Energy-Efficient & Net Zero Laboratory Ventilation Design Practices and Technologies

Garvan Cancer Center, Australia

Masdar City, UAE

ASU: Biodesign Institute

New Apple HQ

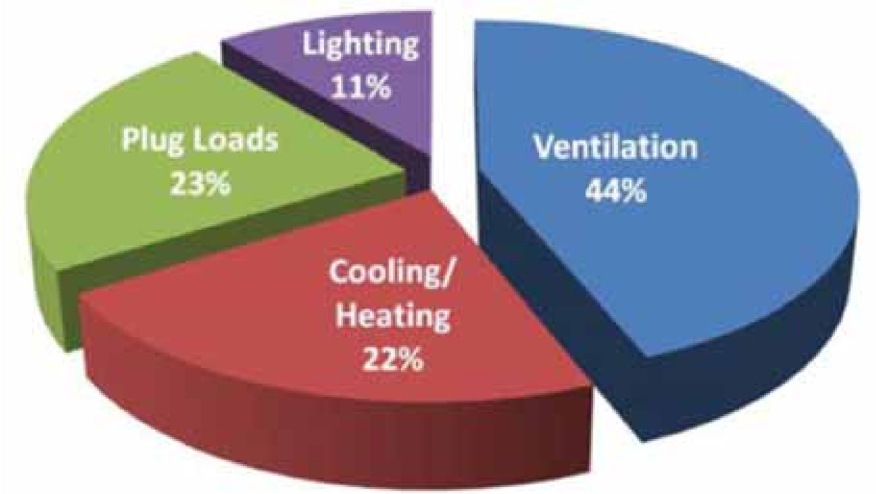
Grand Mosque, Mecca

MGM Macau Casino

Gordon P. Sharp, Aircuity

Why are Labs Important in Terms of Energy?

- Lab Energy Usage:
  - ✓ 5 to 10 times office usage
- Example: Universities:
  - ✓ 2.5 to 10% sq. footage
  - ✓ 10 to 40% site energy usage
- >65 % of lab energy: HVAC



Typical Laboratory Energy Use
(based on NIH Louis Stokes Laboratory)

The HVAC load will typically be 60 to 80% of lab energy!

So What is Net Zero & How Does it Relate to Labs?

- **Could be Net Zero relative to CO_2 or just Energy**
  - ✓ **Relative to energy use is more relevant to Labs**
- **Could be Net Zero for building or for the site**
  - ✓ **Net zero w/ lab using PV possible but 1 lab floor only**
  - ✓ **More realistic is a site based PV or wind turbine**
    - *Masdar Institute of Science & technology (MIST) – Near Net Zero*
    - *Goal was based on site vs. building – uses a 10 MW PV on site*

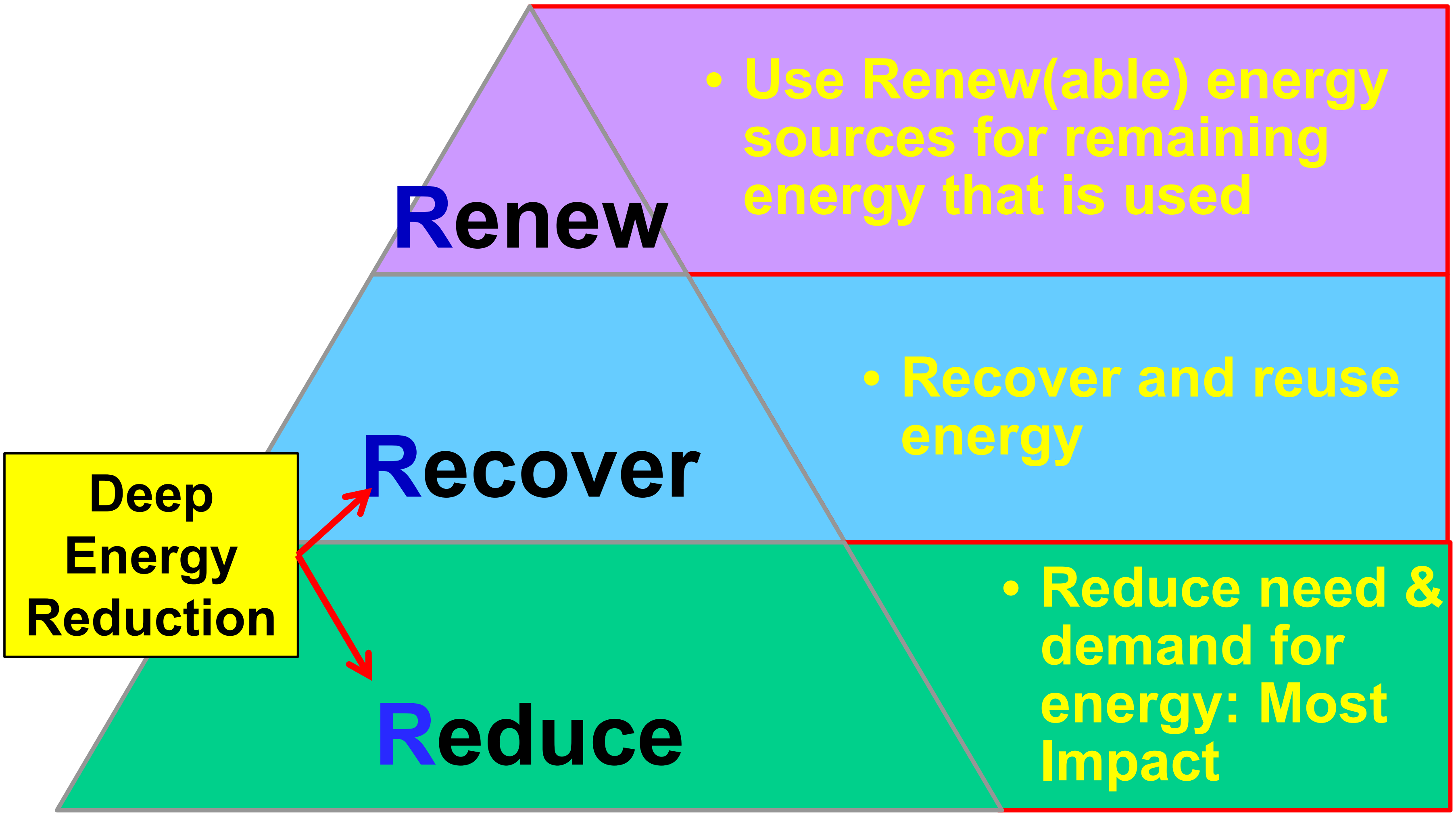
Also Emerging: Net Zero Ready & Near Net Zero

- **"Net Zero Ready" bldgs:**
  - ✓ **Designed for very low energy use**
  - ✓ **Idea is to add renewables later when their cost drops**
- **"Near Net Zero" Bldgs;**
  - ✓ **Like "Net Zero Ready" they are very low energy use**
  - ✓ **Renewables used but less than needed for Net Zero**
    - – *Example of MIST in Abu Dhabi, UAE*

"Net Zero Design" concepts are economically & broadly applicable to cut energy use in any lab building today!

So What is the Plan for Reaching (Near) Net Zero:

- The Three R's Approach to hitting Net Zero:



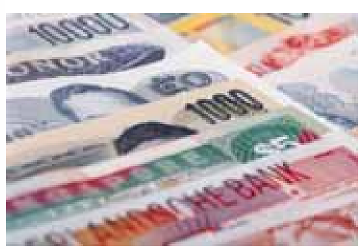
How To Achieve Deep Energy Reduction?

- **A focus on max savings**
  - ✓ **Not a grab bag of many ideas**
    - – *Focus on a few, high impact concepts*
- **Foundation: *Airflow reduction***
  - ✓ **Airflow has greatest energy impact**
  - ✓ **Skin load much less important**
- **Need for a holistic approach to technologies**
  - ✓ **We will use an energy model for 1st cost & energy use**
    - – *Impact of combining low flow design & other concepts non-intuitive*

"In God We Trust, All Others Must Provide Data!"

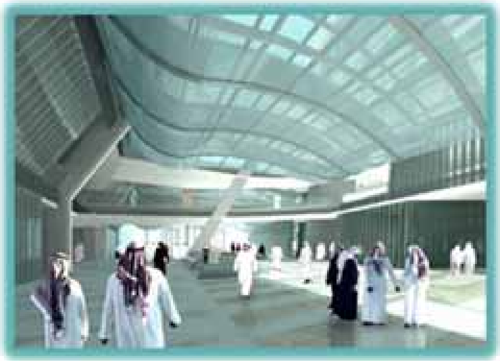
Objectives of This Course

- **Identify high impact HVAC technology/concepts**
  - ✓ **Understand more about applying these approaches**
- **Rank order approaches in terms of savings %**
- **Understand interactions between approaches**
  - ✓ **Look at energy savings holistically vs. individually**
- **Examine predicted savings & first costs**
  - ✓ **Uses a sophisticated lab focused analysis tool**

Low Energy Lab Design Overview

- Introduction to low energy/Net Zero lab design
- Lab energy and first cost analysis tool
- Design issues involved in achieving 2-4 ACH safely
- Applicable technologies and concepts
  - ✓ VAV lab air flow controls
  - ✓ Demand based control
  - ✓ Hydronic cooling & chilled beams
  - ✓ Variable flow exhaust fan control
  - ✓ Low pressure drop design
  - ✓ Heat recovery systems
- Case study examples
- Summary



Kuwait Criminal Evidence Lab

Key Conclusions For Near Net Zero Design:

- **Low ACH design is key to Net Zero Energy**
  - ✓ The foundation for Deep Energy Reduction
  - ✓ Low ACH Design is a Paradigm Shift from 6 - 10 ACH
- **Demand Based Control safely reduces lab ACH**
  - ✓ More airflow when you need it & less when you don’t
- **Cutting energy use can also *Reduce First Cost!***
  - ✓ Less airflow means less HVAC system capacity

Low Flow/Energy Lab Design is a New Paradigm!

- Outside air : Largest energy driver
  - ✓ Reducing OA reduces many energy uses
- Single largest impact on energy :
  - ✓ Demand Based Control of ACH
    - – *ACH = Air Changes per Hour*
- Codes/standards are now supportive
  - ✓ ASHRAE Handbook, NFPA 45-2011, etc.
- Result: Dramatic cut in energy use
  - ✓ Up to >50% lab building energy cut
- And first or capital cost can ***also*** be cut

If these approaches are used a Net Zero lab is possible in Abu Dhabi, although many would call that *not just mission difficult but:* *Mission Impossible!*

THE FOLLOWING **PREVIEW** HAS BEEN APPROVED FOR

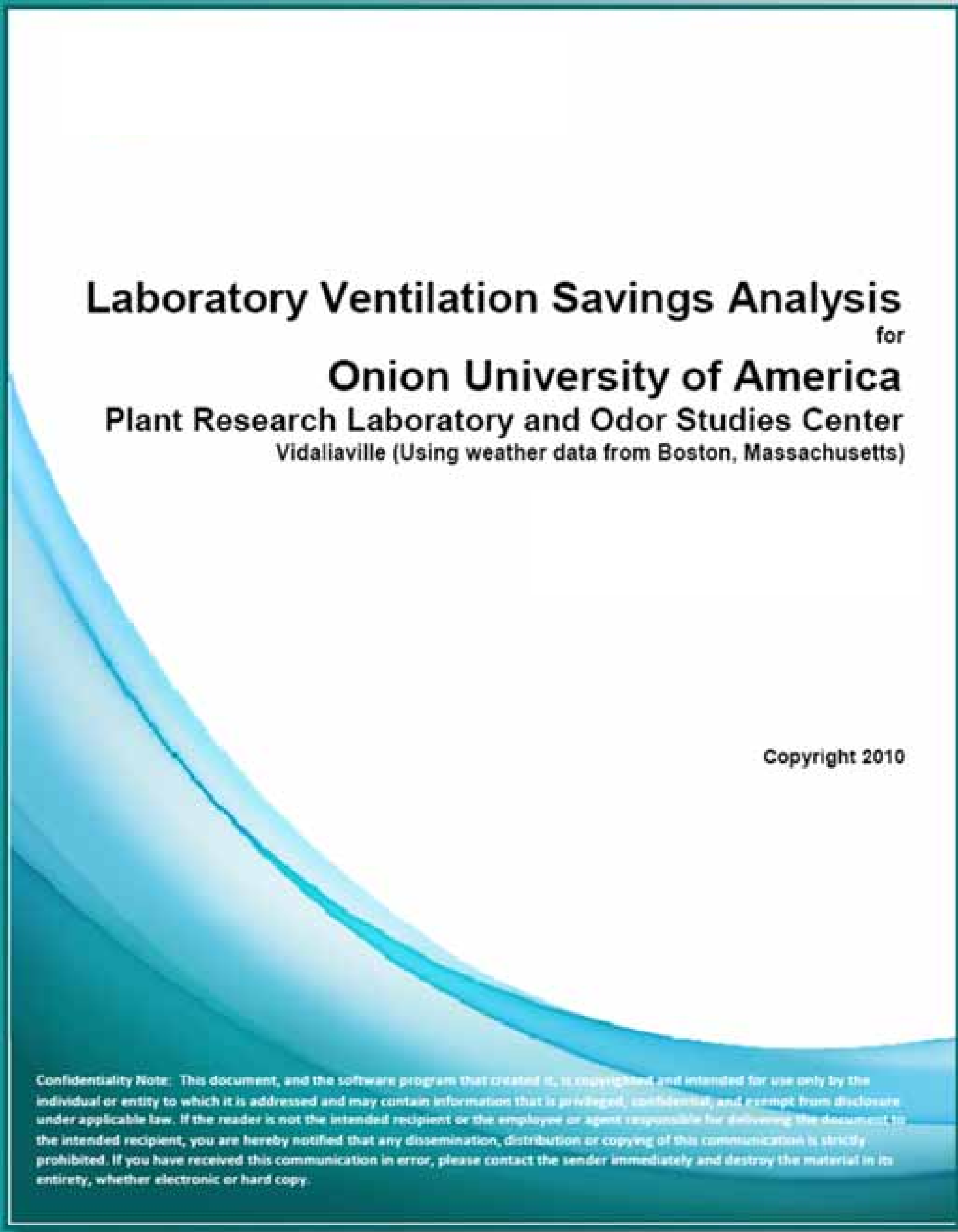
LAB BUILDING DESIGN & OPERATIONS AUDIENCES

BY THE INTERNATIONAL INSTITUTE OF SUSTAINABLE LABORATORIES

www.labratings.com

www.i2sl.org

Lab Building Energy Analysis & ROI Tool



Laboratory Ventilation Savings Analysis

for

Onion University of America

Plant Research Laboratory and Odor Studies Center

Vidaliaville (Using weather data from Boston, Massachusetts)

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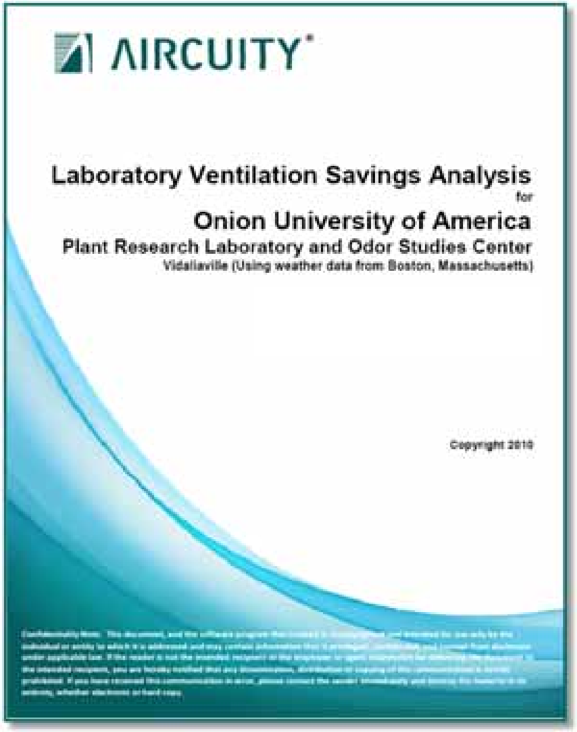
Energy, First Cost, & Payback Analysis Tool

- Lab focused design analysis
  - ✓ Customized analysis engine
- Several utilities have reviewed & approved tool
  - ✓ PG&E, S. Cal. Edison, Con Ed
- Validated by Emcor & others
- BMS company branches have used it
  - ✓ Basis for guaranteed performance contract savings

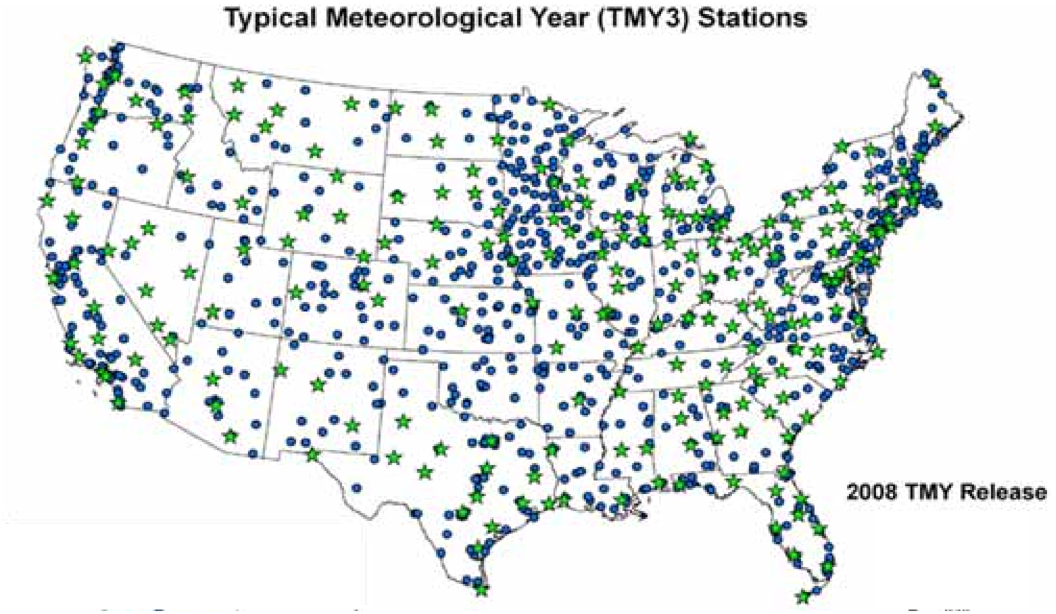


Background & Availability of the Lab ROI Tool

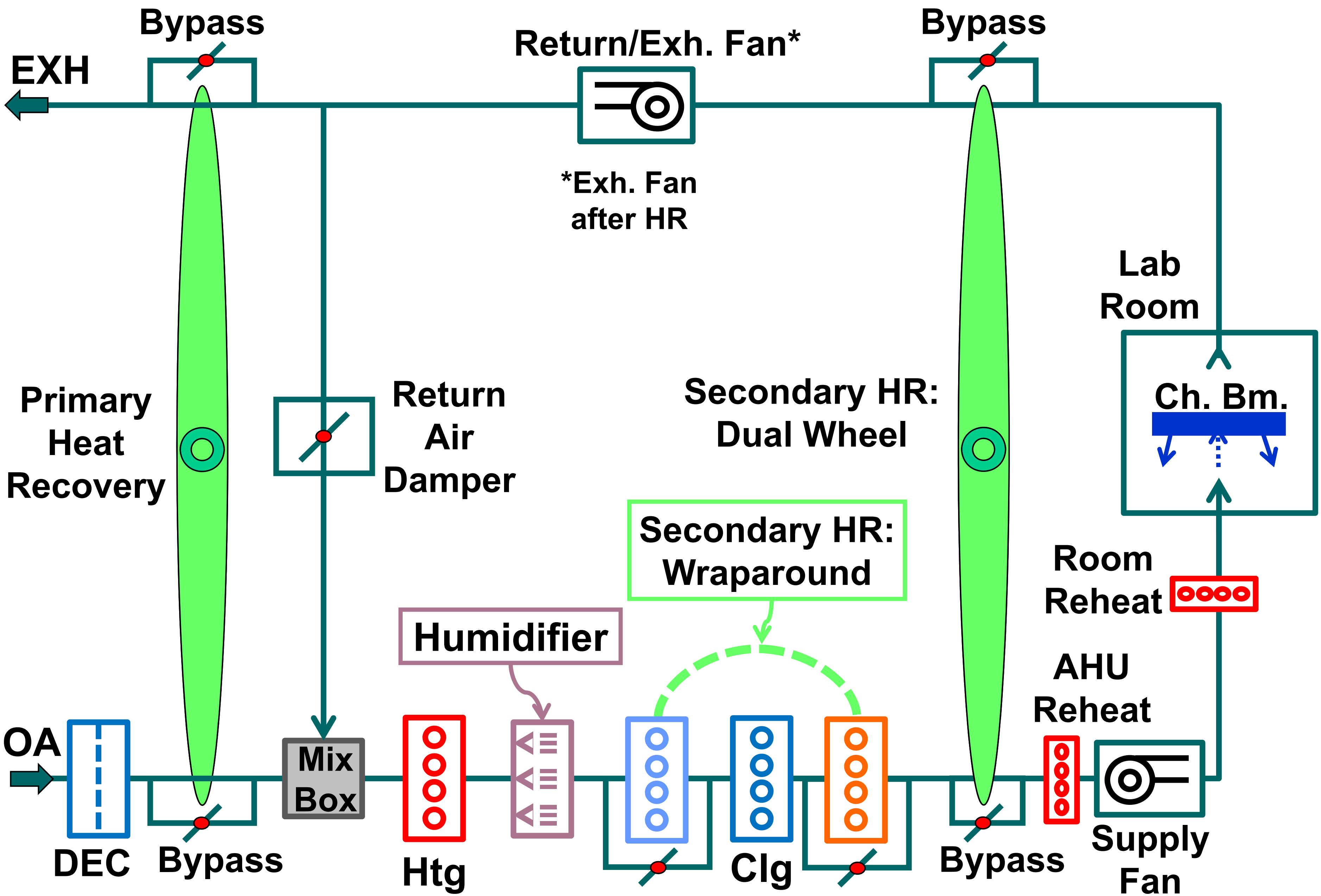
- **First used to evaluate energy & first cost impact of demand based control**
- **Over last 3 years it has been evolving into a general purpose analysis tool**
- **Unique focus on lab airside systems**
- **Availability:**
  - ✓ **Users must be trained to obtain the tool.**
  - ✓ **Tool may be available from I2SL in the future for a reasonable annual fee to cover support & distribution. Annual license is free for now.**
  - ✓ **I2SL & chapters have begun to offer full day training courses for typical workshop fees.**

Uses New Weather Data for Accurate Savings

- **Uses new TMY3 data set**
  - ✓ **"Hotter" (adds 1990 – 2005) vs. Older TMY2 data**
  - ✓ **Incorporates 1700 cities worldwide**
- **Incorporates detailed humidity data**
  - ✓ **Uses 8 humidity values per temp. bin**
  - ✓ **Yields much more accurate results than MCWB data**

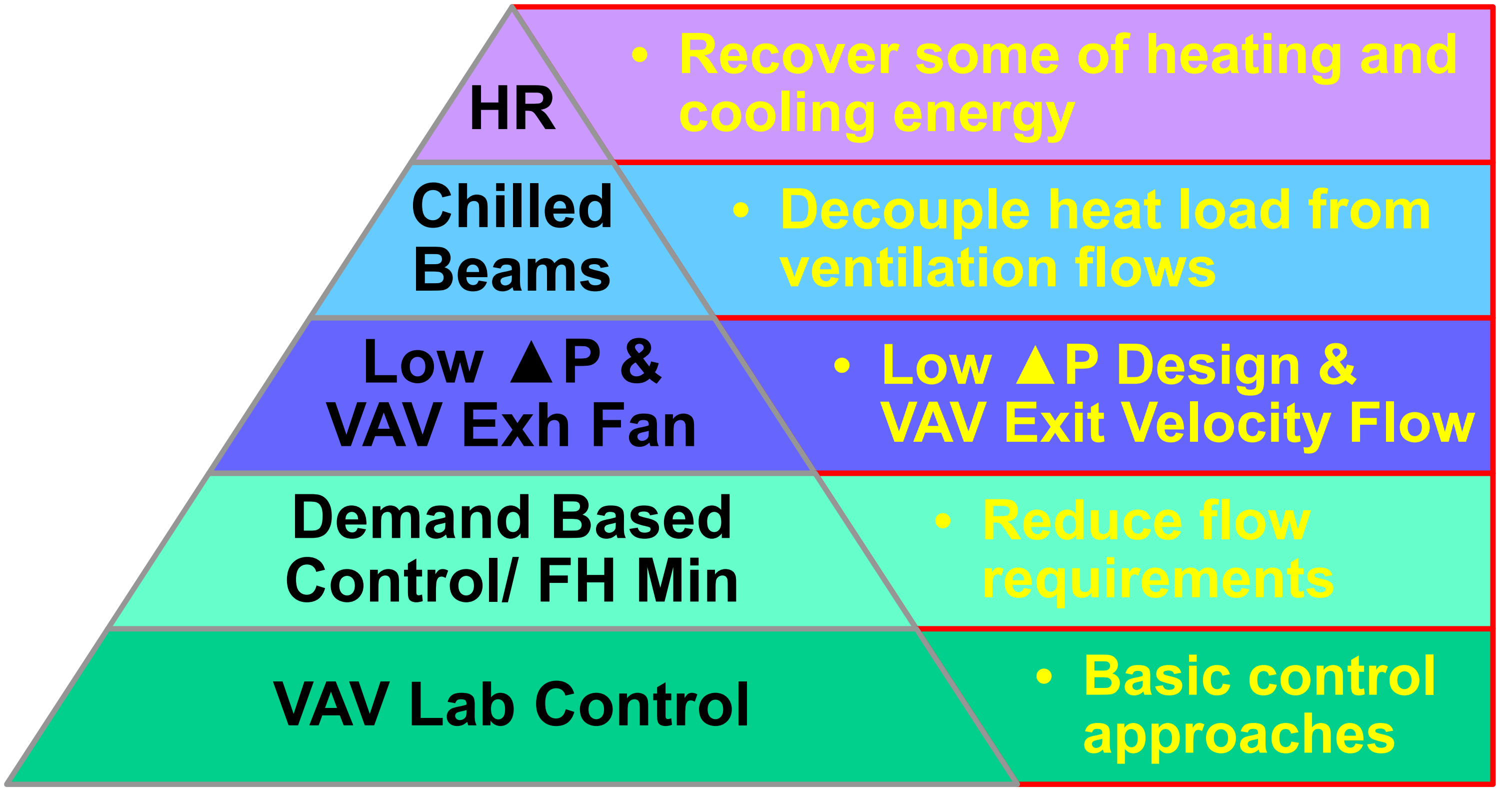


Lab ROI Tool: HVAC System Model



A Holistic Approach for Increased HVAC Savings

- **Individually evaluating systems is suboptimal**
  - ✓ DBC, chilled beams, hoods & heat recovery
- **To optimize lab safety, first cost & energy:**
  - ✓ Combining systems appropriately is best
  - ✓ Also use a layered or pyramid approach:

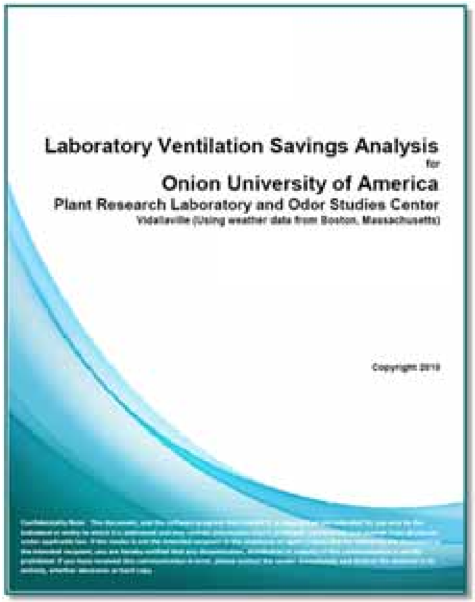


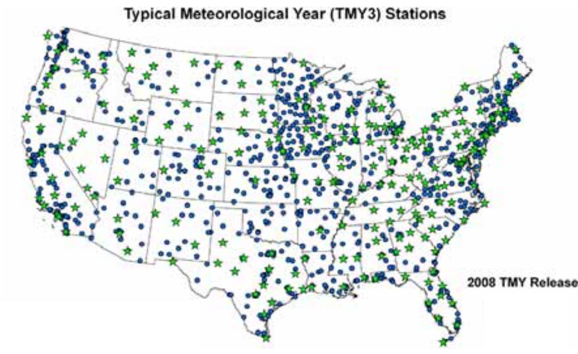
Locations for Analysis Example

- **Using Boston for representative climate city:**
  - ✓ **Boston has both some heating & cooling: a fair avg.**
- **Where relevant other cities used for comparison:**
  - ✓ **Madison & Denver, for a colder climate**
  - ✓ **Atlanta, Phoenix, Wash, & Miami for a warmer climate**
  - ✓ **Los Angeles for a neutral climate**

Boston Example Analysis Assumptions

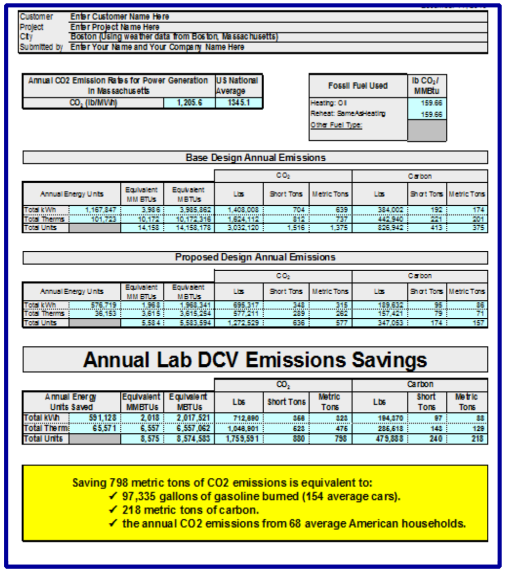
- Model typical bldg. w/ 125K GSF
  - ✓ Lab & lab support area: 50K NSF
  - ✓ Office area: 30K NSF
- Base dilution ventilation:
  - ✓ Conservatively set to 6 ACH
- Energy Cost Assumptions:
  - ✓ Electric: $0.12/kWh Avg
  - ✓ Heating: $1.00/therm
- Low to moderate hoods:
  - ✓ One 6’ hood/ 667 ft.^{2} module (75)
- Manifolded exhaust fans:
  - ✓ 4 fans are staged plus 1 spare





Boston Example Analysis Assumptions

- Room Temp setpoint: 74 DegF
- HVAC System Eff:
  - ✓ Cooling:
    - – *Total COP of chilled water plant: 3.3*
    - – *Eff. Chilled Beam "COP": 4.0*
  - ✓ Heating plant: 75% total eff.
- Typical thermal loading used
  - ✓ 80% of labs at 3 W/ft^2 avg day
  - ✓ 20% of labs at 6 to 9 W/ft^2 avg day
- No humidification used



Customer	Enter Customer Name Here
Project	Enter Project Name Here
City	Boston (Using weather data from Boston, Massachusetts)
Submitted by	Enter Your Name and Your Company Name Here

Annual CO2 Emission Rates for Power Generation in Massachusetts		US National Average
CO_2 (lb/MWh)	1,205.6	1345.1

Fossil Fuel Used	lb CO_2/ MMBtu
Heating: Oil	159.66
Reheat: SameAsHeating	159.66
Other Fuel Type:	

Base Design Annual Emissions

Annual Energy Units		Equivalent MM BTUs	Equivalent MBTUs	CO_2 Lbs	CO_2 Short Tons	CO_2 Metric Tons	Carbon Lbs	Carbon Short Tons	Carbon Metric Tons
Total kWh	1,167,847	3,986	3,985,862	1,408,008	704	639	384,002	192	174
Total Therms	101,723	10,172	10,172,316	1,624,112	812	737	442,940	221	201
Total Units		14,158	14,158,178	3,032,120	1,516	1,375	826,942	413	375

Proposed Design Annual Emissions

Annual Energy Units		Equivalent MM BTUs	Equivalent MBTUs	CO_2 Lbs	CO_2 Short Tons	CO_2 Metric Tons	Carbon Lbs	Carbon Short Tons	Carbon Metric Tons
Total kWh	576,719	1,968	1,968,341	695,317	348	315	189,632	95	86
Total Therms	36,153	3,615	3,615,254	577,211	289	262	157,421	79	71
Total Units		5,584	5,583,594	1,272,529	636	577	347,053	174	157

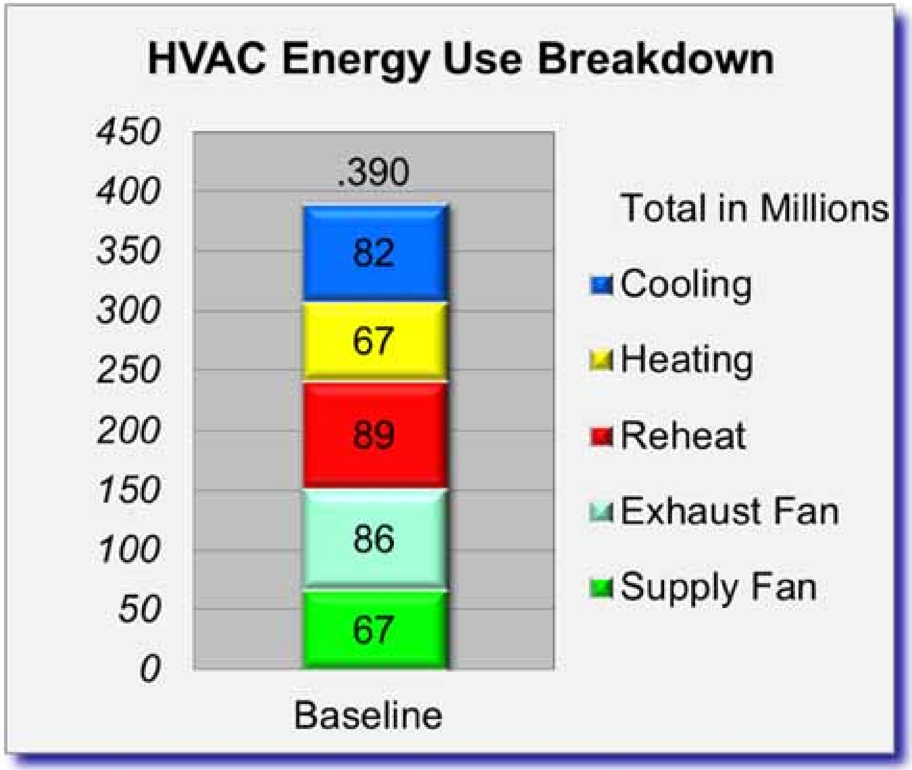
Annual Lab DCV Emissions Savings

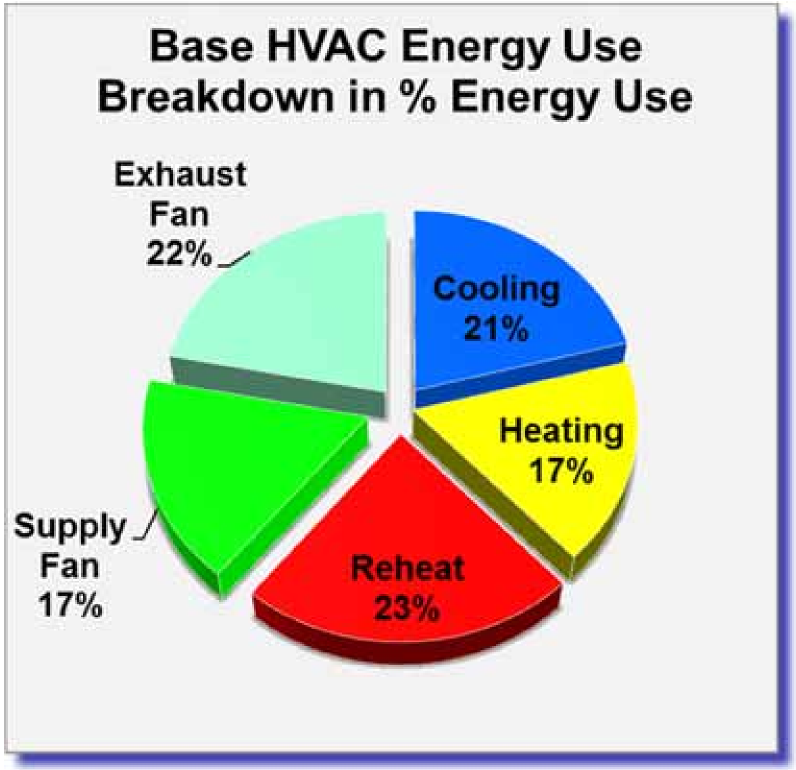
Annual Energy Units Saved		Equivalent MMBTUs	Equivalent MBTUs	CO_2 Lbs	CO_2 Short Tons	CO_2 Metric Tons	Carbon Lbs	Carbon Short Tons	Carbon Metric Tons
Total KWh	591,128	2,018	2,017,521	712,690	358	323	194,370	97	88
Total Therm	65,571	6,557	6,557,062	1,046,901	523	475	285,518	143	129
Total Units		8,575	8,574,583	1,759,591	880	798	479,888	240	218

Saving 798 metric tons of CO2 emissions is equivalent to:
- ✓ 97,335 gallons of gasoline burned (154 average cars).
- ✓ 218 metric tons of carbon.
- ✓ the annual CO2 emissions from 68 average American households.

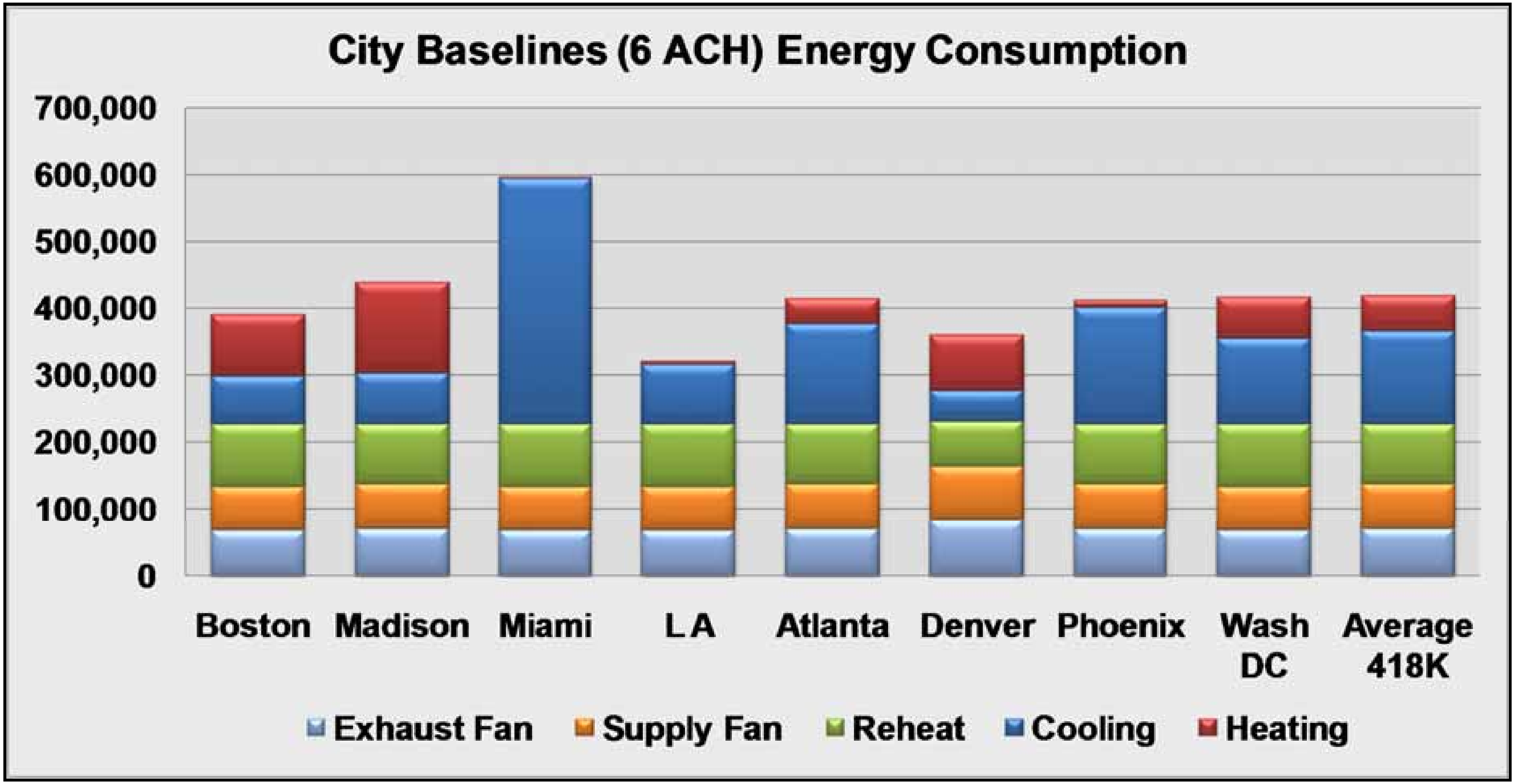
6 ACH Baseline Energy Costs For Boston

- Skin & solar gains typically small compared to OA
- Base flow rate (including offices):
  - ✓ 72.5K cfm day & 63.7K cfm night
- Total baseline energy use is $390K/ year





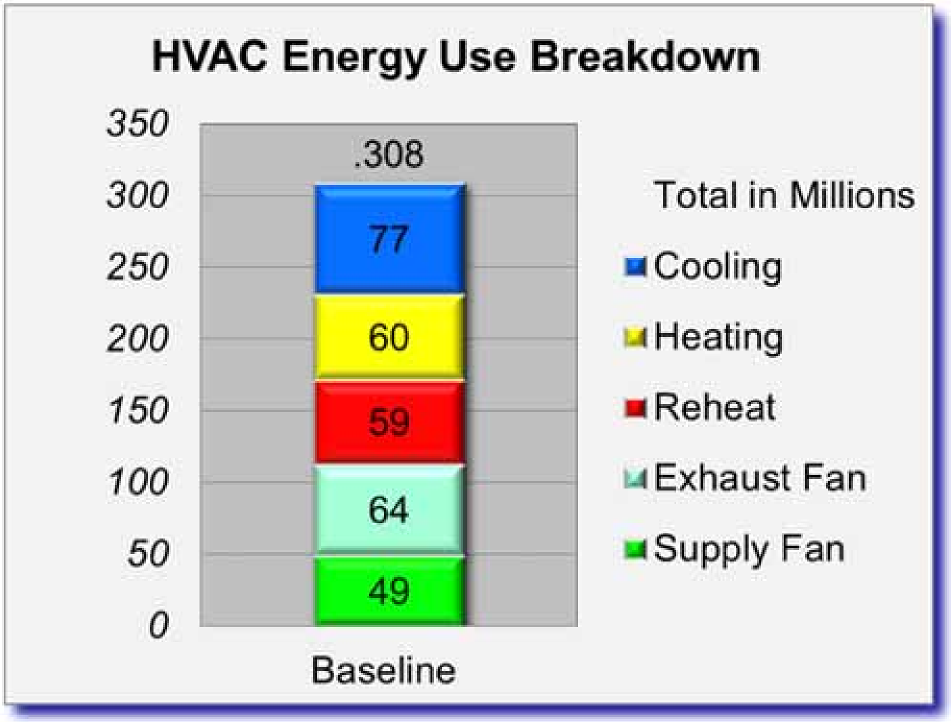
Baseline Cities at 6 ACH

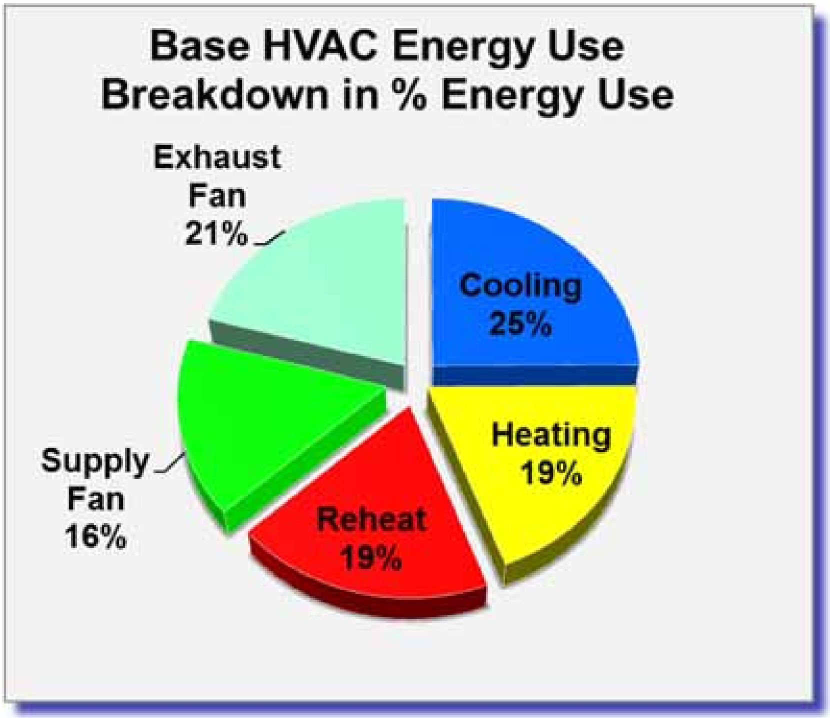


Average Energy Usage is $418K

6 ACH Baseline Energy Costs For Des Moines

- **Uses average Iowa utility rates (less than Boston):**
  - ✓ **Electric rate of $0.09/kWh**
  - ✓ **Gas rate of $.70/Therm**
- **Uses Des Moines, Iowa weather data**
- **Total baseline energy use is $308K/ year**





Holistic Strategies for Increased Savings

- **Individually evaluating systems is suboptimal**
  - ✓ **DBC, chilled beams, hoods & heat recovery**
- **To optimize lab safety, first cost & energy:**
  - ✓ **Combining systems appropriately is best**
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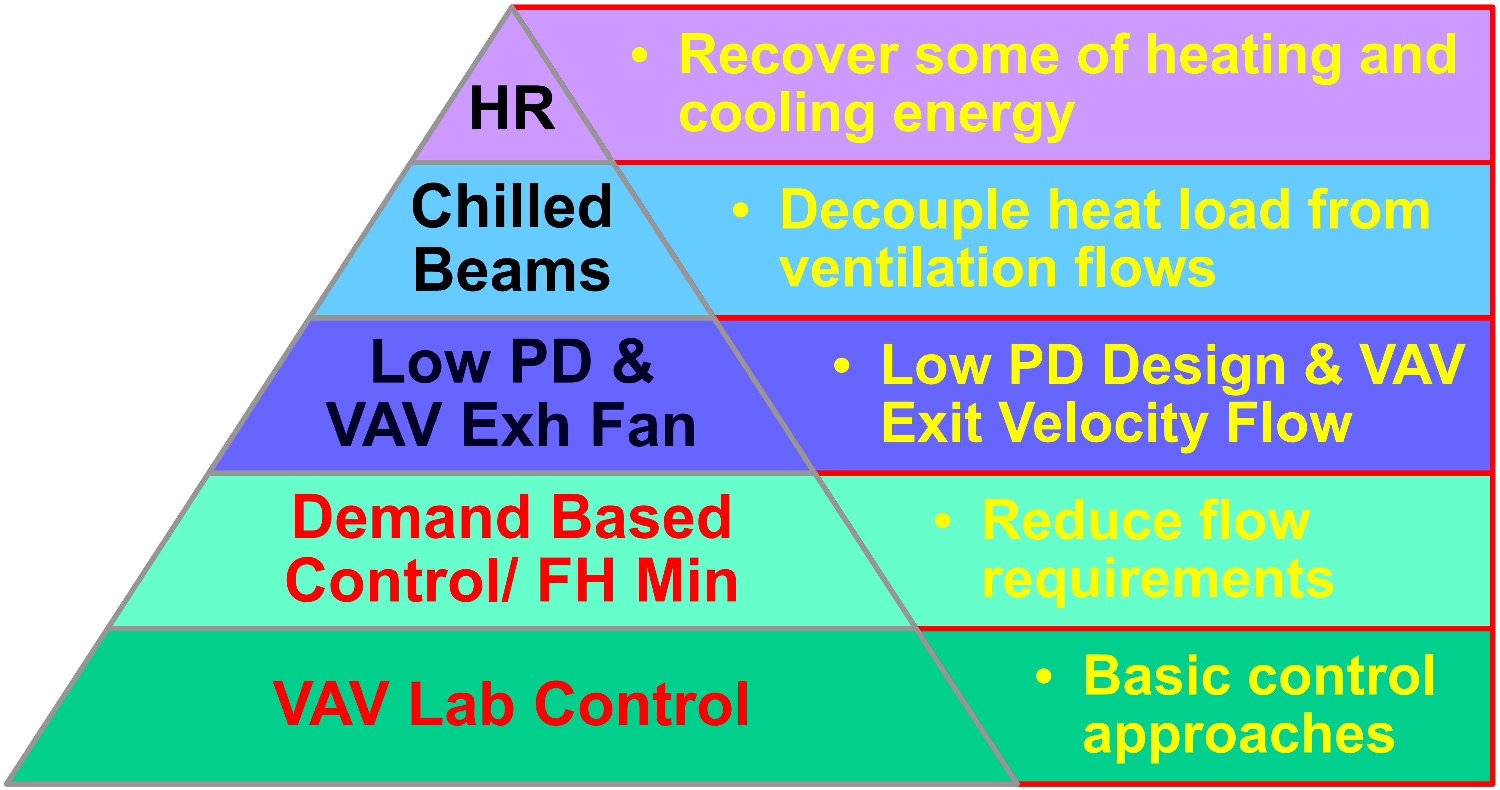
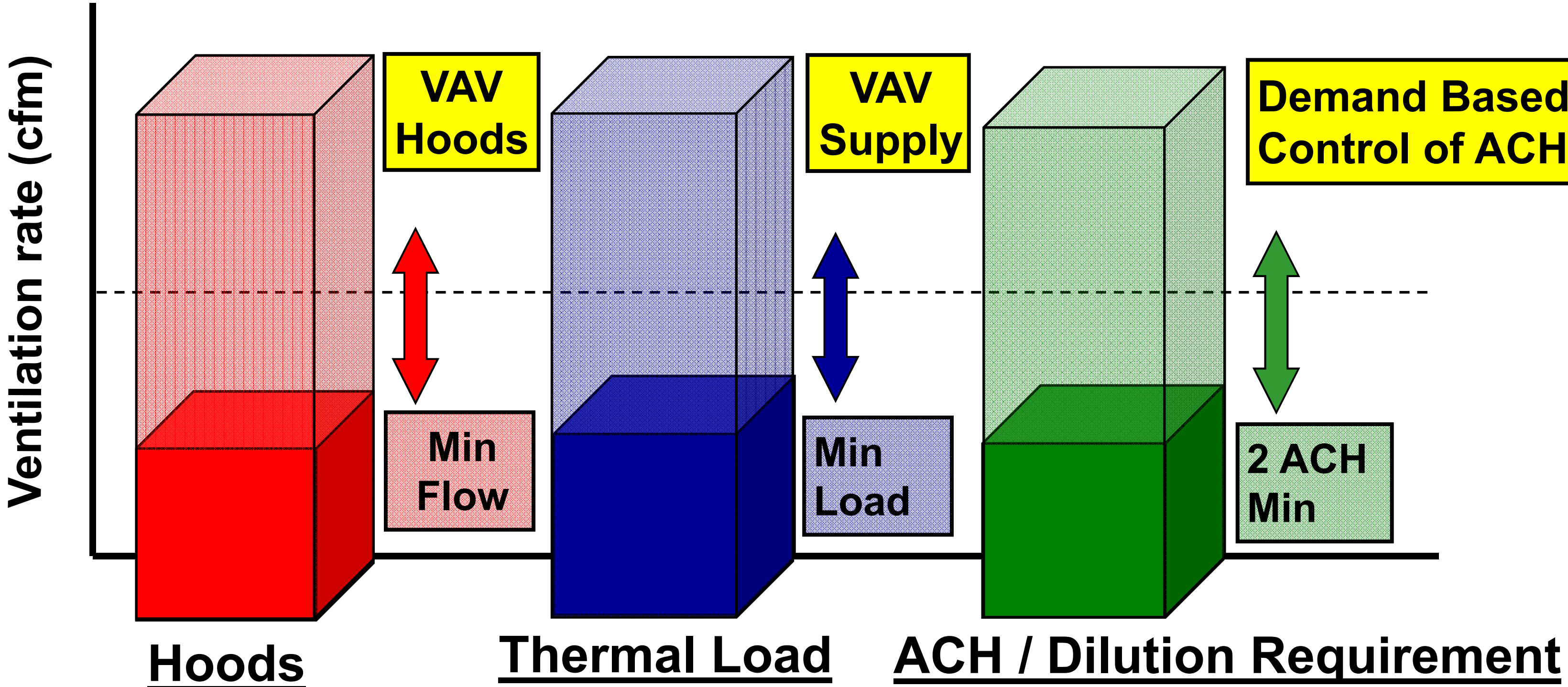


Achieving Down to 2 ACH Safely in Labs

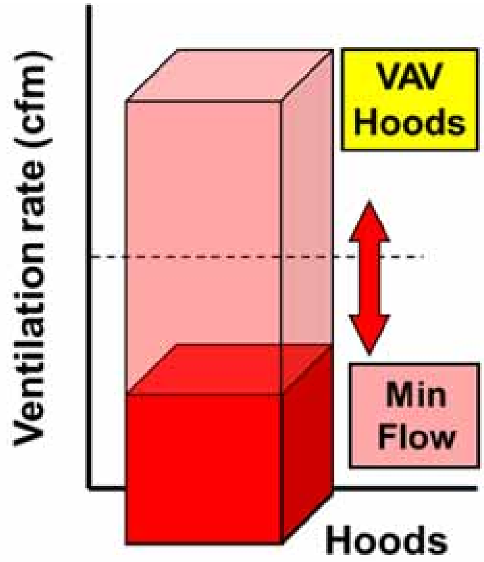
- Goal: Achieve 2 ACH day/night or 3-4 day / 2 night
- What are the drivers of lab airflow that affect this?
  - ✓ Hood flows, thermal loads & ACH rates

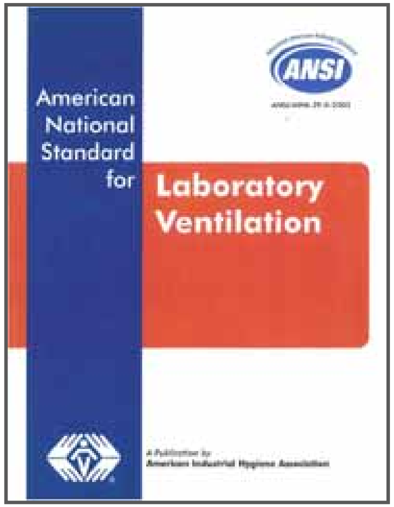


To achieve lab flows down to 2 ACH to reduce energy & 1st cost, *all* flow requirements need to be reduced

Reducing the Fume Hood Flow Drivers

- **For *low* fume hood density:**
  - ✓ **Use VAV hoods, low FV not required**
  - ✓ **Helpful to use 18" design opening**
  - ✓ **For poor sash behavior, use sash closers**
- **For *moderate* density:**
  - ✓ **Also use new ANSI Z9.5 fume hood min:**
    - *Old 6' fume hood min was ~250 cfm*
    - *New 6' fume hood min as low as ~100 cfm*
- **For *high* hood density:**
  - ✓ **Use VAV low FV hoods or VAV & sash closer**
  - ✓ **Ability to hit 2/4 ACH depends on density**
    - *Up to three 6' hoods per 900 ft^2 = 2 ACH*
    - *Up to six 6' hoods per 900 ft^2 = 4 ACH*

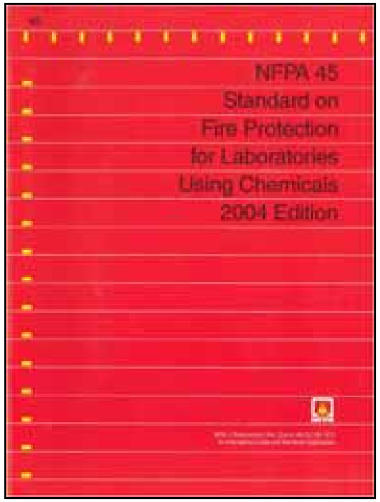


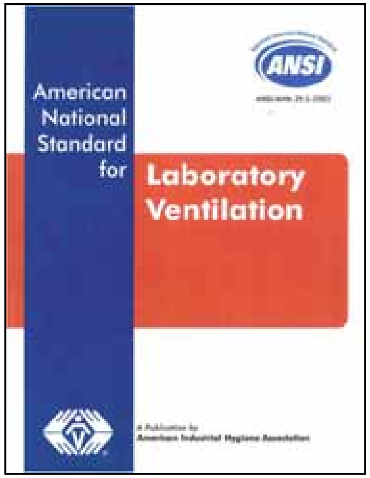


For most labs: min hood flow ≤ 2 to 4 ACH

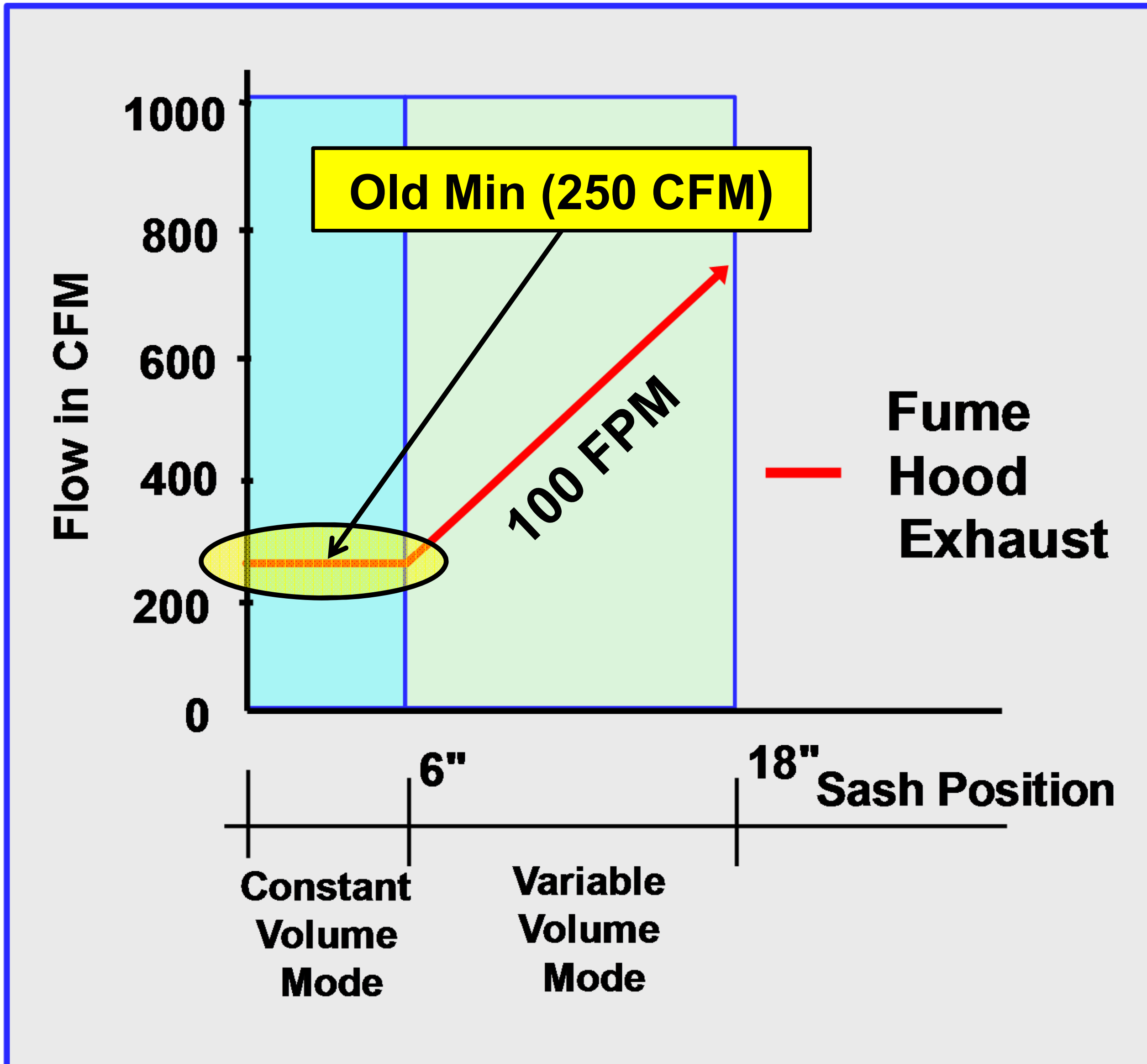
Major Change in Lab Standards: Fume Hood Min Flow

- **New NFPA 45 standard changed:**
  - ✓ **2004 version *recommended* 25 cfm/ ft^2**
  - ✓ **2011 version now only refers to Z9.5**
    - – *Z9.5 is their sole guideline on hood min flow*
- **New ANSI/AIHA Z9.5 standard:**
  - ✓ **2003 version recommended:**
    - – *Larger of 50 cfm/ ft of hood width or 25 cfm/sq ft of bench area*
  - ✓ **2012 version significantly changed:**
    - – *Changed basis of flow to hood ACH (volume)*
    - – *Changed min flow to a range recommendation*
      - • 25 cfm/ft^2 changed to 150 to 375 hood ACH



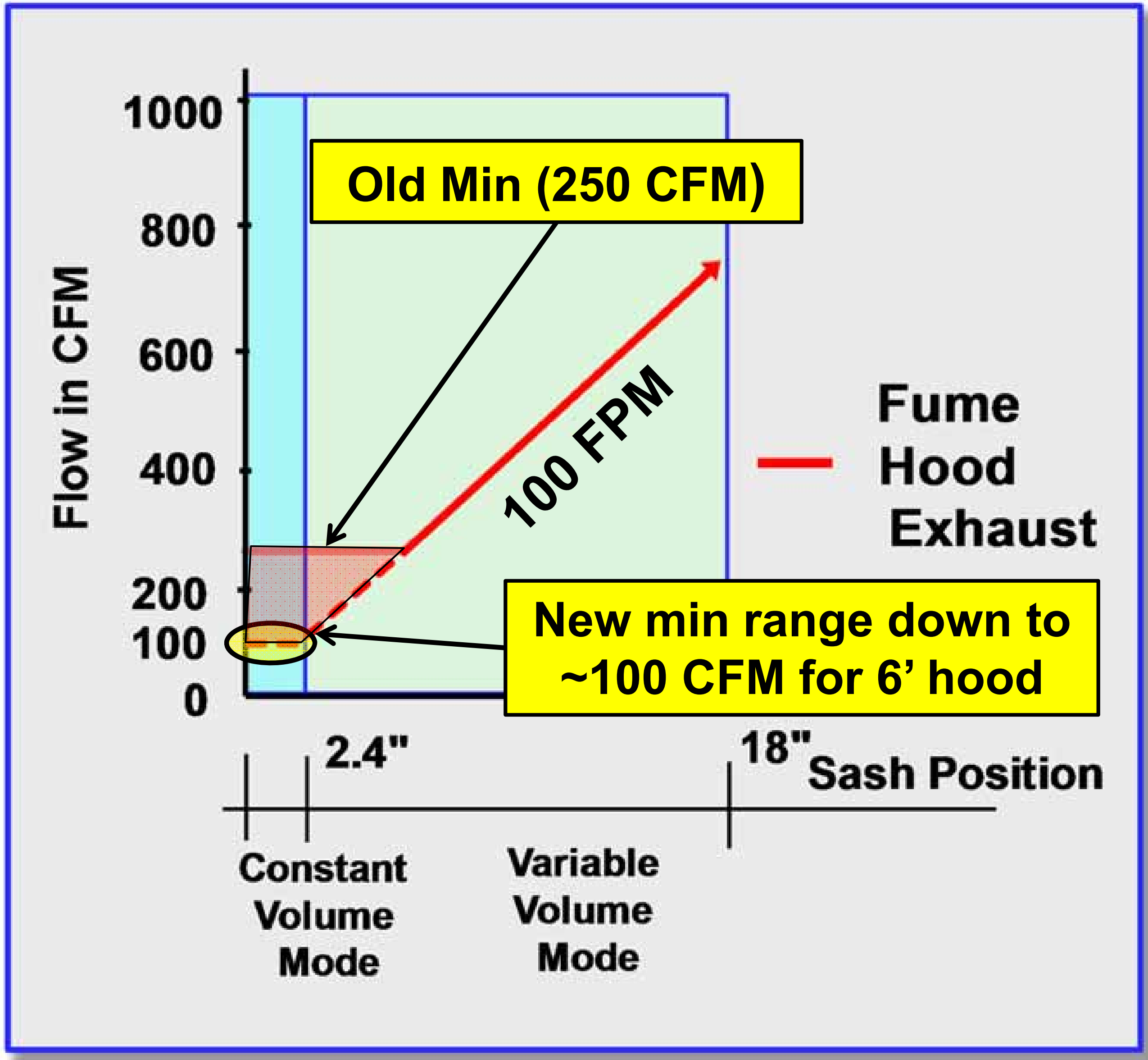


What is the Fume Hood Minimum Flow Rate?



- **Fume Hood Min:**
  - ✓ For VAV hoods
  - ✓ Only affects hood flow for small or closed sash positions
  - ✓ Independent of face velocity
  - ✓ Changing min will <u>not reduce</u> face velocity

What is the VAV Fume Hood Minimum Flow Rate?



- Fume Hood Min:
  - ✓ For VAV hoods
  - ✓ Only affects hood flow for small or closed sash positions
  - ✓ Independent of face velocity
  - ✓ Changing min will not reduce face velocity

Dual Lab Module Min Hood Flow Savings Ex.

- **Assumes control devices are properly sized for flows**
  - ✓ **Also assumes $7.50 cfm/yr. & sashes are closed 70% of time**
- **Lab Case 1 – Old hood min:**
  - ✓ **600 sq. ft by 10 ft ceiling w/ two 6' hood min flows at 250 cfm**
  - ✓ **Minimum ACH = (250 X 2) / (600 X 10/60) = 5.0 ACH min**
- **Lab Case 2 – New hood min:**
  - ✓ **Same as above but w/hood min flows at 100 cfm**
  - ✓ **Min achievable ACH = (100 X 2) / (600 X 10/60) = 2.0 ACH min**
- **Savings is approximately 300 cfm max or 210 cfm avg.**

Energy savings impact of lower min is $1575/yr or $2.63/ sq. ft

Reducing the Fume Hood Flow Drivers

- For *low* fume hood density:
  - ✓ Use VAV hoods, low FV not required
  - ✓ Helpful to use 18" design opening
  - ✓ For poor sash behavior, use sash closers
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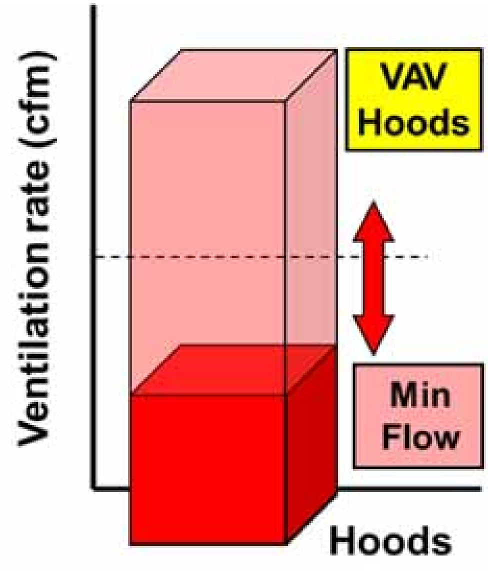

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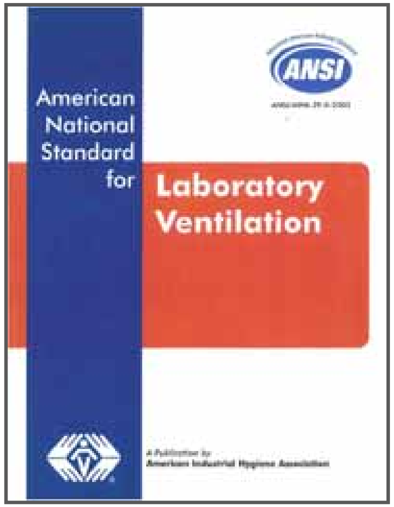
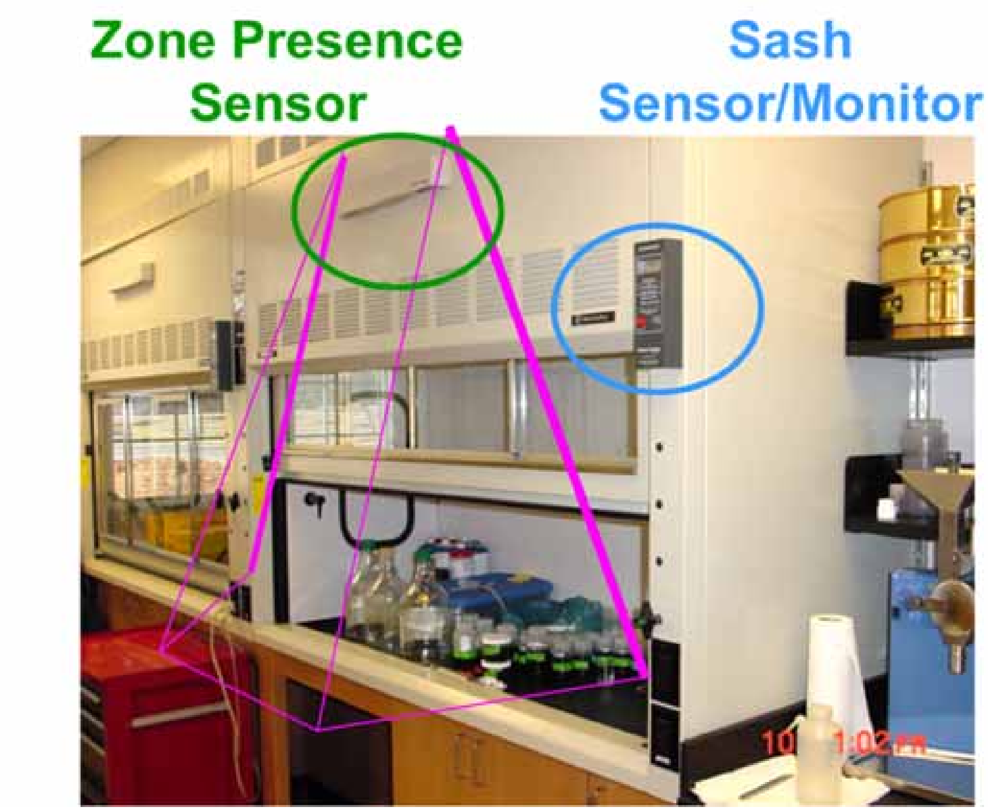


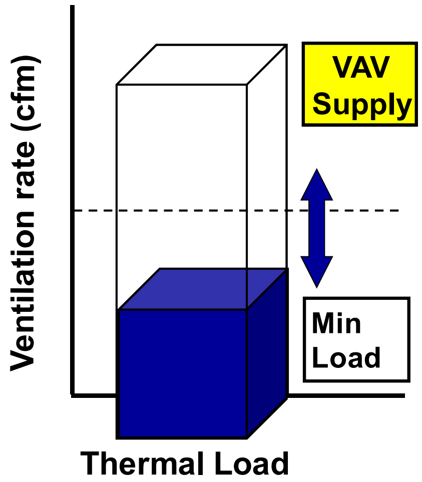
Another Approach to Reduce Hood Airflow

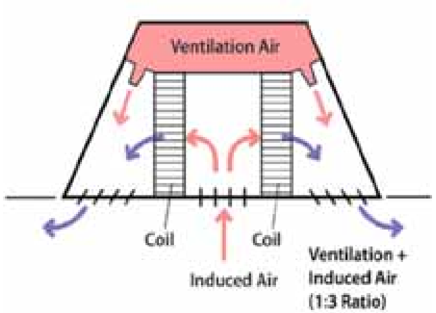
- **Consider fume hood occupancy sensors:**
  - ✓ **Also known as Zone presence sensors**
  - ✓ **Hood face velocity reduced from 0.5 m/s to 0.3 m/s**
    - – *Velocity drops when user walks away and rises when using hood*



Reducing the Thermal Load Flow Drivers

- **Labs 21 & UC Davis study:**
  - ✓ **Avg plug & lighting load: 2.5 to 3 W/ft^2**
  - ✓ **<u><</u>20% of labs may have loads >4 W/ft^2**
- **For these typical avg. rooms:**
  - ✓ **Daytime: Normal thermal loads <u><</u> 4ACH**
  - ✓ **Nighttime: Use temp setback to hit 2ACH**
- **For more flexibility & efficiency**
  - ✓ **Decouple thermal & air flow requirements**
    - *Use chilled beams or hydronic cooling*
  - ✓ **Often can provide first cost advantages**





Although not required, hydronic cooling/chilled beams have many advantages when coupled w/ low ACH design

Reference for Thermal Load Data

- **UC Davis – LBNL Study**
  - ✓ HPAC Article (Sept & Oct, 2005)
- **Measured plug loads in labs**
- **Lighting, solar, people may add another ~ 1 w/sf**

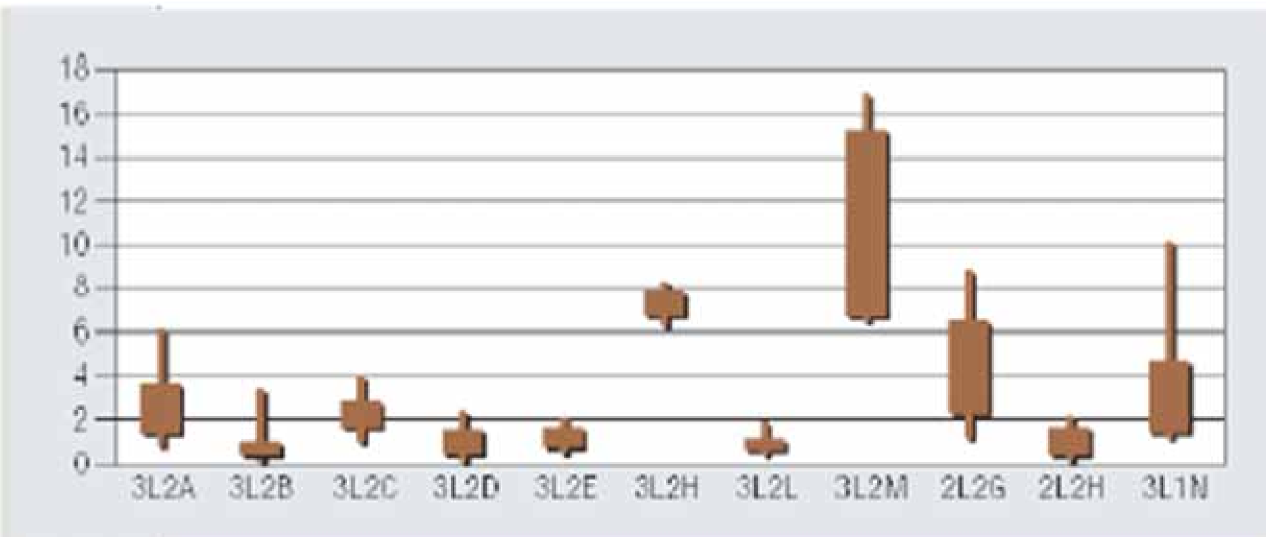
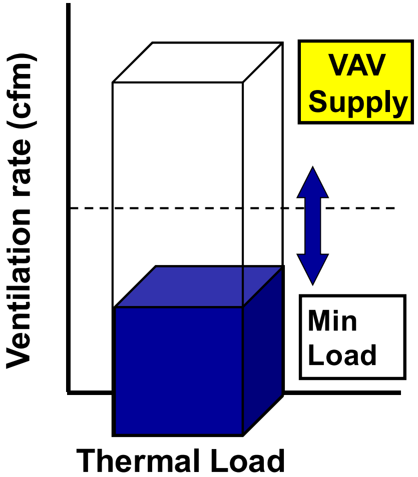
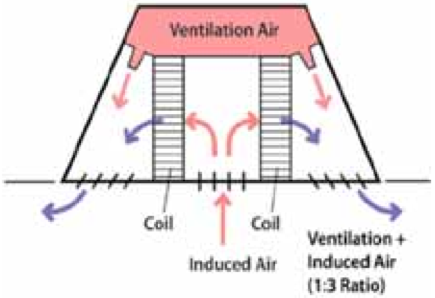


FIGURE 5. Equipment loads measured in 15-min intervals. The top and bottom edges of the boxes represent the 99th and first percentiles of the measurements, respectively, while the ends of the upper and lower lines represent maximum and minimum, respectively.

Reducing the Thermal Load Flow Drivers

- Labs 21 & UC Davis study:
  - ✓ Avg plug & lighting load: 2.5 to 3 W/ft^2
  - ✓ ≤20% of labs may have loads >4 W/ft^2
- For these typical avg. rooms:
  - ✓ Daytime: Normal thermal loads ≤ 4ACH
  - ✓ Nighttime: Use temp setback to hit 2ACH
- For more flexibility & efficiency
  - ✓ Decouple thermal & air flow requirements
    - *Use chilled beams or hydronic cooling*
      - Fan coil units, radiant ceilings, etc.
  - ✓ Often can provide first cost advantages

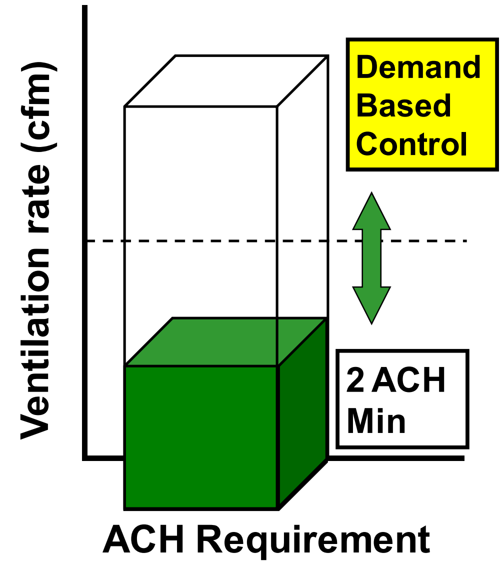




Hydronic cooling/chilled beams have many advantages when coupled w/ low ACH design

Reducing the ACH Rate Flow Drivers:

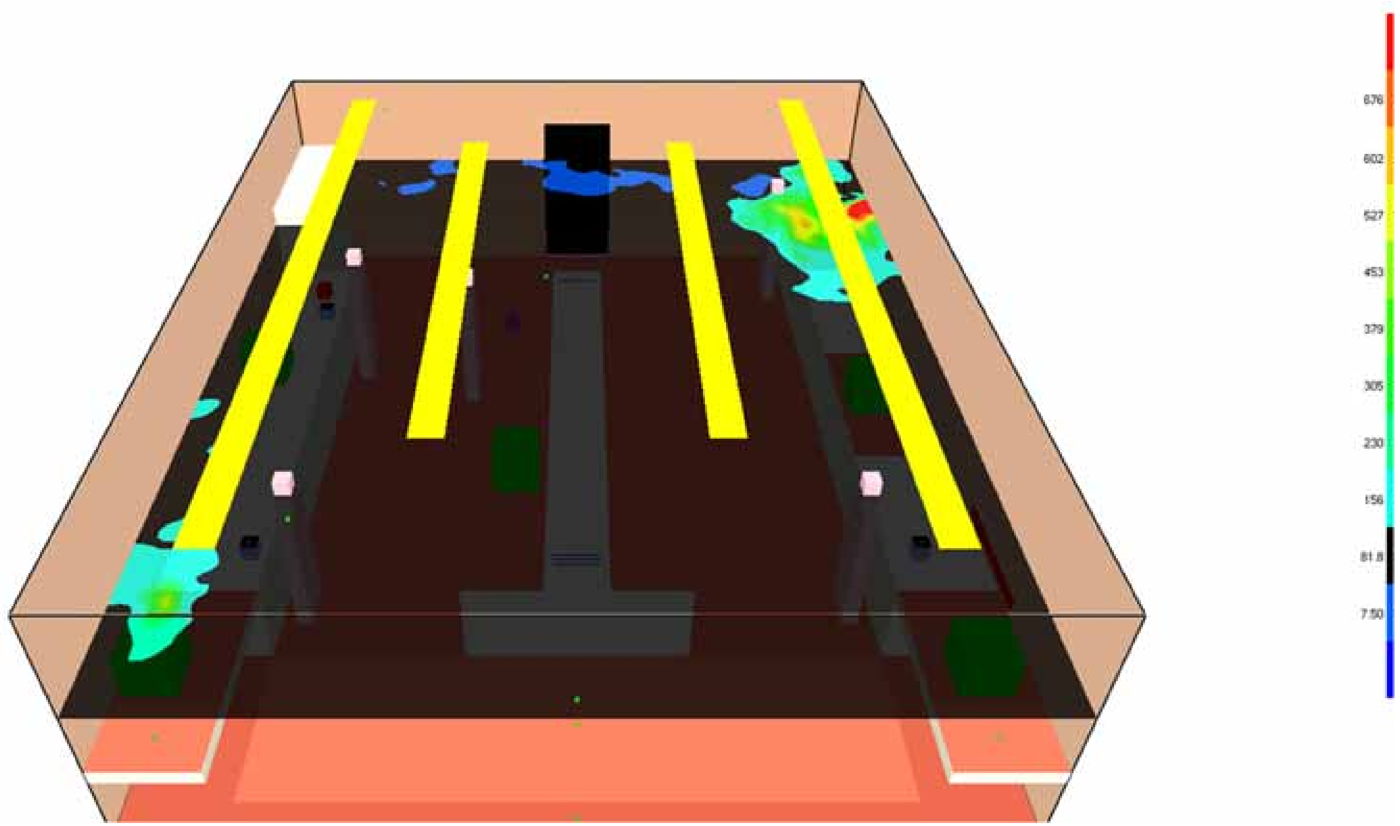
- **One approach to reduce airflow:**
  - ✓ Reduce airflow slightly during unocc. periods
  - ✓ For example 8 ACH occ. and 6 ACH unocc.
- **This has been used, but is it really safe?**
- **Standards and codes have been changing**
  - ✓ NFPA 45-2011: 8 Occ/4 Unocc rates removed
- **2011 ASHRAE Handbook, Lab chapter 16:**
  - ✓ Occ/Unocc Control scope is being limited:
  - ✓ "There should be no entry into the laboratory during unoccupied setback times"
  - ✓ "…Occupied ventilation rates should be engaged possibly one hour or more in advance of occupancy to properly dilute any contaminants."



Occ/Unocc control best used only when lab room access can be controlled

Impact of Higher Air Changes

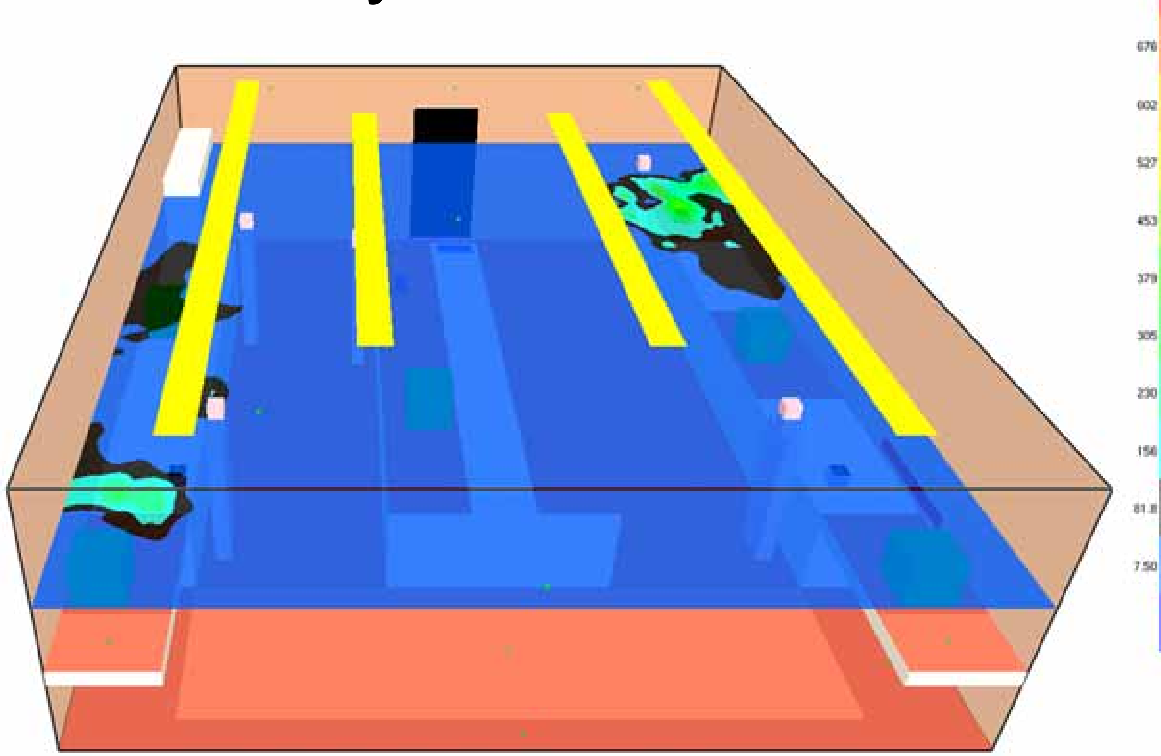
- **Test Case– Teaching Lab**
- **Acetone at 4 ACH**
- **CFD courtesy of Glenn Schuyler's ASHRAE Presentation**



Relative contaminant level: 27 PPM (black)

Impact of Higher Air Changes

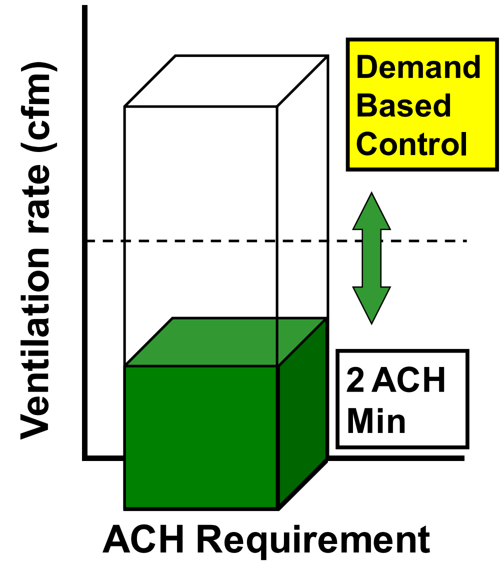
- Test Case– Teaching Lab
- Acetone at 8 ACH
- CFD courtesy of Glenn Schuyler's ASHRAE Presentation

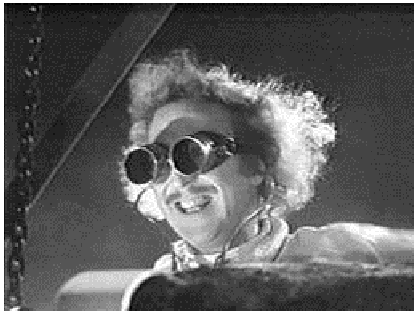


Relative contaminant level: 2.5 PPM (light blue):
Factor of 10 improvement!

Reducing the ACH Rate Flow Drivers:

- **Min lab ACH often fixed at 6-12 ACH**
  - ✓ **Typically becomes largest energy driver**
- **However, lab air is clean > 98% time**
- **But, events happen requiring >6ACH**
  - ✓ **Eliminate fugitive vapors**
  - ✓ **Dilute vapors or particles from spill or:**
    - – *Working outside the hood, improper storage*
    - – *No localized exhaust for instruments*
- **Often little basis for an ACH rate**





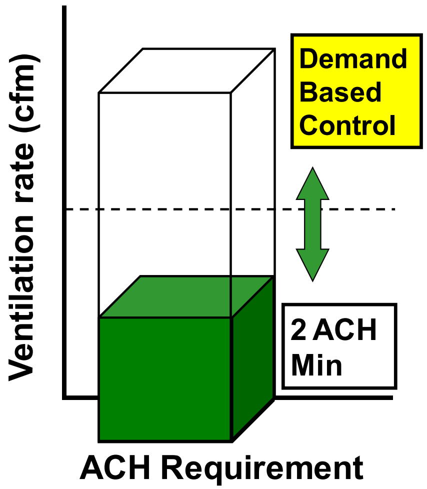
The "human" factor

There is no one ventilation rate that is right all the time:

A more scientific, evidence based approach is needed!

Varying the ACH Rate w/ Demand Based Control

- **Demand Based Control (DBC or CDCV)**
  - ✓ Reduces lab airflow when lab air is "clean"
  - ✓ Increases lab flow when pollutants sensed
- **Fixed min ACH is always too high or low**
- **Equal or better safety w/ the *Best* airflow**
  - ✓ When needed flow can be upped to 8-16 ACH
- **Clean flow setting of 4/2 ACH is typical**
  - ✓ 4/2 ACH best done as day/night vs. occ/unocc
  - ✓ Other approaches: 3/3, 3/2 or 2/2 also used



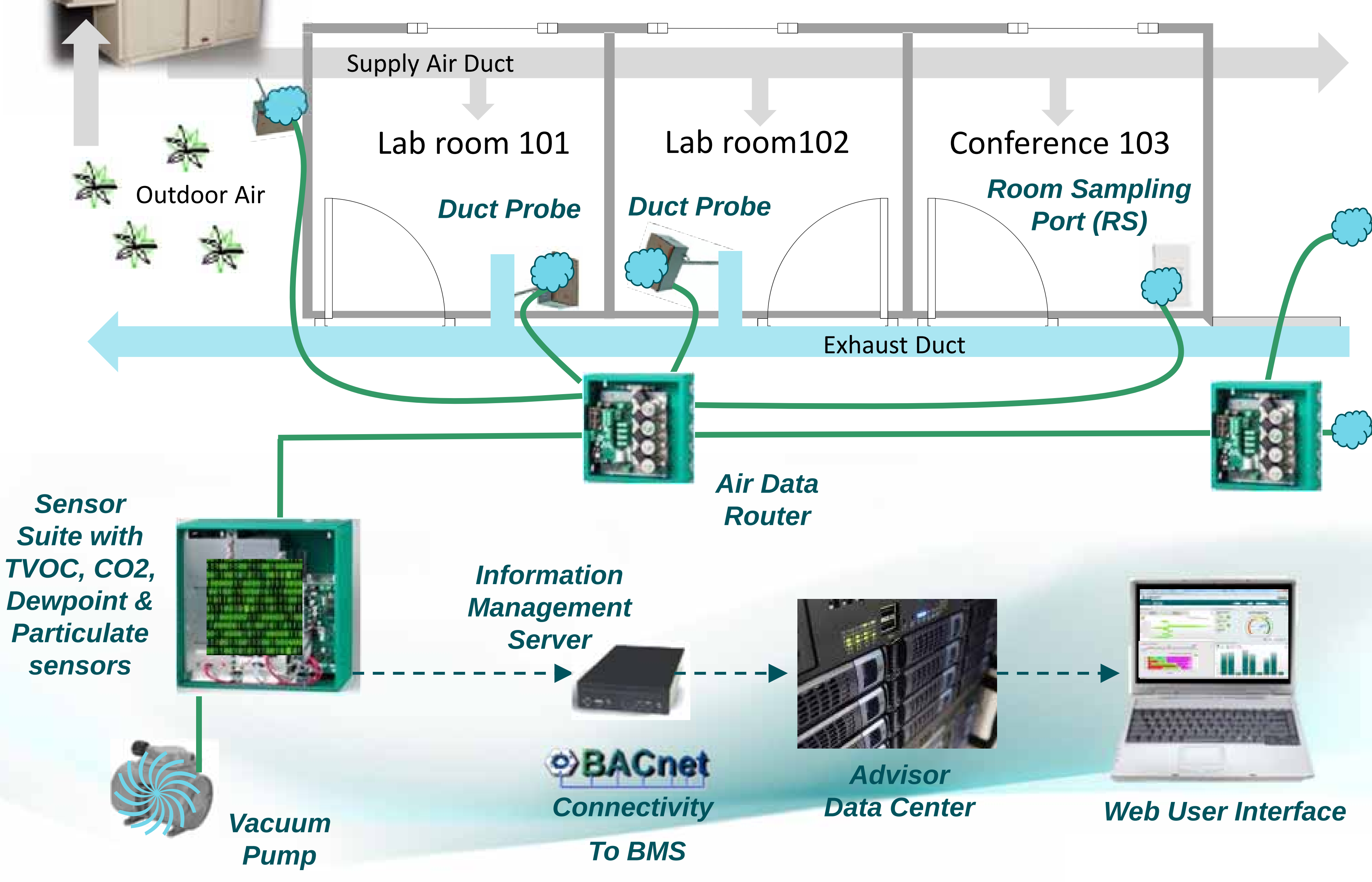
An energy efficient means to purge at 15 ACH *AND*
A safe means to run at 4 to 2 ACH

A Solution: Demand Based Control (CDCV, DBC, etc.)

- Vary dilution/ min ACH's by sensing room IEQ
  - ✓ If room air is clean, dilution airflow can be reduced
  - ✓ If contaminants are sensed, more airflow is provided
- Most lab controls can vary min ACH levels
- Critical piece: Sensing of IEQ parameters:
  - ✓ Lab TVOC's, particles, ammonia, RH, CO, & CO2
- Barriers to date: Cost effectivity & practicality
  - ✓ Sensor cost, long term reliability, & calibration exp.

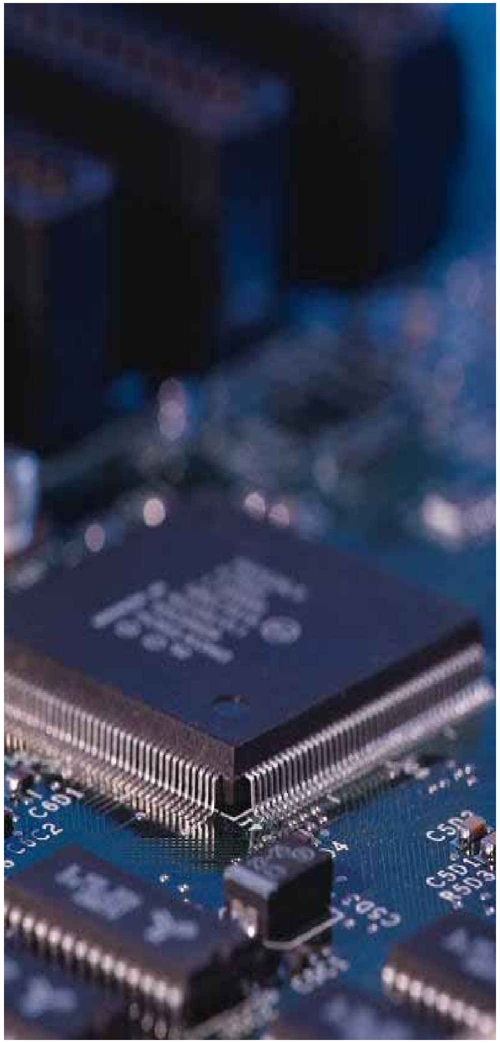
A new cost effective sensing concept is required

Multiplexed Sensing Technology Solution

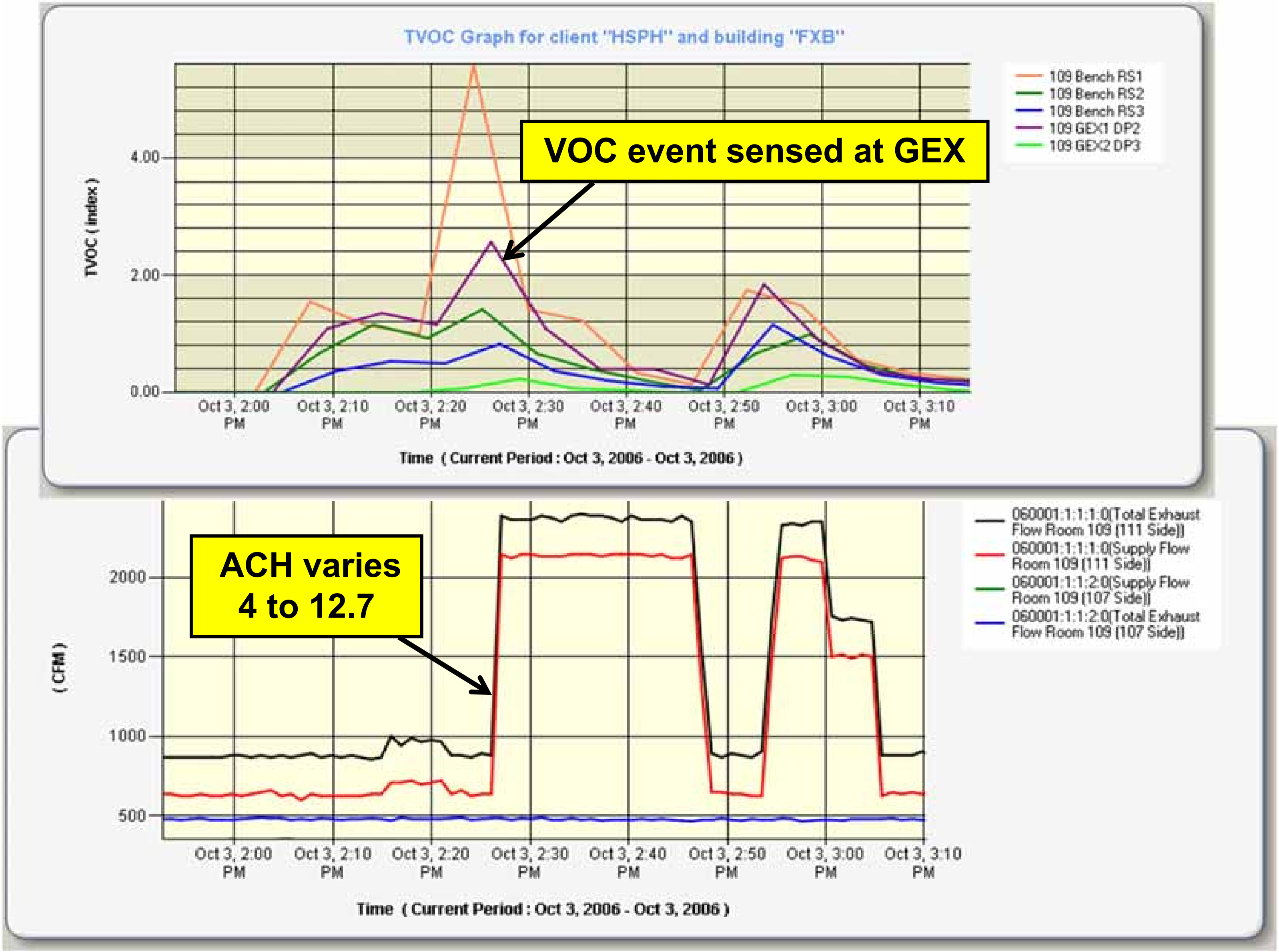


Sensed Parameters

- **Air Cleanliness**
  - ✓ **Total Volatile Organic Compounds**
    - *Photo-Ionization Detector & Metal Oxide Sensor*
  - ✓ **Particles – laser based particle counter**
  - ✓ **Carbon Monoxide (CO)**
- **Comfort &Ventilation**
  - ✓ **Temperature**
  - ✓ **Humidity or Dewpoint**
  - ✓ **Carbon Dioxide (CO_2)**



Normal Lab Operation w/ Dynamic Control



Sensing Lab IEQ Also Helps Ensure Lab Safety

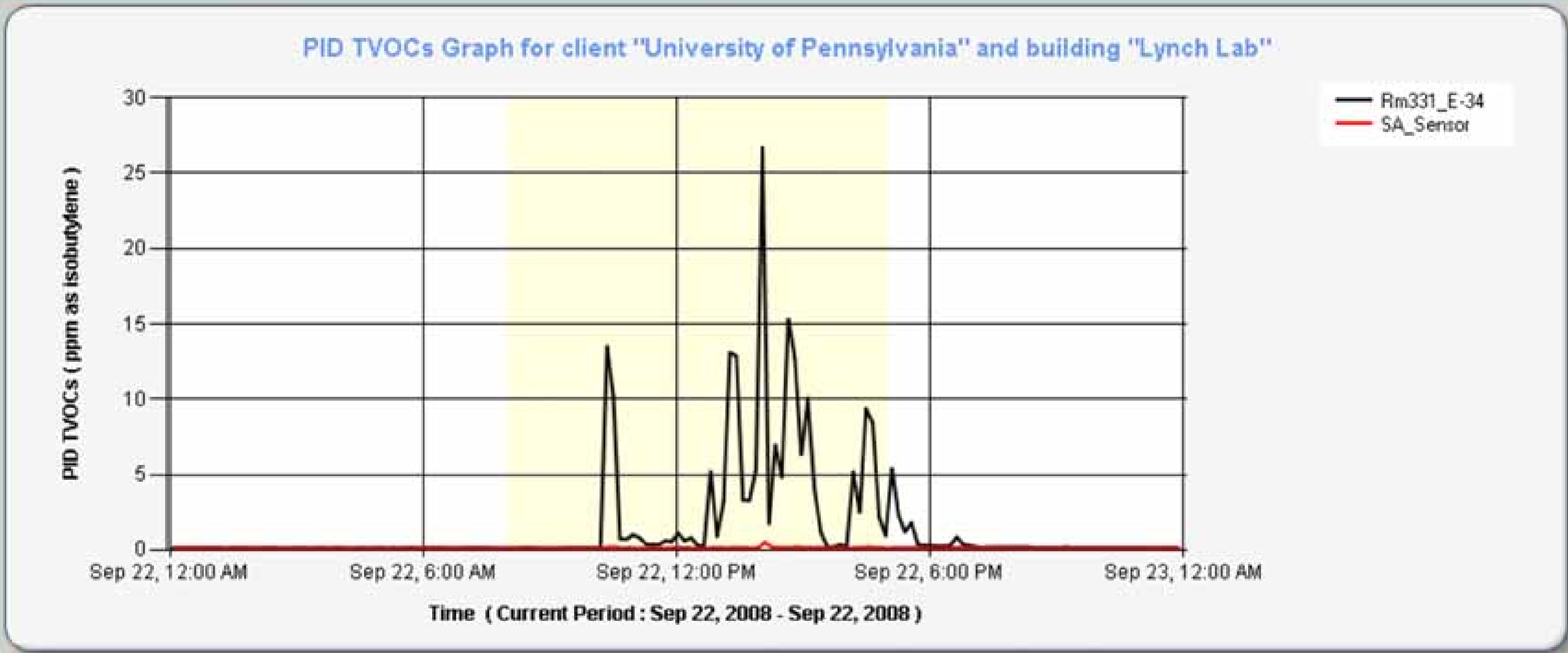
- **Validates the safe operation of a lab**
  - ✓ Detect improper bench use of chemicals
  - ✓ Detect poorly containing fume hoods
  - ✓ Spills & rogue reactions rapidly sensed
- **Allows for safer lab airflow control**
  - ✓ Better hood capture from reduced drafts
  - ✓ Greater dilution provided for spills, leaks, etc.
- **Sources of leaks & emissions can be found**
  - ✓ With fact based data, source control can be used

This system is *NOT* a replacement for using hoods for containment or emergency spill procedures!

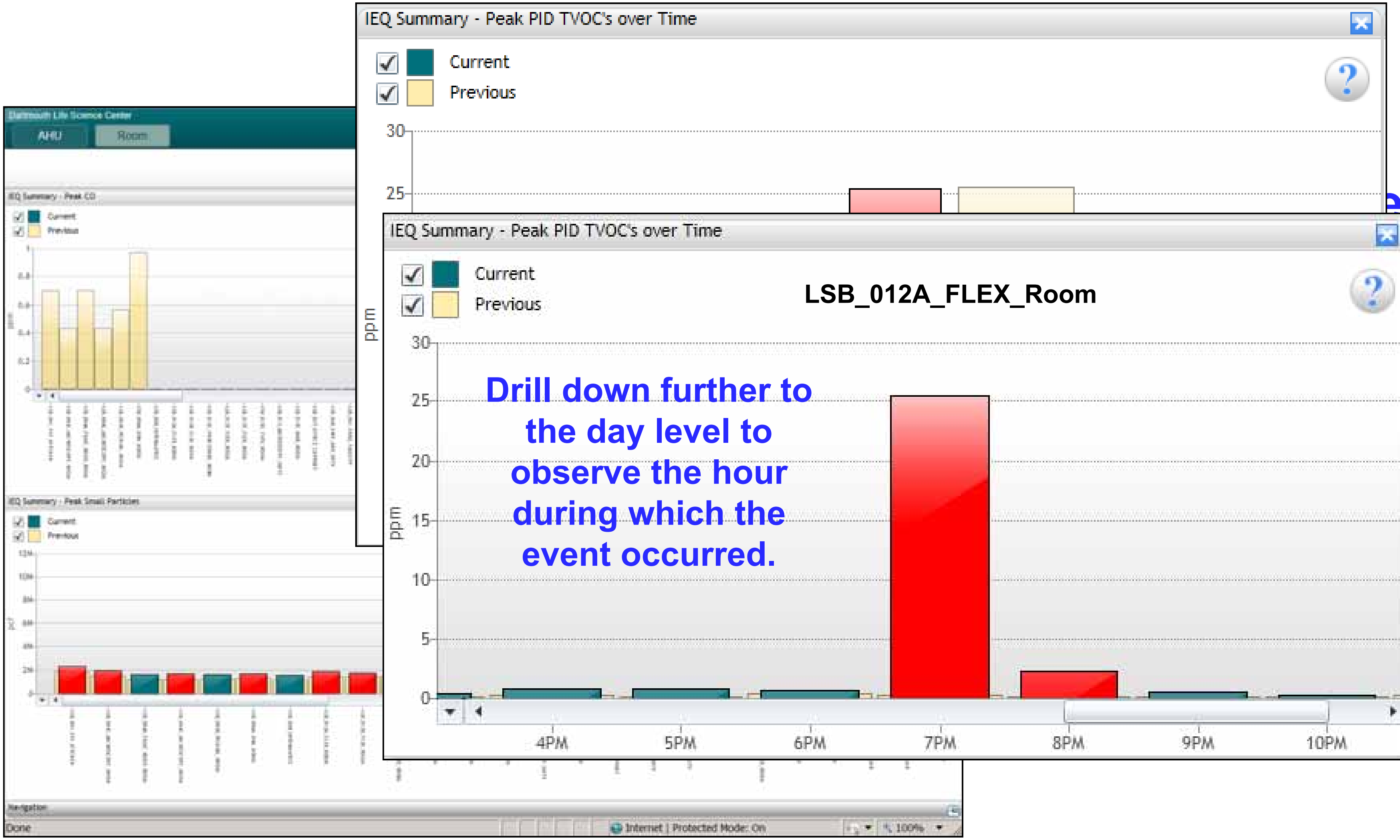
Detection of Improper Lab Practices: **Lynch Life Sciences Labs**

The graph below illustrates what happens to the TVOC levels in a lab when a researcher **improperly vents his experiment**.

A researcher in lab 331 was sticking the exhaust of his mass-spec. into the local snorkel exhaust , then pinched it off with the blast gate. This created elevated TVOC levels in the lab.



Lab IEQ Data can also be Analyzed & Managed



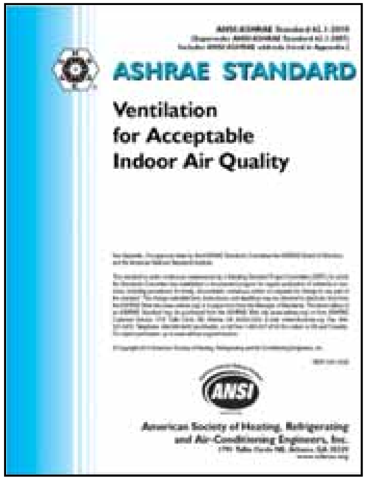
However, Demand Based Control is Not ....

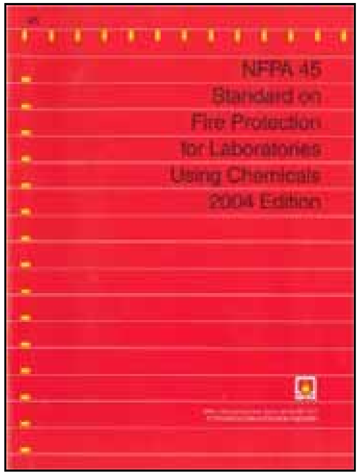
- DBC & its lab IEQ sensing is ***NOT a:***
  - ✓ Toxic gas sensing system
  - ✓ Personal exposure monitoring system
  - ✓ Replacement for fume hood use
  - ✓ Replacement for emergency spill procedures

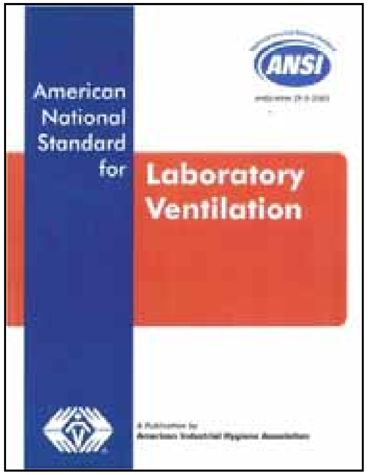
Demand Based Control is a safe energy saving system….
that also has some additional safety benefits

Industry Recommendations on ACH Rates

- **No codes other than ASHRAE 62.1**
  - ✓ **At best for Univ/college labs: 1.2 ACH fresh air**
- **Most fixed ACH values are being dropped:**
  - ✓ **NFPA 45 - 2011: 8 Occ / 4 Unocc rates were removed**
  - ✓ **ANSI Z9.5 does not advocate for any fixed rate:**
    - *"An air exchange rate (air changes per hour) cannot be specified that will meet all conditions."*







Industry Recommendations on ACH Rates & DBC

- **2011 ASHRAE Handbook, Lab chapter 16:**
  - ✓ **…recent university research (Klein et al. 2009) showed a significant increase in dilution and clearing performance by increasing the air change rate from 6 to 8 ach with diminishing returns above 12 ach.**
  - ✓ **…This information indicates that minimum ventilation rates at the lower end of the 6 to 12 air change per hour range may not be appropriate for all laboratories.**
  - ✓ **…As the operation, materials, and level of hazard of a room change, an increase or decrease in the minimum ventilation rate should be evaluated.**
  - ✓ **…Active sensing of the air quality in individual laboratories is an alternative approach for dealing with the variability of appropriate ventilation rates, particularly when energy efficiency is important or when less may be known about the hazard level.**

**Using a single ACH rate such as 6 ACH is not appropriate.
Yale research shows a significant difference from 6 to 8 ACH.**

ASHRAE Handbook Provides New Guidance

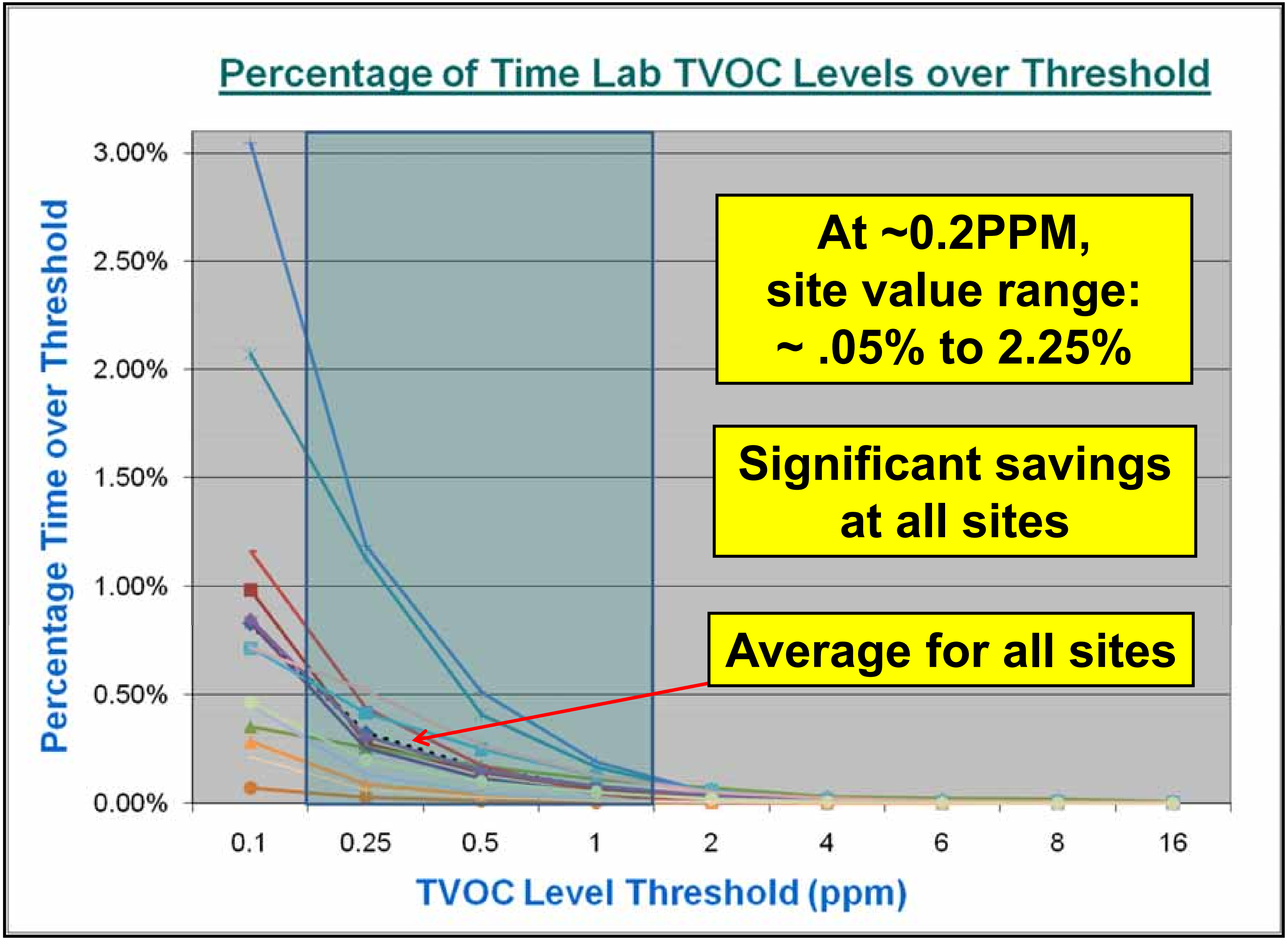
- **New 2011 ASHRAE Handbook, Lab chapter 16:**
  - ✓ **Active/Demand Based Control is recommended:**
    - *"Reducing ventilation requirements in laboratories and vivariums based on real time sensing of contaminants in the room environment offers opportunities for energy conservation."*
    - *"This approach can potentially reduce lab air change rates down safely to as low as 2 air changes per hour when the lab air is 'clean'..."*

2008 Lab IEQ Performance Monitoring Study

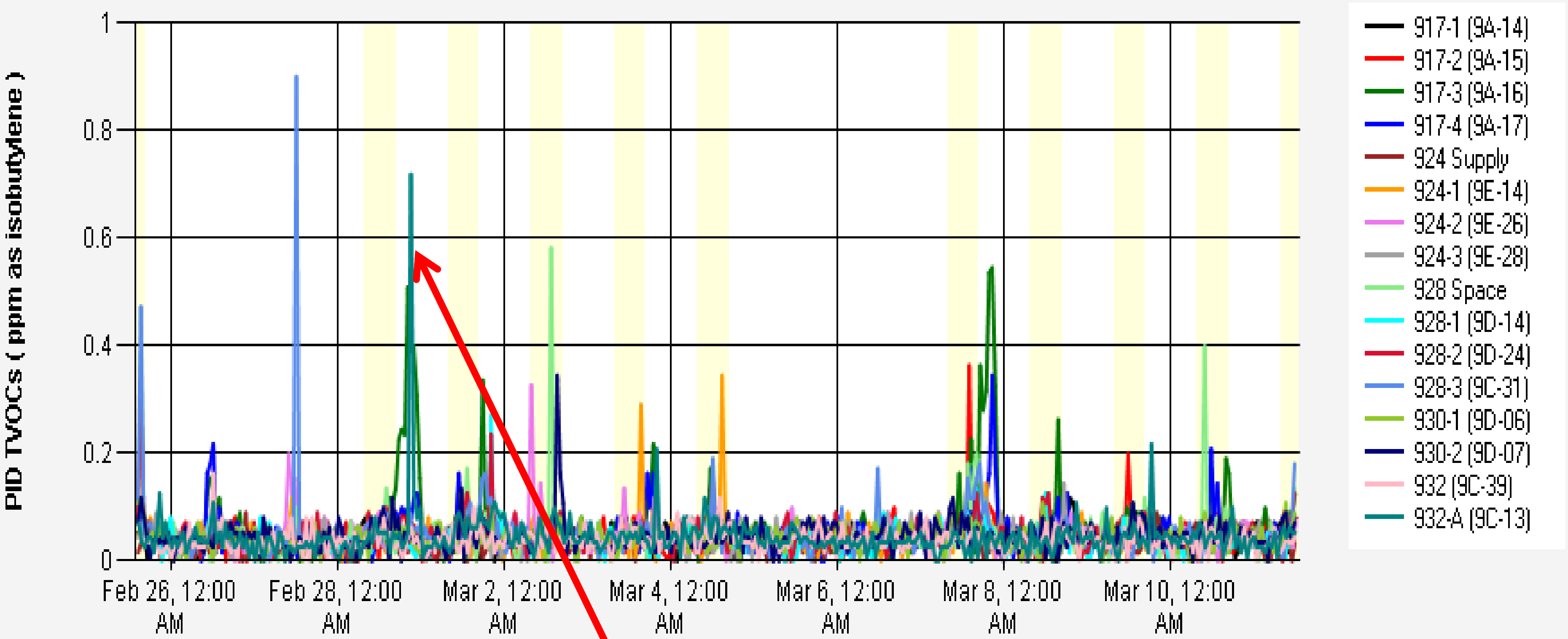
- Largest known study done to date
  - ✓ 1,500,000 lab operating hours analyzed
  - ✓ 20 Million sensor data values recorded
- 18 different sites selected
  - ✓ 6 East, 7 Central, 3 West, 2 Canada
- Over 300 different lab areas
  - ✓ Research: Life sciences, bio, physical chem, etc
  - ✓ Almost all low density labs w/ dynamic control
  - ✓ 3 animal facility sites

*ASHRAE Journal Feb 2010

Average TVOC Levels at 18 Different Sites



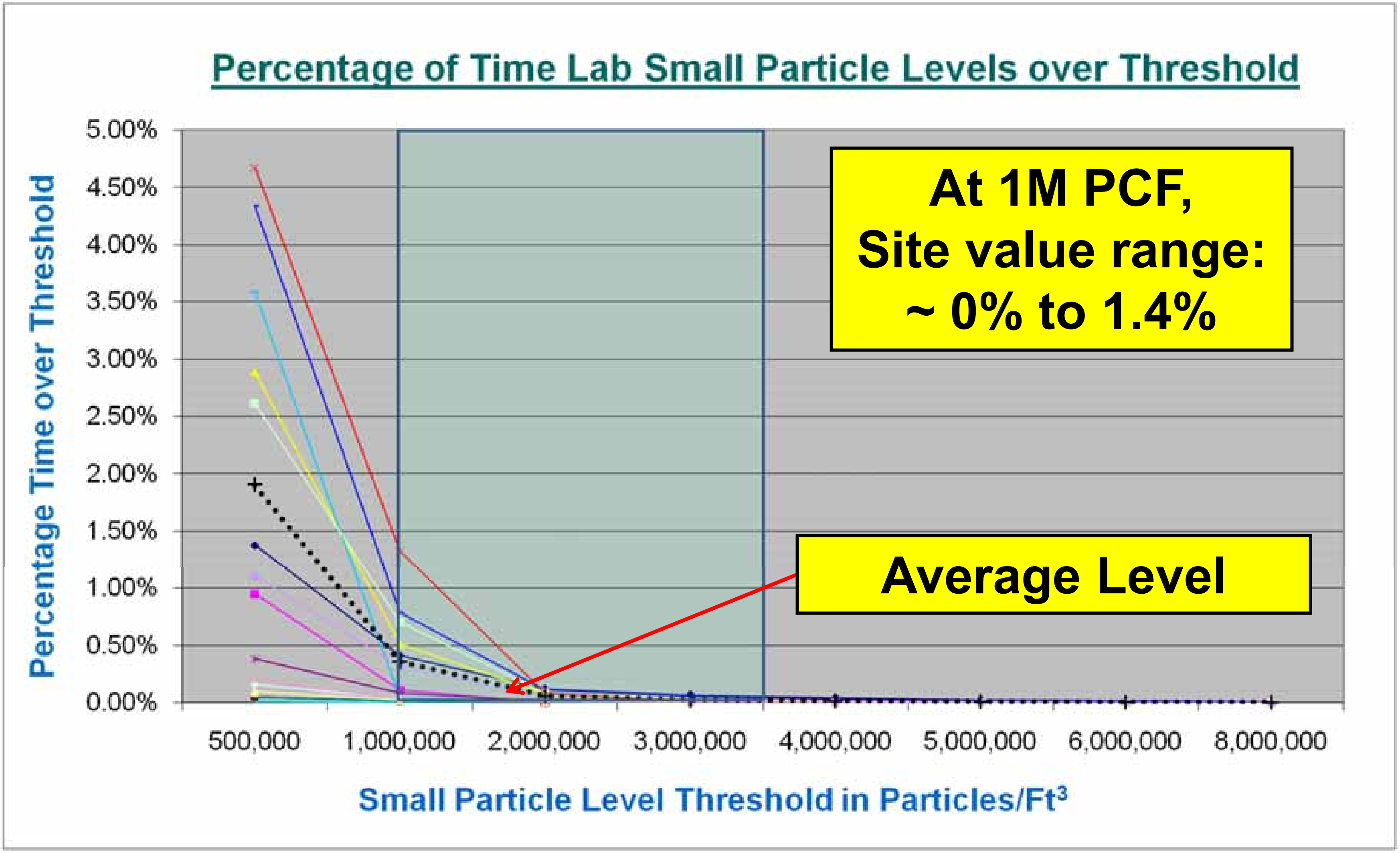
Typical Lab Operation – 2 weeks of TVOCs



Illustrates common "minor" excursions of TVOCs where higher ACH are commanded

Majority of time TVOC's are at or below even 0.1 ppm

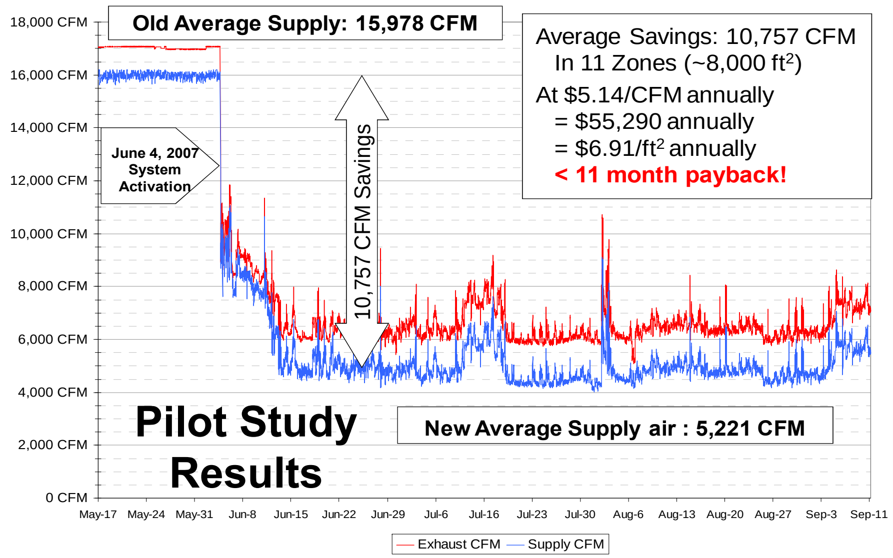
Avg. Differential Particle Levels at 18 Sites



Data shows significant savings at all sites

Lab Case Study: Arizona State University

- **ASU Biodesign Institute Bldgs A & B Retrofit**
  - ✓ Retrofit of Labs and Vivarium
- **LEED® NC Platinum, R&D 2006 Lab of the Year**
  - ✓ Lab DCV pilot in 2007 to look for EE: 65% savings achieved
  - ✓ Full building retrofitted in 2009: $1 Million saved annually
  - ✓ Currently 24 buildings have been retrofitted:
    - *Office, classroom, library, sciences bldgs, sports arena & others*



University Of California Irvine Case Study

Hewitt Hall: Designed in 2001

- Exceeded Title 24 by 23.7%
- Biomedical research
- Re-Commissioned in 2010
- 8 ACH fixed minimum
- 76,905 Square Feet

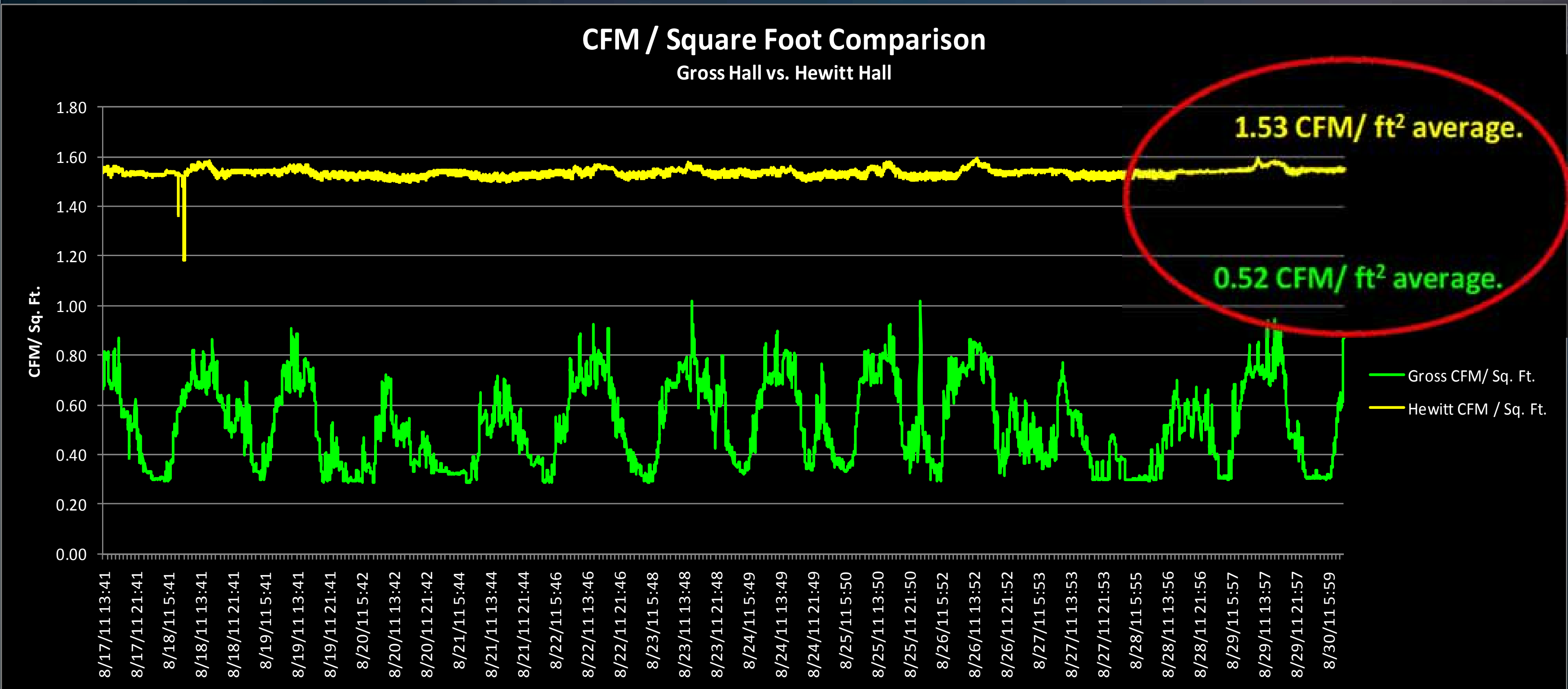
Gross Hall: Designed in 2009

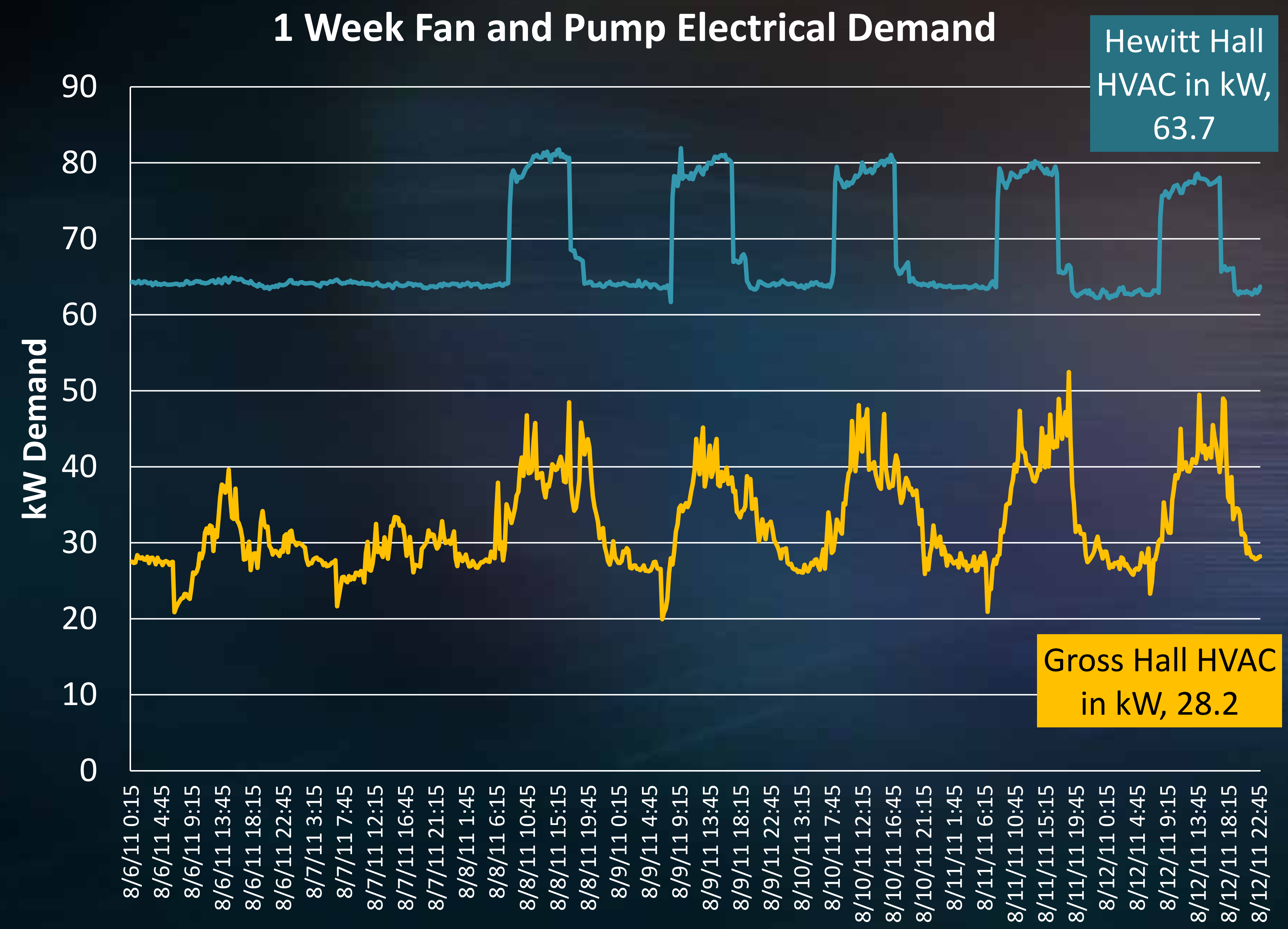
- Exceeded Title 24 by 50.3%
- Biomedical Research
- Submitted: LEED Platinum
- DBC: 4/2 ACH Occ/Unocc
- 94,705 Square Feet

Both buildings similar in layout, function, & use

Lab Air Flow vs. Time For Both Bldgs

Significant DBC energy savings of ~1 CFM/ft2





1 Week Fan and Pump Electrical Demand
Hewitt Hall HVAC in kW, 63.7
Gross Hall HVAC in kW, 28.2
kW Demand
90
80
70
60
50
40
30
20
10
0
8/6/11 0:15
8/6/11 4:45
8/6/11 9:15
8/6/11 13:45
8/6/11 18:15
8/6/11 22:45
8/7/11 3:15
8/7/11 7:45
8/7/11 12:15
8/7/11 16:45
8/7/11 21:15
8/8/11 1:45
8/8/11 6:15
8/8/11 10:45
8/8/11 15:15
8/8/11 19:45
8/9/11 0:15
8/9/11 4:45
8/9/11 9:15
8/9/11 13:45
8/9/11 18:15
8/9/11 22:45
8/10/11 3:15
8/10/11 7:45
8/10/11 12:15
8/10/11 16:45
8/10/11 21:15
8/11/11 1:45
8/11/11 6:15
8/11/11 10:45
8/11/11 15:15
8/11/11 19:45
8/12/11 0:15
8/12/11 4:45
8/12/11 9:15
8/12/11 13:45
8/12/11 18:15
8/12/11 22:45

UCI Now Engaged in Retrofitting 10 Bldgs to DBC

Laboratory Building	Before "Smart Lab" Retrofit		After "Smart Lab" Retrofit	
	Estimated Average ACH	VAV or CV	kWh Savings	Therm Savings
Croul Hall	6.6	VAV	41%	–
McGaugh Hall	9.4	CV	47%	66%
Reines Hall	11.3	CV	77%	77%
Natural Sciences II	9.1	VAV	48%	62%
Biological Sciences 3	9.0	VAV	45%	81%
CALIT2	6.0	VAV	46%	78%
Gillespie Neurosciences	6.8	CV	58%	81%
Sprague Hall	7.2	VAV	71%	83%
Hewitt Hall	8.7	VAV	58%	77%
Engineering 3	8.0	VAV	59%	78%
AVERAGES	**8.2**	**–**	**55%**	**76%**

DBC is the largest contributor (>50 to 75%) of savings!

Other Projects Using Demand Based Lab Control

- Acadia University
- Arizona State University
- Beth Israel Medical Center
- Chicago Botanic Garden
- Cal State Univ., Monterey
- Cal Tech
- Case Western Reserve Univ.
- Colorado Sch. Of Mines
- Children's Hospital of Phil.
- Dalhousie Univ.
- Dartmouth College
- Eli Lilly
- Ferris State University
- Food & Drug Admin. (FDA)
- Ferris State University
- Grand Valley State Univ
- Harvard (HSPH)
- Indiana/Purdue Fort Wayne
- LabCorp – BioRepository
- Masdar Institute (MIST)
- Michigan State University
- Midwestern University
- Ministère de l'agriculture,
- Montreal Heart institute
- Nevada Cancer Institute
- Ohio State University
- Oklahoma State University
- Rice University
- SUNY Stony Brook
- Texas Children's Hospital
- University of Cal Irvine
- University of Iowa
- University of Louisville
- University of Pennsylvania
- Univ. Health Network: MaRS
- Van Andel Institute

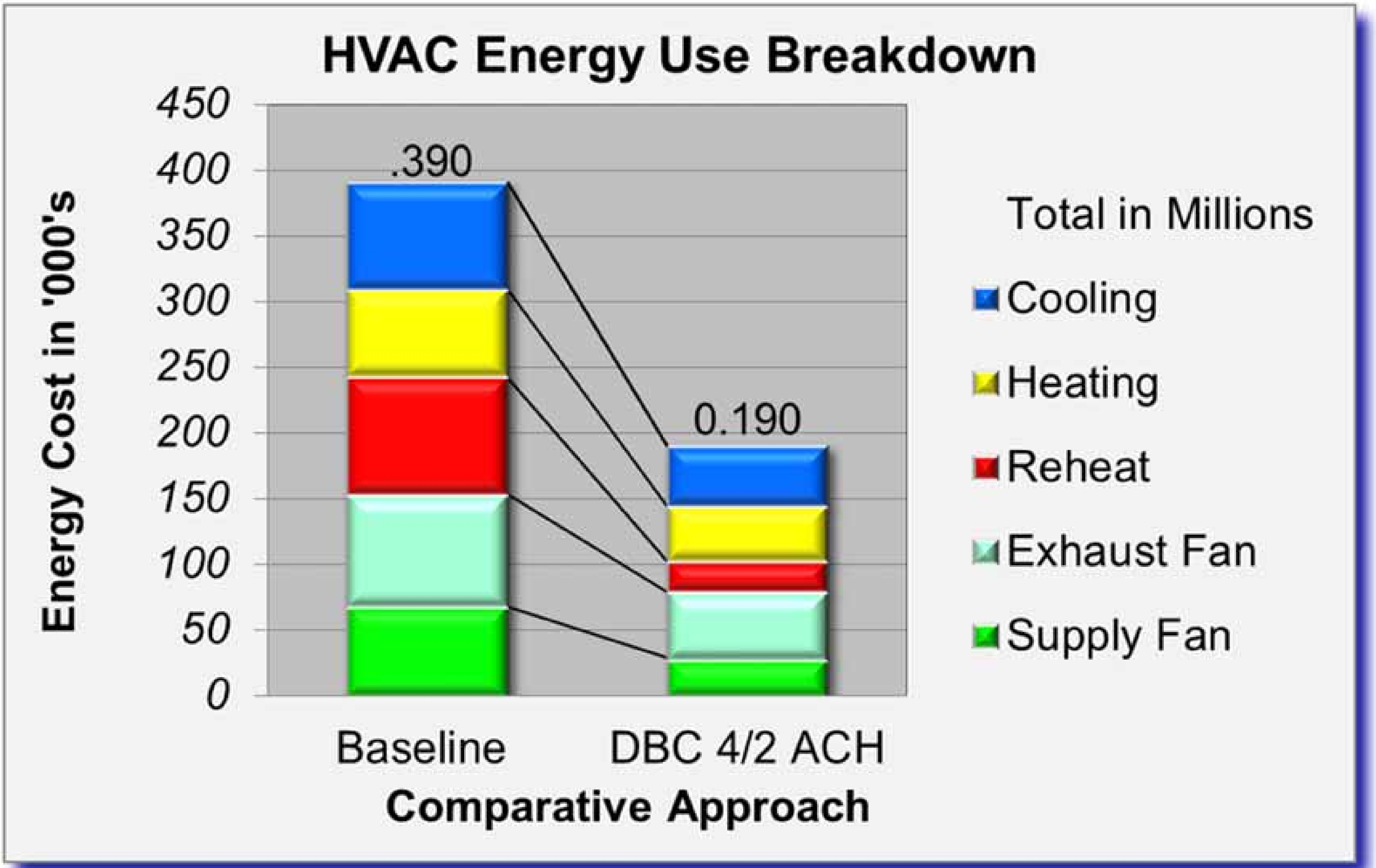
Univ. of Louisville: Bio Med 3

UPENN: Carolyn Lynch Lab

UPenn: TRC

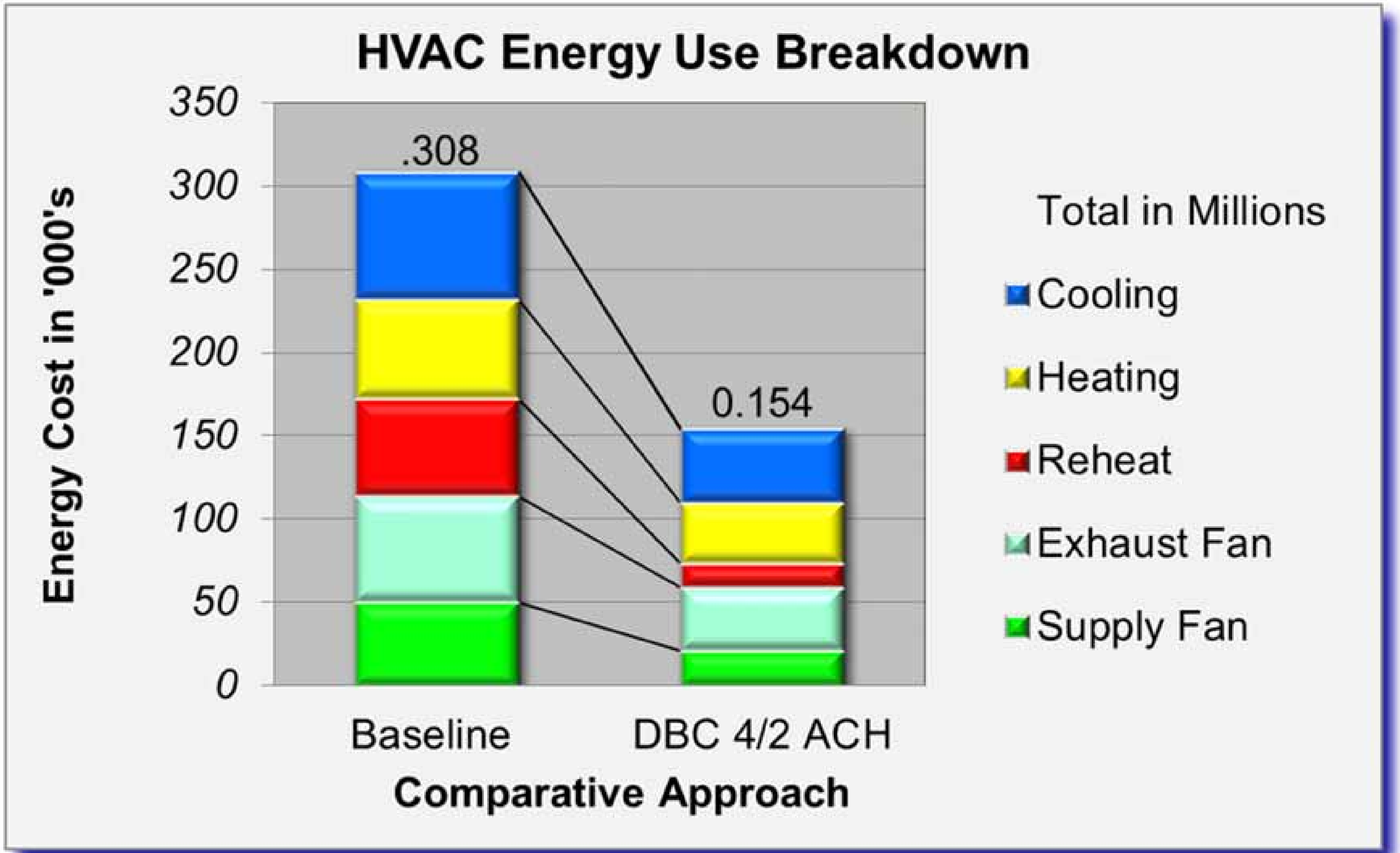
UPenn: "Demand Based Control is our #1 campus ECM"

DBC Energy Savings of 4 Day/2 Night ACH vs. 6 ACH



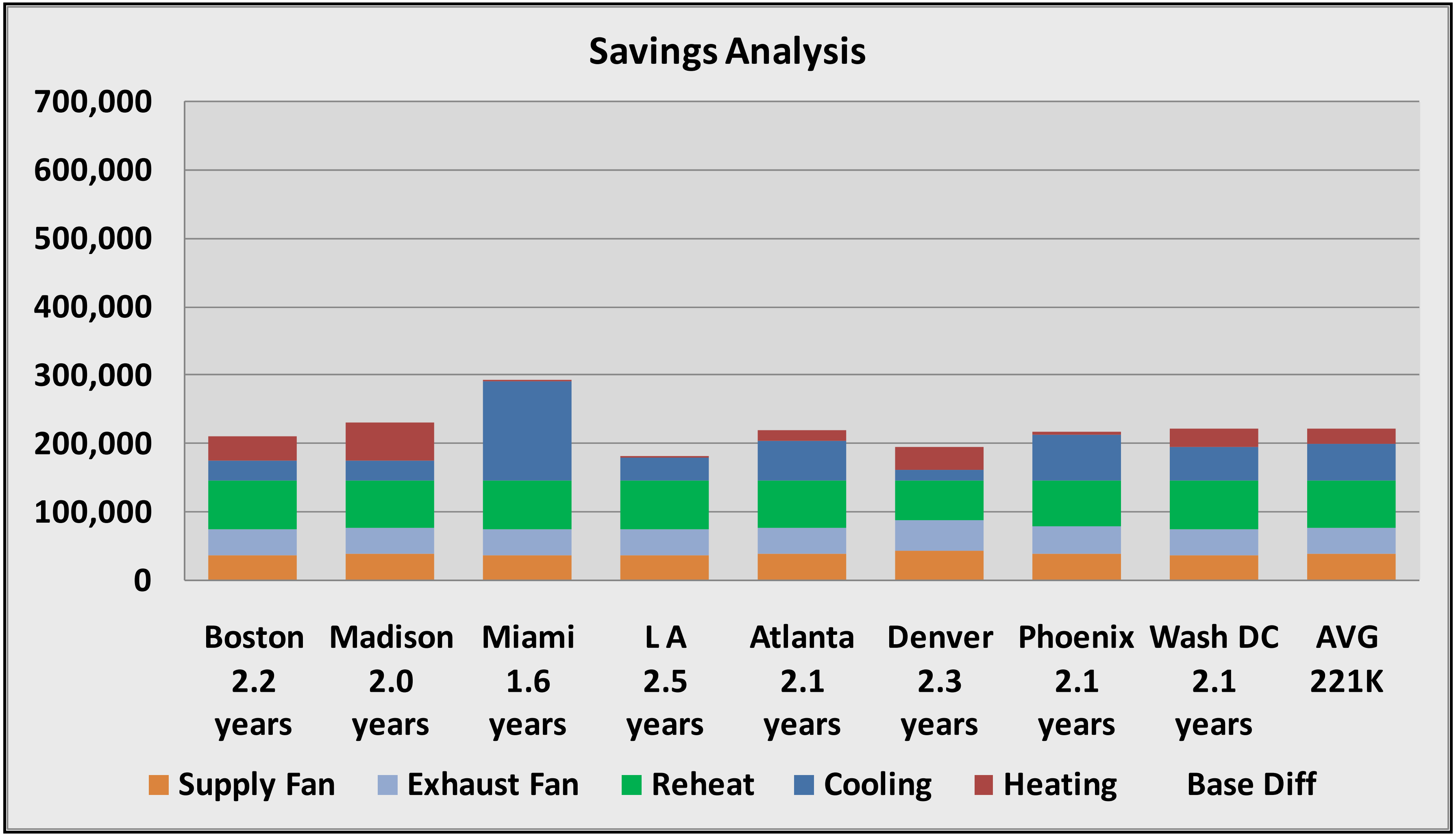
Demand Based Control reduces lab HVAC energy by $200K or by 51% vs. 6 ACH. Payback is 2.2 years.

DBC Energy Savings of 4/2 vs. 6 ACH for Des Moines



Demand Based Control reduces lab HVAC energy by $154K or by 50% vs. 6 ACH. Payback is 2.6 years.

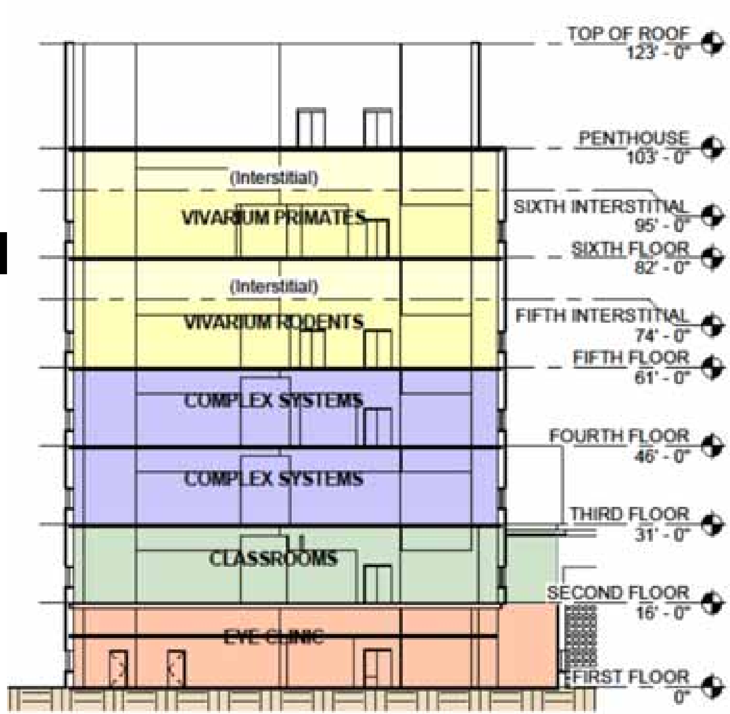
Demand Based Control w/ 4/2 ACH vs. 6 ACH



Average energy savings is $221K or 53% reduction

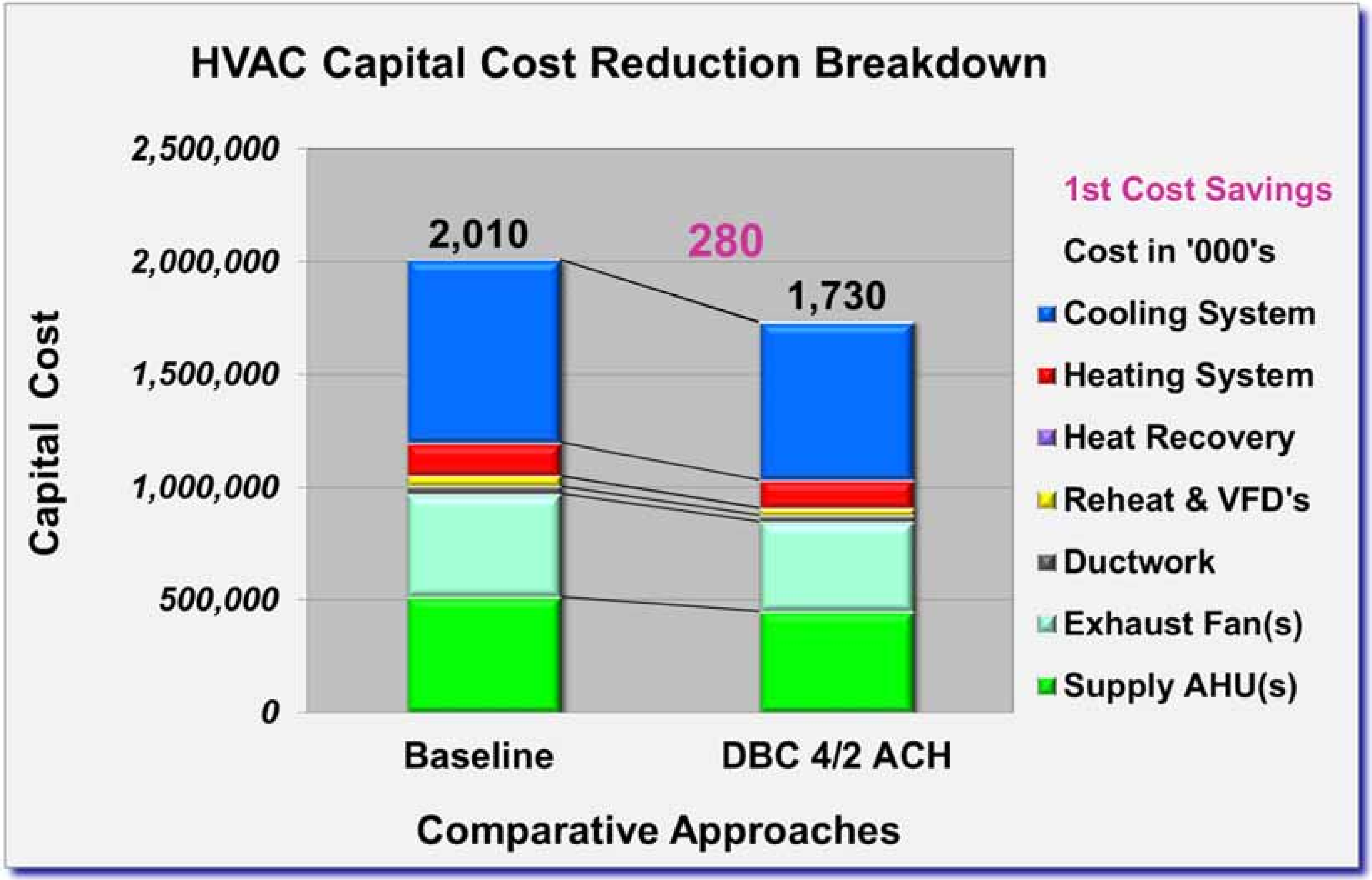
First Cost Saving at Univ. of Houston

- Health & Biomedical Sciences Center / Optometry
  - ✓ 6 Floors, ~150K sq. ft,
  - ✓ 71 labs, 37 vivariums & 24 non-lab zones
- Lab & Vivarium flows reduced:
  - ✓ Labs from 12 ACH to 4 ACH
  - ✓ Vivariums from 15 ACH to 9 ACH
- Installed cost : ~ $500K
- Est. energy savings ~ $250K/ yr
- 2.0 year payback: energy only
- First cost savings up to $1.0M!



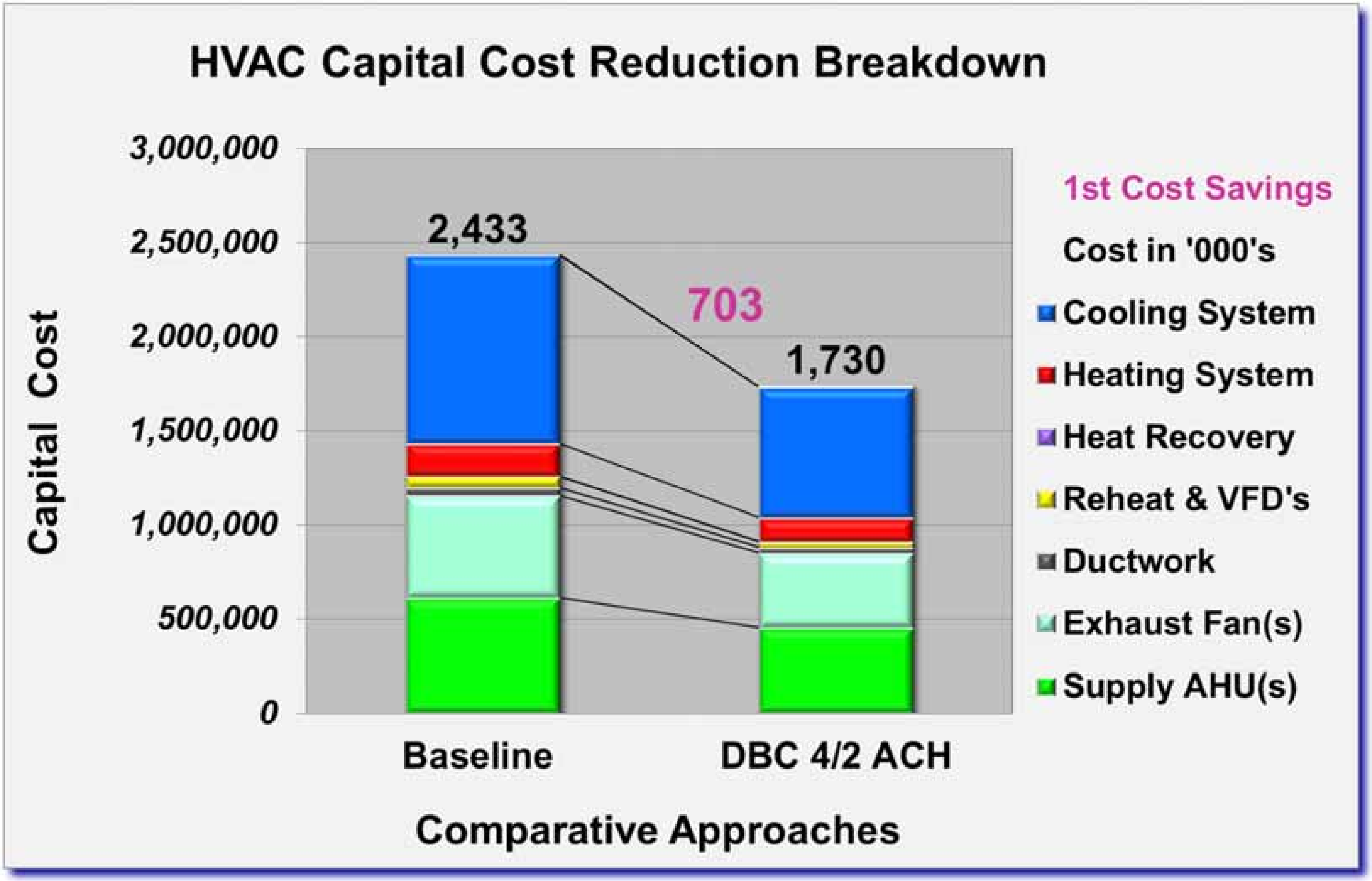
Demand Based Control helped bring project into budget

HVAC 1st Cost Savings of 4/2 ACH vs. 6 ACH



DBC at 4/2 ACH vs. 6 ACH reduces peak HVAC airflow by 13% or ~ $280K. Net payback is: 10.9 months!

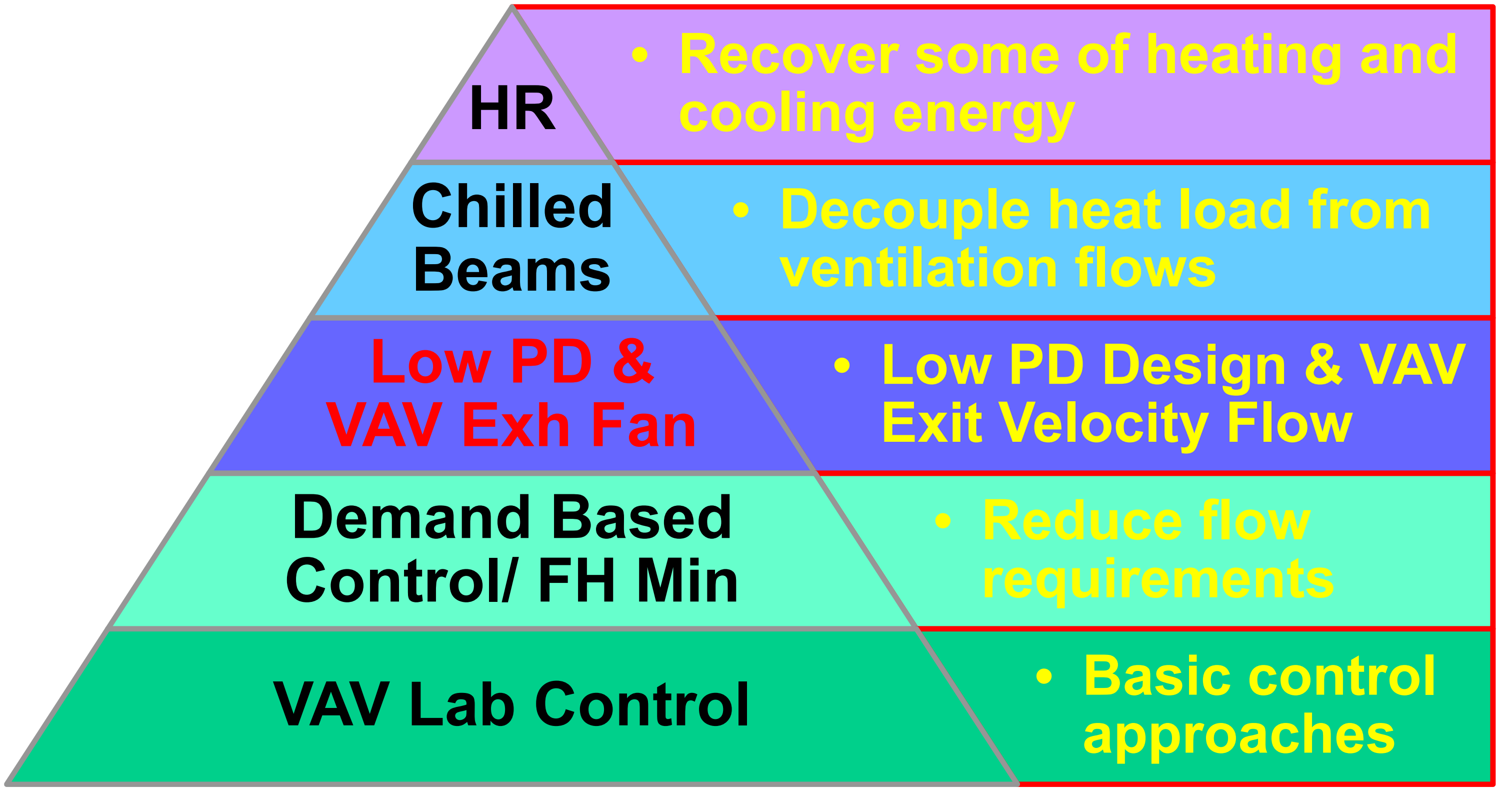
HVAC 1st Cost Savings of 4/2 ACH vs. 8 ACH



DBC at 4/2 ACH vs. 8 ACH reduces peak HVAC airflow by 26% or ~ $703K. Net first cost savings of $238K!

Holistic Strategies for Increased Savings

- **Individually evaluating systems is suboptimal**
  - ✓ DBC, chilled beams, hoods & heat recovery
- **To optimize lab safety, first cost & energy:**
  - ✓ Combining systems appropriately is best
  - ✓ Also use a layered or pyramid approach:



Variable Exhaust Fan Exit Velocity Control

- Exhaust fans typically run at constant flow
  - ✓ High plume discharge needed, $\geq$ 15 m/s exit vel.
  - ✓ Roof air bypass damper used to maintain CV
- To save energy, use multiple fans & stage
  - ✓ Group of fans are staged based on bldg exh. volume
- Better approach: variable speed/freq. control
  - ✓ Fan flow & speed varied based on building load

Even staged exhaust fans often consume >2X the energy vs. VAV

So What's the Catch, Why Not Use VAV?

- CV & staged fan control maintains high exit velocity
  - ✓ Minimizes downwind concentrations from spills, etc.
- Variable volume control decreases exit velocity
  - ✓ Downwind concentrations can increase as the volume flow rate & exit velocity decreases
  - ✓ Typically not allowed due to min. required dilution
- How about a hybrid control approach?
  - ✓ Used staged control/high exit velocities when required
  - ✓ Otherwise use variable control to save more energy

Hybrid control could provide safety & energy savings, but how could it be implemented?

Changes in Criteria Provide Basis for Hybrid Control

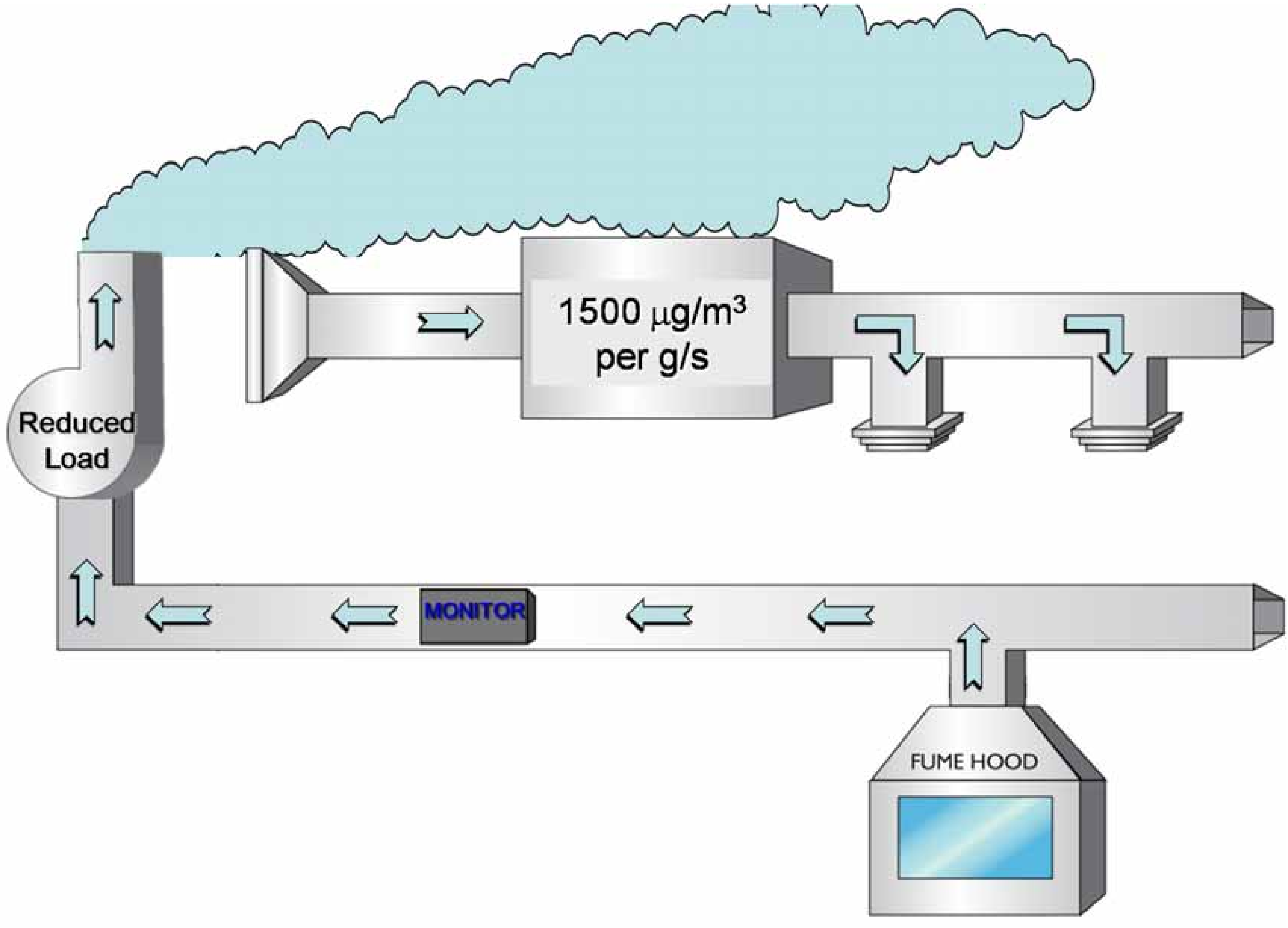
- **Wind speed & direction criteria:**
  - ✓ **Takes advantage of reduced wind condition criteria**
    - – *When wind speed and direction fit certain criteria, VAV engaged*
    - – *Needs wind speed & direction sensing at a fair height above roof*
  - ✓ **Savings will vary based on site wind conditions**
  - ✓ **If wind unsteady or gusting, staged mode can be engaged frequently or for long periods**

Changes in Criteria Provide Basis for Hybrid Control

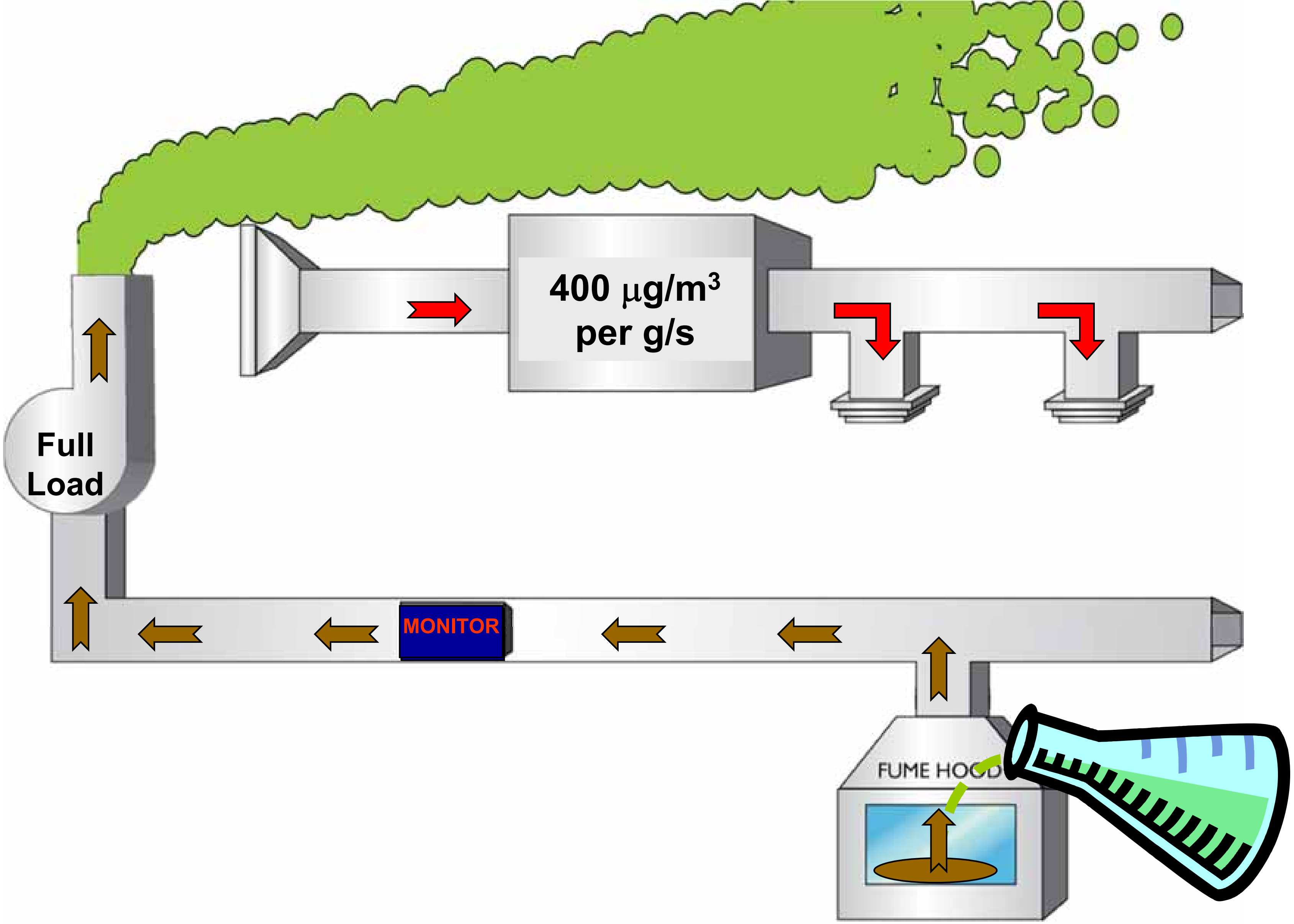
- **Dilution level criteria:**
  - ✓ **Many chemicals don't need high dilution**
  - ✓ **Most plenums "clean" 98 to 99% of time**
  - ✓ **Use active sensing of plenum: DBC app.**
    - *Normally: 98 to 99% of time engage VAV*
    - *If chemicals or particles sensed above threshold:*
      - Override to CV/staged mode for high exit vel.

  - ✓ **Use for labs w/ good exhaust dilution**
    - *Larger systems, life sciences, etc.*
  - ✓ **For few high dilution chemicals not sensed**
    - *Need to limit quantity of chemical used in hoods*

Reduced dilution criteria (DBC of fans) offers simple implementation & potentially greater saving

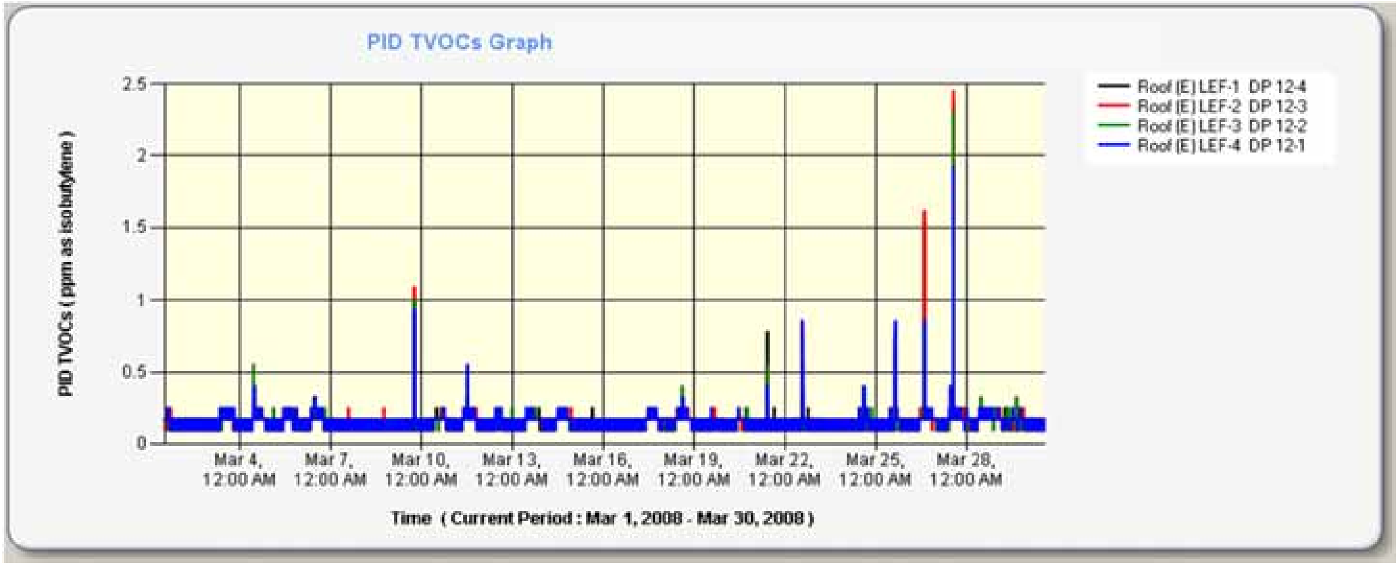


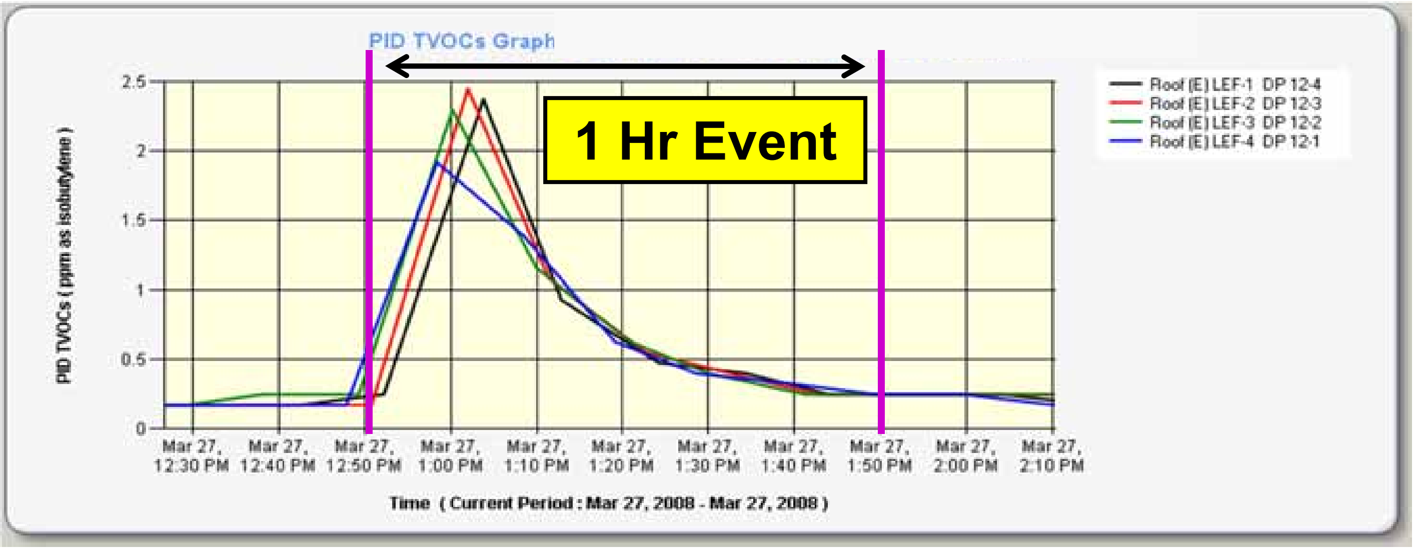
Normal Operation w/ Low or No Contaminants



Higher Dilution Engaged if Contaminants Sensed

Exhaust Fan Monitoring: Medical Research Building

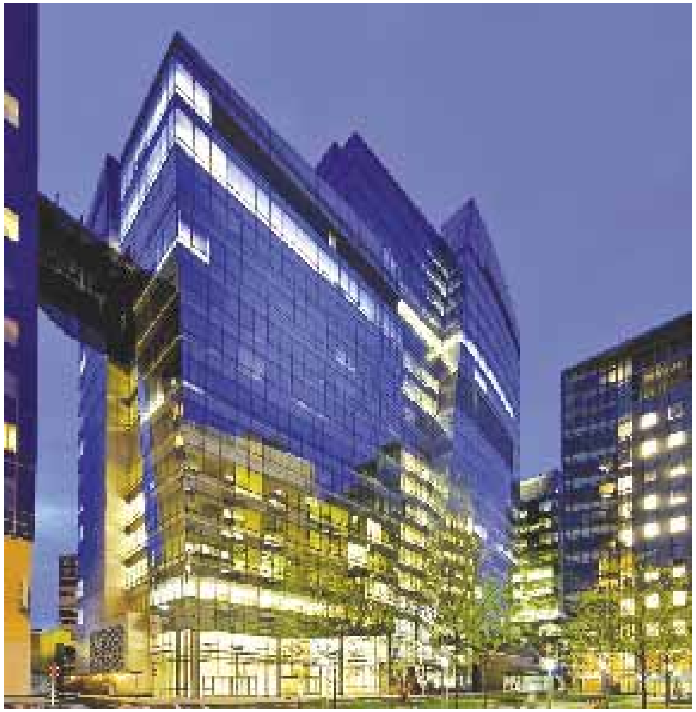




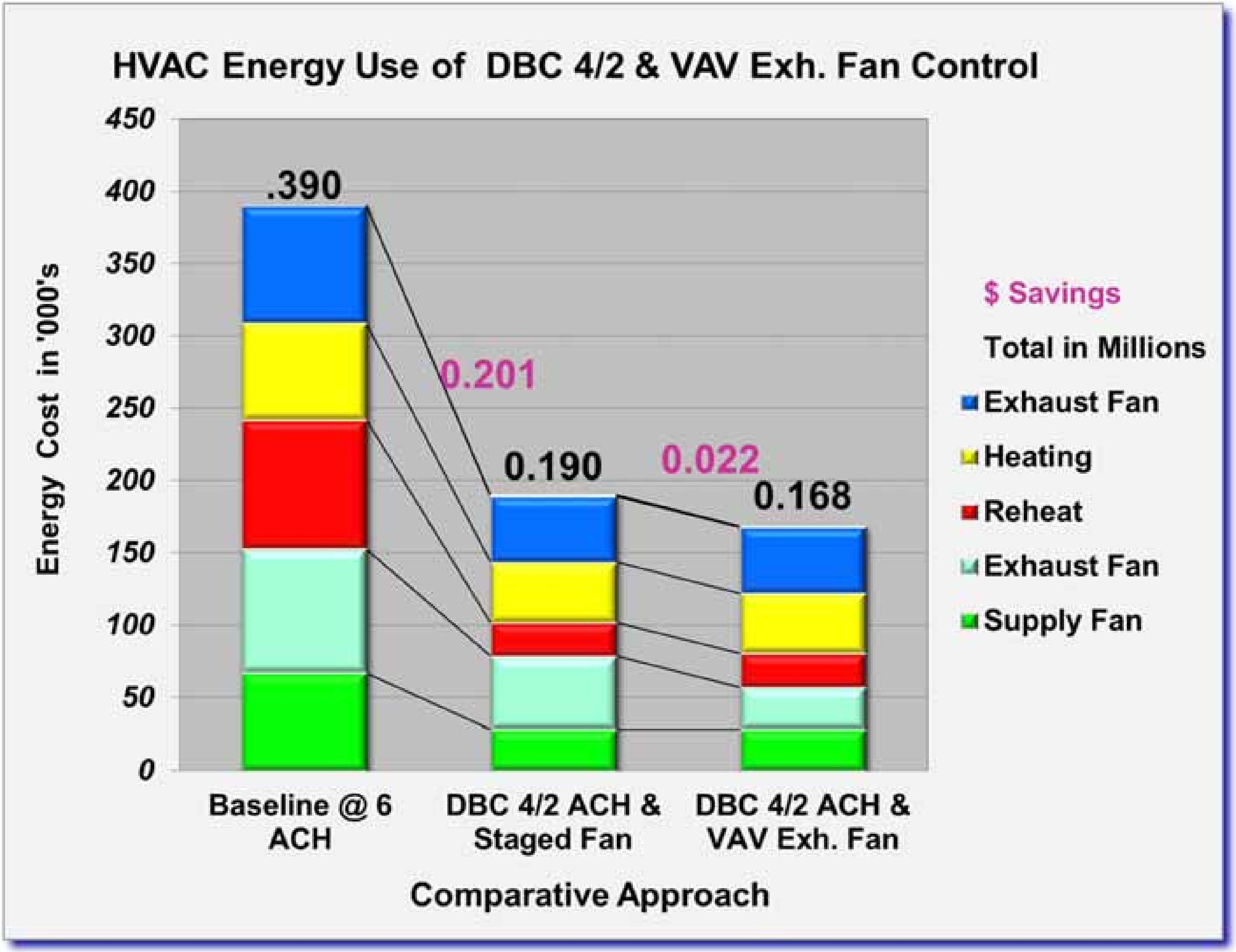
Sample Comparison of Fan Control Energy Use

- CV Exh fan power : $66K - 100%
- Staged fan power : $46K - 69%
- DBC/VAV fan power : $24K - 37%

For VAV control of exhaust fans vs. staged fans: 47% savings



Comparison of Fan Control Energy vs. 6 ACH



For VAV control of exhaust fans vs. staged fans:
Total reduction of $22K or 6% for total reduction of 57%

Low Pressure Drop Design to Lower Fan Static

- Basic approach is to lower airflow velocities
  - ✓ Lower system air (face) velocity
  - ✓ Oversize passive system components including coils, filters, and ductwork
- Evaluate level of air filtration.
  - ✓ Always use lowest pressure-drop filters.
- Eliminate or reduce reheat coils.
- Use low pressure-drop VAV-control devices
- Avoid noise-control attenuators (silencers)
  - ✓ Reduced pressure drop results in smaller, quieter fans that help eliminate silencers.

Lower System Air (Face) Velocity

- **Reduce face velocity with larger-area:**
  - ✓ heating and cooling coils,
  - ✓ filters, and
  - ✓ AHU housings.
- **Recognize that small reductions in face velocity provide large (exponential) energy savings.**

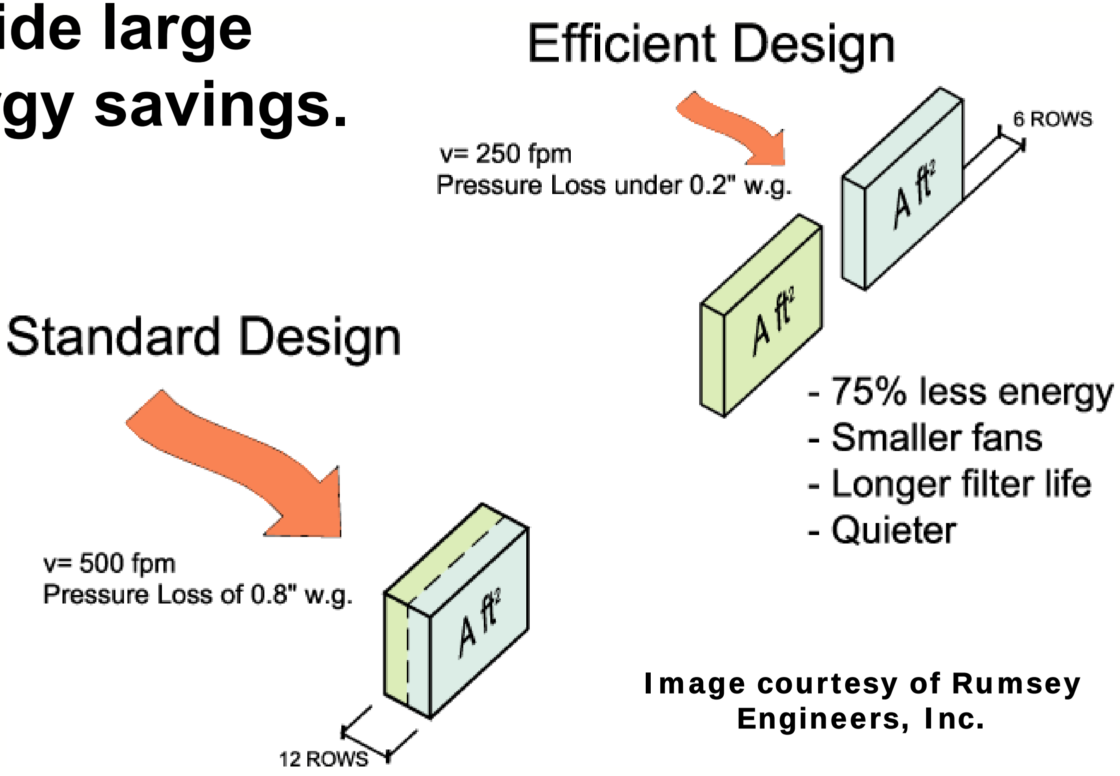


Image courtesy of Rumsey Engineers, Inc.

Optimize ductwork design

- Specify large, round ductwork
  - ✓ Provide sufficient duct space to reduce airflow resistance
- Rationalize duct layout to minimize fittings and bends
- Employ radiused bends rather than square

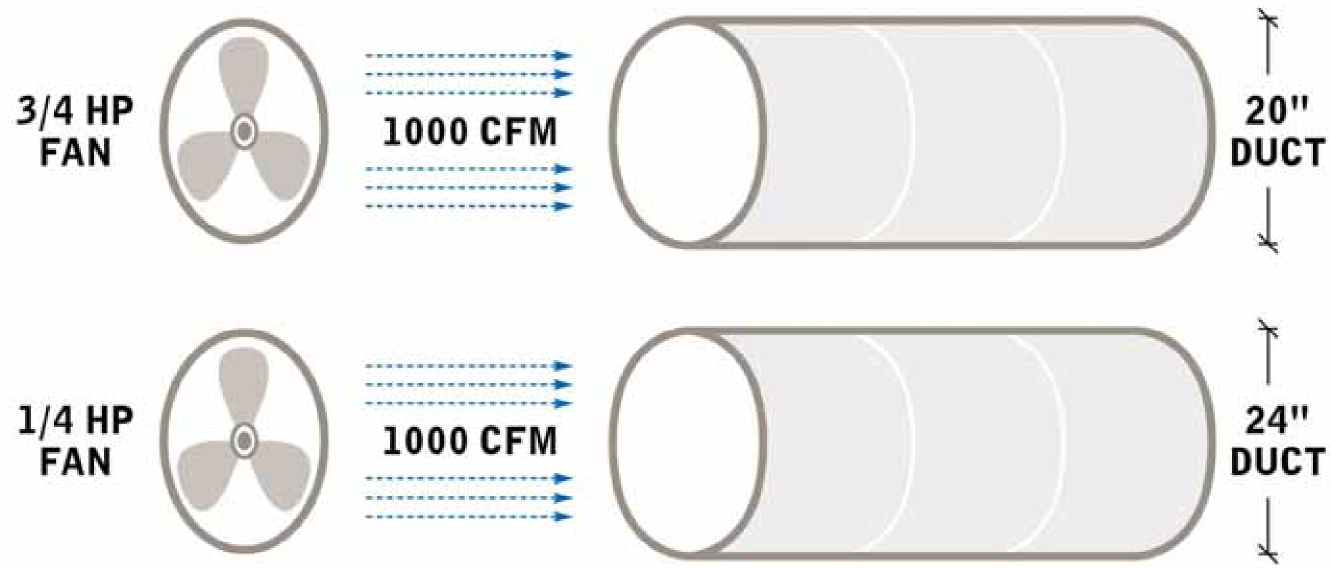
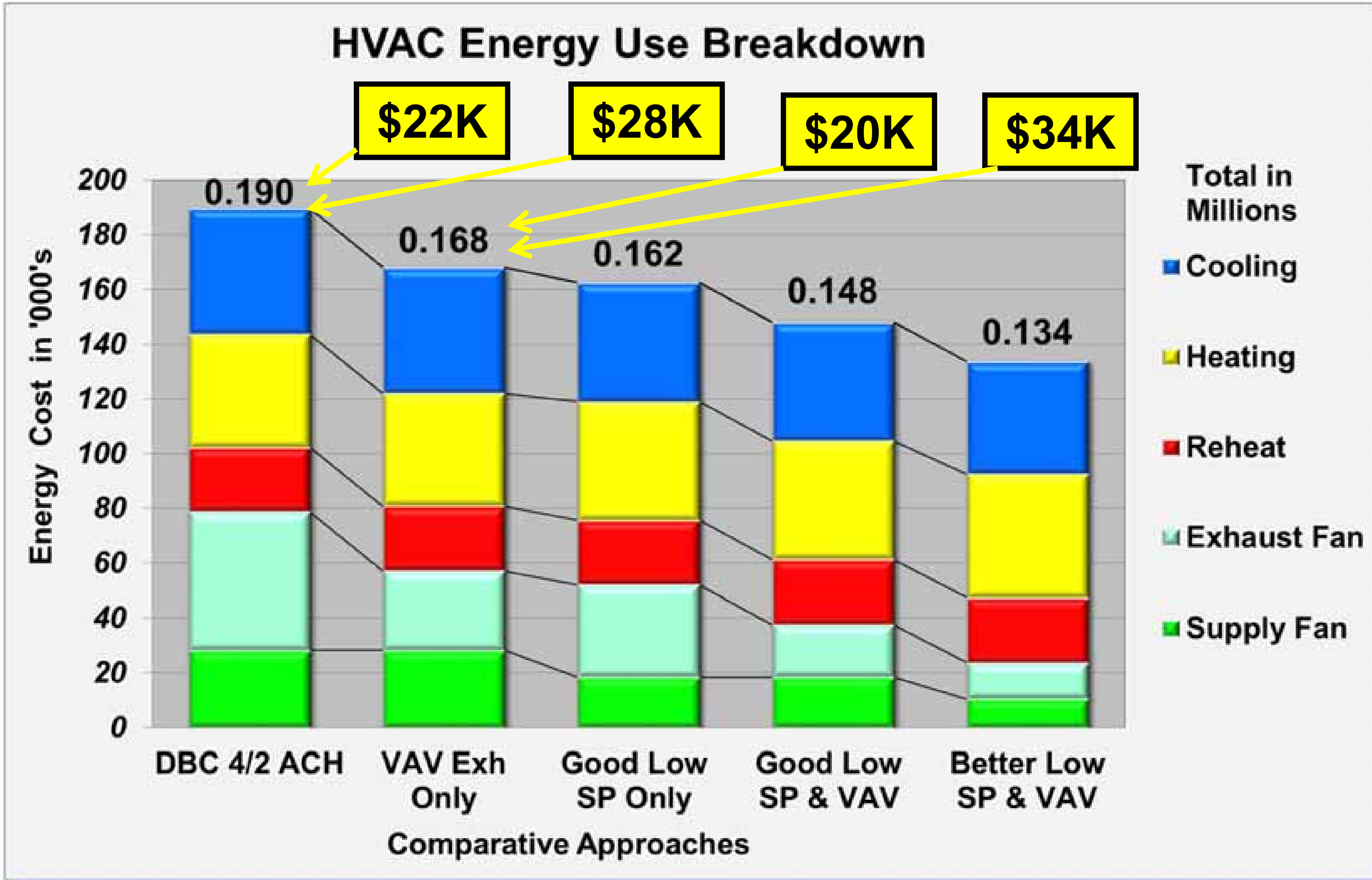


Image courtesy of Rumsey Engineers, Inc.

Low Pressure-Drop Design Guidelines

Component	Standard	Good	Better
Air handler face velocity	**500 fpm**	**400 fpm**	**300 fpm**
Air Handler (itself)	**2.5 in. wc.**	**1.5 in. wc.**	**0.75 in. wc.**
Heat Recovery Device	**1.0 in. wc. X 2**	**0.6 in. wc. X 2**	**0.35 in. wc. X 2**
Flow Control Devices	**Flow Control Devices X 2: .6 to .3 in. wc.**	**Flow Control Devices X 2: .6 to .3 in. wc.**	**Low Pressure Flow Control Devices X 2: .4 to .2 in. wc.**
Zone Temperature Control Coils	**0.5 in. wc.**	**0.3 in. wc.**	**0.15 in. wc.**
Total Supply and Exhaust Ductwork	**4.0 in. wc.**	**2.2 in. wc.**	**1.5 in. wc.**
Exhaust Fan (itself)	**2.0 in. wc.**	**1.5 in. wc.**	**1.0 in. wc.**
Noise Control (Silencers)	**1.0 in. wc.**	**0.3 in. wc.**	**0.0 in. wc. (none)**
Total of Exh & Sup. w/o HR & Silencers	**10.0 in. wc.**	**6.5 in. wc.**	**4.0 in. wc.**

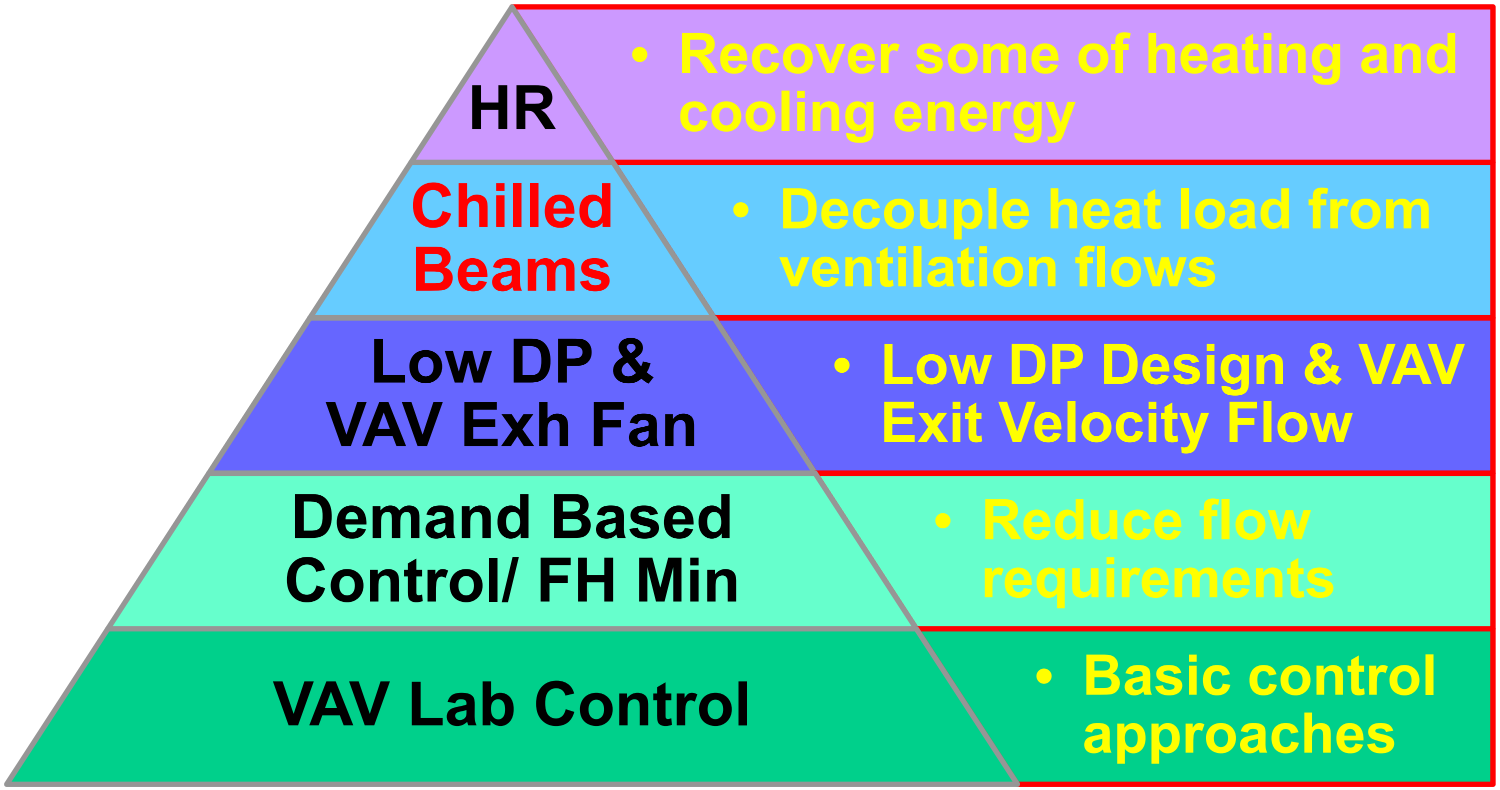
Low PD Energy Reduction w/ DBC 4/2 & VAV Exh. Fan



For low PD w/ DBC & VAV Exh: Savings for Good & Better of $20K & $ 34K or 5.1% & 8.7% (vs. 14% & 24%)

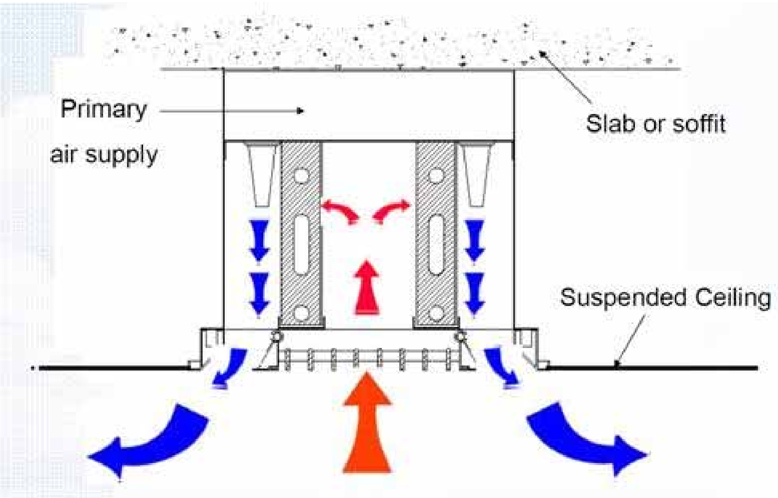
Holistic Strategies for Increased Savings

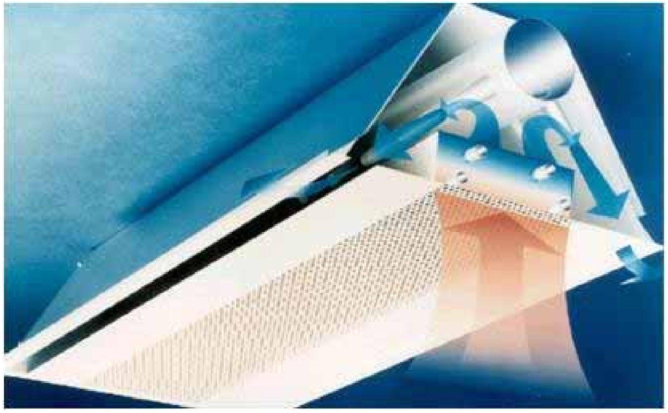
- Individually evaluating systems is suboptimal
  - ✓ DBC, chilled beams, hoods & heat recovery
- To optimize lab safety, first cost & energy:
  - ✓ Combining systems appropriately is best
  - ✓ Also use a layered or pyramid approach:



Hydronic Cooling Solutions: Chilled Beams

- **Active chilled beams**
  - ✓ **Similar to passive beams but with induced air**
  - ✓ **Most complex w/ cost 2X passive but highest cooling**
    - – *Integrated source of airflow usually makes total cost favorable*
  - ✓ **By far most popular, used in offices & labs**
  - ✓ **Usually uses 100% OA**
    - – *Provides ventilation & controlling latent loads*



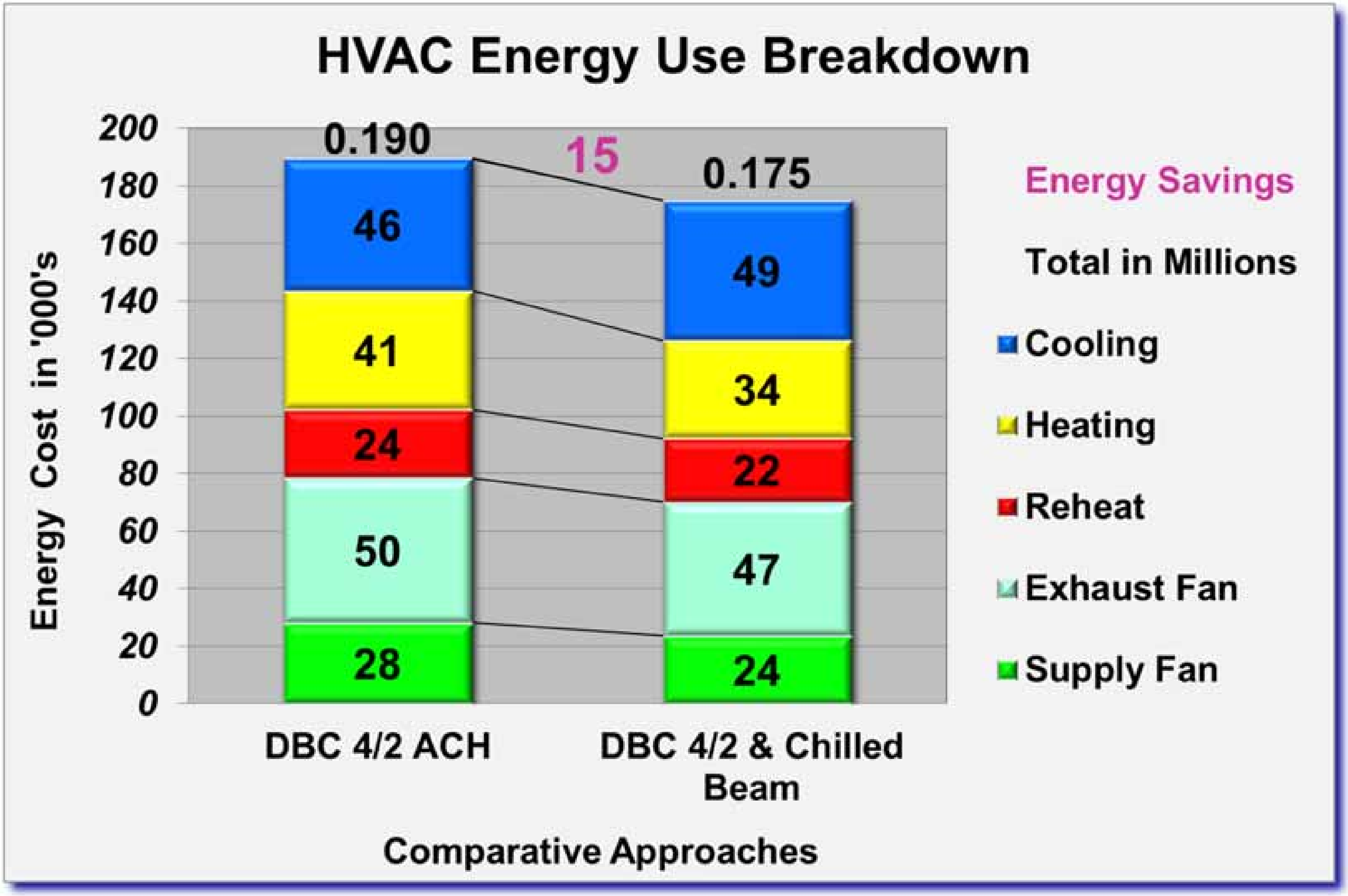


Demand Based Control (DBC) Improves Beam Use

- **Chilled beams at 6 or 8 ACH min:**
  - ✓ **Large overcooling & reheat**
- **Beams at 2- 4 ACH using DBC**
  - ✓ **Greatly cut & eliminate these losses**
- **HVAC system can be downsized**
  - ✓ **Thermal load decoupled from airflow**
  - ✓ **Air system can be resized to 2-4 ACH**
- **DBC cuts beam size vs. heat recovery**
  - ✓ **"Neutral air" sometimes used to cut reheat**
  - ✓ **However, using cool air cuts beam sizing**
    - – *DBC cuts reheat & eliminates need for wraparound HR/ 2 wheels*

The whole (DBC & CB) is greater than sum of the parts.

Chilled Beam Savings w/ DBC 4/2 ACH vs. 6 ACH



For chilled beam w/ DBC: $15K or 4% reduction.
Airflow reduction is ~18% day & ~17% at night

4/2 Project: DBC & Chilled Beams at Cal Poly

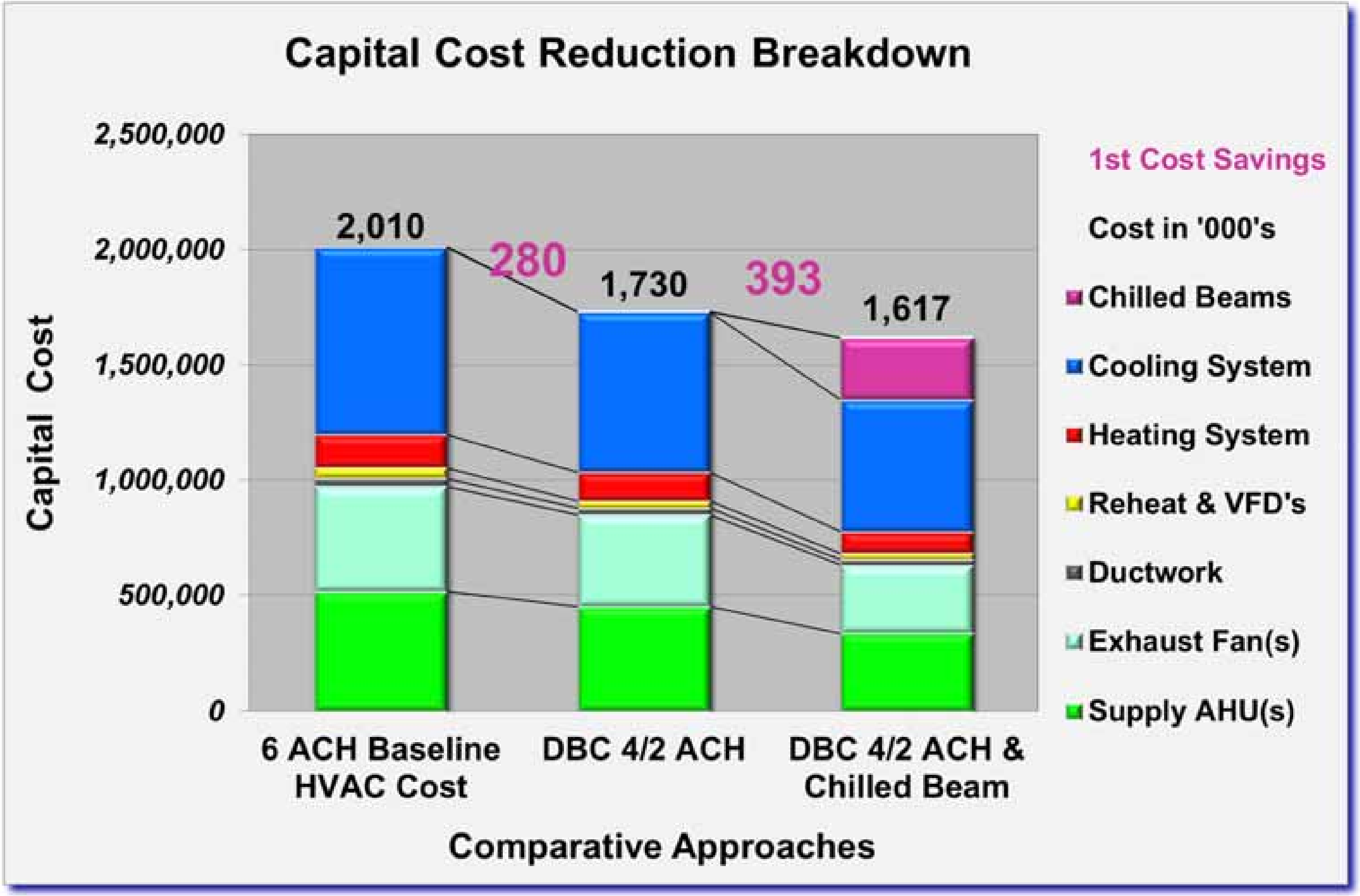
- **Cal Poly Center for Science & Mathematics**
  - ✓ **198,000 GSF, Budget $88 Million**
    - – *"Do the most sustainable project, but only if it doesn't cost more money"*
  - ✓ **Architect: ZGF Architects LLP**
    - – *MEP Engineer: Integral Group / Rumsey Eng.*
- **All lab ventilation air passes through chilled beam**
  - ✓ **Day rate of 4 ACH for full beam cooling**
  - ✓ **Night rate of 2 ACH, beam cooling not needed**
  - ✓ **Purge rate of 8 ACH when contaminants detected**

Cal Poly Center First Cost Savings:

Option	Standard VAV Reheat	DBC with Chilled Beam
AHU ($7.5/CFM)	250,000 CFM	167,000 CFM
EF ($1.75/CFM)	324,000 CFM	256,000 CFM
Ductwork	Standard	Reduced 30%
Diffusers	Standard	Chilled Beam
Piping	Reheat Loop	Heat Loop, Cooling loop
Overall for 198K GSF Bldg	***$716,000 First Cost Reduction*** (based on SD cost estimating exercise)	

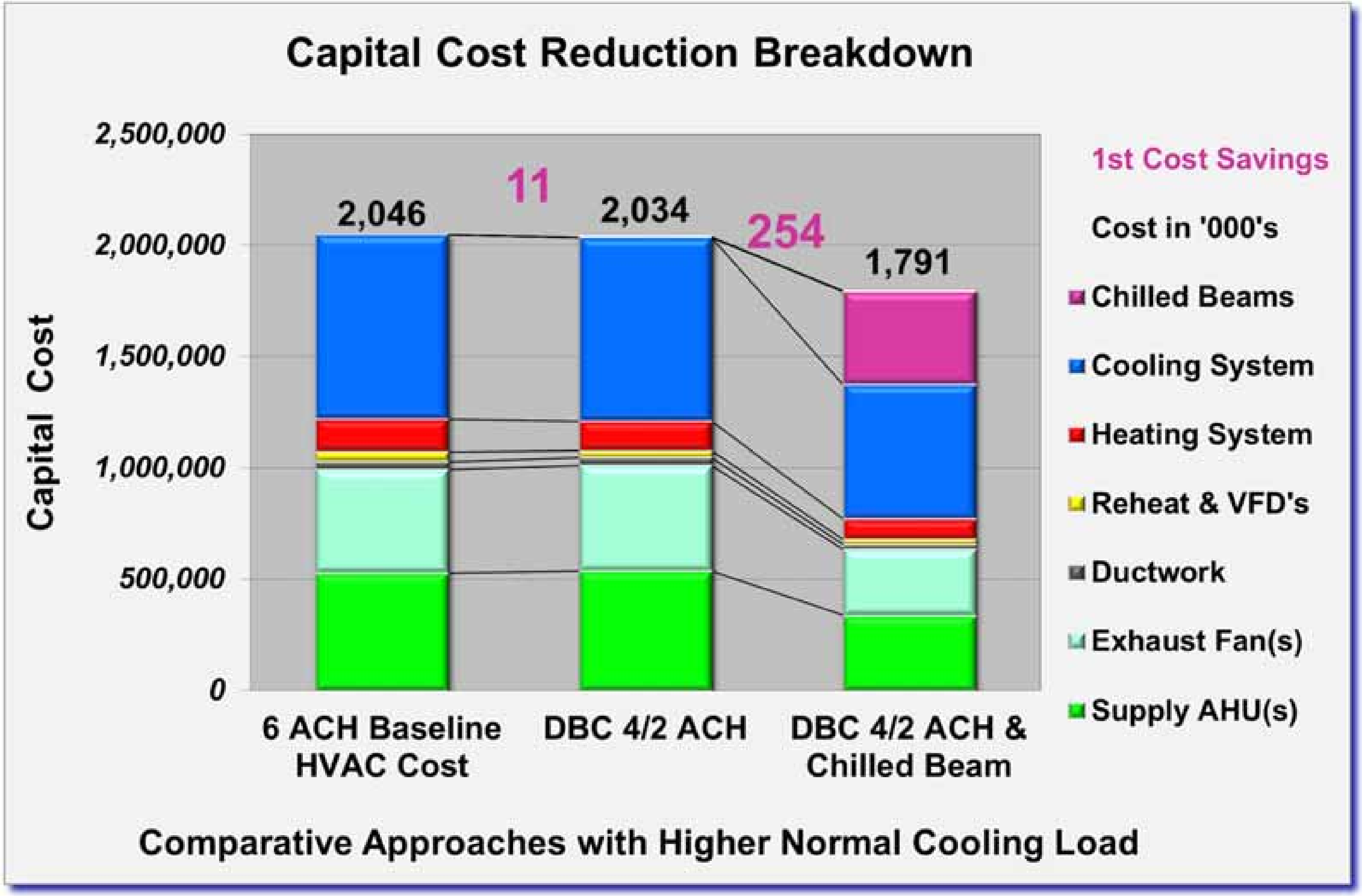
DBC & chilled beams were added in value engineering!

"Right Sizing" Capital Cost Reductions @ 6 ACH



At 6 ACH baseline, gross capital savings of $393K. Chilled Beam (CB) creates net savings of $113K. DBC payback drops to 5.3 months

“Right Sizing” Capital Cost Reductions @ 6 ACH



At 6 ACH w/ higher load (50% greater normal load) chilled beam nets greater capital savings: $254K

2/2 ACH Project: DBC & Hydronic Cooling at Masdar

- **Masdar City: Masdar Inst. of Science & Technology**
  - ✓ **Goal for Masdar Institute (MIST) was to:**
    - *"… making Masdar City one of the world's most sustainable cities.*
    - *"Most significantly, …. do so in a commercially viable manner"*
  - ✓ **Located in Abu Dhabi, UAE.**
  - ✓ **Mixed use lab buildings: MIST 1 A & B: ~ 500K & 1 M GSF**
- **MIST projects using 2 ACH day & night w/ DBC**
  - ✓ **Also has a 14 ACH purge**
  - ✓ **Setup like a DCV DOAS**
    - *Incorporates CO2 DCV as well*

Major Energy & Capital Impact for Near Zero Labs

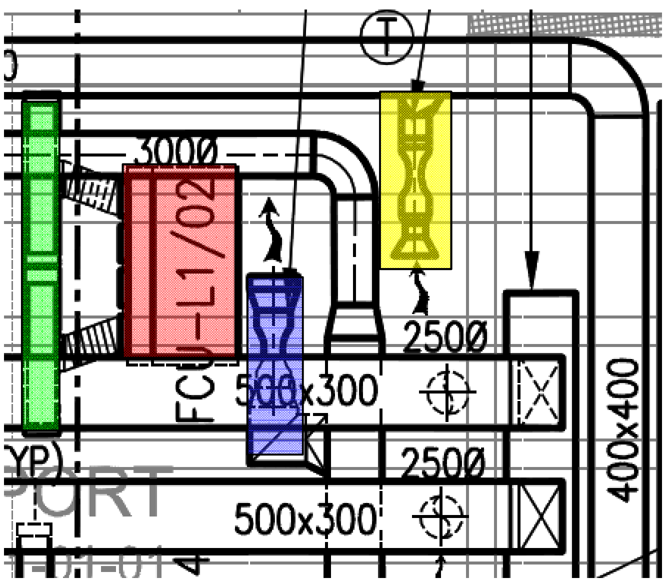
- **Masdar City, Abu Dhabi - Largest net/near zero project**
  - ✓ **Near zero emissions lab w/ Demand Control & chilled beams**
    - *150K m² total, ~ 40K m² of labs: MIST 1 A (Built) & 1B (Under const.)*
  - ✓ **Projected total energy savings: $2 M $ or 9,000 MWh /year**
    - *Labs operate at 2 ACH (day & night), purge up to 14 ACH*
  - ✓ ***Downsized mechanical system to save HVAC capital costs***
  - ✓ **Cuts solar PV capacity by ~ 3.75 MW or ~$20M first cost!**


MIST 1A: 50K sq. m., 15K sq. m labs

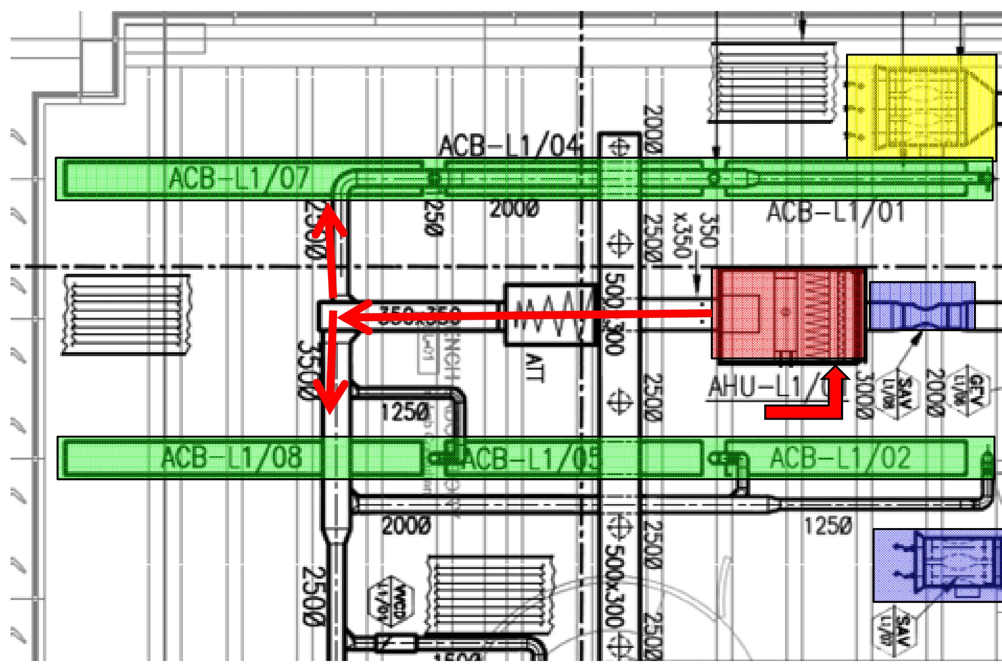
MIST 1A & 1B Room Airflow Control design

- **Two Configurations: Both involve hydronic clg**
  - ✓ **Fan coil lab: ventilation & cooling air totally decoupled**
  - ✓ **CB & Fan powered box: some ventilation air to CB**
- **Decoupling ventilation & clg flow achieves 2/2 ACH**

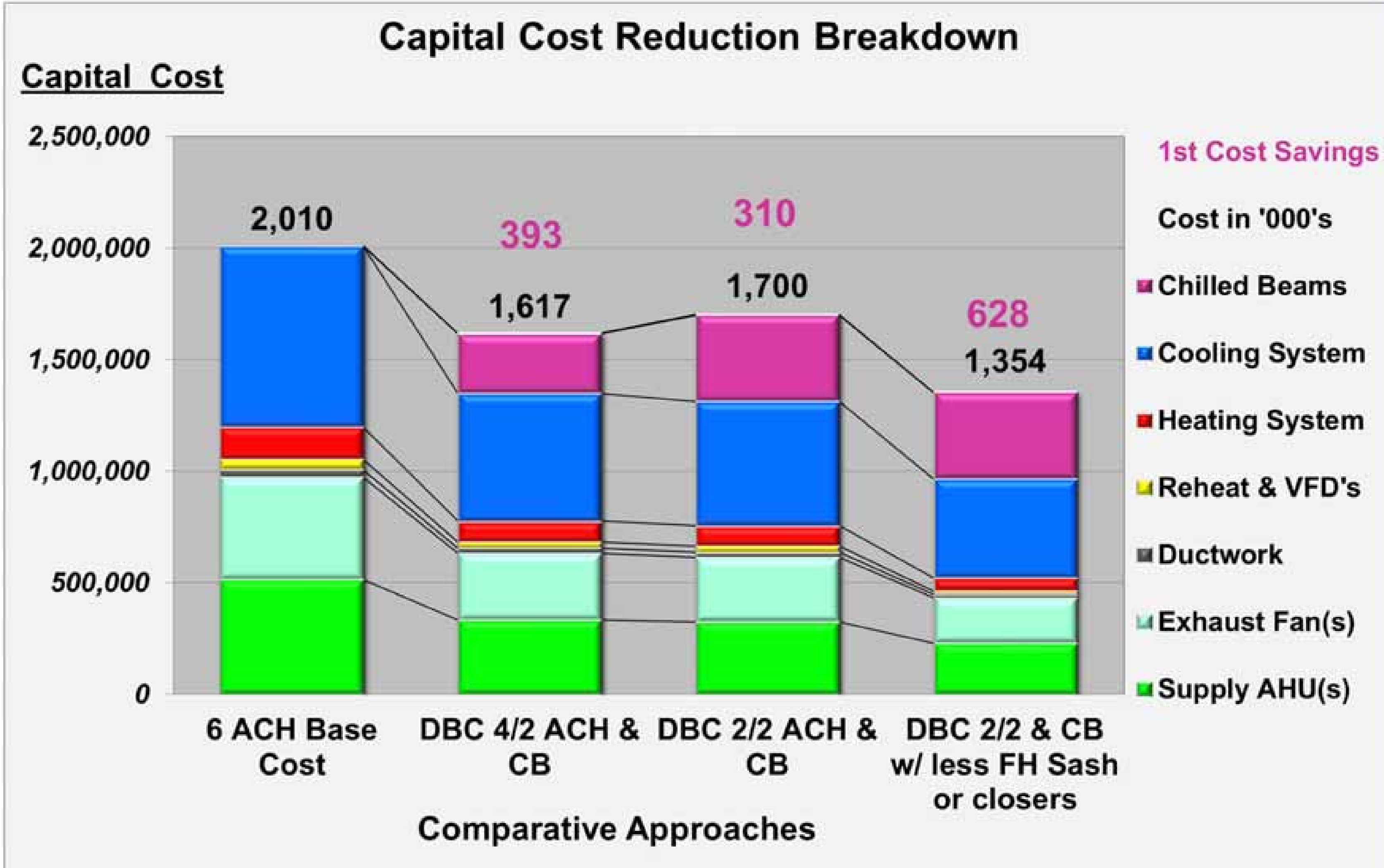
Small Fan Coil Unit:



Chilled Beam & Fan Powered Box:



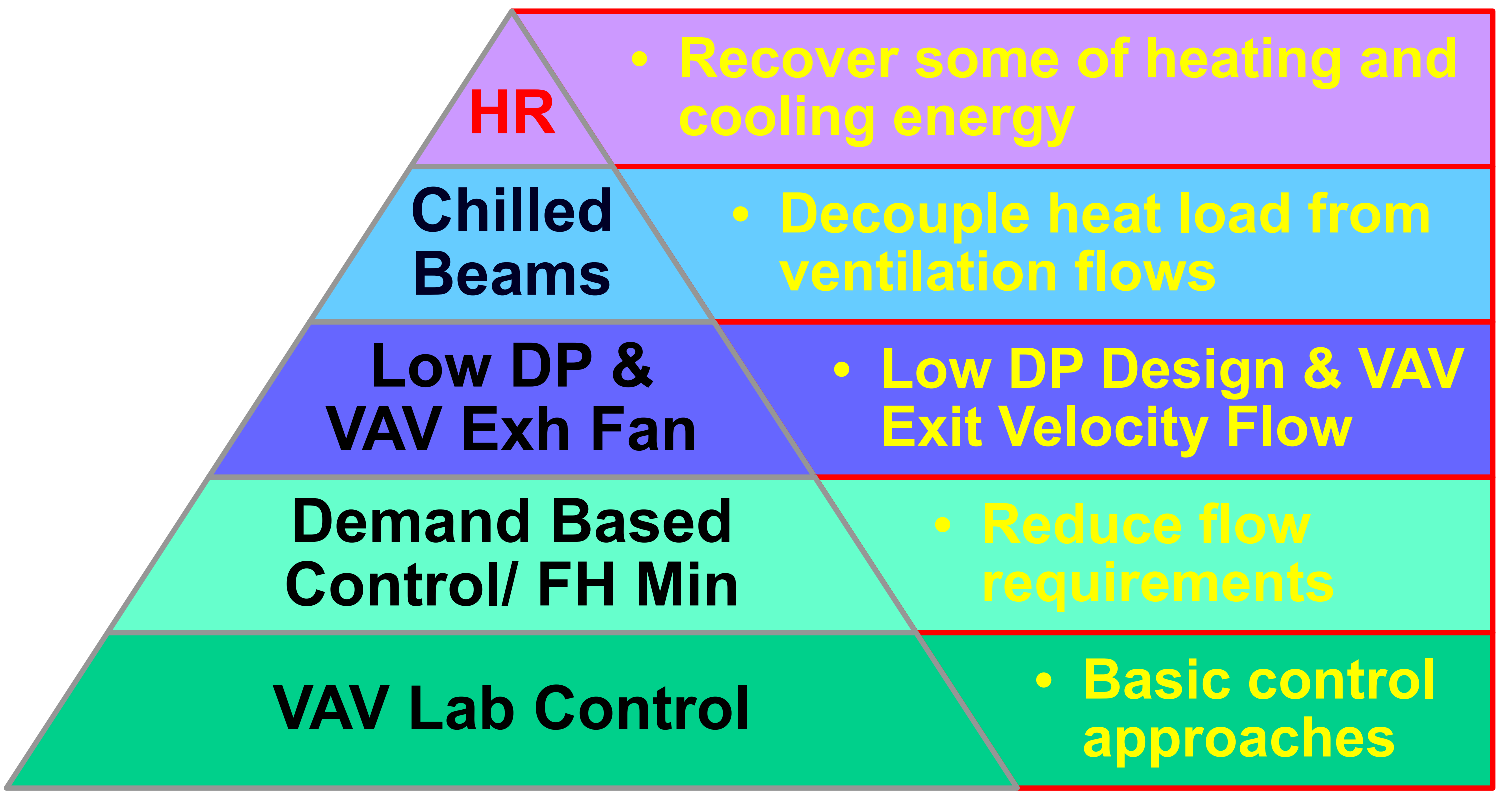
Capital Cost Reduction of 2/2 ACH &CB vs. 6 ACH



Using 2/2 ACH, CB, & reduced FH sash openings generates savings of $628K: Net total savings of $164K

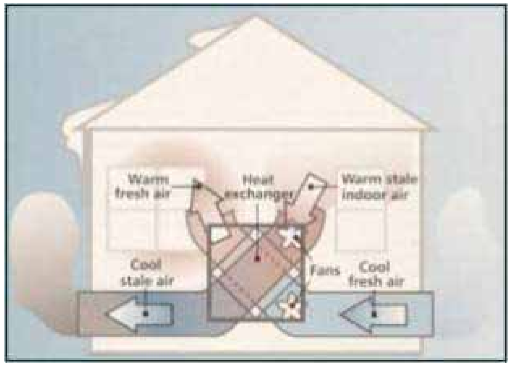
Holistic Strategies for Increased Savings

- Individually evaluating systems is suboptimal
  - ✓ DBC, chilled beams, hoods & heat recovery
- To optimize lab safety, first cost & energy:
  - ✓ Combining systems appropriately is best
  - ✓ Also use a layered or pyramid approach:



Heat & Energy Recovery Benefits

- **Heat Recovery (HR) reuses exhaust energy**
  - ✓ Transfers energy from exhaust to supply air
  - ✓ Can reduce heating and cooling energy costs
- **Significant peak load reductions**
  - ✓ Reduces boiler & chiller costs.
  - ✓ Helps reduce HR investment
- **May provide latent heat recovery**
  - ✓ Some systems can transfer moisture
  - ✓ Humidifies in cold dry weather
  - ✓ Dehumidifies in warm humid weather



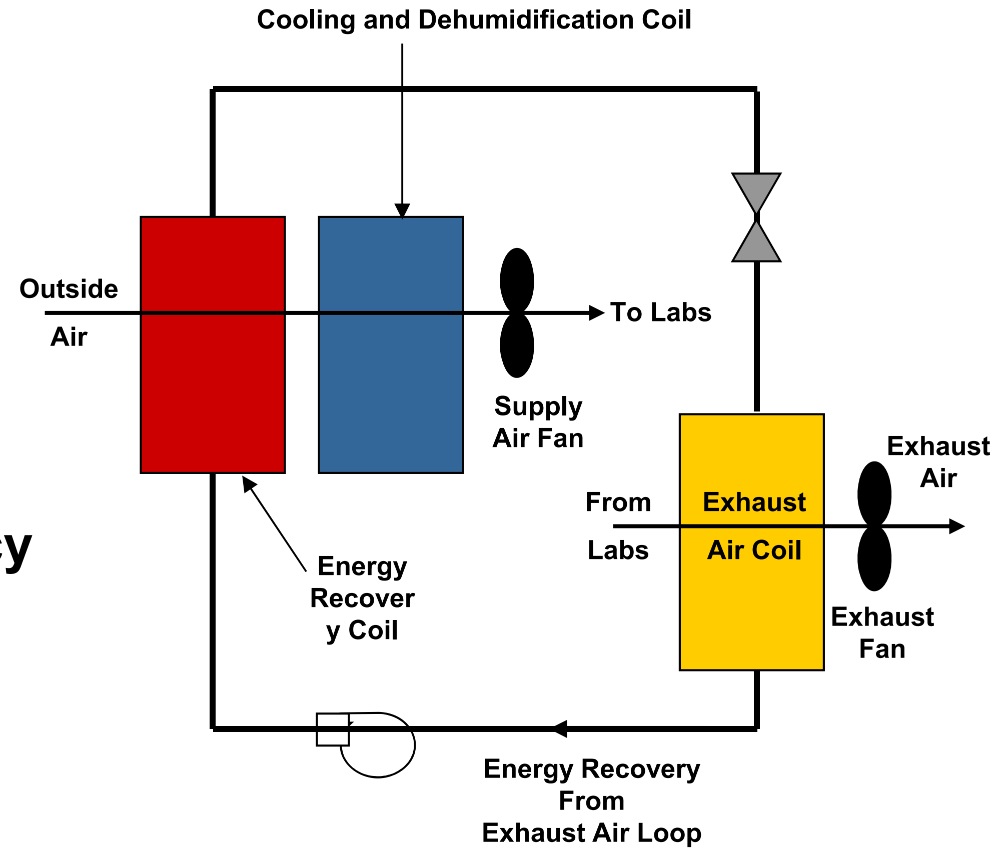
Heat & Energy Recovery Considerations

- **Most applicable to very cold & hot climates**
  - ✓ **Not very effective in moderate climates**
- **Heat recovery is not always good:**
  - ✓ **When economizers would operate, HR wastes energy**
    - *Need to "turn off" HR during these times*
  - ✓ **For colder temperatures HR should be controlled**
    - *Need to vary HR effectiveness to prevent over recovery*
    - *Similar to variable economizer control for temps below supply*
- **Heat recovery savings often overestimated**
  - ✓ **Little cooling heat recovery until OA is > RA Temp**
  - ✓ **75% HR does not save 75% of clg costs, but htg okay**
- **Fan energy increased by pressure drop X2**

Airside Heat Recovery Options

Runaround Coils

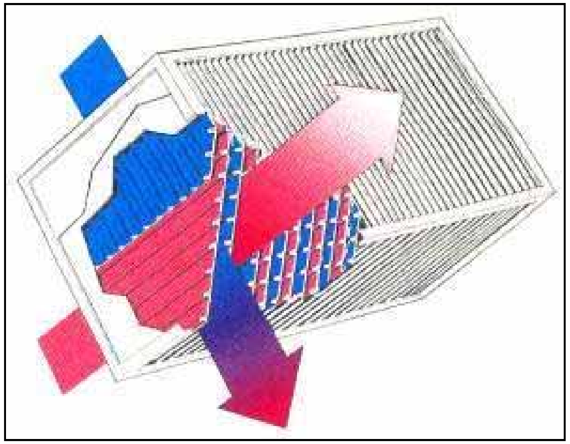
- Pros
  - Greatest airstream separation, flexibility
  - Simple Technology
  - Easily cleaned
  - Minimum space requirements
- Cons
  - Lowest recovery efficiency (55%)
  - High parasitic loads for pumping
  - No latent transfer
  - Poor cooling performance
  - Most moving parts, highest maintenance



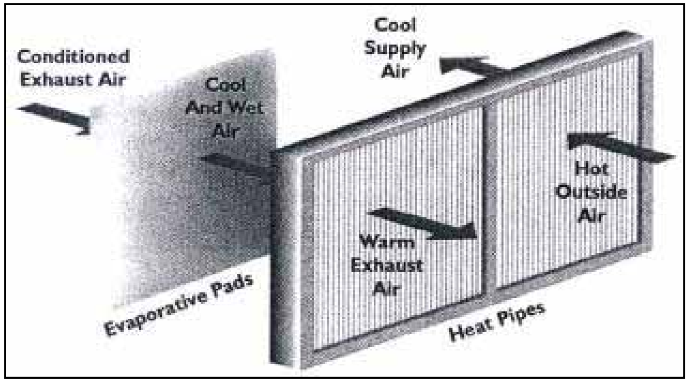
Airside Heat Recovery Options

Plate Heat Exchangers and Heat Pipes

- **Pros**
  - ✓ Good airstream separation
  - ✓ High sensible efficiency (75%) sometimes latent available
  - ✓ Heat pipes easily cleaned
  - ✓ High reliability – no moving parts
  - ✓ Indirect evaporative cooling possible



- **Cons**
  - ✓ May be space intensive
  - ✓ Generally no latent transfer
  - ✓ Plate heat exchangers difficult to clean

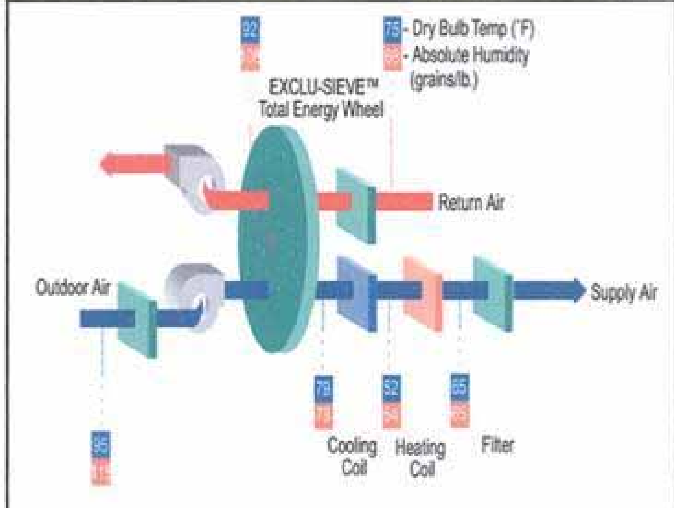


Airside Heat Recovery Options

Heat or Enthalpy Wheels

- **Pros**
  - ✓ Highest sensible and latent efficiency (80%)
  - ✓ May have better cooling savings
  - ✓ Significant reductions in peak heating and cooling loads
  - ✓ Purge minimizes carry over
- **Cons**
  - ✓ Airstream separation issues
  - ✓ Can be space intensive Operational issues
  - ✓ Some contamination will occur

Flow Schematic - Cooling Mode



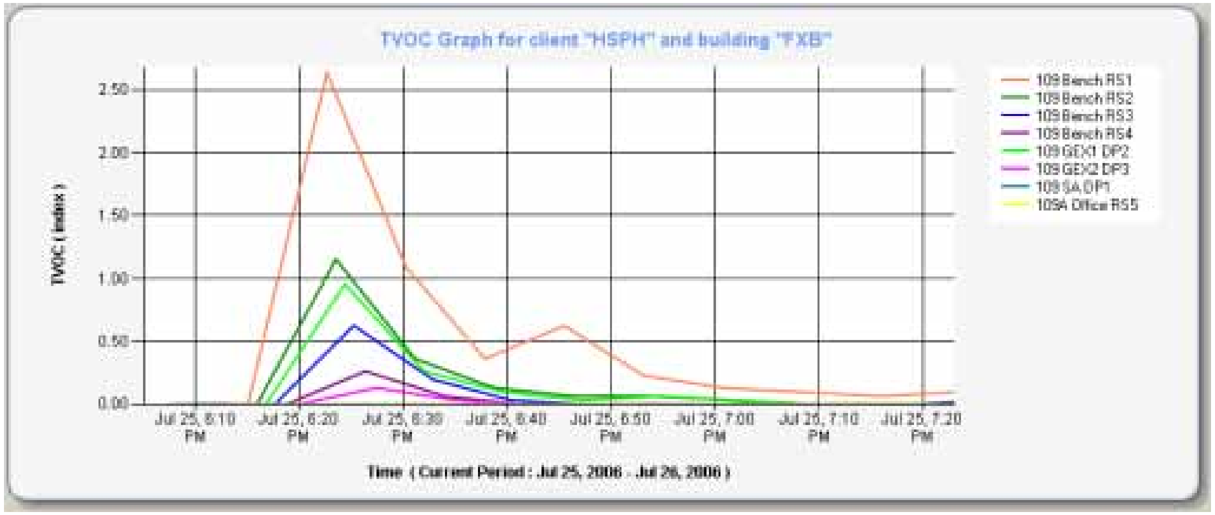
The outdoor air passes through the Total Energy Wheel and is cooled and dehumidified. It is then cooled and dehumidified further by a cooling coil. The hot water heating coil is used during normal heating mode.

Jan. '11 ASHRAE 62.1 interpretation banned any FH exhaust use. Currently not allowed unless EH&S deems safe.

Enthalpy Wheel – Size & Space Factors

An Application for Improving Wheel Safety

- **Enthalpy wheel used on lab general exhaust**
  - ✓ **Cross-contamination safety helped by multiplexed sensing of supply air stream before & after wheel**



Used on Dartmouth College Life Sciences lab building

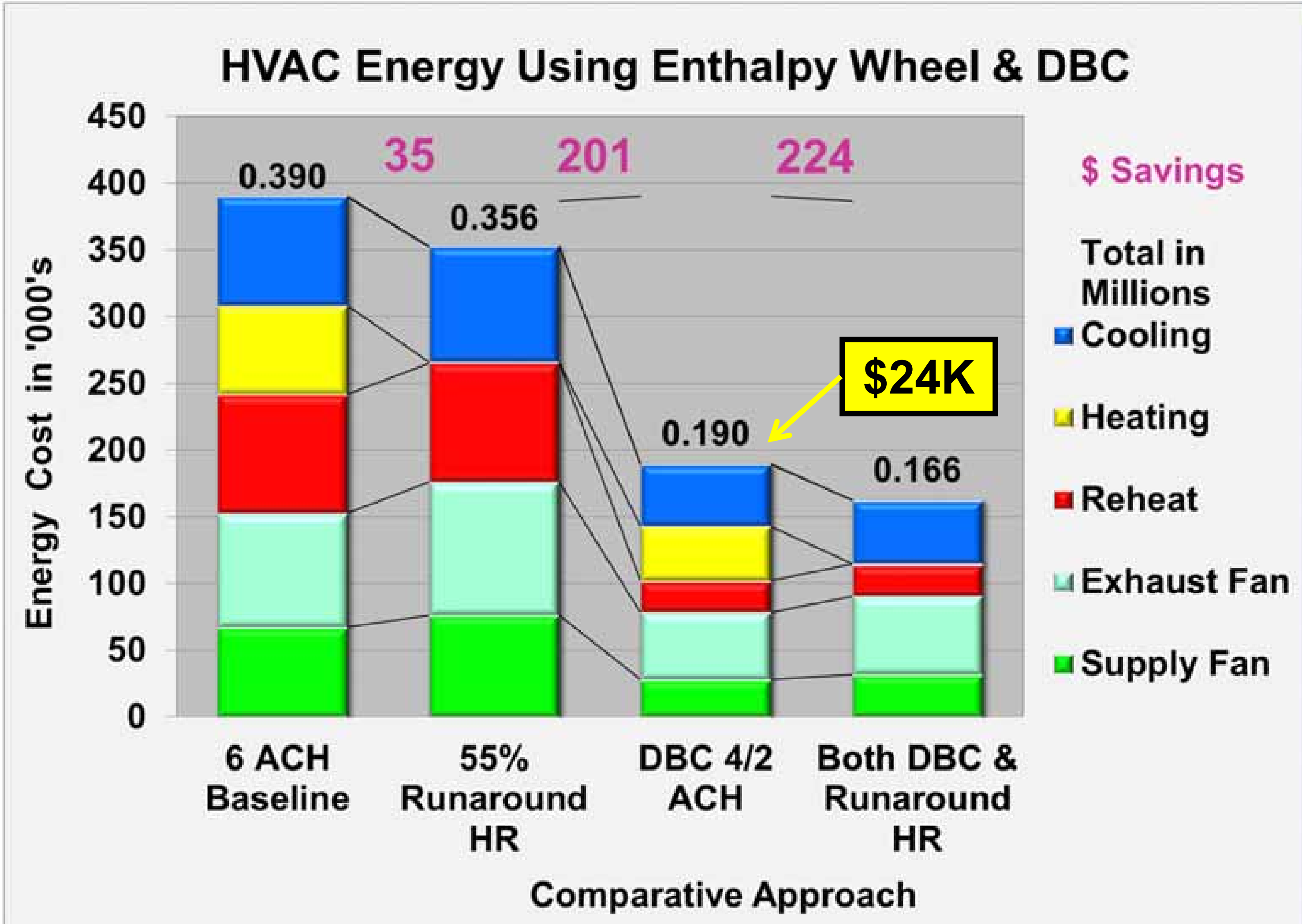
Heat Recovery Systems

Options Summary

Type	*Effectiveness*		*Carryover*	*Reliability*	*Airstream Proximity*	*Comments*
	Sensible	*Latent*				
Enthalpy Wheel	70%-80%	65%-80%	Yes (5 to 0.05%)	Average	Required	Greenest
Heat Pipe	60%-75%	0%*	None	Highest	Required	Contains refrigerant
Plate HX	60%-75%	0%*	None	Highest	Required	
Runaround Loop	50%-60%	0%*	None	Average	Not Required	Glycol or Refrigerant

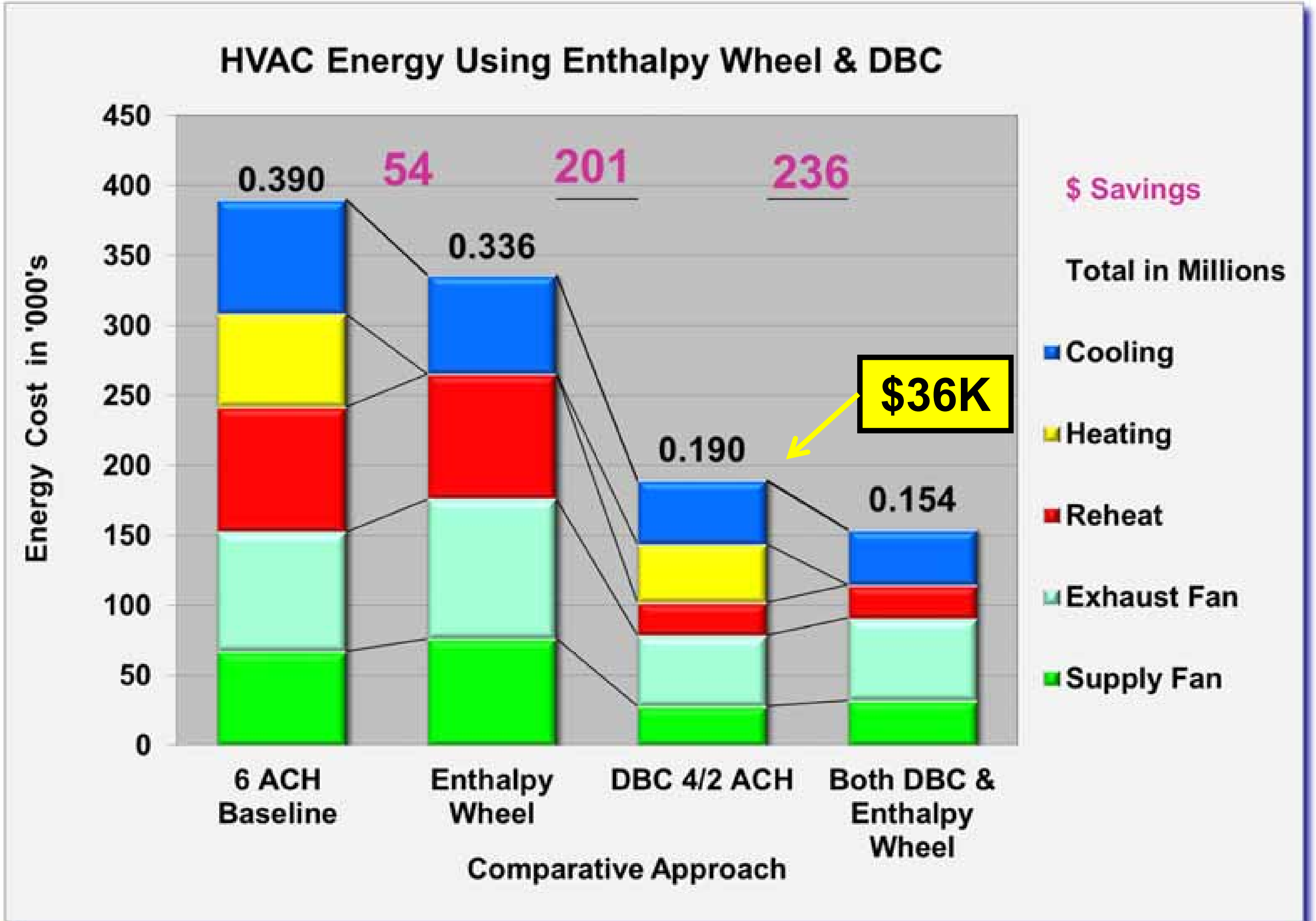
*** Some latent recovery possible if indirect evaporative cooling is employed**

55% Glycol Runaround Savings at 6 ACH



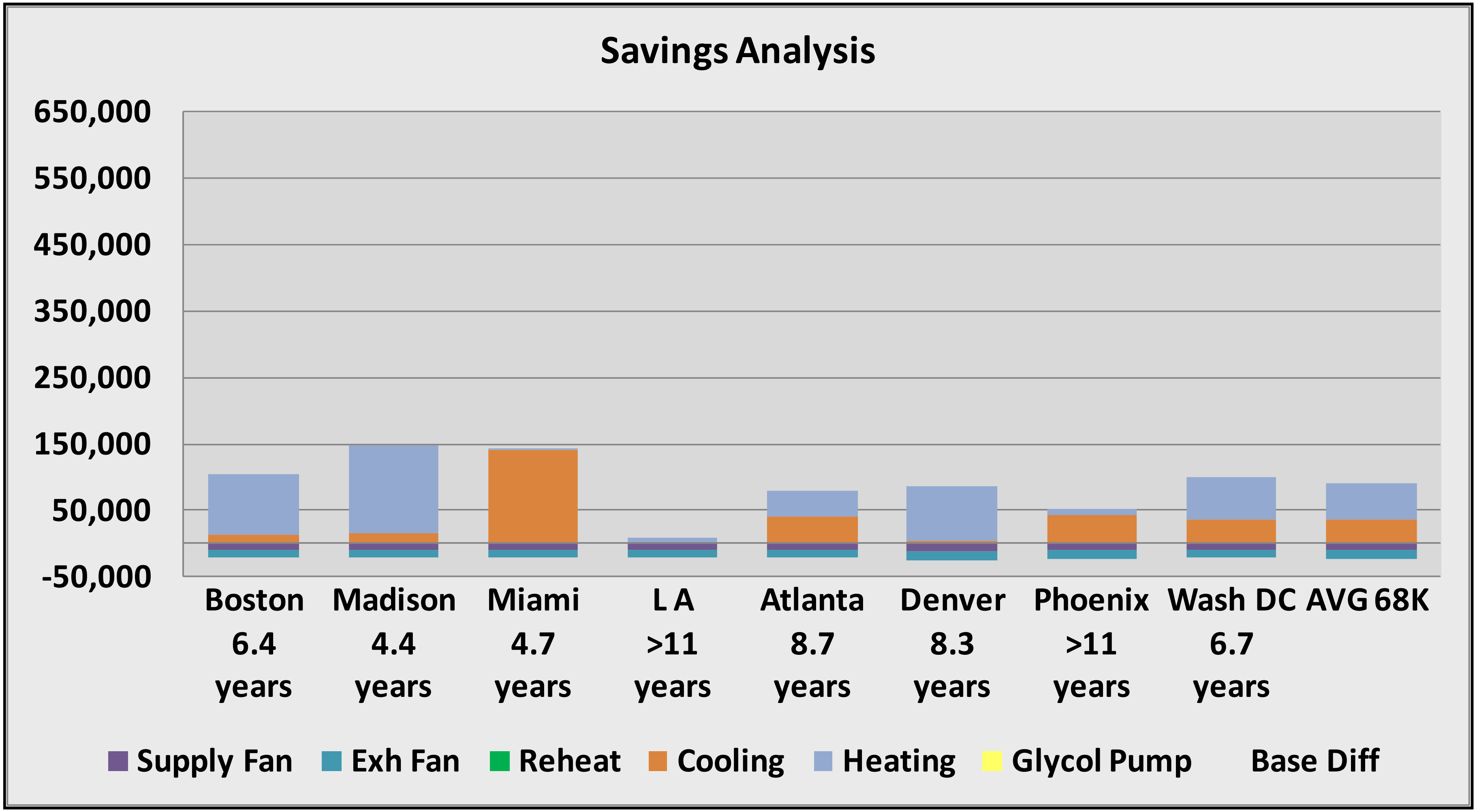
55% Runaround HR w/ 4/2 DBC: only $24K or 6% saving.
HR payback: >15 yrs. even w/ HVAC capital savings!

75% Enthalpy Wheel Savings w/ 4/2 DBC



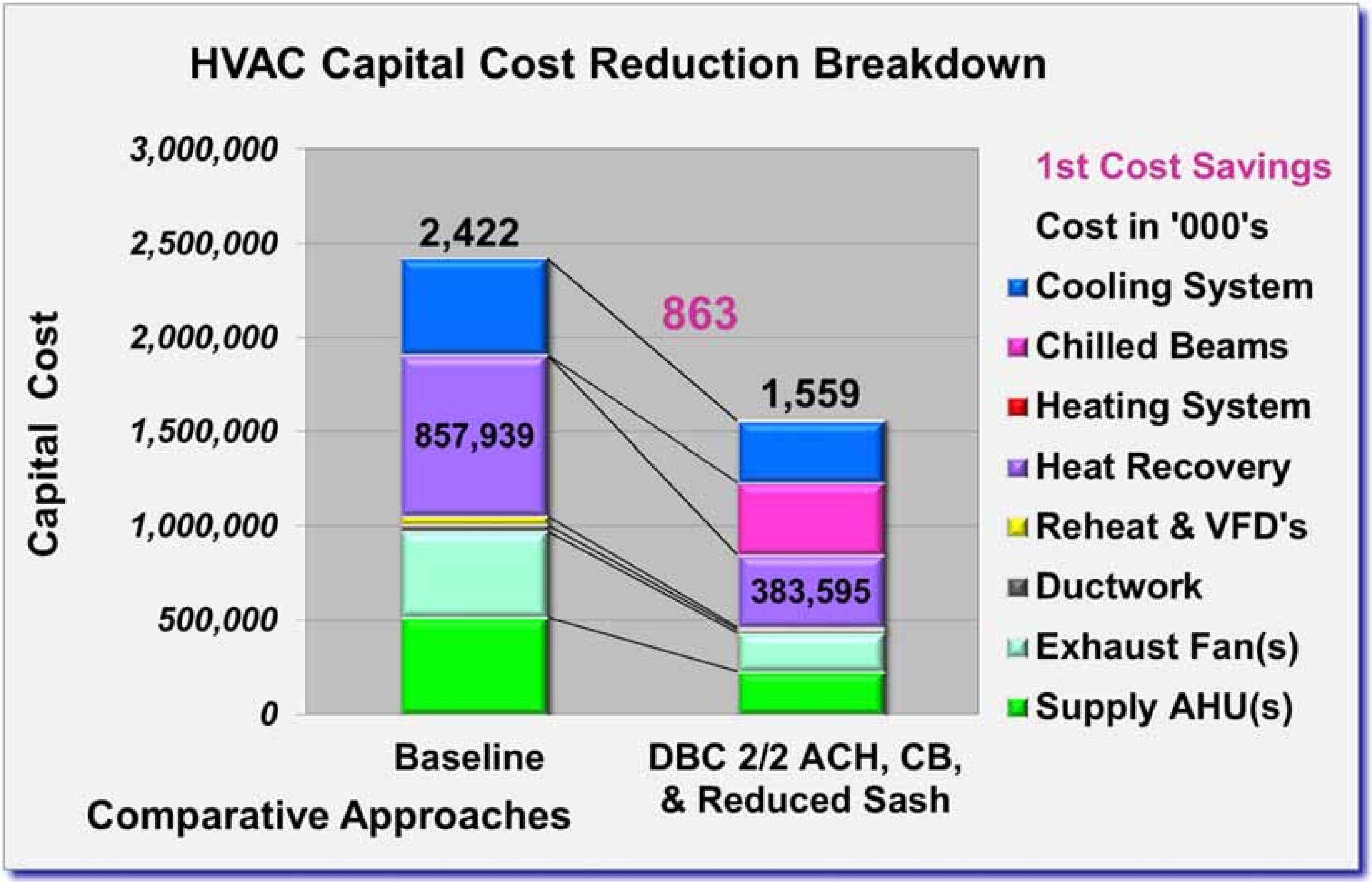
75% Enthalpy HR w/ 4/2 DBC: only $36K or 9% saving. HR payback: 9.7yrs. w/ capital savings

Savings of a 75% Enthalpy Wheel at 6ACH



Average across all cites above: savings is $68K or 16%

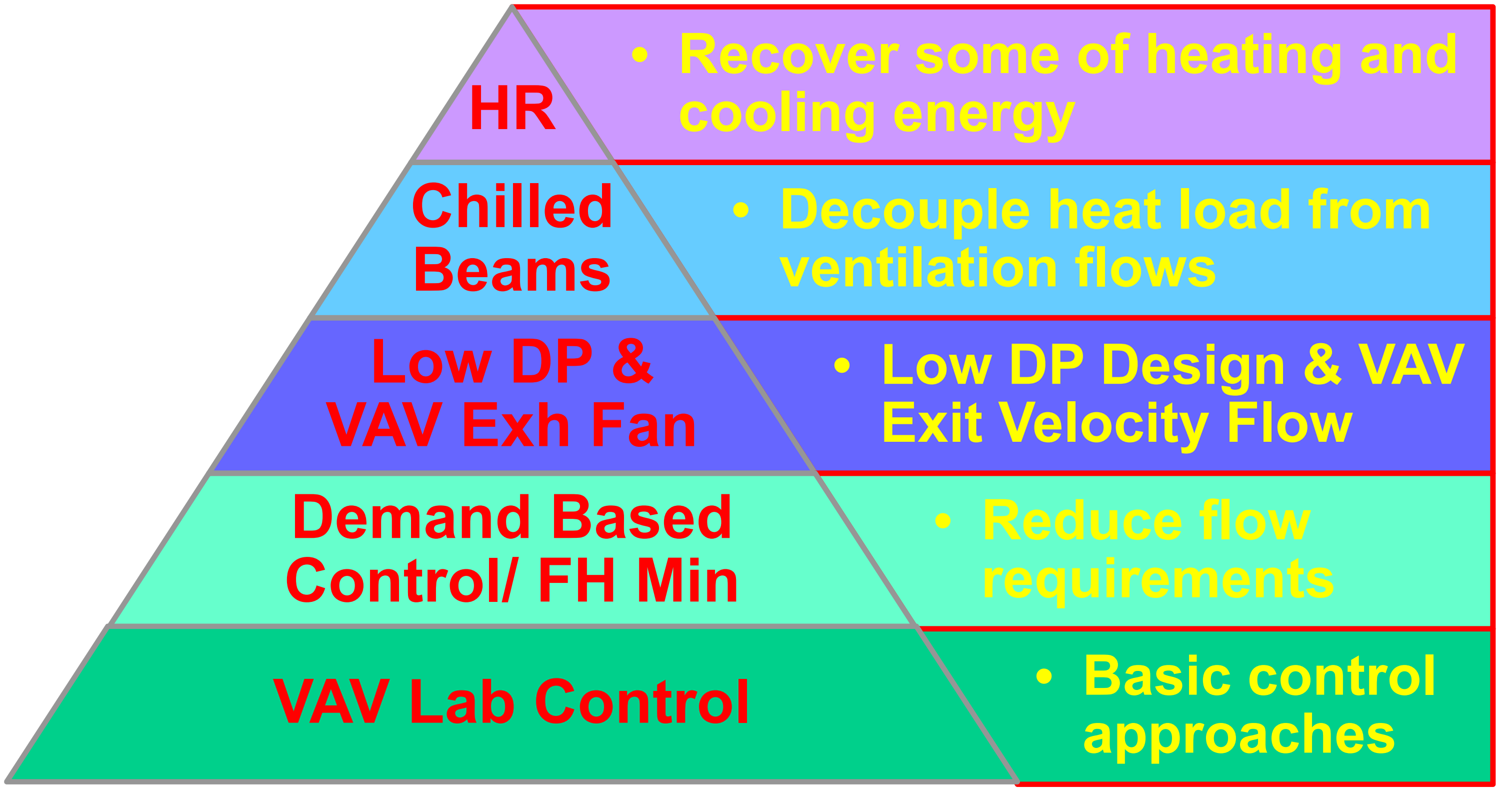
DBC Can Make Enthalpy Wheels More Economic



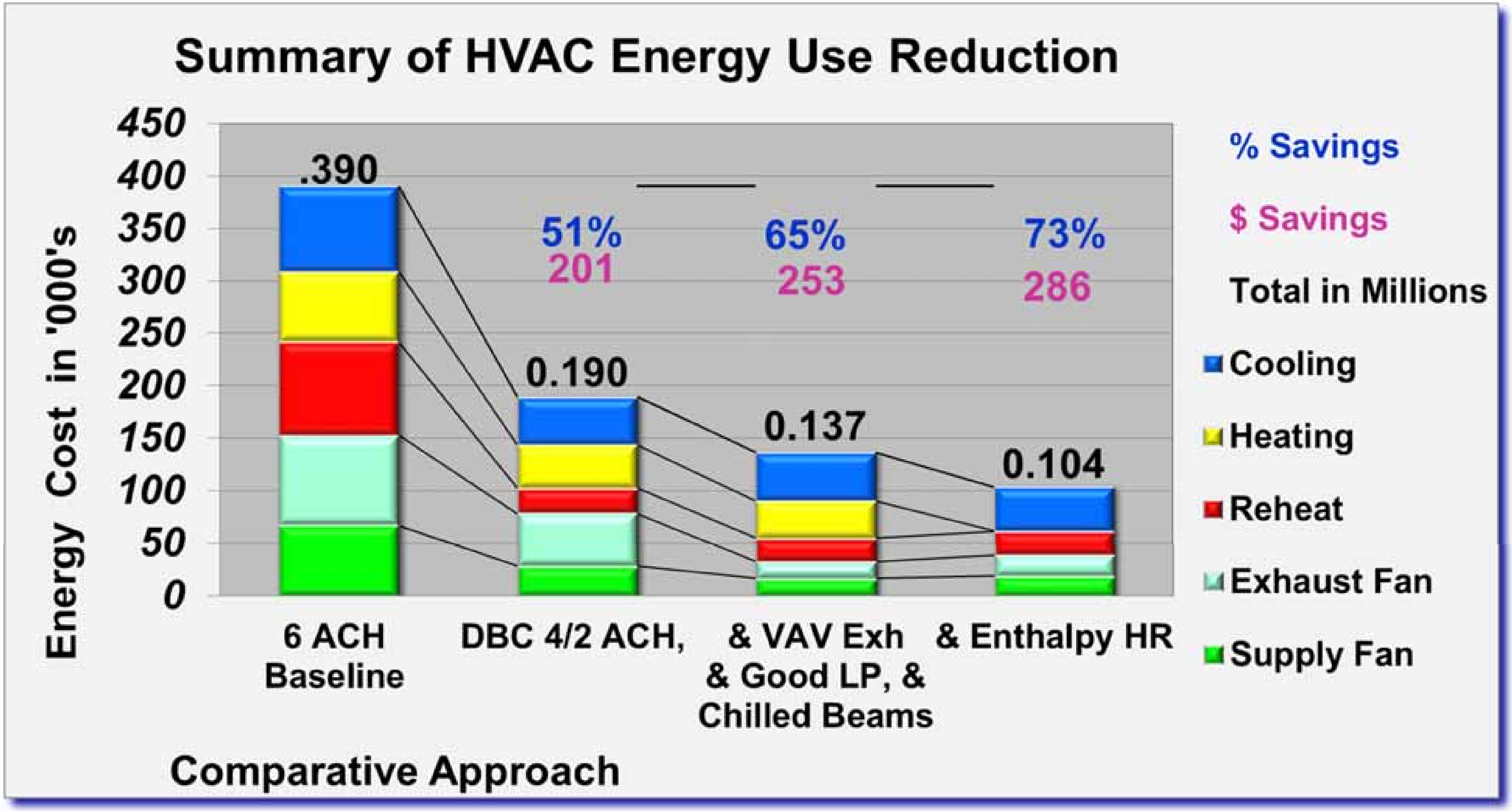
W/ DBC 2/2, CB, & reduced sash: HR savings is reduced to $25 K or 6.4%, but payback improves to 6.9 years

Holistic Strategies for Increased Savings

- **Individually evaluating systems is suboptimal**
  - ✓ DBC, chilled beams, hoods & heat recovery
- **To optimize lab safety, first cost & energy:**
  - ✓ Combining systems appropriately is best
  - ✓ Also use a layered or pyramid approach:

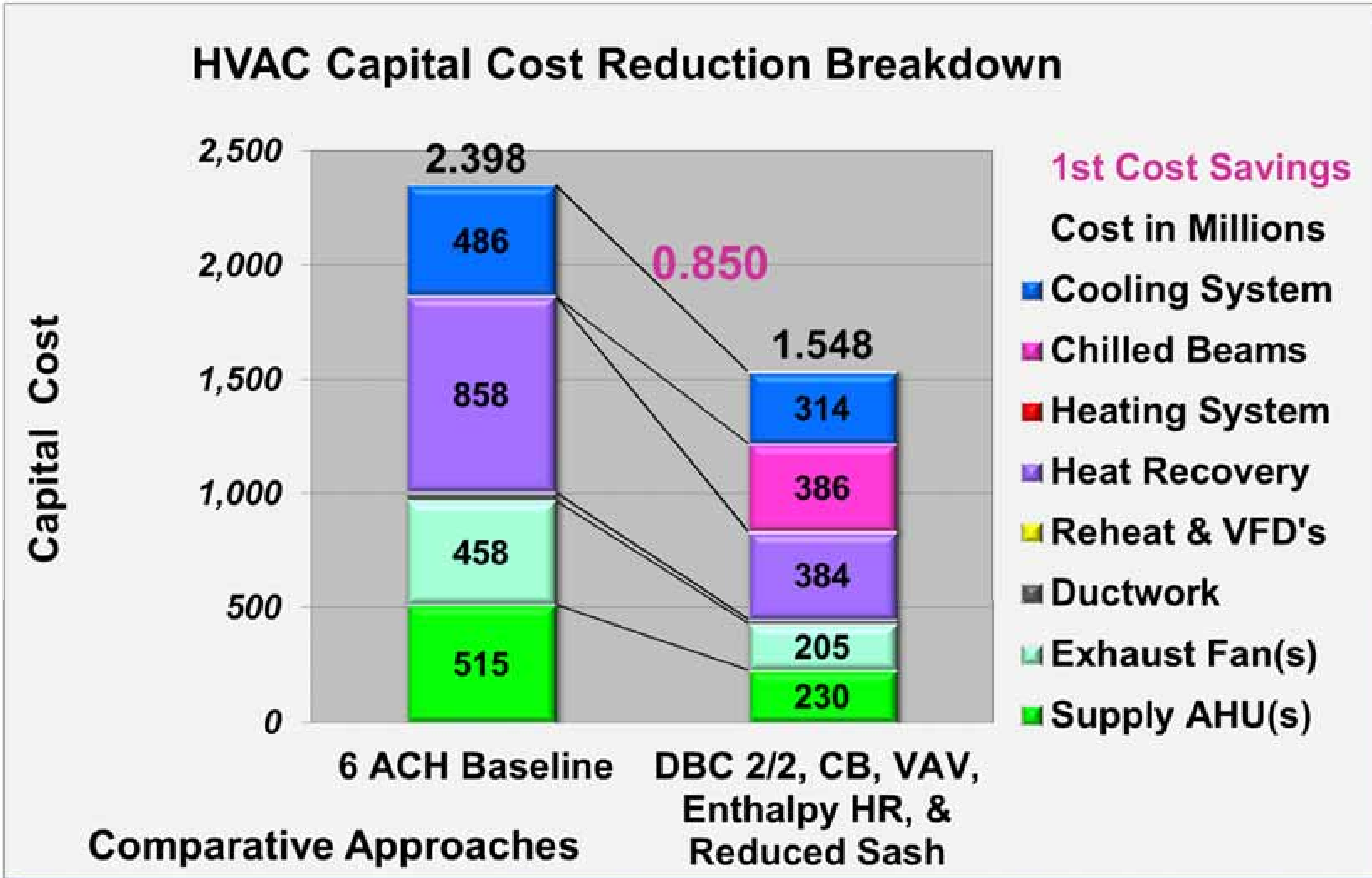


Summary of Technologies & Savings from 6 ACH



Including all approaches, total lab HVAC reduction is 73% or 65% w/o heat recovery!

Summary of Right Sized HVAC Savings at 6 ACH



Total Capital Cost Savings of $850K.
Including DBC the net savings is $386K.

Ventilation Workshop Presentation Summary

- Low ACH design is key to Net Zero Energy
  - ✓ Foundation for Deep Energy Reduction
  - ✓ Demand Based Control helps safely reduces lab ACH
  - ✓ DBC is often $\geq$3X savings of best heat recovery
- Chilled beams/fan coils decouple cooling & airflow
  - ✓ Saves more energy & first cost when used with DBC
- Cutting energy/airflow can also *Reduce First Cost!*

Questions?

For a copy of the presentation, contact:
Gordon Sharp, gsharp@Aircuity.com

Related Topic: Flow Reduction in Vivariums

- New ILAR & AAALAC Guidelines
- Vivarium DBC approach
- Vivarium site analysis
  - ✓ 3 Different types, 100,000 operating hours
- Case study of Univ. of Penn. vivarium

Further ASHRAE Handbook Vivarium Guidance

- **Performance Based Recommendations on ACH**
  - ✓ "The guideline of 10-15 fresh-air changes per hour has been used for secondary enclosures (the room) for many years and is considered an acceptable general standard. Although it is effective in many animal-housing settings, the guideline does not take into account the range of possible heat loads; the species, size, and number of animals involved; ….."
  - ✓ "Active sensing of contaminants in the secondary enclosure and varying the air change rates based on the room environmental conditions is one approach that can be considered to meet these requirements in a more energy efficient manner."

DBC Favorable Language from the 2010 ILAR Guide:

Chapter 3: page 46 (Chapter 5: page 139)

- **VAV systems**

  "These systems offer considerable advantages with respect to flexibility and energy conservation, but should always provide a minimum amount of air exchange, as recommended for general use laboratories"

  "...but variable-volume (VAV) systems may offer design and operational advantages, such as allowing ventilation rates to be set in accordance with heat load and other variables."

aaalac INTERNATIONAL

AAALAC's Belief in Performance Based Criteria

Chapter 3: page 46 (Chapter 5: page 139)

VAV systems

Council interpretation:

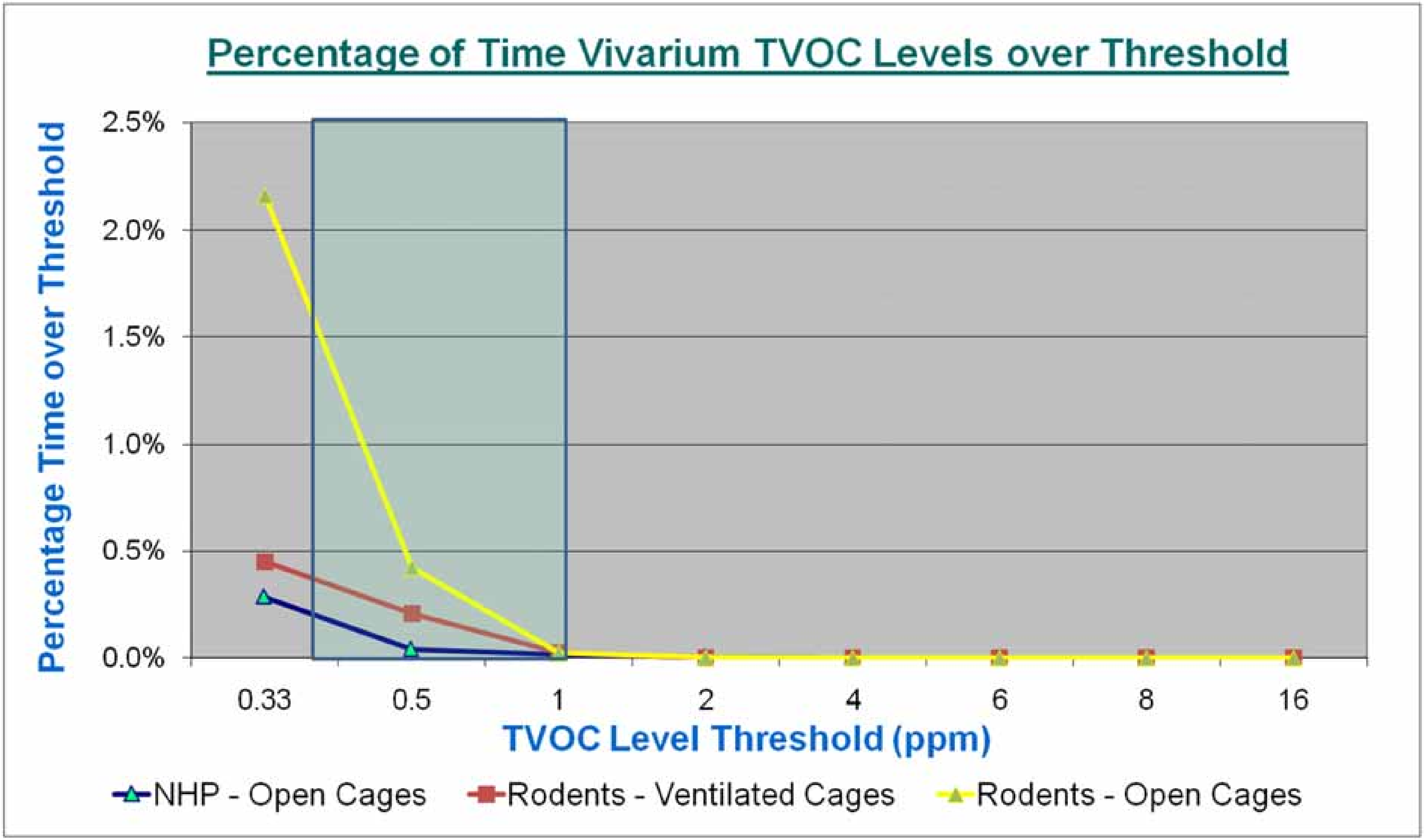
- May allow for an air exchange rate below the previous guideline of 10-15 ach.
- Council will asses **overall air quality and air exchange rate using performance based criteria** that will take into account a variety of circumstances such as: cage type (ventilated cages vs static), whether IVC racks have supply and discharge air from the room (or directly to the building exhaust system), filtration of animal cage exhaust air (if any), animal density, husbandry practices and the overall needs of the animals and the science.
- Assessments will be made via the HVAC reports and on-site evaluations

aaalac INTERNATIONAL

2008: Research Study on Vivarium DCV Data

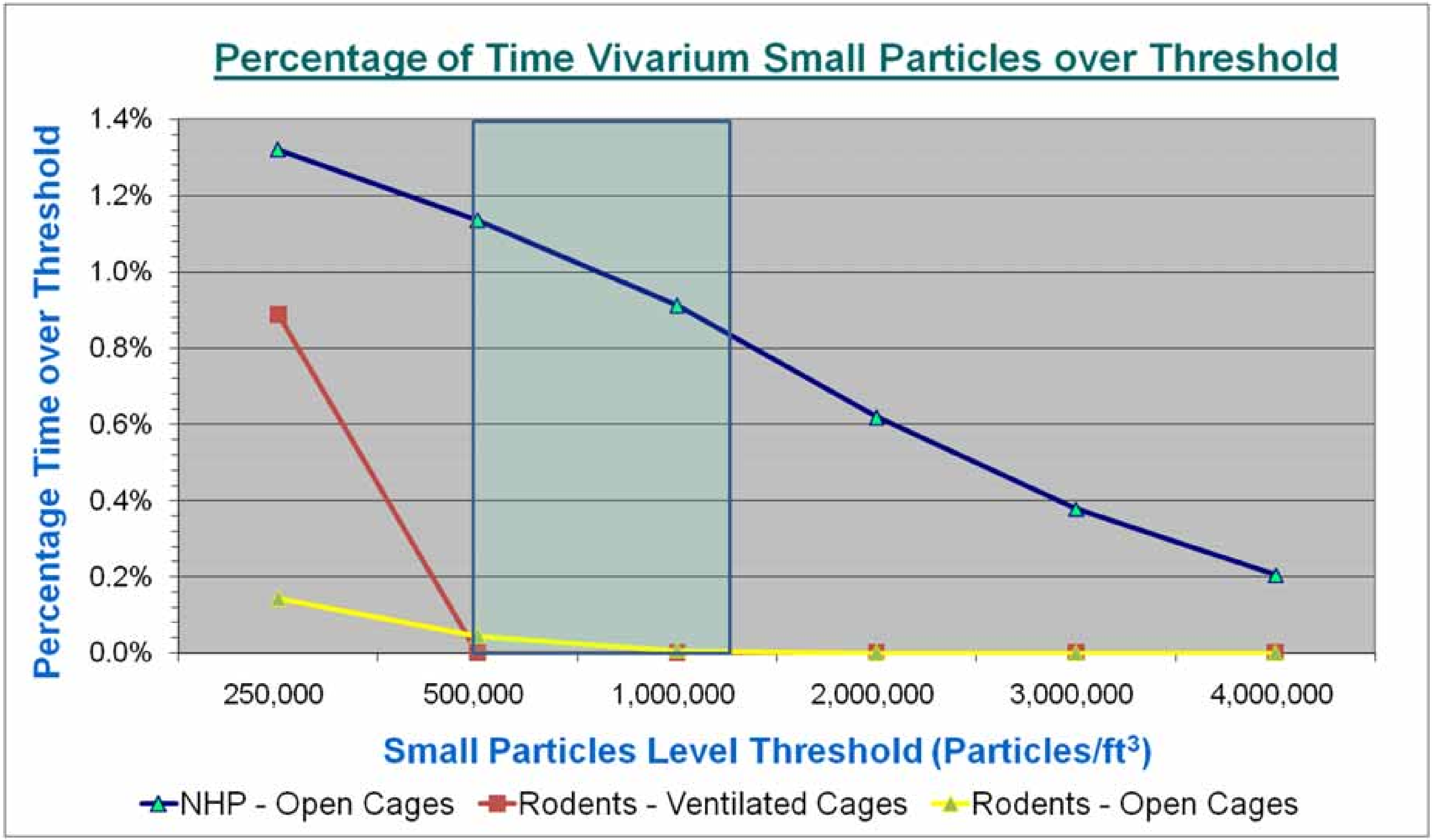
- Applied DBC to 3 vivarium facilities
- Data collected on 3 "worst case" vivarium types
  - ✓ Rodents: open, unventilated cages
  - ✓ Rodents: ventilated cages but exhausted into room
  - ✓ Non-human primates with open cages
- Approx. 100,000 hours of operation analyzed

2008 Data on Animal Room TVOC Data



TVOC/Ammonia impact ~ .2% to 1.5 %

2008 Data on Animal Room Particle Level Data



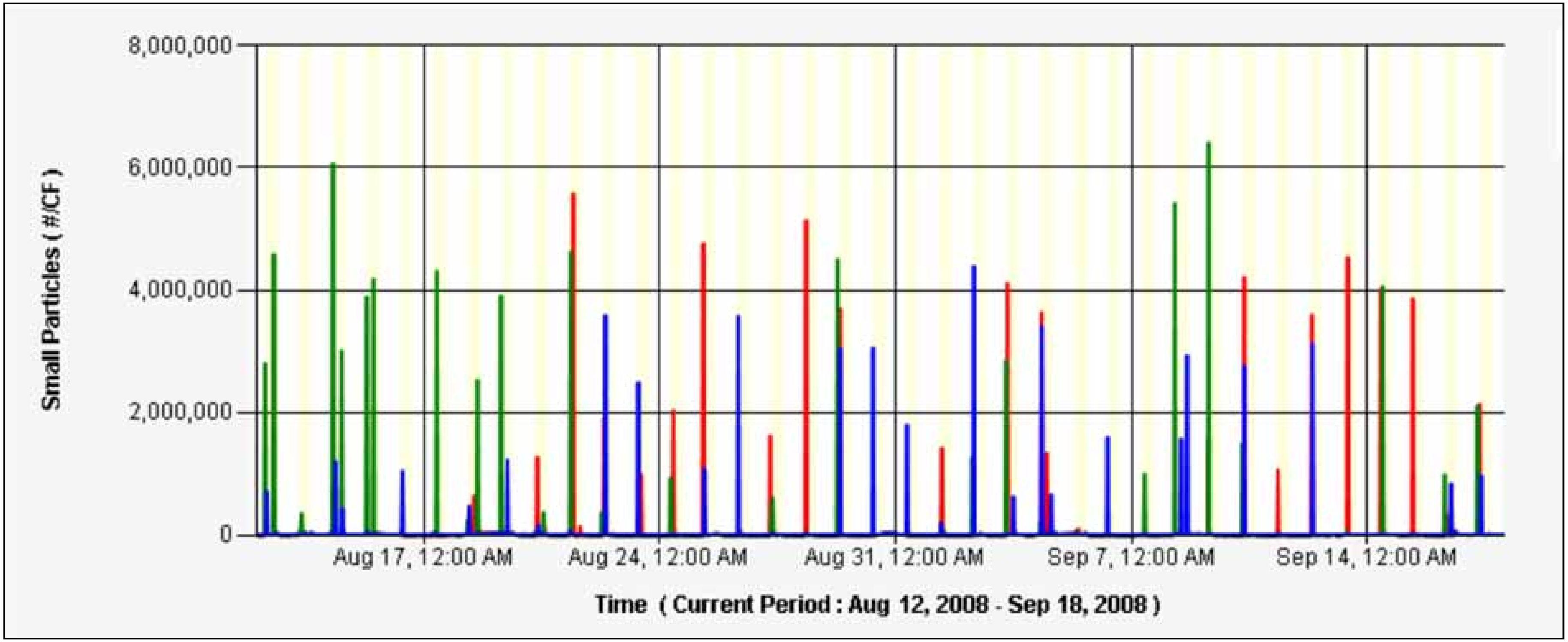
Particle impact on energy: ~0% to 1.2%

Other Benefits to IEQ Sensing in Vivariums


Photo courtesy of Lab Products, Inc., Seaford, DE

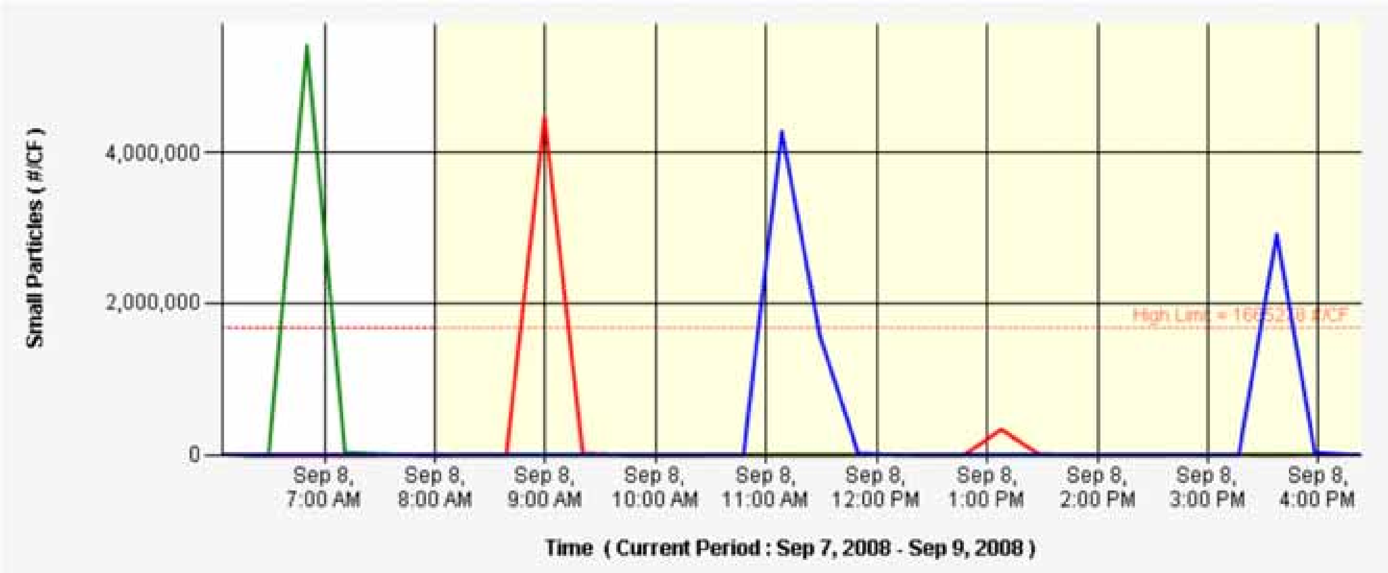
- **Validate safe IEQ room conditions**
  - ✓ **Documents room environment**
    - – *Ensures a clean room environment*
    - – *Facilitates quick diagnosis of problems*
- **Validate efficacy & frequency of cage changing**
  - ✓ **Detect excess particles/allergens from poor practices**
  - ✓ **Ammonia detection may help gage cage change period**
    - – *Possible labor reduction from optimizing cage changes*
- **More accurate & reliable humidity sensing**
  - ✓ **Less intrusive since sensors are remote**
  - ✓ **Affordable factory calibration & higher quality sensors**

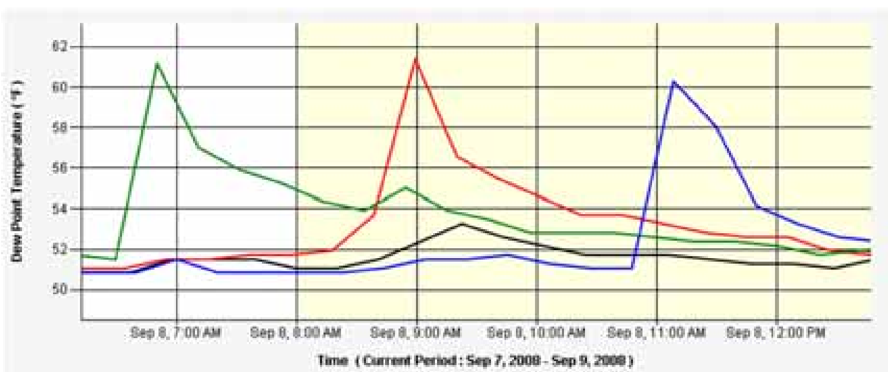
NHP Rooms Showing High Particle Spikes



Particle spikes are large and require increased ventilation.
What could be causing them?

NHP Cage Changes Causing High Particle Spikes

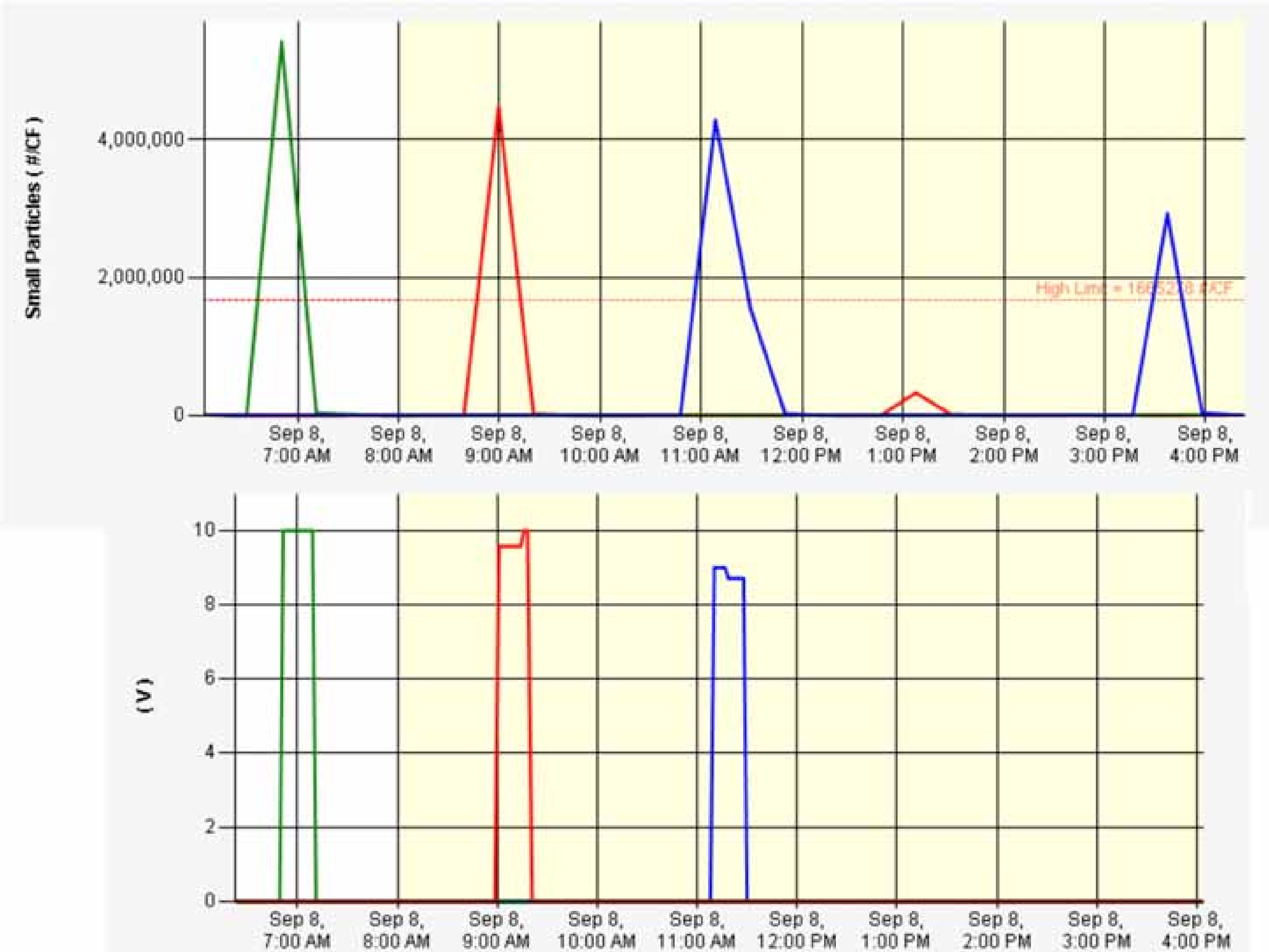




Dewpoint jumps from 51 to ~ 61 degrees F

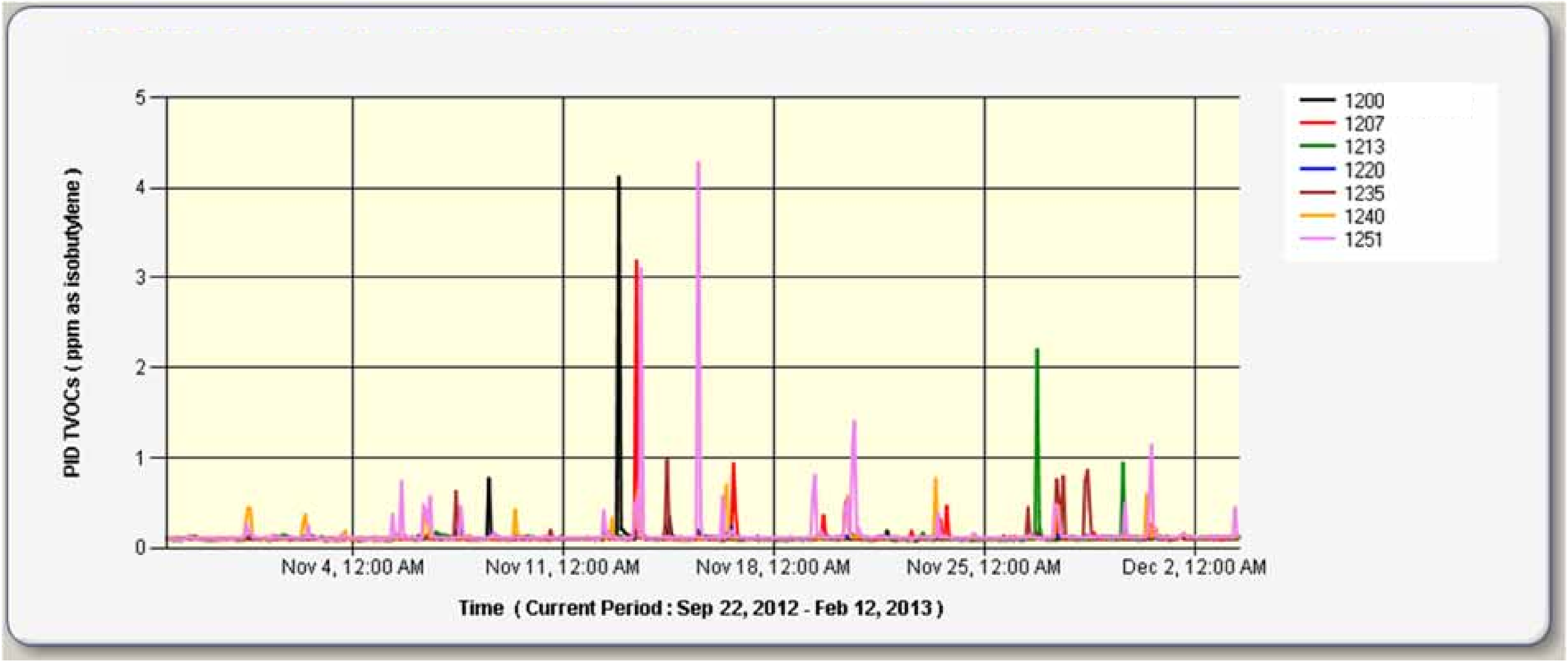
Cage cleaning also creates a spike in dewpoint/humidity

Vivarium DCV Responds to NHP Room Particle Spikes



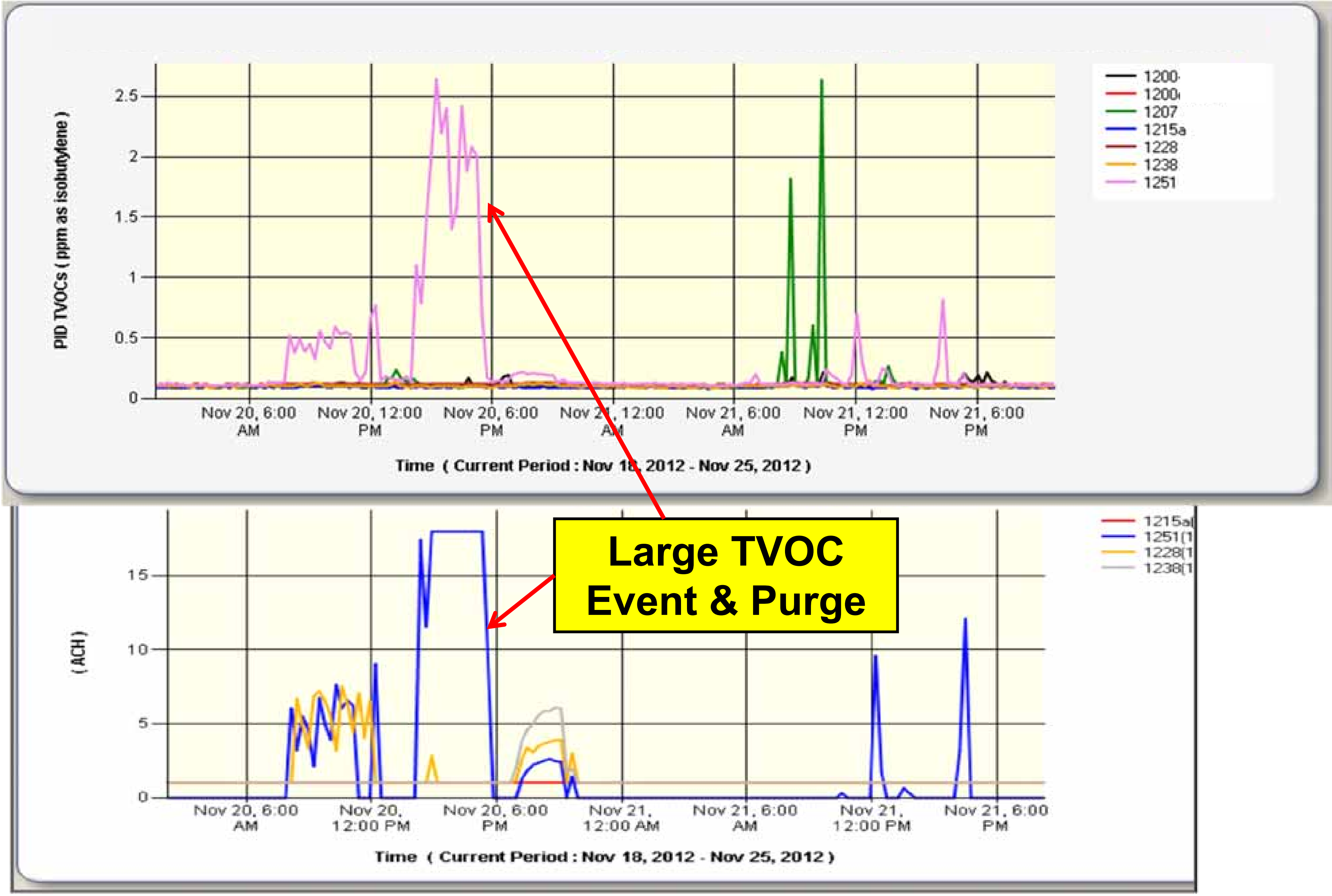
Particle spikes command increase in ACH's

Typical Vivarium Data for TVOC's

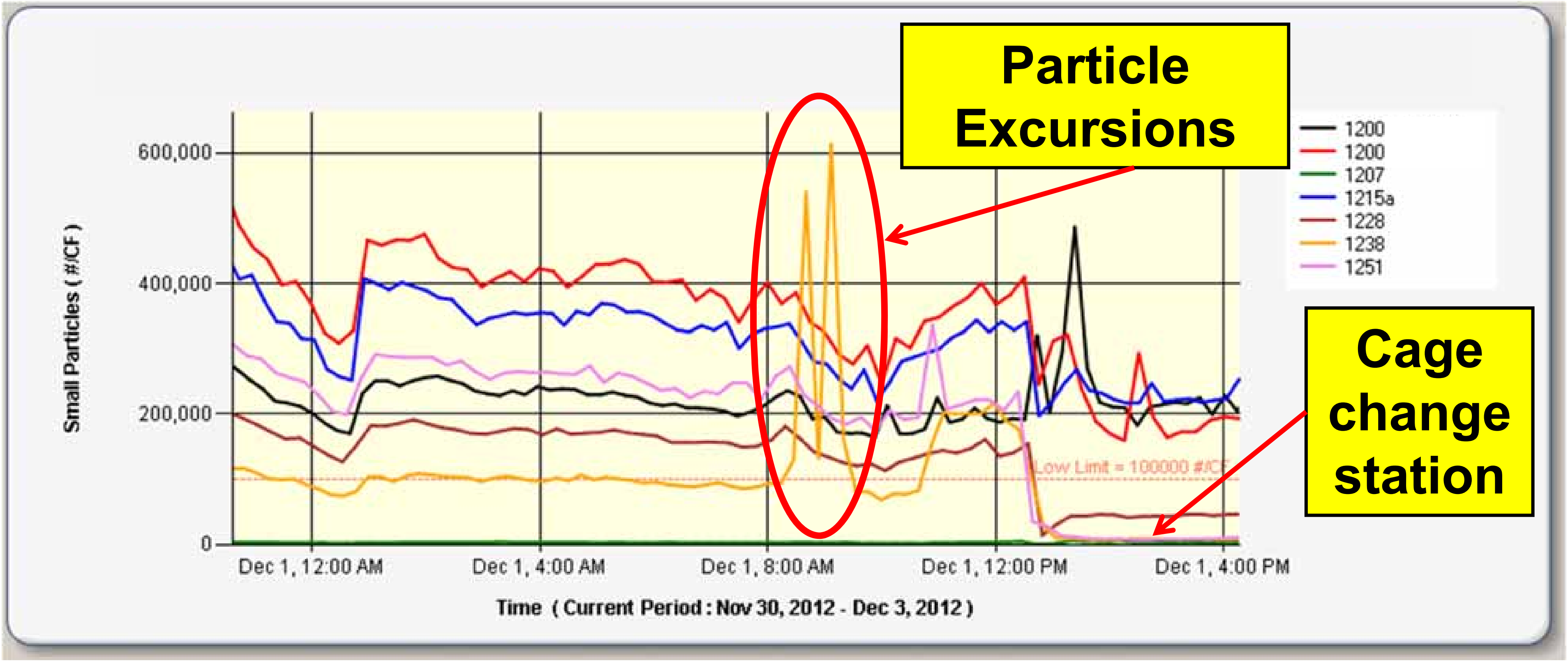


Typical levels are low but TVOC events happen commonly and need increased flow to purge

Significant TVOC Event & Airflow Purging

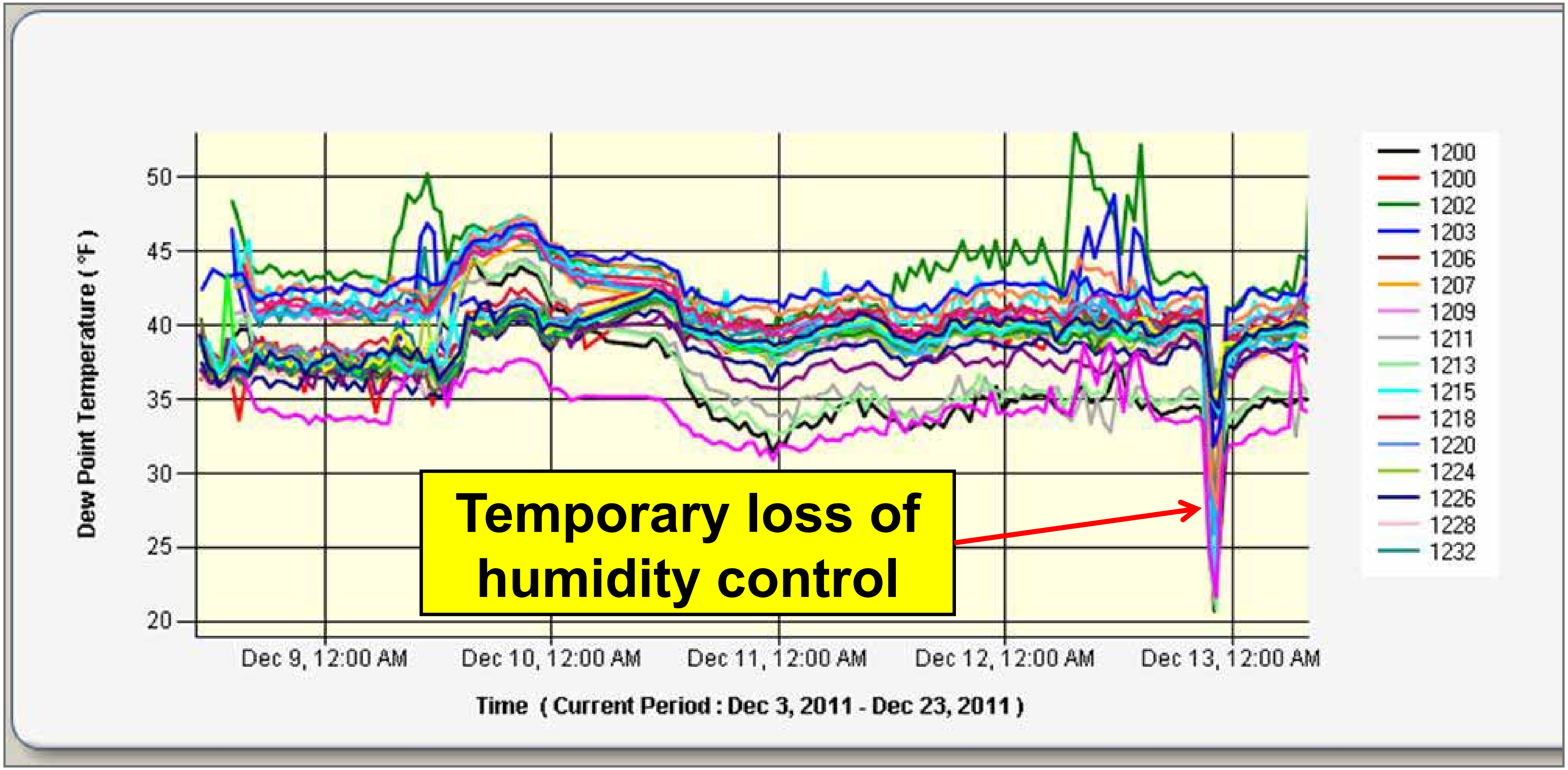


Typical Particle Levels from a Vivarium



Small particle excursion events can be seen as well as use of a cage change station that is cleaning the air

Typical Vivarium Data for Humidity



UPenn Evaluated DBC Impact on Odors (Open Cages)

Vivarium Room	Population Percent Occupied	First Week (11-16-2009) Room Ammonia in PPM No DCV - Min flow at ~10 ACH	Second Week (11-23-2009) Room Ammonia in PPM DCV from 10 to 19 ACH
B	83%	6	0
C	92%	8	2.5
D	96%	6	0
F	22%	0	0
G	44%	9	0
K	40%	5	0

- **Week 1: ACH min dropped to 10 ACH w/ temp override:**
  - ✓ **Odors noticed & 5 to 10 PPM of room ammonia at cage change**
- **Week 2: Demand based control enabled (10 to 19 ACH)**
  - ✓ **Odors absent & 0 to 2.5 PPM room ammonia at cage change**

DBC permits successful safe use of lower ACH

Actual Energy Savings: **Hill Pavilion Vivarium**

Monthly data analysis for Hill Pavilion revealed significant changes throughout the year in the operational costs and air flow reduction for the vivarium spaces.

The CFM savings were more significant in Hill Pavilion than in the other pilot study in Lynch Life Sciences due to a larger delta in the reduction of the ACH rate from a constant 19 ACH to an adaptable ACH rate.

Energy Used WITHOUT	Steam/BTU	Power kWh	CHW/BTU	avrg CFM used	Cost per avg CFM	MTCDE
Total Energy October thru September	1,767,219,960	106,970	575,306,288	5,470	$ 10.10	159
Total $ cost /Typ of Energy	$ 41,113.26	$ 8,022.75	$ 6,112.63			
Toatal $ Spent October thru September	$ 55,248.64					

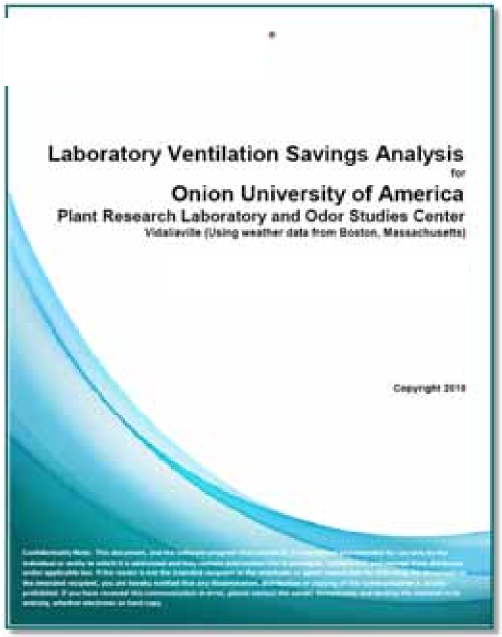
Energy Used WITH	Steam/BTU	Power kWh	CHW/BTU	avrg CFM used	Cost per avg CFM	MTCDE
Total Energy October thru September	988,629,479	68,648	364,861,309	3,475	$ 9.22	96
Total $ cost /Typ of Energy	$ 22,999.84	$ 5,148.63	$ 3,876.65		Max Average ACH	Average Min ACH
Toatal $ Spent October thru September	$ 32,025.12				18.84	10.26

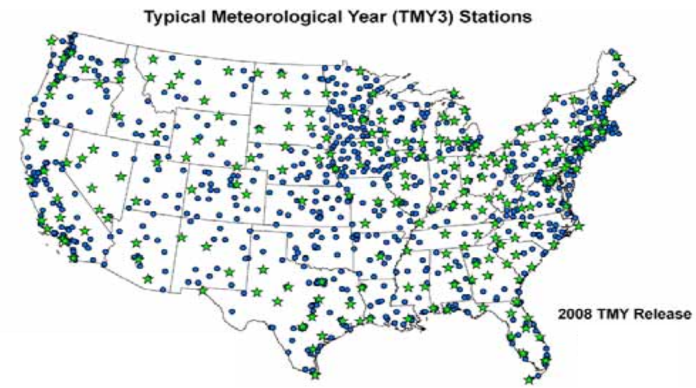
Energy Savings WITH	Steam/BTU	Power kWh	CHW/BTU	avrg CFM Saved	Cost Savings per avg CFM	MTCDE
Total Energy Saved October thru September	778,590,481	38,322	210,444,980	1,995	$ 0.88	63
Total $ cost /Typ of Energy saved	$ 18,113.42	$ 2,874.13	$ 2,235.98			
Toatal $ saved October thru September	$ 23,223.52					

42 % Reduction in cost!!

Low ACH Animal Facility Design Example

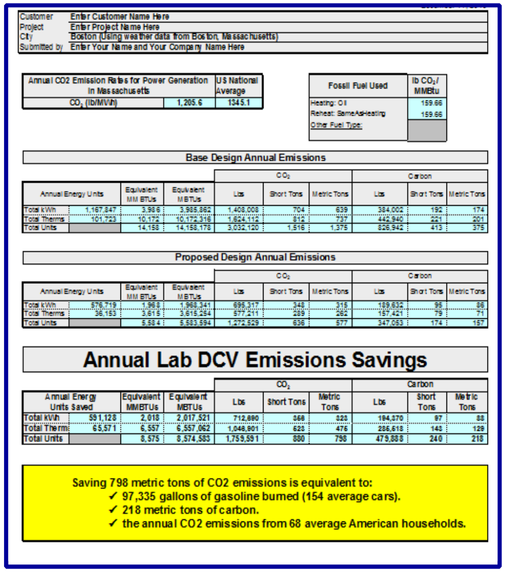
- Model typical 30K NSF vivarium
- Assume 100 rooms at 300 ft^2 avg.
- Evaluate impact of DBC
  - ✓ Proposed DBC min. rate of 6/4 ACH
  - ✓ Compare alone & w/ chilled beams
- Look at impact of heat recovery:
  - ✓ Glycol loop (No Enthalpy wheels due to ammonia carryover)
- Assume baseline of 15 ACH
- Use Boston for weather data





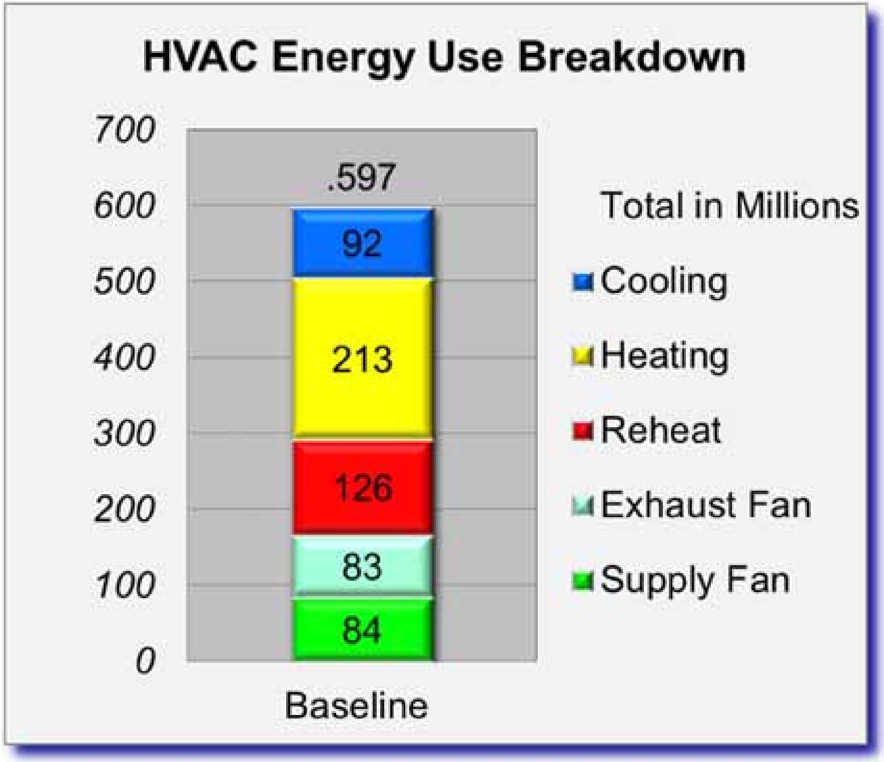
More Vivarium Analysis Assumptions

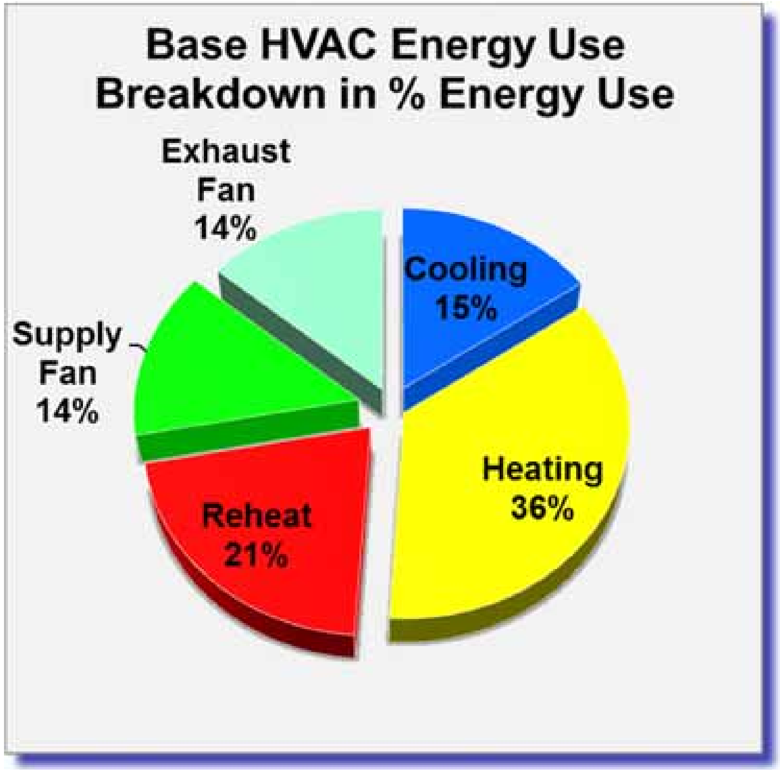
- Room Temp set to 74 DegF
- Energy Cost Assumptions:
  - ✓ Electric: $.11/kWh
  - ✓ Gas: $1.00/therm
- Include humidification (steam)
- Assume avg. day cooling loads:
  - ✓ 20% - 3 watts/ft^2
    - – *Procedure space – Light load*
  - ✓ 60% - 6 watts/ft^2
    - – *Moderate thermal load for animal spaces*
  - ✓ 20% - 12 watts/ft.
    - – *High thermal load animal spaces*



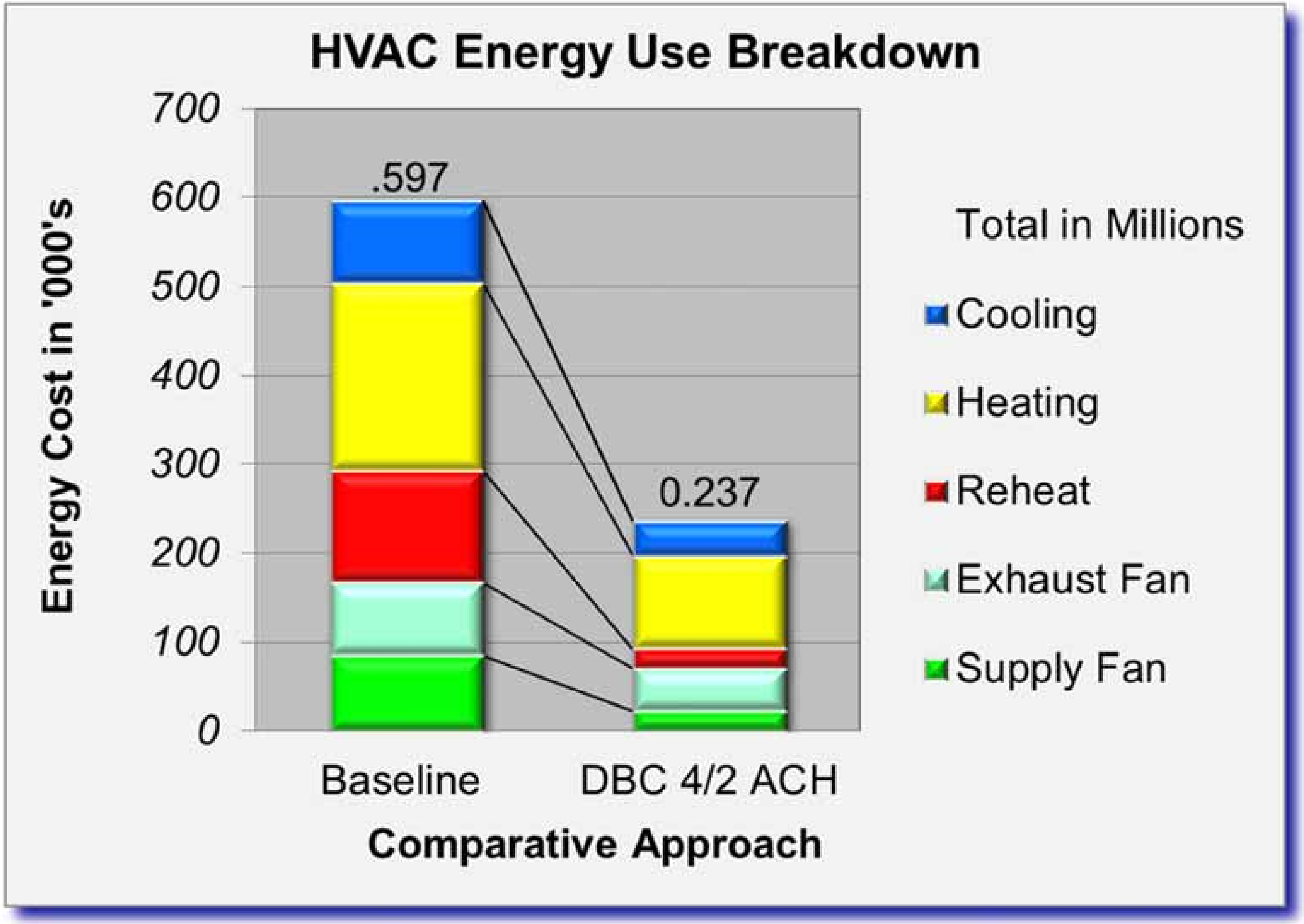
15 ACH Baseline Energy Costs For Boston

- Skin & solar gains typically small compared to OA
- Base flow rate of Vivarium: 82.5K cfm
- Total baseline energy use is $597K/ year



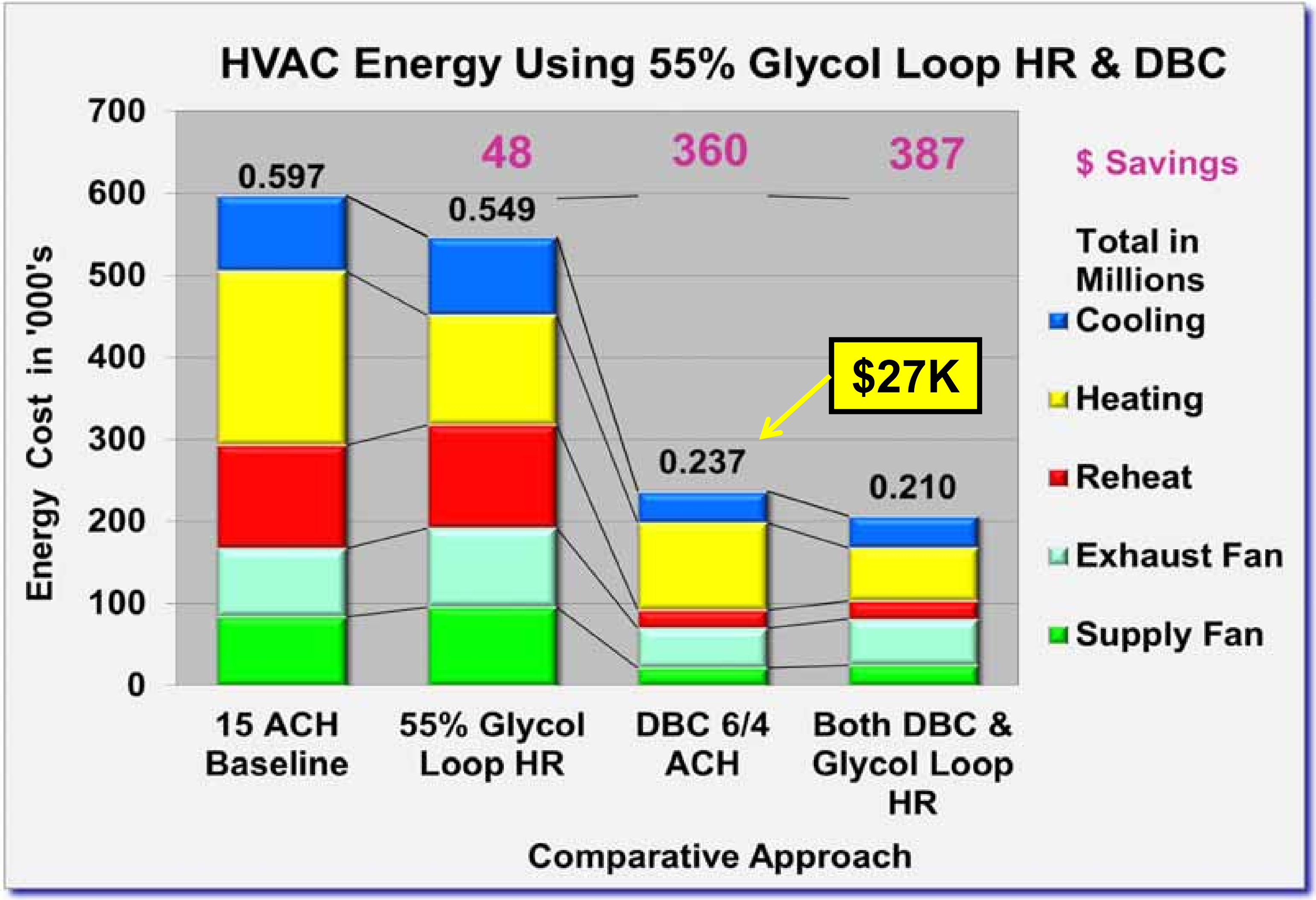


DBC Energy Savings of Min Flow of 6 Day/4 Night



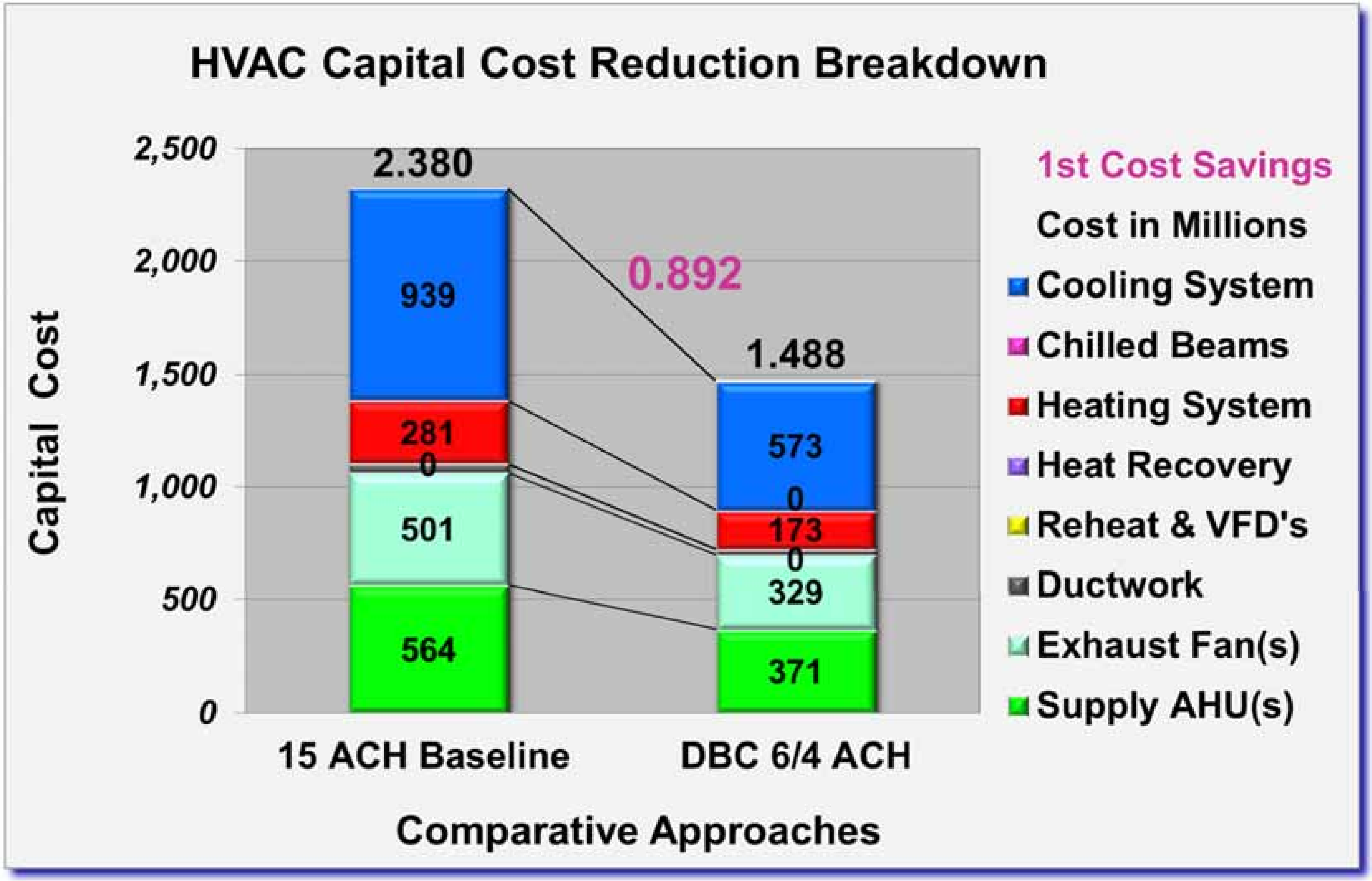
Demand Based Control reduces vivarium HVAC energy by $360K or by 60% vs. 15 ACH. Payback is 1.4 yrs.

55% Glycol Runaround Heat Recovery Savings



55% Runaround HR w/ 6/4 DBC: only $27K or 4.5% saving.
HR payback: 8 yrs. even w/ HVAC capital savings!

HVAC 1st Cost Savings of 6/4 ACH vs. 15 ACH



DBC at 6/4 ACH vs. 15 ACH reduces peak HVAC airflow by 34% or ~ $892K. Net first cost savings of: $376K!

Ventilation Workshop Presentation Summary

- Low ACH design is key to Net Zero Energy
  - ✓ Foundation for Deep Energy Reduction
  - ✓ Demand Based Control helps safely reduces lab ACH
  - ✓ DBC is often $\geq$3X savings of best heat recovery
- Chilled beams/fan coils decouple cooling & airflow
  - ✓ Saves more energy & first cost when used with DBC
- Cutting energy/airflow can also *Reduce First Cost!*

Questions?

For a copy of the presentation, contact:
Gordon Sharp, gsharp@Aircuity.com