The Green Labs Symposium – Driving Lab Sustainability in the Boston Area

Executive Summary

The Boston Green Ribbon Commission's green labs symposium, co-hosted by the GRC Higher Education Working Group (led by Harvard University) and the Health Care Working group (led by Health Care Without Harm), brought together more than 150 lab experts from the higher education, healthcare, and biotech sectors to explore shared challenges and successes in lab sustainability. Presentations from energy efficiency leaders, lab safety specialists, and executives showed that *deep* reductions in lab energy consumption are not only possible but are repeatable, predictable, low-risk investments with the power to enhance occupant safety and engagement. Speakers identified key features of successful projects: leadership support, thorough exposure control assessments, stakeholder communication, and the *information layer* – the intelligent use of building data to optimize and sustain efficiency and operations. The Green Ribbon Commission recognizes laboratory energy efficiency as an essential part of Boston's Climate Action Plan; this document highlights the technologies and tactics that are driving this vital shift in the Boston area and beyond.

The Boston Green Ribbon Commission

The Boston Green Ribbon Commission is a multi-sector group of business, institutional, and civic leaders working to develop shared strategies for addressing climate change in coordination with Boston's city leadership and the city's Climate Action Plan. The group's two key areas of focus are greenhouse gas emissions reductions and climate preparedness. The Commission has identified the region's many laboratory facilities as a key sector in which energy reductions are essential if climate targets are to be met. By facilitating information exchange via events such as the green labs symposium and this document, the Commission aims to advance Boston's progress towards meeting the city's climate targets.

The Symposium

Held March 27, 2014 on Harvard's campus, the symposium attracted a capacity crowd from the healthcare, biotech, and higher education sectors, including building operators, energy managers, company executives, utility company personnel, and environmental health experts. Introductory remarks by Commission leaders were followed by keynote addresses on occupant engagement from Allen Aloise of Harvard's Chemistry department; on the importance of building information management from Phil Wirdzek from the International Institute for Sustainable Labs; and on the renowned Smart Labs program at the University of California, Irvine (UCI) from vice chancellor Wendell Brase. There followed an in-depth workshop on the UC Irvine program and presentations on four local lab efficiency success stories: Millipore's Mobius II cleanroom facility, UMass Medical School's Lazare Research Building (LRB), Northeastern University's Egan Research Center (ERC), and the Massachusetts General Hospital network (MGH). The day finished with a set of small group discussions geared to facilitate sharing of strategies and ideas between symposium participants.

Labs: a Challenge and an Opportunity

Laboratory spaces are traditionally seen as a challenge to energy efficiency efforts, but their high energy intensity also presents a significant opportunity for energy savings. The scale of the opportunity was illustrated by presenters from the higher education sector: at Harvard University, lab facilities occupy 25% of the university's floor space but account for 50% of its energy consumption; at UC Irvine, lab buildings are responsible for two thirds of core campus energy use. It was reported that lab energy use intensities (EUIs) are many times greater than those of office buildings and are higher on average than the EUIs of data center facilities

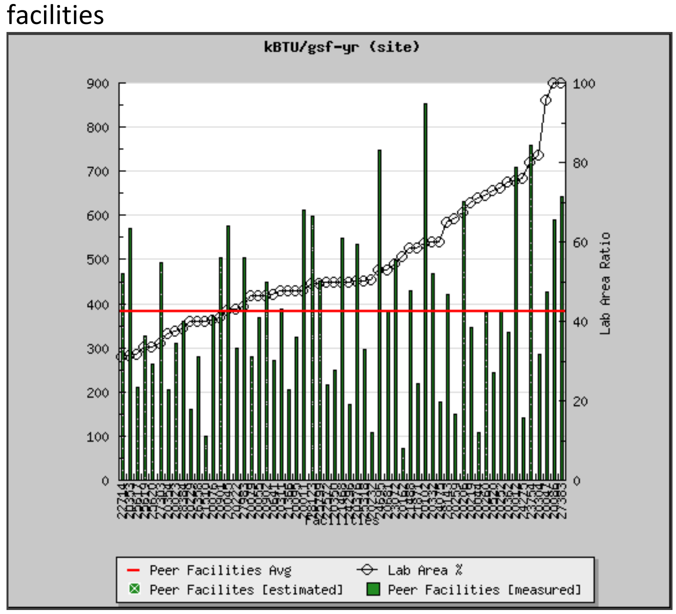

Figure 1: Lab site energy intensity for climate zone 5A (from Labs21 benchmarking tool)

Several speakers outlined the challenges facing lab efficiency projects. The "typical lab" does not exist: the majority of labs have unique requirements relating to chemical usage and storage, exposure control, space conditioning (temperature and humidity), pressurization, specialized equipment, and occupancy at unusual hours. At many institutions, lab usage density is increasing over time. Existing mechanical systems and controls often vary widely in design, capability, and flexibility (even between labs within the same facility). Risk aversion and outdated engineering rules of thumb frequently lead to the blanket application of conservative airflow policies in an attempt to ensure occupant safety and comfort. However, the case studies presented at the conference – the UC Irvine Smart Labs example in particular – illustrate convincingly that lab safety is enhanced as part of a comprehensive efficiency and ventilation management strategy.

The UC Irvine Smart Labs program: a Template for Energy Efficient Labs

UC Irvine initiated its Smart Labs program in 2008, in response to California's Global Warming Solutions Act of 2006 and as a pilot for the University of California system. By all accounts, the program has been wildly successful: of the more than ten lab buildings tackled so far, energy savings of at least 50% (excluding plug loads) have been achieved in all but one. These deep savings are not simply the result of inefficient starting conditions: since 1991, UCI has aimed to exceed energy code requirements by 30% for all new buildings. The majority of the buildings involved in the Smart Labs program were considered to be relatively efficient prior to their upgrades.

The Smart Labs approach is uniform and repeatable, while focusing on the unique requirements of each space. Simply put, the program consists of seven steps which can be easily adapted for use in other regions:

1) **Prerequisites**: the building systems must be brought to a basic minimum standard, including direct digital VAV controls, manifolded exhaust systems, differential pressure control of hydronic distribution pumps, fixing known issues and problems, and installing sub metering equipment.
2) **Real-time centralized demand-controlled ventilation** controls based on occupancy and measured air quality. Where possible, lab airflow rates are reduced to 2 air changes per hour (ACH) during unoccupied periods and 4 ACH during occupied hours. Minimum ventilation rates are assigned based on detailed hazard assessments of each space; see below for details.
3) **Lighting efficiency** improvements save energy directly and also result in reduced space cooling loads, enabling further airflow reductions. High airflow rates cannot often be justified on cooling grounds alone: UCI reported on a lab sub metering

Laboratory Buildings		Before Smart Lab Retrofit			After Smart Lab Retrofit		
Name	Type*	Estimated Average ACH	VAV or CV	Was more efficient than code?	kWh Savings	Therm Savings	Total Savings
Croul Hall	P	6.6	VAV	~20%	40%	40%	40%
McGaugh Hall	B	9.4	CV	no	57%	66%	59%
Reines Hall	P	11.3	CV	no	67%	77%	69%
Natural Sciences 2	P, B	9.1	VAV	~20%	48%	62%	50%
Biological Sciences 3	B	9.0	VAV	~30%	45%	81%	53%
CALIT2	E	6.0	VAV	~20%	46%	78%	58%
Gillespie Neurosciences	M	6.8	CV	~20%	58%	81%	70%
Sprague Hall	M	7.2	VAV	~20%	71%	83%	75%
Hewitt Hall	M	8.7	VAV	~20%	58%	77%	62%
Engineering 3	E	8.0	VAV	~30%	59%	78%	69%
Averages	–	**8.2**	**VAV**	**~20%**	**57%**	**72%**	**61%**
*Key: P = physical sciences, B = biological sciences, E = engineering, M = medical sciences.							

Figure 2: Results of the Smart Labs program at UC Irvine

study in which 65% of the lab area sampled showed average plug loads of less than 1 W/sf.

4) **Exhaust fan energy reductions**: stack velocity and exhaust fan speed are reduced by eliminating bypass air. Exhaust stack heights are often increased to minimize re-entrainment; changes are informed by wind tunnel studies.
5) **Air-side pressure drop reductions**: because fan speeds drop considerably as a result of item #2 above, sound attenuators can often be removed; this leads to further fan energy reductions.
6) **Fume hood standby airflow reductions**, based on ANSI Standard Z9.5-2012. For qualified hoods, standby (sash closed) exhaust airflow rates can be reduced by as much as half (from approximately 375 hood air changes per hour to 200-250).
7) **Final and continuous commissioning** to ensure that all components are operating and meeting performance specifications, including the **"information layer**" component to keep facilities and EH&S staff continuously updated about the operation of the building.

Components of the UCI approach were implemented at each of the local case study sites: comprehensive controls upgrades (ERC); air-side system recommissioning (LRB); creation of an information layer for continuous commissioning (LRB, MGH); and airflow reductions via fume hood upgrades (LRB, MGH), demand-controlled ventilation (Millipore, LRB), occupancy-based controls (MGH), and rebalancing based on lab safety assessments (ERC, MGH).

The Smart Labs program appears to be readily adaptable for use in the Boston area. A local version might include consideration of exhaust air heat recovery (a part of the MGH project), an important component of efficient ventilation systems in the Northeast that is not warranted by the climate in Orange County, CA. A further regional difference relates to California's restrictive OSHA requirements for fume hood face velocities during occupied periods. Because this restriction does not apply in Massachusetts, there exists greater potential for energy savings associated with modern high-performance fume hoods with face velocities as low as 60 fpm (high-efficiency fume hood retrofit kits were installed at LRB, where hood face velocities were reduced to 70 fpm).

Both at UC Irvine and at the four local facilities, it was notable that deep energy savings were achieved through the application of well-understood and tested

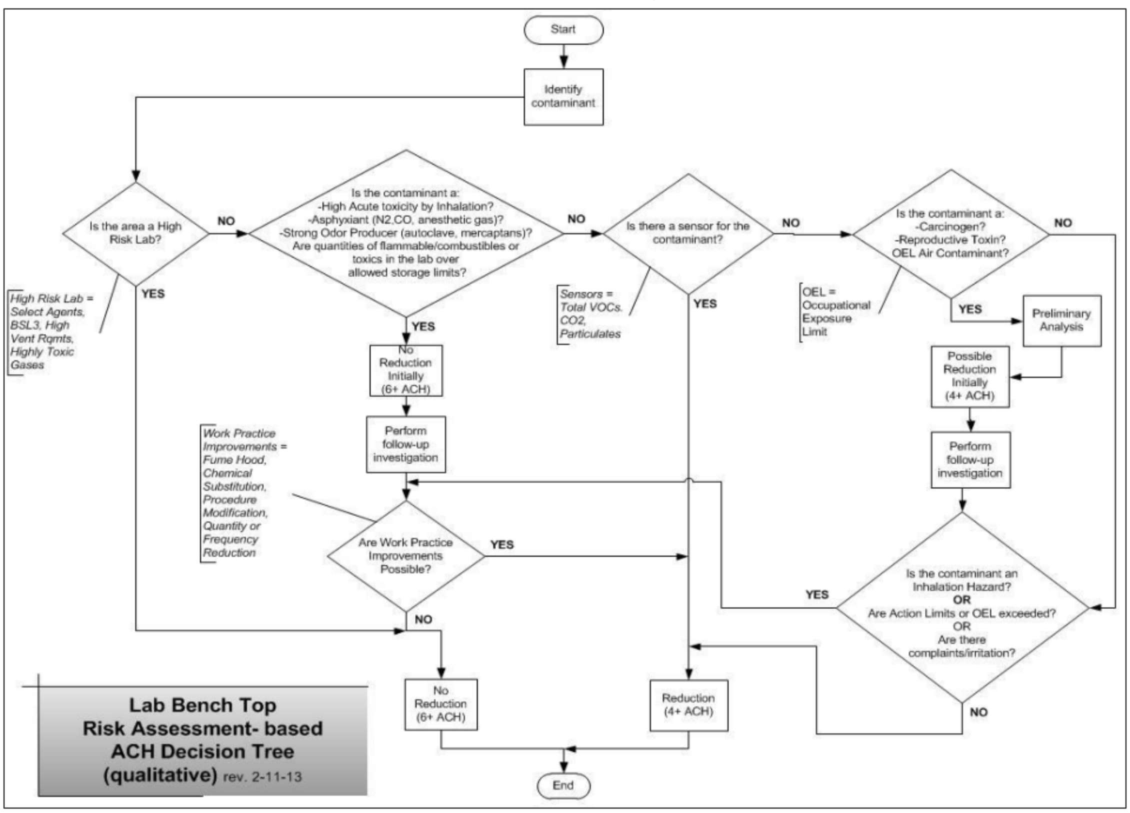

Figure 3: Example Smart Labs risk assessment decision tree

technologies in concert with a focused approach to lab safety. Other common features of these successful projects included strong leadership buy-in, strategic energy goals, and dedicated, capable facility personnel.

Safety Assessments

A core component of the Smart Labs approach is a careful determination of ventilation requirements ("control banding") for each lab space. The Smart Labs risk assessment process is funded in part by the program's energy cost savings and involves identification of each of the chemicals used in the lab, of exposure mitigation possibilities, of the chemicals' detectability by available sensors, and of the quality of air distribution in the space. In some spaces, a helium bubble machine was used to probe for areas of "dead air." (The risk assessment protocol now calls for tracer gas analysis, which has been shown to be a more effective method than the helium bubble approach.) By carefully banding each space and by fully understanding the capabilities of any proposed monitoring equipment, informed decisions are made on ventilation requirements and lab safety is optimized. Airflow changes are implemented only where the risk assessment process validates the change; approximately 20% of UCI's lab spaces have been found to be unsuitable for ventilation rate reductions.

The implementation of a lab ventilation management program (required by ANSI Z9.5-2012) at the completion of any upgrade project ensures that safety improvements are maintained and that ventilation requirements are reassessed upon any change in lab use.

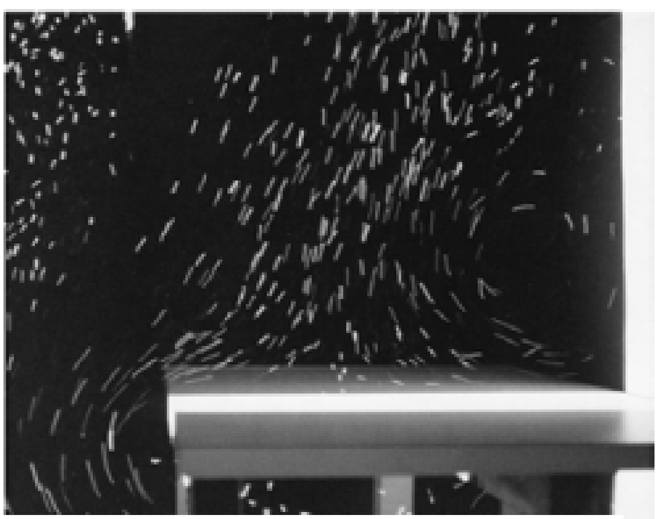

Figure 4: Helium bubble testing of airflow patterns

Knowledge is Power, Safety, and Efficiency

The intelligent use of building information is now central to any discussion of lab sustainability. Real-time feedback on equipment performance and space conditions is increasingly being used to optimize and sustain performance and safety.

Demand-Controlled Ventilation for Labs: At UC Irvine, at LRB, and at Millipore, active monitoring of lab air quality enhances safety by providing real-time, zone-level data on contaminants to facility personnel. Energy savings are achieved by reducing airflow when air quality is high; the air change rate is automatically increased in zones in which elevated contaminant levels are detected. Such systems permit lab ventilation to be adaptive to the (measured) dynamic needs of each space, and eliminate the arbitrary assignment of dilution airflow rates.

The demand-controlled ventilation system should be chosen according to the facility's needs; the case studies presented at the symposium showcased two types of control:

1) Particle counters are used to monitor ISO Class 7 validated clean room spaces at Millipore's Mobius II facility. Airflow rates are controlled to maintain particle counts within the allowed limits. Despite deep airflow and energy reductions over industry standard practice, the Mobius II clean room consistently operates at particle concentrations of less than half of the maximum allowance.

2) UCI and LRB implemented centralized demand-controlled ventilation (CDCV) systems in research and teaching lab spaces. For each lab space, these systems deliver supply and return air samples at 15-minute intervals to central sensor suites which measure the concentration of a range of chemical and particulate contaminants. Lab ventilation rates are modulated as needed to maintain contaminant levels below recommended limits.

With the delivery of real-time air quality data, facilities and EH&S staff are continuously updated on lab conditions. Where the contaminants of concern are readily detectable by available sensors, and where proper safety procedures are in place, demand-based provision of dilution air can yield deep energy savings while elevating lab safety.

Figure 5: Monitoring lab airflow via dashboard software

The Information Layer: The knowledge gained from real-time building data allows performance and safety enhancements to be sustained. An effective and increasingly popular method of receiving building data is via "dashboard" software which processes BMS outputs to generate useful metrics and alerts. Software can be built in-house or purchased from a broad spectrum of vendors.

At LRB and at UCI, real-time air quality and airflow data are provided via dashboard and reporting software produced by their CDCV system vendor. At Mass General Hospital, facilities staff receives "energy alarms" from their custom-built reporting system: users are alerted to simultaneous heating and cooling, low loop delta-T, unusual occupancy patterns, and many other performance-related issues. The energy alarm system is a vital component of MGH's continuous commissioning program to preserve performance improvements.

The UCI team also uses electrical and thermal sub metering to monitor energy end uses in each Smart Lab building. The use of sub metering ensures that energy savings are understood, quantified, and maintained.

Sharing energy use metrics with building occupants can boost occupant engagement and lead to additional energy benefits such as those achieved in Harvard's chemistry department (see below).

The Importance of Occupant Engagement

Lab occupants are habitually overlooked (or regarded as a necessary inconvenience) in efficiency projects; researchers, especially students, do not often see the direct benefits of energy efficiency. A common feature of successful projects is the involvement of all stakeholders in any proposed improvements: collaboration between owners, facilities staff, and EH&S personnel are essential. In addition, building occupants can be engaged via town hall meetings, occupant training sessions, or public display screens showing live updates of energy usage and performance data.

Occupant engagement can also drive additional energy savings. By tapping into the competitive nature of its resident researchers, Harvard's chemistry department has saved an estimated $200,000 per year through its fume hood sash-closing competition. The occupants of each month's best-performing lab are rewarded with a (relatively inexpensive) wine and cheese party. A key feature of this highly successful behavioral program is the provision of lab airflow readout panels at the entrance to each lab. The panels (another example of the information layer at work) encourage responsible sash management by allowing researchers to gauge and contextualize their lab's energy performance.

Figure 6: Hood airflow display in one of Harvard's chemistry labs

Funding and Economics

At UC Irvine and across the US, building energy efficiency remains a more cost-effective investment than renewable energy systems.

Some individual efficiency projects yield rapid returns, but significant capital investment is required to implement comprehensive, deep energy retrofit projects like those described by many of the day's presenters. Leadership support is essential: UC Irvine issued revenue bonds to fund the Smart Labs program. With a typical payback period of 5-8 years for Smart Lab buildings, the program has consistently exceeded bond revenue requirements. The economics are expected to be similar in the Boston area; utility rates in Massachusetts are comparable to those in California.

All four local case study projects took advantage of the exemplary utility incentive programs available in Massachusetts; early involvement of the utility company was cited by Northeastern University as being central to the success of its extensive controls upgrade project. Sizable resources, both technical and financial, have been mobilized by the utilities to drive aggressive reductions in lab energy use. Both major utilities (NSTAR and National Grid) offer flexible financing and incentives for retrocommissioning work, technical assistance studies, and capital projects, and both companies provide enhanced incentives for organizations with strategic energy management plans (e.g. Mass General Hospital). Utility incentives can often be optimized via the pursuit of comprehensive retrofit projects, capturing both low-hanging fruit and deeper energy savings.

Non-energy benefits: The day's presenters cited multiple non-energy benefits of energy efficiency projects. At UC Irvine, a portion of the Smart Labs energy cost savings has been channeled into additional lab safety personnel and deferred maintenance items. Further non-energy benefits include water savings due to reduced cooling tower loads (at ERC); reduced wear on equipment when running at lower speed due to load reductions (UCI); and improved site safety (UCI now has the lowest workers' compensation rates in the UC system). Additionally, continuous commissioning via the information layer reduces the need for large-scale recommissioning projects.

Conclusions

The day's presentations and discussions revealed that many of the traditional barriers to lab energy efficiency have been removed. Deep energy retrofits have been shown to provide reliable return on investment and to boost lab safety, and utility incentive programs can help to defray project costs. Securing top leadership support is essential to obtaining the required capital funding and to the alignment of organizations in the pursuit of ambitious energy reduction goals. Staff resources must be committed to energy reduction programs, and all stakeholders must be involved in the process. Deep lab energy savings are a vital piece of Boston's Climate Action Plan, and they are within reach.

-Alison Farmer, PhD