Safely Cut Your Laboratory Energy Usage in Half

A Labs21 2012 Annual Conference

Pre-Conference Training Session

Better Buildings CHALLENGE
U.S. DEPARTMENT OF ENERGY

UNIVERSITY of CALIFORNIA • IRVINE

Your Presenters

- **Wendell C. Brase**
  Vice Chancellor, Administrative and Business Services
  Chair, University of California Climate Solutions Steering Group
- **Matt Gudorf**
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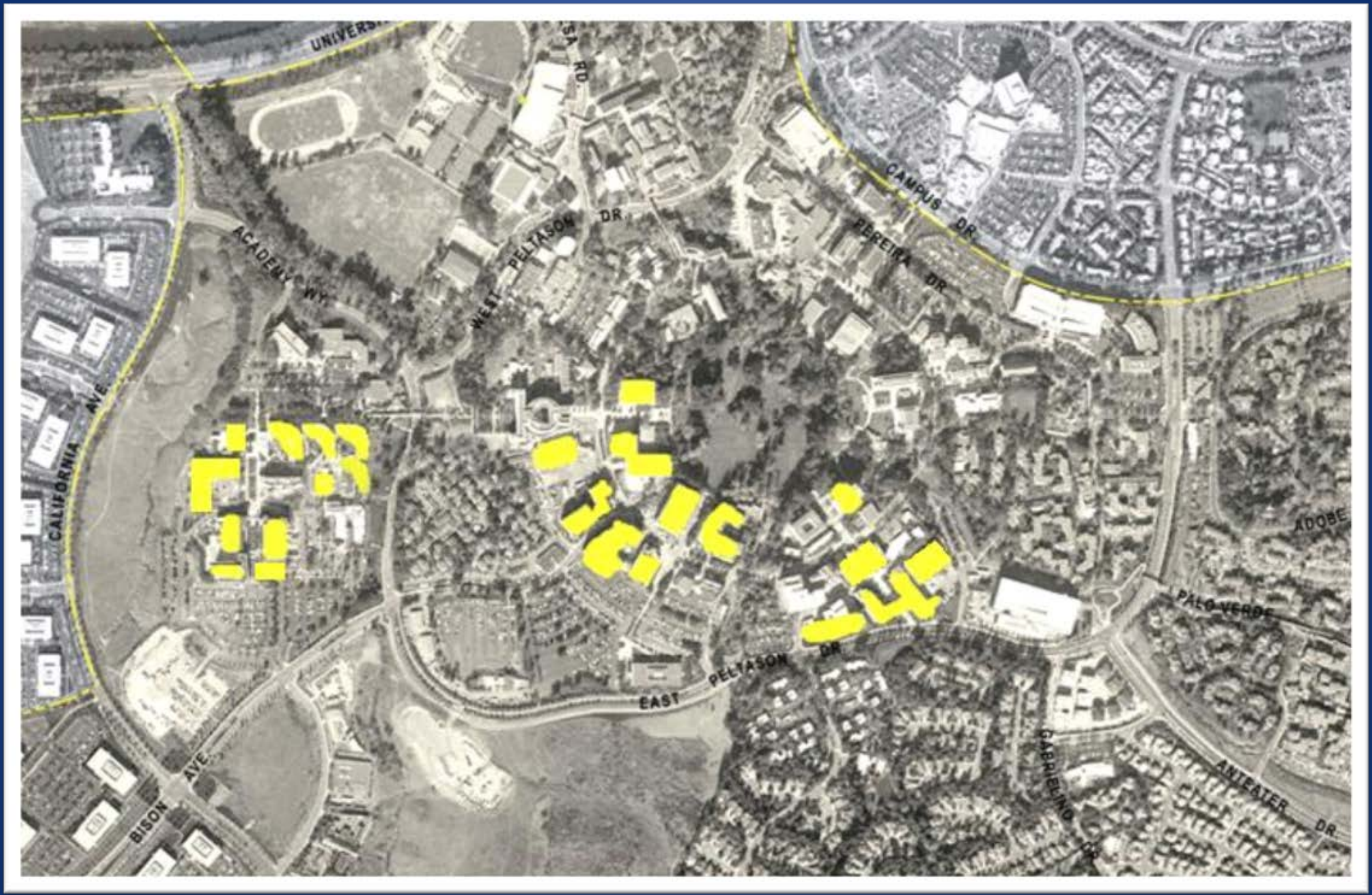
- **Fred R. Bockmiller**
  Manager, Engineering Group

Learning Outcomes

1. Why focus on laboratories?
2. Can we afford a “smart lab” retrofit?
3. Are savings greater than 50% really possible?
4. Can these savings only be realized with new construction?
5. Can we afford to keep a “smart lab” smart?
6. What if our energy costs differ from those in California?

Why laboratories?



They use 2/3 of the energy at research universities!

Today's Agenda

- Welcome and Introductions
- UC Irvine's Smart Labs Initiative
- Introduction to Smart Labs
- Prerequisites for Smart Labs
- Submetering
- Smart Labs Characteristics
  - Building Envelope
  - Lighting
    - Participatory Exercise
- BREAK
  - Mechanical System
    - Centralized Demand Controlled Ventilation
    - Lab Bench Top Risk Assessment
    - Participatory Exercise
- Low-Flow Fume Hoods
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- Return on Investment and Commissioning
- The Future of Smart Labs
- Conclusion and Wrap-Up

What is a "Smart Lab"

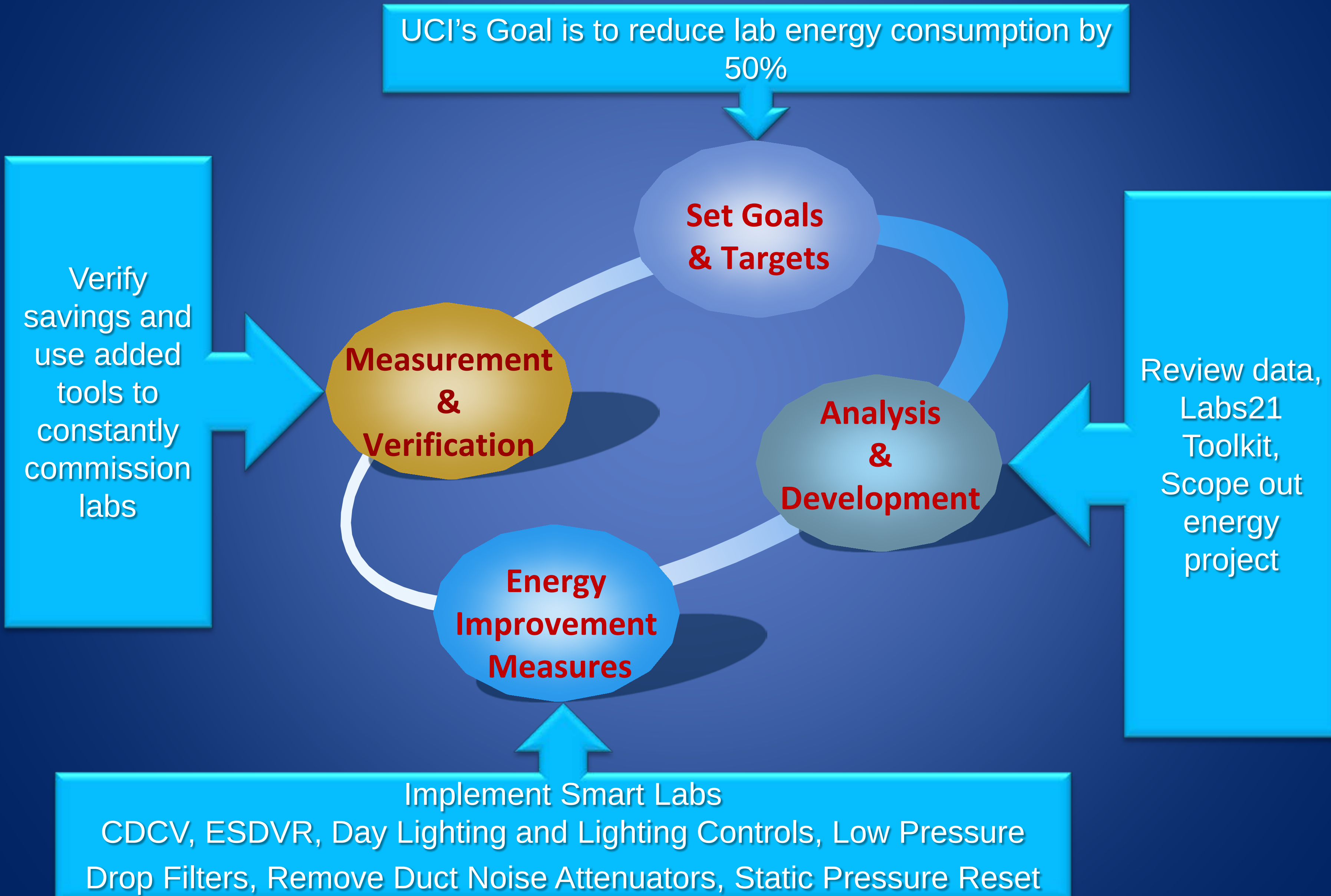
- "Smart Labs" are newly constructed or retrofitted laboratories that reduce building system energy consumption by 50% or more, augment established safety protocols and designs, and provide a data stream effectively commissioning the building at all times.

Smart Lab Evolution

- UC Irvine's Smart Labs Initiative includes multiple features that were piloted and verified before campuswide deployment.

- Making the deep energy cuts that are required to meet a 50% savings goal requires that theories be tested, perceptions changed, and results evaluated.

Lab Efficiency Cycle



Retrofitting or New Construction

With the exception of the building shell, all Smart Labs retrofits can be completed in occupied buildings with minimal lab interruptions.

- Service interruptions are directed in the contract for duration, timing, and notification that must be given.
- Scope of work may or may not include temporary supply and exhaust fans
- Contractors must work with air flowing both supply and exhaust with all shutdowns minimized even when this increases the number of steps or amount of work
- Town hall meetings prior to construction with building occupants
- Posted construction schedules in hallways and email updates
- 2-week in-person notice given to each individual lab

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Prerequisites of a Smart Lab

1. Constant air volume (CAV) to variable air volume (VAV)
2. Pneumatic to direct digital control
3. Individual exhaust to manifolded exhaust
4. Differential pressure control for pumps
5. Thermostat location and other existing challenges

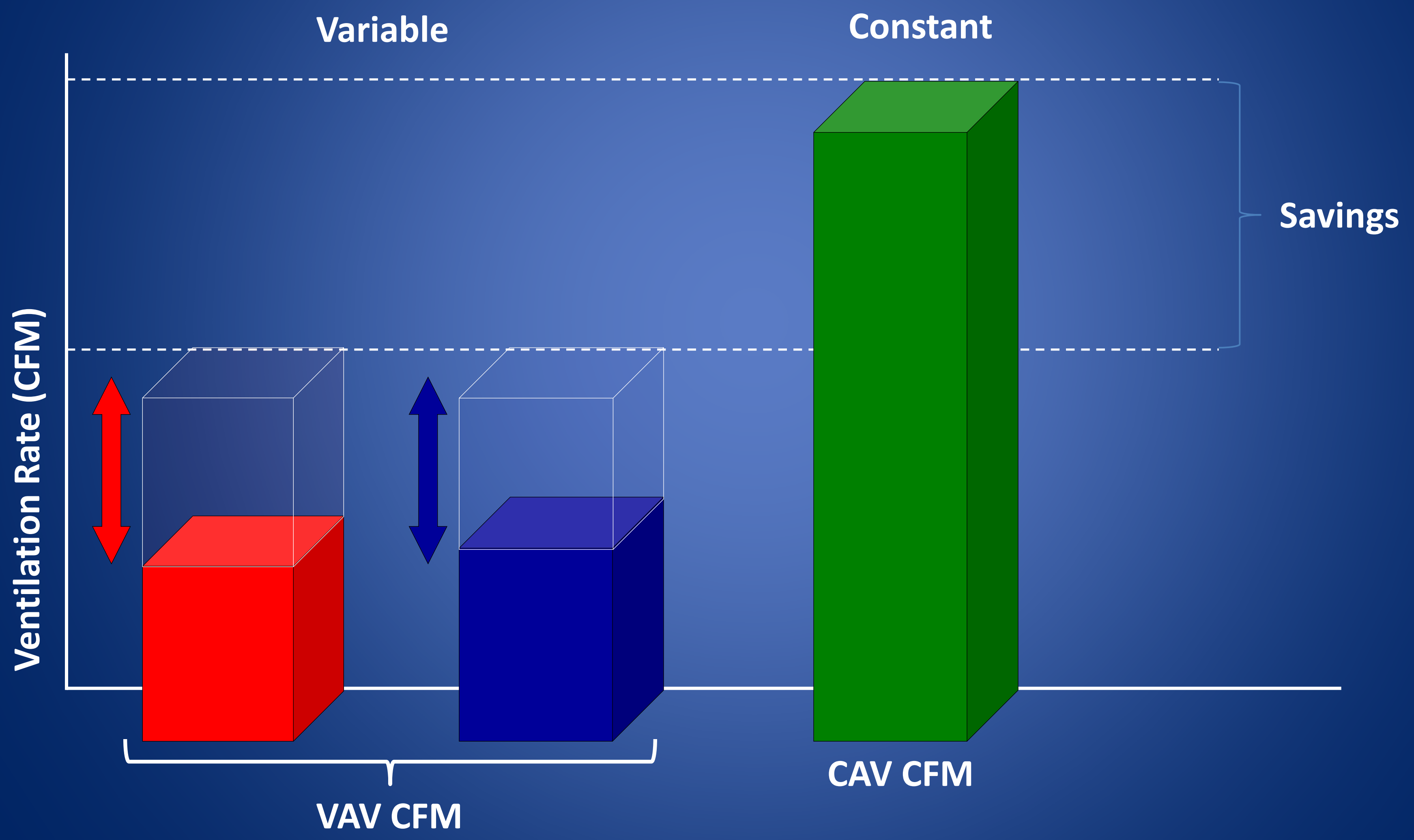
When building load varies …

Shouldn't the HVAC system follow?

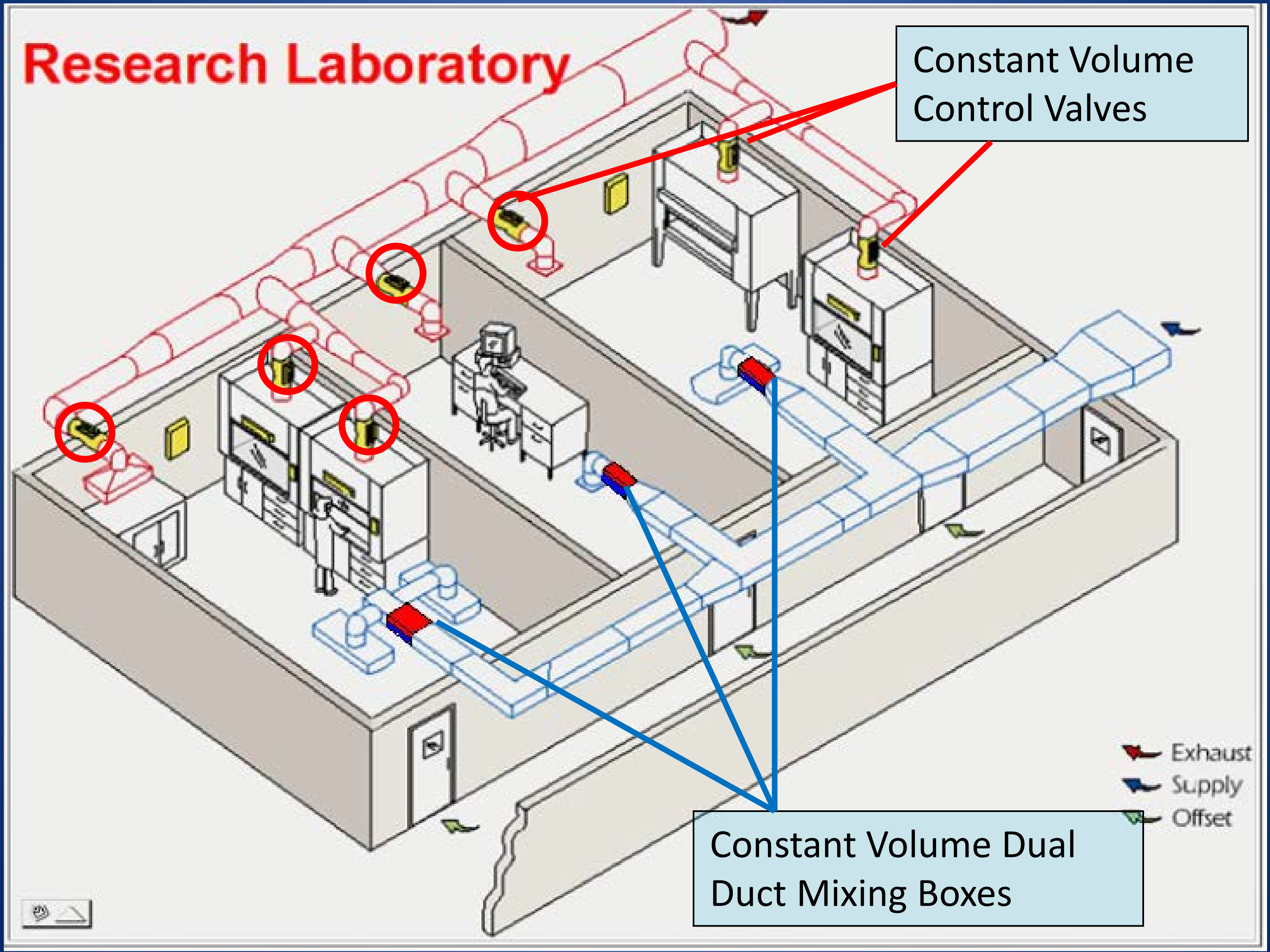
– Constant Air Volume – supply and exhaust flow rate remains the same independent of:
  - Fume hood sash position
  - Thermal demand
  - Occupancy

– Variable Air Volume – supply and exhaust changes depending on:
  - Fume hood sash position
  - Thermal Demand
  - Occupancy

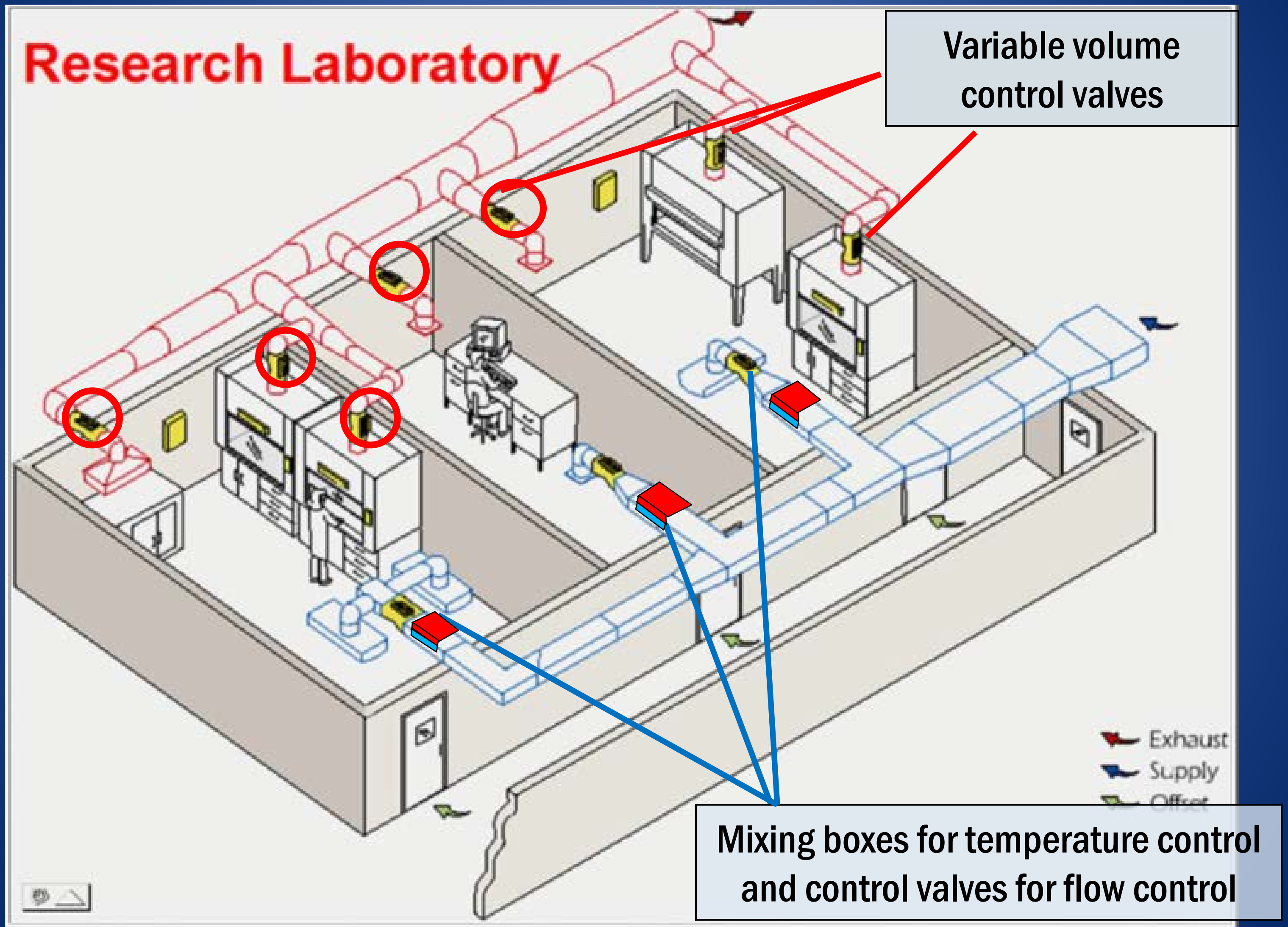
Variable | Constant Air Volume



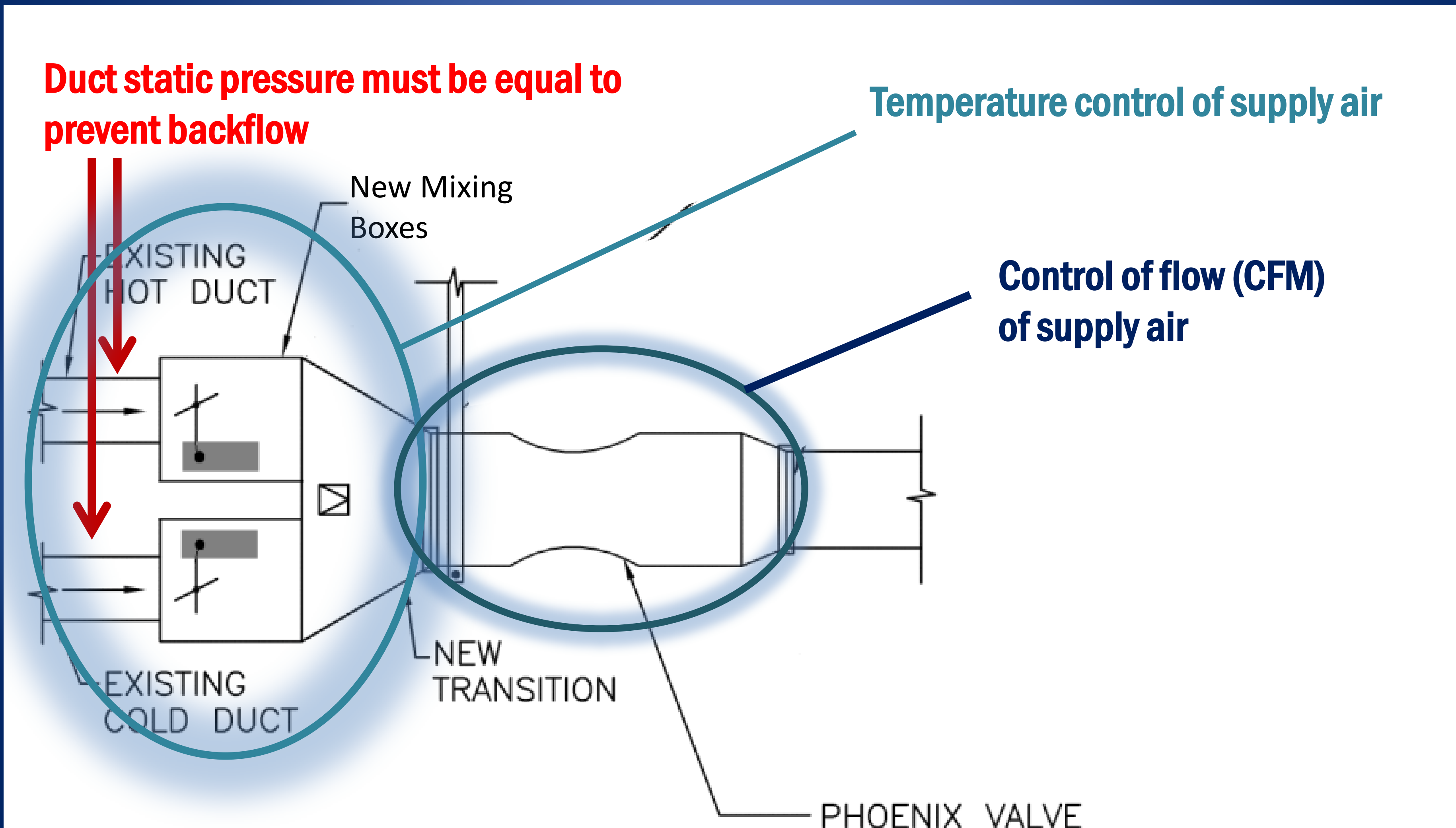
Typical Lab Prior to Retrofit



Typical Lab Post-Retrofit



Dual Duct to Control Valve Connection for Lab Supply Air and Proper Setup



Pneumatic Control to Direct Digital Control

Direct Digital Controls

- Do not require frequent calibration
- Can perform complex sequences
- Can receive instructions from a master computer
- Can transmit to a master computer information such as damper position, room temperature, supply air quantity, and supply air temperature

Individual Exhaust

Some buildings have 1 exhaust fan per fume hood, zone, or possibly multiple zones

- Typically small motors
- No variable frequency drives installed
- No redundancy in case of failure
- No static pressure control
- High level of maintenance required

Manifolded Exhaust

N+1 Exhaust Fans connected to a common plenum

- Premium efficient motors
- Variable frequency drives installed
- Control based on static pressure of the exhaust duct responding to increase or decrease in demand
- Redundancy allowing for increased safety and no lab downtime during service

Manifold Exhaust Duct

- Use a high quality, properly braced, industrial grade isolation damper
- Inspect for leaking air
- Check for proper slope to avoid pooling water

Constant Flow to Variable Flow

For maximum energy savings, reliability, and turn down, convert building heating water systems to variable volume.

- Add Variable Frequency drives to the pumps
- Replace 3-way valves with Pressure Independent Control Valves (PIC-V)
  - Valve leakage wastes energy. Do not just close the bypass the best practice is to replace the valve.
- Check each VAV box for valve leakage, replacement of 2-way valves may be necessary. Leak-by is a significant energy waste.
- Install differential pressure monitoring and reset schedule

Location, Location, Location

Heat-generating equipment placed next to thermostats wastes energy.

Fixing the Known

If you have known issues in your lab, you need to address them now or as part of the retrofit (Smart Lab retrofits can resolve your deferred maintenance nightmare).

- Failed lab air control valves
- Stuck dampers
- Broken actuators
- Static pressure sensors that are failed or need recommissioning
- Dirty duct work
- Occupant installed snorkels, ductwork taps, other interesting "improvements"
- Over ridden VFD's

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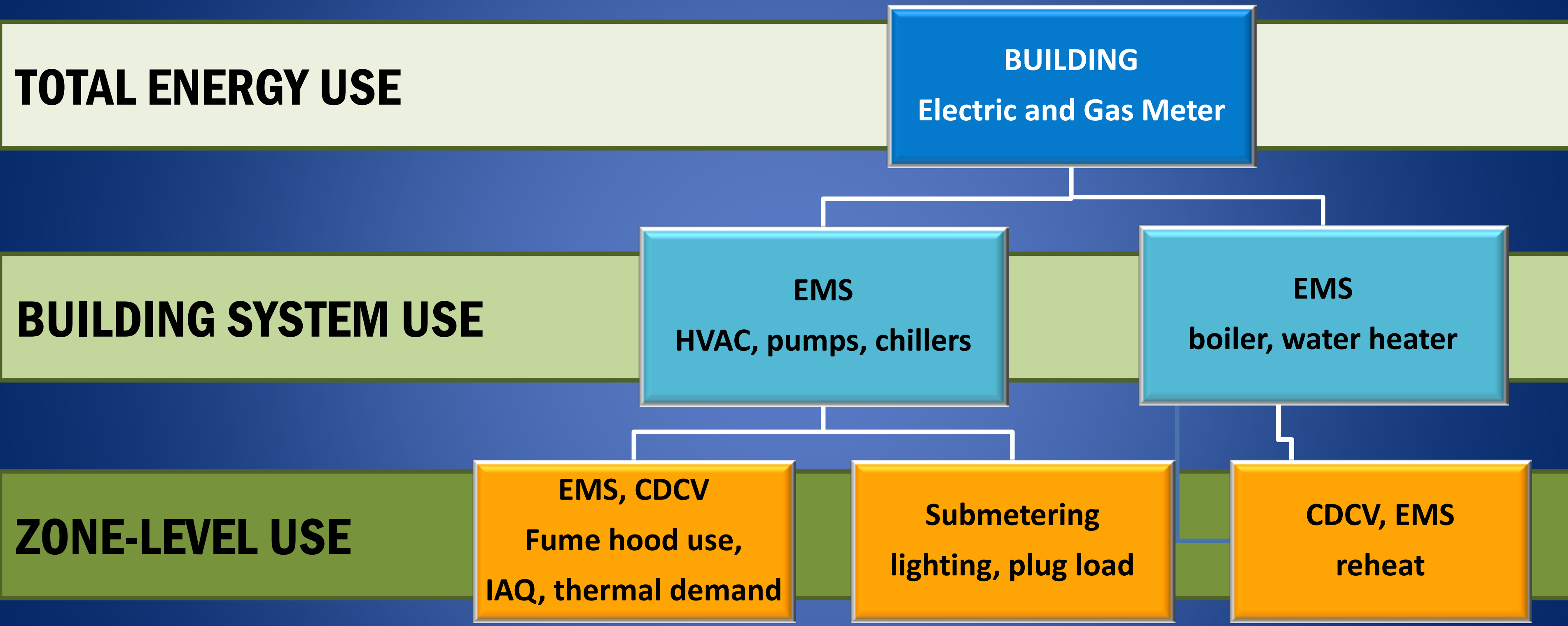
Monitoring and Verification Capabilities

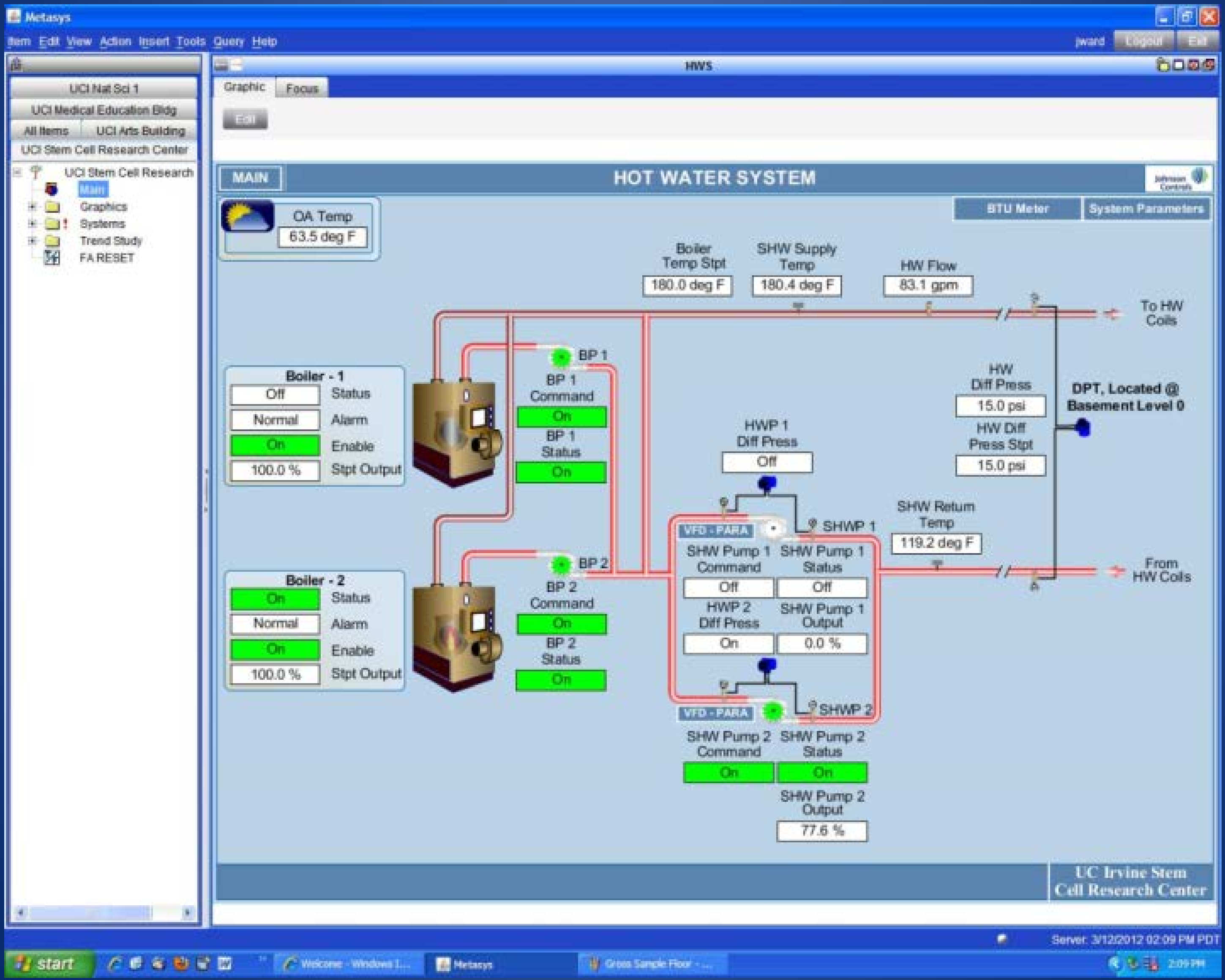
1. What level of metering do you have?
2. What level of metering do you need?
3. Where is the information you need?
4. What metrics should I trend and make decisions with?

Look Closer … Find More Savings



At the zone level, measurement and verification resolution are so high
That you are essentially constantly commissioning the building .

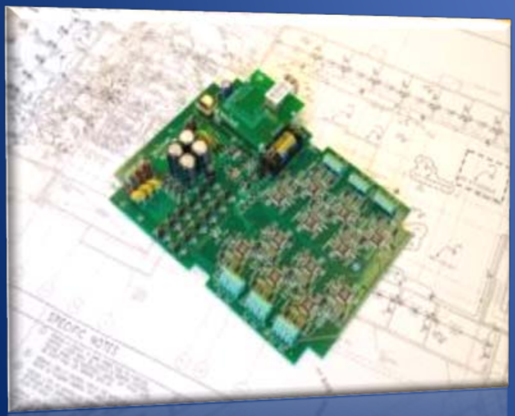
Building Management System



Cost-Effective Submetering

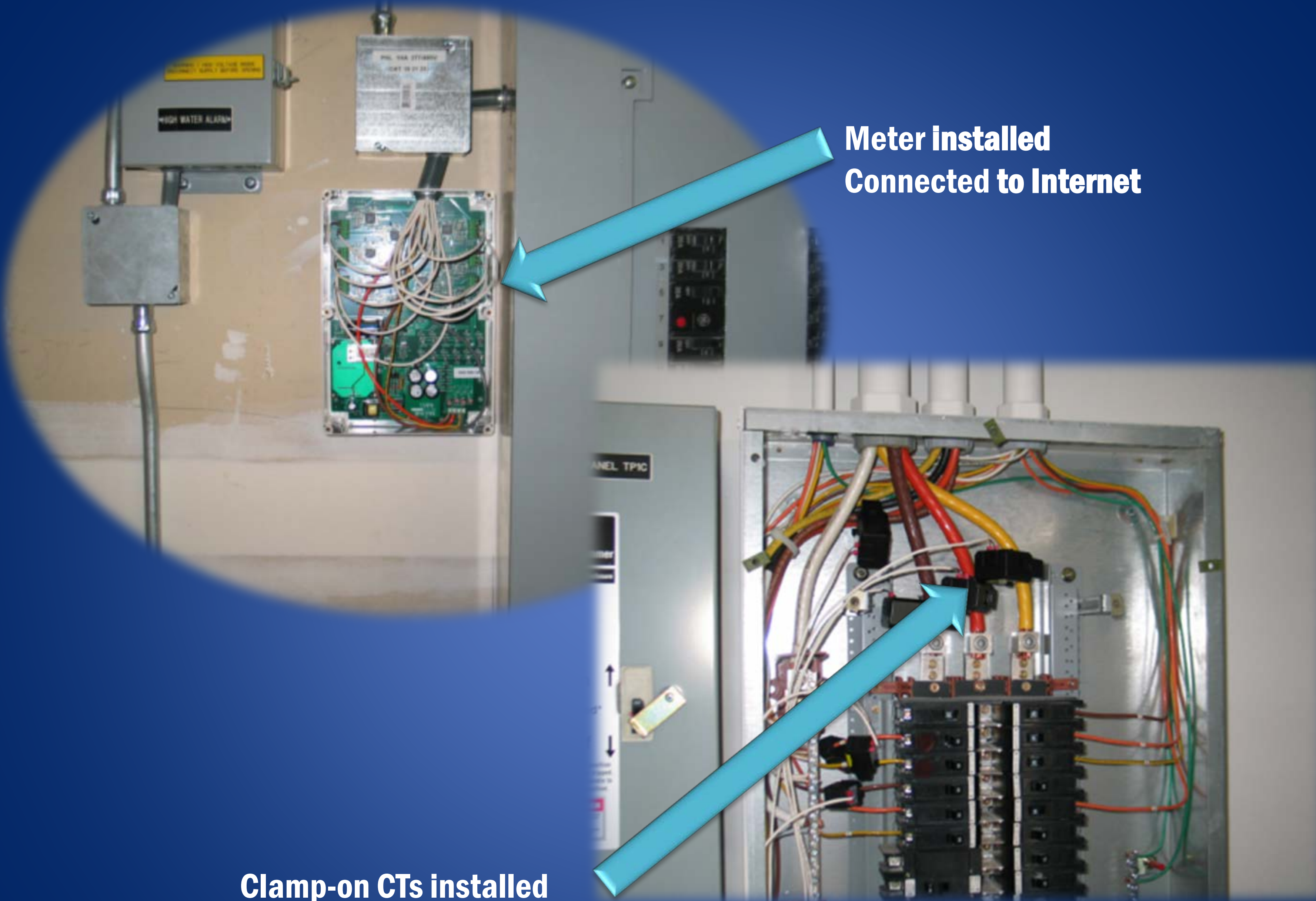
Meter Specs

- 12 channels per board
- Meter accuracy +/- 0.5% (0.25% typical)
- V, I, active energy, reactive energy, power factor

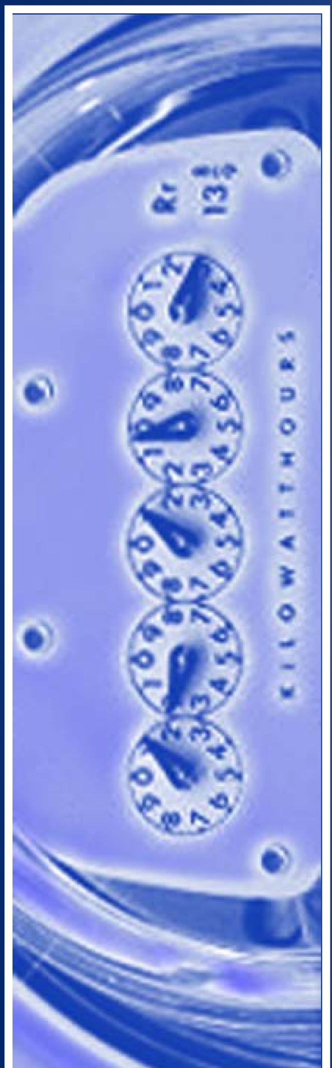


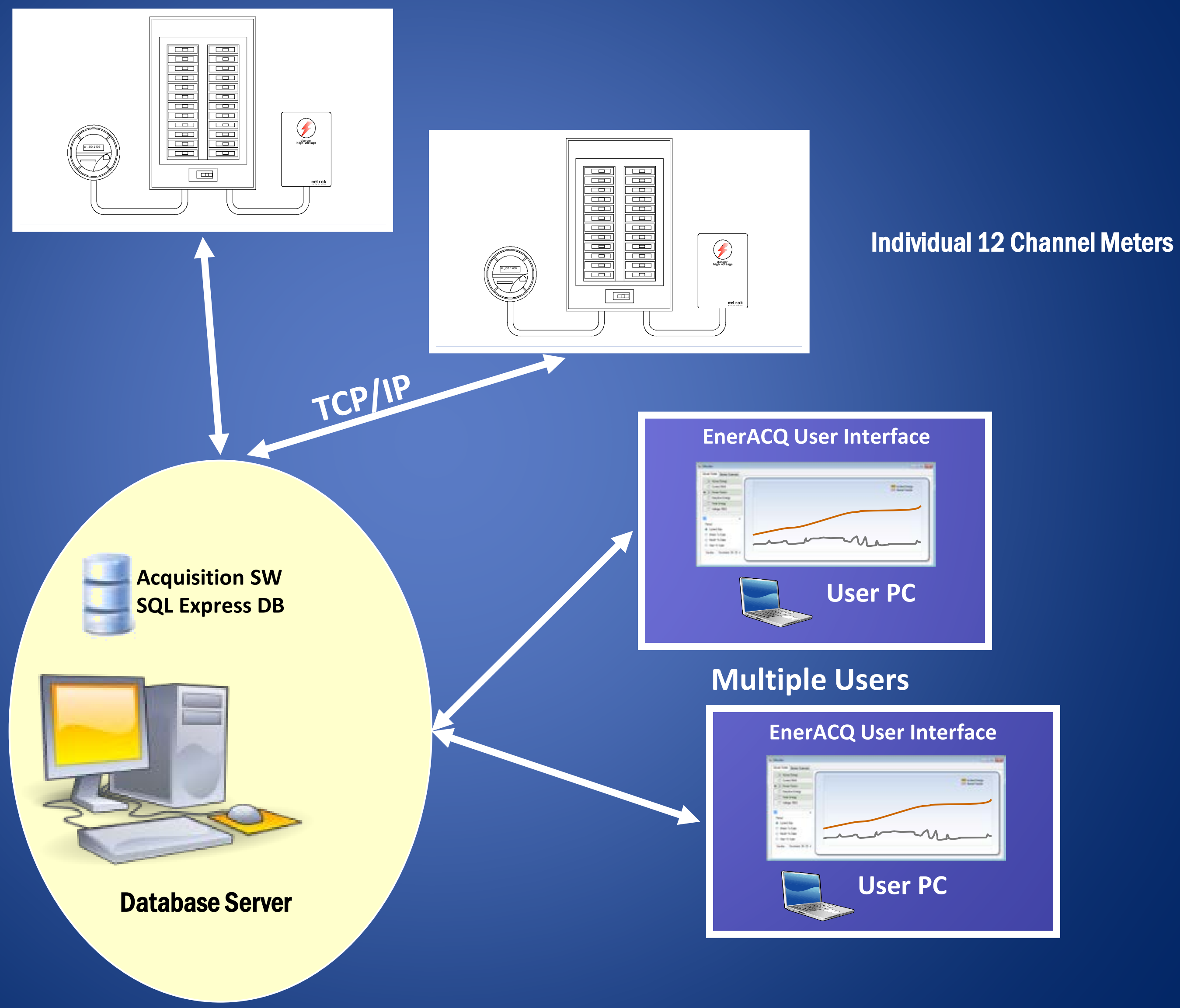
Current Transformer Specs

- Sensor accuracy +/- 1%
- Current transformers 60-400 amps
- Clamp-on installation

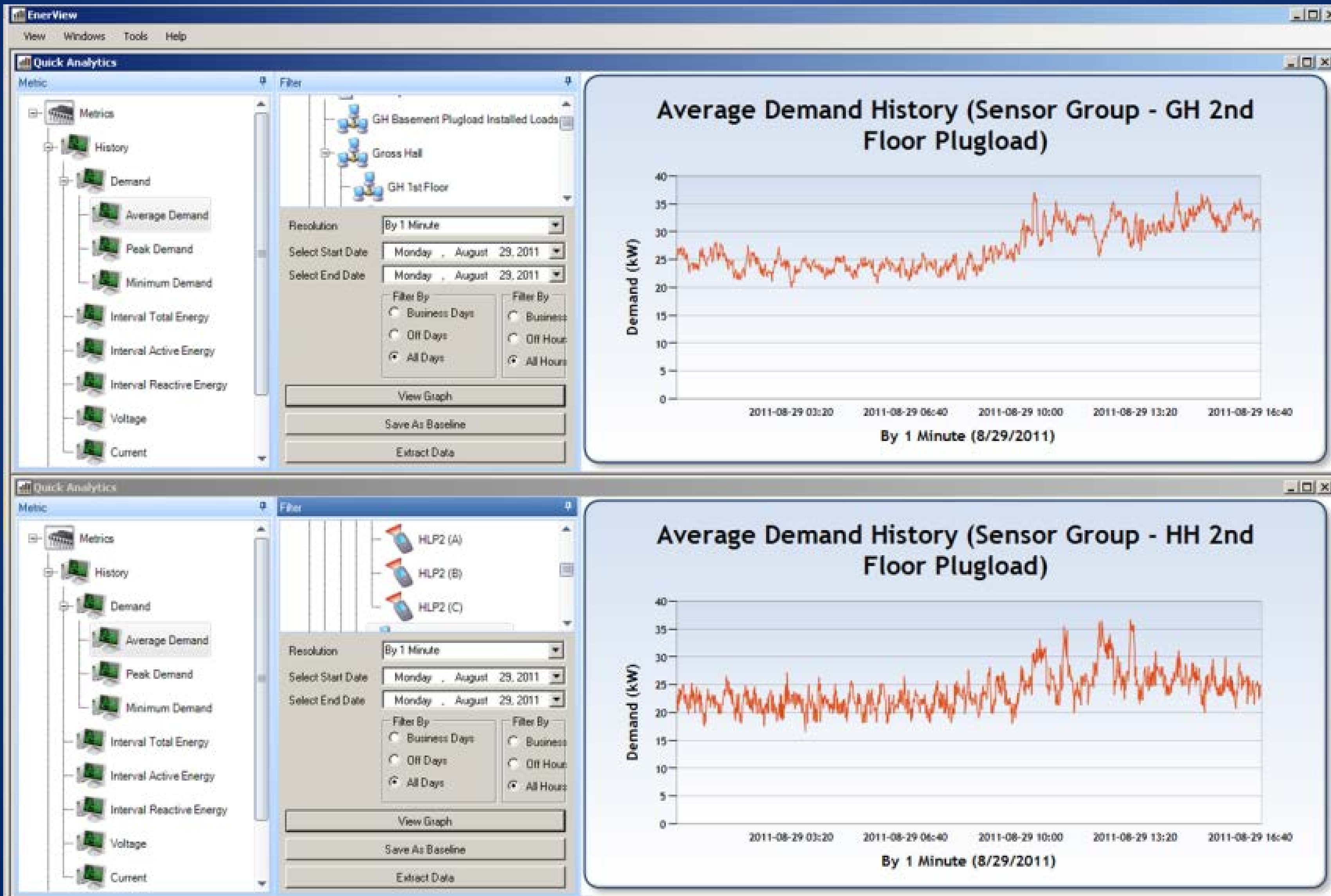

Meter installed
Connected to Internet
Clamp-on CTs installed

System Description





Visualization of Lab Energy Use



Metrics That Can Lead to Action

LEED®
Energy Star®
Labs 21 Benchmarks

Total Building Load

Watts / Square Foot
Therms / Square Foot

Lighting

Watts / Square Foot
Interior Load vs Exterior Load
Daytime Load vs Nighttime Load
Lighting Load per Floor

HVAC

Watts / Square Foot
Therms / Square foot
Daytime Load vs Nighttime Load
CFM per Zone

Plug Load

Watts / Square Foot
Daytime Load vs Nighttime Load
Plug Load per Floor
Fixed Load vs User Load

Information that is actionable

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Smart Lab Characteristics

1. Building Envelope
2. Lighting
3. Mechanical System
4. Lab Equipment Selection

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Building Envelope

HVAC system size

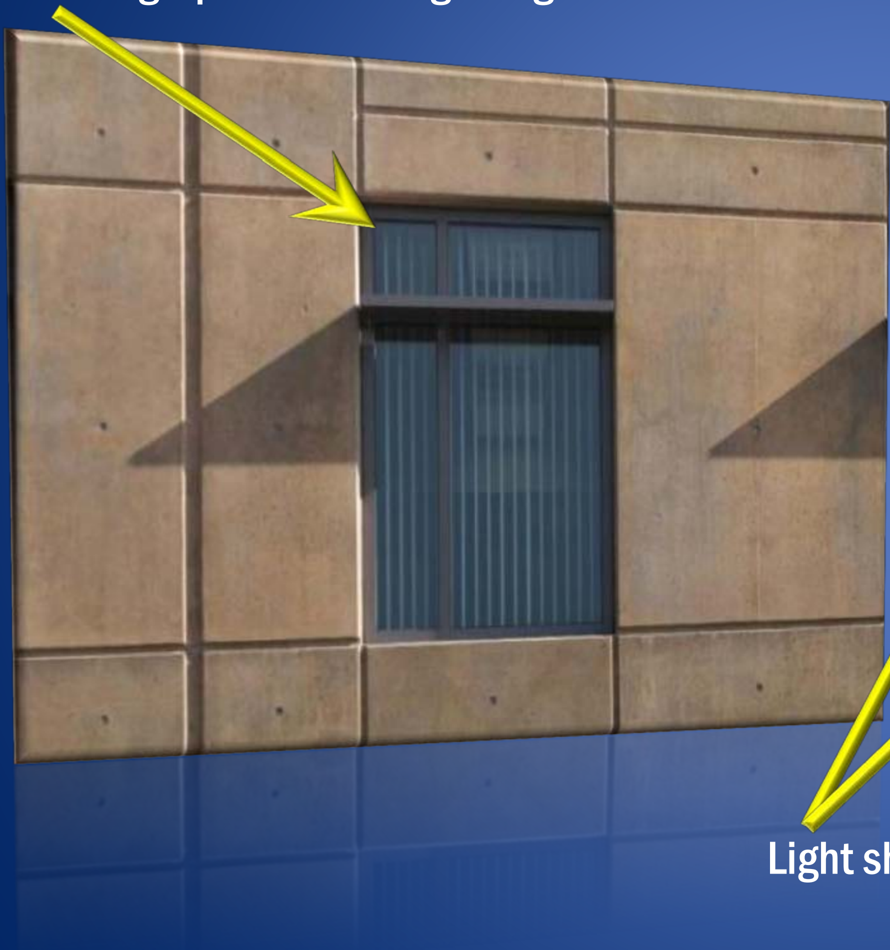
Lighting requirements

Environmental impact

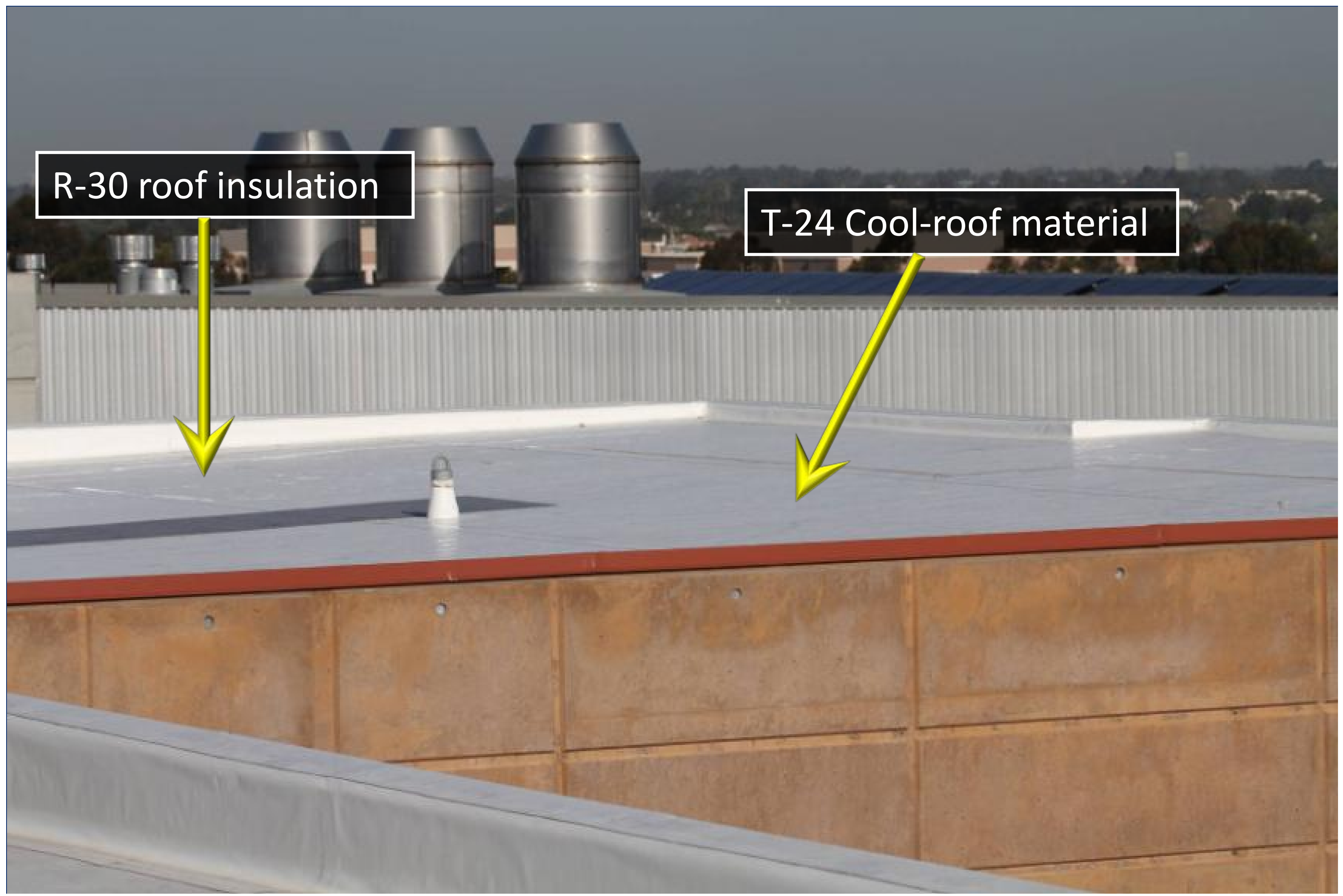
Building shell is No. 1 driver

Building Envelope

Building Envelope



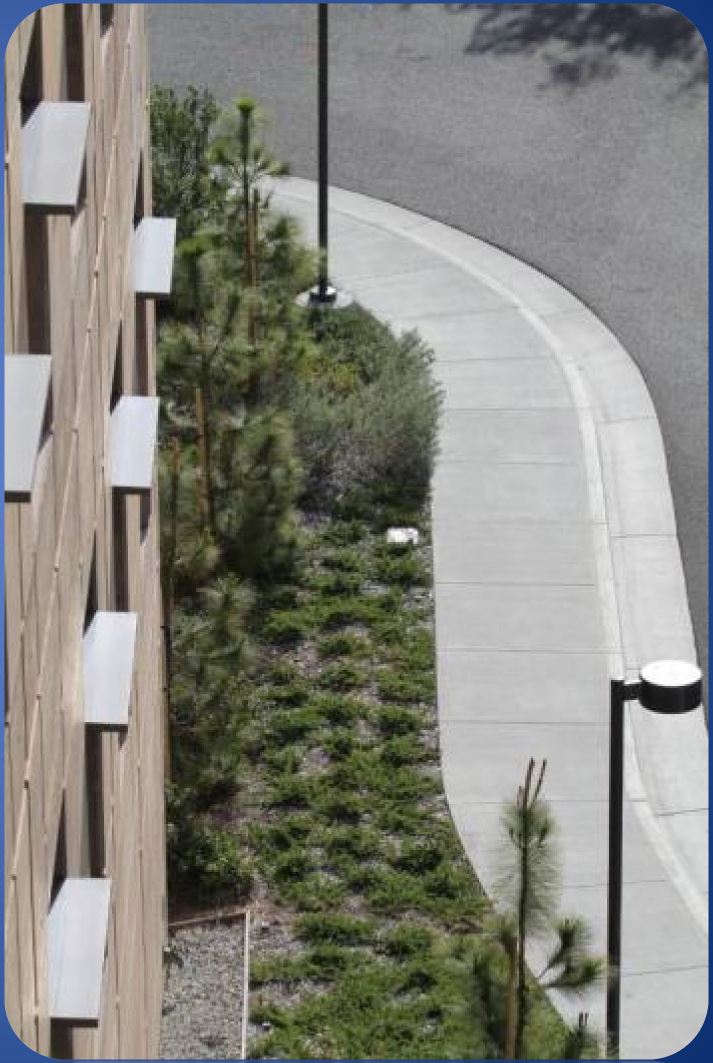
Building Envelope



Building Envelope

Landscape belts at building perimeters reduce heat and reflection impacts

Drought-tolerant vegetation uses minimal reclaimed water



Right-Sized Air Handlers & Exhaust

Low-Velocity Air Handling Units
350 fpm Face Velocity

Increased duct size

Low-pressure drop filters

NEMA premium efficiency motors

Why use high volume ductwork?
Low-Velocity Exhaust Ductwork

- Low pressure drop laboratory air system design
- Low velocity air distribution system
- Low velocity exhaust ductwork

Increased duct size

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Lighting

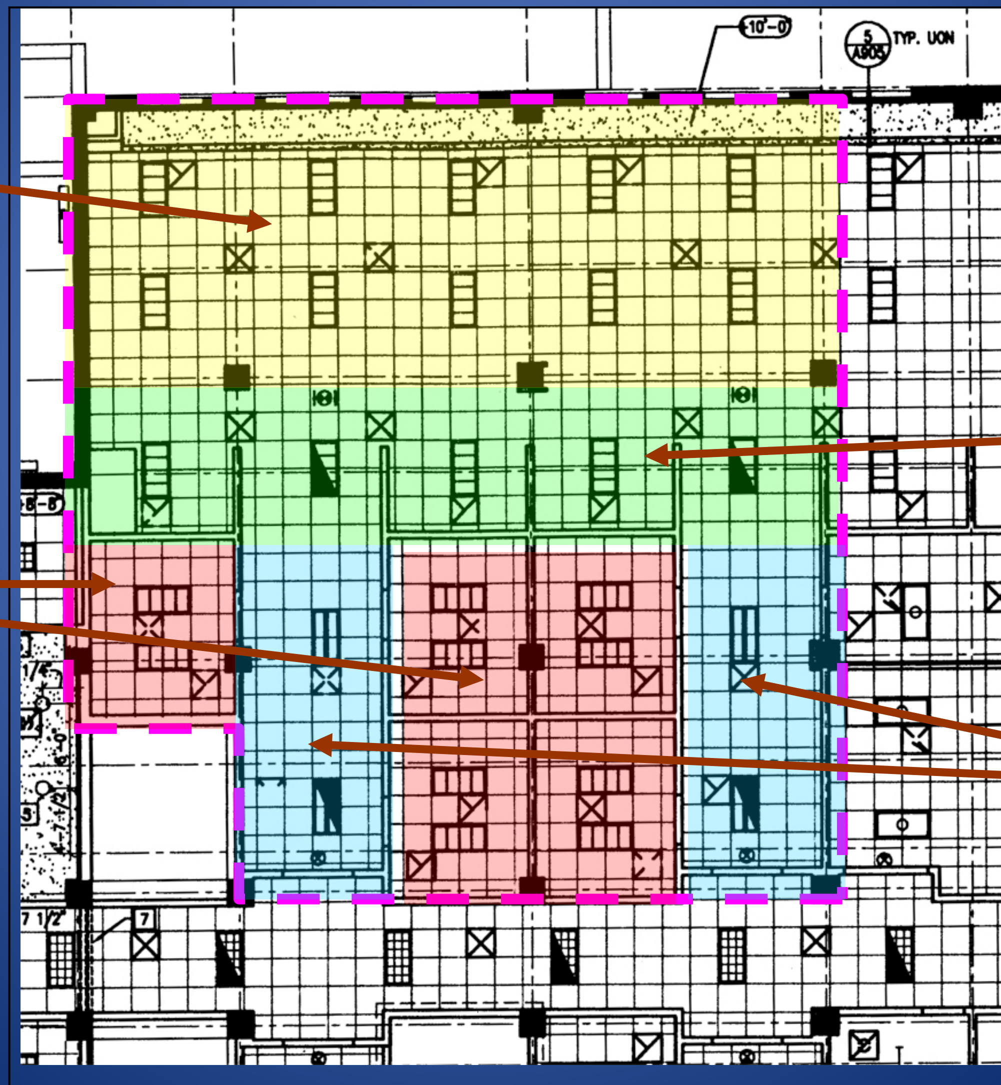
- Lighting should be as flexible as possible.
- Provide task lighting when additional illumination
- is needed.
- Encourage occupants to be conscious of their lighting needs.
- Do not discount the synergistic savings from eliminating heat produced by over-illuminated spaces.

What Is Your Lighting Power Density?

LPD = (Watts / Area) x Occupancy Sensor x Circuiting Strategy x Day lighting

Lab Area LPD
from 1.1 to 0.6

Prep Room LPD
from 2.0 to 1.0



Lab Prep LPD
from 1.0 to 0.4

Corridor LPD
from 0.6 to 0.3

Non Daylighting Areas

32 Watt T8	→	25 Watt T8
NLO Ballast .87-.90 BF	→	RLO Ballast .71 BF

This retrofit on a 4 lamp fixture, on 4380 hours a year, saves 170 kWh per year.

UC Irvine retrofitted ~15,000 fixtures campuswide, saving 2,550,000 kWh per year!

We had ZERO complaints!

Automatic Daylighting Controls

Lab areas within 15 feet of windows and all private offices and conference rooms are equipped with automatic daylighting controls.

Daylighting Without the Glare

Sequence

Auto on to 50%

Manual on to 100%

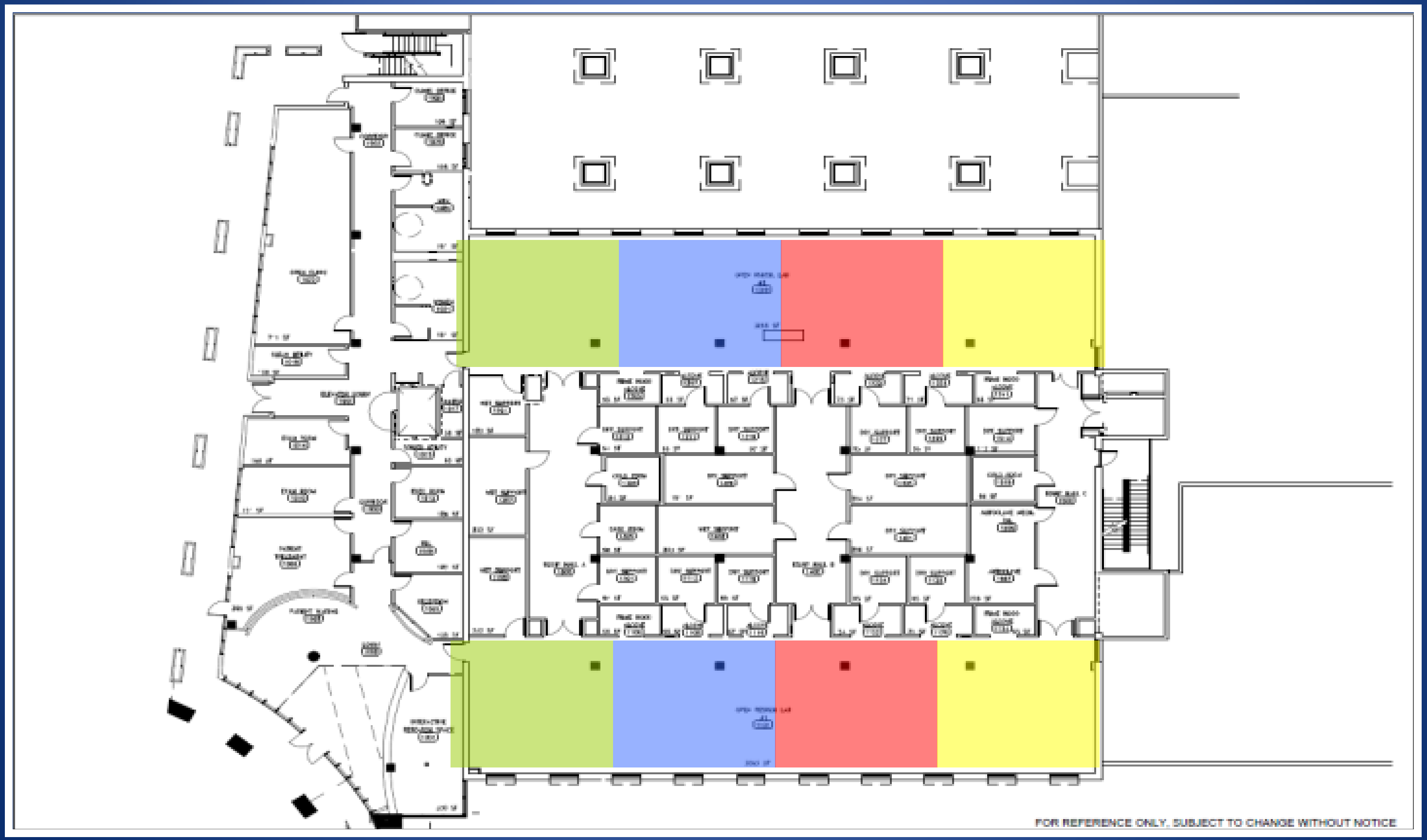
Auto off

Lighting

Lighting is controlled per lab bay -- not per lab -- to maximize savings.

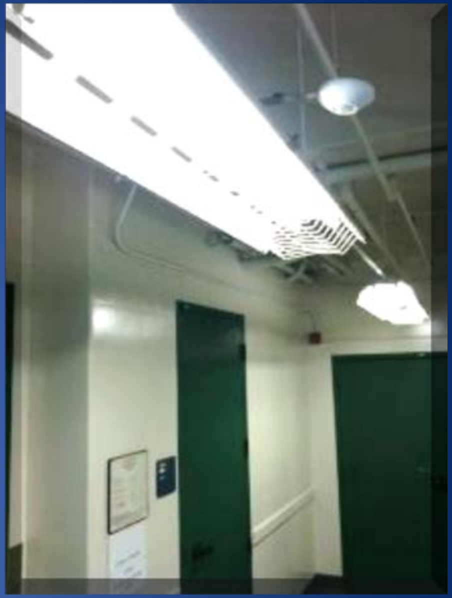
Lighting

Lighting is controlled per lab bay -- not per lab -- to maximize savings.



LED Task Lighting

Bi-Level Lighting in Stairwells and Corridors



Corridor lighting is often on all year, 24 hours a day, and represents a good opportunity for occupancy sensing.

Bi-level lighting in stairwells is another opportunity that should not be overlooked.

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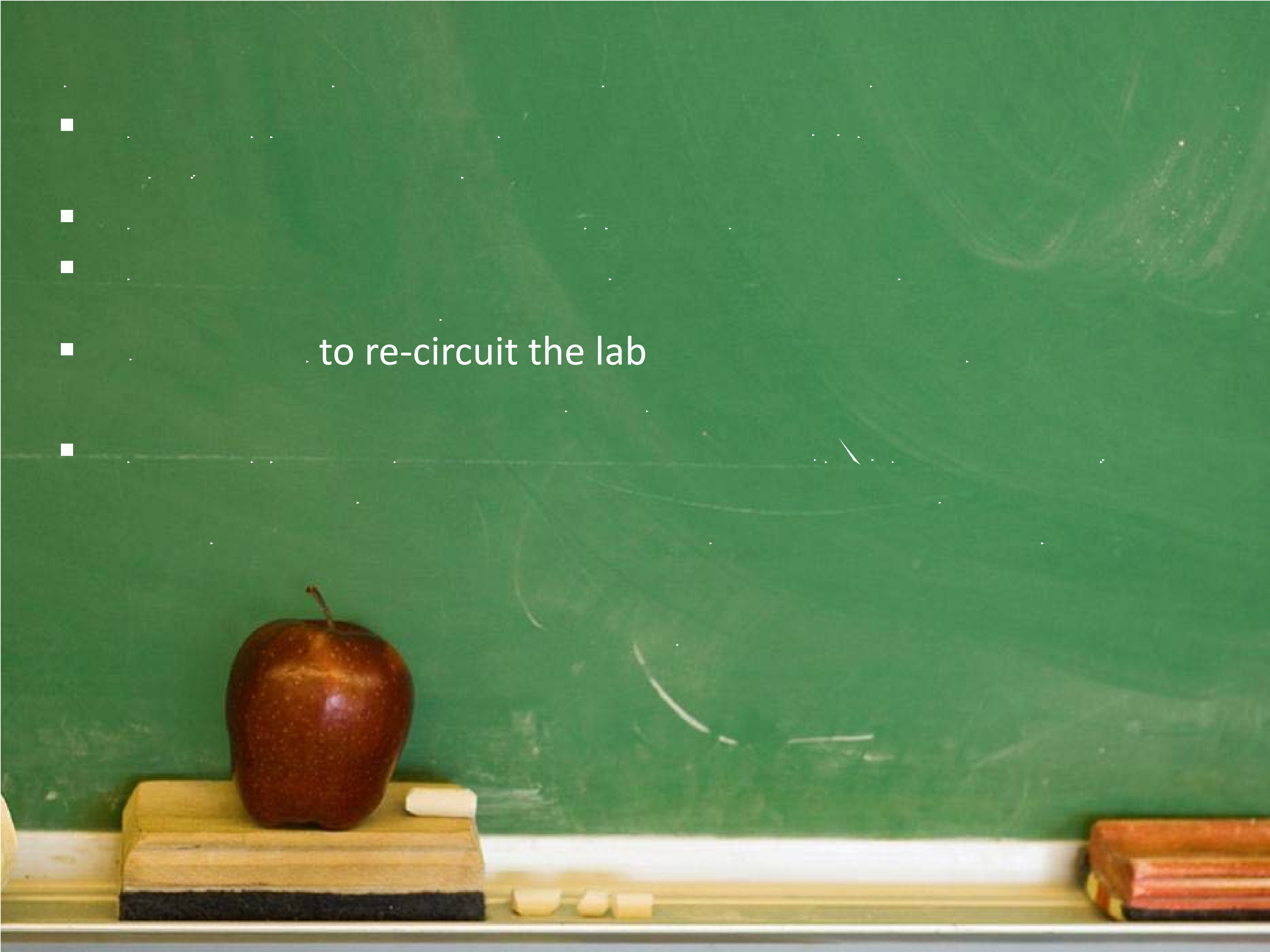
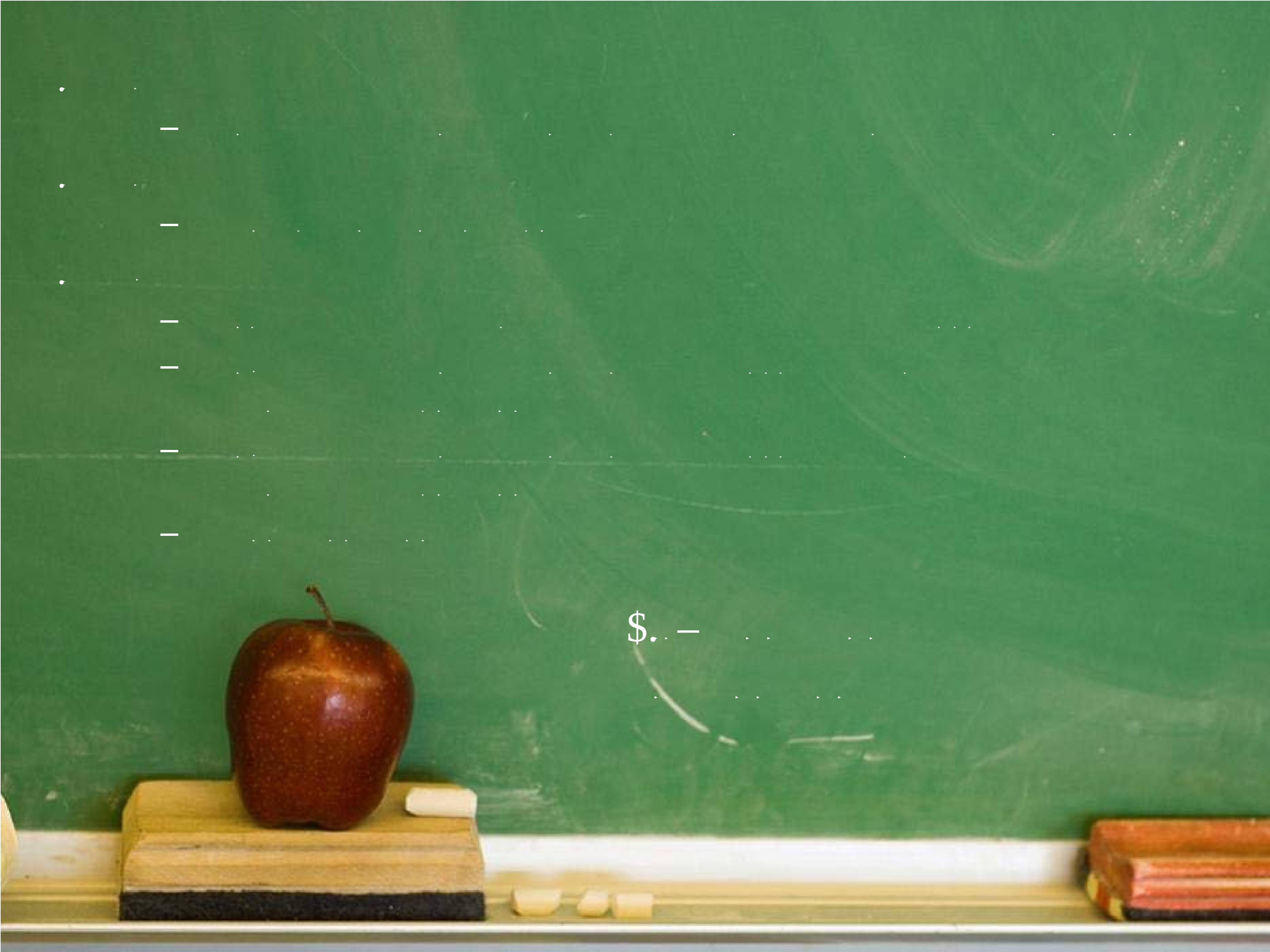

to re-circuit the lab



TAKE A BREAK

The training session will resume in 10 minutes.

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Mechanical System

- Maximize occupant comfort
- Minimize air change rates
- Maintain lab safety
- Provide a right-sized system that is both variable and efficient
- Make use of dashboards to review energy consumption and indoor air quality

What is an Air Change Rate

Air Change Rate - Imperial Units

Air change rate - air changes per hour - can be expressed in imperial Units as

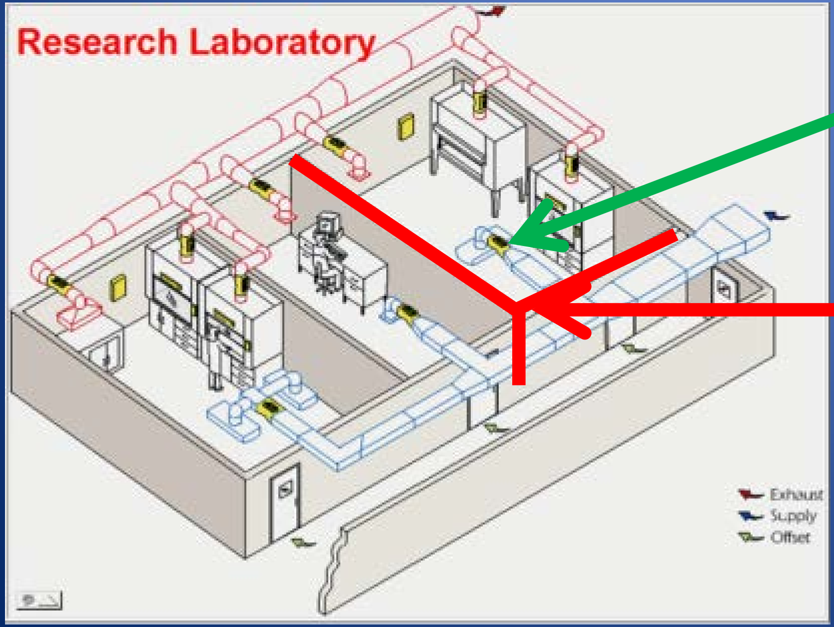
$$n = 60\, q / V$$

Where

n = air changes per hour

q = fresh air flow through the room (Cubic Feet per Minute, cfm)

V = volume of the room (Cubic Feet)

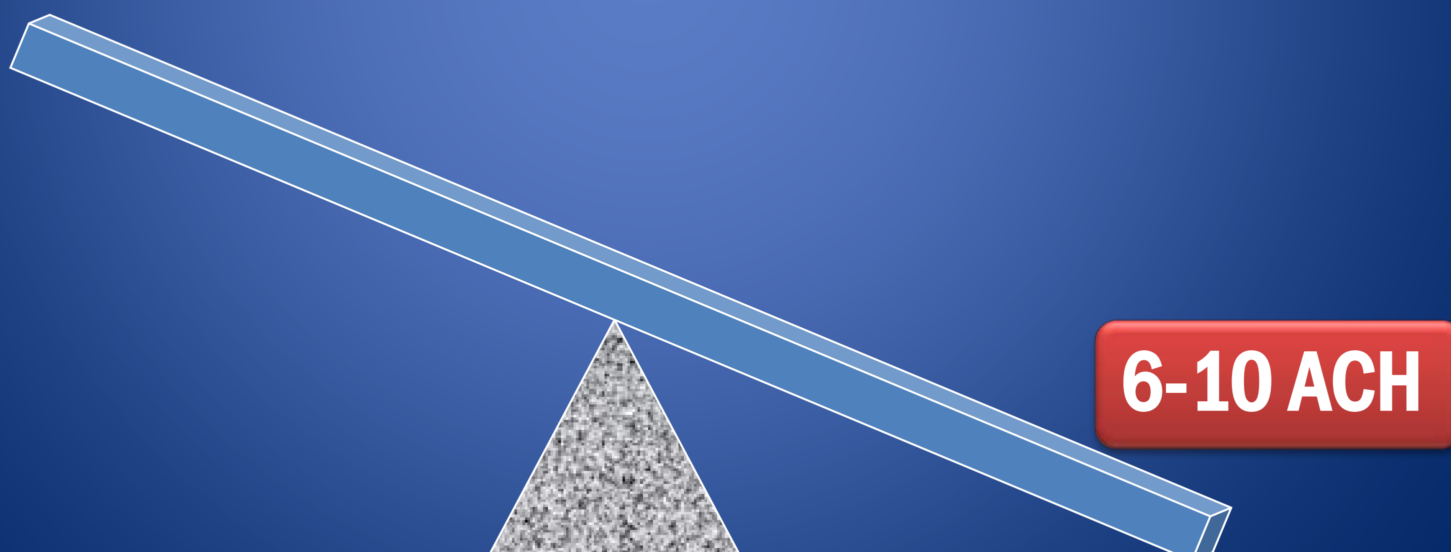


q = supply in CFM

V = Length x Width x Height

Mechanical System Balance

- Autoclaves
- Ultra-low temp freezers
- Refrigerators
- Incubators
- Water purification systems
- Microscopes
- Computers
- Shake tables
- Lighting
- Occupants
- Building shell
- Windows



High air change rates often exceed all of the lab's process and operational loads.

Mechanical System Balance

Autoclaves
Ultra-low temp freezers
Refrigerators
Incubators
Water purification systems
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Shake tables
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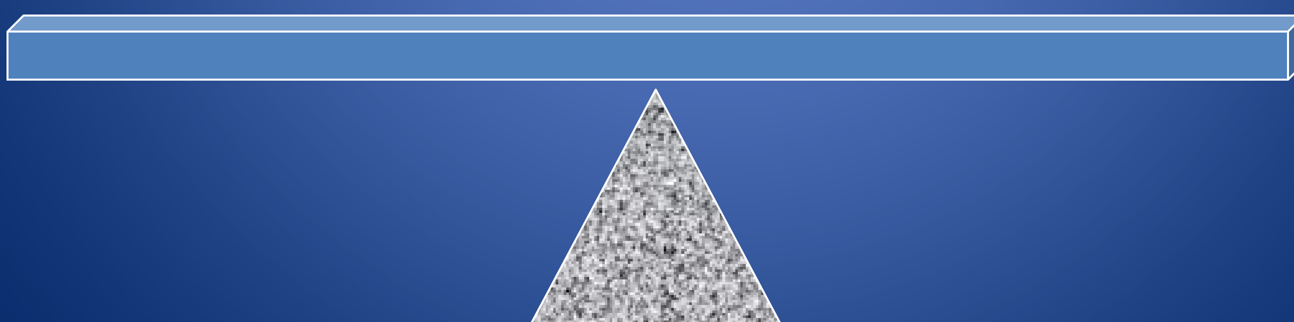
Windows

REHEAT

6-10 ACH



Balance to the room is brought about by adding varying amounts of reheat.

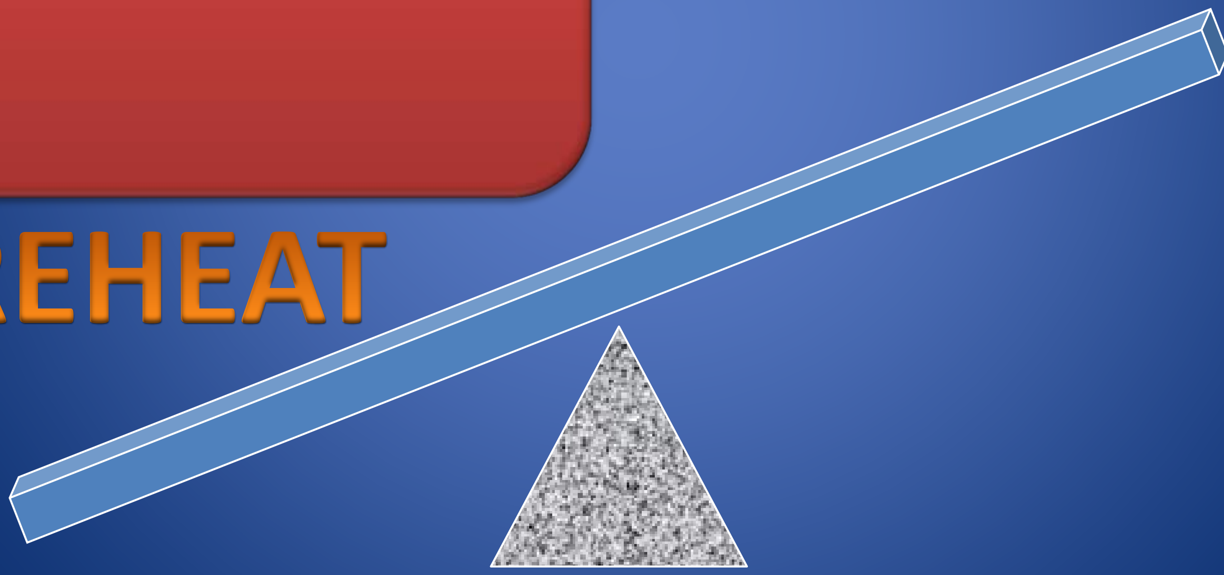
Mechanical System Balance

Autoclaves
Ultra-low Temp Freezers
Refrigerators
Incubators
Water purification systems
Microscopes
Computers
Shake tables

Lighting
Occupants
Building Shell
Windows

REHEAT

2-4 ACH



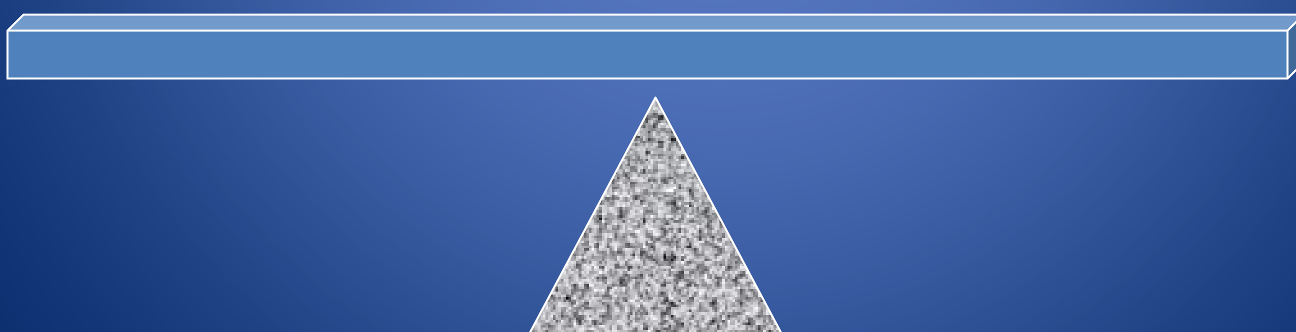
Lowering the air change rate with the installation of a CDCV system swings the balance the other way.

Mechanical System Balance

Autoclaves
Ultra -low temp freezers
Refrigerators
Incubators
Water purification systems
Microscopes
Computers
Shake tables

Lighting
Occupants
Building Shell
Windows

2-4 ACH



Lower air change rates more closely match the natural lab process load, reducing both fan power and reheat.

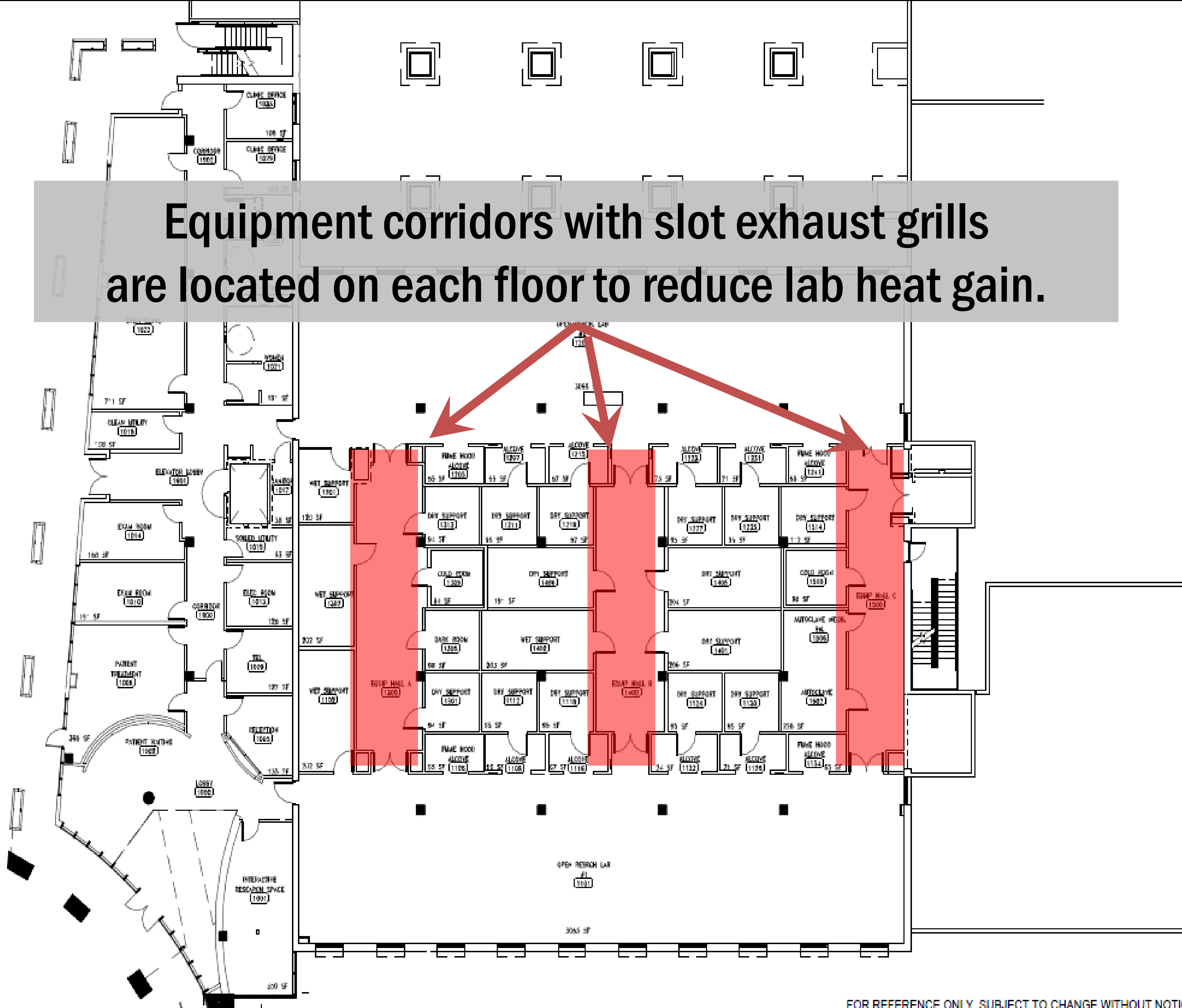
Lab HVAC Load

Process heat gain from lab equipment is the primary source of internal heat gain in many facilities.

- Autoclaves
- Ultra-low temperature freezers
- Refrigerators
- Incubators
- Water purification systems
- Microscopes
- Computers
- Shake tables

You need a plan to deal with the heat!

Equipment corridors with slot exhaust grills are located on each floor to reduce lab heat gain.



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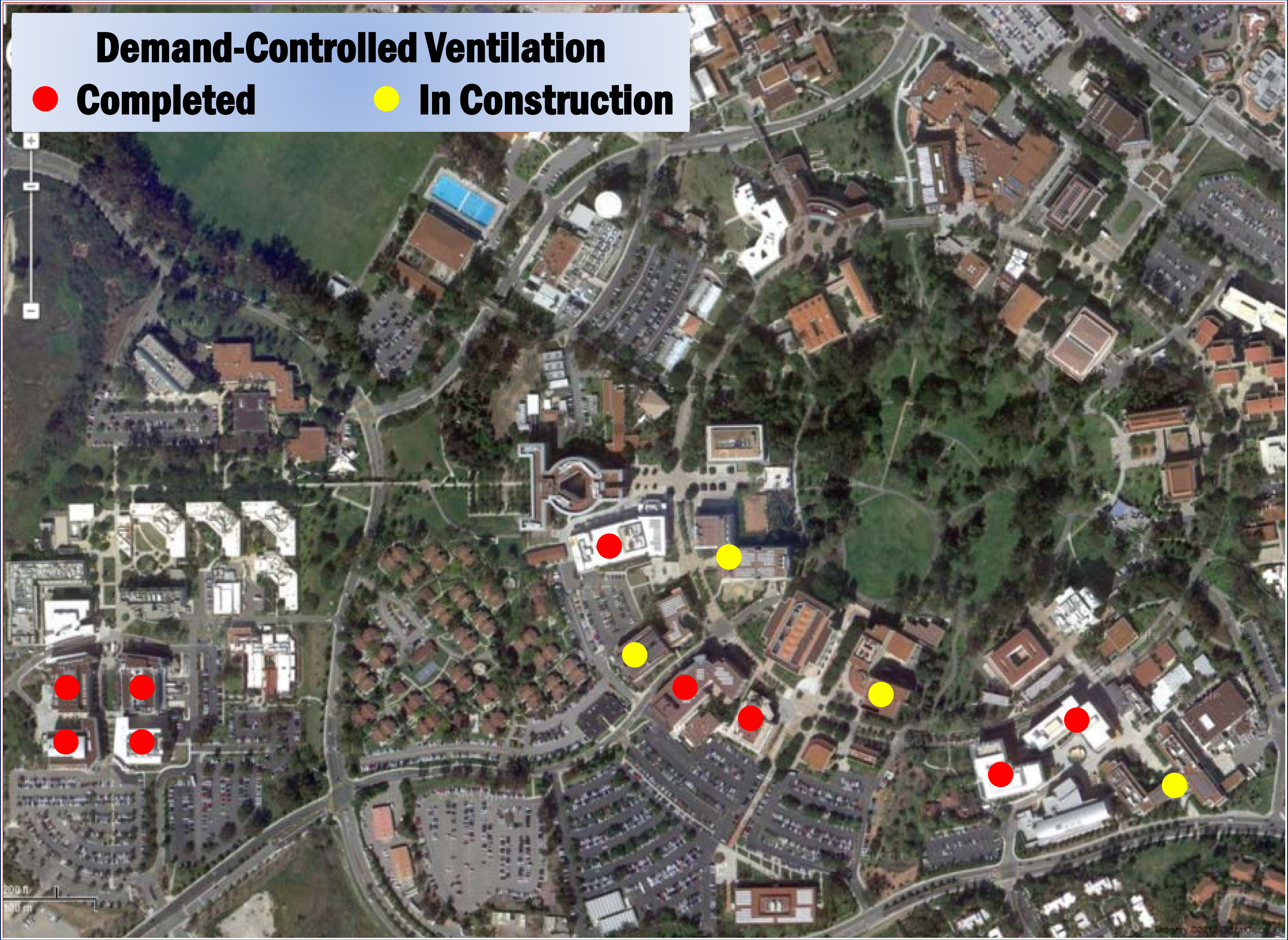
Centralized Demand Controlled Ventilation

- Monitors the indoor air quality of multiple zones through a network of structured cables and air data routers
- Analyzes the sampled air with a series of sensors
- Provides the lab air control system with an input for increased ventilation when necessary.
- The system is only an input to your lab air control system, no different than a thermostat, or sash position sensor.

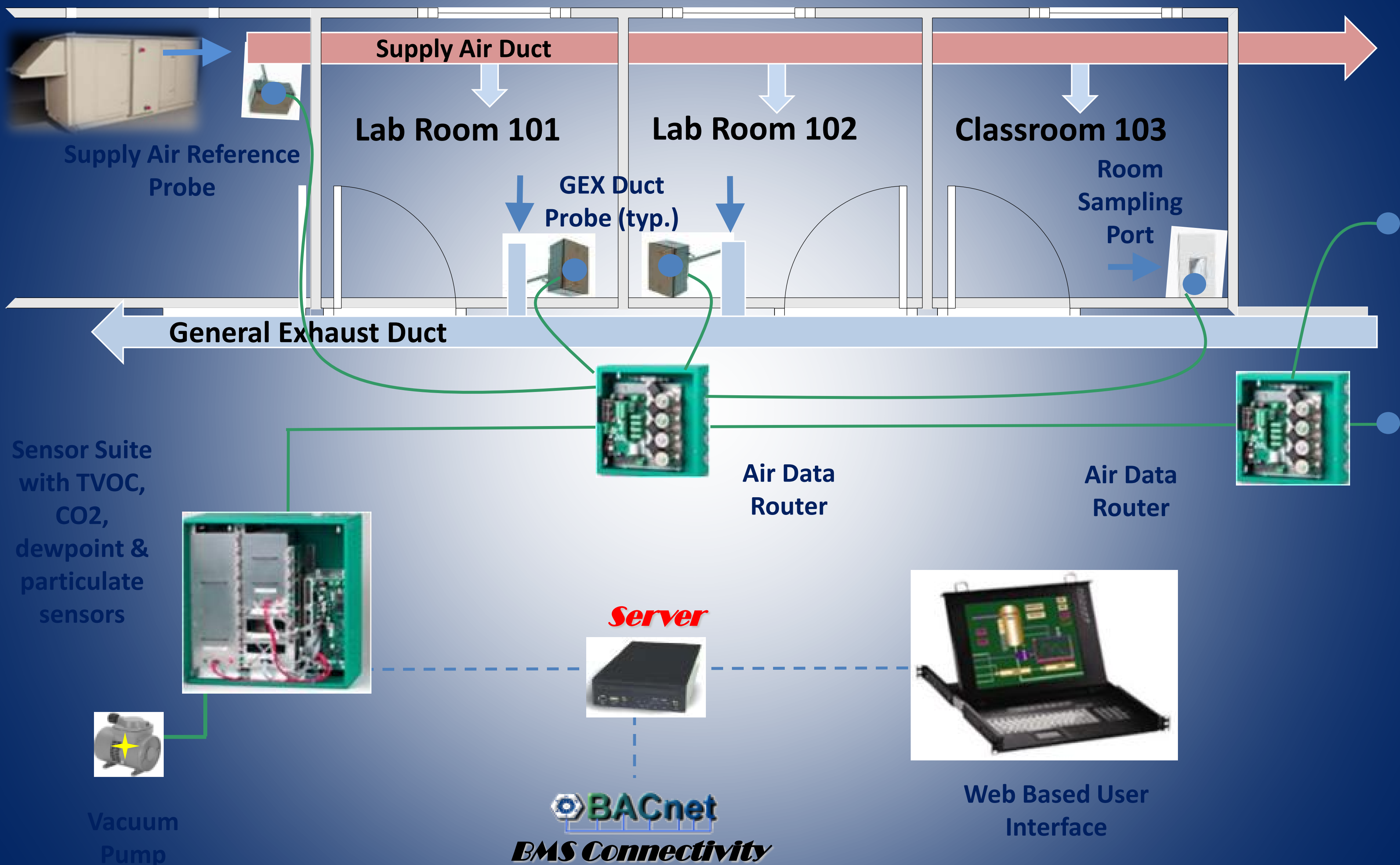
Target is 4 air changes per hour in occupied labs
and 2 air changes per hour in unoccupied labs.


Demand-Controlled Ventilation
Completed
In Construction

C
D
C
V

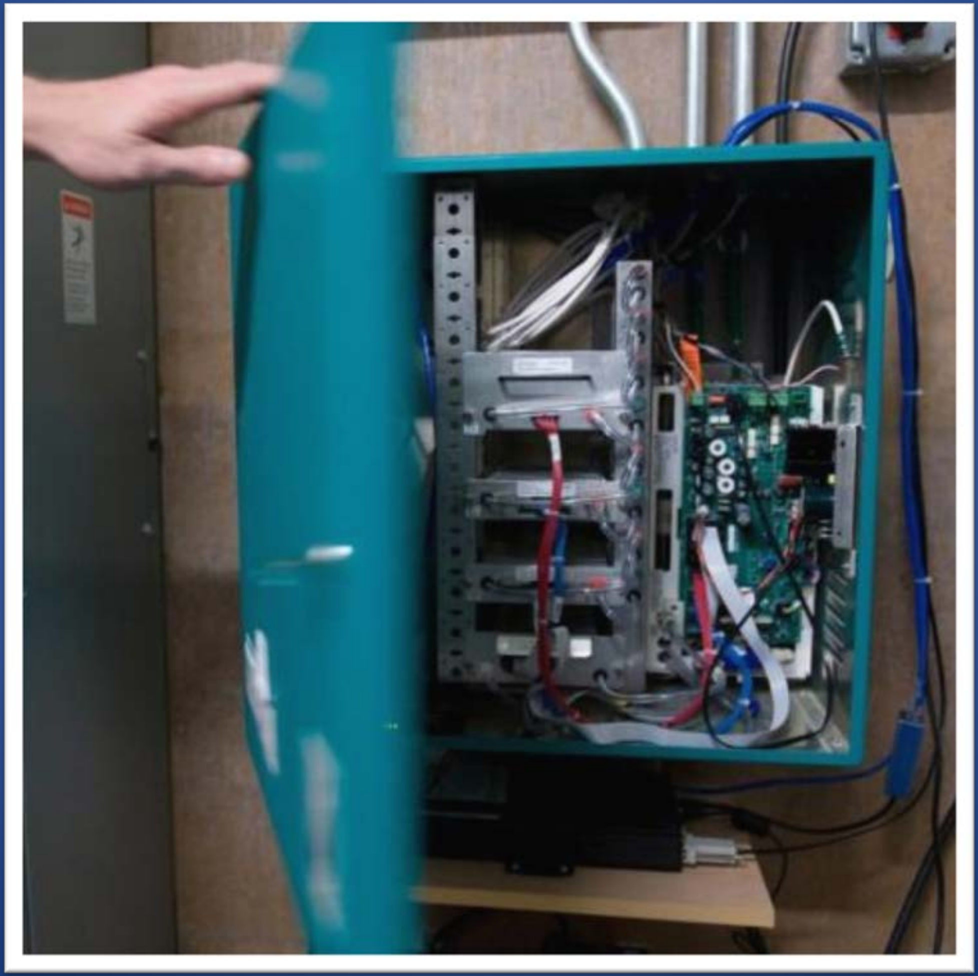
1. Room sensor mounted in general exhaust duct samples a packet of air
2. Packet of air is routed to the Sensor Suite
3. Sensors measure indoor air quality
4. Information Management System determines need for increased ventilation, commands VAV controllers, and serves data to a web server.
5. System monitoring is available via a web based interface.

CDCV System Architecture



CDCV Components

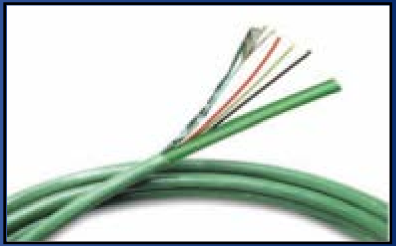
Sensor Suite



Vacuum Pump

Air Data Router

Structured Cable



Duct Probe

CDCV - Sensors

Type	Sensors	Activation Range		Units
		Low	High	
TVOC	PID (10.63V)	0.1	1.0	ppm
TVOC	Metal Oxide (MOS)	0.3	3.0	ppm
CO_2	NDIR	300	3,000	ppm
Particulate	Optical	500,000	5,000,000	pcf
CO	Electrochem	2	20	ppm

Smart Labs - Added Features

UC Irvine seeks to continuously update the lab air control system with safety and energy saving features.

Safety

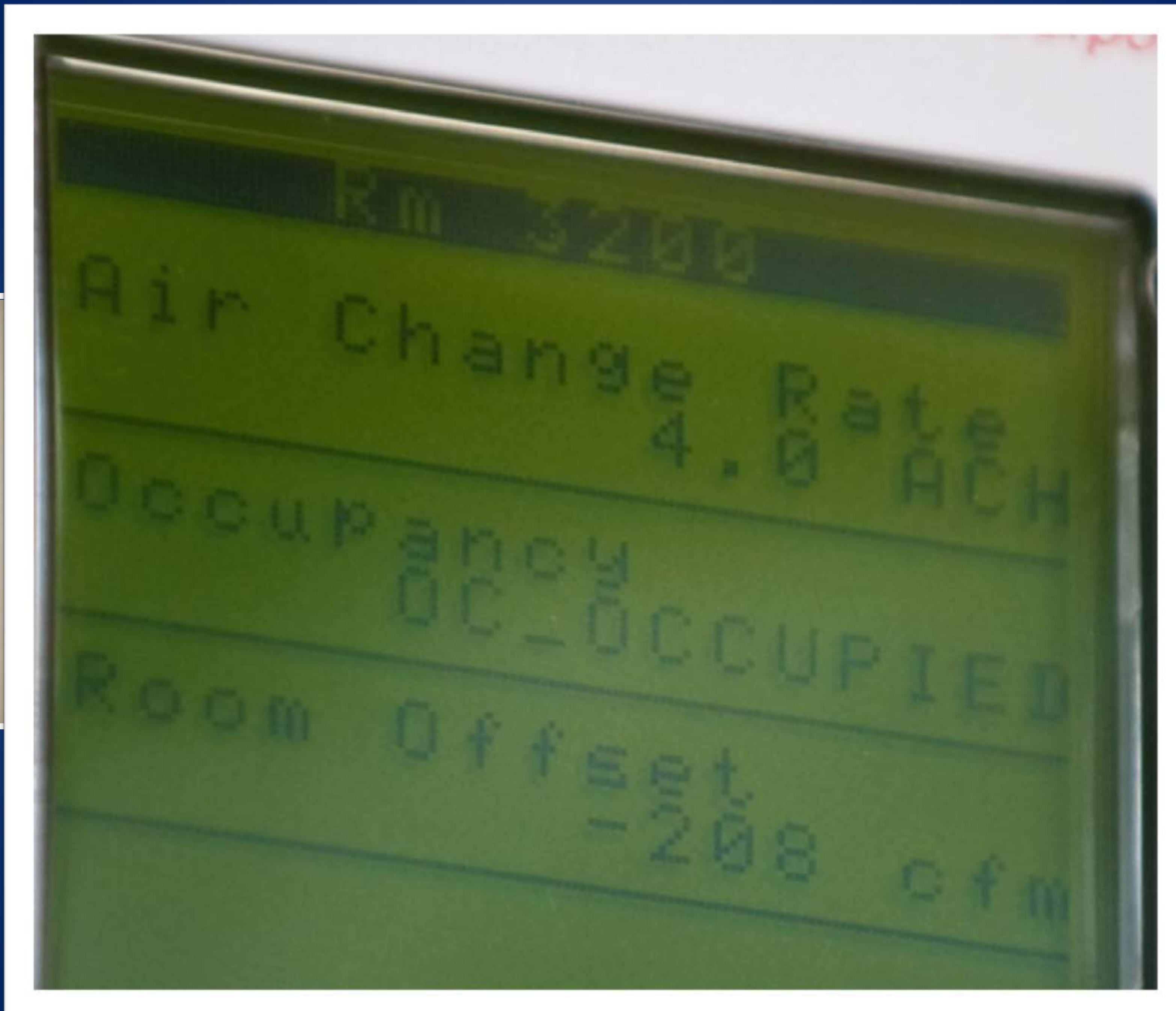
- Red Buttons
- Lab display unit (LDU)

Energy Savings

- Occupancy sensors

Red Buttons

Red Button – In the event of a chemical spill or other event requiring increased ventilation in a lab, an emergency ventilation override button has been installed. Pressing this button will increase air change rates to maximum while maintaining negative lab pressurization.



Hall

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Smart Lab "Safety Net"

Welcome to Sue and Bill Gross Hall
A CIRM Institute

As you may be aware, Gross Hall is one of the most energy efficient lab buildings in the United States. Please take a moment to review these unique features.

Centralized Demand Controlled Ventilation – The *Aircuity* system installed in Gross Hall research laboratory spaces, monitors indoor air quality and adjusts supply and exhaust air delivery based upon indoor contaminant levels. The automated system samples packets of air and then analyzes them with a battery of sensors to determine air change rates required for each zone. The sensors are calibrated every six months and the system is monitored via a web interface.

Red Button – In the event of a chemical spill or other event requiring increased ventilation in a lab, an emergency ventilation override button has been installed. Pressing this button will increase air change rates to maximum while maintaining negative lab pressurization. This button should **not** be pressed in the event of a fire!

Occupancy Controlled HVAC – The Smart Lab design of the ventilation system includes occupancy based air change rate controls. Occupancy sensors will allow for air change rate reductions during unoccupied periods. The system does not affect fume hood ventilation. Upon initial entry after a long period of inactivity, the lab may feel stuffy, please allow a few minutes for the room to normalize.

Lab Ventilation Display Unit – The display panel located on the wall of each lab allows occupants to check the status of the room's air change rate, as well as ensure that the occupancy sensors are working properly. Please note that the panels are labeled Phoenix Controls Corporation and have a 3" x 3" LCD screen. Air change rates should remain at approximately 4 air changes per hour (ACH) when the lab is occupied and 2 ACH when unoccupied.

Operable Windows – Gross Hall has been equipped with operable windows in offices and conference rooms. The heating and air-conditioning system is interlocked with the operation of the windows. Therefore, opening a window will turn off mechanical ventilation to that zone.

Occupancy Controlled Lighting – After manually turning on the lights with via a light switch, the overhead lights will automatically turn off during unoccupied periods. Overhead lighting may also be turned off manually. We encourage everyone to turn off all lights whenever they leave the laboratory for an extended period.

Natural Interior Lighting/Automatic Overhead Lighting Reduction - The Gross Hall is designed to maximize interior illumination via natural lighting. In addition, the overhead interior lights are connected to photosensors that control the intensity of the interior lighting based upon the availability of outdoor light.

Finelite LED Task Lighting – Task lighting will be provided to users who require additional lab bench top lighting. To receive task lighting, please contact Customer Service Representative Sherry Long at 824-6221.

Energy Efficient Filtration/Better Indoor Air Quality – Gross Hall is equipped with energy saving high efficiency Merv 14 particulate filters. The result: lower energy costs and improved indoor air quality.

Occupant Training

Describes Smart Lab features

Laboratory is a "System"

HVAC elements must work together as a system for contaminant control:

1. Primary control – Local exhaust ventilation (at source of contaminant generation)
2. Secondary control – Dilution of room air (ACH)

A key focus of the bench top risk assessment is to drive contaminants into primary controls whenever possible.

Primary (Source) Control – Fume Hood

Primary (Source) Control - Snorkel

Primary (Source) Control - Glove Box

Laboratory is a "System"

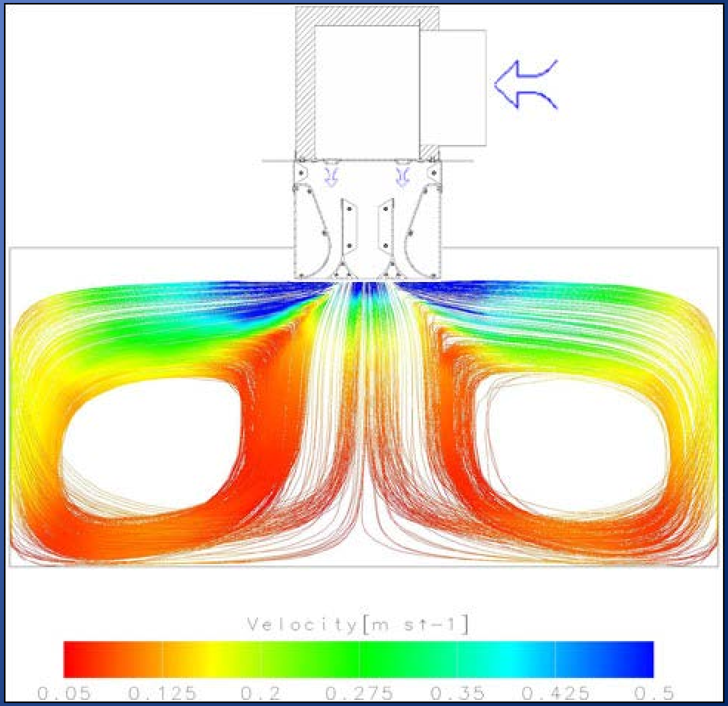
For contaminant control, critical to have:

- All HVAC elements in balance and maintained
- Fume hood commissioning & placement
- Good air mixing to avoid contaminant build-up & achieve effective dilution

Air Mixing for Good Air Quality

- Air diffusers are key to promote better air mixing
- Explore various diffuser styles
- Evaluate air mixing – smoke studies or computational fluid dynamics (CFD)
- Separate air diffusers

  and air returns



Good Air Mixing – Fabric Air Diffuser

Less air turbulence to fume hoods

Air Changes per Hour (ACH)
(secondary control – dilution ventilation)

- 6+ ACH → 4/2 ACH setback with occupancy sensing
- CDCV senses chemical and increases ACH
- Sensor failure must "fail safe" to 6 ACH
  - Sensor suite does not detect all chemicals
- Visual signal to occupant of ACH
- Emergency exhaust red button

Question: Is Increased ACH Safer?

"Specification of Airflow Rates in Laboratories" by Tom Smith, Exposure Control Technologies, Conclusions:

– ACH as a metric for dilution is "too simplistic".
– Must consider other factors that lead to exposure, (i.e. contaminant generation rate, air mixing, etc.)
– "Increased airflow [may increase] contaminant generation and distribution throughout the space"
– May lead to "false sense of safety"

Answer: Not Necessarily

Alternatives to simply increasing ACH:

- Base air exchange rate on contaminant generation
- Review lab practices, especially outside fume hood
- Attain proper air mix ratios
- Reduce overall ACH to save energy and increase ACH as needed via “smart controls

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Implementing CDCV

Risk Assessment of Lab Bench Top Processes to Ensure Safety in Smart Labs

- Energy savings can be achieved without compromising safety
- Lab ACH determination requires:
  - Active EH&S involvement in bench top risk assessment of lab operations with lab staff
  - Contaminant source control
  - Reassessment when lab changes occur
  - Current/complete chemical inventories

Step 1 - Lab Bench Top Risk Assessment Process

Conduct room-by-room hazard screening

- Industrial hygienist (IH) evaluates worker exposure
- Review chemicals inventory/operations
- Interview lab staff
- Review engineering controls
- Focus is outside of fume hood

Lab Bench Top Screening Process

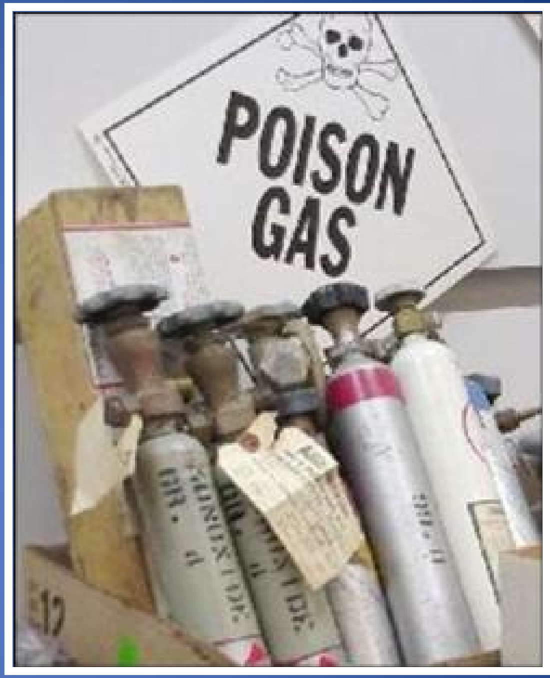
- Compare screening data with risk assessment criteria
- Enter screening data in database
  - If follow-up needed, no ACH reduction
  - If no follow-up needed, reduce ACH

Risk Assessment Criteria

High-risk labs – no ventilation reduction

- Biosafety Level 3 (airborne biohazard)
- Highly toxic gases
- Special ventilation requirements
- Chemicals/operations identified as high risk by bench top assessment or follow-up exposure monitoring
- Fire area control limits exceeded

Risk Assessment Criteria



- Chemicals of Concern
  - Acutely toxic by inhalation
  - Asphyxiants
  - Anesthetic gases
  - Carcinogens
  - Reproductive toxins
  - Air contaminants that have occupational exposure limits (PELs, TLVs)
  - Strong odor producers

Risk Assessment Criteria

Fire Concern

- Flammables/combustibles/toxics - amounts stored over fire control area limits
- 6 ACH at all times
- Reduce amounts!

Risk Assessment Criteria

Animal Allergen Concern

Airborne Allergens (proteins) from animal dander

- No exposure limits for allergens
- 6+ ACH at all times in 24/7 animal areas

The most allergenic animals are:

- Mice
- Rats
- Guinea pigs

Step 2 – Industrial Hygiene Follow-Up

Post Initial Risk Assessment

- Follow-up for chemicals of concern
  - Lab staff exposure monitoring studies
  - Work with lab staff to improve work practices

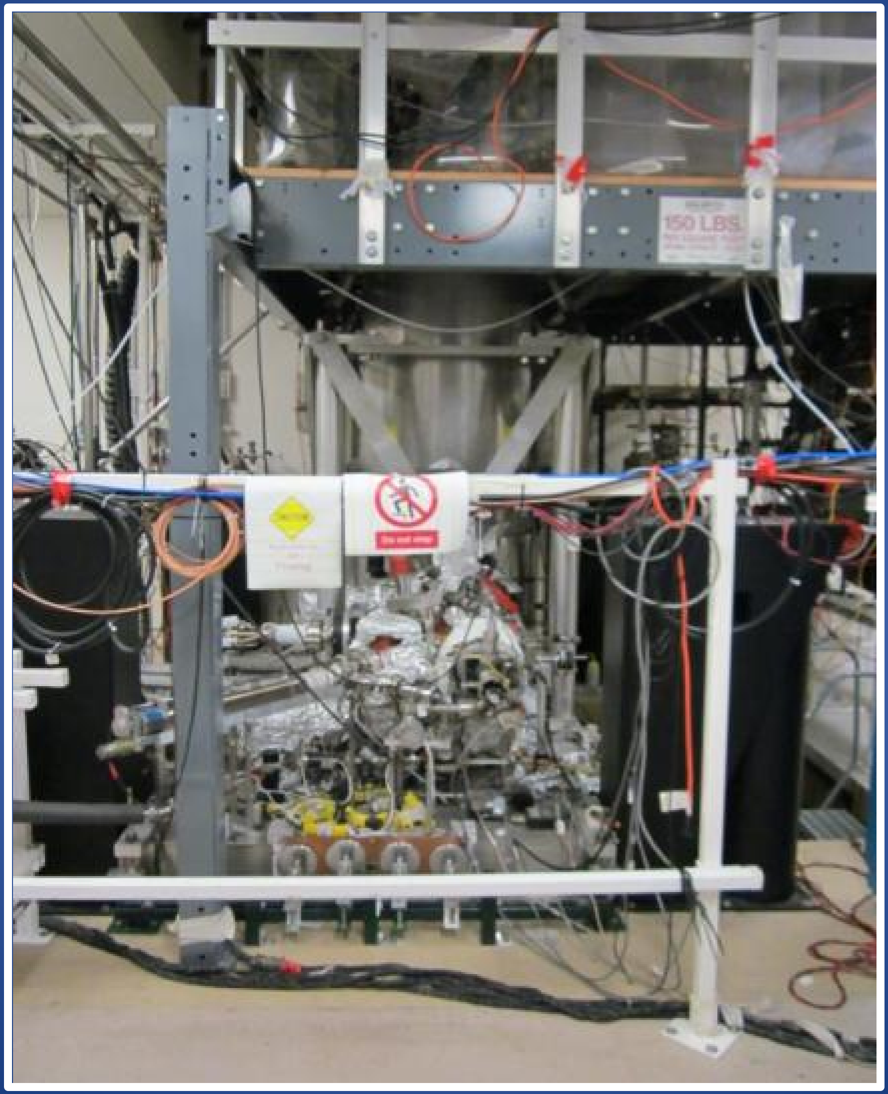
Step 2 – Industrial Hygiene Follow-Up

Post Initial Risk Assessment

- Follow-up for chemicals of concern
  - Ventilation <u>reduction</u> possible if exposures can be controlled (improved work practices)
  - ACH may be <u>increased</u> until work practices are improved

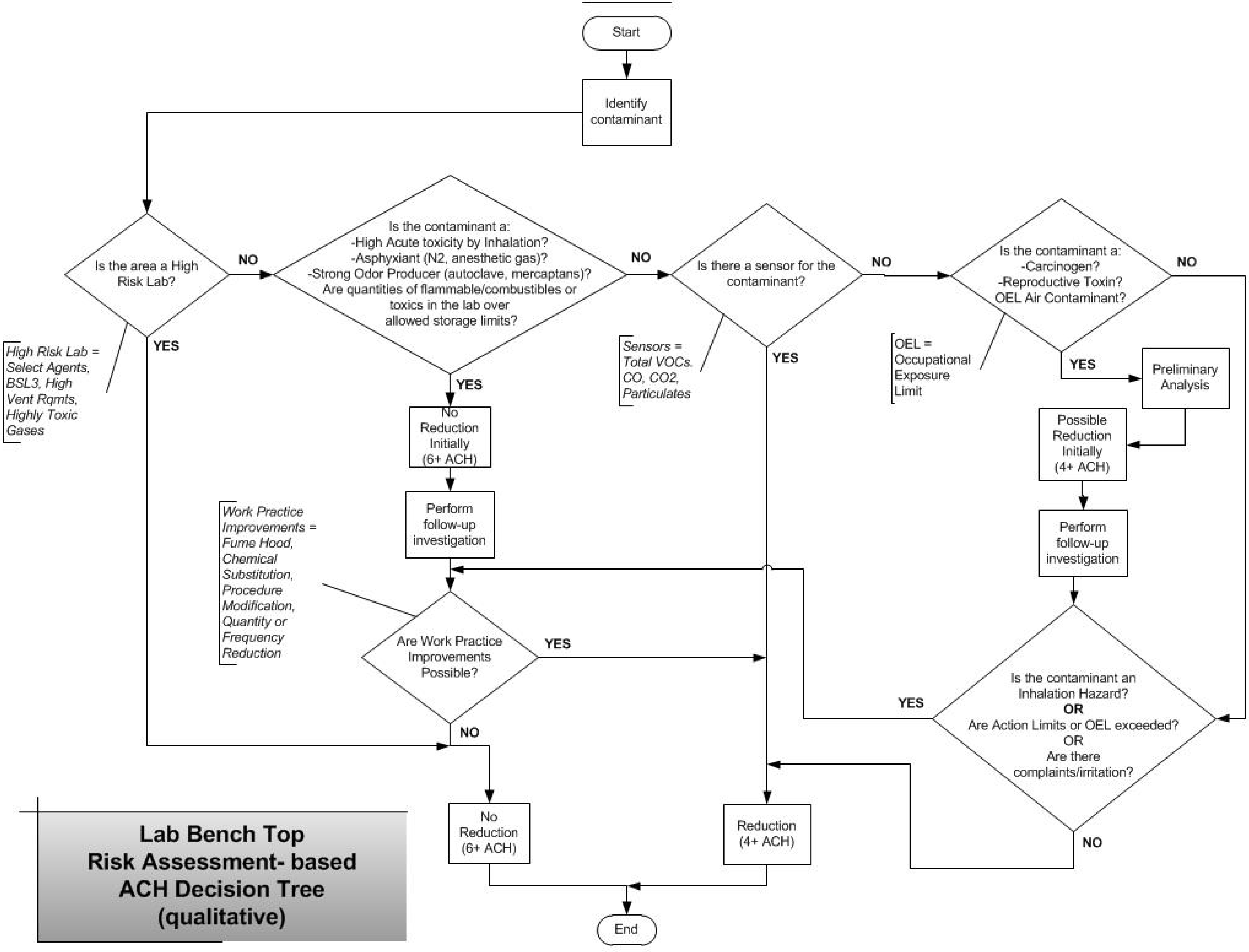
High or Low Hazard Lab?

High or Low Hazard Lab?



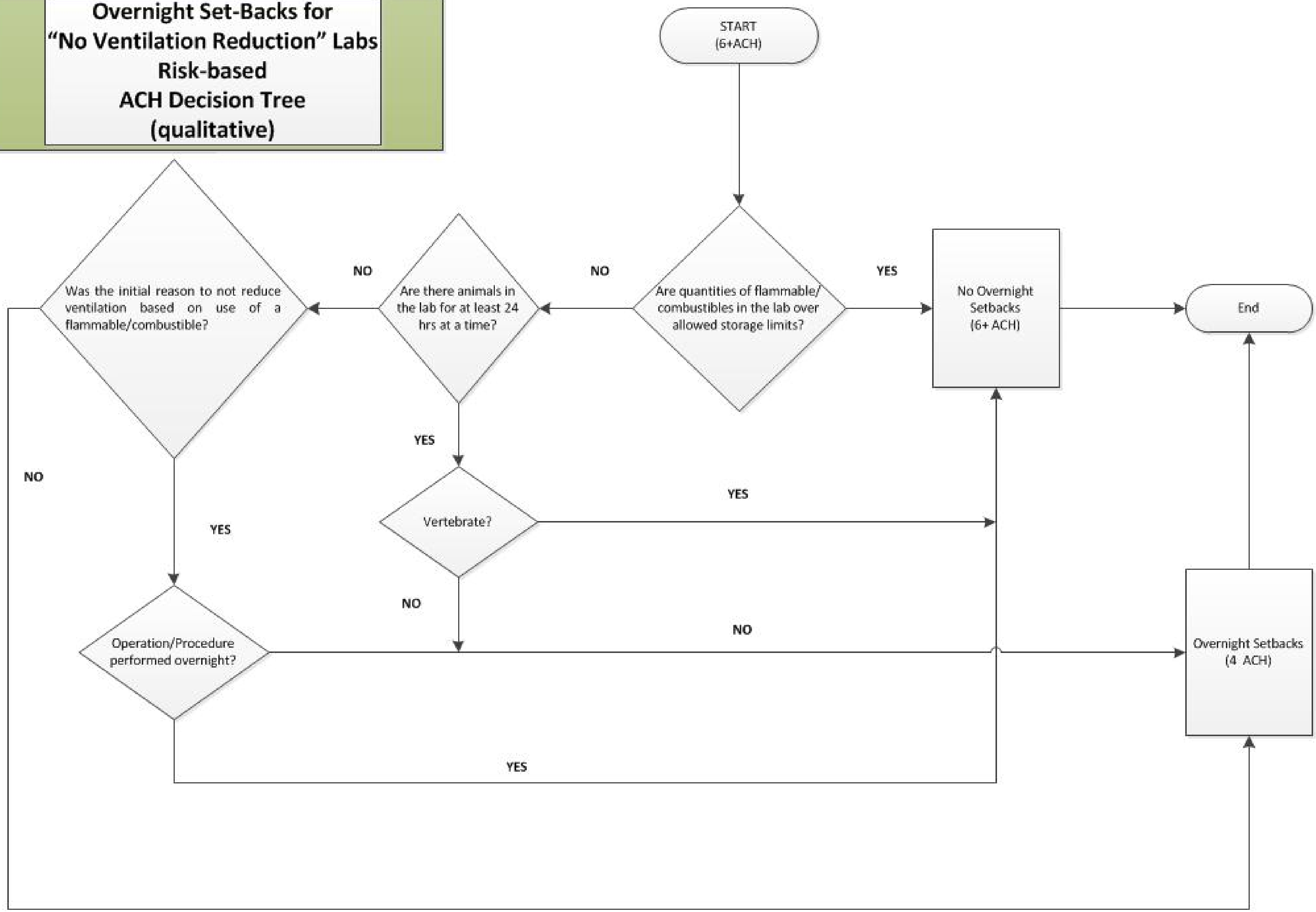
High or Low Hazard Lab?

High or Low Hazard Lab?



Lab Bench Top Risk Assessment- based ACH Decision Tree (qualitative)

Overnight Set-Backs for "No Ventilation Reduction" Labs Risk-based ACH Decision Tree (qualitative)



CDCV and Risk – Challenges

- Lack of “universal” CDCV sensor for all chemicals
- Ongoing need for risk assessments of lab operations
- Changes in research operations and staff
- Incomplete chemical inventories
- Great variety of hazardous operations and chemicals
- Uncertainty of health effects of chemicals

CDCV and Risk – Challenges

EH&S resource demand for

- Ongoing need for hazard assessments
- Exposure monitoring
- Work practice corrections
- Potential complaint investigations
- Training

Risk Assessment – Next Steps

- Develop system to identify changes in lab operations
- Re-assess bench top operations:
  - New researchers arrive
  - Lab moves (notification!)
  - Periodic re-assessments

- Promote current/complete chemical inventories

Lowered ACH is not "sustainable" without EH&S risk assessments and management of change!

Lab ACH Reductions

Based on Risk Assessments Results to Date

- 13 lab buildings (~250 labs)
- 1540 lab rooms assessed
- 1346 lab rooms - reduced ACH (~87%)
- 194 lab rooms - not reduced ACH (~13%)

Risk Assessment Conclusions

- Energy savings can be achieved without compromising safety
- Lab ACH determination requires:
  - Flexibility (evolving process)
  - Contaminant source control
  - Active EH&S involvement in risk assessment of lab operations with lab staff
  - Reassessment when lab changes occur

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Low Flow/High Performance Fume Hoods

Quick Summary

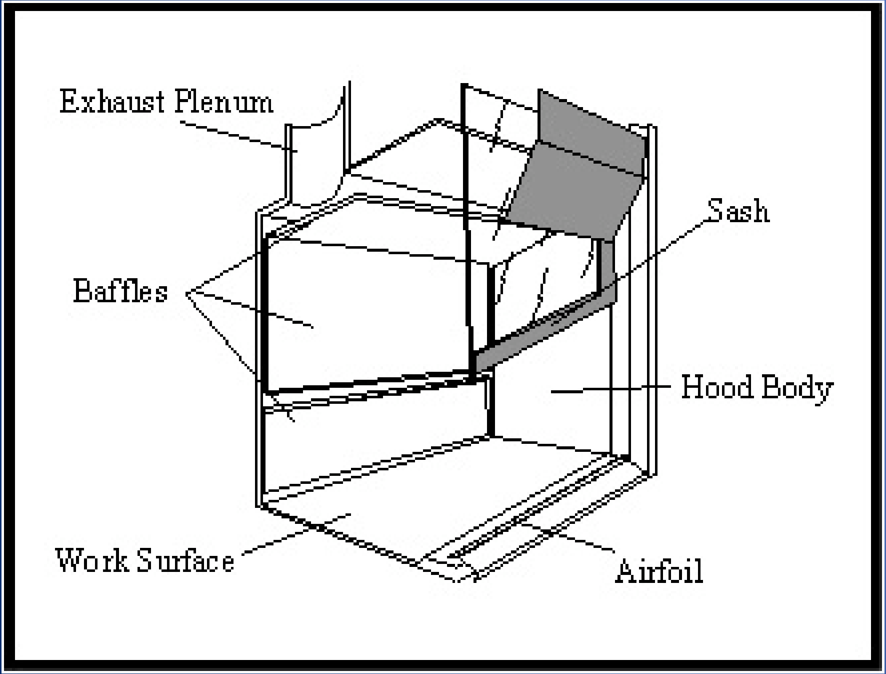
- Another potential solution in the energy savings tool kit
- Provides the ability to add fume hoods to buildings with limited HVAC capacity
- Designed to perform at lower face velocities
- Study completed to compare low flow vs. standard fume hoods

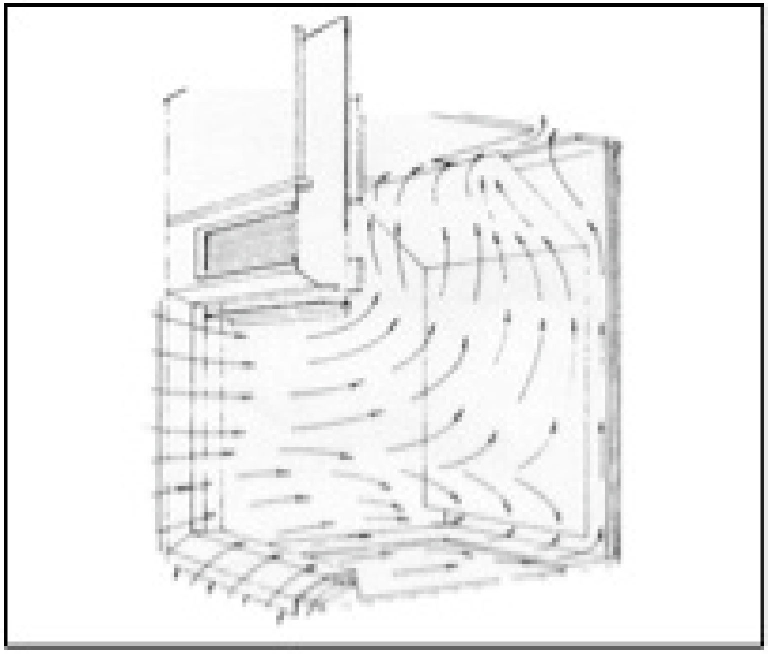
Fume Hood Regulations

- Federal OSHA Standard
  - Face velocity not specified
  - 13 Carcinogens exception
- Cal-OSHA Standard
  - 100 fpm face velocity
- Low flow fume hoods allowed in 49 states

Traditional Hood Design

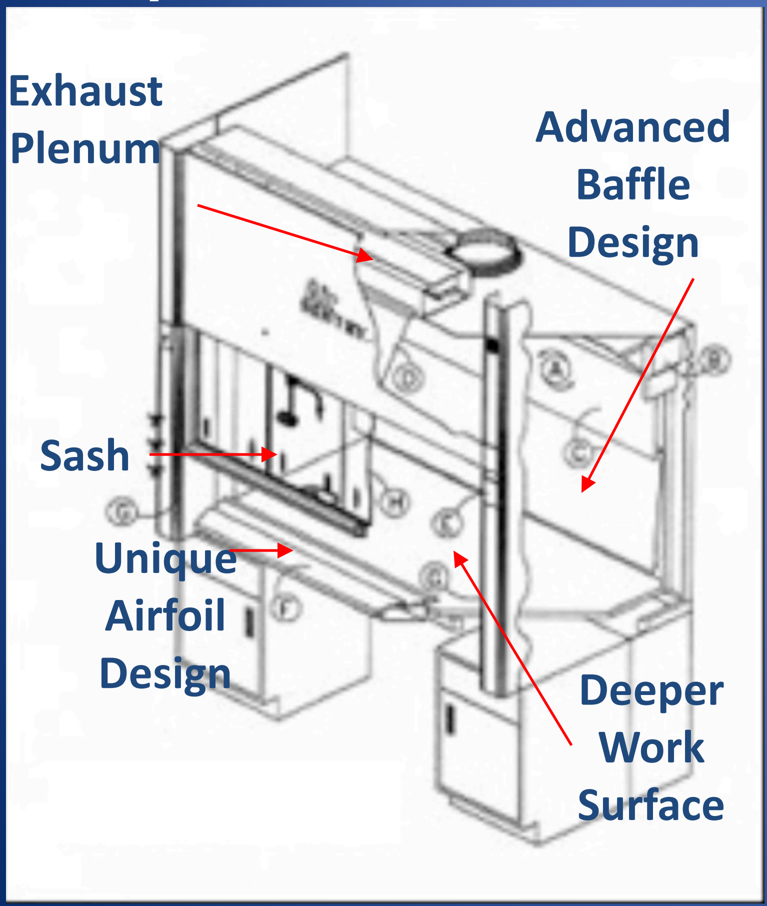
- Components & Air Flow

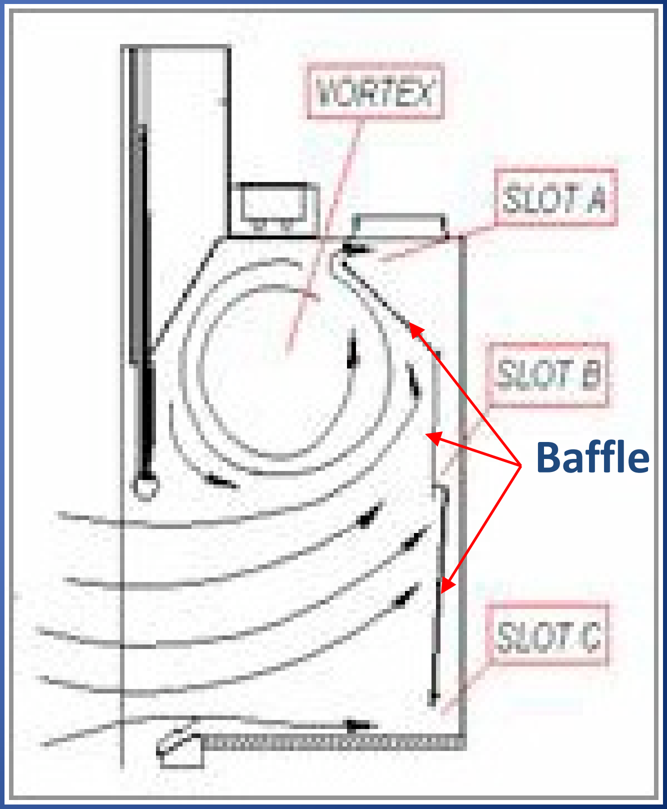




Low Flow Fume Hood Design

- Components & Air Flow





Increased Hood Depth

Study Objectives

1. Can low flow fume hoods operating at less than 100 fpm provide equal or better protection than a traditional fume hood operating at 100 fpm?

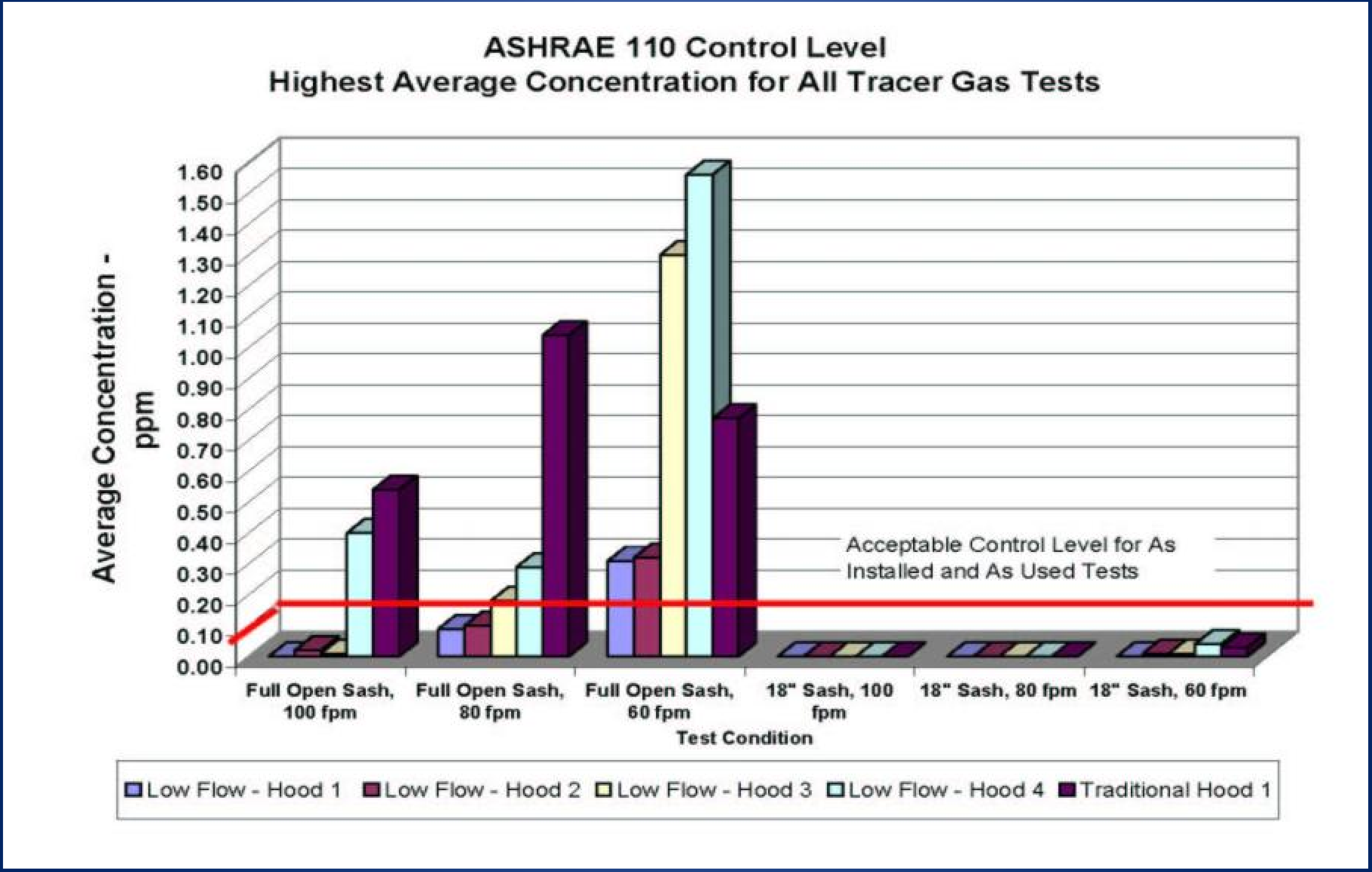
2. What is the minimum velocity and operating conditions where satisfactory performance can be confidently provided?

3. What factors affect performance?
   - average face velocity
   - turbulence of face velocity
   - cross draft velocity
   - pedestrian walk-bys

Low-Flow Fume Hood Study Conclusions

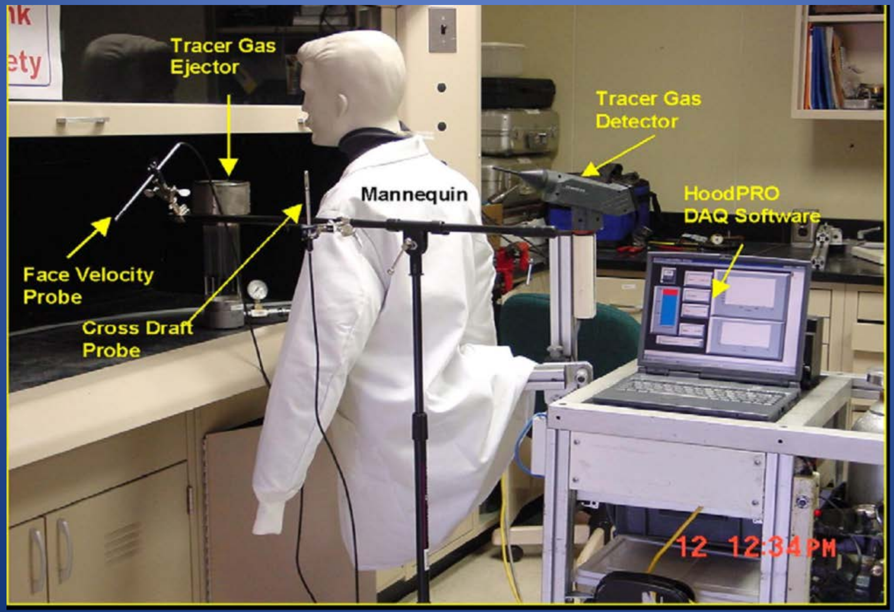
- All hoods - performed best at 18” sash height
  - All tracer gas results were well under 0.1ppm “as used” ASHRAE criteria
  - At 100, 80, and 60 fpm
- All low flow hoods performed better than standard hood at 80 & 100 fpm full open sash

Low-Flow vs. Standard Fume Hood Study Results
Highest Average Concentration for Tracer Gas Tests



Factors Affecting Performance

- Continuous cross draft (50 fpm) most impactful at 45 to hood
- Walk-by drafts were less impactful
- Hood placement critical to avoid cross drafts



Low-Flow Fume Hood Next Steps

- Cal OSHA - granted UC Irvine permanent variance for use with conditions
  - 80 fpm average face velocity
  - ASHRAE 110 testing annually for 3 years, then every 3rd year thereafter
- Requesting modification to variance to allow use campus-wide, then UC wide
- Creating decision tree for use!

Decision Tree for Low Flow Fume Hood Retrofits or Replacements

1	Does the room have more than one fume hood?	Yes = potential candidate No = potential candidate— Go to question six.
2	Can the lab space accommodate the deeper footprint of a low flow hood?	Yes = potential candidate No = not a candidate— END
3	Is the building Constant Volume?	Yes = potential candidate. No = potential candidate— However, the existing hoods should have hood occupancy sensors and a control system already (such as setback or sash closers) which reduce potential savings of Low Flow Hood as a replacement for an existing hood.
4	Is the hood served by a single fan?	Yes = potential candidate— Skip to question five. No = potential candidate— Skip to question eleven.
5	Is the fan belt driven?	Yes = potential candidate— Go to question ten. No = Go to question seven.
6	Does the hood serve as the minimum ventilation system for the space?	Yes = not a candidate— END No = potential candidate— Return to question two.
7	Does the direct drive fan have a variable speed drive?	Yes = potential candidate—Skip to question nine. No = potential candidate
8	Does the direct drive fan have a throttling valve at the inlet?	Yes = potential candidate No = not a candidate—END
9	Is the variable speed drive already running at minimum?	Yes = not a candidate— END No = potential candidate
10	Will reducing flow adversely affect the stack discharge velocity?	Yes = not a candidate— END No = candidate— END
11	Does the manifolded system have a bypass?	Yes = candidate— END No = not a candidate— END

TAKE A BREAK

The training session will resume in 10 minutes.

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- BREAK
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Exhaust Stack Discharge Volume Reduction

JUST SAY NO TO BYPASS AIR

Exhaust Stack Discharge Volume Reduction (ESDVR)

- What is bypass and how much energy is wasted?
- If so much energy is wasted, what can we do about it?
- Steps in the wind-tunnel study process
- Stack extensions
- Other implementation results
- Next steps: wind-responsive controls
- Participatory exercise

What is a bypass?

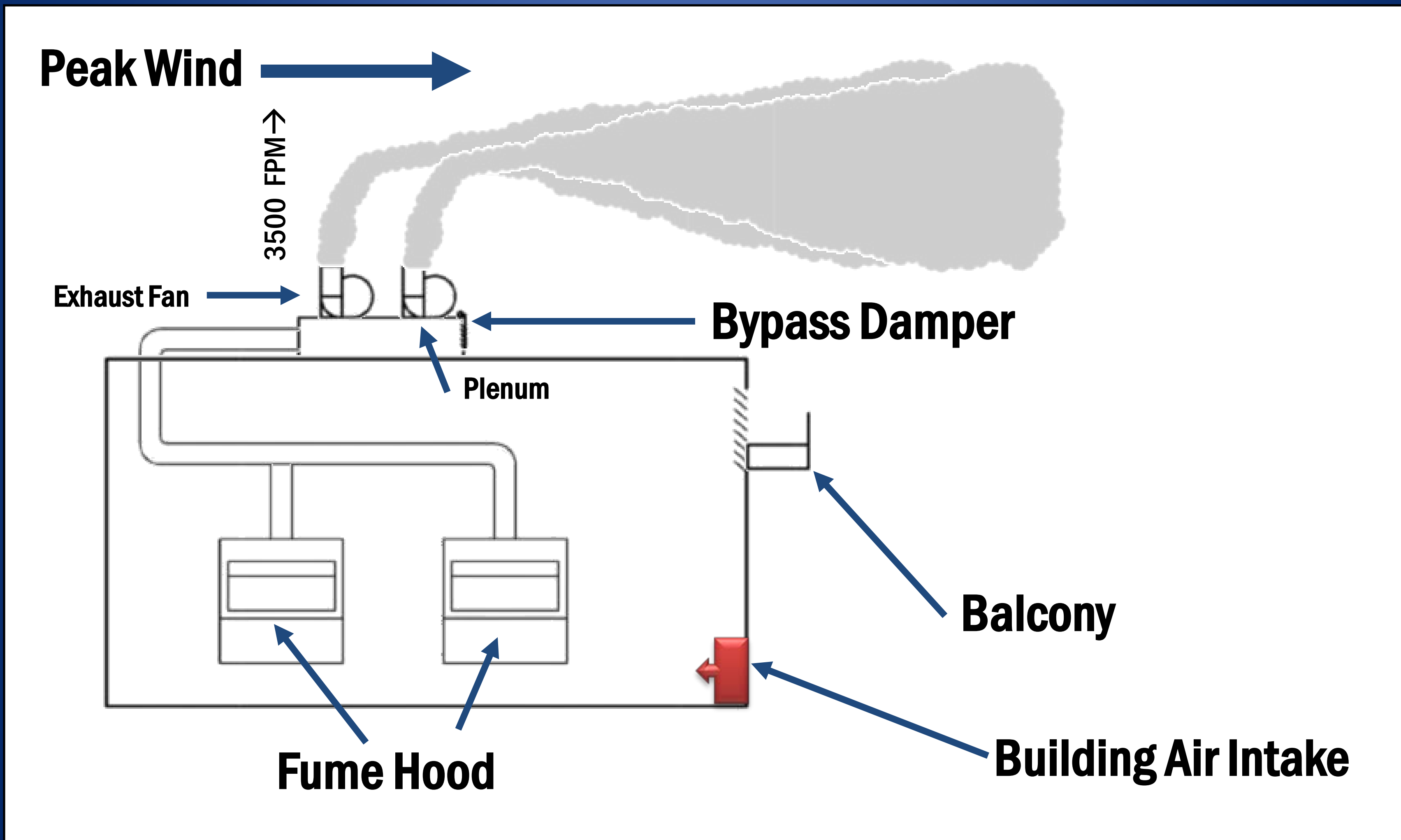
This is a High-Plume Discharge Fan. Bypasses are also fitted to systems with other types of fans.

The bypass brings outside air from the roof through the fan to ensure design velocity out the top of the stack regardless of flow through the building, thus creating a constant-volume system out of a variable-volume system and wasting energy.

Why have a bypass?

- Allows the system to operate safely and maintain a minimum velocity of discharge to ensure that the plume of air rises up sufficiently to avoid re-entrainment to the building or contamination of adjacent buildings.
- Allows constant-speed and volume fans to work with variable-volume flow from the building
- Provide a simple means of controlling static pressure in the exhaust ducting

Lab Exhaust Diagram



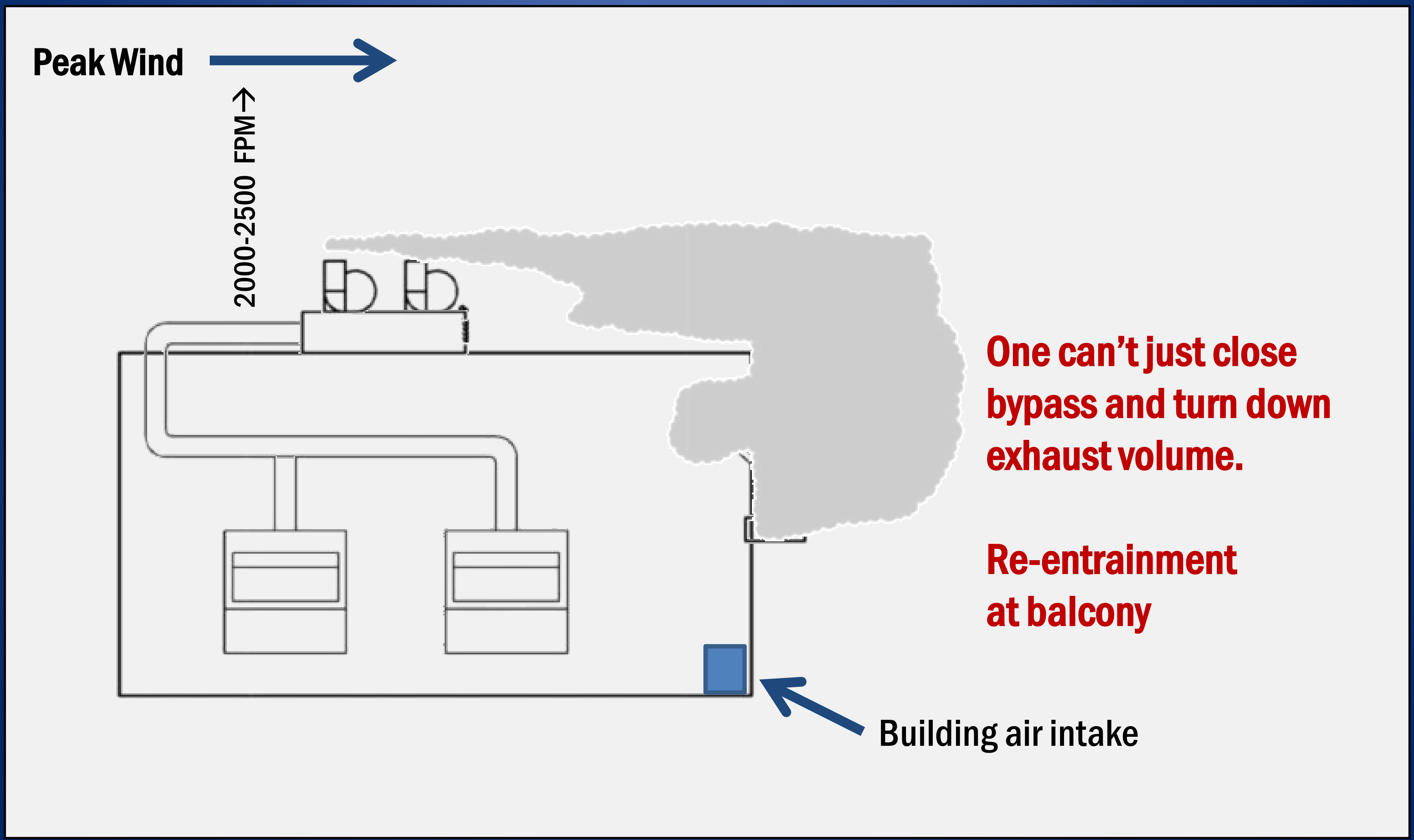
How much energy is wasted?

- If building flow is 25,000 cfm and required flow from the stack to attain 3,500 fpm is 50,000 cfm, the energy wasted is 50% at a minimum.
- By reducing the flow in the stack one also reduces the pressure drop in the stack and therefore the effect on energy savings is compounded.
- Each situation is specific to the site.

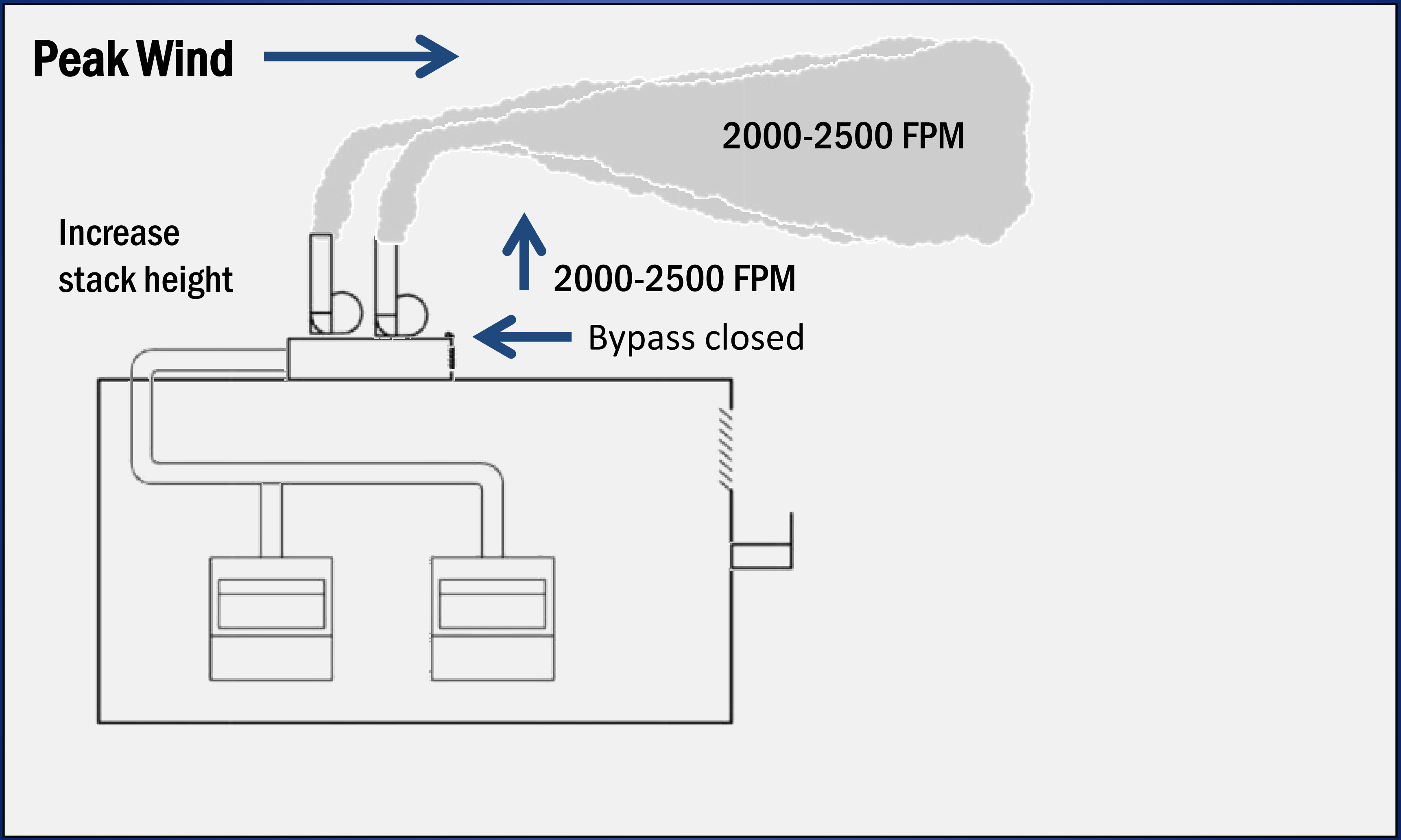
If so much energy is wasted, what can we do about it?

- Detailed modeling in a wind tunnel to determine the minimum exhaust velocity required as opposed to standard practice
- Install variable-speed drives to reduce fan flow
- Program control system to run multiple fans in parallel with a goal of 0% bypass

What about closing bypass and letting fans “ride the curve”?

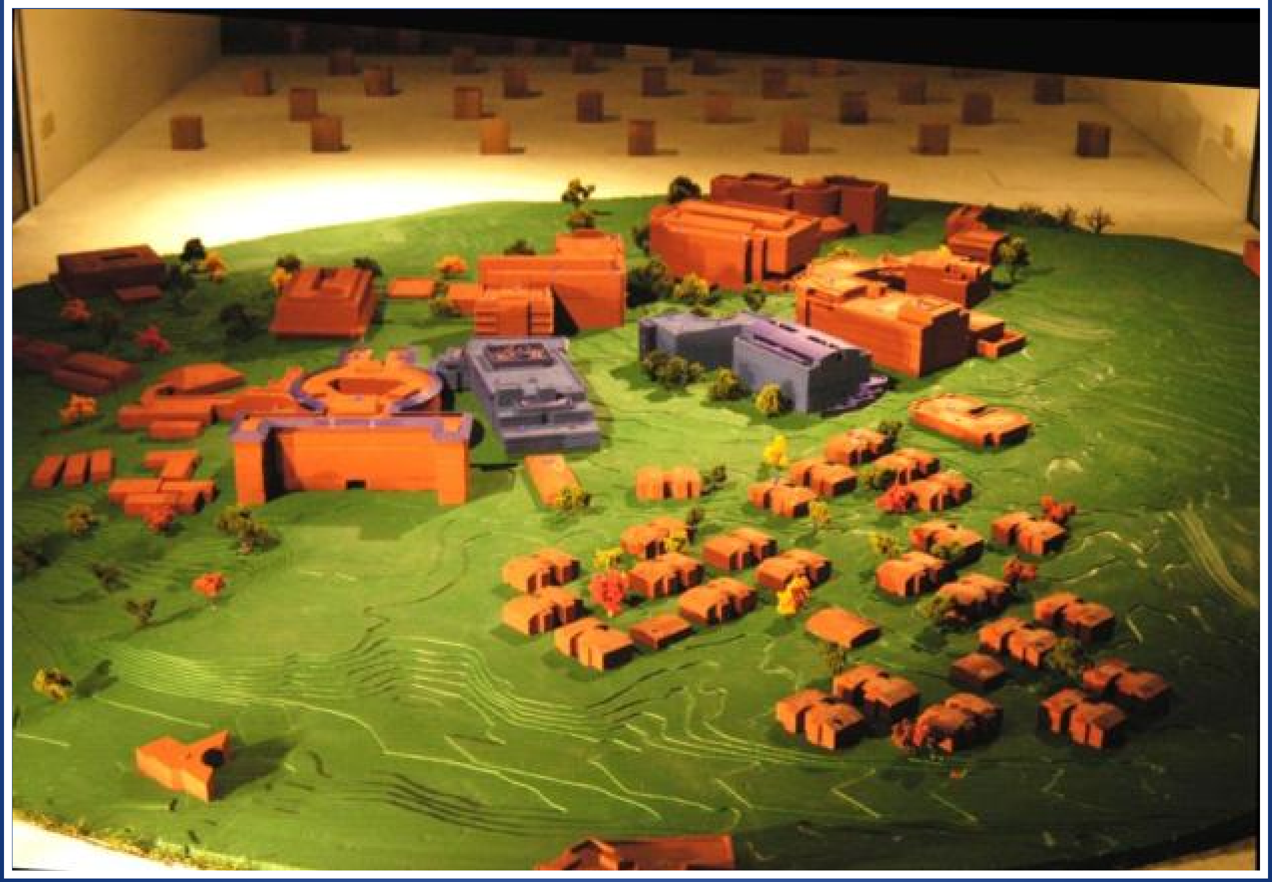


What about raising stack height?



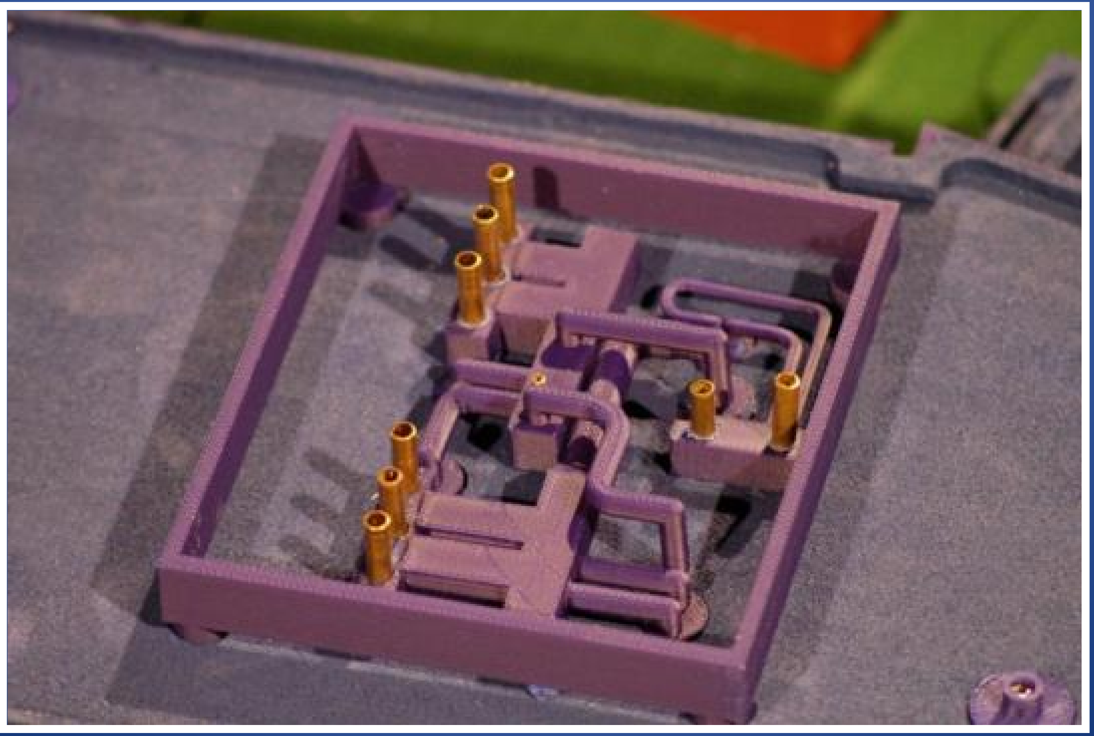
Steps in the wind-tunnel study process

1. Build model of campus



Steps in the wind-tunnel study process

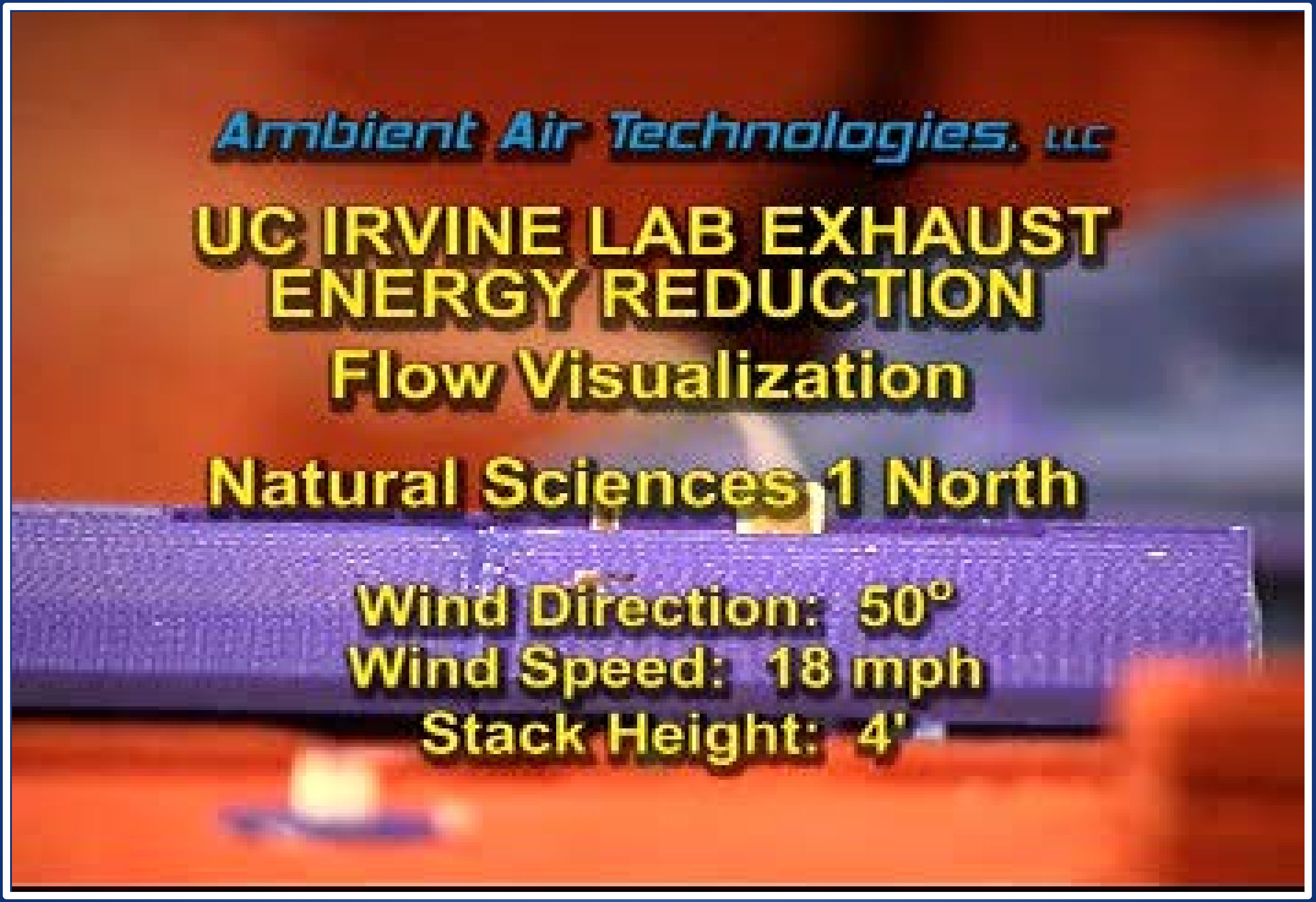
1. Build model of campus
2. Install model stacks



Steps in the wind-tunnel study process

1. Build model of campus
2. Install model stacks
3. Install air sampling points ("receptors")

Flow Visualization | Natural Sciences 1



Flow Visualization | Natural Sciences 1

Stack Extensions

1. Extraordinary savings
    1. Small costs up front
    2. Passive system that has no maintenance costs
    3. Reduced fan energy in one case by 78%
2. But what about the “ugliness” factor?

The Ugliness Non-Factor: Before

The Ugliness Non-Factor: After

Implementation

- Install variable frequency drives (VFD)
- Close bypass dampers
- No stack extension needed
- Annual energy savings: 581,749 kWh

Sprague Hall

Implementation

Natural Sciences II

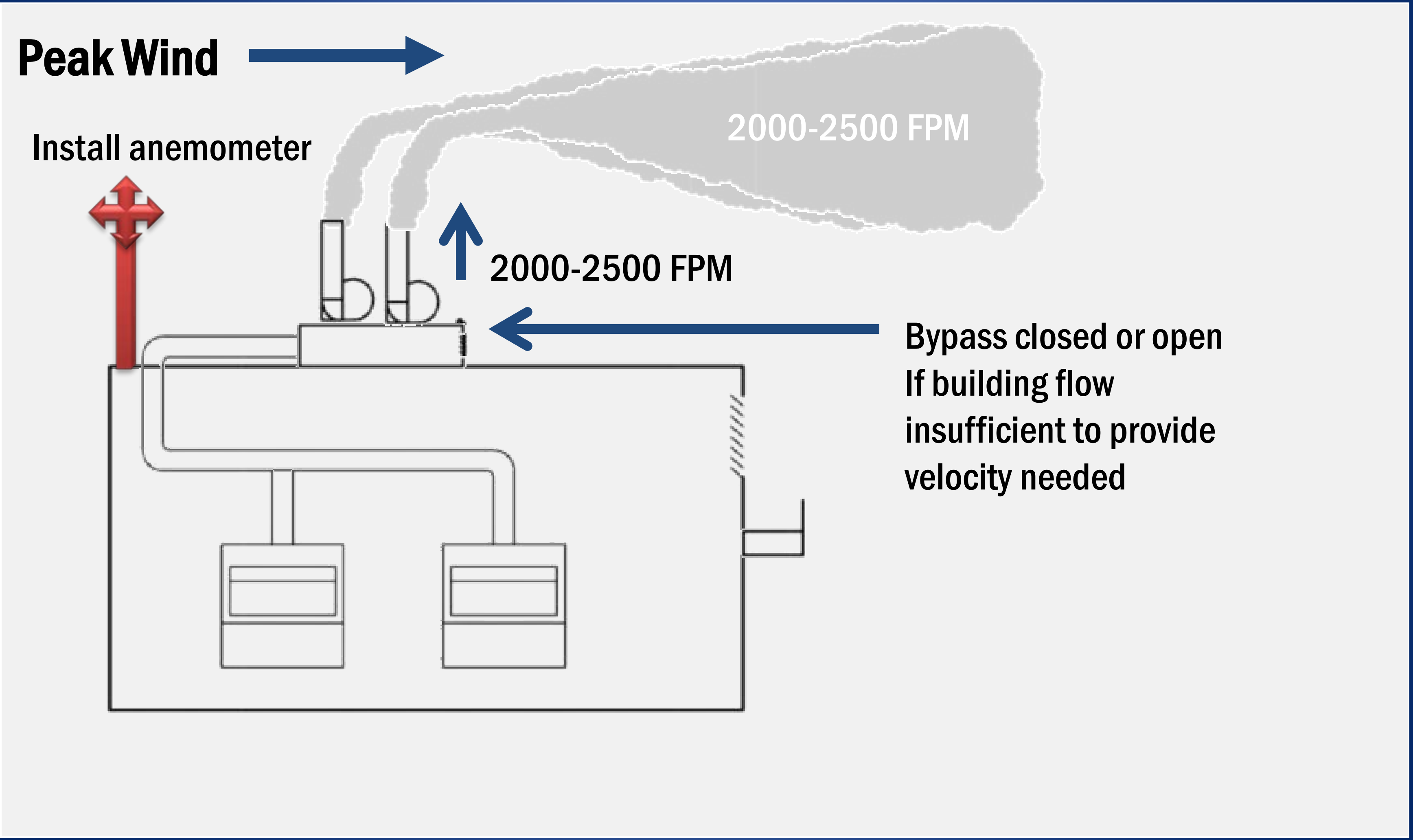
- Install variable frequency drives (VFD)
- Static pressure reset
- 4' stack extensions
- Annual energy savings: 928,722 kWh

Implementation

- No stack extensions
- Install variable frequency drives (VFD)
- Static pressure reset
- Annual energy savings: 286,594 kWh

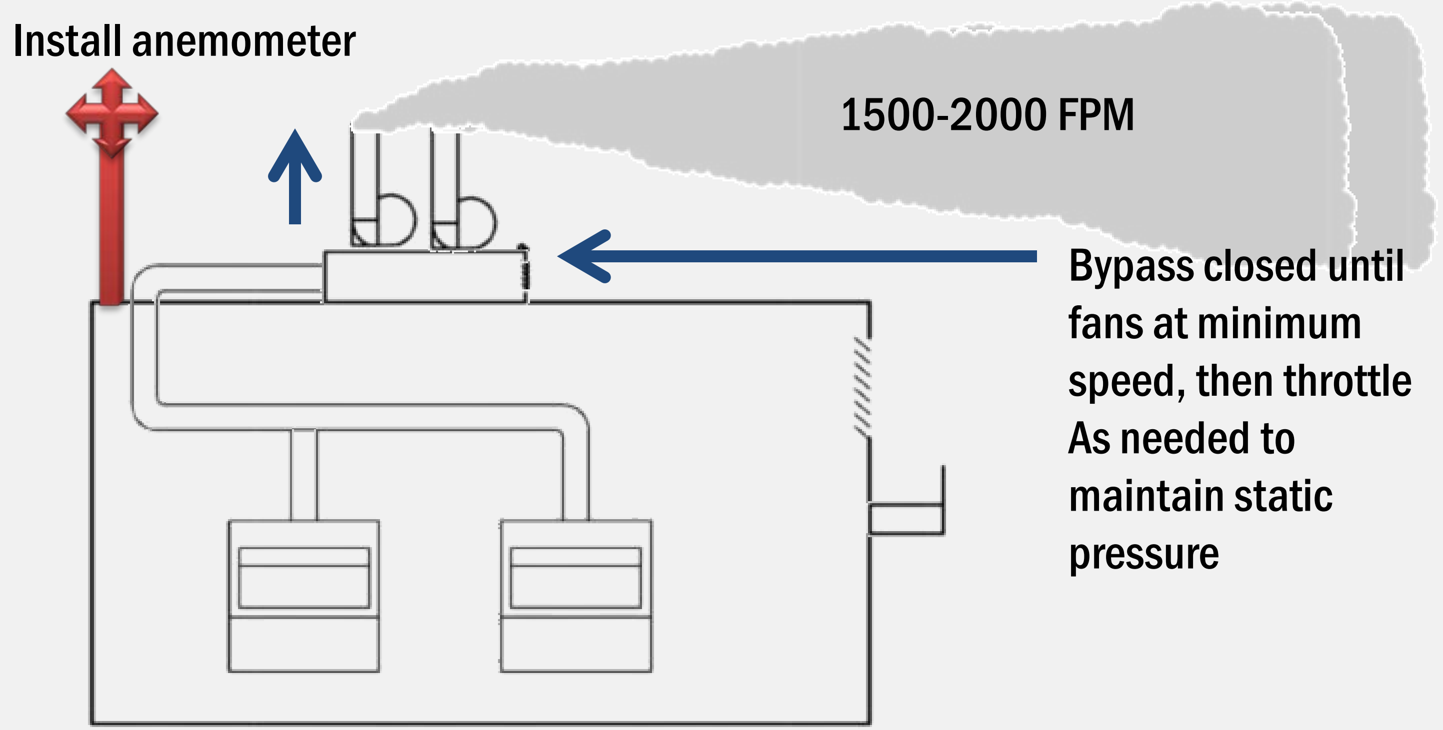
Hewitt Hall

Can we do better?

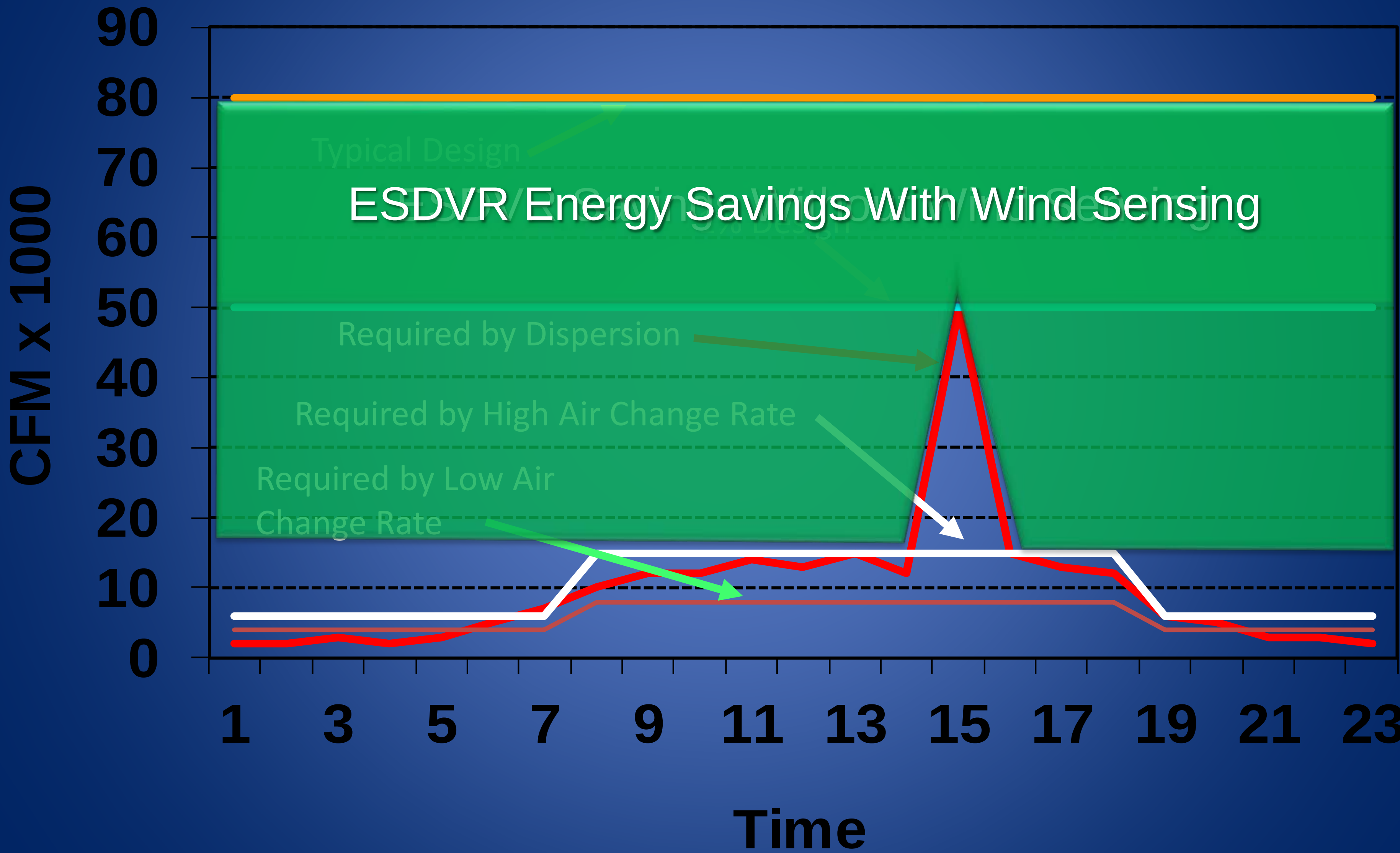


Can we do better?

No Wind



Typical Timeline
Exit Velocity Requirements



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Plug Load

- Outside the direct control of the facility manager
- Growing rapidly with increases in automated lab equipment
- Control or containment?
- What is your experience?

A Pristine (Unassigned) Lab


Fisherbrand
Axygen
Quality


CLEAR AREA


TITAN


NOTICE
CLEAR AREA

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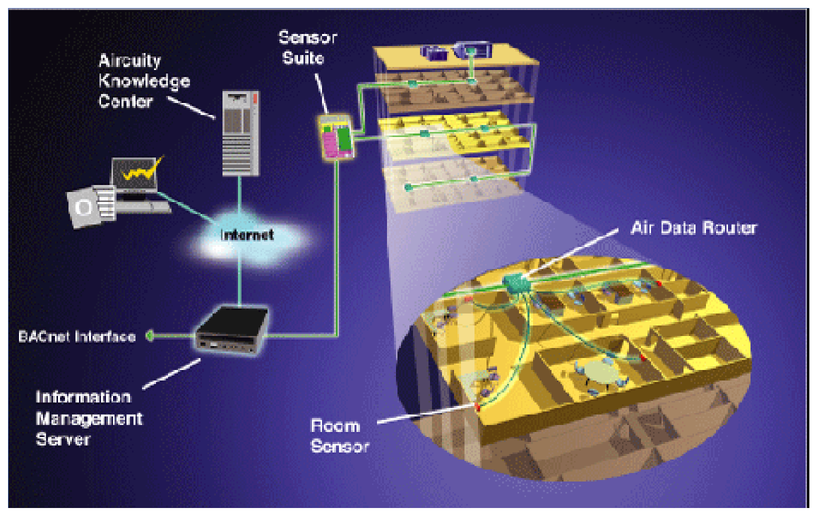
CDCV System

Dashboard and Data Trends for Each Zone

- Air change rates (ACR)
- Internal air quality (IAQ)
- Sash position of each fume hood
- Occupancy
- Relative humidity
- Temperature
- Total supply
- Total exhaust

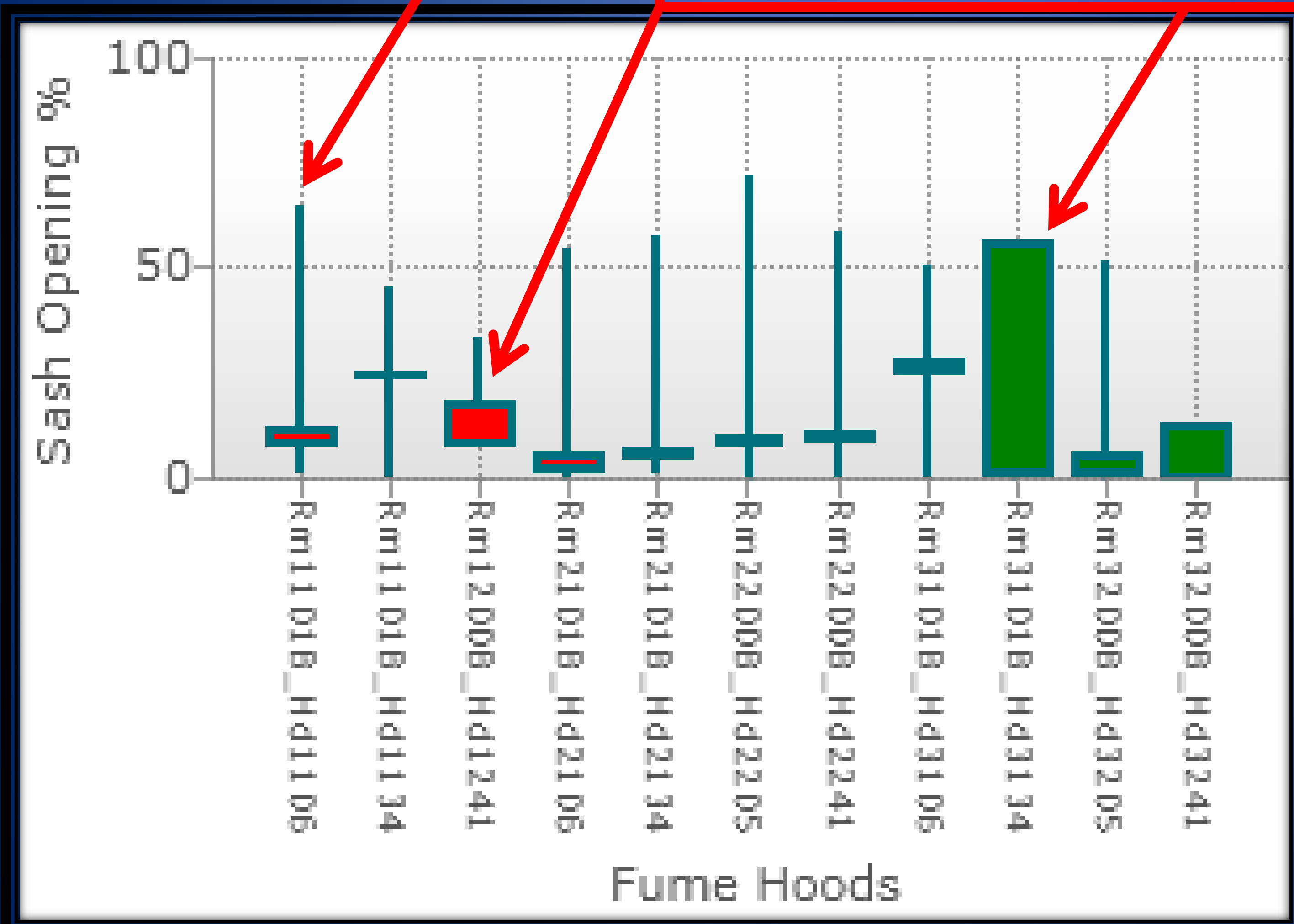


Visualization of lab HVAC use

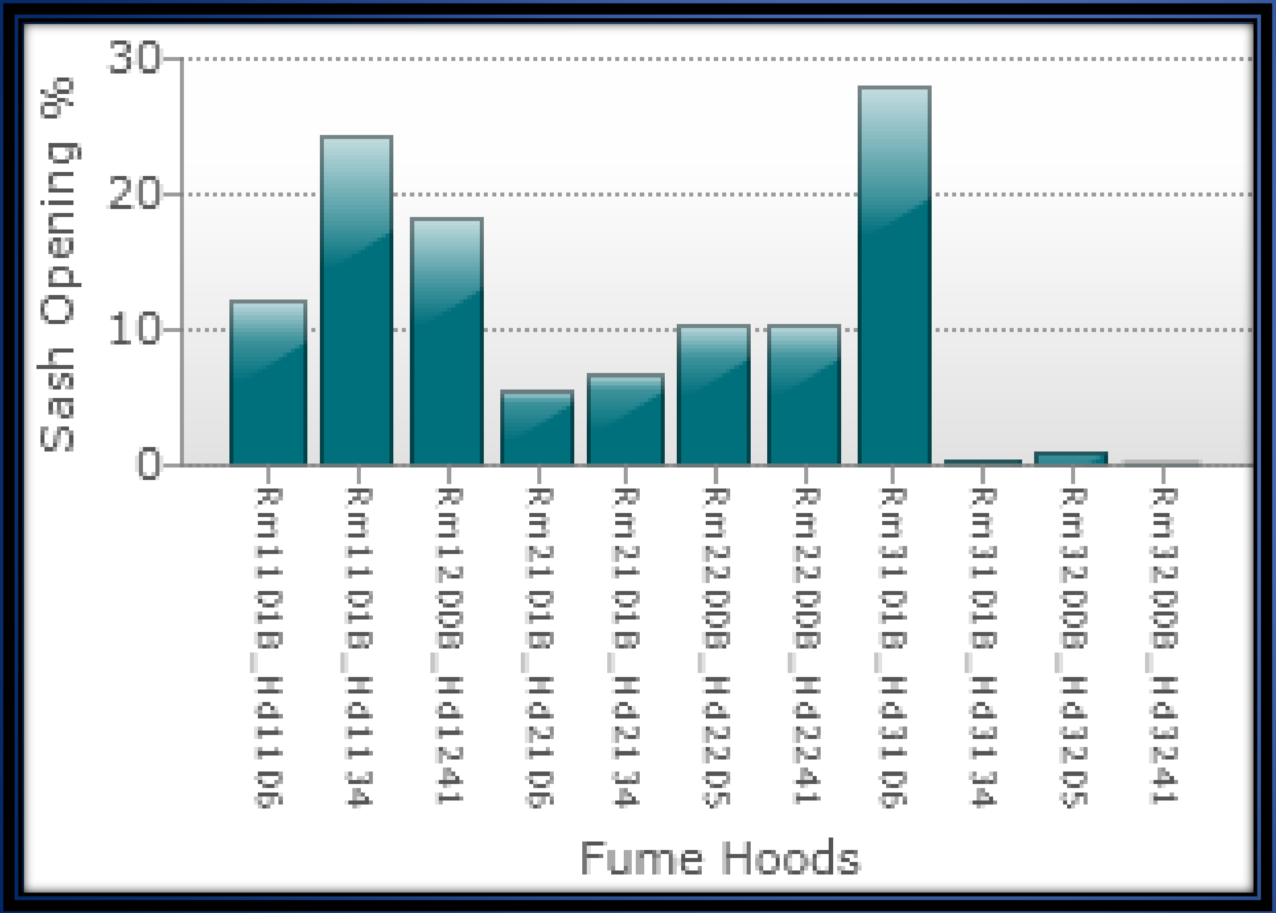
Monitoring Fume Hood Usage

- Fume hood usage range
- This hood shows usage between 0% open and 65% open

- Change in average sash position from the month prior
- Red indicates poorer average green indicates improved average sash management



How many hoods are in use right now in your lab and how far open are the sashes?

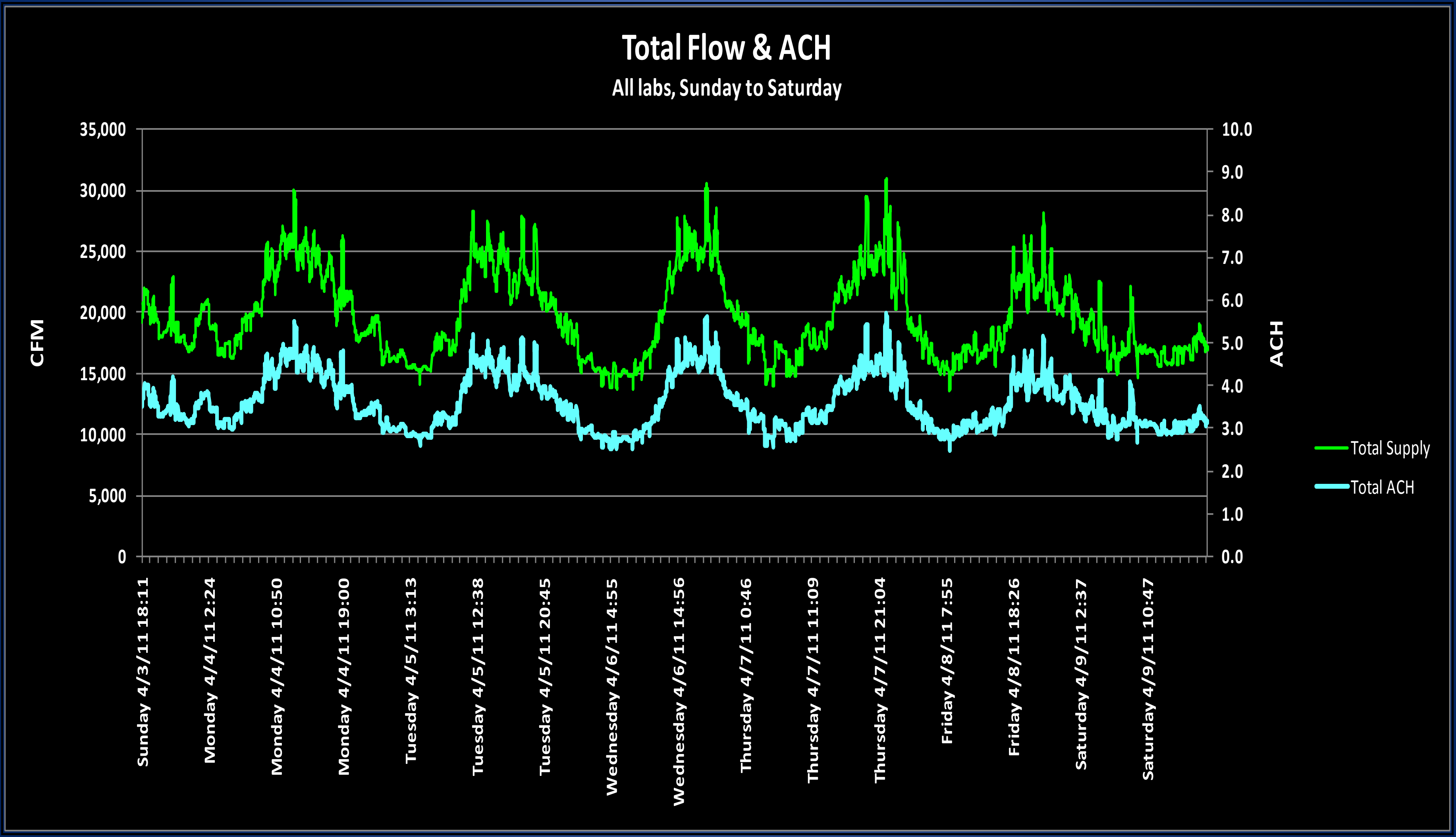


Smart Labs are not just controls and sensors.

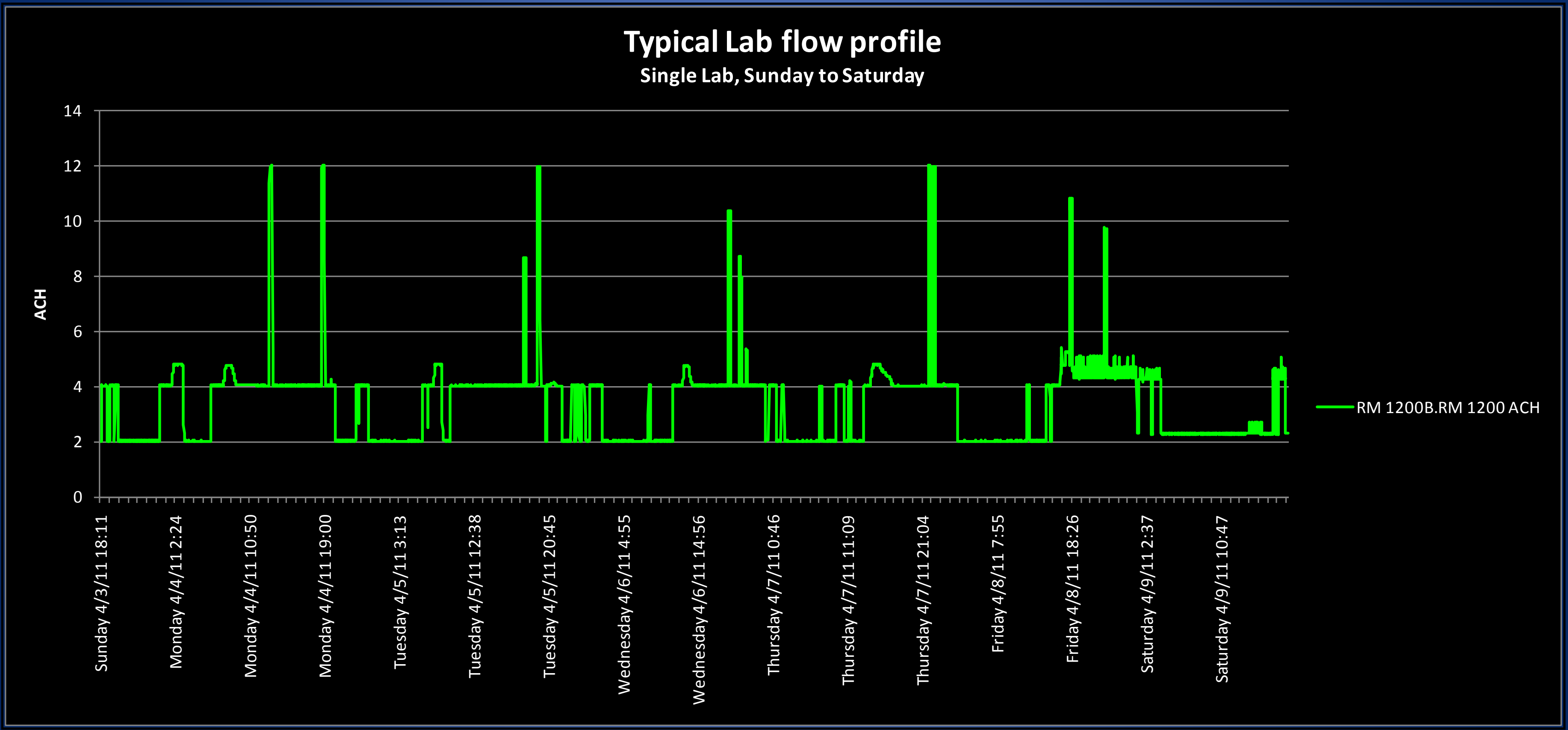
Smart Labs provide real time feedback as well as monthly reporting data that is actionable.

Return on investment is directly affected by lab practices.

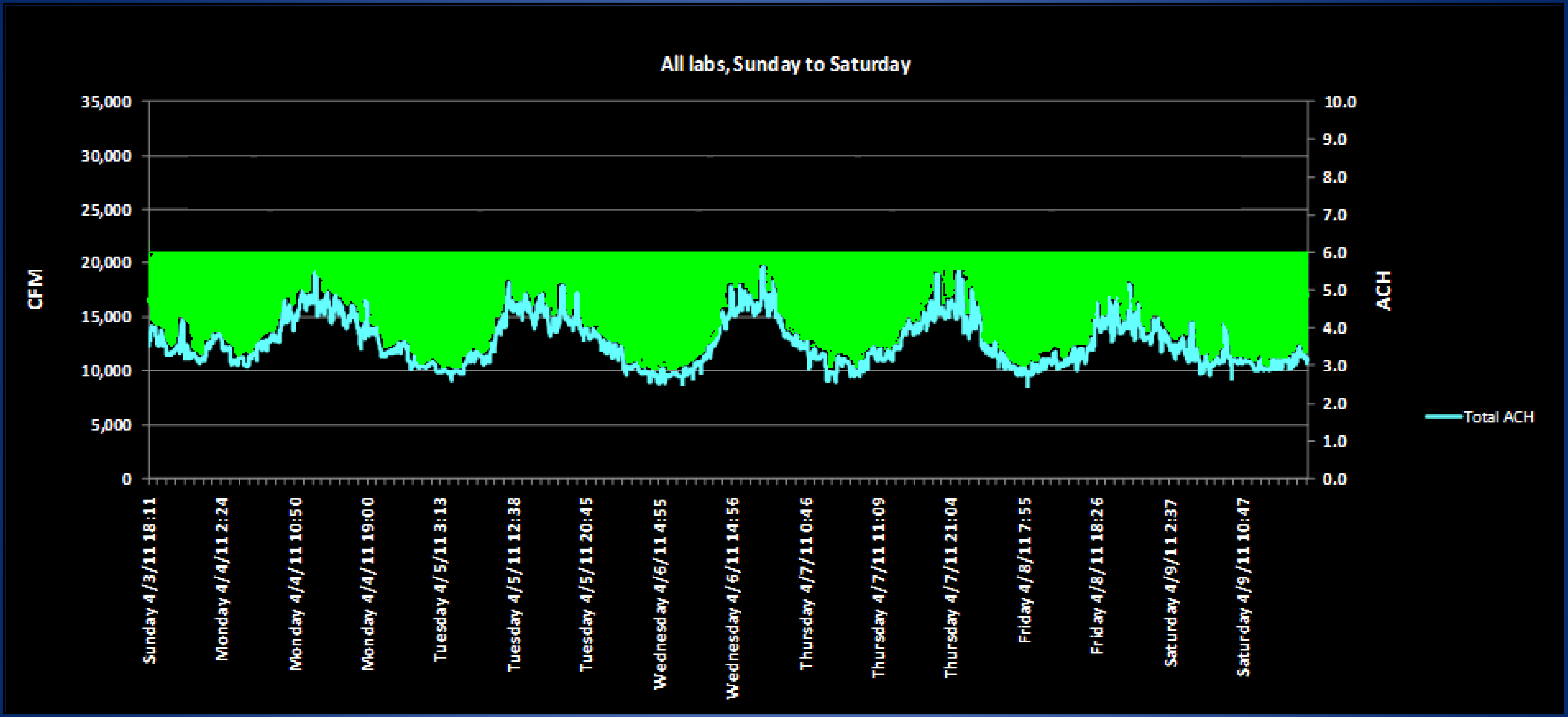
Total Flow and ACH Profile
Six-Day Period



Air Change Rates for Room 1200
Graphed Over Six Days



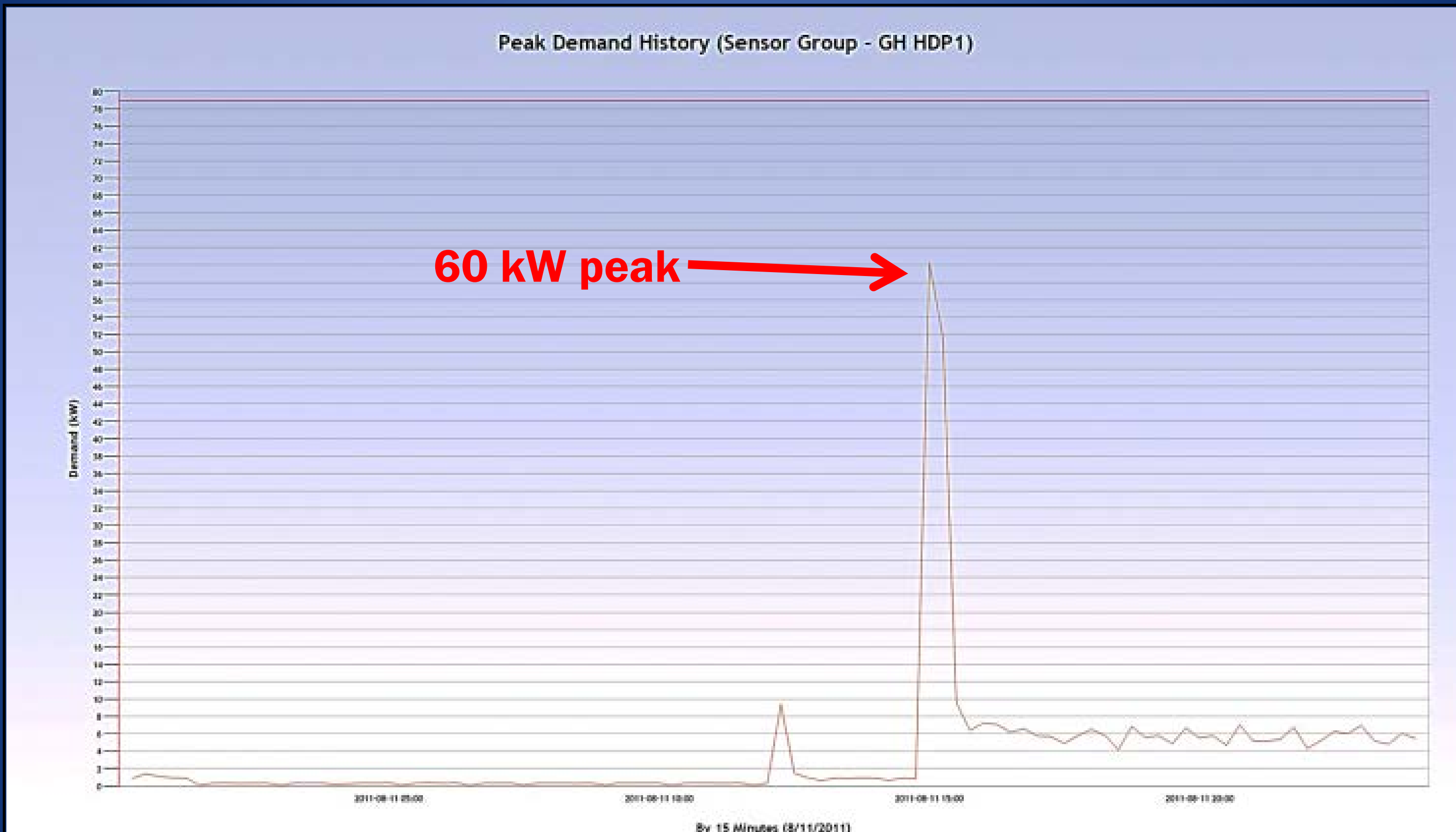
What does energy savings look like?



The delta between 6 air changes per hour in previous labs designs and the 4/2 ACH of Gross Hall is yielding ~$58,000 per year in energy savings.

Zone-Level Resolution Can Lead to Peak Demand Savings

Autoclave In Gross Hall

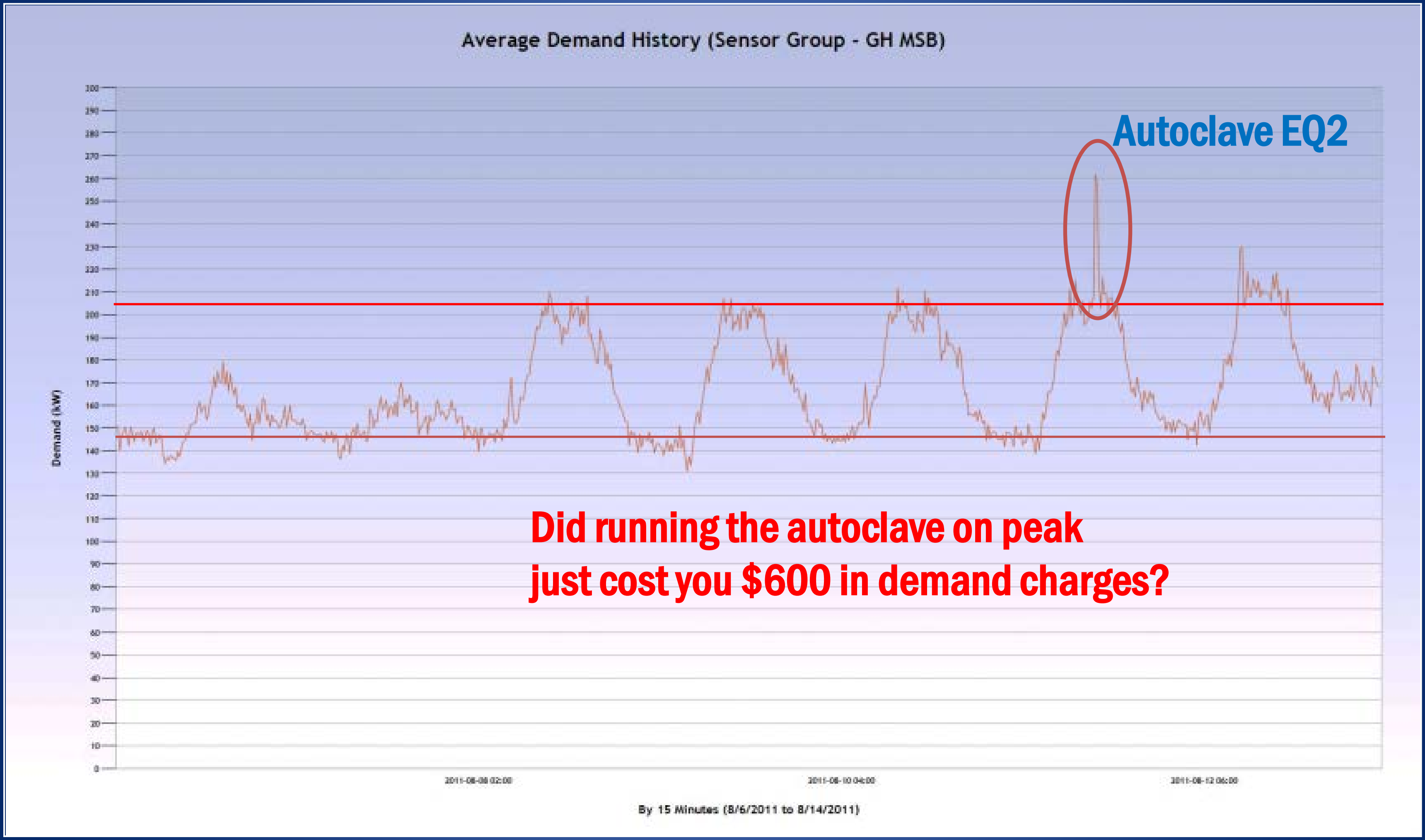


HDP1

Panel Name	Floor	Parent Panel	MSB Circuit	Voltage	Configuration	VA (A)	VA (B)	VA (C)	VA Detail	I(A)	% of Panel	% Measured
EQ2	1	HDP1	HDP1	480	Wye	24,942	24,942	24,942	74,825	90	58.4%	100%
EQ4	1	HDP1	HDP1	480	Wye	10,254	10,254	10,254	30,761	37	24.0%	100%
EQ3	1	HDP1	HDP1	480	Wye	7,482	7,482	7,482	22,447	27	17.5%	100%
Total						**42,678**	**42,678**	**42,678**	**128,033**	**154**	**100%**	**100%**

HDP1 is a distribution board on the 1st floor. It is responsible for feeding several equipment loads, autoclave units EQ2, EQ3, and EQ4. HDP1 is fed directly from the main switchboard at 480/277 volts. The board maximum current rating is 225 amps. The largest load on HDP1 is the medium autoclave EQ2, which is rated at 75kVA.

Zone-Level Resolution Can Lead to Peak Demand Savings



Gross Hall average site demand ranges from a baseline of 148kW to an average peak of 205 kW

Hewitt Hall vs. Gross Hall

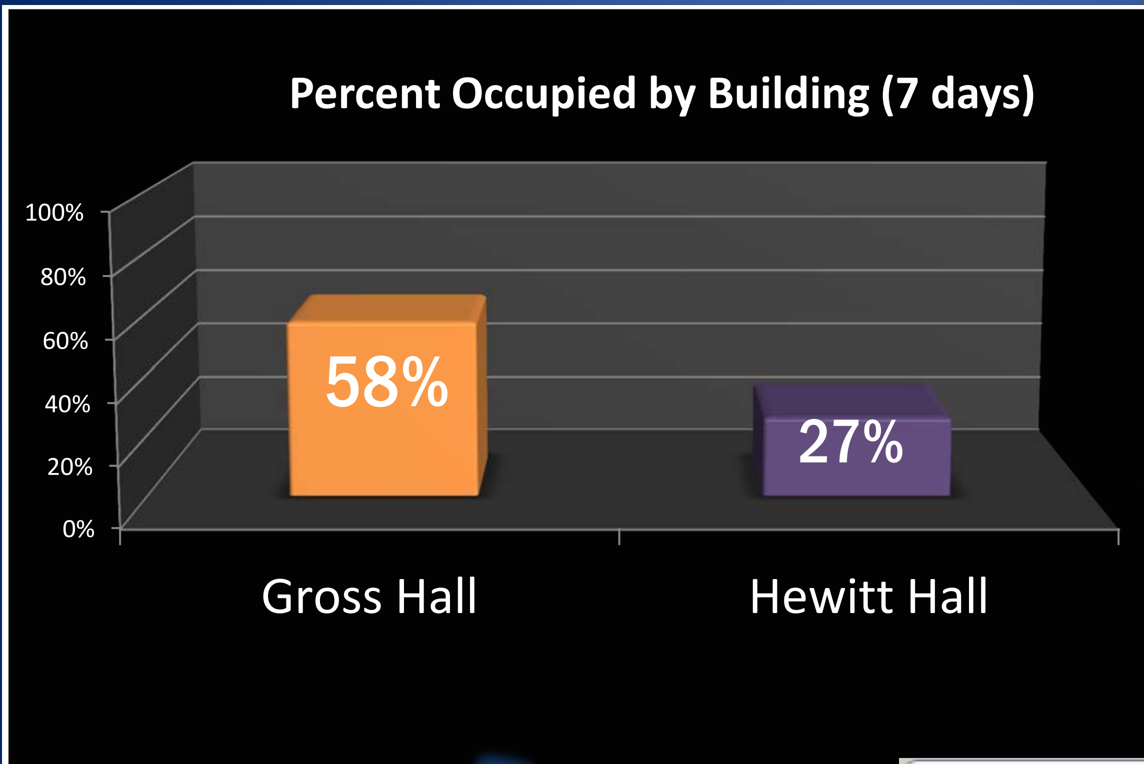
Designed in 2001

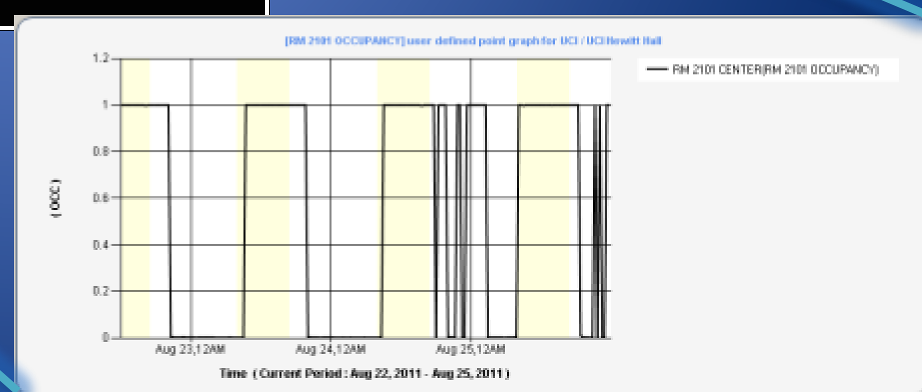
- Exceeded Title 24 by 23.7%
- Biomedical research
- Lighting upgrade in 2009
- Exhaust stack discharge velocity Reduction in 2009
- Re-commissioned in 2010
- 76,905 square feet

Designed in 2009

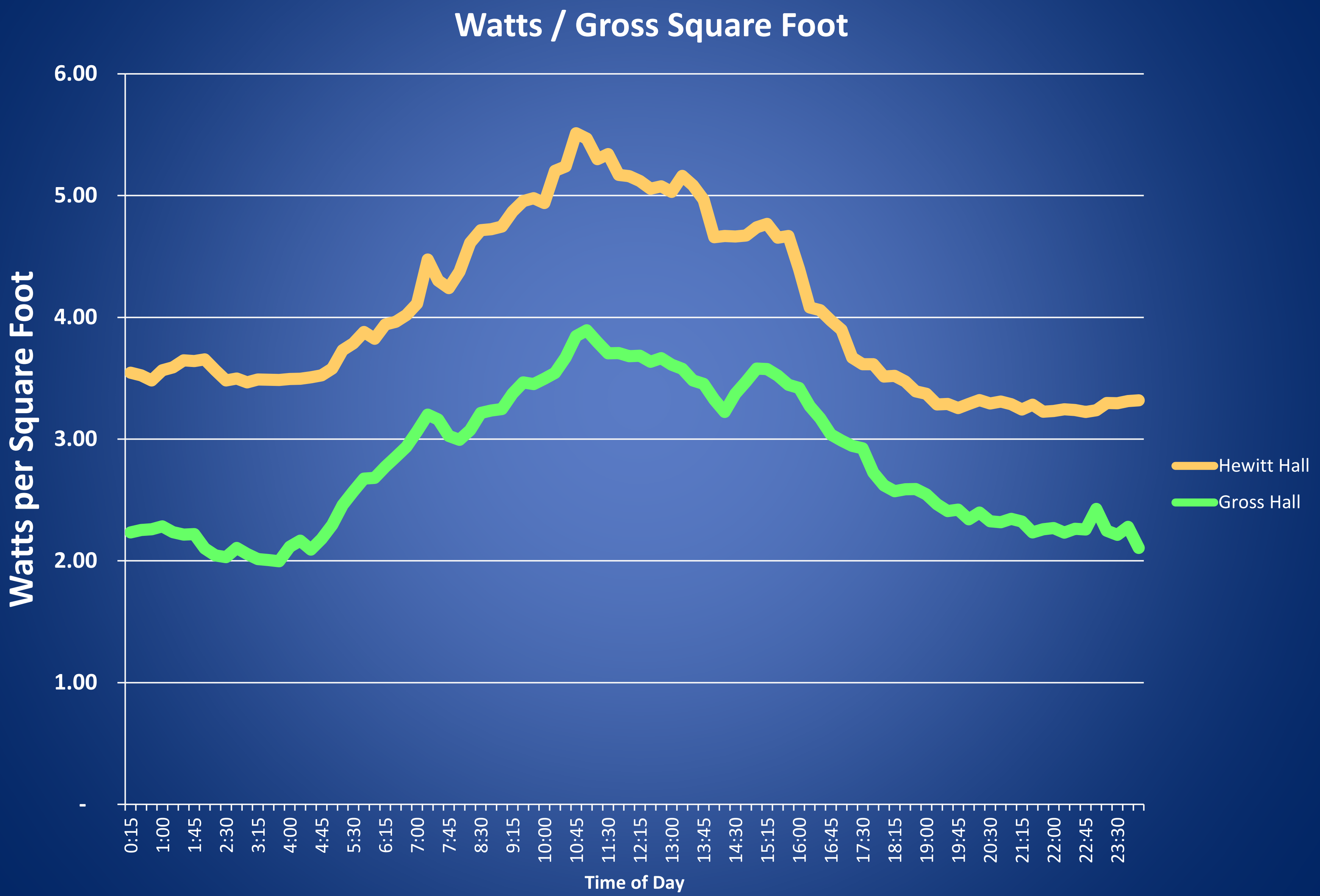
- Exceeded Title 24 by 50.4%
- Biomedical research
- Designated LEED Platinum - NC
- 94,705 square feet

Gross Hall's Lab Utilization Nearly Twice Hewitt Hall's





Building Load Per Square Foot

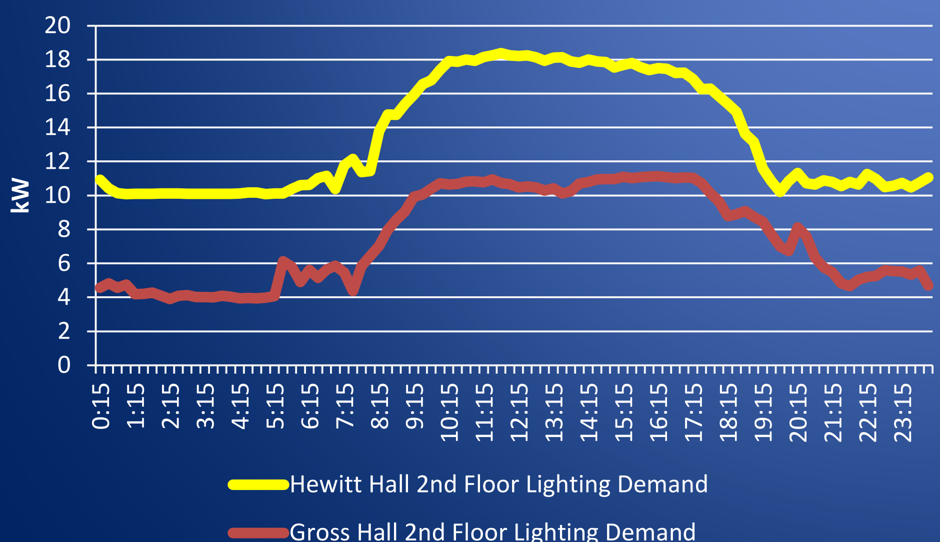


Lighting

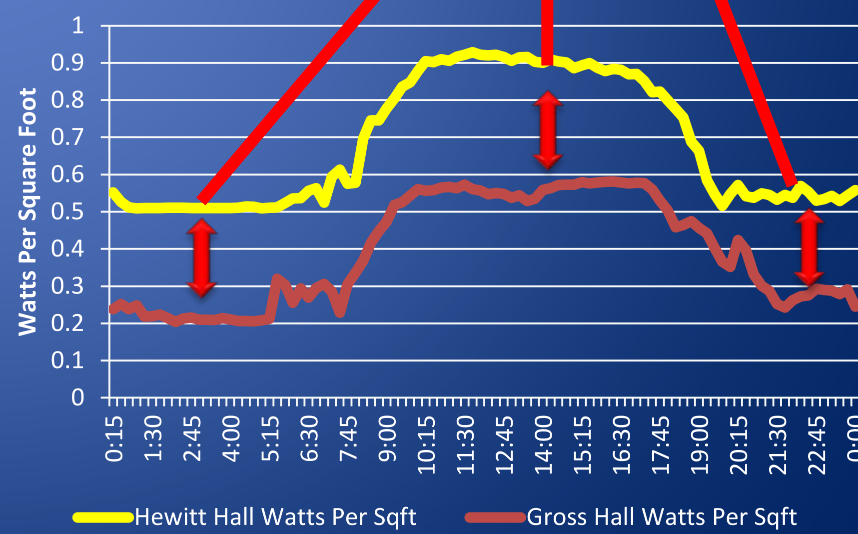
Previous Best Practice	Space Type	**Gross Hall**
0.9 watts/sqft	Offices	**0.49** watts/sqft
1.1 watts/sqft	Labs	
1 watts/sqft	Overall Conditio	

0.3W/1000 x 8760 x$0.105kWh= $0.2759 /SqFt

24 Hour Demand Curves



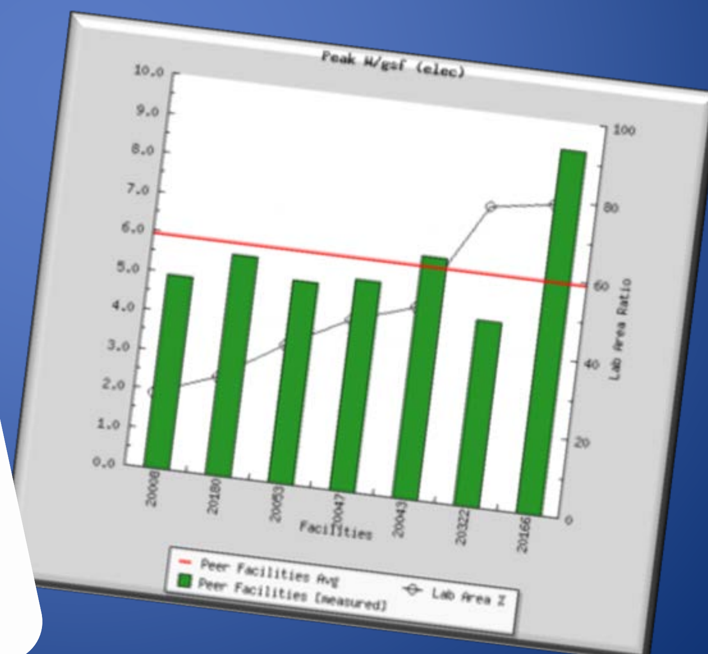
24 Hour Actual Watts Per SQFT



Benchmarking

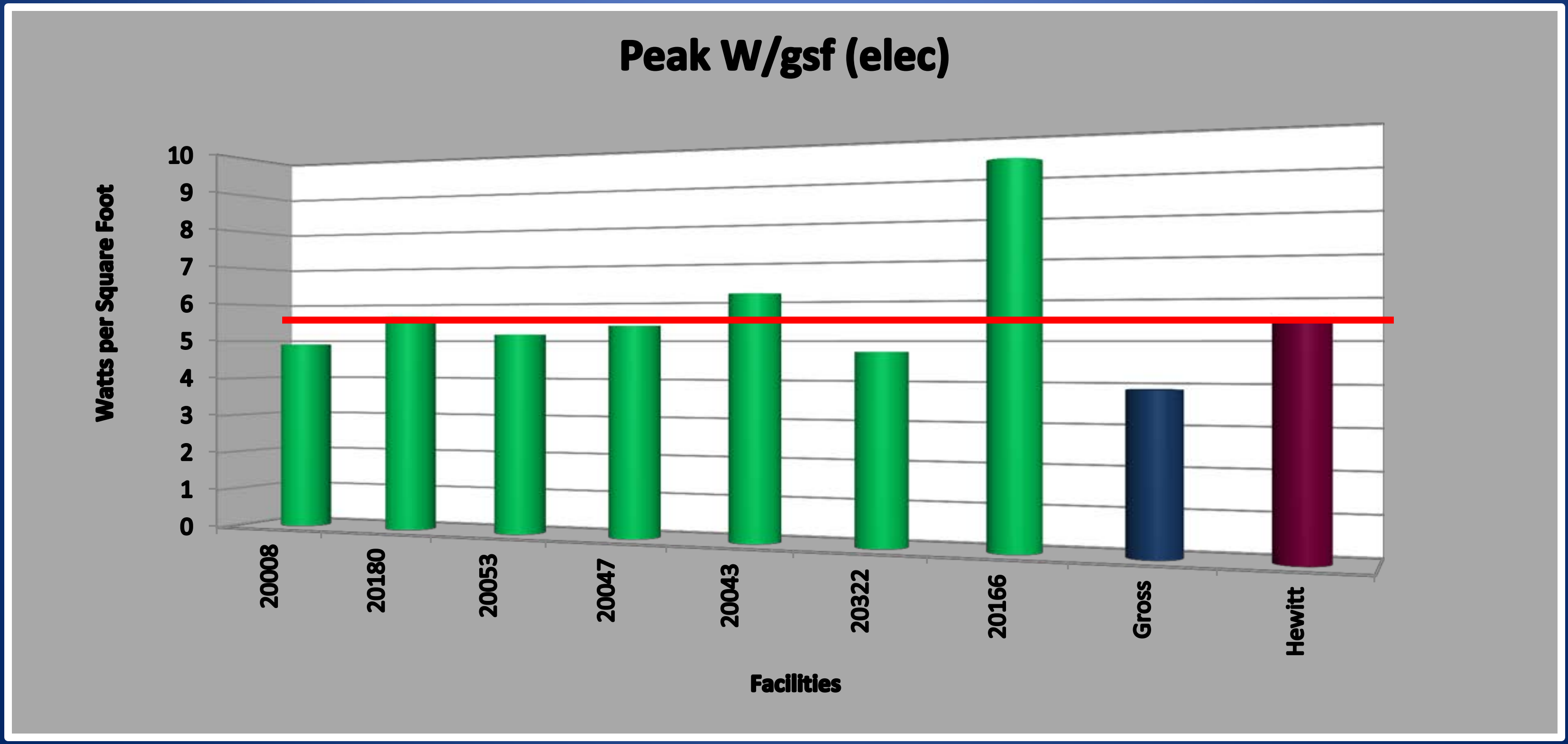
It is easy to see how campus labs compare to each other but what about across the country?

http://labs21benchmarking.lbl.gov/CompareData.php



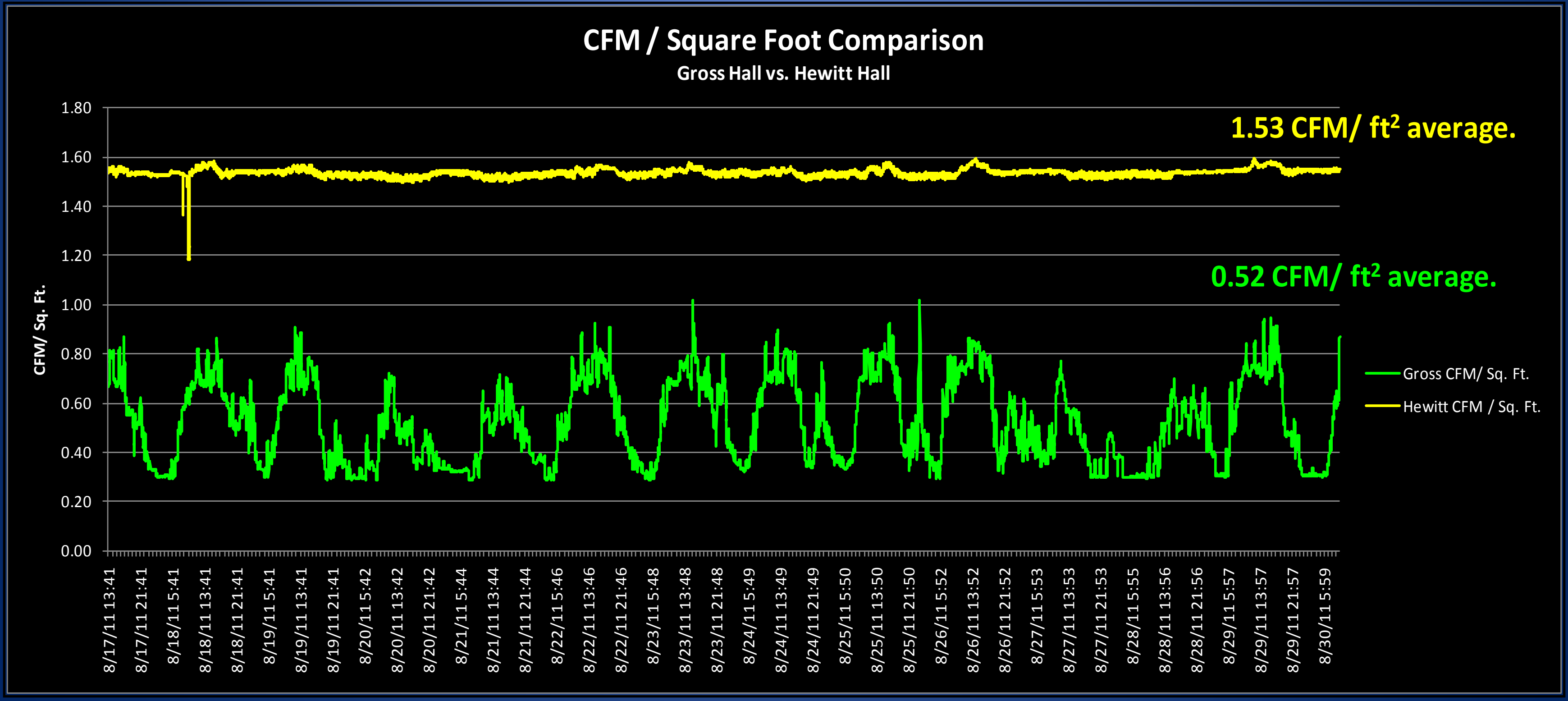
Adding Hewitt and Gross Halls

- Hewitt is right at the average
- Gross Hall beats the most efficient lab benchmarked by 18%

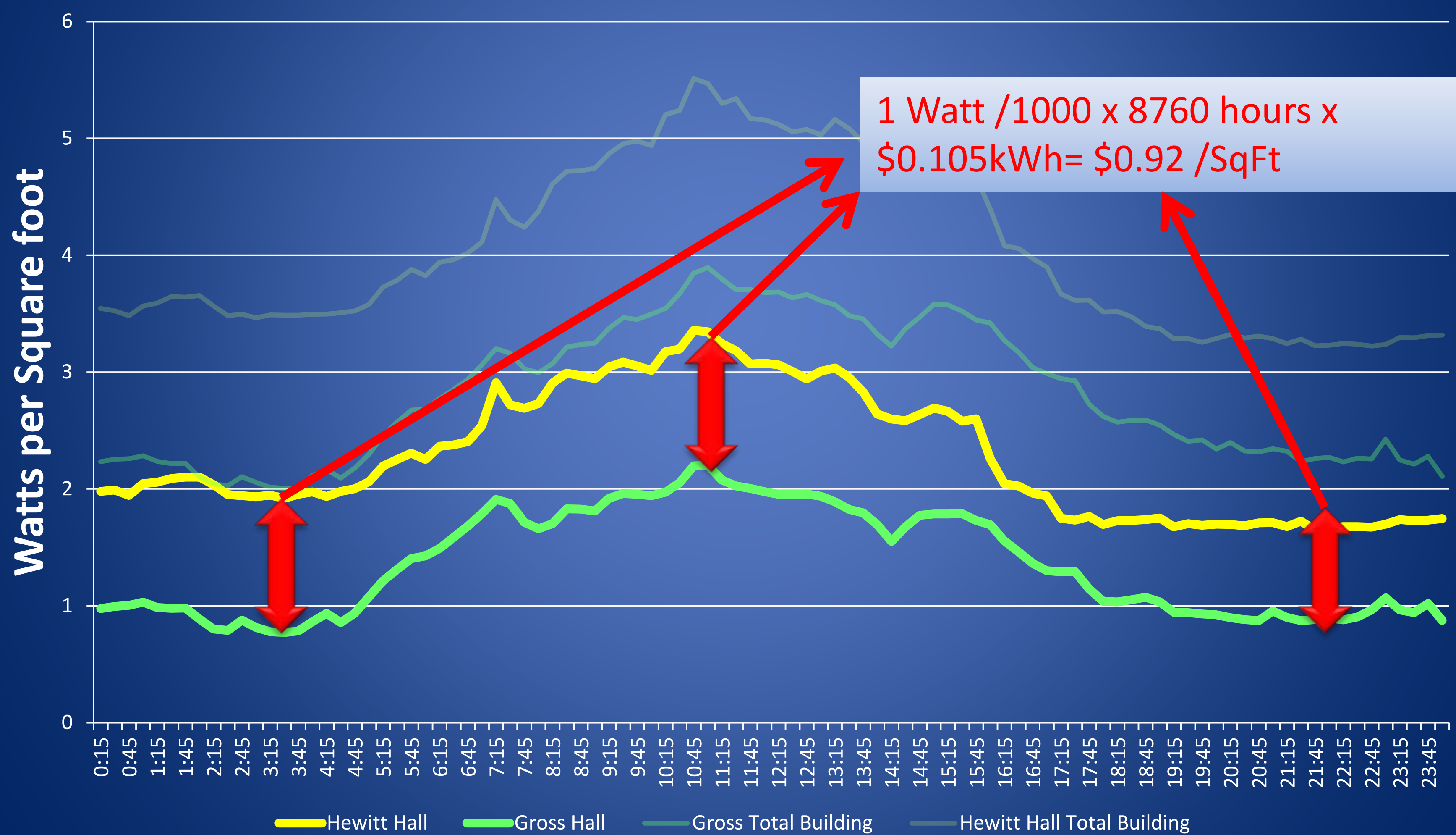


Lab Air Flow vs. Time

- The HVAC savings of 1 CFM/ft2 at $4-5 per CFM can reduce operational significantly.
- A 1 CFM reduction at Hewitt Hall in just the open lab bays would reduce operational cost by $83,250 per year



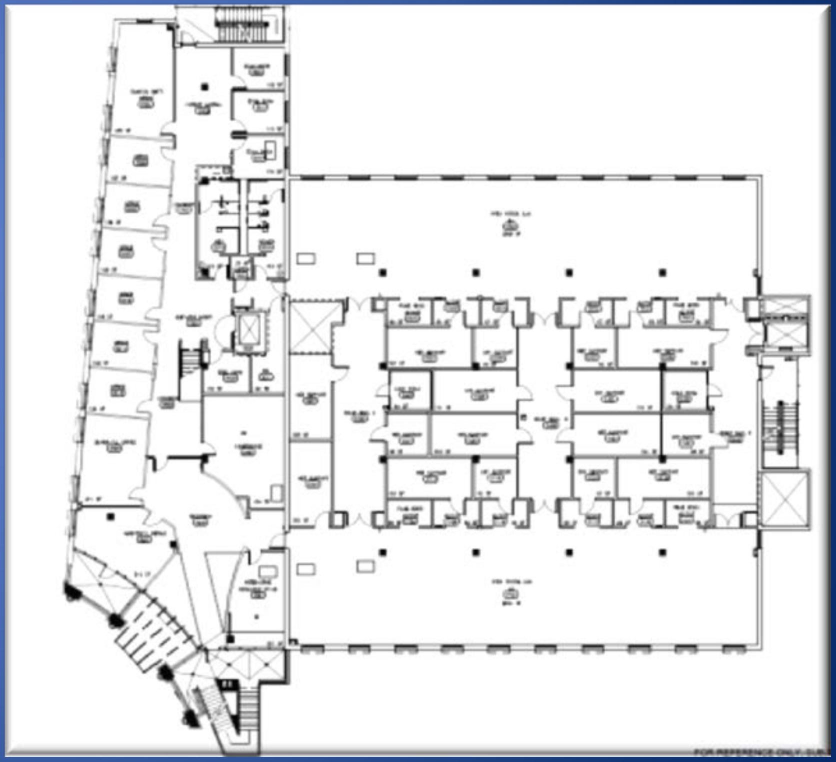
AHU + EF + Pumps + Chilled Water =
Building Square Feet



Comparing Two Similar Floors

Hewitt Hall – 2nd floor

Gross Hall – 2nd floor



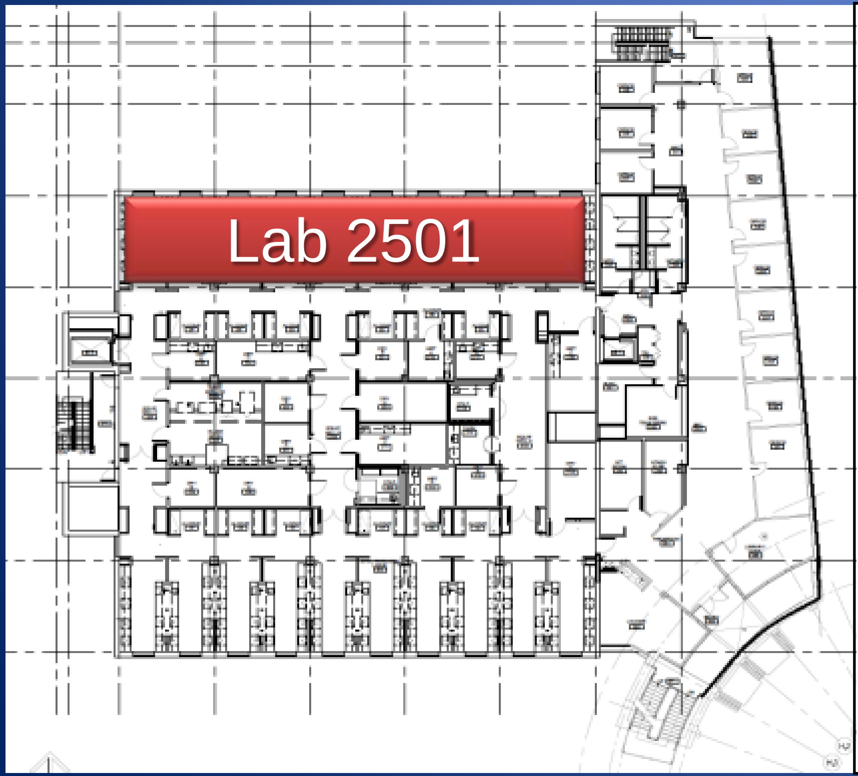
Lab Air Supply and Exhaust

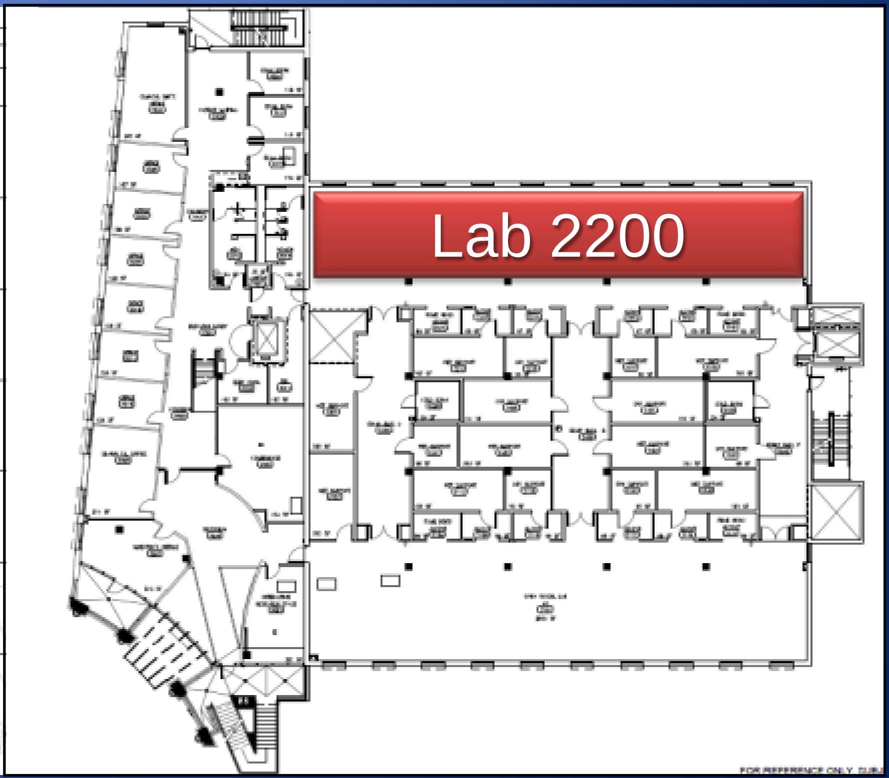
Hewitt Hall – 2nd floor

- 6 Air changes per hour minimum
- No set back during unoccupied periods
- Zone presence sensors on fume hoods

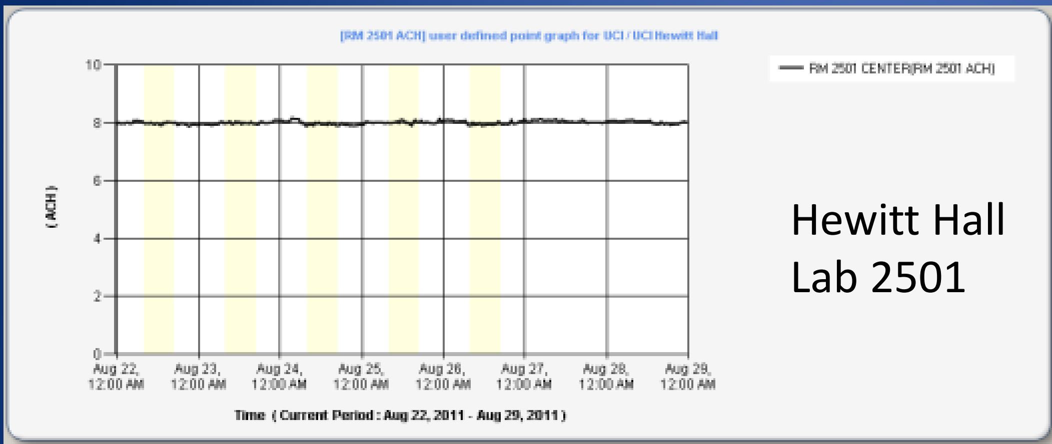
Gross Hall – 2nd floor

- 4 Air changes per hour minimum occupied
- 2 Air Changes per hour minimum unoccupied
- Zone presence sensors on fume hoods
- Centralized Demand Controlled Ventilation system adjusting ACH for indoor air quality.



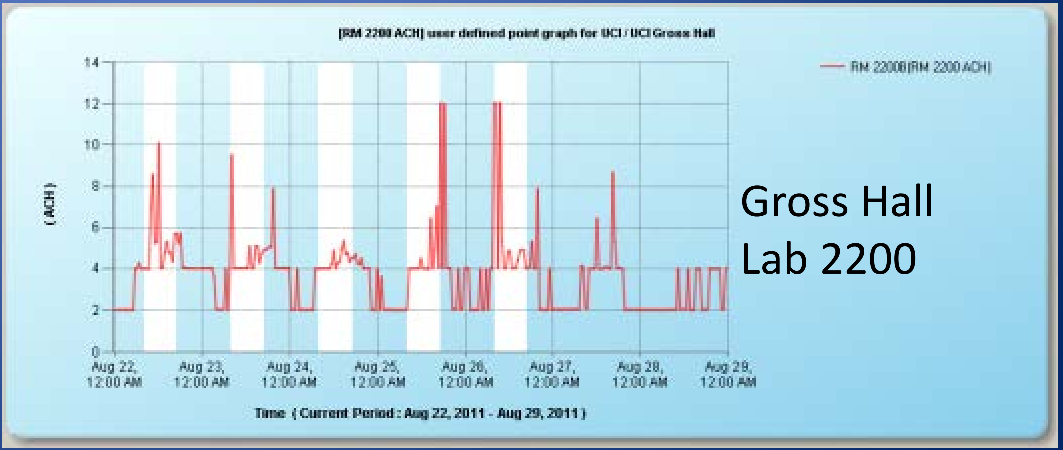


Evidence of Where Building's HVAC Energy Savings are Achieved



- Air change rates are dependent on sash position and thermal demand.
- Lab 2501 averages 8 air changes per hour

- Air change rates are dynamic responding to occupancy, IAQ, sash position, and thermal demands
- Lab 2200 averages 4 air changes per hour



Continuous Commissioning

-- Meaningful analysis and reports
-- Actionable information
-- Verification of actions taken: physical and behavioral

CDCV

- Find failed lab air control valves
- Review of fume hood sash management
- Ensure safe lab air quality
- Find excessive air flows due to point sources of heat

Submetering

- Monitoring of fans, pumps, and lighting control systems
- Verification of energy retrofits
- Reduce demand charges by modifying operations

BMS

- Locate simultaneous heating and cooling
- Reset of static pressure to minimum required
- Control run times of office areas

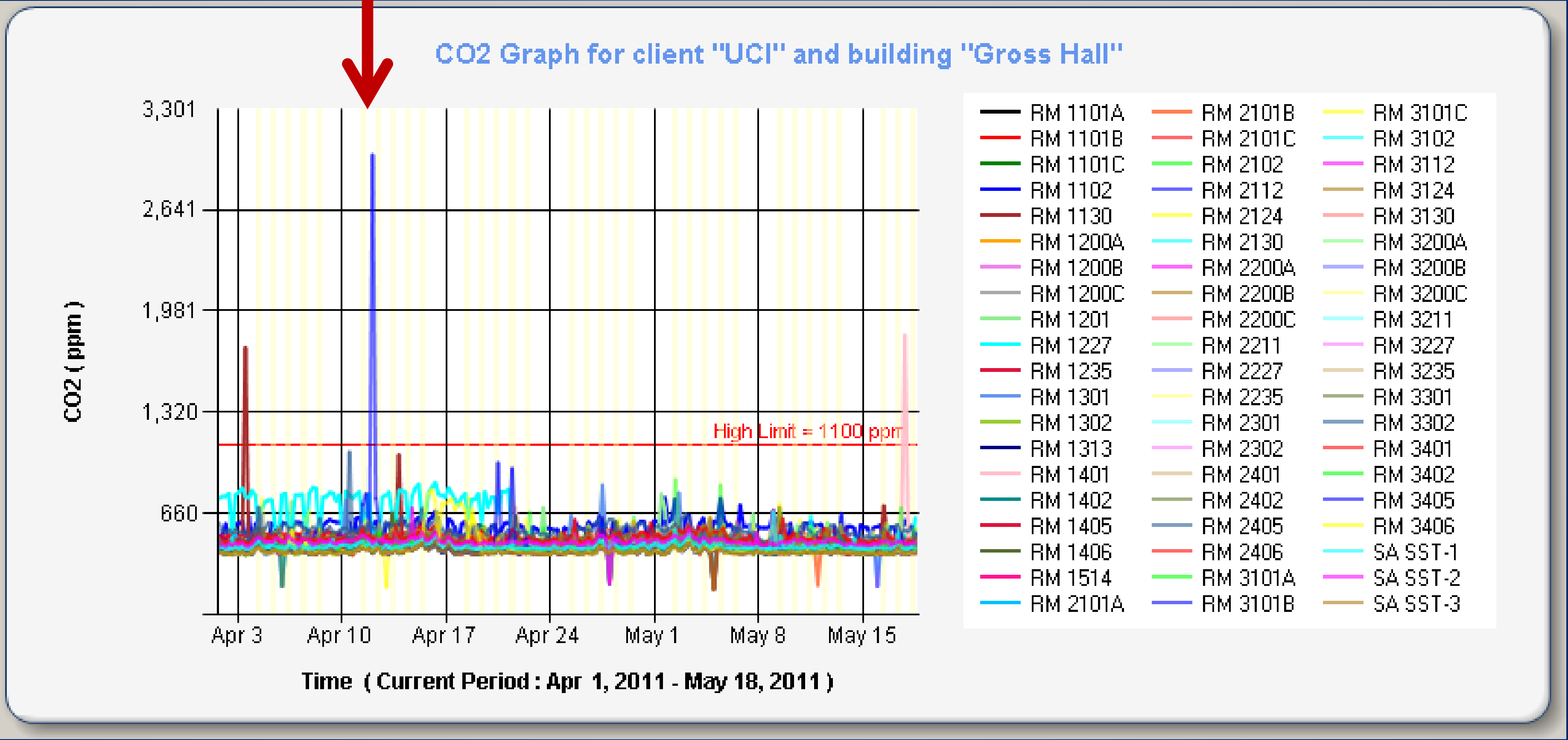
Troubleshooting a CO_2 leak With the CDCV System

- Researcher connects 4 tanks of CO_2 to the lab distribution system and within 8 hours they are empty.

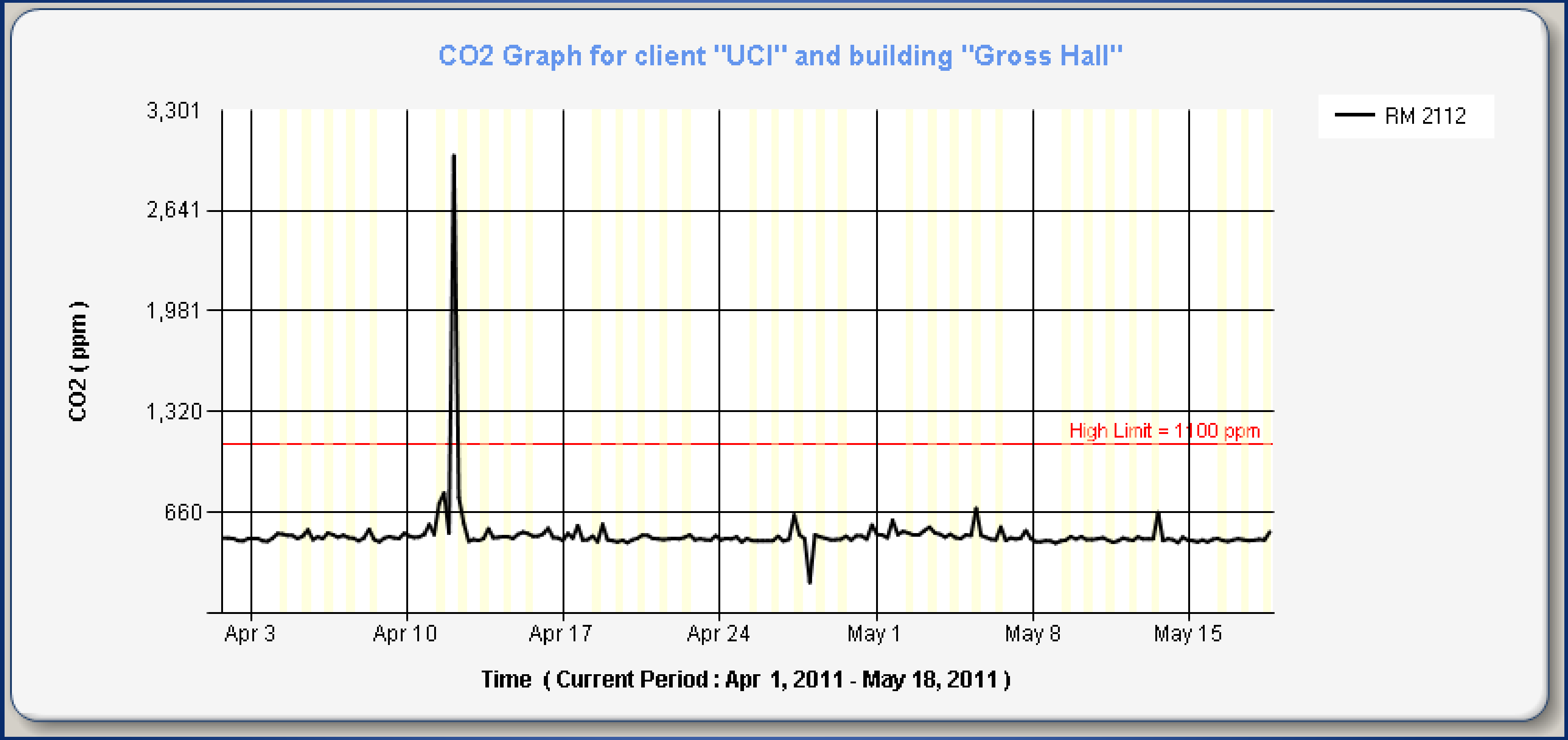
- To find the leak the research staff could have spent hours soaping lines and connections and wasting additional gas listening for the leak.

Researcher first plotted all rooms for CO_2

Suspected location of CO_2 leak

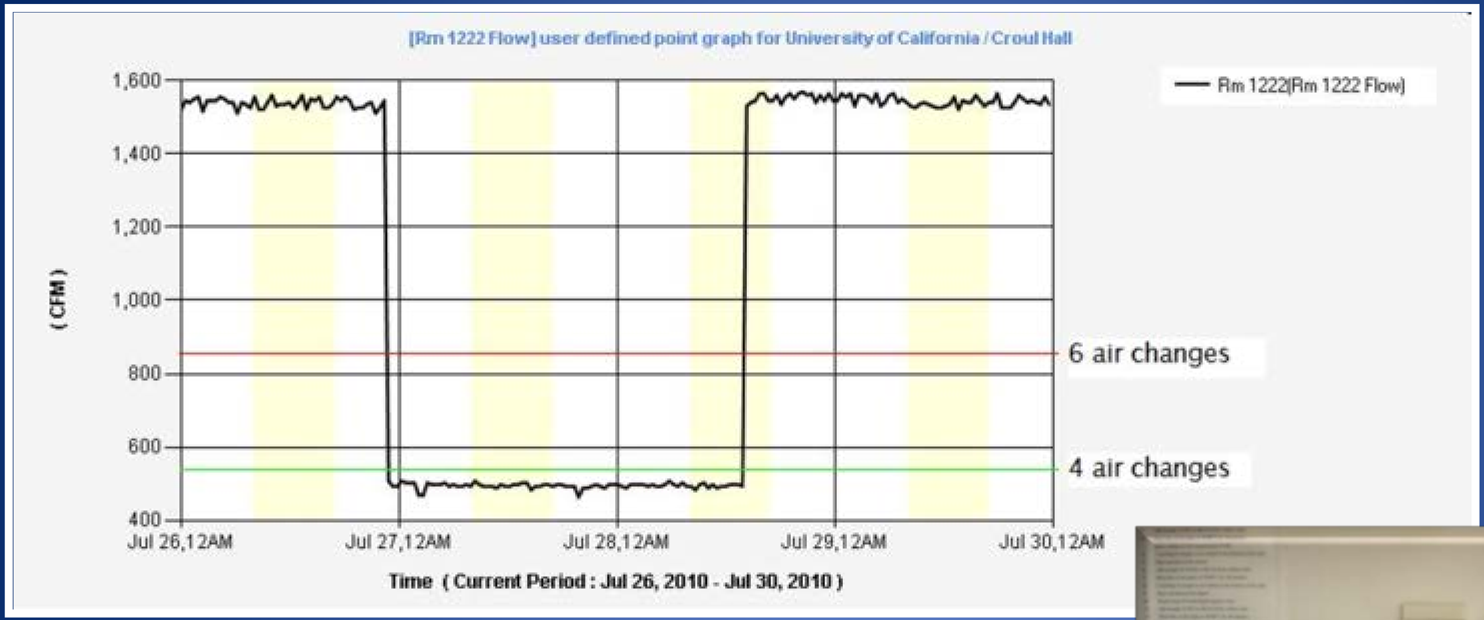


Researcher Then Plotted the Room with the Suspected CO_2 Leak



The leak was quickly located and repaired!

Discovery of Lab Equipment Driving Thermal Demand



The Knowledge Center has been used to locate lab equipment placed too close or under thermostats.

TAKE A BREAK

The training session will resume in 10 minutes.

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- Welcome and Introductions
- UC Irvine's Smart Labs Initiative
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  - Building Envelope
  - Lighting
    - Participatory Exercise
- BREAK
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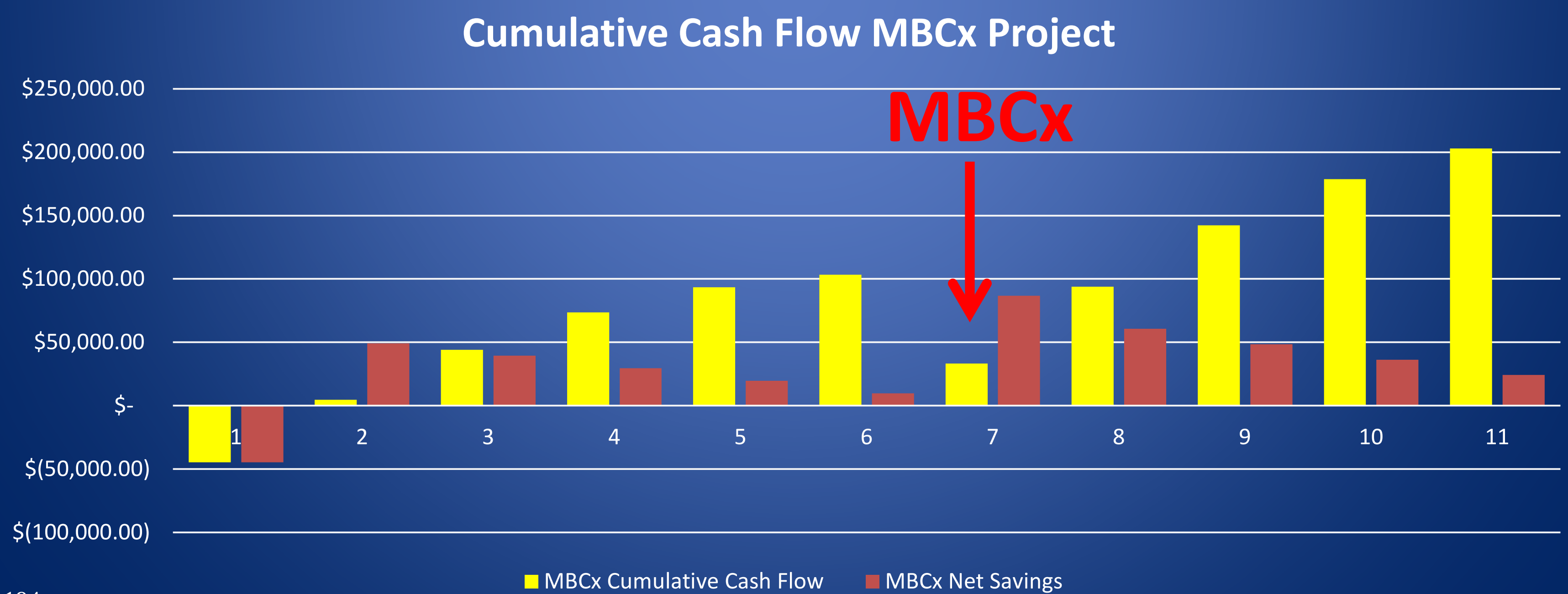
Return on Investment

Commissioning

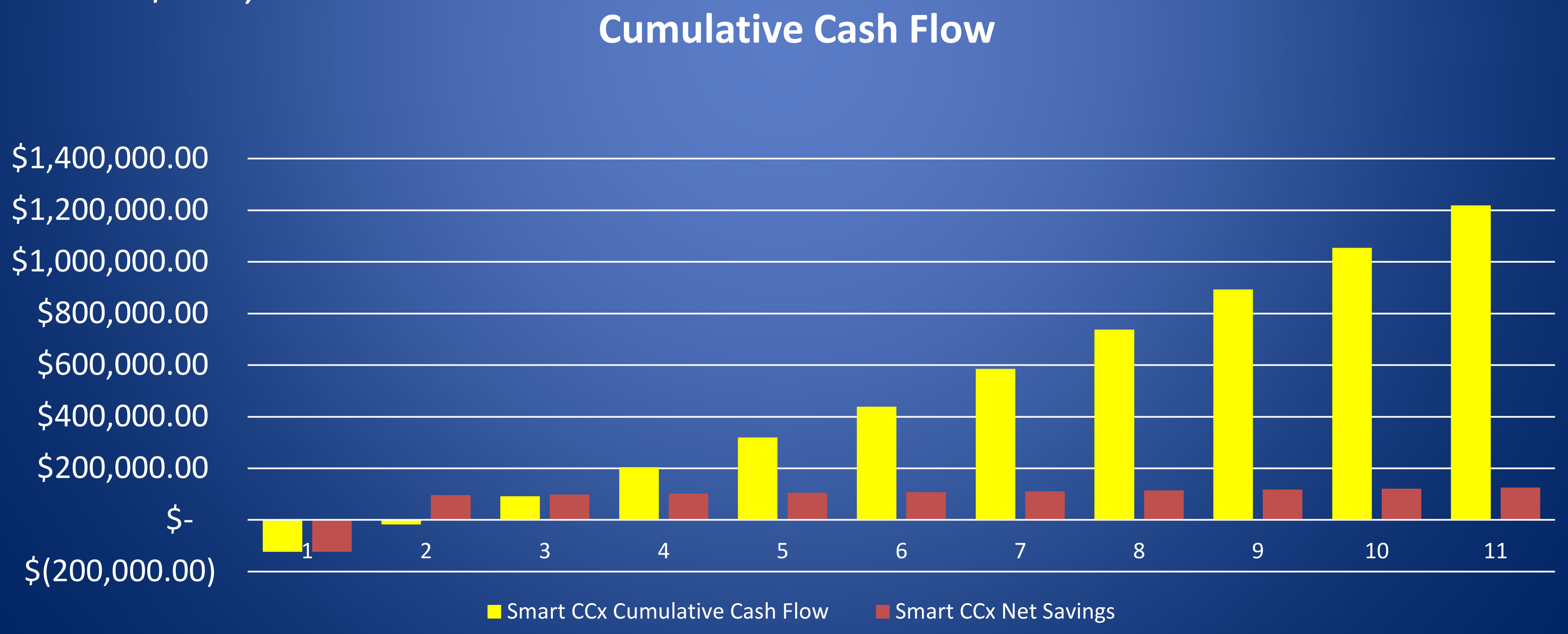
- Cx, Rx, MBCx is approximately $2 per SqFt
- Hewitt Hall MBCx $131,309
- Net present value for 10 years (MBCx every 5 years) Hewitt Hall $113,590



Return on Investment

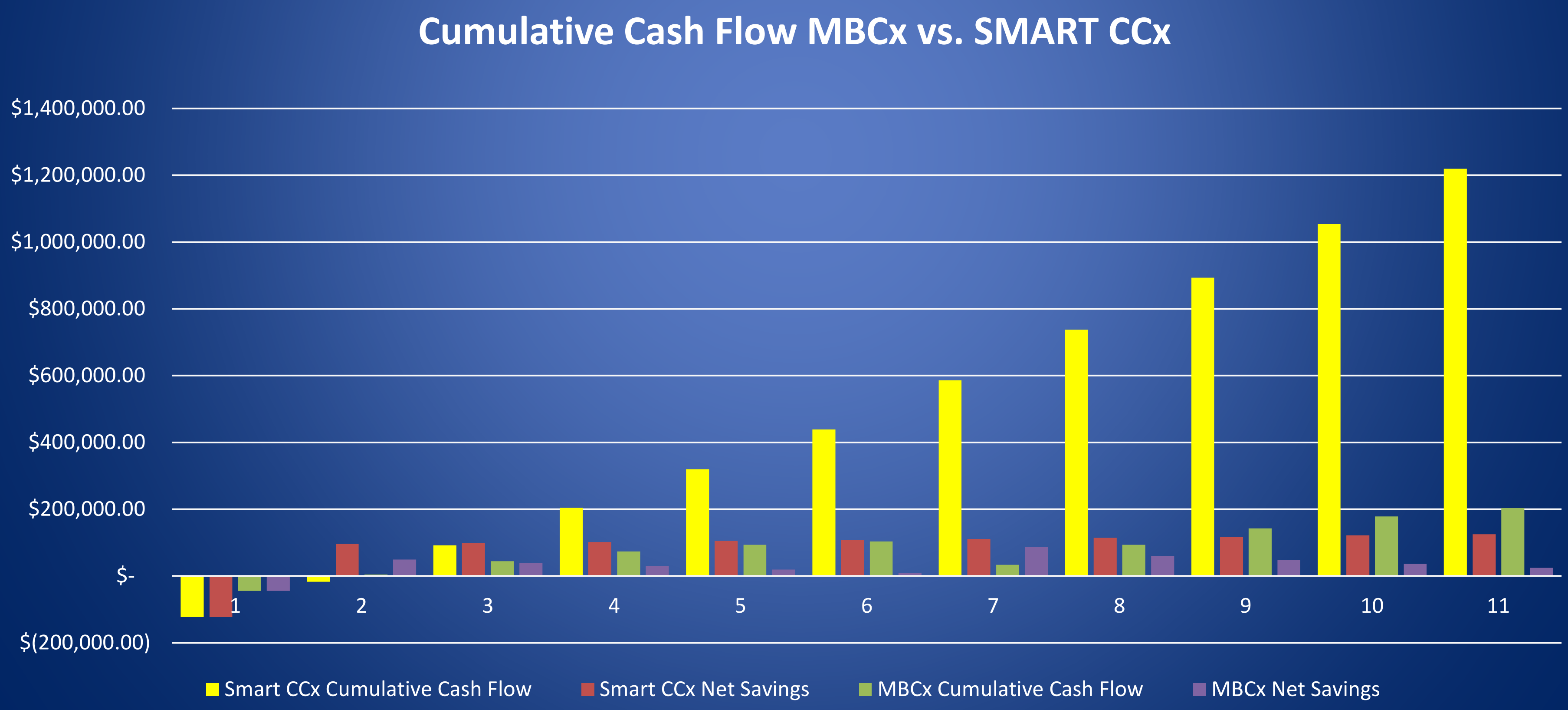
Sub metering and monitoring your lab can be very competitive with the cost of a single commissioning effort.

- CDCV ~$3.12 per SqFt
- Sub metering $0.20 per SqFt
- Hewitt Hall Sub Metering and CDCV $302,888
- Net present value for Hewitt Hall continuous commissioning (10 years) $665,903



Return on Investment

Smart CCx – although a larger initial investment – provides for greater long-term savings as well as strategic analysis, monitoring, and savings that cannot be accomplished with traditional MBCx.



Results:

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%	41%	60%	55%
McGaugh Hall	B	9.4	CV	No	40%	66%	47%
Reines Hall	P	11.3	CV	No	70%	76%	72%
Natural Sciences 2	P,B	9.1	VAV	~20%	48%	62%	50%
Biological Sciences 3	B	9.0	VAV	~30%	45%	81%	60%
Calit2	E	6.0	VAV	~20%	46%	78%	62%
Gillespie Neurosciences	M	6.8	CV	~20%	58%	81%	61%
Sprague Hall	M	7.2	VAV	~20%	58%	82%	71%
Hewitt Hall	M	8.7	VAV	~20%	58%	77%	69%
Engineering Hall	E	8.0	VAV	~30%	59%	78%	61%
Averages		**8.2**	**VAV**	**~20%**	**55%**	**76%**	**58%**

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

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Future of Smart Labs at UC Irvine

Research and development of Smart Labs is an ongoing process that will continue to make our labs more energy efficient and safer.

- Minimum Fume Hood Flow Study
- LED Lighting System
- New Lab Display Units

Minimum Fume Hood Flow Study

- UC Irvine desires to reduce energy use in labs by minimizing the exhaust flow through VAV fume hoods when the sash is closed
- Evaluate whether exhaust flow can be safely reduced below current design flow of 25 cfm/ft^2 of work surface
- Determine the min recommended exhaust flow for VAV hoods located throughout the UCI campus.

AIHA/ANSI Z9.5 Laboratory Standard

- The new ANSI Z9.5 Standard recommends basing the minimum flow on the internal volume of the fume hood and internal air change per hour(ACH) where a range of 375 ACH to as low as 150 ACH is proposed
- 375 ACH is roughly equivalent to 25 cfm/ft^2 and150 ACH is roughly equivalent to 10 cfm/ft^2

AIHA/ANSI Z9.5 Laboratory Standard

Safety Considerations:

- The processes and materials generated within the hoods
- Hood containment and dilution of hazardous concentrations within the hood
- Potential for increased corrosion
- The ability to measure and control flow
- Effect on duct transport and stack discharge velocities

Preliminary Test Results
New Safe Flow Set Points

- Current flow set point is 375 ACH
- Minimum ACH for safe containment – ACH min
- Flow reduction from design from 375 ACH

	6 ft Hood A	5 ft Hood B	6 ft Hood C	5 ft Hood D
ACH Min	165	230	200	220
Flow Reduction - ACH	210	145	175	155

Energy Savings

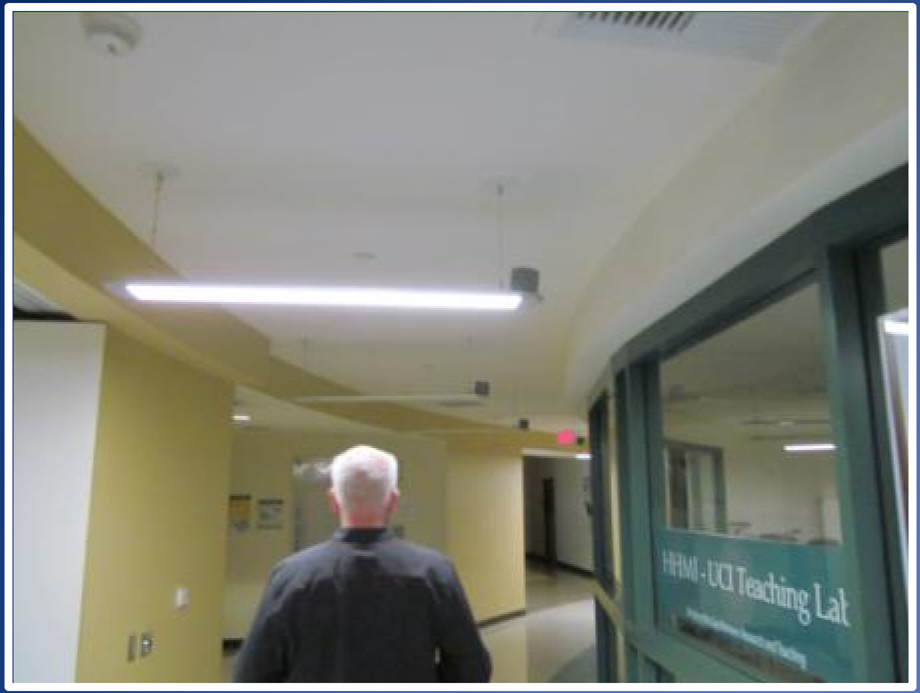
- To be determined over the next 6 to 12 months

Implementation Plan

- Implement in one building
- Full campus roll-out

LED Lighting System

- LED lights with integrated smart controls
- Precisely control lighting levels
- Occupancy, daylighting, and temperature sensors at each fixture
- Real-time energy management and reporting
- Real-time monitoring of each fixture and group
- Demand response capable

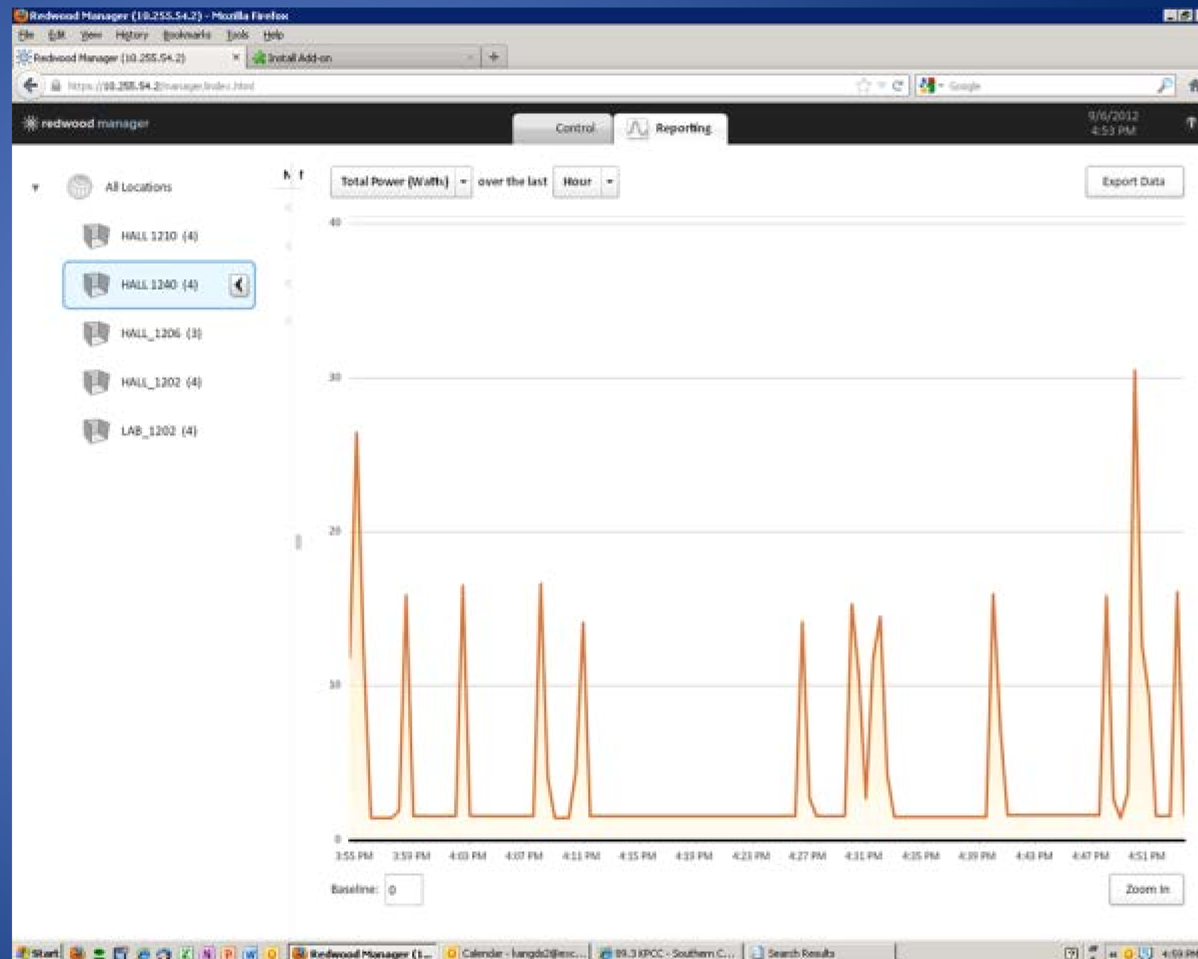


LED lighting fixtures

- Pendant Mount
- 2x2 or 2x4
- Can

LED Lighting System

- Real time and historic monitoring
- Trend energy use
- Failure Notfication



Lab Display Units

UCI working with CalIT[2] are developing a new LDU that displays

- Ventilation Data
- Environmental Health and Safety Hazard and Emergency Information
- Energy Saving Tutorial

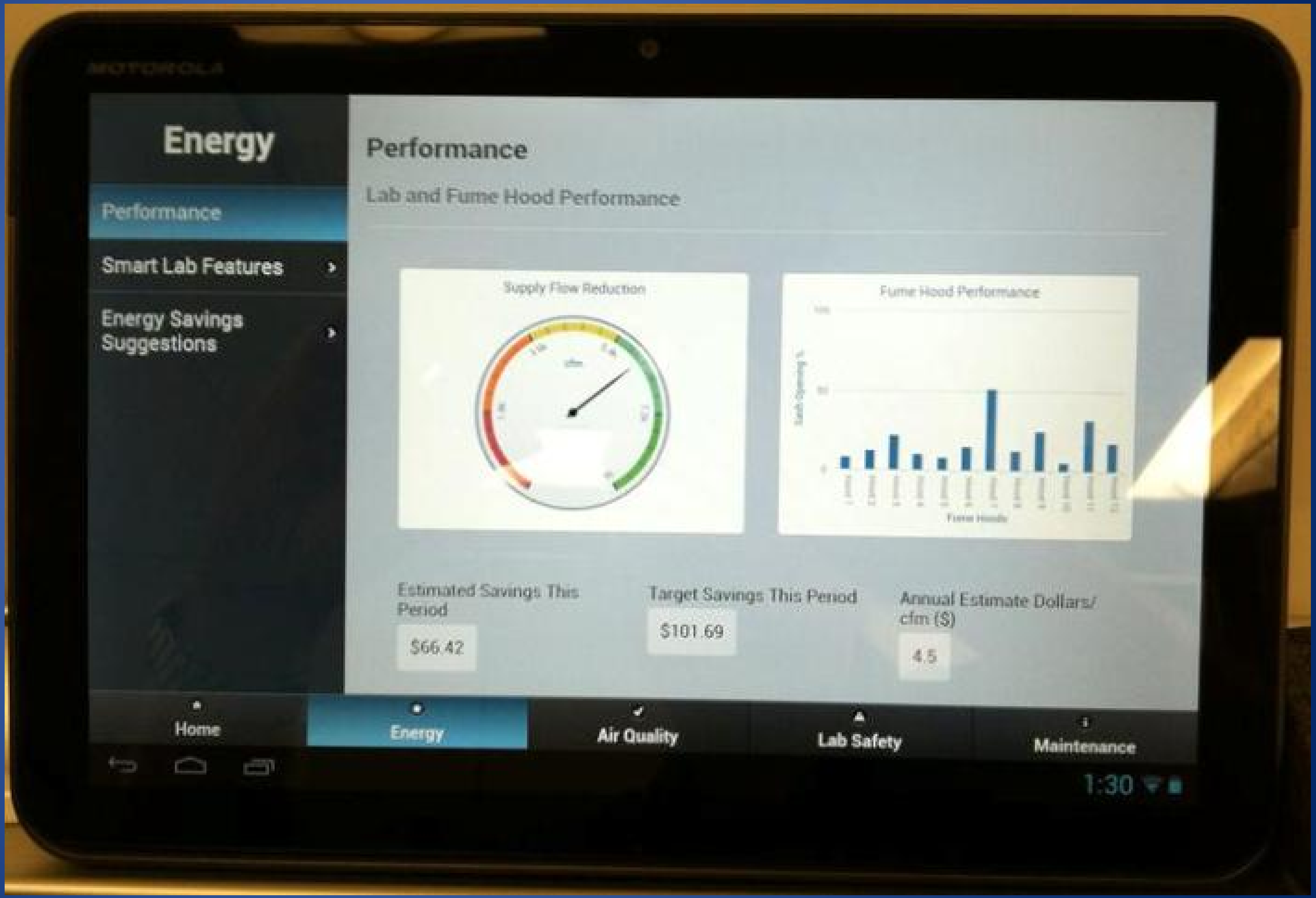
Lab Display Units

Touchscreen

Android based display

Graphical output of any Bacnet point

Capable of showing
- Training videos
- Chemical inventories
- Scheduling
- Contact information



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Smart Lab Energy Design Parameters

Parameters/Features	Recent Best Practices	Smart Lab
Air-handler/filtration airspeeds	400 ft./min. max.	350 ft./min. max.
Total system (supply + exhaust) pressure-drop	~6 in.w.g.	<5 in.w.g.
Duct noise attenuators	Few	None
Occupied lab air-changes/hr. (ACH)	6 ACH	4 ACH w/contaminant sensing
Unoccupied air-change setback	No setback	2 ACH w/contaminant sensing + reduced thermal inputs while building "coasts" during setback
Low-flow/high-performance fume hoods and/or automatic sash-closers	No	Yes, where hood density warrants
Exhaust stack discharge velocity	~3,000 FPM	No fixed standard; building-by-building analysis typical 1,000-1,500 FPM >1,500 FPM only if/when necessary to avoid re-entrainment
Lab illumination power-density	~.9 watt/SF	<.6 watt/SF w/LED task lighting where needed
Fixtures near windows on daylight sensors	No	Yes
ENERGY STAR freezers and refrigerators	Some	Most
Outperform CA Title 24	20-25%	>50%

Smart Labs Summary

- Reduce building energy consumption by ~50%
  - Reduce air changes with CDCV
  - Reduce illumination power density
  - Reduce building exhaust discharge air speeds
- Increased staff oversight
  - Increased mechanical repairs to more complex systems
  - Increased software updates/adjustments to control systems
  - Increased EH&S oversight of labs
- Significant energy $avings

Revisiting the Learning Outcomes

1. Why focus on laboratories?
2. Can we afford a “smart lab” retrofit?
3. Are savings greater than 50% really possible?
4. Can these savings only be realized with new construction?
5. Can we afford to keep a “smart lab” smart?
6. What if our energy costs differ from those in California?

UCIRVINE

QUESTIONS?

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