U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy


FEMP FIRST THURSDAY SEMIN@RS 2.0

What you need to know...online, live, and anytime.

# Labs, Data Centers, and High Tech Facilities

Instructors: Dale Sartor, Lawrence Berkeley National Laboratory
Paul Mathew, Lawrence Berkeley National Laboratory
FEMP Expert: Will Lintner, Federal Energy Management Program

www.femp.energy.gov/training

FEMP Federal Energy Management Program

# Learner Objectives

**After completing this seminar, the learner will:**

1. Discuss the benefits and cost savings potential of improving energy efficiency in labs, data centers, and other high tech facilities
2. Suggest technologies for improving energy efficiency in data centers in areas such as IT equipment, software, air management, humidity control, and free and liquid cooling
3. Suggest technologies for improving energy efficiency in labs and high tech facilities including hoods, ventilation/air changes, and HVAC systems
4. Discuss ways to improve energy efficiency through improved operations and maintenance
5. Discuss FEMP resources to support energy efficiency in labs, data centers, and high tech facilities

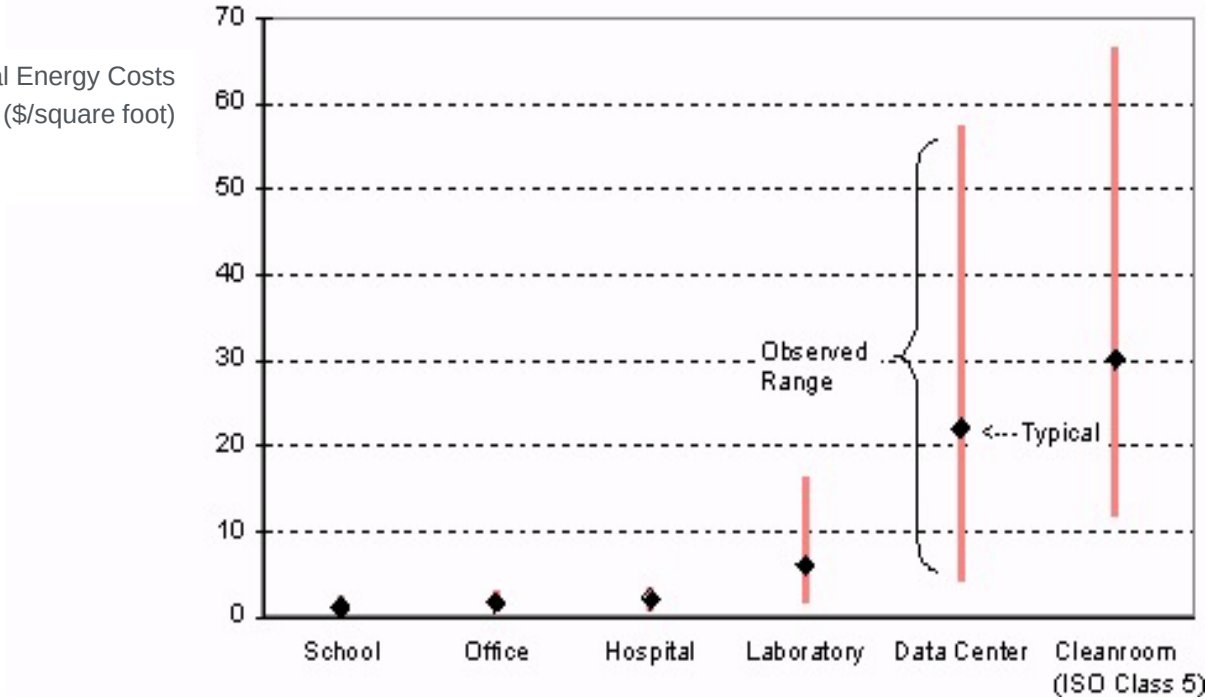
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Overview

*Spallation Neutron Source Central Lab and Office Building at Oak Ridge National Laboratory, Oak Ridge, TN*

# High Tech Buildings are Energy Hogs

## Comparative Energy Costs
## High-Tech Facilities *vs.* Standard Buildings



# Meeting Federal Requirements for Energy Efficiency

## EISA 2007

Energy intensity reductions in Federal facilities relative to a 2003 baseline:

- 2011 – 18% reduction
- 2015 – 30% reduction

# Federal Requirements: Data Centers

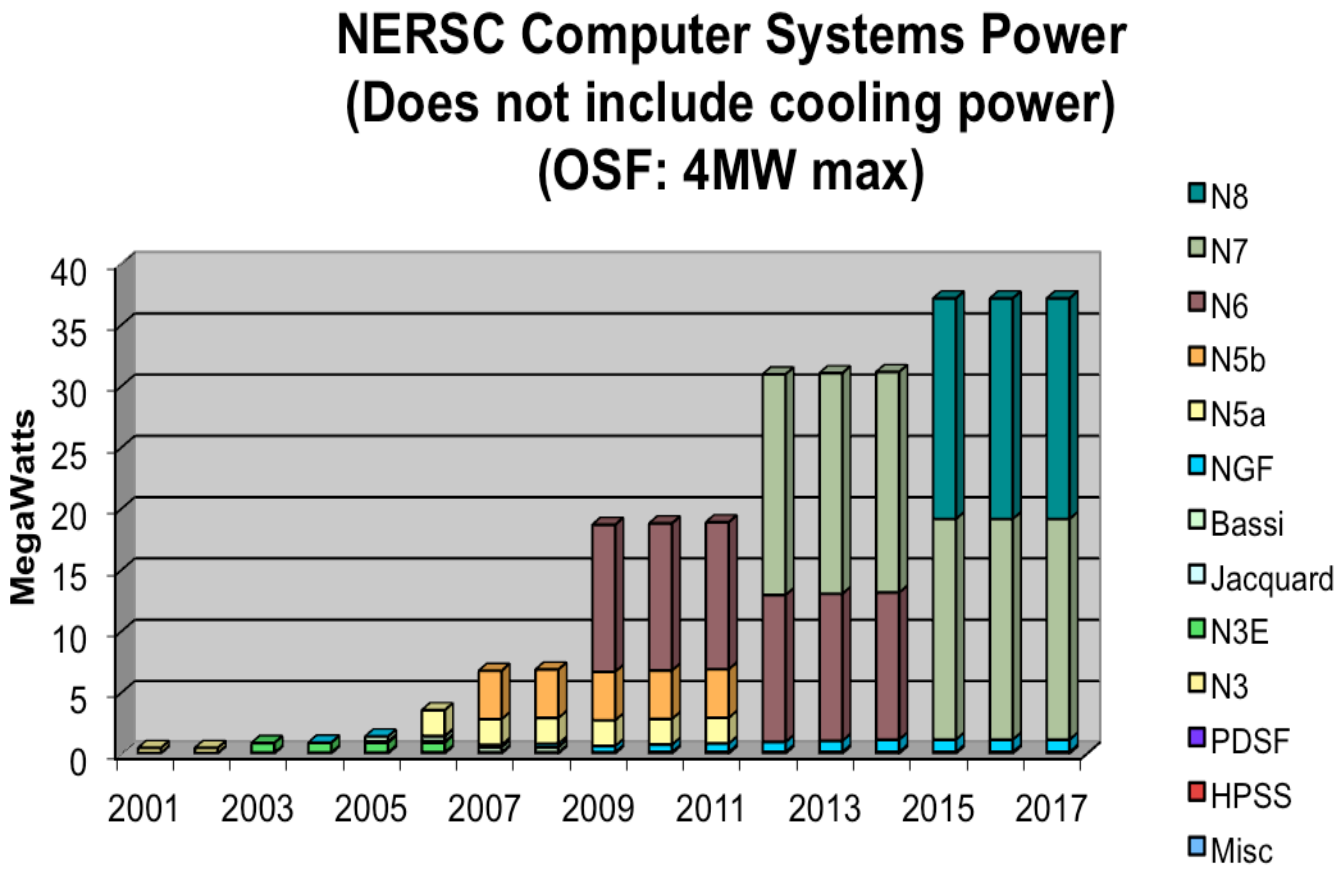
- **EISA: Section 432, and 453**
  - Directs DOE and EPA to initiate a voluntary national data center information center
  - Directs Federal agencies to conduct energy and water audits and benchmark buildings
- **Federal Data Center Consolidation Initiative (FDCCI)**
  - Aggressive goal of decommissioning 800 Federal data centers by 2015
- **Executive Order 13514**
  - Directs Federal agencies to implement best management practices for energy efficient management of servers and Federal data centers

# Energy Efficiency in Data Centers

# Data Centers are Energy Intensive

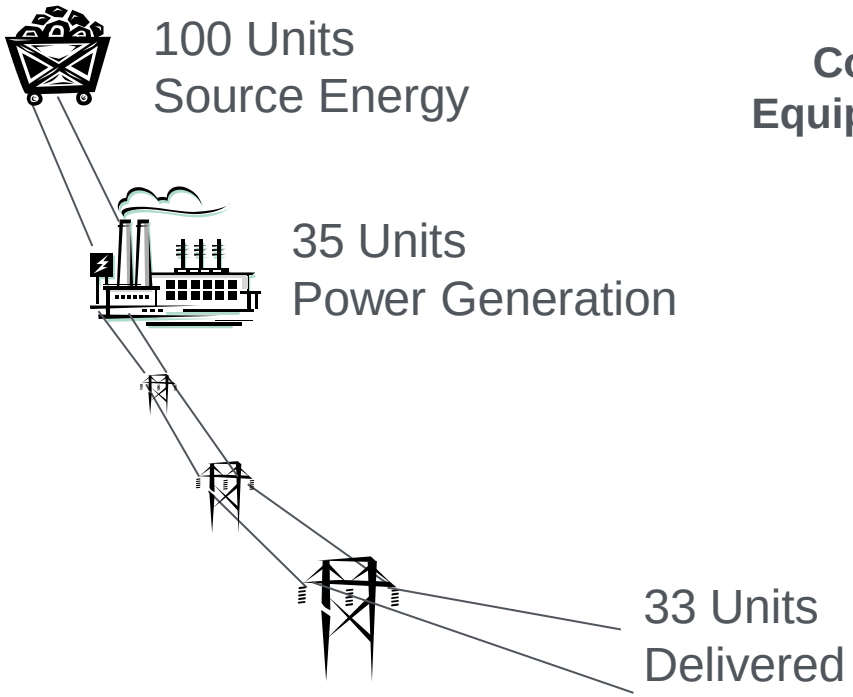
- Server racks now designed for > 25+ kW
- Surging demand for data storage
- Typical facility 1MW
- Some facilities >20 MW
- 1.5% of U.S. consumption in 2006
- Cost of electricity and related infrastructure more costly than the capital cost of IT equipment

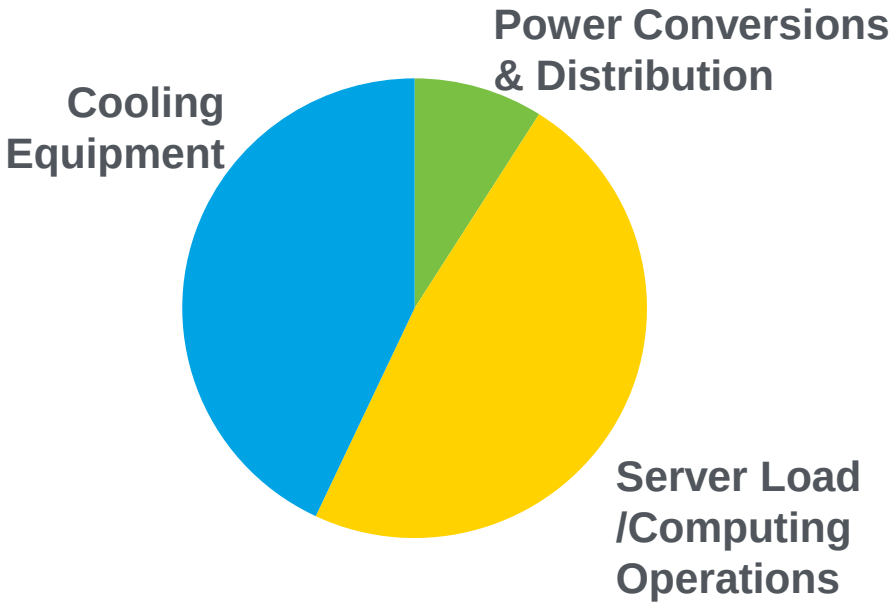
# LBNL Feels the Pain



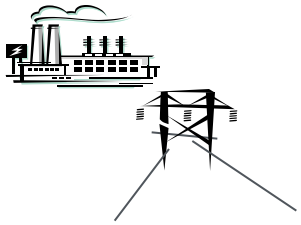
# Energy Efficiency = Useful Computation / Total Source Energy

## Typical Data Center Energy End Use = 15% (or less)



# Opportunities for Energy Efficiency



Server innovation
Virtualization
High efficiency power supplies
Load management

Better air management
Move to liquid cooling
Optimized chilled-water plants
Use of free cooling
Heat recovery

**Power Conversion & Distribution**

**Server Load/ Computing Operations**

**Cooling Equipment**

High voltage distribution
High efficiency UPS systems
Efficient redundancy strategies
Use of DC power

**On-site Generation**

On-site generation including fuel cells and renewable sources
CHP applications
(Waste heat for cooling)

# Potential Benefits of Data Center Efficiency

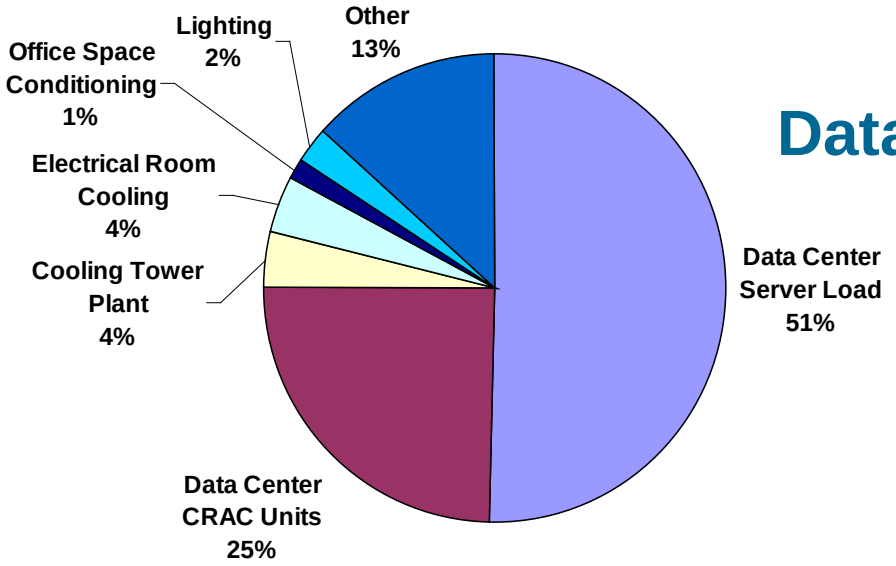
- 20-40% savings typical
- Aggressive strategies can yield 50+% savings
- Also extends life and capacity of infrastructures
- But is mine good or bad?

# Benchmarking for Success

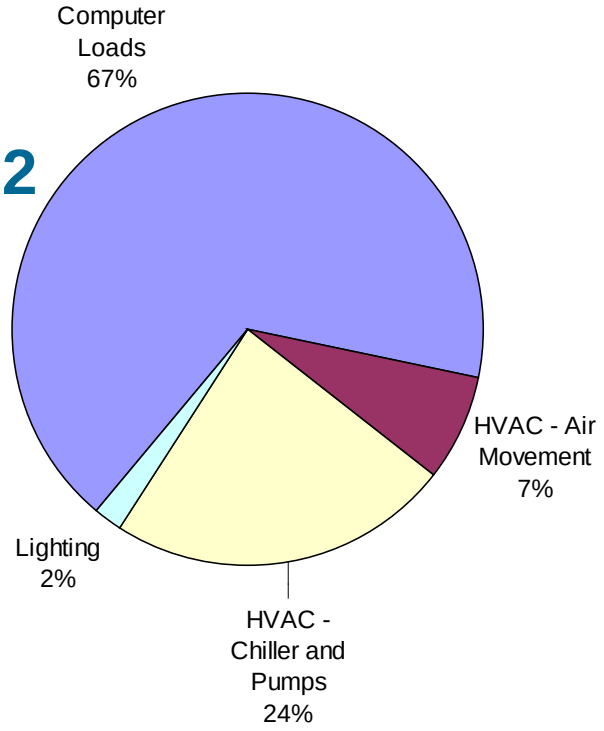
## Benchmarking

- Allows comparison to peers
  - Wide variation
- Helps identify best practices
- Helps select projects to address
- Allows measure of progress

# Data Center Energy Usage Varies

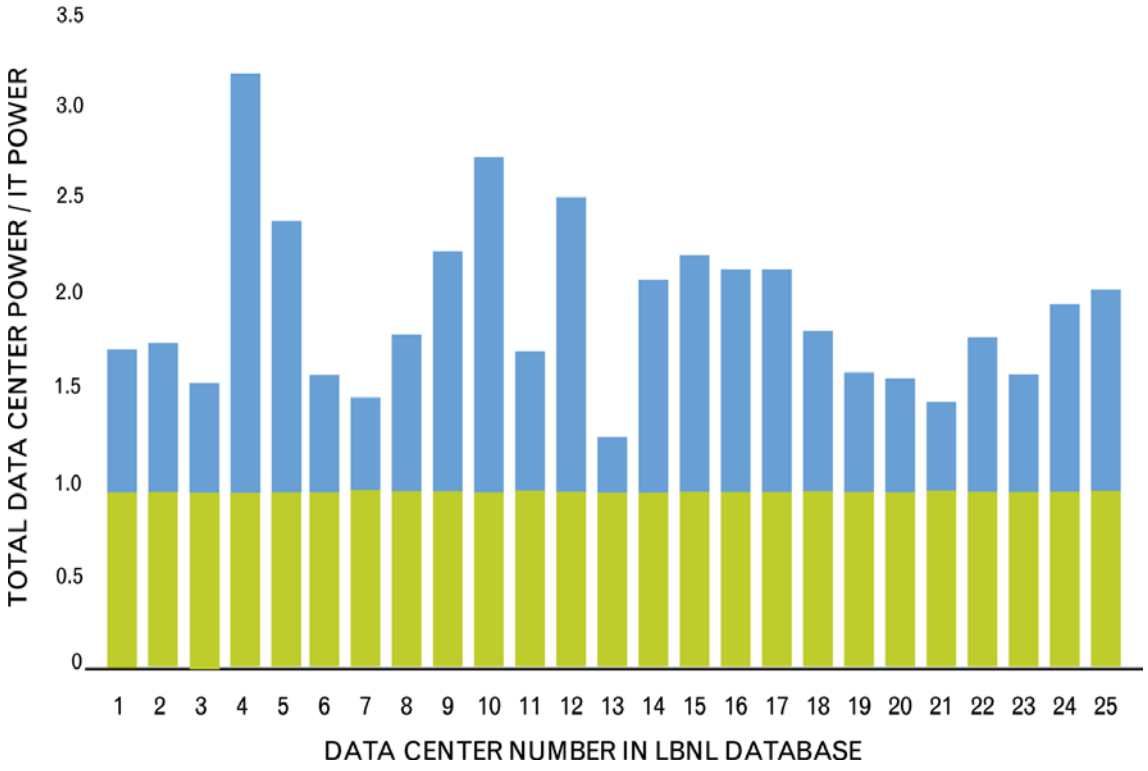


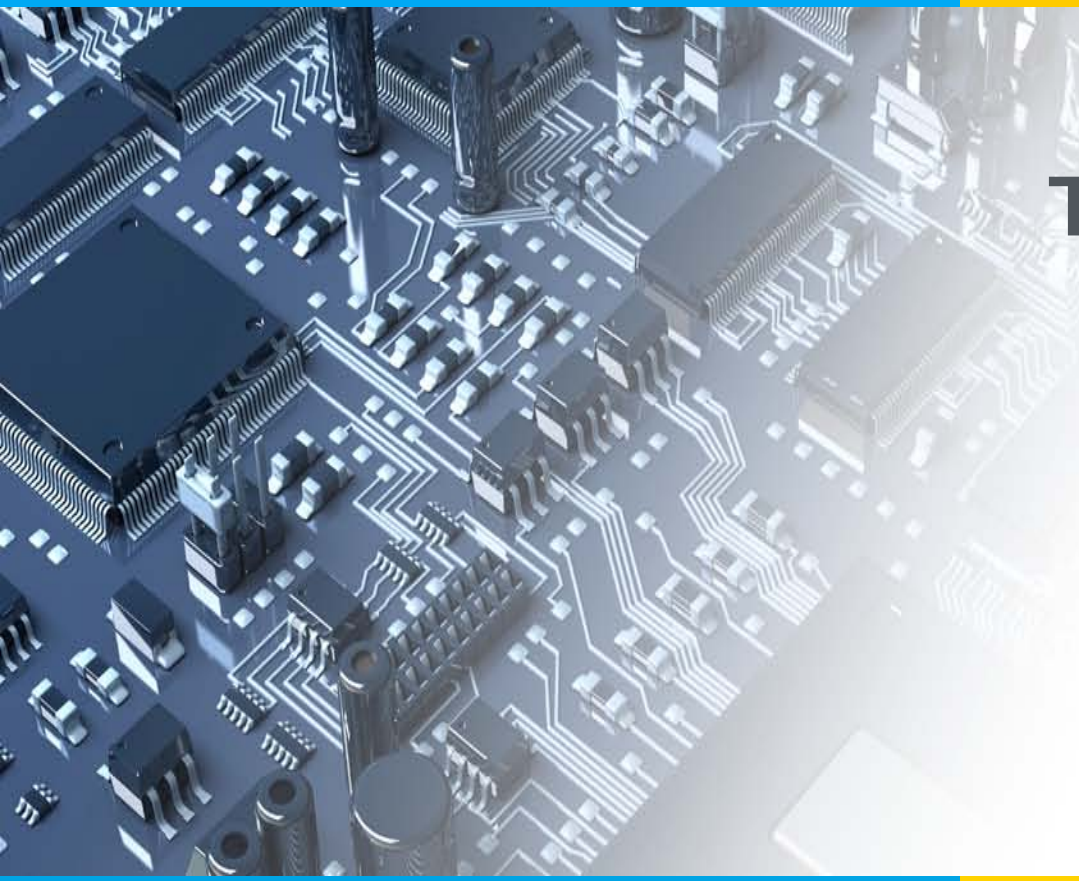

## Data Center 1




## Data Center 2

# High Level Metric: Power Utilization Effectiveness (PUE) = Total Data Center Power/IT Power





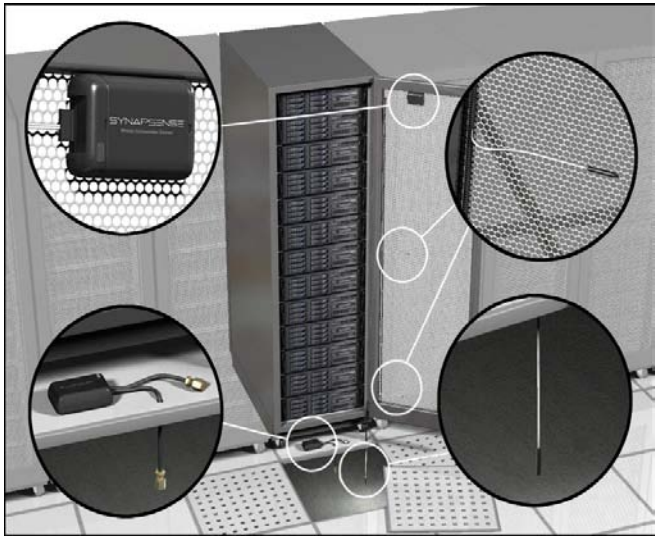
# Technologies and Best Practices for Data Centers

# Improvements in IT Equipment – Servers

- Computational efficiency
- Consolidation and virtualization (high utilization)
- Use Energy Star® servers
- Data storage management
- Enable power management capabilities
- Multiplier effect

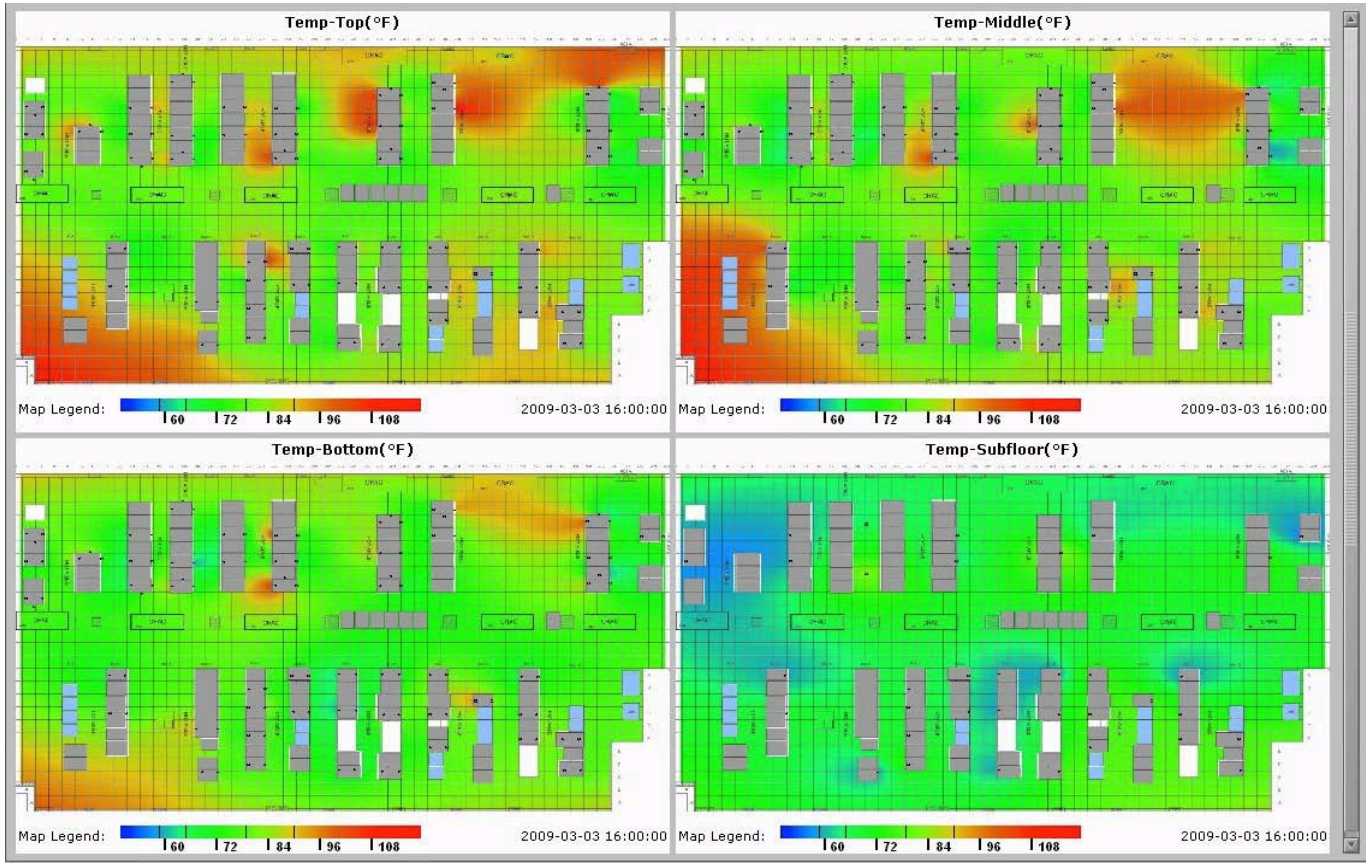
# Use IT to Save Energy in IT

- Operators lack visibility into data center environment
- Provide same level of monitoring and visualization of the physical space as we have for the IT environment
- Measure and track performance
- Spot problems early

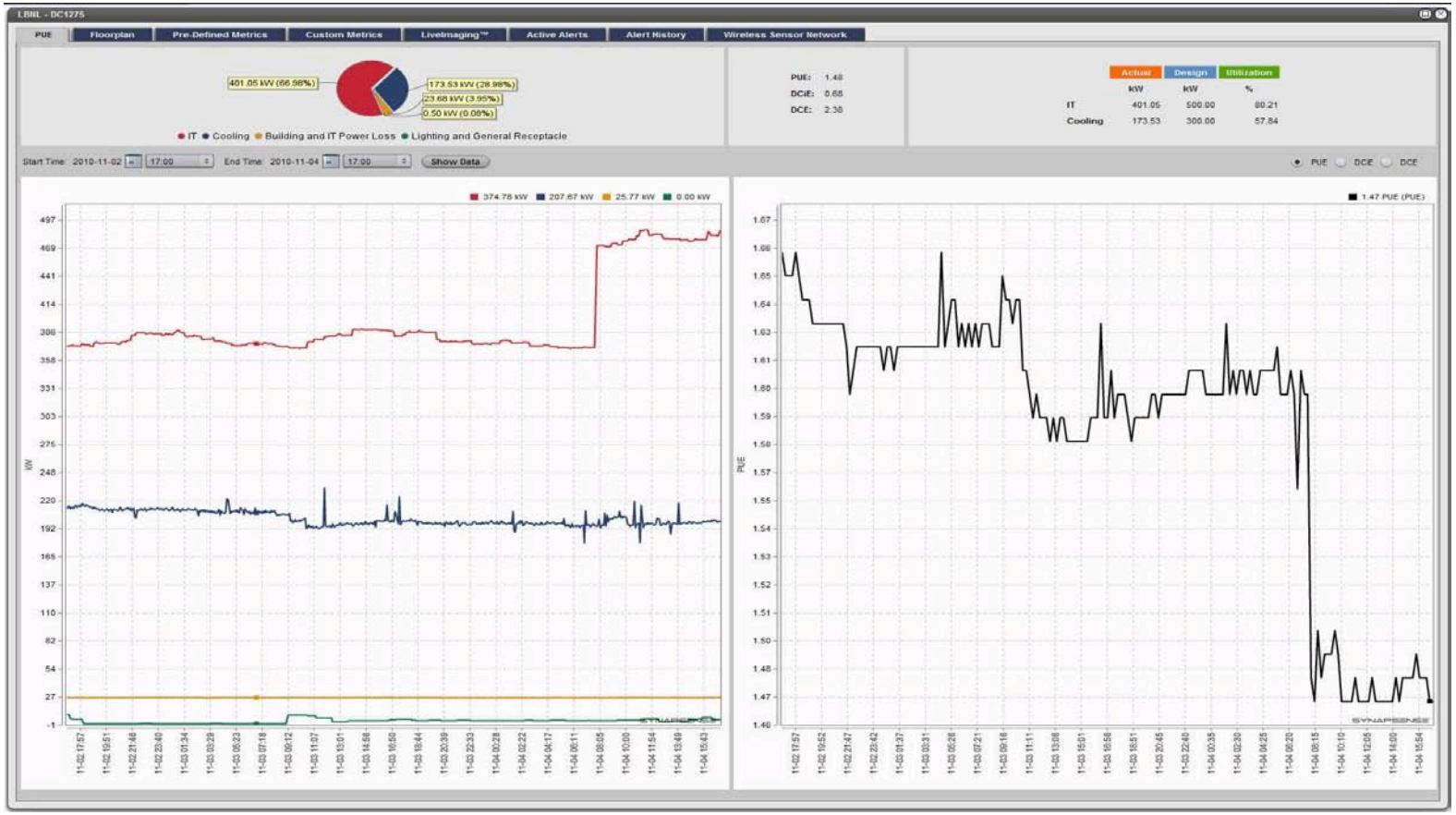



source: SynapSense

# Visualization Getting Much Better

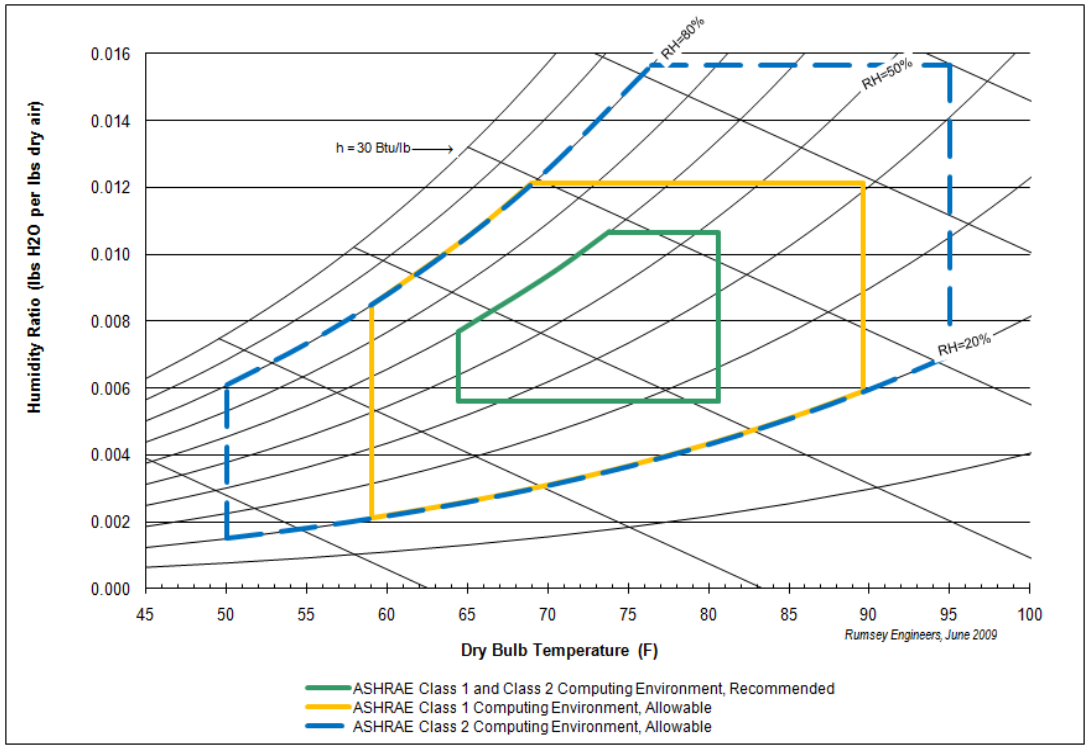


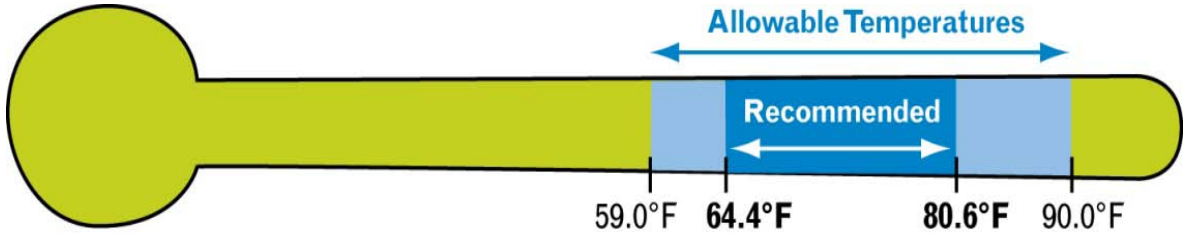
# Real-time PUE Display



# Adjust Environmental Conditions

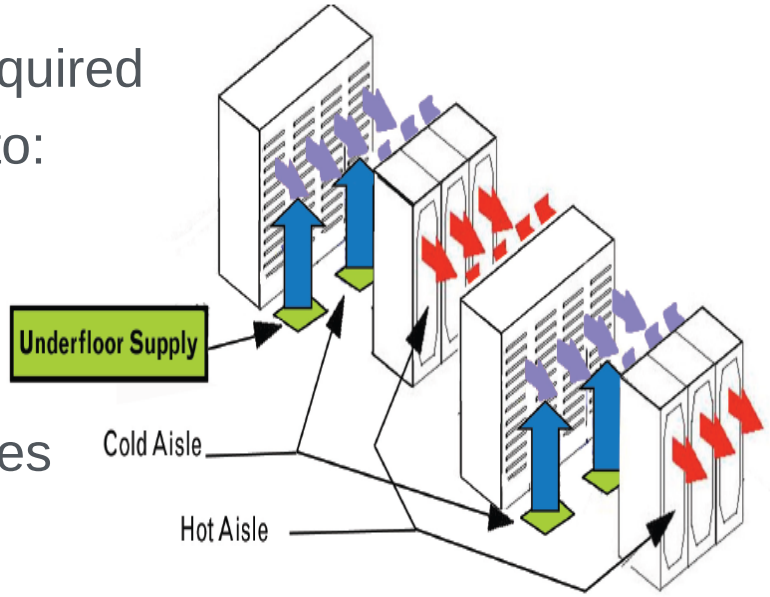
Use ASHRAE Recommended and Allowable ranges of temperature and humidity



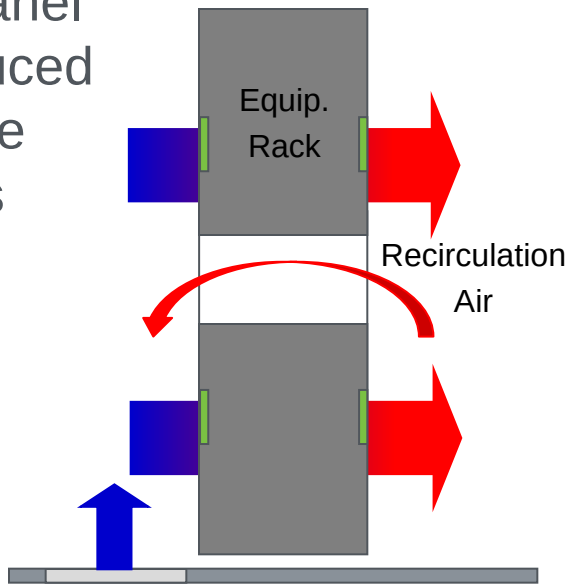
# Improve Air Management

- Generally more air circulated than required
- Air mixing and short circuiting leads to:
  - Low temperature supply
  - Low Delta T
- Use hot and cold aisles
- Improve isolation of hot and cold aisles
  - Reduce fan energy
  - Improve AC efficiency
  - Increase cooling capacity

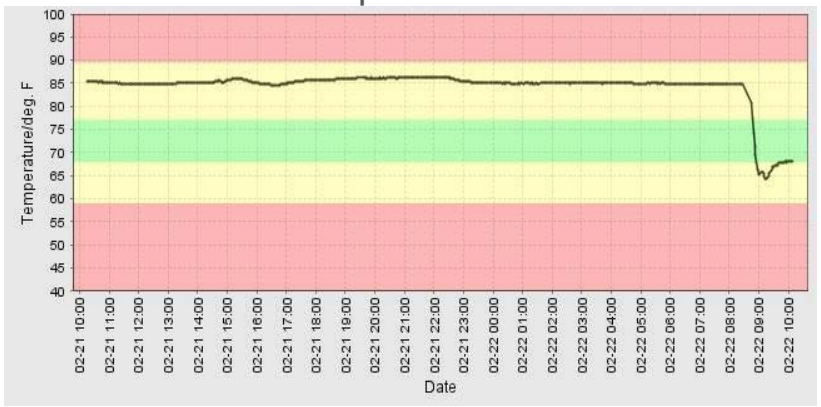


# Air Management: Blanking Panels

One 12” blanking panel added reduced temperature 20 degrees




Top of rack




SynapSense™

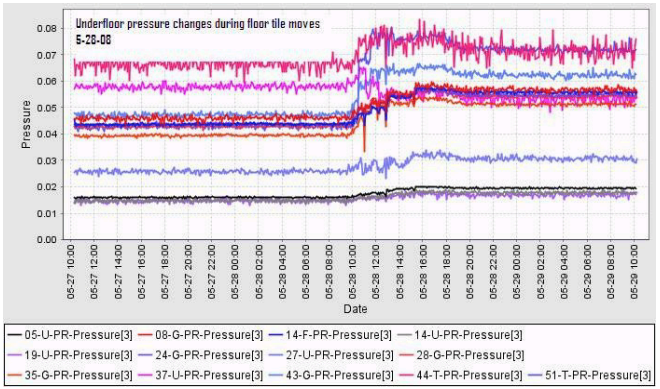
Middle of rack


SynapSense™

# Air Management: Tune Floor Tiles

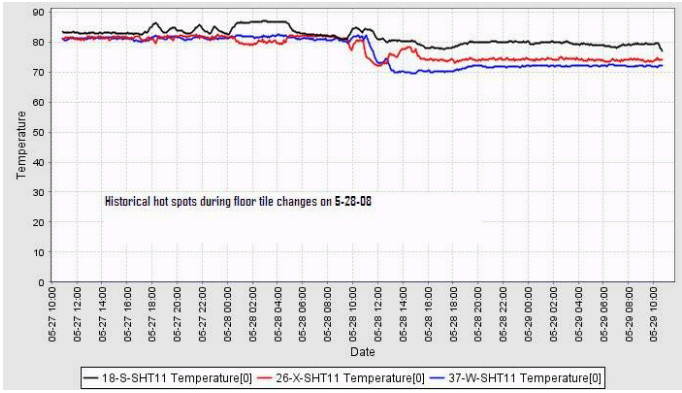
- Too many permeable floor tiles
- Optimize airflow
  - under-floor pressure
  - rack-top temperatures
  - data center capacity increases

Under-floor pressures




SynapSense™

Rack-top temperatures




SynapSense™

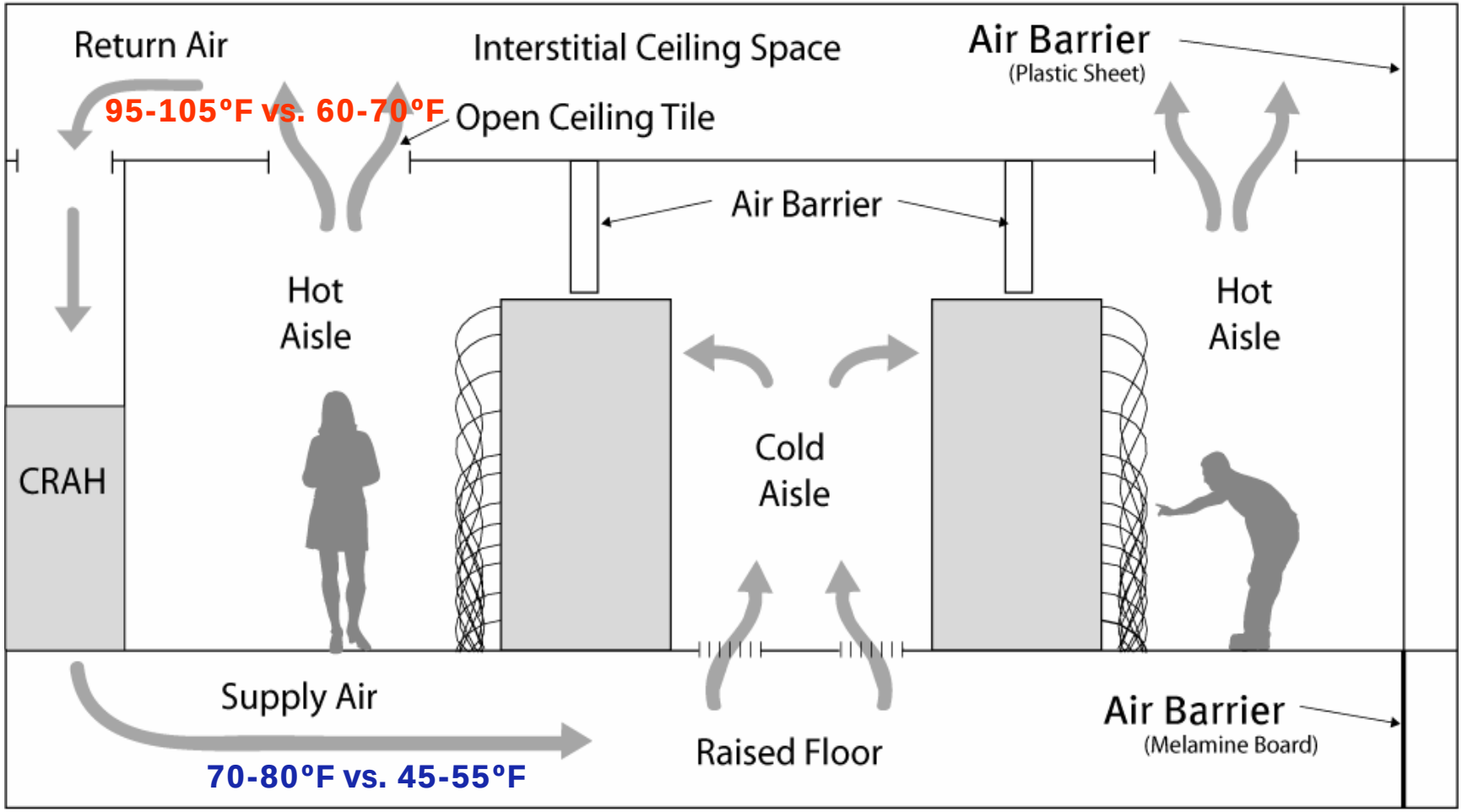
# Air Management: Enclose Return Air

- Overhead plenum converted to hot air return
- Return registers over hot aisles
- CRAC intakes extended to overhead

**Before**

**After**

# Air Management – Air Curtains


Return Air
95-105°F vs. 60-70°F
Interstitial Ceiling Space
Open Ceiling Tile
Air Barrier
(Plastic Sheet)
Air Barrier
Hot Aisle
Hot Aisle
CRAH
Cold Aisle
Supply Air
70-80°F vs. 45-55°F
Raised Floor
Air Barrier
(Melamine Board)

# Use Free Cooling

- Outside-air economizers
  - Effective 24/7 load
  - Must consider humidity
- Water economizers
  - No contamination question
  - Can be in series with chiller
- Let's get rid of chillers in data centers

# Emerging Technology: Liquid Cooling

- Liquid is more efficient than air for heat transfer
- Cooling with tower only or chiller assisted
  - Both options better than DX CRAC units

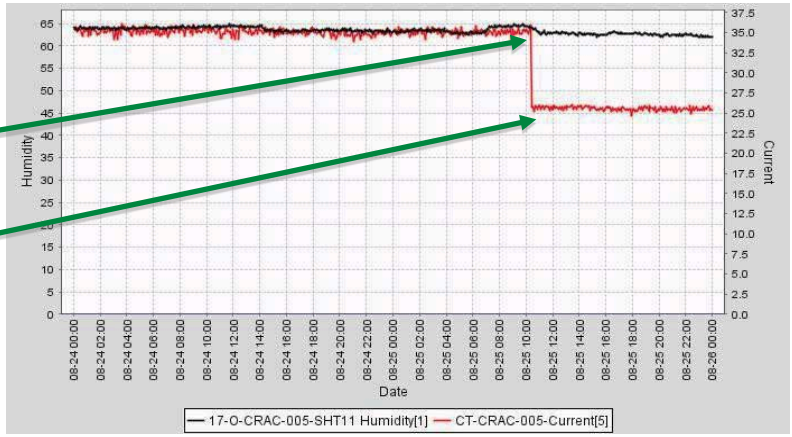
# Improve Humidity Control

| | Visalia Probe | | | CRAC Unit Panel | | | |
|---|---|---|---|---|---|---|---|
| | Temp | RH | Tdp | Temp | RH | Tdp | Mode |
| AC 005 | 84.0 | 27.5 | 47.0 | 76 | 32.0 | 44.1 | Cooling |
| AC 006 | 81.8 | 28.5 | 46.1 | 55 | 51.0 | 37.2 | Cooling & Dehumidification |
| AC 007 | 72.8 | 38.5 | 46.1 | 70 | 47.0 | 48.9 | Cooling |
| AC 008 | 80.0 | 31.5 | 47.2 | 74 | 43.0 | 50.2 | Cooling & Humidification |
| AC 010 | 77.5 | 32.8 | 46.1 | 68 | 45.0 | 45.9 | Cooling |
| AC 011 | 78.9 | 31.4 | 46.1 | 70 | 43.0 | 46.6 | Cooling & Humidification |
| | | | | | | | |
| Min | 72.8 | 27.5 | 46.1 | 55.0 | 32.0 | 37.2 | |
| Max | 84.0 | 38.5 | 47.2 | 76.0 | 51.0 | 50.2 | |
| Avg | 79.2 | 31.7 | 46.4 | 68.8 | 43.5 | 45.5 | |

- Eliminate inadvertent dehumidification
- Use ASHRAE allowable RH and temperature
- Eliminate equipment fighting

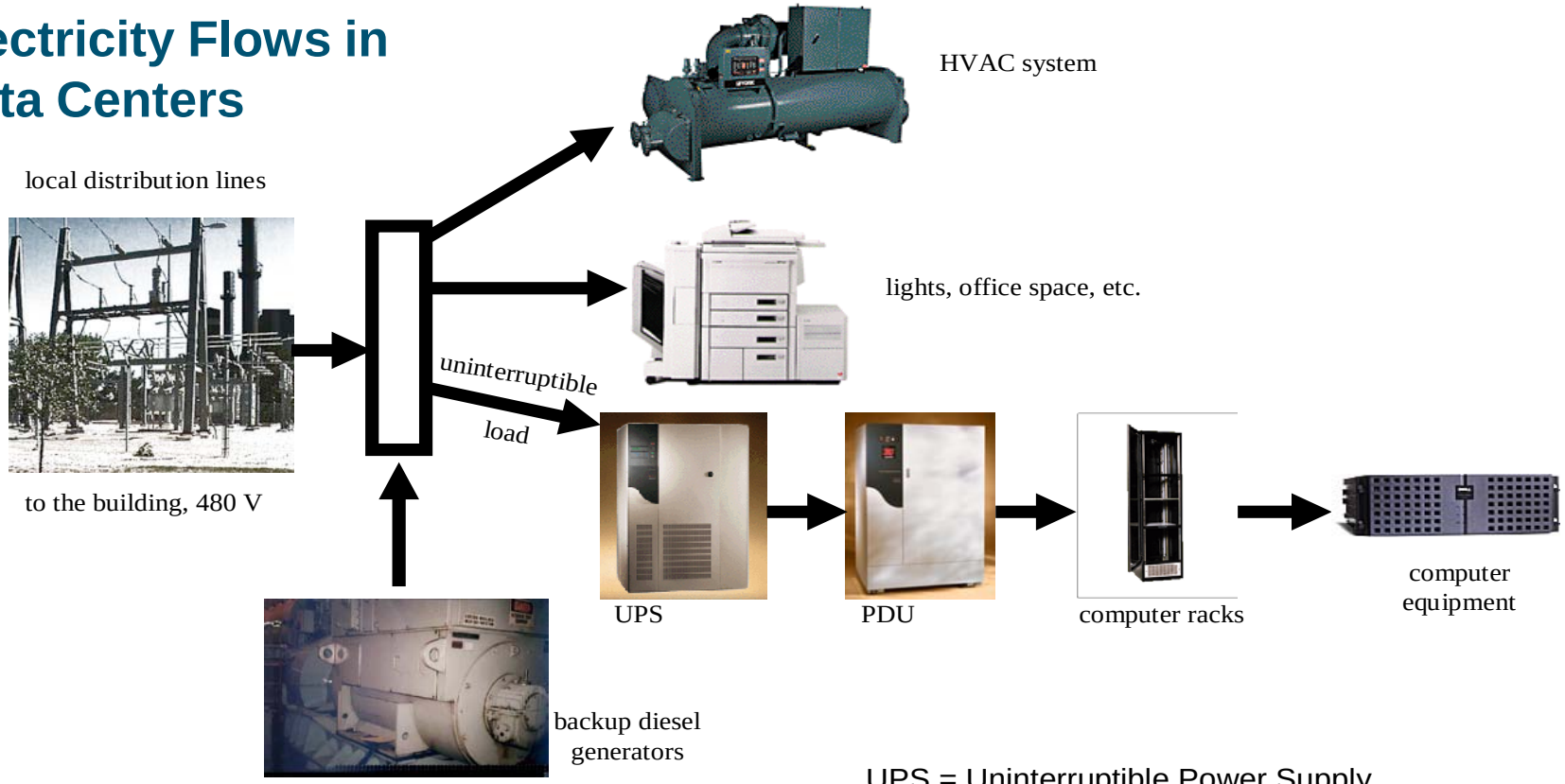
**Humidity down 3%**

**CRAC power down 28%**



# Power Chain Conversions Waste Energy

## Electricity Flows in Data Centers




UPS = Uninterruptible Power Supply

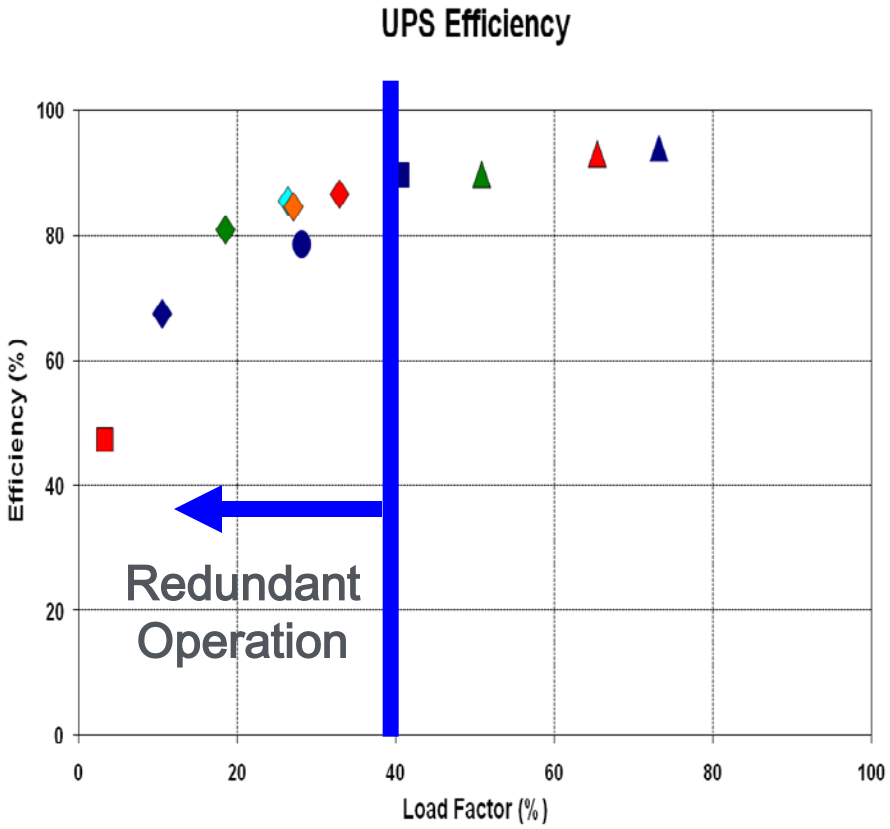
PDU = Power Distribution Unit;

# Select and Configure Power Supplies for Greater Efficiency

**80 PLUS Program** offers certification of efficient power supplies

# Reconsider Redundancy

- What does redundancy cost?
- Different strategies have different energy penalties (e.g. 2N vs. 1+N)
- Redundancy in electrical distribution reduces efficiency
- Other options: redundancy in the network rather than data center

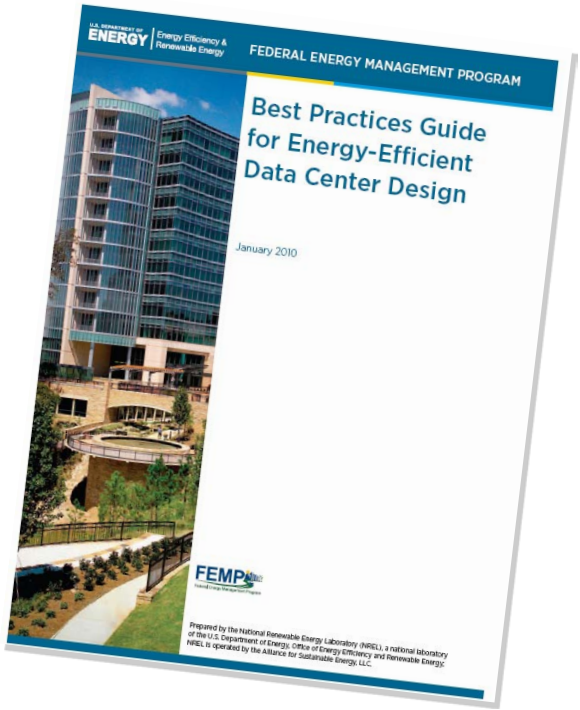


# Improving Operations and Maintenance: Best Practices

- Get IT and Facilities people working together
- Use life-cycle cost of ownership analysis
- Document design intent and provide training
- Benchmark and track existing facilities
- Re-commission as part of maintenance

# Resources for Energy Efficiency in Data Centers

- Quick-Start Guide
- Analysis Tools
- Best Practices Guide
- Benchmarking Guide
- Data Center Programming Guide
- Technology Case Study Bulletins
- Procurement Specifications




**http://www1.eere.energy.gov/femp/program/dc_resources.html**

# Data Center Energy Profiler (DC Pro)

High-Level Profiling and Tracking Tool

- Overall efficiency (Power Usage Effectiveness PUE)
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction
  - Air management
  - Electrical systems
  - IT equipment
  - Cooling


Save ENERGY Now

**http://www1.eere.energy.gov/industry/datacenters/software.html**

## DOE/ASHRAE Awareness Training

- One-day training
- Target audience: data center and facility operators

## DC Certified Energy Practitioner (DCEP)

- Three-day generalist workshop with two options
  Training certificate track
  (no pre-qualifications, training only, training certificate)
- Training & exam (training, DCEP certificate)
- Target audience: DC personnel, consultants & service providers
- Specialist tracks: Electrical, Air Management, HVAC* and IT*

***coming soon**

FEMP Federal Energy Management Program

http://www1.eere.energy.gov/femp/program/data_center.html

BERKELEY LAB

http://hightech.lbl.gov/datacenters.html

ENERGY STAR

http://www.energystar.gov/index.cfmc=prod_development.server_efficiency

Save ENERGY Now ®

http://www1.eere.energy.gov/industry/datacenters/

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# FEMP

Federal Energy Management Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

# Energy Efficiency in Labs

*Science and Technology Facility (S&TF), NREL, Golden, CO*

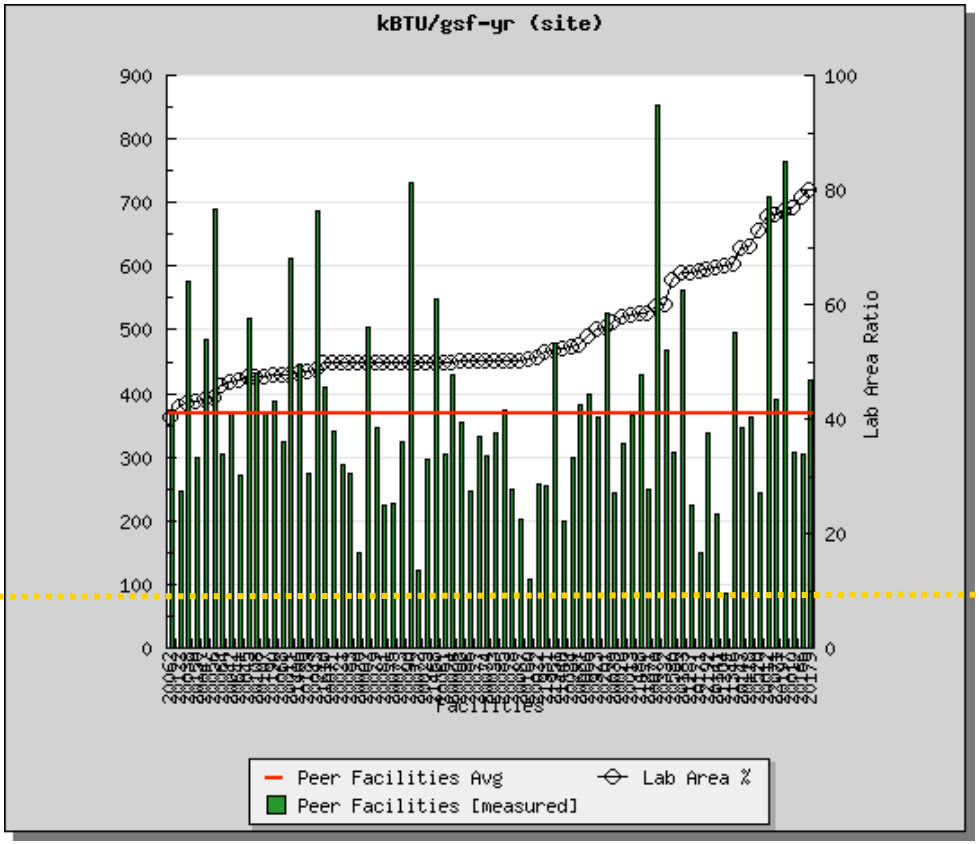
# Labs are Energy Intensive

- 3-8 times as energy intensive as office buildings
- 30-50% improvement over standard practice
- Triple bottom line
  - Reduce life cycle costs
  - Improve workplace quality and safety
  - Reduce environmental impact

NREL PIX18839

# Lab Energy Intensity

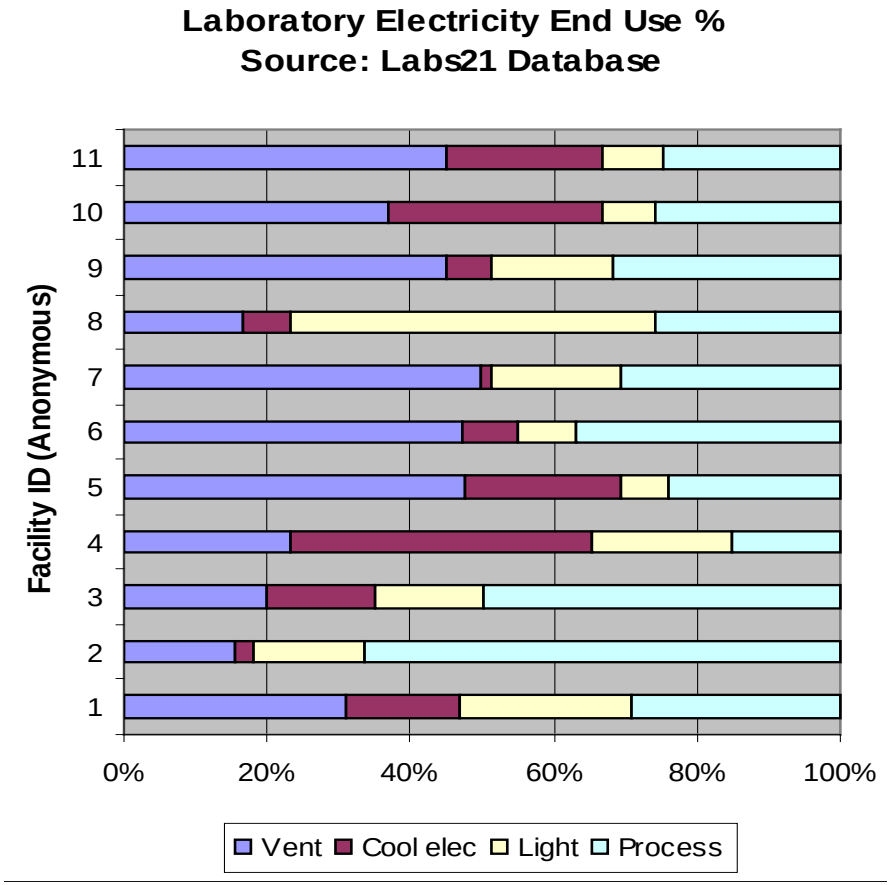
**Total Site Energy Use Intensity BTU/sf-yr for various laboratories in the Labs21 Benchmarking Database**




***Typical Office Building***

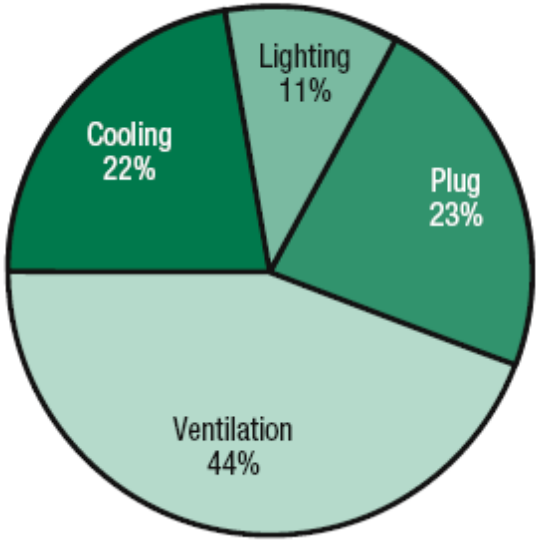
# Lab Energy Use Dominated by HVAC

- Ventilation is the largest component of energy consumption
- In some labs, a 10-20% improvement in ventilation is equivalent to total lighting energy use



# Five Biggest Opportunities

1. **Scrutinize the air changes:** Optimize ventilation rates
2. **Tame the hoods:** compare options
3. **Drop the pressure drop:** use lower pressure-drop HVAC designs
4. **Get real with plug loads:** right-size HVAC systems
5. **Just say no to re-heat:** Minimize simultaneous heating and cooling




*Annual electricity use in Louis Stokes Laboratory, National Institutes of Health, Bethesda, MD*

# #1 Scrutinize the Air Changes

*Air change rates have large peak and total cost impact*

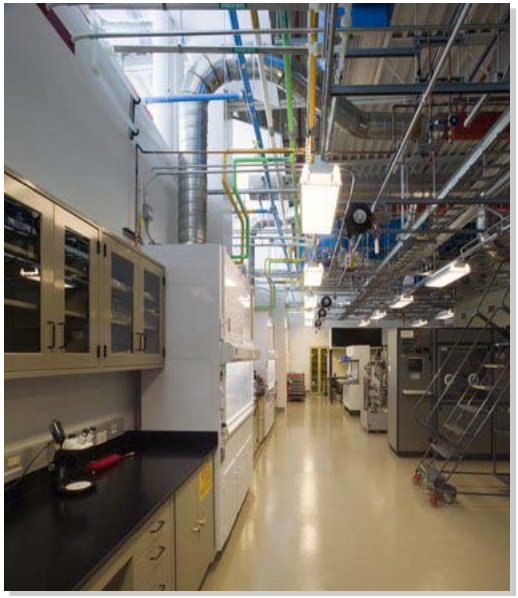
- Don't assume air changes are driven by thermal loads
- What do you use as minimum air change rate (ACR)?
  - Why? Why? Why?
- When is ten or more air changes safe and six air changes (or less) not?

# #1 Scrutinize the Air Changes: Options

- cfm/sqft rather than ACR
- Panic switch concept
- Cascading air from clean to dirty
- Setback ACR when lab is unoccupied
- Demand controlled ventilation
  (based on monitoring of hazards and odors)
- Control Banding (one rate doesn't fit all)
- Modeling and simulation for optimization

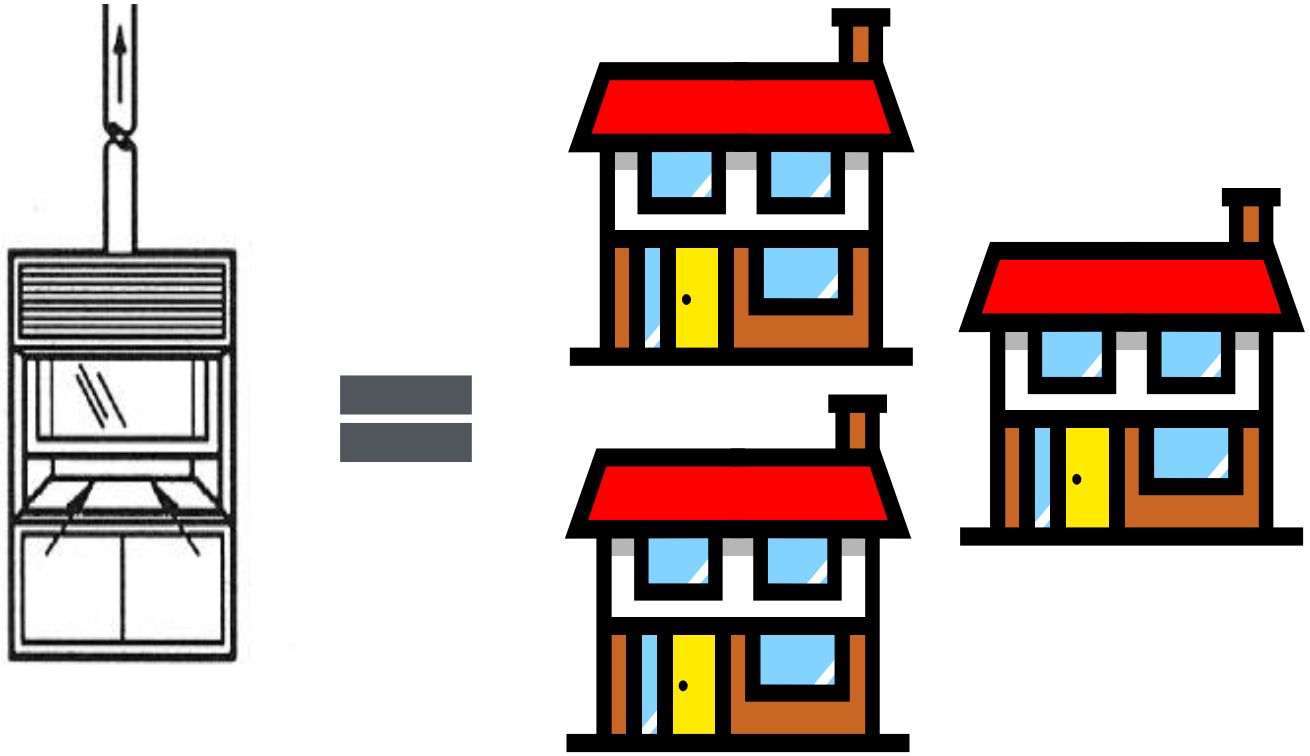
# #1 Scrutinize the Air Changes

- Ventilation effectiveness is more dependent on lab and HVAC design than air change rates (ACR)
- High ACR can have a negative impact on containment devices



NREL PIX 14973

# #2 Tame the Hoods: Fume Hood Energy Consumption

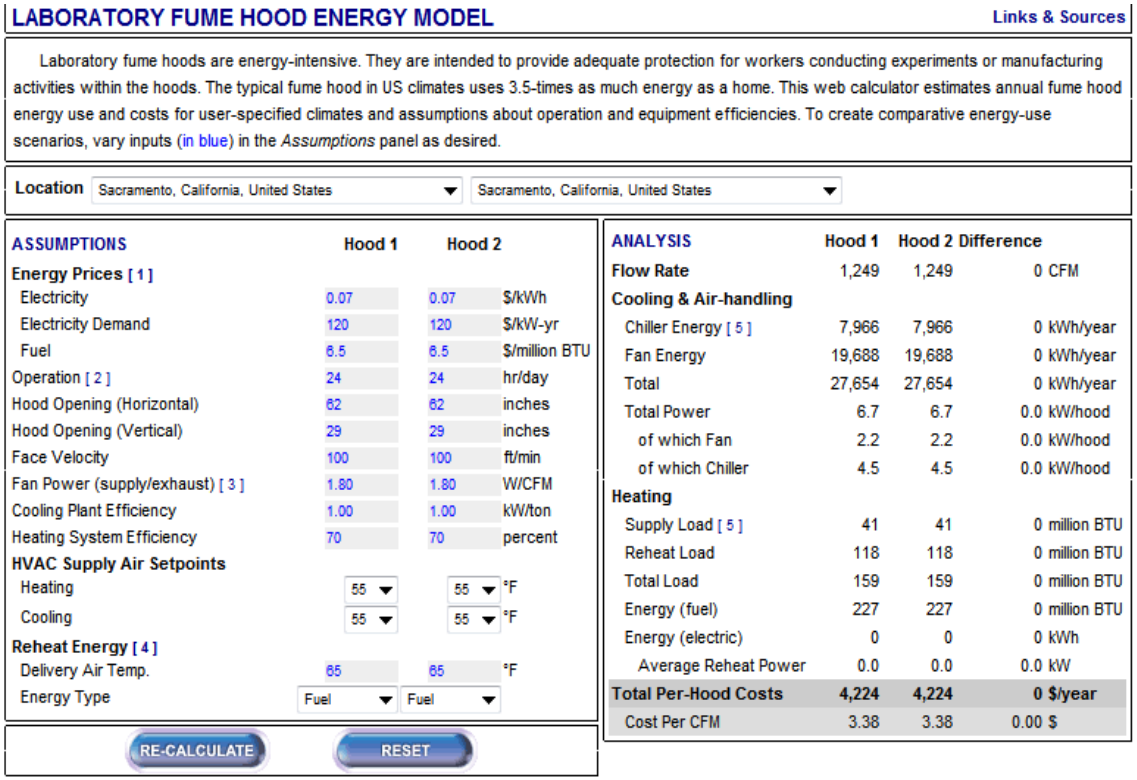


# #2 Tame the Hoods

1. Reduce the number and size of hoods
2. Restrict the sash opening
3. Use occupied and un-occupied setpoints
4. Use variable air volume (VAV)
5. Use auto sash closures
6. Consider high performance hoods

NREL PIX 15436

# Fume Hood Savings Calculator



**LABORATORY FUME HOOD ENERGY MODEL** — Links & Sources

Laboratory fume hoods are energy-intensive. They are intended to provide adequate protection for workers conducting experiments or manufacturing activities within the hoods. The typical fume hood in US climates uses 3.5-times as much energy as a home. This web calculator estimates annual fume hood energy use and costs for user-specified climates and assumptions about operation and equipment efficiencies. To create comparative energy-use scenarios, vary inputs (in blue) in the *Assumptions* panel as desired.

Location: Sacramento, California, United States | Sacramento, California, United States

| ASSUMPTIONS | Hood 1 | Hood 2 | |
|---|---|---|---|
| **Energy Prices [1]** | | | |
| Electricity | 0.07 | 0.07 | $/kWh |
| Electricity Demand | 120 | 120 | $/kW-yr |
| Fuel | 6.5 | 6.5 | $/million BTU |
| Operation [2] | 24 | 24 | hr/day |
| Hood Opening (Horizontal) | 62 | 62 | inches |
| Hood Opening (Vertical) | 29 | 29 | inches |
| Face Velocity | 100 | 100 | ft/min |
| Fan Power (supply/exhaust) [3] | 1.80 | 1.80 | W/CFM |
| Cooling Plant Efficiency | 1.00 | 1.00 | kW/ton |
| Heating System Efficiency | 70 | 70 | percent |
| **HVAC Supply Air Setpoints** | | | |
| Heating | 55 | 55 | °F |
| Cooling | 55 | 55 | °F |
| **Reheat Energy [4]** | | | |
| Delivery Air Temp. | 65 | 65 | °F |
| Energy Type | Fuel | Fuel | |

RE-CALCULATE | RESET

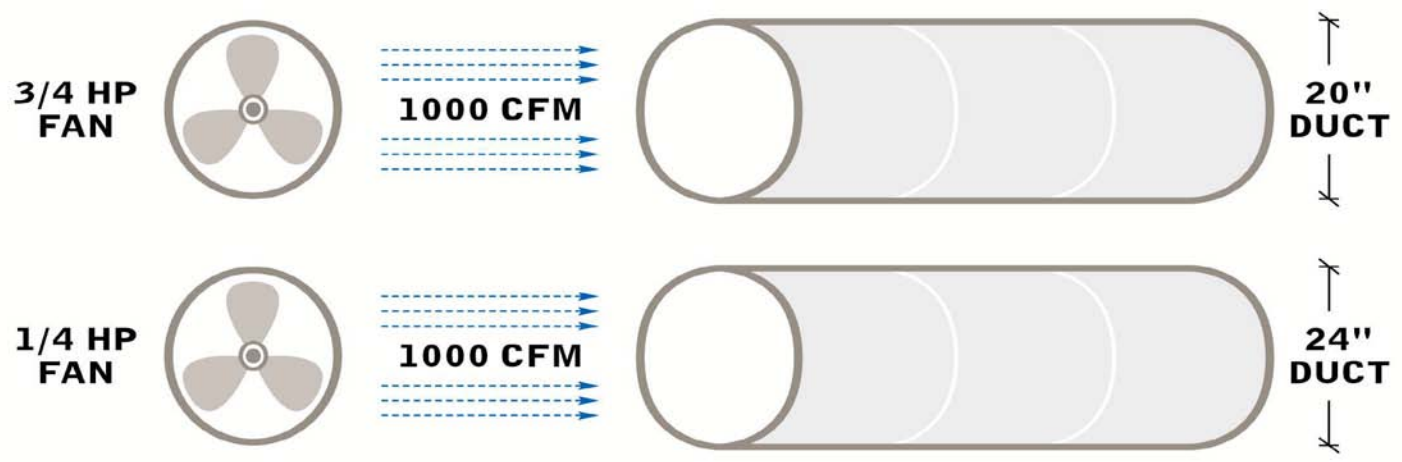
| ANALYSIS | Hood 1 | Hood 2 | Difference |
|---|---|---|---|
| **Flow Rate** | 1,249 | 1,249 | 0 CFM |
| **Cooling & Air-handling** | | | |
| Chiller Energy [5] | 7,966 | 7,966 | 0 kWh/year |
| Fan Energy | 19,688 | 19,688 | 0 kWh/year |
| Total | 27,654 | 27,654 | 0 kWh/year |
| Total Power | 6.7 | 6.7 | 0.0 kW/hood |
| of which Fan | 2.2 | 2.2 | 0.0 kW/hood |
| of which Chiller | 4.5 | 4.5 | 0.0 kW/hood |
| **Heating** | | | |
| Supply Load [5] | 41 | 41 | 0 million BTU |
| Reheat Load | 118 | 118 | 0 million BTU |
| Total Load | 159 | 159 | 0 million BTU |
| Energy (fuel) | 227 | 227 | 0 million BTU |
| Energy (electric) | 0 | 0 | 0 kWh |
| Average Reheat Power | 0.0 | 0.0 | 0.0 kW |
| **Total Per-Hood Costs** | **4,224** | **4,224** | **0 $/year** |
| Cost Per CFM | 3.38 | 3.38 | 0.00 $ |

***Calculator web site:***

**http://fumehoodcalculator.lbl.gov/**

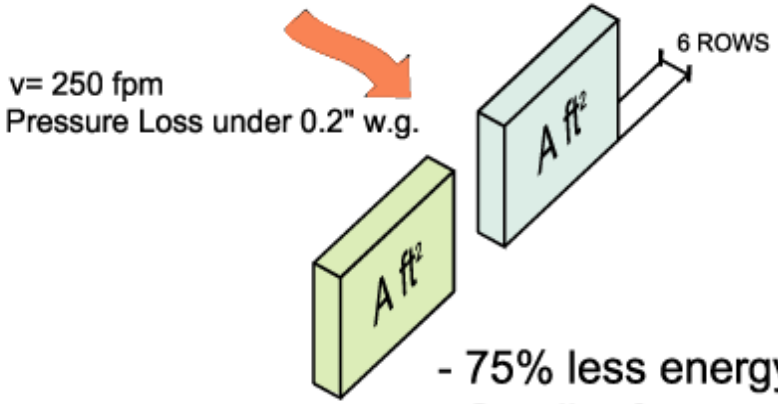
# #3 Drop the Pressure Drop

- Up to one half HVAC energy goes to fans
- How low can you go?



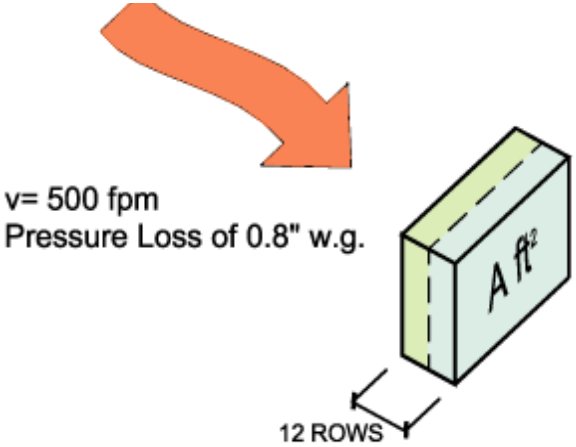
# #3 Low Pressure Drop Design

## Efficient Design

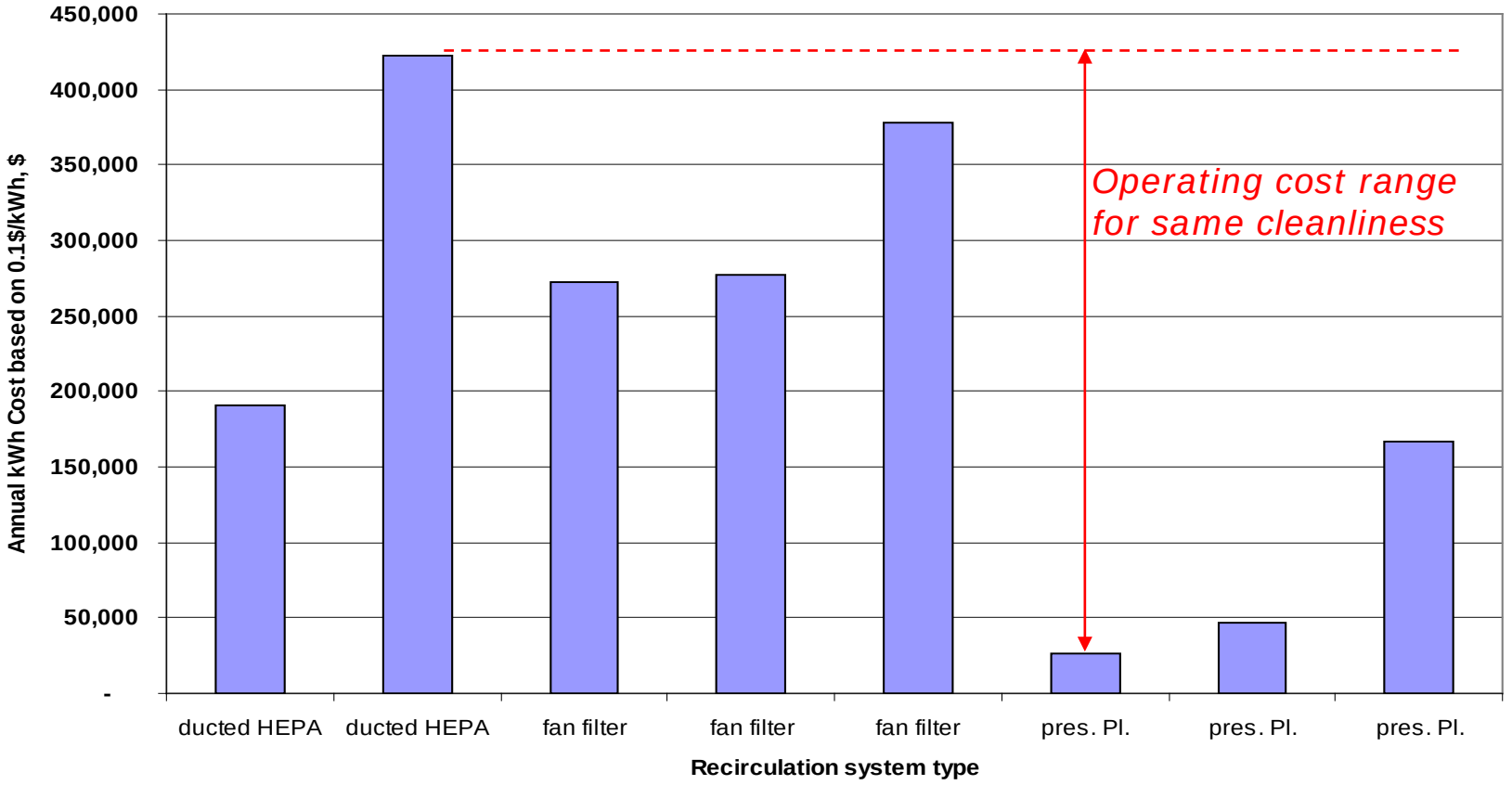



- 75% less energy
- Smaller fans
- Longer filter life
- Quieter

## Standard Design

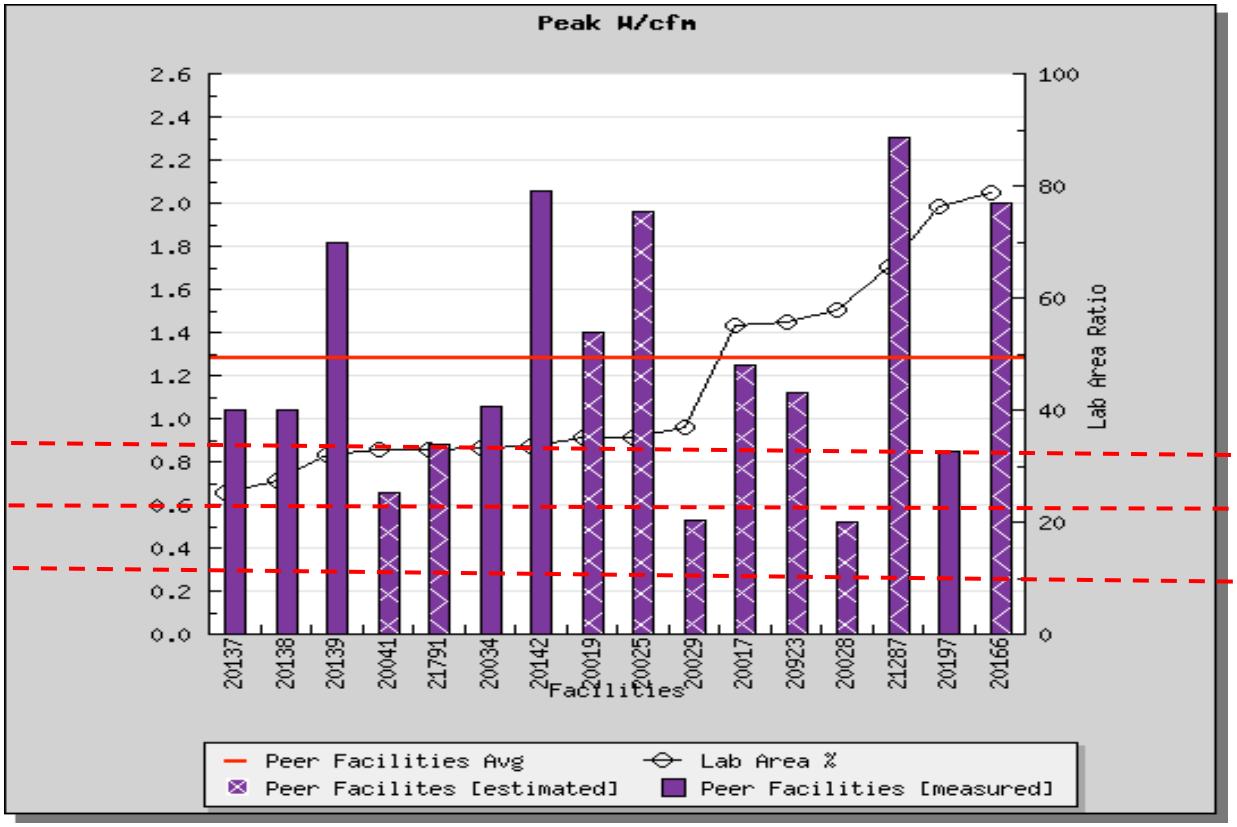


# Annual Energy Costs – Recirculation Fans (Class 5, 20,000 sqft)



| Component | Standard | Good | Better |
|---|---|---|---|
| Air handler face velocity | 500 | 400 | 300 |
| Air Handler | 2.5 in. w.g. | 1.5 in. w.g. | 0.75 in.w.g. |
| Heat Recovery Device | 1.00 in. w.g. | 0.60 in. w.g. | 0.35 in. w.g. |
| VAV Control Devices | Constant Volume, N/A | Flow Measurement Devices, 0.60 - 0.30 in. w.g. | Pressure Differential Measurement and Control, 0.10 in. w.g |
| Zone Temperature Control Coils | 0.5 in. w.g. | 0.30 in. w.g. | 0.05 in. w.g. |
| Total Supply and Return Ductwork | 4.0 in. w.g. | 2.25 in. w.g. | 1.2 in. w.g. |
| Noise Control (Silencers) | 1.0” w.g. | 0.25” w.g. | 0.0” w.g. |
| **Total** | **9.7” w.g.** | **6.2” w.g.** | **3.2” w.g.** |
| **Approximate W / CFM** | **1.8** | **1.2** | **0.6** |

# Labs 21 Benchmarking Tool – Vent W/cfm




*standard*

*good*

*better*

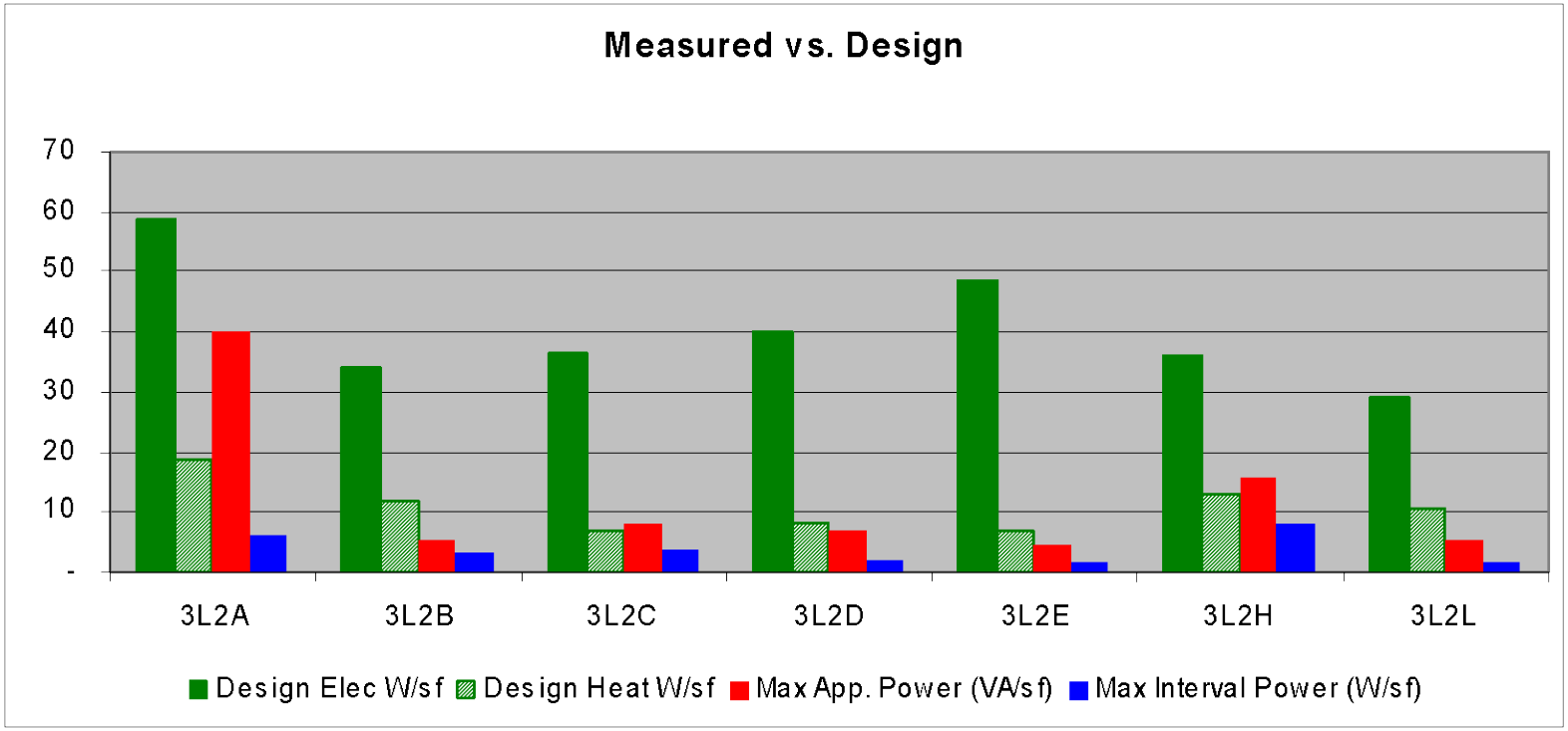
**Standard, good, better benchmarks as defined in "How-low Can You go: Low-Pressure Drop Laboratory Design" by Dale Sartor and John Weale**

# #4 Get Real with Plug Loads

- Save capital cost and operating cost
- Measure actual loads in similar labs
- Design for high part- load efficiency
  - Modular design approaches
- Plug load diversity in labs increases reheat

# Measured vs. Design – UC Davis Case Study

Significant over-sizing not unusual



# Measured Plug Loads in Labs

## Sandia PETL Lab

- Designed for 6 W/nsf
- Metered data: 1.8 W/nsf (avg.), 2.7 W/nsf (peak)

## Fred Hutch Cancer Research Center

- Phase 1 designed for 15-30 W/nsf
- Phase 2 reduced design to 8 W/nsf based on Phase 1 experience

## Pharmacia

- Designed for 12 W/nsf
- Metered data: 2.7 W/nsf

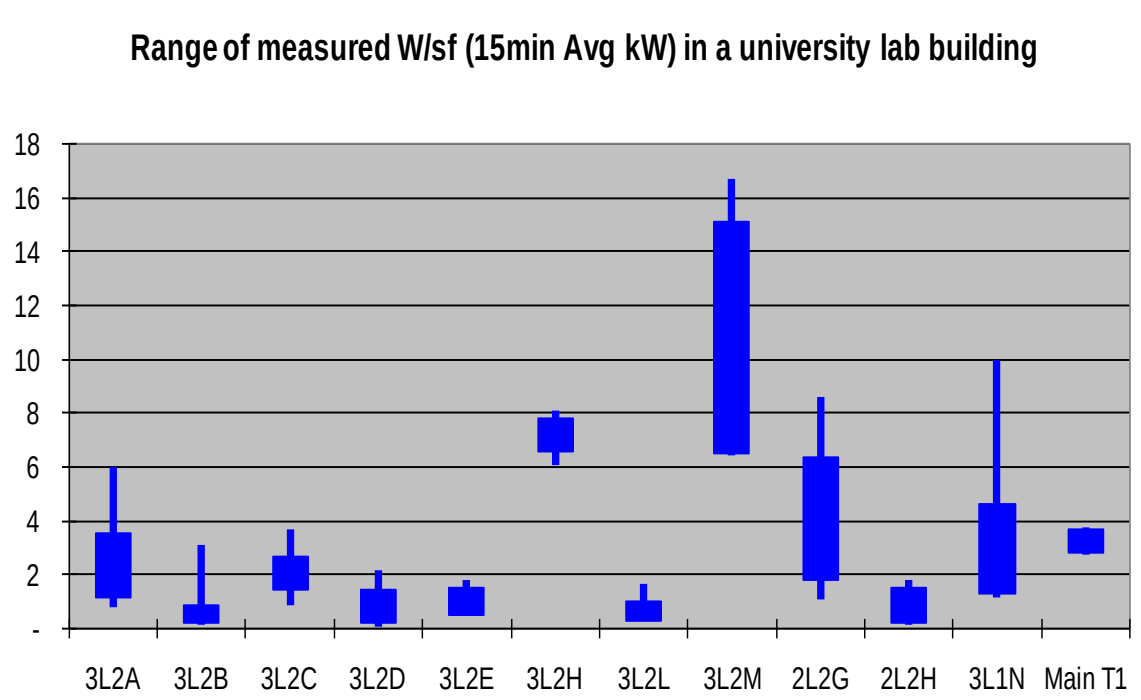
# Benefits of Right-sizing at LBNL-MFL

- $2.5 million first cost savings for right-sizing HVAC systems
  - Based on measured data from comparable labs
- LEED Gold
  - Rightsizing savings allowed additional green features with 4% cost savings over baseline

*The Molecular Foundry*
*Lawrence Berkeley National Laboratory*

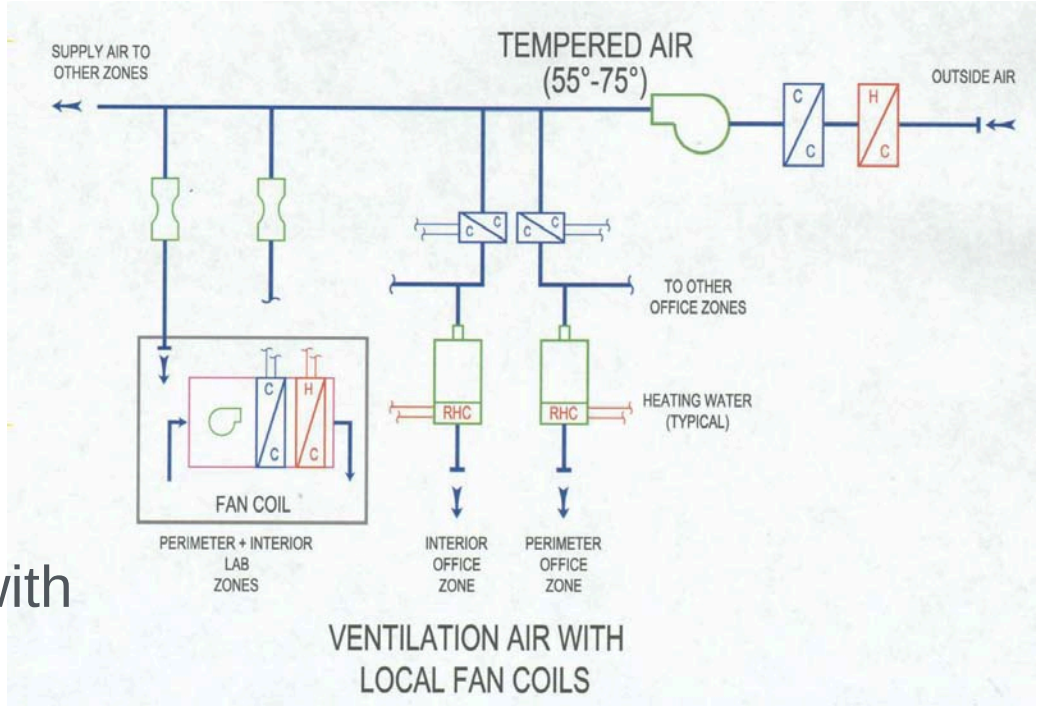
# #5 Just Say No To Reheat (Simultaneous Heating and Cooling)

High-load areas require lower supply air temperature, so reheat occurs in other spaces



# System Alternatives to Minimize Reheat

- Dual-duct systems
- Ventilation air with:
  - Zone control
  - Fan coils
  - Radiant cooling
  - Inductive cooling coils (Cool Beams)
- Possible free cooling with water side economizer



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

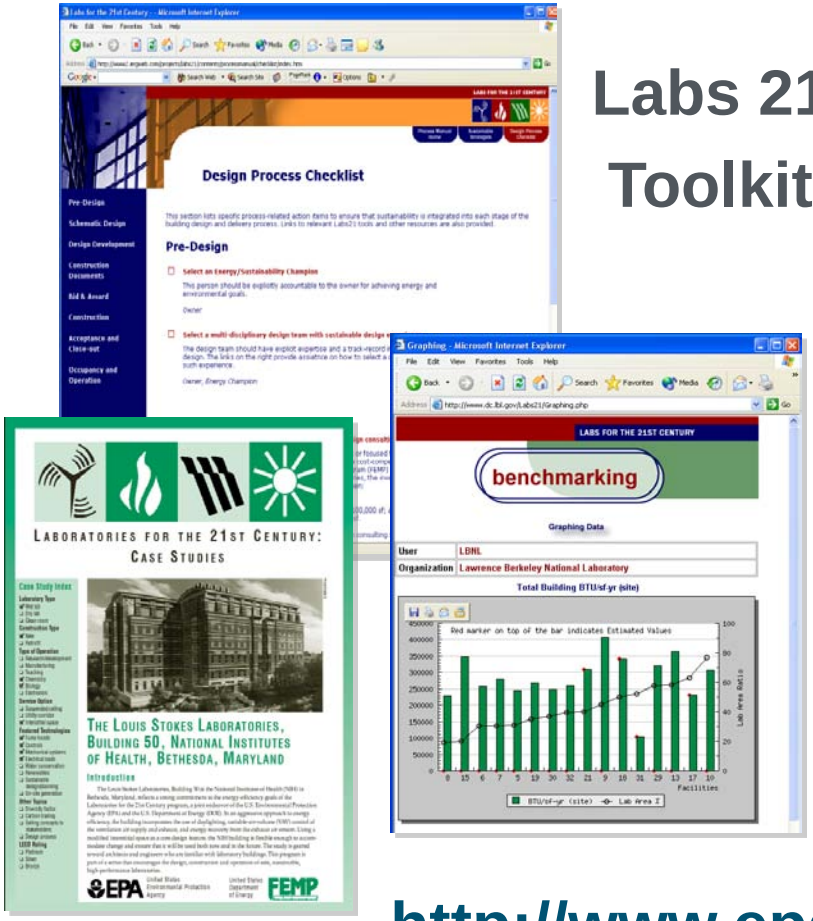
# Resources for Energy Efficiency in Labs

*Oak Ridge National Laboratory, TN*


Founded by the DOE Federal Energy Management Program and EPA Facilities Management and Services Division to improve the environmental performance of U.S. laboratories

- Optimize whole building efficiency on a life-cycle basis
- Assure occupant safety
- Minimize overall environmental impacts

**http://www.labs21century.gov**



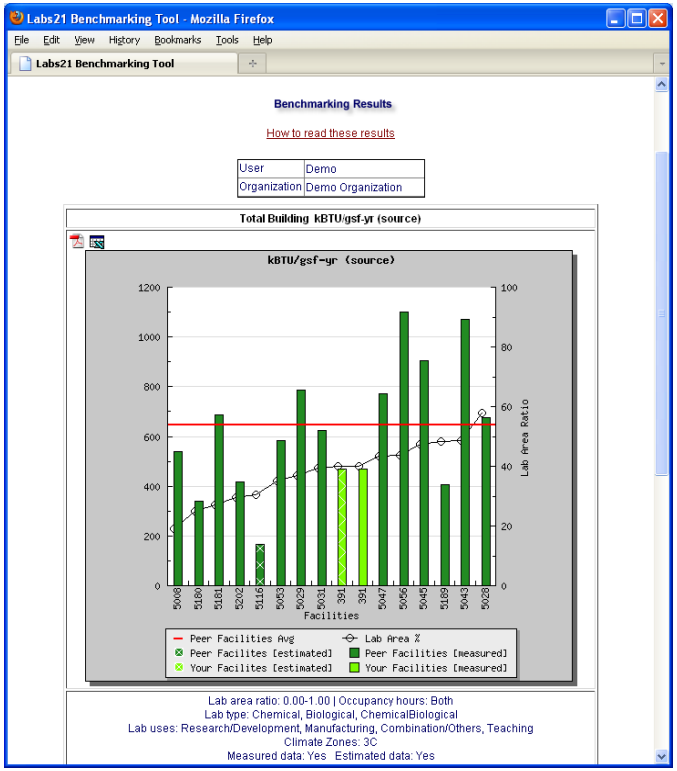

# Labs 21 Toolkit

- **Core information resources**
  - Design Guide
  - Case Studies
  - Energy Benchmarking
  - Lab Energy Efficiency Profiler
  - Lab Equipment Efficiency wiki
  - Best Practice Guides
  - Climate Neutral Campuses
- **Design process tools**
  - Environmental Performance Criteria
  - Design Intent Tool
  - Labs21 Process Manual

**http://www.epa.gov/lab21gov/toolkit/**


## LEEP

## http://leep.lbl.gov/




# Labs21 Benchmarking

## http://labs21benchmarking.lbl.gov/

# Contacts and Questions


## Will Lintner

Federal Energy Management Program
202.586.3120
william.lintner@ee.doe.gov

## Dale Sartor

Lawrence Berkeley National Laboratory
510.486.5988
dasartor@lbl.gov

## Paul Mathew

Lawrence Berkeley National Laboratory
510.486.5116
PAMathew@lbl.gov