Work Smarter, Not Harder: Improving Energy Efficiency and Safety through Smarter Ventilation

Preprint

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Work Smarter, Not Harder: Improving Energy Efficiency and Safety through Smarter Ventilation

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ABSTRACT HEADING

Ventilation is a key component to maintaining healthy, safe indoor air quality. Especially important in laboratories, ventilation is the first line of defense against airborne hazards produced during research activities. Though a vital component, laboratory ventilation systems are often victim to ineffective operation, posing a risk to the most important asset—the researchers. Furthermore, system inefficiencies can lead to up to 50% wasted energy. To improve both energy efficiency and safety in laboratories, we present the Smart Labs Toolkit—a resource developed by the U.S. Department of Energy Federal Energy Management Program and the International Institute for Sustainable Laboratories that guides laboratory stakeholders through a straight-forward, holistic approach to achieve dynamic, high-performance laboratories. Smart Labs enable safe and efficient world class science to occur in laboratories through high-performance methods. A Smart Labs program employs a combination of physical, administrative, and management techniques to assess, optimize, and manage high performance laboratories.

We will focus on a central component of the Smart Labs approach—the Laboratory Ventilation Risk Assessment, a systematic process for identifying risk due to airborne hazards to inform the operation of dynamic ventilation that optimizes safety and efficiency. Case studies of organizations who have successfully implemented Smart Labs ventilation management programs will also be shared. In learning ventilation strategies successful in critical laboratory environments, learn the tools and resources needed to successfully manage energy in any building through smarter, safer ventilation.

INTRODUCTION TO HIGH PERFORMANCE LABS

In the built environment, ventilation clears the air of contaminants, providing safe, clean air for the occupants to breath. In a lab environment, ventilation air sweeps hazardous materials and bi-products generated through research to exhaust out the contaminants. However, to meet the ventilation requirement to remove hazards, labs often consume 3 to 5 times more energy than that of office buildings in the same climate. There are an estimated 153,000 labs in the U.S. with an average energy intensity of 242 kBtu/ft^2 (Shehabi et al. 2017). Ventilation can account for 40% to as much as 85% of total energy use (National Renewable Energy Laboratory and International Institute of Sustainable Laboratories n.d.). Figure 1 shows the end use load distribution in a typical laboratory.

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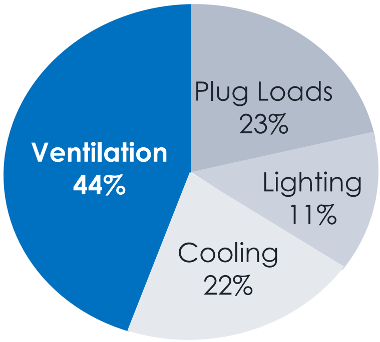


Figure 1 Annual electricity use distribution in Louis Stokes Laboratory, National Institute of Health, Bethesda, MD (Bell 2008).

With such extensive energy consumption, energy efficiency improvements in lab spaces can lead to greater savings, increased resilience, and a greater reduction in emissions. Typical case studies indicate savings opportunities in the 30% to 50% range for labs, largely in relation to ventilation improvements. To successfully achieve the savings opportunities in these mission critical spaces, an ongoing programmatic approach must be implemented. At the center of the program lies a cross-cutting team that includes "facility designers, users, industrial hygienists, safety officers, security, operators and maintenance staff." A key member of the team is typically an HVAC Engineer, whose "decisions or recommendations...may significantly affect construction, operation, and maintenance costs" (American Society of Heating Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE) 2019).

By coordinating efforts across the organizational structure, a team-based programmatic approach can result in long-term adoption and improvement of operations. After initial efforts gain traction for the program, the team can build the momentum for ongoing improvements to realize persistent savings.

BACKGROUND OF SMART LABS

To achieve the goal of improving laboratories and aid the building operators and owners, the Smart Labs process was developed and includes results of best practices and lessons learned from the Better Buildings Smart Labs Accelerator.

Smart Labs enable safe and efficient world class science to occur in laboratories through high-performance methods. A Smart Labs program employs a combination of physical, administrative, and management techniques to assess, optimize, and manage high performance laboratories. A core element of a Smart Labs program is the design and operation of labs based on containing ventilation risk as determined by a laboratory ventilation risk assessment (LVRA).

The Smart Labs Toolkit

To help owners and operators navigate the process, the Smart Labs Toolkit describes a systematic process that helps laboratory owners and operators plan and cost-effectively achieve safe, efficient, and sustainable laboratories. The process includes four phases that guide a team in evaluating the current state of lab operations and making improvements that rapidly improve energy efficiency and safety in laboratory buildings.

As shown in Figure 1, the four phases of the process—Plan, Assess, Optimize, Manage—are a dynamic cycle, rather than a linear checklist. After the initial Plan phase, the approach involves ongoing assessment, optimization, and management of facilities. The driver of this process is a Smart Labs Program with involved management, effective facility operations, and informed researchers that ensure continued progress.

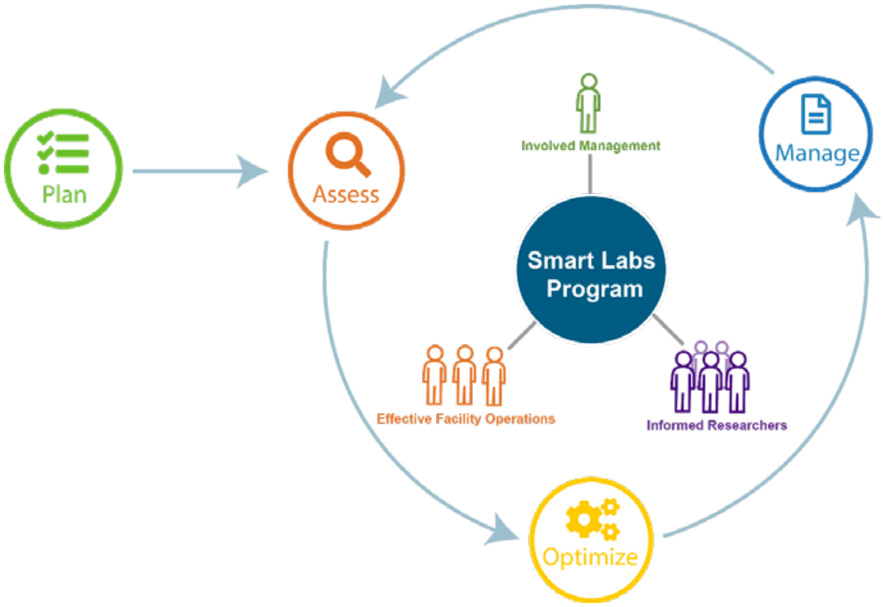


Figure 2 Smart Labs Toolkit process showing how to approach development of high-performance safe and sustainable labs. (Image Credit: Amanda Kirkeby, NREL)

Each part of the process includes multiple steps with a deliverable at the end of each step to document the process.

- Plan: Form a team comprised of lab stakeholders, benchmark buildings to rank opportunities and prioritize efforts, and then develop a strategic plan for cost-effective implementation.
- Assess: Conduct a LVRA, perform audits of energy, water, and resilience, systems, and develop a scope of work for optimizing systems.
- Optimize: Execute meaningful projects in a financially feasible way to improve lab building systems.
- Manage: Implement a lifecycle performance management plan to continue to achieve safe and efficient labs with documentation for when changes occur.

Through careful execution of this process, labs can achieve tremendous, ongoing savings.

VENTILATION IN SMART LABS

Air is the primary carrier of heat, moisture, contaminants, and airborne hazards in and around laboratory buildings. As a result, the laboratory ventilation system's primary function is to mitigate risk to people, property, and the environment by effectively controlling airborne hazards. Key strategies for proper ventilation system design and operation to achieve high ventilation effectiveness are highlighted in Figure 3. When applied, these strategies effectively remove airborne hazards emitted during research activities from the space to improve both safety and energy efficiency.

In general, clean supply air should sweep across the space and out exhaust paths, clearing airborne contaminants effectively from the space without significant recirculation or stagnation. The system design includes the appropriate type, size, and quantity of high-performance exposure control devices (ECDs), such as fume hoods, that provide the primary containment of airborne hazards. A computational fluid dynamics (CFD) analysis of the space can be used to optimize the airflow patterns and inform the type, size, and location of air supply diffusers and exhaust points-—including ECDs. CFD modeling can direct design decisions to provide directional sweep of conditioned air from entry to exit and achieve high ventilation effectiveness. With high ventilation effectiveness, ventilation rates can be minimized while still improving safety through the effective, efficient removal of contaminants from the space.

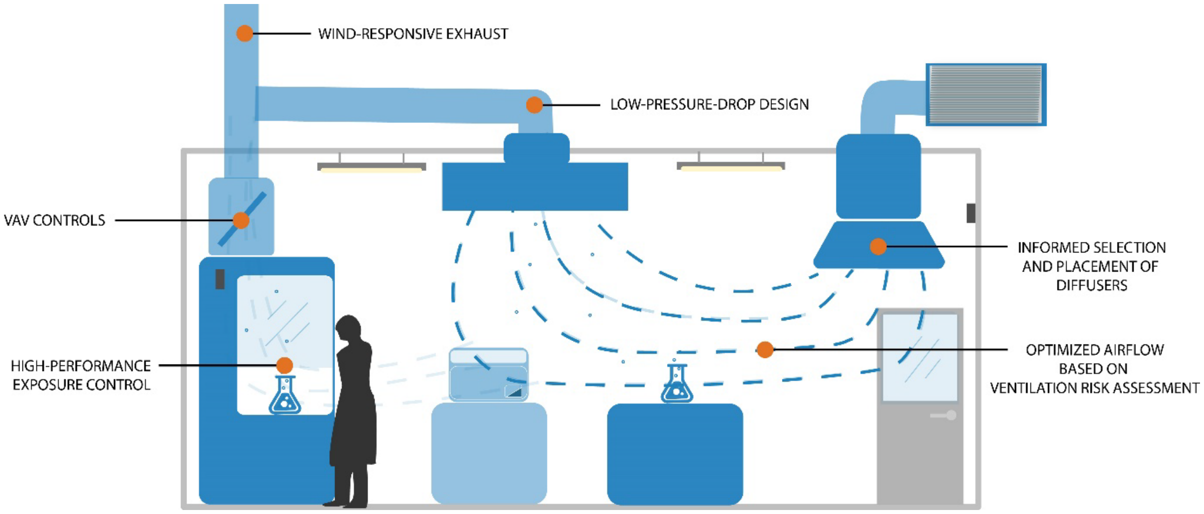
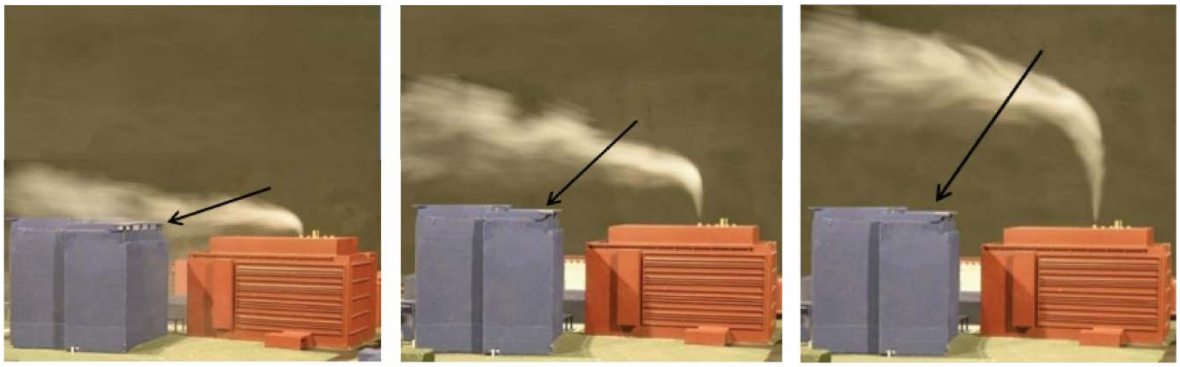


Figure 3 Key strategies for achieving high ventilation effectiveness in laboratory environments. (Image Credit Amanda Kirkeby, NREL)

Laboratory exhaust systems must be designed and operated to avoid adverse re-entrainment of the effluent at critical surrounding locations. Dispersion (wind tunnel) modeling should be used to determine the location, height, and discharge velocity of exhaust stacks to avoid adverse re-entrainment of effluent. The dispersion modeling results can also be used to reduce the discharge velocity safely based on wind speed and direction to save additional fan energy.



Adverse air quality (low-velocity, low-energy)

Optimal balance of energy and air quality

Wasted energy potential (high-velocity, high-energy)

Figure 4 Dispersion modeling example (Image Courtesy of CPP, Inc.).

Laboratory variable air volume (VAV) systems should be used to safely control laboratory ventilation. The entire ventilation system should be designed to minimize fan energy by using low air pressure drop design and selection of efficient fans. The VAV system must precisely control supply and exhaust air volume and room pressurization based on the ventilation risk assessment and occupancy to provide the right amount air at the right time in the right place to mitigate risk to people while minimizing energy use.

LABORATORY VENTILATION RISK ASSESSMENT

The Laboratory Ventilation Risk Assessment (LVRA™), developed by 3Flow and the University of California Irvine, is a systematic process for characterizing risk due to airborne hazards to inform the operation of dynamic ventilation that optimizes safety and efficiency. The LVRA is a key part of the Smart Labs Program Assess phase and should be incorporated into the ongoing cycle of assess, optimize, and manage. Periodic assessments following the process outlined below allow for a dynamic approach to changes over time, such as a change in research activities or the organizations tolerance to risk.

The LVRA process, outlined in Figure 5, involves a survey of the lab environment, all exposure control devices within the lab, and characterization of risks associated with each. The survey includes a description of the lab type and the ECDs in the lab, evaluation of the device or lab space purpose, condition, and processes, and an assessment of the risk using determined criteria and rating presented below. The evaluation criteria for both lab environment and ECD surveys assesses characteristics of hazards in the space in following five categories:

- Type of hazards and procedures including use of highly toxic chemicals
- Generation of hazards (i.e. gases, vapors, mists, dusts)
- Quantity of materials used or generated during lab procedures
- Frequency and duration of hazard generation
- Exposure control devices (ECDs) in the lab, their use and appropriateness.

The overall process is described in further detail in the LVRA User Guide (Smith 2019).

The laboratory ventilation risk assessment process utilizes risk control bands in the evaluation of risk for laboratory spaces, fume hoods, and other ECDs. Risk control bands characterize the risk of exposure to airborne hazards generated during laboratory scale procedures, ranging from negligible (a risk value of 0) to special or extreme (a risk value of 4). Through the survey, a risk control band is assigned to each characteristic using evaluation criteria outlined in the LVRA User Guide (Smith 2019). Each characteristic is evaluated independently. For example, significant quantities of low-hazard chemical would drive the quantity assessment category. However, associated with a research activity the chemical or activity associated with the highest generation rate may be differ   may be associated with one chemical that is used in small quantities throughout the lab. with the highest peak generation rate.

which is weighted based on its impact on risk. A weighted score is used to characterize overall risk, yielding a risk control band for each ECD and for the lab environment. Each risk control band is associated with a hazard emission scenario and related standards. For the lab environment, risk control bands correspond with the Classification of Laboratory Design Levels (American Society of Heating Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE) 2018). Fume hood requirements are also taken into consideration. Comparing the requirements and recommendations, minimum and maximum room airflows are determined for ECDs and HVAC systems serving the lab: the greater the risk, the higher the airflow that is required for the space.

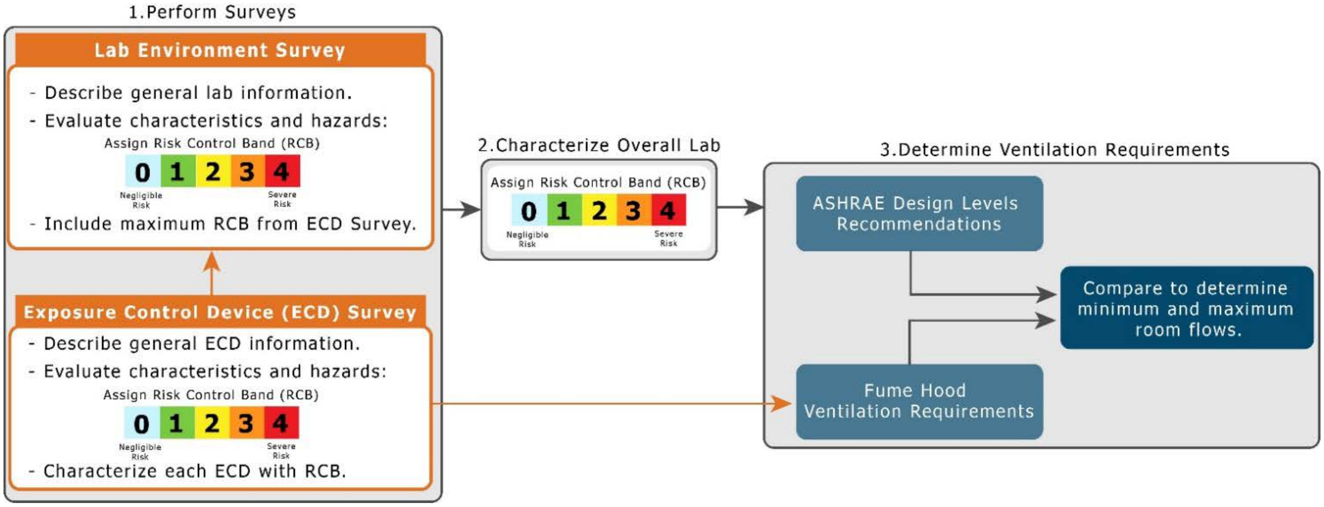


Figure 5 LVRA tool process (Image credit: Amanda Kirkeby, NREL)

A qualified facilities or EH&S professional with knowledge of mechanical ventilation and occupational safety and health should conduct the assessment (National Renewable Energy Laboratory and International Institute of Sustainable Laboratories n.d.). The Smart Labs Toolkit includes a free, spreadsheet-based tool to assist with gathering the data to determine lab ventilation requirements. When the tool evaluation is completed, the findings and conclusions should be reviewed by a licensed professional engineer and/or certified industrial hygienist prior to implementation of any recommendations (National Renewable Energy Laboratory and International Institute of Sustainable Laboratories n.d.).

CASE STUDY: UNIVERSITY OF MINNESOTA

Incorporating the LVRA process into a Smart Labs Program, with ongoing, periodic assessments can prove a challenge for even the most dedicated team within the organization. Establishing a clear procedure and roles around the assessment is crucial to successful adoption. The University of Minnesota has developed an effective workflow that incorporates the LVRA into their approach for ongoing, dynamic laboratory ventilation management.

The team prioritizes efforts through an initial characterization of laboratory spaces to determine which spaces are good candidates for LVRA strategies (CITE: https://smartlabs.i2sl.org/cs-umn.html). For example, chemistry teaching labs with minimal hazards are prime candidates; whereas special high-hazard labs that require strict containment strategies, such as those hosting biological safety hazards, for which an LVRA is not appropriate. Several criteria, including that inform a decision tree provide a clear pathway for each laboratory space

After an initial characterization of the lab, the LVRA survey is performed in-house by UMN's industrial hygienist. Using the LVRA tool, the key hazards in each lab are addressed. for insight into how changes in the lab space may effect ventilation needs

While not applicable in unique cases where ventilation is not an appropriate control (e.g. some biological contaminants and nanomaterials), the LVRA provides an effective method for

CONCLUSION

In learning ventilation strategies successful in critical laboratory environments, learn the tools and resources needed to successfully manage energy in any building through smarter, safer ventilation.

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