A Holistic Overview of Technologies and Strategies to Achieve Deep Energy Reductions in Laboratories

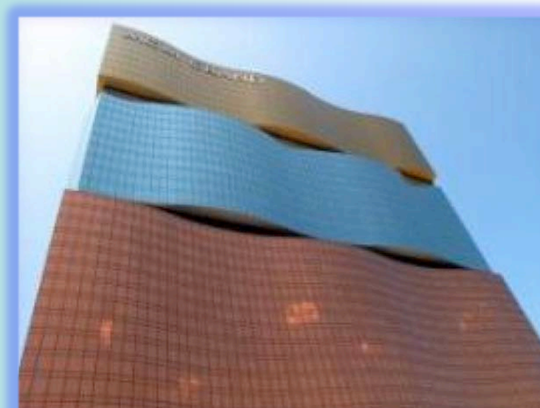
New Apple HQ

Masdar City, UAE

Grand Mosque, Mecca

ASU: Biodesign Institute

UHN: MaRS TMDT



MGM Macau Casino

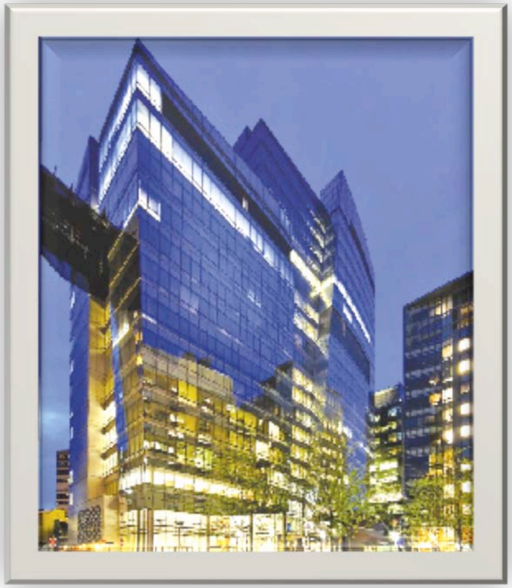
Gordon P. Sharp, Aircuity

Presentation Overview For Deep Energy Reduction

- Introduce low flow lab design innovation
- Introduce a new tool for lab energy analysis
- Describe approaches/issues to safely hit 2 ACH
- Explain Demand Based Control
  - ✓ 1st cost & energy savings impacts
- Describe low ACH case studies
- Analyze other innovative technologies

Low Flow/Energy Lab Design: A New Paradigm

- **A focus on max savings**
  - ✓ **Not a grab bag of many ideas**
    - – *Focus on a few, high impact concepts*
- **The foundation: *Airflow reduction***
  - ✓ **Airflow has greatest energy impact**
  - ✓ **Can also reduce lab's first cost!**



- **Need for a holistic approach to technologies**
  - ✓ **Use energy models for first cost & energy impact**
    - – *Impact of low flow design & combining concepts often non-intuitive*

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

Goal: Dramatically Reduce Lab Energy Use

- **Outside air use: Largest energy driver**
  - ✓ Reducing OA reduces many energy uses
- **New technologies can help:**
  - ✓ Demand Based Control of ACH
  - ✓ Chilled beams
- **Plus codes/standards also changing**
  - ✓ New versions of NFPA 45, Z9.5, ASHRAE
- **Result: Dramatic cut in energy use**
  - ✓ Labs can often run as low as 2 ACH
  - ✓ Vivariums can run as low as 4 to 8 ACH

If these approaches are used a Net Zero lab is possible even 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

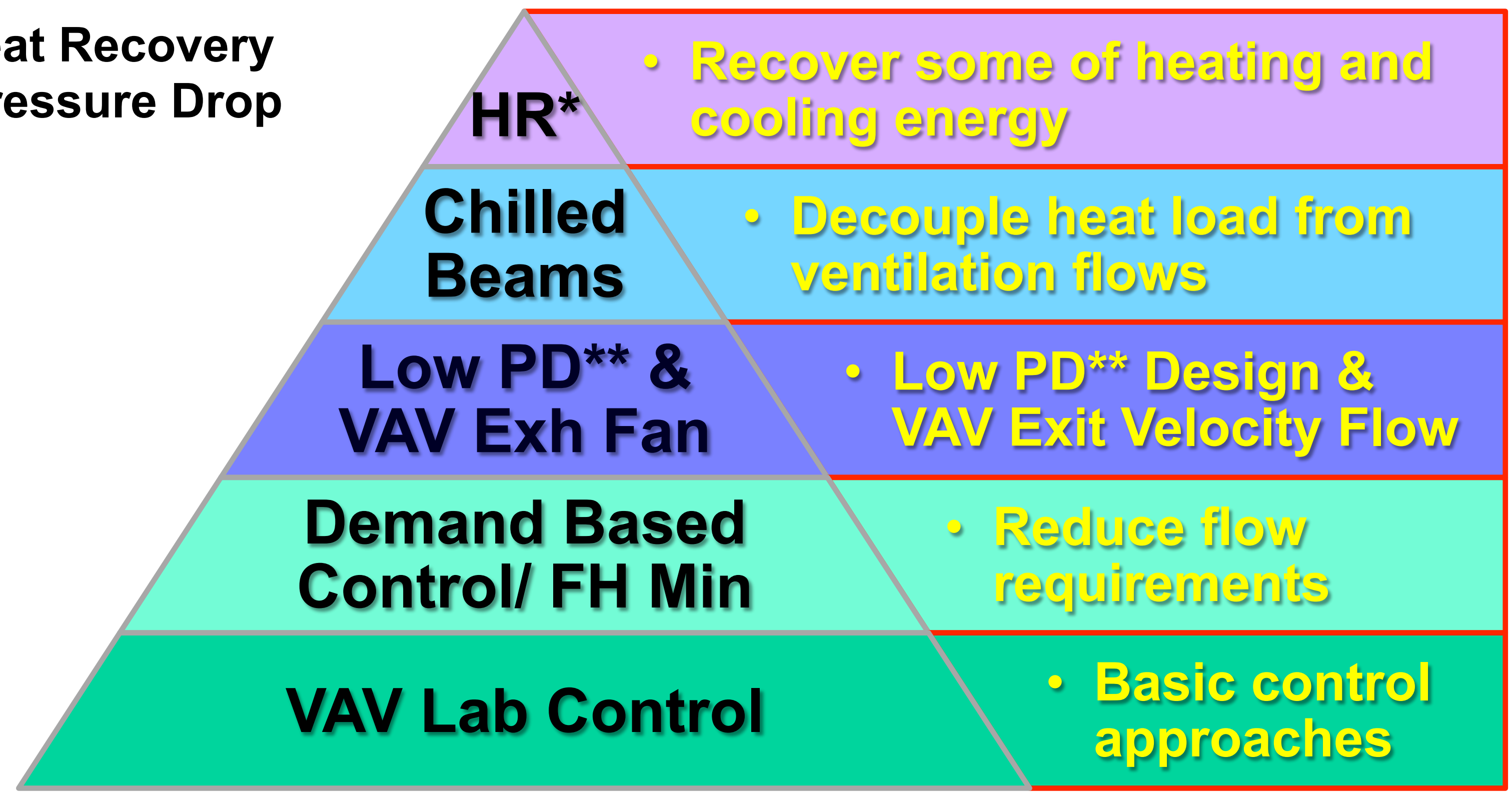
www.labratings.com

www.i2sl.org

Holistic Strategies for Increased Savings

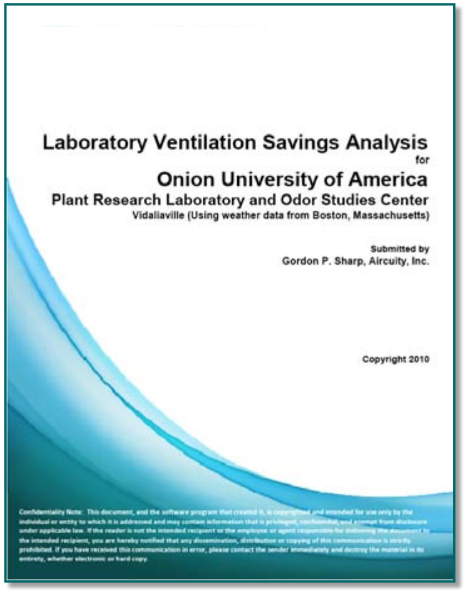
- **Individually evaluating systems is suboptimal**
  - ✓ DBC, chilled beams, hoods & heat recovery all interact
- **To optimize lab safety, first cost & energy:**
  - ✓ Combining systems based on analysis of ***Net*** benefits
  - ✓ Also use a layered or pyramid approach:

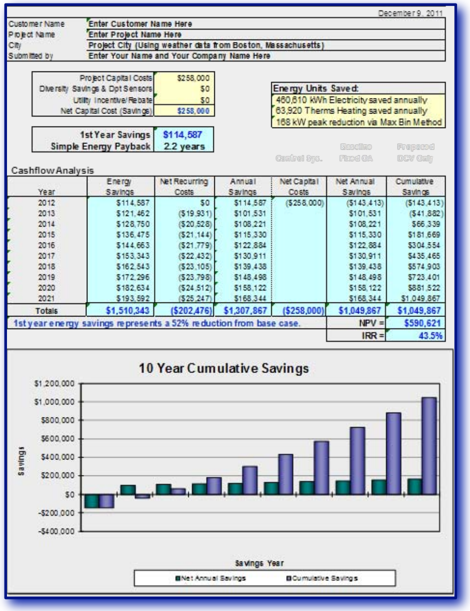
*Heat Recovery
**Pressure Drop



Energy, First Cost, & Payback Analysis Tool

- **Lab focused design analysis**
  - ✓ **Customized lab analysis engine**
  - ✓ **Calculates both energy & 1st cost**
  - ✓ **Powerful "What If" tool for design**
- **Reviewed & approved by utilities**
  - ✓ **PG&E, S. Cal. Edison, Con Ed**
  - ✓ **Calculates Rebate incentives**
- **Validated by Emcor & JCI**
- **To be used by US DOE**
- **Holistic broad range tool**
  - ✓ **For many technologies & concepts**
    - *Heat recovery, chilled beams, etc.*





December 9, 2011

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

Project Capital Costs	$258,000
Diversity Savings & Dpt Sensors	$0
Utility Incentive/Rebate	$0
Net Capital Cost (Savings)	$258,000

Energy Units Saved:
460,610 kWh Electricity saved annually
63,920 Therms Heating saved annually
168 kW peak reduction via Max Bin Method

1st Year Savings	$114,587
Simple Energy Payback	2.2 years

Cashflow Analysis

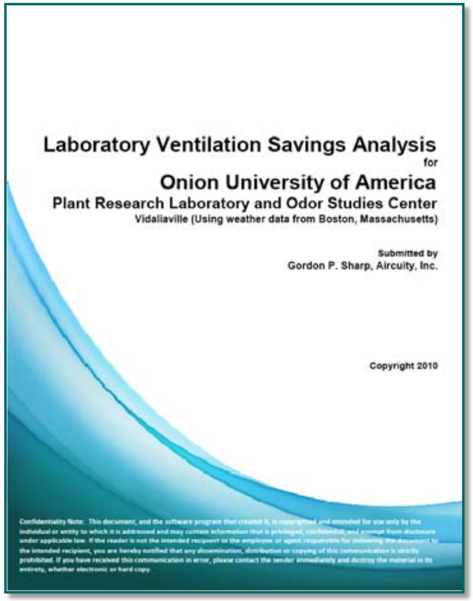
Year	Energy Savings	Net Recurring Costs	Annual Savings	Net Capital Costs	Net Annual Savings	Cumulative Savings
2012	$114,587	$0	$114,587	($258,000)	($143,413)	($143,413)
2013	$121,462	($19,931)	$101,531		$101,531	($41,882)
2014	$128,750	($20,528)	$108,221		$108,221	$66,339
2015	$136,475	($21,144)	$115,330		$115,330	$181,669
2016	$144,663	($21,779)	$122,884		$122,884	$304,554
2017	$153,343	($22,432)	$130,911		$130,911	$435,465
2018	$162,543	($23,105)	$139,438		$139,438	$574,903
2019	$172,296	($23,798)	$148,498		$148,498	$723,401
2020	$182,634	($24,512)	$158,122		$158,122	$881,522
2021	$193,592	($25,247)	$168,344		$168,344	$1,049,867
Totals	$1,510,343	($202,476)	$1,307,867	($258,000)	$1,049,867	$1,049,867

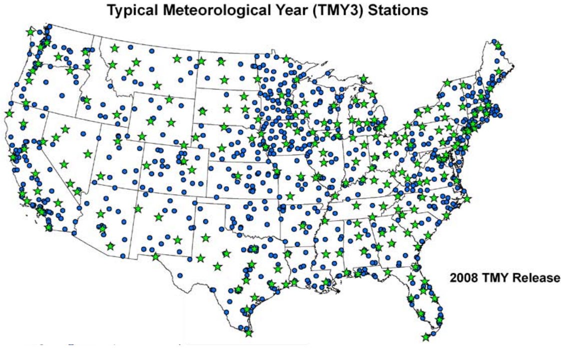
1st year energy savings represents a 52% reduction from base case.

NPV =	$590,621
IRR =	43.5%

Toronto Example Analysis Assumptions

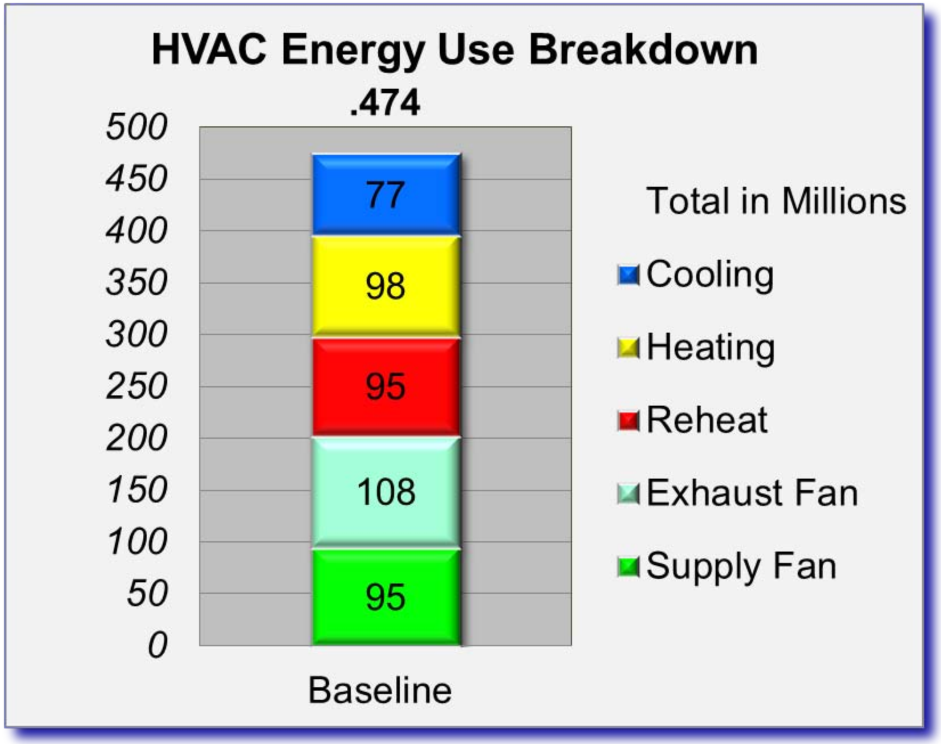
- **Model typical bldg. w/ 125K GSF**
  - ✓ Lab & lab support area: 50K NSF
  - ✓ Office area: 30K NSF
- **Base dilution ventilation:**
  - ✓ Typically 6 to 12 ACH, assume avg. of 8
- **Energy Cost Assumptions:**
  - ✓ Electric: $0.13/kWh Avg
  - ✓ Heating: $0.80/therm
  - ✓ $800/kW Demand & $.1/m3 gas incentive
- **Low to moderate hoods:**
  - ✓ One 6' hood/ 667 $ft.^2$ module (75)
- **Manifolded exhaust fans:**
  - ✓ 4 fans are staged plus 1 spare

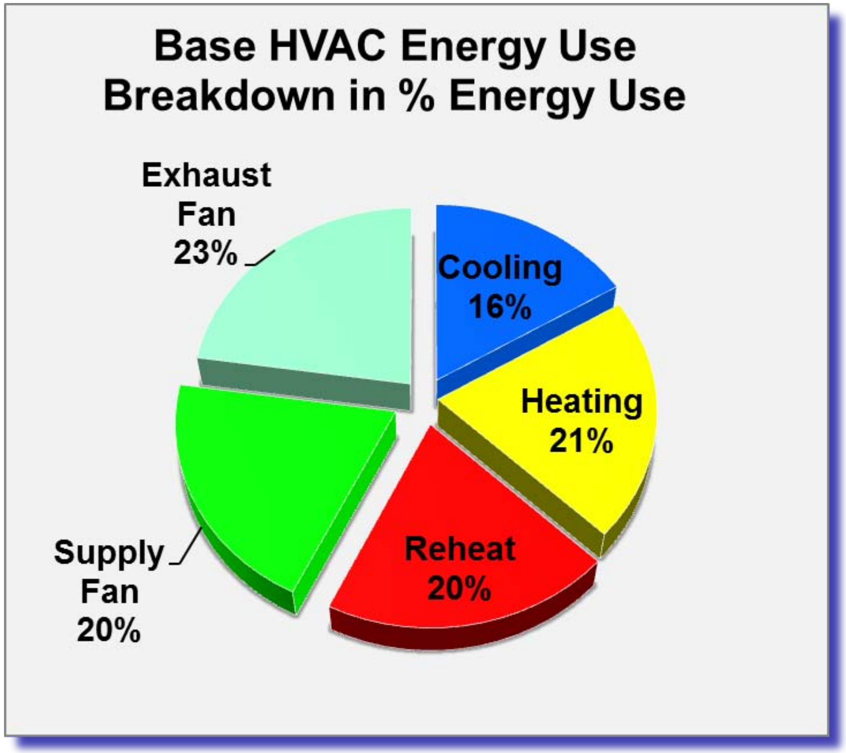




8 ACH Baseline Energy Costs For Toronto

- **Skin & solar gains typically small compared to OA**
- **Base flow rate (including offices):**
  - ✓ **151.6K m^3/hr day & 138K m^3/hr night**
- **Total baseline energy use is $474K/ 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
  - ✓ Also use a layered or pyramid approach:

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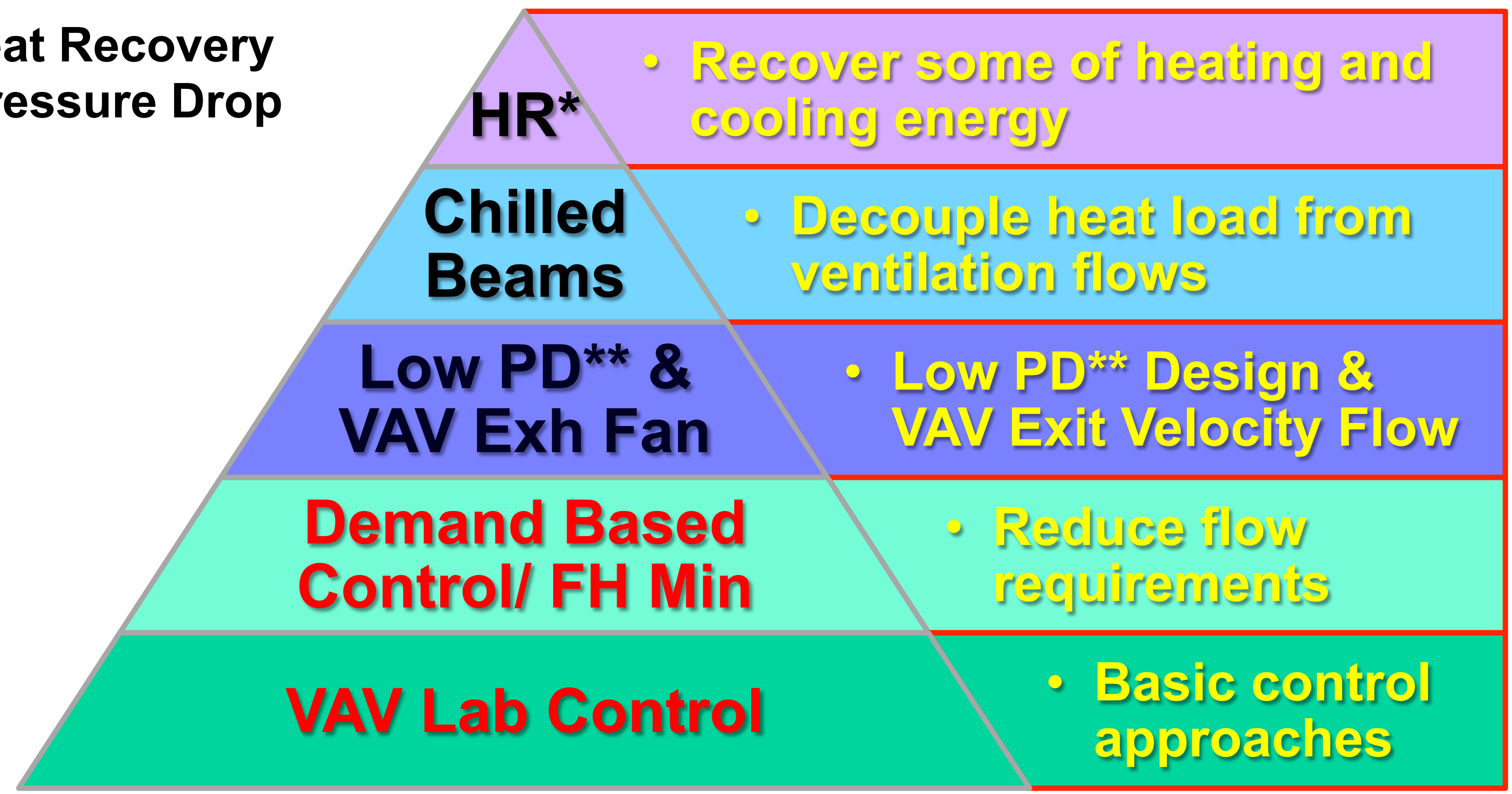
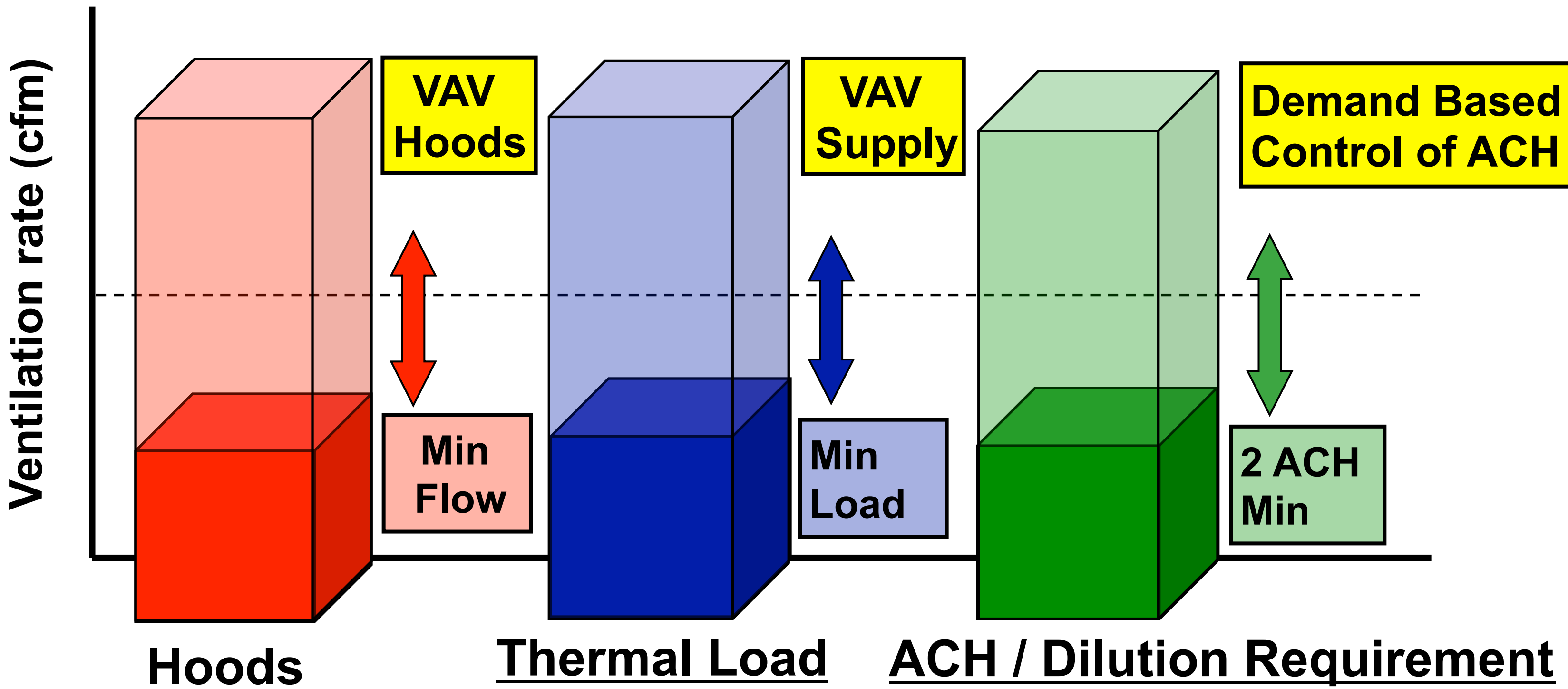
**Pressure Drop



Achieving Down to 2 ACH Safely in Labs

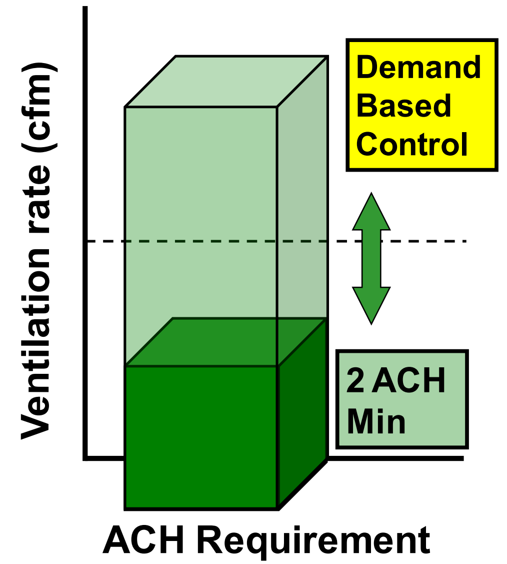
- **Goal: Achieve 2 ACH day/night or 3-4 day / 2 night**
- **What are the drivers of lab airflow that affect this?**
  - ✓ Hood flows, thermal loads & ACH rates



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

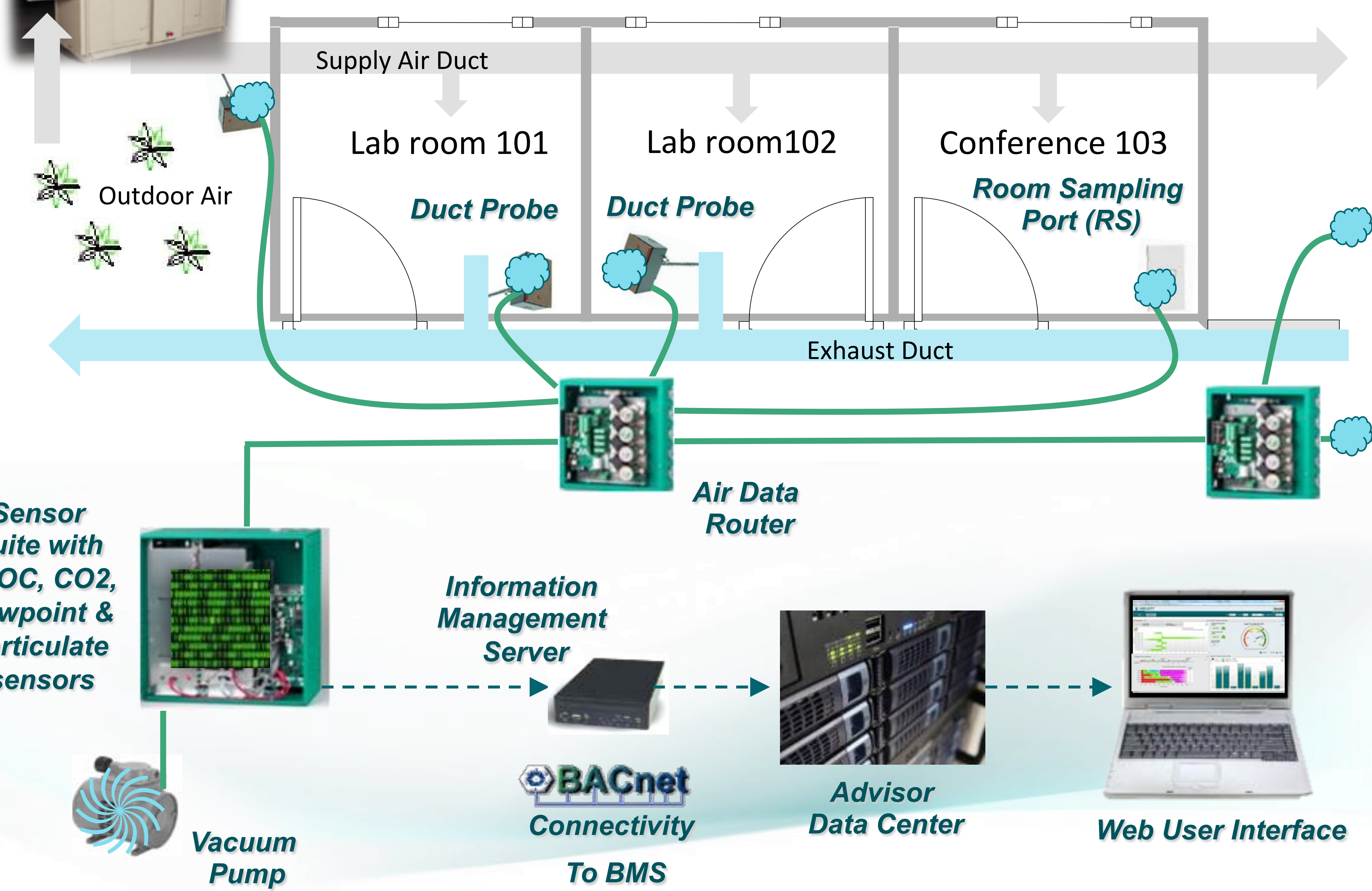
Reducing/Varying the ACH Rate Flow

- Demand Based Control (DBC) solution
  - ✓ Reduces lab airflow when lab air is "clean"
  - ✓ Increases lab flow when pollutants sensed
- Studies show lab air clean > 98% time
- Equal or better safety w/ the ***Best*** airflow
  - ✓ A fixed min ACH flow is always to high or low
  - ✓ 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
    - *Using 3/2 ACH better & more cost effective*
    - *Clean flow of 2 ACH (even during day) is best*

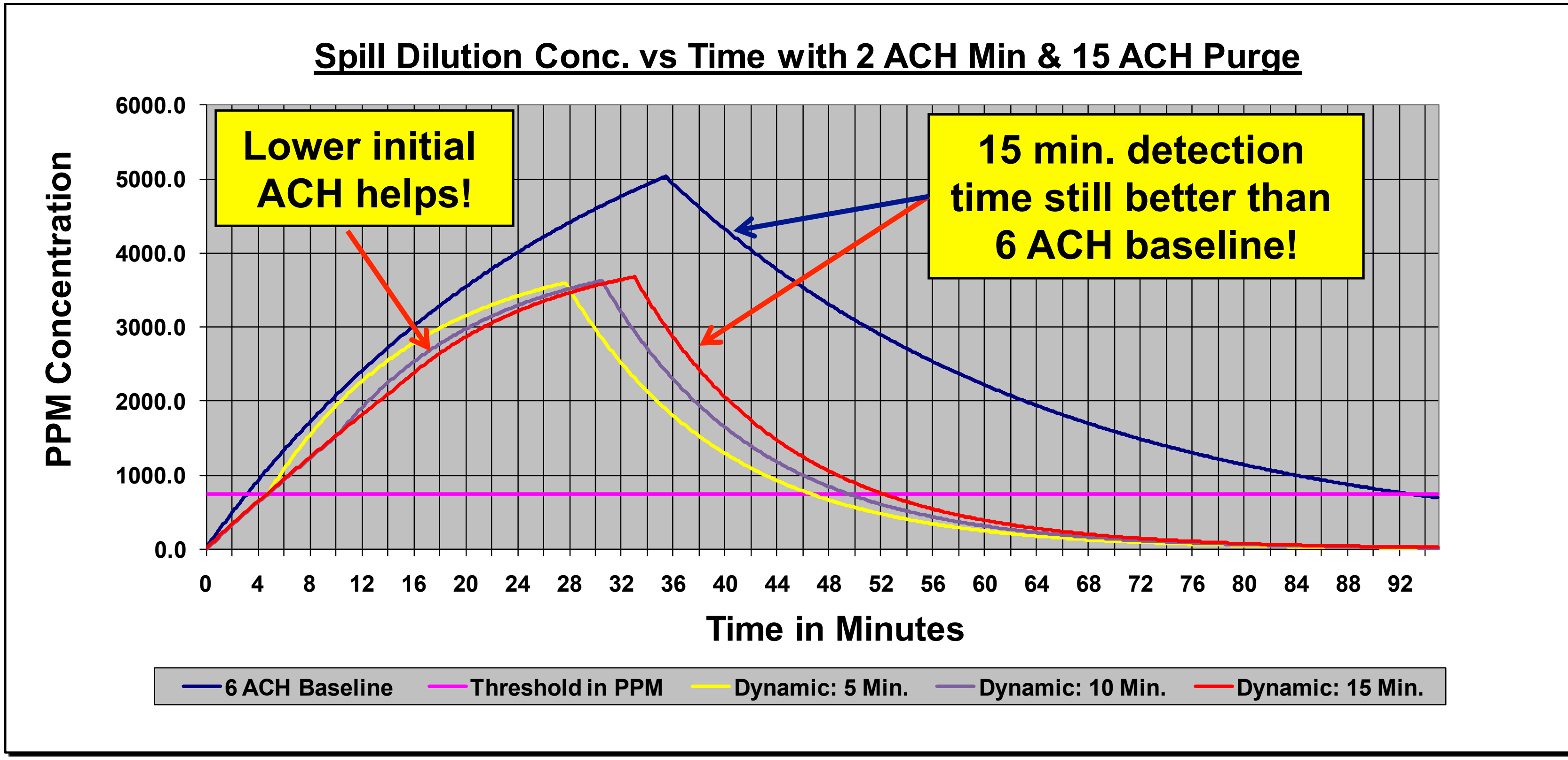


Demand Based Control (DBC) provides a safe means to achieve 2 ACH

Multiplexed Sensing & Air Control Technology



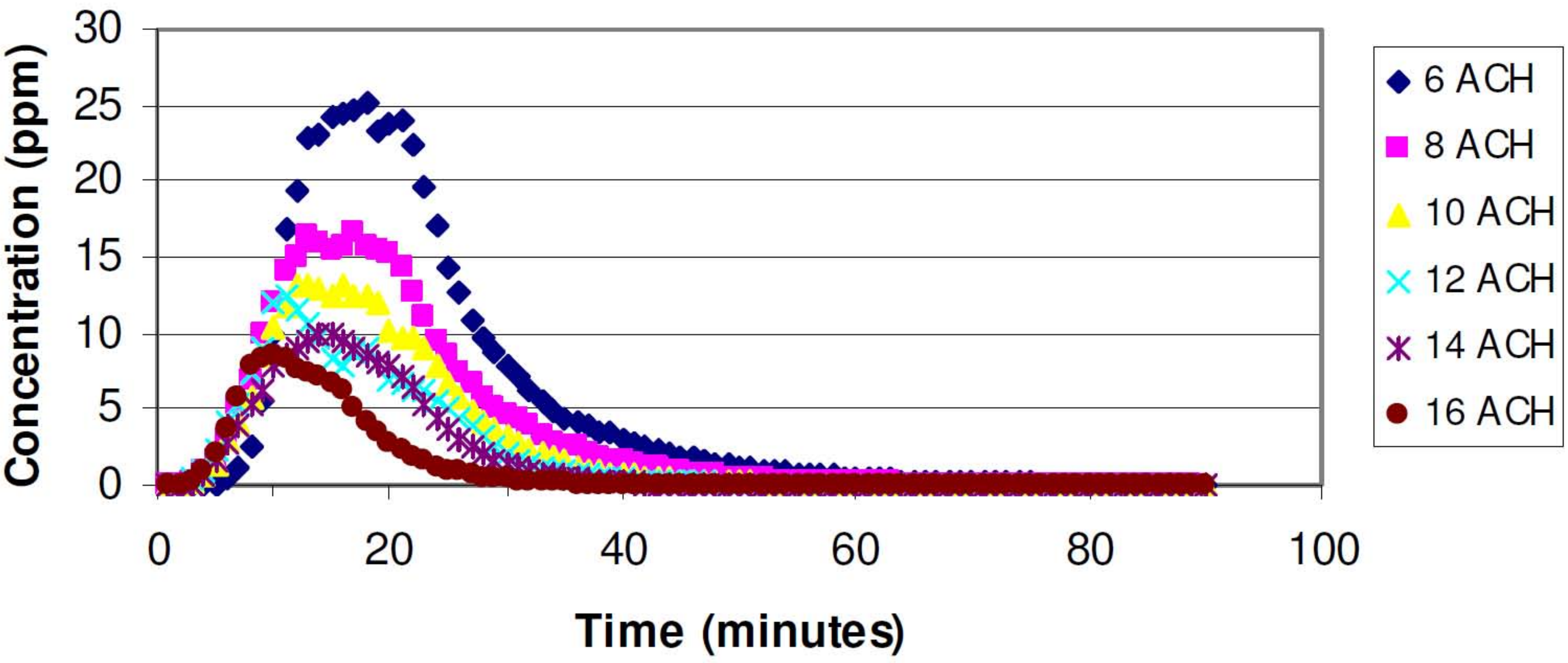
Impact of Dynamic Control on Dilution Rates



- 1.5 L spill of acetone in 200 sq ft lab room, 1 sq. m spill
- After vaporized, dynamic system hits TLV in 20 vs. 60 min
- After 2 hours dynamic control has dropped level to 2.6 PPM
  - ✓ After 2 hours, 6 ACH system is at 302 PPM or 116 times higher!

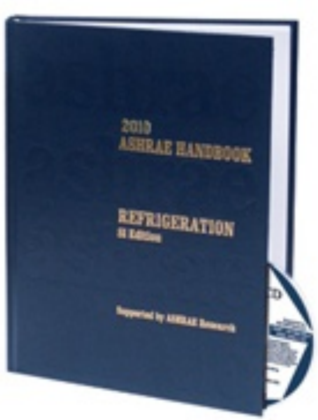
Dynamic control approach is always less than 6 ACH baseline

Impact of Air Velocity on Actual Yale Spill Results



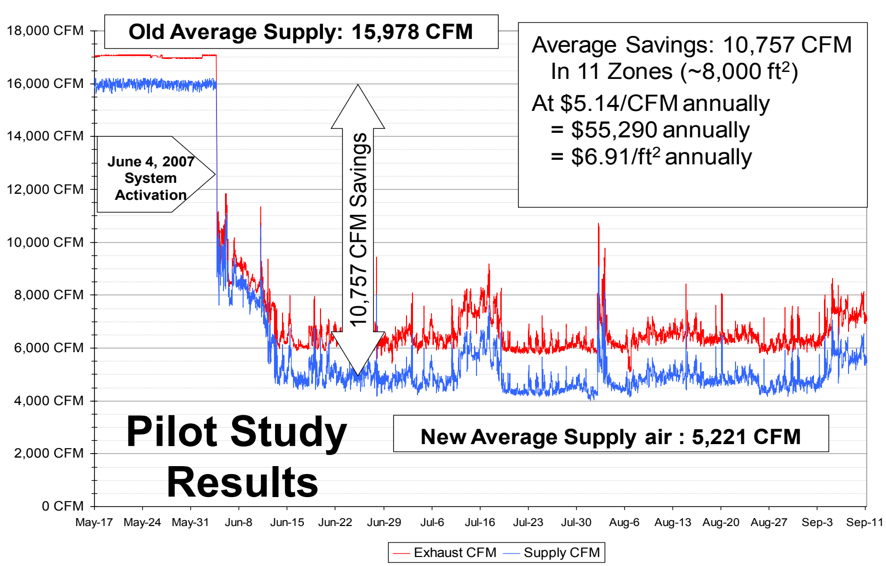
ASHRAE Handbook Provides New Guidance

- **New 2011 ASHRAE Handbook, Lab chapter 16:**
  - ✓ **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'..."*



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 (Bldg. B)**
  - ✓ Lab DCV pilot in 2007 to look for EE: 65% savings achieved
  - ✓ Full building (A&B) retrofitted in 2009: $1 Million saved/year
  - ✓ Currently 24 buildings have been retrofitted:
    - *Office, classroom, library, sciences bldgs, sports arena & others*



UHN's Toronto Medical Discovery Tower (TMDT) @ MaRS

- **400,000 ft^2 Lab building**
  - ✓ 12 Floors of Labs
  - ✓ 2 Floors Vivarium
- **Retrofit Project**
- **Results: ~$1M savings/yr**
- **Payback ~ 2.5 years**

UHN TMDT Typical Results – Floor 5

	CFM (Pre-Retrofit)	CFM (Post-Retrofit)	CFM Saved	Cost Per CFM	Total Savings
As Per Proposal	38,781	22,281	16,500	$7.90	$130,350
Actual	38781	20,025	18,756	&7.90	$148,200 !

Total savings for just one floor was ~ $148,200. Exceeded target by $17,900!

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

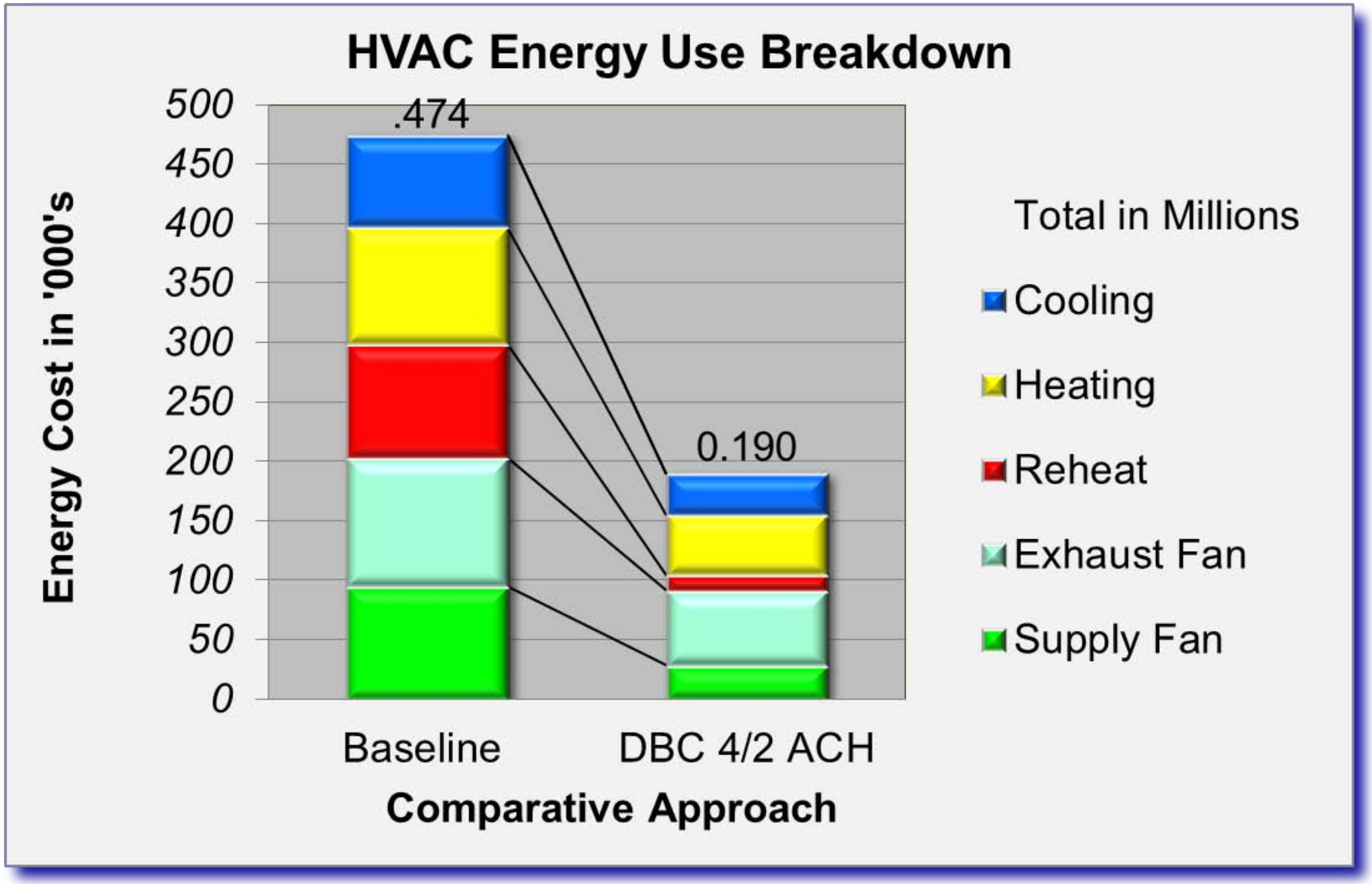
Univ. of Louisville: Bio Med 3

UPENN: Carolyn Lynch Lab

UPenn: Fisher

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

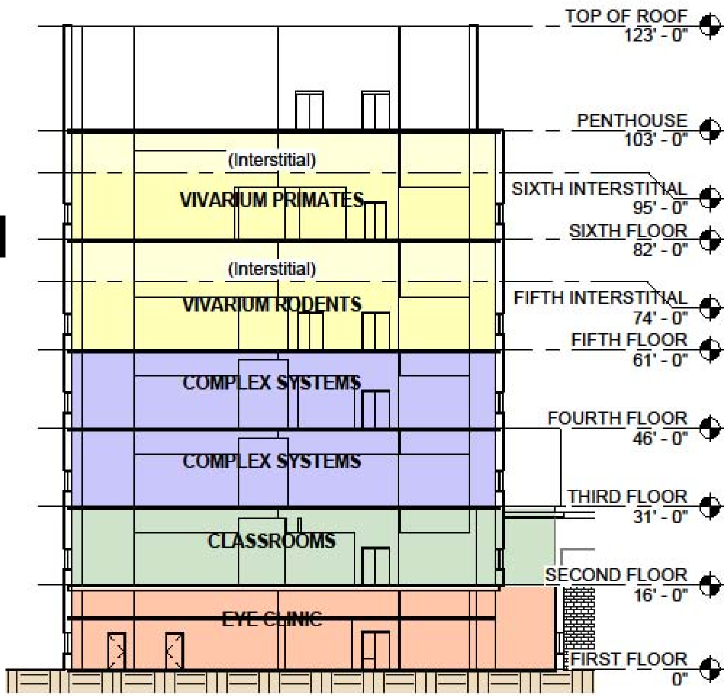
Toronto “DBC” Energy Savings of 4/2 ACH vs. 8 ACH



Demand Based Control reduces lab HVAC energy by $284K or 60% vs. 8 ACH. Payback is 9.1 months with $295K utility incentive or 1.8 years w/o incentive.

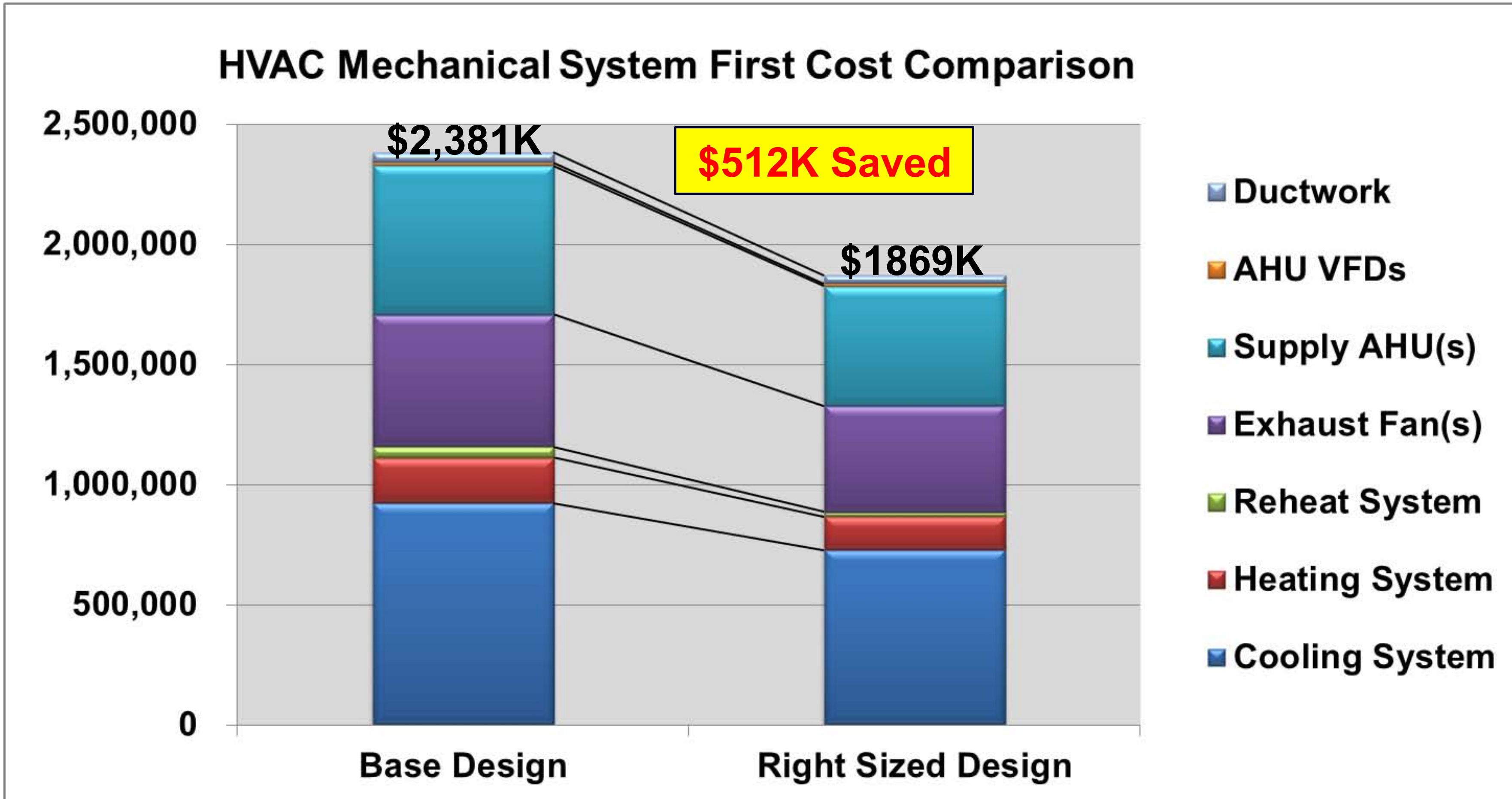
First Cost Saving at Univ. of Houston

- 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. 8 ACH



DBC at 4/2 ACH vs. 8 ACH reduces peak HVAC airflow by 20% or ~ $512K. Net 1st cost savings : $296K!

Holistic Strategies for Increased Savings

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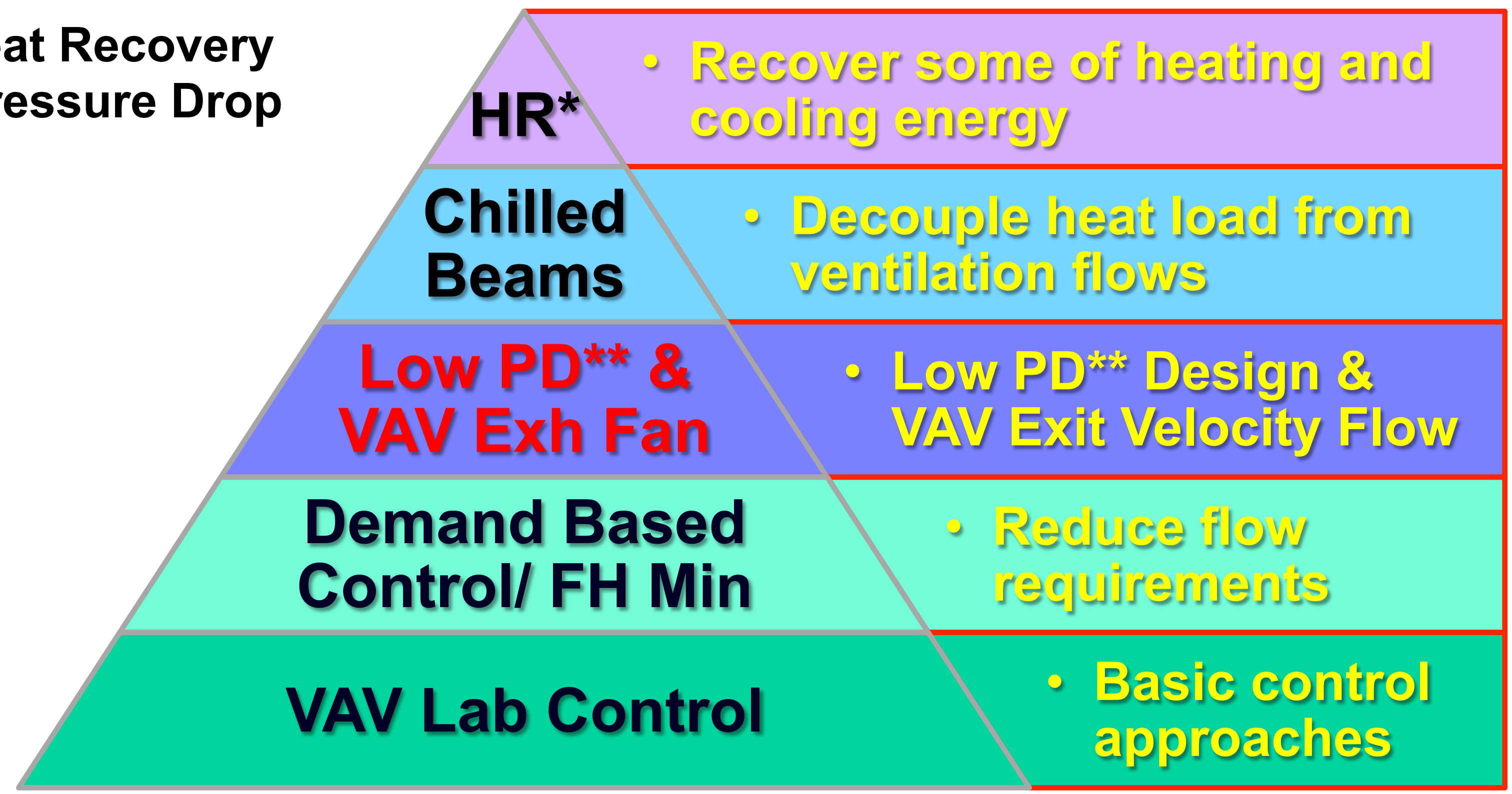
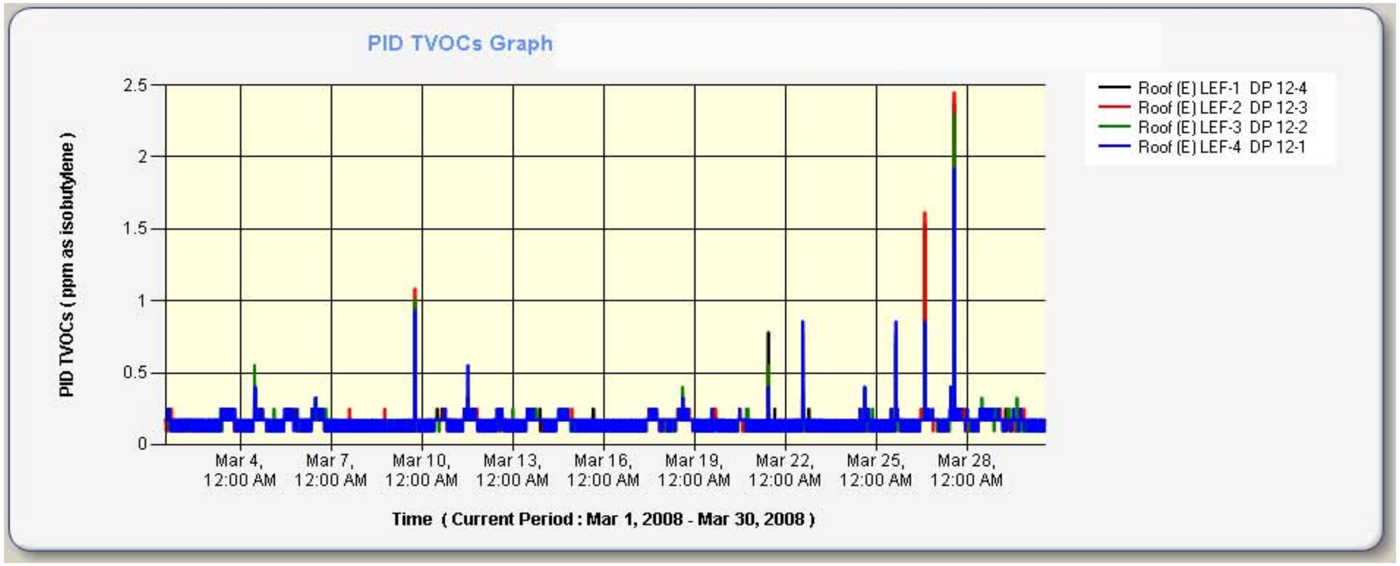


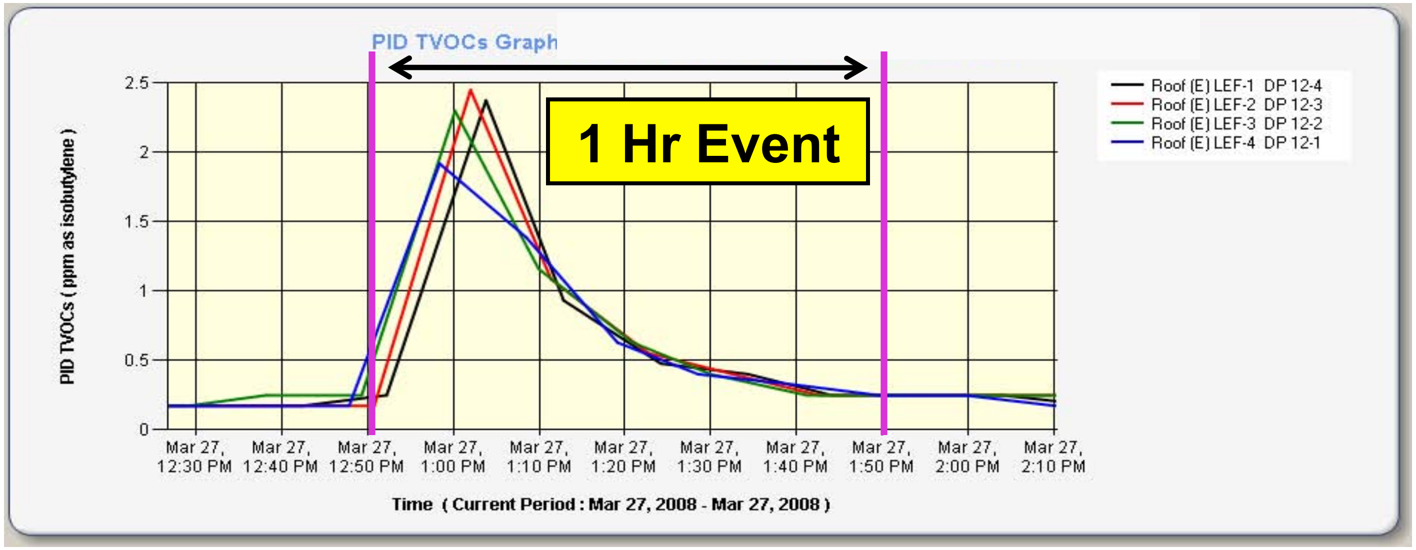
Variable Exhaust Fan Exit Velocity Control Innovation

- **Exhaust fans typically run at constant flow**
  - ✓ 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
  - ✓ Use plenum IEQ monitoring to control exhaust fans
    - *Demand Control applied to Exhaust Fans*

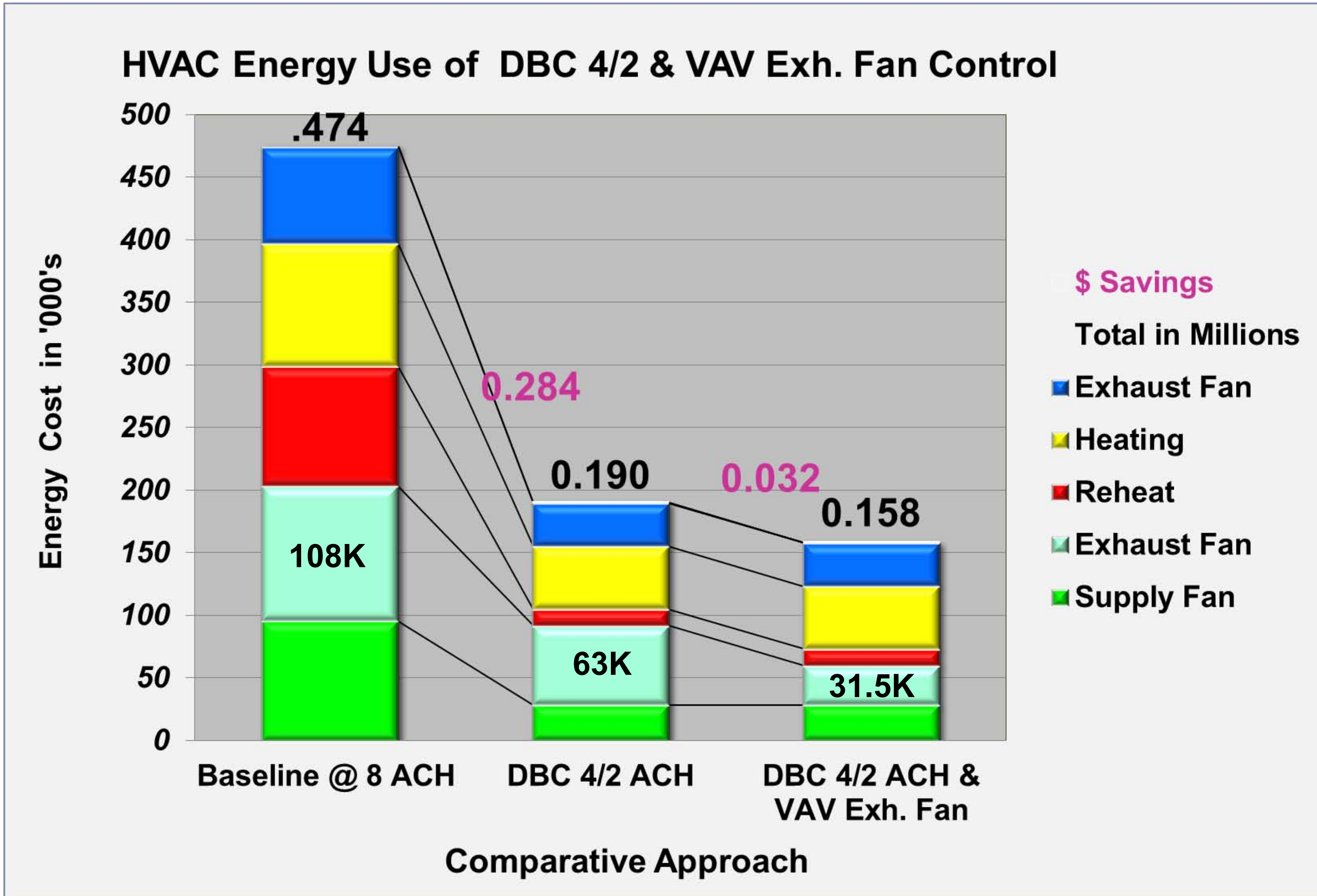
Even staged exhaust fans often consume ≥2X the energy vs. VAV

Exhaust Plenum Monitoring: Medical Research Bldg.





Comparison of Fan Control Energy vs. 8 ACH

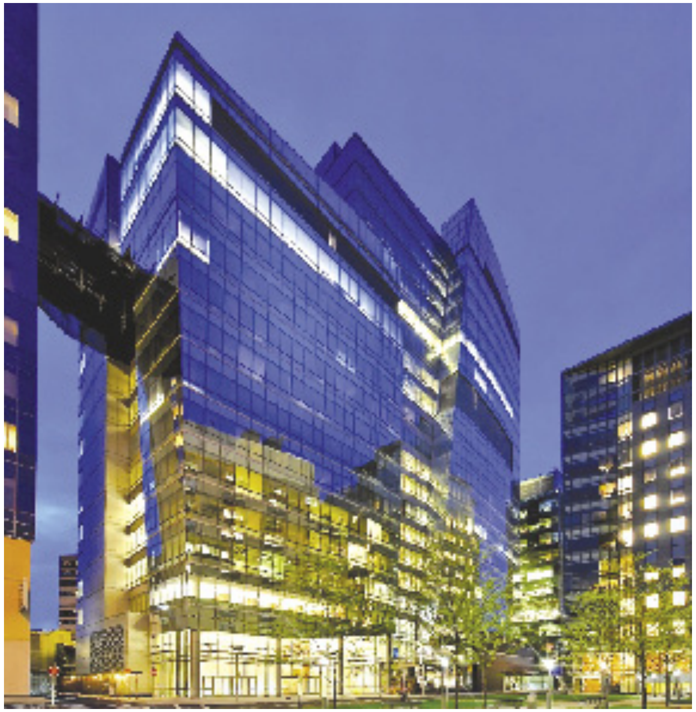


For VAV control of exhaust fans vs. staged fans:
Total reduction of $32K or 7% for total reduction of 67%

Summary Comparison of Fan Energy Use

- **CV Exh fan power : $108K - 100%**
- **Staged fan power : $63K - 58%**
- **DBC/VAV fan power : $31.5K - 29%**

For Demand Based Control of exhaust fans vs. staged fans: 50% savings

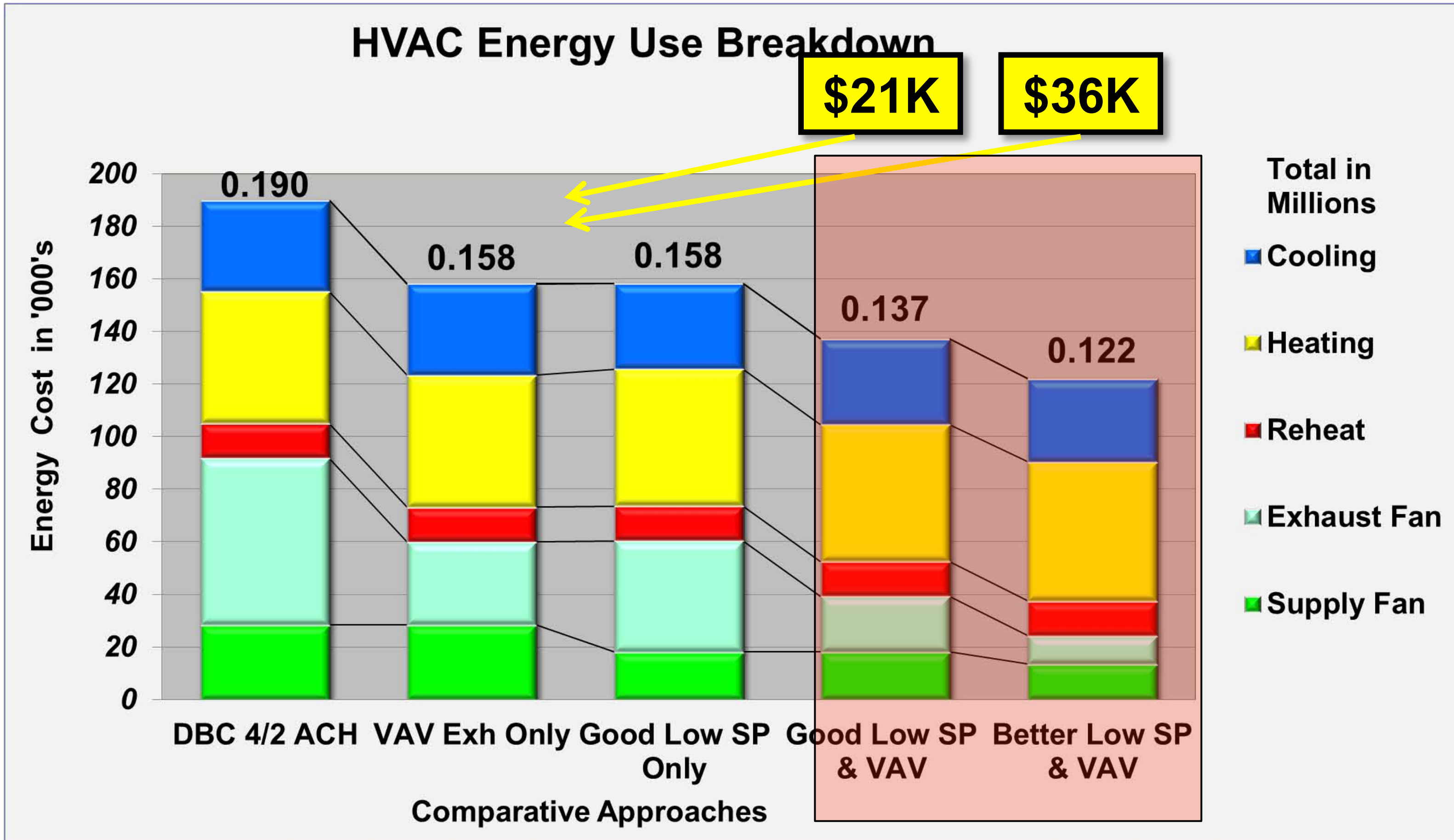


Low Pressure-Drop Design Guidelines

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

PD=Pressure Drop, SP= Static Pressure drop



Assuming w/ DBC & VAV Exhaust: for "Good" PD: savings of $21K (4.4%). "Better" PD: savings of $36K (7.6%) ("Better" PD w/ no DBC or VAV, savings of $72K or 15%)

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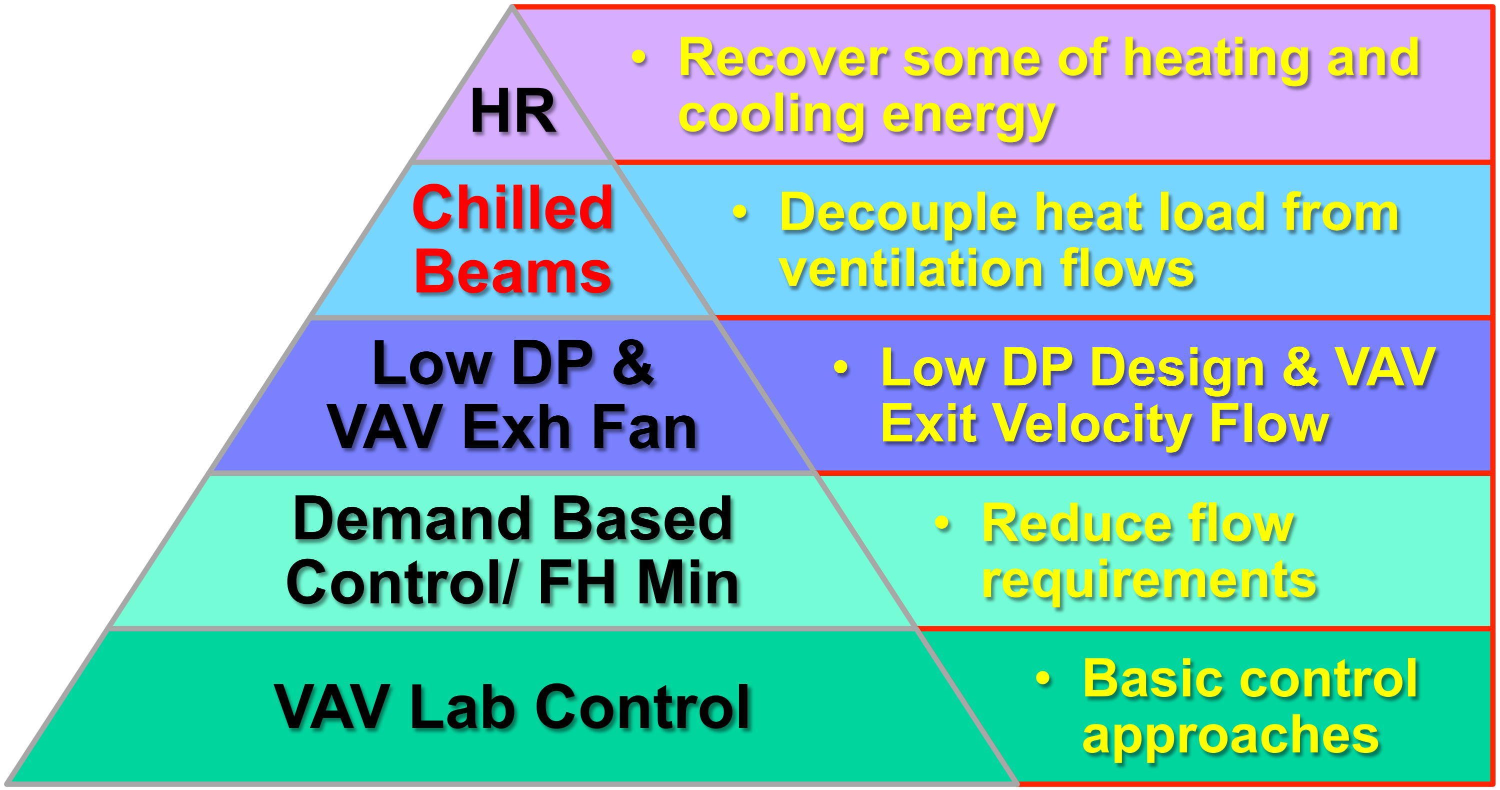
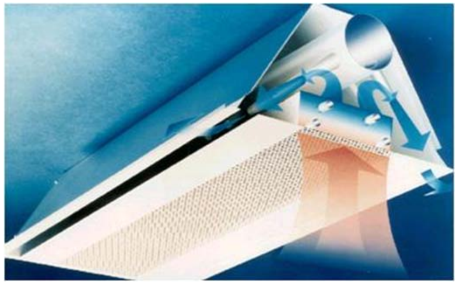


Demand Based Control (DBC) Improves Beam Use



- 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.

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

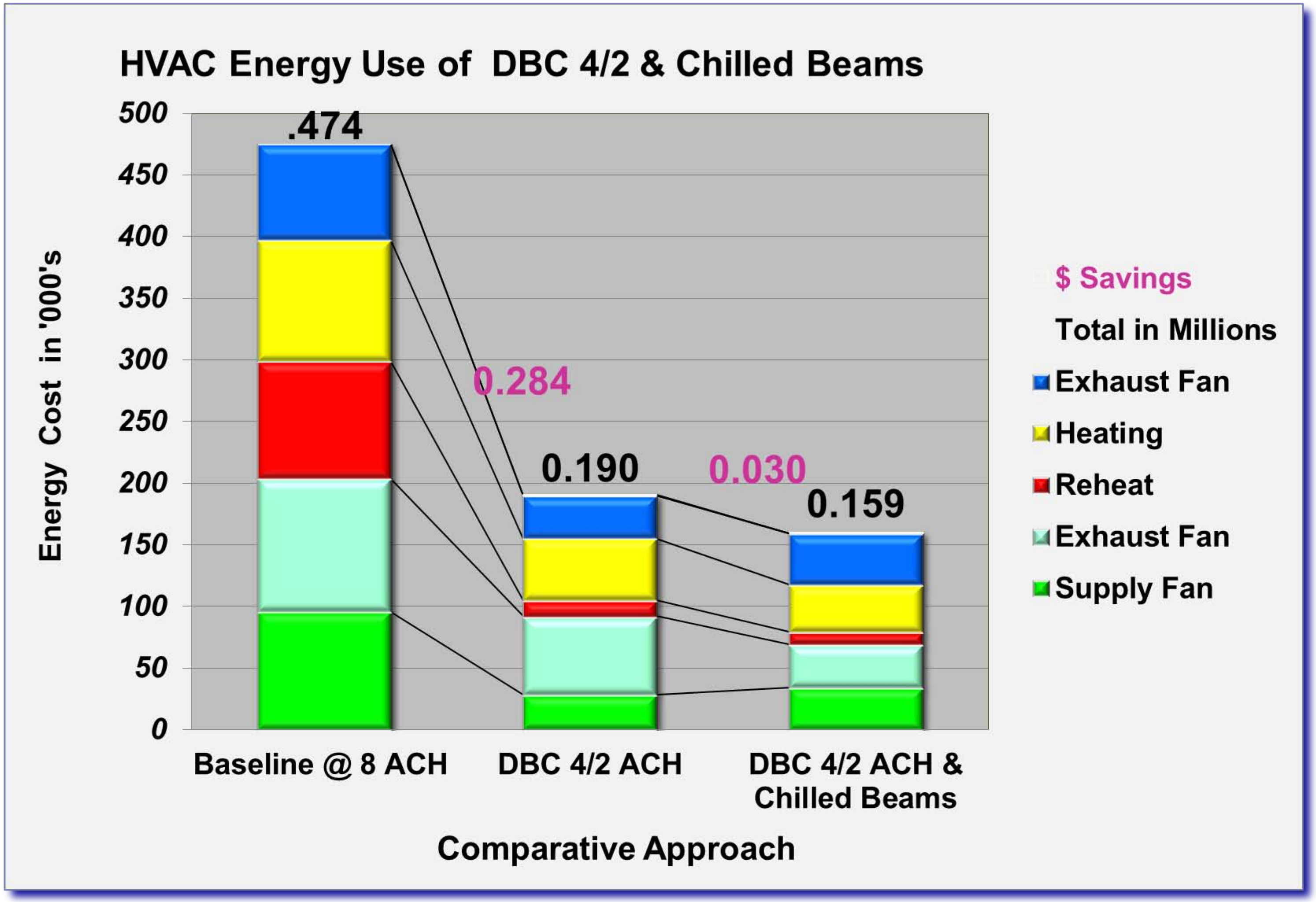
- Cal Poly Center for Science & Mathematics
  - ✓ 198,000 GSF, Budget $88 Million
    - *"Do the most sustainable project, but only if it doesn't cost more money"*
  - ✓ Architect: ZGF Architects LLP
    - *MEP Engineer: Integral Group / Rumsey Eng.*
- All lab ventilation air passes through chilled beam
  - ✓ 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)	

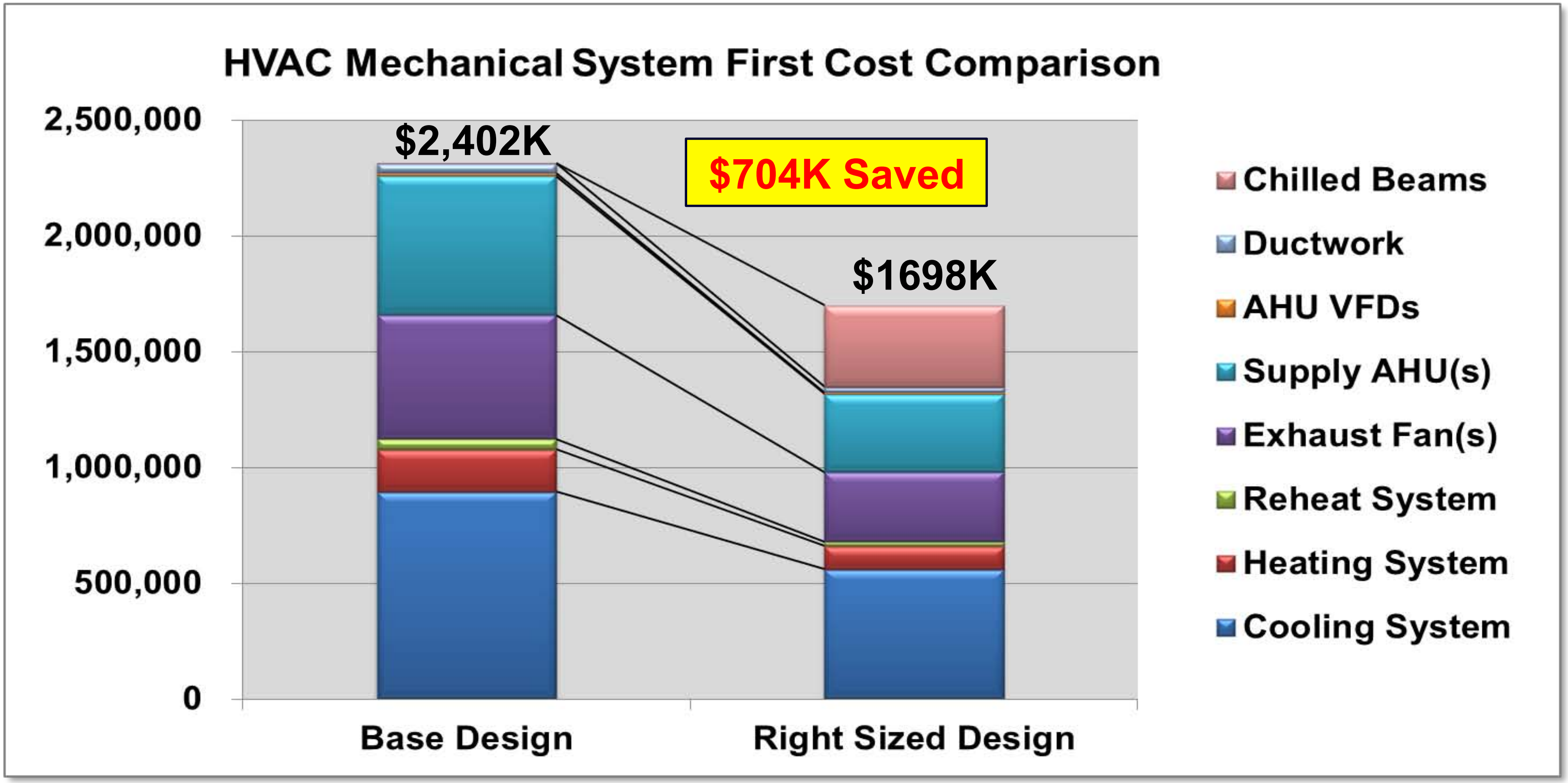
DBC & chilled beams were added in value engineering!

Chilled Beam Savings w/ DBC 4/2 ACH vs. 8 ACH



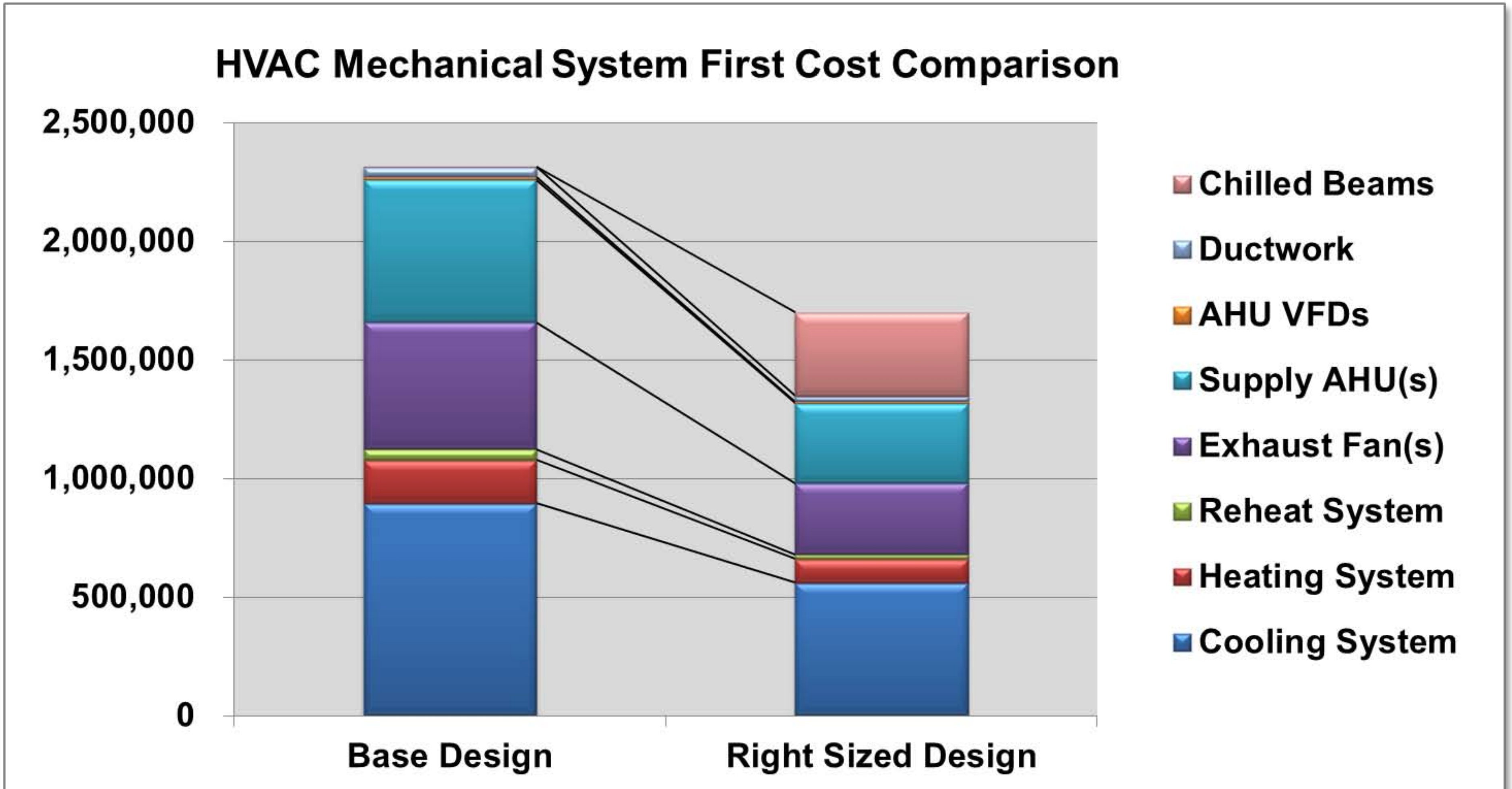
For chilled beam w/ DBC: $30K or 6% reduction.
Airflow reduction is 20%

1st Cost Savings Using Chilled Beams & 4/2 ACH



Vs 8 ACH, Chilled Beams (CB) at 4/2 ACH has net capital savings of $704K. This is $192K more than w/o CB. Including DBC cost, net savings is $550K!

"Right Sizing" Capital Cost Reductions @ 6 ACH



Versus 8 ACH baseline, gross capital savings of $393K. Chilled Beam (CB) creates net savings of $113K. DBCpayback drops to 5.3 months

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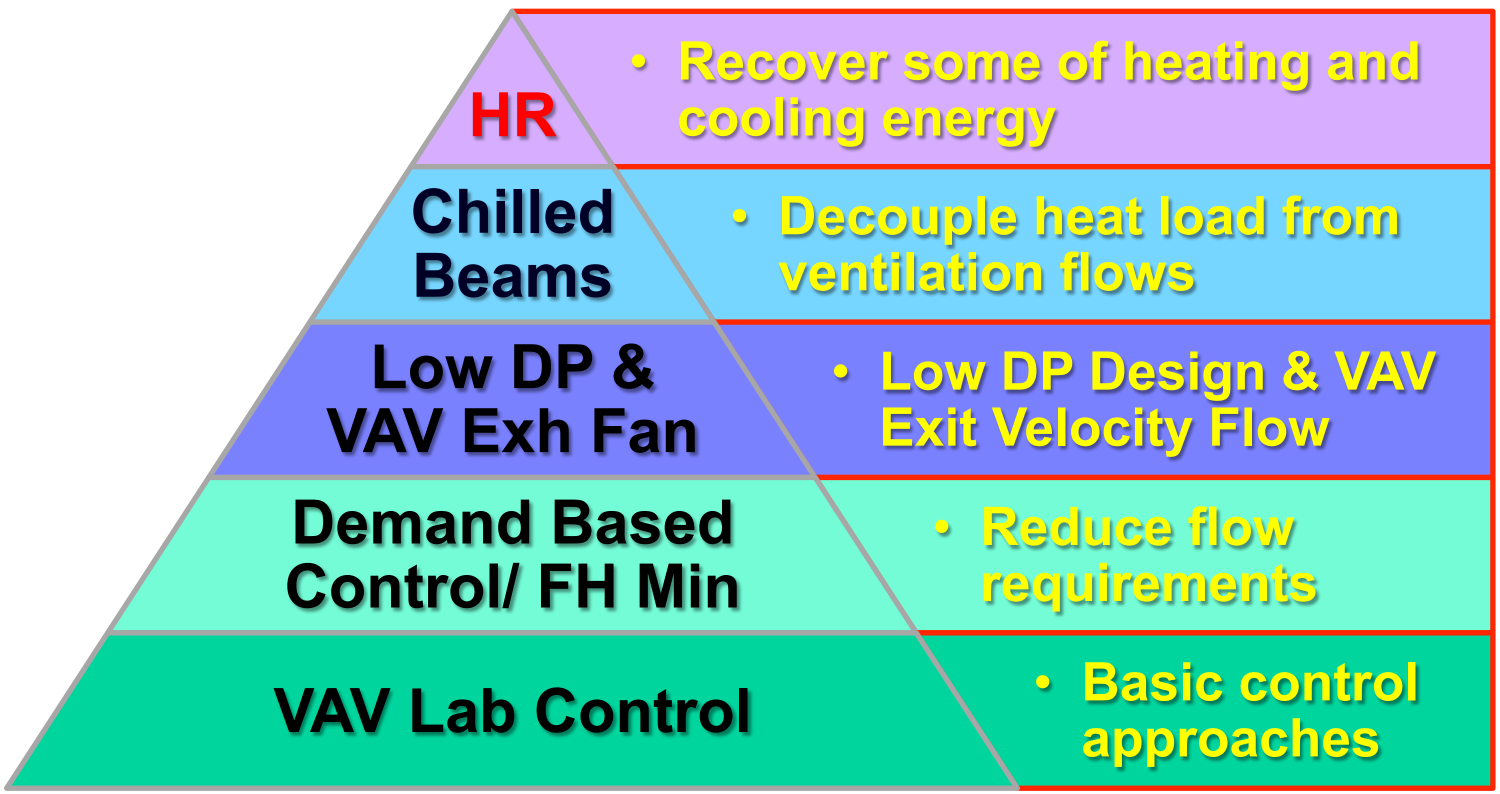
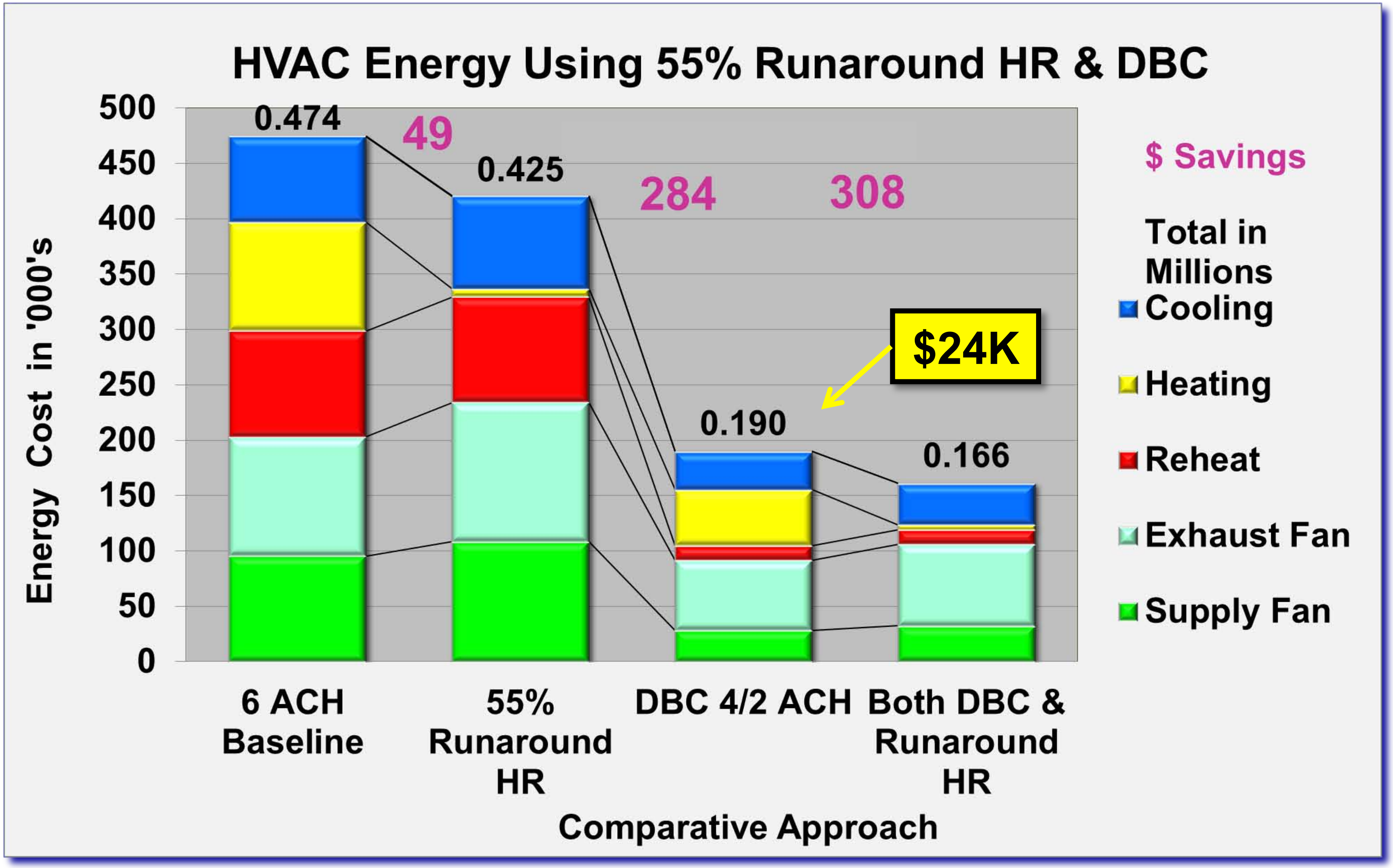
- **Individually evaluating systems is suboptimal**
  - ✓ DBC, chilled beams, hoods & heat recovery
- **To optimize lab safety, first cost & energy:**
  - ✓ Combining systems appropriately is best
  - ✓ Also use a layered or pyramid approach:

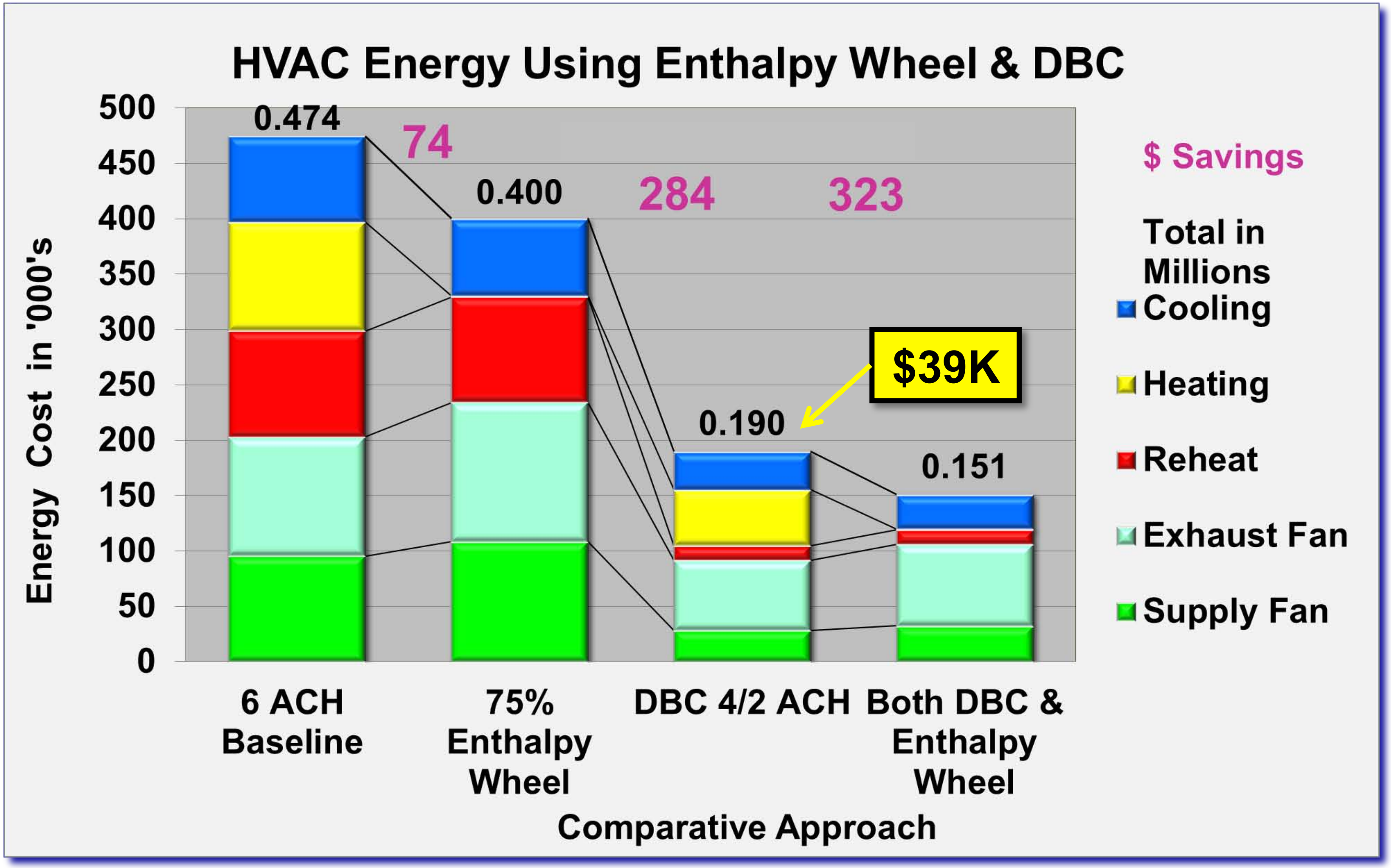


55% Glycol Runaround Savings at 6 ACH



55% Runaround HR w/ 4/2 DBC: only $24K or 5% saving.
HR payback: 9 yrs. even w/ HVAC capital savings

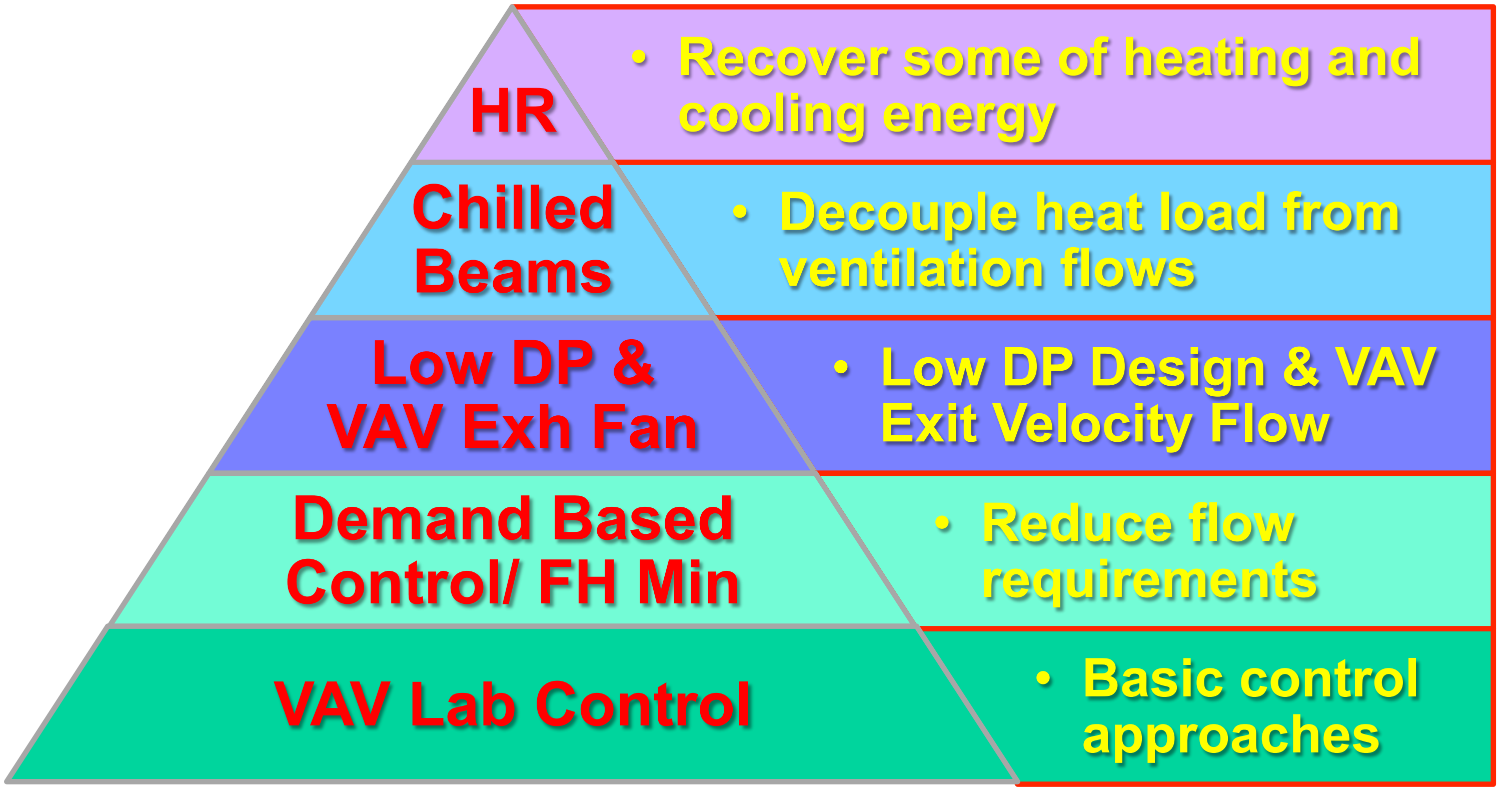
75% Enthalpy Wheel Savings w/ 4/2 DBC



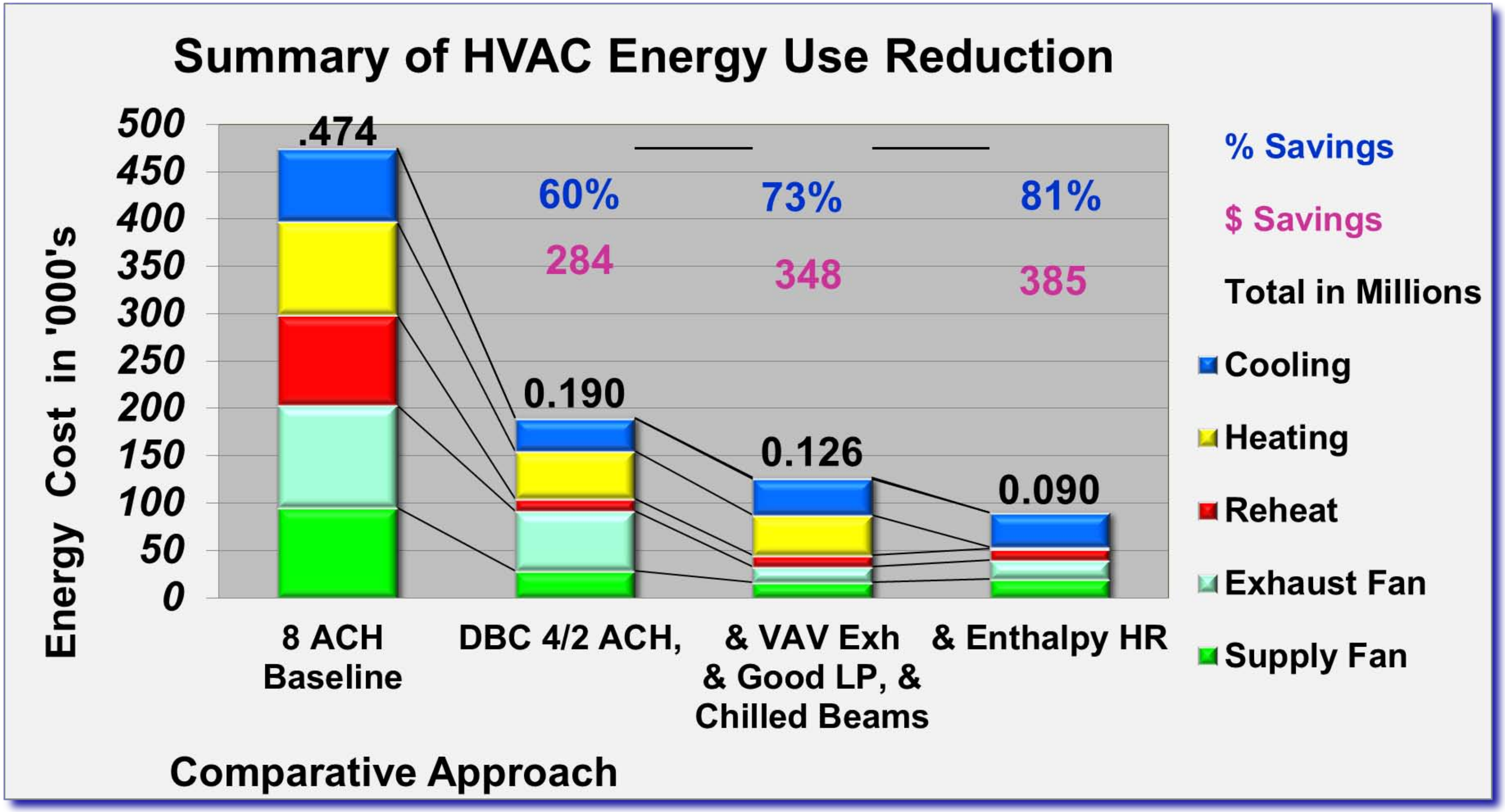
Enthalpy HR w/ 4/2 DBC (room exhaust only): Only $39K or 8% savings. HR payback: 3.4yrs. due to capital savings

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:

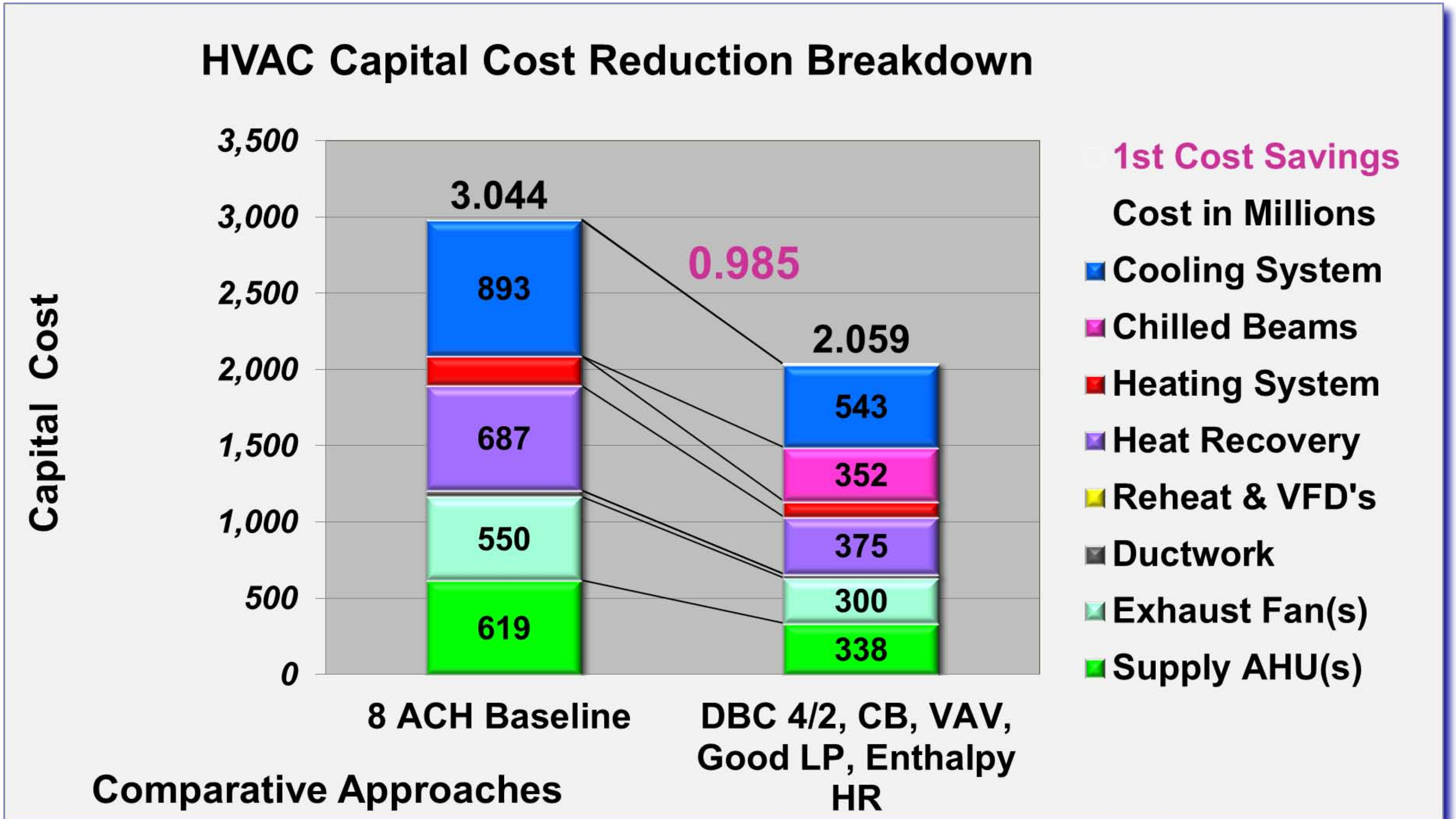


Toronto Example: All Approaches for Min. Energy



Including all approaches, total lab HVAC reduction is 81%!
HR payback for last $36K savings: > 15 years w/o diversity or 4.5 years w/ diversity.

Toronto Example: Right Sized HVAC Capital Savings



Total Capital Cost Savings of $985K. Including DBC: Net Savings is $693K w/ utility incentive and $473K w/o!

Demand Based Control Presentation Summary

- **Airflow reduction is the best savings approach**
  - ✓ **Energy savings can be reduced by 40 to $80^{+}\%$**
  - ✓ **Capital cost savings can be achieved as well**
- **DBC makes chilled beams more effective**
  - ✓ **2- 4 ACH cuts reheat & shares cooling w/ beams**
- **DBC is often ≥3X savings of best heat recovery**
  - ✓ **Adding heat recovery to DBC may work in some areas**

Questions?

For a copy of the presentation, contact:
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