Smart Labs

Improving Lab Facilities to Meet Decarbonization Goals

Visit the Toolkit @ **SmartLabs.i2sl.org**

NREL/PR-5500-89116

Instructors

Instructors

Rachel Romero
National Renewable Energy Laboratory

Otto Van Geet
National Renewable Energy Laboratory

Learning Objectives

- Understand key elements of a Smart Lab, which are the key drivers of researcher safety and energy use within lab spaces;
- Understand the significance of ventilation in laboratory decarbonization efforts;
- Understand the complexity of the challenges that laboratories face in regard to decarbonization;
- Develop a culture of sustainability to engage occupants in integrating decarbonization into operational best practices

SMART LABS TOOLKIT

Agenda

- Introductions
- Introduction to Smart Labs
- Best Practices in Lab Design
- Plan
- Laboratory Benchmarking Tool
- Break (15 Minutes)
- Assess
- Choose Your Own Adventure
- Optimize
- Break (15 Minutes)
- Manage
- Working with Scientists
- Decarbonizing Labs
- Closing

Icebreaker

Describe your position at your organization in **one** word

Share your challenges

✓Name

✓Affiliation

✓Share 1 challenge in your lab spaces

SMART LABS

Introduction

Understanding Smart Labs and the Smart Labs Toolkit

FEMP
Federal Energy Management Program

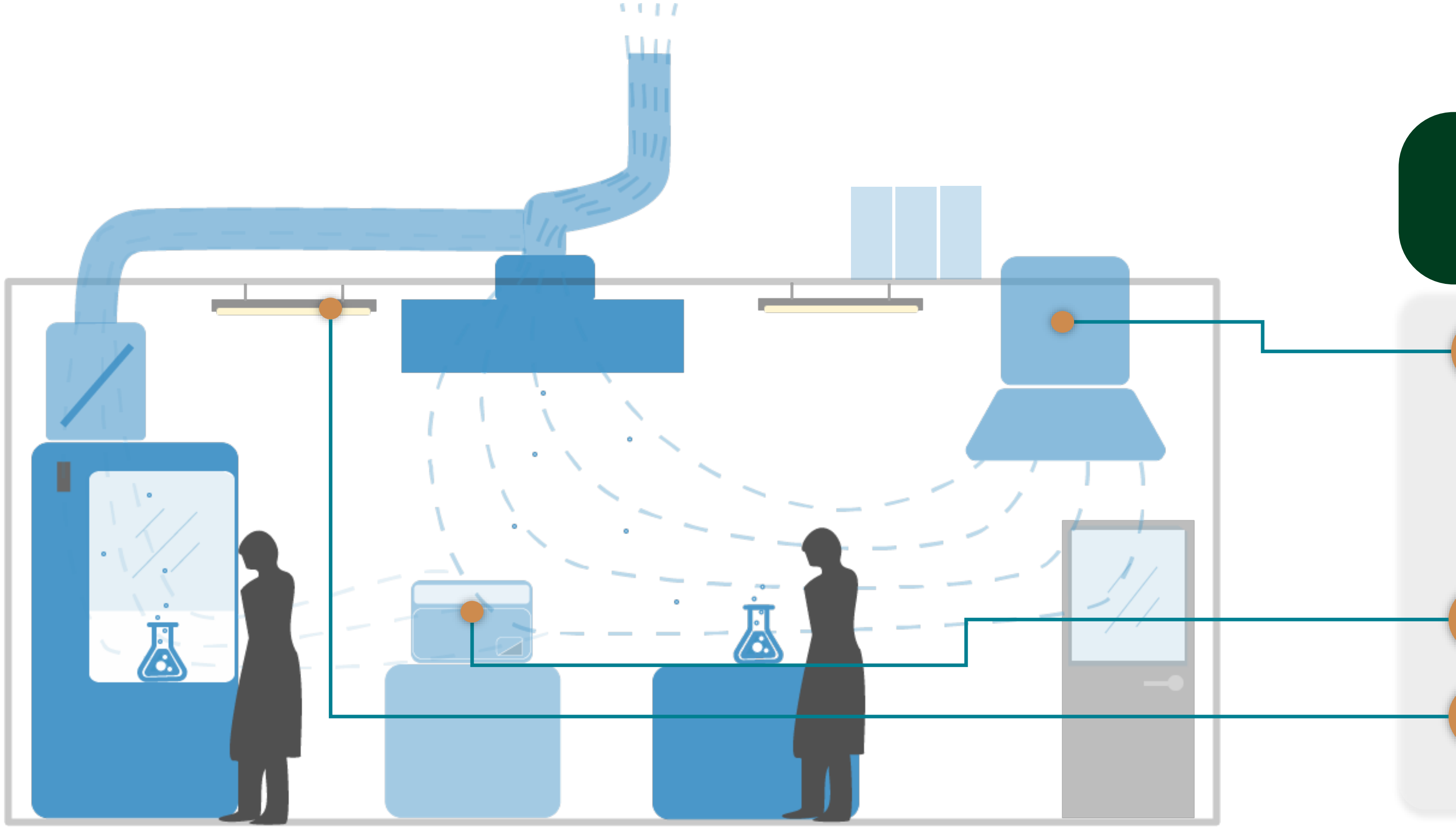
Why Labs?

Laboratories typically use **3 - 4 (up to 10) times more energy** than an average office building.

20% - 40%
Cost-saving opportunities in labs

$1-2 Billion
Potential energy savings across US labs

Energy Use in Laboratories



Top 5 Energy Users

1. **Ventilation**
2. Cooling
3. Heating
4. Plug Loads
5. Lighting

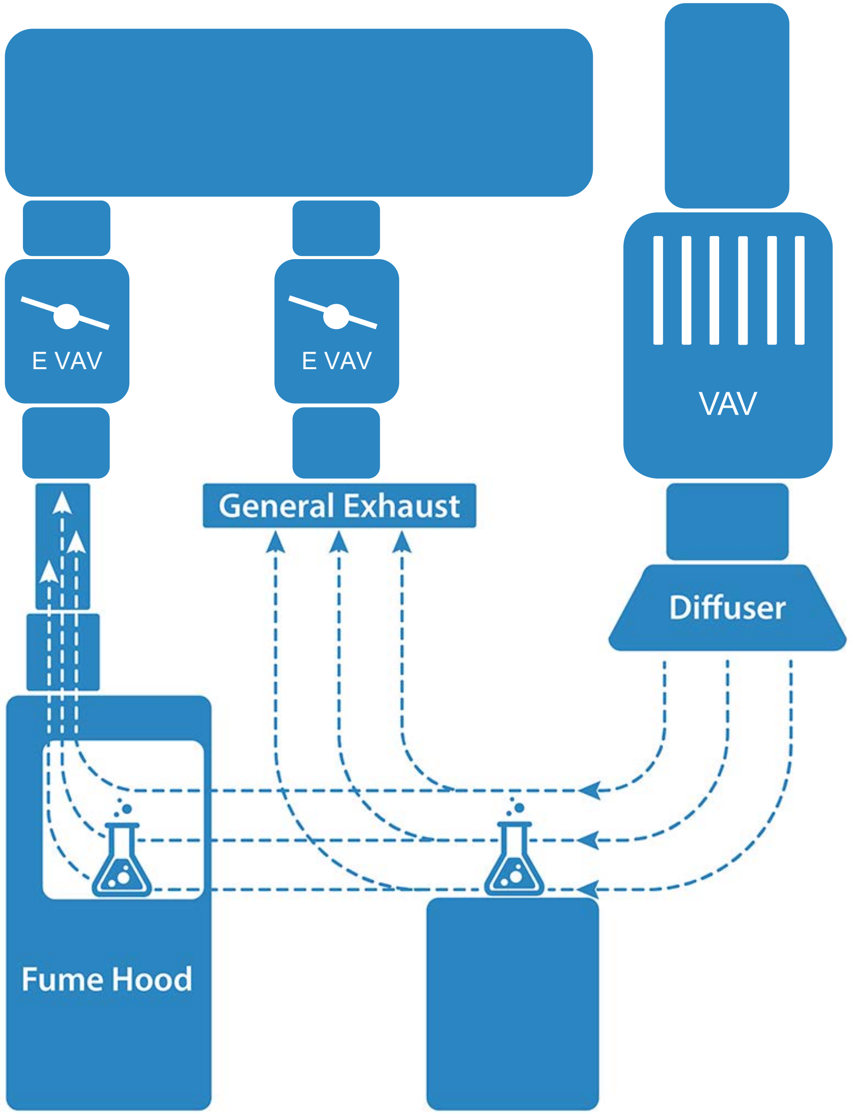
Big Picture Impact

There are over **150,000 U.S. lab buildings** where **500,000 people** collectively depend on laboratory systems to **keep them safe**.

Even high-performance airflow systems **can lose up to 50% of their controlability** within five years.

Yet…

ACH ≠ Improved Safety



* Values estimated from study completed by Lawrence Berkeley National Laboratory, entitled "Characterizing the Laboratory Market" and OSHA's overview of laboratories

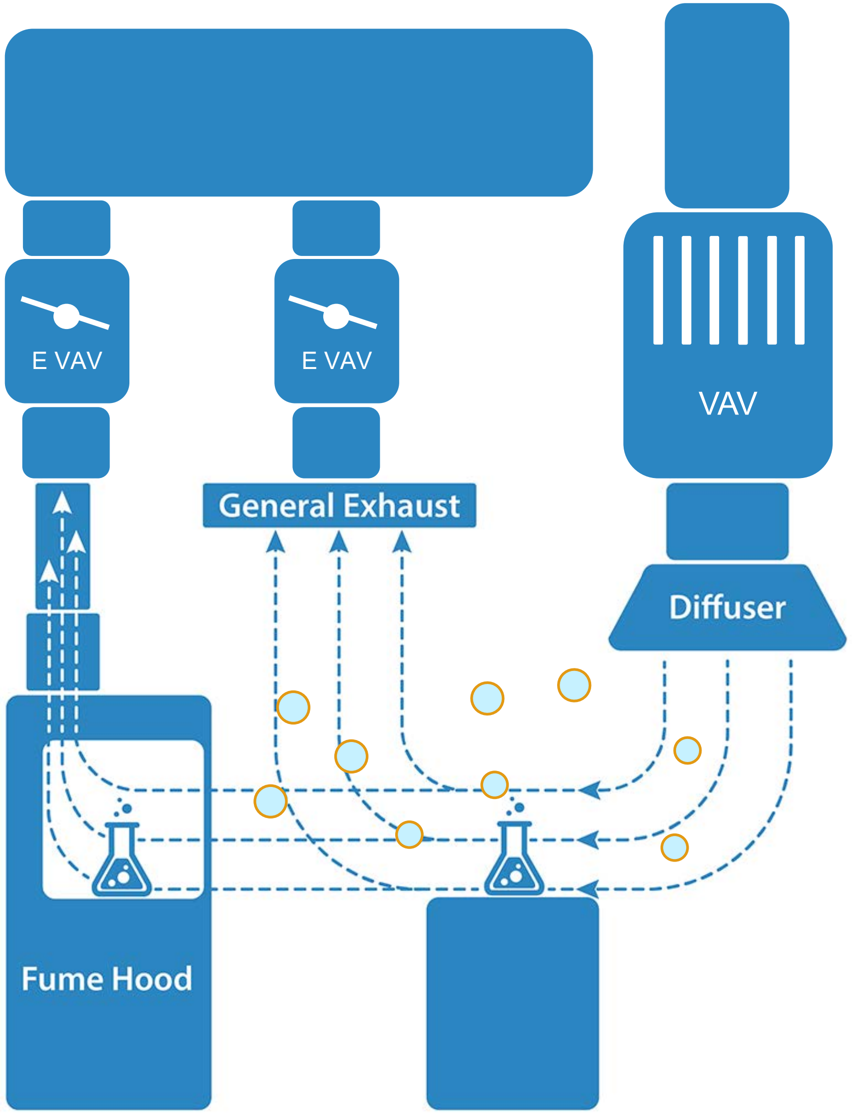
Big Picture Impact

ANSI Z9.5: Laboratory Ventilation…

- Discusses how air flow rate is just one factor that **safeguards** workers from harmful airborne contaminants
- Recommends a **ventilation risk assessment** to determine minimum airflow rates

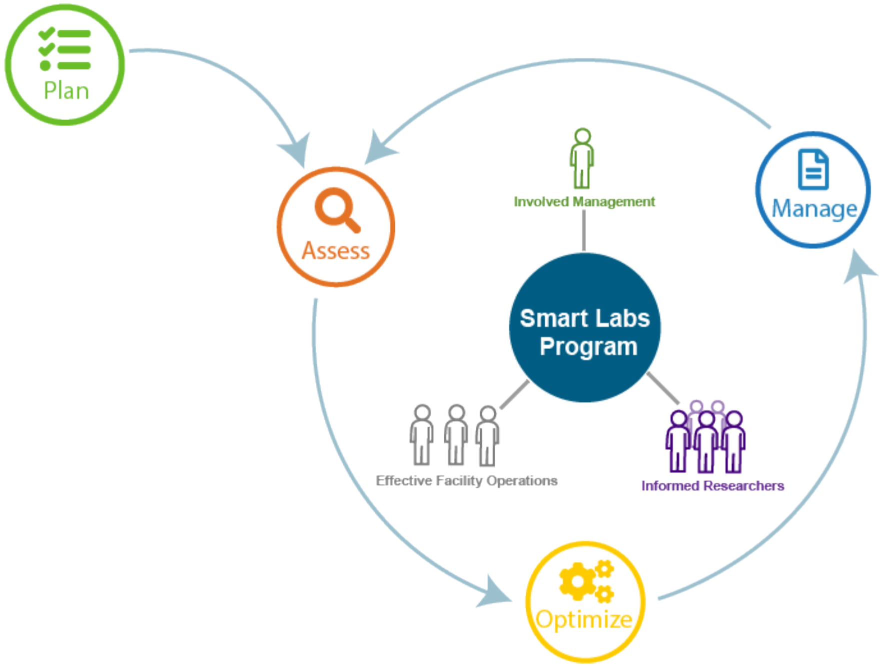
Pattern of airflow

↑ ACH ≠ Improved Safety



* Values come from study completed by Lawrence Berkeley National Laboratory entitled "Characterizing the Laboratory Market" and OSHA's overview of laboratories

The Future is…Smart Labs!



A Smart Labs program enables **world class science** through the design and operation of **safe and efficient** high-performance labs.

✓ Optimize safety ✓ Improve energy efficiency ✓ Reduce costs ✓ Maintain high performance laboratories

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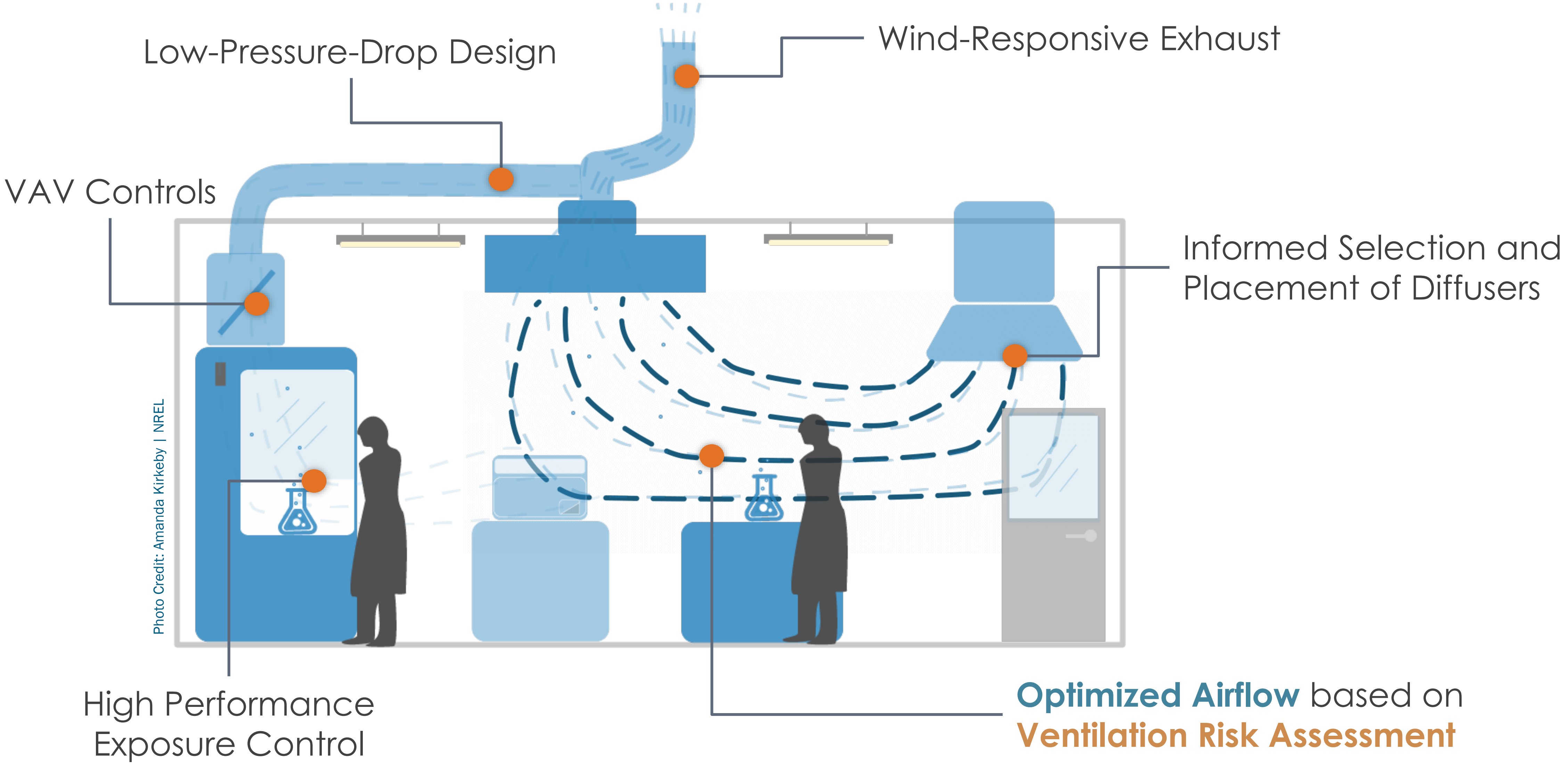
High Ventilation Effectiveness



SMART LABS TOOLKIT

The Smart Labs Process

Plan

Form a team comprised of lab stakeholders, profile buildings, and develop a strategic plan for cost-effective implementation.

Manage

Implement a lifecycle performance management plan to continue to achieve safe and efficient labs.

Assess

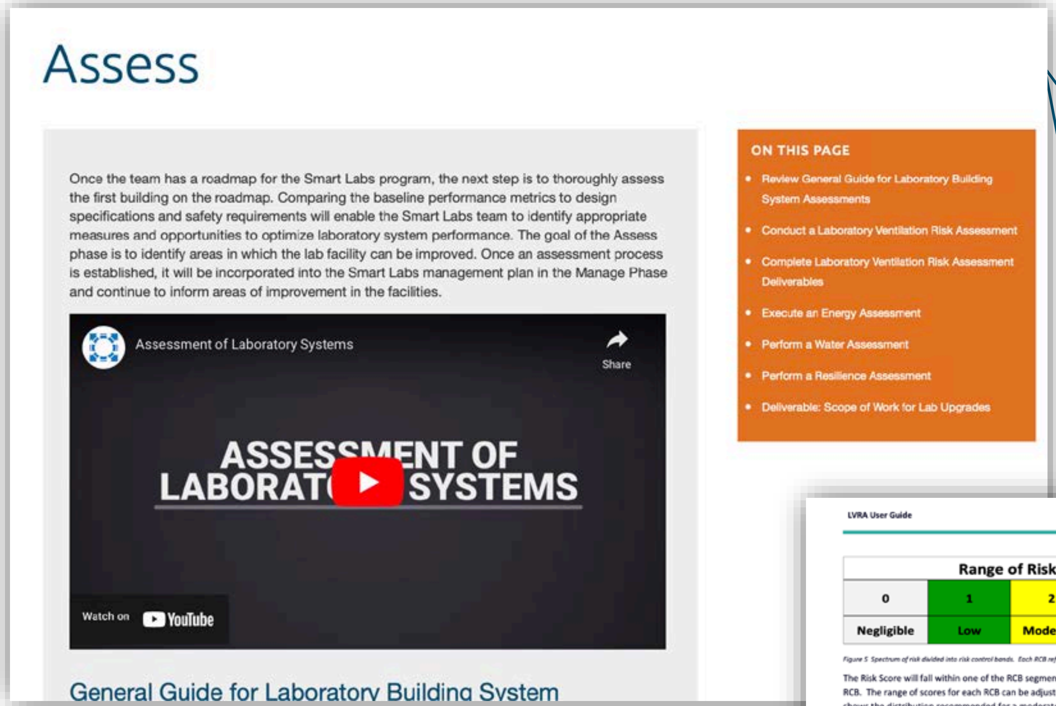
Review the laboratory ventilation system and other building systems to develop a scope of work for optimizing systems.

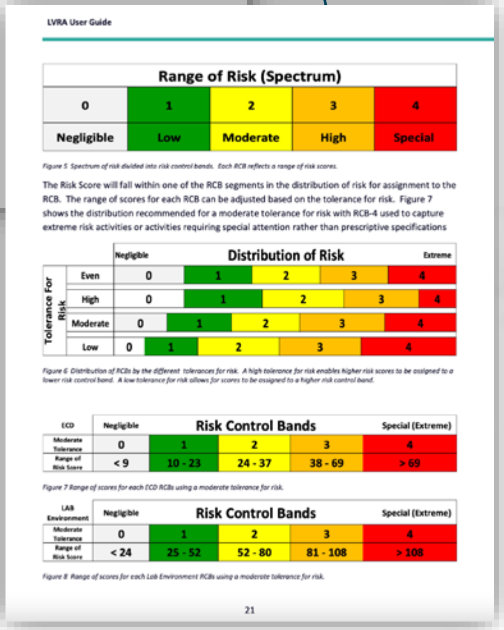
Optimize

Execute meaningful projects to improve building systems in laboratories.

The Smart Labs Toolkit

Visit the Toolkit @ **SmartLabs.i2sl.org**





LVRA User Guide

Range of Risk (Spectrum)				
0	1	2	3	4
Negligible	Low	Moderate	High	Special

Figure 5 Spectrum of risk divided into risk control bands. Each RCB reflects a range of risk scores.

The Risk Score will fall within one of the RCB segments in the distribution of risk for assignment to the RCB. The range of scores for each RCB can be adjusted based on the tolerance for risk. Figure 7 shows the distribution recommended for a moderate tolerance for risk with RCB-4 used to capture extreme risk activities or activities requiring special attention rather than prescriptive specifications

Tolerance For Risk	Negligible — Distribution of Risk — Extreme				
Even	0	1	2	3	4
High	0	1	2	3	4
Moderate	0	1	2	3	4
Low	0	1	2	3	4

Figure 6 Distribution of RCBs by the different tolerances for risk. A high tolerance for risk enables higher risk scores to be assigned to a lower risk control band. A low tolerance for risk allows for scores to be assigned to a higher risk control band.

ECD	Negligible	Risk Control Bands			Special (Extreme)
Moderate Tolerance	0	1	2	3	4
Range of Risk Score	< 9	10 - 23	24 - 37	38 - 69	> 69

Figure 7 Range of scores for each ECD RCBs using a moderate tolerance for risk.

LAB Environment	Negligible	Risk Control Bands			Special (Extreme)
Moderate Tolerance	0	1	2	3	4
Range of Risk Score	< 24	25 - 52	52 - 80	81 - 108	> 108

Figure 8 Range of scores for each Lab Environment RCBs using a moderate tolerance for risk.

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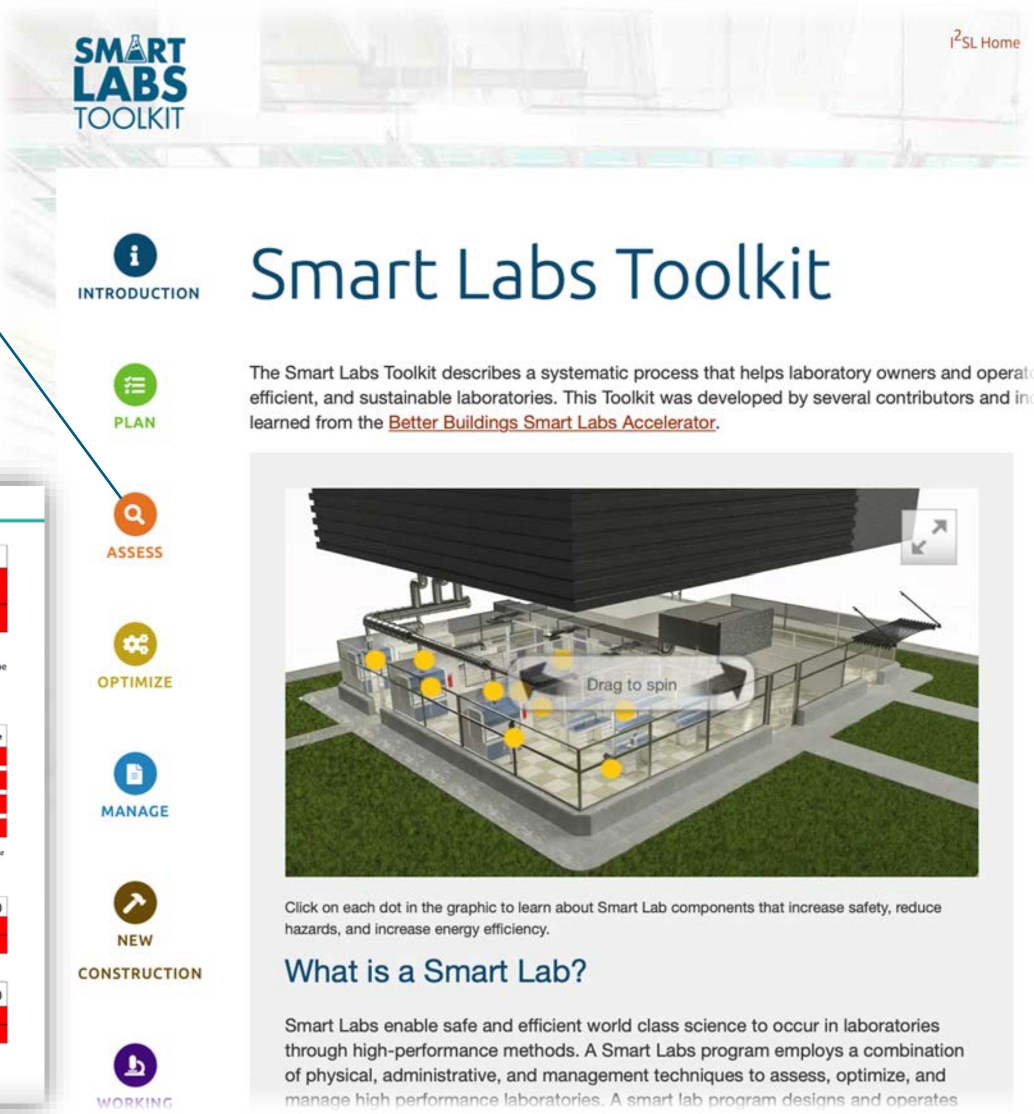


- ✓ Partner Case Studies
- ✓ Step-by-step Guidance
- ✓ User Friendly Tools & Calculators
- ✓ Helpful Resources & Templates
- ✓ Best Practice Guides

Best Practices in Lab Design

Smart Labs

Visit the Toolkit @ **SmartLabs.i2sl.org**

The HVAC Resource Map for Laboratories

The **HVAC Resource Map** is..

A graphical interface that provides quick access to information on:

- ✓ **Design**
- ✓ **Operations** and **maintenance** best practices
- ✓ **Energy** and **water** efficiency measures

In 100% outside air HVAC systems.

The Resource Covers…

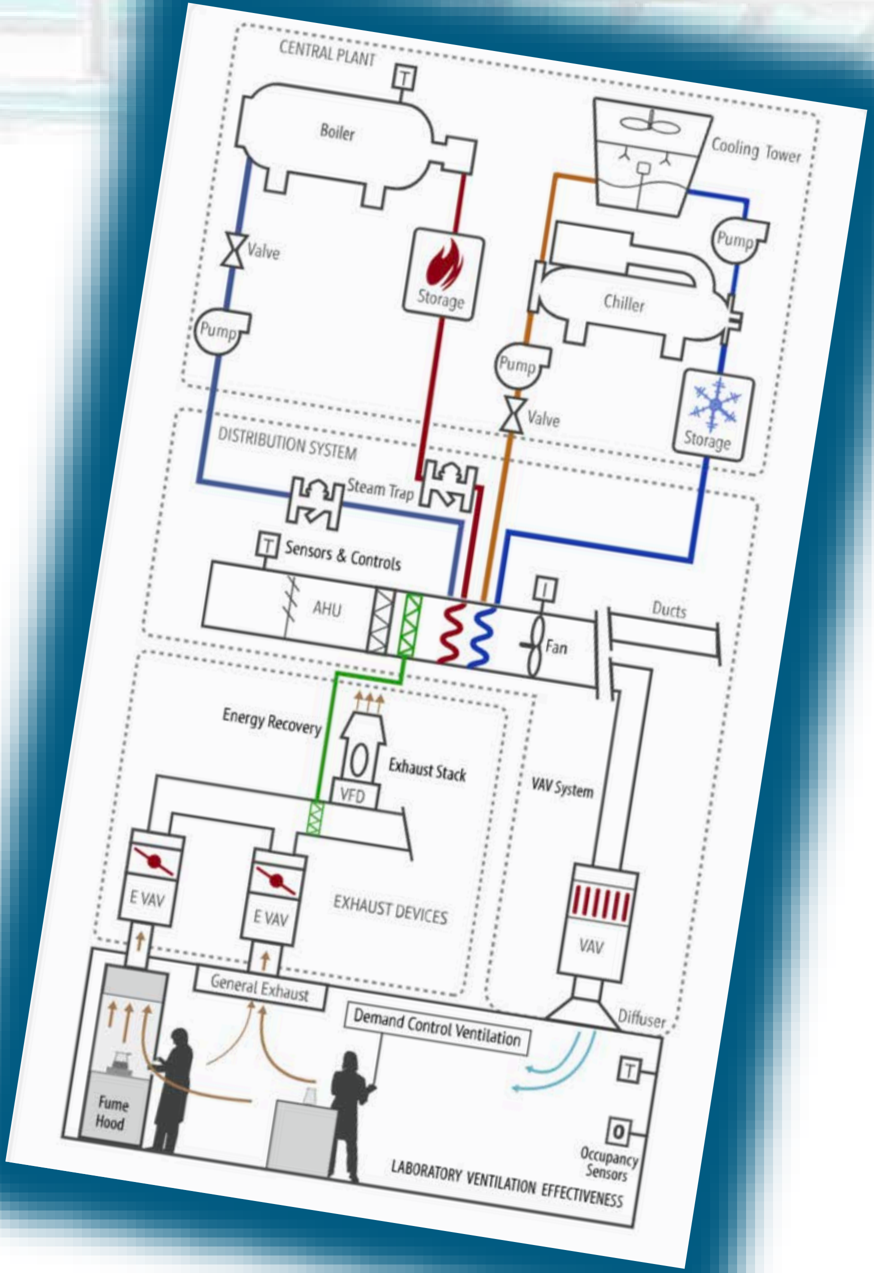
- ✓ The Central Plant
- ✓ Distribution Systems
- ✓ Zone Systems

Who Should Use the Map?

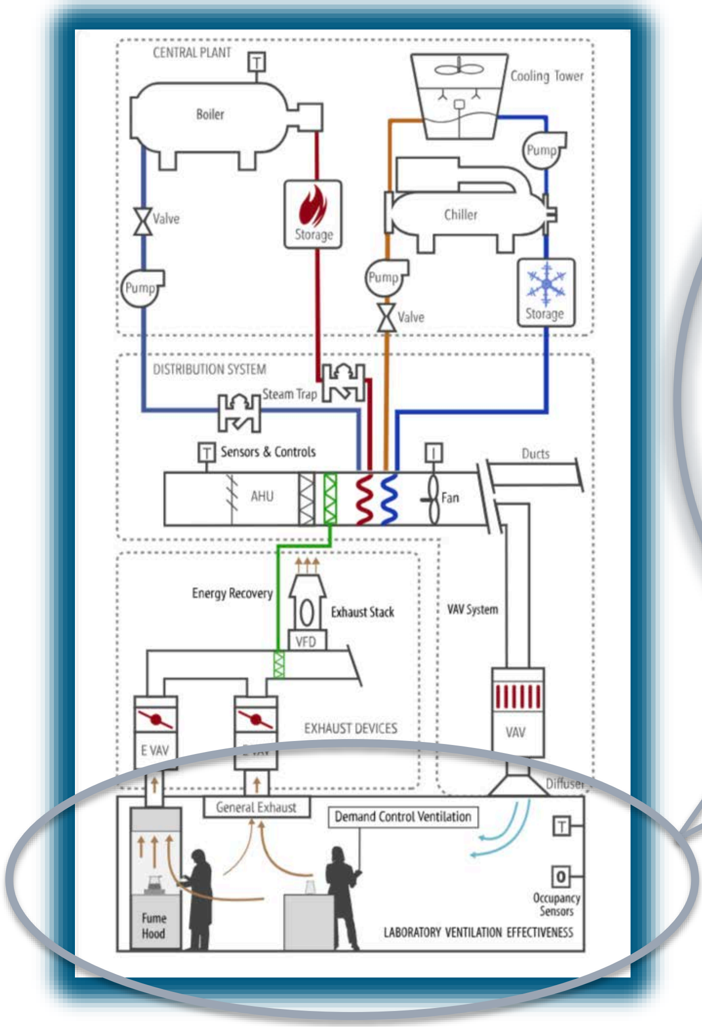
The Primary Audiences for the map are

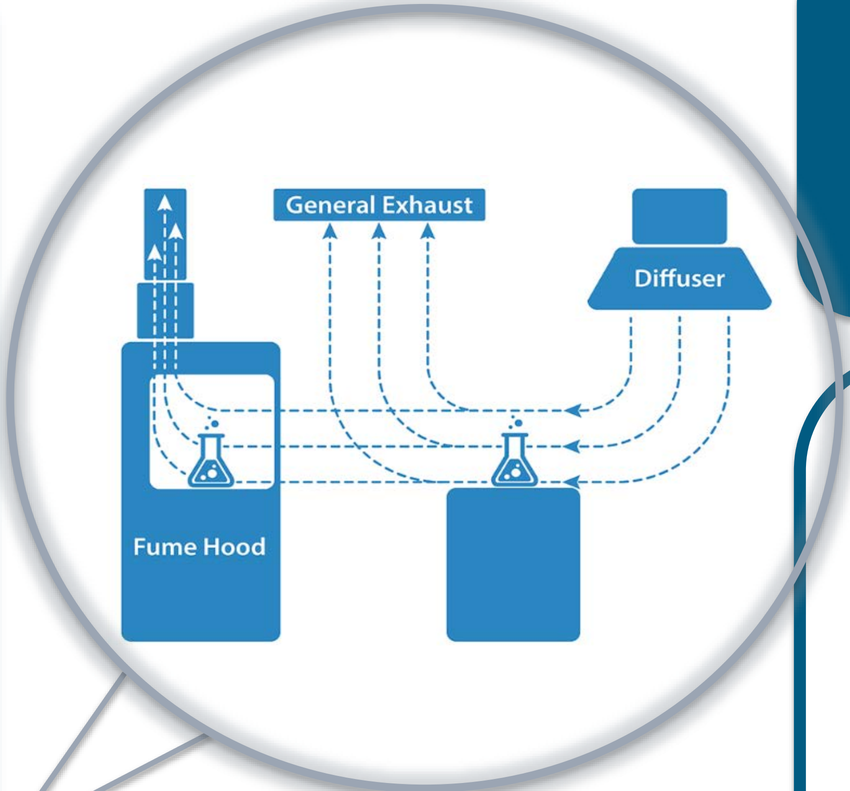
✓ Facilities Managers
✓ Operations Staff
✓ Design Engineers

Photo Credit: Bryan Bechtold/ NREL 77427



Lab Space: Laboratory Ventilation Effectiveness





Airflow patterns determine:

Air velocities
Air temperatures
Concentration of contaminants

Optimizing the flow path of supply and contaminated air improves the ventilation effectiveness for:

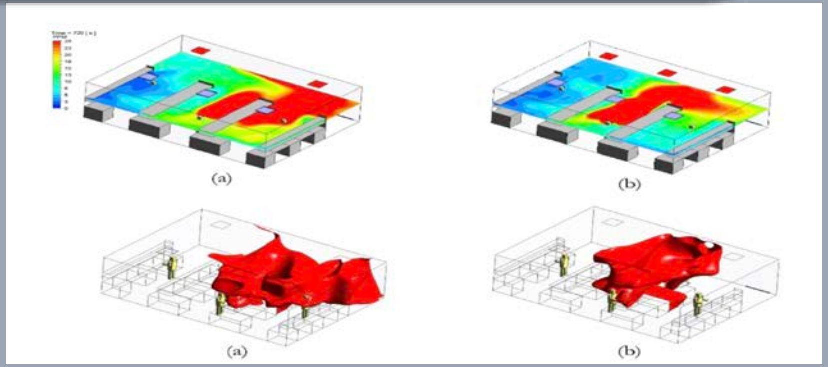
- ✓ Safe Labs
- ✓ Energy Efficient Labs
- ✓ Sustainable Labs

Computational Fluid Dynamics (CFD)

What is CFD?

A science that deals with the simulation and analysis of

- ✓ Fluid flow
- ✓ Heat Transfer
- ✓ Mass Transfer
- ✓ Similar transport processes



Why CFD?

Yield 3D information on **HVAC** design like…

- ✓ Air velocity
- ✓ Pressure
- ✓ Temperature
- ✓ Chemical concentrations
- ✓ Plume dispersion

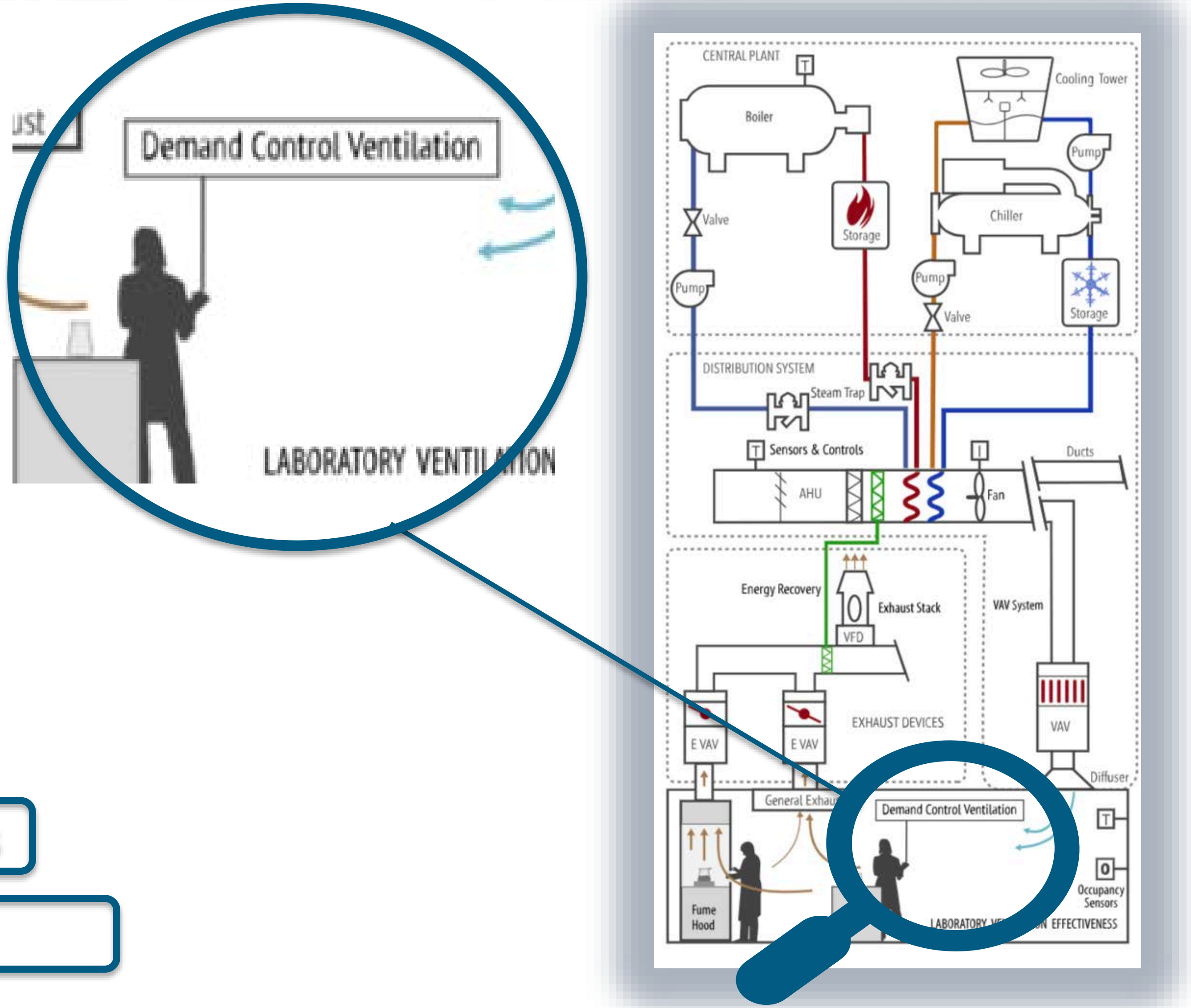
Lab Space: Demand Control Ventilation

- Demand-controlled ventilation (DCV) uses **real-time** information
- **Vary ventilation rates** to directly meet needs at a given time

DCV Systems Improve:

Lab Safety and Cleanliness

Energy Efficiency

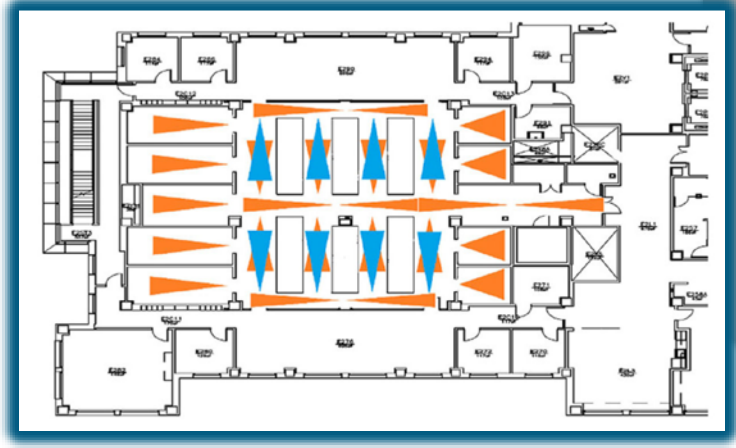


Lab Space: Occupancy Sensors

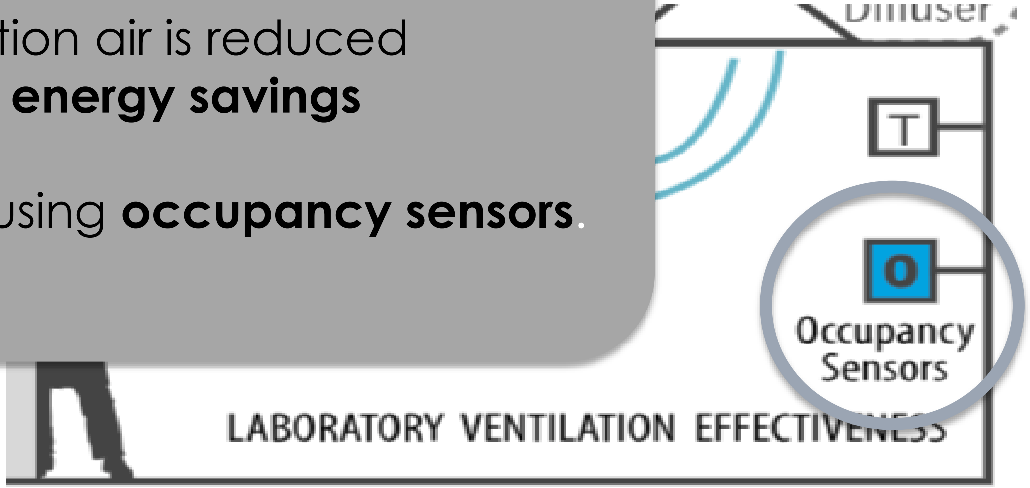
Presence or lack there of of occupants within an environment will alter what lighting and ventilation would result in such optimal conditions.

- ✓ Lights can be shut off
- ✓ The ventilation air is reduced
- ✓ Results in **energy savings**

This is accomplished using **occupancy sensors**.



Innovative Occupancy Sensor Layout by Emory University to control laboratory ventilation.
Image courtesy of Chris Fox, Emory University



Lab Space: Exposure Control Devices

Contain the hazardous chemical in the laboratory environment at the source

(Primarily **Fume Hoods**)

"Shut the Sash"

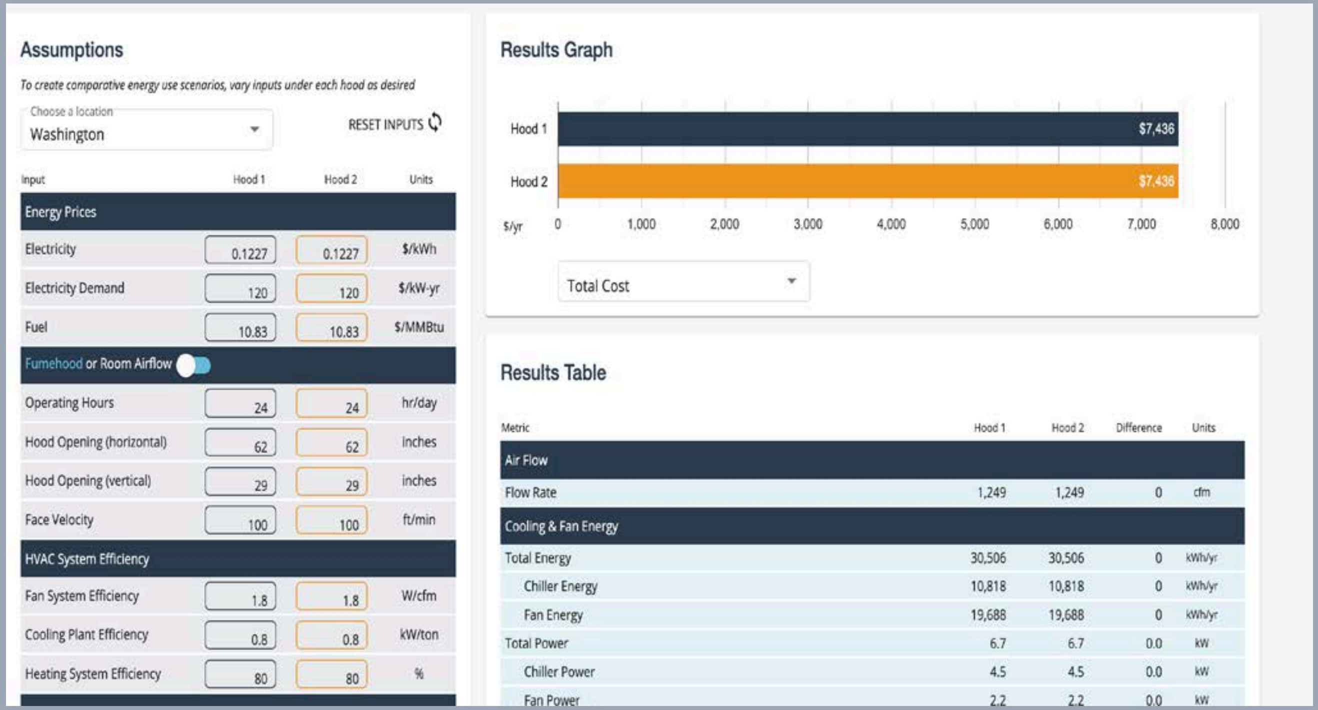
Laboratory Ventilation Risk Assessment

Operations & Training (ASHRAE 110)

Photo Credit: Shames Stevens/ NREL

Laboratory Fume Hood or Room Airflow Energy Modeler

BERKELEY LAB



https://fumehoodcalculator.lbl.gov/

- ✓ Estimates annual fume hood or room airflow energy use and costs
- ✓ Compare two operating modes
- ✓ Outputs in heating energy, cooling energy, fan energy, and costs

Lab Space: Building Energy Modeling

Provides helpful insight into how energy is used throughout a building

For **new construction**..

- ✓ Predict energy performance
- ✓ Model capacity of systems to meet changing requirements

Lab Energy Model

- ✓ Open-source building energy modeling platform
- ✓ Create laboratory prototype building

Lab Space: Energy Benchmarking for Labs

https://lbt.i2sl.org/

Compares the energy use of your lab buildings with similar facilities

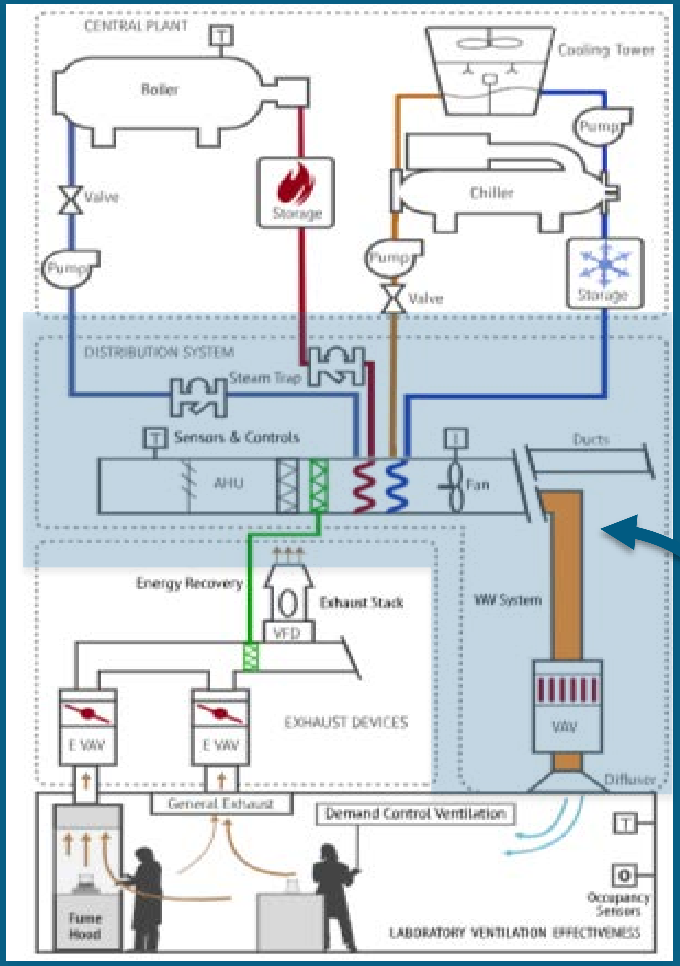
Start by selecting the metrics to benchmark like **HVAC energy** and collect data for each metric.

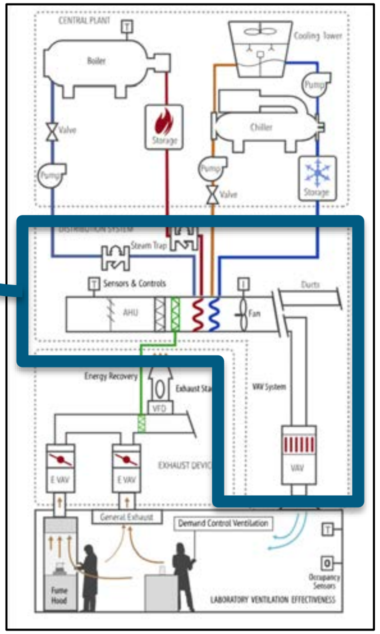
Can link between the LBT and ENERGY STAR Portfolio Manager

Low Pressure Drop design

- ✓ Low pressure drop design has savings potential of up to **65%**
- ✓ **Minimizing** pressure drop starts by establishing a system pressure requirements
- ✓ Mindful **equipment** selection and exhaust ductwork can reduce pressure drop

Refer to: I2SL Best Practice Guide on Low Pressure Drop HVAC Design for Laboratories





Air Handling Units

- ✓ Air handling units (AHUs) are devices that **transfer heat** between water/refrigerant and air
- ✓ These devices **provide** air supply throughout a building
- ✓ An important component of the AHU is the filter and its **effectiveness**.
- ✓ Design face velocity of **400 FPM** or less, operate all AHUs (including backup) to **minimize face velocity**

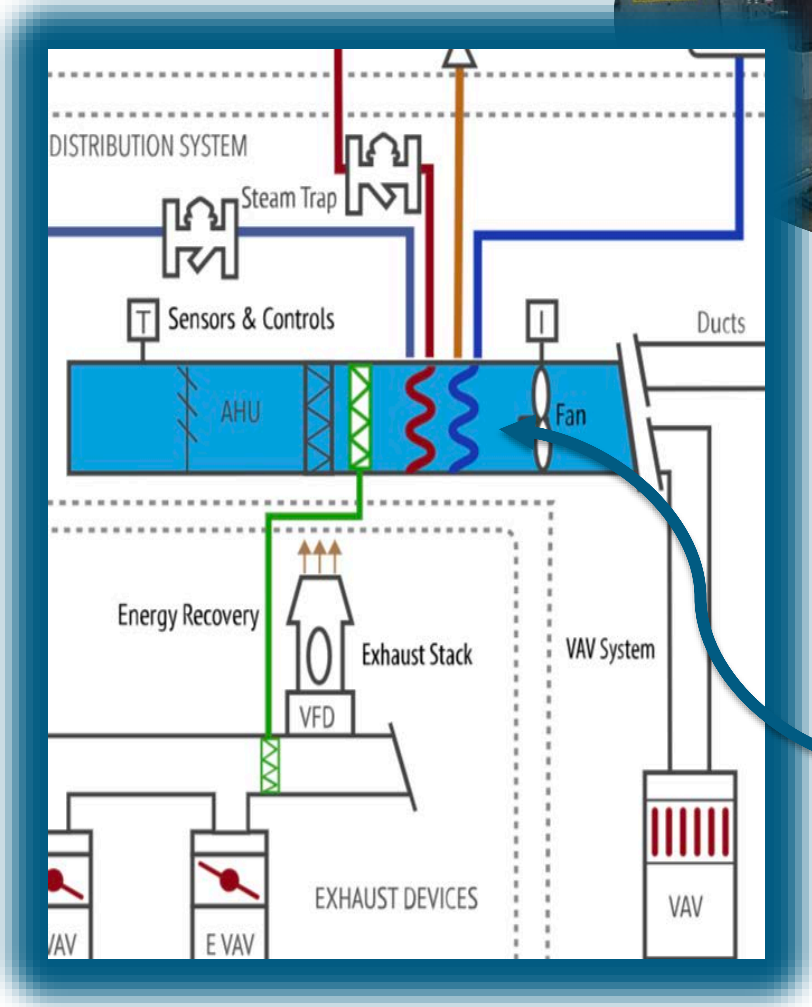
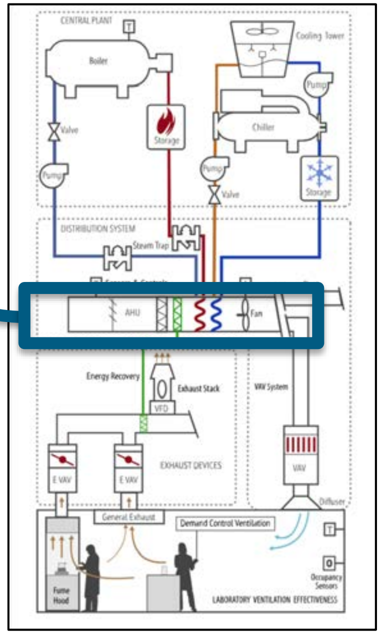


Photo Credit: Dennis Schroeder/NREL 38457

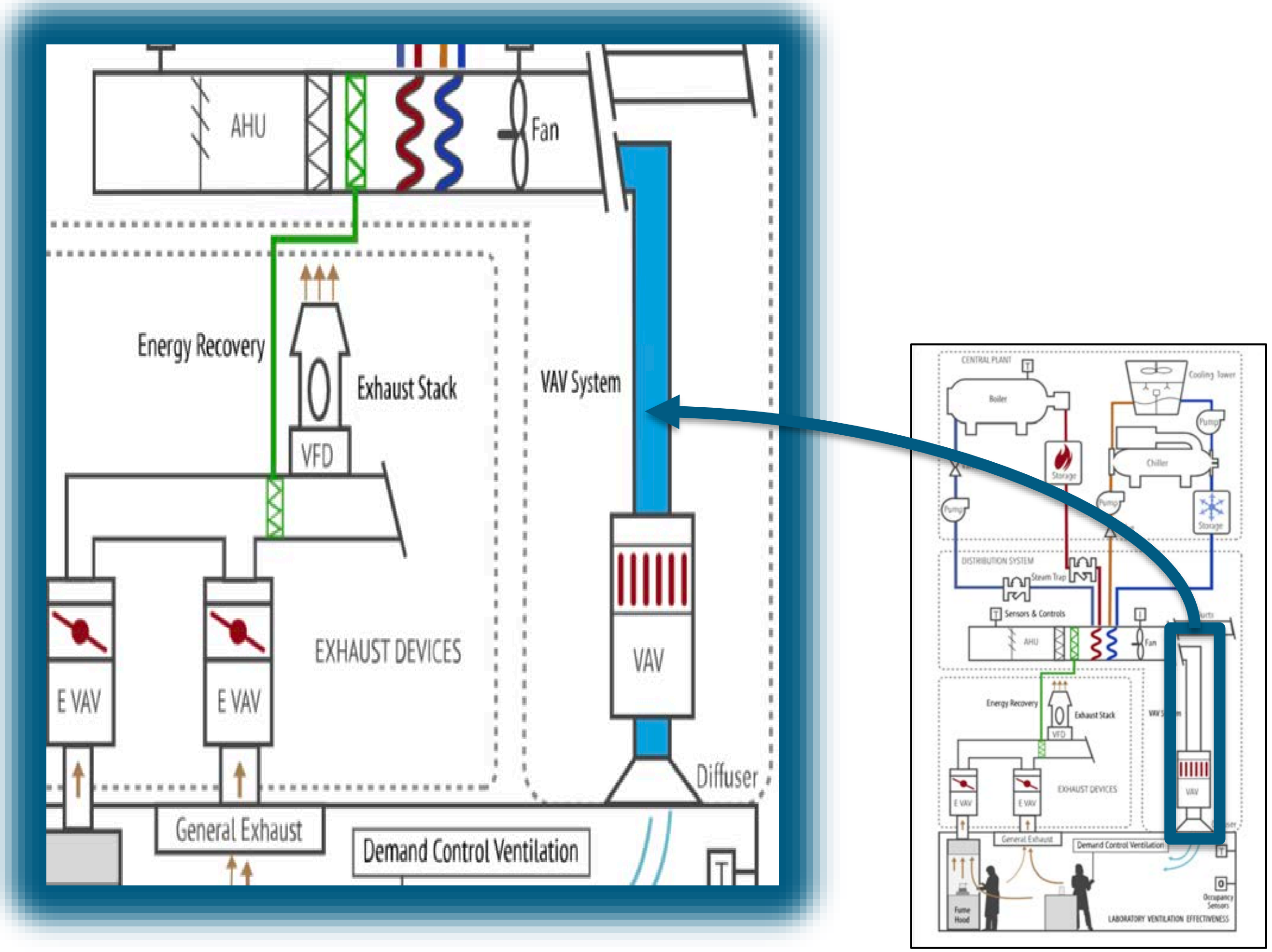


Variable Air Volume Systems (VAV)

✓ VAV systems **solve** issues of excess airflow

✓ Improves **energy efficiency by** optimizing airflow

✓ Laboratory VAV system must control the exhaust and supply air systems **together**

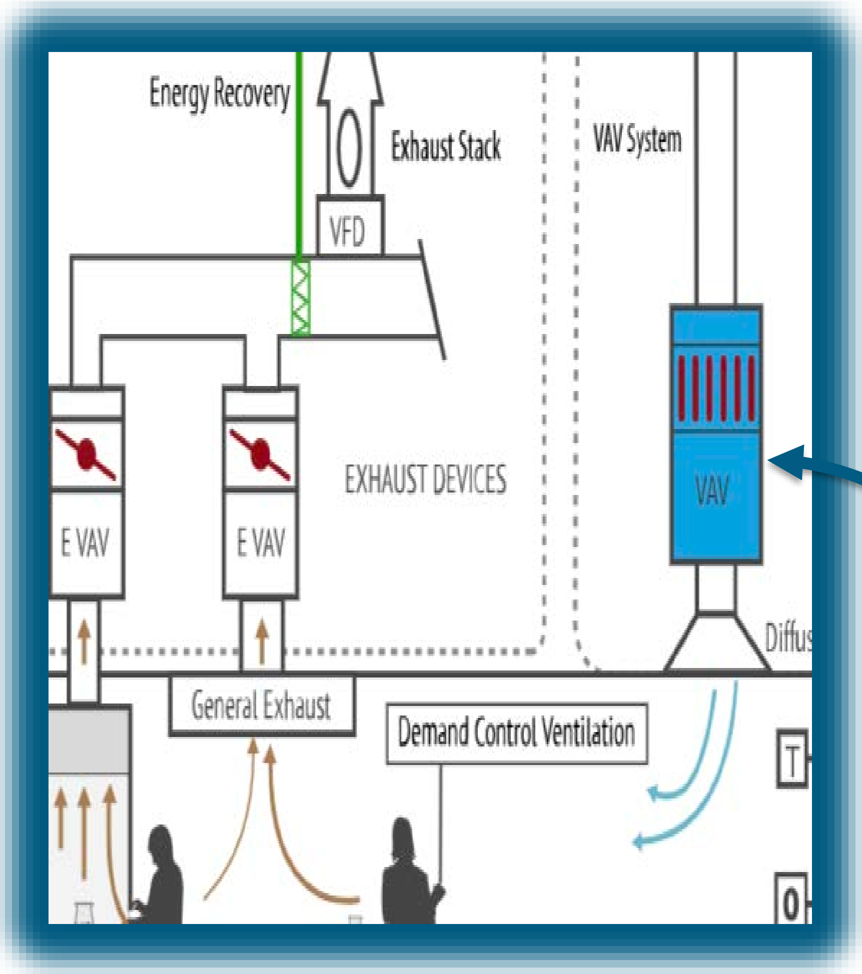


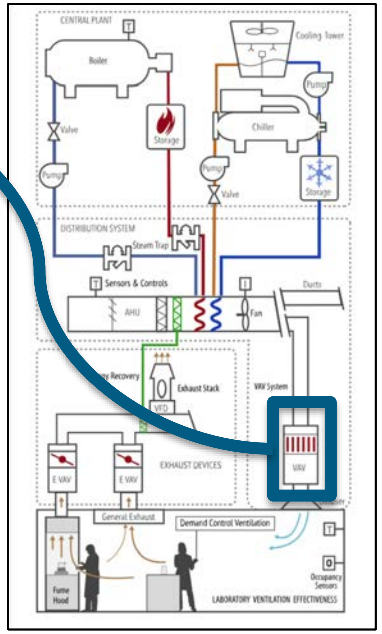
Variable Air Volume (VAV) Boxes

✓ VAV box is an **airflow control** device at the zone level

✓ Box selection is important to ensure **overall efficiency** of the ventilation and heating/cooling system

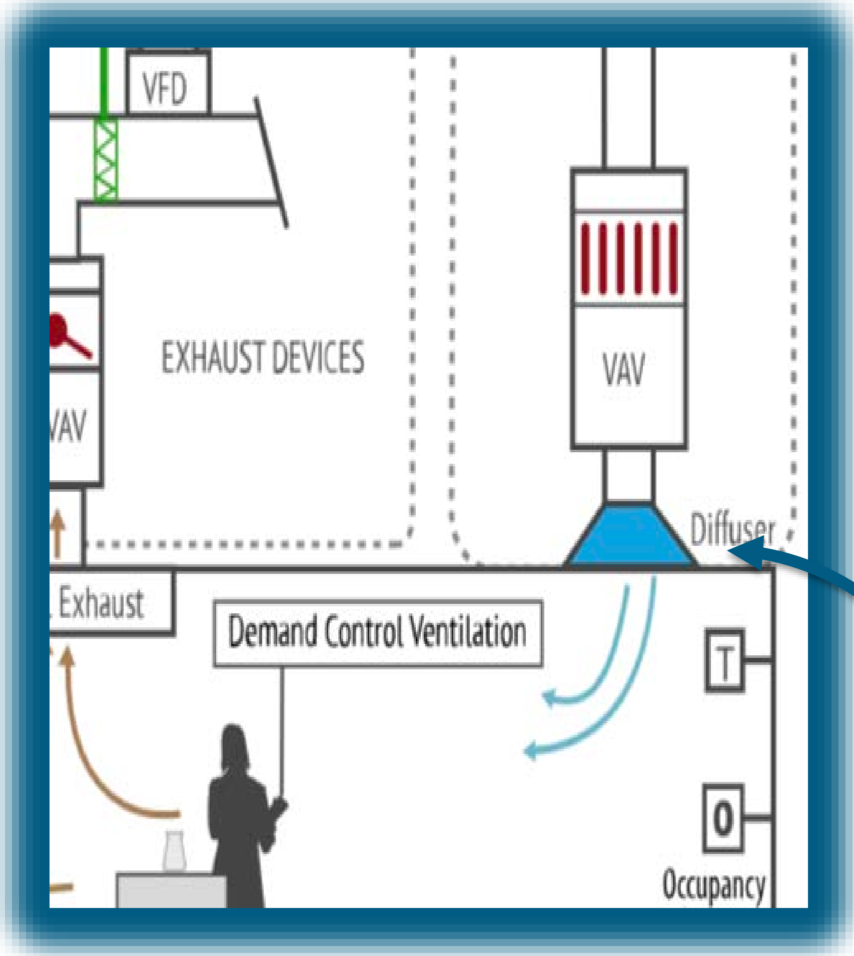
✓ The supply air and exhaust air must be **tracked** to ensure proper lab pressurization

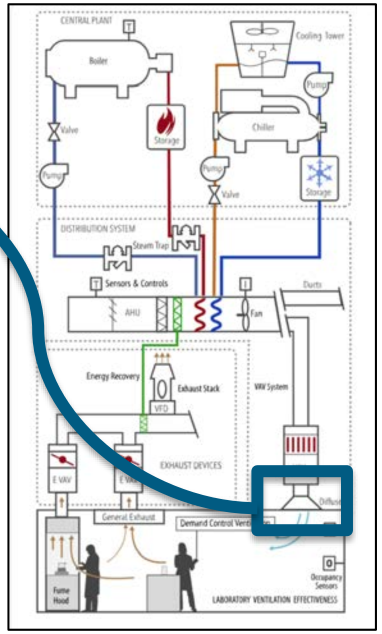




Diffusers

- ✓ Laboratories present **unique** requirements for supply air to provide a safe environment
- ✓ Location and sizing of **diffusers** are important for ventilation effectiveness
- ✓ Use **radial** or **laminar** flow diffusers in labs, do **NOT** use mixing flow diffusers



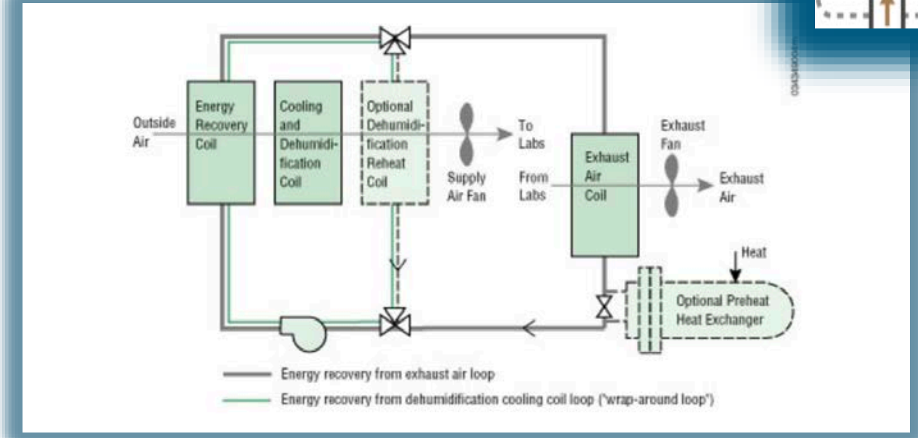


Energy Recovery

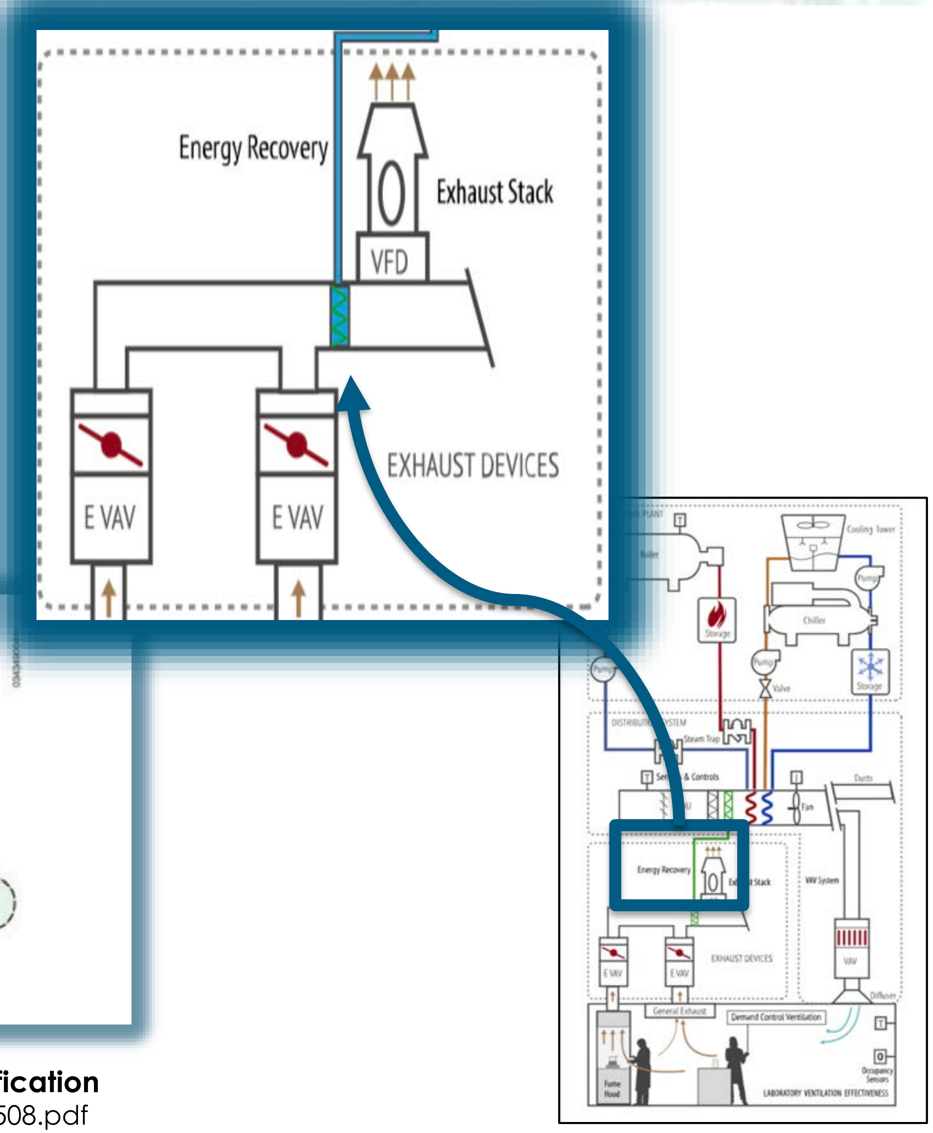
Energy recovery systems transfer heat between the outdoor air and exhaust air streams.

Strategies for energy recovery

- ✓ Run Around Loops
- ✓ Energy Recovery Wheels
- ✓ Heat Pipes



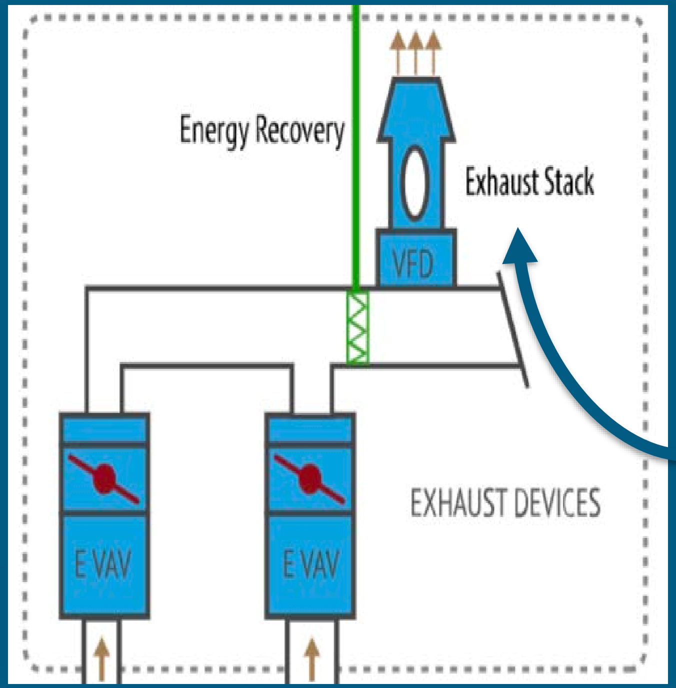
Run-Around Energy Recovery Loop with Dehumidification
https://www.i2sl.org/documents/toolkit/bp_recovery_508.pdf

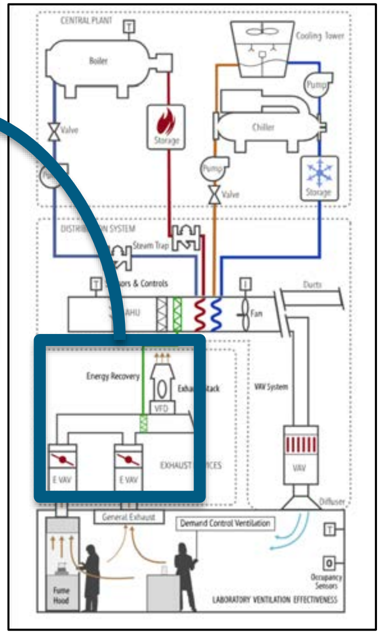


Optimized Exhaust Stack Design

Ways to design an optimized stack discharge system

- ✓ Strategy 1: Passive VAV
- ✓ Strategy 2: Active VAV with Anemometer
- ✓ Strategy 3: Active VAV with Chemical Monitor





Designing and Operating Sustainable Laboratory Exhaust Systems
https://www.i2sl.org/_files/ugd/59662e_aa67e16f48d64be69845277e9e4367d9.pdf

Optimized Exhaust Stack Design

Optimized Stack Design Tab on HVAC Resource Map:

References:
I2SL Best Practice Guide:
Designing and Operating Sustainable Laboratory Exhaust Systems.


Best Practices Guide
Designing and Operating Sustainable Laboratory Exhaust Systems

International Institute for Sustainable Laboratories

AUGUST 2021

Introduction

This guide provides general guidance on the design and operation of laboratory exhaust systems to avoid adverse re-entrainment of the effluent at critical surrounding locations. It also offers various quantitative approaches (dispersion modeling) that can be used to determine expected concentration (or dilution) levels resulting from exhaust system emissions. In addition, the guide describes methodologies that can be employed to operate laboratory exhaust systems in a safe and energy efficient manner by using variable air volume (VAV) technology.

Studies have shown a direct relationship between

by closing the sash and leaving the immediate area; thus, reducing exposure to the chemical vapors. Conversely, the presence of the toxic or odorous fumes at an air intake, which can distribute the chemical vapors throughout the building, typically cannot be easily mitigated. The only option may be to evacuate the entire building, which results in an immediate loss of productivity and a long-term reduction in occupant satisfaction with the working conditions.

Dispersion modeling predicts the amount of fume re-entry, or the concentration levels expected at critical receptor locations, with the goal of defining a "good" exhaust and intake design that limits concentrations below an established design

- ✓ Guide provides guidance on the **design and operation of laboratory exhaust systems**.
- ✓ Various **quantitative approaches** used to determine expected concentration levels.
- ✓ Describes methodologies used in a **safe and energy efficient** manner.

Smart Labs

Plan

Visit the Toolkit @ **SmartLabs.i2sl.org**

SMART LABS TOOLKIT

FEMP Federal Energy Management Program

The Smart Labs Process

Plan

- Build a team of lab stakeholders
- Profile buildings to prioritize efforts
- Develop a strategic plan for cost-effective implementation

Build Your Smart Labs Team

Identify Smart Labs Coordinator

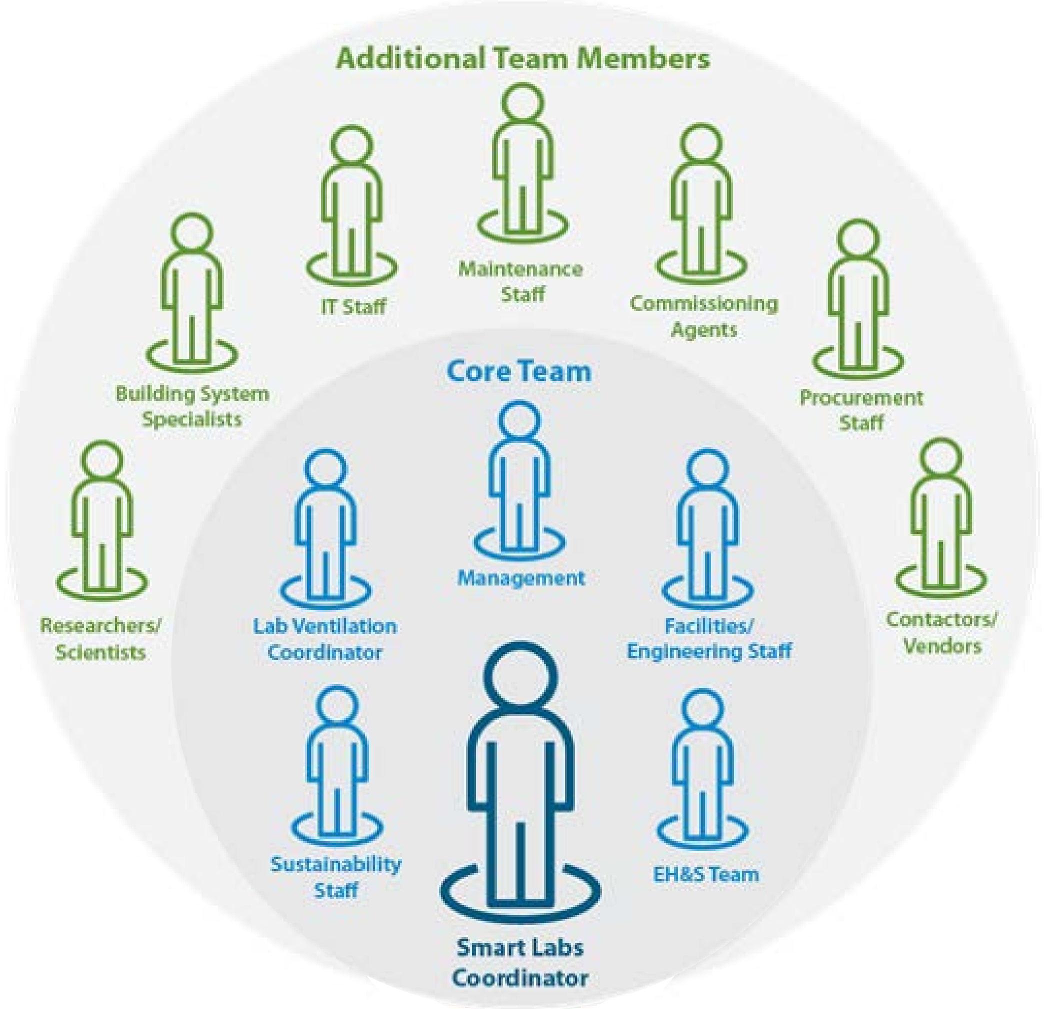
- ✓ Maintain lines of communication
- ✓ Schedule tasks
- ✓ Manage information
- ✓ Implement projects
- ✓ Ensure program deliverables

Engage management

- ✓ Understand complexity, safety, and efficiency of laboratories
- ✓ Ensure program has the necessary support to succeed

Create a diverse team of experts

Smart Labs Program



Working Together in Labs

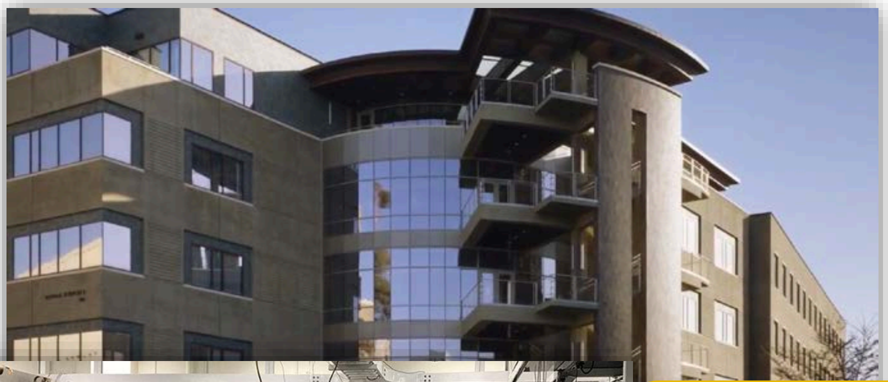
Engineer

Industrial Hygienist

- ✓ Smart Labs principles require both parties to be involved
- ✓ Laboratory Ventilation Risk Assessment (LVRA) takes inputs from both parties

Become a Smart Labs Champion

University of California - Irvine



61% energy savings

Improved safety through fault detection

"People willing to buck the status quo and question all the assumptions which have been touted as best practices for not just years but decades."
-Wendell Brace, UC Irvine

Visit the Toolkit @ **SmartLabs.i2sl.org**

Become a Smart Labs Champion

Could be you!

Recognize accomplishments

Oversees progress of efforts

✓ Develop reports and funding strategies

Coordinate efforts among Smart Labs team and stakeholders to achieve program goals

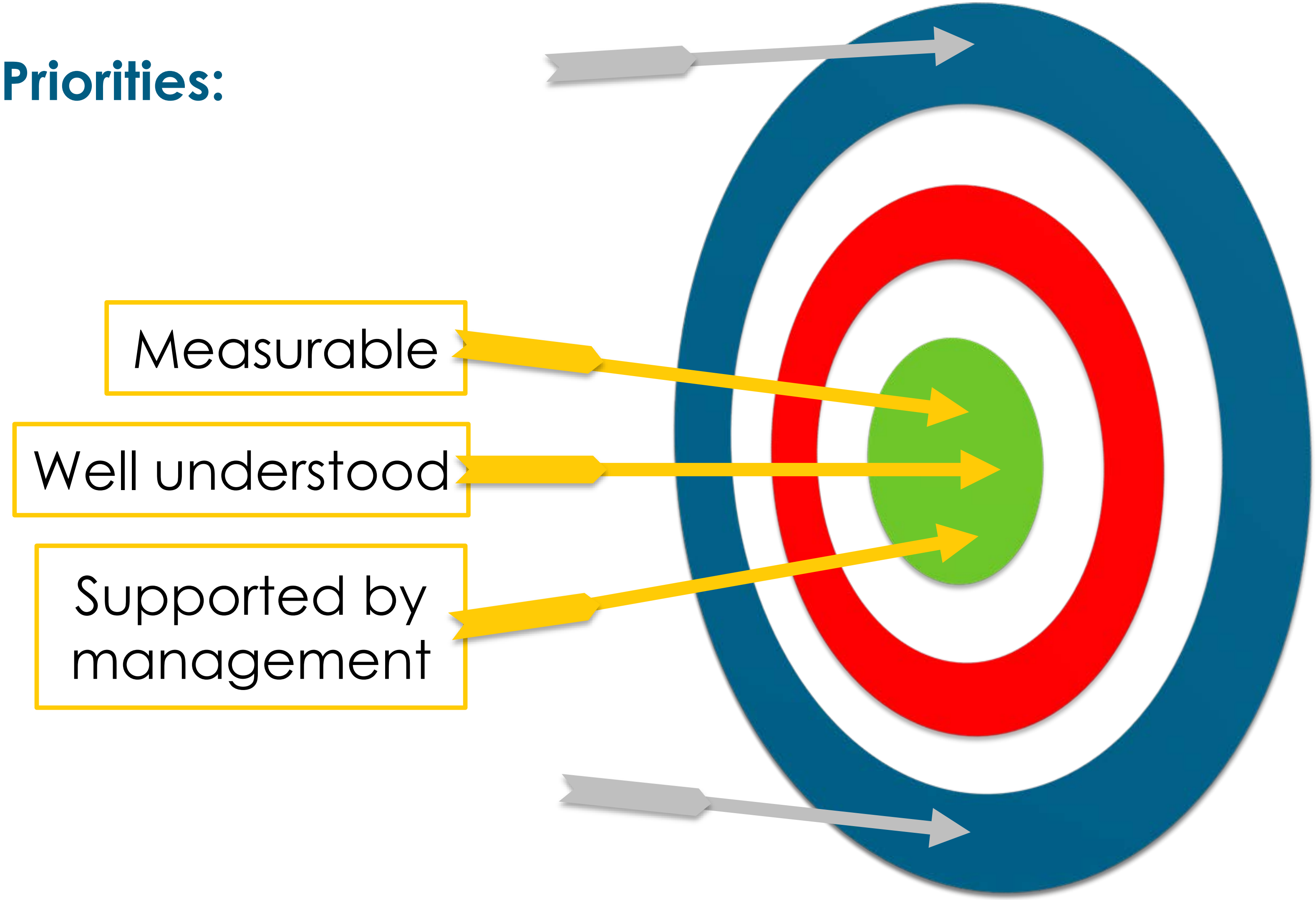
NREL 42538

Suzy Belmont, NREL

Define Program Goals

Common Goals and Priorities:

- Improve safety
- Reduce energy use
- Optimize lab conditions
- Lower operating costs
- Reduce deferred maintenance



Gather Your Baseline

Baseline

Set of metrics for buildings that describe the **current status** of energy, airflow, water, and other **consumers**.

- ✓ Gather Building Documentation
- ✓ Inventory Hazardous Chemicals
- ✓ Calculate Key Performance Metrics

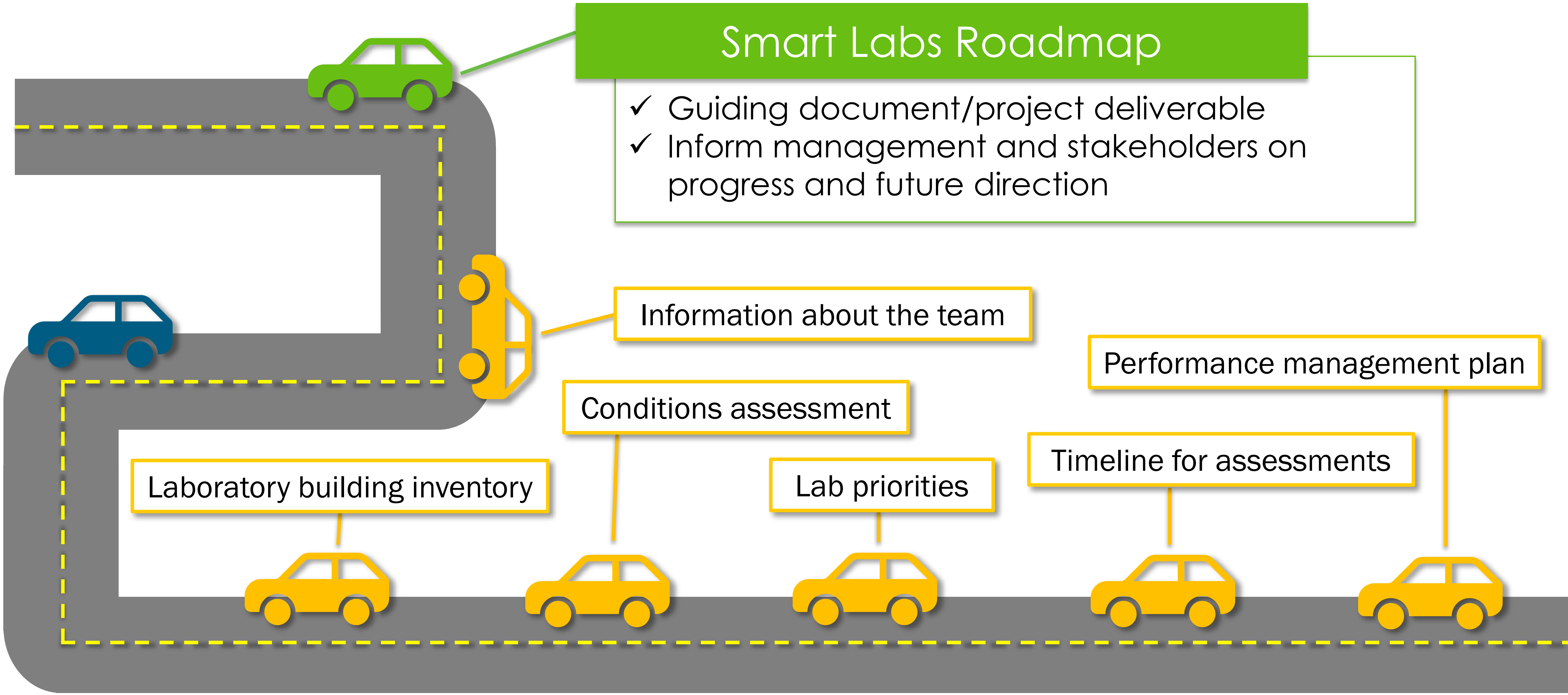
Visit the Toolkit @ **SmartLabs.i2sl.org**

Building Information Example

Building Name	Lab #1	Lab #2
Year Built	1988	2002
Building Area (ft^2)	71,000	80,800
Total Lab Area (ft^2)	35,500	24,240
Number of Labs	15	17
Lab Type(s)	Chemistry	R&D
Number of Occupants	115	233
Occupancy Hours	12	10
HVAC System Type(s)	CAV	VAV
Lighting System Type(s)	Fluorescent	LED
Fuel Type(s)	Boiler	Boiler
Analytics	Sensors	EMIS
EUI	311	353

- ✓ Total energy consumption (EUI, CFM in lab areas)
- ✓ Establish current conditions
- ✓ Identify major consumers
- ✓ Evaluate usage patterns or anomalies

Smart Labs Roadmap



Laboratory Benchmarking Tool

SMART LABS TOOLKIT

Visit lbt.i2sl.org

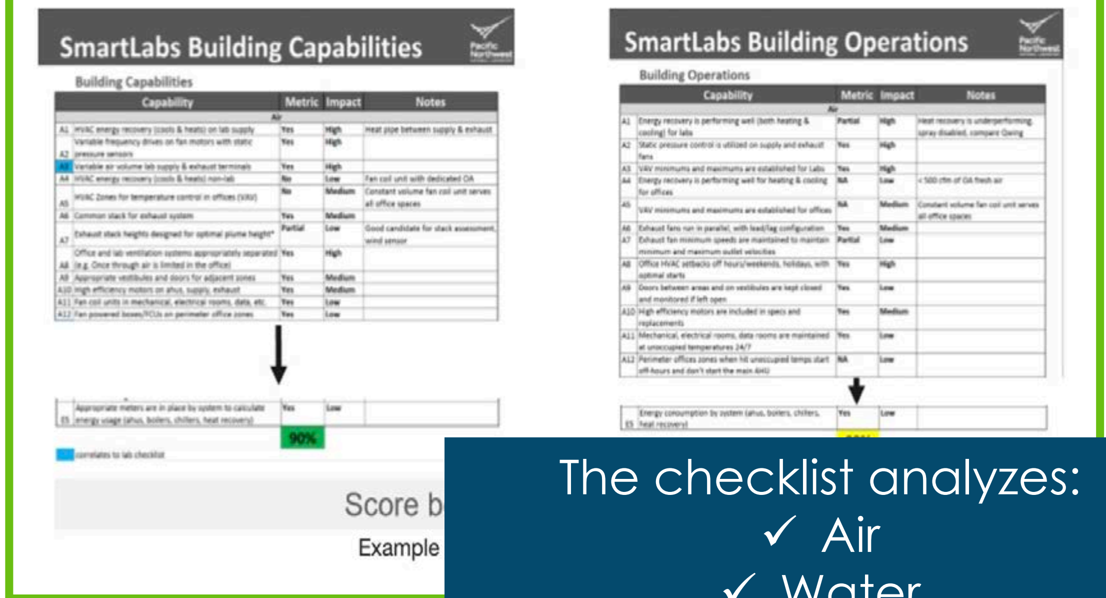
Identifying **Smart Lab** Opportunities at **Pacific Northwest National Laboratory**

Pacific Northwest NATIONAL LABORATORY

PNNL's sustainability team focused on reducing water and energy consumption

Implemented a **Smart Labs** program

Working with Emory University, PNNL developed a **Smart Labs Checklist**



The checklist analyzes:

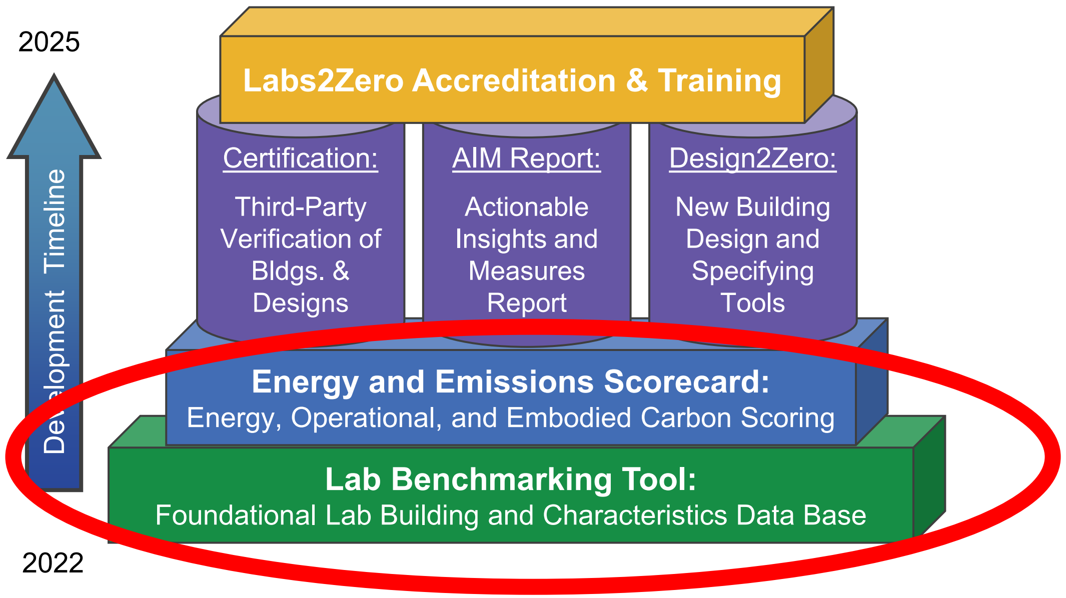
- ✓ Air
- ✓ Water
- ✓ Controls
- ✓ Lighting
- ✓ Energy

See more on the Smart Labs Checklist Case Study at Smart Labs Toolkit- PNNL

Intro to the Laboratory Benchmarking Tool and the Labs2Zero Energy Score

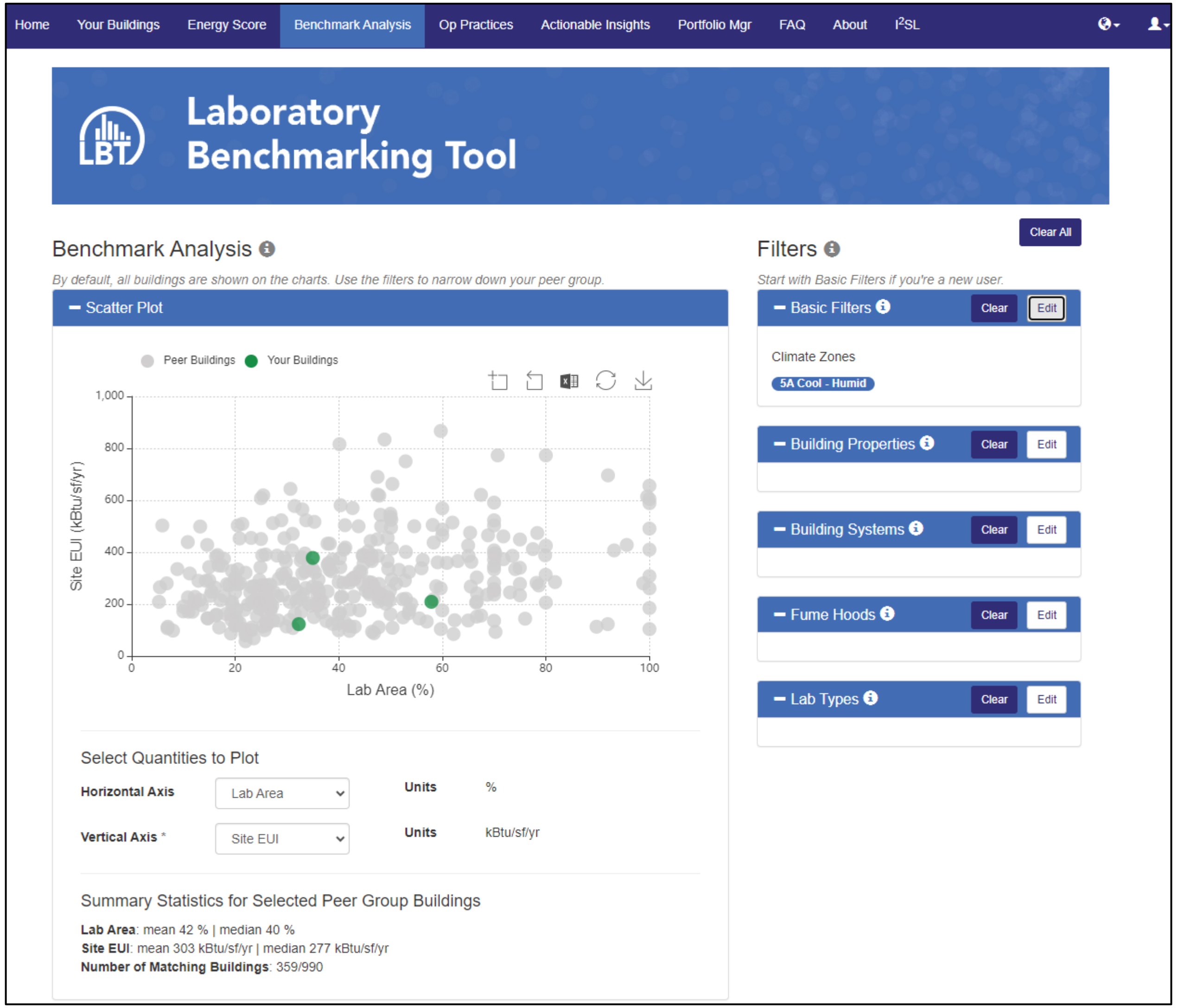
Two Labs2Zero Tools You Can Use Today

- The Laboratory Benchmarking Tool
  - The only meaningful way to compare lab building energy performance
- The Pilot Energy Score
  - A new, better way to compare lab building energy performance



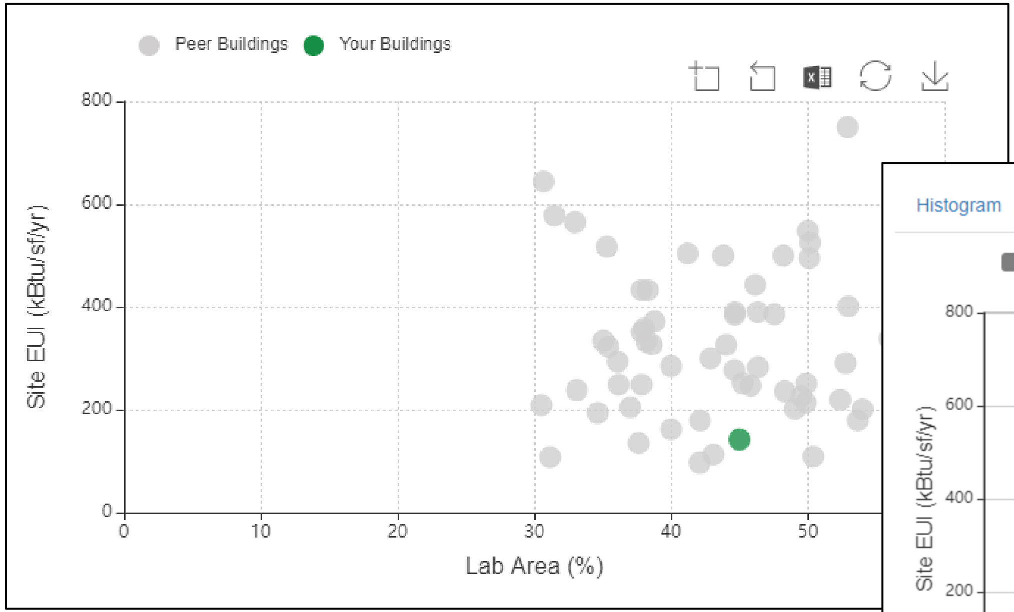
The Laboratory Benchmarking Tool

- Analytics tool & database of 1000+ buildings
- Benchmarking by filtering
  - Select peer buildings with similar functional requirements
  - Compare EUIs and other metrics
- **Free to use**
- lbt.i2sl.org



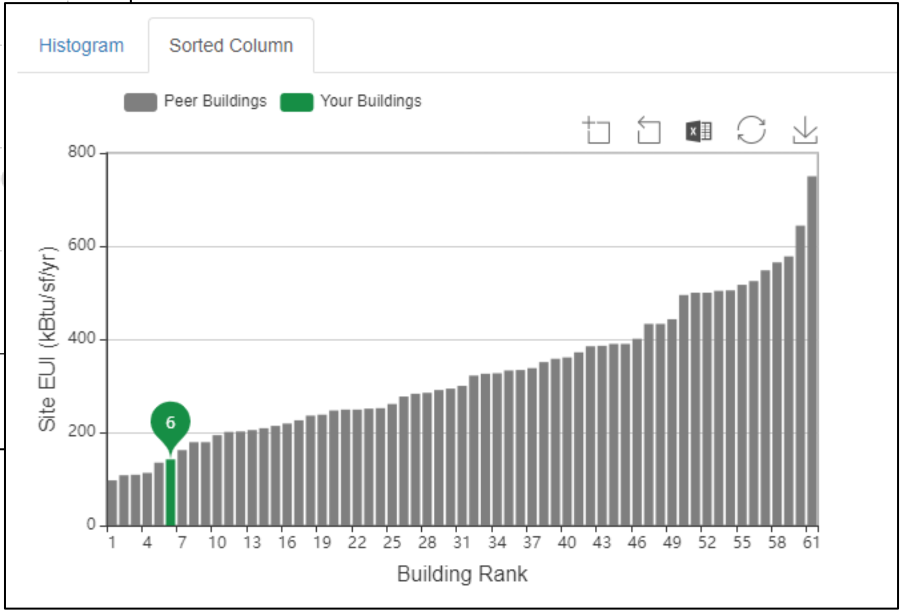
Benchmarking Example

- **Example:** bio/biochem university building with 45% lab space by area in Toronto (climate zone 5A)
- Iterative process



Summary Statistics for Selected Peer Group Buildings

Lab Area: mean 44 % | median 44 %
Site EUI: mean 330 kBtu/sf/yr | median 311 kBtu/sf/yr
Number of Matching Buildings: 60/990



Filters

Clear All

Start with Basic Filters if you're a new user.

Basic Filters — Clear | Edit

Lab Types

Biology | Combination (Bio/Chem)

% Lab Area (Net Lab Area / Total Gross Area)

30.00 to 60.00 %

Climate Zones

5A Cool - Humid

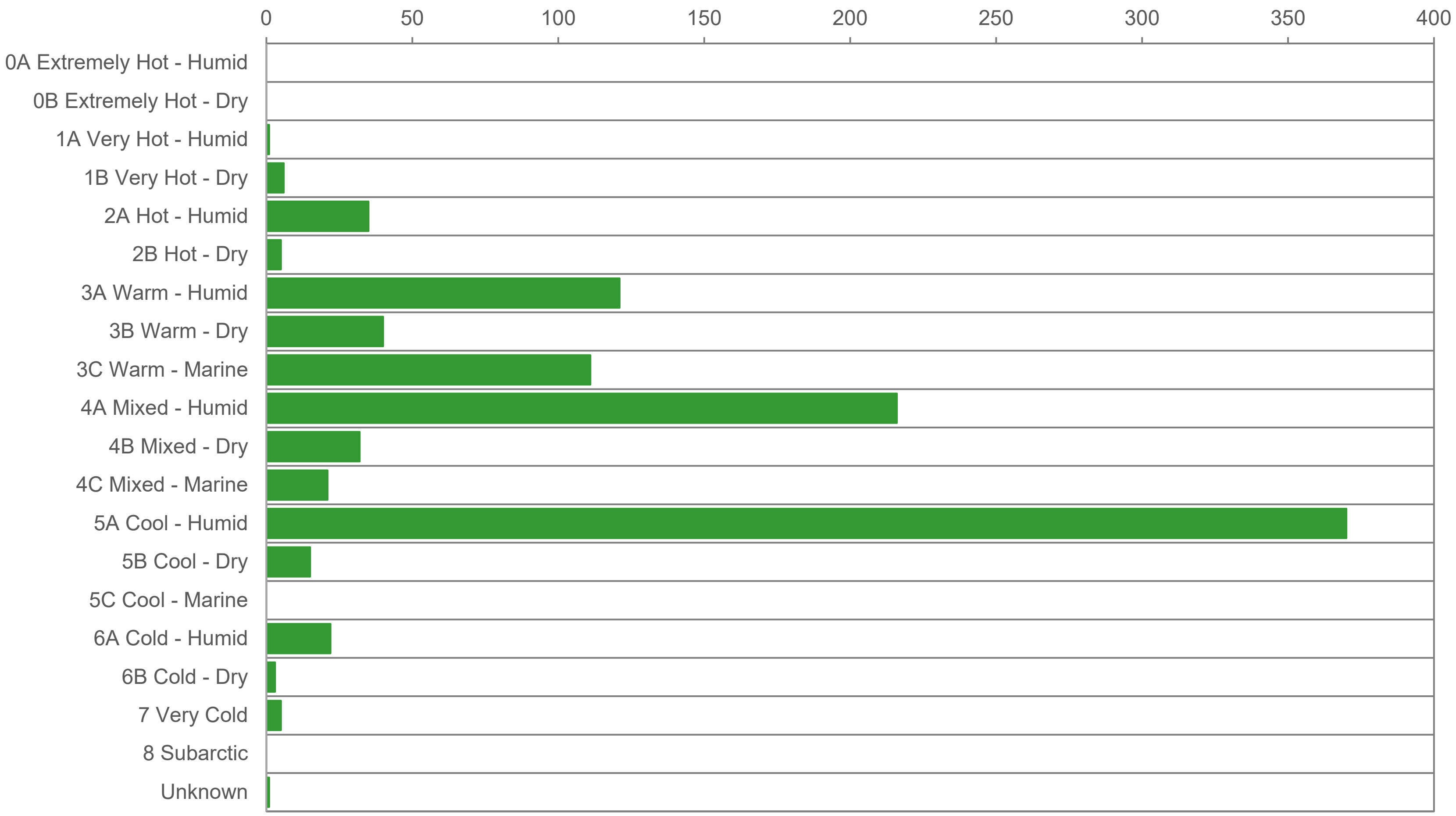
Building Properties — Clear | Edit

Organization Type

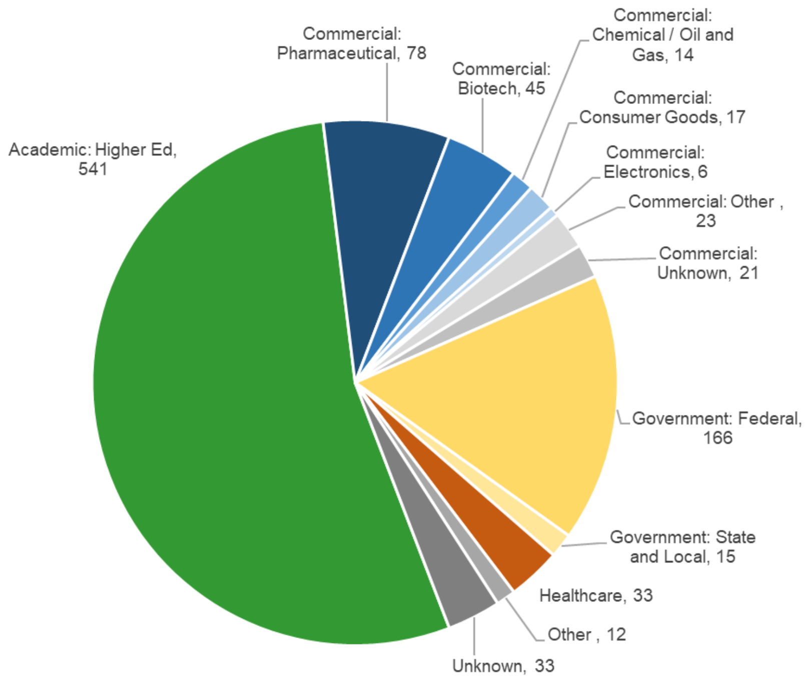
Academic: Higher Ed

Other Climate Zones in the Peer Group

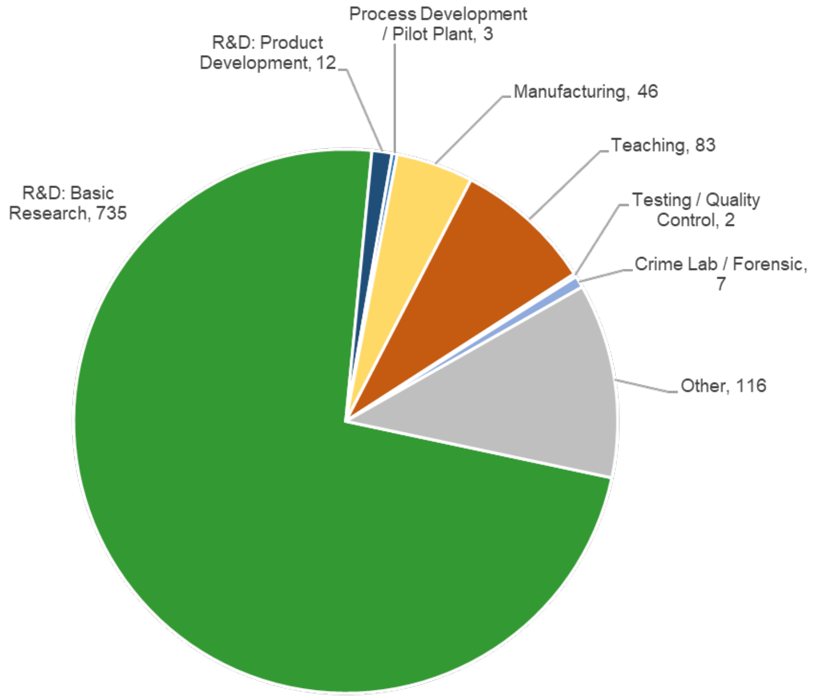
- 5A is the richest dataset
- Some colder zones are not as well represented

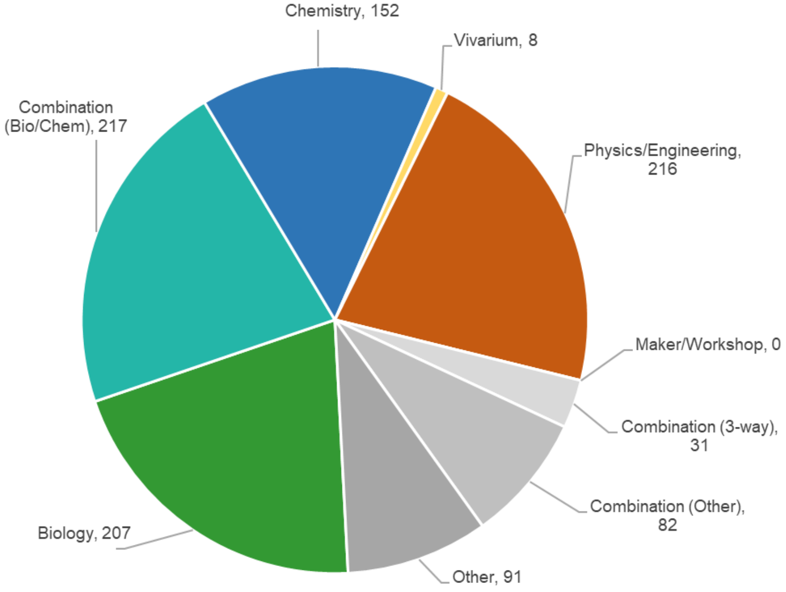


More Peer Group Database Stats



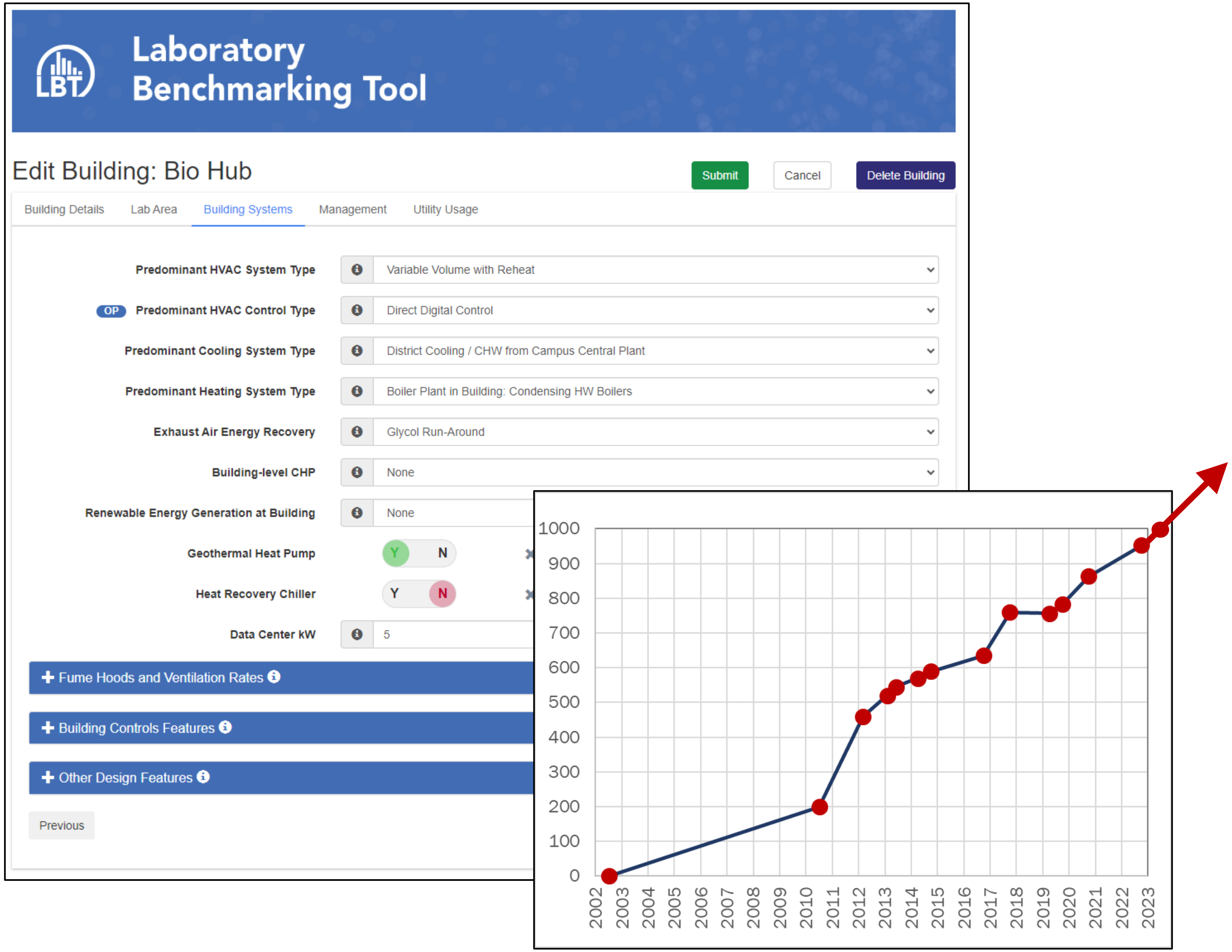
- Many types are represented
- Largest groups are Higher Ed, R&D, Bio/Chem





Laboratory Benchmarking Tool

The LBT: A Community Tool



Number of buildings in database

- The LBT collects data too
- Enter data in the **Your Buildings** tab of the LBT
- User-submitted data is QC'd, anonymized, and added to the peer group database
- **Internationalized in 2022**
    - Metric units and global locations
    - Only a few non-US peer group buildings so far

Getting Started With The LBT: Tips

- **100+** data fields per building
- Only **~1 dozen** mandatory entries (marked with *)
- Basic data entry: **15 min** per building if data available
  - Entering more data allows more detailed comparisons with other buildings

Quick Start Guide

- linked here

Full list of fields

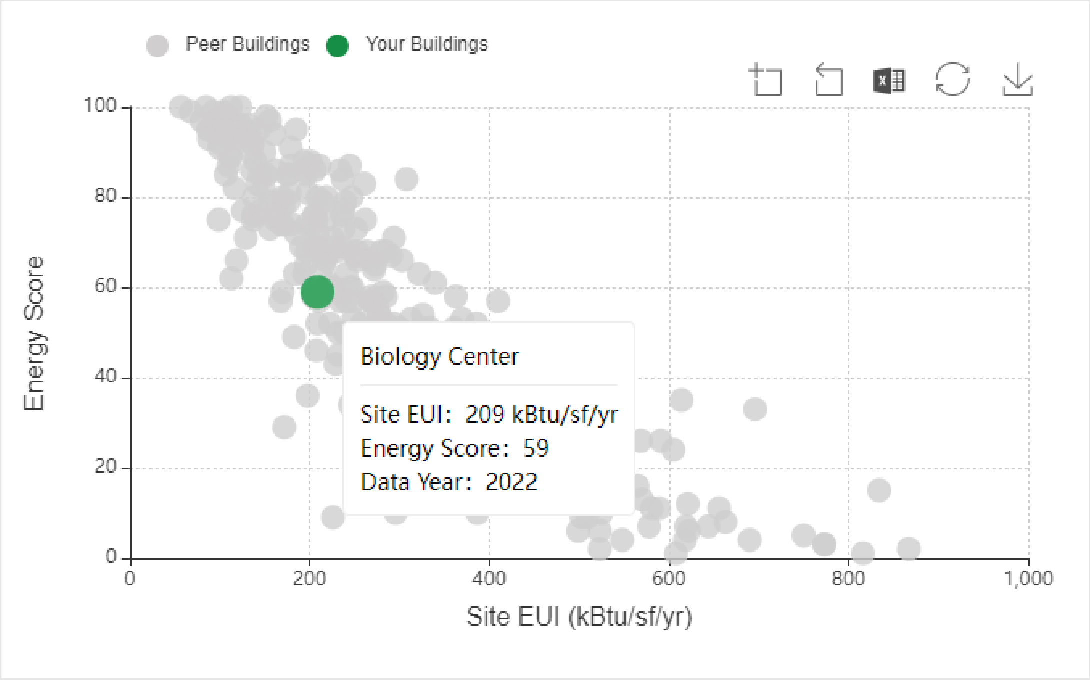
- link to doc

Basic benchmarking process

- link to doc

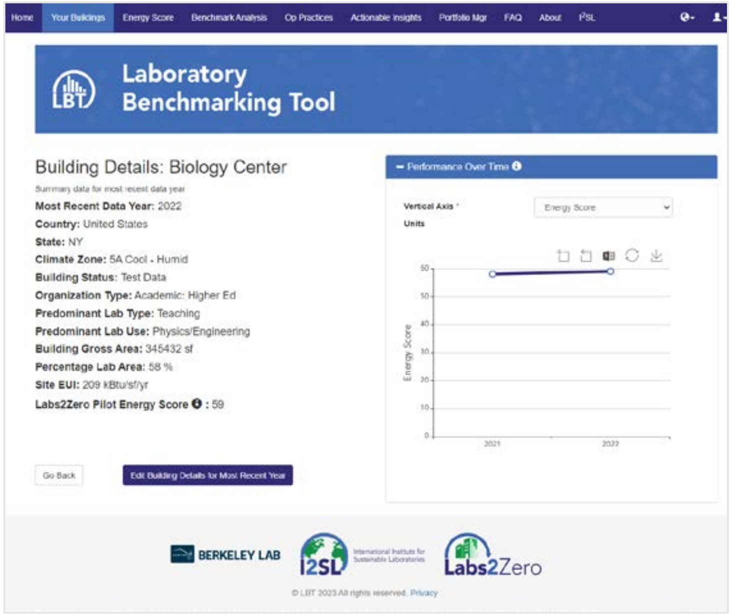
NEW: Pilot Energy Scores

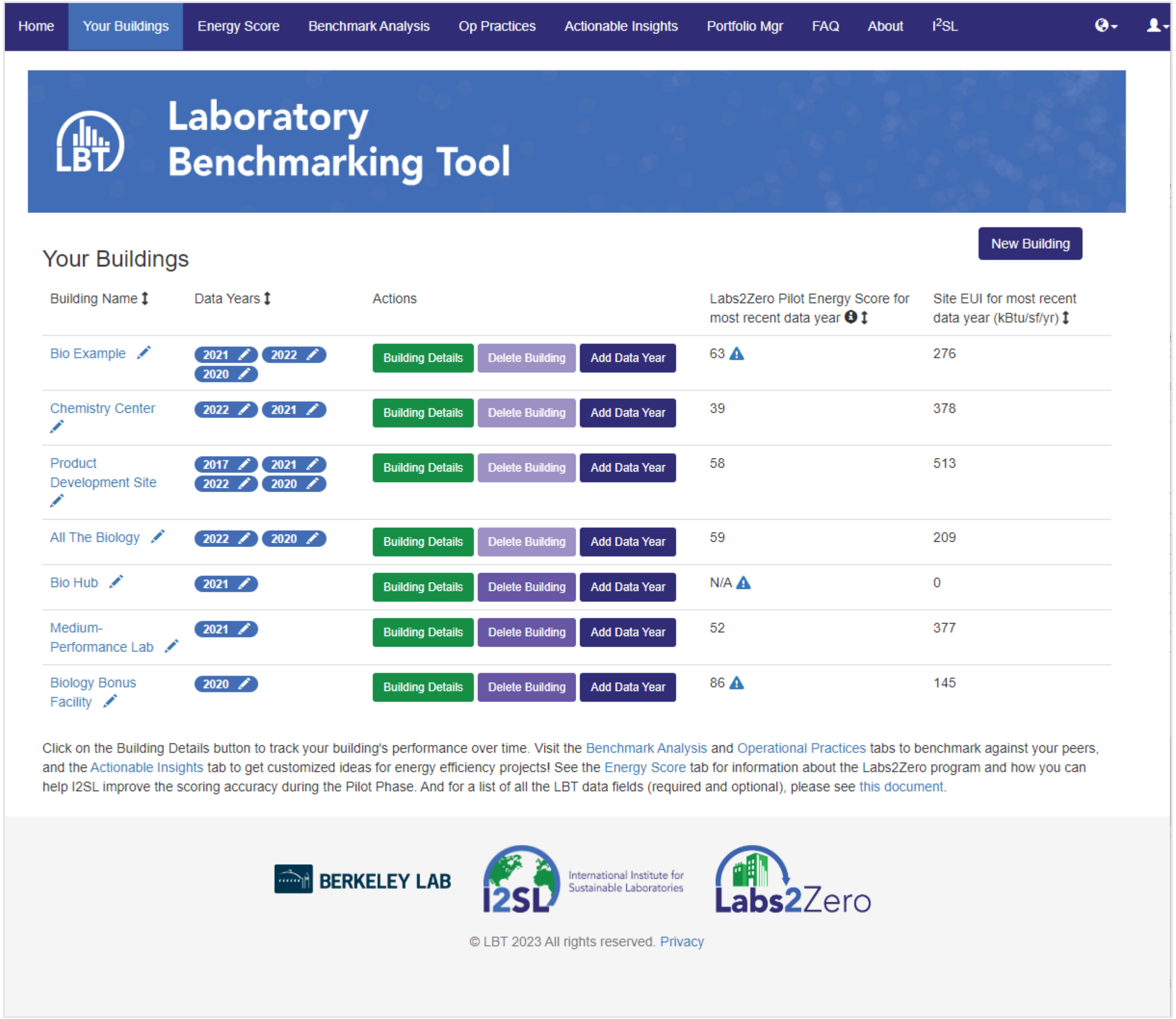
- **Now displayed for all buildings**
  - Your scores are only visible to you
  - Peer group building scores are shown; peer group buildings are anonymous



NEW: Pilot Energy Scores

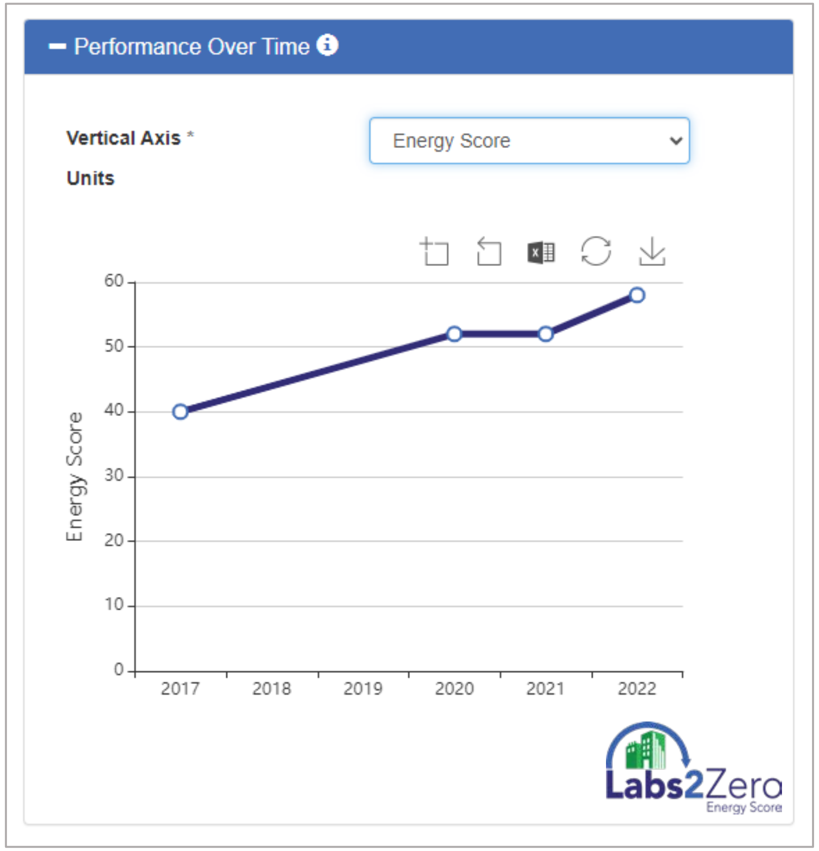
- See a summary of your buildings' scores in Your Buildings tab
- Click on Building Details to see more info on individual facilities

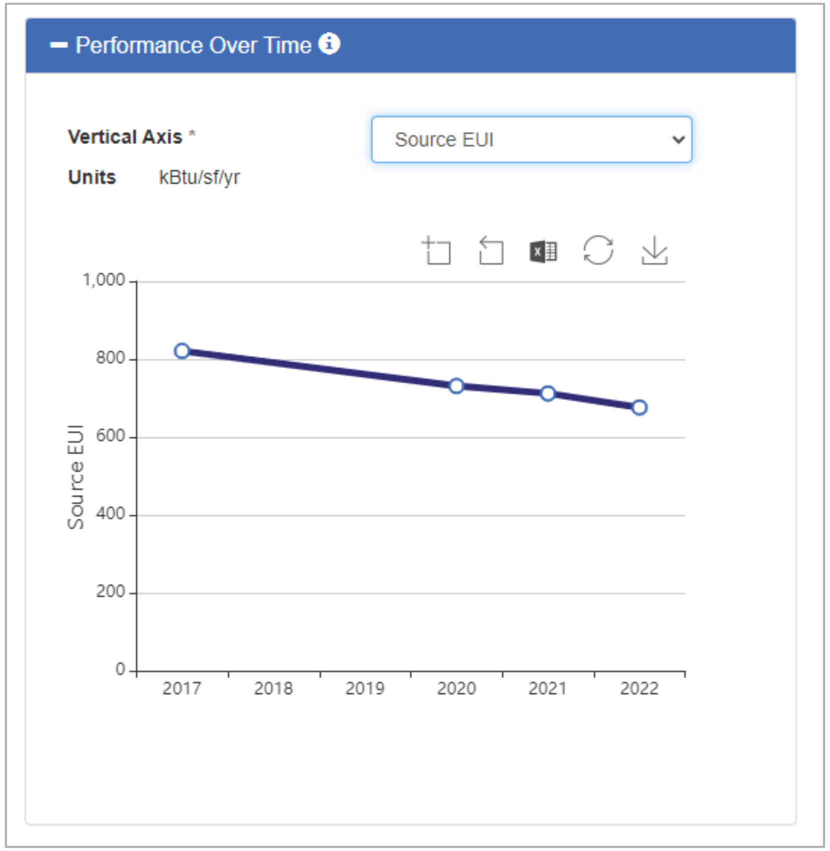




NEW: Longitudinal Benchmarking

- View building performance over time for many metrics
  - Only Energy Score is weather normalized





Development of the Energy Score

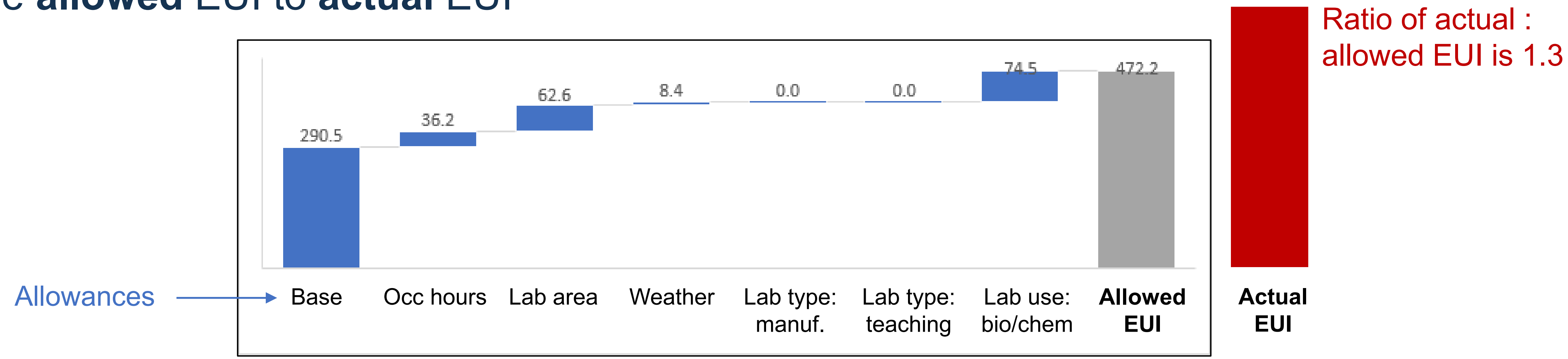
- The LBT peer group database of ~1000 buildings was used to develop the score
  - Statistical analysis used to develop a rating system
  - Buildings rated relative to others in the database by adjusting for functional requirements of each lab building
  - Similar to the method used by the EPA to generate ENERGY STAR® scores

Laboratory Benchmarking Tool

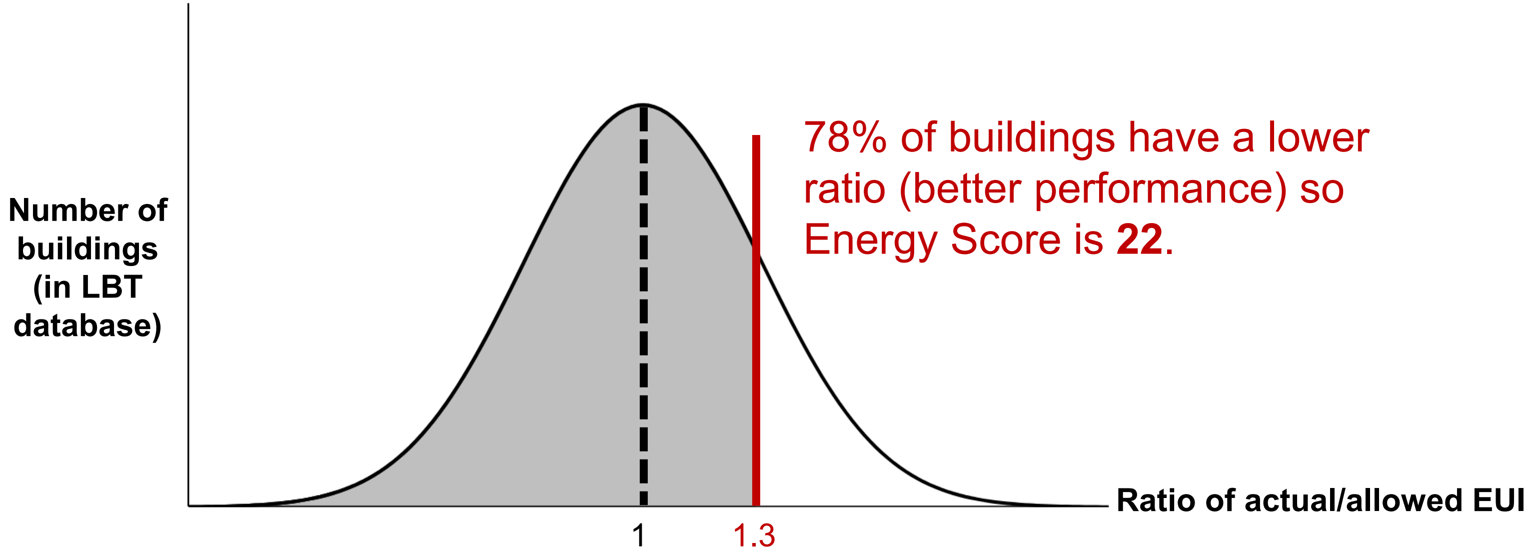
Scoring methodology was developed by **LBNL** in collaboration with the Labs2Zero Energy Score **Technical Advisory Council**

How The Energy Score Works

1. Compare **allowed** EUI to **actual** EUI



2. Convert ratio to a **1-100 score**



The Energy Score Pilot Phase

- **Pre-launch**
  - Piloted with ~8 organizations
  - Database-wide checks to look for bias
- **Post-launch pilot phase** October 2023 to mid-2024
  - Rev1 score will follow
- **Seeking feedback** from you on the Pilot Energy Score

Now is the best time to provide feedback:

1. Enter your data via the LBT (lbt.i2sl.org)
2. View your scores
3. Send us feedback at lbt@i2sl.org

Labs2Zero Energy Score

Pilot Phase: Caveats and Needs

- Warnings generated where we need more data or analysis:

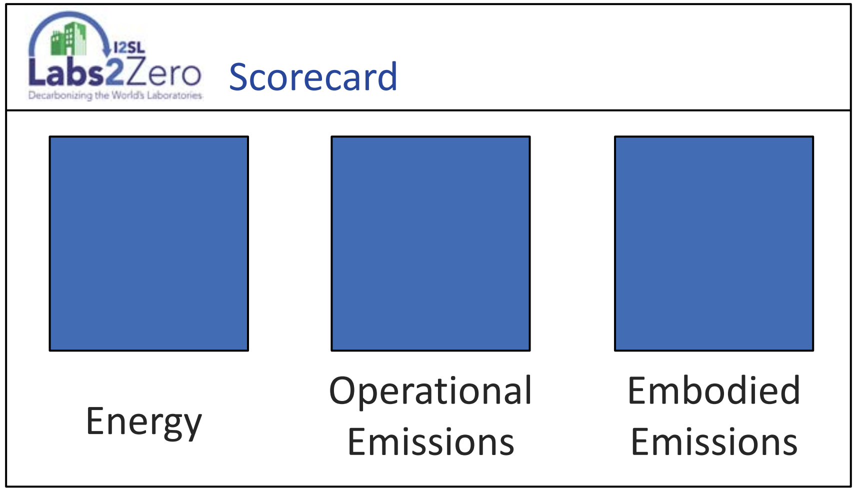
Warning Type	Building Properties	Action for Users
Unreliable Score (not enough data)	Vivarium, Maker/Workshop, Manufacturing, R&D: Process Development, Pilot Plant, Testing/QC, Crime Lab/Forensic, Healthcare labs.	Request to submit more data for these types of facilities so we can incorporate them in the Rev1 score.
Unreliable score (more analysis needed)	Low lab area, esp. for bio/chem facilities.	Use scores with caution; await updated analysis in Rev1.
Unreliable score (user input issues)	Lab types of Unknown or Other, very high or very low energy score, high % lab area, low occupancy hours/wk.	Check data entries and contact us with any feedback.
Unreliable score (historical issues)	Data year = 2020.	Use Covid-era scores with caution.

- More data known to be needed for some facility types:
  - **Vivarium, manufacturing, crime labs**
  - **Labs in very cold climates**

What's Next?

Questions?
Please contact
info@i2sl.org

- **Energy Score**
  - Data collection during pilot phase – your input is requested
  - Release rev1 score in 2024
- **Operational Emissions Score**
  - Aiming for pilot release in 2024
  - Location-based emissions only for pilot
- **Embodied Carbon Score**
  - Data collection effort is underway – please contribute if you have LCA data
  - Benchmarking tool and pilot score planned for 2024
- **AIM Report**
  - In development
  - Initial release planned for 2024



Plan: Key Takeaways

Gather available data on building system performance using Toolkit resources

Assemble a diverse Smart Labs team with management "buy in"

Define clear and measurable implementation goals

Produce a Smart Labs roadmap prior to conducting a building assessment and implementing any measures

15 Minute Break!

1

Smart Labs

Assess

SMART LABS TOOLKIT

Visit the Toolkit @ **SmartLabs.i2sl.org**

FEMP Federal Energy Management Program

The Smart Labs Process

Assess

- Conduct in-depth audits of laboratory buildings
- Focus on the ventilation systems
- Develop a scope of work for system optimization

Plan

- Build a team of lab stakeholders
- Profile buildings to prioritize efforts
- Develop a strategic plan for cost-effective implementation

Module Overview

- Conduct a laboratory ventilation risk assessment
  - Laboratory Ventilation Basics
  - Ventilation Best Practices
- Conduct an energy, water, and resilience assessment
  - Baseline Performance
  - Energy Security Plan
- Develop a Scope of Work
  - Improvement Measures
  - Economics of Measures

SMART LABS

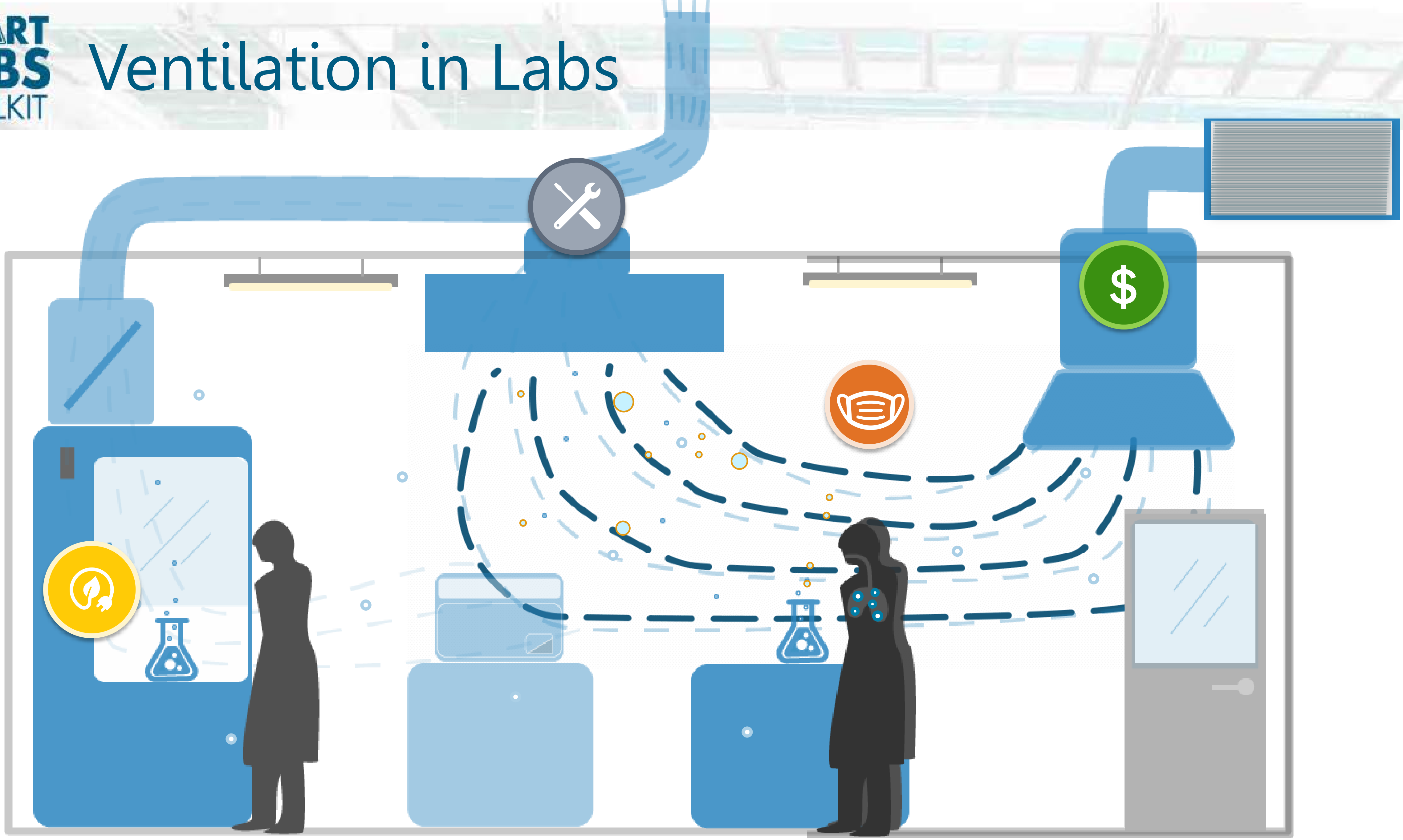
SmartLabs.i2sl.org

Assess

Conduct a Laboratory Ventilation Risk Assessment

FEMP
Federal Energy Management Program

Ventilation in Labs



Ventilation in Labs

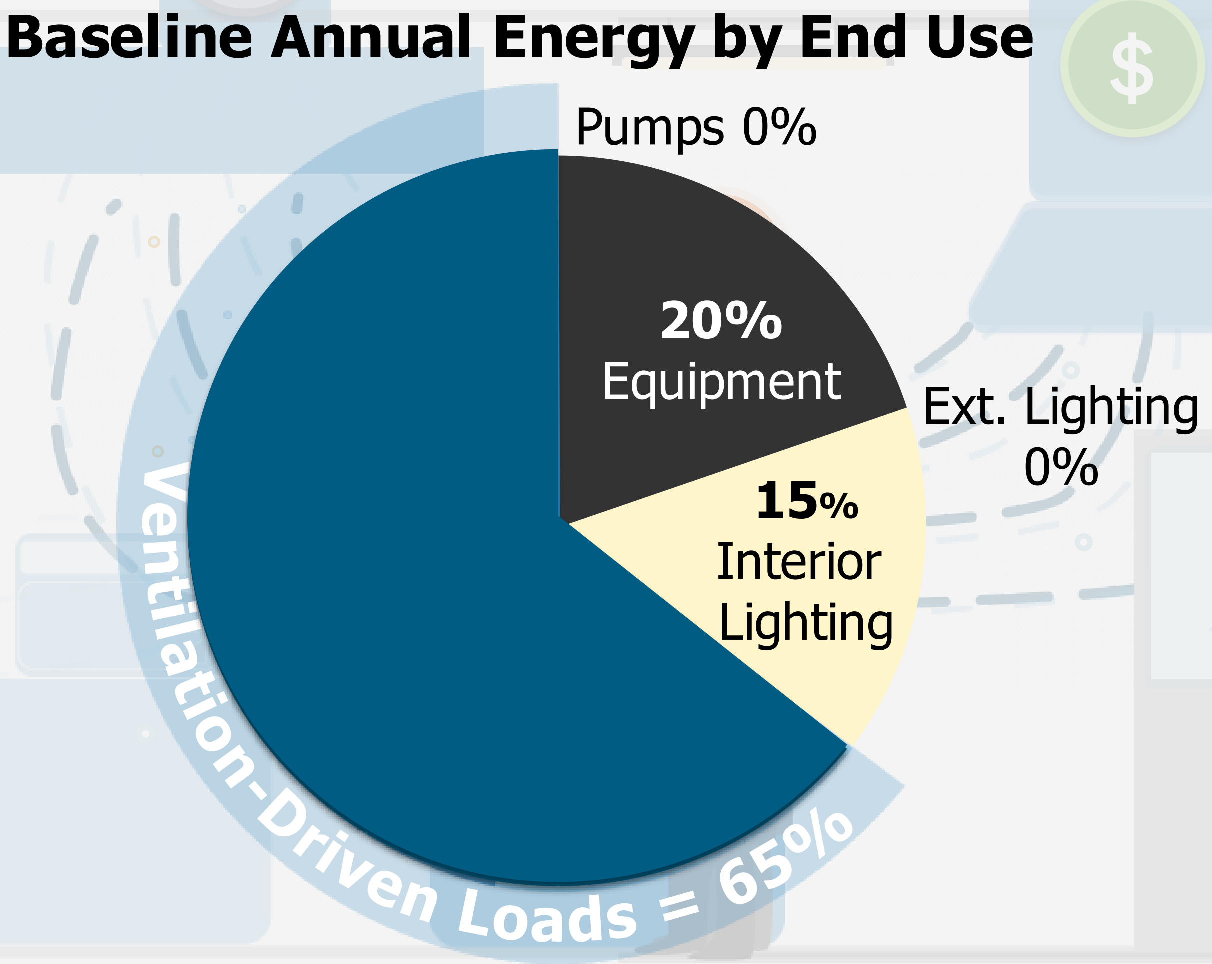
SMART LABS TOOLKIT

First line of defense in controlling airborne hazards

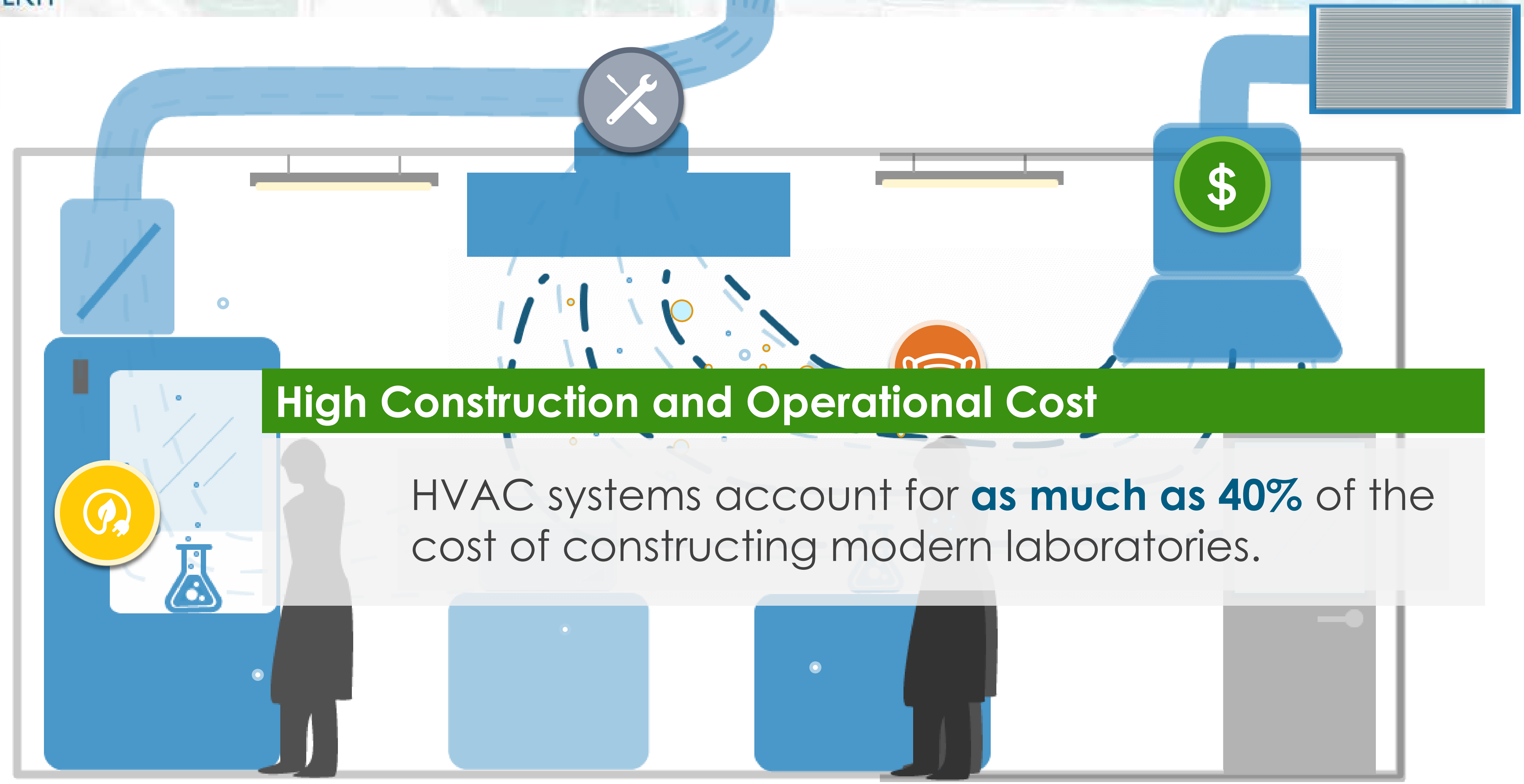
1. **Safety** is the number one priority
- **Question** everything
- **Avoid** assumptions

Ventilation in Labs

Largest energy consumer in a laboratory



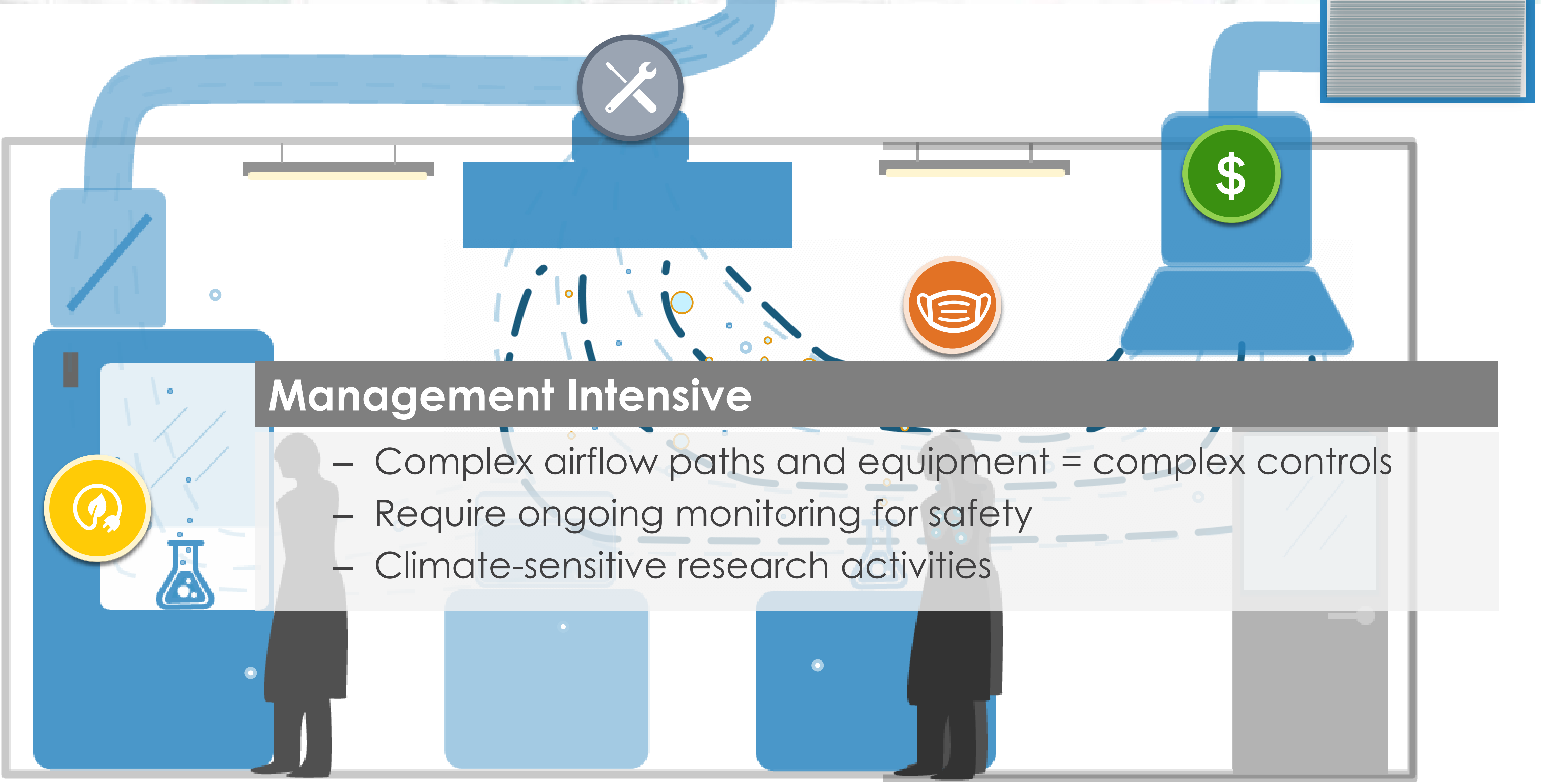
Ventilation in Labs



High Construction and Operational Cost

HVAC systems account for **as much as 40%** of the cost of constructing modern laboratories.

Ventilation in Labs



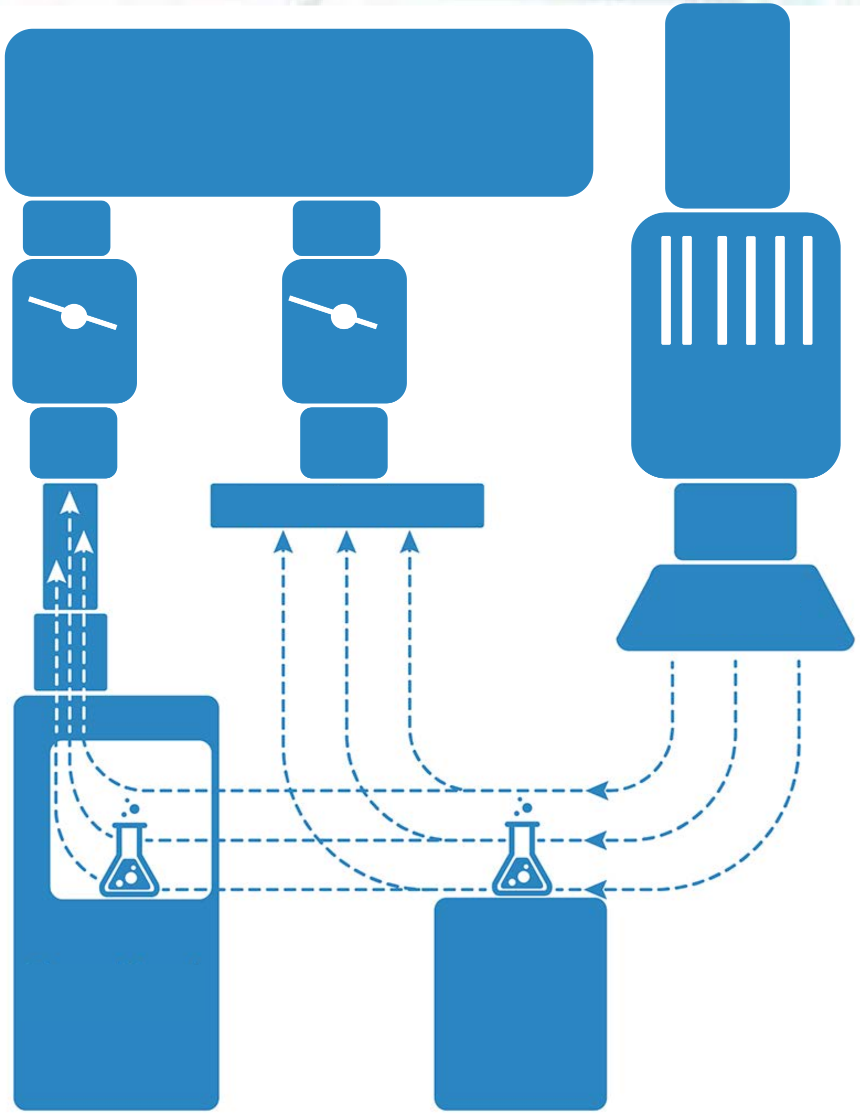
Management Intensive

- Complex airflow paths and equipment = complex controls
- Require ongoing monitoring for safety
- Climate-sensitive research activities

Laboratory Ventilation Basics

Gather available system data

1. Understand Design Specifications



Laboratory Ventilation Basics

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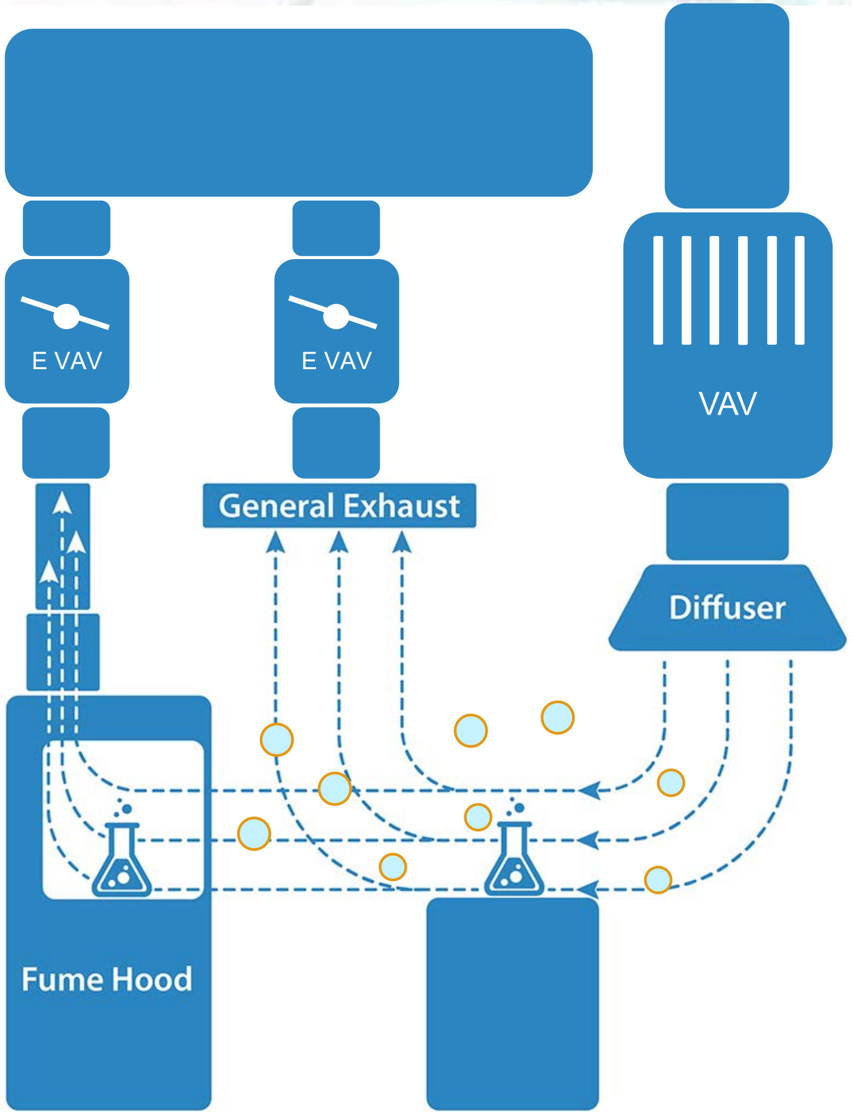


Ventilation Design Specifications

SMART LABS TOOLKIT

Gather available system data

1. Understand Design Specifications

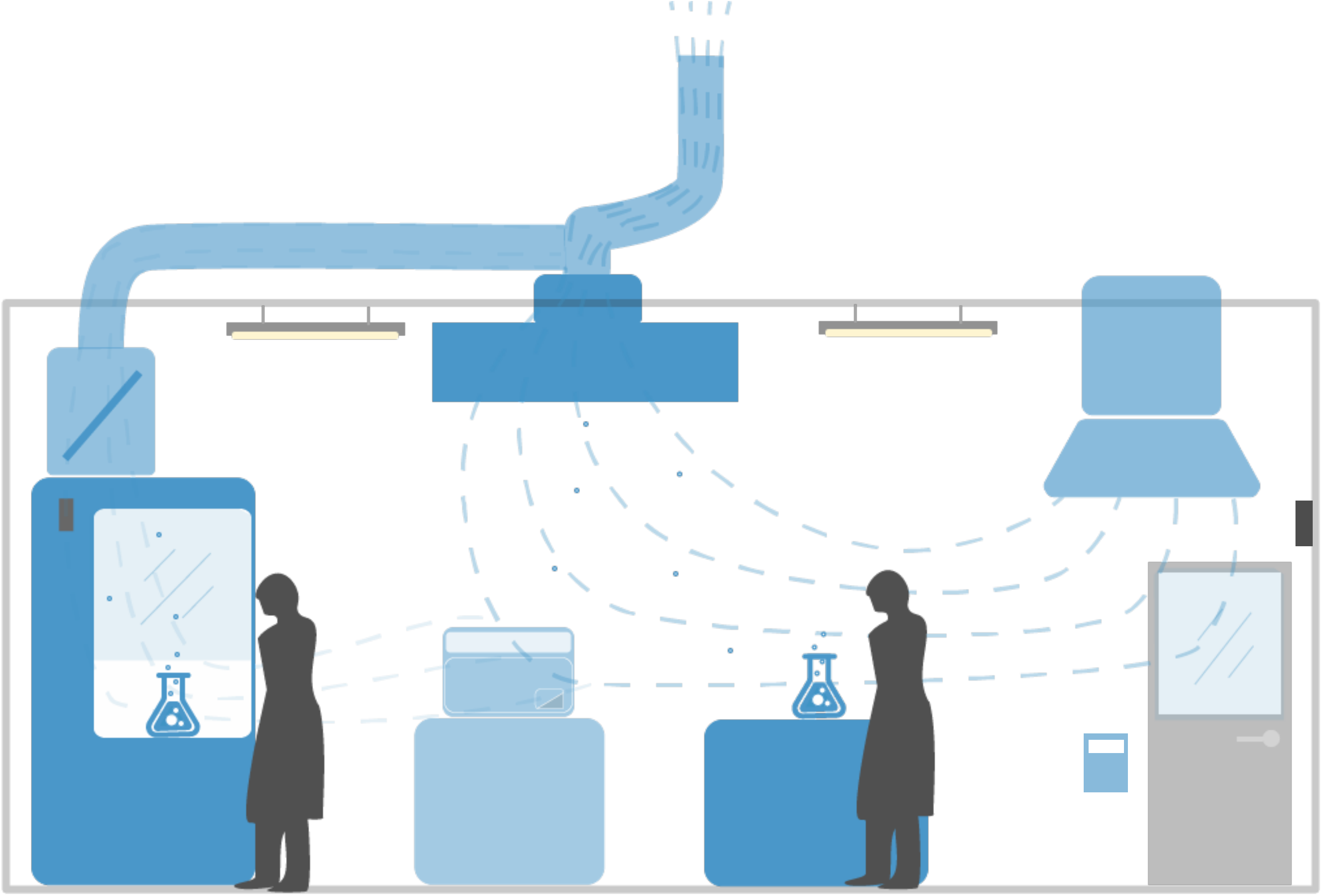


Photo Credit: Amanda Kirkeby | NREL

Typical Office Air Changes per Hour

2-3 ACH

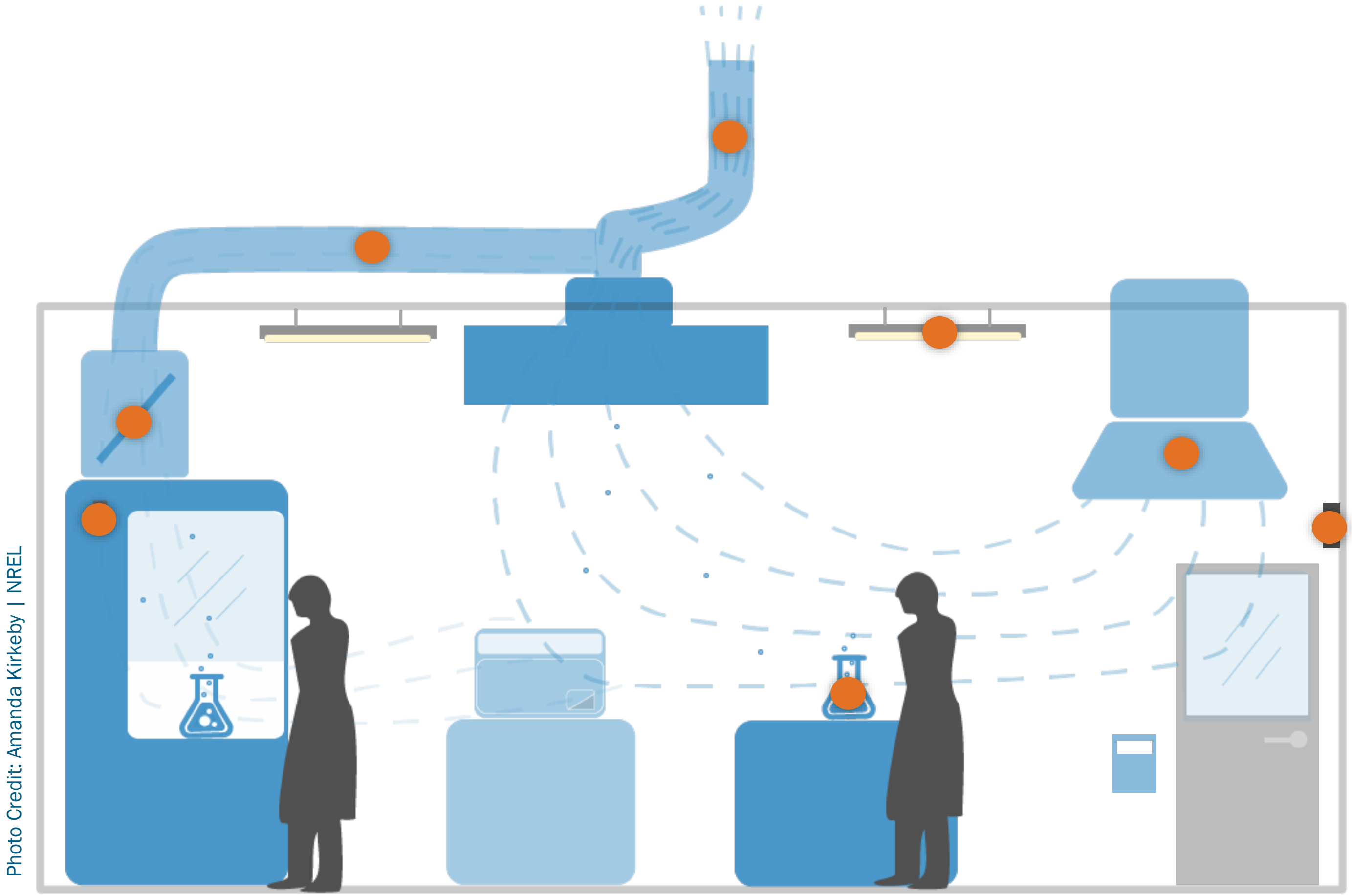
Airflow Requirements

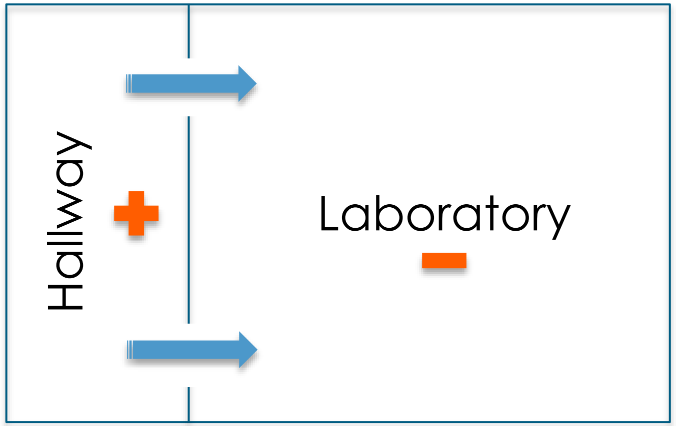
- ✓ Occupant safety and comfort
- ✓ Meet of required differential pressure between adjacent spaces

Ventilation Design Specifications

Gather available system data

1. Understand Design Specifications





Airflow Requirements

- ✓ Occupant safety and comfort
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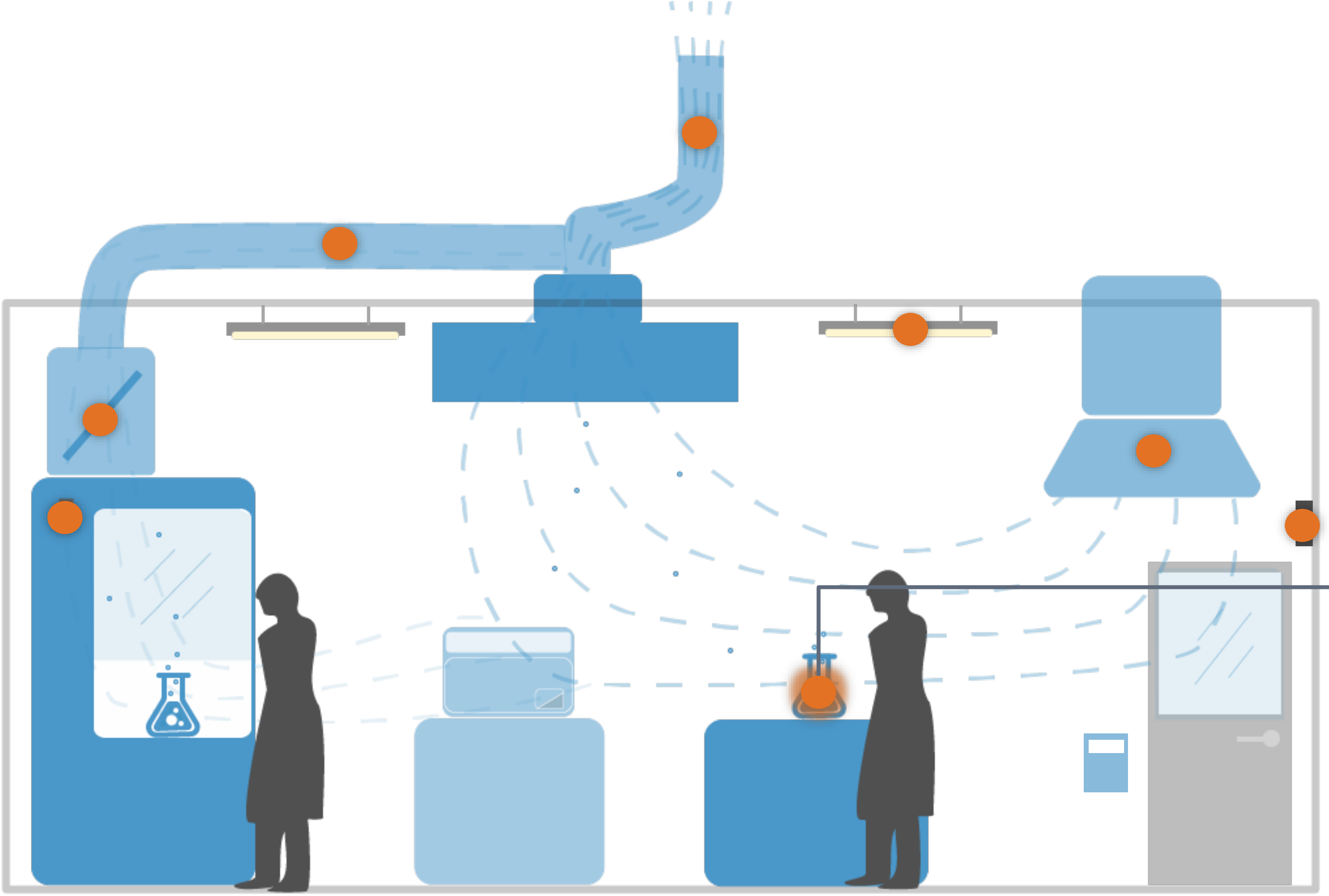


Photo Credit: Amanda Kirkeby | NREL

NREL 03350

LBNL XBD202003-00075

Hazard Evaluation

A systematic process for **determining the level of risk associated with airborne hazards** that can be mitigated through use of ventilation.

Ventilation Design Specifications

Gather available system data

1. Understand Design Specifications

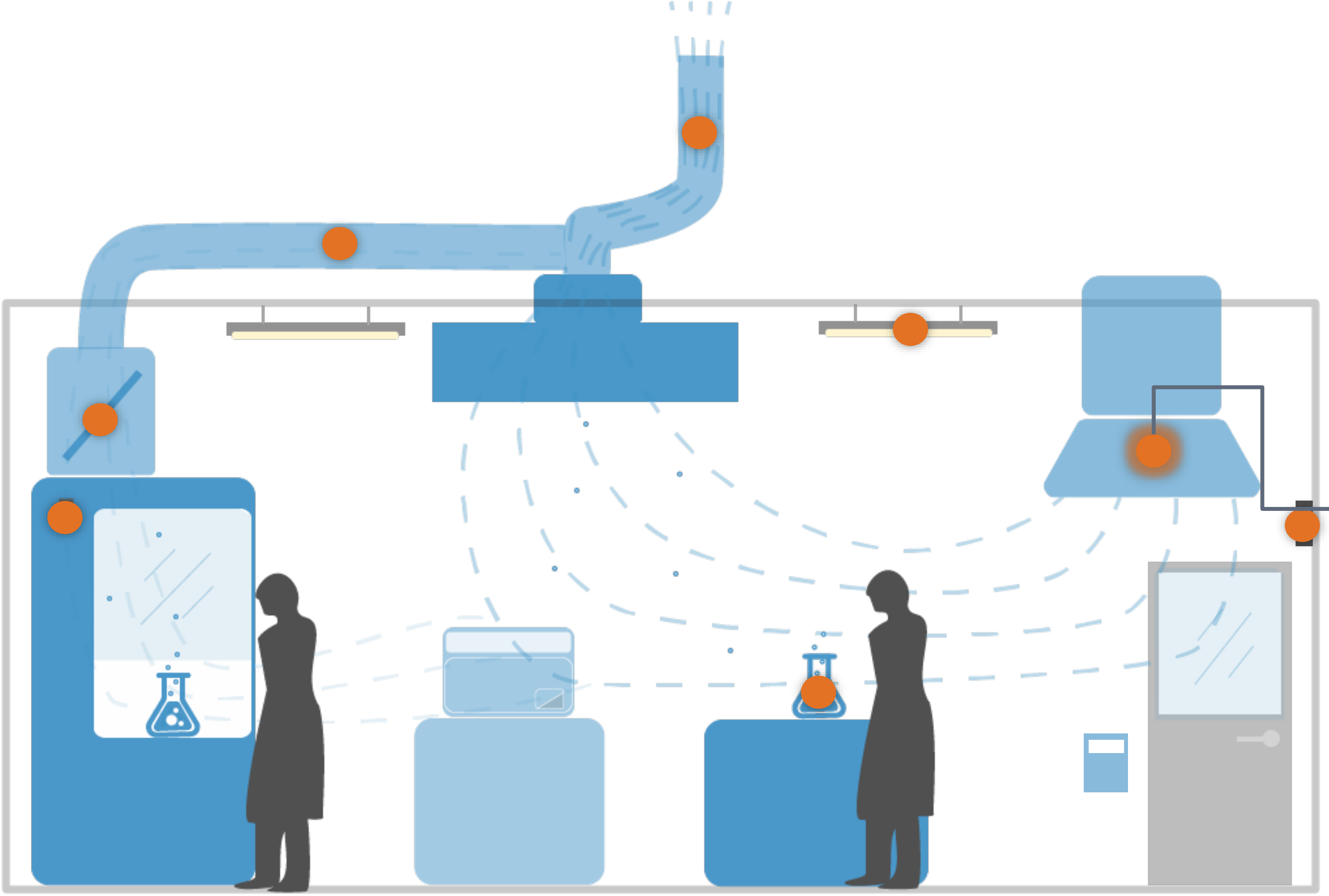
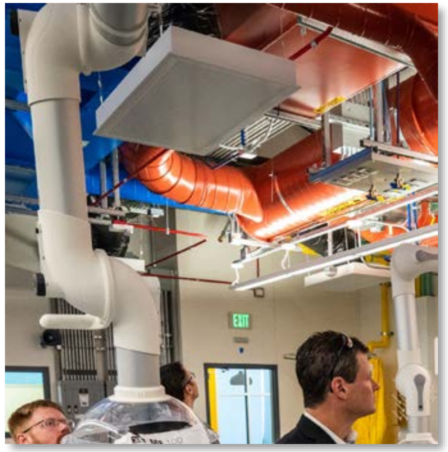


Photo Credit: Amanda Kirkeby | NREL

NREL 75735



NREL 12354

Ventilation System Layout

An **informed ventilation design** should consider the:

- ✓ Type
- ✓ Placement
- ✓ Quantity of ventilation devices.

Ventilation Design Specifications

Gather available system data

1. Understand Design Specifications

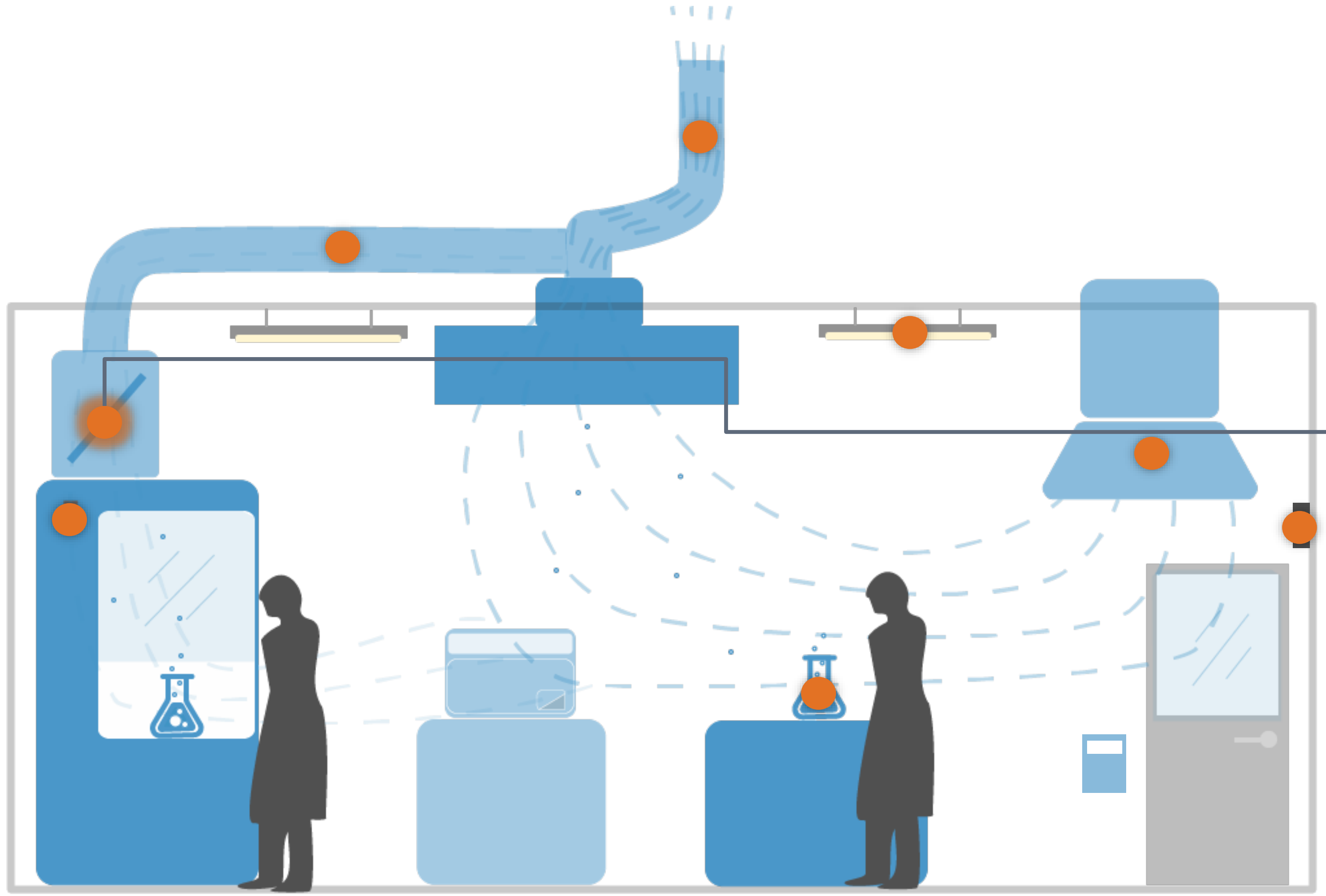


Photo Credit: Amanda Kirkeby | NREL

NREL 10988

NREL 10985

NREL 19320

Air Volume Controls

Variable (VAV)	Constant (CAV)
Comprised of **sensors, actuators, and flow dampers** to modulate flow.	Provide a **constant flow of air** to satisfy the maximum demand.

Ventilation Design Specifications

Gather available system data

1. Understand Design Specifications

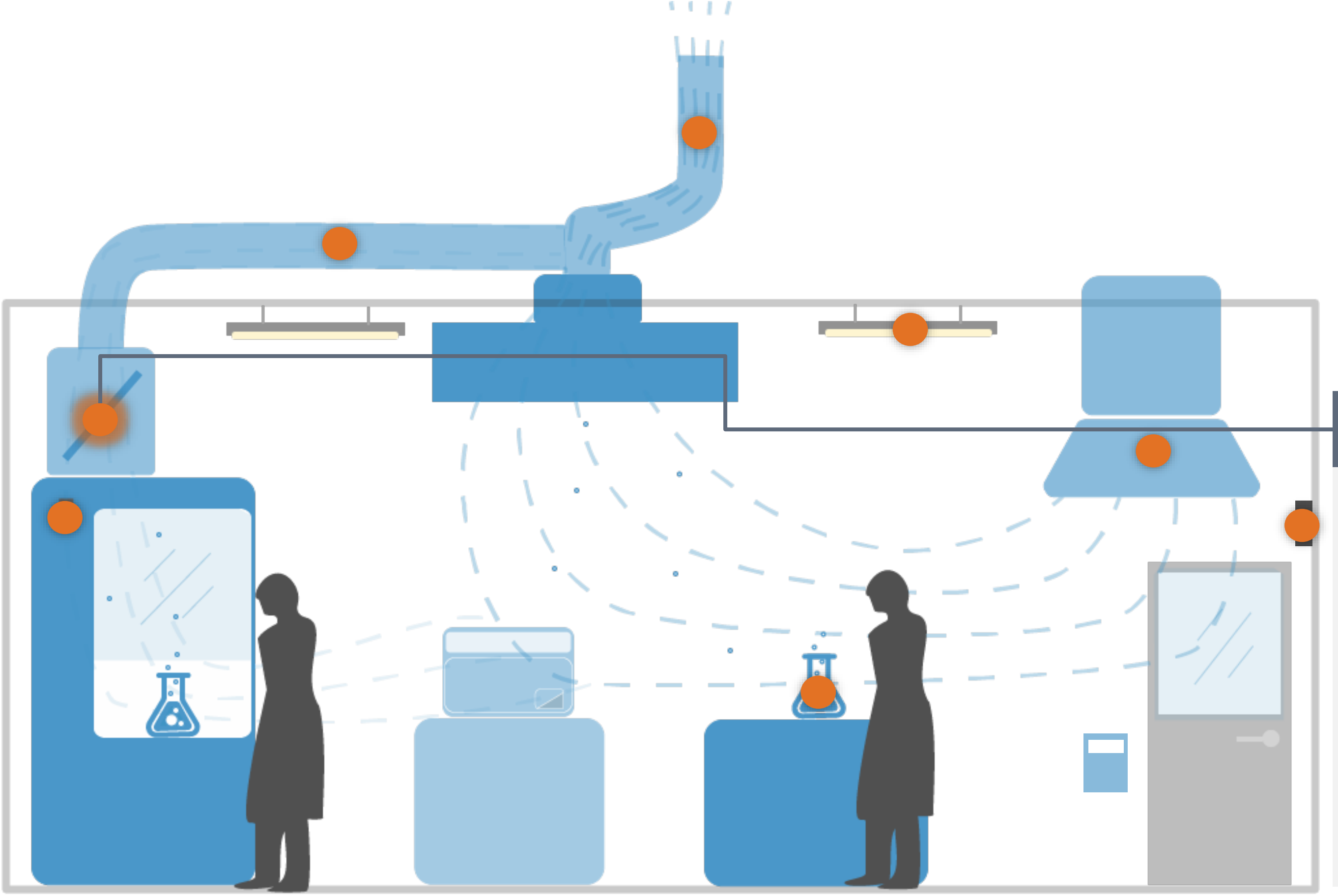


Photo Credit: Amanda Kirkeby | NREL


NREL 10988
NREL 10985
NREL 19320

Air Volume Controls	
Variable (VAV)	Constant (CAV)

Ventilation Design Specifications

Gather available system data

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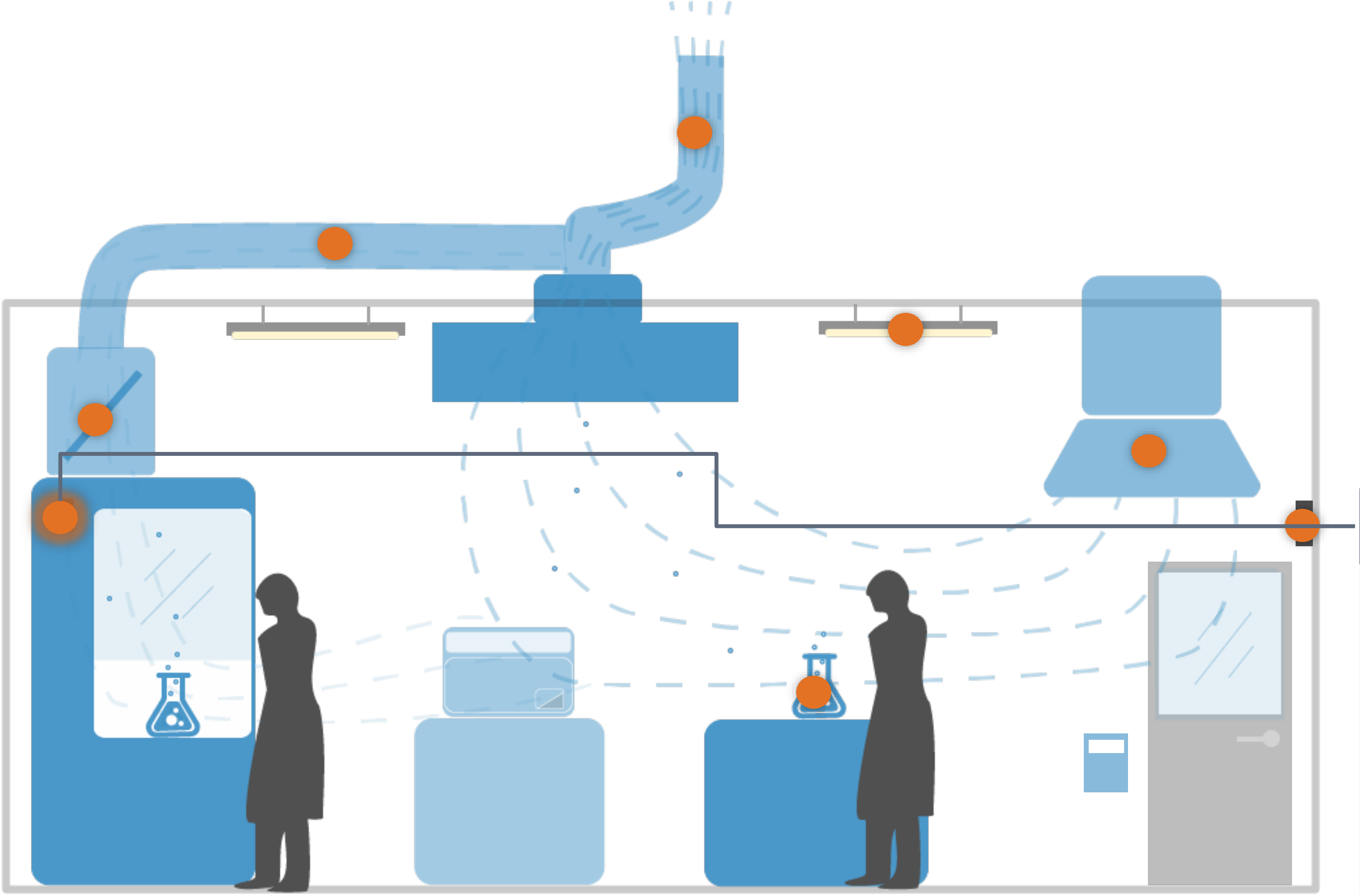


Photo Credit: Amanda Kirkeby | NREL

NREL 15436

NREL 70142

Exposure Control Devices

Assist with the **source capture of contaminants**.

✓ Decrease reliance on room dilution ventilation

Document the **which** and **where**?

Ventilation Codes and Standards

Gather available system data

1. Understand Design Specifications

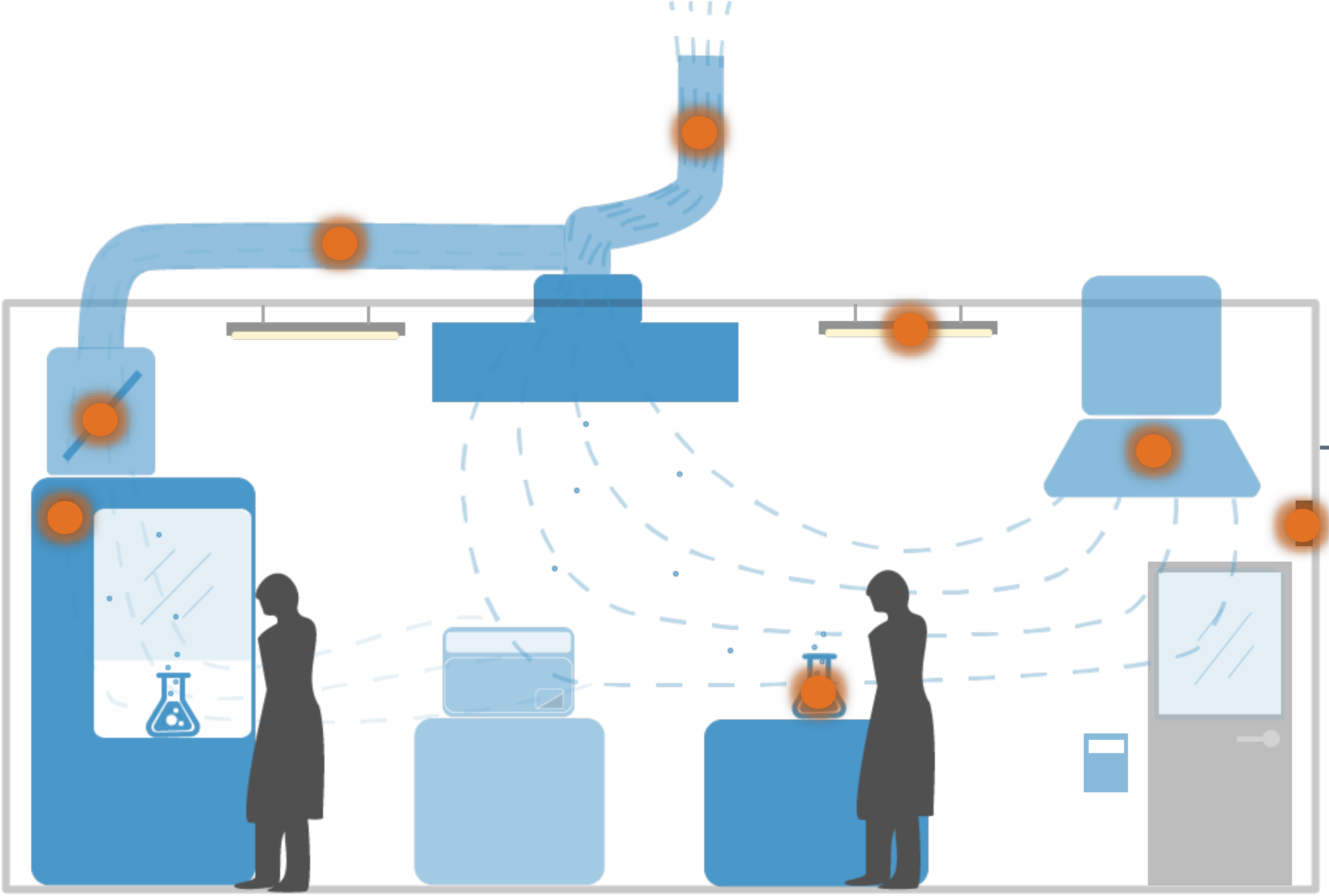


Photo Credit: Amanda Kirkeby | NREL

Pattern of airflow

↑ ACH

System Design and Operating Requirements

Must comply with mandatory provisions set by **related codes and standards**.

✓ Waivers granted for quantitative testing.

Laboratory Ventilation Risk Assessment

Establish a Baseline

1. Laboratory Ventilation Risk Assessment

Risk Level	Description
0	Negligible
1	Low
2	Moderate
3	High
4	Extreme

Laboratory Ventilation Risk Assessment (LVRA)

Method to provide ventilation designers and laboratory safety personnel with **a systematic, effective process to assess risk.**

Assessment Categories

✓ Type of hazards and procedures


NREL 36559

Laboratory Ventilation Risk Assessment

Establish a Baseline

1. Laboratory Ventilation Risk Assessment

Risk Level	Description
0	Negligible
1	Low
2	Moderate
3	High
4	Extreme

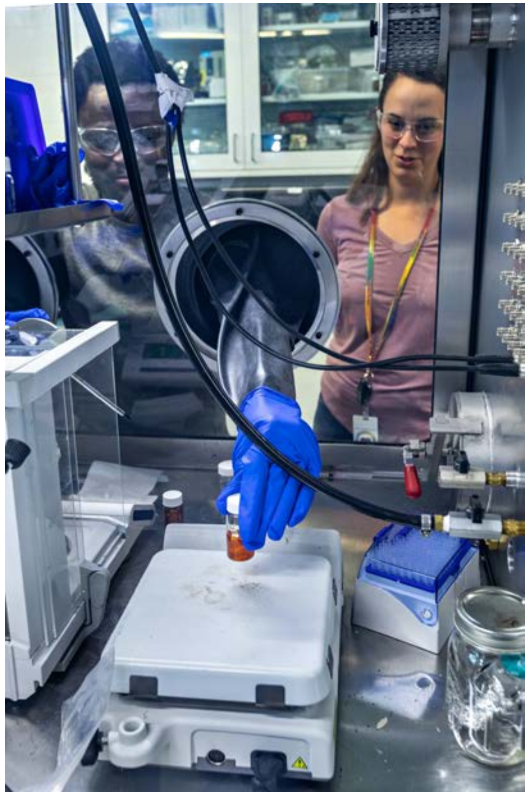
Laboratory Ventilation Risk Assessment (LVRA)

Method to provide ventilation designers and laboratory safety personnel with **a systematic, effective process to assess risk.**

Assessment Categories

- ✓ Type of hazards and procedures
- ✓ Generation characteristics of each hazard
- ✓ Quantity of materials used or generated
- ✓ Frequency and duration of hazard generation
- ✓ Containment by exposure control devices

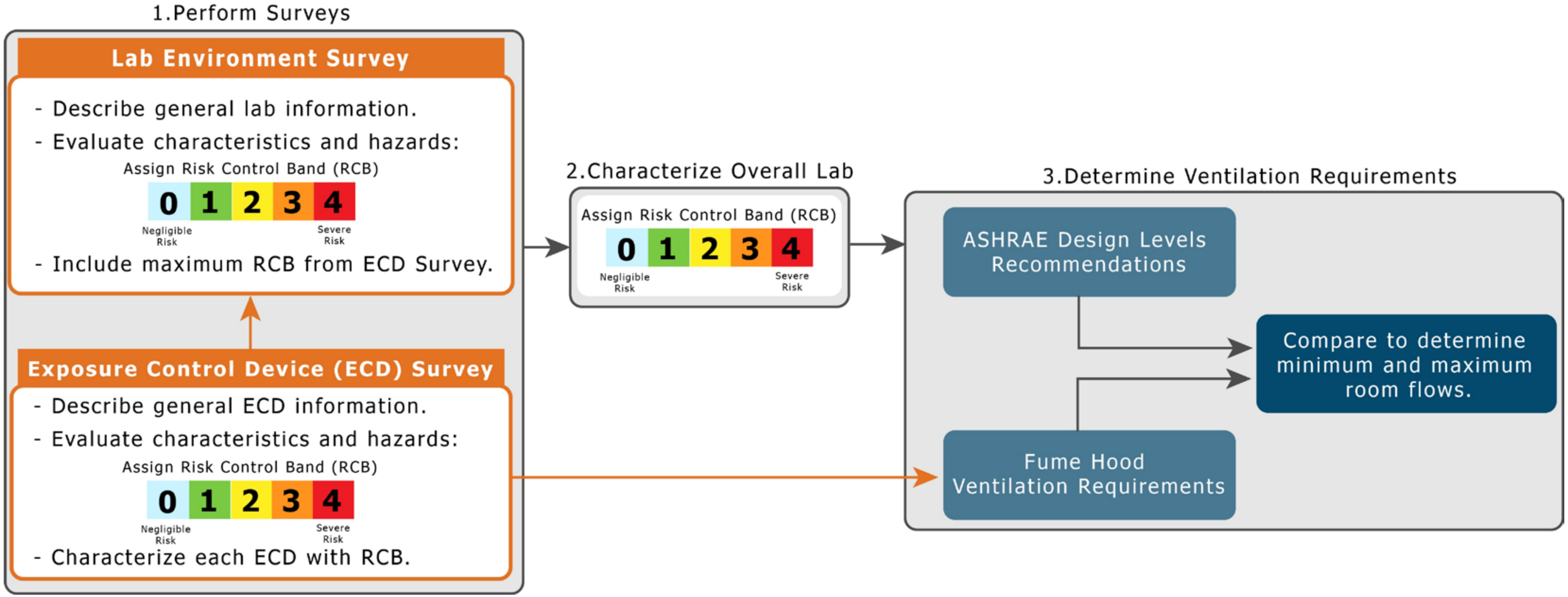
NREL 70139



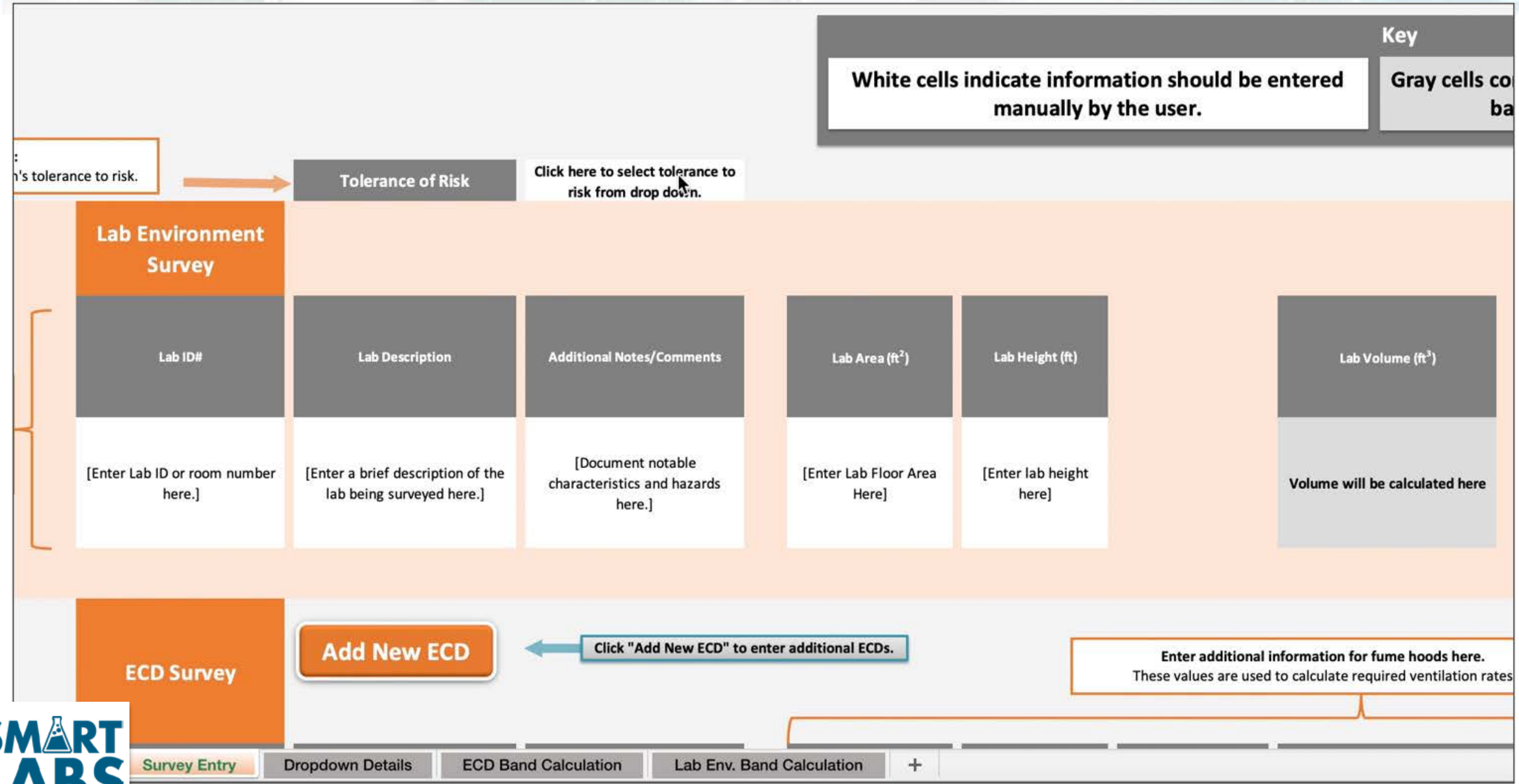
Laboratory Ventilation Risk Assessment

Establish a Baseline

1. Laboratory Ventilation Risk Assessment



Laboratory Ventilation Risk Assessment Tool



Laboratory Ventilation Risk Assessment Tool

Facility and Research Staff

Environmental Health & Safety Professionals

Industrial Hygienists

Each lab facility has its own unique hazards…

…use the LVRA Tool as a framework to get in the right direction.

Smart Lab Tips for Success

Identify Improvement Measures

Develop a Scope of Work

Tips for Success

Start with an almost-Smart Lab.

Customize to your organization's processes.

Develop a plan for recurring LVRAs.

SMART LABS TOOLKIT

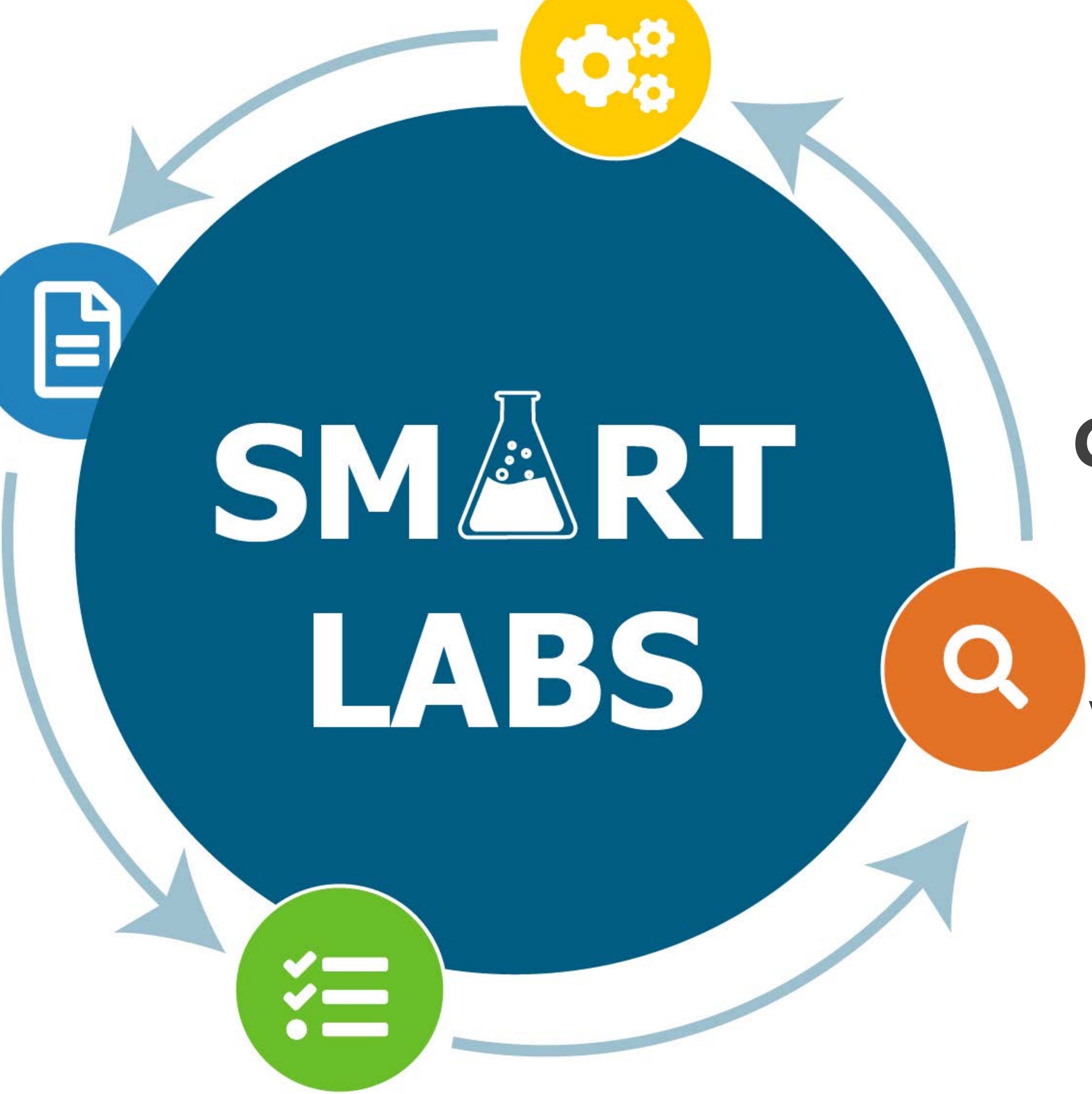
Assess Key Takeaways

Ventilation best practices in laboratories are critical to reducing exposure to hazards

Conducting a ventilation risk assessment is a vital step to ensuring staff safety

Determine the right amount of ventilation includes many considerations

Ventilation performance testing will determine current airflows and improvements for peak performance



Choose Your Own Adventure

Complete the Laboratory Ventilation Risk Assessment (LVRA)

Setting the Stage

Join Suzy, Energy Manager, and Phil, Industrial Hygienist, for a LVRA!

Note: This is a simplified example of an LVRA; there are more inputs into this analysis than reflected here.

Phil has completed the ECD Survey. He reports:

- ✓ The organization has a **medium** risk tolerance
- ✓ The **maximum RCB** for an exposure control device was 3 - moderate
- ✓ The exposure control devices (ECDs) are **appropriate** for the lab
- ✓ There are enough ECDs **available** in the lab.

Let's go!

Where would you like to go?

Chemistry Building

- Aging infrastructure
- Currently running at 8 ACH all the time
- 1000 ft^2 lab with 10 ft tall ceilings

Photo Credit: Rachel Romero, NREL

Life Sciences Building

- Brand new equipment and digital controls
- Currently running at 8 ACH all the time
- 1000 ft^2 lab with 10 ft tall ceilings

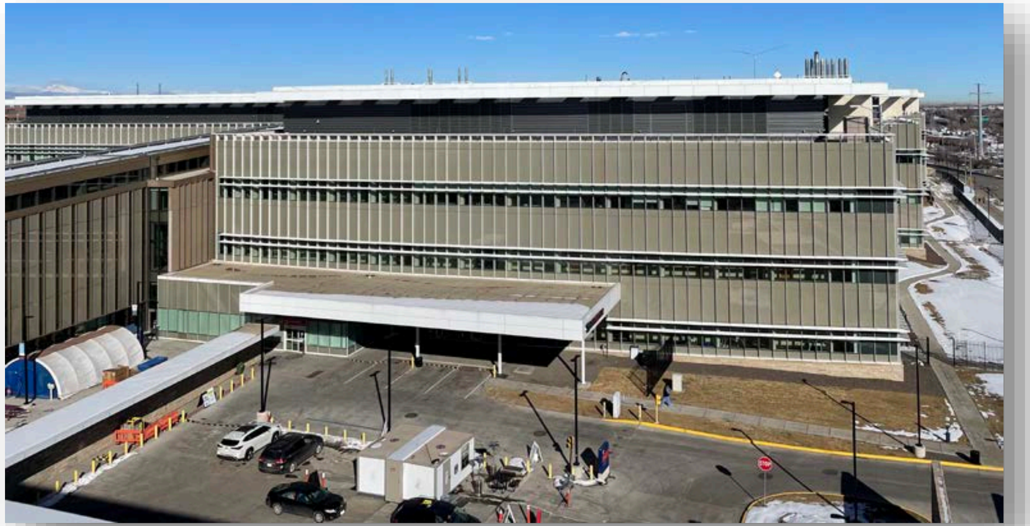


Photo Credit: Rachel Romero, NREL

Enter the Chemistry Lab

Peak hazard on the bench is calcium chloride with an exposure limit of 600 ppm

Aggregate volume of all hazards stored in the lab (excluding the fume hoods) is 25 grams

Research in the lab changes about once a month

Researchers try to keep their lab in good condition, but many times it can get cluttered

How would you rate the risk level?

	Risk Level A	Risk Level B
Hazard Exposure	2 Moderate	0 Negligible
Quantity of Hazard	3 High	2 Moderate
Change and Housekeeping	0 Negligible	2 Moderate

Enter the Life Sciences Lab

Peak hazard on the bench is isopropyl alcohol with an exposure limit of 200 ppm

Aggregate volume of all hazards stored in the lab (excluding the fume hoods) is 12 liters

Research in the lab changes usually about once a year

Researchers keep the lab clean with only slight clutter

How would you rate the risk level?

	Risk Level A	Risk Level B
Hazard Exposure	2 Moderate	3 High
Quantity of Hazard	3 High	4 Extreme
Change and Housekeeping	1 Low	0 Negligible

Chemistry Lab with Calcium Chloride

Only a small number of small containers are seen in the workspace

The containers with calcium chloride are not located very close to an ECD

Researchers work with hazards on the benchtop manually and sometimes with a piece of equipment

Facility manager says the supply and exhaust have a 1.4 V^{EFF} (ventilation effectiveness) rating, considered moderately effective

How would you rate the risk level?

	Risk Level A	Risk Level B
Generation Potential	1 Low	3 High
Generation Location	3 High	2 Moderate
V^{EFF} & Generation Method	2 Moderate	1 Low

Chemistry Lab with Calcium Chloride

Only a small number of small containers are seen in the workspace

The containers with calcium chloride are not located very close to an ECD

Researchers work with hazards on the benchtop manually and sometimes with a piece of equipment

Facility manager says the supply and exhaust have a 1.4 V^{EFF} (ventilation effectiveness) rating, considered moderately effective

How would you rate the risk level?

	Risk Level A	Risk Level B
Generation Potential	1 Low	3 High
Generation Location	3 High	2 Moderate
V^{EFF} & Generation Method	2 Moderate	1 Low

Life Sciences Building with Isopropyl Alcohol

IPA has a low vapor pressure with a generation potential of 0.2 lpm

Most of the benchtop work with isopropyl alcohol is located very close to an ECD

Researchers manually work with hazards on the benchtop (no equipment)

Facility manager tells you the supply and exhaust have a V^{EFF} (ventilation effectiveness) rating of 1.2, considered effective

How would you rate the risk level?

	Risk Level A	Risk Level B
Generation Potential	2 Moderate	4 Extreme
Generation Location and Method	1 Low	2 Moderate
Ventilation Effectiveness	1 Low	0 Negligible

Life Sciences Building with Isopropyl Alcohol

IPA has a low vapor pressure with a generation potential of 0.2 lpm

Most of the benchtop work with isopropyl alcohol is located very close to an ECD

Researchers manually work with hazards on the benchtop (no equipment)

Facility manager tells you the supply and exhaust have a V^{EFF} (ventilation effectiveness) rating of 1.2, considered effective

How would you rate the risk level?

	Risk Level A	Risk Level B
Generation Potential	2 Moderate	4 Extreme
Generation Location and Method	1 Low	2 Moderate
Ventilation Effectiveness	1 Low	0 Negligible

SMART LABS TOOLKIT

Congratulations!!

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	39
Lab Environment RCB	1

Incorporate

Calculate

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

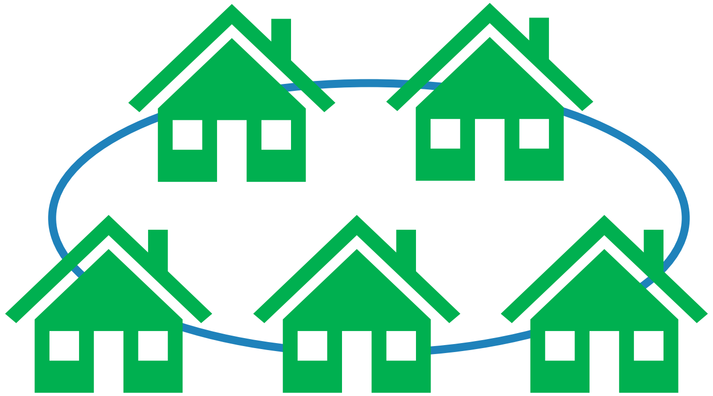
The lab's new air change rate is now:

4 ACH Occupied & 2 ACH Unoccupied

In just one lab, you avoided…

63% of Energy Costs

= $4,387 per year



What Now?

Return to Labs?

Managing Change?

Uh-oh! Mistake Made Somewhere

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	63
Lab Environment RCB	2

Incorporate

Calculate

The lab's new air change rate is now:

6 ACH Occupied & 3 ACH Unoccupied

Close! Not quite…

34% more energy than necessary =

Waste **$1,300 per year**

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

What Now?

Return to Labs?

Managing Change?

Uh-oh! Mistake Made Somewhere

Maximum RCB from ECD Survey	3

Incorporate

Total Weighted Risk Score	57

Calculate

Lab Environment RCB	2

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

The lab's new air change rate is now:

6 ACH Occupied & 3 ACH Unoccupied

Close! Not quite…

34% more energy than necessary = Waste **$1,300 per year**

What Now?

Return to Labs?

Managing Change?

Oof! Multiple Mistakes Made

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	81
Lab Environment RCB	3

Incorporate

Calculate

The lab's new air change rate is now:

8 ACH Occupied & 4 ACH Unoccupied

Close! Not quite…

50% more energy than necessary = Waste **$2,600 per year**

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

What Now?

Return to Labs?

Managing Change?

Congratulations!!

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	70
Lab Environment RCB	2

Incorporate

Calculate

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	**0-24**	**25-52**	**53-80**	**81-108**	**109-160**

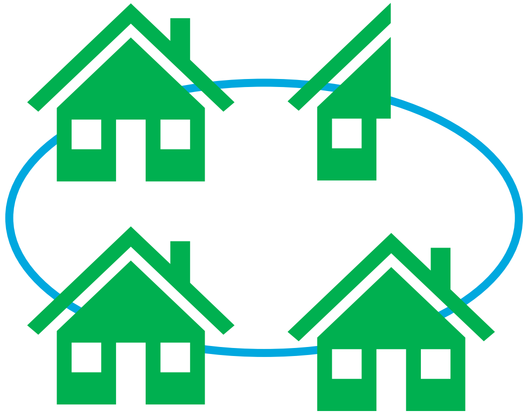
ASHRAE Classification of Laboratory Design Levels

The lab's new air change rate is now:

6 ACH Occupied & 3 ACH Unoccupied

In just one lab, you avoided…

44% of Energy Costs
= $3,071 per year



What Now?

Return to Labs?

Managing Change?

SMART LABS TOOLKIT

Uh-oh! Mistake Made Somewhere

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	83
Lab Environment RCB	3

Incorporate

Calculate

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

The lab's new air change rate is now:

8 ACH Occupied & 4 ACH Unoccupied

Close! Not quite…

25% more energy than necessary =

Waste **$1,300 per year**

What Now?

Return to Labs?

Managing Change?

Uh-oh! Mistake Made Somewhere

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	94
Lab Environment RCB	3

Incorporate

Calculate

The lab's new air change rate is now:

8 ACH Occupied & 4 ACH Unoccupied

Close! Not quite…

25% more energy than necessary = Waste **$1,300 per year**

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

What Now?

Return to Labs?

Managing Change?

Oof! Multiple Mistakes Made

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	107
Lab Environment RCB	3

Incorporate

Calculate

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

The lab's new air change rate is now:

8 ACH Occupied & 4 ACH Unoccupied

Close! Not quite…

25% more energy than necessary =

Waste **$1,300 per year**

What Now?

Return to Labs?

Managing Change?

Managing Change

A couple months go by when the researchers from the chemistry lab come back to you, Suzy, and Phil.

They want to use **dichloroethylene** in an upcoming experiment.

If everything else at the lab remains the same….

Assessment Categories	
Hazard Exposure	?
Quantity	2
Generation Rate or Potential	1
Generation Method	2
Generation Location	3
Change Dynamics	2
Housekeeping	2
Ventilation Effectiveness	2

How would you rate this new risk level?

	Risk Level A	Risk Level B
Hazard Exposure	2 Moderate	3 High

Managing Change

A couple months go by when the researchers from the life sciences lab come back to you, Suzy, and Phil.

They want to use **dichloroethylene** in an upcoming experiment.

If everything else at the lab remains the same….

Assessment Categories	
Hazard Exposure	?
Quantity	3
Generation Rate or Potential	2
Generation Method	1
Generation Location	1
Change Dynamics	1
Housekeeping	1
Ventilation Effectiveness	1

How would you rate this new risk level?

	Risk Level A	Risk Level B
Hazard Exposure	2 Moderate	3 High

Congratulations!!

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	81
Lab Environment RCB	3

Incorporate

Calculate

The lab's new air change rate is now:

8 ACH Occupied & 4 ACH Unoccupied

…since a level-3 carcinogen has been introduced to the lab.

Improved safety

Remember the weight

Evaluation Criteria	Weight Multiple
Hazard	14
Quantity	2
Potential or Rate of Generation	12

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

What Now?

Return to Labs?

Try Again?

Congratulations!!

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	84
Lab Environment RCB	3

Incorporate

Calculate

The lab's new air change rate is now:

8 ACH Occupied & 4 ACH Unoccupied

…since a level-3 carcinogen has been introduced to the lab.

Improved safety

Remember the weight

Evaluation Criteria	Weight Multiple
Hazard	14
Quantity	2
Potential or Rate of Generation	12

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

What Now? | Return to Labs? | Try Again?

Uh oh! Mistake Made

Maximum RCB from ECD Survey	3
Total Weighted Risk Score	70
Lab Environment RCB	2

Incorporate

Calculate

The lab's air change rate remains at:

6 ACH Occupied & 3 ACH Unoccupied

...even though a level-3 carcinogen has been introduced to the lab.

Remember the weight

❌ Less safety

Evaluation Criteria	Weight Multiple
Hazard	14
Quantity	2
Potential or Rate of Generation	12

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	**0-24**	**25-52**	**53-80**	**81-108**	**109-160**

ASHRAE Classification of Laboratory Design Levels

What Now? | Return to Labs? | Try Again?

Uh oh! Mistake Made

Maximum RCB from ECD Survey	3

Incorporate

Total Weighted Risk Score	67

Calculate

Lab Environment RCB	2

Risk Control Band	0	1	2	3	4
Occupied ACH Recommended	1.7	4	6	8	10
Unoccupied ACH Recommended	1.7	2	3	4	10
Tl. Weighted Risk Score	0-24	25-52	53-80	81-108	109-160

ASHRAE Classification of Laboratory Design Levels

The lab's new air change rate is now:

6 ACH Occupied & 3 ACH Unoccupied

…but a level-3 carcinogen has been introduced to the lab.

Remember the weight

Less safety

Evaluation Criteria	Weight Multiple
Hazard	14
Quantity	2
Potential or Rate of Generation	12

What Now?

Return to Labs?

Try Again?

Optimize – Coming Soon

Assess

Conduct an Energy, Water, and Resilience Assessment

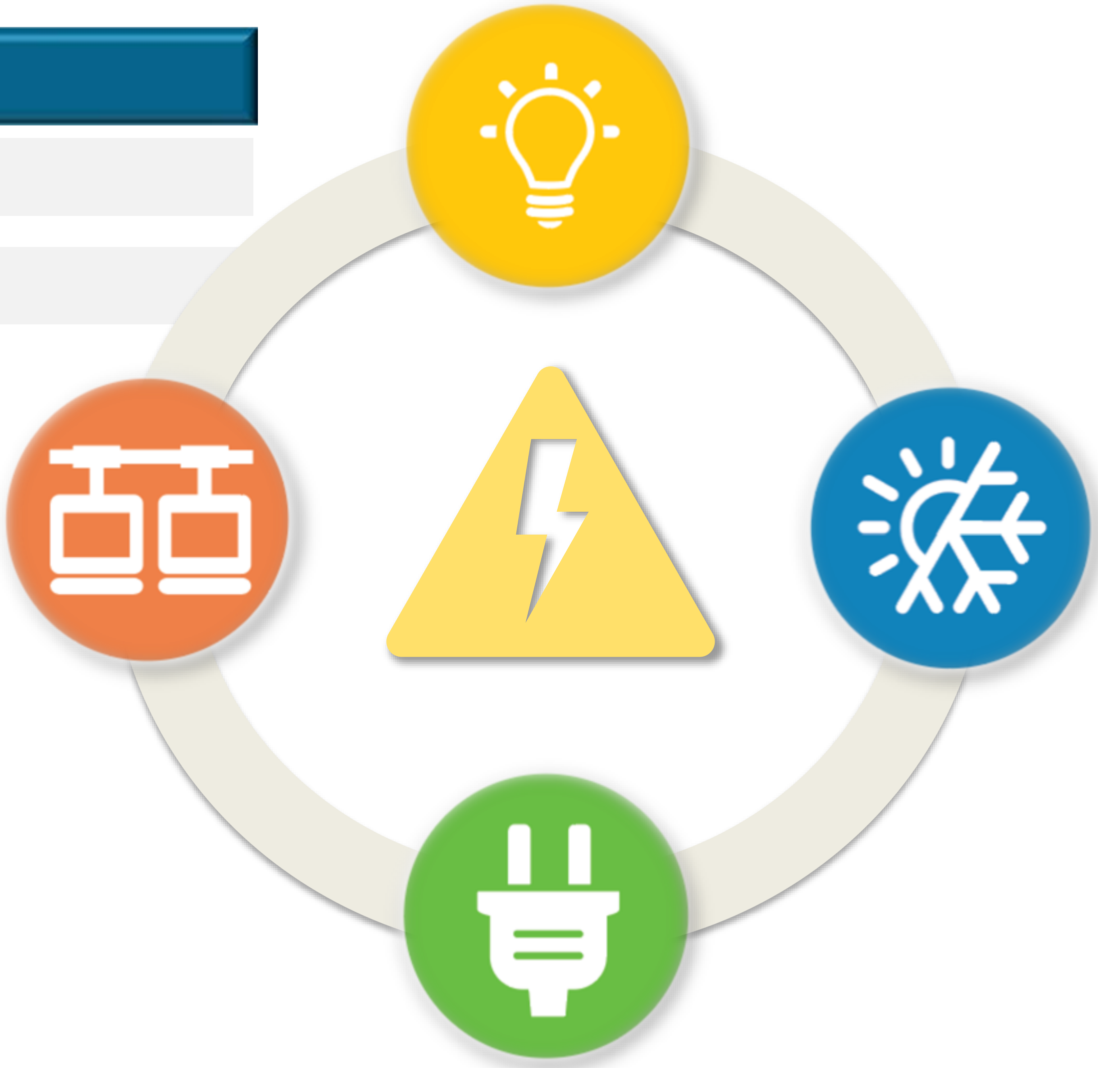
FEMP
Federal Energy Management Program

Execute an Energy Assessment

Gather available system data

1. Energy Consumption Data
2. Water Consumption Data

- HVAC systems
- Lighting
- Plug loads
- Controls



Execute an Energy Assessment

Gather available system data

1. Energy Consumption Data
2. Water Consumption Data

NREL 63094

HVAC systems

- ✓ Account for:
  - ✓ 45 – 85% of total energy use
  - ✓ 40% construction cost.

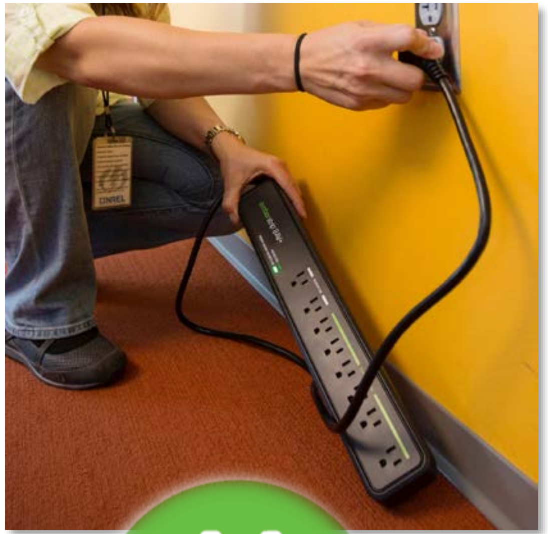
- ✓ Collect nameplate data
- ✓ Conduct a performance test
- ✓ Visually inspect for maintenance issues

Execute an Energy Assessment

Gather available system data

1. Energy Consumption Data
2. Water Consumption Data

NREL 27375



NREL 46053

Plug loads

Refers to any energy used by equipment that is plugged into an outlet.

✓ Which devices? ✓ How much?

- ✓ Water baths
- ✓ Ice machines
- ✓ Centrifuges
- ✓ Microscopes
- ✓ Computers
- ✓ …and more!

On average, a conventional ultra-low temperate (ULT) freezer uses 20 kWh of energy **per day**.

- ✓ Metering and utility bill data
- ✓ Data plate information
- ✓ Document the age of the equipment

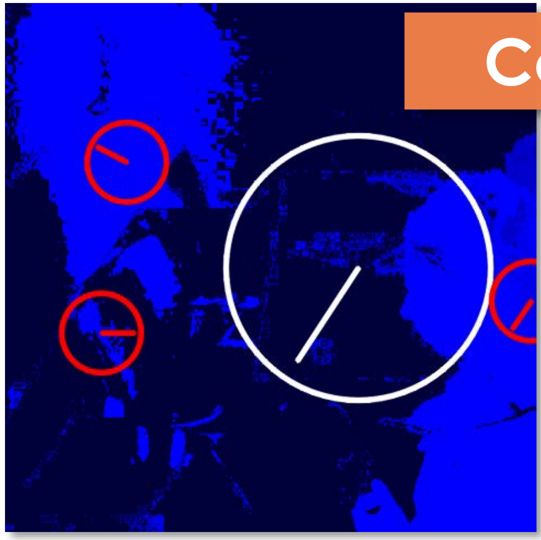
Execute an Energy Assessment

Gather available system data

1. Energy Consumption Data

2. Water Consumption Data

NREL 27415



NREL 500056

Controls

Devices that help laboratory facility managers monitor the building's current set of conditions.

Devices that are essential to a building automation system (BAS), so that the right energy is supplied at the right time.

Occupancy sensors:
- ✓ Fume hood velocity
- ✓ Lighting

Execute a Water Assessment

Gather available system data

1. Energy Consumption Data

2. Water Consumption Data

PNNL 2016

Dennis Schroeder / NREL

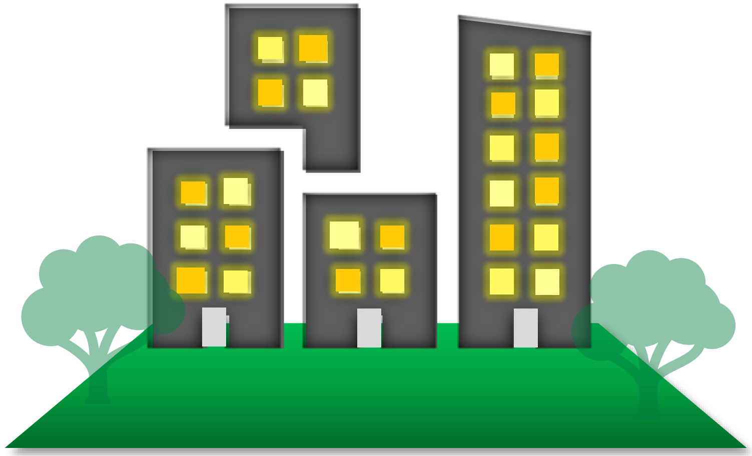
Identify water sources

- ✓ Larger cooling and process loads
- ✓ Operation of specialized equipment (autoclaves, glasswashers)

Execute a Resilience Assessment

Gather available system data

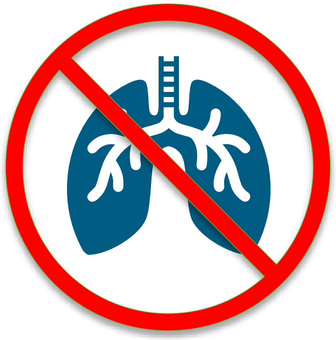
1. Vulnerability Assessment



Execute a Resilience Assessment

Gather available system data

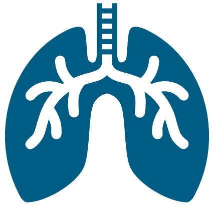
1. Vulnerability Assessment

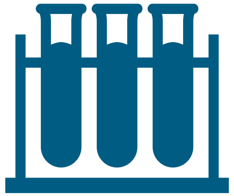


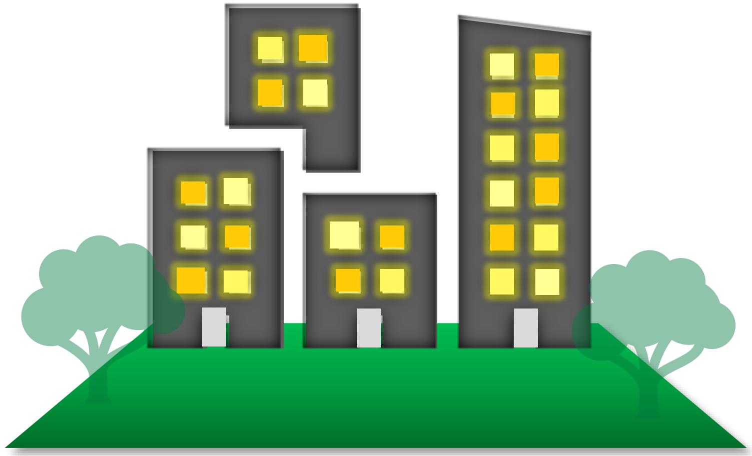
Execute a Resilience Assessment

Gather available system data

1. Vulnerability Assessment







Assess

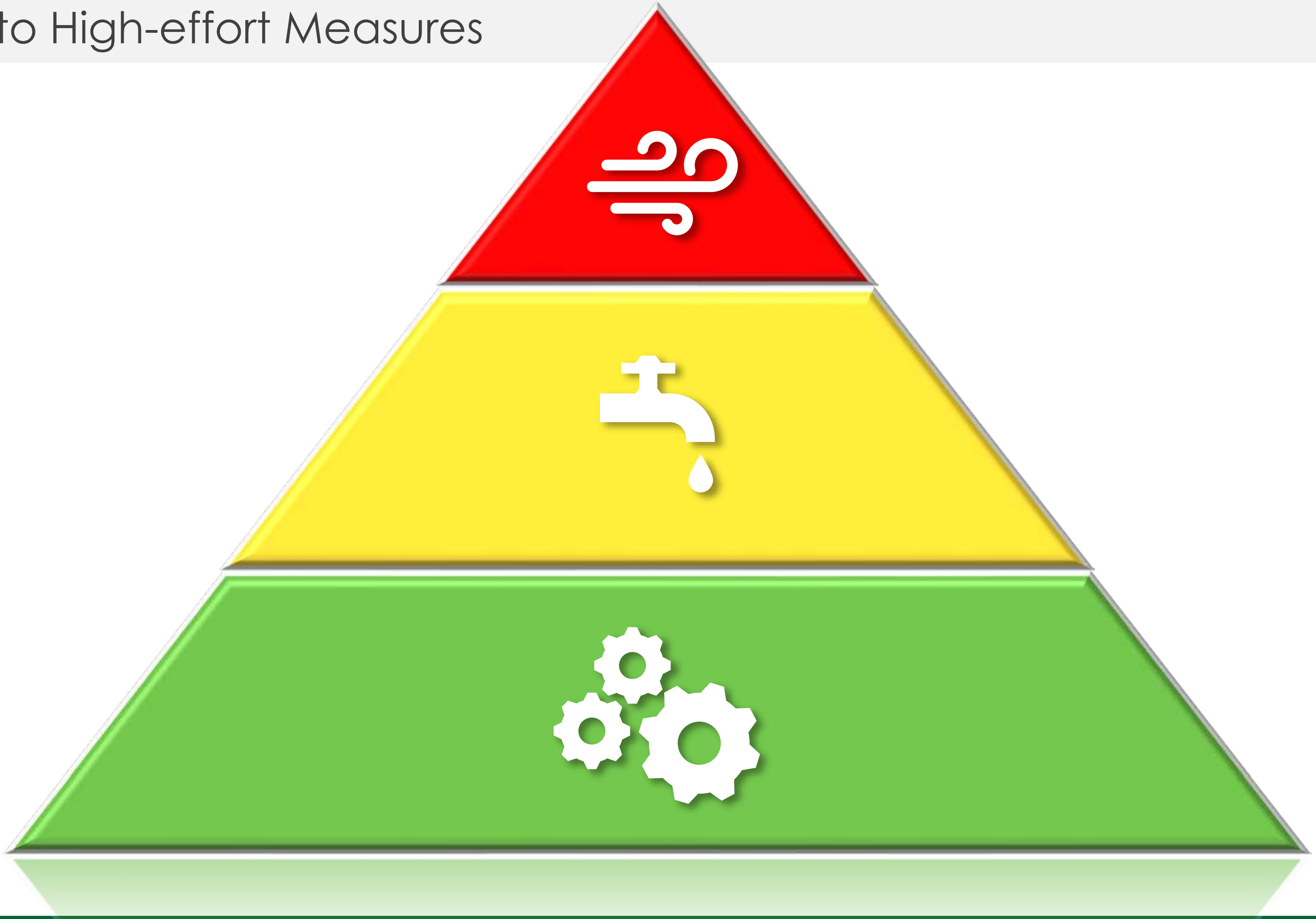
Develop a Scope of Work

FEMP
Federal Energy Management Program

Build Program Momentum

Identify Improvement Measures

1. Low-effort to High-effort Measures



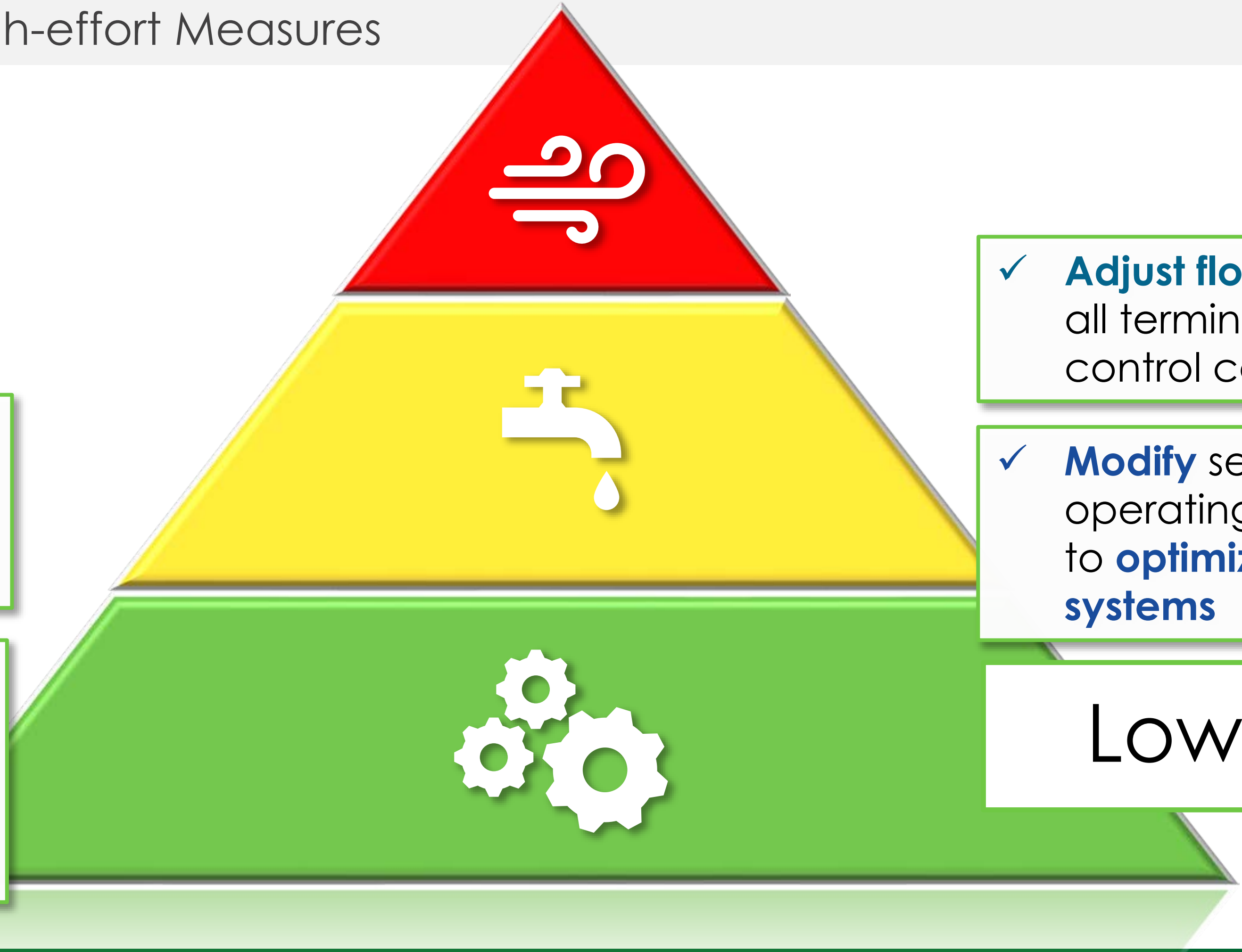
Build Program Momentum

Identify Improvement Measures

1. Low-effort to High-effort Measures

Colorado School of Mines

- ✓ **Calibrate** building automation system, airflow controls, and system sensors
- ✓ **Challenge** operation of systems, such as lab environment, exposure control devices, and fume hood controls



- ✓ **Adjust flow and calibrate** all terminals and flow control components
- ✓ **Modify** setpoints and operating specifications to **optimize HVAC systems**

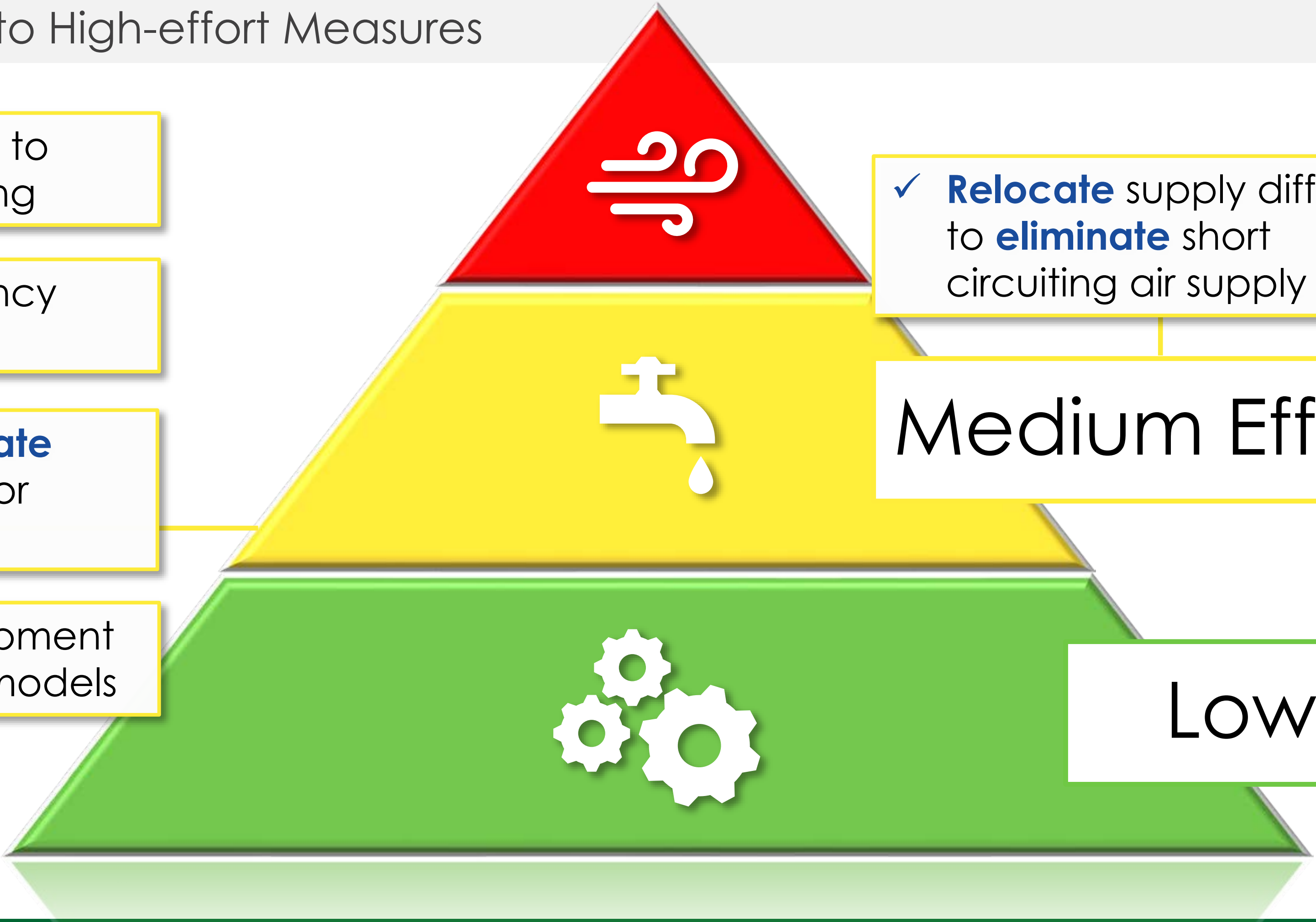
Low Effort

Build Program Momentum

Identify Improvement Measures

1. Low-effort to High-effort Measures

- ✓ **Upgrade** lab lights to efficient LED lighting
- ✓ **Install** high-efficiency aerators
- ✓ **Remove or hibernate** hoods, canopies, or snorkels
- ✓ **Upgrade** lab equipment to more efficient models



- ✓ **Relocate** supply diffusers to **eliminate** short circuiting air supply

Medium Effort

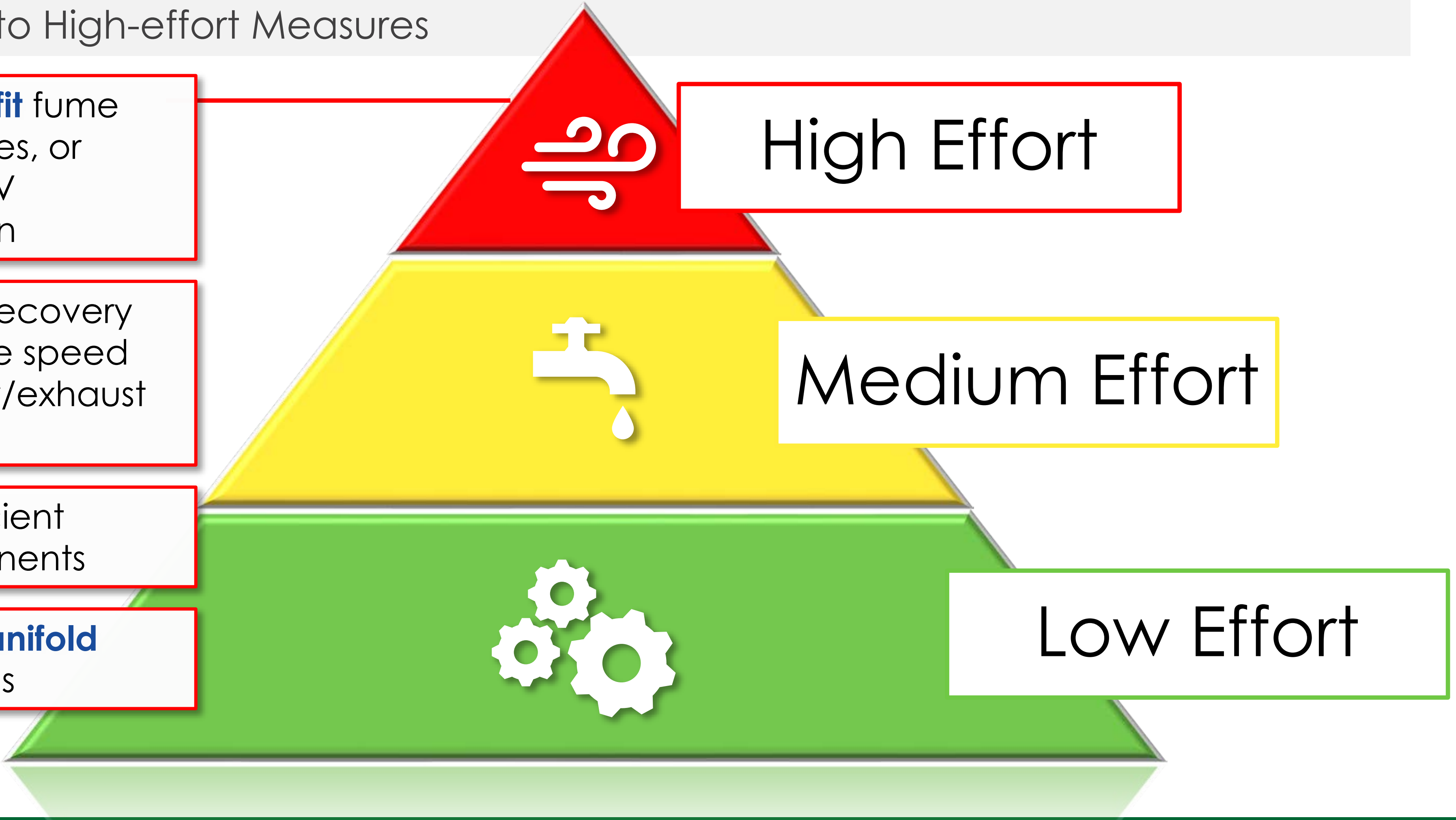
Low Effort

Build Program Momentum

Identify Improvement Measures

1. Low-effort to High-effort Measures

- ✓ **Modify or retrofit** fume hoods, canopies, or snorkels for VAV implementation
- ✓ **Install** energy recovery and/or variable speed drives in supply/exhaust systems
- ✓ **Replace** inefficient system components
- ✓ **Upgrade or manifold** exhaust systems



Scope of Work

Develop a Scope of Work

1. Components to a Scope of Work
2. Economics of Measures

Results from systems assessment

Goals of the Smart Labs Program

Improvement measures

Anticipated energy savings

Scope of Work

Section 1

Section 2

Section 3

Section 4

Argonne National Laboratory Incorporates a Smart Labs Program

ANL enhanced existing campus-wide sustainability efforts with new resources and a network of laboratory partners

2017

ANL launched a pilot of its retro commissioning program

2018

ANL joined the SLA, a DOE program committed to the adoption of best practices

2019

Foundation set by ANL's existing sustainability infrastructure for its Smart Labs program

Learn more about ANL's Smart Lab Program Case Study on the toolkit

Assess Key Takeaways

Verify performance of all building systems

Integrate energy security systems to strengthen lab capabilities

Incorporate labs into resilience planning

Develop scope of work to optimize building systems

Smart Labs

Optimize

The Smart Labs Process

Assess

- Conduct in-depth audits of laboratory buildings
- Focus on the ventilation systems
- Develop a scope of work for system optimization

Plan

- Build a team of lab stakeholders
- Profile buildings to prioritize efforts
- Develop a strategic plan for cost-effective implementation

Optimize

- Execute meaningful projects with demonstrable payback
- Develop a building management plan outlining dynamic management to further optimize operations

Implement Improvement Measures

LBNL XBD200002-00233-02

LBNL XBD200406-00269-04

Low Effort

NREL 75785 & NREL 75726

Examples

- ✓ Modify HVAC setpoints
- ✓ Calibrate building automation systems
- ✓ Adjust air flow controls
- ✓ Tune operational systems

Implement Improvement Measures

LBNL XBD200002-00233-02

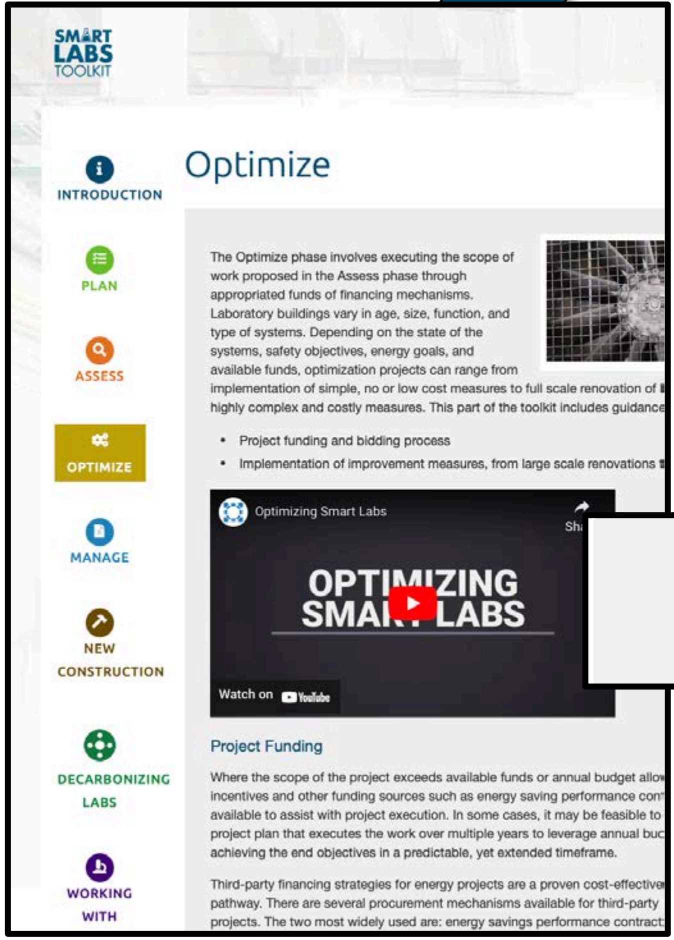
Medium Effort

- ✓ **Efficient** LED lighting, including LED microscopy
- ✓ **High-efficiency** faucet aerators
- ✓ **Upgrade** lab equipment (autoclaves, freezers)
- ✓ **Remove** hibernate hoods, canopies, or snorkels
- ✓ **Relocate** supply diffusers to eliminate short circuiting

High Effort

- ✓ Fume hoods, canopies, or **VAV snorkels**
- ✓ VAV controls and **demand control ventilation**
- ✓ Energy recovery or **variable fan drives**
- ✓ Inefficient system **replacement**
- ✓ **Upgrade or manifold** exhaust stack and fan systems

Optimize: Alternative Financing



Alternative Financing

- When traditional funding does not exist:
  - ✓ Third party financing strategies
  - ✓ Public-Private Partnerships
  - ✓ Alternative Procurement Methods

Project Funding

- Up-front Capital or Internal Funding
- Federal and State Incentives
- Bonds
- Energy Savings Performance Contracts (ESPCs)
- Utility Energy Services Contracts (UESCs)
- Power Purchase Agreements (PPA)

Project Funding Sources

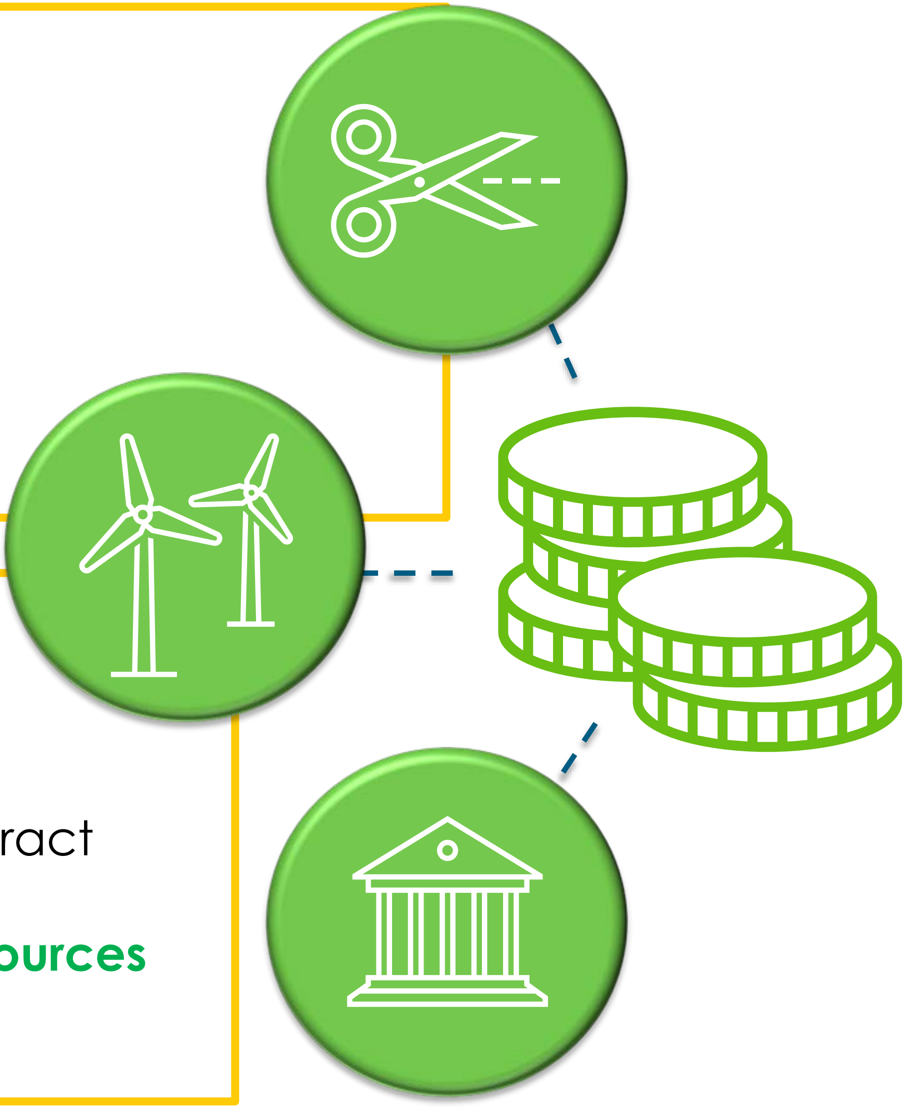
Energy Savings Performance Contract (ESPC)

- Partnership with energy savings company (ESCO)
- An ESCO:
  - ✓ **Constructs** energy-reduction projects
  - ✓ **Conducts** comprehensive energy audit
  - ✓ **Arranges** necessary financing for project
  - ✓ **Guarantees** energy savings

NREL 48962

Utility Energy Savings Contract (UESC)

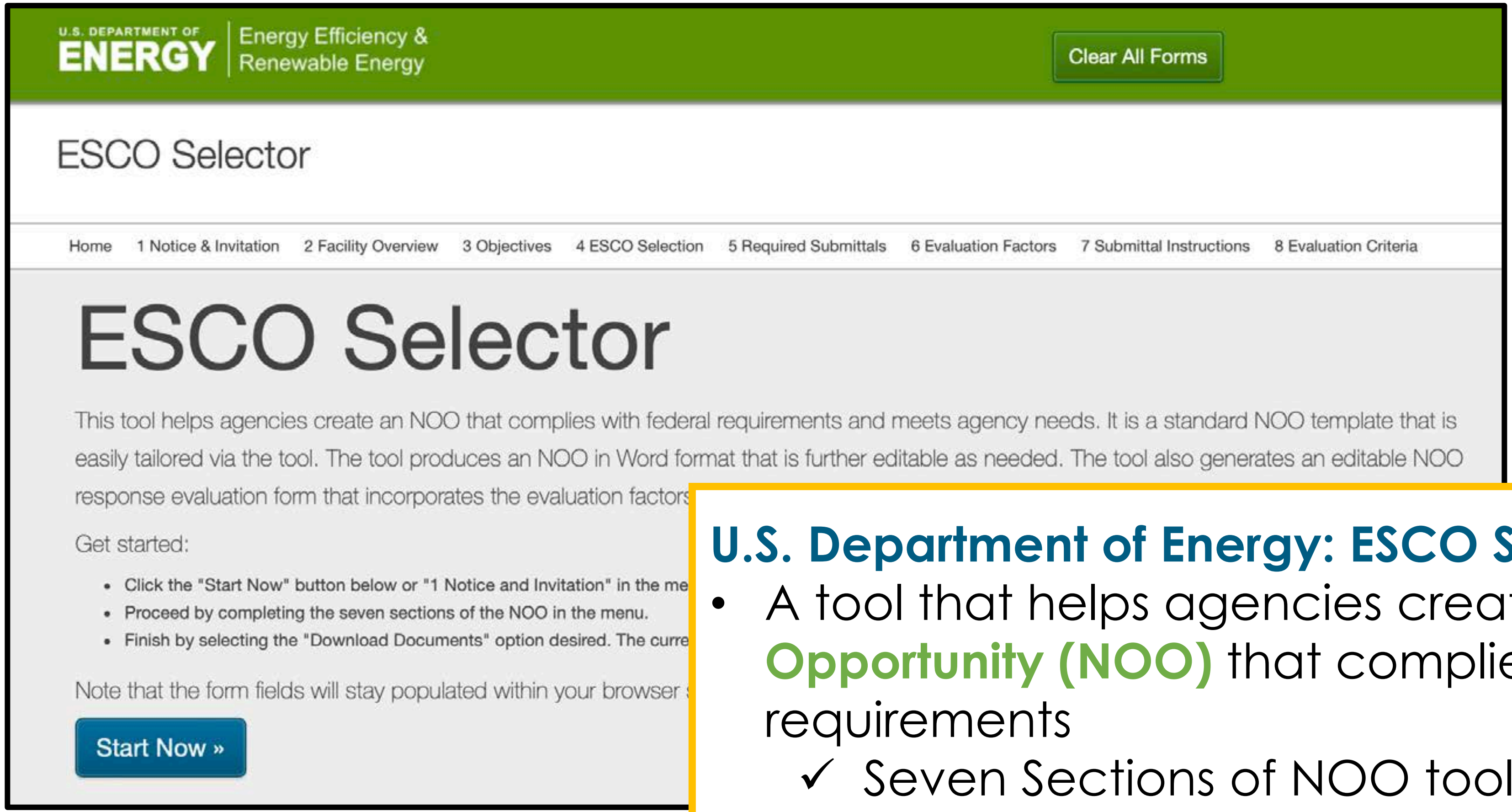
- Performance contract with utility
- Save **time and resources**



Basic Beginning ESPC Process Steps

1 Acquisition Planning	The agency or site puts their team together to decide their goals and acquisition strategy
2 Contractor Selection	If the acquisition is ESPC, use NOO (Notice of Opportunity) as a starting point to capture facility description, project goals and requirements
3 ESCO Selected	ESCO is then selected and then the Preliminary Assessment begins with agency support

ESCO Selector Tool

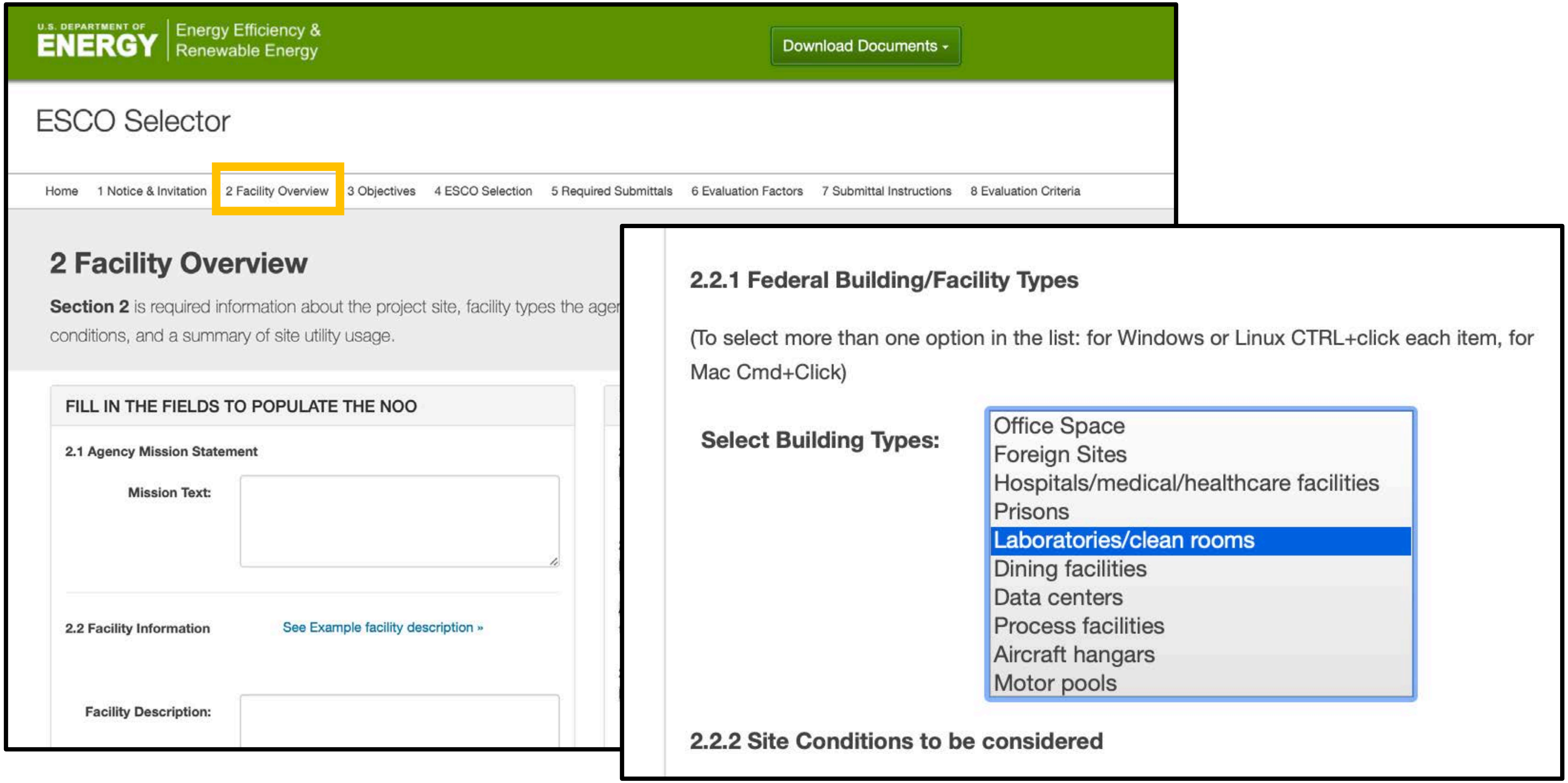


U.S. Department of Energy: ESCO Selector Tool

- A tool that helps agencies create a **Notice of Opportunity (NOO)** that complies with federal requirements
  - ✓ Seven Sections of NOO tool
  - ✓ Various templates available for NOO drafting
  - ✓ Easily tailored

Visit esco-selector.ornl.gov

Select Building Type as Laboratory (Step 2)



SMART LABS TOOLKIT

Implementing a Smart Labs Program (Step 3)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Download Documents

ESCO Selector

Home | 1 Notice & Invitation | 2 Facility Overview | 3 Objectives | 4 ESCO Selection | 5 Required Submittals | 6 Evaluation Factors | 7 Submittal Instructions | 8 Evaluation Criteria

3 Statement of Objectives

Section 3 is the agency's statement of objectives for the procurement described by the NOO. Section 3.1 is a genera
and Section 3.2 calls for statement of 2 - 3 of the agency's highest-priority objectives.

Learn more about stating objectives»

Learn more about objectives and matching evaluation criteria»

3.2.1 General Project Objectives »

Entering objectives and related evaluation criteria

Implement a Smart Laboratory Program

ECM (Energy/Water Conservation Measures)

3.2.5 Objectives for Specific ECMs »

and automation system points

- [ ] Consider Monitoring-Based Commissioning
- [ ] Consider Data Center Improvements
- [ ] Implement 50001-Ready Program
- [x] Implement a Smart Laboratories Program

Project Funding Sources

Power Purchase Agreement (PPA)

- Finance renewable energy projects on-site or off-site
- Agreement to **purchase power system generates**
- Developers own, operate, and maintain system

NREL 17393

Appropriated Funds

- Labs vary in **age, size, function,** and type of systems
- Identify appropriate measures to **optimize** lab system performance

Supervise Project Upgrade Activity

NREL 69958

NREL 10854

NREL 65827

Tips for success

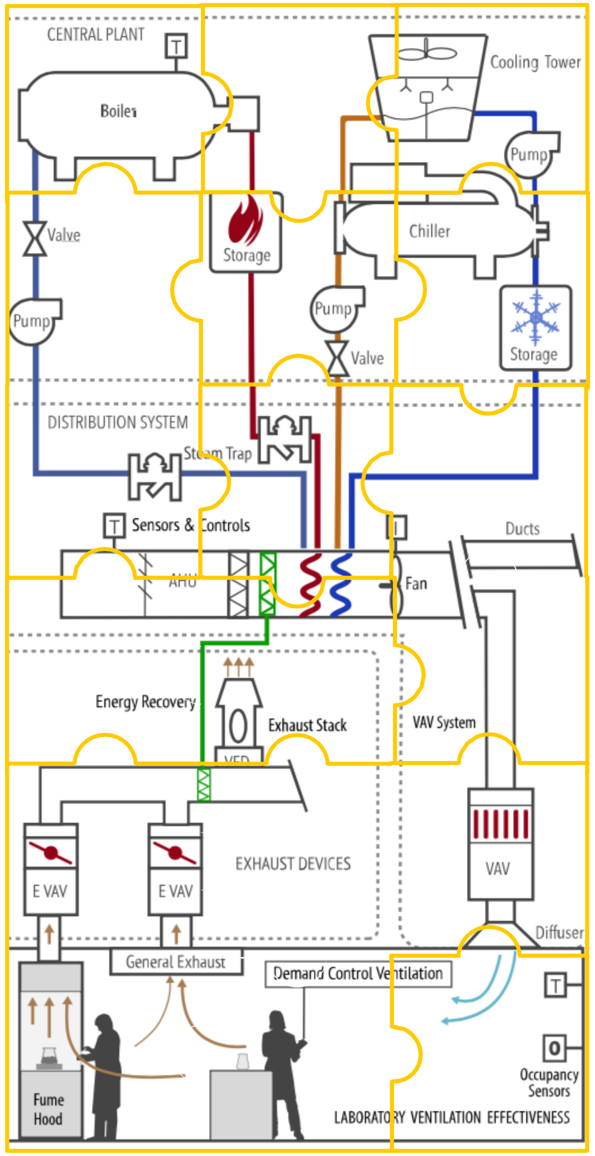
- ✓ Select contractors **with lab experience**
  - Validate qualifications
- ✓ Seek out multiple bids
  - Lowest bid ≠ best value
- ✓ Be **specific** in scope of work
- ✓ Define **process and expectations**
- ✓ Maintain **open lines** of communication
- ✓ **Be a champion** from start to finish

Optimize Through Commissioning

Commissioning

Process to ensure a building's operating systems are working as designed.

- High-performance airflow systems can lose up to **50% of their control ability within 5 years**
- Perform **lab surveys** and **system tests**
- Work with **third-party companies** that provide commissioning services
- **Fault detection sensors** notify staff automatically of changes in performance



Creating a Building Management Plan

Building Management Plan

- ✓ Documentation on **new baselines**
- ✓ Equipment **inventories**
- ✓ **Up-to-date** airflow specifications
- ✓ Key **performance** indicators
- ✓ Standard **operating procedures** for tests maintenance, and schedules

NREL 38455

Laboratory Benchmarking Tool

Risk Level	Description
0	Negligible
1	Low
2	Moderate
3	High
4	Extreme

Visit the Toolkit @ **SmartLabs.i2sl.org**

Key Takeaways

Identify funding streams early on to maximize impact

Seek out contractors with a **proven track record** of successful upgrades in laboratory buildings

Use **commissioning as a tool** to improve lab operations and identify future projects

Finish with documenting a **Building Management Plan**

15 Minute Break!

1

Smart Labs

Manage

The Smart Labs Process

Assess

- Conduct in-depth audits of laboratory buildings
- Focus on the ventilation systems
- Develop a scope of work for system optimization

Manage

- Implement a lifecycle performance management plan
- Apply lessons learned in improving additional facilities on the campus

Plan

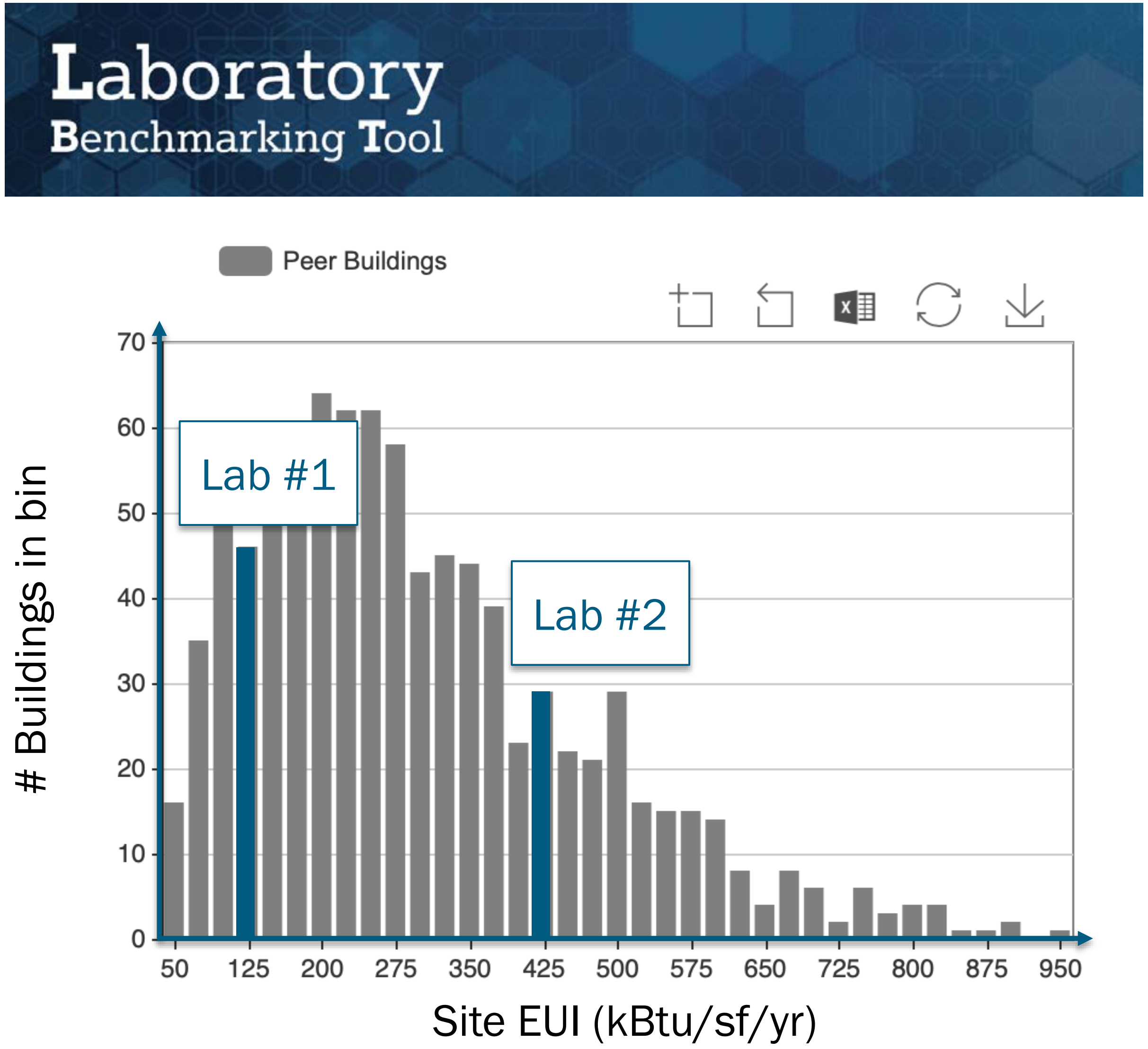
- Build a team of lab stakeholders
- Profile buildings to prioritize efforts
- Develop a strategic plan for cost-effective implementation

Optimize

- Execute meaningful projects with demonstrable payback
- Develop a building management plan outlining dynamic management to further optimize operations

Ongoing Benchmarking and Analytics

Building Name	Lab #1	Lab #2
Year Built	1988	2002
Building Area (ft^2)	71,000	80,800
Total Lab Area (ft^2)	35,500	24,240
Number of Labs	15	17
Lab Type(s)	Chemistry	R&D
Number of Occupants	115	233
Occupancy Hours	12	10
HVAC System Type(s)	CAV	VAV
Lighting System Type(s)	Fluorescent	LED
Fuel Type(s)	Boiler	Boiler
Analytics	Sensors	EMIS
EUI	311	353

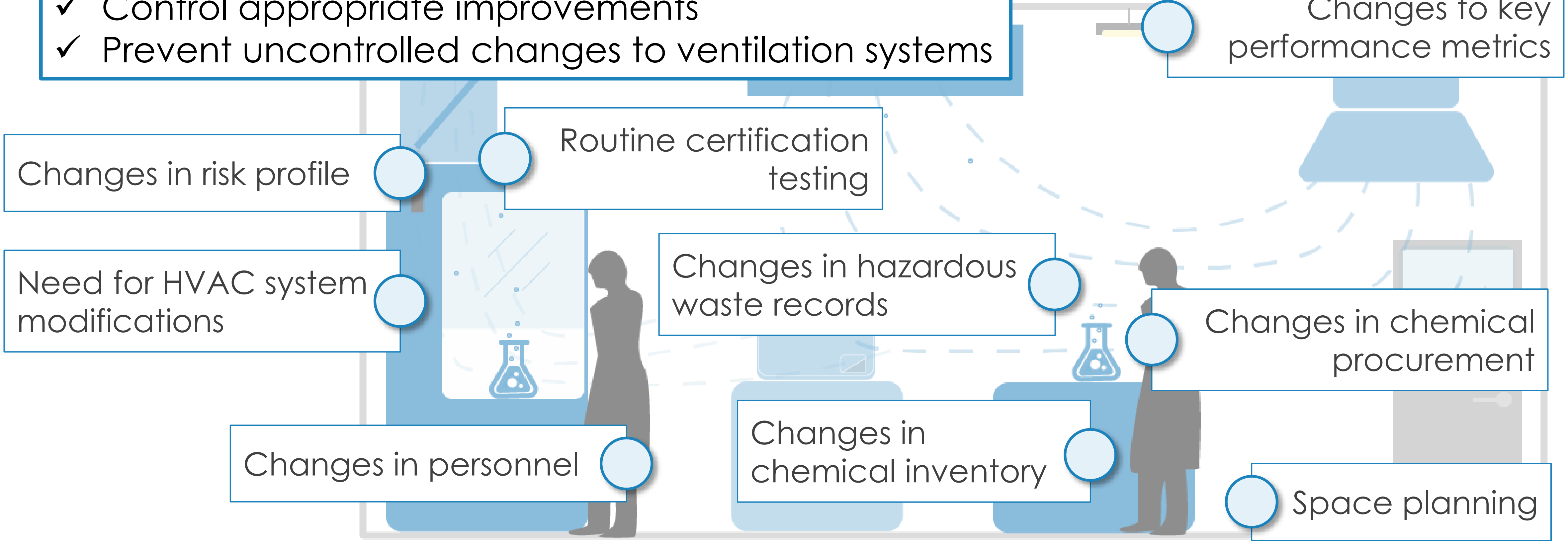


Managing Change

Change Management Plan

Ensures **safe and efficient operation** of laboratory buildings by providing the necessary steps to:

✓ Control appropriate improvements
✓ Prevent uncontrolled changes to ventilation systems



Laboratory Ventilation Management Plan

Laboratory Ventilation Management Plan (LVMP)

The **Laboratory Ventilation Management Plan** (LVMP) provides

- ✓ **Framework** and **process**
- ✓ Helps manage laboratory ventilation systems
- ✓ Continues to **meet functional requirements**

SMART LABS TOOLKIT

LVMP Objectives

Provide a Framework to Balance...

- ✓ Laboratory safety
- ✓ Financial Costs
- ✓ Energy Efficiency
- ✓ Carbon Emissions
- ✓ Equipment Lifetime and Operation

Photo Credit: Werner Slocum | NREL

The LVRA and the LVMP

The **Laboratory Ventilation Risk Assessment** sets the **baseline** for the **Laboratory Ventilation Management Plan**

The LVMP **includes** the LVRA Process

LVRAs **conducted annually** and when new hazards enter the lab

LVMP **manages** change with information from the LVRA

Both LVRA and LVMP **build** on each other

Laboratory Ventilation Management Program

ANSI/ASSP Z9.5

Standard on lab ventilation

Describes:

- Recommended practices for design and operation of ventilation systems
- Defines requirements for organization LVMPs

LVMP

Laboratory Ventilation Management Plan

- "Sets forth procedures, guidelines and specifications for design, selection, operation, use, and maintenance of laboratory ventilation equipment"

The LVMP Template

Non-regulatory standards include: [*some possible standards to consider are listed, add or remove from the list as you see fit*]

- *ASHRAE Classification of Laboratory Ventilation Design Levels*
- *ANSI/ASSP Z9.5-2022 Standard on Laboratory Ventilation*
- *ANSI Airborne Hazards Safety Standard*
- *BMBL (Biosafety in Microbiological and Biomedical Laboratories) standards*

Pick, choose, or insert your own information

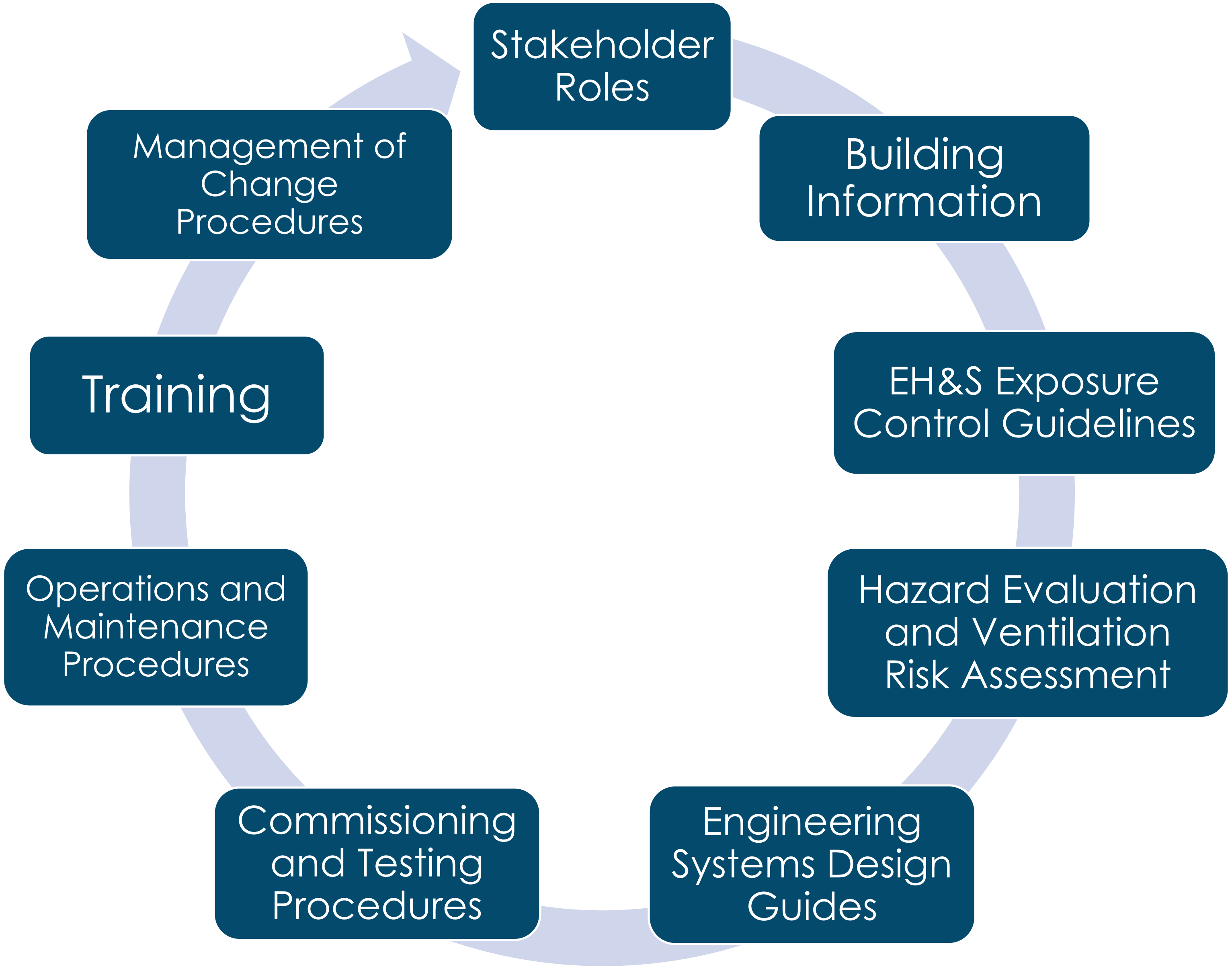
b) Internal Requirements

In order to meet [*your organization name*]'s standards, this program complies with:

- [*insert links to organization plan, program, policy, standard, guide, or requirement such as a design guide, university energy plan, or local exhaust program*] and [*insert link to other organization plan, standard, guide, or requirement*].

Links/places to insert your own documentation

LVMP Components



The LVMP Template

The LVMP template is the **KEY** to maintaining everything the Smart Labs program implements

The document maintains safety and high performance

Continue to complete the form for ongoing operational efficiency

The Critical Role of a **Lab Ventilation Management Program** Coordinator

LVMPs are the primary way to control exposure to airborne hazards and improve air quality.

BERKELEY LAB

Coordinator Responsibilities

Implementation and Administration of the Building LVMP

Document, Review, Organize, and Control

Monitoring HVAC Performance

Management of Change

Click here to view the Lawrence Berkely National Laboratory LVMP coordinator case study on the toolkit

Key Takeaways

Verify performance and quality of upgrade measures

Create a management plan that includes how to adapt to future needs

Continually monitor equipment and adjust operation as required

Report early success and summarize savings including lessons learned

Working with Scientists

Why Scientists and Researchers?

Researchers dictate how a lab operates

Scientists can become partners in Smart Lab efforts

Photo Credit: Dennis Schroeder | NREL

Researchers affect safety and energy consumption

Many scientists are unaware of their impact

Green Chemistry Principles

Aid researchers to make **safer and less hazardous** choices in labs

The 12 Principles of Green Chemistry

A framework for designing or improving materials, products, processes and systems.

1. Prevent Waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometric)
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

Photo Credit: American Chemical Society

↓ **Air Changes per Hour (ACH)**

Step 1: Read the 12 principles and determine **how they apply** to the lab

Step 2: Use the **DOZN Tool** to identify the impact of specific chemicals

Biology labs	
Engineering labs	Score chemicals according to 12 principles
Biophysics labs	Improve experimental design for synthesis

Equipment Best Practices

Autoclaves

- Turn off or put in standby mode when not in use
- Consolidate loads through sharing or schedules
- Install a water-saving device
- Upgrades to more efficient models

Equipment Best Practices



ACH

VAV Fume Hood

LBNL XBD200101-00194-02

Fume Hoods

- Keep fume hoods shut for occupant safety
- VAV fume hoods can lead to energy savings

Photo Credit: Harvard University

SMART LABS TOOLKIT

Equipment Best Practices

- ☑ Defrost freezers regularly (**10% reduction**)
- ☑ Clean units, inventory samples, and share space
- ☑ Adjust setpoints from -80°C to -70°C (**30% reduction**)
- ☑ Replace old units with more efficient freezers

Ultra-Low Temperature (ULT) Freezers

freezer challenge

2024

INTERNATIONAL LABORATORY FREEZER CHALLENGE

Starts **January 1st** through **July 1st**

Any lab around the world can participate!

WWW.FREEZERCHALLENGE.ORG

- ✓ The Freezer Challenge is a program organized by My Green Lab and the International Institute for Sustainable Laboratories (I2SL)
- ✓ Promotes cold storage best practices
- ✓ Take actions that benefit the planet through energy efficiency also benefiting the scientists

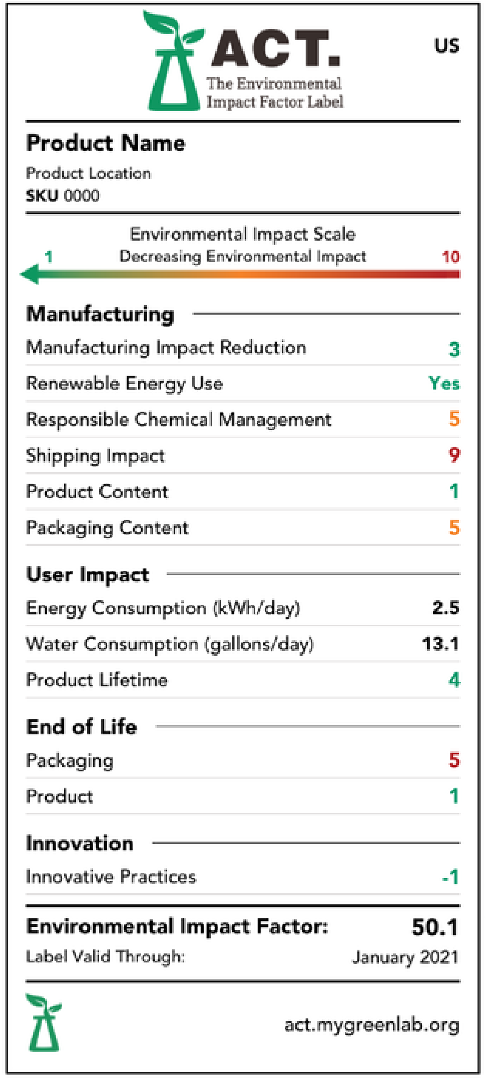
Green Lab Ambassador Program

Introductory training resource offered through **My Green Lab** to drive sustainability in laboratories.

Educates lab professionals on how they can:

- **Reduce** the impact of their research on
  - Energy, waste, and water through
  - Green chemistry and procurement
- **Distinguish** themselves in the lab community
- **Demonstrate** commitment to Smart Lab principles

MyGreenLab.org



Green Lab Ambassador Program

Scientists and researchers offer **deep insights** into lab operations

My Green Lab Ambassador Program can **engage staff in sustainable** lab behavior

Green chemistry is **smart chemistry**

Equipment-specific best practices lead to **reduced energy consumption** and better outcomes

Apply

Decarbonizing Labs

What is Decarbonization?

Remove carbon emissions from an organization’s systems and operations

Photo Credit: Werner Slocum / NREL

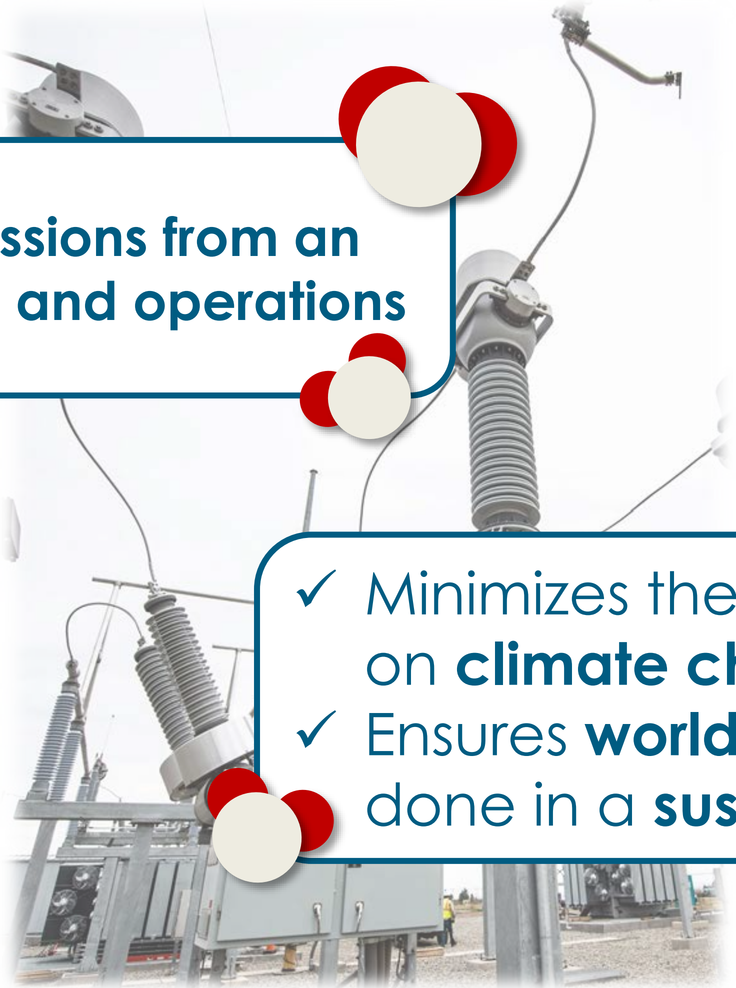


Photo Credit: Dennis Schroeder / NREL

- ✓ Minimizes the **impact** a facility has on **climate change**
- ✓ Ensures **world class science** is being done in a **sustainable manner**

Photo Credit: Werner Slocum / NREL

Decarbonizing Labs

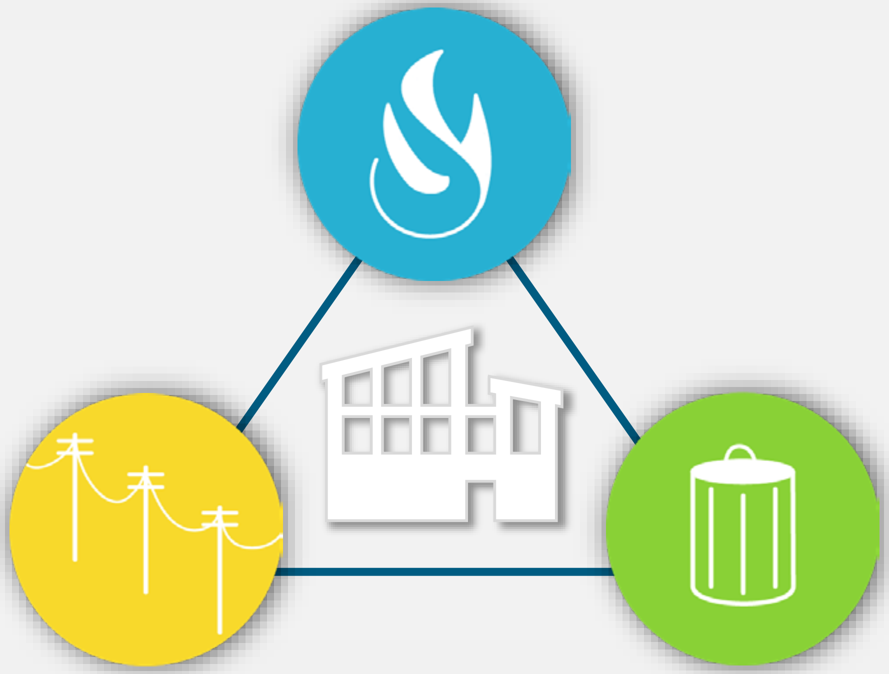
Energy Efficiency

Reduces a building's energy loads, decreasing dependence on fossil fuels

Renewable Generation

Produces energy from clean energy sources where the supply cannot be depleted or can be reliably restored

Scope 1



Scope 2

Scope 3

Electrification

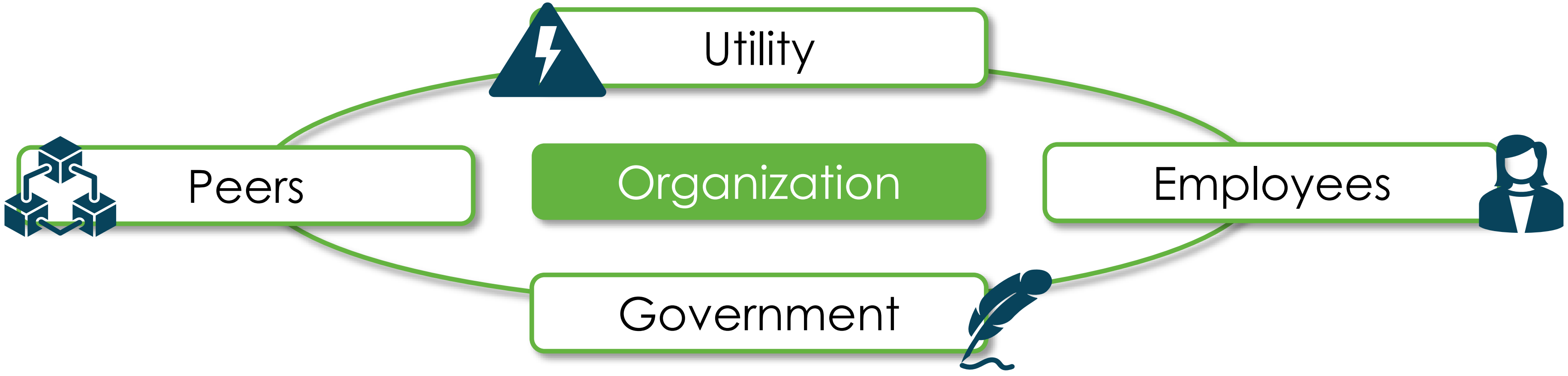
Converts technologies that rely on fossil fuels to using electricity

Demand Flexibility and Grid Interaction

Shifts a building's energy loads to non-peak demand, reducing strain on the grid

Plan: Decarbonization Roadmap

- Contain existing goals and commitments
- Understand regulatory compliance standards your organization
- Collect resources and guidelines that can be used in the planning process
- Encourage employee personal engagement



Establish a Baseline of Current Operations

Plan & Assess: Carbon Emissions Metrics

Scope 1

What are they?

Any GHG emissions that take place directly on the facility's site. The most substantial source comes from the direct combustion of fossil fuels.

Establish a Baseline

- ✓ Collect fuel consumption data
- ✓ Translate into emissions from direct combustion data
- ✓ Evaluate long-term property plans

Common Fuels

- ✓ Natural Gas
- ✓ Diesel
- ✓ Gasoline
- ✓ Fuel oil
- ✓ Biomass (in some cases)

Common Sources

- ✓ Facility operations for normal use
- ✓ Back-up generators for emergency use
- ✓ Chemical usage

HVAC systems account for 45-85% of the total energy used in laboratories.

Photo Credit: Werner Slocum / NREL

Plan & Assess: Carbon Emissions Metrics

Scope 2

What are they?

GHG emissions that result from a facility's activities but only occur indirectly as the sources that create emissions are owned or controlled by a different organization.

Establish a Baseline: Two Approaches

Location-Based

Calculates the average GHG emissions from the electric grid at a specific location after establishing a boundary.

Market-Based

Looks at an organization's contractual obligations with different energy providers to determine individual emissions.

Scope 2 emissions account for at least a third of the world's total GHG emissions.

Source: Greenhouse Gas Protocol Scope 2 Guidance

Photo Credit: Dennis Schroeder / NREL

Plan & Assess: Carbon Emissions Metrics

Scope 3

What are they?

GHG emissions that occur throughout an organization's respective value chain, where activities extend beyond the scope of an organization's ordinary operations.

Establish a Baseline

- ✓ Identify organization's upstream and downstream activities
- ✓ Expect to encounter significant informational barriers

Upstream Activities

Materials that flow **into** an organization:

- ✓ Commuting to work
- ✓ Capital goods like equipment

Downstream Activities

Materials that flow **out** of an organization:

- ✓ Project deliverables
- ✓ End-of-life treatment of products

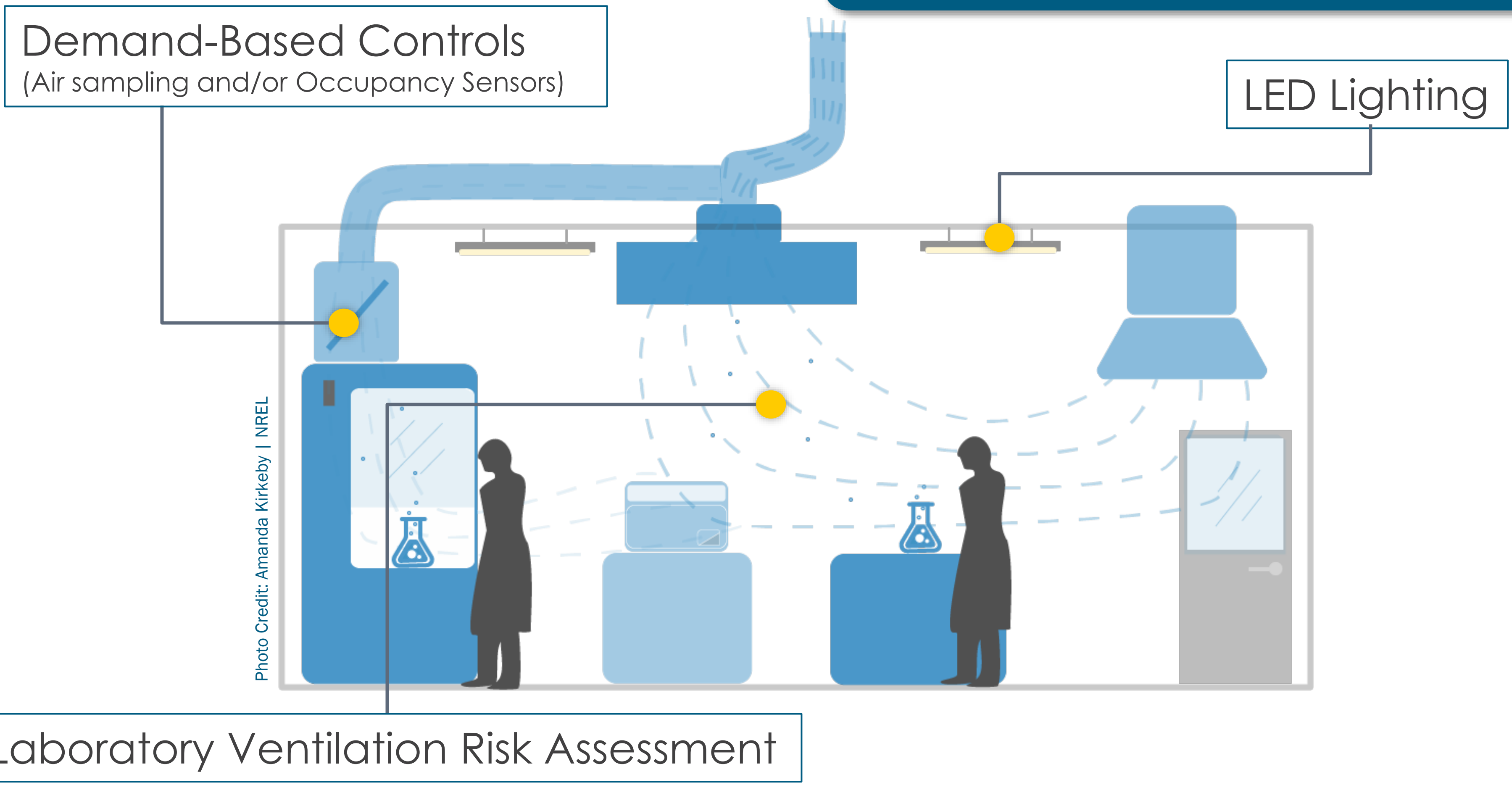
Scope 3 emissions often make up most of an organization's carbon footprint.

Photo Credit: Dennis Schroeder / NREL

Optimize: Four Pillars of Decarbonization

Energy Efficiency

Reduces a building's energy loads, decreasing dependence on fossil fuels.



Optimize: Four Pillars of Decarbonization

Electrification

Converts technologies that rely on fossil fuels to electricity.


Photo Credit: Rachel Romero, NREL

Common technologies to replace:

- ✓ Boilers, Furnaces
- ✓ Water heaters
- ✓ Vehicle Fleets

Alternative technologies:

- ✓ Low-energy heat pumps
- ✓ Heat recovery chillers

Benefits:	Drawbacks:
✓ 100% energy efficient in heating a space ✓ Lower emissions and reduced hazard	x First costs can be more expensive than fossil fuel heating methods

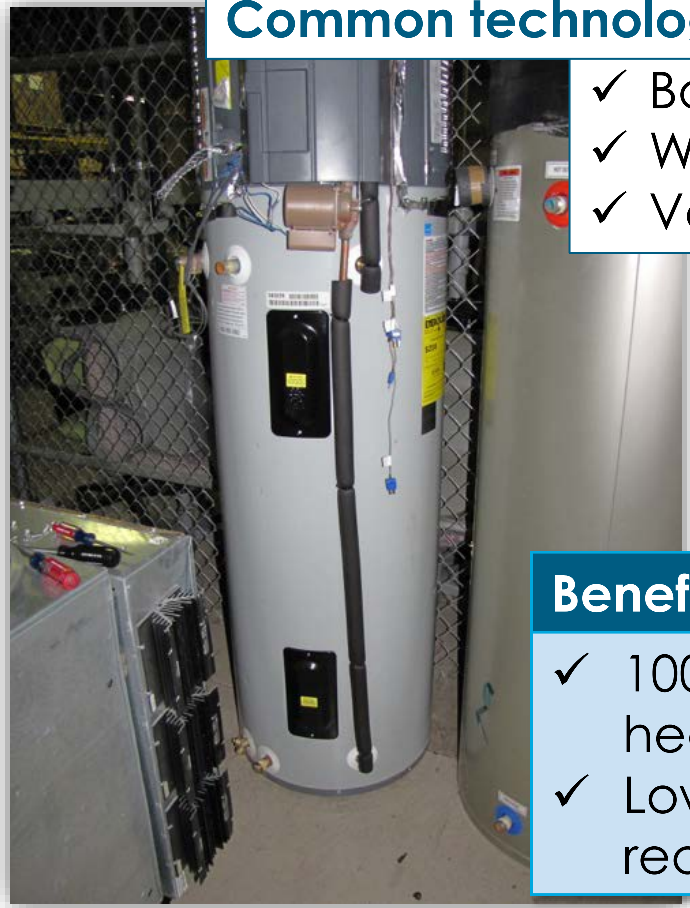


Photo Credit: Bethany Sparn / NREL

Optimize: Four Pillars of Decarbonization

Renewable Generation

Produces energy from clean energy sources where the supply cannot be depleted or can be reliably restored.

Photo Credit: Dennis Schroeder / NREL

On-site Generation

- ✓ Solar Photovoltaics
- ✓ Wind
- ✓ Solar Thermal

Photo Credit: Dennis Schroeder / NREL

Storage Options

- ✓ Batteries
- ✓ Thermal energy storage tanks

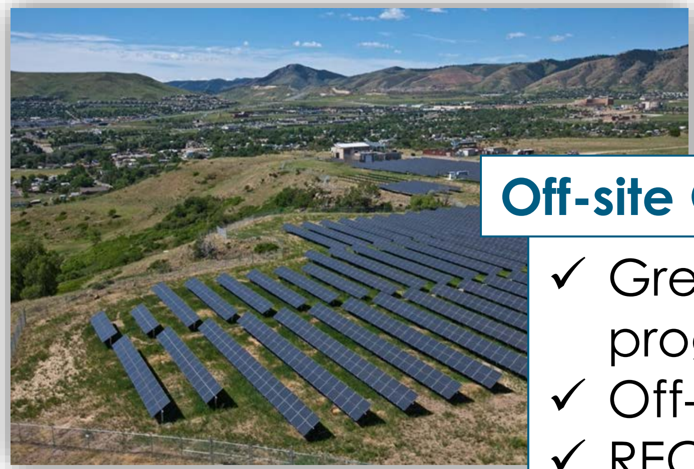


Photo Credit: Pat Corkery

Off-site Generation

- ✓ Green electricity programs
- ✓ Off-site PPAs
- ✓ RECs

Optimize: Four Pillars of Decarbonization

Demand Flexibility and Grid Interaction

Energy Management Information System (EMIS)

- Weather stations
- IoT devices
- BAS controls
- Fault detection
- Utility bills
- DERs
- Submeters

Benefits in a Lab

- ✓ Operate equipment outside of peak hours
- ✓ Condense equipment loads

Photo Credit: Dennis Schroeder / NREL

Shifts a building's energy loads to times of outside of peak demand, reducing strain put on the grid.

Manage: Progress on Decarbonization Goals

"Are we seeing the carbon savings we want?"

If No…

"What needs to change?"

- ✓ Formulate new plan
- ✓ Consult alternative resources

If Yes…

"How can savings be maintained?"

- ✓ Document successful strategies
- ✓ Quantify GHG emissions
- ✓ Identify further reduction opportunities
- ✓ Continuously monitor building performance

Photo Credit: Dennis Schroeder / NREL

Decarbonizing Checklist

Get the ventilation right!

- Conduct recurring LVRAs
- Modify setpoints and operating specs to optimize HVAC systems

Consider energy recovery

- Exhaust energy recovery
- Heat recovery chillers
- Other sources of waste heat:
  - Data centers
  - Sewer pipelines

Install heat pump, air-source or ground source

Key Takeaways

Take inventory of how building operations impact emissions

Set goals for your lab to reduce its emissions

Define your **decarbonization goals**

Determine steps to incorporate the four pillars into operations

SMART LABS

Closing

Key Takeaways

FEMP Federal Energy Management Program

Share 1 action/item you will take away from this workshop

Overview of Working Groups

Why Working Groups?

Huge opportunity to...

- Generate energy savings
- Reduce GHG emissions

Working Group will help organizations work towards...

- Energy efficiency requirements for federal buildings
- Decarbonization goals listed under E.O. 14057

Since organizations...

- Face similar challenges
- Share joint processes

Use the QR Code to join the Smart Labs Partner List

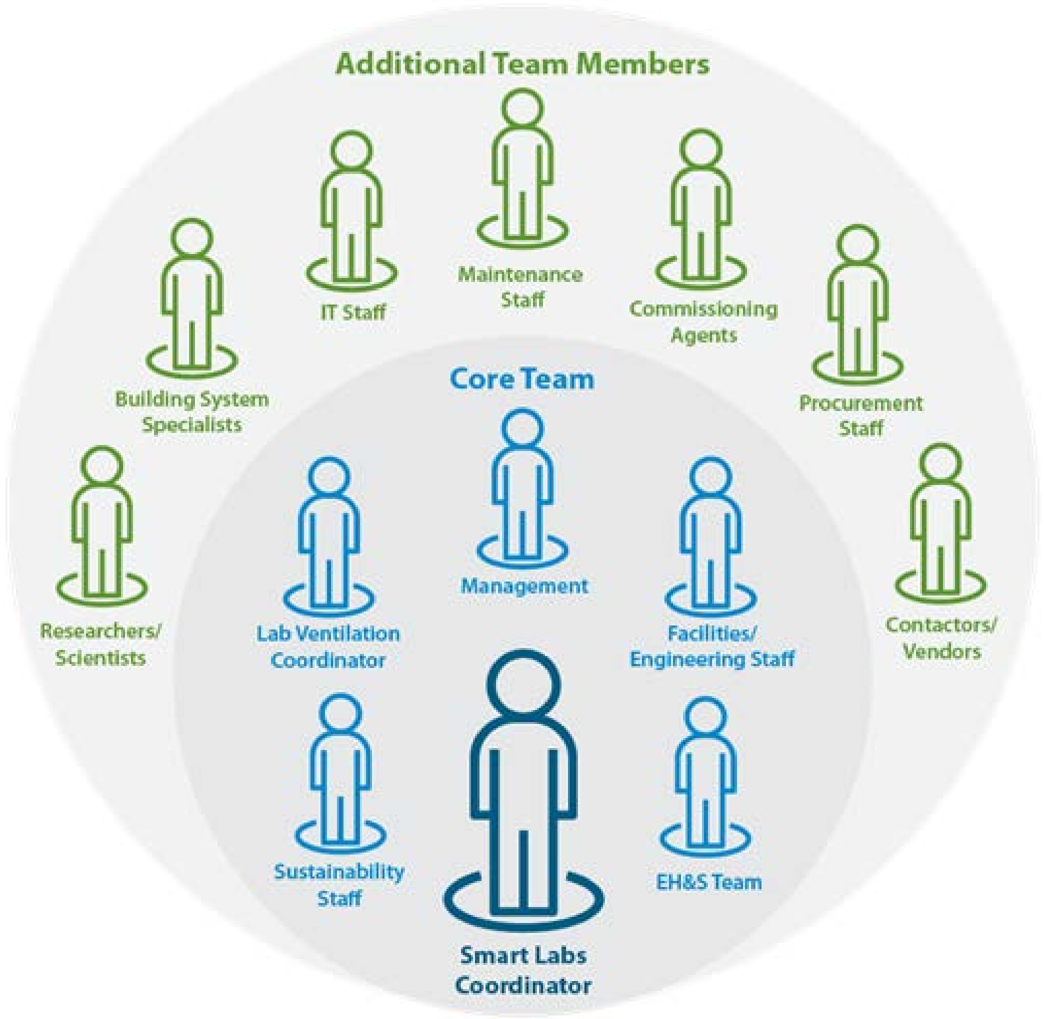
* Number of federally-owned laboratories estimated from *Advancing Commercialization of Digital Products from Federal Laboratories*, published under the National Library of Medicine.

Work Together in Smart Labs

Who is this Group For?

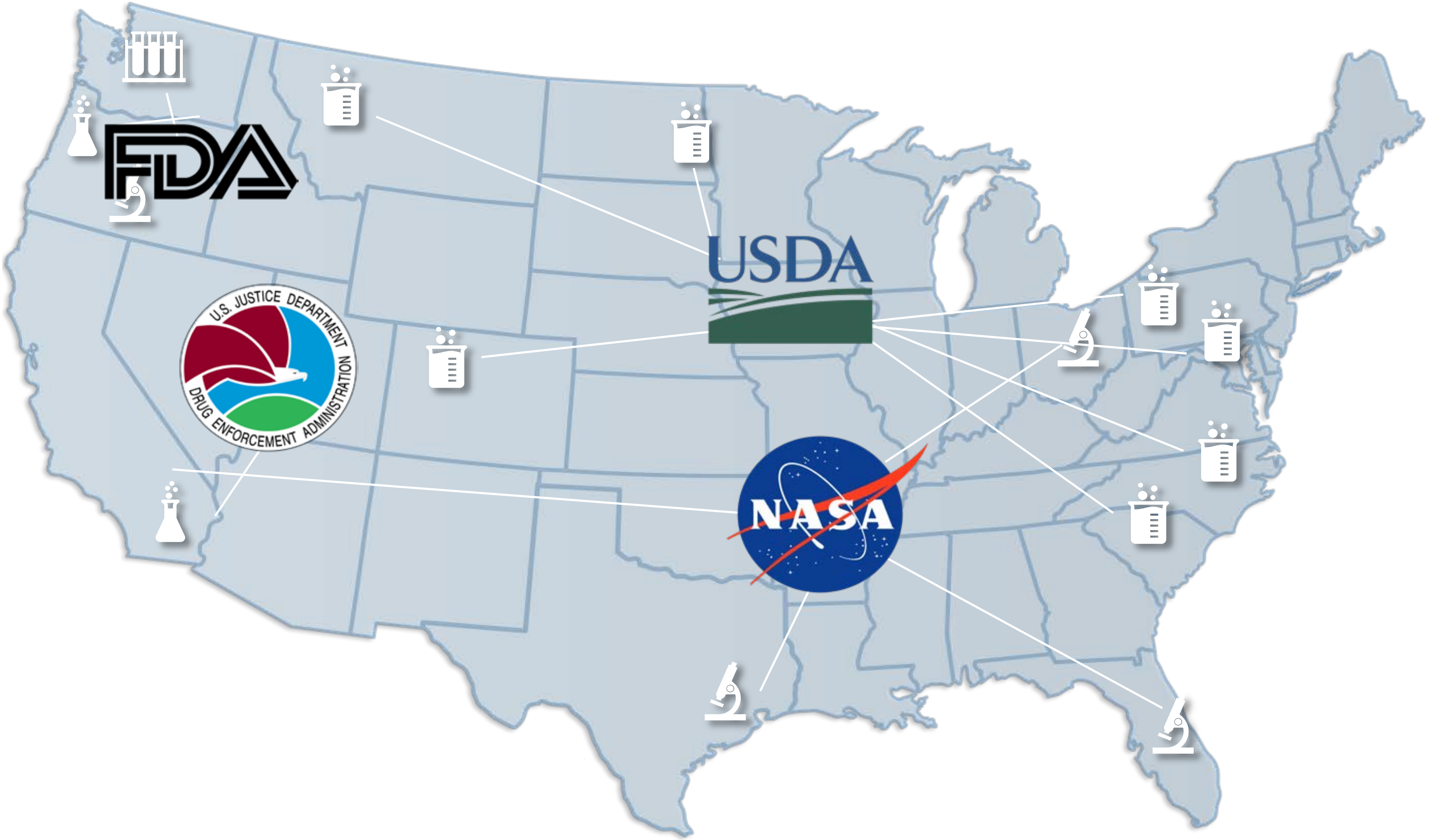
- Building managers
- Environmental health and safety professionals
- Industrial hygiene professionals
- Facility engineering
- Sustainability managers
- Energy managers
- Analytics and controls maintenance staff
- Engaged researchers
- Principal investigators
- Program managers

Smart Labs Program



* Number of federally-owned laboratories estimated from *Advancing Commercialization of Digital Products from Federal Laboratories*, published under the National Library of Medicine.

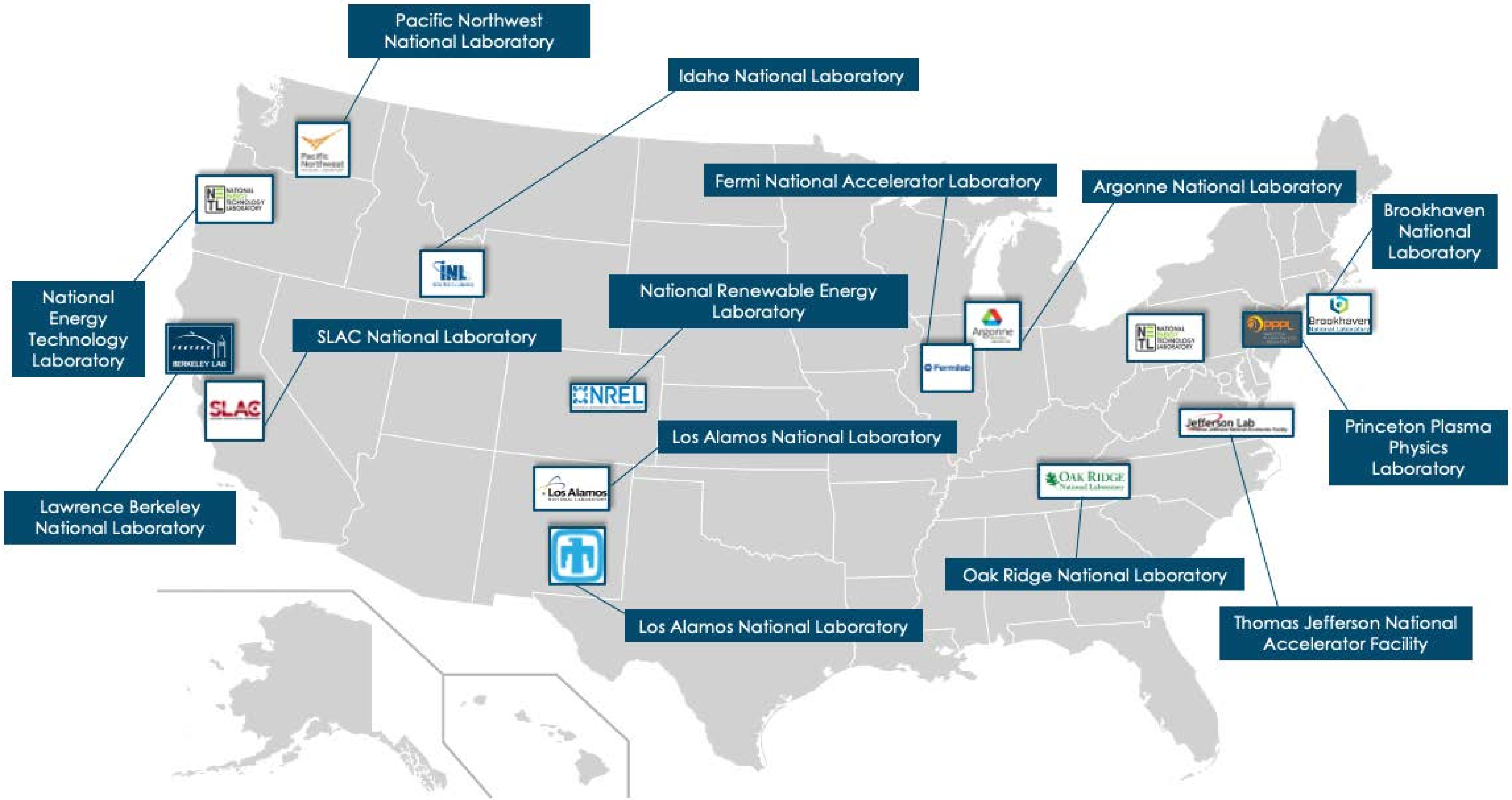
Federal Labs Working Group



The Federal government owns over 310+ laboratories!

* Number of federally-owned laboratories estimated from *Advancing Commercialization of Digital Products from Federal Laboratories*, published under the National Library of Medicine.

Smart Labs for National Labs



Ways We Can Help

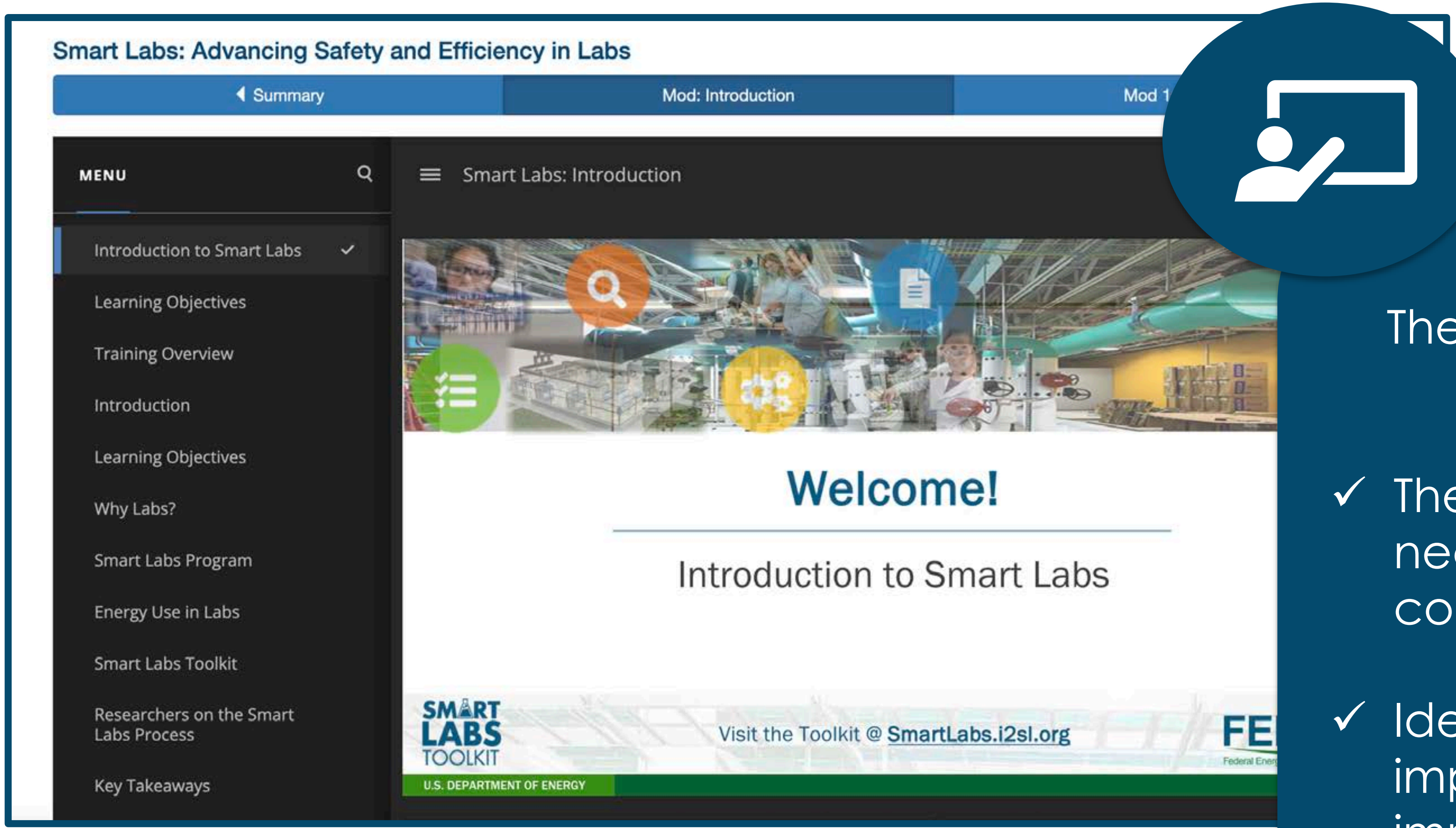
- ✓ Provide technical assistance
- ✓ Review program of requirements, designs, etc.

- ✓ Identify funding opportunities and savings
- ✓ Give feedback on LVRAs

- ✓ Connect with training resources
- ✓ Create networking within lab communities

Reach out to us!

Smart Labs Training



[The Smart Labs Training](#)

The Smart Labs training provides:

- ✓ The framework necessary to assemble a collaborative team
- ✓ Identify and implementing efficiency improvements.

I2SL Annual Conference

September 29 - October 3, 2024 | St. Louis, Missouri

The I2SL Annual Conference and Technology Fair focuses on laboratory:

- ✓ Energy Efficiency
- ✓ Decarbonization
- ✓ Sustainability

Nearly 600…

- ✓ Lab owners
- ✓ Operators
- ✓ Designers
- ✓ Engineers
- ✓ Managers
- ✓ Builders
- ✓ Developers

✓ Education Week 2024 brings the combined braintrust of I2SL, SLCan, and other international partners right to your laptop

✓ Lab owners, managers, operators, and supporters from the university, government, or nonprofit community can save on registration, and members receive an even bigger discount!

VIRTUAL

INTERNATIONAL

April 15-18

2024

Education Week

Cohosted by I2SL, EGNATON, and SLCan

Register Today!

A Global View on Laboratory Sustainability

Federal and National Labs Meetup

Room 403 on Tuesday, March 26 from **12:30pm-1:30pm**

- ✓ Meet up with other lab professionals at EEx to discuss shared successes and challenges!
- ✓ Please grab your lunch and join us for a low key discussion around improving lab facilities. No need to register; just show up!

Questions?

Thank you!

Rachel Romero
National Renewable Energy Laboratory
Rachel.Romero@nrel.gov

Otto Van Geet
National Renewable Energy Laboratory
Otto.VanGeet@nrel.gov

NREL Transforming ENERGY

FEMP Federal Energy Management Program

References and Resources

SMART LABS TOOLKIT

LVRA Tool

- Correct Pathway for the Chemistry Lab: Assessment Categories

Choose the most accurate description for each characteristic from the dropdown menu. All characteristics must be assigned a value for the risk control band to be calculated.
A rating from 1 to 4 will be assigned automatically based on your choice. (Additional details available in the Dropdown Details and Lab Env. Band Calculation tabs.)

After the survey information for each ECD is entered below in Step 3, the maximum value will be populated here.

Hazard Exposure limit for the peak hazard not contained by ECD	Quantity Aggregrate volume of all hazards	Generation Rate Peak generation rate for any hazard not contained by an ECD	Generation Method Peak generation method for any hazard not contained by an ECD	Generation Location Peak generation location for any hazard not contained by an ECD	Change Dynamics Frequency of changes in the lab environment	Housekeeping General order and cleanliness of the lab	Availability of Exposure Control Devices	Appropriateness of Exposure Control Devices	Ventilation Effectiveness	Maximum Risk Control Band from ECD survey	Lab Environment Risk Control Rating
> 500 ppm or >2000 mg/m3	1-10 L or 10-100 g	<0.1 lpm | small # of small containers | Low VP	Intermittent (Manual or equipment)	Low-Middle or High-Middle (not very close)	1 change/month	Cluttered	Yes	Yes	Moderately effective	3	39
0	2	1	2	3	2	2	0	0	2	3	1

Choose the most accurate description for each characteristic from the dropdown menu. All characteristics must be assigned a value for the risk control band to be calculated.
A rating from 1 to 4 will be assigned automatically based on your choice. (Additional details available in the Dropdown Details and ECD Band Calculation tabs.)

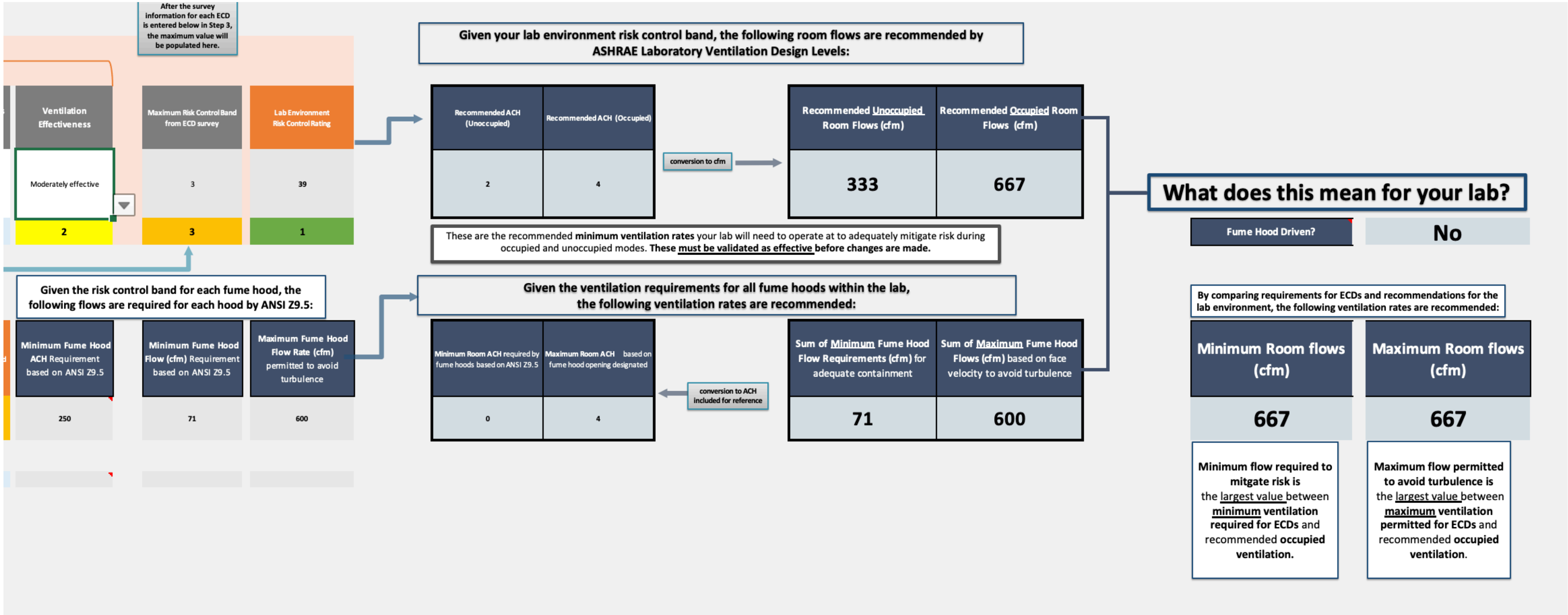
Given the risk control band for each fume hood, the following flows are required for each hood by ANSI Z9.5:

Hazard - Enter the exposure limit for the peak hazard contained by ECD	Quantity - Enter the total volume of all hazards	Generation Rate - Enter the peak generation rate for any hazard contained by ECD	Generation Method Peak generation method for any hazard contained by ECD	Generation Location Peak generation location for any hazard contained by ECD	Change Dynamics Frequency of change in the ECD	Housekeeping General order and cleanliness of the lab	ECD Risk Rating	ECD Risk Control Band	Minimum Fume Hood ACH Requirement based on ANSI Z9.5	Minimum Fume Hood Flow (cfm) Requirement based on ANSI Z9.5	Maximum Fume Hood Flow Rate (cfm) permitted to avoid turbulence
5-50 ppm or 20-250 mg/m3	1-500 ml or 1-100 g	<0.1 lpm (e.g., evaporation)	Manual	Well contained by ECD/Very close to capture device	1 change/month	Some Clutter	38	3	250	71	600
2	2	1	1	1	2	1					

Instructions | Summary | Survey Entry | Dropdown Details | ECD Band Calculation | Lab Env. Band Calculation | +

LVRA Tool

- Correct Pathway for the Chemistry Lab: Recommended ACHs



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LVRA Tool

- Correct Pathway for the Life Sciences Lab: Assessment Categories

Hazard Exposure limit for the peak hazard not contained by ECD	Quantity Aggregrate volume of all hazards	Generation Rate Peak generation rate for any hazard not contained by an ECD	Generation Method Peak generation method for any hazard not contained by an ECD	Generation Location Peak generation location for any hazard not contained by an ECD	Change Dynamics Frequency of changes in the lab environment	Housekeeping General order and cleanliness of the lab	Availability of Exposure Control Devices	Appropriateness of Exposure Control Devices	Ventilation Effectiveness	Maximum Risk Control Band from ECD survey	Lab Environment Risk Control Rating
150-300 ppm or 500-1000 mg/m3	10-20 L or 0.1-1 kg	<0.3 lpm [Large # of small containers | Small # of large containers, Low Vapor Pressure](e.g., High VP/Stirring)	Manual	Low (very close to capture device)	1 change/year	Some Clutter	Yes	Yes	Effective	3	70
2	3	2	1	1	1	1	0	0	1	3	2

Choose the most accurate description for each characteristic from the dropdown menu. All characteristics must be assigned a value for the risk control band to be calculated.
A rating from 1 to 4 will be assigned automatically based on your choice. (Additional details available in the Dropdown Details and ECD Band Calculation tabs.)

Given the risk control band for each fume hood, the following flows are required for each hood by ANSI Z9.5:

Hazard - Enter the exposure limit for the peak hazard contained by ECD	Quantity - Enter the total volume of all hazards	Generation Rate - Enter the peak generation rate for any hazard contained by ECD	Generation Method Peak generation method for any hazard contained by ECD	Generation Location Peak generation location for any hazard contained by ECD	Change Dynamics Frequency of change in the ECD	Housekeeping General order and cleanliness of the lab	ECD Risk Rating	ECD Risk Control Band	Minimum Fume Hood ACH Requirement based on ANSI Z9.5	Minimum Fume Hood Flow (cfm) Requirement based on ANSI Z9.5	Maximum Fume Hood Flow Rate (cfm) permitted to avoid turbulence
5-50 ppm or 20-250 mg/m3	1-500 ml or 1-100 g	<0.1 lpm (e.g., evaporation)	Manual	Well contained by ECD/Very close to capture device	1 change/month	Some Clutter	38	3	250	71	600
2	2	1	1	1	2	1					

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LVRA Tool

SMART LABS TOOLKIT

- Correct Pathway for the Life Sciences Lab: Recommended ACHs

After the survey information for each ECD is entered below in Step 3, the maximum value will be populated here.

Ventilation Effectiveness	Maximum Risk Control Band from ECD survey	Lab Environment Risk Control Rating
Effective	3	70
1	3	2

Given your lab environment risk control band, the following room flows are recommended by ASHRAE Laboratory Ventilation Design Levels:

Recommended ACH (Unoccupied)	Recommended ACH (Occupied)
3	6

conversion to cfm

Recommended Unoccupied Room Flows (cfm)	Recommended Occupied Room Flows (cfm)
500	1000

These are the recommended **minimum ventilation rates** your lab will need to operate at to adequately mitigate risk during occupied and unoccupied modes. **These must be validated as effective before changes are made.**

Given the risk control band for each fume hood, the following flows are required for each hood by ANSI Z9.5:

Minimum Fume Hood ACH Requirement based on ANSI Z9.5	Minimum Fume Hood Flow (cfm) Requirement based on ANSI Z9.5	Maximum Fume Hood Flow Rate (cfm) permitted to avoid turbulence
250	71	600

Given the ventilation requirements for all fume hoods within the lab, the following ventilation rates are recommended:

Minimum Room ACH required by fume hoods based on ANSI Z9.5	Maximum Room ACH based on fume hood opening designated
0	4

conversion to ACH included for reference

Sum of Minimum Fume Hood Flow Requirements (cfm) for adequate containment	Sum of Maximum Fume Hood Flows (cfm) based on face velocity to avoid turbulence
71	600

What does this mean for your lab?

Fume Hood Driven?	No

By comparing requirements for ECDs and recommendations for the lab environment, the following ventilation rates are recommended:

Minimum Room flows (cfm)	Maximum Room flows (cfm)
1000	1000

Minimum flow required to mitgate risk is the largest value between **minimum ventilation required for ECDs** and recommended **occupied ventilation.**

Maximum flow permitted to avoid turbulence is the largest value between **maximum ventilation permitted for ECDs** and recommended **occupied ventilation.**

LVRA Tool

Weighted Calculations for ECD Survey

How it Works

This is a reference sheet only; no data entry is required.
This sheet describes how the ECD weighted risk score is calculated.

1. Ratings, on a scale of 1 to 4, are inputted for each evaluation criteria in ECD Survey tab. (Ratings in table below represent maximum values.)

2. Each rating is weighted by the associated weight multiple in this table to calculate weighted risk score. The sum of these scores is the **Total Weighted Risk Score**.

3. The Total Weighted Risk Score is used to determine the appropriate Risk Control Band from the Risk Score ranges in the table below. Tolerance level is determined by the organization's tolerance for risk. The table below is used as a reference for the ECD Risk Control Band designated for the weighted risk score calculated in the Survey Entry Tab.

ECD Parameter Rating and Weighting Table

Evaluation Criteria	Rating	Weight Multiple	Weighted Risk Score	Sensitivity or Importance
Hazard	4	10	40	43%
Quantity	4	3	12	13%
Potential or Rate of Generation	4	5	20	22%
Method of Generation	4	1	4	4%
Generation Location	4	1	4	4%
Dynamic or Potential for Change	4	2	8	9%
Housekeeping	4	1	4	4%
Totals	**28**	**Total Weighted Risk Score**	**92**	**100%**

Risk Score Range for each Risk Control Band (Based on Tolerance of Risk)

Low Tolerance	Medium Tolerance	High Tolerance	Risk Level
0 - 4.6	0 - 9.2	0 - 18.4	0
4.7 - 9.2	9.3 - 23.0	18.5 - 46.0	1
9.3 - 18.4	24 - 36.8	46 - 64.4	2
18.5 - 50.6	36.9 - 69.0	64.5 - 82.8	3
50.7 - 92.0	70 - 92.0	82.9 - 92.0	4

Total Weighted Risk Score = Sum of weighted risk scores for all evaluation criteria.

LVRA Tool

Weighted Calculations for Lab Survey

How it Works

This is a reference sheet, no entries are required.
It is password protected to prevent unintentional changes that may alter the integrated formulas and calculations in the ECD Survey tab.
To make changes, click "Review" > "Unprotect Sheet" and enter the password **LVRAtool.**

1. Ratings, on a scale of 1 to 4, are inputted for each evaluation criteria in ECD Survey tab. (Ratings in table below represent maximum values.)

2. Each rating is weighted by the associated weight multiple in this table to calculate weighted risk score. The sum of these scores is the **total weighted risk score.**

3. The Total Weighted Risk Score is used to determine the appropriate Risk Control Band from the Risk Score ranges in the table below. Tolerance level is determined by the organization's tolerance for risk. (The default is Medium tolerance).

Lab Environment Rating and Weighting Table

Evaluation Criteria	Rating	Weight Multiple	Weighted Risk Score	Sensitivity or Importance
Hazard	4	14	56	35%
Quantity	4	2	8	5%
Potential or Rate of Generation	4	12	48	30%
Method of Generation	4	1	4	3%
Generation Locations	4	2	8	5%
ECD Availability	4	1	4	3%
Appropriate ECDs	4	1	4	3%
Ventilation Effectiveness (V_{eff})	4	3	12	8%
Dynamic or Potential for Change	4	2	8	5%
Housekeeping	4	1	4	3%
Maximum ECD	4	1	4	3%
Totals	44	Total Weighted Risk Score	160	100%

Risk Score Range for each Risk Control Band (based on Tolerance level)

Low Tolerance	Medium Tolerance	High Tolerance	Risk Level
0 - 8.0	0 - 24.0	0 - 40.0	0
8 - 16.0	25 - 52.0	41 - 80.0	1
17 - 32.0	53 - 80.0	81 - 112.0	2
33 - 88.0	81 - 108.0	113 - 144.0	3
89 - 160.0	109 - 160.0	145 - 160.0	4

Total Weighted Risk Score = Sum of weighted risk scores for all evaluation criteria.