austin, Yale, Harvard, Stanford, UC Davis, UC Riverside) have implemented Green Labs programs, overseen, in many cases, by a full-time staff person, plus students; faculty assist part-time as well. The F&S Safety and Compliance group offered the Cornell program as a proposed example of what we should be doing for lab ventilation management going forward. A description of the Cornell program is attached.

Connection to iCAP Goals (a few sentences):

The iCAP specifies energy conservation as a main category in which to achieve numerous goals contributing to the carbon neutrality target specified in the iCAP. The energy conservation objectives that connect to a Green Labs program include:

- Strengthen centralized conservation efforts focusing on building systems, to achieve a 30% reduction in total campus building energy use by FY20.
- Engage and incentivize the campus community in energy conservation, including a comprehensive energy conservation campaign, with at least 50% of units participating by FY20.
- Maintain or reduce gross square footage (through space efficiency and space utilization).

Perceived Challenges (a few sentences):

In talking with other universities' Green Labs program coordinators, they have stressed that these behavioral change initiatives are time and labor intensive. They require a coordinator who has the interpersonal skills to build working relationships with faculty, PI's, lab managers, building managers and students. Some coordinators also monitor mechanical systems associated with fume hoods, autoclaves, freezers, etc that require specialized knowledge to troubleshoot problem areas. Consistent follow up is needed with current lab personnel and students who turn over regularly. Many programs use a self-assessment tool, like we use in our Certified Green Office program. Implementation of the assessment has to be adapted for the needs of the labs. Close work with safety and compliance personnel is also needed.

While creating a new position is always a challenge in times of financial constraints, the universities we have talked to say that, as the program progresses, the coordinator position may begin to pay for itself through energy savings.

We note that the responsibility for most of the equipment (fume hoods, freezers, autoclaves, etc.) affected by this program are a departmental responsibility. Departments fund the upkeep of most of this equipment. How can the departments be motivated to participate in this proposed program? Generally speaking, we think that departments will be approachable on this item, based upon our retro-commissioning experiences, but there will be challenges. The best probability of a positive outcome is for <u>one on one interaction to occur</u>, raising energy awareness and producing real changes in lab users' behavior. One of our theories is that equipment/labs are forgotten over time and there is always the hope that a research grant might arrive in the near future and lab space will be needed at that point in time. We can't afford to operate labs for long periods of time (say 3 years plus) in anticipation of further funding or usage.

Suggested unit/department to address implementation:

- Facilities and Services. iSEE can help support the communication aspect, i.e., messaging about energy savings. (Collaboration will be needed among several groups, e.g., lab managers, faculty, safety and compliance staff.)

Anticipated level of budget and/or policy impact (low, medium, high):

- Moderate. We ask iSEE to advise on the funding. Could DRS and/or the Provost office be approached?

Individual comments are required from each SWATeam member (can be brief, if member fully agrees):

Team Member Name	Team Member's Comments
Marian Huhman	After much discussion and research on ways to maximize energy conservation and build sustainable and consistent practices among lab users, I believe a position dedicated to Green Labs management is needed.
Yun Yi	Task layout on the document is a critical and fundamental role in campus sustainability. It requires a significant amount of collaboration, specific knowledge on each equipment usages, specifications and so on. I recommend a new hire to firstly works on an in-depth campus-wide survey on current fume hoods and refrigerator conditions and develop a strategical document that recommends how to maintain systems sustainably
Fred Hahn	Objectives and goals are clear. Move forward.
Karl Helmink	In my opinion, this proposed work is consistent with the ICAP document, and an increased effort is needed in this area. Collaboration between depts. will be needed.
Dhara Patel	A green labs initiative is crucial to reducing energy consumption at a university that prides its STEM programs, and cost savings easily justify a paid position to give such an initiative proper attention.
Alex Dzurick	This is a huge area to save energy and a great goal for this research university.

Comments from Consultation Group (if any; these can be anonymous): From Paul Foote, Academic Hourly, F&S. The biggest factor benefitting from this position is energy consumption per square foot, consumption in labs can be as much as five times greater than other campus spaces. Collaborating Green Lab initiatives will significantly impact all major components previously mentioned, create further awareness among the university community and develop lasting behavioral change throughout society.

From Olivia Webb: I fully support this recommendation. It is anomalous for such a preeminent research university as ours to be without a sustainable labs program, and I have met several faculty members who expressed surprise and disappointment at our lack of comprehensive programming. This effort does need a dedicated staff member in order to succeed. I would also support the inclusion of those involved in shaping this recommendation in the hiring process, especially the composition of a job description.

Explanation and Background (can be supplied in an attachment):

- FY16 Energy Consumption Table- - Top 175 Buildings on UIUC Campus—Buildings with Labs Highlighted
- Other Universities:
    - Cornell Lab Ventilation Management Program
    - Validating Cost and Energy Savings from Harvard's Shut the Sash Program

VALIDATING COST AND ENERGY SAVINGS FROM HARVARD'S SHUT THE SASH PROGRAM

Tackling energy use in labs

Quentin Gilly | *Senior Coordinator Faculty of Arts and Sciences Green Labs Program, Office for Sustainability*

HARVARD UNIVERSITY | Sustainability

Inside this report...

Fume hood behavior change programs provide opportunity to reduce costs and increase energy efficiency

Chemical fume hoods are one of the most energy intensive aspects of laboratory operation. Laboratories at Harvard University account for 22% of space, but are responsible for 44% of energy consumption. According to a report from Louis Stokes Laboratories, 44% of the energy used in their labs is directly related to ventilation. Harvard's Shut the Sash Program was created to reduce energy and save utility costs in line with its aggressive climate goals, while also facilitating a safe and sustainable culture in the laboratories.

Background

In order to safely handle materials such as volatile organic compounds, acids, and solvents, fume hoods are a necessity. Fume hoods provide a contained work space, known as the "cabinet", which is ducted outside of the building. Supply fans bring air in through the cabinets, and exhaust fans pull air through the lab, and out of the building. The user can adjust the hood's movable window, known as the "sash," to access the cabinet. Air is then driven away from the user at a proper rate, known as the "face velocity," to reduce exposure risk. Air that is pulled through the cabinet comes from inside the lab space, which is delivered by the building's heating, ventilation and air conditioning (HVAC) system. An example of a fume hood in operation can be seen in Figure 1. Fume hoods can place tremendous pressure on a HVAC system because they are constantly exhausting newly conditioned air out of a building. Due to the energy needed to maintain safe air flow rates, operational costs, per fume hood, can be equivalent to the average energy used by three U.S. homes.

Typically, laboratory ventilation is measured in air changes per hour (ACH). At Harvard, our labs operate at six-eight ACH when occupied, and four ACH when unoccupied. This is much higher than a typical residential or office space. Fume hoods are typically factored into these air changes. Even when closed, fume hoods are always responsible for some ventilation. If many fume hoods are consolidated in a small area, they can be the primary HVAC driver. At Harvard, reports have shown that certain labs can achieve 12-15 ACH, simply due to the ventilation required to operate the hoods.

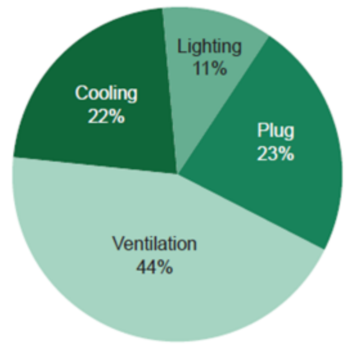


Figure 1. Annual electricity use in Louis Stokes Laboratory, National Institutes of Health, Bethesda, MD.

Verifying the results of behavior change programs in laboratories

Harvard's Shut the Sash Program was launched in 2005 when the Department of Chemistry & Chemical Biology (CCB) began exploring new ways to encourage people to shut fume hood sashes, and reduce the amount of air exhausted from labs. CCB is a fume hood intensive department, housing 278 fume hoods in a small four-building complex. Currently, 187 of these fume hoods are variable air volume (VAV) while the rest are constant air volume (CAV). CAV fume hoods operate with a constant flow, regardless of the position of the sash. VAV fume hoods change the air flow based on sash position. When a VAV fume hood is closed, the air flow is reduced to a lower cubic feet per minute (CFM). As the sash is raised, the CFM will increase. Fume hood CFM can range tremendously depending on size and intended use.

According to Jerome Connors, former Associate Director of CCB, the energy saved by the Shut the Sash Program through efficiencies to the HVAC system was approximately 70%. Utility savings are estimated at $200,000-$250,000 per year, with a greenhouse gas emissions savings at 300-350 metric tonnes of carbon dioxide equivalent (MTCDE).

Over the past ten years, some labs have left and new labs have joined the competition. Through all of the

HARVARD'S SHUT THE SASH PROGRAM

The Shut the Sash Program is an ongoing monthly competition between 19 labs with VAV fume hoods to encourage lab behavior change. Each lab has a customized CFM goal based on number of fume hoods, number of researchers, and type of research being conducted. Labs that achieve their goal are entered into a lottery for a party, which typically includes pizza and prizes.

Labs that consistently meet their goal are invited to a wine and cheese party, which takes place biannually. Staff, student, and faculty participation supports the program, and Harvard's Environmental Health & Safety department encourages shutting fume hood sashes to avoid accidental exposure. The program is managed by the Faculty of Arts and Sciences Green Program, a division of Harvard's Office for Sustainability, with significant help from CCB building operations staff and Siemens engineers.

changes, the competition has essentially operated the same way. Little change is needed to maintain the competition. Notably, some lab managers have applauded the competition, saying it helps foster team building and provides a common goal for researchers working on individual projects.

Beginning in late 2014, reports highlighted a number of locations where closing fume hoods would yield energy savings. Before jumping at the opportunity to expand the Shut the Sash Program, it was decided that an assessment should be done to verify the estimated cost and energy savings resulting from the Shut the Sash Program.

Data indicated that Shut the Sash participants practiced thoughtful management of their fume hoods. In addition, evidence indicated that automatic sash closers could be a useful alternative. Instead of having researchers close fume hood sashes, this technology shuts sashes automatically by sensing when a researcher is no longer present.

The design of the experiment was simple; fume hood sash management through behavior change in Shut the Sash labs was compared to labs that have automatic sash closers. As a control, we compared these to fume hoods that had neither automation nor competition. Fume hoods in three buildings were compared to hoods used in Shut the Sash: Engineering Science Laboratories, (ESL), Sherman Fairchild, (Fairchild), and Biological Laboratories, (Biolabs). These buildings are less fume-hood-dense than CCB, but savings could be found by closing hood sashes.

Data was collected over a two-month period on these buildings using the Siemens building automation system (BAS).

Delivering real energy and cost savings

The Sherman Fairchild laboratory building was chosen for the study because their labs have automatic sash closers installed on all of their fume hoods. ESL and Biolabs were chosen because VAV fume hoods, not already participating in Shut the Sash Program, were identified for their potential energy savings. Data availability by date can be seen in Figure II.

Distribution of fume hoods by count can be seen in Figure III. Note that ESL and Biolabs reported fume hood trends in 30-minute intervals as "Open" or "Closed" while CCB and Sherman Fairchild reported in 30-minute trends as current CFM. This inconsistency, as well as variability in fume hood size and face velocity, meant that we had to make some generalizations about fume hood operational cost.

Finding the average fume hood size and CFM was an important component of this study. With the help of Siemens specialists, as well as building managers and engineers, a consensus was established as an average fume hood. Those values were input in the Lawrence Berkeley Fume Hood Calculator. An example of the calculator can be seen in Figure IV. Cost per CFM per year as estimated at $7.43, which was in the range of expected cost, given Harvard's 2015 electricity price of 12.5 cents per kilowatt hour (kWh). Average annual cost of operation was estimated at $4,459 per hood.

Using the free statistics software RStudio, exhaust trends from all fume hoods in the study were graphed and analyzed. To determine if users of individual fume hoods had "good" or "bad" behavior, openings were identified in four categories. Less than five hours = good behavior, more than five hours = need for improvement, more than 12 hours = poor behavior, and more than 24 hours = worst behavior. An example of these graphs can be seen in Figure V, where they were graphed over one-week periods.

Analysis of the three fume hood treatment criteria yielded some notable results (see Table 1). First, there was very similar cost associated with operating fume hoods in Shut the Sash, and those with automatic sash closers. The cost of operating fume hoods in no treatment fume hoods was over $1,000 more per year, per fume hood.

In addition to total cost, it was necessary to verify if the sash operational cost was affected by researcher activity, since some fume hoods could be used more than others. The metric median-open-hours represents the median length of time that a fume hood is open across all open periods of a given sampled week. Median number of hours is used to summarize the length of open periods due to the skewed nature of open period lengths.

The distribution of this metric displayed below, shows that CCB and Sherman Fairchild have the shortest median hood openings, with most hoods in these groups opening for less than five hours, the timeframe identified in this study as "good behavior." This figure also highlights the high number of fume hoods in Biolabs and ESL that exhibited poor occupant behavior, with an average median open period of 69 consecutive hours and 33 hours respectively.

Results of the study confirmed that the Shut the Sash competition continues to save Harvard in excess of $200,000 per year and 300+ MTCDE. In addition, it made the case for expanding the competition to additional areas on campus where regular closing of VAV fume hood sashes could find savings.

Expanded paybacks

Based on the results of this study, Harvard's Shut the Sash was expanded to an additional 18 labs in September 2015, including labs in the Department of Molecular & Cellular Biology, Department of Organismal & Evolutionary Biology, and the Harvard John A. Paulson School of Engineering and Applied Sciences. These labs were chosen due to the

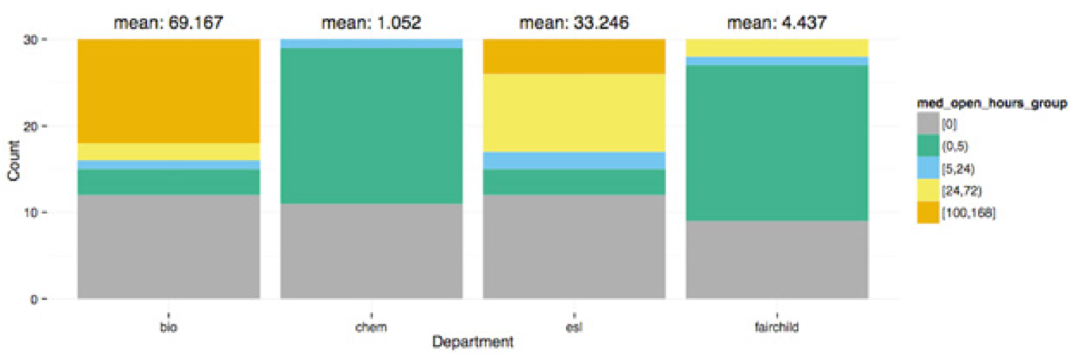


Table 1: Fume Hood Operation

TREATMENT	AVERAGE CFM	COST
Automation	231	$1,716
Shut the Sash	250	$1,858
None (Control)	409	$3,039

Note: The Shut the Sash Program is in Chemistry, and researchers use these hoods more frequently.

HOW TO START A SHUT THE SASH PROGRAM ON YOUR CAMPUS

To start a Shut the Sash competition on a research campus, work with building operations and engineers to locate VAV fume hoods where savings can be captured.

Once those locations are found, request exhaust trend reports from your BAS staff.

Download the package provided by the link at: http://www.green.harvard.edu/shut-the-sash, and follow the instructions in the appendix of this paper. This will provide you with summary statistics and graphs.

Finally, work with your building operations staff and engineers to determine the average fume hood size on your campus. Then use the Lawrence Berkeley Fume Hood Calculator to determine the cost per CFM at on your campus.

Report your findings to senior leaders if the data indicates that a Shut the Sash competition would yield savings.

way their fume hoods interact with the HVAC system, and are expected to yield additional savings of $50,000-$73,000 per year.

The new Shut the Sash competition is kept separate from the existing competition. An important consideration for ongoing environmental competitions in labs is to keep the size of the competition appropriate so that each lab has a chance of winning every one to two years.

In conclusion, an effective way to reduce lab operational cost, while pleasing lab occupants, is through a Shut the Sash competition. Once the BAS is setup to trend VAV hoods, the competition can be run on a modest budget. The competition is run by the labs coordinator for the FAS Green Program with a commitment of 10 hours per month, and an annual budget of $4,500.

LESSONS LEARNED

While exploring the buildings and labs during this study, one reoccurring theme became clear. Several scientists working in labs equipped automatic fume hood sash closers did not speak highly of the technology. They remarked that the technology tends to beep often, and closes at inopportune times.

Sherman Fairchild Building Manager, Paul Tighe, mentioned, “People have actually disabled the sensors and jammed pencils into the buzzers.”

About Harvard’s commitment to sustainability

Harvard is confronting the challenges of climate change and sustainability through research across disciplines, giving our students the tools to tackle complex global challenges, and acting on campus to model an institutional pathway to a more sustainable, low-carbon future. The Harvard Sustainability Plan, launched in 2014, aligns the University under a set of goals and priorities in five key topic areas – energy and emissions, campus operations, nature and ecosystems, health and wellbeing, and culture and learning. In 2008, President Drew Gilpin Faust and the Deans approved Harvard University’s most ambitious sustainability goal: a long-term commitment to reduce the University’s greenhouse gas emissions by the maximum practicable rate aligned with the best available science, and a short-term goal to reduce greenhouse gas emissions 30% by 2016, including growth, from a 2006 baseline.

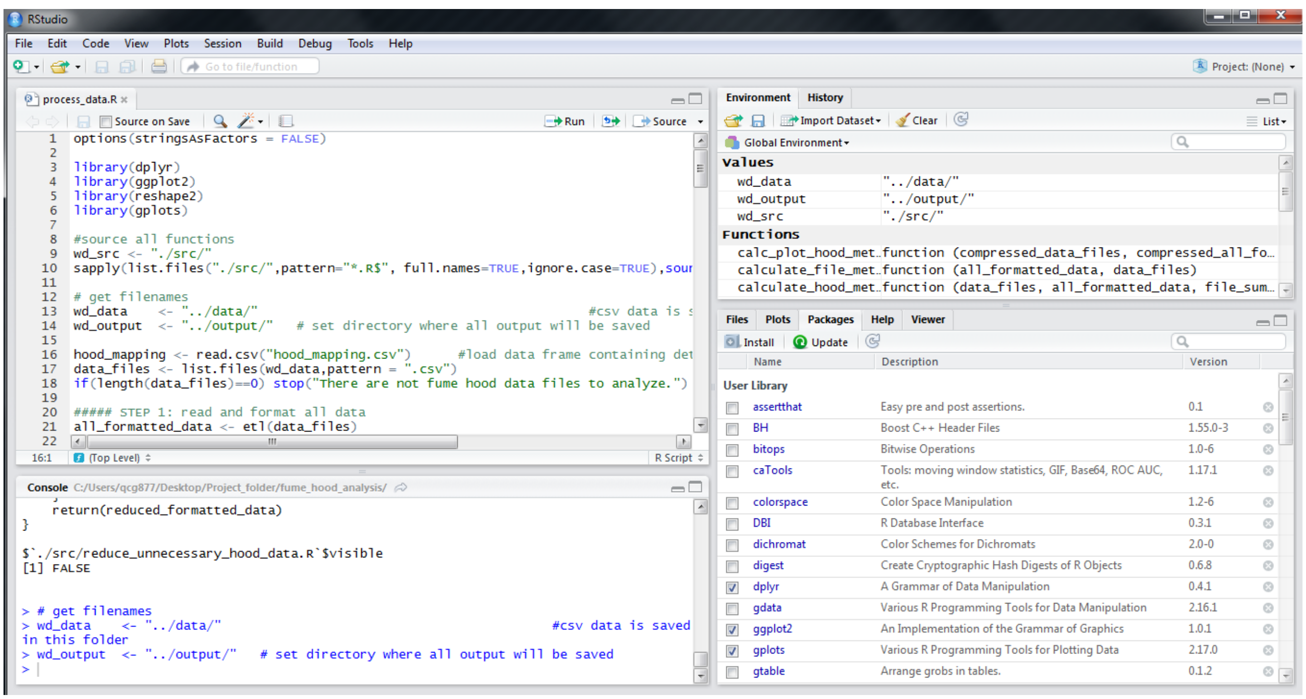
The Harvard Office for Sustainability brings faculty, students, and staff together to set and achieve goals for a healthier, more efficient and sustainable future. By connecting research and teaching with on-campus action, OFS works to model scalable and cost-effective solutions that enhance the well-being of the campus community and ultimately strengthen the University’s academic mission.

Appendix I: Getting started with RStudio

This section will discuss the steps necessary to handle fume hood data files using RStudio. The scripts can handle either .csv or .txt files, and have been designed to handle a different formatting from the Siemens system. *Requires experience with R and may only work with Microsoft Windows.

- Step 1: Download RStudio.
- Step 2: Run RStudio and install the following R packages:
  - plyr
  - dplyr
  - ggplot2
  - reshape2
- Step 3: Download files from appendix II and setup directory structure shown in appendix III. It will need to contain:
  - Fume_hood analysis repository containing .csv and .R files
  - A data folder which you will put .csv data files with your fume hood data
  - An output folder into which all PDF figures and .csv output will be saved
- Step 4: Open up and run the R script 'process_data.R' in RStudio. This is the master script to perform the main fume hood data analysis.

R Studio Screenshot



Appendix II: Download scripts and process files

Click here to download the files and arrange them as shown in Appendix III. Zip will contain:

src folder	bug fix
.Rhistory	update code and visuals
README.md	update readme
hood_mapping.csv	bug fix
process_data.R	bug fix - error handling
report_visual.R	bug fix - error handling
visualize_data_summary_by_dept.R	bug fix - error handling
Example_fumehood_file.csv	example for formatting
Example_fumehood_file.txt	example for formatting

Appendix III: Directory structure for RStudio

```
+--Project folder
|    +-- fume_hood_analysis          (directory with cloned github repository)
|      +-- README.md
|      +-- hood_mapping.csv          (csv file with names of all fume hoods and their buildings)
|      +-- process_data.R            (script to process data)
|      +-- src                       (directory contains data processing, analysis functions)
+-- data                             (directory contains csv files with raw fume hood data)
+-- output                           (directory to save any graphs, output from calculations)
```

Appendix IV: Run the RStudio script

- Step 1: In RStudio go to Session ==> Set Working Directory ==> process_data.R
- Step 2: Place fume hood reports in 'data folder' of your directory.
- Step 3: Run each command one-by-one in the process_data.R file. This can be achieved by clicking on the first line of the process_data.R file, and pressing Ctrl+Enter one line at a time.
  *Note: Only run Step 2 if you have more than on fume hood file to process.
- Step 4: Proceed through steps 1 - 4 of the Process_data.R file. This should output most of the graphs and summary statistics you want. Continue through step 7 for additional statistics.
- Step 5: Collect your data from the output folder.

Debug: If you receive an error warning at any time, then the .csv or .txt file is formatted in a way that cannot be handled

by this program. Make sure the source files are formatted like the examples provided in the download.
*Note that the program is designed to handle additional variations beyond the example formats provided.

Appendix V: Average fume hood at Harvard Faculty of Arts & Sciences

Electricity - $0.125/kWh

Electricity Demand - $1/kW-year

Fuel - $24/million BTU

Operation - 24 hours/day

Hood Opening (Horizontal) - 48 inches

Hood Opening (Vertical) - 18 inches

Face Velocity - 100 feet/min

Fan Power (supply/exhaust) - 1.8 W/CFM

Cooling Plant Efficiency - .75 kW/ton

Heating System Efficiency - 90%

Heating - 65° F

Cooling - 55° F

Delivery Air Temperature - 68° F

Energy Type - Fuel

Flow Rate - 600 CFM

Chiller Energy - 2,840 kWh/year

Fan Energy - 9,461 kWh/year

Total - 12,300 kWh/year

Total Power - 3.2 kW/hood

of which fan - 1.1 kW/hood

of which chiller - 2.2 kW/hood

Heating supply load - 92 million BTU

Reheat load - 17 million BTU

Total Load - 109 million BTU

Energy (fuel) - 121 million BTU

Energy (electric) - 0 kWh

Average Reheat Power - 0 kW

Total Per-Hood Costs - $4,459/year

Cost per CFM - $7.43

Appendix VI: Metrics used to evaluate hood-weeks

Metric	Equation
Proportion of open intervals	$prop.open = \frac{\sum_{p=1}^{n} open.intervals_p}{total.intervals}$
Median open hours	$med.open.hrs = \frac{(n+1)}{2}\ th\ open.intervals\ term$
Proportion of open intervals exceeding 5 hours	$prop.open.exceeding.5 = \frac{\sum_{p=1}^{n} (intervals.5)_p}{total.intervals}$ $where\ intervals.5 = \begin{cases} 0, & open.intervals_p \leq 10 \\ open.intervals_p - 10, & open.intervals_p > 10 \end{cases}$ *and 10 is the number of 30-minute intervals in 5 hours*
For above metrics,	*n is the total number of open sash periods for a given hood-week* *open.intervals$_p$ is the number of intervals in open-period p* *total.intervals is the total number of intervals on a given hood-week*

Figure I: Fume hood in use

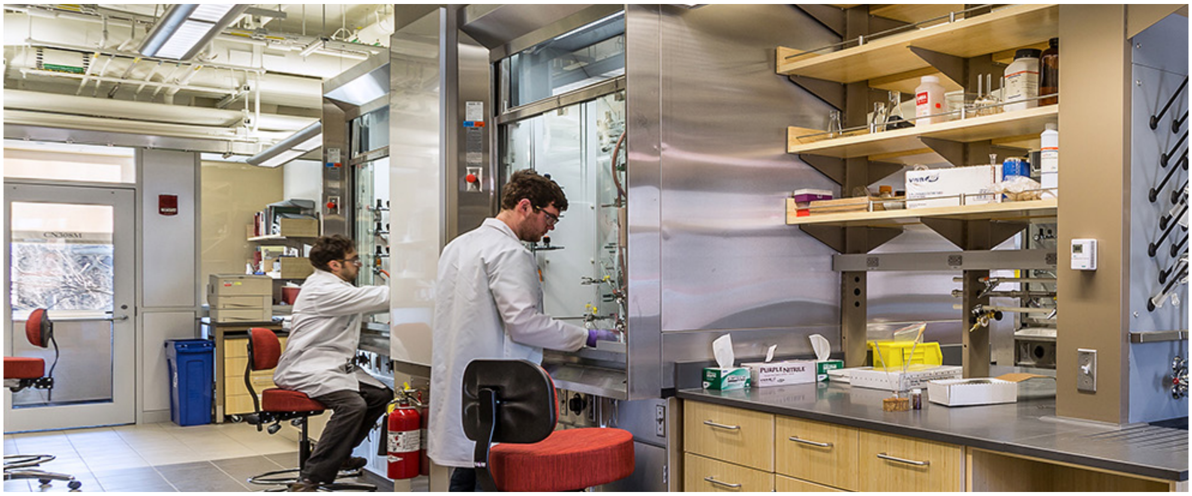
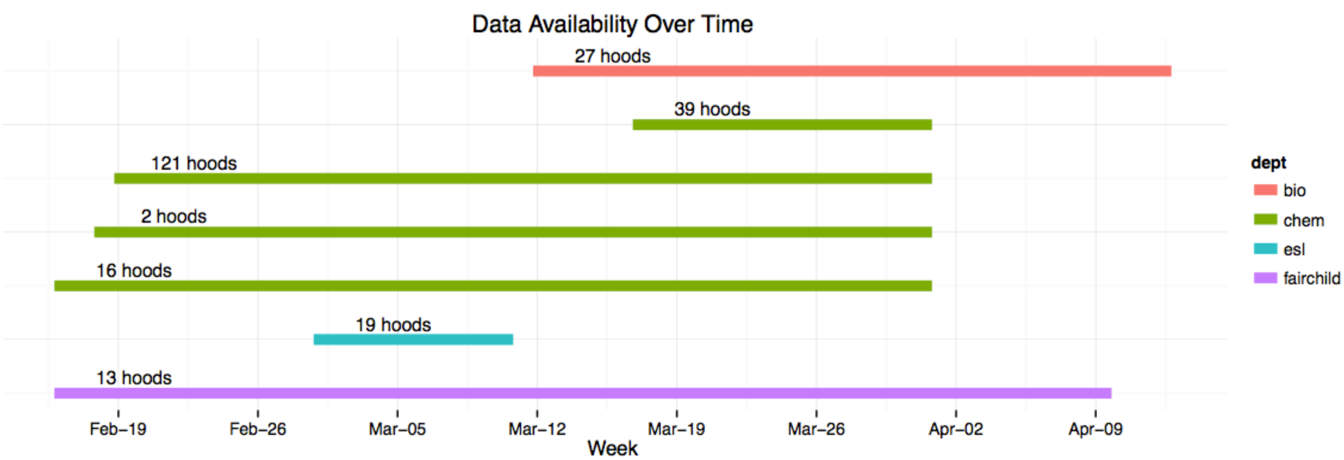


Figure II: Data availability by space



Key for figure II:

bio = Biological Laboratories (control)

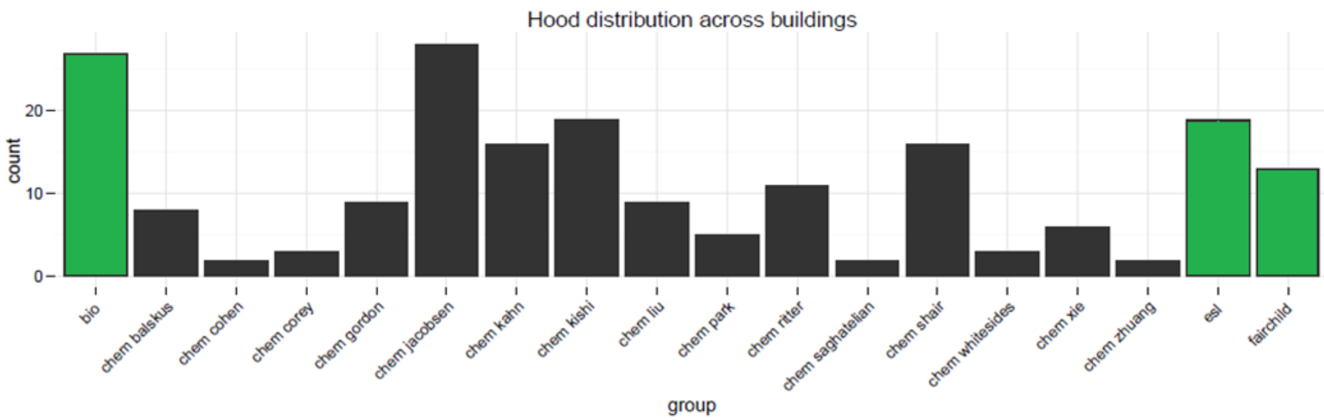
chem = CCB (shut the sash)

esl = Engineering Science Laboratories (control)

fairchild = Sherman Fairchild (automatic sash closers)

Whole-building fume-hood-count distribution is shown in green. For CCB, fume hoods for individual labs are shown in black. The purpose is to emphasize how many fume hoods individual labs in CCB have compared to entire lab buildings.

Figure III: Count of fume hoods by space



Key for figure III:

bio = Biological Laboratories (control)

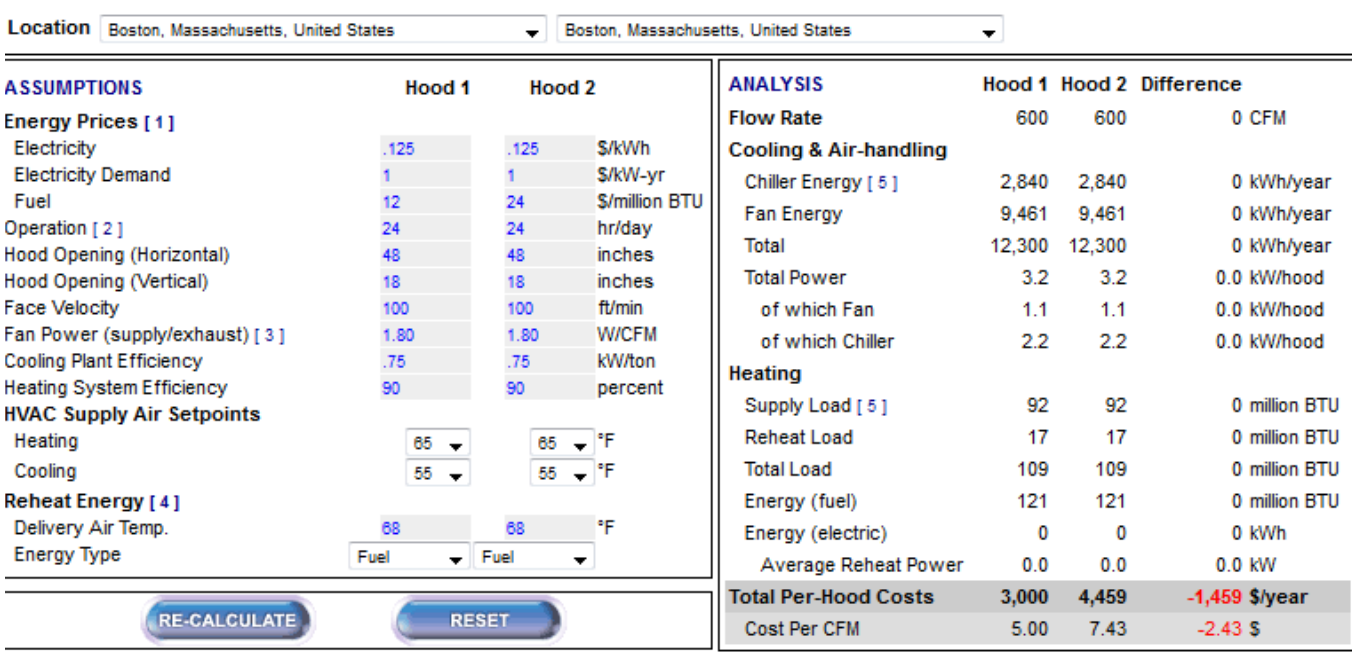
chem = CCB (shut the sash)

esl = Engineering Science Laboratories (control)

fairchild = Sherman Fairchild (automatic sash closers)

Whole-building fume-hood-count distribution is shown in green. For CCB, fume hoods for individual labs are shown in black. The purpose is to emphasize how many fume hoods individual labs in CCB have compared to entire lab buildings.

Figure IV: Lawrence Berkeley Fume Hood Calculator



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

ASSUMPTIONS	Hood 1	Hood 2	
Energy Prices [1]			
Electricity	.125	.125	$/kWh
Electricity Demand	1	1	$/kW-yr
Fuel	12	24	$/million BTU
Operation [2]	24	24	hr/day
Hood Opening (Horizontal)	48	48	inches
Hood Opening (Vertical)	18	18	inches
Face Velocity	100	100	ft/min
Fan Power (supply/exhaust) [3]	1.80	1.80	W/CFM
Cooling Plant Efficiency	.75	.75	kW/ton
Heating System Efficiency	90	90	percent
HVAC Supply Air Setpoints			
Heating	65	65	°F
Cooling	55	55	°F
Reheat Energy [4]			
Delivery Air Temp.	68	68	°F
Energy Type	Fuel	Fuel	

RE-CALCULATE | RESET

ANALYSIS	Hood 1	Hood 2	Difference
Flow Rate	600	600	0 CFM
Cooling & Air-handling			
Chiller Energy [5]	2,840	2,840	0 kWh/year
Fan Energy	9,461	9,461	0 kWh/year
Total	12,300	12,300	0 kWh/year
Total Power	3.2	3.2	0.0 kW/hood
of which Fan	1.1	1.1	0.0 kW/hood
of which Chiller	2.2	2.2	0.0 kW/hood
Heating			
Supply Load [5]	92	92	0 million BTU
Reheat Load	17	17	0 million BTU
Total Load	109	109	0 million BTU
Energy (fuel)	121	121	0 million BTU
Energy (electric)	0	0	0 kWh
Average Reheat Power	0.0	0.0	0.0 kW
Total Per-Hood Costs	3,000	4,459	-1,459 $/year
Cost Per CFM	5.00	7.43	-2.43 $

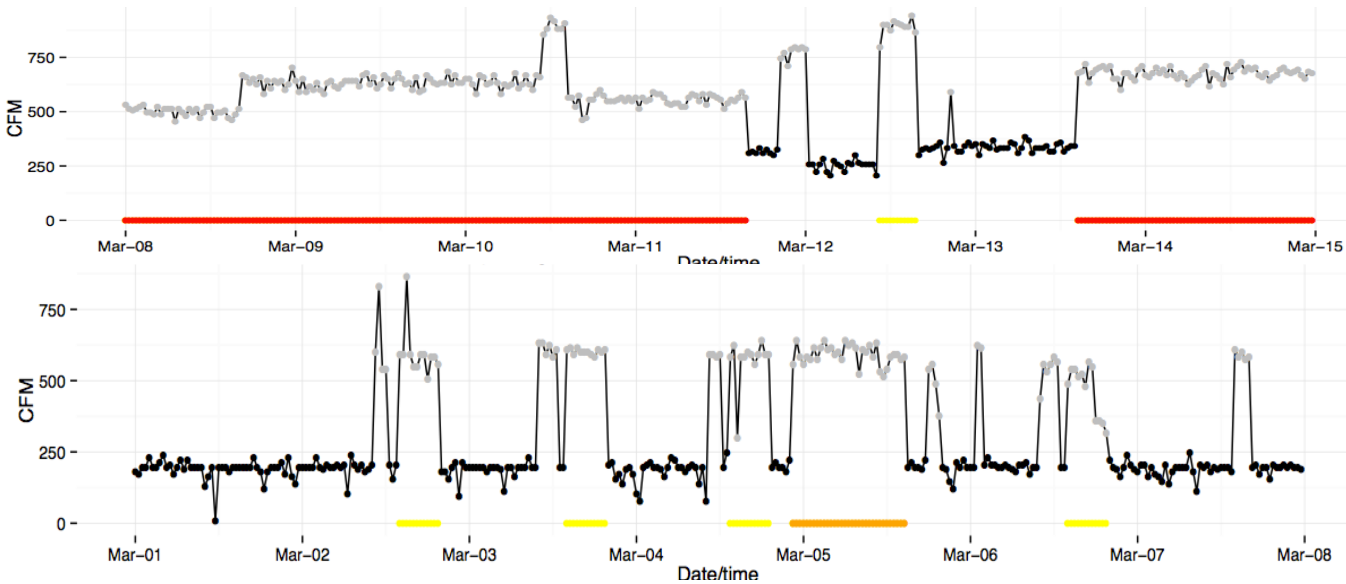
Figure V: Fume hood week behavior graphs

< 5 hours – Good behavior

> 5 and < 12 hours – Sash accidentally left open

>12 hours <24 hours – Poor behavior, sash likely left open overnight

> 24 hours – Worst behavior, sash left open all weekend, or no consideration



Cornell University
Environmental
Health and Safety

Laboratory Ventilation Management Program

Jerry Gordon, Associate Director
Ellen Sweet, Laboratory Ventilation Specialist
Cornell Department of Environmental Health and Safety

2/8/2016

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1. Introduction

This Laboratory Ventilation Management Plan (LVMP) provides guidance for balancing the safety value of ventilation in the laboratories on the Ithaca and Geneva Cornell campuses with the financial and “carbon” costs associated with the energy required to supply this air. On these campuses, laboratory spaces use a disproportionate amount of the University’s energy and carbon budget (nearly 50% of the energy’s heating and cooling load for 33% of the campus floor space). This is largely due to the demands of laboratory ventilation; in particular the energy required to condition air to maintain temperature requirements in the laboratory. Therefore optimization of laboratory ventilation is a key element in reaching the goal envisioned in Cornell’s Climate Action Plan of a climate neutral campus by 2035. The purpose of this LVMP is to delineate the laboratory ventilation program’s scope and provide procedural guidance for anyone who is affected by or has responsibility for the ventilation of laboratories at the University. These stakeholders are outlined below.

For the purposes of this plan, “laboratory ventilation” refers to the once-through movement of air through spaces that is used to maintain the quality of a laboratory environment where hazardous chemicals are used. Specialized ventilation systems which serve high hazard operations are excluded from this program; however, managers of these systems are encouraged to include energy conservation as a key element in the facility’s operations.

Questions about the details of this plan should be referred to the Cornell Chemical Hygiene Officer or Laboratory Ventilation Specialist.

2. Objectives

The overriding aim of the lab ventilation program is to maintain the safety and health of lab workers while contributing to the energy reduction goals of the entire campus. Based on benchmarking with other research campuses, our overall target is to reduce the laboratories’ normalized carbon footprint by at least 20% from 2010 to 2020. This is accomplished by assessing chemical usage in existing labs, ventilation effectiveness and housekeeping in existing labs and identifying the ones that can be ventilated at a 25% airflow rate reduction. It will also be accomplished with the existence of design standards for new construction and renovation that utilize a variety of strategies. Experience at Cornell University Ithaca has shown that up to 80% of laboratories outside chemistry-specific research laboratories can operate safely at the moderate ventilation rate. This determination must be made on a lab by lab basis and reassessed periodically, generally every three years or when research operations change significantly.

3. Relevant Requirements

External Requirements

There are few regulatory requirements that address laboratory ventilation issues and none in a way that prescribes specific criteria. The OSHA Laboratory Standard (29 CFR 1910.1450 Subpart Z Appendix A) contains the most detailed information about the components of a ventilation system for chemical hygiene purposes, including the quantity of the general ventilation rate. But it does not provide airflow rate requirements. Therefore, this document outlines a working partnership between Cornell’s laboratory workers and administration, the Facilities Services Energy and Sustainability Department, and the Department of Environmental Health and Safety which supports the safe and sustainable operation of laboratory ventilation systems. It is an integrated management plan for the design, use, monitoring, and maintenance of the ventilation systems in campus laboratories.

This program is based on two American National Standards Institute standards developed by the American Industrial Hygiene Association: ANSI Z9.5 for Laboratory Ventilation and ANSI Z10 for Occupational Health and Safety Management Systems. The first of these standards outlines the mechanical and management elements required for the appropriate use of laboratory ventilation to protect worker health and safety. The second standard describes the elements of a management system which support the ongoing improvement of the program over time by providing the Key Performance Indicators outlined in Chapter 8, which monitor the plan's performance (see Figure 1).

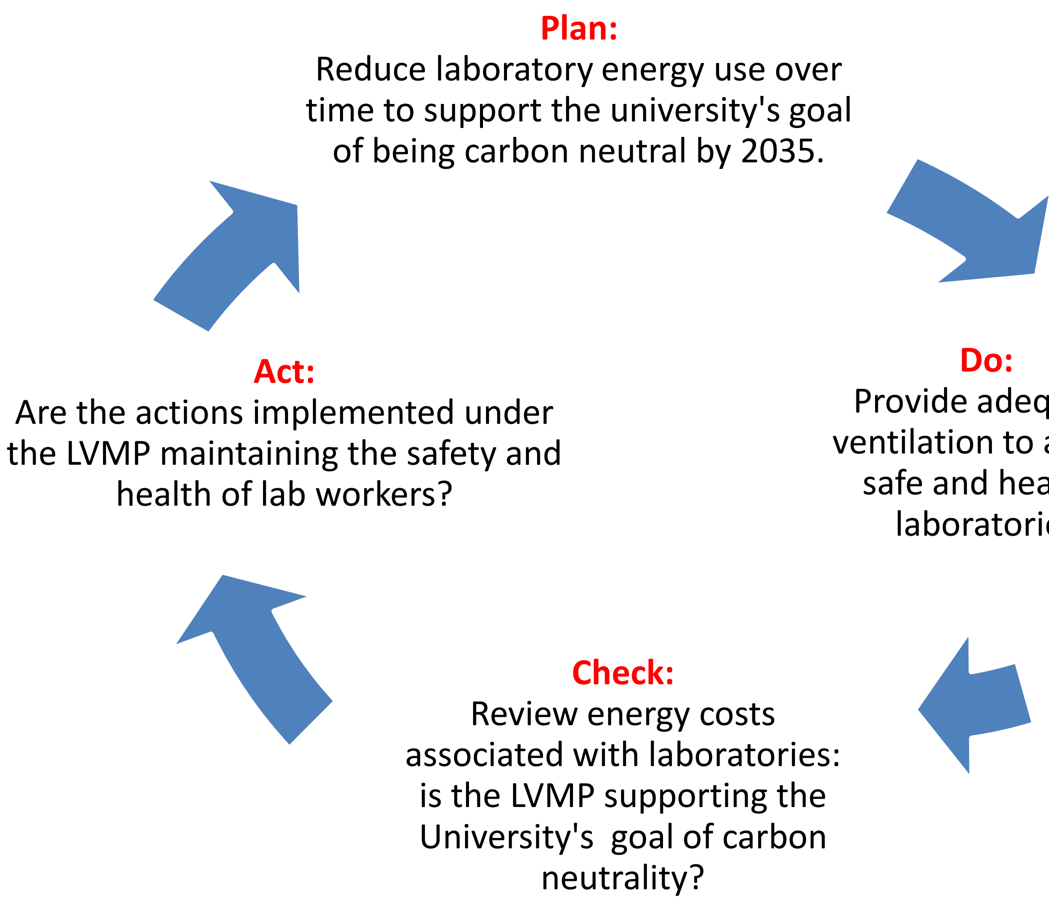

Figure 1: Overview of Laboratory Ventilation Monitoring Process

Internal Requirements

The University's Health and Safety Policy 8.6 is the governing policy that states Cornell's commitment to, and describes the departmental and individual responsibilities for, maintaining the safety of everyone in the Cornell community. In order to comply with this policy, the laboratory ventilation optimization outlined in this plan will be managed within the constraint of supporting safe laboratories that carry out the teaching, research and service missions of the University.

In order to achieve its Climate Action Plan (CAP) goal of reaching carbon neutrality by 2035 and to cost effectively reduce energy use as part of ongoing cost reduction efforts, Cornell University is “implement(ing) a broad program of energy conservation on the Cornell campus.” The CAP notes that laboratory spaces use a disproportionate amount of the University’s energy and carbon budget. This is largely due to the heating and conditioning demands of laboratory ventilation; therefore optimization of laboratory ventilation is a key part of reaching this goal. This issue is also a core element of the Green Development Actions identified by the Climate Action Plan, which include implementing “low energy use standards for new buildings…to reduce the need for future energy and maintenance costs.”

4. Stakeholders

The strategy for this program recognizes that laboratory ventilation encompasses both a wide variety of stakeholders and widely varying laboratory ventilation system designs, conditions, uses, and effectiveness around campus. The system described in this management plan will maintain the health and safety of lab occupants while optimizing the ventilation rates to meet the sustainability goals of the University,

The stakeholders involved in this program are organized into four broad groups according to their involvement with the laboratory ventilation operations. The breakout of responsibilities and tracking indicators for these groups is outlined below. Tracking indicators measure the activities of the various stakeholders group as they fulfill their role.

	Stakeholder Groups	Role
1	Laboratory workers, supervisors and administration	Directly involved in laboratory operations and planning
2	Infrastructure, Properties and Planning, and Environmental Health and Safety staff	Provides facility support and institutional oversight of laboratory work on campus
3	External authorities such as OSHA, EPA and AIHA committees	Sources of external safety and health standards for campus laboratory practices
4	Campus Community	Establishes and tracks energy usage and carbon budgets for laboratory operations on campus

Scope for Laboratory Workers, Supervisors and Administration

For the purpose of the lab ventilation program, “lab occupants” includes employees and students in several subgroups. The first involves individuals who are directly impacted by the decisions made about the ventilation provided to a specific lab or group of labs because they work with hazardous chemicals in the laboratory. Other members of this group are Laboratory Supervisors and Principal Investigators who are the first line managers of specific spaces. These people direct the choices of chemicals used in their labs, where equipment is placed and how work will be performed. They also supervise the training of employees and students. A third subgroup in

Group 1 is department chairs, deans and departmental safety representatives, who allocate and monitor use of lab space.

Scope for Infrastructure, Properties and Planning (IPP) and EHS

This group is comprised of support staff from IPP and Environmental Health and Safety who make observations and recommendations about the design and operation of specific lab ventilation systems. This group includes EHS staff that conduct fume hood commissioning and certifications, risk assessment and review of ventilation adequacy. They provide recommendations about laboratory equipment selection and placement, and provide general safety training for lab occupants. Facilities Services includes those who provide the design of laboratory spaces and facility maintenance, mechanical support and operational budget management. The Energy Management Office staff within IPP is the group responsible for identifying, promoting and implementing energy conservation opportunities in campus laboratories. It provides continuous laboratory systems monitoring and maintenance with improved energy usage in mind.

This LVMP builds upon current practices by these stakeholders. The Hood Housekeeping Score and Control Banding of the entire laboratory room indicators are the two elements added to current practice of this group.

Scope for External Authorities and Peers

This group encompasses external groups who do not manage laboratory ventilation systems at Cornell, but provide technical standards for minimum performance and best practices. They are concerned about the health and safety of laboratory workers and the potential climate impacts and energy costs associated with lab operations. These groups include professional technical committees, government regulators and agencies such as the Department of Energy. In addition to providing minimum performance requirements and best practices, these organizations look to Cornell as a model for best practices with regard to laboratory ventilation management.

Scope for Campus Community

This group includes the Campus Community and Public who are concerned about both the health and safety of laboratory workers and the potential climate impacts associated with campus laboratory operations. They are represented by the Cornell administration, which helps determine the type and conditions of work appropriate to be conducted through funding decisions and legal requirements.

5. Roles and Responsibilities

The stakeholder groups outlined above have varying responsibilities with regard to laboratory ventilation. These responsibilities are outlined in this section, with indicators that will be used to track the success of these groups in meeting these responsibilities. The indicators are organized in a way to create a "balanced scorecard" that includes safety and sustainability indicators and assess both leading and lagging measures of performance. These indicators are more fully described in Section 8.

Laboratory Workers, Supervisors and Administration

Roles	Responsibilities	Tracking Indicator
Laboratory workers	Maintain good chemical housekeeping practices	Trend in Hood Housekeeping Score (HHS) as seen at the time of annual recertification and during EHS drop in visits
Laboratory workers	Properly use containment devices and understand the impact of laboratory ventilation in their work area on their work practices	HHS and EHS inspections results show improvement
Laboratory supervisor and/or principal investigator	Lead chemical hazard assessment of laboratory work; identify and implement less hazardous chemical operations when possible.	Trend in Control Band assignments for lab work over time
Laboratory supervisors and academic administration	Identify and implement opportunities to decommission hoods or reduce general ventilation flow-rate or plug-load	Number of hoods decommissioned or labs whose Control Banding assignment is lowered

Infrastructure Properties and Planning (IPP) and Environmental Health and Safety

Roles	Responsibility	Tracking Indicator
IPP mechanics	Monitor face velocity of fume hoods	Number of hoods with face velocities outside 120% of recommended value
Energy Management staff and shops mechanics	Continuously commission laboratory ventilation systems and implement and track hood decommissioning	Trends in energy consumption of laboratory buildings
IPP and EHS staff	Observe hood housekeeping conditions during hood certification and other lab visits	Use of HHS to educate occupants about the proper use of fume hoods
IPP, EHS staff, Energy Management staff, building coordinators and Departmental Safety Representatives	In consultation with Laboratory Ventilation Specialist, approve opportunities for hibernating hoods (see section 7.3), reduced general ventilation flow-rates or fume hood face velocities	Reductions in laboratory ventilation rate implemented
EHS Laboratory Ventilation Specialist and Energy Outreach Coordinator	Provide education and outreach to lab occupants about safe and sustainable general ventilation and fume hood practices	Number of laboratory consultations to apply good ventilation practices to their lab
Energy Management staff	Maintain metrics database that converts building ventilation rates to financial and carbon costs	Decrease in financial and carbon operating costs of laboratory ventilation on campus
Campus Laboratory Planners and Designers	In consultation with facilities management and EHS, develop laboratory designs with ventilation operating costs in mind	Ventilation Control Band distribution and number of fume hoods installed relative to campus benchmarks
IPP Managers	Assign laboratory facilities to minimize ventilation requirements to support the work being conducted	Lab ventilation control bands appropriately reflect chemical use in labs
EHS staff	Conduct risk assessments of lab operations with ventilation effectiveness a central component	Appropriate ventilation rates assigned to lab spaces to maintain safety of occupants

Professional Peers

Roles	Responsibilities	Tracking Indicator
Laboratory science peers, nationally and internationally	Review of ventilation program impacts upon science developed in Cornell laboratories	Adoption of similar practices by other campuses
IPP and EHS peers nationally	Establish external standards for best practices and performance with regard to laboratory safety and carbon emissions	Ongoing compliance with external standards

Campus Community

Roles	Responsibilities	Tracking Indicator
President and Provost	Assure that financial and carbon operating costs are included as part of laboratory facility planning	Upper level support of the CAP efforts over time
Cornell Sustainability	Track energy usage and carbon footprint of laboratories on campus	Metrics for success of energy conservation initiatives
Public	Understand and be publically involved with energy consumption within the county	Public interest in energy reduction efforts of the University

6. Training

Elements of each group's role in the laboratory ventilation program are included in departmental and Environmental Safety training programs. This Environmental Safety training program is currently being expanded in order to spread the awareness and knowledge of lab ventilation stakeholders more broadly.

7. Operational Tools

Standard Procedures

The following section lists the operational procedures and documentation that organize the Laboratory Ventilation Program. Cross departmental policies and procedures are also provided with links to the appropriate websites.

7.1.1 Fume Hood Commissioning and Annual Inspection Procedure

This procedure outlines routine practices associated with fume hood installation and oversight by support staff.

7.1.2 Design and Construction Standards

This standard describes Cornell's expectations for laboratory ventilation design during laboratory construction and renovation. See Standard 230540 for Laboratories at **http://cds.fs.cornell.edu/toc.cfm**.

7.1.3 Carbon Dioxide Ventilation Effectiveness Protocol

This procedure describes the process for assessing laboratory ventilation effectiveness in specific laboratories in order to support a laboratory ventilation control banding assignment for the laboratory.

Job Tasks

The following section lists the daily job plans specific to individual activities.

7.2.1 Fume Hood Recertification

This job plan specifies requirements for testing and inspection of individual fume hoods on an annual basis. Specific assignments and results are managed by the Infrastructure Properties and Planning Maximo system.

7.2.2 Fume Hood Commissioning

Conducted by EHS this is the final verification of proper operation and inventorying of new fume hoods.

7.2.3 Fume Hood Maintenance

Fume hoods are to operate within the face velocity parameters recommended by Environmental Health and Safety. Those that are outside of this range, as indicated by the certification sticker on the fume hood, are to have a work order issued by the building coordinator if safety related or the Energy Management office if energy related to have the hood face velocity corrected.

Fume Hood Hibernation

Hoods which will not be used for chemical containment purposes for at least 3 months can be "hibernated" by request of the Facilities Control Shop, Energy Conservation and Controls Team (ECCT). This is initiated within the Maximo database system as a service request.

7.4 Forms

Forms can be found at: https://sp.ehs.cornell.edu/lab-research-safety/chemical-safety/lab-ventilation/Pages/default.aspx

See Maximo database for performance information and history about individual hoods

See building control system for information about current room ventilation rates

8. Recordkeeping, Reporting & Monitoring

Key Performance Indicators

The key indicators measure the performance of the program by providing feedback loops that can be monitored and adjusted. The leading indicators for this program are Green Laboratories and Hood Housekeeping. The Green Labs concept is an initiative used to drive the choices of chemical usage toward less hazardous options and equipment placement within a room with the effectiveness of the ventilation in mind. Hood Housekeeping is a scorecard for fume hood usage made from observations by EHS staff and facilities maintenance staff. The two lagging indicators are measurements of actual energy usage as measured by the Energy Management staff after changes have been made. Chemical Safety Conditions is accomplished by monitoring improvements from a variety of tracking methods from other established EHS programs and feedback mechanisms.

Indicator Groups	Indicator	Oversight Department	Type of Indicator
Plan: Green Laboratories	Distribution of labs in Laboratory Ventilation Control Bands on campus	EHS Lab Ventilation Program	Leading Sustainability
Do: Hood Housekeeping	Improvements in Hood Housekeeping Score	EHS Lab Ventilation Program	Leading Safety
Check: Energy Use	Amount of energy used, and consequent carbon emissions, by Cornell labs on an annual basis	ECI and Sustainability Program	Lagging Sustainability

Act: Chemical Safety Conditions	Improvement in laboratory safety observations, based on EHS audit scores, IAQ concerns, and hazmat responses	EHS Lab Ventilation Program	Lagging Safety

Control Band Assignment

This rating system is based on the chemical usage and housekeeping of individual spaces. The rating is based on the control banding protocol outlined in the EHS procedure. This data will be used to identify trends in the intensity of laboratory chemical use over time. This will be stored on the Cornell EHS Sharepoint team-site and potentially in the Maximo database or Facilities Space Inventory.
Although we recognize 4 bands that exist in labs that have single-pass airflow, the control banding assignment only involves the first 2. The following are examples of labs that do meet the criteria for reaching the moderate ventilation rates that are being used to meet energy conservation goals.

Ventilation Rates potentially higher than 8 ACH (occupied):

1) Ventilation systems that require higher rates due to environmental condition needs, such as clean rooms;
2) Labs where the stability of temperatures or humidity are important for the processes occurring in the space and will be negatively impacted with the ventilation rate reduction;
3) Small labs with a fume hood in which the general airflow rates are driven higher to meet the exhaust requirements of the hood (fume hood driven rooms);
4) Labs with high human or animal occupancy;
5) Labs whose chemical operations change so often that effective oversight of their ventilation is not possible with current EHS resources.

Ventilation Rates Lower than 6 ACH (occupied):

1) Low hazard/low volumes of chemicals in use;
2) Human occupancy and personal odor control is the main driver for ventilating the space;
3) Intermittent chemical sources that require single-pass air but do not constitute as a “significant chemical source;
4) Lab support spaces that meet the definition of a lab but where there is little or no lab work occurring;
5) Labs where the maintenance of temperature is the main river, but where there is a fan coil unit or other less energy intensive technology to maintain space temperature.

Laboratory ventilation control bands	General ventilation rate
Design-to ventilation	8 ach occupied / 4 ach unoccupied
Moderately ventilated	6 ach occupied / 3 ach unoccupied
Low laboratory ventilation provided	single pass air required, but ventilation rate is determined by specific operating schedules or other management practices
Specialized ventilation required	to be determined by engineering analysis

Hood Housekeeping (HHS)

During annual hood certification visits laboratory hood uses are assessed according to the scale below. This scale is based on best practices for safe and sustainable fume hood use. Trends in these scores will be used to design laboratory worker training and education efforts. This information is put into the Maximo database for each hood upon annual certification.

Hood Housekeeping Score (HHS)		Reason for concern
1	Hood decommissioned	None
2	Hood on, used for a single chemical process or well organized multiple purposes	None
3	Hood on, but empty or being used for storage	Sustainability
4	Hood on, crowded or used for competing multiple chemical uses	Safety
5	Hood on and contamination evident	Safety
The higher the Hood Housekeeping Score, the more serious the concern		

Goals and Gap Analysis 2012

Stakeholder Perspective	Current Situation	Where you'd like to be over a specific time frame? (SMART Goals)	How the Gap can be filled	Change leader
Laboratory population	Little practical training about appropriate fume hood use is currently available	Development of an occupants "hood use review" – a form that occupants could fill out to determine when a hood is required for a specific chemical process GOAL: Such a form is available in July, 2013.	Develop 'Hood Use Review" form. This should support culture shift where lab occupants participate in hazard review of their space and will support proper hood use instruction for lab population.	EHS
Laboratory population	Few fume hoods have undergone hood hibernation (temporary decommissioning).	Observations indicate that around 30% of hoods are not used for chemical processes. But are on when not needed; wasting ventilation air. GOAL: 20% of fume hoods on campus are in hibernation by 2015	Include this process in Facilities Customer Service.	Green Labs Program
Laboratory population	Green Chemistry principles are inconsistently applied across campus.	Broad application of Green Chemistry Principles within laboratories as outlined by EPA and ACS GOAL: 20% of labs adopt the *beyond benign*	Green Chemistry outreach program to laboratories with 4 key elements: solid waste, ventilation conservation, decreasing chemical hazards and	Green Labs Program

		Green Chemistry Commitment by 2014	reducing plug-load	
Facilities and EHS support services	"Housekeeping" only communicated through lab inspection program with no follow-up. There is a corrective action issued to PI, but the frequency of inspections is low.	Hood Housekeeping ratings for hoods (to be collected in Maximo) GOAL: HHS System in place by July 2013:	Instruct Steve Phayre to rename column, provide Steve Palmer with rating system and anyone else who views the hood inventory	EHS / ECI partnership
Facilities Services	If the hood is found to be operating above 120 fpm it is a priority for adjustment	Fume hoods across campus that operate between 80-120 fpm. GOAL: Reduced number of fume hoods operate above 120 fpm each year	Instruct Steve Palmer and Rick Bishop that tickets are to be issued for hood above range	ECI outreach and EHS
Facility and EHS support services	Control banding system for labs needs further development and implementation	Control Banding is in common use and a general awareness exists of how it is accomplished among lab population GOAL: Form available by October, 2013	Need total development of the banding part of the LVM Program.	EHS
Energy Management Program and EHS	Many laboratories are currently ventilated at rates above the design standard of 8 ach occupied / 4 ach unoccupied	Survey operational laboratories for ventilation reduction opportunities	All buildings are identified for survey by March, 2013 (accomplished); 50% of buildings are adjusted by January, 2014 and reminder	Energy Management and EHS

			are adjusted by January, 2015	
Facilities Services and EHS	Outdated Laboratory Design standard requirements	Update Laboratory Design standard to reflect best practices described in the Labs-21 program materials	Discussion with facilities engineering design section	EHS
External peer groups	Peer review of scientific program development upon submission of written work or presentation	Frequent opportunities for peer review via manuscripts, presentations, standards development, etc GOAL: 2 national presentations or papers on the Green Labs and/or lab vent program each year	Continue to seek outreach opportunities with appropriate groups, including American Chemical Society, AASHE ERAPPA, and Labs 21	Facilities Services and EHS
Campus community	Specific tracking of carbon footprint indicator directly tied to LVMP	Public messages describing Cornell's conservation efforts with regards to lab sustainability GOAL: Public recognition of lab role in achieving climate change	Incorporate metrics done by ECI, but calculate portion afforded specifically to lab vent.	Facilities Energy Management (ECI)

8.5 Goals and Gaps 2014

Stakeholder Perspective	Current Situation	Goals	How the Gap can be filled	Change Leader
Laboratory population	Little practical training about appropriate fume hood use is currently available	Hood Housekeeping scoring system is easily available to lab staff GOAL: Score made available with lab inspection reports in December, 2014.	Create action items in lab inspection reports that includes HHS. This will support culture change that support lab occupant participation in hazard reviews of their space and proper hood use instruction.	EHS
Laboratory population	No lab community awareness of sustainability efforts with respect to lab ventilation.	General knowledge of lab ventilation energy usage on campus by end 2015.	Include sustainability in lab trainings, inspections and other communications with lab population. It is currently part of all introductory lab safety trainings.	Lab Ventilation and Green Labs programs
Laboratory population	Green Lab principles are inconsistently recognized across campus.	Broad application of Green Chemistry Principles. Sustainability of labs a common concern of lab population. GOAL: 10% of labs become Green Lab certified by end 2016	Green Lab outreach program to laboratories with 5 key elements: solid waste, ventilation and water conservation, decreasing chemical hazards and reducing plug-load.	Green Labs and Lab Ventilation Program