How to Reduce Energy Use in Your Labs by Up to 50%

Big Ten & Friends Conference

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Course Description

Labs have high exhaust requirements and large equipment loads, contributing to energy usage intensities five to ten times those of typical office buildings. Facilities in hot and humid climates face special challenges: most hours of the year require cooling, and 100% outside air systems have large latent energy loads.

This presentation will discuss general strategies for designing and operating high-performance, energy-efficient laboratories, with an emphasis on features to enhance the performance of HVAC systems. Air handling systems usually account for the largest amount of energy usage in a lab and are therefore the most important component of an energy-efficient system. First, airflow should be reduced as much as possible.

Strategies such as reducing cooling loads in the space, reducing the air exhausted by fume hoods and other exhaust sources, and reducing the required air change rate of the space will be discussed. Strategies that can further reduce energy use, including demand-controlled ventilation and energy recovery systems, will all be discussed.

Learning Objectives

At the end of this session, participants will be able to:

1. Identify energy-efficiency considerations for laboratory planning
2. Identify ways to reduce cooling loads with efficient equipment and lighting
3. Describe the process for determining an appropriate airflow to a lab space, and strategies for reducing airflow
4. Summarize options for reducing the energy required for cooling and reheat
5. Understand additional elements of high-performance laboratory design
6. Summarize best practice strategies for achieving energy usage reductions of up to 50%
7. Summarize options to enhance HVAC system performance

Why Focus on Laboratories?

Labs are energy-intensive.

- Labs21 / I^{2}SL data indicates that labs consume about 3-8 times as much energy as a typical office building.
- On some campuses, labs consume two-thirds of total campus energy usage.

Most existing labs can reduce energy use by 30% to 50% with existing, cost-effective technology.

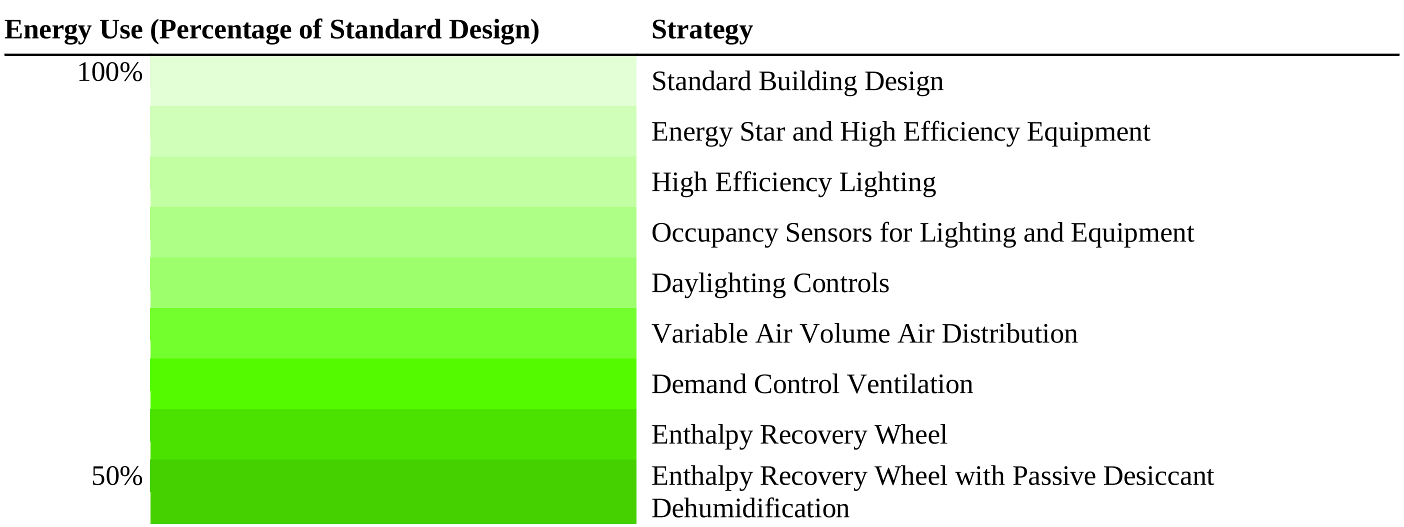
Reducing laboratory energy use will significantly reduce carbon dioxide emissions.

Benefits of a High-Performance Lab

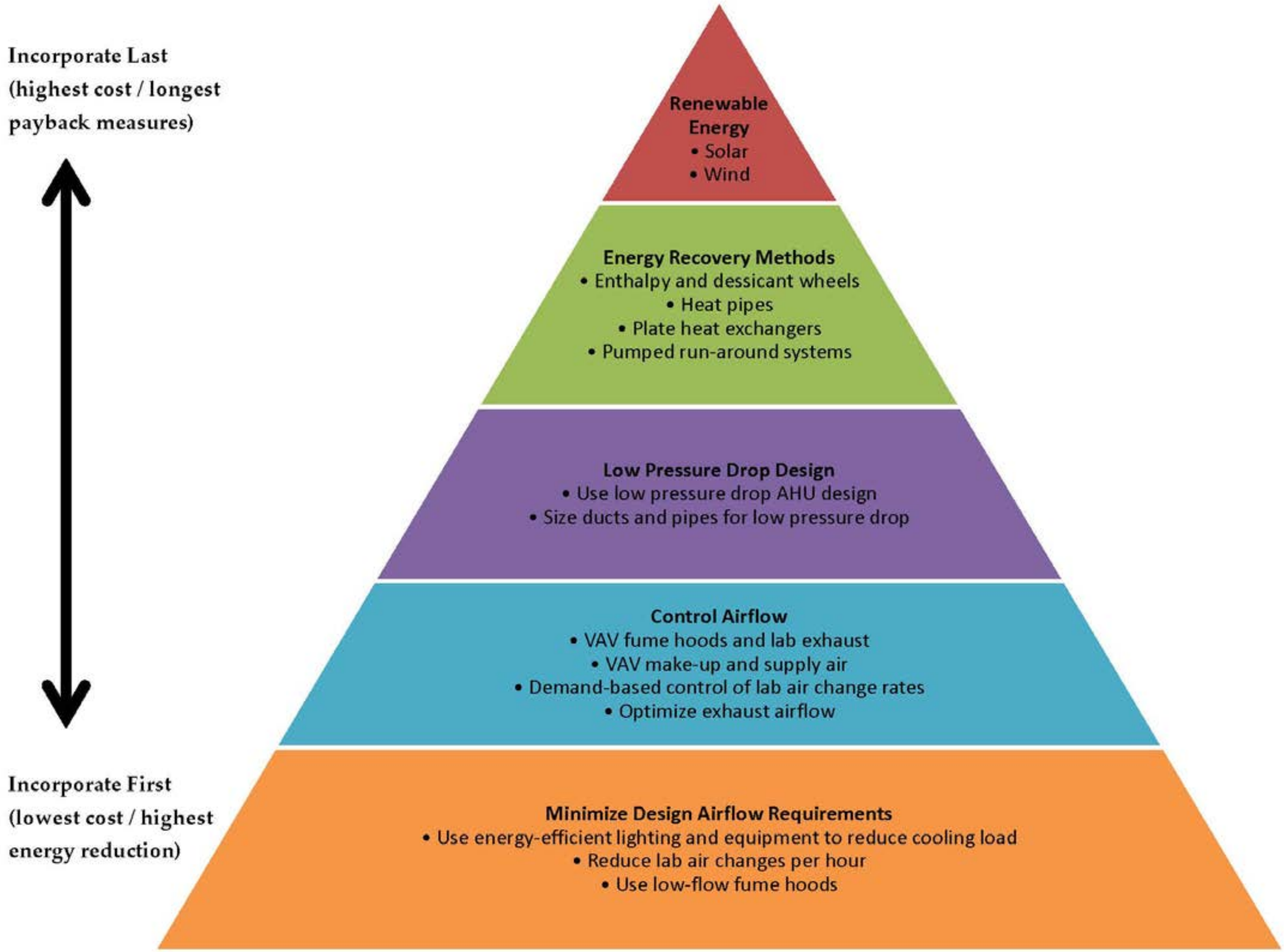
- Reduced operating costs.
- Improved environmental quality.
- Expanded capacity.
- Increased health, safety, and worker productivity.
- Improved maintenance and reliability.
- Enhanced community relations.
- Superior recruitment and retention of scientists.

Potential Savings

- This presentation provides specific strategies that can result in energy-efficient and eco-friendly laboratory designs, reducing energy use by as much as 30% to 50% (compared with a laboratory designed to comply with ASHRAE Standard 90.1)



Energy-Efficiency Strategies



Energy-Efficiency Strategies: Step 1

- Incorporate lowest cost/ highest energy-savings features first.

Minimize Design Airflow Requirements:

- **Use energy efficient lighting and equipment to reduce cooling load**
- **Reduce lab air changes per hour**
- **Use low-flow fume hoods**

Use the Most Efficient Lighting Option

- Exit signs – LCDs
- Stairwells – two-position LEDs
- Outdoor/parking structures – LEDs
- General office – T8s/T5s or LEDs
- Occupancy sensors
- Photocell control/ daylighting
- Task lighting
- Signage/elevators

Select and Specify Energy-Efficient Lighting Products

- Lamps
- Ballasts
- Fixtures
- Life-cycle cost effectiveness

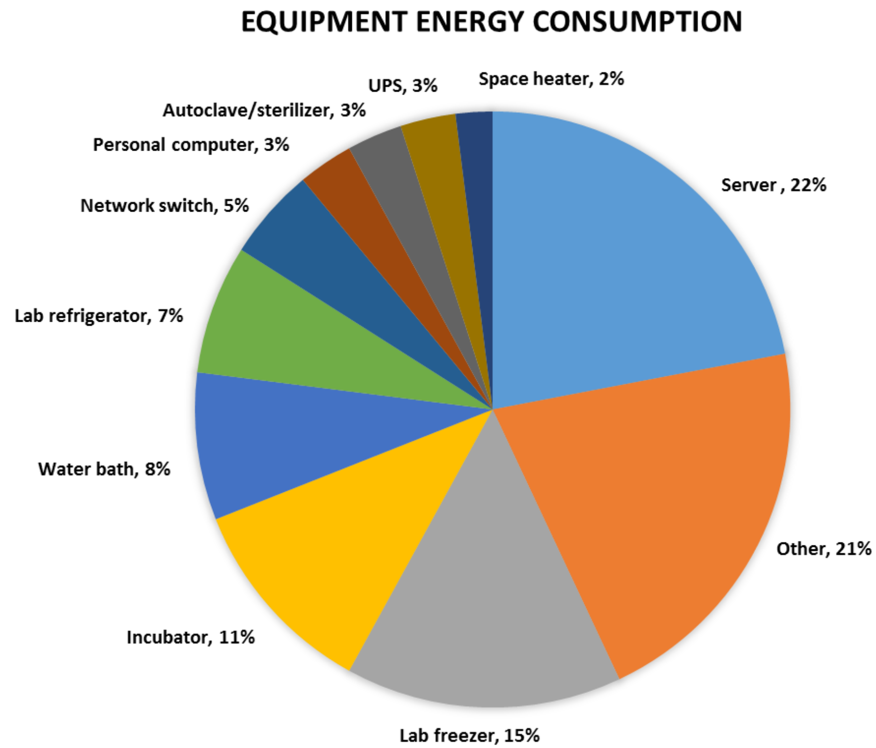
Lamp type	Lumens/W	Life hours
T-12 FL	80 L/W	24,000 HR
T-8 FL	80-100 L/W	24,000 - 30,000 HR
T-5 FL	90-100 L/W	24,000 -30,000 HR
T-8 FL ELL	85-95 L/W	46,000 -50,000 HR
LED	100-110 L/W *	50,000 HR

CREE and Phillips 200 L/W LED

* Omni-directional

Minimize Process and Equipment Energy Use

- Stanford University's 2014 survey of equipment energy consumption indicates that lab freezers, incubators, water baths, refrigerators, and autoclave/sterilizers represent nearly 50% of total campus equipment energy use.



Use Energy-Efficient Equipment

- "Research-grade" autoclaves are available that use significantly less energy and water than "medical-grade" units
- "Research-grade" is for light duty (less than five cycles per day)

Medical vs. Research	
Medical-Grade	Research-Grade
Vacuum pumps	No vacuum pump necessary
Inefficient steam jackets	No steam jacket necessary
Must be run 24/7 or risk harm to the unit	Can be powered down for long periods
"High-throughput": designed for 24/7 hospital use, over a dozen cycles per day	"Light duty": less than five cycles per day
Consumes up to 150 gallons of water per cycle ("water conservation kits" can reduce this to 50 gallons per cycle)	Consumes as little as 4 gallons per cycle

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Use Energy-Efficient Equipment

- Much more efficient freezers are now available
  - Ultra-low temperature freezers with Stirling engines; 30% to 50% savings
  - Minimize the number of freezers and other large energy-consuming equipment
  - Centralize to allow equipment to be shared by the maximum number of labs

Check out the North American Laboratory Freezer Challenge: http://freezerchallenge.org

Minimize Design Airflow Requirements

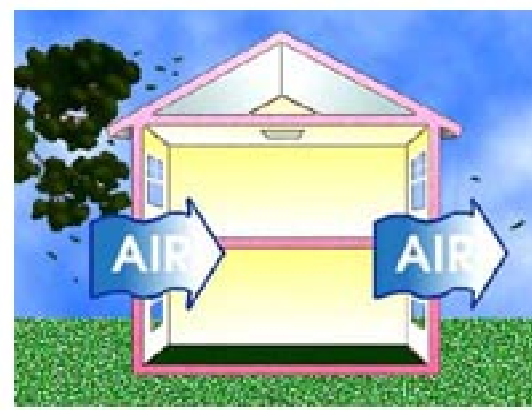
- Determine driver of lab airflow rate – largest of:
  1. **Make-up air** required to offset the total exhaust (fume hoods, snorkel exhausts, some types of biosafety cabinets).
  2. The required lab **air change rate (**ACH).
  3. The airflow required to adequately **cool the space.**

Minimize Design Airflow Requirements

- Minimize number of hoods
- Minimize size of hoods (can a 4-ft hood suffice in lieu of a 6-ft version?)
- Use low-flow / high-performance hoods

Minimize Design Airflow Requirements

- Scrutinize lab **air change rates (ACH)**:
  - The Labs21 Design Guide section on room air change rates states: "The conventional, 'national consensus standard' has been 4 to 6 outside air changes per hour recommended for a 'safe' B-occupancy laboratory."
  - Suggest using **4 ACH maximum** in standard laboratories.
  - Consider increasing ACH only when absolutely necessary, such as for carcinogenic materials.

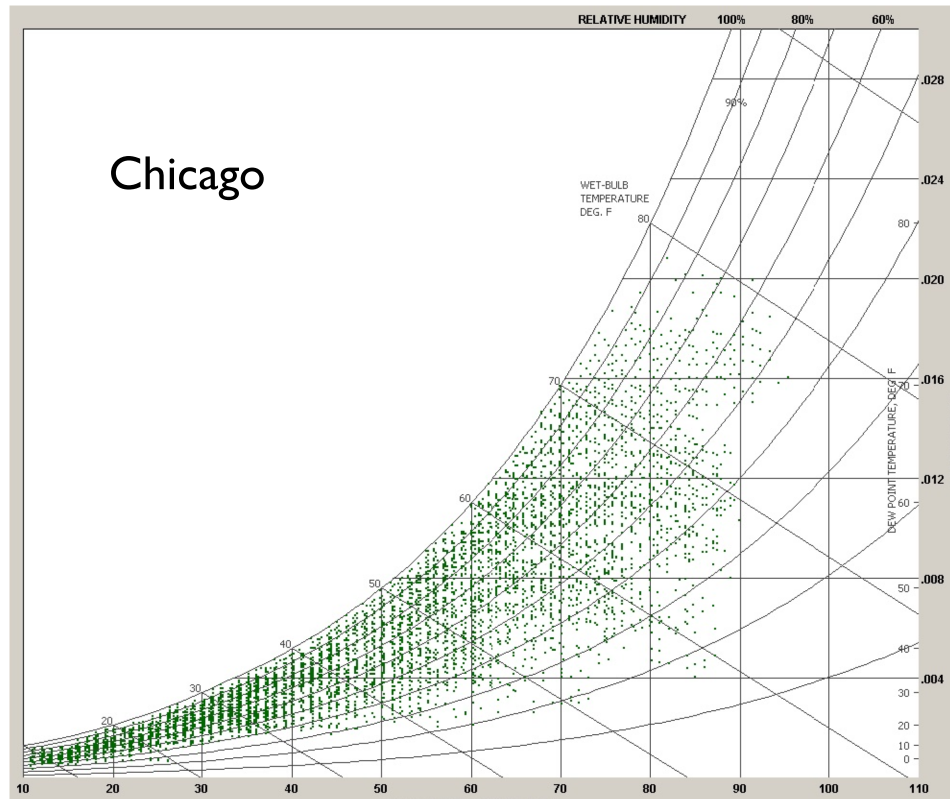


Typical ACH Guidelines

Agency	Ventilation Rate
ASHRAE Lab Guides	4-12 ACH
UBC – 1997	1 cfm/ft^2
IBC – 2003	1 cfm/ft^2
IMC – 2003	1 cfm/ft^2
U.S. EPA	4 ACH Unoccupied Lab – 8 ACH Occupied Lab
AIA	4-12 ACH
NFPA-45-2004	4 ACH Unoccupied Lab – 8 ACH Occupied Lab
NRC Prudent Practices	4-12 ACH
OSHA 29 CFR Part 1910.1450	Recommends 4-12 ACH
ACGIH 24th Edition, 2001	Ventilation depends on the generation rate and toxicity of the contaminant and not the size of the room.
ANSI/AIHA Z9.5	Prescriptive ACH is not appropriate. Rate shall be established by the owner!

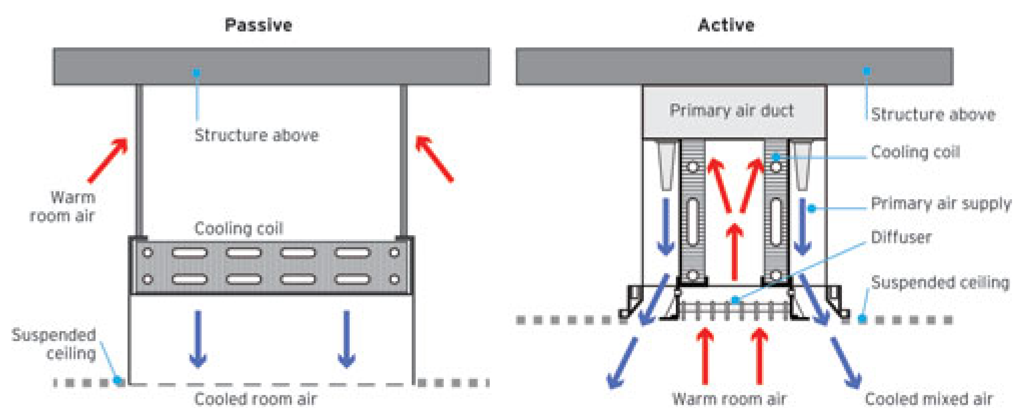
Minimize Design Airflow Requirements

- Next, determine airflow required to **cool the lab**
  - Thermal load calculations shall be performed in accordance with ASHRAE procedures



Minimize Design Airflow Requirements

- Strategy to reduce cooling airflow:
  - If thermal loads are high and driving the airflow, consider decoupling the thermal load from the room airflow by using water-based cooling:
    - Chilled beams
    - Fan coil units
- Be careful of condensation on chilled beams if humid air can enter the space.



ACTIVE AND PASSIVE CHILLED BEAMS IN COOLING MODE

Energy-Efficiency Strategies: Step 2

- Incorporate the next-highest level on the pyramid – still relatively low cost, with high energy savings.

Control Airflow:

- **VAV fume hoods and lab exhaust**
- **VAV make-up and suppy air**
- **Demand-based control of lab air change rates**
- **Optimize exhaust airflow**

Control Airflow

Airflow is actively modulated below the design maximum during part load or unoccupied conditions.

Reduction is in response to certain criteria in the lab:

- Temperature, sash position, air quality

This reduces fan, heating, cooling and dehumidification energy consumption at the AHU.

Control Airflow

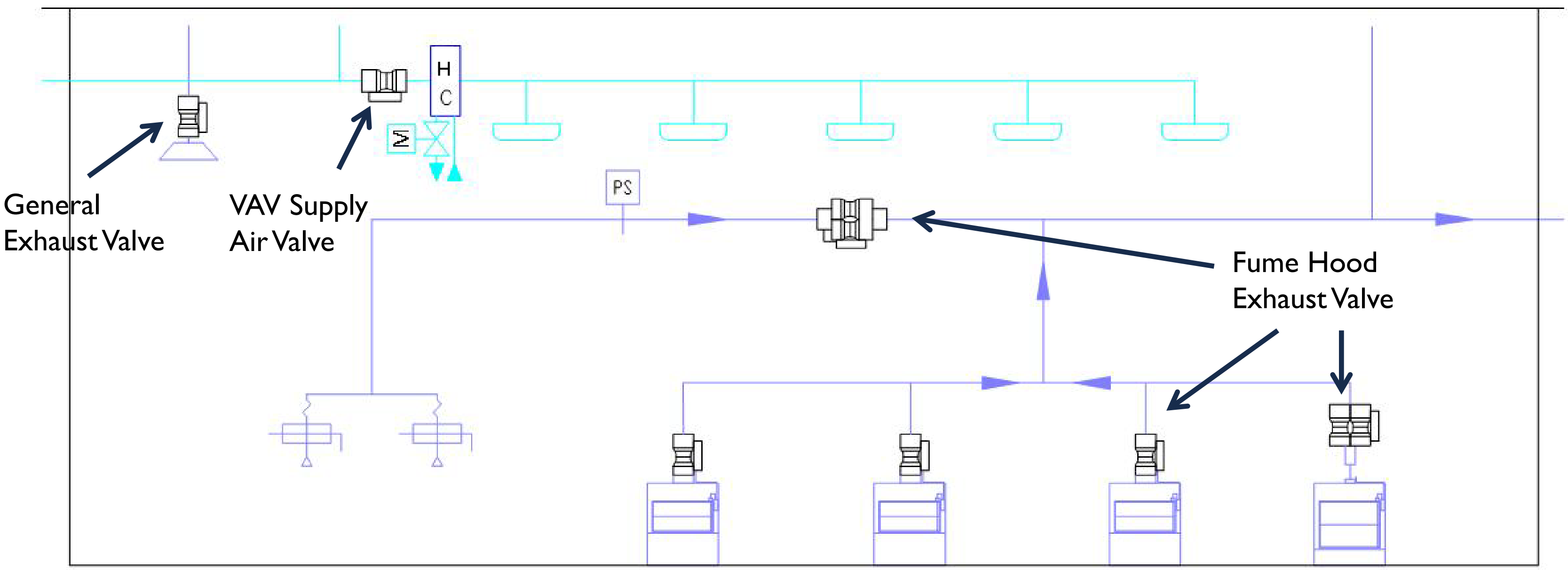
- Fume hoods
  - Use variable air volume (VAV) exhaust devices:
    - Allows for reduction of flow when sash is not fully open or when hood is not in use.
    - Consider occupancy sensors, auto sash closers
  - Use VAV in combination with high-performance (low-flow) fume hoods.

Control Airflow

- Specify **ventilated cage racks** in animal labs
  - Lower room air change rates (from 10 to 15 to 8 to 10)
  - Provide better conditions for the animals
  - Reduce frequency of cage changes

Control Airflow

- **VAV terminal units** (such as Venturi valves) will be required on:
  - Each fume hood
  - Groups of snorkels
  - Some biosafety cabinets
  - Supply air from AHU

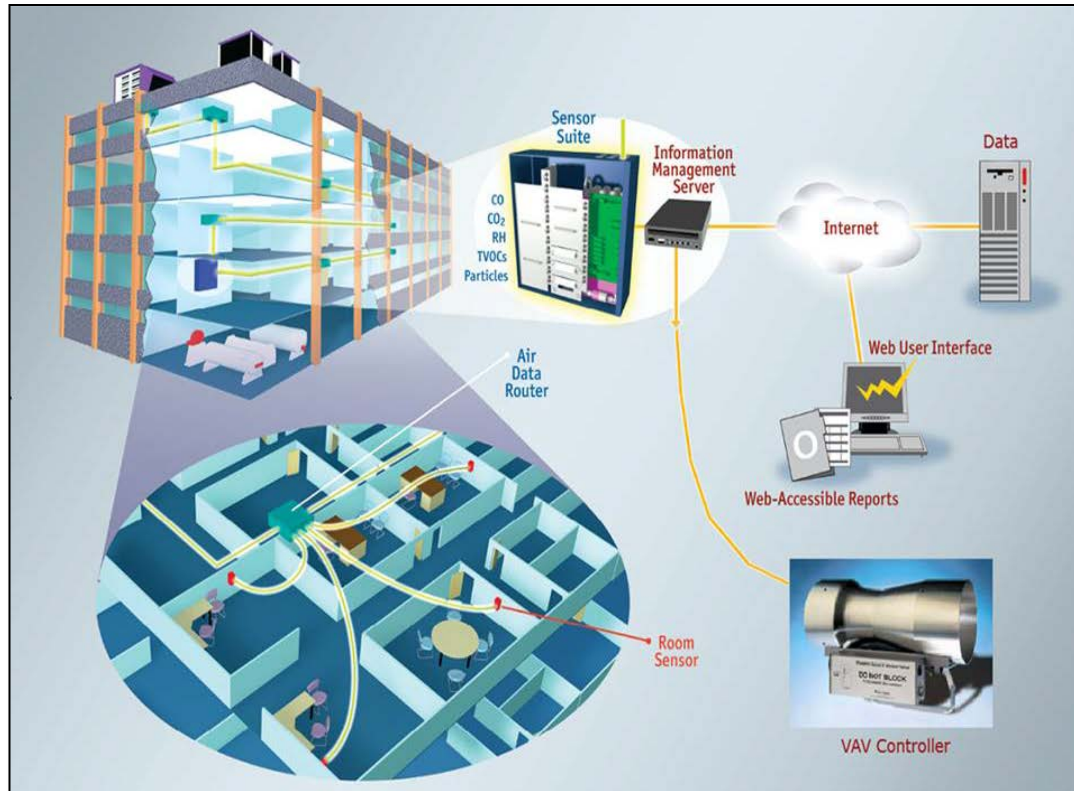


Control Airflow

➢ **Demand-based** ventilation controls

- Actively measures quality of air in labs by sensing for certain chemicals.

- Lab air change rates are reduced when not necessary to control air quality in the lab.



Energy-Efficiency Strategies: Step 3

- Incorporate the third-highest level on the pyramid – mid-range cost with good energy savings.

Low Pressure Drop Design:

- **Use low pressure drop AHU**
- **Size ducts and pipes for low pressure drop**

Low Pressure Drop Design

95% MERV 14 Filter Typical Pressure Drops	
Filter Type	Pressure Drop (inches WG)*
Standard 12-inch-deep box-style rigid media filters	0.61
12-inch-deep low pressure drop V-bank type mini-pleat filters	0.37
Electronic filters	0.20
*Initial clean filter pressure drops @ 500 fpm	

Low Pressure Drop Design

Up-size cross section of AHU to reduce face velocity and pressure drop across filters, cooling coils, etc.

- Traditional design: 500 fpm
- Low pressure drop design: 300 fpm (or as low as space allows)

Low Pressure Drop Design

For a **10,000 cfm AHU**, cross-sectional dimensions will increase from:

5 ft wide by 4 ft tall
to
6 ft wide by 5.5 ft tall

The net incremental cost is small:

- Bigger sheet metal box
- Coils, filters are larger
- Motors, VFDs are smaller
- Can often eliminate sound attenuators, mist eliminators

Result: Simple, reliable energy savings over the life of the AHU!

- **Can never be "overridden"**

Low Pressure Drop Design

- Reducing pressure drop in AHU reduces the power required to drive the fan:
  - Fan at 10,000 cfm and **7” w.g**. static pressure = **13.5 kW/18.0 bhp**
  - Fan at 10,000 cfm and **4” w.g**. static pressure = **5.8 kW/7.8 bhp**

Low Pressure Drop Design

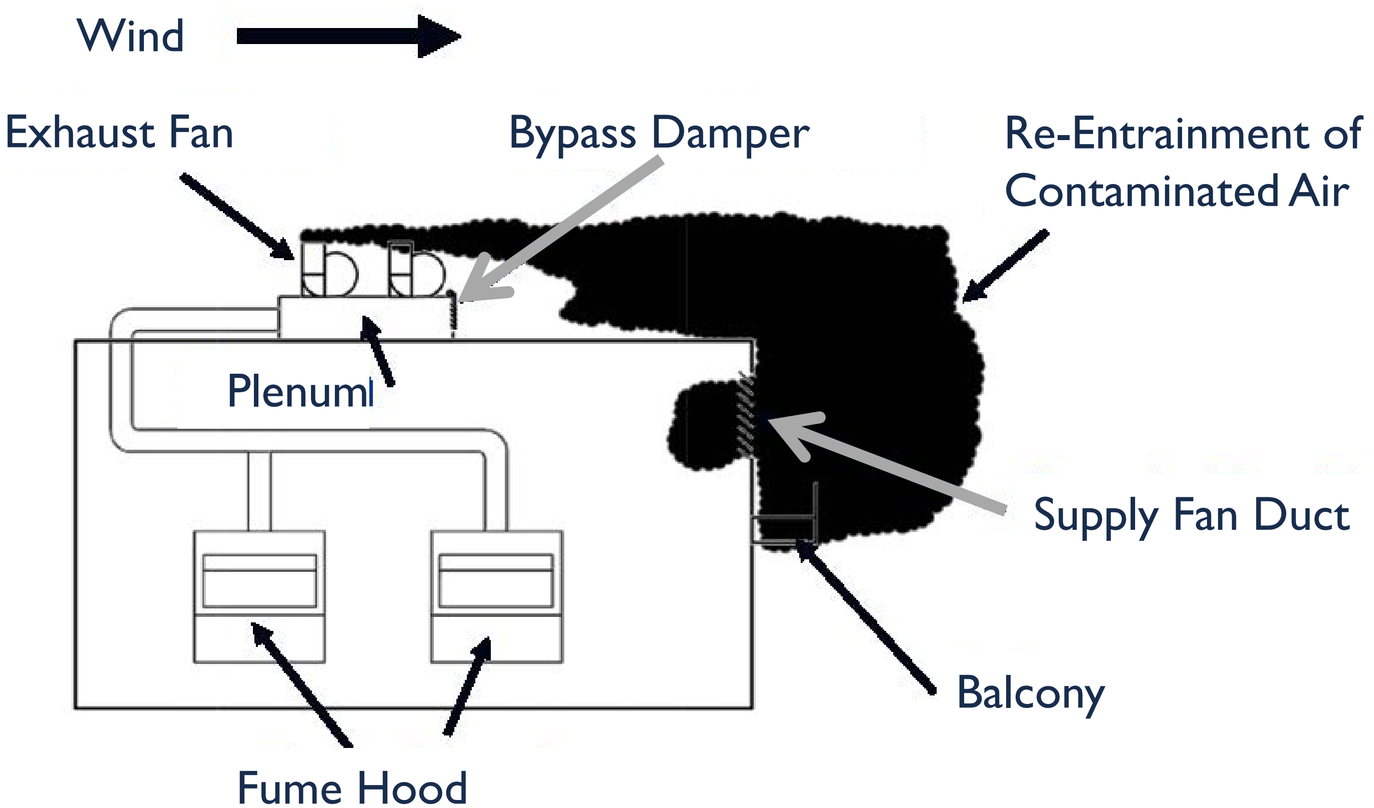
- Options analysis for 30,000-cfm CV AHU:
  - **Base case (500 fpm):** Pre and secondary filters, preheat coil, cooling coil, single centrifugal fan, conventional final filters, 5-ft sound attenuators
  - **Option 1 (400 fpm):** Pre and secondary filters, preheat coil, cooling coil, fan array, low pressure drop final filters, 3-ft sound attenuators
  - **Option 2 (300 fpm):** Pre filters, preheat coil, cooling coil, fan array, low pressure drop final filters, no sound attenuators

Low Pressure Drop Design

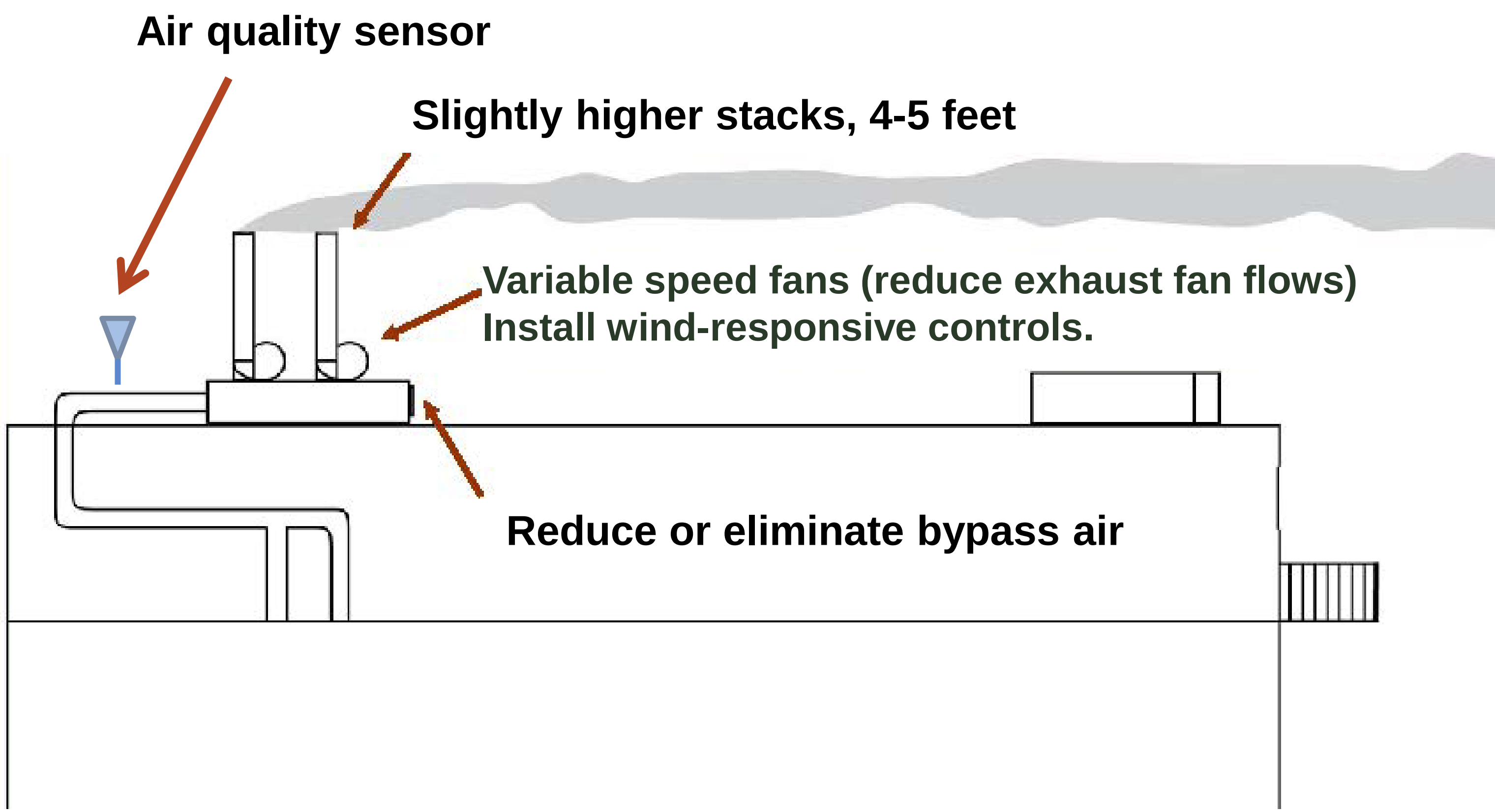
- 400 fpm design is usually a "no brainer!"
- Between 300 fpm and 400 fpm will have a good payback

	Design Static Pressure	AHU First Cost	Annual Energy Reduction Compared With Base Case	Simple Payback	Utility Demand-Side Management Incentive
Base case (500 fpm)	8.5″ w.g.	$150,000	-	-	-
Option 1 (400 fpm)	6.0″ w.g.	$145,000	$4,400	Immediate	$3,655
Option 2 (300 fpm)	4.5″ w.g.	$160,000	$10,200	Two months	$8,384

Optimize (Minimize) Exhaust Airflow: Conventional Design



Exhaust Energy Reduction Solutions



Energy-Efficiency Strategies: Step 4

- Incorporate energy recovery —
  higher energy savings for higher cost.

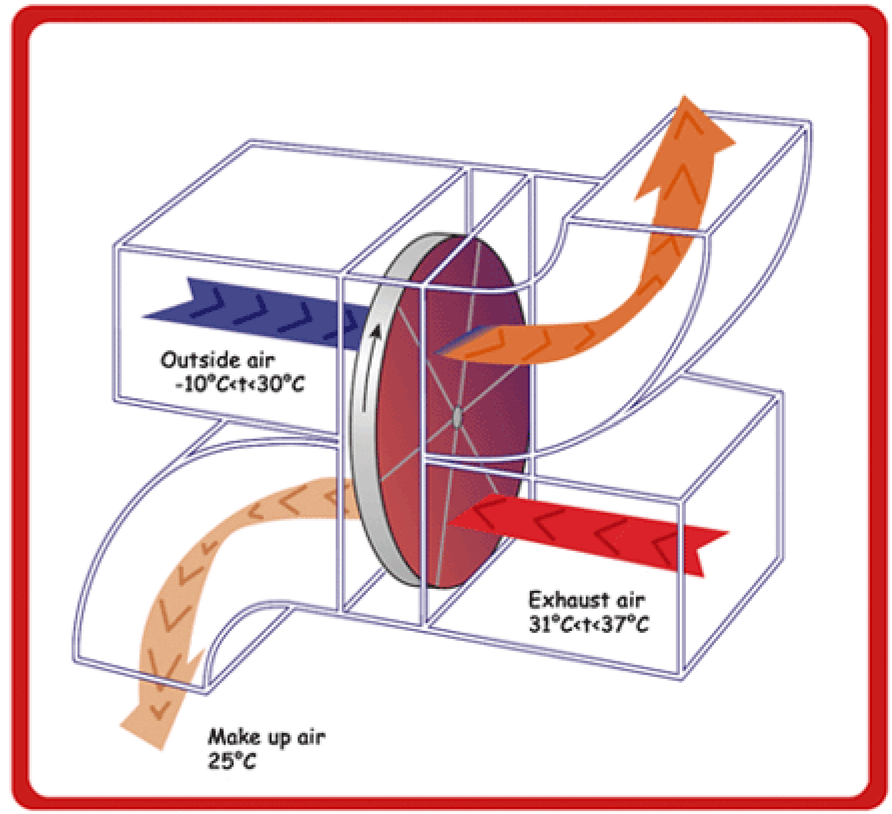
Energy Recovery Methods:
- Enthalpy and desiccant wheels
- Heat pipes
- Plate heat exchangers
- Pumped run-around systems

Air-to-Air Energy Recovery

- Now may be required by IECC, depending on airflow and & OA
- Sample code energy recovery requirements (ASHRAE 90.1-2010): Grand Rapids (Zone 5A)
  - HR required if AHU>5,500 cfm and 30%<OA≤40%
  - HR required if AHU>4,500 cfm and 40%<OA≤50%
  - HR required if AHU>3,500 cfm and 50%<OA≤60%
  - HR required if AHU>2,000 cfm and 60%<OA≤70%
  - HR required if AHU>1,000 cfm and 70%<OA≤80%
  - HR always required when OA >80%

Air-to-Air Energy Recovery

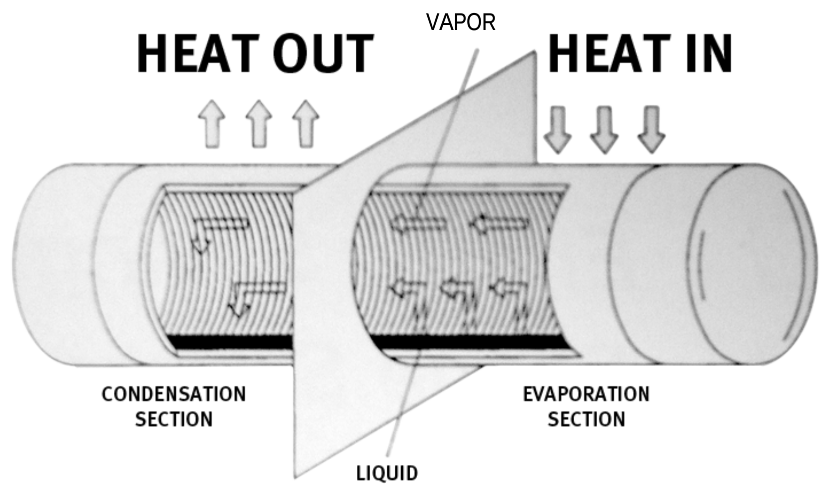
- Wheels
  - Enthalpy and desiccant
  - Highest effective recovery
  - Restrictions: not for hazardous exhaust
  - Need adjacent airstreams



A diagram of a rotary heat exchanger, or "heat wheel" (From Uptime Technology BV)

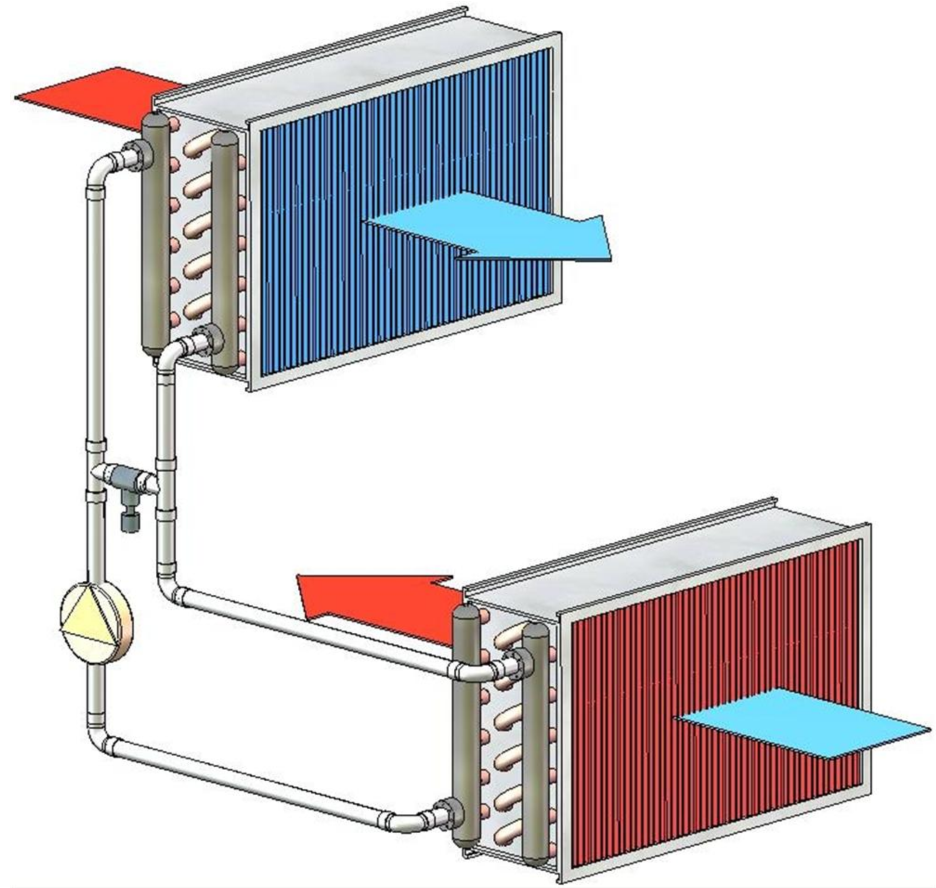
Air-to-Air Energy Recovery

- Heat pipe
  - Effective recovery
  - Little maintenance
  - No moving parts
  - Requires less space than wheels

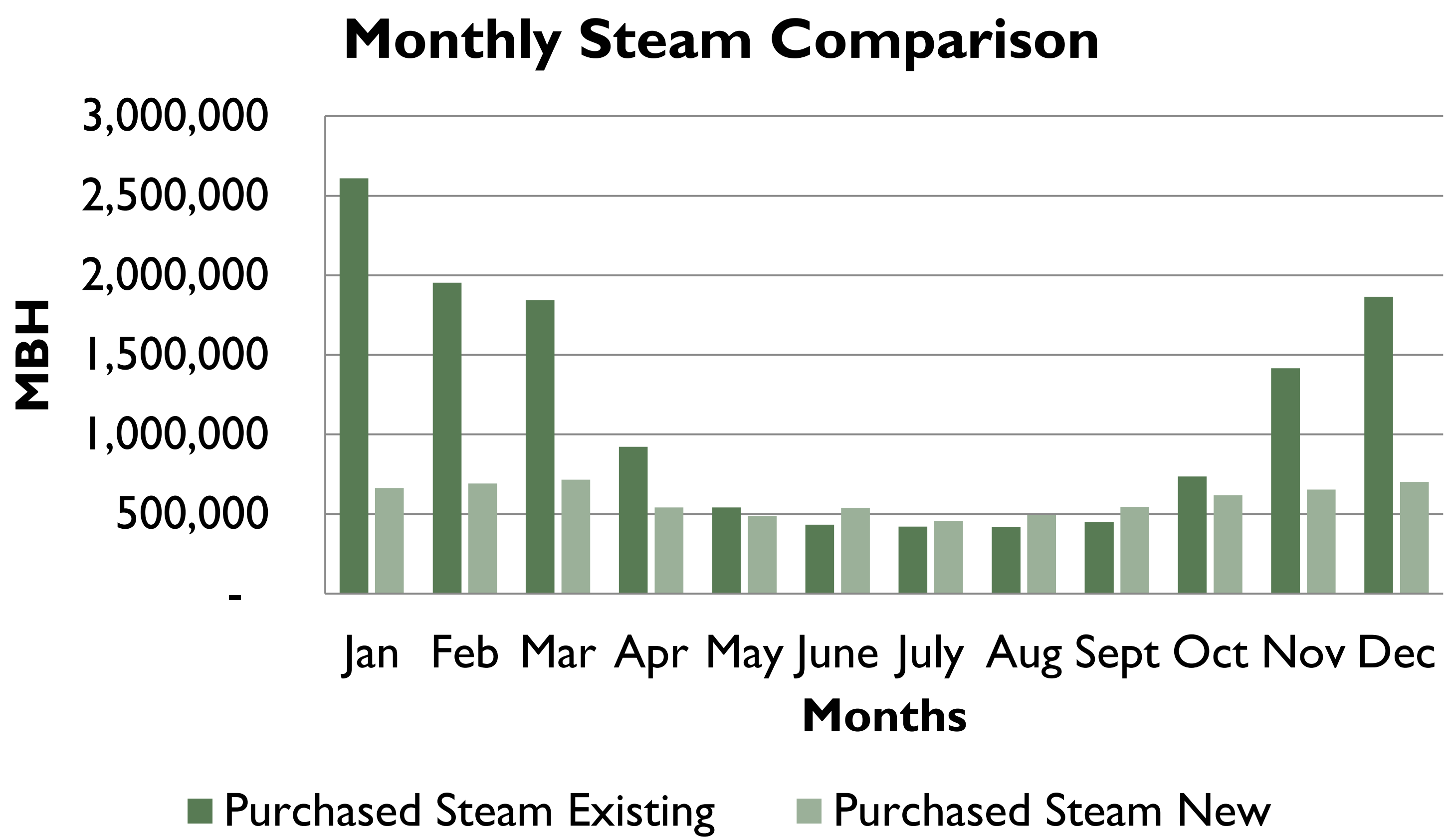


Air-to-Air Energy Recovery

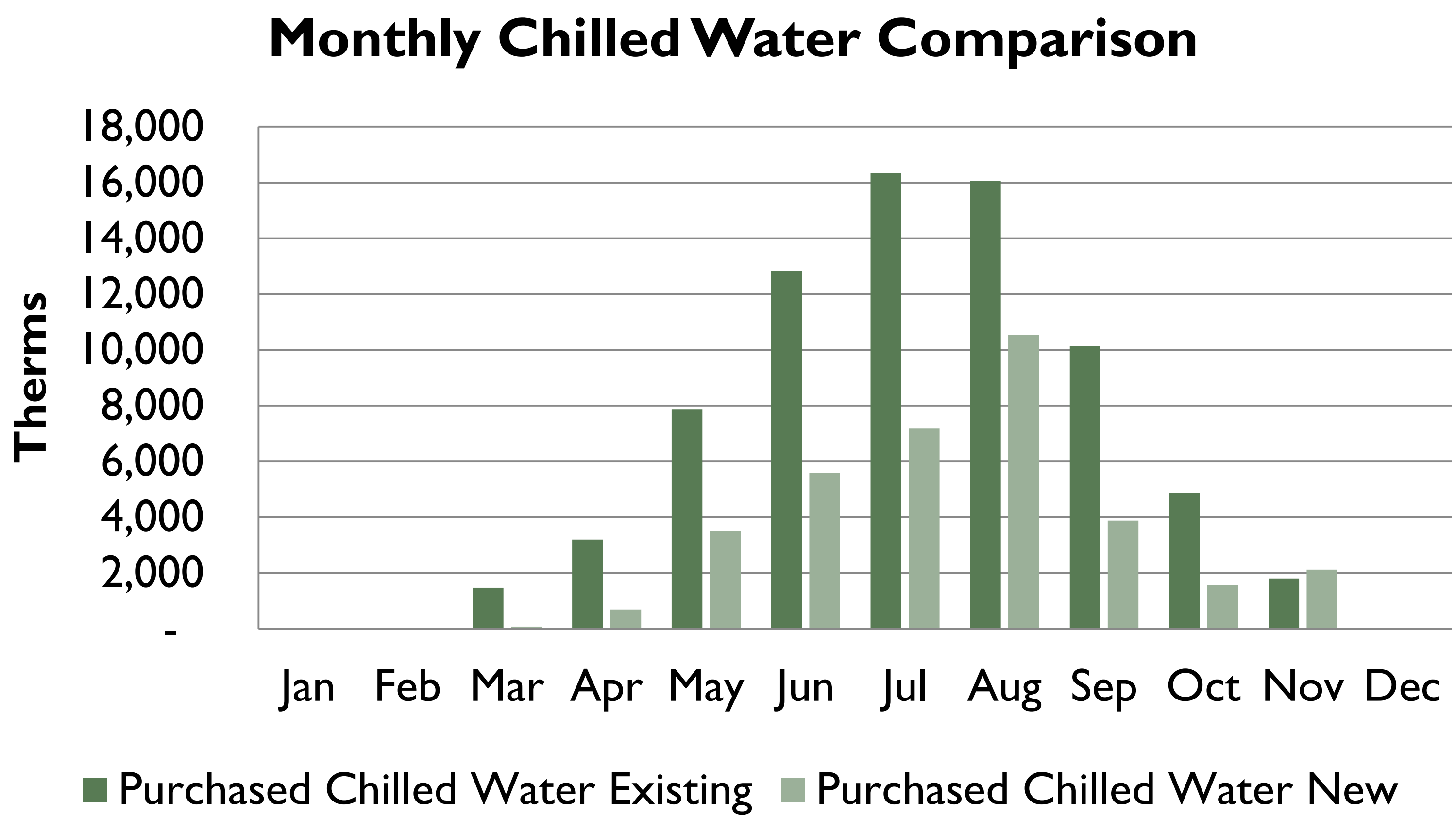
- Pumped run-around
  - Glycol or refrigerant
  - Less effective recovery
  - Maintenance required
  - Airstreams can be far apart
  - Most common option for retrofits



UIC – College of Pharmacy Energy Recovery



UIC – College of Pharmacy
Energy Recovery



Benchmarking / Best Practices

- What are other high-performing lab facilities doing?

Benchmarking / Best Practices

➢ University of California, Irvine: Smart Labs Initiative
http://www.ehs.uci.edu/programs/energy/index.html

Goal: Outperform ASHRAE Standard 90.1/CA Title 24 by 50%

- Exceeded 50% reduction from base year to 2016

Combine initiatives such as:

- Demand-controlled ventilation (DCV)
- Low-flow/high-performance fume hoods
- Reduced building exhaust stack airspeeds
- Energy-efficient lighting

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UC-Irvine Smart Lab Parameters

	Current Best Practice	Smart Lab Parameters
Air-handler/filtration airspeeds	400 ft/min. max	350 ft/min. max
Total system (supply + exhaust) pressure drop	6 in. w.g.	<5 in. w.g. (incl. dirty filter allowance)
Duct noise attenuators	Few	None
Occupied lab air changes/hr (ACH)	6 ACH	4 ACH w/contaminant sensing
Night air-change setback (unoccupied)	No setback	2 ACH w/ occupancy + contaminant sensing + no thermal inputs during setbacks
Low-flow/high-performance fume hoods	No	Yes, where hood density warrants
Fume hood face velocities	100 FPM	70 FPM (low-flow hoods)
Fume hood face velocities (unoccupied)	100 FPM	40 FPM (low-flow hoods)
Fume hood auto-closers	None	Where hood density is high
Exhaust stack discharge velocity	~3,500 FPM	Reduce or eliminate bypass air, wind-responsive controls
Lab illumination power-density	0.9 watt/SF	0.6 watt/SF w/LED task lighting
Fixtures near windows on daylight sensors	No	Yes
Energy Star freezers and refrigerators	No	Yes
Outperform CA Title 24 by…	20-25%	50%

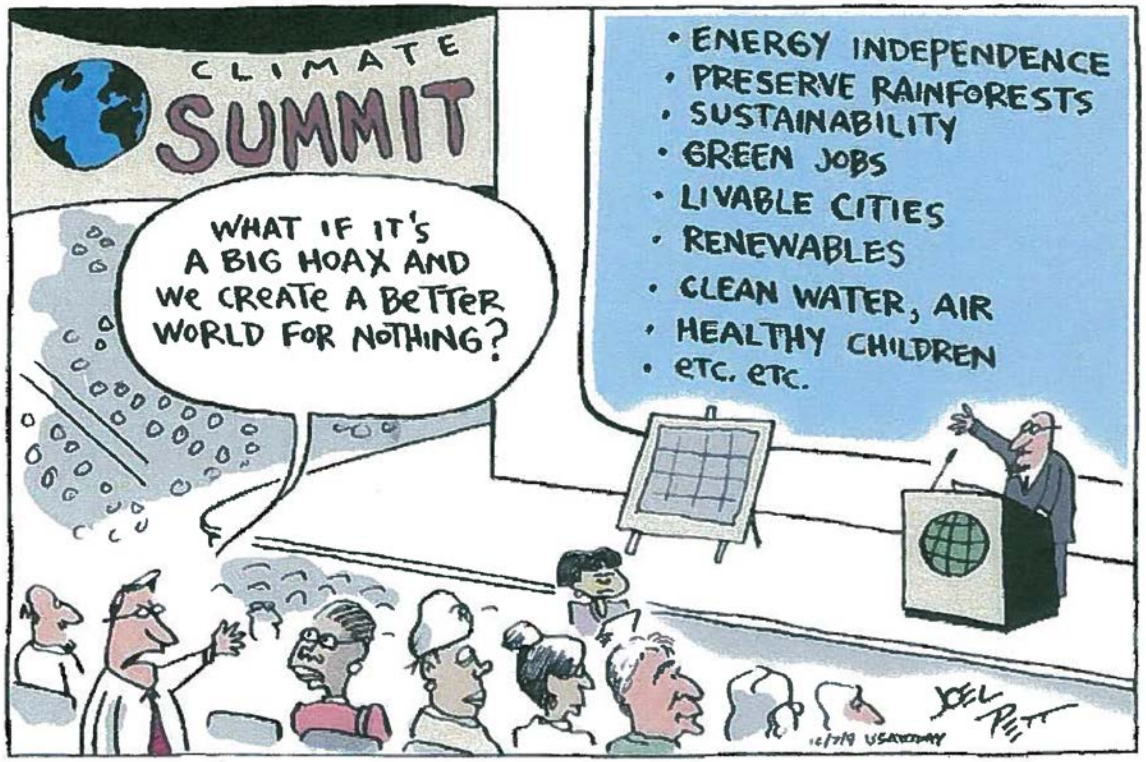
University of Illinois at Chicago

Molecular Biology Research Building Energy Audit

- **Facility**
  242,000-square-foot laboratory building on urban campus
- **Project**
  Thirteen energy cost reduction measures (ECMs) were Identified. Estimated annual energy cost savings were $844,483, representing a 12.8% ROI and a **46% energy cost reduction**.

ECMs focused on:

- Converting the air distribution system from CV to VAV
- Recovering heat from exhaust
- Reducing occupancy-related energy usage
- Optimizing control sequences
- Resetting static pressure setpoints
- Improving efficiency of constant-flow CHW/CW pumps
- Revising O&M procedures for efficiency and optimal use of staff hours



Questions?

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