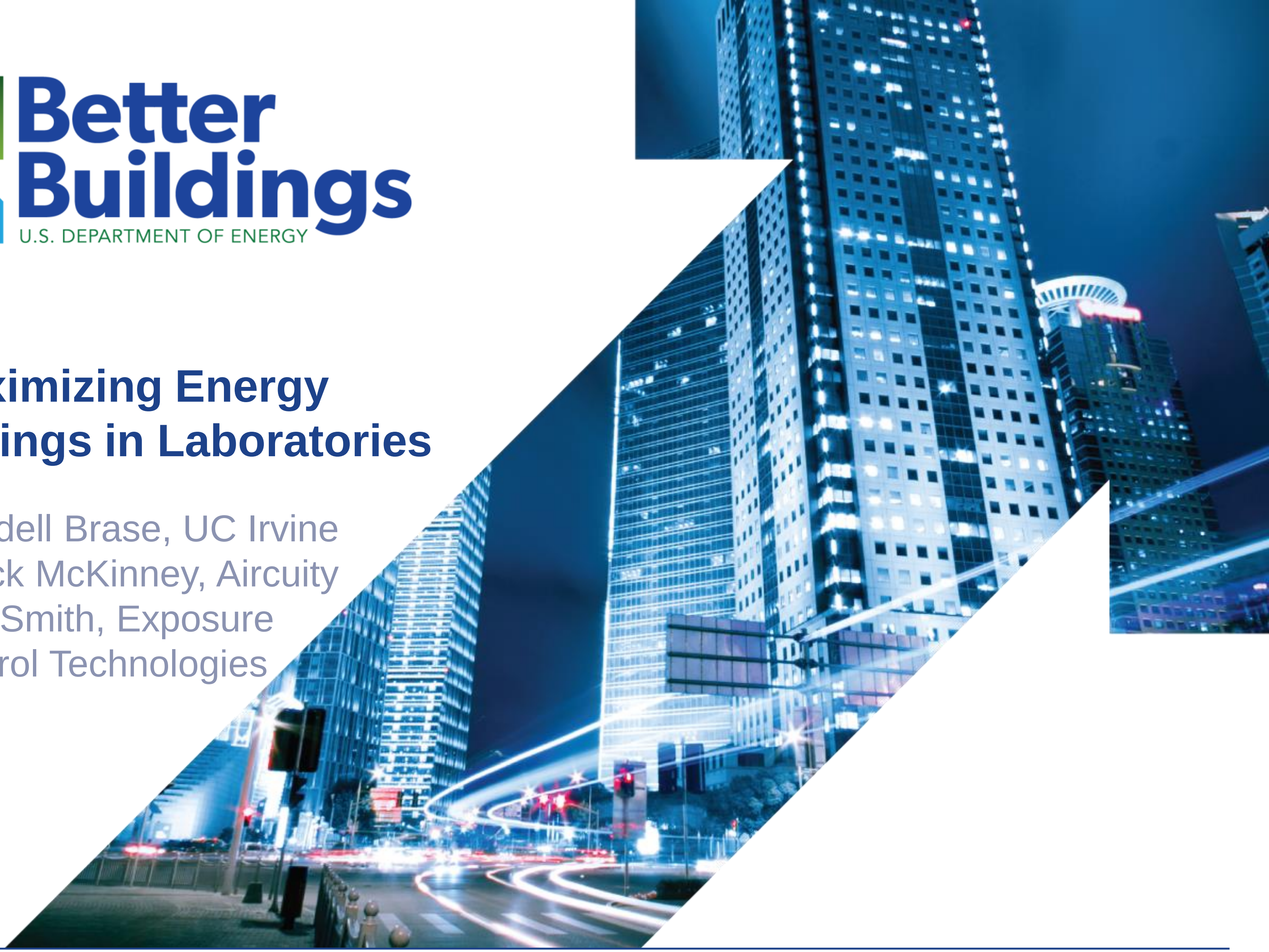
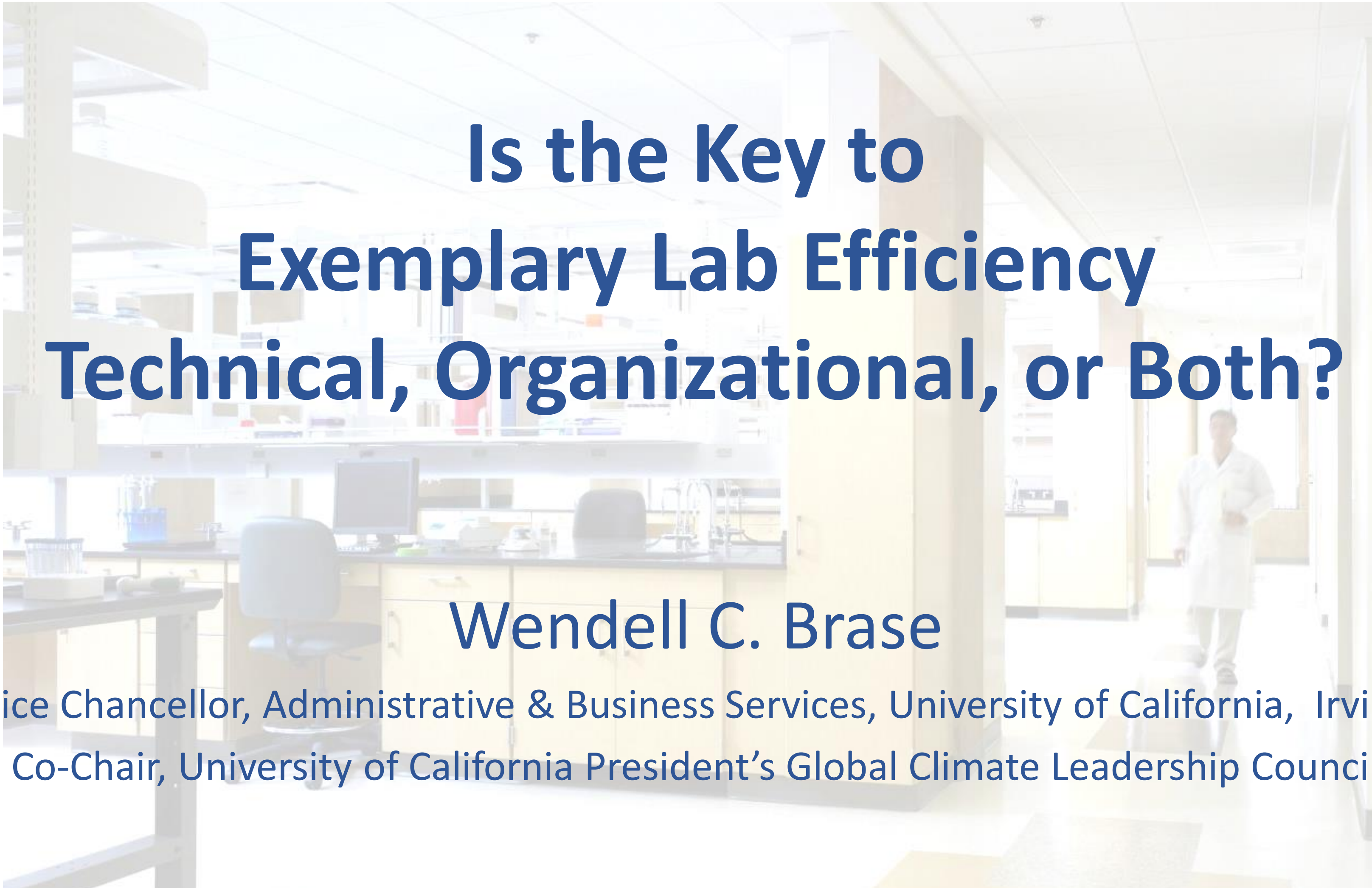
Better Buildings
U.S. DEPARTMENT OF ENERGY

Maximizing Energy Savings in Laboratories

Wendell Brase, UC Irvine
Chuck McKinney, Aircuity
Tom Smith, Exposure Control Technologies



U.S. DEPARTMENT OF ENERGY



Is the Key to Exemplary Lab Efficiency Technical, Organizational, or Both?

Wendell C. Brase

Vice Chancellor, Administrative & Business Services, University of California, Irvine

Co-Chair, University of California President's Global Climate Leadership Council

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Smart Building

Just enough energy at just the right time

How:

– Challenge all accepted design practices
– Use software and sensors to make building systems dynamic and "smart"

Smart Lab Key Elements

1. Retrofit constant volume to variable-air volume
2. Optimize safe air-change rates
3. Improve lighting efficiency
4. Optimize exhaust fan discharge airspeed
5. Reduce pressure drops throughout system
6. Optimize fume hood standby ventilation
7. Continuously commission

Smart Labs Resources

- Boston Green Labs Symposium Videos
  http://green.harvard.edu/campaign/green-labs-symposium

- UC Irvine Smart Labs Initiative
  http://www.ehs.uci.edu/programs/energy/

Critical-Path Steps to Exemplary Performance

1. Get the organizational culture ready
2. Adopt a challenging goal
3. Understand true scale of the challenge
4. Develop scalable strategy
5. Adopt interim milestones
6. Governing board/leadership alignment and support
7. “Mainstream” delegated responsibilities
8. Staff with appropriate talent
9. Build a team
10. Foster breakthrough thinking
11. Prepare to weather setbacks
12. Dedicated source of program financing
13. Simple project approval process
14. Pilot new concepts initially
15. Use “information layer” to verify and sustain performance

Organizational Development

- Get the organizational culture ready!
- Build a team
- Foster breakthrough thinking
  - Challenge status quo
  - Question accepted limits
  - Think comprehensively: re-engineer whole systems
- Prepare to weather setbacks

Performance Improvement Resources

- Sustainable Performance Improvement
  http://www.abs.uci.edu/resources/sustainable.html

- Survey of Management and Organizational Patterns
  http://www.abs.uci.edu/resources/deptsurvey.html

RESULTS

Where did we start ?

Laboratory Building		BEFORE Smart Lab Retrofit		
Name	Type[1]	Estimated Average ACH	VAV or CV	More efficient than code?
Croul Hall	P	6.6	VAV	~ 20%
McGaugh Hall	B	9.4	CV	No
Reines Hall	P	11.3	CV	No
Natural Sciences 2	P,B	9.1	VAV	~20%
Biological Sciences 3	B	9.0	VAV	~30%
Calit2	E	6.0	VAV	~20%
Gillespie Neurosciences	M	6.8	CV	~20%
Sprague Hall	M	7.2	VAV	~20%
Hewitt Hall	M	8.7	VAV	~20%
Engineering Hall	E	8.0	VAV	~30%
Averages		**8.2**	**VAV**	**~20%**

- All of these are existing buildings
- Multiple types of science represented
- Starting air change rates often higher than we expected
- Mix of mechanical system designs
- Most buildings were already very efficient.

Type: P = Physical Sciences, B = Biological Sciences, E = Engineering, M = Medical Sciences

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UC Irvine's Smart Labs Initiative

Laboratory Building		BEFORE Smart Lab Retrofit			AFTER Smart Lab Retrofit		
Name	Type [1]	Estimated Average ACH	VAV or CV	More efficient than code?	kWh Savings	Therm Savings	Total Savings
Croul Hall	P	6.6	VAV	~ 20%	48%	40%	40%
McGaugh Hall	B	9.4	CV	No	57%	66%	59%
Reines Hall	P	11.3	CV	No	67%	77%	69%
Natural Sciences 2	P,B	9.1	VAV	~20%	48%	62%	50%
Biological Sciences 3	B	9.0	VAV	~30%	45%	81%	53%
Calit2	E	6.0	VAV	~20%	46%	78%	58%
Gillespie Neurosciences	M	6.8	CV	~20%	58%	81%	70%
Sprague Hall	M	7.2	VAV	~20%	71%	83%	75%
Hewitt Hall	M	8.7	VAV	~20%	58%	77%	62%
Engineering Hall	E	8.0	VAV	~30%	59%	78%	69%
Averages		**8.2**	**VAV**	**~20%**	**57%**	**72%**	**61%**

Type: P = Physical Sciences, B = Biological Sciences, E = Engineering, M = Medical Sciences

Unforeseen Benefits of Smart Labs Retrofits

- Deferred maintenance
- Safety/air quality longitudinal data
- No need for periodic commissioning
- Data to understand and target more opportunities
- Reduced wear and failure rates for fan motors and bearings
- Cleaner air in laboratories

CFO Concerns

- Low-risk investment
- Consistency of costs and benefits
- Sustainable performance
- Debt-coverage ratio

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Presented at U.S. Department of Energy's 2015 Better Buildings Summit
Session: Maximizing Energy Savings in Laboratories
Wednesday, May 27, 2015

AIRCUITY®

Safe, Smart & Efficient Airside Solutions

Laboratory Energy Saving Solutions

Reducing energy, improving operation and enhancing safety goals

Chuck McKinney, VP Sales & Marketing

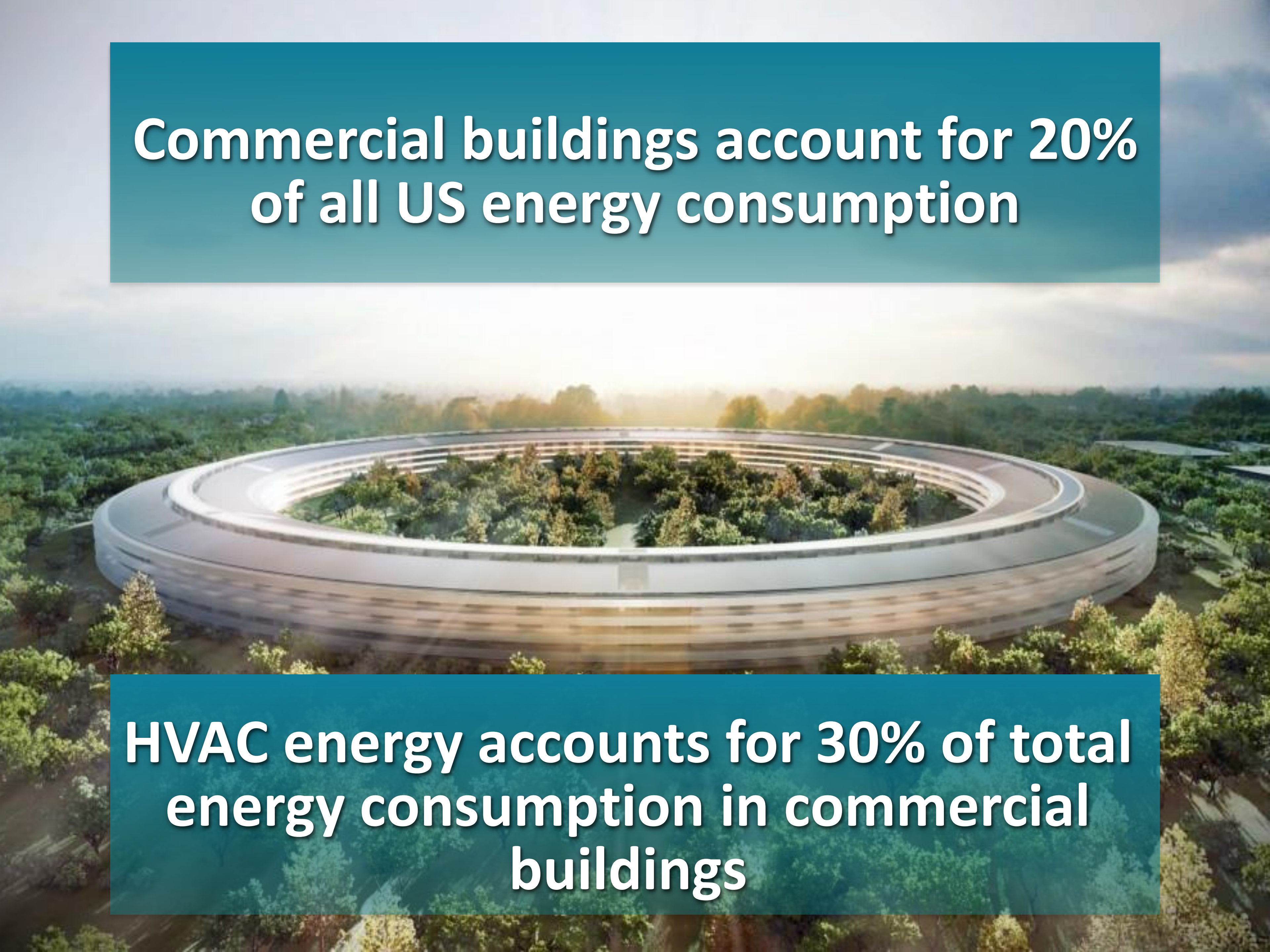
May 27, 2015

Learning Objectives

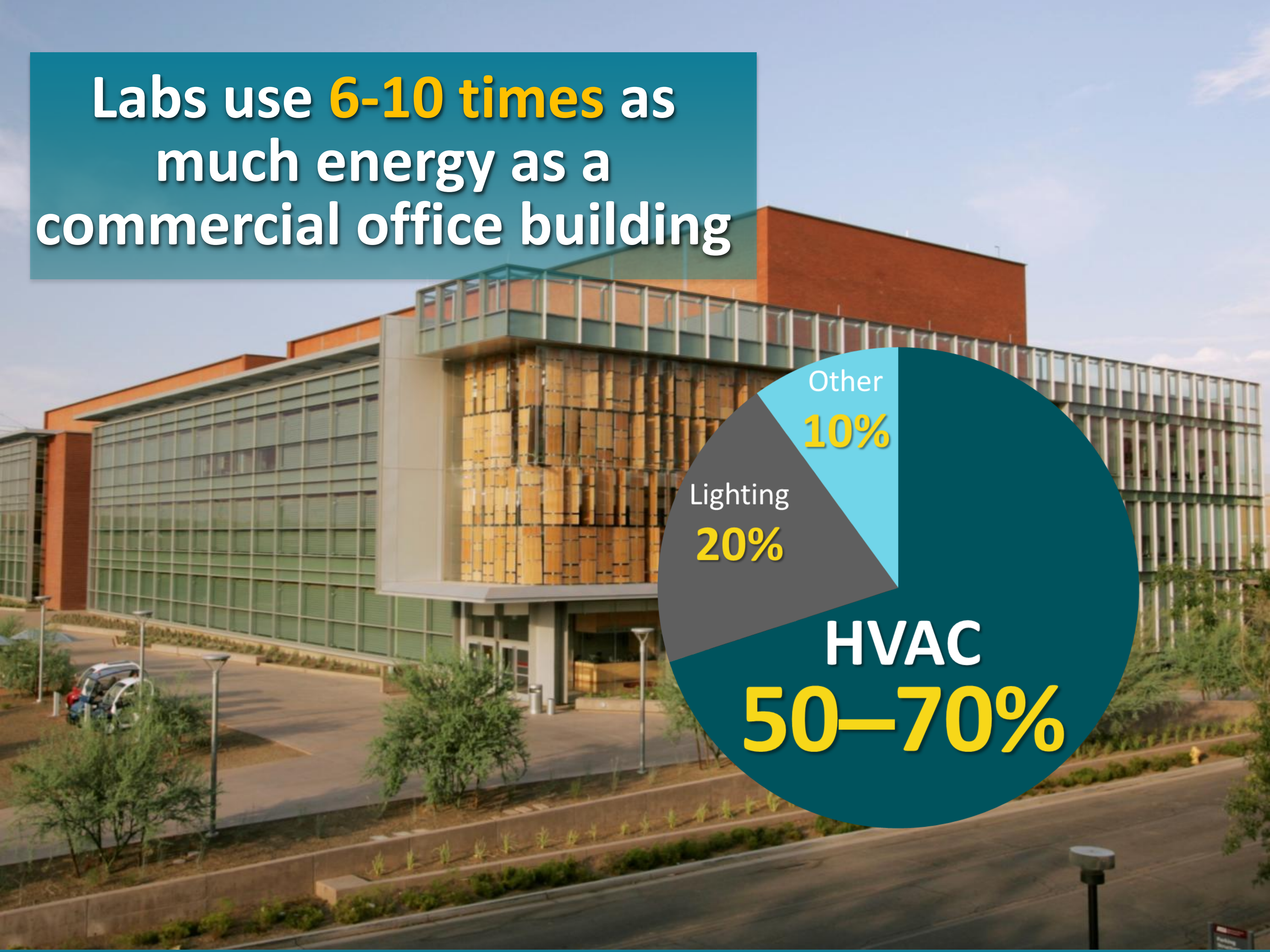
Use ROI analysis to identify candidates for Airside Efficiency

Understand

Airside Efficiency

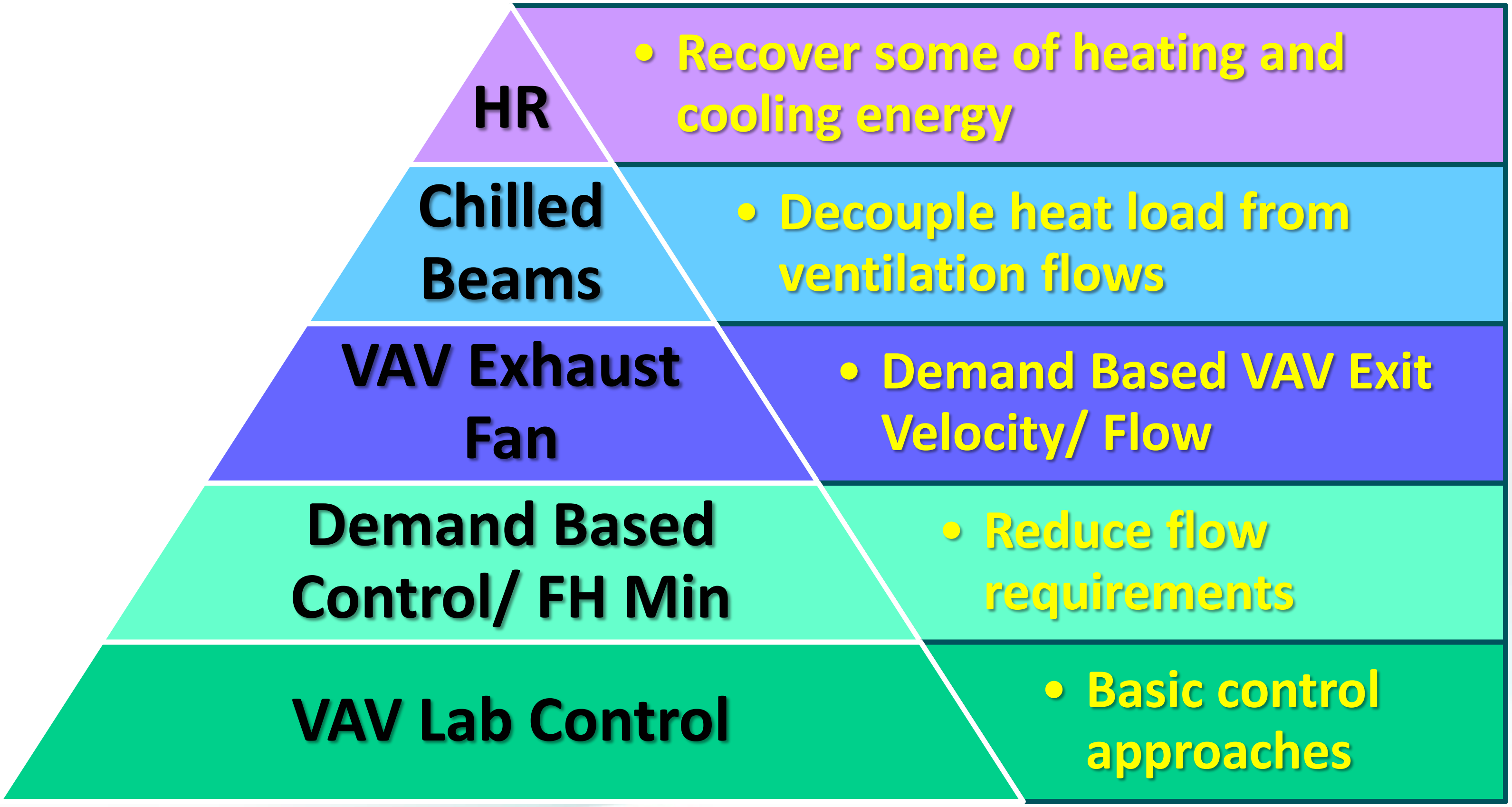

Commercial buildings account for 20% of all US energy consumption
HVAC energy accounts for 30% of total energy consumption in commercial buildings

Labs use 6-10 times as much energy as a commercial office building



Holistic Strategies for Increased Savings

- **To optimize lab safety, first cost & energy:**
  - Combining systems appropriately is best
  - Use a layered or pyramid approach:



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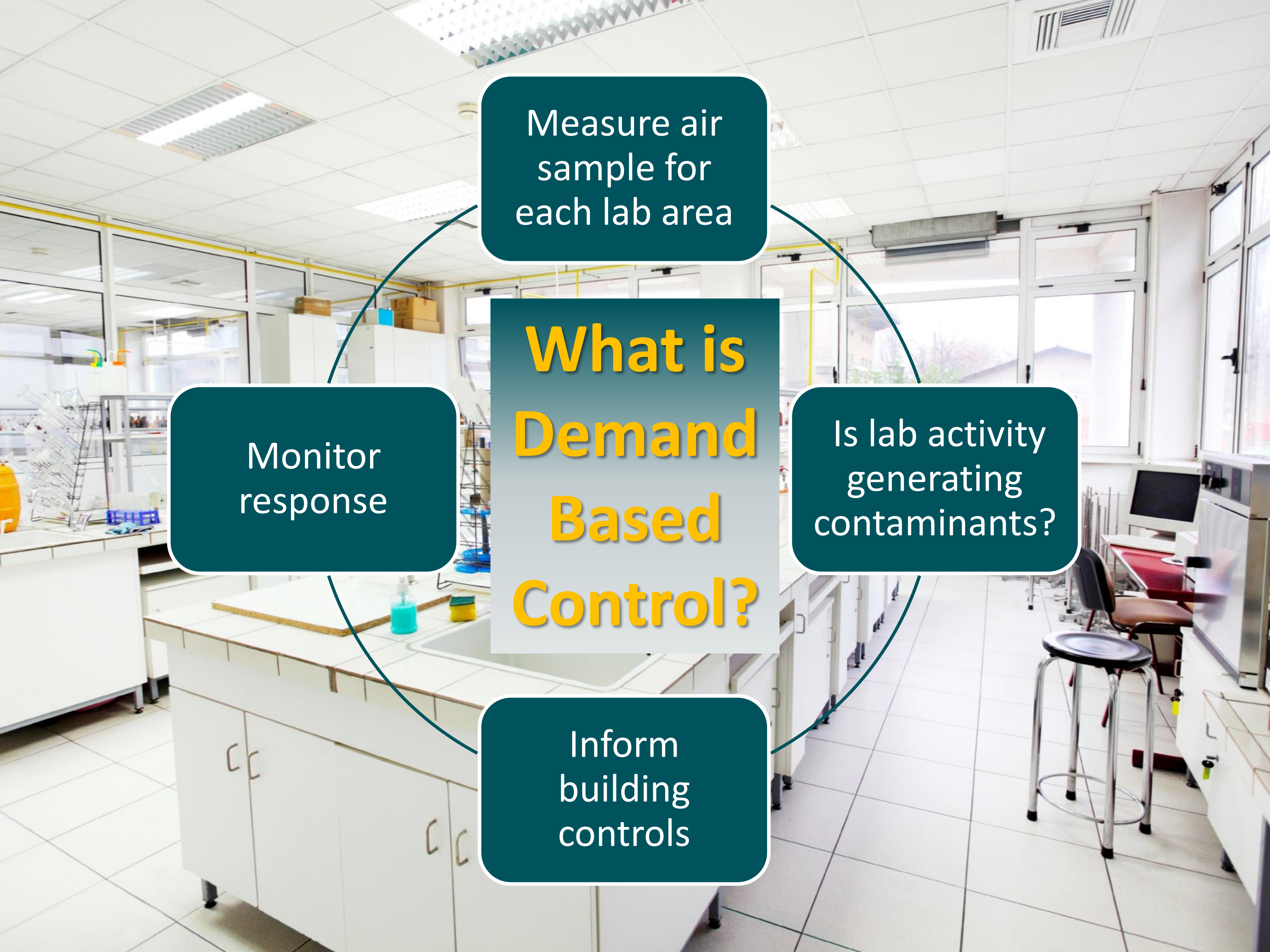
Demand Based Control: adjust air change rates based on IEQ information

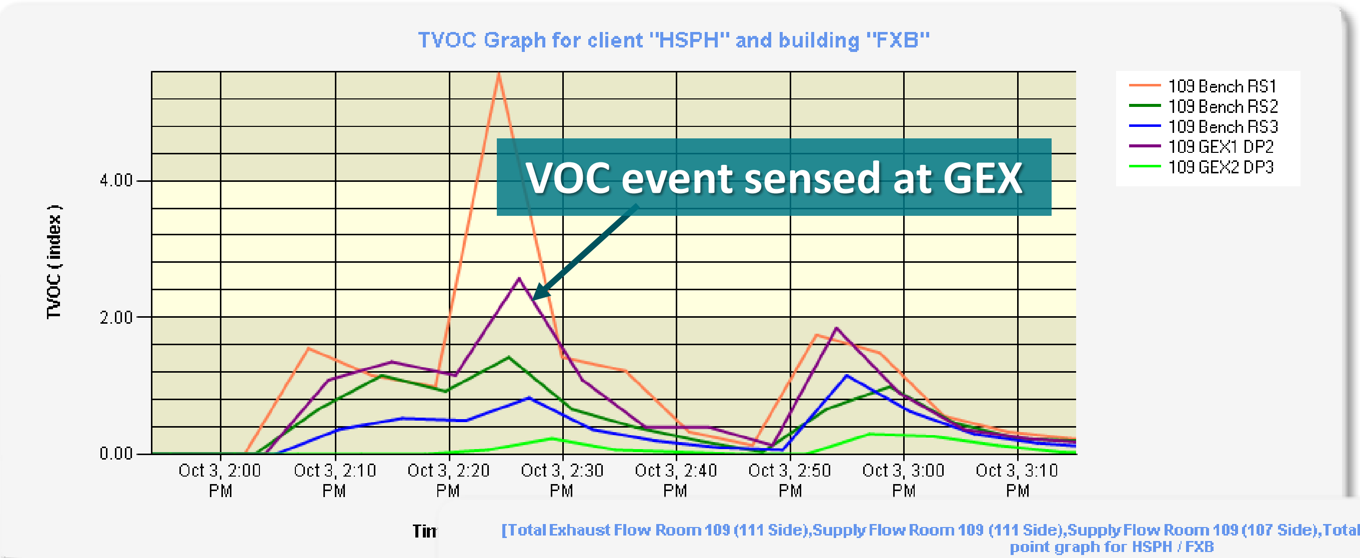
Hood Flows

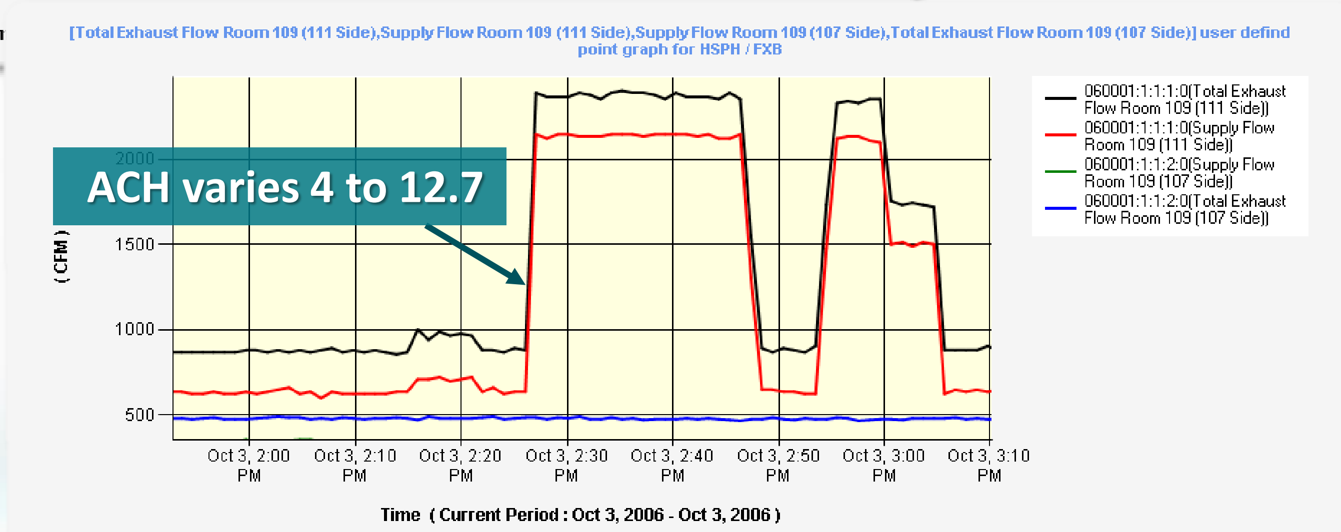
Thermal Load

ACH/Dilution Requirement


What is Demand Based Control?
Measure air sample for each lab area
Is lab activity generating contaminants?
Inform building controls
Monitor response

Normal lab operation with dynamic control





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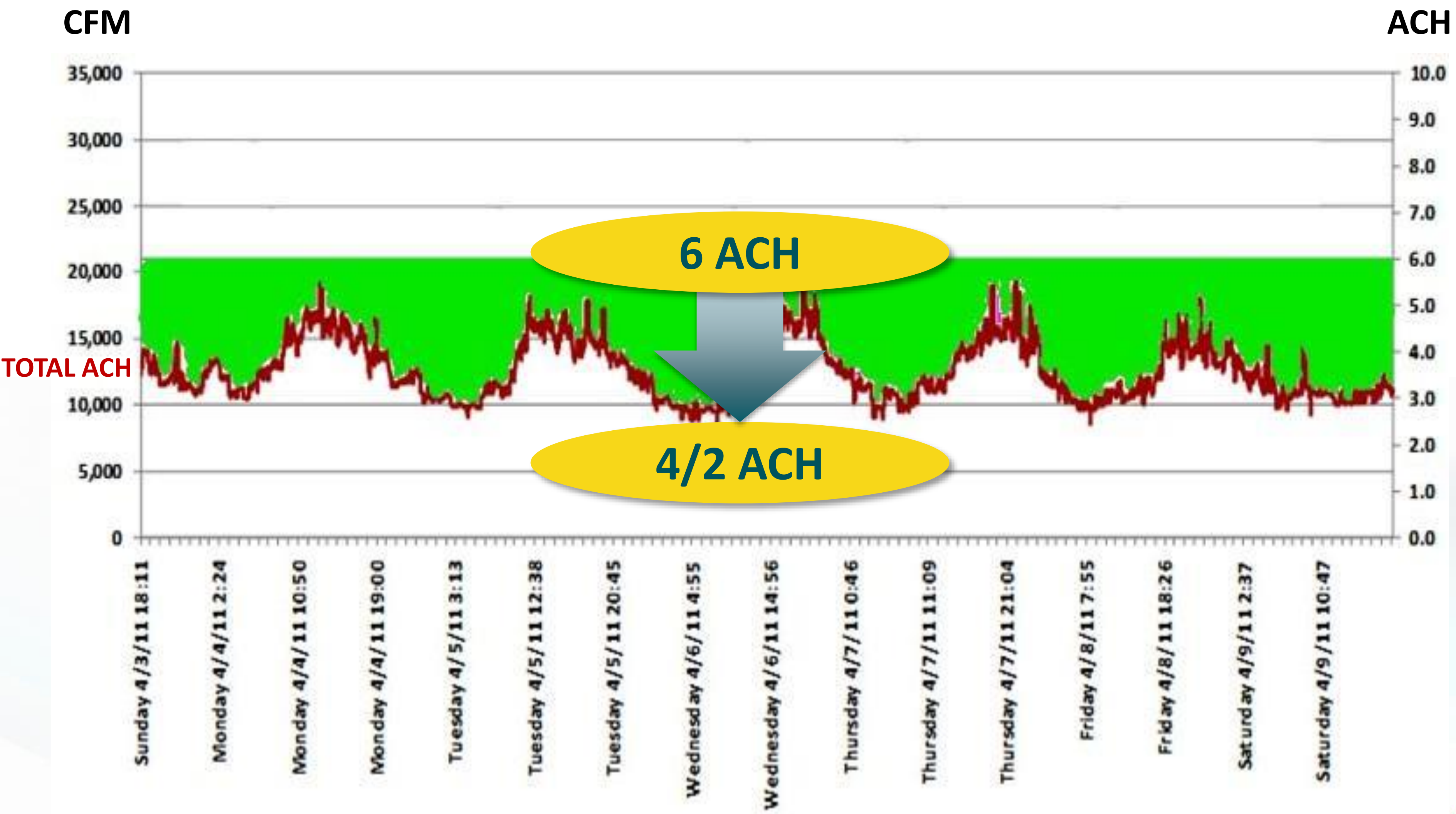
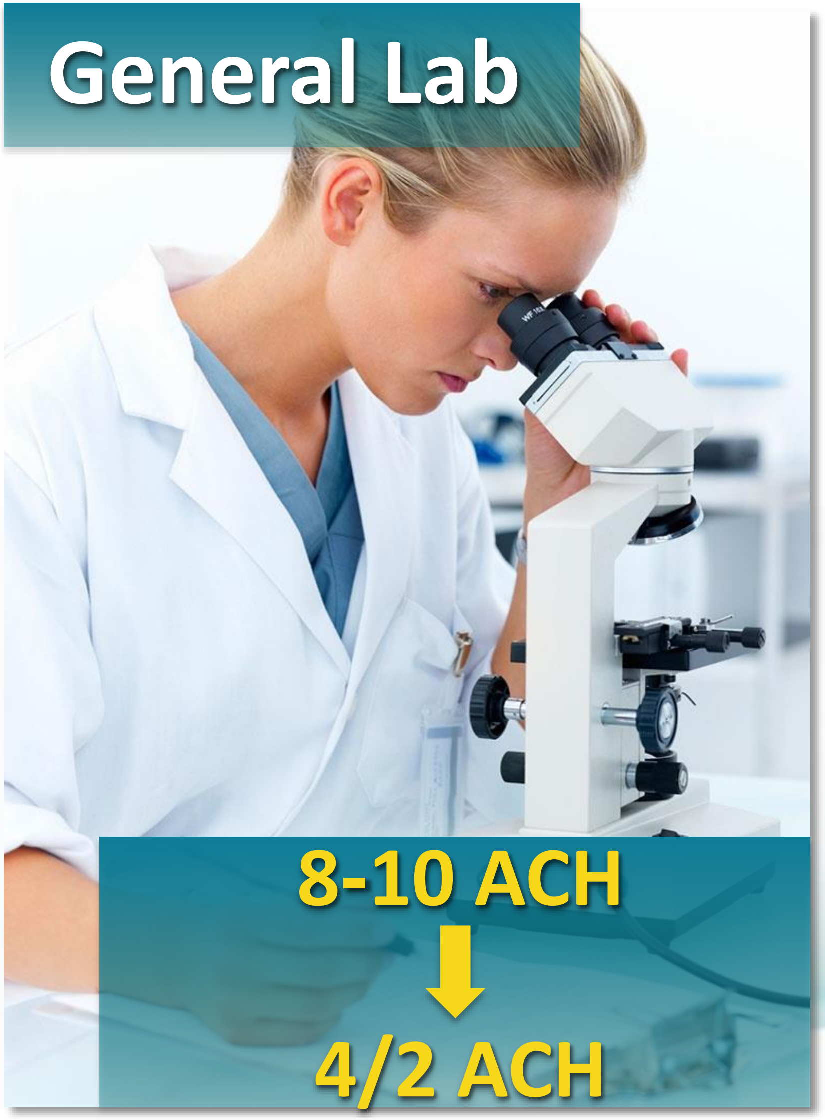
A week of energy savings



The impact of DBC in labs

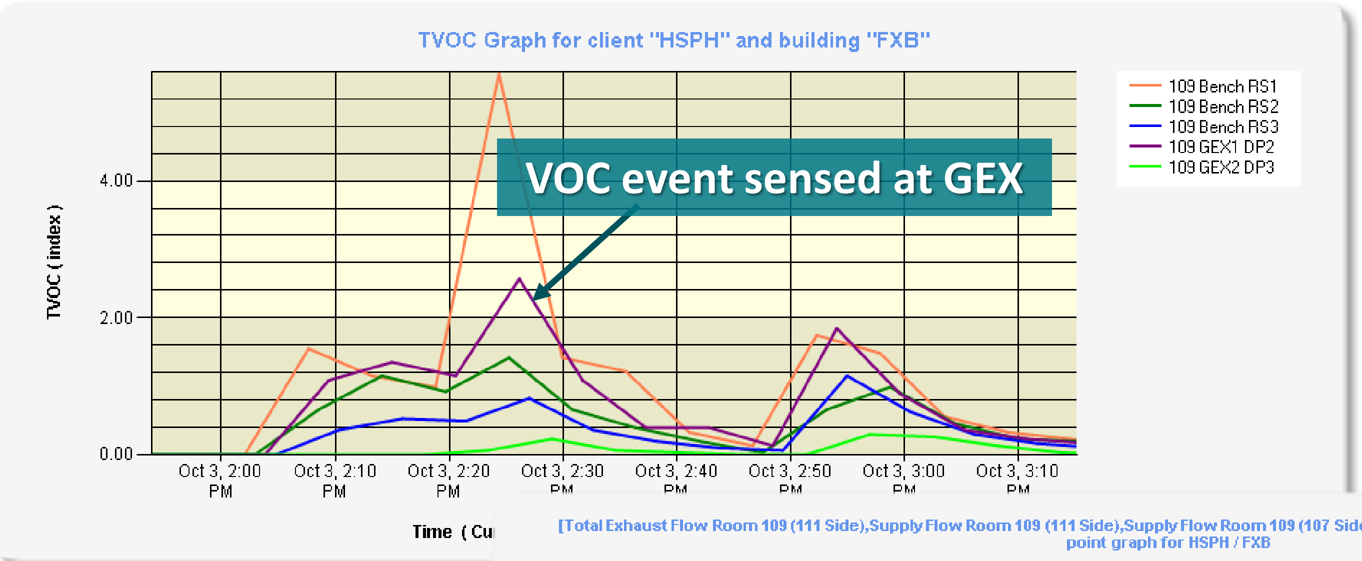


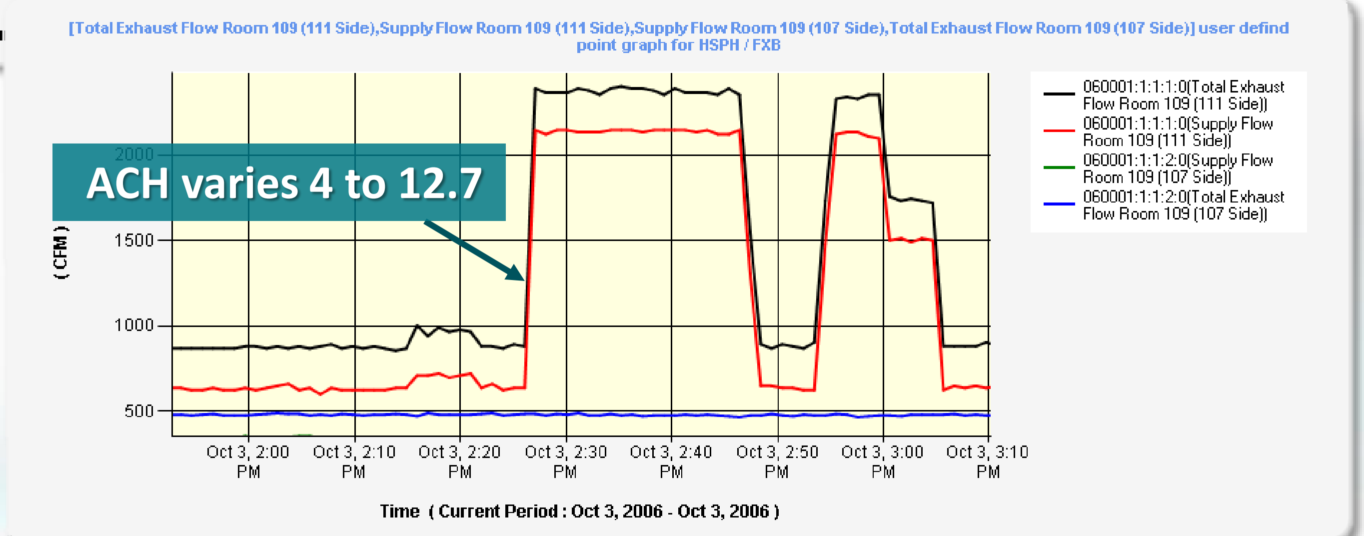
It’s hard to know what’s going on in all labs all the time

"Our goal is to find the sweet spot where we maximize energy savings without compromising safety."

Marc Gomez
Assistant Vice Chancellor
Facilities Management/
Environmental Health & Safety
University of California, Irvine

DBC: because one ACH is never correct





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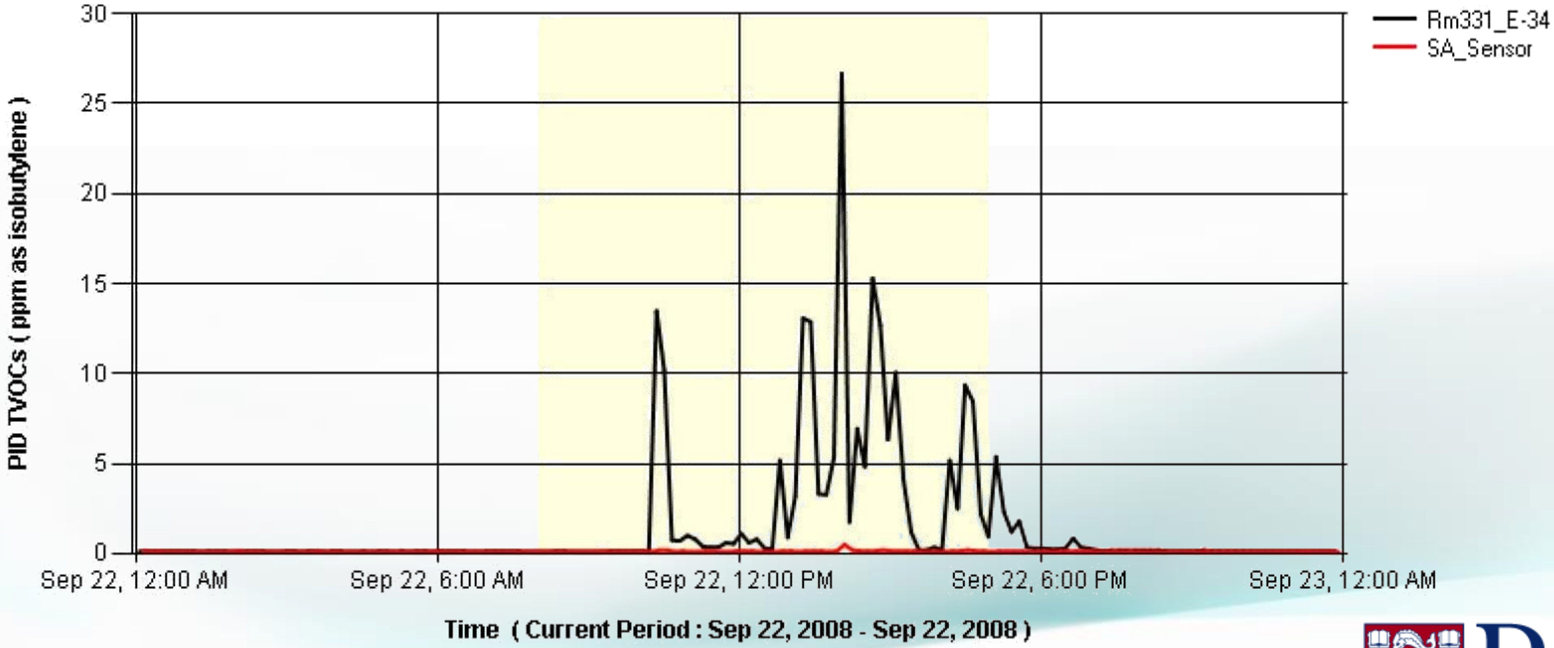
Detection of improper lab practices

A lab researcher sticks the exhaust of his mass-spec into the local snorkel exhaust then pinches it off with the blast gate, creating elevated TVOC levels in the lab.

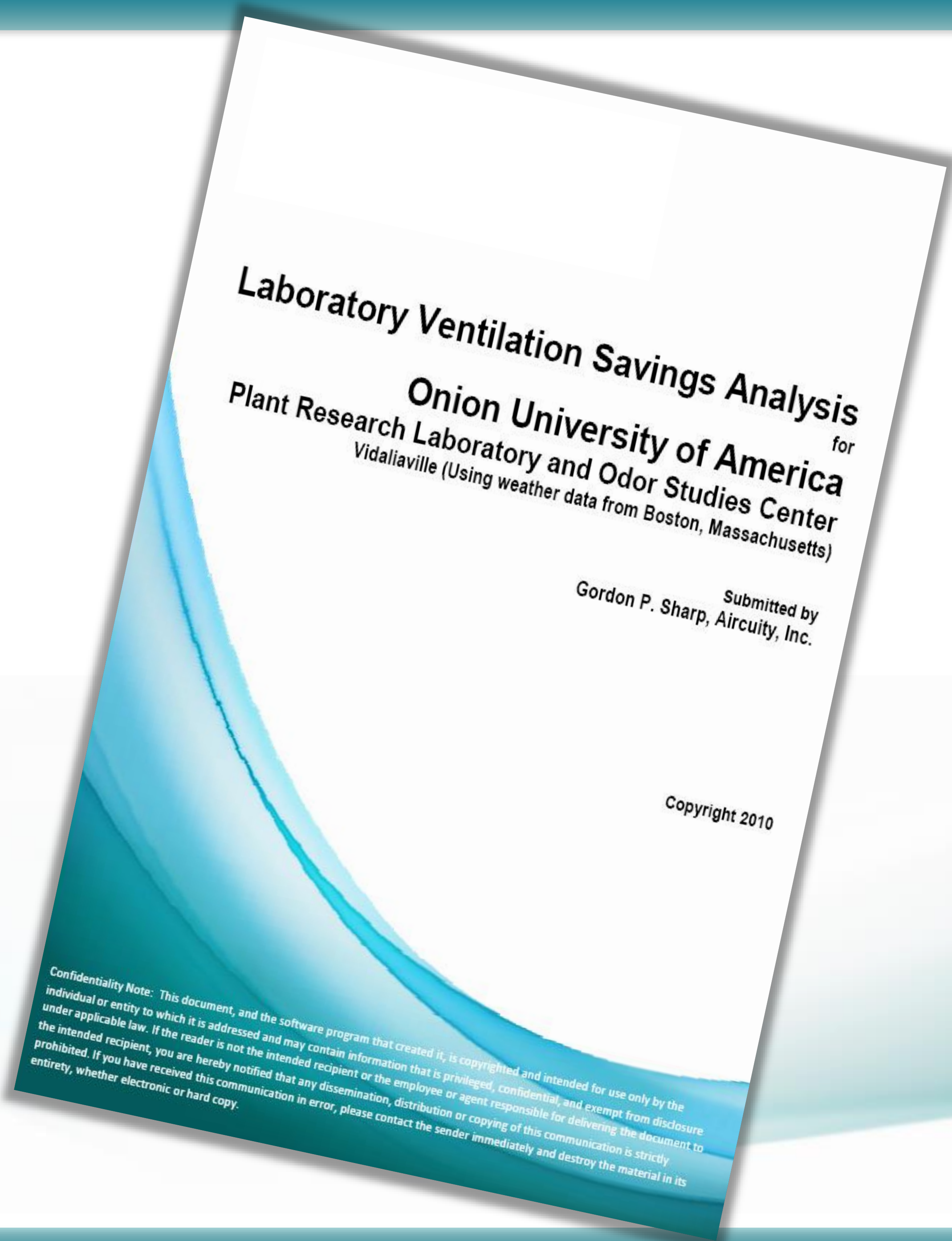


Penn
University of Pennsylvania

Information can drive alignment…

Energy Analysis & ROI Tool

A report customized for each building's unique conditions


Laboratory Ventilation Savings Analysis

for

Onion University of America

Plant Research Laboratory and Odor Studies Center

Vidaliaville (Using weather data from Boston, Massachusetts)

Submitted by

Gordon P. Sharp, Aircuity, Inc.

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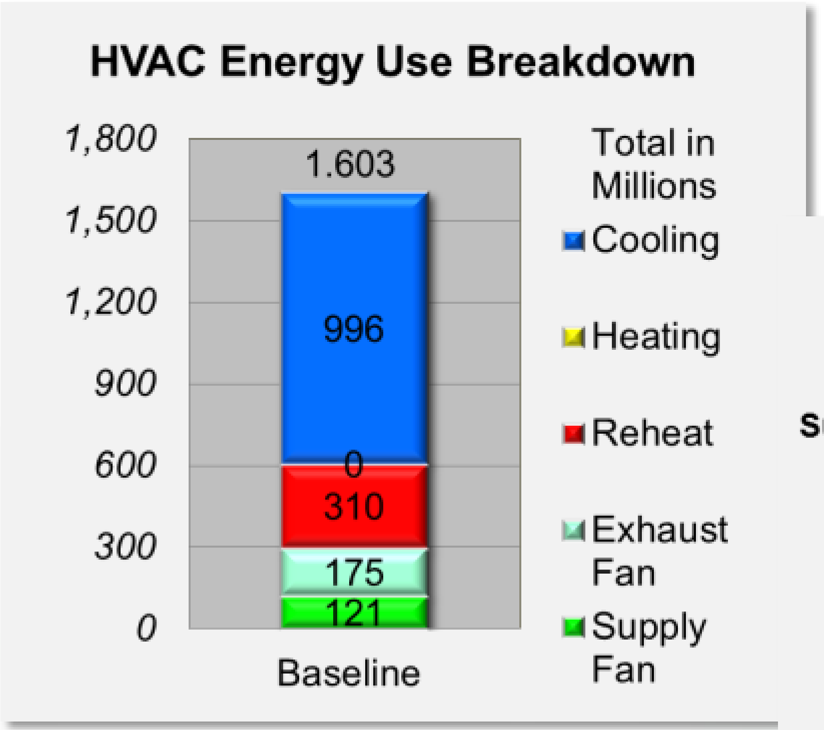
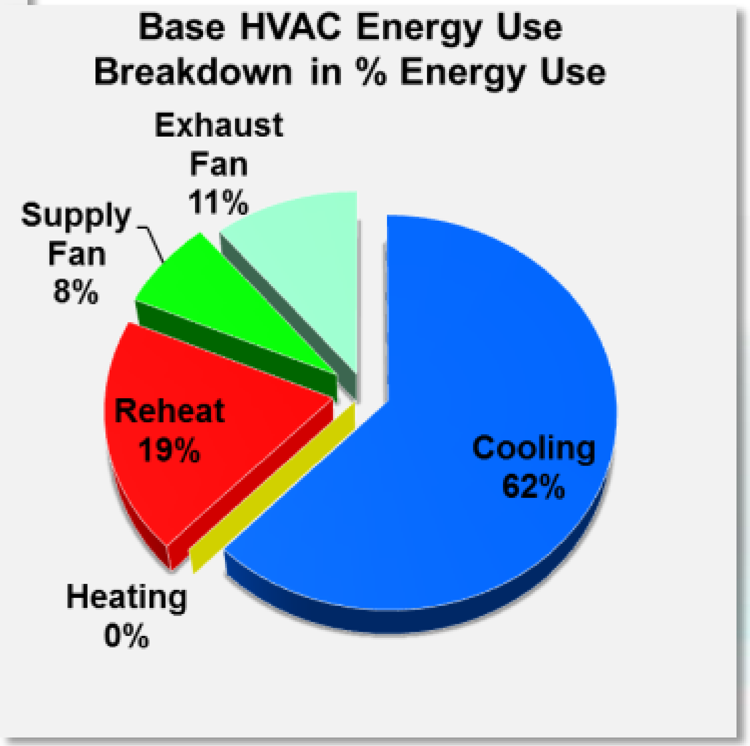
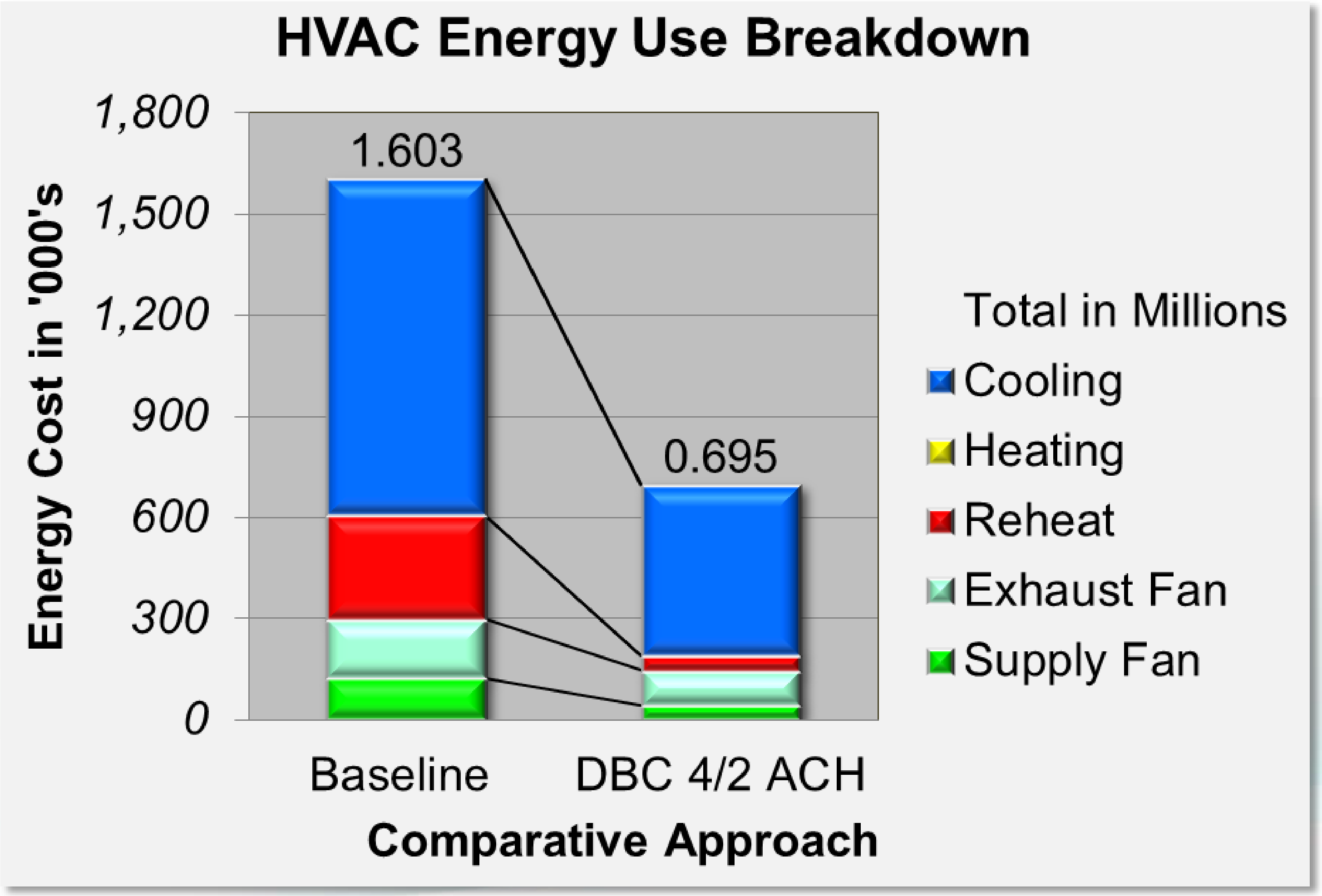
Graphically displays your current energy usage





Compares the results of the status quo versus taking action



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Rice
Masdar Institute
Harvard
California Institute of Technology 1891
Johnson & Johnson
Bristol-Myers Squibb
Arizona State University
The University of Iowa
Princeton University
Beth Israel Deaconess Medical Center
Michigan State University
State University of New York — To Learn — To Search — To Serve — 1948
Université Concordia University
UCI University of California, Irvine
Case Western Reserve University Est. 1826
FDA
Cal Poly
Texas Children's Hospital
Dartmouth
Kansas Bioscience Authority
Penn University of Pennsylvania
Novartis
Memorial Sloan-Kettering Cancer Center
University of Nebraska Lincoln
UC San Diego
Lilly
Yale University
Aircuity

Thank You!

Safe · Smart · Efficient

AIRCUITY®

Lab Energy & Safety Optimization Process

Deliver Return on Investment with a Lab Ventilation Management Program

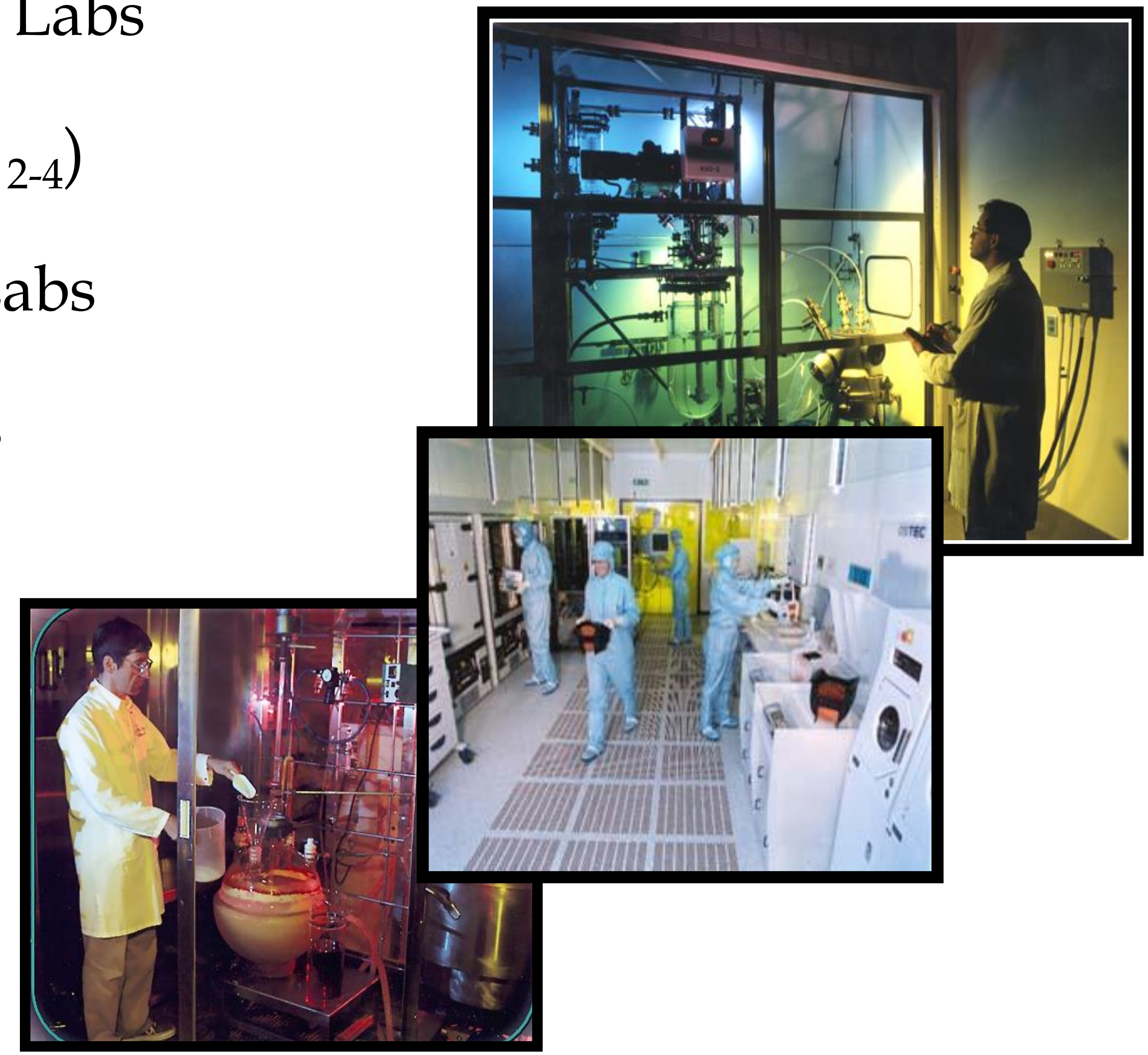
Thomas C. Smith

ECT, Inc.

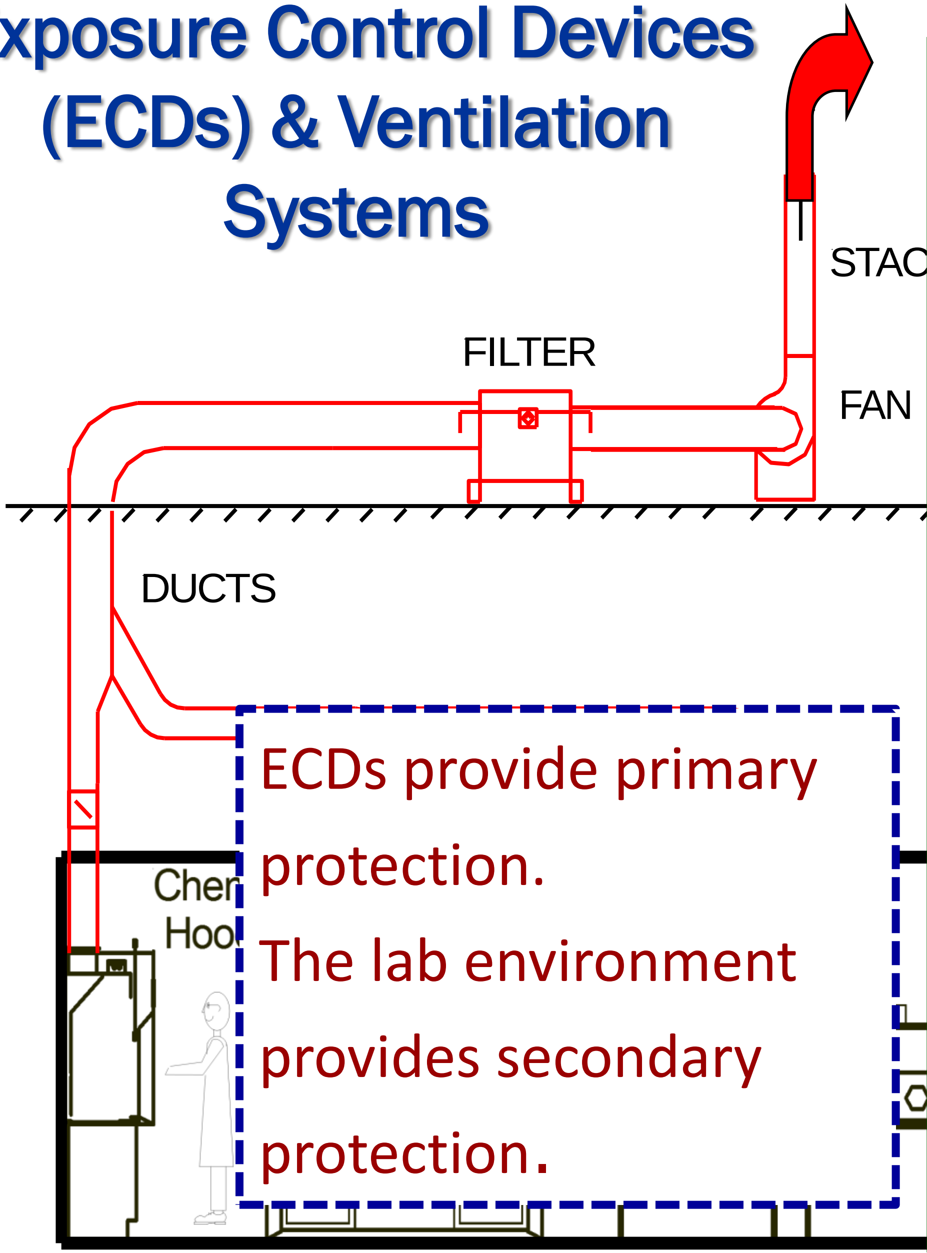
Exposure Control Technologies, Inc.
919-319-4290
tcsmith@labhoodpro.com

Critical Control Environments

- Chemical and Rad Labs
- Biology Labs (BSL $_{2\text{-}4}$)
- Nanotechnology Labs
- Animal Vivariums
- Clean Rooms
- Isolation Suites



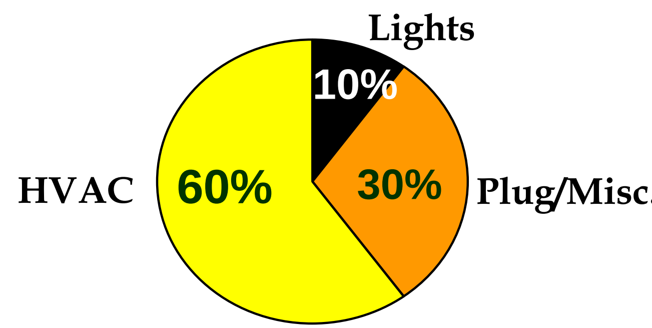
Exposure Control Devices (ECDs) & Ventilation Systems



ECDs provide primary protection.

The lab environment provides secondary protection.

- Laboratory Utilities ≈ $5 to $20 per sq. ft.



- Lab HVAC ≈ $3 to $9 per cfm-yr
- As much as 50% of energy can be wasted by inefficient and ineffective HVAC
- Excess flow can be due to poor design and operation of fume hoods and high air change rates
- 15% - 30% of fume hoods may not meet ANSI standards for performance and many labs do not maintain proper air balance

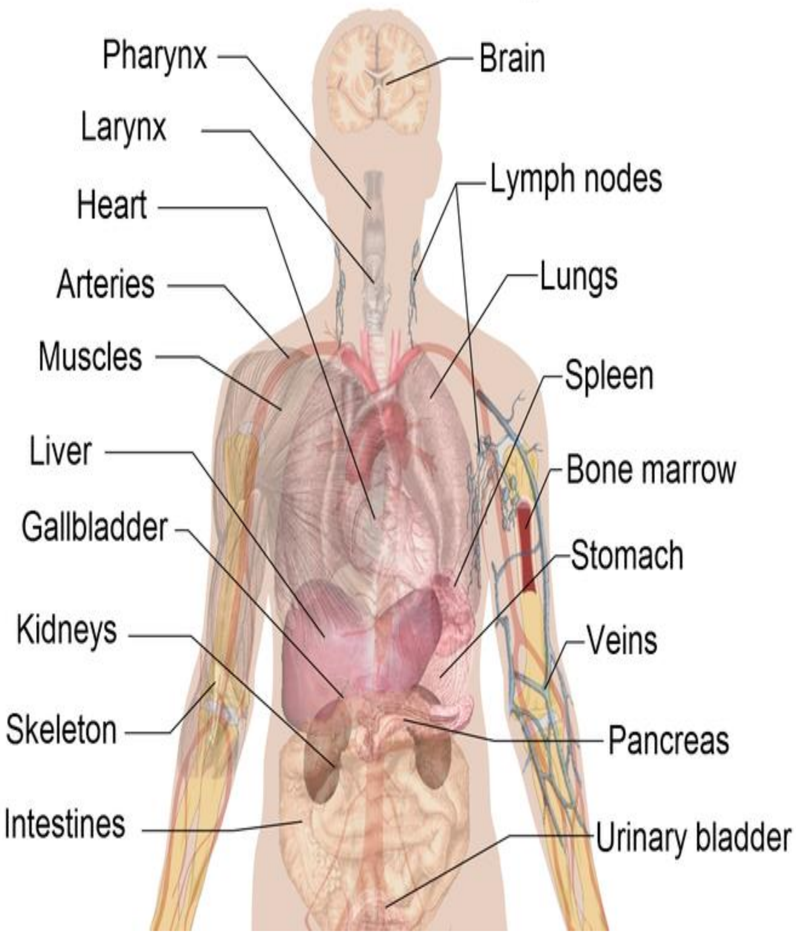
Potential for Adverse Health Effects from Airborne Hazards in Labs

Inhalation Hazards

- Types of Materials
- Toxicity
- Generation Rate
- Concentration
- Duration of Exposure

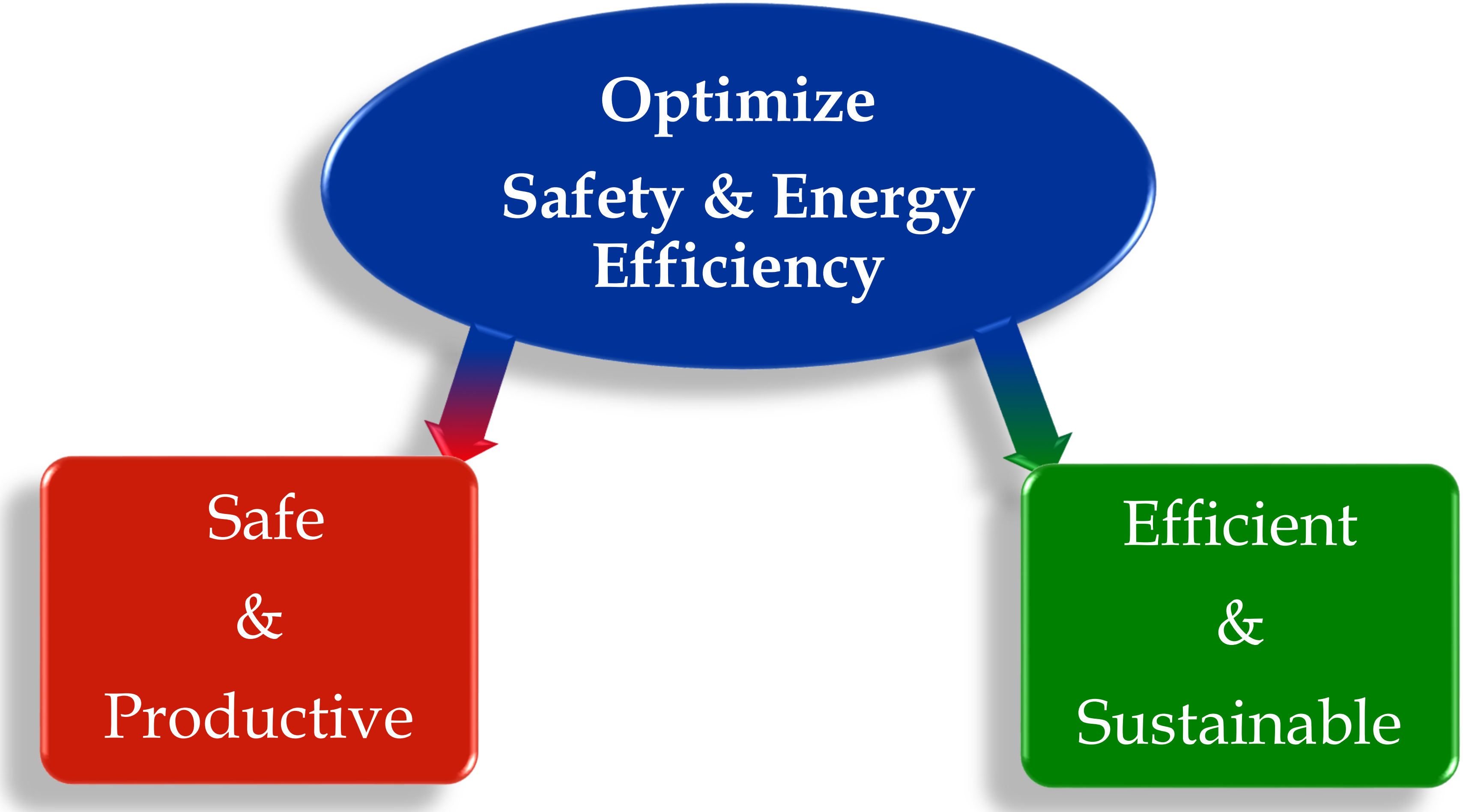
Physical Hazards

- Dermal Exposure
- Fire & Explosion



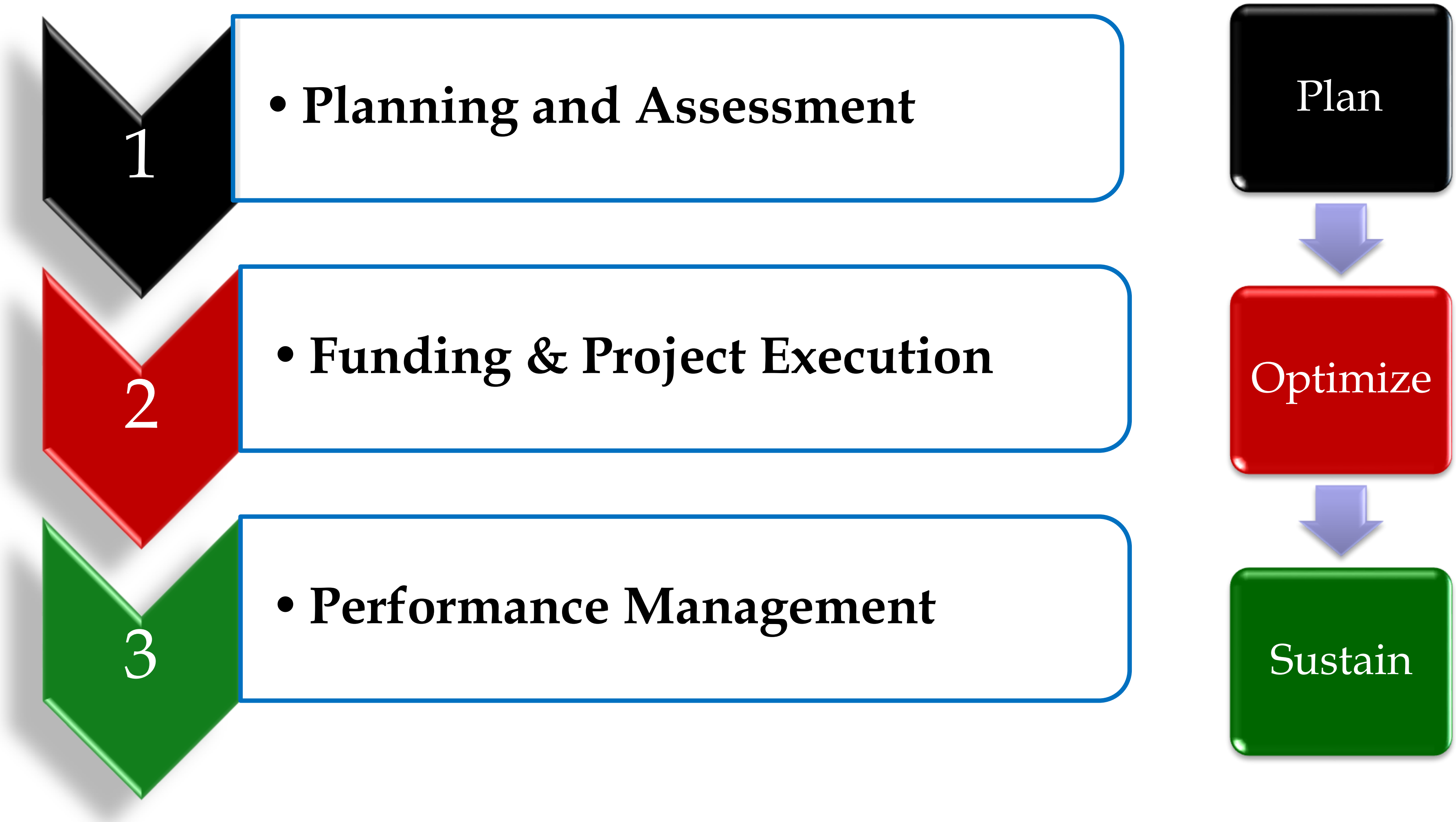
Dose = Concentration x Duration of Exposure

High Performance Laboratories



- Common Objectives • Realistic Goals • Teamwork

Lab Energy & Safety Optimization Process



Lab Energy & Safety Optimization Process

Phase 1 – Planning & Assessment

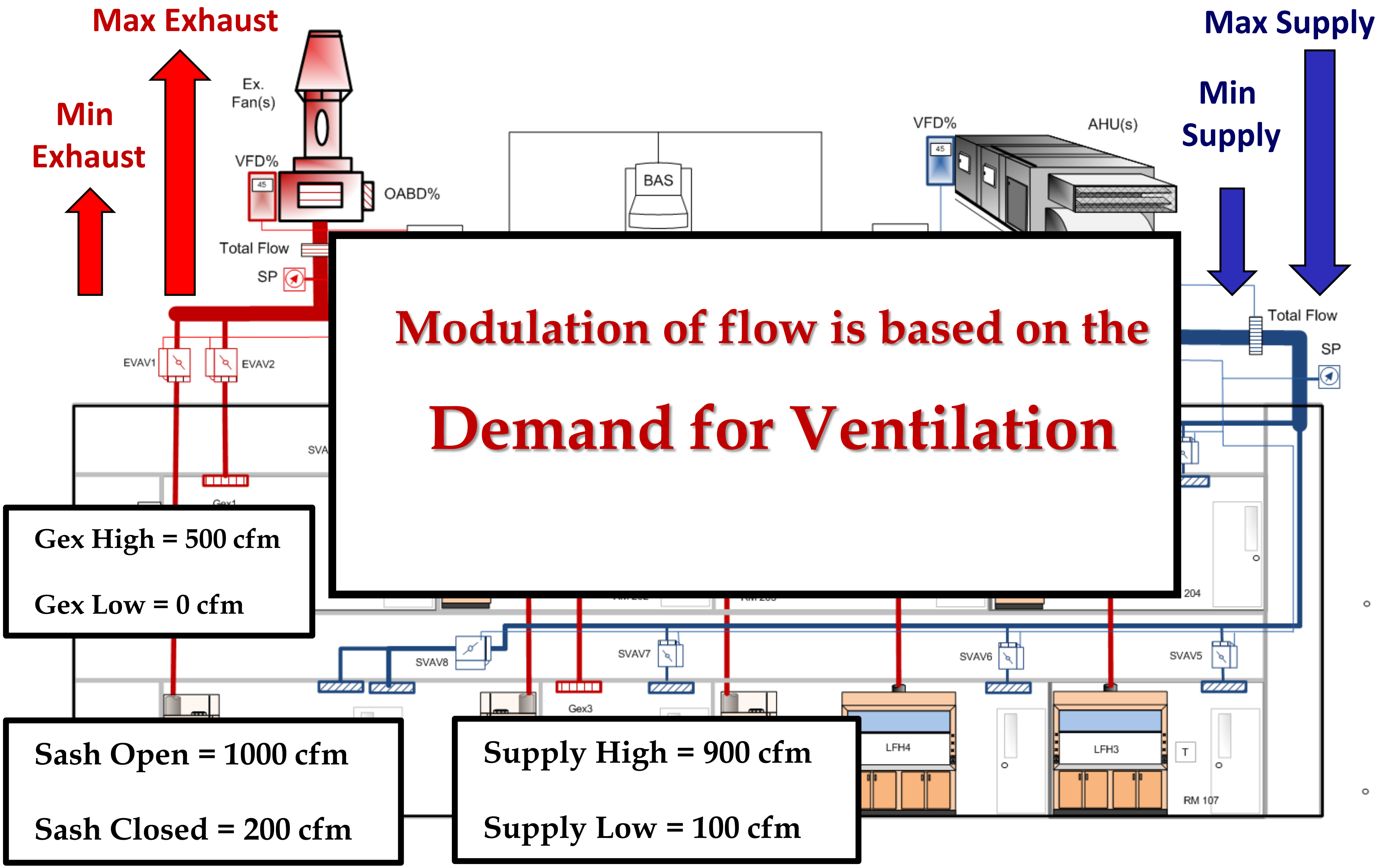
- Interdisciplinary Team
- Lab Energy and Safety Assessment
  - Survey Labs, Hoods and Systems
  - Evaluate the Demand For Ventilation
  - Determine Required Operating Specifications
  - Determine Performance Improvement Measures
  - Predict Energy Savings
  - Determine Scope of Work and Costs
- Prioritize Opportunities by Benefits & ROI

Demand for Ventilation

- **Safety**
  - Hood Exhaust Flow
  - Laboratory Pressurization
  - Dilution (ACH)
- **Comfort & Productivity**
  - Temperature
  - Humidity
- **Occupancy & Utilization**

Minimum flow and range of modulation required to meet the functional requirements of the lab

Laboratory Ventilation System



Determine the Demand For Ventilation and Required Operating Specifications

Laboratory Ventilation Risk Assessment

- **Survey Laboratory Environment**
- **Survey and Inventory Ventilated Devices**
- **Evaluate Hazards & Processes**
- **Categorize Risk Using Control Bands**
- **Establish Appropriate Operating Specifications**
  - Minimum Laboratory ACH
  - Minimum Fume Hood Flow
  - Exhaust Stack Discharge Requirements

Laboratory Ventilation Control Bands

Control Band Parameters

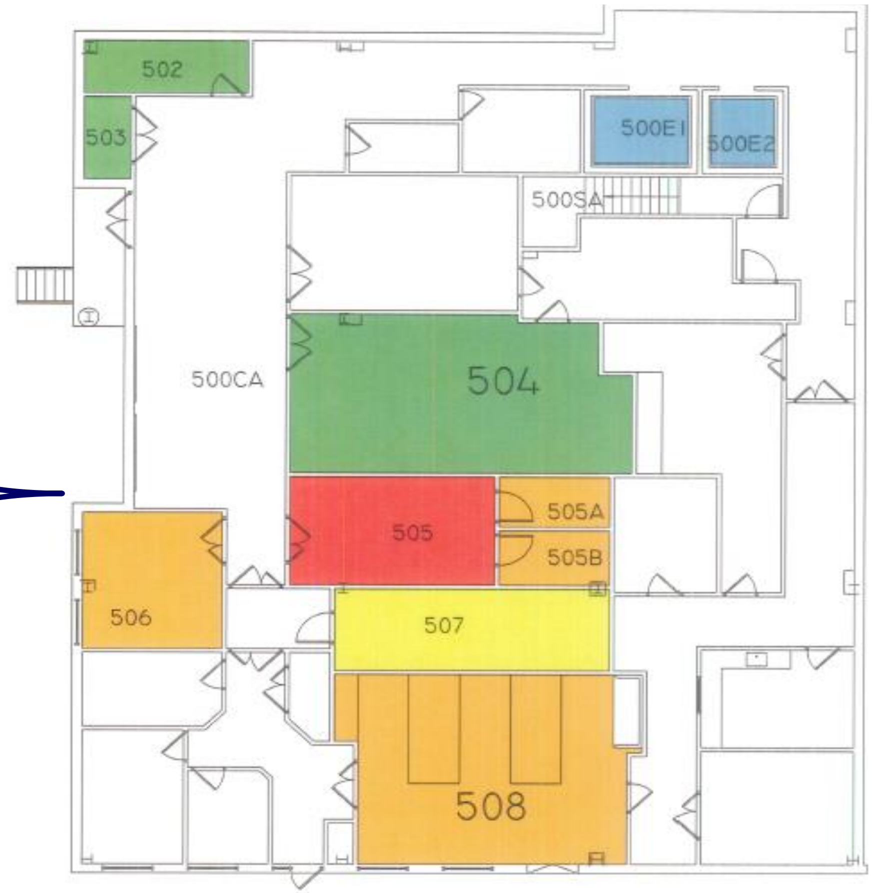
- Chemical Hazard Rating
- Quantity of Hazardous Material
- Chemical Generation Potential
- Method and Duration of Generation
- Generation Source Location(s)
- ECD Availability and Appropriateness
- Potential for Change
- Housekeeping - Lab Practices
- Ventilation Effectiveness (Sweep)

Risk Control Band	Description
0	**Negligible**
1	**Low**
2	**Moderate**
3	**High**
4	**Very High**
5	**Extreme**

Laboratory Ventilation Control Bands

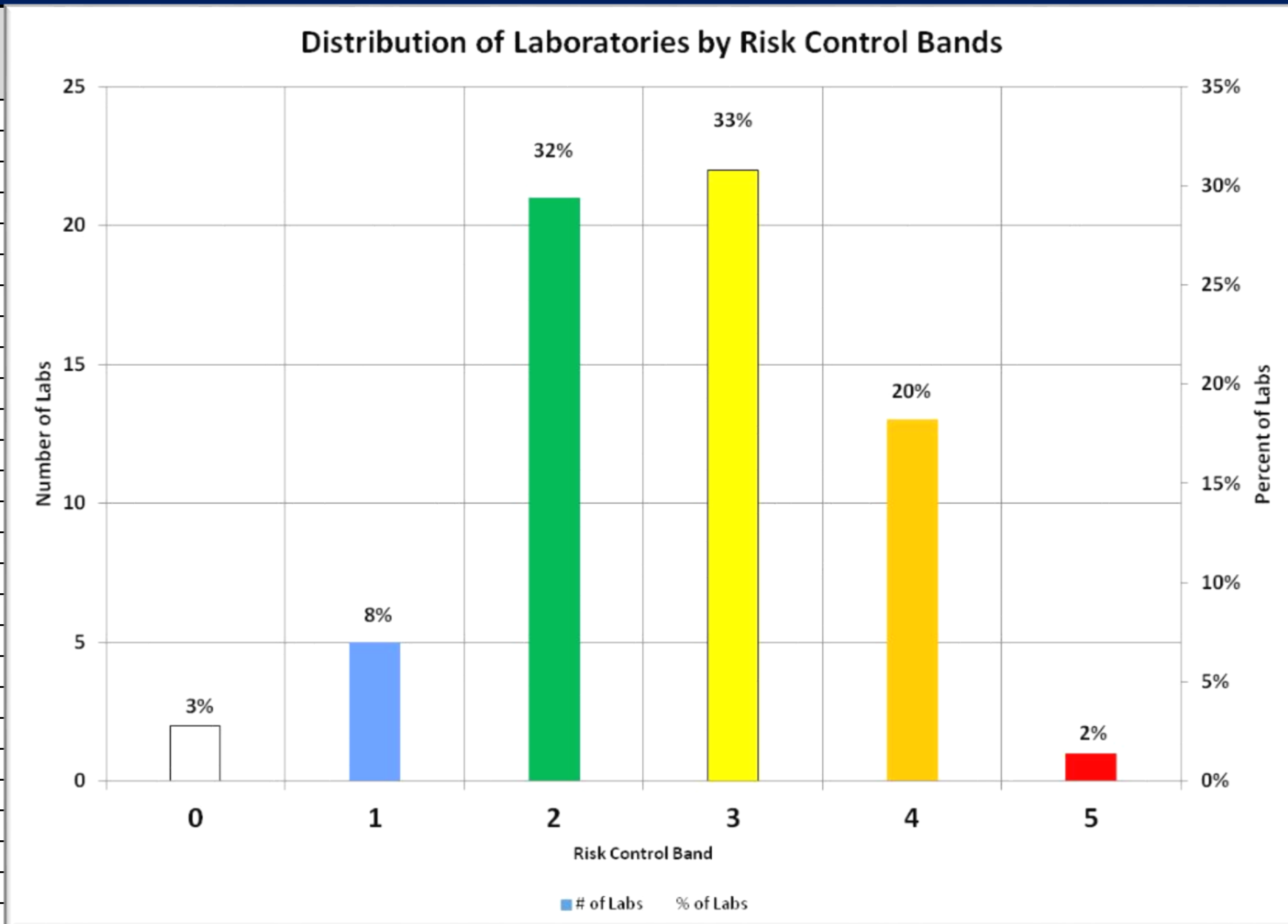
- Parameters and Weighting Adapted to Unique Labs
- Recommend ACH & Risk of Recirculating Lab Air
- Evaluate Lab Construction, Pressurization, Need for Monitoring, etc.

Total Score	Control Band	ACH
< 8	0	< 2
9 - 17	1	< 4
18 - 34	2	> 4
35 - 51	3	> 6
52 - 67	4	> 8
≥ 68	5	> 10



Distribution of Labs by Control Bands

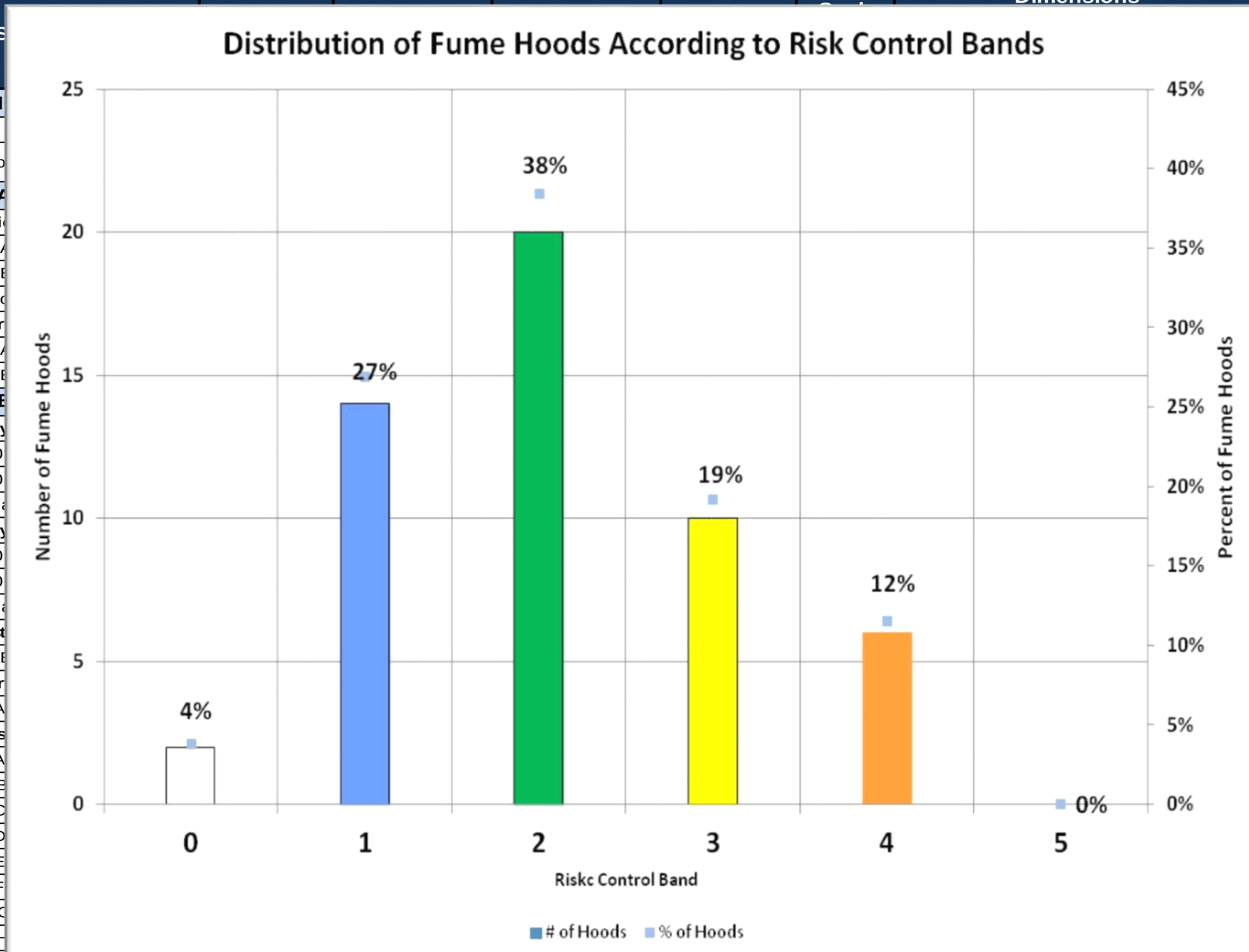
Lab Control Band Parameters



Lab	Control Band	Min. ACH
ENGINEERING 1528	3	6
ENGINEERING 1530	4	8
ENGINEERING 1531	3	6
ENGINEERING 2152	2	4
ENGINEERING 2255	4	8
ENGINEERING 2256	4	8
ENGINEERING 2260	3	6
ENGINEERING 2264	3	6
ENGINEERING 2265	3	6
ENGINEERING 2266	2	4
ENGINEERING 2525	4	8
ENGINEERING 2530	1	2
ENGINEERING 2535	5	10
ENGINEERING 2553	1	2
ENGINEERING 2565	1	2
ENGINEERING 2570	2	4
ENGINEERING 2575	3	6
ENGINEERING 2575A	3	6
ENGINEERING 3136	2	4
ENGINEERING 3140	3	6
ENGINEERING 3140A	2	4
ENGINEERING 3150	3	6
ENGINEERING 3153	1	2
ENGINEERING 3214	2	4
ENGINEERING 3235	3	6
ENGINEERING 3235A	2	4
ENGINEERING 3246	2	4

Distribution of Fume Hoods by Control Bands

Fume Hood & S	Dimensions	Current Hazard Control Band
LOWER LEVEL N		
Shipping Area		
012 Fume Hoo		n/a
LOWER LEVEL LA		
010 Chemical Dynami		
Fume Hood /		3
Fume Hood E		3
Relocated Fume Hc		3
011 Physical Chemistr		
Fume Hood /		3
Fume Hood E		3
FIRST FLOOR LAE		
110 Organic Chemistry		
Fume Hood A (10		2
Fume Hood B (10		2
Fume Hood C (Wa		3
111 Organic Chemistry		
Fume Hood A (10		2
Fume Hood B (10		2
Fume Hood C (Wa		3
111A Organic Chemist		
Fume Hood E		2
117 Physical Chemistr		
Fume Hood A		4
118 Advanced Chemis		
Fume Hood A		0
Fume Hood B		0
Fume Hood C		0
Fume Hood D		4
Fume Hood E		4
Fume Hood F		4
Fume Hood G		3
Fume Hood H		0



Lab Environment Airflow Spreadsheet

- Air Supply Flow
- Transfer Air
- Exhaust Flow
- Calculated Room ACH

Airflow Set Points					Supply		Transfer	Exhaust					Calculated Metrics	
									Qex-Cond	Qex-ED	Qex-dP	Qex-ACH		
					Room Supply Flows		Transfer Flow	System Info	Qex for Exhaust Devices		Room Exhaust Flows		Resultant ACH	
					Max/Min of Qs Conditioning, Qs dP, Qs ACH		Greater of door or 10%	Tags, ID, type, etc.	Sash Open/In Use	Sash Closed/Not In Use	Max/Min based on Exh Devices, dP, Cond., or ACH		Based on Room Exhaust Flows	
Room #	Room Description	Area (ft^2)	Height (ft)	Volume (ft^3)	Room Flow @ Max (cfm)	Room Flow @ Min (cfm)	Greater of Door and 10% Max Exh (cfm)	Exhaust Type	Max Flow (FH @ 18 in.) (cfm)	Min Flow (FH min. of 25 cfm/ft^2 of work surface) (cfm)	Room Max Flow (cfm)	Room Min Flow (cfm)	Max ACH	Min ACH
118	Chemistry	802	9.5	7619	3025	735	325	FH-VAV	838	229	3350	1060	26	8
								FH-VAV	838	229				
								FH-VAV	838	229				
								[illegible]	[illegible]	[illegible]				
204	General Purpose	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
222	Biology	854	9.5	8113	794	549	150	[illegible]	[illegible]	[illegible]	944	699	7	5
								Snorkel	0	0				
								GX						

Supply Terminal Min and Max Flow

Hood and Gex Terminal Min and Max Flow

Lab Min and Max ACH

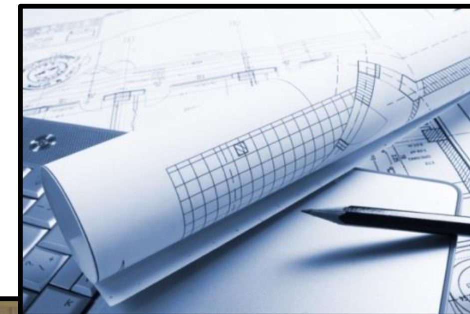
Lab Safety & Energy Optimization Process
Modify Systems to Meet Demand

- Remove or Hibernate Unnecessary Hoods
- Modify Inefficient Hoods
- Replace & Retrofit Traditional Fume Hoods
- Upgrade CAV & VAV Controls
- Optimize Temperature & Humidity Controls
- Install Demand Control Ventilation
- Reduce / Reset System Static Pressure
- Optimize Exhaust Fan and AHU Operation
- Implement Energy Recovery

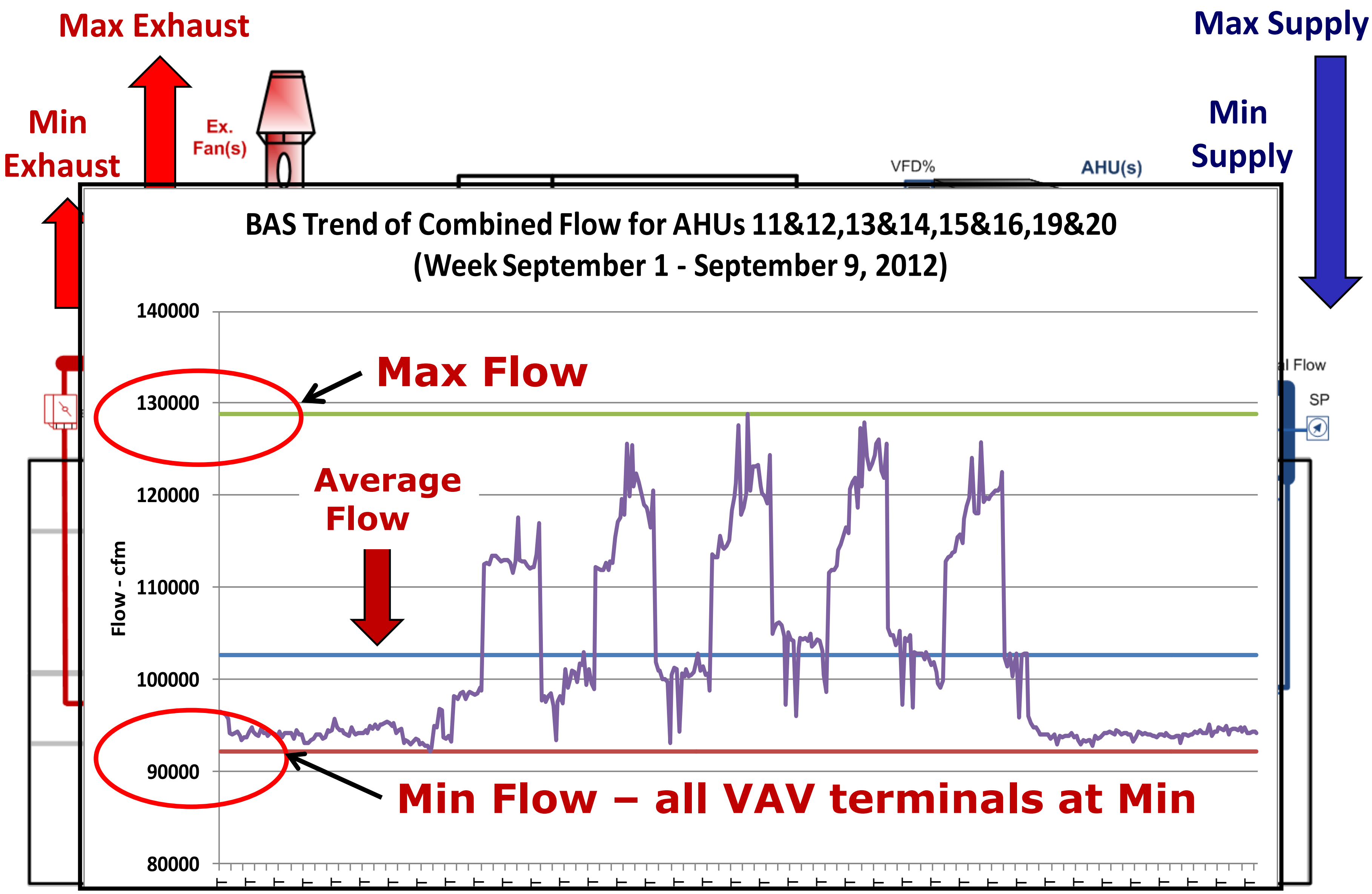
Lab Energy & Safety Optimization Process

Phase 2 – Funding & Project Execution

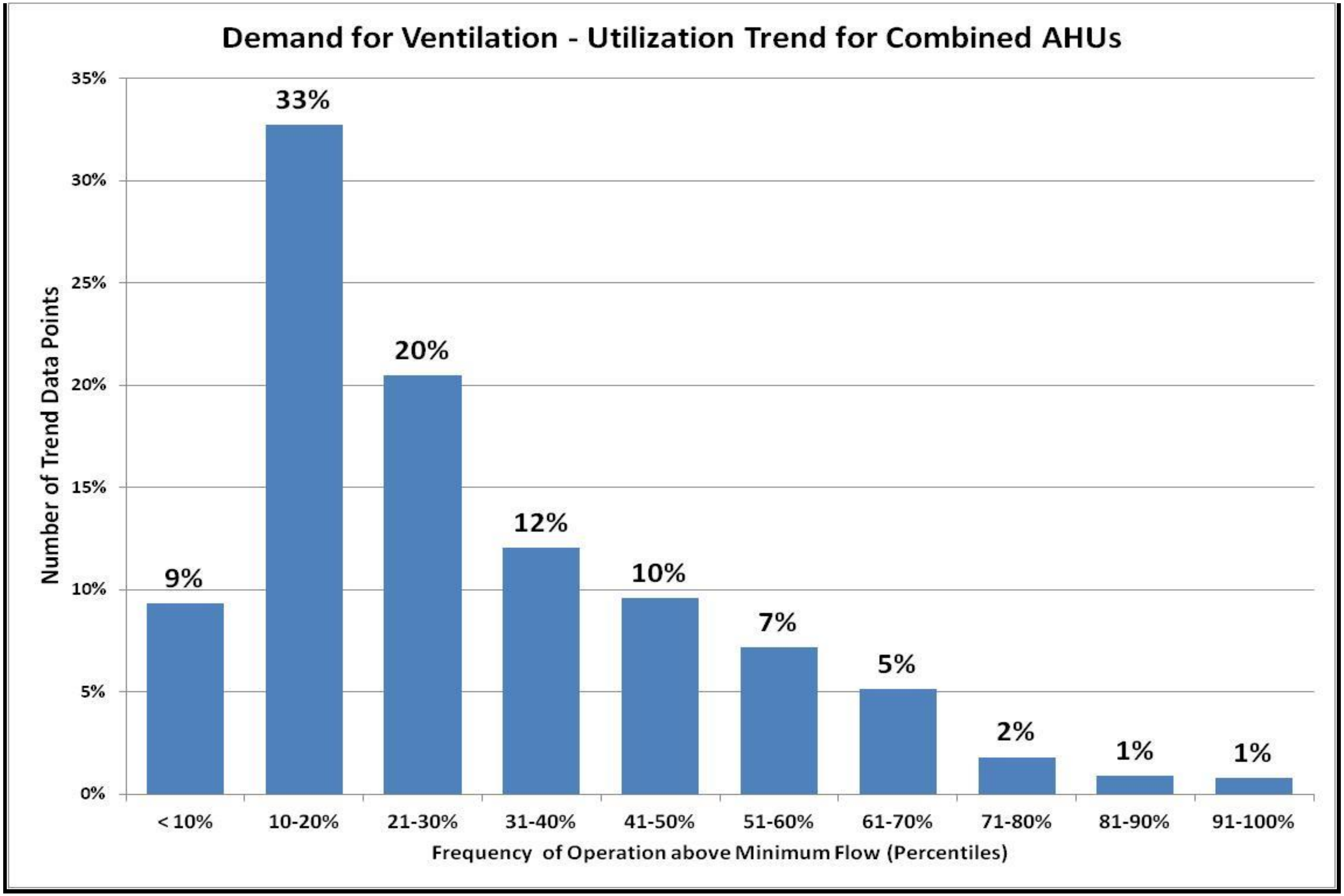
- **Phase 2a - Funding Sources**
  - Internal Facility Budget
  - Utility Rebates & Incentives
  - Performance Contracts
- **Contractor Qualification & Selection**
- **Phase 2b – Project Engineering**
  - Design Upgrades & System Modifications
  - Develop TAB & Cx Plans
- **Phase 2c –Renovation / Construction Project**
  - Implement Selected PIMs & ECMs
  - Retrofit Lab Hood Systems
  - Verify Performance and Energy Savings



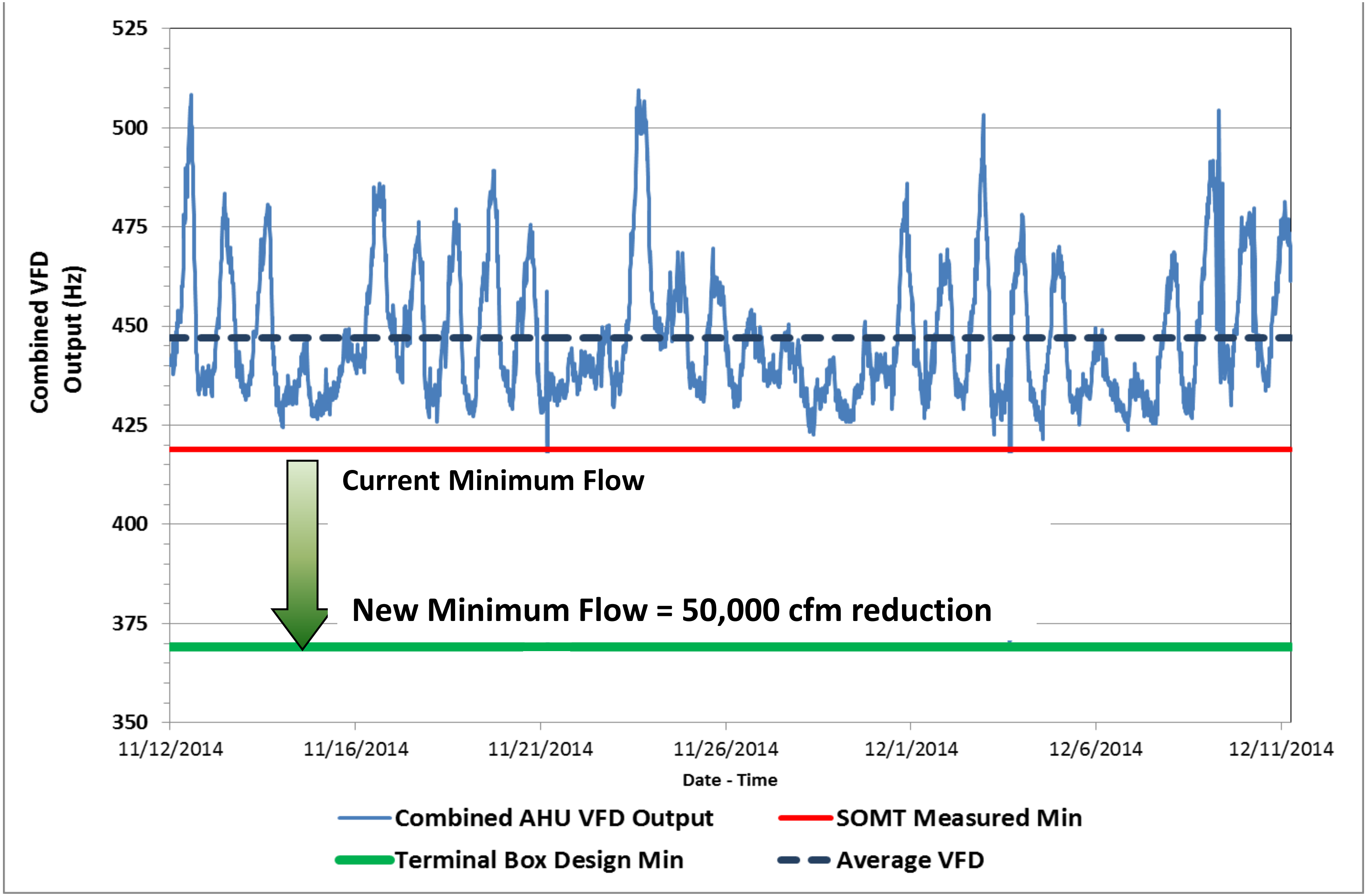
Lab Ventilation System - VAV Flow Specifications



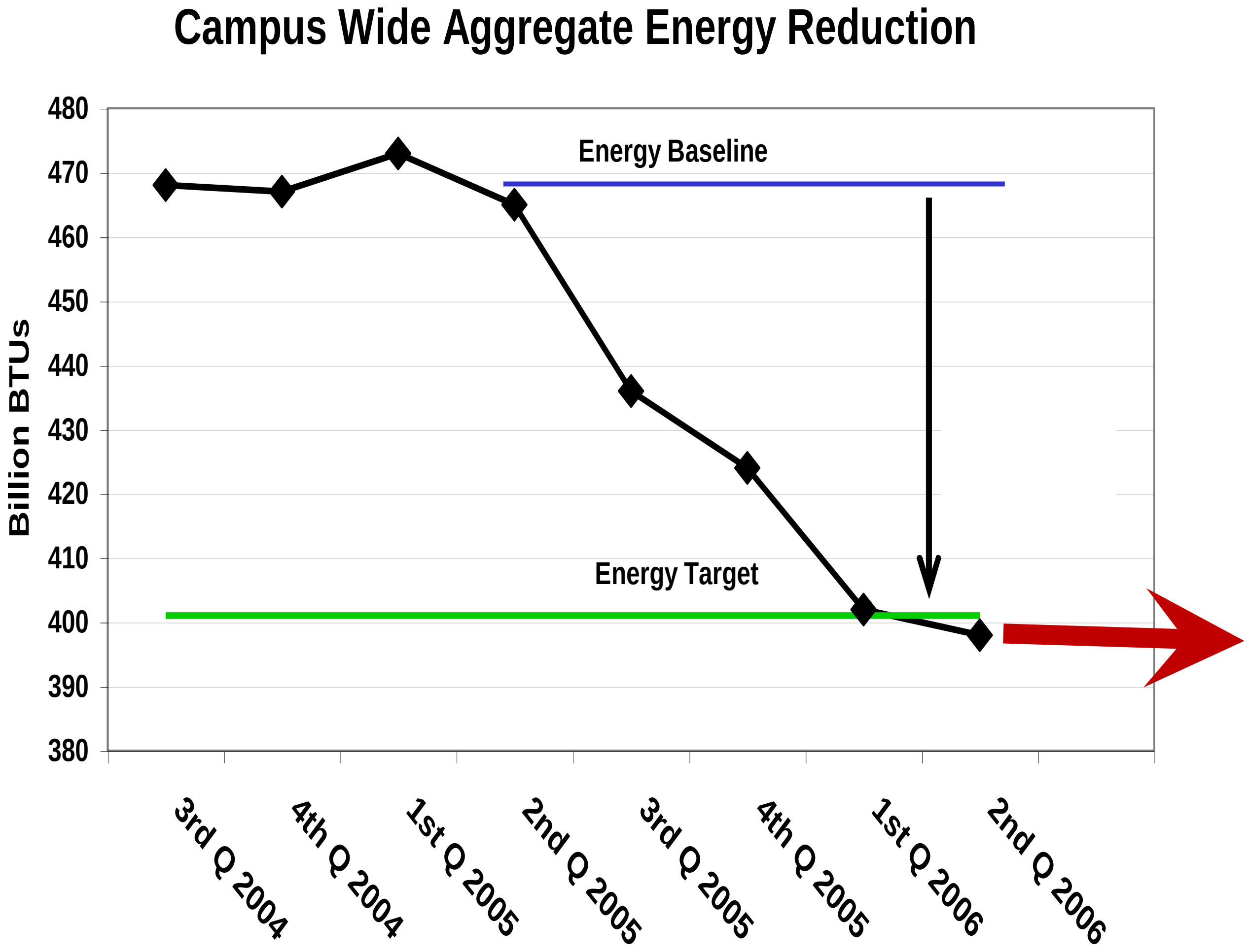
Demand for Ventilation and System Utilization



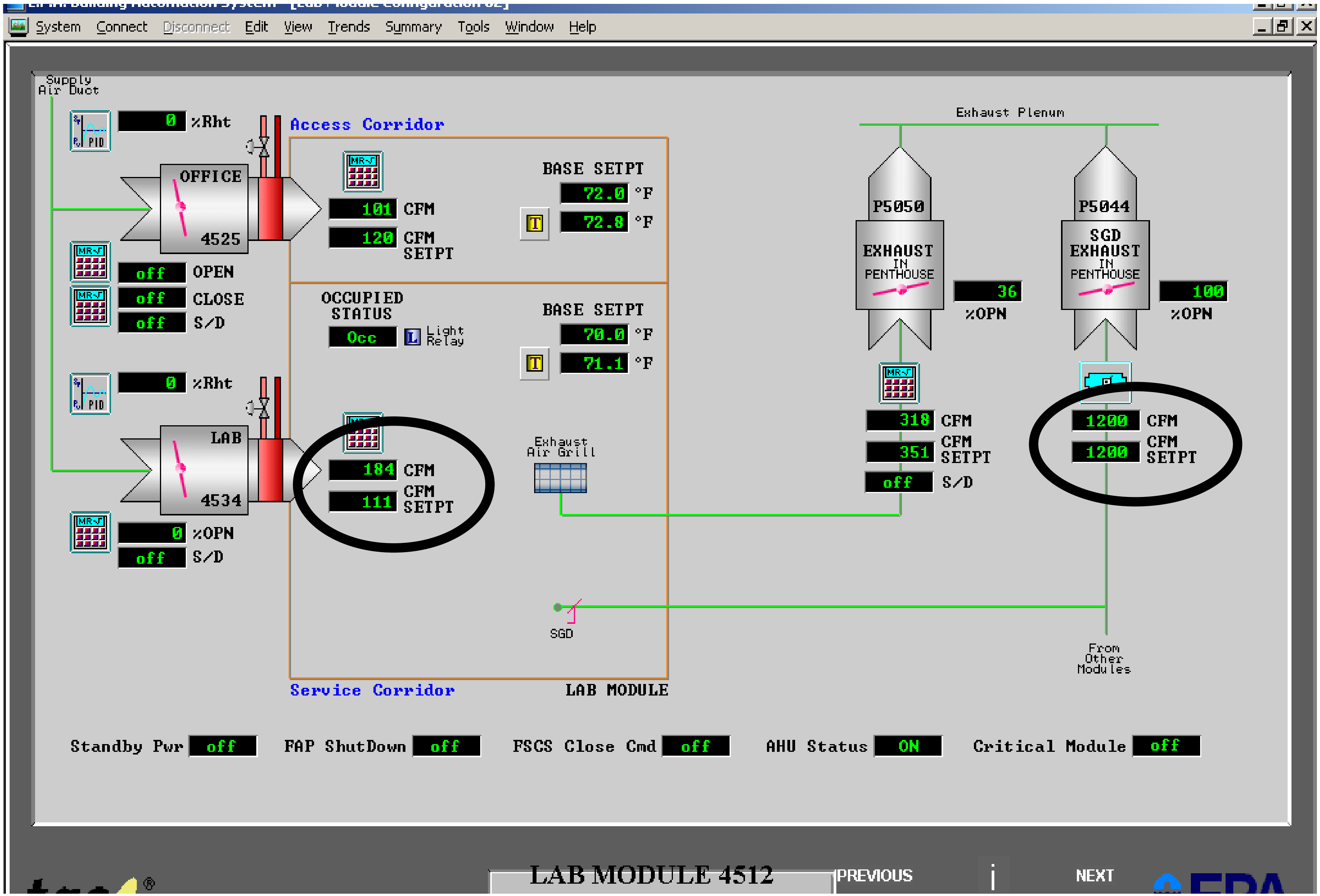
Airflow Trend Based on Demand For Ventilation



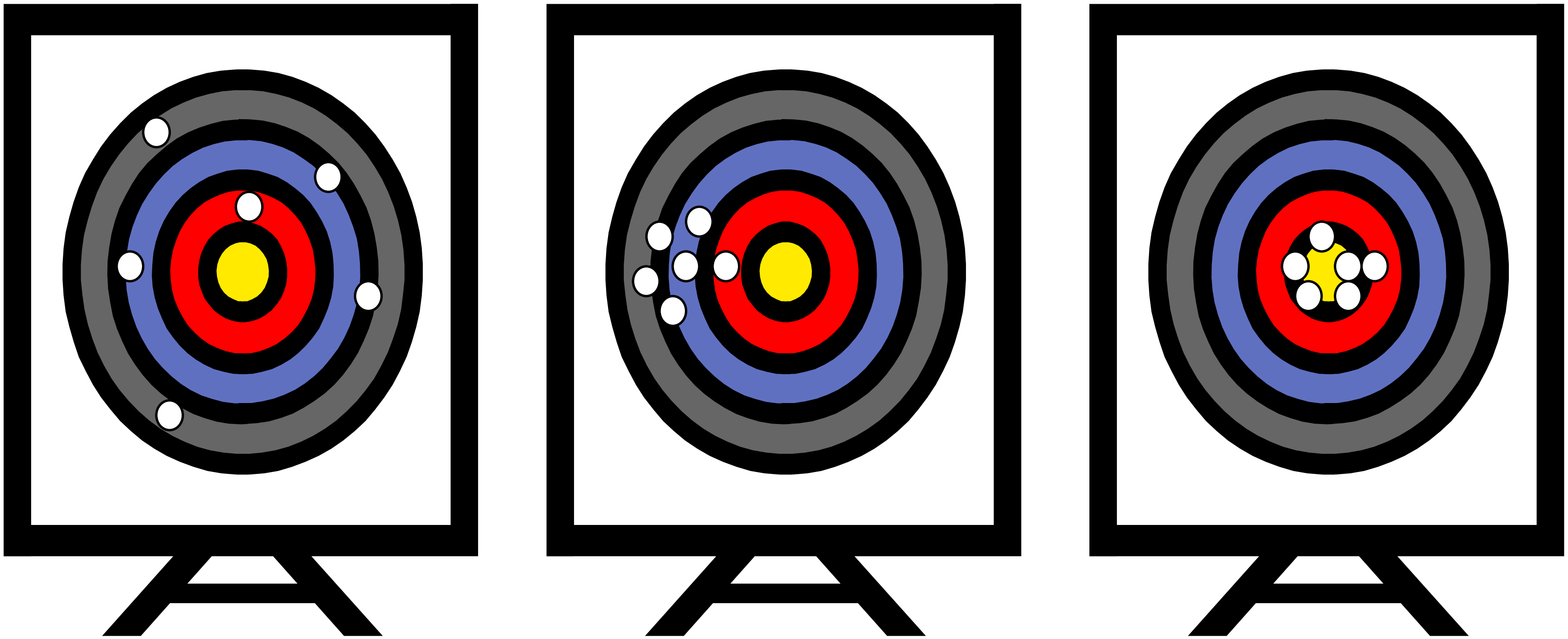
Safe & Energy Efficient, but Sustainable?



Maintaining Performance of VAV Controls



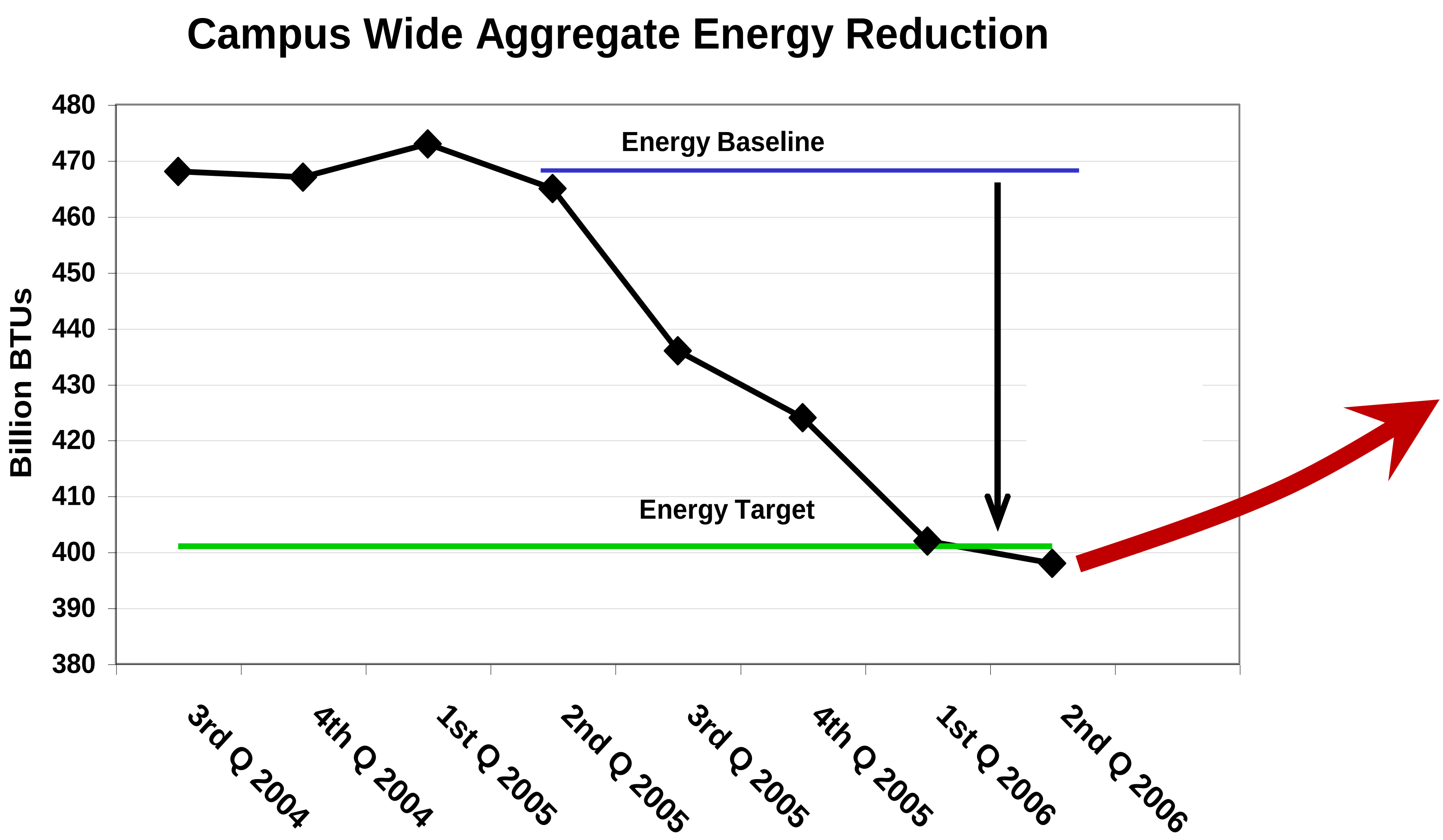
Quality Data - Accuracy and Precision



VAV Controls Can degrade

30-50% within 5 years

Safe, Energy Efficient and Sustainable ??



Laboratory Ventilation Management Plan

Lab Energy & Safety Optimization Process

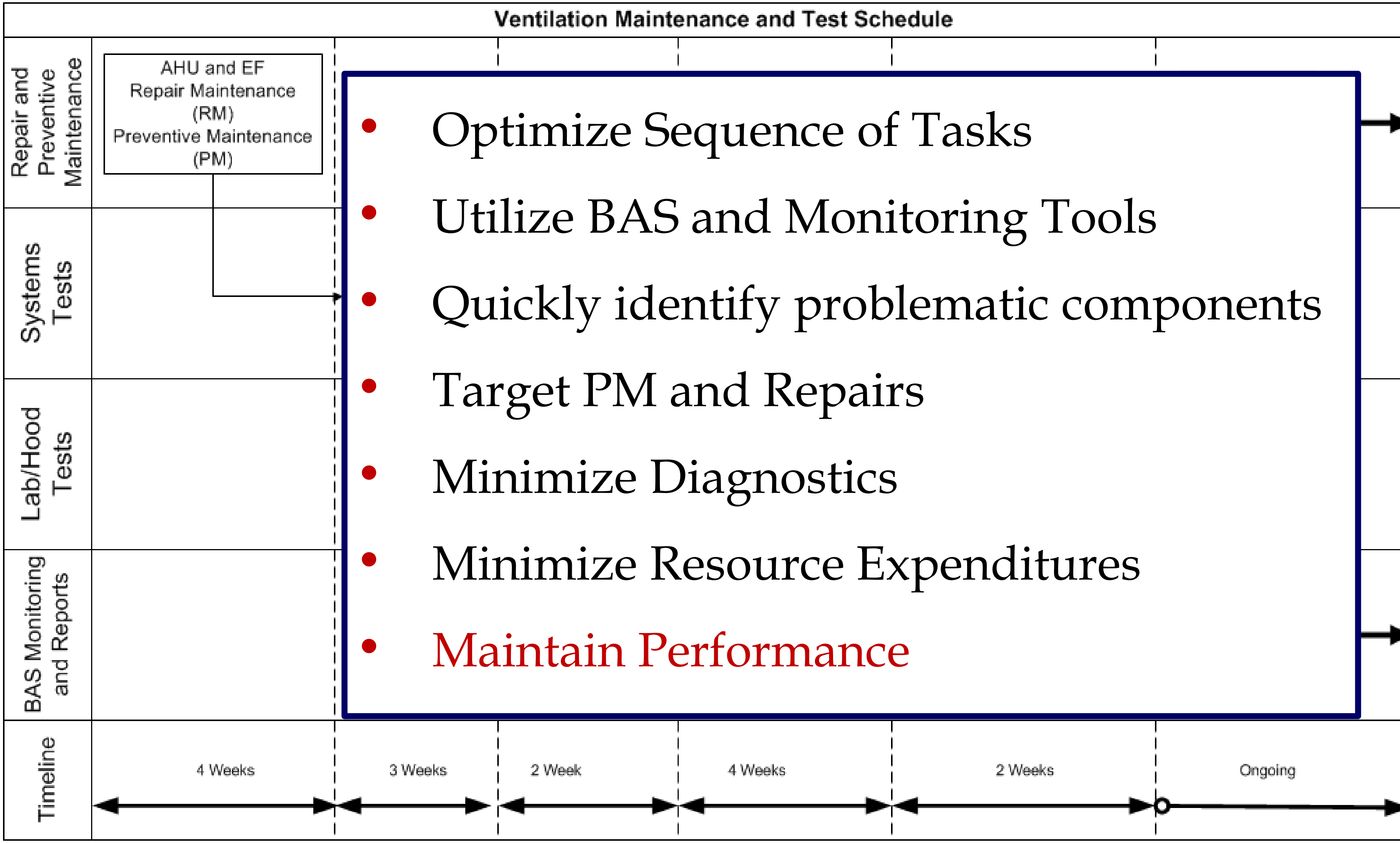
- **Phase 3 – Lab Ventilation Management (LVMP)**
  - Organization and Responsibilities
  - Collaboration & Communication
  - SOP's for Testing and Maintenance
  - Metrics, Monitoring & BAS Utilization
- **Management of Change**
- **Personnel Training**
- **Design & Commissioning Standards**
- **Required By ANSI Z9.5-2012**

Components of a LVMP

- Component 1 – Program to Coordinate Stakeholder Efforts
- Component 2 – Specific Operating Plans for Buildings

Component 1	LVMP	**Coordinate Efforts** • Management • Facilities Engineering • Environmental Health & Safety • Facilities Maintenance • Lab Staff • Contractors	**Standardize Operations** • Lines of Communication • Management of Change • Guidelines and Specifications • Generic Procedures • Training • Document Control
Component 2	LVMP - Building Operational Plans	**Building Documentation** • Equipment Inventory • As Built Drawings • Flow and Operating Specs	**Building Operation** • Tasks • Schedules • Specific SOPs • Reporting

Maximize Effectiveness of Maintenance



- Optimize Sequence of Tasks
- Utilize BAS and Monitoring Tools
- Quickly identify problematic components
- Target PM and Repairs
- Minimize Diagnostics
- Minimize Resource Expenditures
- Maintain Performance

Lab Energy & Safety Optimization
Train Personnel

- Lab Personnel
- Facility Maintenance
- Building Operators

Conclusions and Recommendations

- Laboratories can be safe, energy efficient and sustainable
- The Demand for Ventilation determines the required operating specifications
- A Lab Ventilation Risk Assessment determines the Demand for Ventilation
- VAV systems modulate flow based on the demand for ventilation
- Special tests and methods are required to manage complex VAV systems
- Maintaining safe and energy efficient operation requires maintaining performance and managing change over time
- The Return on Investment depends on maintaining performance
- A Lab Ventilation Management Program provides the tools to maintain the systems, manage change and protect the return on investment

LVMP = ROI

Lab Energy & Safety Optimization Process

High Performance Laboratories

- Safe
- Energy Efficient
- Sustainable

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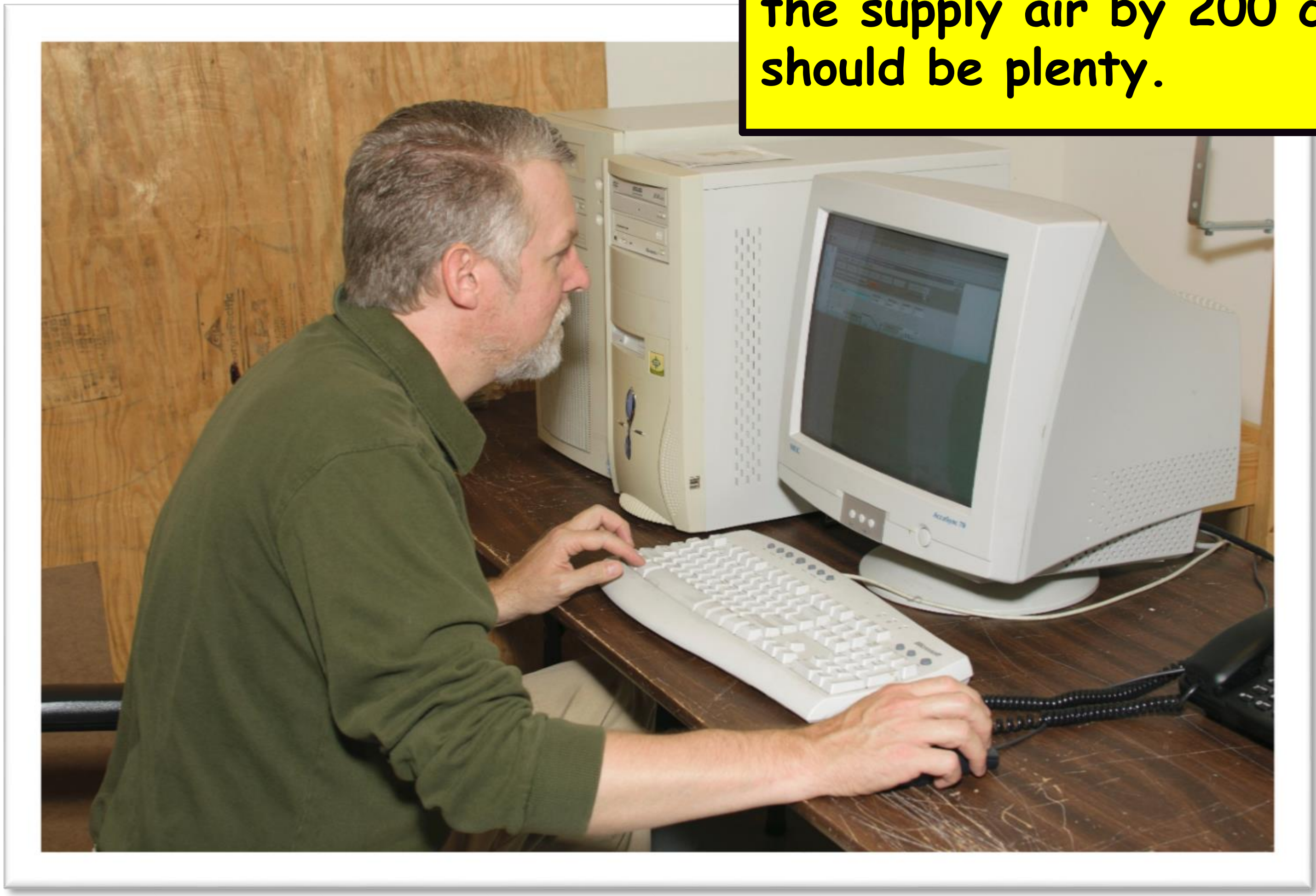
Importance of the LVMP

Management of Change

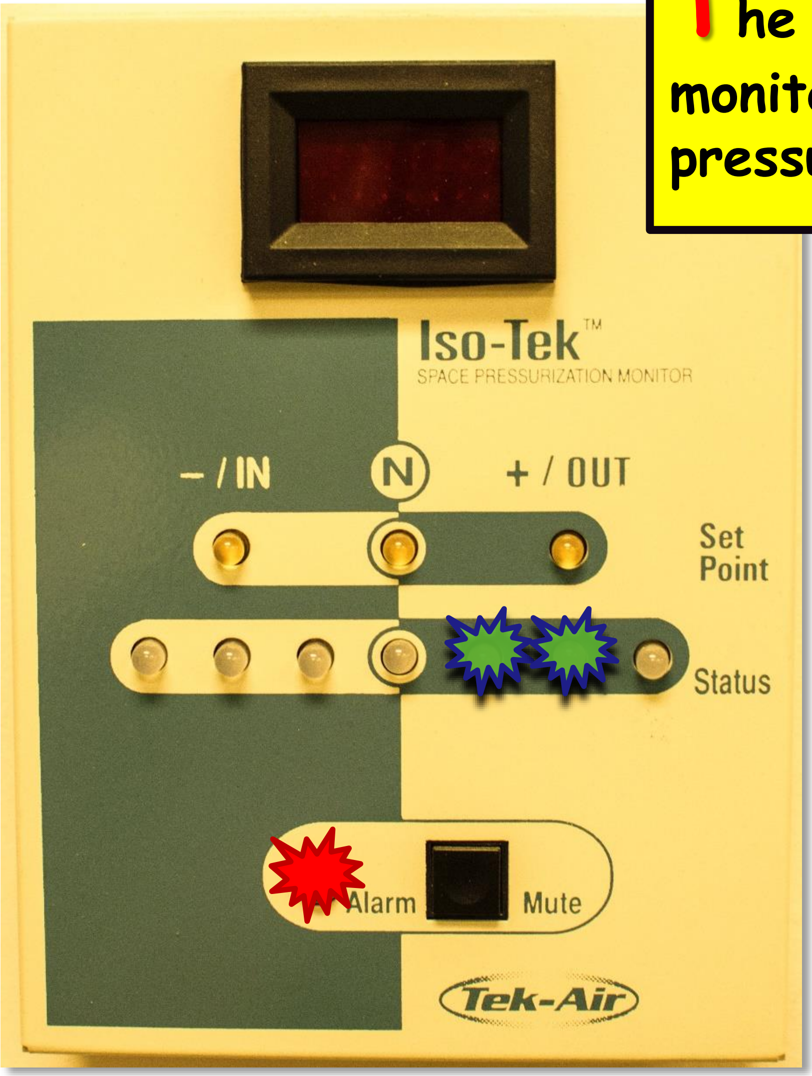

My lab is really hot!

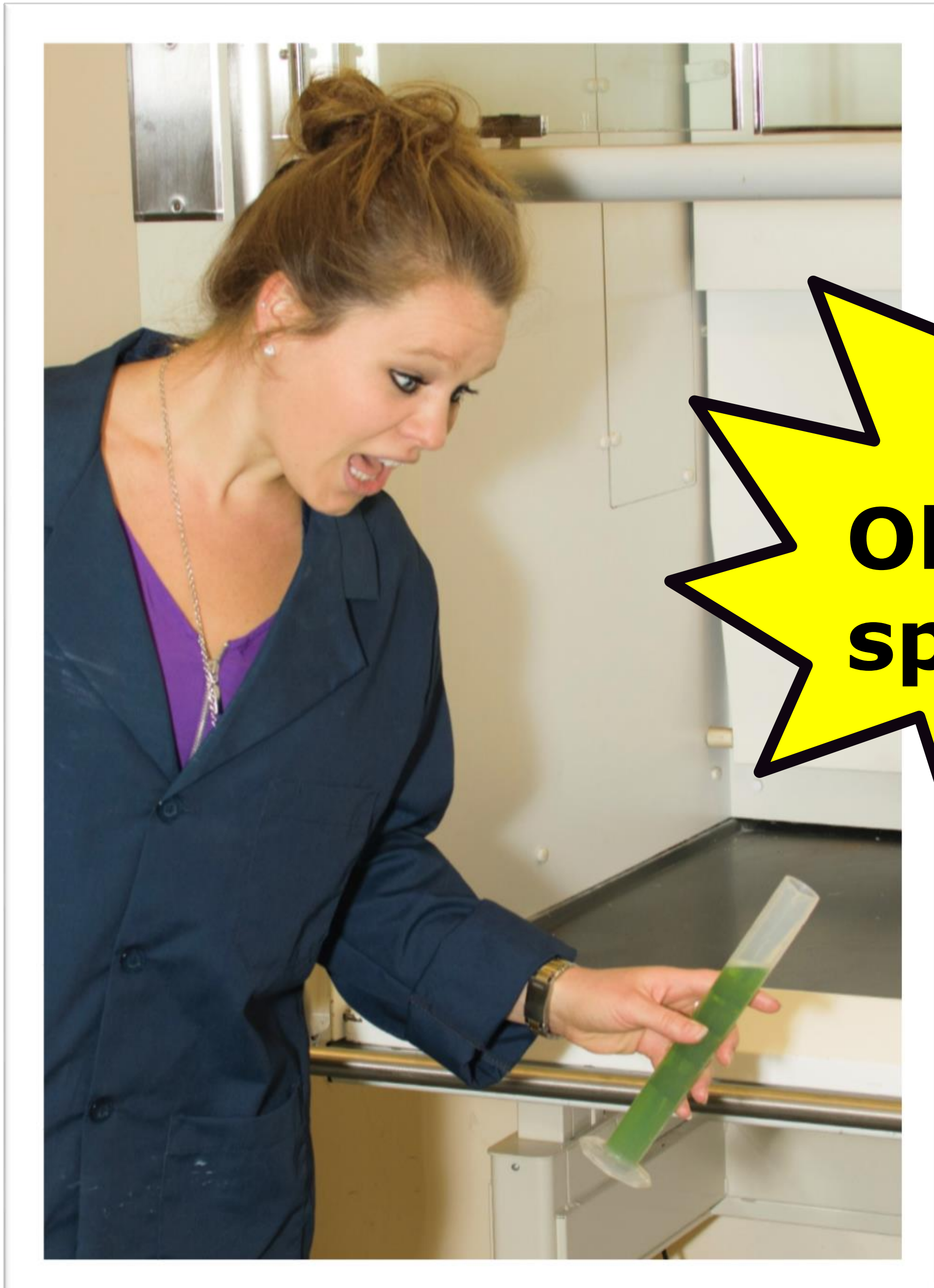

I'll take care of it.



Our technician decides the lab needs more air, so he increases the supply air by 200 cfm. This should be plenty.

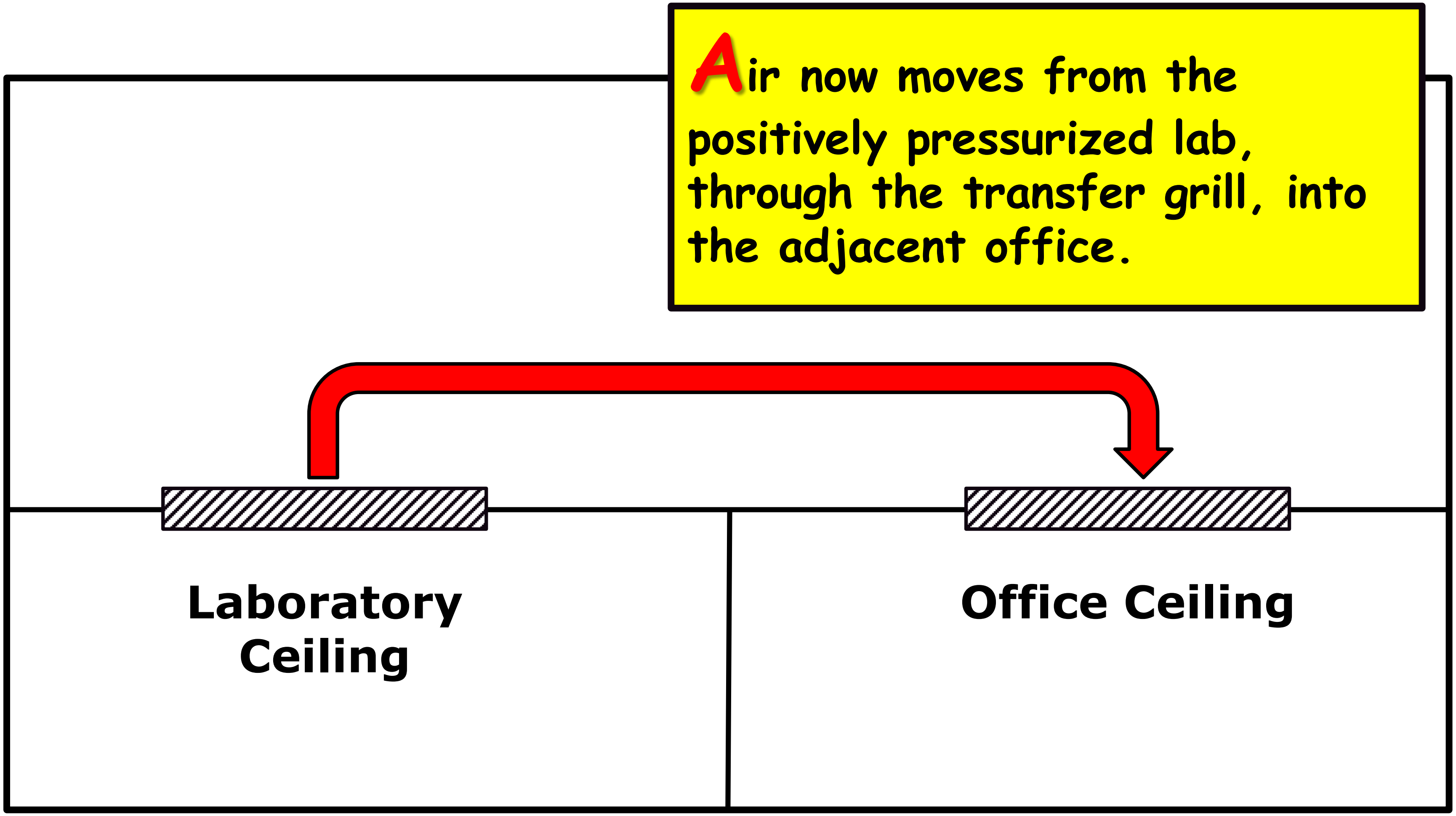
The differential pressure monitor is now indicating positive pressure.



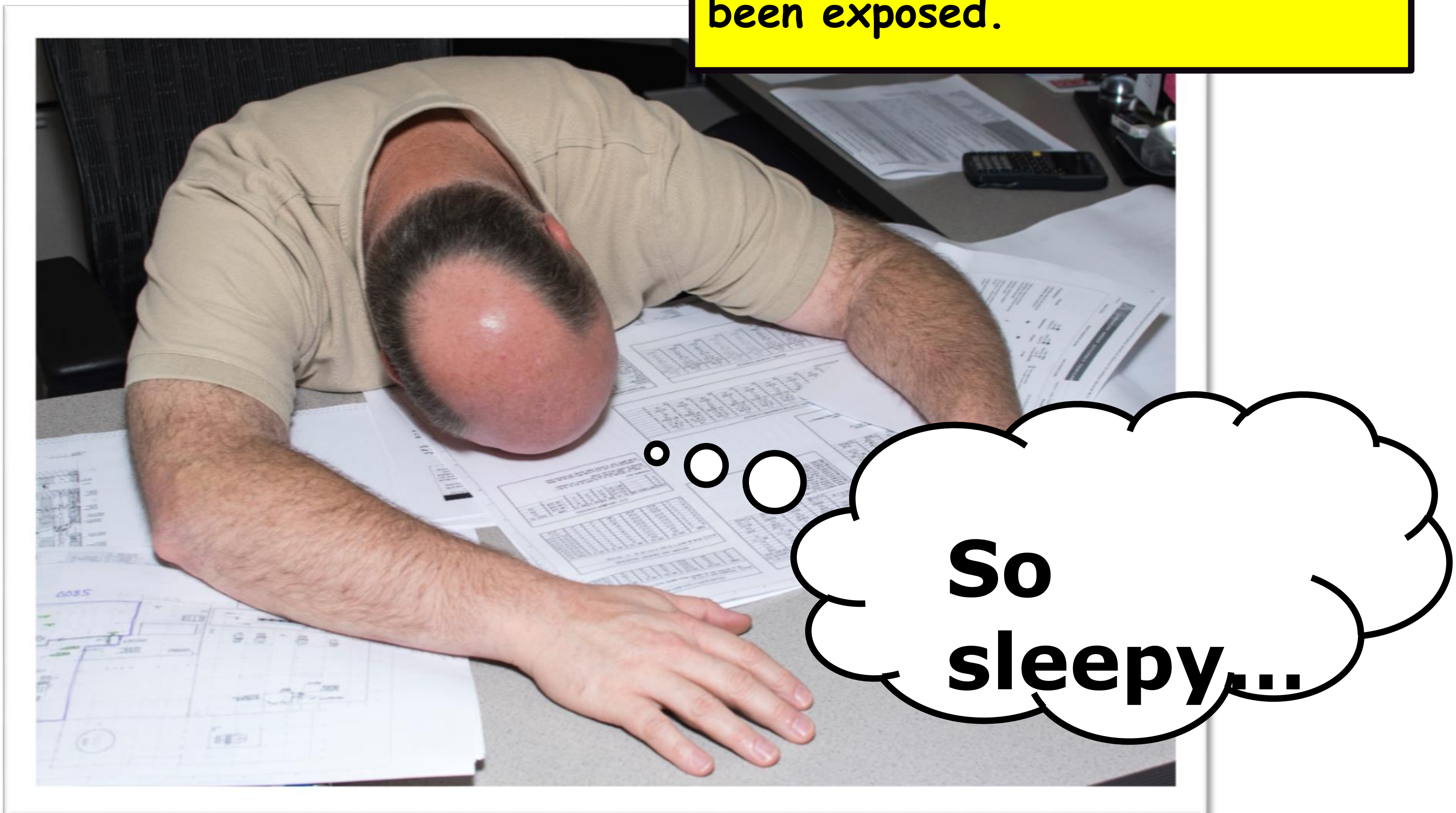


Oh No!! A spill…


It’s much cooler now...


Air now moves from the positively pressurized lab, through the transfer grill, into the adjacent office.
Laboratory Ceiling
Office Ceiling

Our office worker has now been exposed.



This never would have happened if our technician had a Laboratory Ventilation Management Program.