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

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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 / I2SL 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.
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).

<table>
<thead>
<tr>
<th>Energy Use (Percentage of Standard Design)</th>
<th>Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>Standard Building Design</td>
</tr>
<tr>
<td></td>
<td>Energy Star and High Efficiency Equipment</td>
</tr>
<tr>
<td></td>
<td>High Efficiency Lighting</td>
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<td></td>
<td>Occupancy Sensors for Lighting and Equipment</td>
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<td></td>
<td>Daylighting Controls</td>
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<td></td>
<td>Variable Air Volume Air Distribution</td>
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<tr>
<td></td>
<td>Demand Control Ventilation</td>
</tr>
<tr>
<td>50%</td>
<td>Enthalpy Recovery Wheel</td>
</tr>
<tr>
<td></td>
<td>Enthalpy Recovery Wheel with Passive Desiccant Dehumidification</td>
</tr>
</tbody>
</table>
Energy-Efficiency Strategies

Incorporate Last
(highest cost / longest payback measures)

Renewable Energy
- Solar
- Wind

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

Low Pressure Drop Design
- Use low pressure drop AHU design
- Size ducts and pipes for low pressure drop

Control Airflow
- VAV fume hoods and lab exhaust
- VAV make-up and supply air
- Demand-based control of lab air change rates
- Optimize exhaust airflow

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

Incorporate First
(lowest cost / highest energy reduction)
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

<table>
<thead>
<tr>
<th>Lamp type</th>
<th>Lumens/W</th>
<th>Life hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-12 FL</td>
<td>80 L/W</td>
<td>24,000 HR</td>
</tr>
<tr>
<td>T-8 FL</td>
<td>80-100 L/W</td>
<td>24,000 - 30,000 HR</td>
</tr>
<tr>
<td>T-5 FL</td>
<td>90-100 L/W</td>
<td>24,000 -30,000 HR</td>
</tr>
<tr>
<td>T-8 FL ELL</td>
<td>85-95 L/W</td>
<td>46,000 -50,000 HR</td>
</tr>
<tr>
<td>LED</td>
<td>100-110 L/W *</td>
<td>50,000 HR</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Medical vs. Research</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medical-Grade</strong></td>
</tr>
<tr>
<td>Vacuum pumps</td>
</tr>
<tr>
<td>Inefficient steam jackets</td>
</tr>
<tr>
<td>Must be run 24/7 or risk harm to the unit</td>
</tr>
<tr>
<td>“High-throughput”: designed for 24/7 hospital use, over a dozen cycles per day</td>
</tr>
<tr>
<td>Consumes up to 150 gallons of water per cycle (&quot;water conservation kits&quot; can reduce this to 50 gallons per cycle)</td>
</tr>
</tbody>
</table>
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**

<table>
<thead>
<tr>
<th>Agency</th>
<th>Ventilation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHRAE Lab Guides</td>
<td>4-12 ACH</td>
</tr>
<tr>
<td>UBC – 1997</td>
<td>1 cfm/ft²</td>
</tr>
<tr>
<td>IBC – 2003</td>
<td>1 cfm/ft²</td>
</tr>
<tr>
<td>IMC – 2003</td>
<td>1 cfm/ft²</td>
</tr>
<tr>
<td>U.S. EPA</td>
<td>4 ACH Unoccupied Lab – 8 ACH Occupied Lab</td>
</tr>
<tr>
<td>AIA</td>
<td>4-12 ACH</td>
</tr>
<tr>
<td>NFPA-45-2004</td>
<td>4 ACH Unoccupied Lab – 8 ACH Occupied Lab</td>
</tr>
<tr>
<td>NRC Prudent Practices</td>
<td>4-12 ACH</td>
</tr>
<tr>
<td>OSHA 29 CFR Part 1910.1450</td>
<td>Requires 4-12 ACH</td>
</tr>
<tr>
<td>ACGIH 24th Edition, 2001</td>
<td>Ventilation depends on the generation rate and toxicity of the contaminant and not the size of the room.</td>
</tr>
<tr>
<td>ANSI/AIHA Z9.5</td>
<td>Prescriptive ACH is not appropriate. Rate shall be established by the owner!</td>
</tr>
</tbody>
</table>
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.
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 supply 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
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

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>Pressure Drop (inches WG)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard 12-inch-deep box-style rigid media filters</td>
<td>0.61</td>
</tr>
<tr>
<td>12-inch-deep low pressure drop V-bank type mini-pleat filters</td>
<td>0.37</td>
</tr>
<tr>
<td>Electronic filters</td>
<td>0.20</td>
</tr>
</tbody>
</table>

*Initial clean filter pressure drops @ 500 fpm
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
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

<table>
<thead>
<tr>
<th></th>
<th>Design Static Pressure</th>
<th>AHU First Cost</th>
<th>Annual Energy Reduction Compared With Base Case</th>
<th>Simple Payback</th>
<th>Utility Demand-Side Management Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base case (500 fpm)</strong></td>
<td>8.5” w.g.</td>
<td>$150,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Option 1 (400 fpm)</strong></td>
<td>6.0” w.g.</td>
<td>$145,000</td>
<td>$4,400</td>
<td>Immediate</td>
<td>$3,655</td>
</tr>
<tr>
<td><strong>Option 2 (300 fpm)</strong></td>
<td>4.5” w.g.</td>
<td>$160,000</td>
<td>$10,200</td>
<td>Two months</td>
<td>$8,384</td>
</tr>
</tbody>
</table>
Optimize (Minimize) Exhaust Airflow: Conventional Design

Wind → Exhaust Fan → Bypass Damper → Re-Entrainment of Contaminated Air

Plenum → Supply Fan Duct

Fume Hood → Balcony
Exhaust Energy Reduction Solutions

- Slightly higher stacks, 4-5 feet
- Variable speed fans (reduce exhaust fan flows)
- Install wind-responsive controls.
- Reduce or eliminate bypass air

Air quality sensor
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
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

Monthly Steam Comparison

- Purchased Steam Existing
- Purchased Steam New

Months
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

MBH
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
UIC – College of Pharmacy Energy Recovery

Monthly Chilled Water Comparison

Therms

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Purchased Chilled Water Existing  Purchased Chilled Water New
What are other high-performing lab facilities doing?
Benchmarking / Best Practices

- University of California, Irvine: Smart Labs Initiative

**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
## UC-Irvine Smart Lab Parameters

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