

Is it possible to reduce the green house gas emissions linked to energy use in MIT labs?

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1. Introduction

The nature of environmental problems facing our societies is complex and wide reaching. Sustainable development is not just another category of environmental, social and economic problems we face; it is a way of thinking about these issues. If we do not learn to think about global environmental degradation in a more effective way, we will continue to make little progress in reducing them. Part of the intellectual challenge of sustainable development, therefore, is that we must learn how to solve several problems at once.

Global warming is a worldwide problem that everyone —governments, industry, communities and individuals— should contribute to solve to make a real difference.

In 1992, the United Nations Earth Summit in Rio de Janeiro produced a Framework Convention on Climate Change (UNFCCC) aimed at the “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” (art.2 UNFCCC). Most of the countries, including the United States, ratified this non binding agreement that entered into force two years later.

In 1997 the Conference of the Parties of the UNFCCC adopted the Kyoto Protocol which added binding targets - quantified emission limitations and reduction commitments – and timetables to the framework Convention.

As of 29 April 2005, 150 states and regional economic integration organizations have deposited instruments of ratifications, accessions, approvals or acceptances of the Protocol (UNFCCC website). The United States of America, the world’s largest emitter of green house gases (GHG) has not ratified the Protocol yet.

However, there are many initiatives underway in USA at regional, state and local level.

In August 2001, for example, the New England States and the Eastern Canadian Provinces adopted a regional Climate Change Action Plan to reduce GHG emissions to 1990 levels by the year 2010, with a further 10% reduction by 2020. The Massachusetts Climate Protection Plan adopted in 2004, represents the Massachusetts commitment to achieve the goals established in the Regional Plan and even attempt to exceed the regional emissions targets.

Within Massachusetts, the City of Cambridge represents one of the few Municipalities that have adopted their own Climate Protection Plan. The goal is ambitious since it aims at reducing GHG emissions by 20 % from 1990 levels, by 2010. Cambridge is also part of the International Campaign “Cities for Climate Protection” which includes about 150 cities in the United States, and 675 participants worldwide.

Major Cambridge based institutions and companies are already taking actions to reduce their own impact. The Massachusetts Institute of Technology is one of those.

This study focuses on GHG emission reduction through energy conservation opportunities at the MIT campus.

Our main focus is concentrated on wet labs and in particular, on one of the most energy intensive equipment of a wet lab which is the fume hood.

In this report, after describing our decision making process and the methodology used, we try to find an answer to the following question: is it possible to reduce GHG emissions linked to energy use in the MIT labs?

2. Background

In this chapter we describe our decision making process. How did we get to our research question? Which are the steps that we followed while merging ourselves into the green house gas issue?

2.1 Broad look on the role of high educational institutions in the environmental issues

Climate change, acid rain, deforestation, species extinction, fisheries depletion, soil erosion, toxic buildup in ecosystems, water, land and air pollution and ozone depletion are some of the most important environmental problems that are forming a web of destruction around the world. The solution of these problems requires professionals with multi level problem solving skills, professionals that can work collaboratively in interdisciplinary teams to solve problems from a holistic point view. Hence, the role of universities becomes imperative.

Universities can give students and future leaders the intellectual tools for doing that. U.S. colleges and universities influence the standards for higher education throughout the world. They also serve a larger international student body than in any other country. It is incumbent upon American higher education to contribute to solving the global challenge of sustainable development (Clugston and Calder 2002).

In particular, Universities with an excellent global reputation like MIT attract a significant amount of international students and in that sense they could make an impact not only nationally but internationally too.

According to Anthony Cortese there is a growing demand at colleges and universities in the United States and internationally for environmental education and for institutions to reduce the environmental impact of their own operations. This effort must be encouraged (Cortese 1999).

Through out the evolution of Higher Education for Sustainable Development in the U.S we can see that in Massachusetts, Institutions played and are still playing an important role in the scaffolding of “how” to become a

greener campus and through that process educate on sustainability. Universities like Tufts, University of Massachusetts, Harvard, MIT, Boston University, just to mention a few, have all been to some degree active in this process.

Anthony Cortese mentions in his paper “Education for sustainability (the university as a model of sustainability)” that without strong outside influence higher education is not likely to change its direction far enough or fast enough. What are those Universities doing regarding worldwide environmental problems like climate change? Besides the external pressure of the compliance with environmental rules, do they have other reasons to work on efficient resource management on campus? Basically, what exactly is going on these campuses?

Those are the first questions that we asked to ourselves when we started thinking about the focus of our study.

We decided to focus on MIT, mainly because we could have easier access to the necessary sources of information.

2.2 Why focus on Labs?

Once we decided to investigate MIT activities to reduce GHG emissions, we choose to restrict our area of study to specific intensive energy consumptive spaces.

This brought our choice towards lab space.

According to the US Environmental Protection Agency (EPA) and the US Department of Energy (DOE) a typical laboratory uses far more energy (5 to 10 times) and water per square foot than a typical office building, due mainly to intensive ventilation requirements.

Within the MIT campus, in particular, if we consider the usage of energy among different kind of room use (academic, wet lab, residential, and service), the wet labs are the most energy intensive spaces. The percentages of energy consumption are represented in figure 1.

Within a wet laboratory, fume hoods are one of the biggest sources of energy drain.

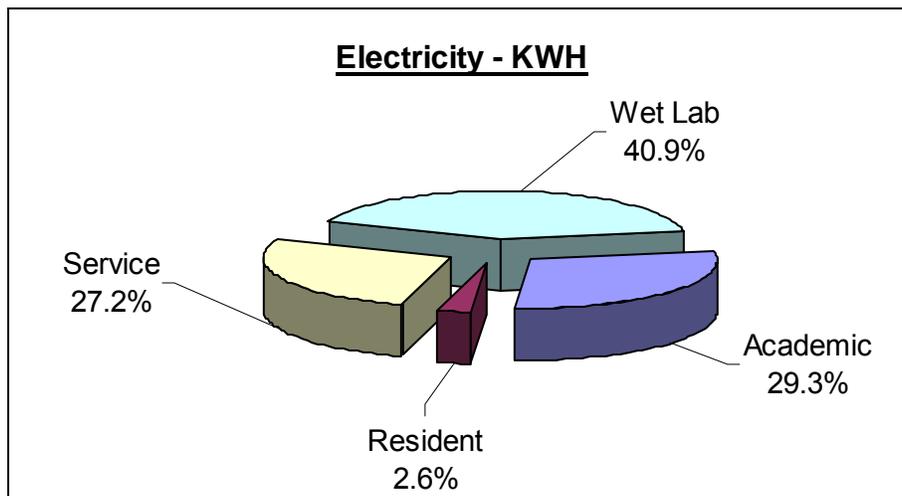
At this stage, we defined our research question which is: “*Is it possible to reduce the Greenhouse Gas emissions linked to energy use in MIT laboratories?*”.

To approach such a question, a beginning was made by familiarizing with the relevant aspects of the MIT campus, which included recently renovated labs. Since the use of energy requires knowing the amount of energy used, a look at the metering system was also found to be essential. It was also thought to be beneficial to look at relevant projects currently in progress. These ideas put into perspective some way of going about finding an answer to our question.

Table 1: Energy use by utility system within MIT

	Gross area - Sq Ft	Electricity - KW	Electricity - KWH
Academic	2,662,698	9,569.0	52,711,488
Resident	1,578,815	576.0	4,765,997
Service	4,904,336	6,580.3	48,959,844
Wet Lab	1,309,863	12,355.6	73,713,285
Total	10,455,713	29,080.8	180,150,614

Figure 1: Energy use (%) by utility system within MIT



Source: MIT campus building model 2003.

We also thought that it would have been interesting to examine the changes that occurred, if any, in the labs planning and/or operating system, after EPA fined in 1998 MIT for the violation of certain requirements of the Resource Conservation and Recovery Act (RCRA). As a consequence of the latter, in 2001 MIT entered into a Consent Decree to:

- achieve compliance with RCRA
- complete supplementary environmental project
- make improvements to MIT environmental management system

While collecting information on laboratories we discovered the existence of an EPA and DOE voluntary program called Laboratories for 21st Century (Labs 21) dedicated to improving the performance of U.S. labs with particular attention to the energy efficiency issue.

Before entering the details of our study, it is necessary to describe the main object of our research, the fume hood and talk briefly about the Labs 21.

2.3 Fume hoods

This section defines a fume hood and examines its function.

For the purpose of this study, a fume hood may be simply defined as *an exhaust system used for removing hazardous gases and vapors generated from ongoing experiments in a workspace*. While a fume hood may be considered a primary means of protection and first defense to minimize chemical exposure to research workers from inhalation of hazardous vapors, it is also a device that has the potential to be the biggest energy consumer depending on how it is used.

The fume hood protects users from inhaling chemicals by constantly pulling air into the hood and exhausting it out of the building. The system may either use a complete hood in case of larger experiments or sometimes snorkel systems are used for local and minimal exhaust. (figure 3).

This mechanism of exhausting air from the fume hood requires the use of energy, which is the primary concern of this study.

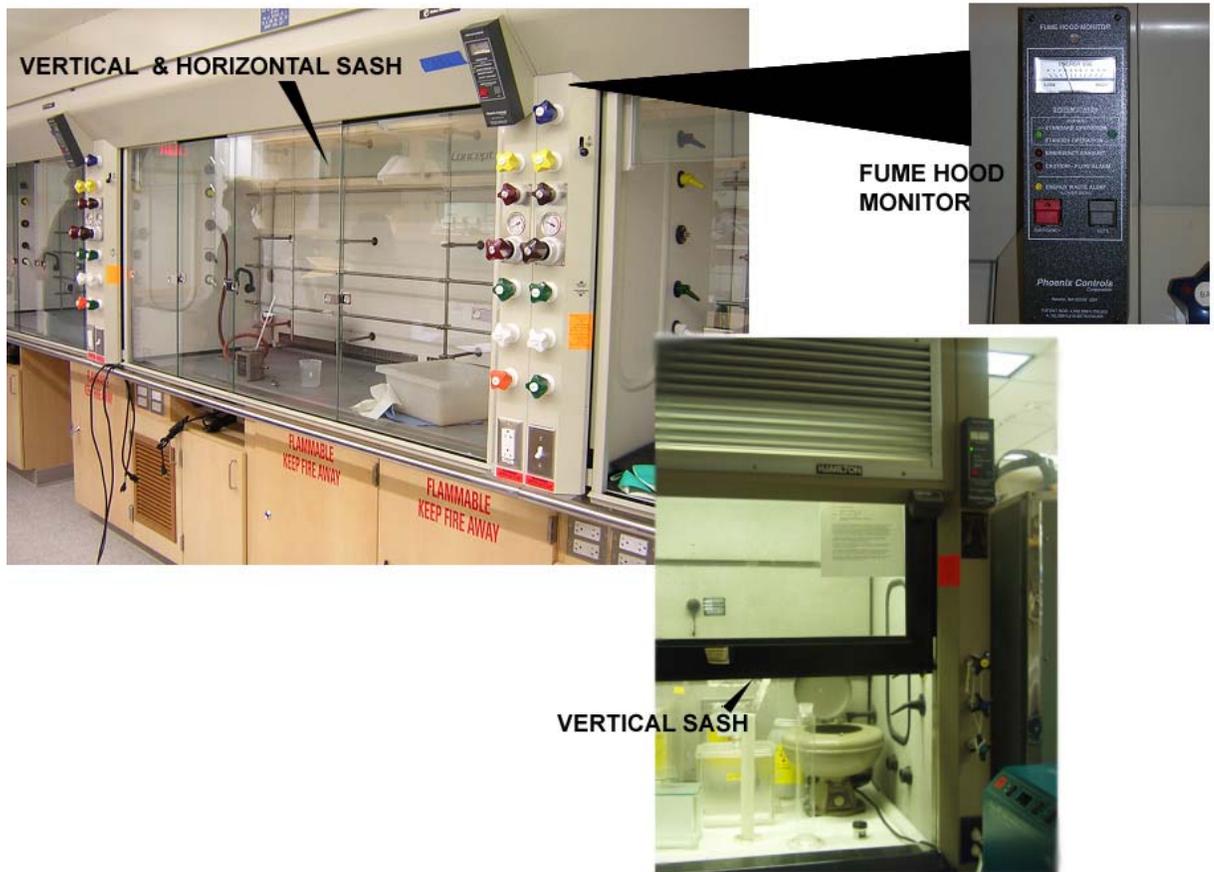
Energy use therefore depends on the position of the sash (the term used to describe the movable glass panel that covers the face area of a fume hood). Sashes can be vertical, horizontal, or a combination of the two opening (see picture 2.1).

There are many types of hoods available, each with its own design and function based on either the Constant Air Volume principle (CAV) or the Variable Air Volume Principle (VAV).

The acceptable range of the average face velocity (measurement of the average velocity at which air is drawn through the face to the hood exhaust) is 60-100 feet per minute (fpm). If non-carcinogenic materials are being used the acceptable face velocity for minimally hazardous materials is 50 fpm. The ideal average face velocity is 100 fpm for most operations. Most hoods installed today are at 100 fpm. The variable air volume hoods differ from constant air volume hoods because of their ability to vary air volume exhausted through the hood depending on the hood sash position while maintaining a constant face velocity regardless of the sash position. VAV hoods are becoming the preferred hood due to the elimination of excess face velocity that can generate turbulence leading to contaminated air spillage, endangering the worker. They also reduce the total quantity of supply and exhaust air to a space when not needed, thereby reducing use of energy.

The current technology in fume hood system may be seen in the effective integration of the fume hoods and ventilation components by the **Phoenix System**. Its pertinent points may be summarized as follows.

Picture 2.1: A complete Phoenix System fume hood



- The Phoenix system controls energy use by monitoring sash height and correspondingly regulating the amount of airflow into the hood (see picture 2.1).
- Lower sash heights result in less air exhausted by the hood. This reduces the energy requirement of the hood itself as well as the building system that must supply conditioned make-up air to the room. An alarm if fitted to indicate any fully wide open sashes.
- In addition, the Phoenix controls are equipped with a motion sensor. When there is no movement present, the exhaust air is further reduced.

2.4 Laboratories for the 21st Century program

Labs 21 is a voluntary program established by the EPA and the United States Department of Energy (DOE) to improve the environmental performance of U.S. laboratories and in particular, their energy efficiency. . It consists of three components: training and education, partnership programs, tool kit . The latter includes design guides, case studies, a performance rating system, best practices, and other tools.

Labs21 Environmental Performance Criteria (EPC) is a rating system specifically designed for laboratory facilities. It is based on Leadership in Energy & Environmental Design (LEED) Building Rating System established by the United States Green Building Council (USGBC) for improving environmental building performance. However, LEED focuses on commercial or residential buildings, not laboratories. Therefore, the EPA and DOE established Labs21 to make environmental standards specifically for laboratories.

- **Purpose**

This program provides mainly energy-efficient strategies for designing and equipping the laboratories of the 21st century.

- **Benefits**

According to US EPA, if half of all American laboratories can reduce their energy use by 30%, the nation could reduce its annual energy consumption by 84 trillion BTUs - equivalent to the annual energy consumption of 840,000 household -. This would decrease CO₂ emission by 19 million tons equivalent to removing 1.3 million cars from U.S. highways.

- **Check point**

Conditioning Ventilation air: energy-efficient technologies (variable-air-volume (VAV) fume hood and heat recovery)

3. Methodology

The methodology we used in our study includes, but it is not limited to, the following:

Literature review: This consisted of web site searches and review of other relevant documents such as the consent decree of MIT, report on fume hoods by Duke University and the Environmental Health and Safety (EHS) manual.

Group discussion: The numerous guest speakers brought our attention to many aspects that could be included in our project. The presentation that was required to be done by the group also helped to narrow down the focus into the ultimate question. Various inter and intra team discussions provided opportunities to view the focus of the project from different angles.

Interviews: The various members of the group met with different people who had some relevance to sustainable development. These were mainly people in MIT in the capacity of academic or administrative staff.

Field visit: The group also made some field visit to various building of interest which included an extensive tour of the Dreyfus Building (building No. 18), the Genzyme building, a Green Campus tour and a quick look around building No. 68.

Survey: A very simple survey was carried out based on a few questions which were meant to capture the mind frame of the laboratory users in building No. 18. The survey consisted of some direct questions as well as a few multiple choice questions. The multiple choice questions were put in with a purpose to direct focus on the topic which could otherwise blow out of proportion on the issue of sustainable development. This survey will be discussed in details at a later stage (See appendix A for a copy of the questionnaire).

4. Observations

In following the above methodology, the group was able to discern a few observations from the various tasks.

4.1 Observation from interviews and field visit

From interviews and discussions, it was found that many lab buildings on MIT campus are not metered.

Building 68 was recommended to be inspected based on the fact that it is a renovated lab building that which has a metering system in place.

Unfortunately this visit was not possible due to unavailability of persons in charge. The presence of this metering system is important because it serves not only as a base energy use estimate for other similar types of building on campus but also for cost estimating for research grants and other funding purposes.

A discussion with the administrator officer of the Department of Chemistry, Richard Wilk, clearly showed that Building No. 18 had undergone complete renovation (started in 2002 and completed in 2004). This renovation included features many of which were energy saving methods such as energy efficient windows (with infra red screens), central exhaust system, new fume hood system, increasing natural light in the labs as well as a new roofing system.

Discussion with various people brought to light that energy efficient buildings would be welcome especially from the point of view of recurring and operational costs. A suggestion that surface time and again, seemed to be that while planning a project, the entire cost of the project, meaning life cycle costs as well as environmental costs, should be taken into account. This was not done previously because in many projects the people who made decisions on the capital cost of the project differed from those responsible for the operational costs. It was also noted that energy saving measures are not required as per the law. In other words, these are voluntary actions taken by institutions or organizations.

Julie Paquette, a current MIT graduate student, participated as an engineer in an advisory group that conducted a national survey to assess the case for a thorough review of current standards and codes to further drive energy efficient lab design and operations. According to her, MIT is more inclined to invest in energy efficient lab design and operations for new constructions rather than for renovations. This is because renovation projects are typically funded by individual research grants from outside, and therefore funding is mainly applied to the most important research group.

She asserts that guidelines for the laboratory renovation projects should be created to satisfy the environmental improvement.

Another interesting issue that she mentioned is that laboratory designers

tend to build laboratories with extra capacity because they consider future expansions but often the projections could be inaccurate. For example, when a designer plans the size of a chilling water system, the design engineer estimates one thousand two hundred tons, but actual maximum load required is only three hundred and typical load is less than one hundred fifty tons. This situation shows lack of feedback in the operating system. To avoid that, she suggests that the designer, contractor, operator and client need to work together at the very beginning of the project.

Observations made during the field visit are mainly centered on the visit to building No. 18. It was observed that this building boasted of the state-of-art-technology for fume hoods. It has the Phoenix system which clearly display to the user of the fume hoods the energy used at that instant. (See picture 2.1) The fume hoods were outfitted with the double sashes, both vertical and horizontal ones, for safety reasons as well as for energy efficiency purposes.

An automatic alarm goes go off if the sashes are open completely, to warn of huge air volume suction. Sensors are present to detect movement in front of the fume hoods. In the absence of movements, the fume hoods automatically lower the air flow velocity thereby saving energy even if the sashes are left open. There are also occupancy sensors for lighting system. With this sophisticated system in place, it is now left for the users to actually put these devices to maximum efficient use. The behavioral aspect was also noted during the visit and it was found that many fume hoods are left open (see picture 2.3).

Some experiments were observed to be completely set up in the fume hood itself, which raised the question of its necessity (see picture 2.3).

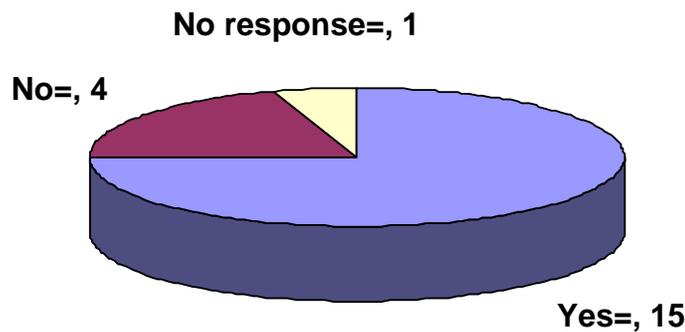
The other important observation was obtained from the result of the short survey that was carried out.

4.2 Simple survey

The behavior of researchers in a laboratory building influences CO₂ emission caused by energy consumption. Researchers spend most their time in the laboratories and use fume hoods. To have a general idea of the researchers view, regarding the energy intensity of lab spaces compared to other spaces on campus, this small scale crude survey was implemented. The survey consists of five questions and involved twenty at random researchers (PhD, post doc, graduate students and undergraduates) working in Building 18.

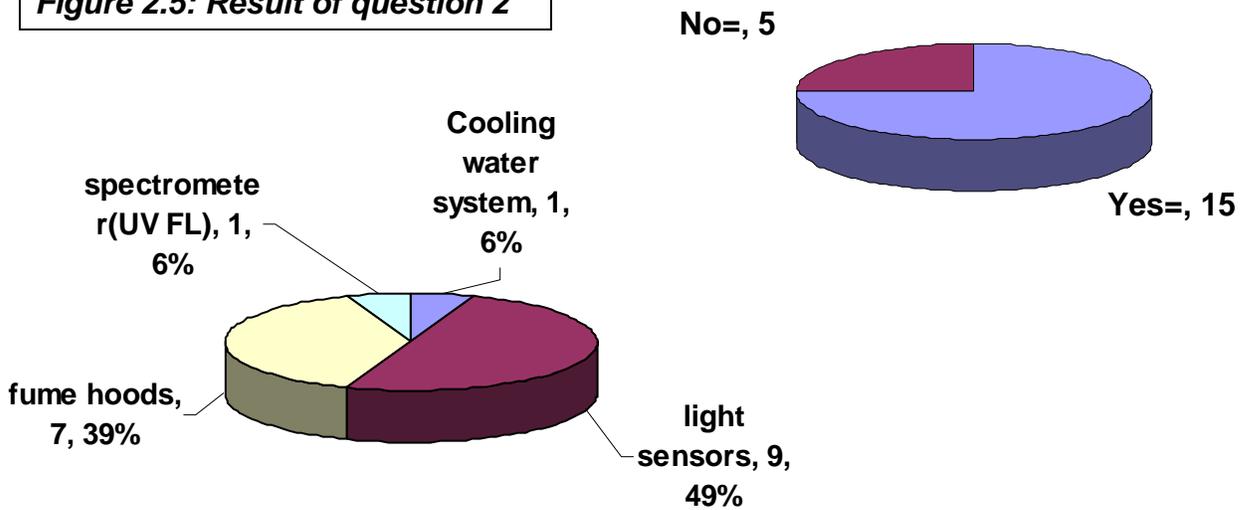
The first question asked whether or not they were aware of the energy intensity of their lab space compared to a classroom or office area. Fifteen people said yes. Seventy five percent of researchers answered that they know about the energy intensity of their laboratories. (Figure 2.4)

Figure 2.4: Result of question 1



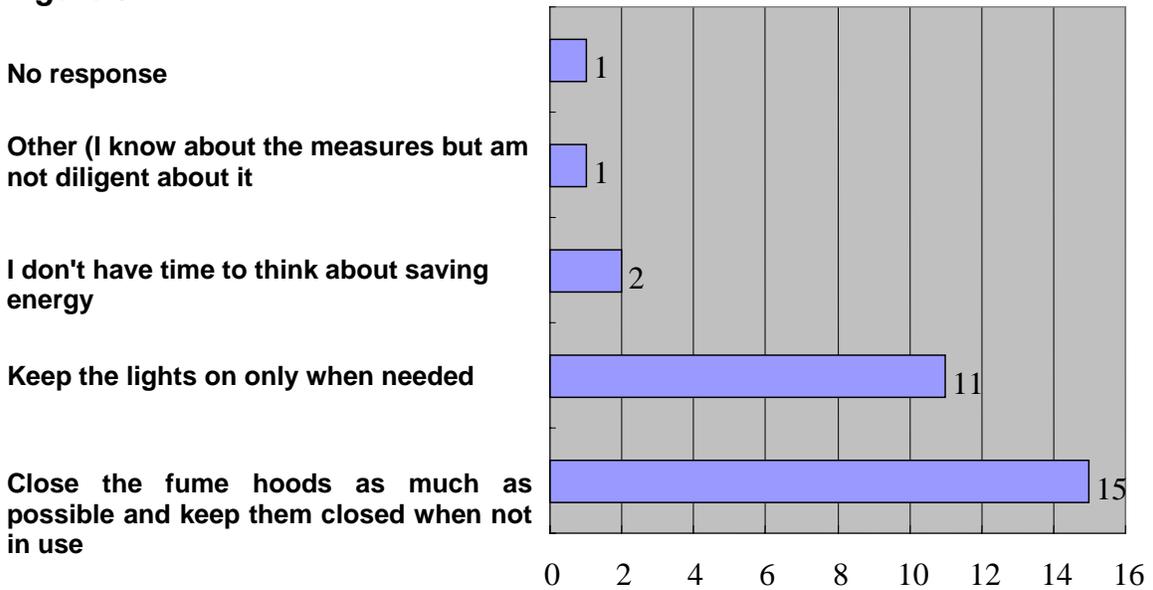
The second question asked whether they were aware of any measures to reduce the energy use in their lab space. If they answered “yes,” the next question asked what they thought such measures were. There were 15 yeses that show half of them talked about light sensor (49%) rather than fume hoods(39%) even though the fume hoods should have top priority when energy saving is considered. This result might be indicating a lack of awareness of the researchers surveyed. (Figure 2.5)

Figure 2.5: Result of question 2



The third question asked about what they were doing to try to save energy in their laboratories. Multiple choices were given. Fifteen indicated that they closed the fume hoods as much as possible and kept them closed when

Figure 5.1

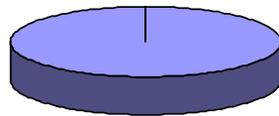


they are not in use. Eleven said that they kept the light on only when it is needed (Figure 2.6).

The fourth question asked about if they knew the optimal use of fume hood regarding to safety and energy. There were one hundred percent of yeses regarding safety, but for energy use, there were only fifty percent of yes (see figure 2.7).

Figure 2.7: Result of question 4

Regarding to safety?



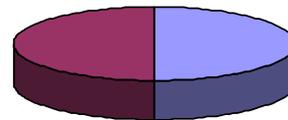
yes= 20

100%

Regarding to energy?

no= 10

50%



yes=10

50%

The fifth question asked them to make suggestions if they had any. There were several suggestions, such as that all new equipment should be energy efficient, or that more energy efficient chilled water systems were necessary. The most interesting response was that radios in the laboratories should be turned off. The following list shows the responses as written by the researchers.

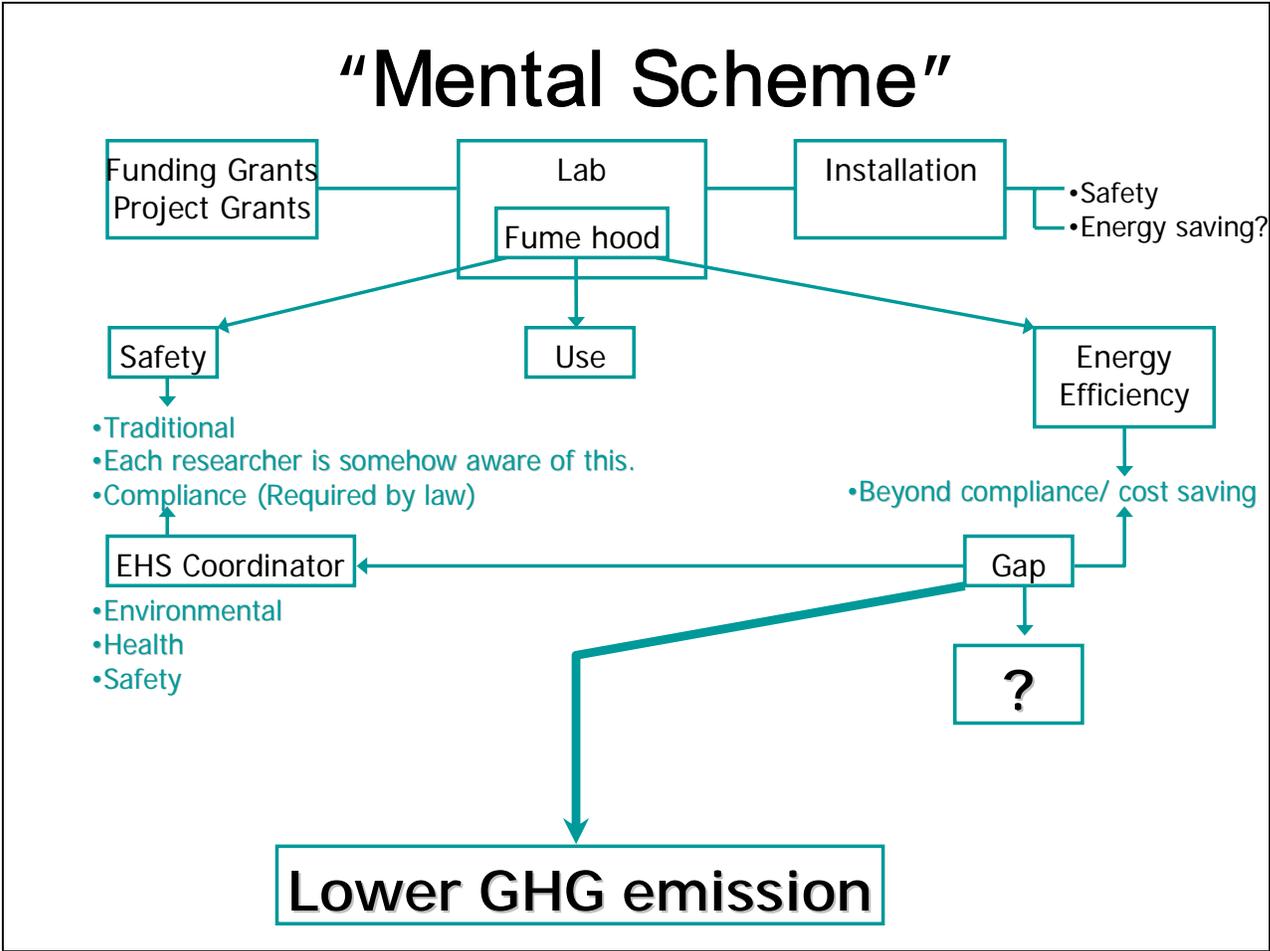
- All new equipment should be energy efficient.
- More efficient chilled water systems
- Personal efforts
- Light sensors
- Air con more cooler than needed, heat more than necessary
- Automatic hoods
- Lower air flow circulation at night
- Can't think of anything
- Turning off instruments – lights in the fume hoods
- Vacuum pump power – turn off
- Turn off radios

4.3 The importance of training

Due to the energy intensity of fume hoods in lab systems, the phoenix one mentioned earlier come in handy to have a more efficient use of energy. But the operators of fume hoods (researchers) are mainly familiar with the safety aspects of the fume hoods and not really with the energy consumption aspect, meaning

that the implementation of a system like the phoenix system without a proper training to the users might have no positive effect on the decrease in energy consumption. (See also fig 2.8)

Figure 2.8: Mental Scheme



5. Benefits of conserving energy in the labs: The Duke University study and the Berkley fume hood report

5.1 A summary of the Duke report

5.1.1 Introduction

In the summer of 2003, the Duke University and the Labs 21 program of the EPA conducted a study under a voluntary partnership. The aim of the study was to quantify benefits associated with low cost administrative controls that promote the efficient operation of laboratory fume hoods. Laboratory fume hoods were chosen as the focus of this study due to the fact that they are typically the largest energy consumer in the laboratory and their prevalence in most laboratories. Fume hoods consume energy directly through exhaust fans, flow monitors, fume hood lighting, and other fume hood mechanical devices. They also consume a great deal of energy indirectly from the associated heating and cooling costs of exhausted air.

Duke University's Levine Science Research Center (LSRC) was chosen as the site for this study due to its high concentration of fume hoods and its automated fume hood monitoring system.

This study is presented in this work because of the relevance it has to the situation of Building 18 on the MIT campus. This recently renovated chemistry building has a total of 200 fume hoods all equipped with double sashes and a phoenix system.

5.1.2 Some previous calculated cost

According to the Duke report, various studies have been conducted to address the costs associated with laboratory fume hood operations and patterns in fume hood utilization. The annual cost of a cubic foot of airflow in a laboratory facility has been estimated to range from \$2 to \$7. The Colorado School of Mines estimated their costs at \$2 per cfm, Grossman estimated the cost around \$3 per

cfm, Bentsen estimated the cost around \$4 per cfm, and Ryan estimated the cost to be from \$4 to \$5 per cfm. Variation in these estimates stems from differences in energy costs, climate, and efficiencies of HVAC systems. Another reason for the discrepancy is that many estimates only include the direct energy costs, while others estimates include differed maintenance costs, extended equipment life, etc. The annual cost of a cubic foot of airflow in LSRC is estimated to be \$3, based on the buildings historical energy consumption and certain assumptions. (For more detailed calculations of energy cost per cfm sees section 2.4 of the Duke report.)

Numerous articles have been published that contain estimates the typical amount of time a laboratory operator spends at their fume hood on a daily basis. The amount of time a fume hood is used appears to be a function of (1) the number of laboratory personnel per fume hood, (2) the type of laboratory facility, and (3) the type of research that is being conducted. The average daily fume hood utilization estimates range from less than one hour per day to almost twelve hours per day. Grossman estimates that the typical laboratory operator spends 1-2 hours per day at their fume hood. In a survey conducted by Rabiah and Welkenbach, a survey of six University of Michigan departments found that fume hoods were open from 1 hour to 11 hours per day depending on the department. In a study published by Phoenix Controls actual fume hood utilization at a pharmaceutical company was measured and the results of study indicated that the average hood was used for less than an hour and a half each day. It is believed that fume hoods in LSRC are directly utilized for an average of two to six hours per day based on conversations and observations.

5.1.3 Short description of the methodology

Basically they chose two different lab areas within the LSFC and use the researchers per space as a control and an experimental group. The study was than split up in two phases. Table 5.1 gives a brief description of this lay out.

Table 5.1: layout of the Duke Study

	Control group	Experimental group
Phase 1 (Baseline hood utilization)	No training	No training
Phase 2	No training	Training

Important details about their methodologies will be briefly listed as follows:

- **Duration:** 7 weeks study.
- **Training:** The experimental group received individual one-on-one training that took 1 day. A Handout given the researchers and magnets posted on the fume hoods were used to reinforce the information given.
- **Type of fume hood:** 4 feet wide, two stages (operating two flow rates one at a sash height < or = to 2 inches and an other at height > 2 inches) and vertical sashes
- **Monitoring:** Both phases were remotely monitored unbeknownst to the laboratory personnel. Intervals of 15 minutes were used to monitor the face velocity of each fumehood.

For more detailed information on specifics in the methodology see Duke report.

5.1.4 Results

- Data collected during phase one of the study indicated that the fume hoods in Pharmacology rarely operated at low flow rates.
- Thirty-six out of the 42 fume hoods operated at high flow rates for 24 hours per day during phase one, which indicated that the fume hood sashes were virtually never closed below two inches.
- Figure 5.1 below illustrates the initial high response to the administrative controls that begins to decline after the first week. Figure 5.2 shows the change in high flow operation time from phase one to phase two for the individual fume hoods.

Figure 5.1

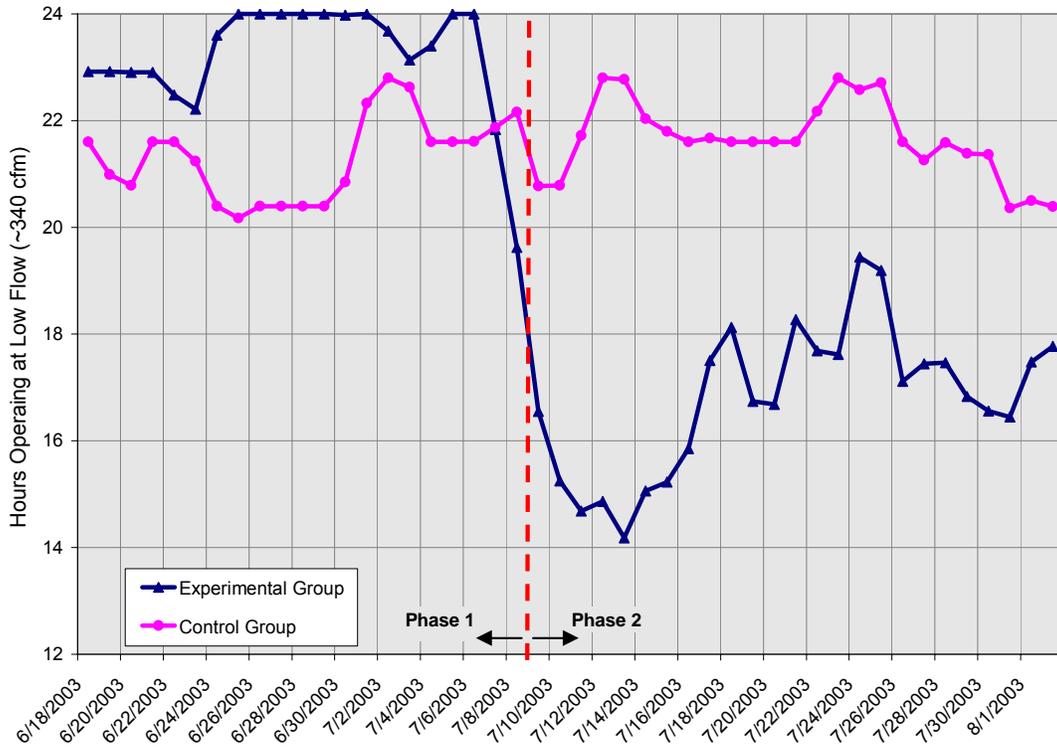
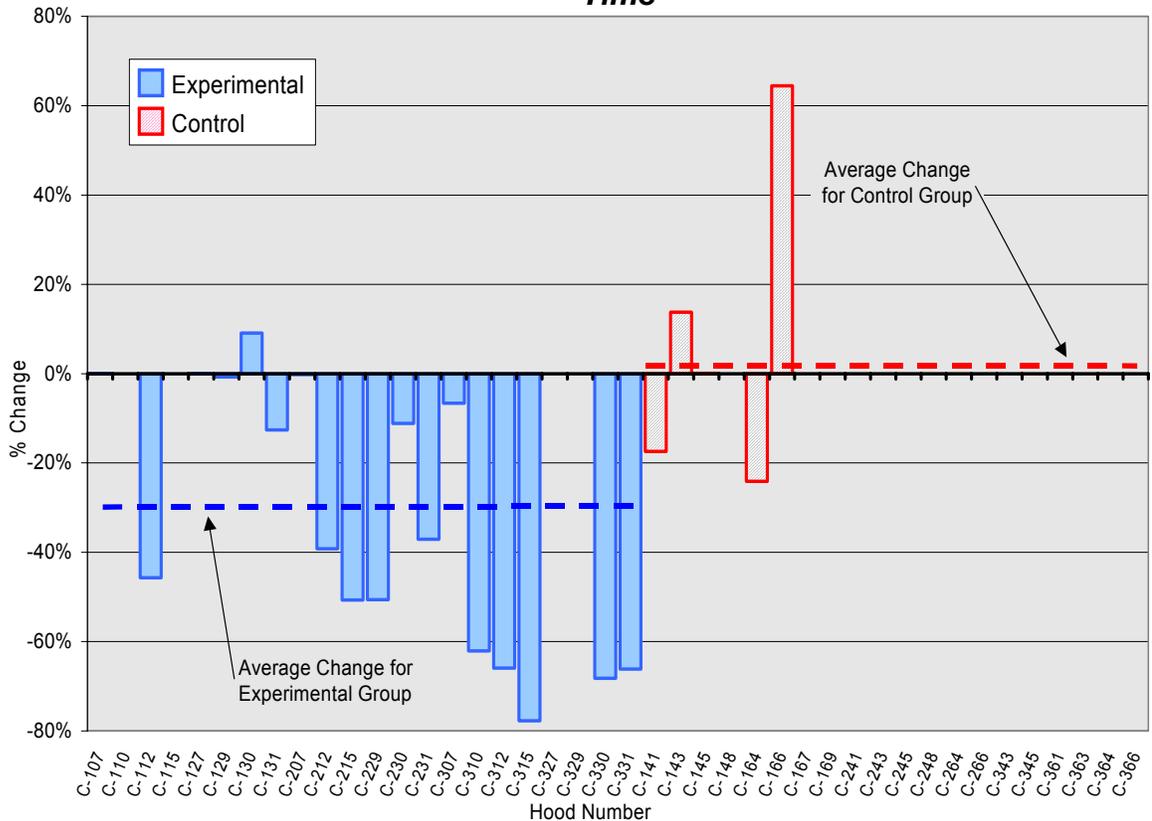


Figure 5.2. Percentage Change in High Flow Operation Time



5.1.5 Duke Report Conclusion

The implementation of administrative controls to reduce fume hood energy consumption can be both effective and economical. The capital costs associated with administrative controls are typically less than most other energy conserving options. Those implemented in this study would take approximately one day to implement in 50 laboratories. Administrative controls are also advantageous because they heighten awareness of energy consumption and can create secondary savings through producing behavioral changes in employees.

There was an approximate 6-hour sustained decrease in the high flow operation time among the fume hood personnel that experienced administrative controls. There was an approximate 6 hour sustained decrease in the high flow operation time among the fume hood personnel that experienced administrative controls. This 6-hour decrease in high flow operation translates into a savings of \$1,000 to \$11,000 annually if all 48 fume hoods in the Pharmacology Department are subjected to administrative controls.

It is important to mention though that there is a remaining challenge for the real success of a project like this. There must be a ongoing project that can continuously reinforce the initial training of the lab personnel in order to keep the new work habits and in a long term even convert those in regular day-to-day habits.

5.2 Implications for MIT

The above is an example that can very well work in labs like the one in Building 18 at MIT. These labs are already provided with a phoenix system that among other things give a right-on-spot reading of the energy consumption in situ. If there is a way to record these readings a pilot study like the one done at Duke University can give much insight on how to effectively train the lab personnel and achieve considerable energy savings. This latter would be than automatically translated into GHG- emission reduction for the campus.

But it is also important to think ahead. Are there other fume hood systems that can give at least the same savings but with less investment? Should the

Institution invest in Phoenix systems for the entire campus and rely on the success (if any) of the training in building 18 to promote energy conservation?

In an attempt to answer these questions an Internet search brought us to a report on the Berkeley Fume hood. The most interesting feature of this type of fume hood is that it works with lower face velocities that can be translated into less energy consumption.

5.3 The Berkeley fume hood

5.3.1 Introduction

According to the Berkeley report conventional fume hoods rely solely on pulling air through the hood's open sash from the laboratory, around the worker, and through the hood workspace.

The generally accepted "face velocity" is around 100 feet per minute, depending on hazard level. Interestingly, recent research shows that increasing face velocity (and, consequently, air volume and energy use) does not tend to improve containment. Instead, errant eddy currents and vortexes are induced in the hood and around hood users as airflows into the hood, reducing containment effectiveness and compromising worker safety (Figure 5.3 below).

Typical fume hoods exhaust large volumes of air at great expense. Furthermore, the energy to filter, move, cool or heat, and in some cases scrub (clean) this air is one of the largest loads in most facilities and tends to drive the sizing (first cost) and energy use of the central heating, ventilating and air-conditioning systems in the buildings in which the hoods are located. Fume hoods are a major factor in making a typical laboratory four- to five-times more energy intensive than a typical commercial building. A six-foot-wide hood exhausting 1200 cubic feet per minute, 24 hours per day, consumes 3.5-times more energy than an average house.

This report further states that. the most common energy-efficient modifications to traditional fume hoods are based on use of outside air (auxiliary air) or variable air volume (VAV) control techniques. While these approaches can save energy, they are complicated and costly to implement and operate.

Innovation is hampered by various barriers stemming from existing fume hood testing/rating procedures, entrenched industry practices, and ambiguous and contradictory guidance on safe levels of airflow. These conditions make this technology area ripe for public interest research and development aimed at introducing innovative alternatives to current practice.

5.3.2 The proposed system

To address the shortcomings of existing approaches and to promote innovation in the marketplace, Lawrence Berkeley National Laboratory (LBNL) has developed and patented a promising new technology—The Berkeley Hood—that reduces the hood’s airflow requirements by up to 70 percent while enhancing worker safety by supplying most of the exhaust air between the hood's operator and work area

The LBNL containment technology uses a "push-pull" displacement airflow approach to contain fumes and move air through a hood (Figure 5.4).

Displacement air “push” is introduced with supply vents near the top and bottom of a hood’s sash opening. Displacement air “pull” is provided by simultaneously exhausting air from the back and top of the hood. These low-velocity airflows create an “air divider” between an operator and a hood’s contents that separates and distributes airflow at the sash opening (unlike an air curtain approach that uses high-velocity airflow). When the face of a hood is protected by an airflow with low turbulent intensity, the need to exhaust large amounts of air from the hood is largely reduced. The air divider technology is simple, protects the operator, and delivers dramatic cost reductions in a facility’s construction and operation.

5.3.3 Benefits as presented in the report

When cutting airflow by up to 70 percent in standard laboratory fume hood installations, we estimate that laboratories could save 8,000 Gigawatt-hours (GWh) of electricity demand annually, 1,900 megawatts of electrical peak

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generating capacity, and 73 TBTUs in associated space-heating fuel (see the report's appendix for further detail). This energy savings equates to about \$1.2 billion per year, or \$2,100/year per replaced hood.

The aforementioned savings include the ancillary benefits reduced energy costs associated with pre-heating and –cooling the air provided to laboratories (Figure 5.5).

Beyond ventilation reduction and associated energy savings, the Berkeley Hood offers design features that deliver a range of benefits:

- Simpler design than state-of-the-art variable air volume (VAV) fume hood systems offers more certain energy savings, coupled with easier and less expensive installations and maintenance.
- Constant volume operation ensures energy savings are independent of operator interface.
- Improved containment reduces dangerous airflow patterns, eddy currents, and vortexes.
- Clean room air flowing, into the operator's breathing zone reduces potential hazard from fumes.
- Thanks to lower fan power, offers robust peak-power savings, whereas other approaches to fume-hood efficiency do not.

In new construction projects, designers specifying the Berkeley Hood can achieve savings in energy, construction, and maintenance costs. While the Berkeley Hood itself is expected to have a direct first-cost premium over a current standard hood, this cost can be offset with first-cost savings from smaller ducts, fans, and central plants, as well as simpler control systems than those used for VAV, offering lower overall first cost than standard or VAV hood systems.

In retrofit projects, Berkeley Hood users can receive critical HVAC system benefits beyond energy savings. Many laboratories are “starved” for air as their need for hoods has grown over the years. As a result, low supply or exhaust

airflows cause inadequate exhaust, in some cases, potentially leading to contaminant spills from the hood. Since increasing supply airflow is very costly in most cases, many laboratories cannot add new hoods. By replacing existing hoods with Berkeley Hoods, users can increase the number of hoods or improve exhaust performance, or both. The final result is improved research productivity, enhanced safety, and lower energy bills.

This represents an interesting option that MIT might consider for future renovation and/or constructions, if it is really committed to the GHG-emission reduction plan of the Cambridge city.

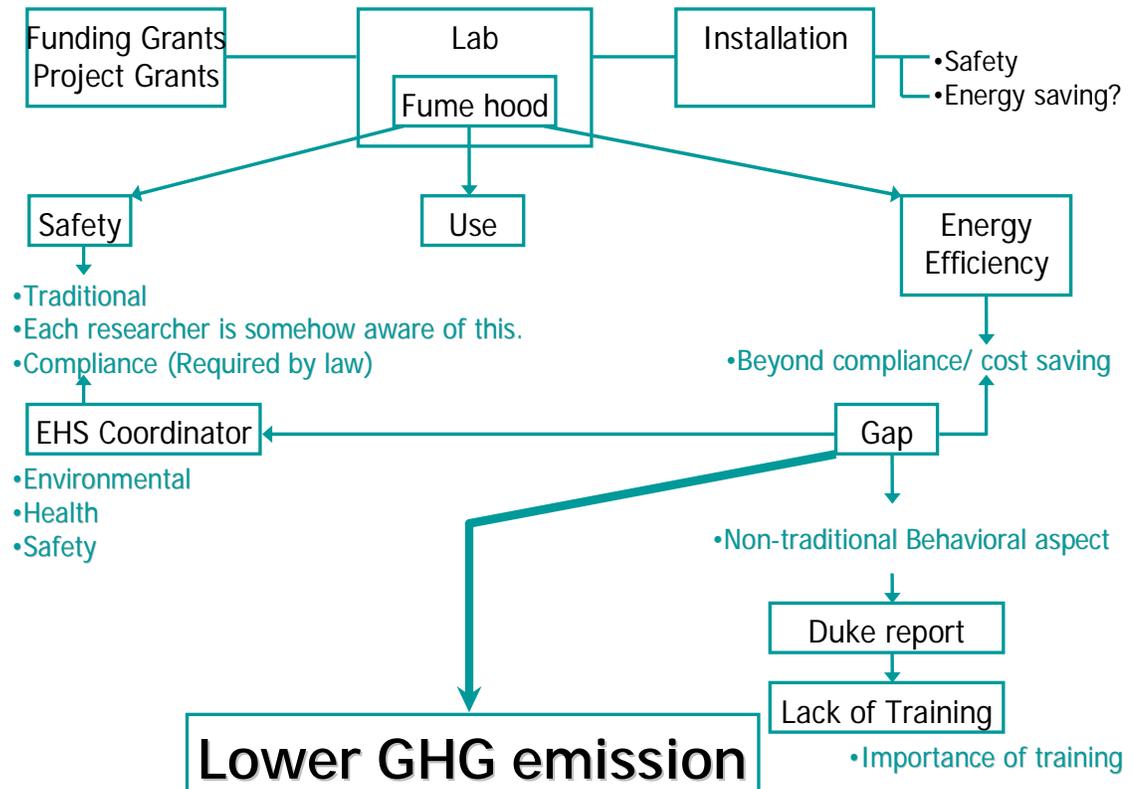
6. Recommendations

6.1 The mental scheme

Fume hoods are required by law, for safety reasons. Energy efficiency on the other hand is not required by law, making any effort to do so a beyond compliance action. The fume hoods in building 18 are all equipped with the phoenix system that as mentioned before presents tremendous opportunities to save energy. This latter can be translated into GHG-emissions reduction for the campus. But as seen from the Duke and Berkley report the introduction of technologies like the phoenix system without the proper training in the use of the system will not provide the potential savings in energy consumption.

In the mental scheme below we present MIT's opportunity to effectively benefit from the investment in the phoenix system as a gap that can be filled by the provision of careful designed training to the lab personnel.

"Mental Scheme"



6.2 Recommendations

By using the existing structure of the lab management we propose the following recommendations:

1. Pilot project for improving the behavioral aspect

Having fume hoods completely equipped with phoenix system like in building 18 creates a big opportunity to set up a pilot project that aims at the conservation of energy through the proper use of the fume hoods:

- A controlled area should be chosen in an area to do a similar study as the one the Duke University conducted. The main difference should be the non discrimination between a control and an experimental group.
- Training should be provided to all the lab personnel by the EHS coordinator(s) of the area. For this to work there must be a planning group consisting of all the stakeholders representatives of the lab.
- Collaboratively they should design, implement and evaluate the pilot project. The real challenge here will be how to sustain the behavioral chain.
- For the latter we recommend to have a support system for the training by using the existing communication network together with complementary visual aids (such as emails, meetings, posters, magnets and so far and so on).
- It is also fundamental in the implementation, to have a metering system in order to record the energy use and have historical data.
- It is also important to create incentives schemes to engage the lab users into the energy conservation project.
- In addition, it is important to involve in the project people who are passionate in championing the cause.

2. Improving the planning and operational process

- In planning a project, such as building a new lab, the integration of the total cost is essential. This means taking into consideration, the life cycle costing and environmental cost in addition to the capital cost.
- There is also the need to provide a clear communication means between the person(s) in charge of the lab and the maintenance staff of the lab. The needs of the lab-in-charge should be clear to the maintenance staff in order to enable an effective service to attend these needs.

7. Conclusion

We consider that it is crucial to have pilot projects because this can shed light on pitfalls in the project. This will help to ensure success once the problem is applied on a larger scale.

The specific conditions of each wet lab should be taken into consideration in the application of the training program regarding energy conservation, rather than a simple reproduction of earlier experiences with other labs.

The combination of the right use and the technology of fume hoods in a laboratory represents a big opportunity to reduce energy consumption and thereby contributing to GHG reduction on MIT campus.

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WEB SITES

<http://unfccc.int/2860.php>

<http://www3.iclei.org/co2/ccpmems.htm>

<http://www.labs21century.gov/>

Appendix A

PLANNING FOR SUSTAINABLE DEVELOPMENT COURSE

QUESTIONNAIRE

Male Female

Qualification (grad. student., PhD, etc.)

1. Are you aware of the energy intensity of a lab space compared to a classroom or office area?

yes no

2. Did you notice any measures that try to reduce the energy use in your lab?

yes no

if yes, which ones?

3. What are you doing to try to save energy in your lab?

close the fume hoods as much as possible and keep them closed when not used

keep the lights on only when needed

I don't have time to think about saving energy

Other (please specify).....

.....

.....

4. Do you know the optimal use of the fume hood:

a) regarding to safety? yes no

b) regarding to energy? yes no

5. Do you have any suggestions on how to be more energy efficient in a lab?

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THANKS A LOT FOR YOUR HELP!