Deep Energy Efficiency Strategies for University Buildings

Smart Lab Design, Implementation, and Results

Matt Gudorf
Campus Energy Manager

UCIrvine | University of California

Agenda

1. Smart Lab Metering and Dashboards
2. Smart Lab vs. Previous Best Practice
3. Lab Energy Use, 2001 vs. 2010
4. Smart Continuous Commissioning

Environmental and Economic Considerations

- UC Irvine is signatory to the Presidents Climate Action Commitment
- The University of California will design and build all new laboratory buildings to a minimum standard equivalent to a LEED™-NC "Silver" rating.
- The University of California policy for all new building projects, other than acute-care facilities, to outperform the required provisions of the California Energy Code (Title 24) energy-efficiency standards by at least 20 percent. (UC Irvine's goal is to outperform by 50%)
- First cost vs. lifecycle is not only economic but environmental.

Lab Efficiency Cycle

UCI's Goal is to reduce lab energy consumption by 50%

Verify savings and use added tools to constantly commission labs

Review data, Labs21 Toolkit, Scope out energy project

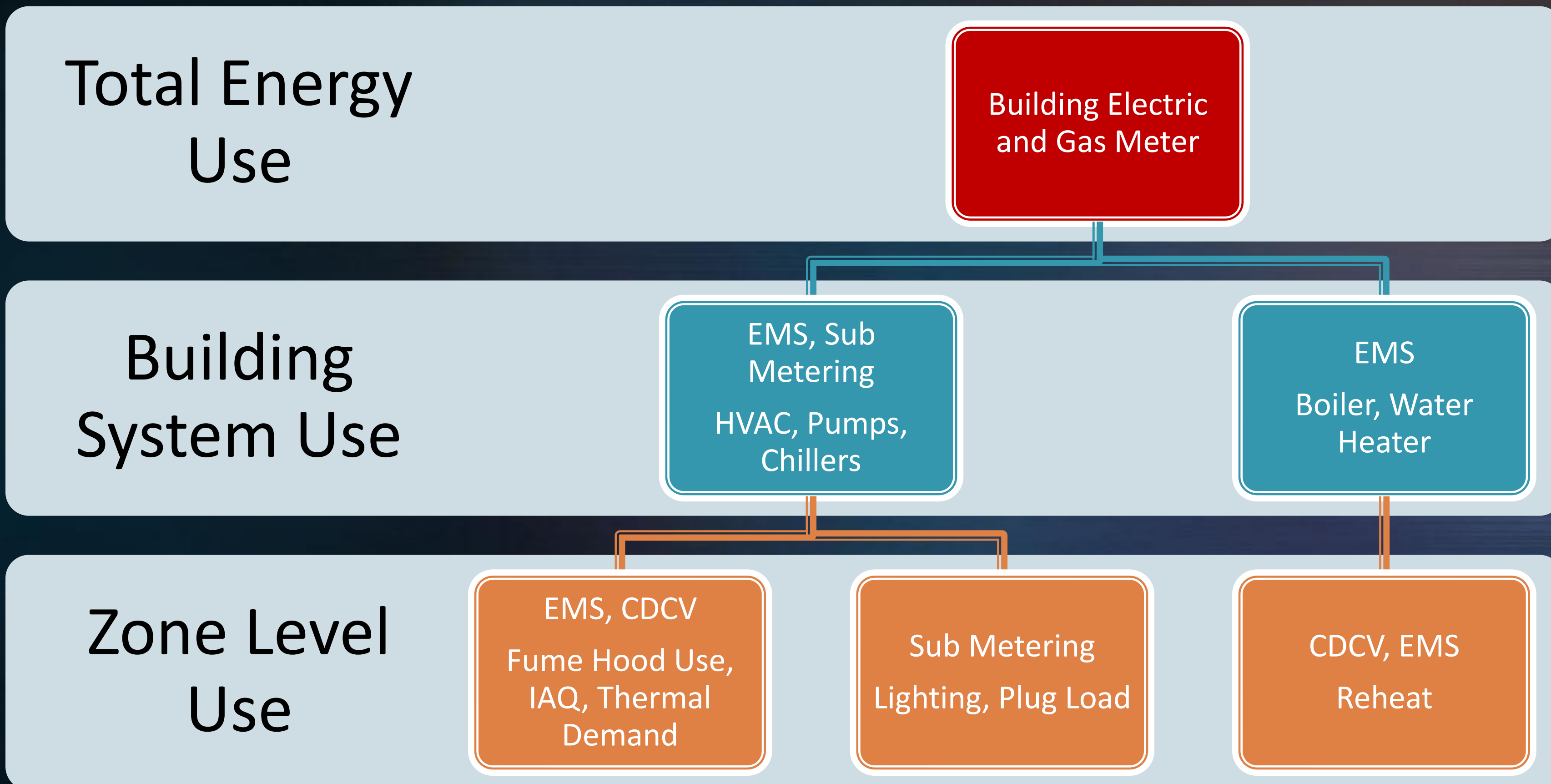
Implement Smart Labs

CDCV, ESDVR, Day Lighting and Lighting Controls, Low Pressure Drop Filters, Remove Duct Noise Attenuators, Static Pressure Reset

Previous Best Practice vs. Smart Lab

	2001 Best Practice	**Gross Hall 2010 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. (incl. dirty filter allow.)
Duct noise attenuators	Few	None
Occupied lab air-changes/hr. (ACH)	6 ACH	4 ACH w/contaminant sensing
Night air-change setback (unoccupied)	No setback	2 ACH w/occupancy + contaminant sensing
Fume hood face-velocities	100 FPM	100 FPM
Fume hood face-velocities (unoccupied)	100 FPM	60 FPM (Zone Presence Sensors)
Exhaust stack discharge velocity	~3,500 FPM	~2,100 FPM Wind Tunnel Modeled
Lab illumination power-density	0.9 watt/SF	0.6 watt/SF w/LED task lighting
Fixtures near windows on daylight sensors	No	Yes
Energy Star freezers & refrigerators	No	Yes
Out-perform CA Title 24	20-25%	50%

If you can’t see where the energy is going, finding savings will be difficult.



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

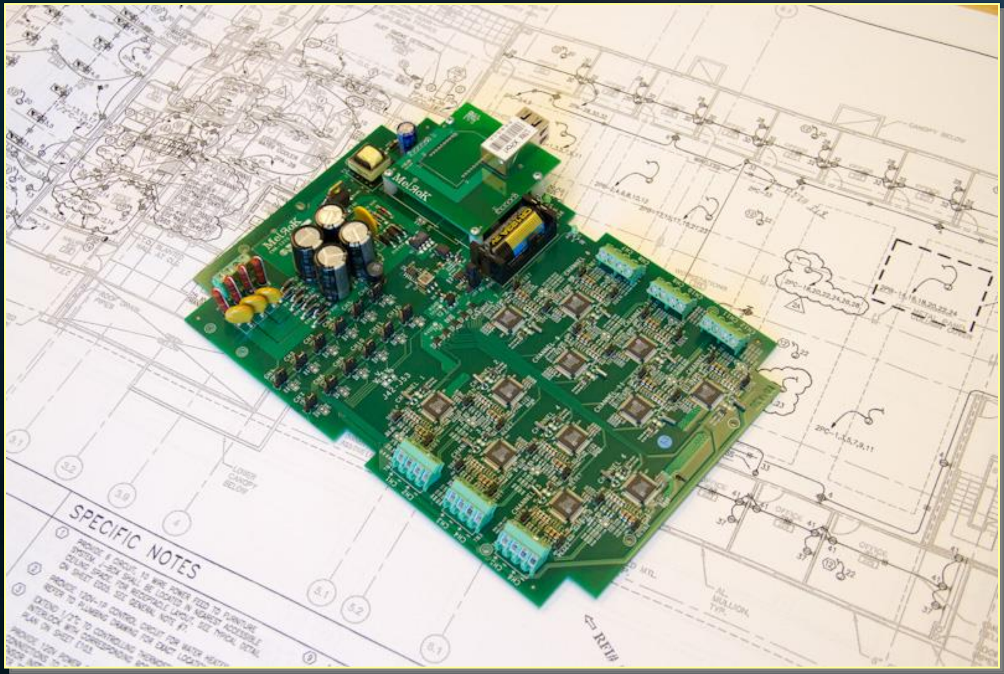
Cost Effective Sub Metering

Meter Specs

- 12 Channels Per Board
- Meter accuracy: +/- 0.5% (0.25% Typ.)
- V, I, Active Energy, Reactive Energy, Power Factor

Current Transformer Specs

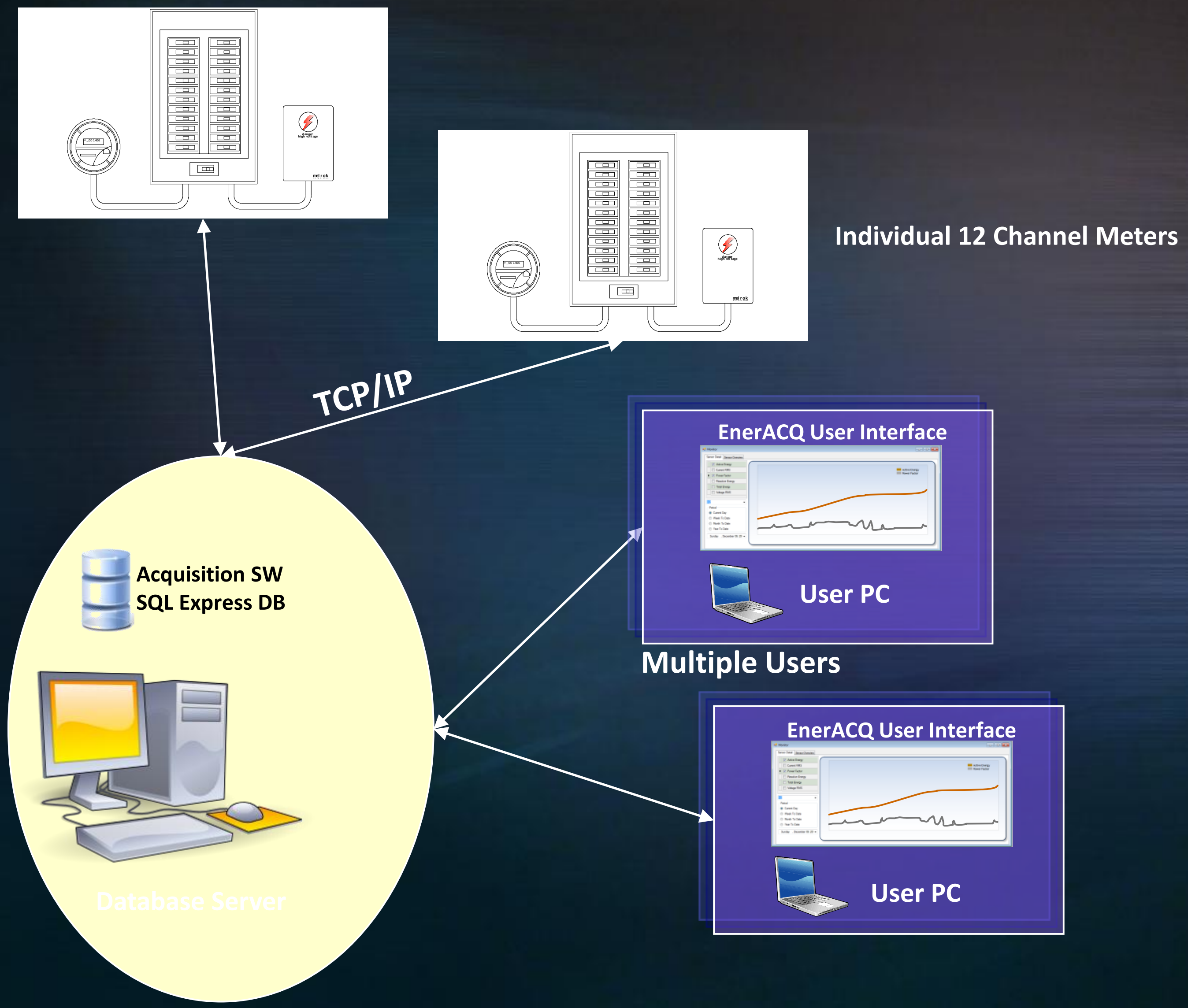
- Sensor Accuracy: +/- 1%
- CT's 60-400 Amps
- Clamp on installation



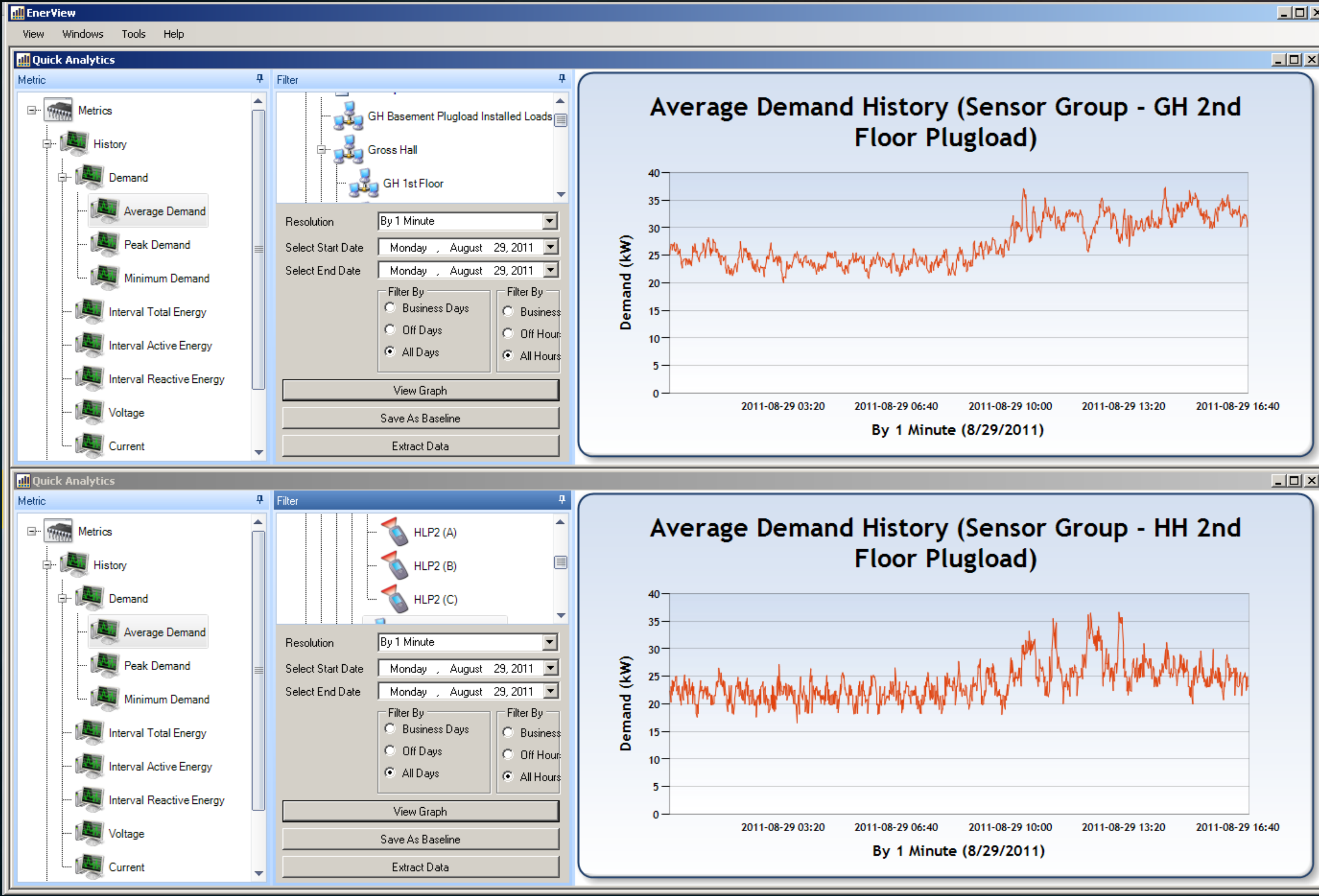

WARNING / HIGH VOLTAGE INSIDE
DISCONNECT SUPPLY BEFORE OPENING
HIGH WATER ALARM
PNL 1HA 277/480V
CKT 19 21 23


PANEL TP1C

System Description

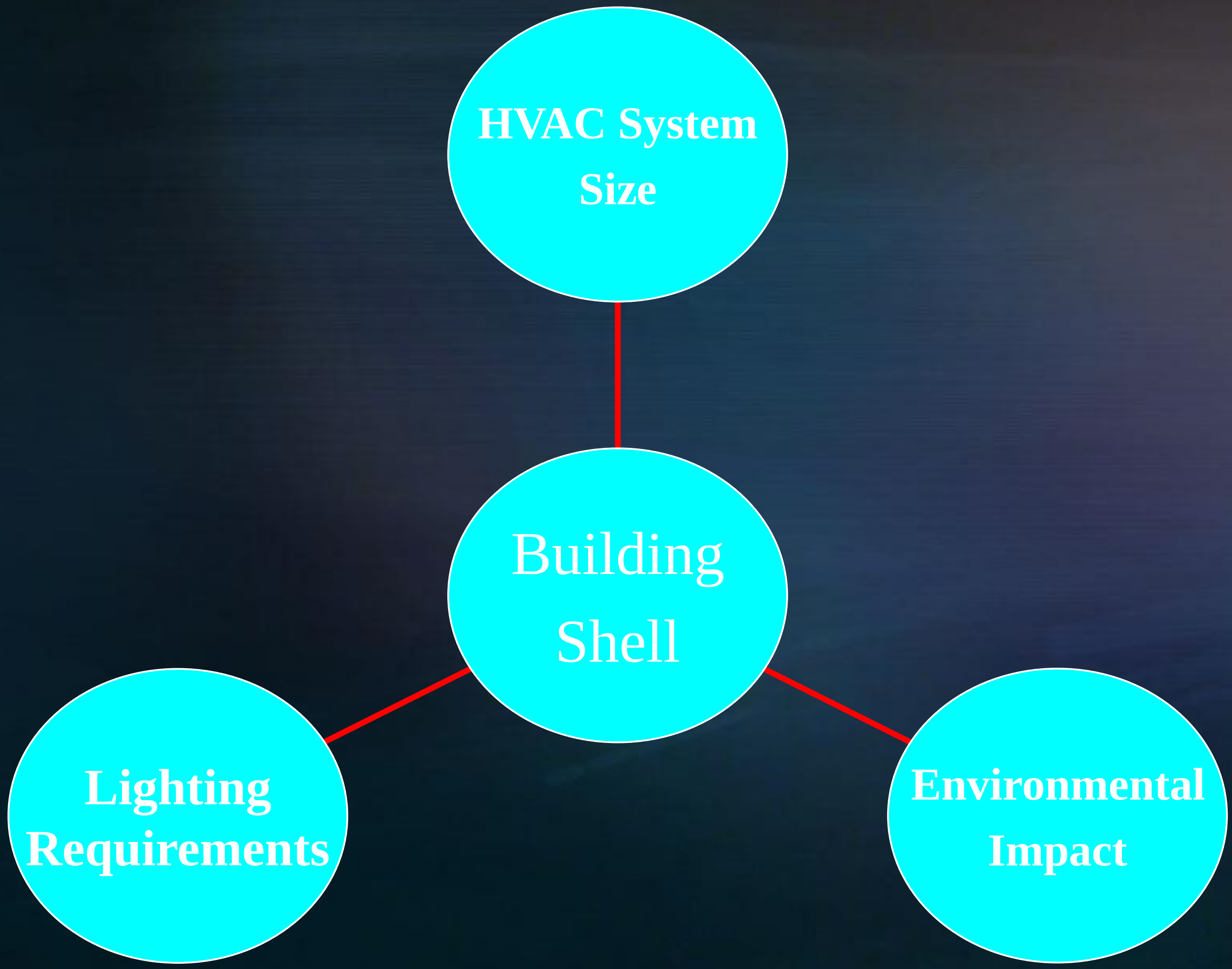


Visualization of lab energy use



BUILDING ENVELOPE

The building shell will effect every system within the facility



BUILDING ENVELOPE

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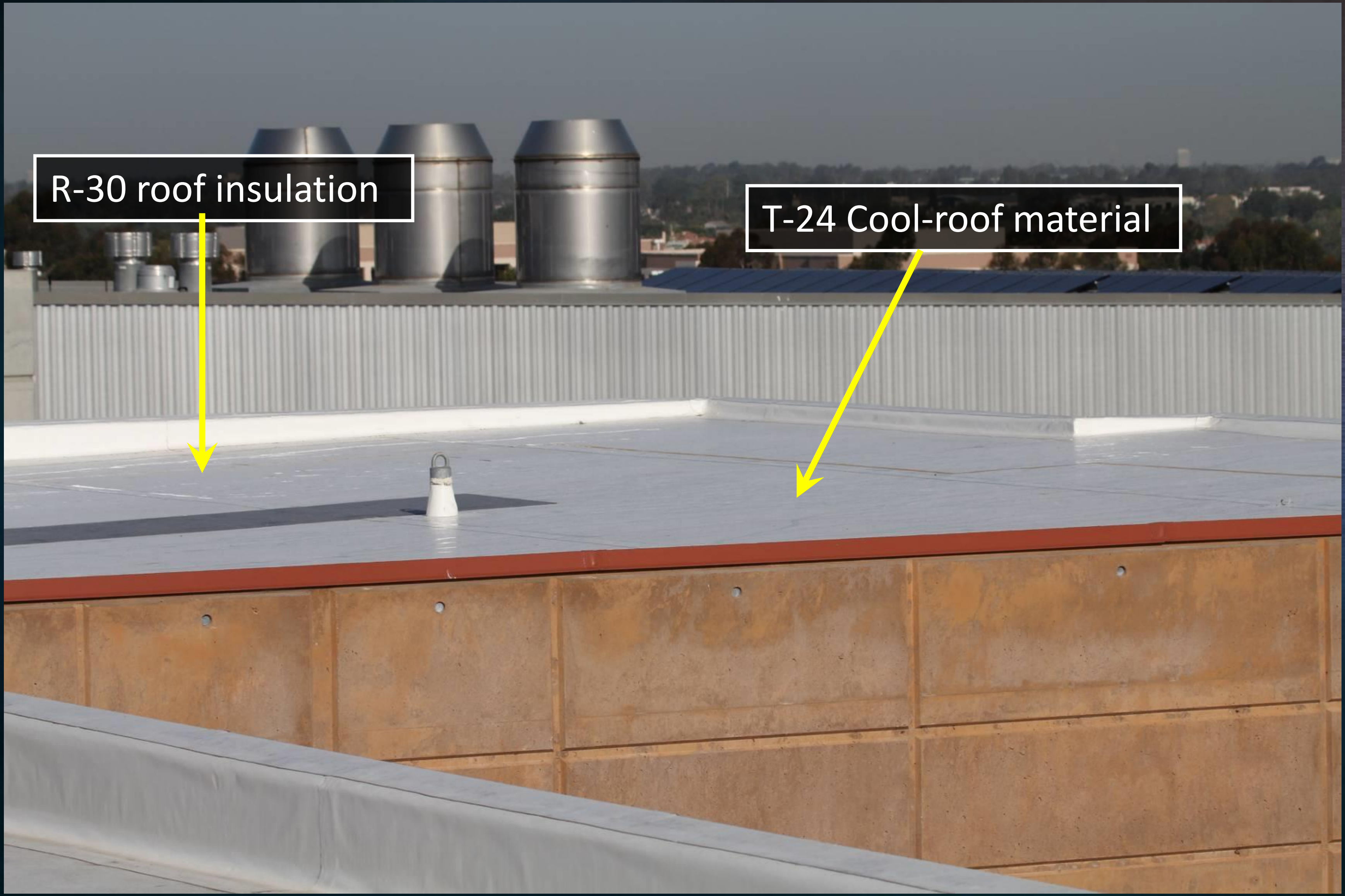
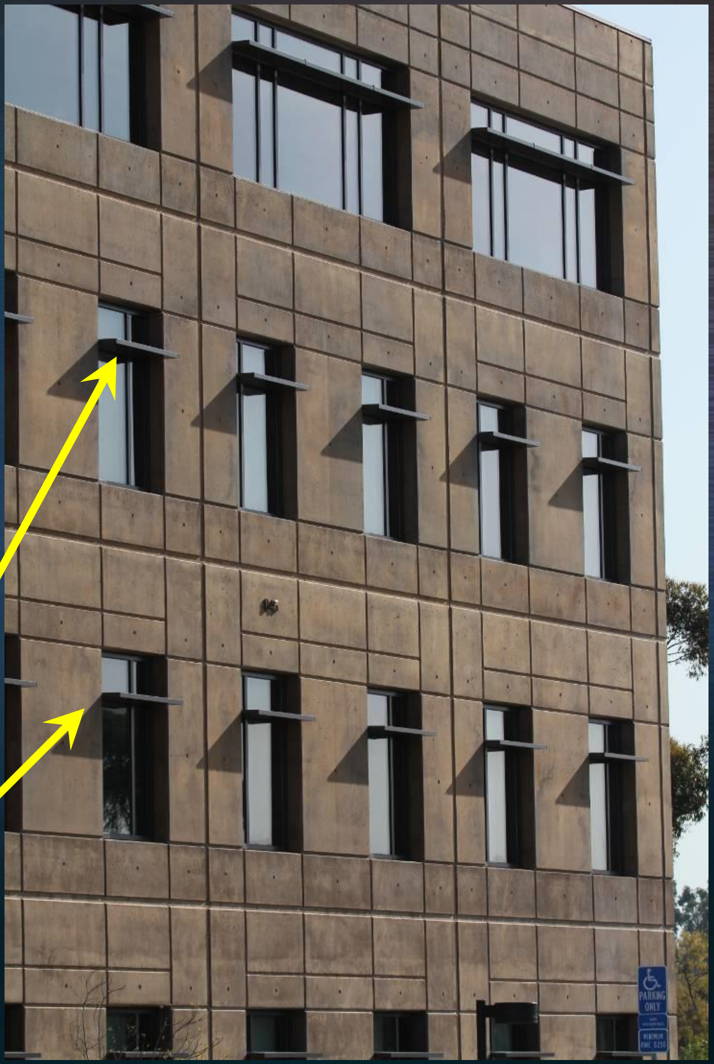


BUILDING ENVELOPE

Ultra-high-performance glazing

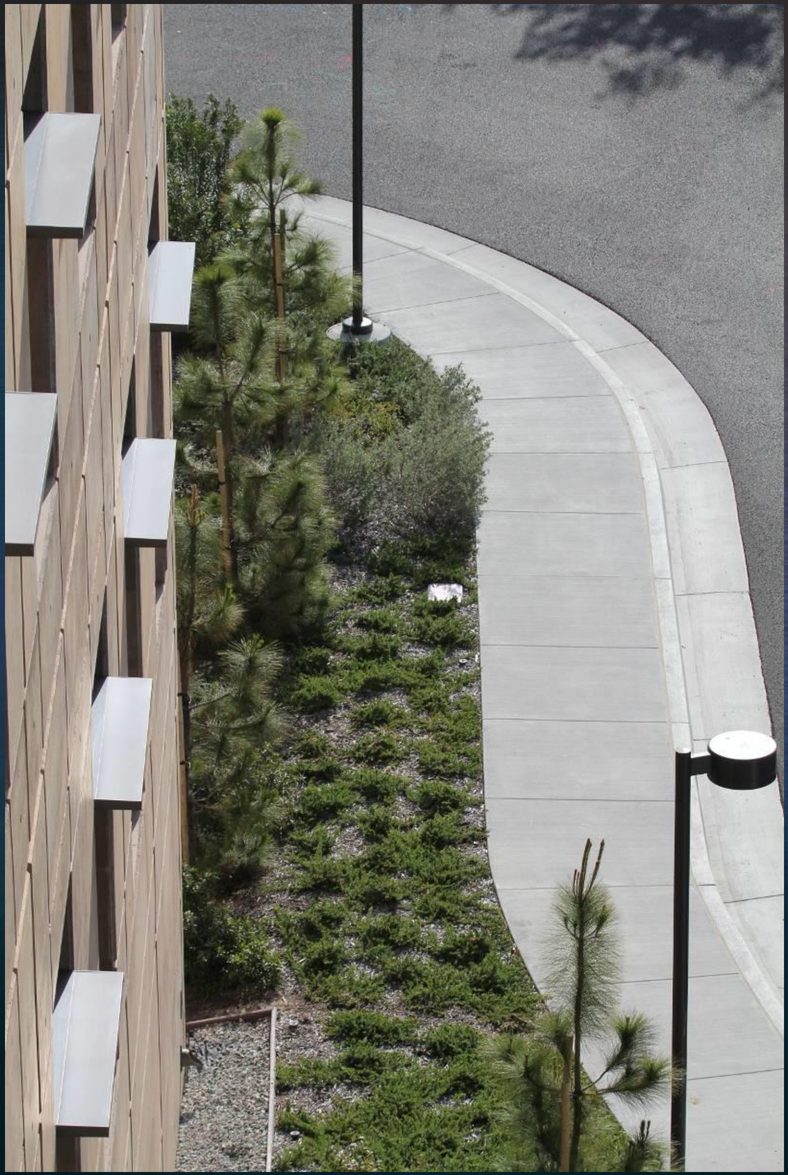


Light Shelves

BUILDING ENVELOPE

Landscape belts at building perimeters reducing heat and reflection impacts

Drought tolerant vegetation using minimal reclaimed water



LIGHTING

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

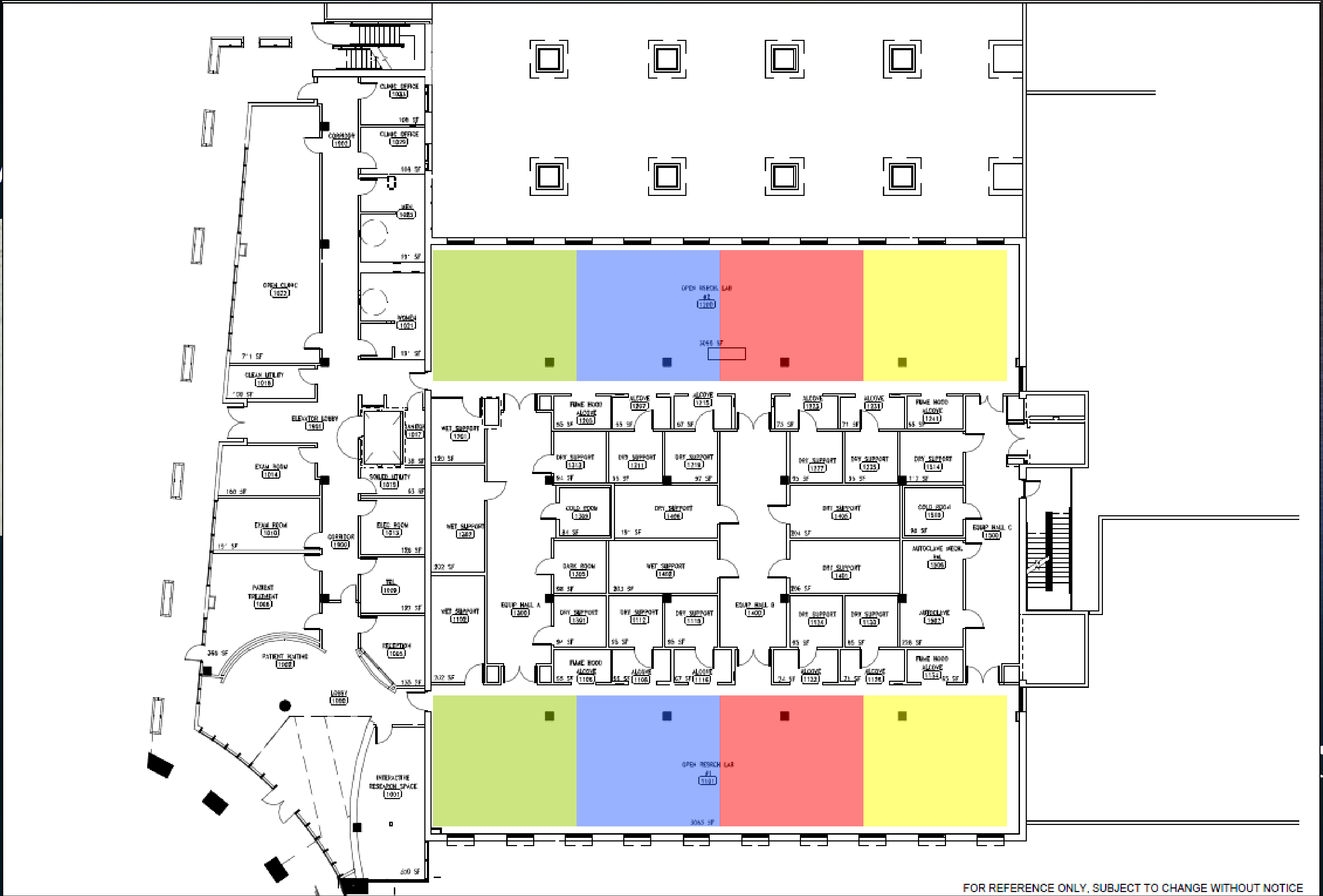
LIGHTING

Perforated Window Blinds
Make use of daylighting without the glare

LIGHTING

Lab areas within 15’ of the window line and all private offices and conference rooms are equipped with automatic daylighting controls

LIGHTING



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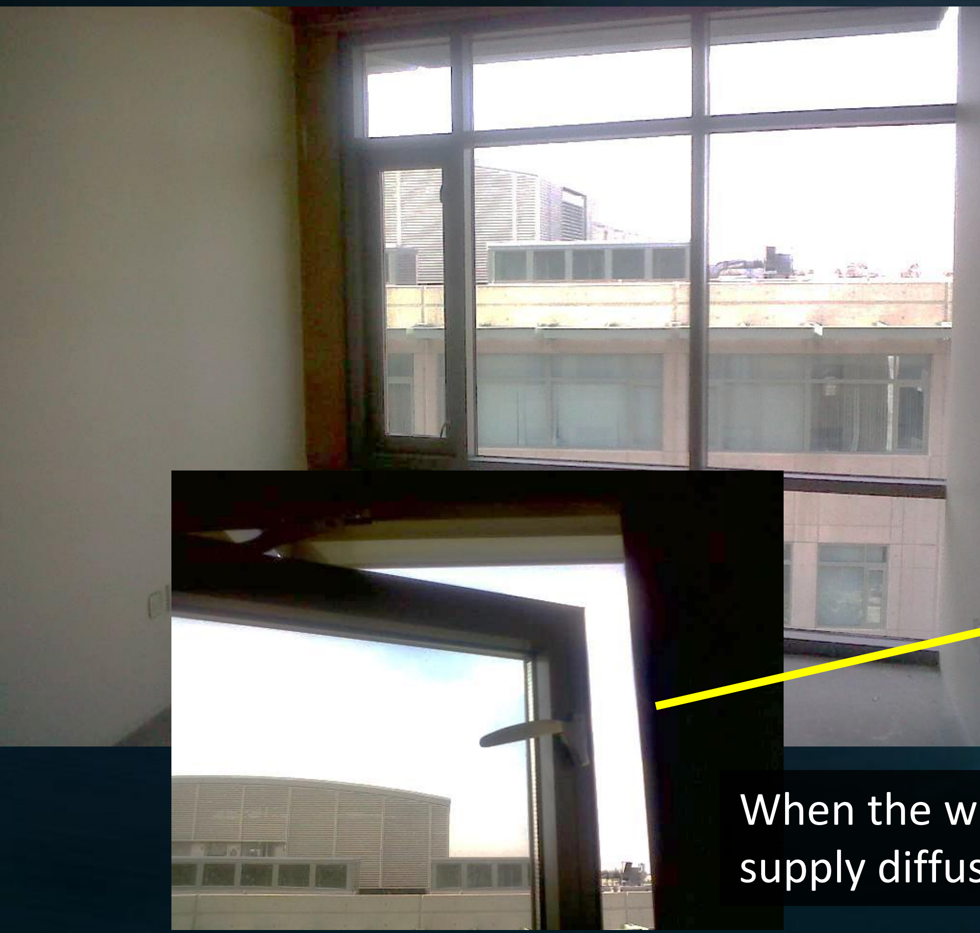
LED Task Lighting

Mechanical System

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

Natural Ventilation

Operable Windows Interlocked with HVAC System



When the window opens the supply diffuser is closed

Centralized Demand Controlled Ventilation

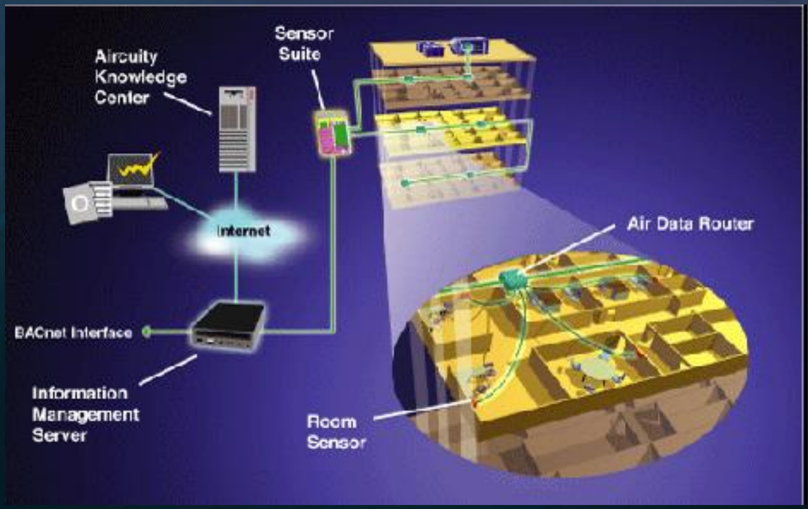
1. **Monitors the indoor air quality of multiple zones through a network of structured cables and air data routers**
2. **Analyzes the sampled air with a battery of sensors**
3. **Provides the lab air control system with an input for increased ventilation when necessary.**
4. **The system is only an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

Minimum of 4 air changes per hour in occupied labs
Minimum of 2 air changes per hour in un-occupied labs

CDCV System

Dashboard and Data Trends for each zone:

- Air Change Rates
- IAQ
- Sash position of each fume hood
- Occupancy
- Relative Humidity
- Temperature
- Total Supply
- Total Exhaust



CDCV

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.

Added Features

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

Safety

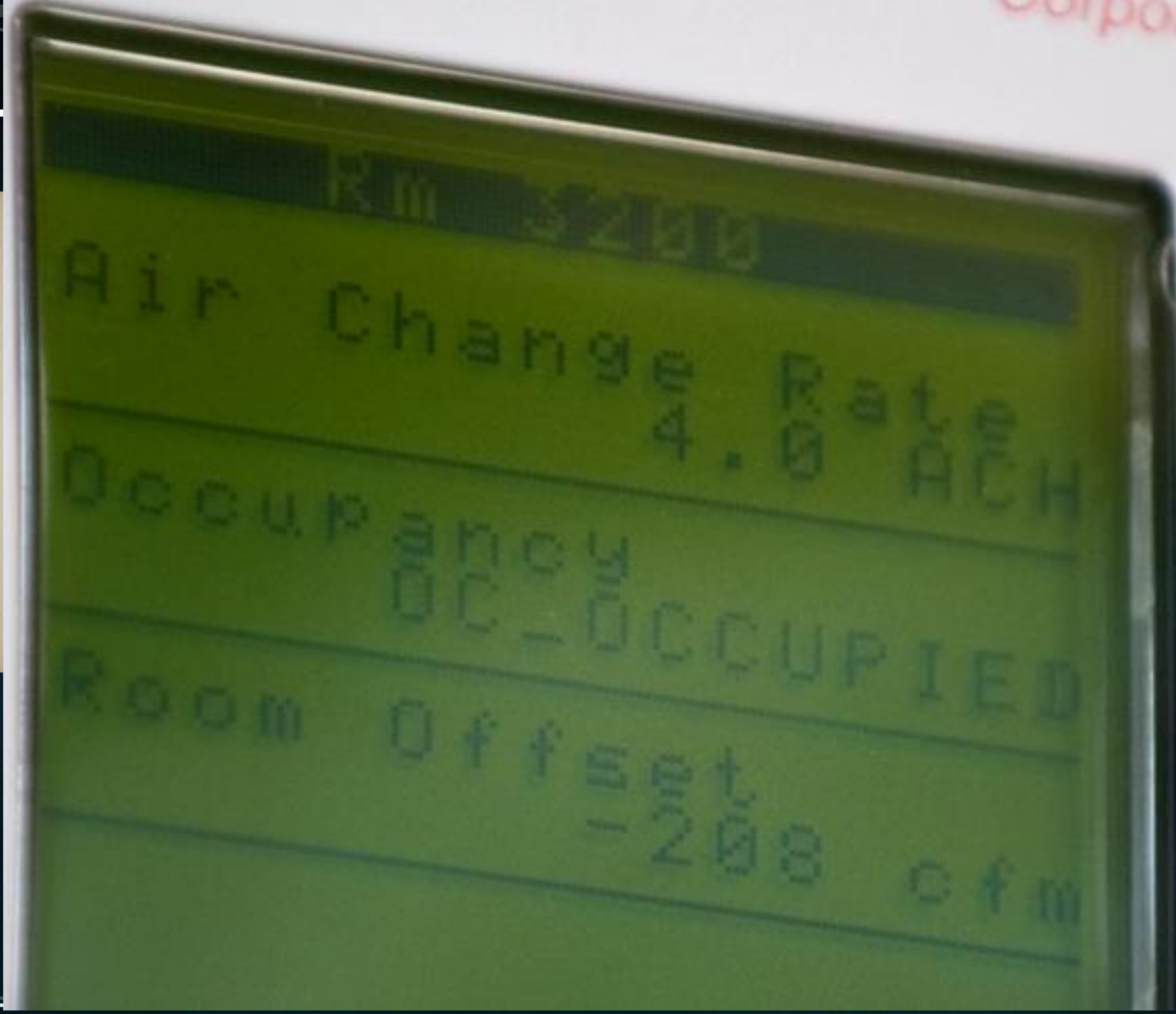
- Red Buttons
- LDU (Lab display unit)

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. This button should **<u>not</u>** be pressed in the event of a fire!



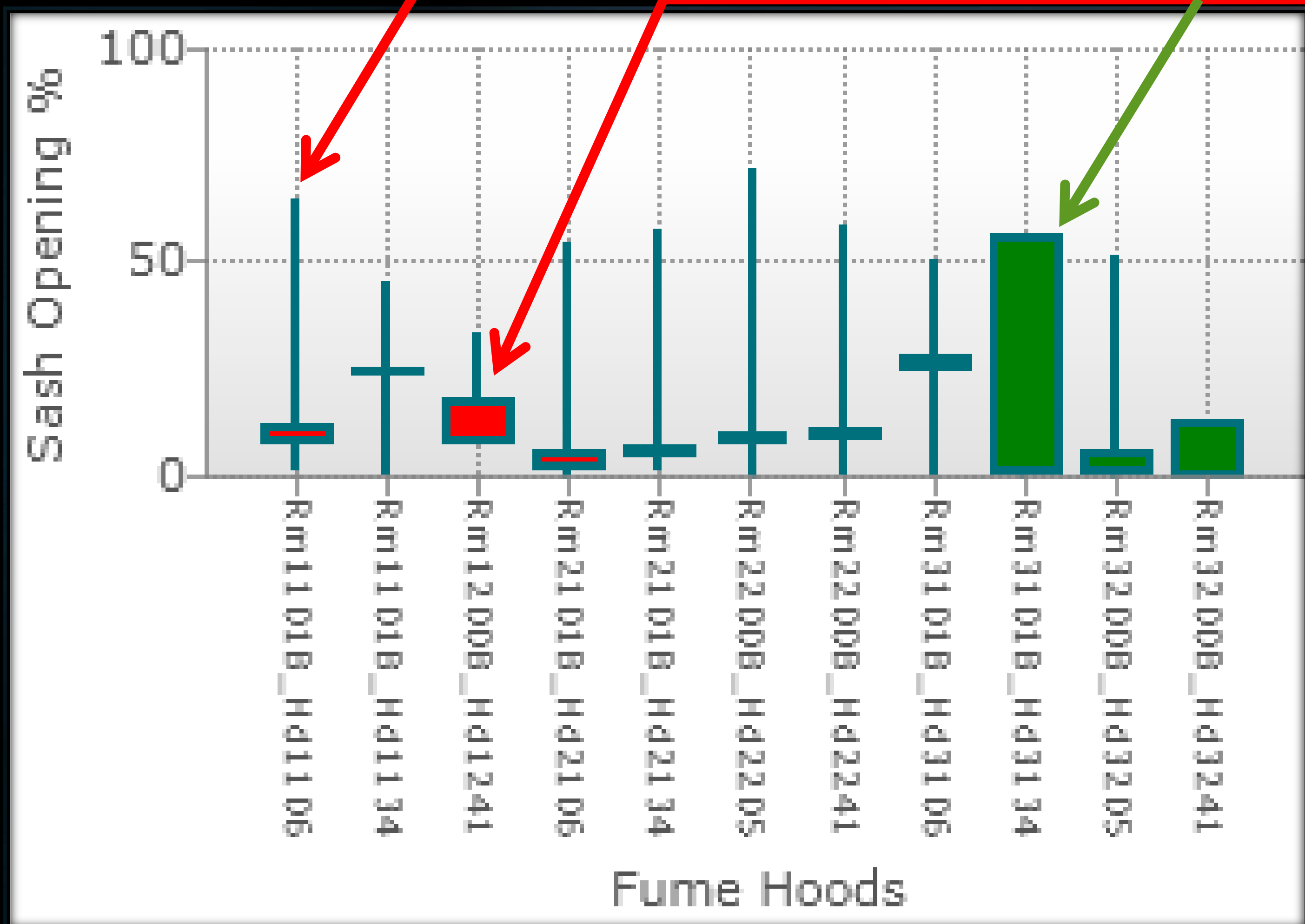
Air Change Rate
4.0 ACH
Occupancy
OC_OCCUPIED
Room Offset
-208 cfm

Visualization of lab HVAC use

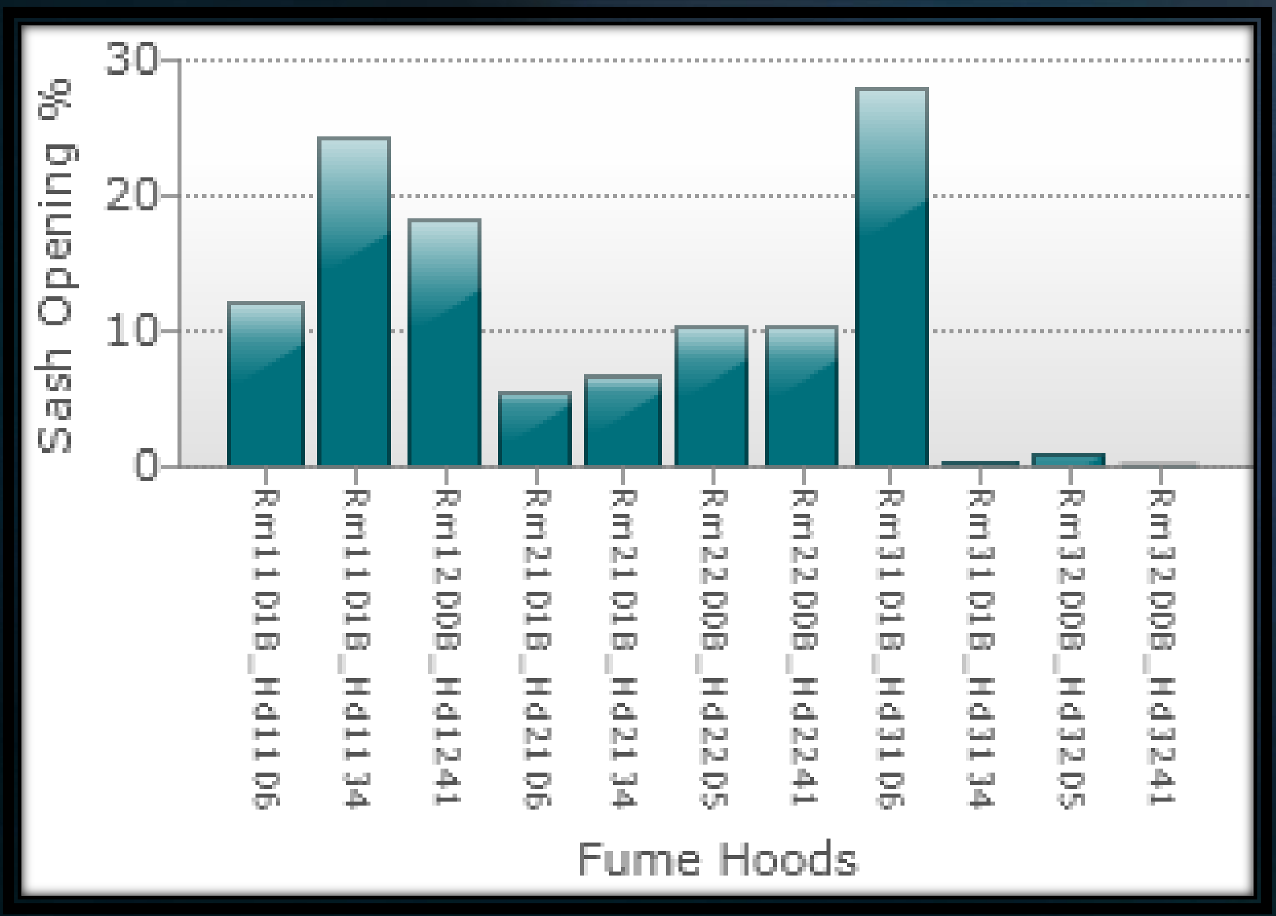
Monitoring Fume Hood Usage

- 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?

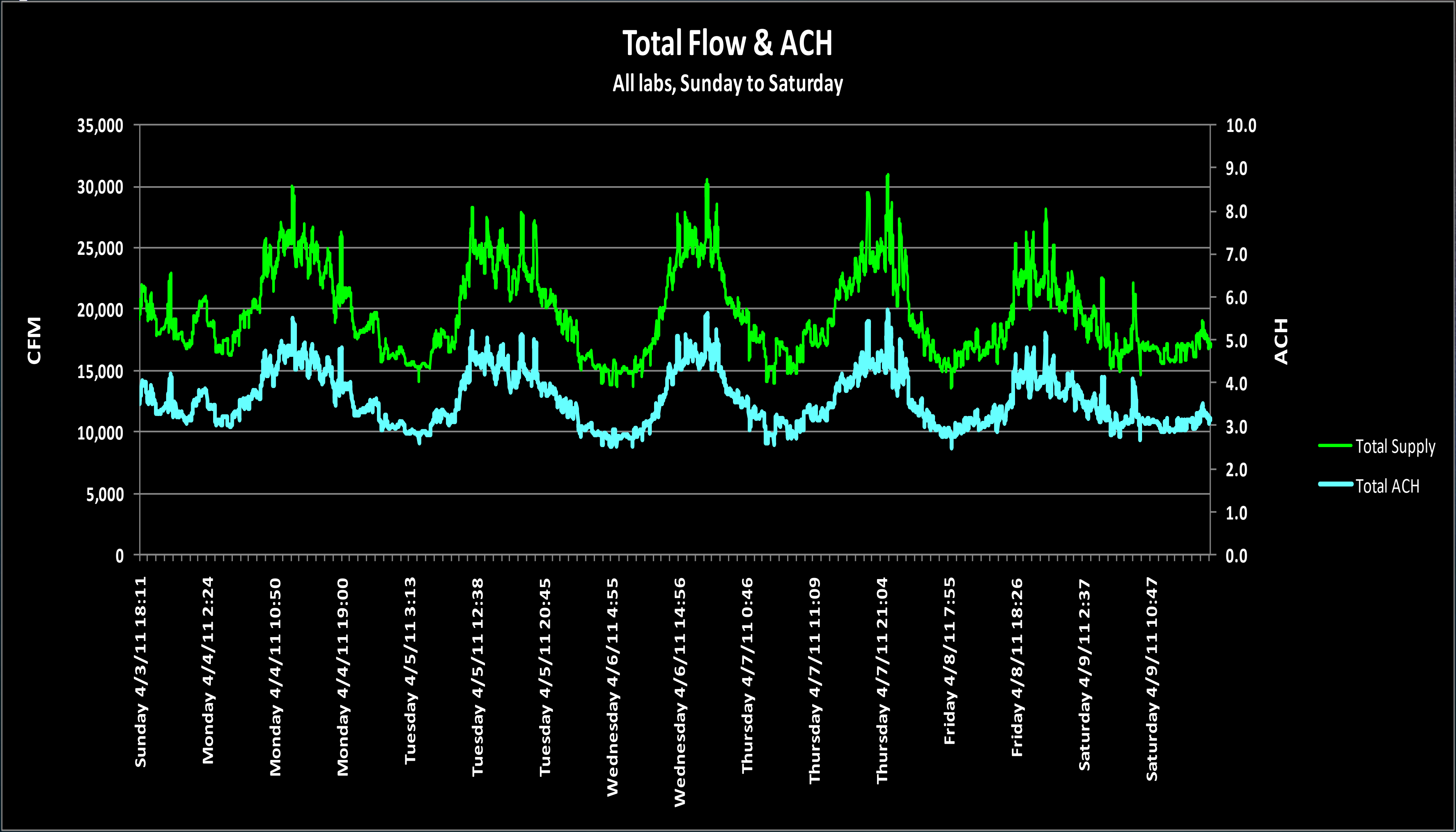


Smart Labs are not just controls and sensors.

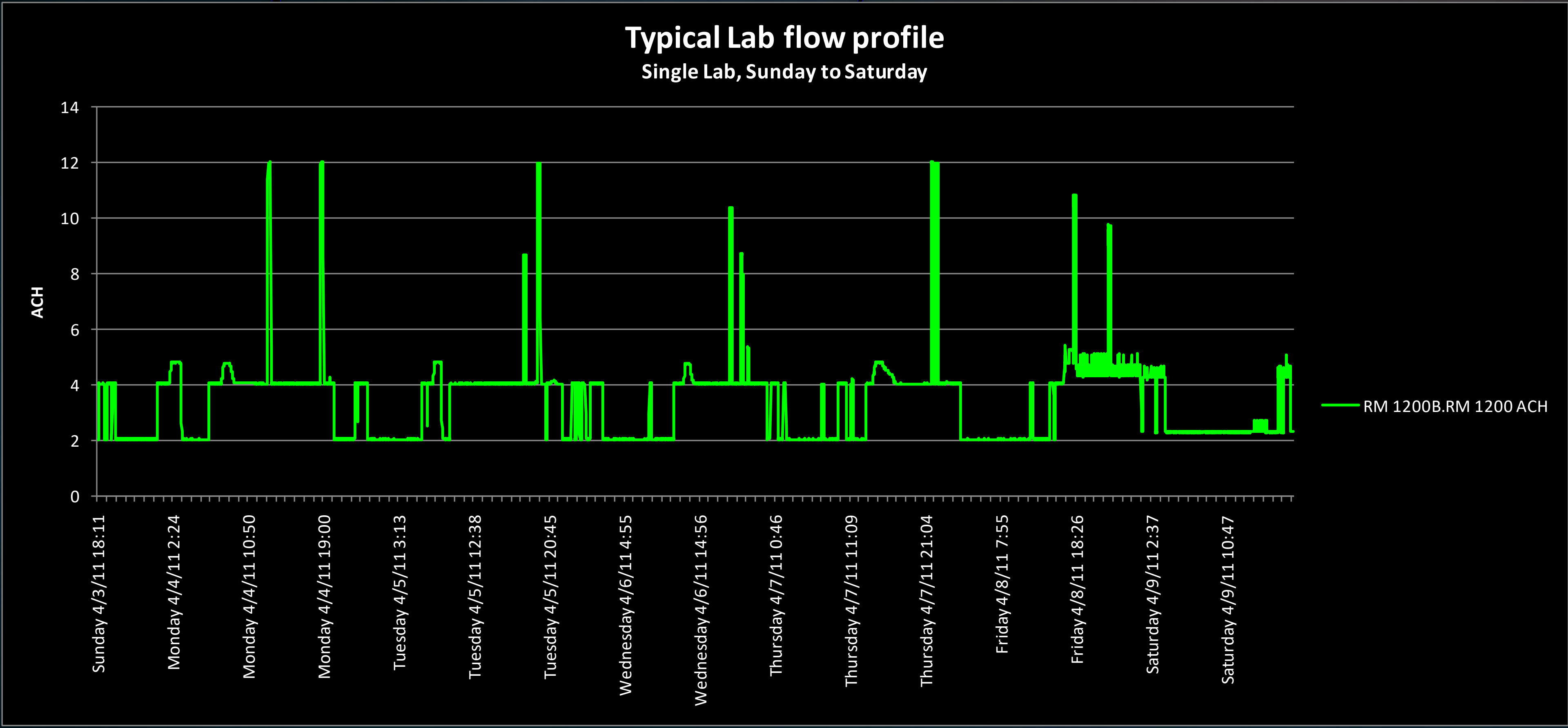
Smart Labs provide real time feedback as well as monthly reporting data that is actionable.

Return on investment is directly affected by lab practices.

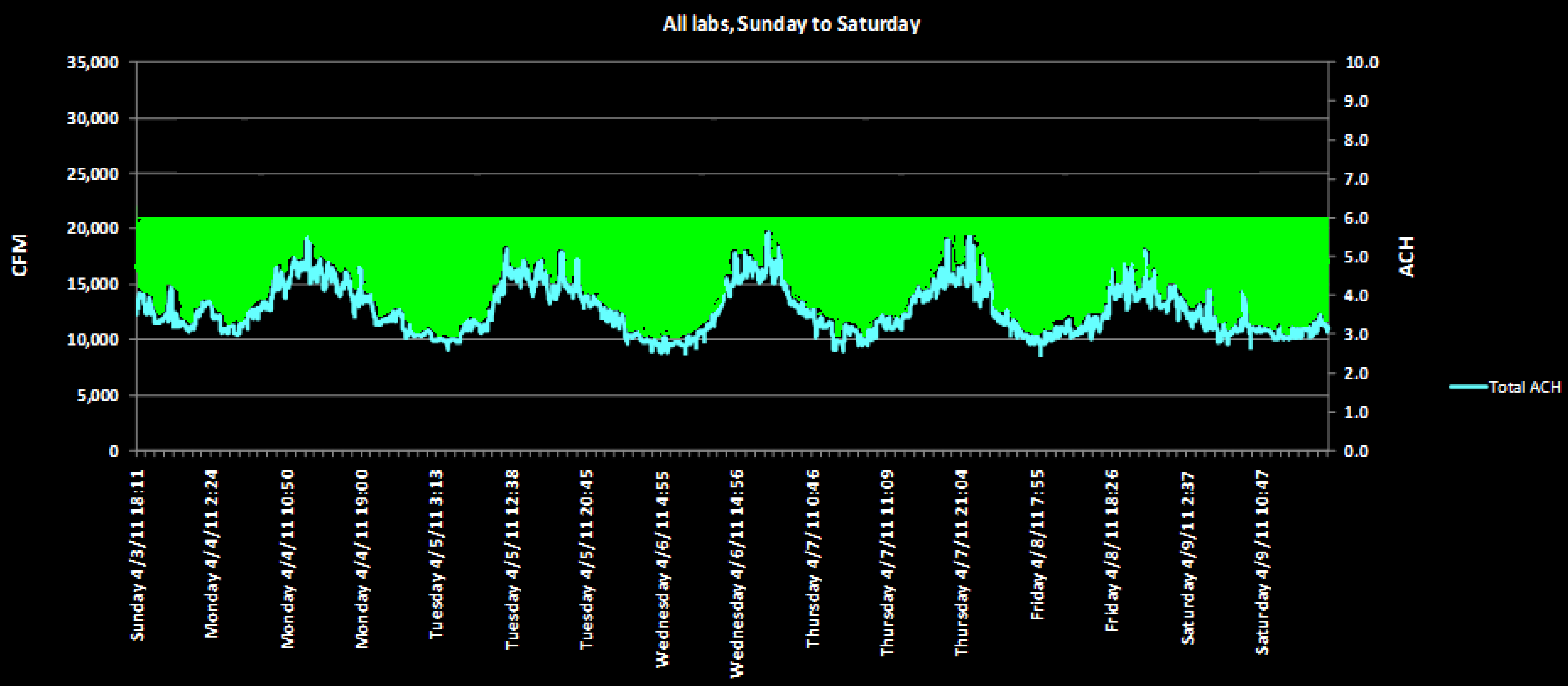
Total flow & ACH profile for six day period



Air Change Rates for Room 1200 Graphed over 6 days



What does energy savings look like?



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

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

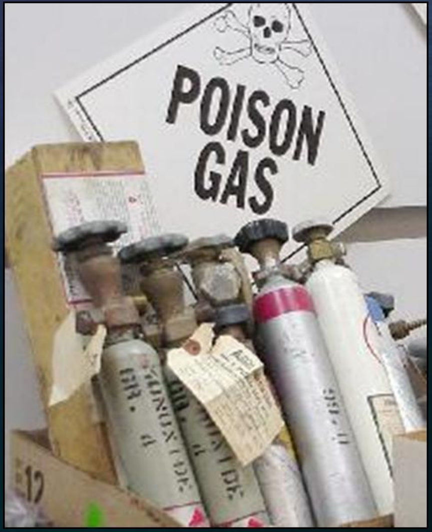
- Alternatives to simply increasing ACH:
  - Base air exchange rate on contaminant generation
  - Review lab practices
  - Attain proper air mix ratios
  - Reduce overall ACH to save energy and increase ACH as needed via “smart controls”

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

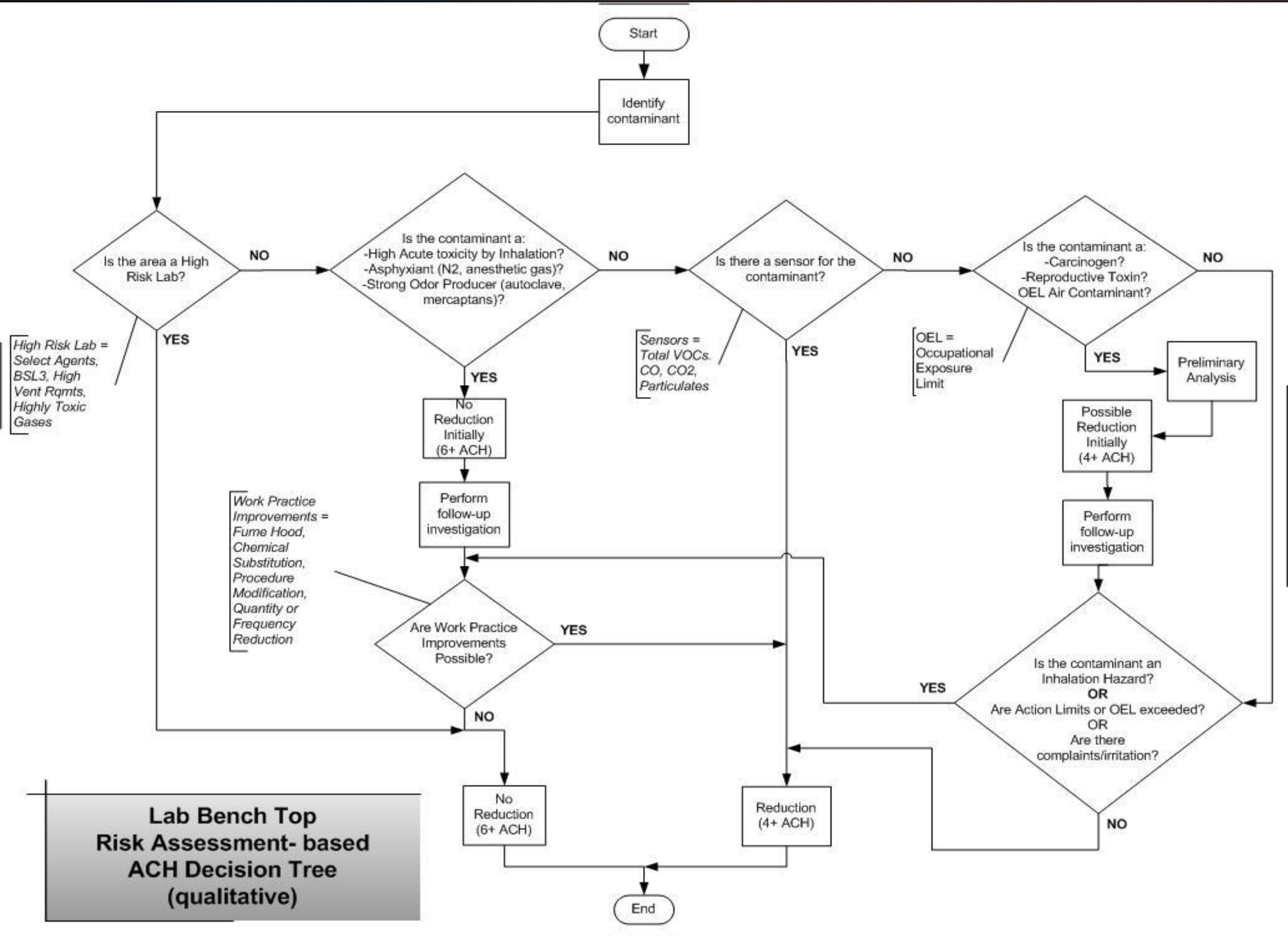
- Energy savings can be achieved without compromising safety
- Lab ACH determination requires:
  - Active EH&S involvement in bench top risk assessment of lab operations with lab staff
  - Contaminant source control
  - Reassessment when lab changes occur
  - Current/complete chemical inventories
  -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

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
  - Follow Up



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



Other Considerations

- Good practice:
  - Control contaminants at the "source"
  - Don't rely only on general dilution for control
  - Review lab operations/chemicals
  - Communication with lab staff
- ACH & exposure:
  - Exposure limits are not based on ACH
  - No known correlation between ACH and exposure or disease

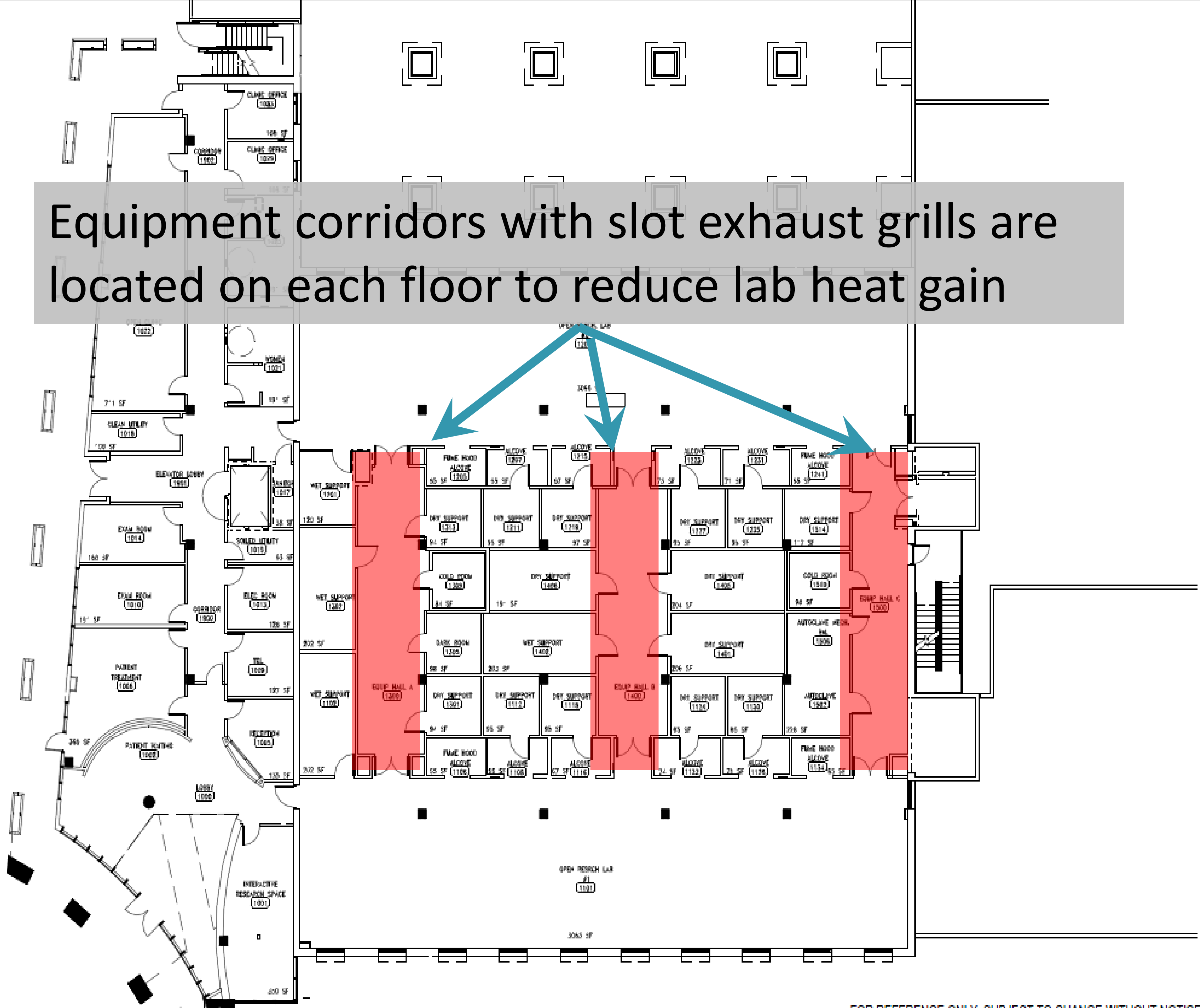
Lab HVAC Load

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

- Autoclaves
- Ultra Low Temp Freezers
- Refrigerators
- Incubators
- Water purification systems
- Microscopes
- Computers
- Shake Tables

There must be 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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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

Low velocity exhaust ductwork

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

} Increased duct size

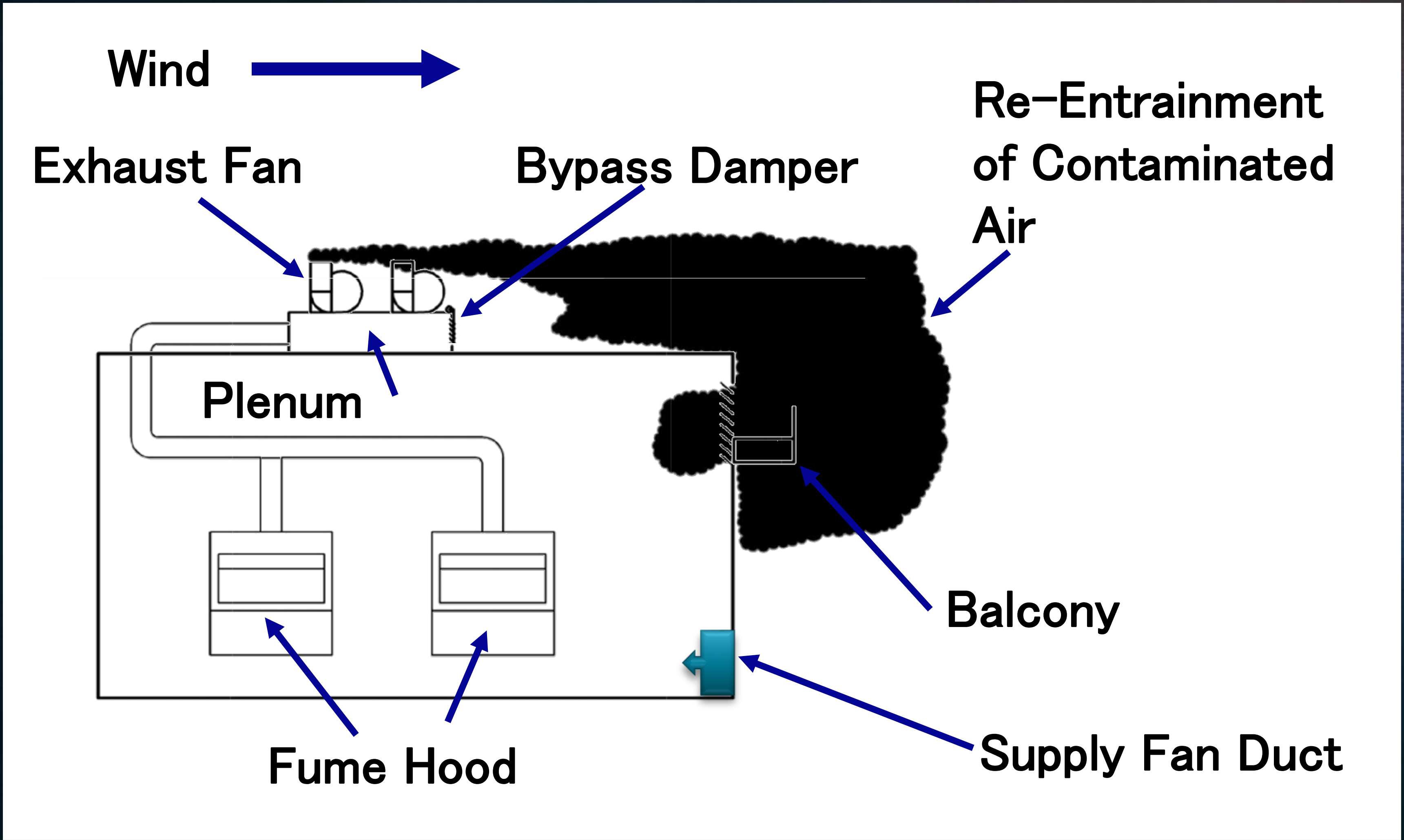
Wind Tunnel Testing
Challenge Conservative Assumptions

Exhaust Stack Discharge Velocity Reduction "ESDVR"

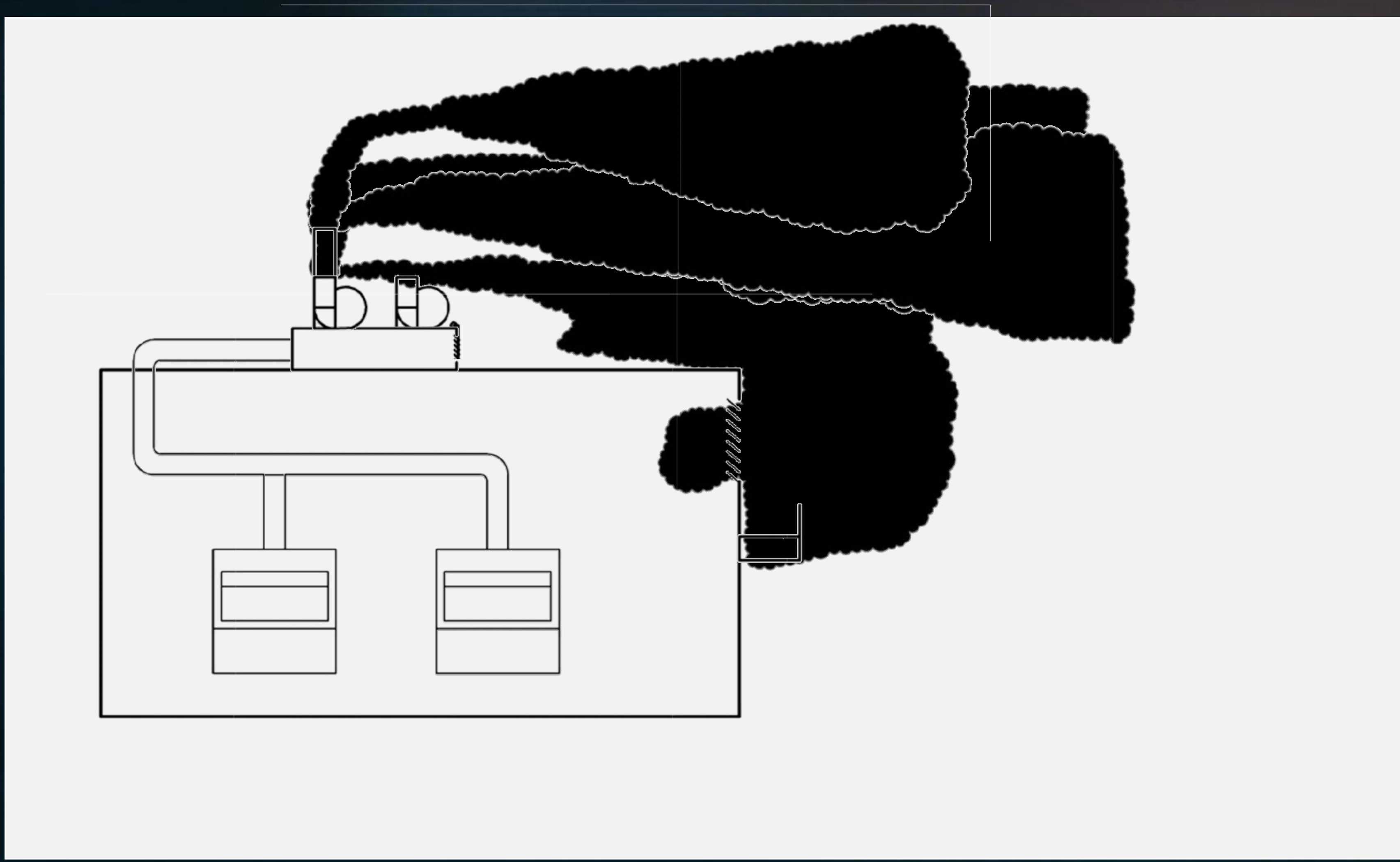
1. Detailed modeling in a wind tunnel to determine the minimum exhaust velocity required as opposed to standard practice
2. BMS configuration running 1, 2, or all 3 fans with a goal of 0% bypass

Resulted in a 27% Fan Power Savings

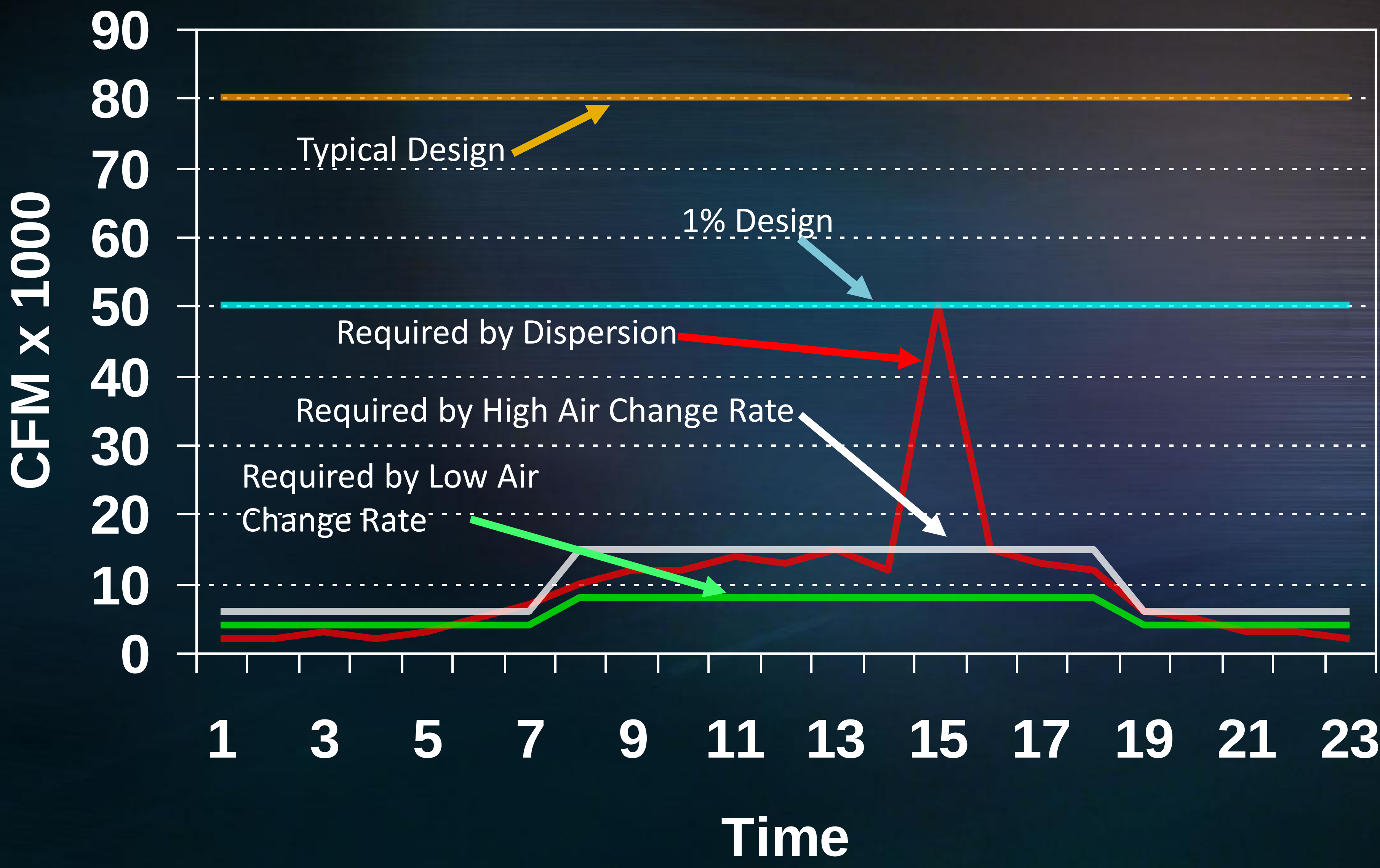
Lab Exhaust Diagram Animated



Wind Tunnel Testing



Typical Timeline of Exit Velocity Requirements

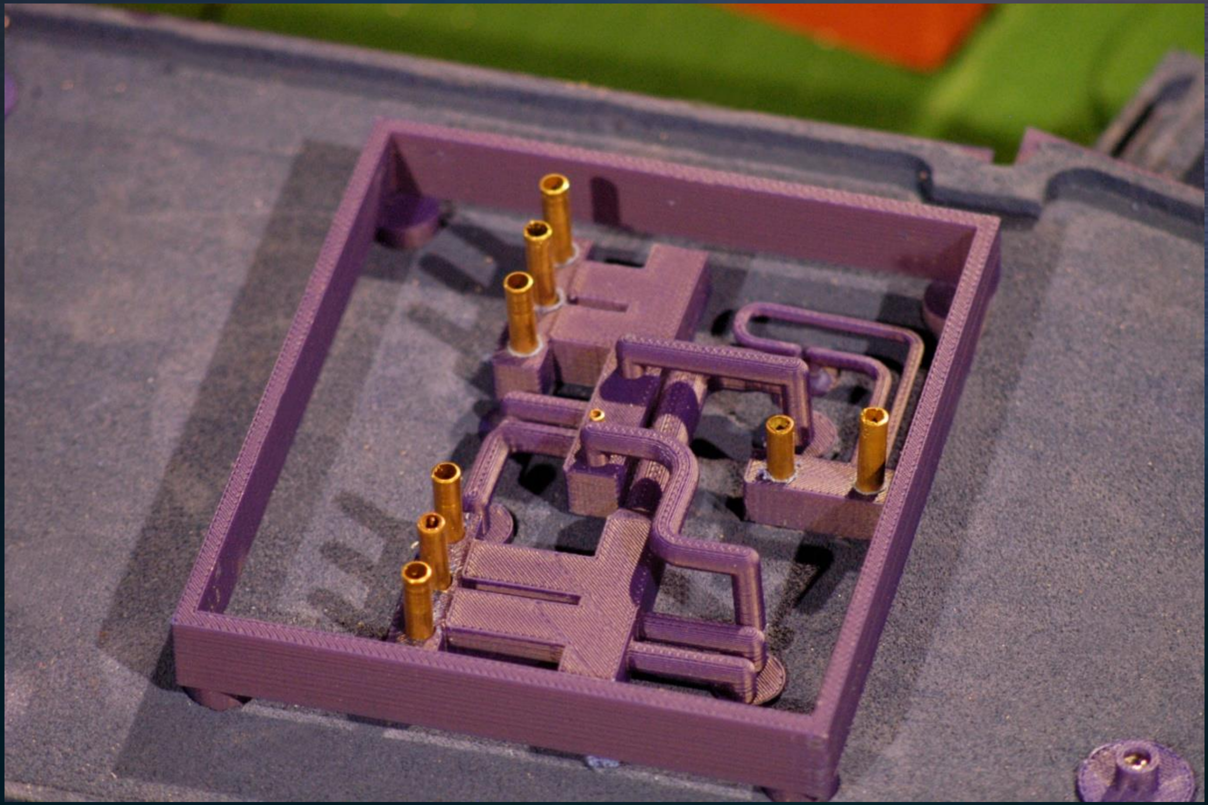


Wind Tunnel Testing

- Build model of campus

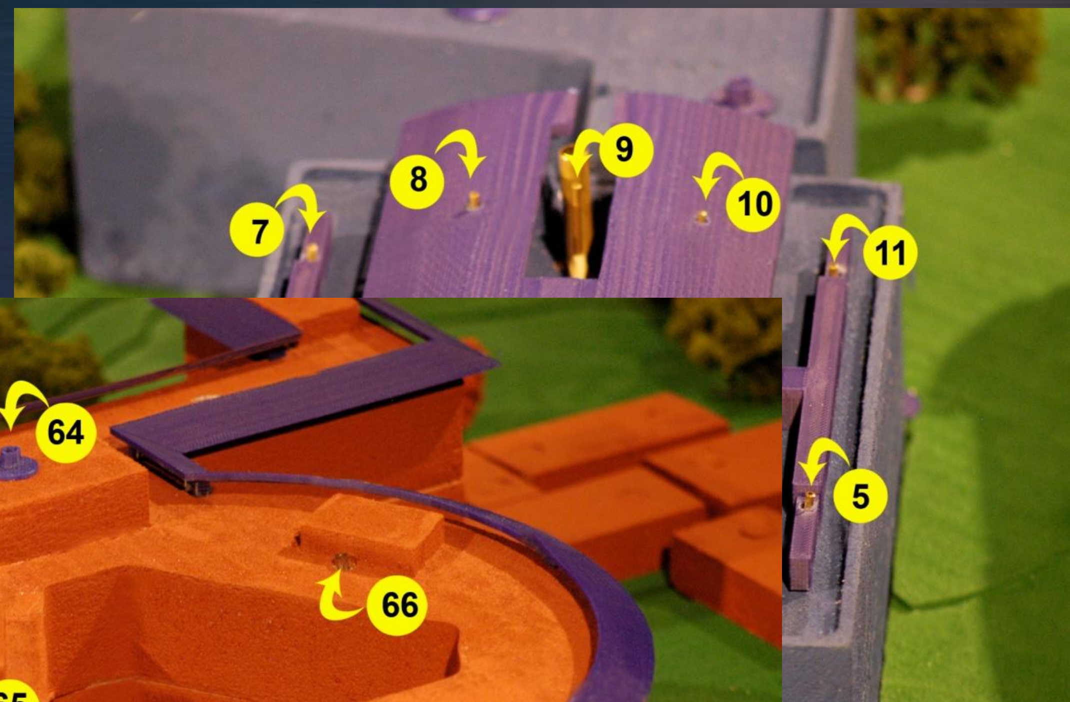
Wind Tunnel Testing

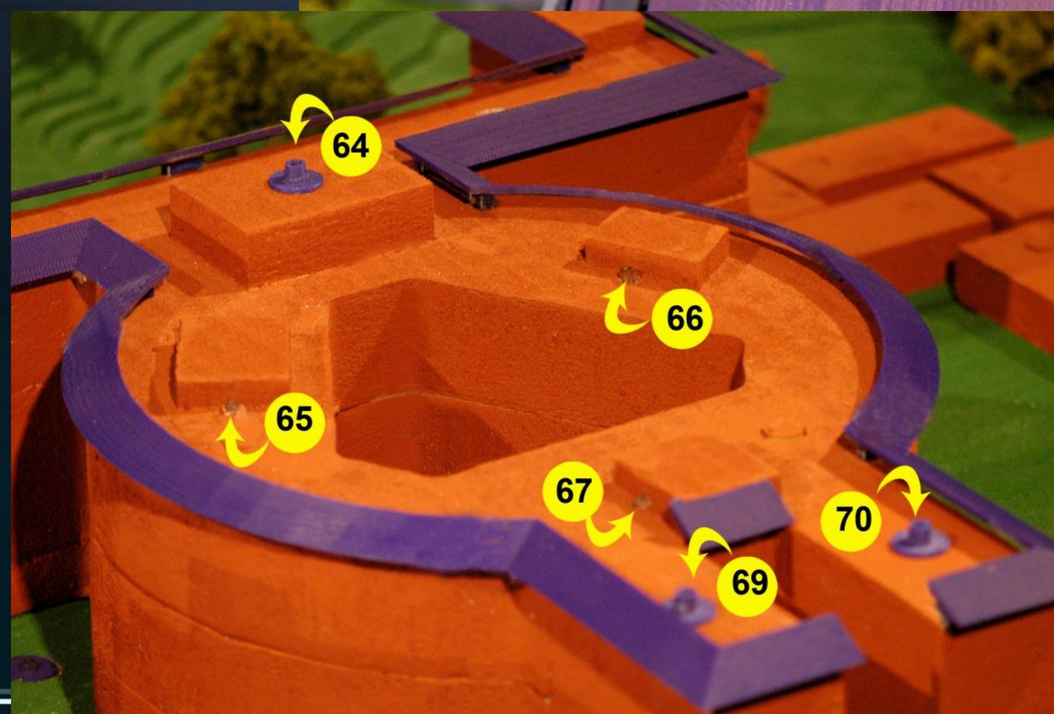
- Build model of campus
- Install model stacks



Wind Tunnel Testing

- Build model of campus
- Install model stacks
- Install air sampling points ("receptors")





Hewitt Hall vs. Gross Hall

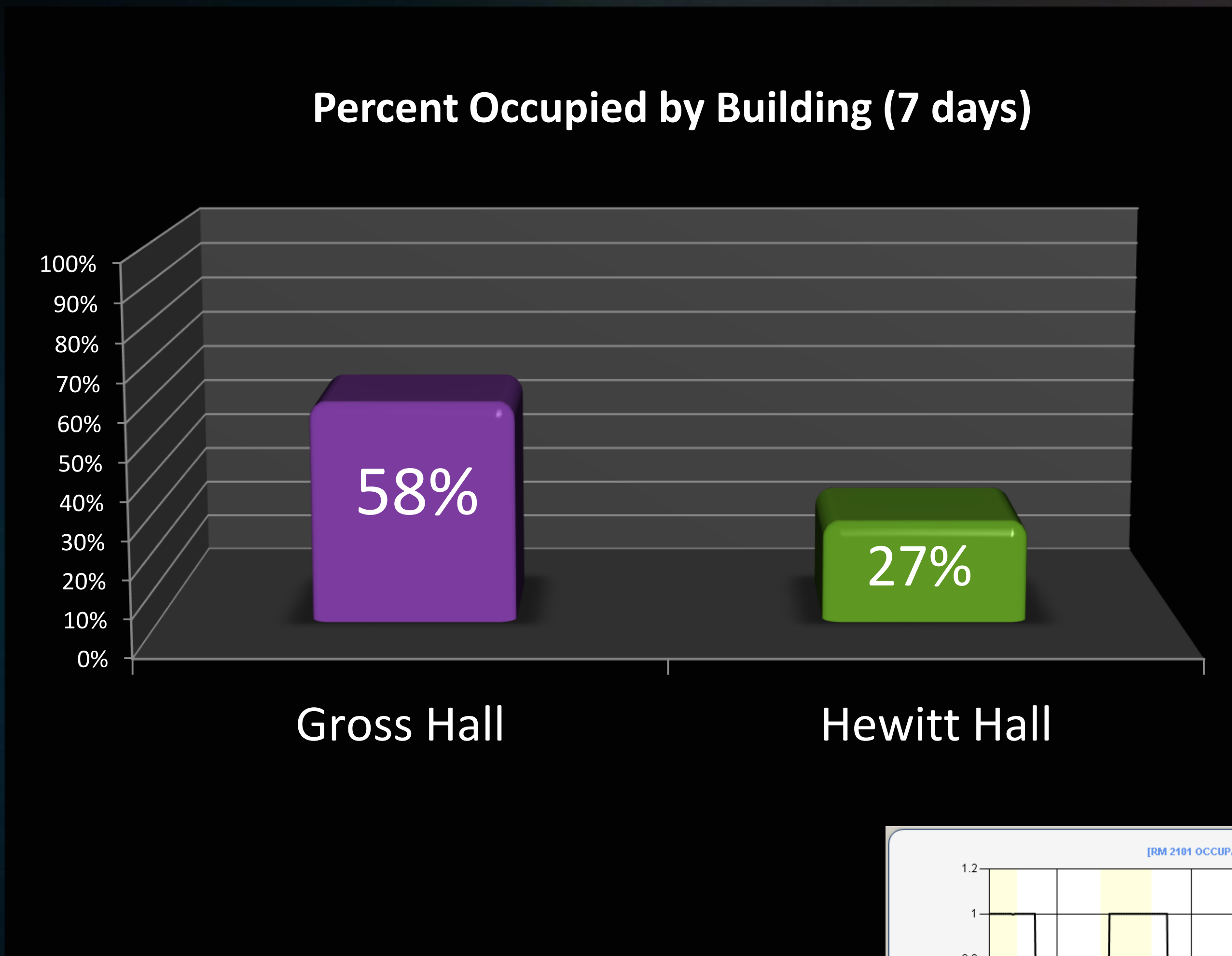
Designed in 2001

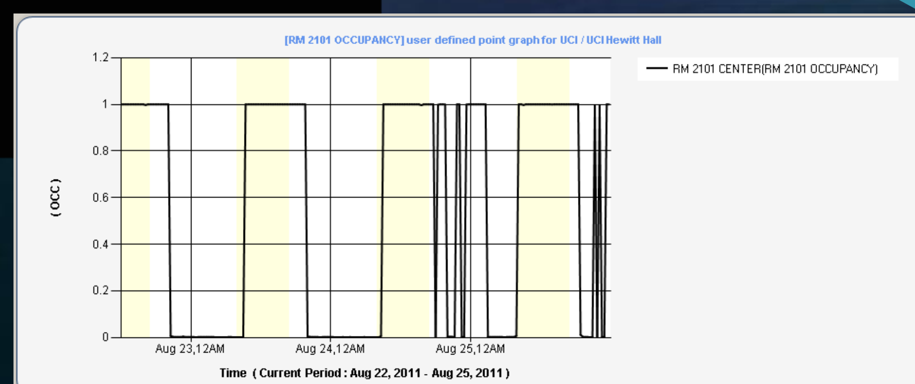
- Exceeded Title 24 by 23.7%
- Biomedical research
- Lighting upgrade in 2009
- Exhaust Stack Discharge Velocity Reduction in 2009
- Re-Commissioned in 2010
- 76,905 Square Feet

Designed in 2009

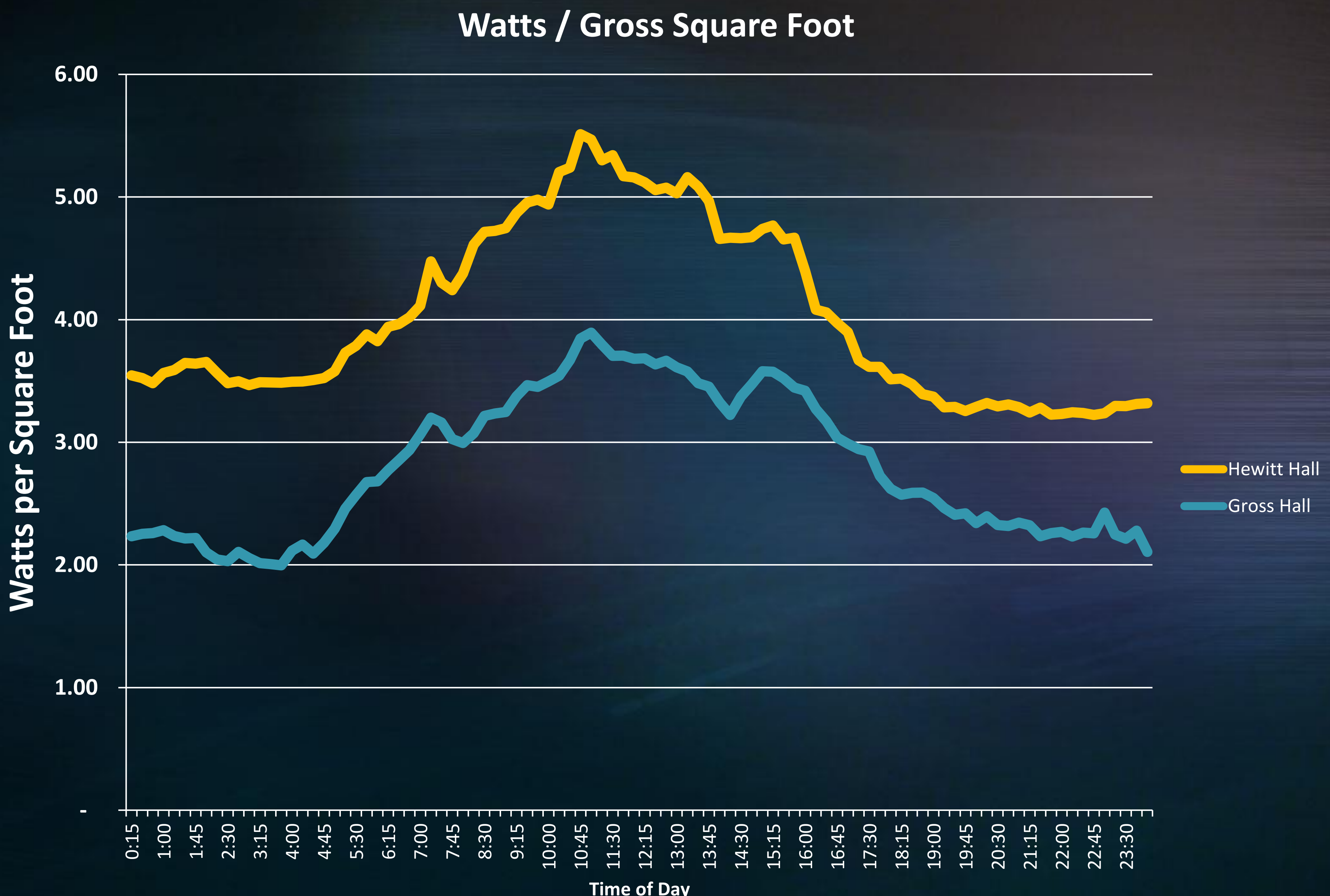
- Exceeded Title 24 by 50.4%
- Biomedical Research
- Submitted to USGBC for LEED Platinum certification
- 94,705 Square Feet

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



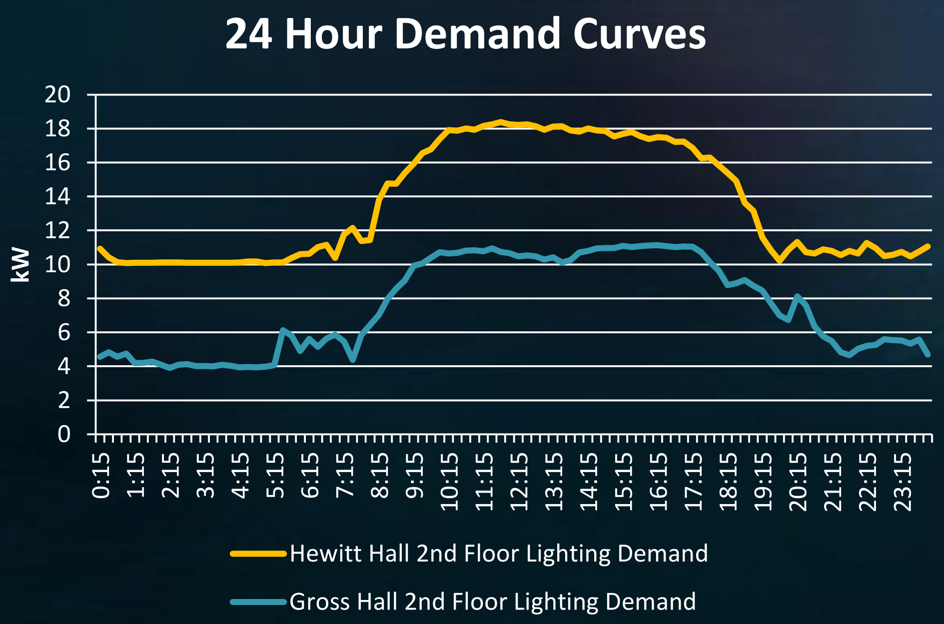


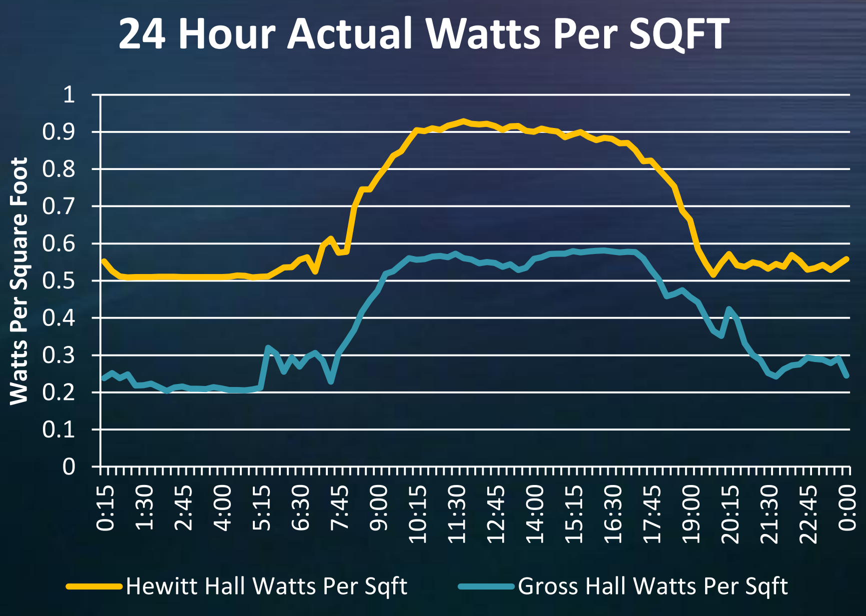
Building Load Per Square Foot



Lighting

Previous Best Practice	Space Type	Gross Hall
0.9 watts/sqft	Offices	**0.49** watts/sqft
1.1 watts/sqft	Labs	**0.66** watts/sqft
1 watts/sqft	Overall Conditioned Space	**0.61** watts/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


benchmarking

Choose Metrics and Filtering Criteria

More Information

Guest User. (Regular Users log in **here**)

Select metric:

System Total Building

Energy / Efficiency Metric: Peak W/gsf (elec)

Specify data filtering criteria:

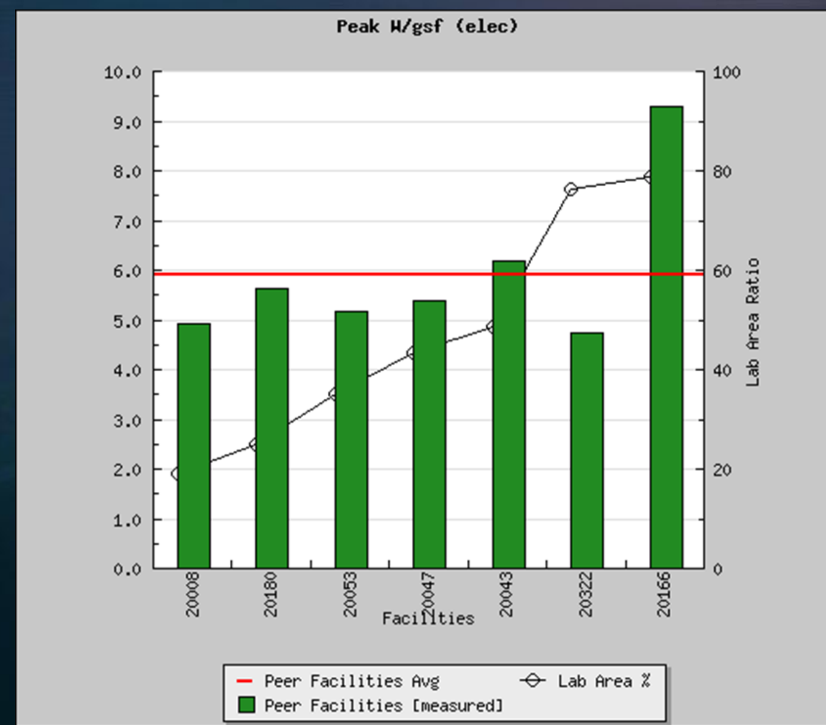
1. Lab Area / Gross Area ratio
   is greater than or equal to 0 and is less than or equal to 1.00
2. Occupancy hours per week
   - ○ Standard (≤80 hours)
   - ○ High (>80 hours)
   - ◉ Both (all data)
3. Lab Type
   - ☐ Chemical
   - ☑ Biological
   - ☑ Chemical/Biological
   - ☐ Physical
   - ☐ Combination/Others

4. Lab Use
- ☑ Research/Development
- ☐ Combination/Others
- ☐ Manufacturing
- ☐ Teaching

5. Climate [Climate Code, Climate Type, Representative City]
(Click here to see map of climate zones)
- ☐ 1A, **Very Hot - Humid** (Miami, FL)
- ☐ 2A, **Hot - Humid** (Houston, TX)
- ☑ 2B, **Hot - Dry** (Phoenix, AZ)
- ☐ 3A, **Warm - Humid** (Memphis, TN)
- ☑ 3B, **Warm - Dry** (El Paso, TX)
- ☑ 3C, **Warm - Marine** (San Francisco, CA)
- ☐ 4A, **Mixed - Humid** (Baltimore, MD)
- ☑ 4B, **Mixed - Dry** (Albuquerque, NM)
- ☐ 4C, **Mixed - Marine** (Salem, OR)
- ☐ 5A, **Cool - Humid** (Chicago, IL)
- ☐ 5B, **Cool - Dry** (Boise, ID)
- ☐ 6A, **Cold - Humid** (Burlington, VT)
- ☐ 6B, **Cold - Dry** (Helena, MT)
- ☐ 7, **Very Cold** (Duluth, MN)
- ☐ 8, **Subarctic** (Fairbanks, AK)

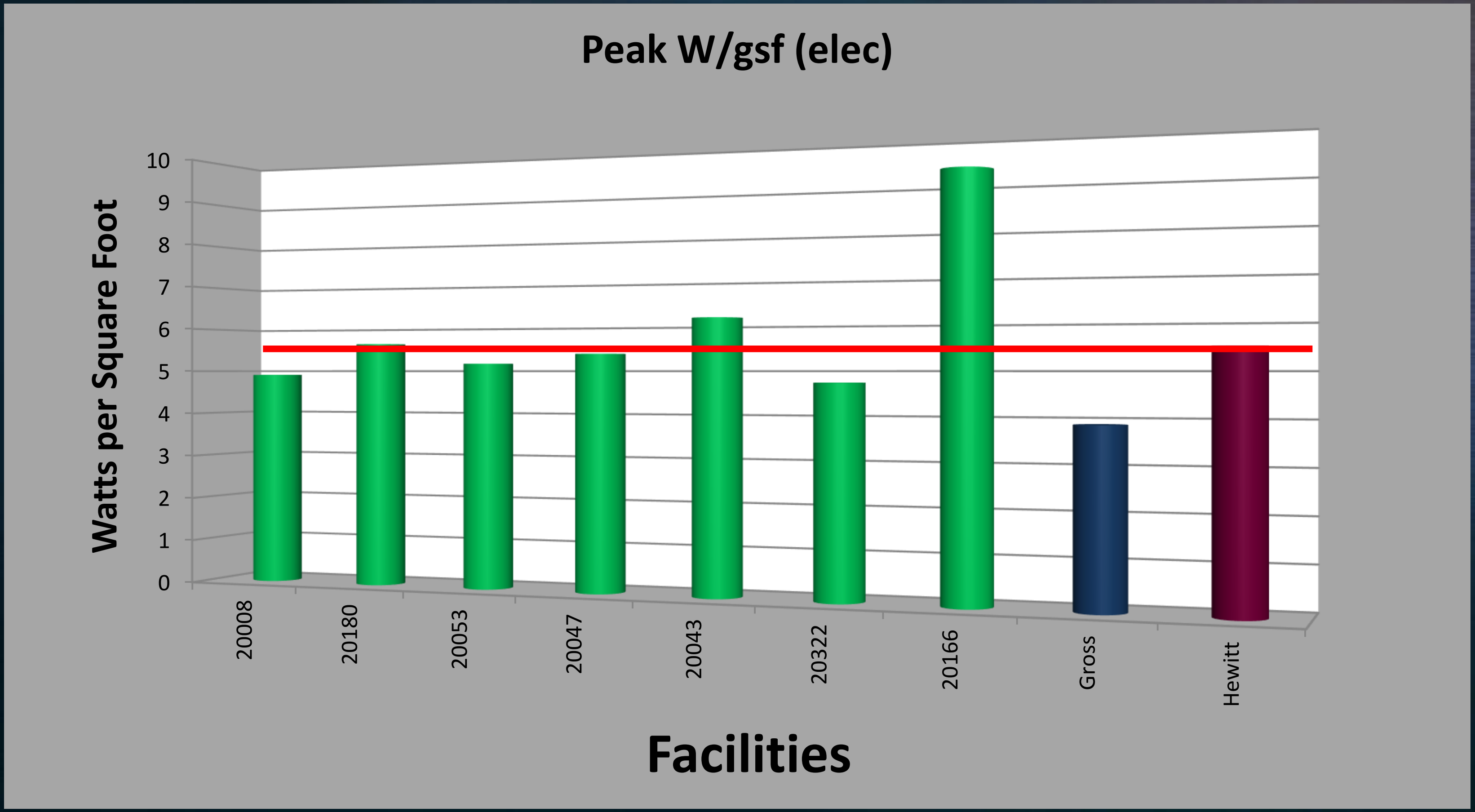
6. Measured and Estimated data
- ☑ Measured
- ☐ Estimated

Reset Values | Continue...



Adding Hewitt and Gross Halls

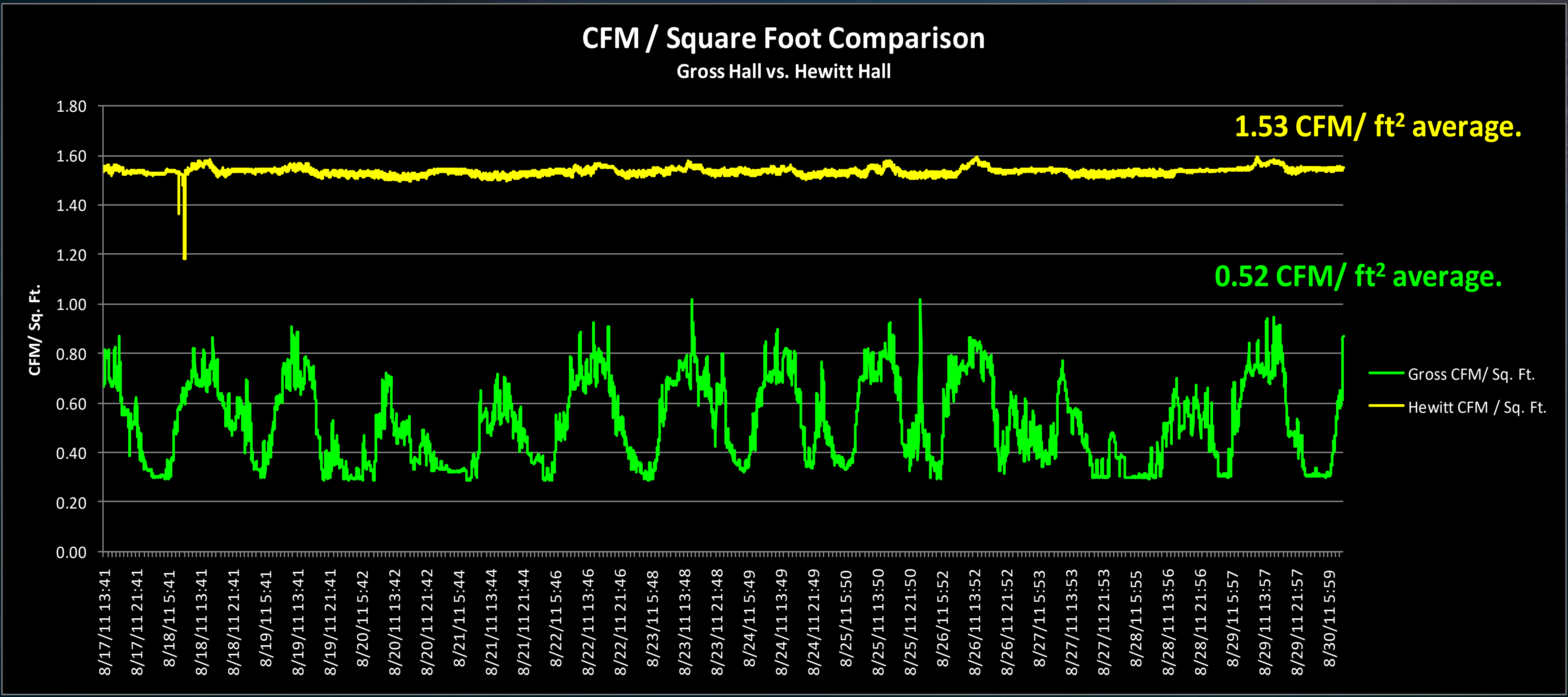
- Hewitt is right at the average
- Gross Hall beats the most efficient lab benchmarked by 18%



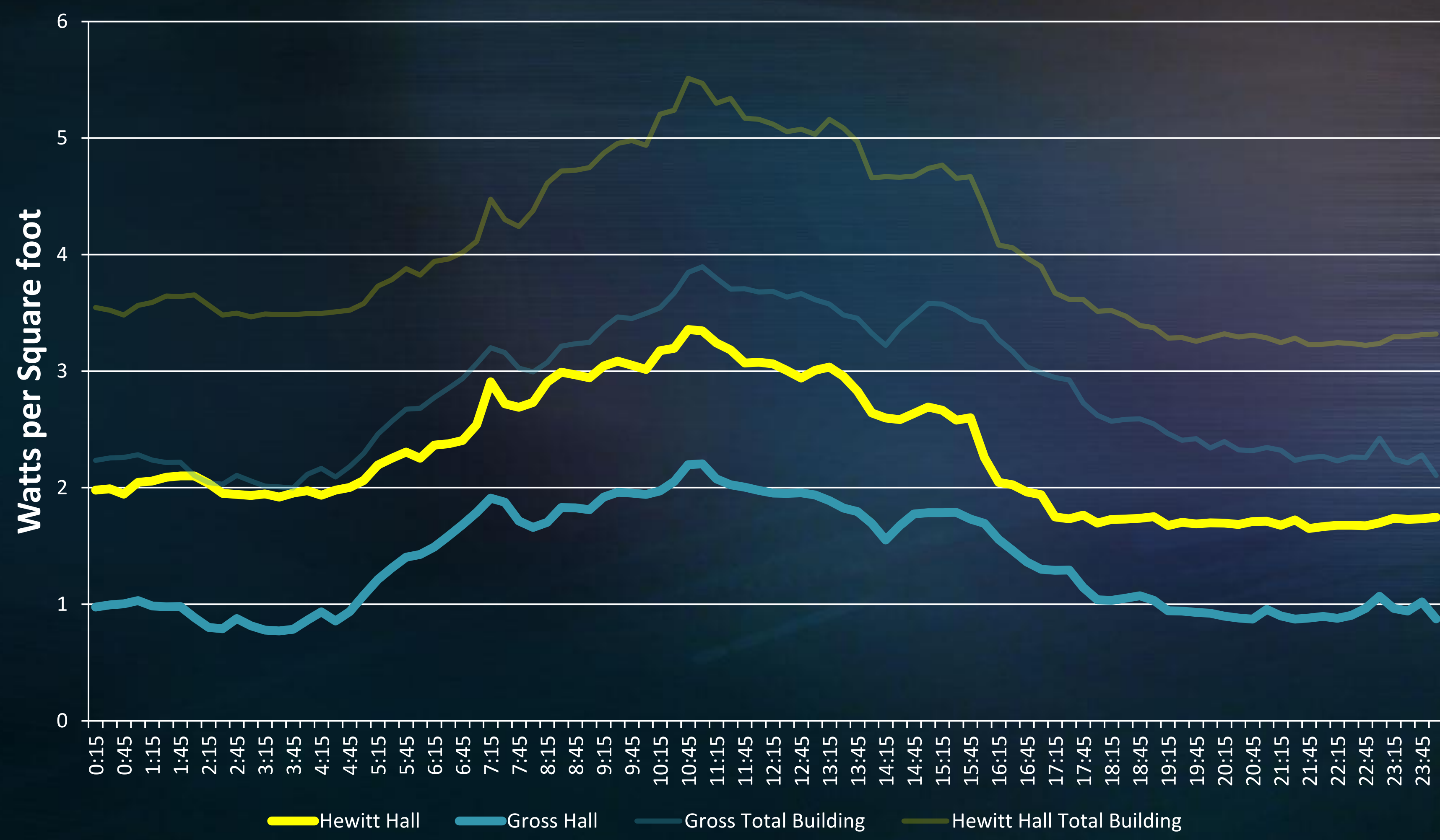
Lab Air Flow vs. Time

The HVAC savings of 1 CFM/ft2 at $4-5 per CFM can reduce operational significantly.

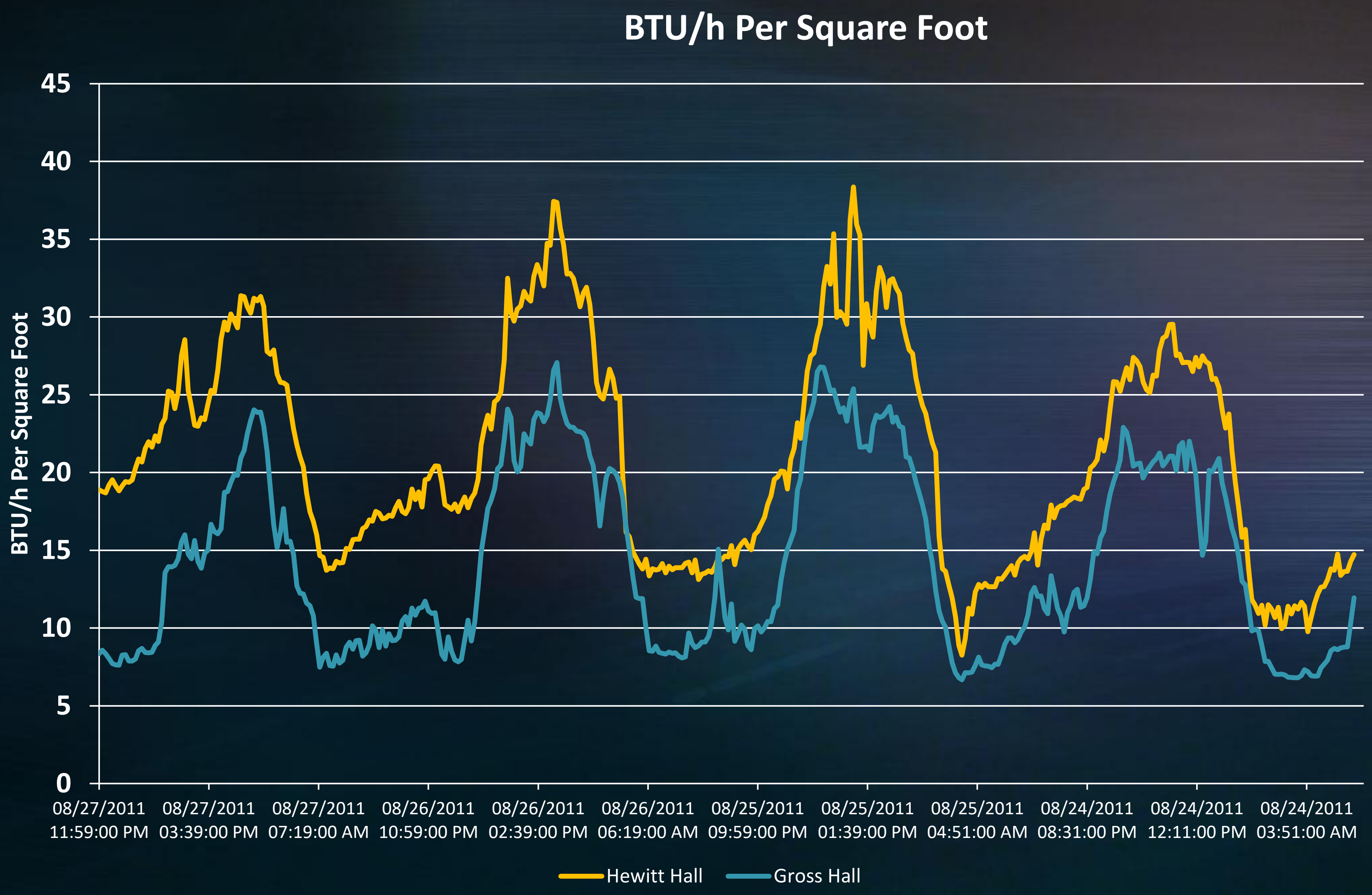
A 1 CFM reduction at Hewitt Hall in just the open lab bays would reduce operational cost by $83,250 per year



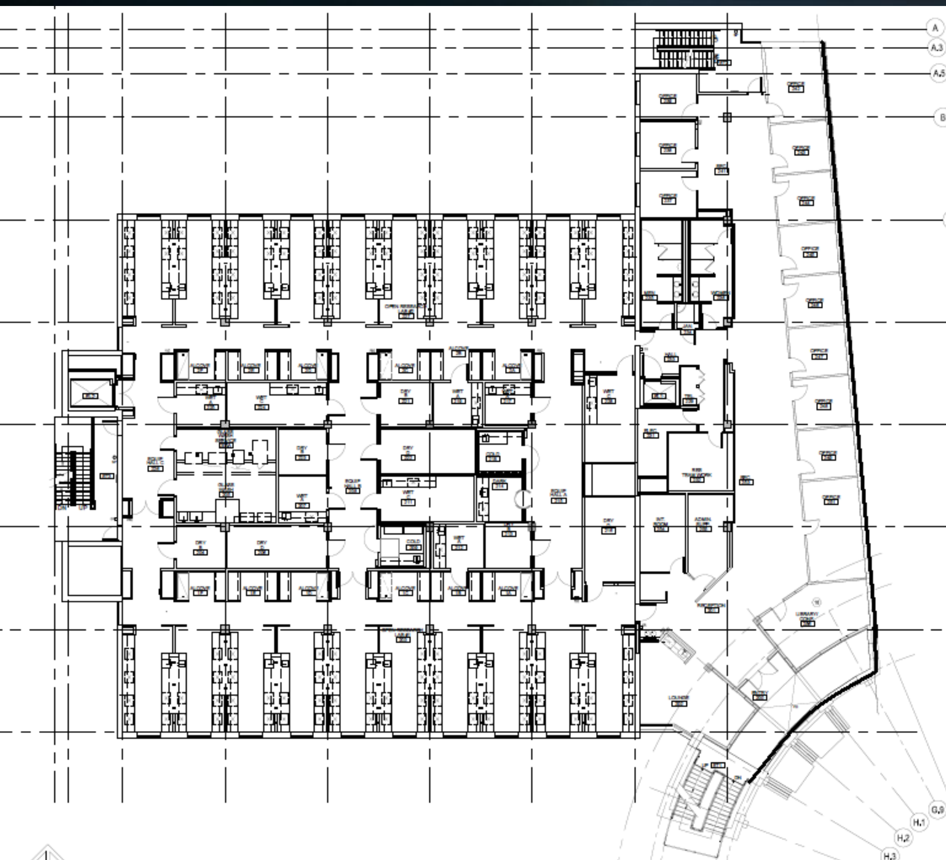
AHU + EF + Pumps + Chilled Water = Building Square Feet

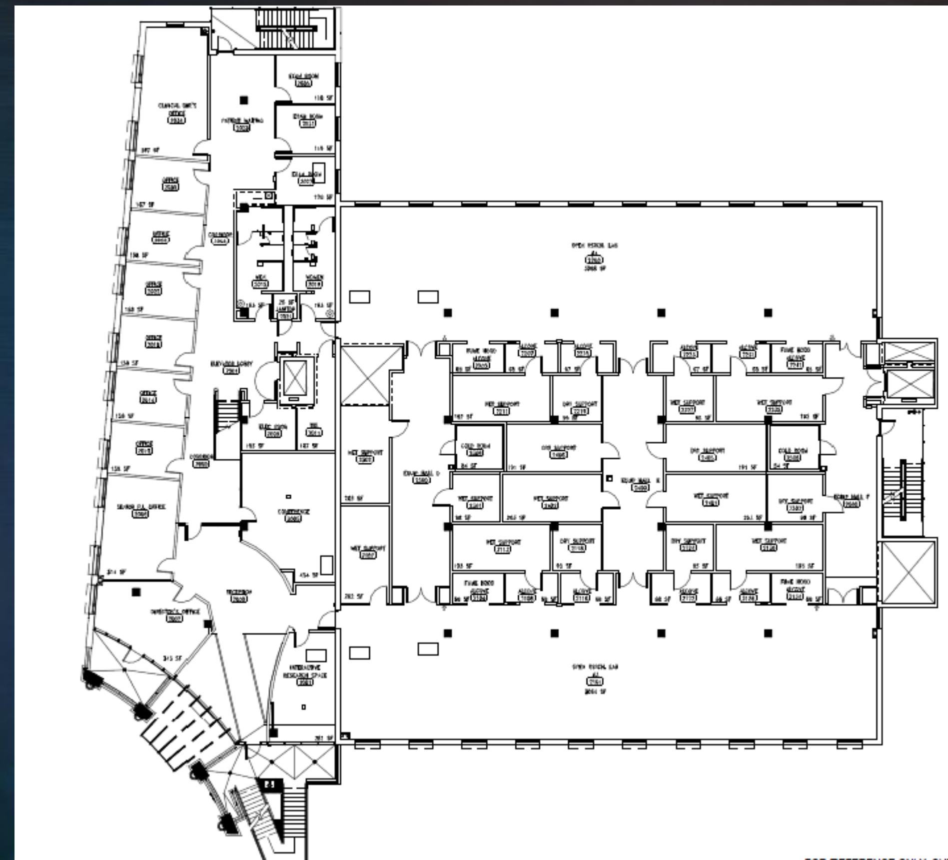


Chilled Water Use



Comparing 2 Similar Floors





Hewitt Hall vs. Gross Hall

2nd Floor

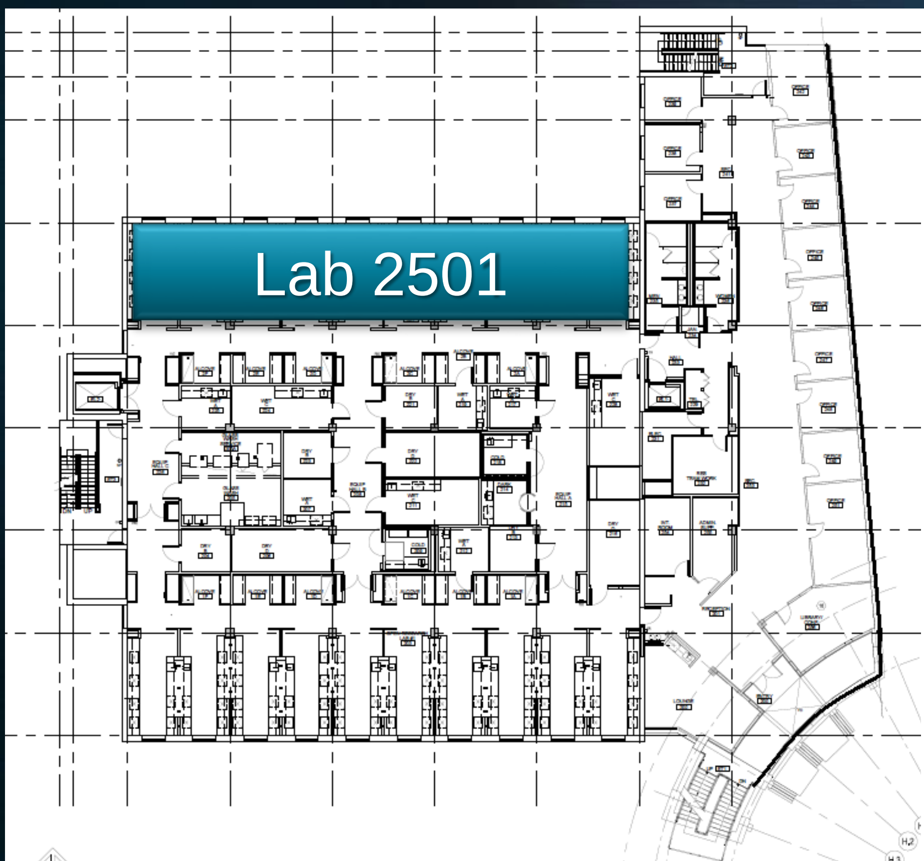
Lab Air Supply and Exhaust

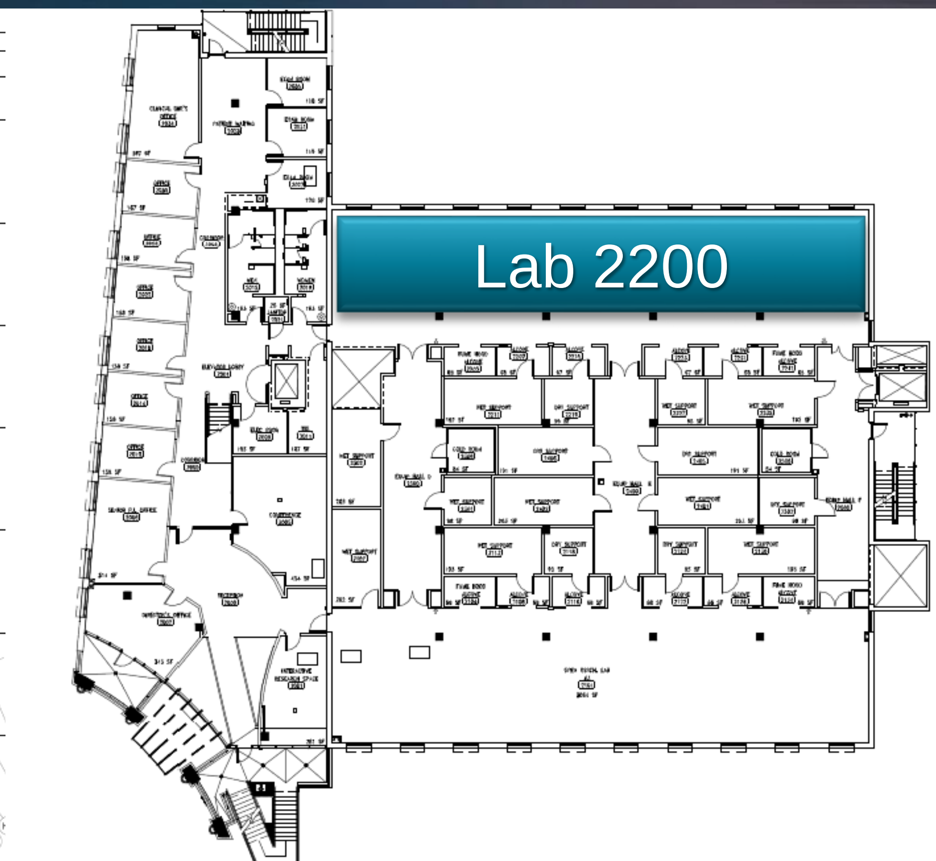
Hewitt Hall 2nd Floor

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

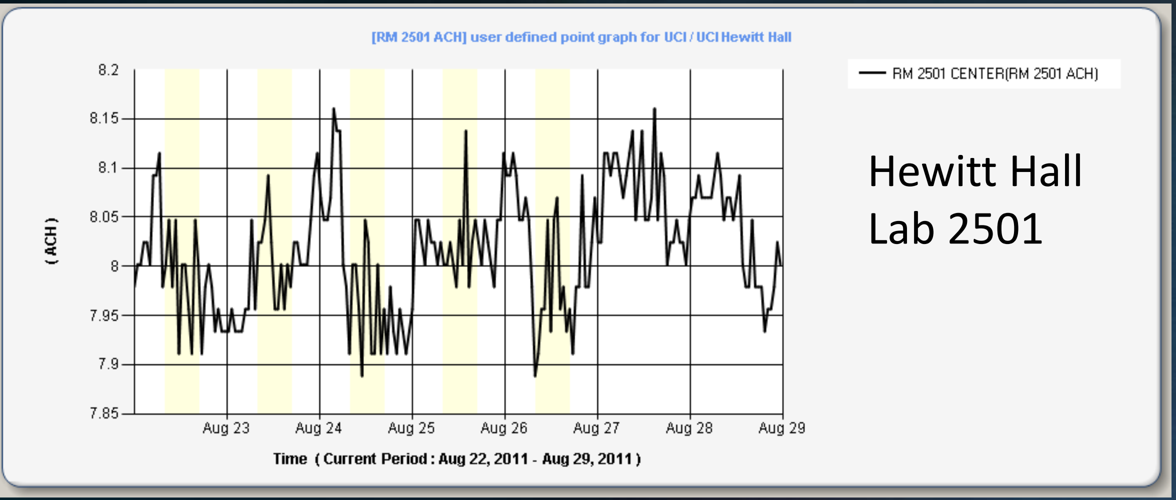
Gross Hall 2nd Floor

- 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.



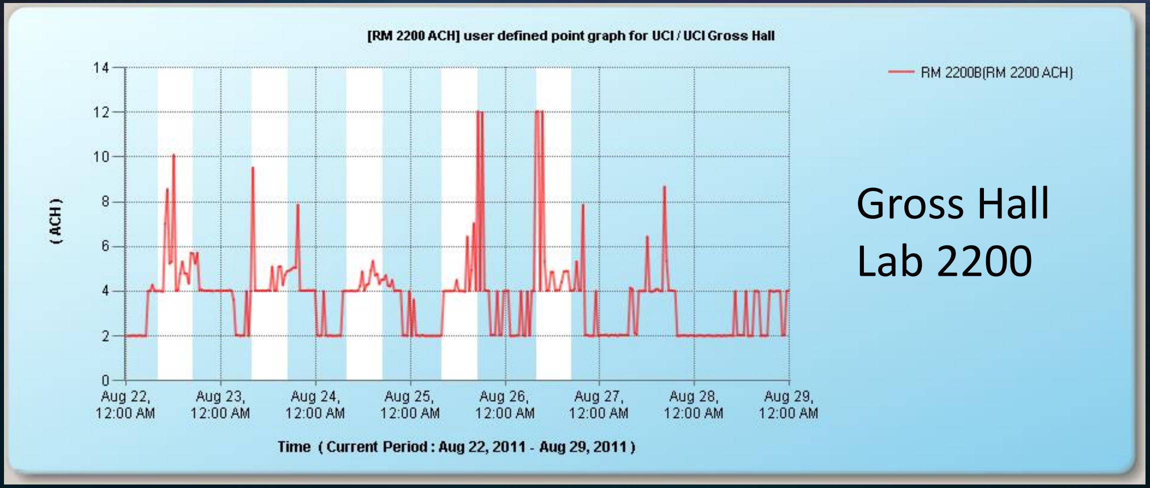


Evidence of where the buildings HVAC energy savings are achieved



- 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

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

Sub Metering

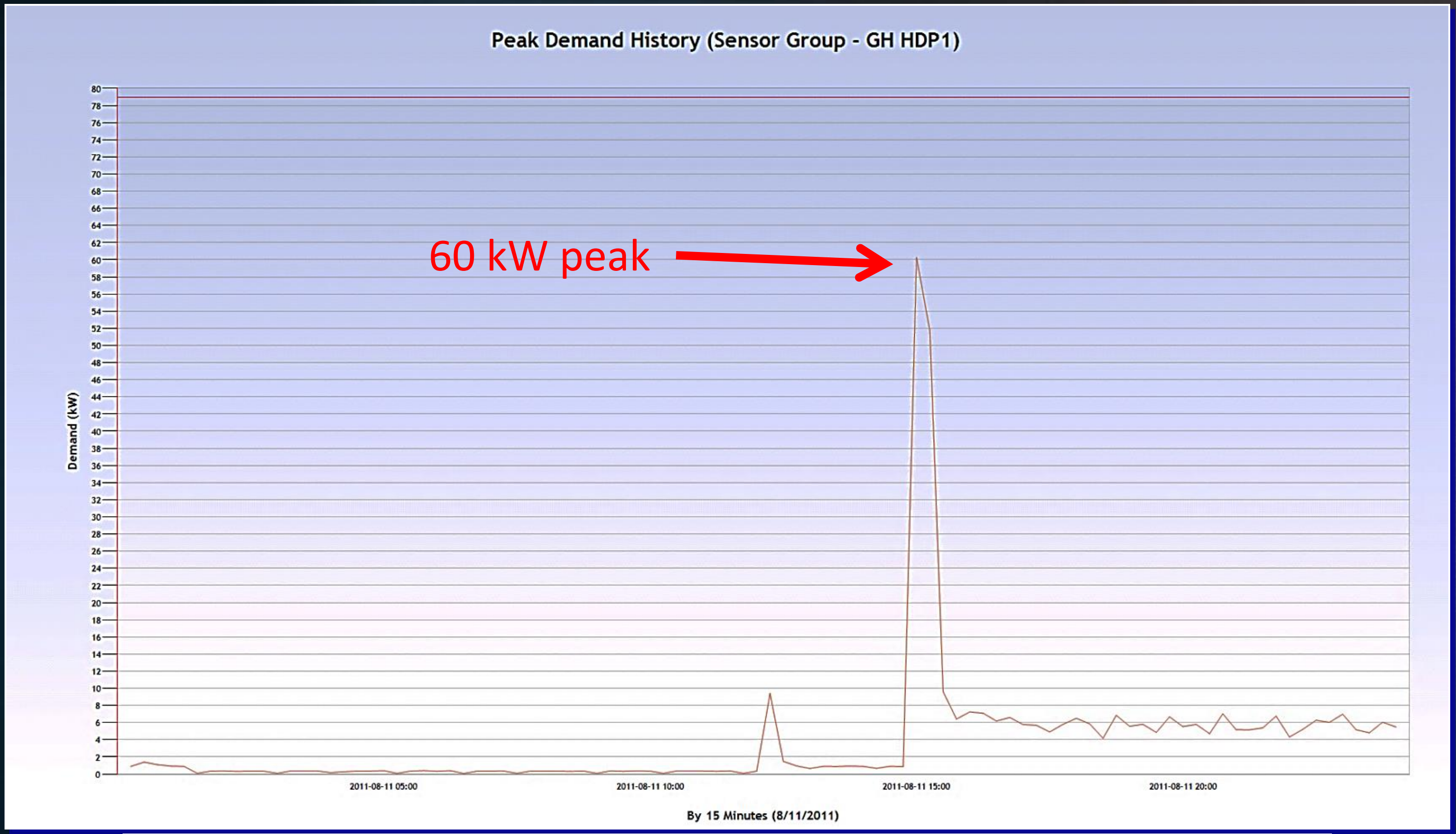
- Monitoring of fans, pumps, and lighting control systems
- Verification of energy retrofits
- Reduce demand charges by modifying operations

BMS

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

Zone level resolution can lead to peak demand savings

Autoclave In Gross Hall

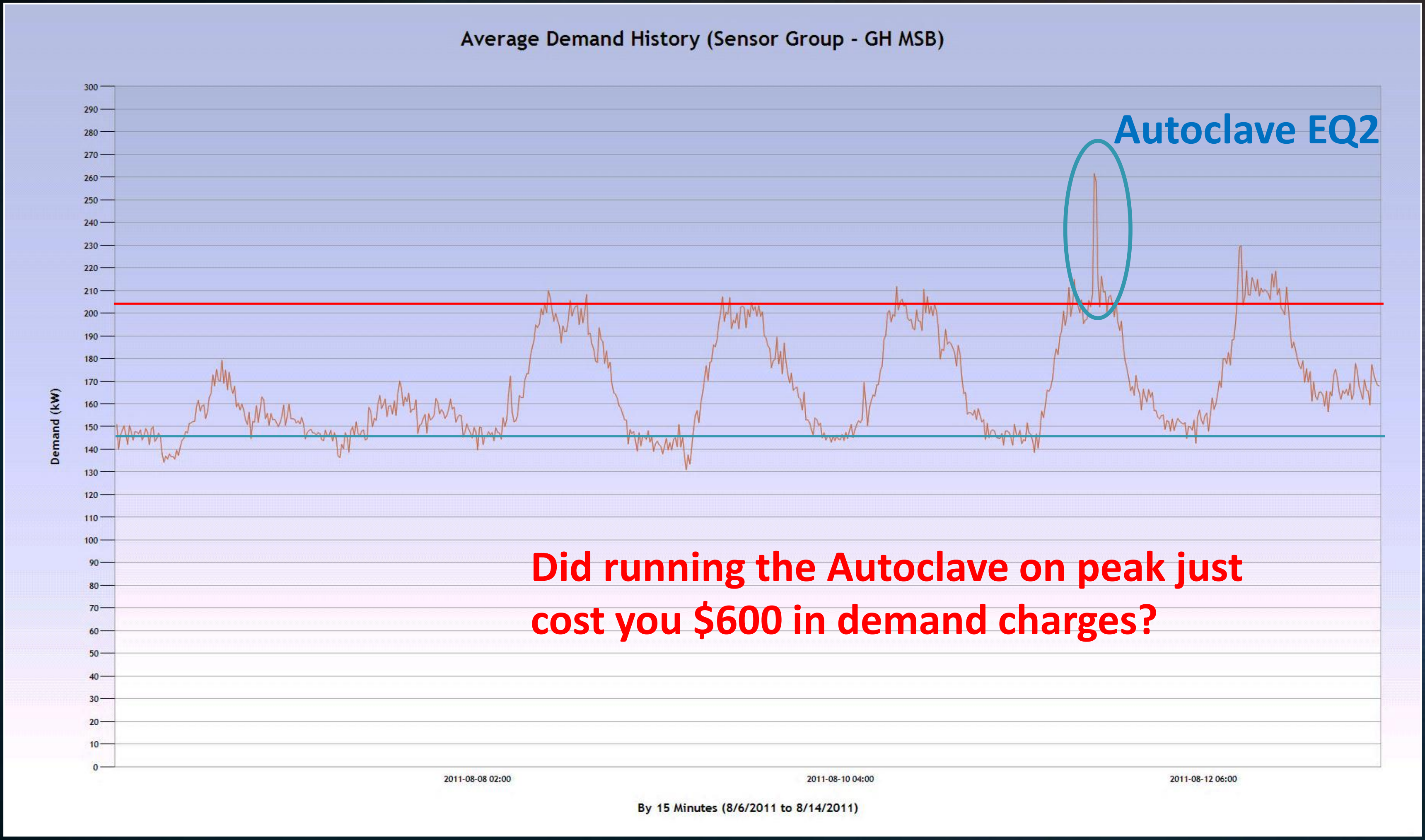


HDP1

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

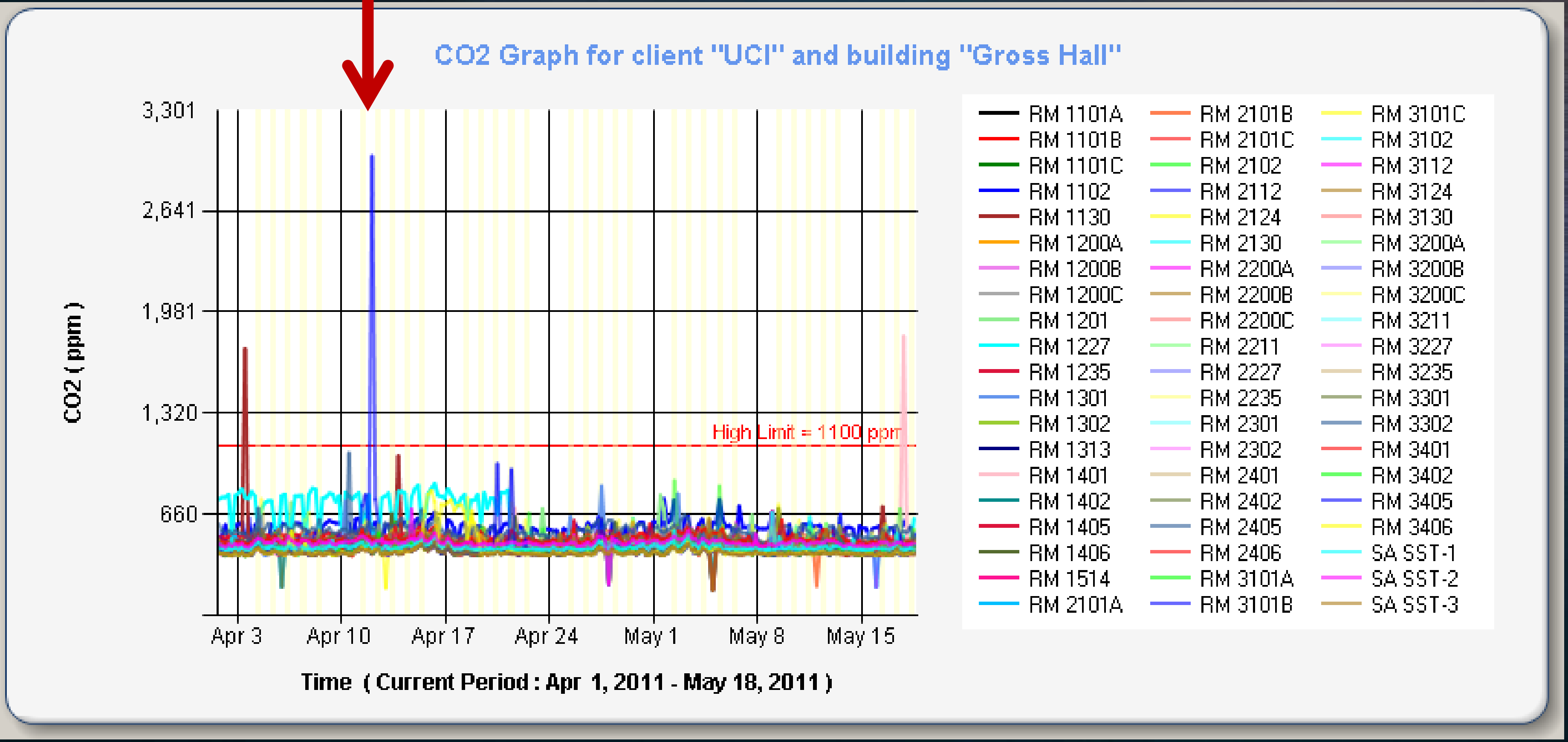
Troubleshooting a CO_2 leak with the CDCV System

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

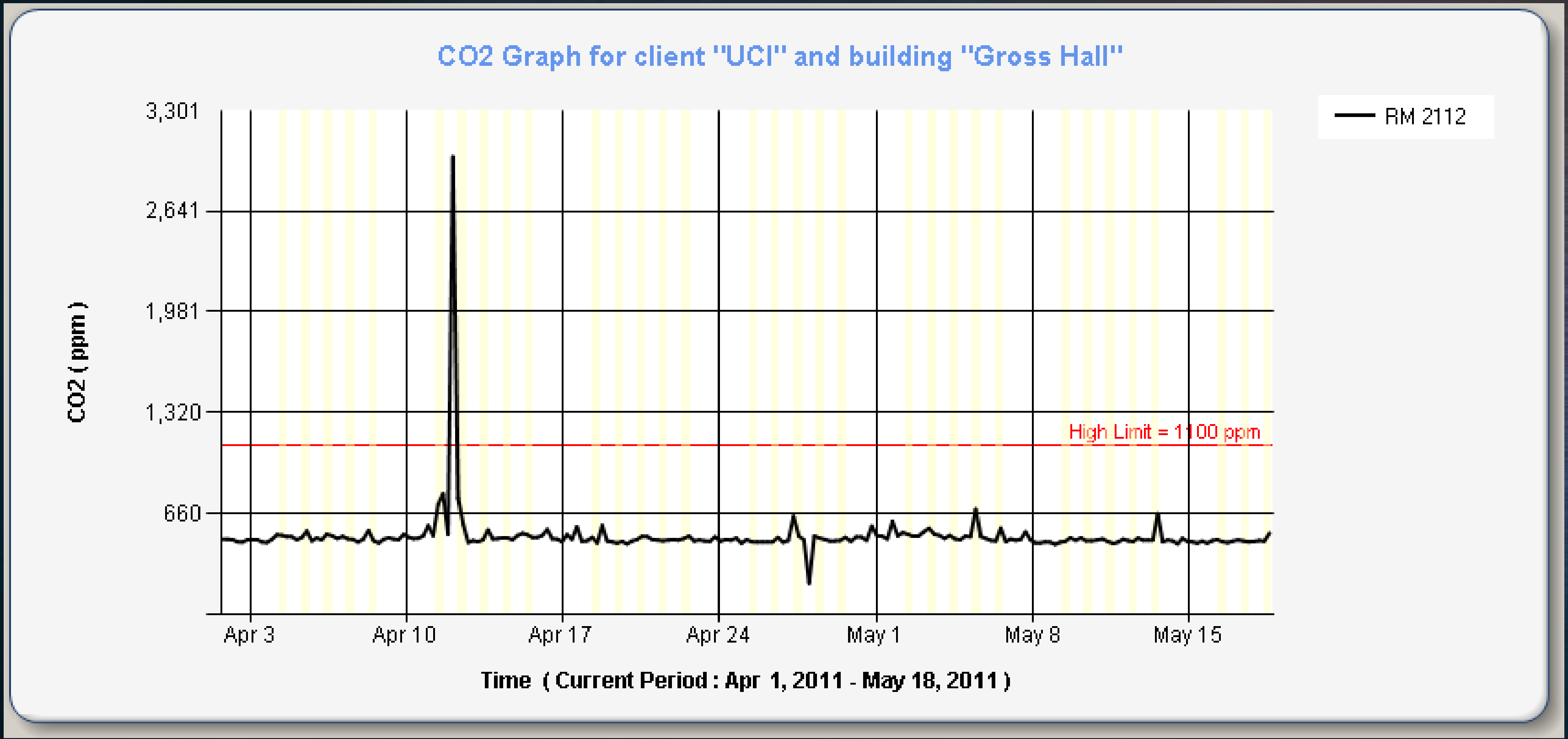
To find the leak the research staff could have spent hours soaping lines and connections and wasting additional gas listening for the leak.

Researcher first plotted all rooms for CO2

Suspected location of
CO2 leak

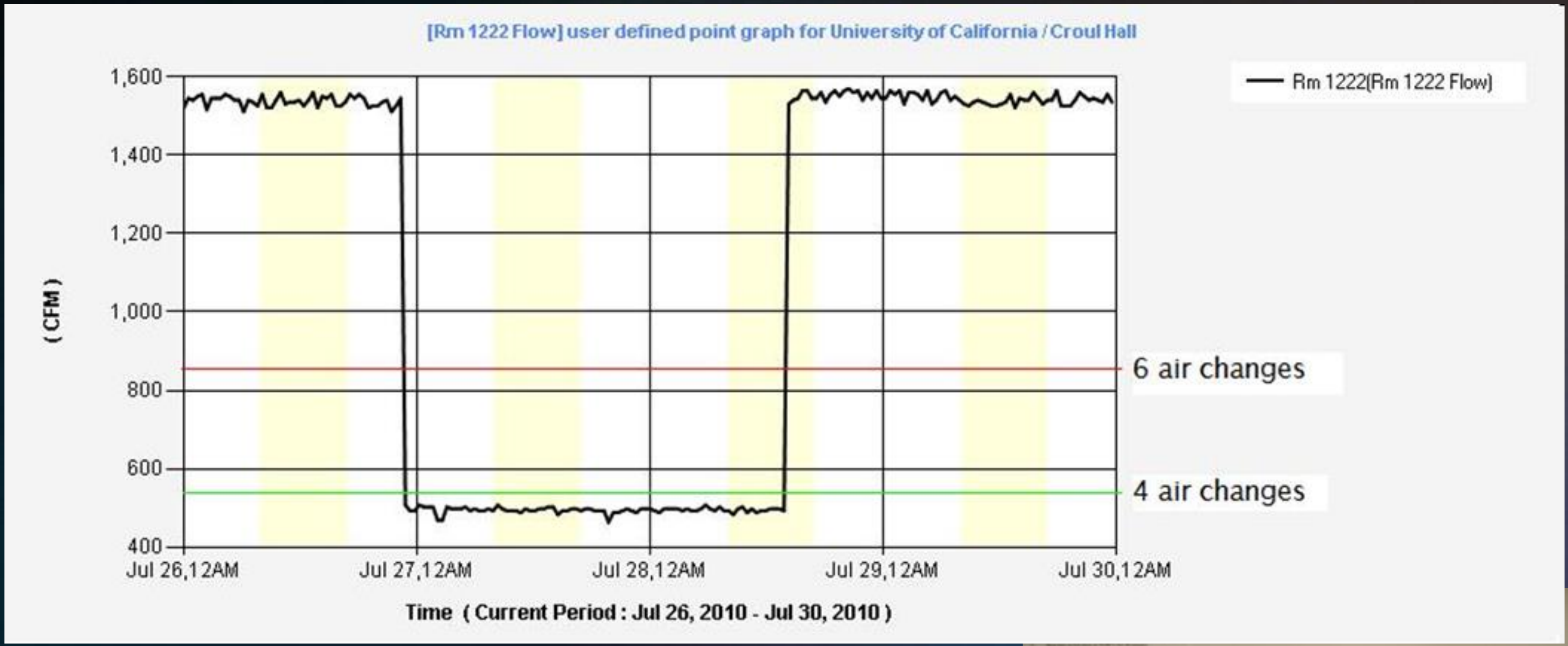


The PI then plotted the room with the suspected CO2 leak:



It was quickly located and repaired

Discovery of Lab Equipment Driving Thermal Demand

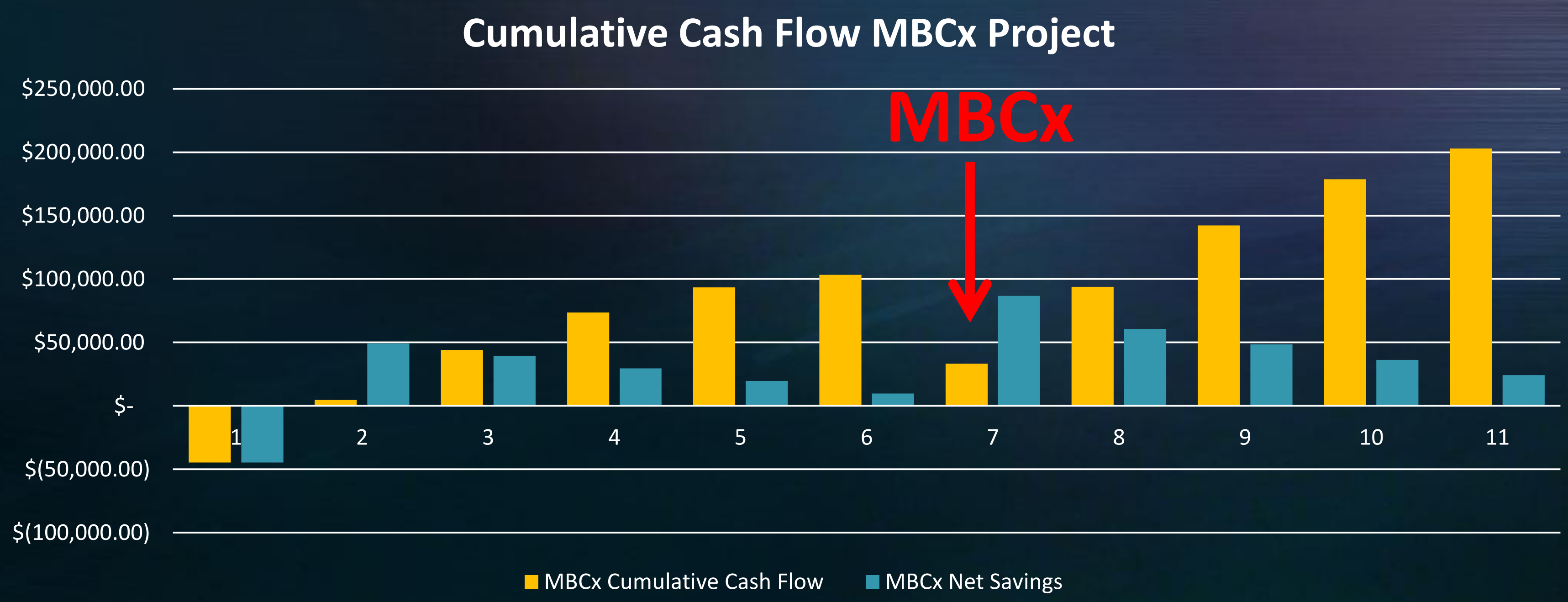


The Knowledge Center has been used to locate lab equipment placed too close or under thermostats

Return on Investment

Commissioning

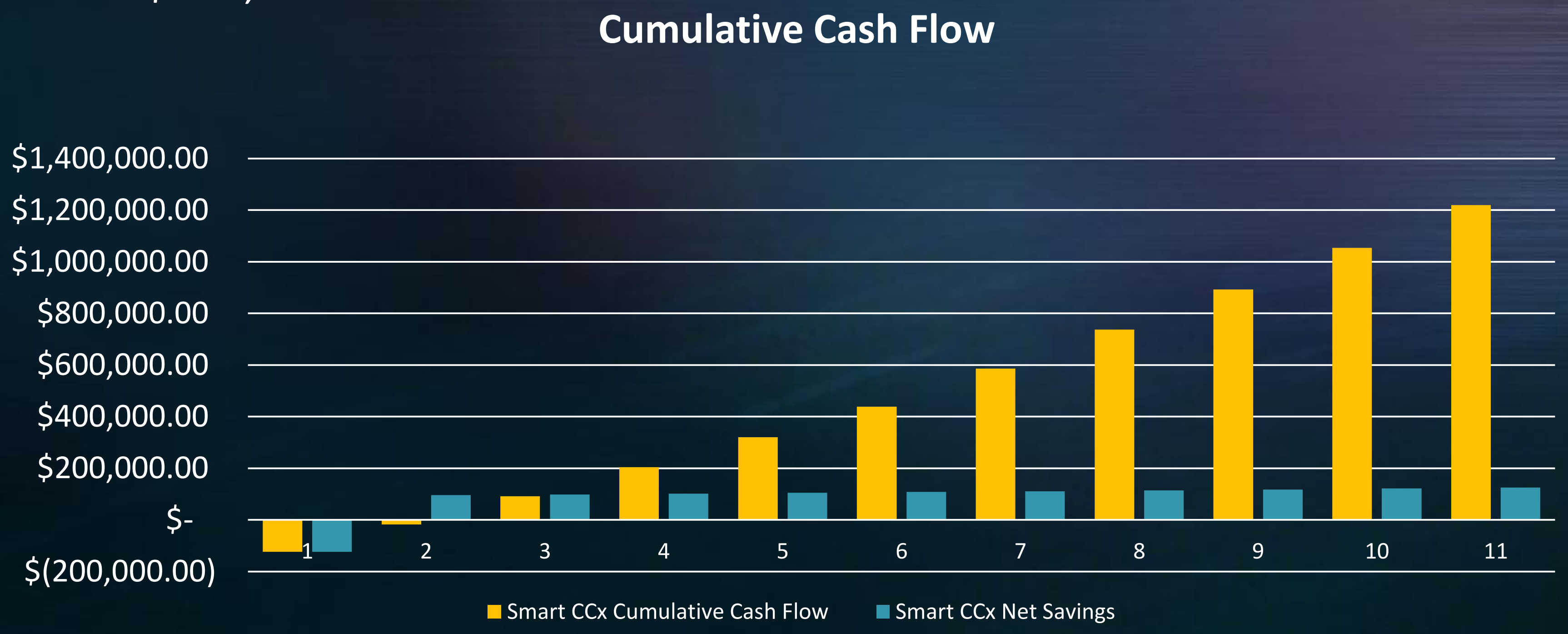
- Cx, Rx, MBCx is approximately $2 per SqFt
- Hewitt Hall MBCx $131,309
- Net present value for 10 years (MBCx every 5 years) Hewitt Hall $113,590



Return on Investment

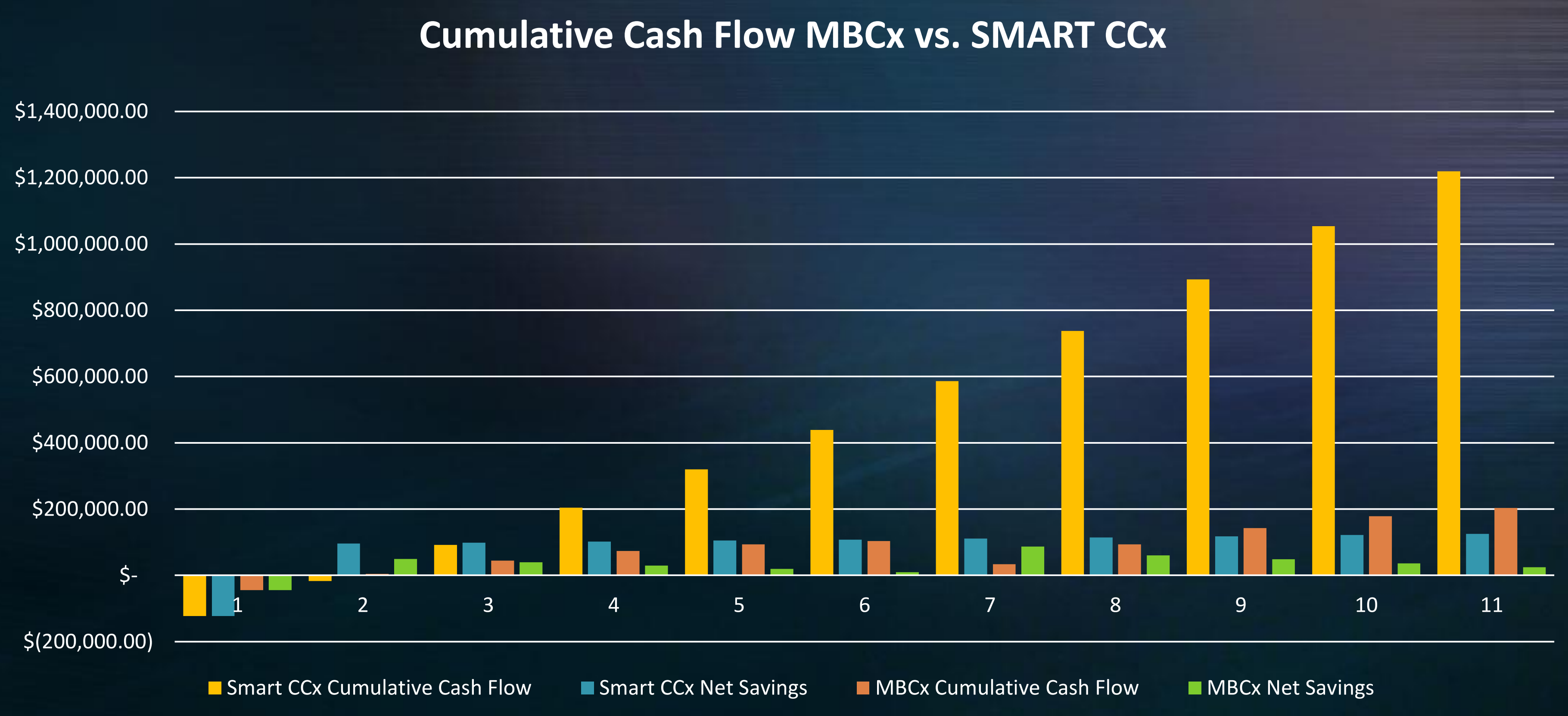
Sub metering and monitoring your lab can be very competitive with the cost of a single commissioning effort.

- 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 can not be accomplished with traditional MBCx



The Smart Lab developed at UCI has many individual features that UC Irvine has piloted over the last three years before being incorporated into Gross Hall.

In order to make the deep energy cuts that are required to meet a 50% savings goal, theories must be tested, perceptions changed and results evaluated.

WATER CONSERVATION MEASURES

Stormwater runoff control

Drought tolerant landscape selection

Reclaimed irrigation water

Water conserving plumbing fixtures

Ultra-low flush Urinals

Dual-flush Toilets

Smart Lab "Safety Net"

Welcome to Sue and Bill Gross Hall
A CIRM Institute

Sue and Bill Gross Hall

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
  - Occupant welcome brochure
  - "Red Button" signage

ROOM AIR PURGE SYSTEM

Press button in the event of chemical spill or release.
After activation, leave the building and call 911.

DO NOT ACTIVATE FOR A FIRE

Smart Labs Considerations/Challenges

Maintenance

- Mechanical Repairs to more complex systems
- Software updates/adjustments to BMS Controls
- Sensor calibration/replacement of CDCV system
- Calibration of sash sensors, zone presence sensors, etc.

Questions?