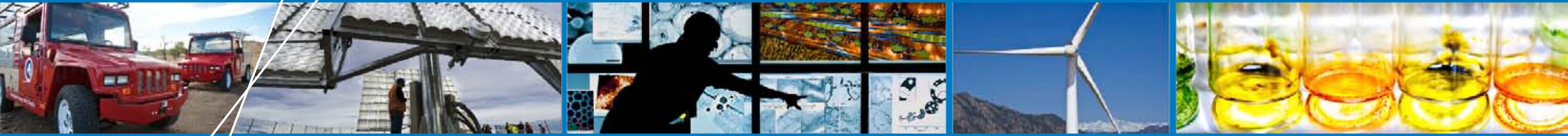
Top ECMs for Labs and Data Centers



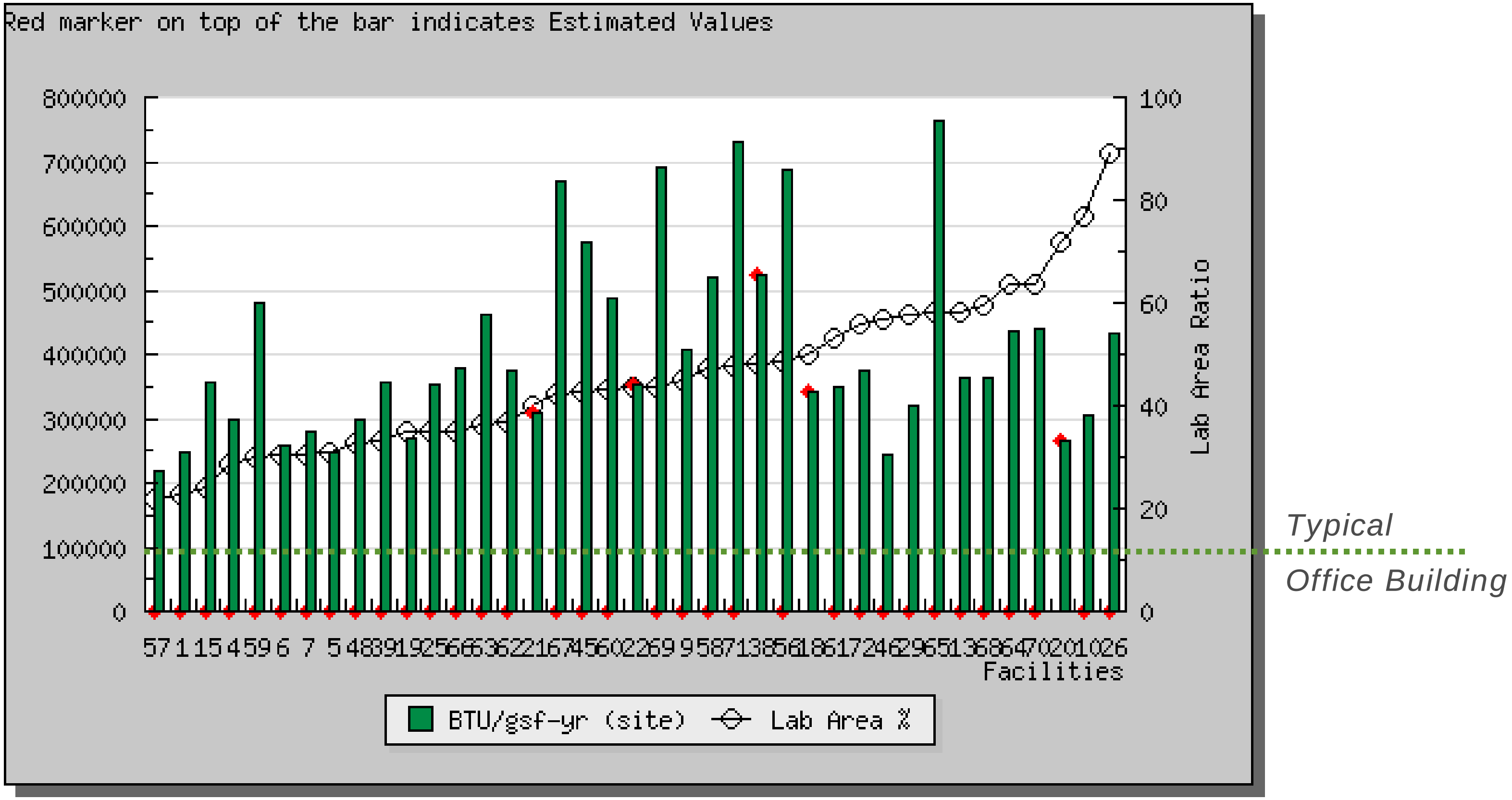
FUPWG

Otto Van Geet, PE

October 10, 2012

Labs are Energy Hogs!

- **3 to 8 times as energy intensive as office buildings**



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

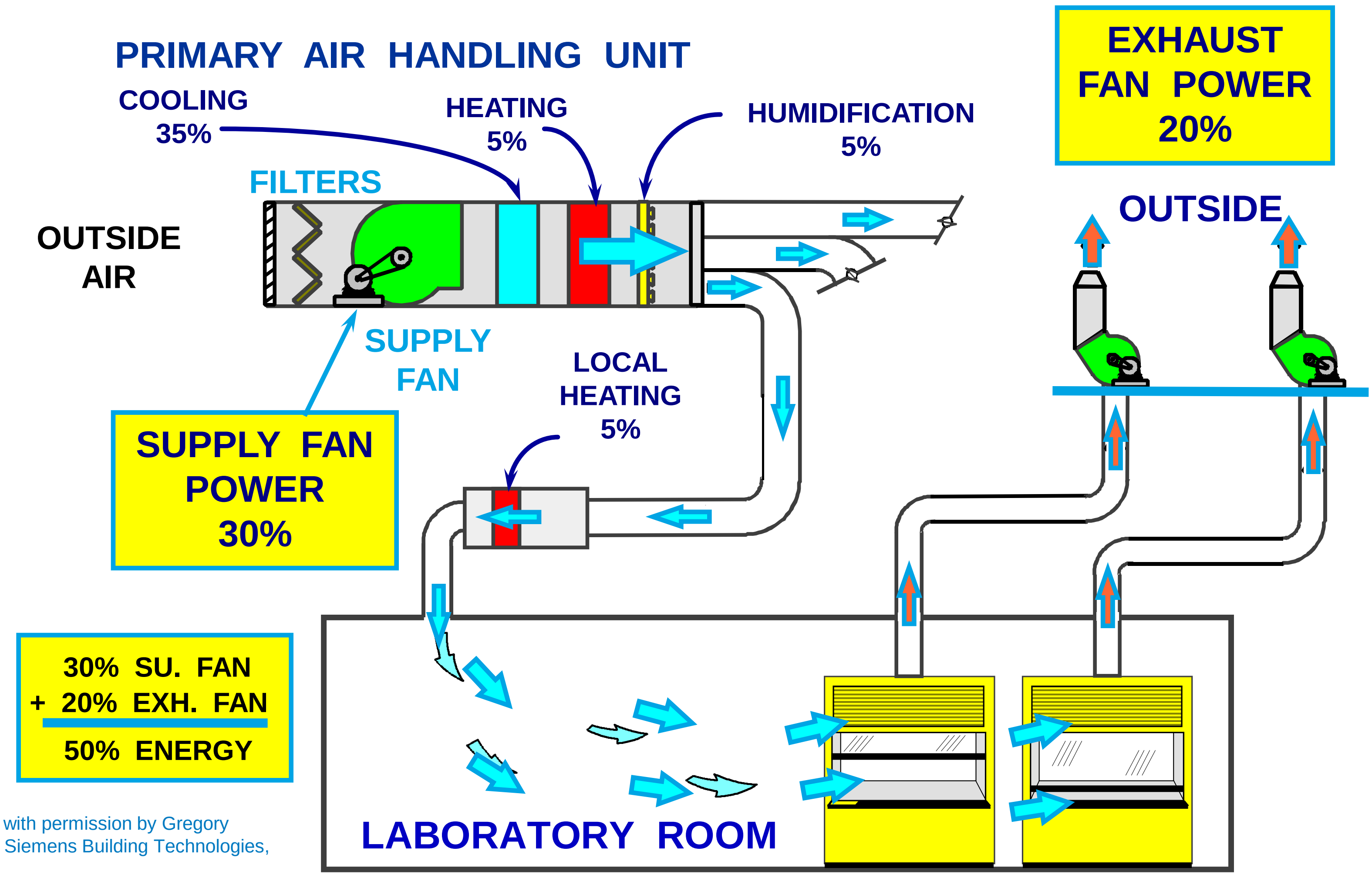
Labs21 Toolkit

- ***Core information resources***
  - Design Guide
  - Case Studies
  - Energy Benchmarking
  - Best Practice Guides
  - Technical Bulletins
- ***Design process tools***
  - Env. Performance Criteria
  - Labs21 Process Manual

Six BIG HITS

1. Scrutinize the air changes:
   Optimize ventilation rates
2. Tame the hoods:
   Compare exhaust device options
3. Get real with loads:
   Right-size HVAC systems
4. Just say no to re-heat:
   Minimize simultaneous heating and cooling
5. Drop the pressure drop:
   Use lower pressure-drop HVAC designs
6. Use energy recovery in most climates

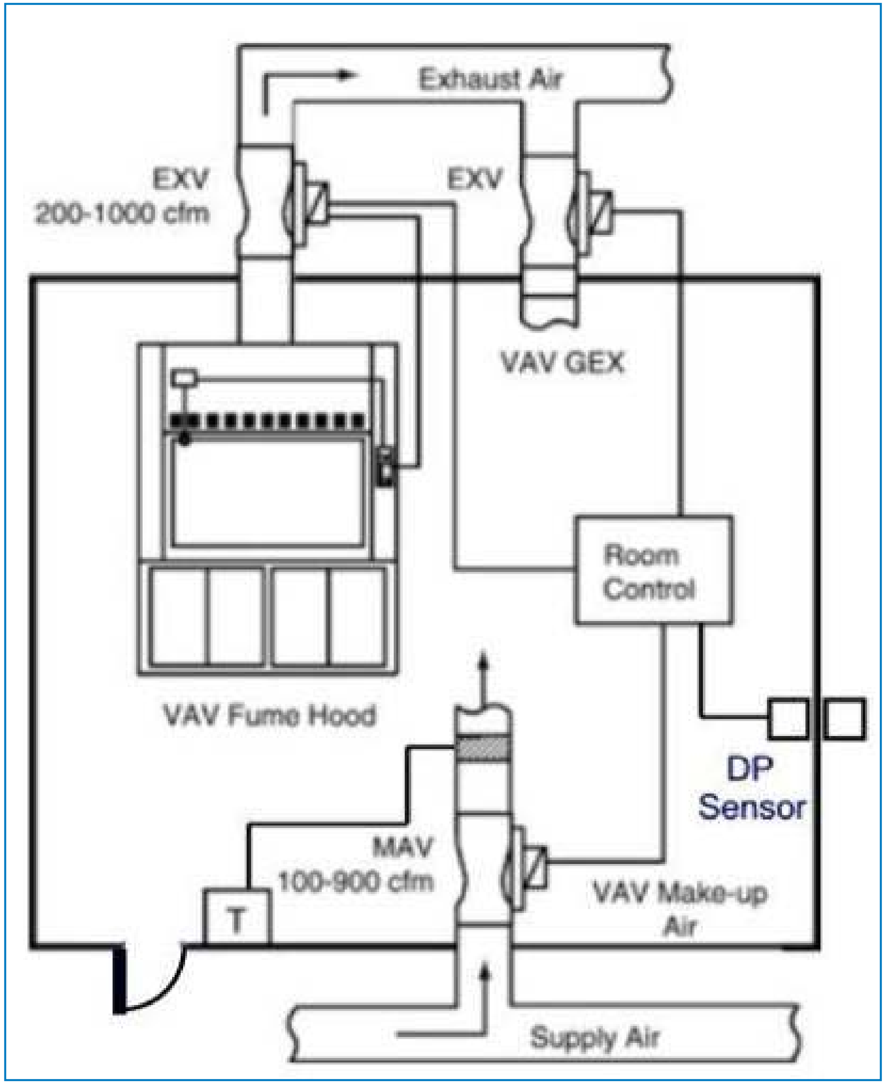
Basic Lab HVAC System



Adapted with permission by Gregory DeLuga, Siemens Building Technologies, Inc.

Basic VAV System Diagram

- Sash position monitored by control system.
- Control system modulates damper in fume hood exhaust duct.
- Feedback maintains precise air flow for sash position.
- Supply make-up air modulates to maintain negative room pressure differential.
- Coordinates both supply & exhaust offset and lab differential pressure.
- Temperature control provided by modulating supply air temperature with coil.



#1 Scrutinize the Air Changes

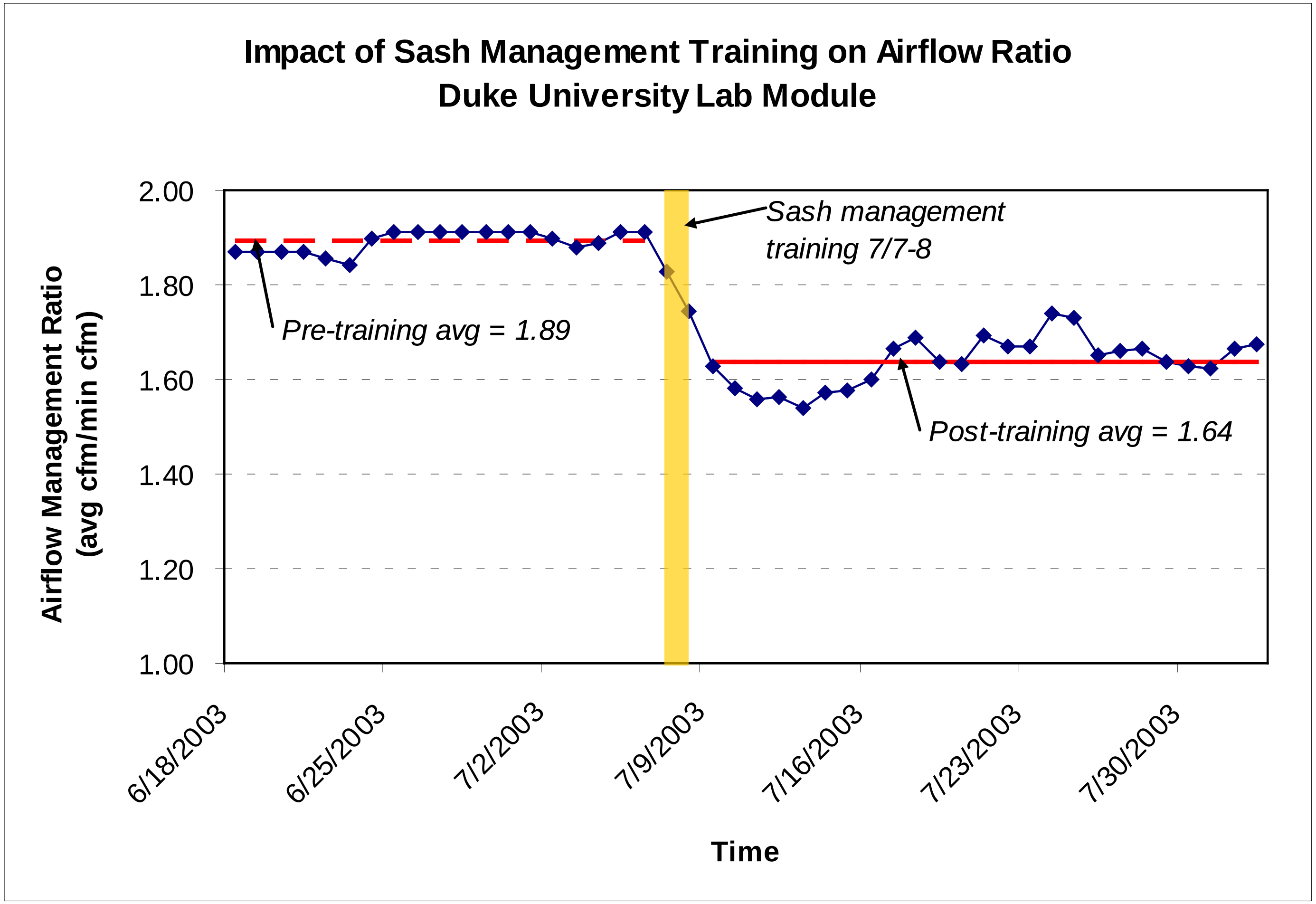
- **Most Labs are over ventilated**
- **Options to consider**
  - cfm/sqft rather than ACR
  - Panic switch concept
  - Cascading air from clean to dirty
  - Setback ACR when lab is unoccupied
  - Demand controlled ventilation (based on monitoring of hazards and odors)
  - Control Banding (one rate doesn't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

- **Ventilation effectiveness is more dependent on lab and HVAC design than air change rates (ACR)**

#2 Tame the Hoods

1. Reduce the number and size of hoods
2. Restrict the sash opening
3. Use Two “speeds” occupied and un-occupied
4. Use variable air volume (VAV)
5. Consider high performance hoods
6. Say no to Auxiliary Air hoods and canopy hoods

Impact of Sash Management Training



#3 Drop the Pressure Drop

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

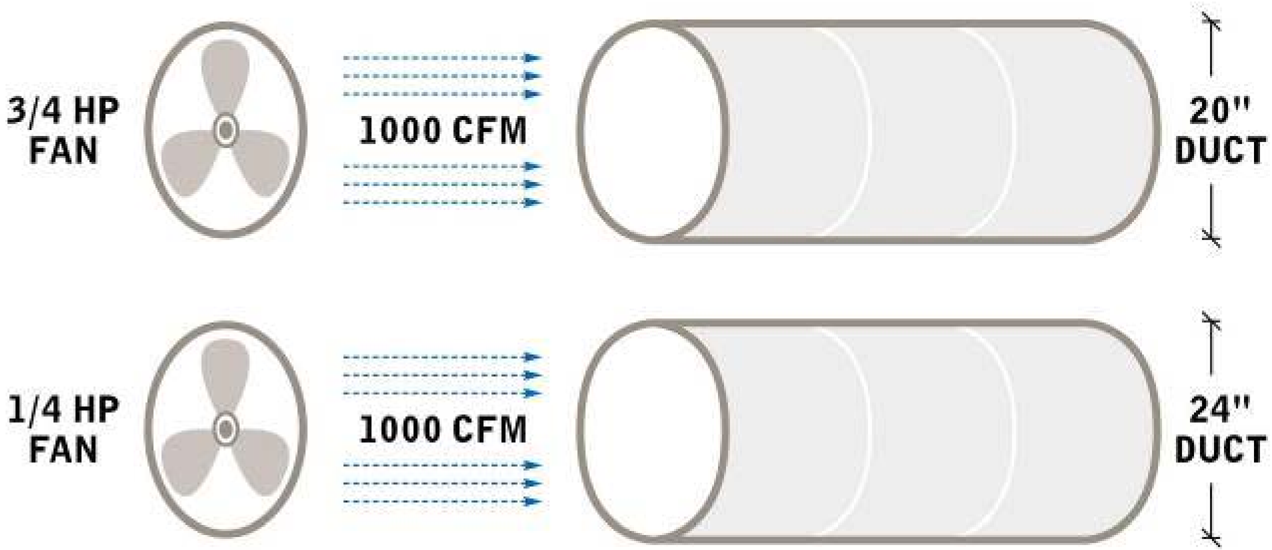


Image courtesy of Rumsey Engineers, Inc.

Low Pressure Drop Design

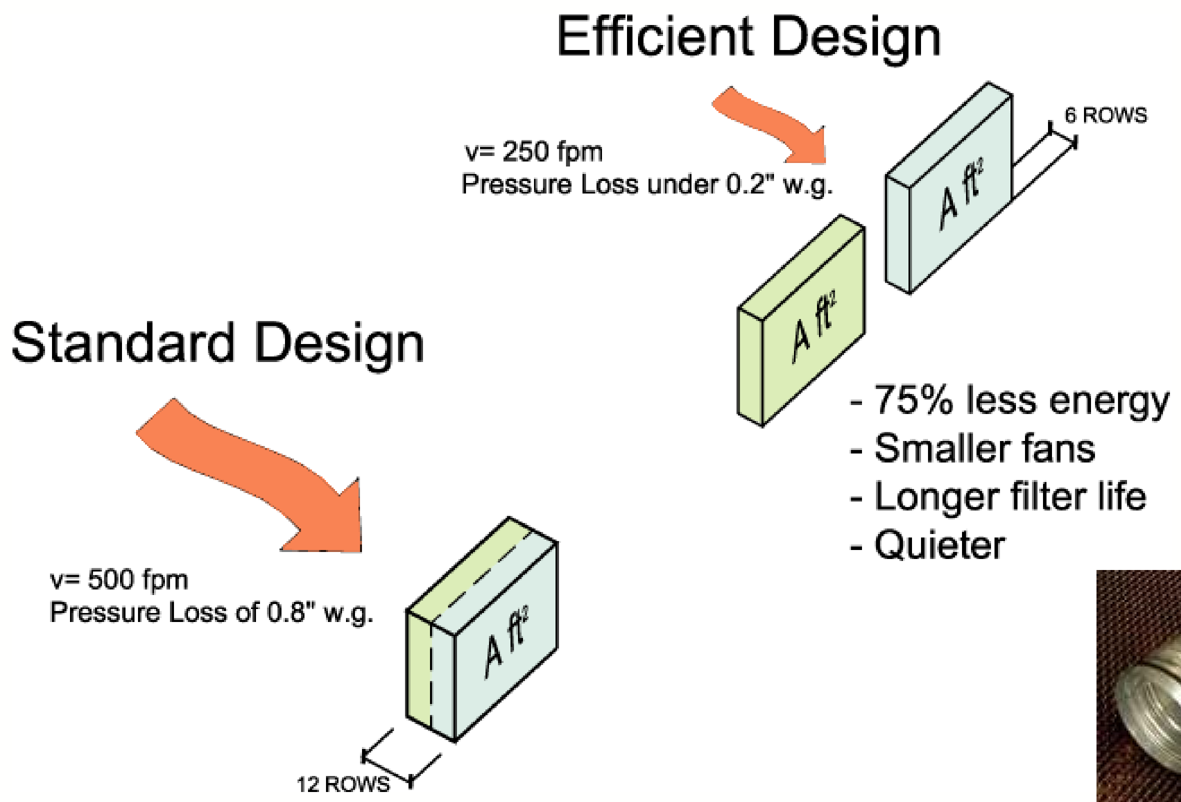


Image courtesy of Rumsey Engineers, Inc.

Low Pressure-Drop Design Guidelines

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.
Exhaust Stack	0.7” w.g. full design flow through entire exhaust system, Constant Volume	0.7” w.g. full design flow through fan and stack only, VAV System with bypass	0.75” w.g. averaging half the design flow, VAV System with multiple stacks
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

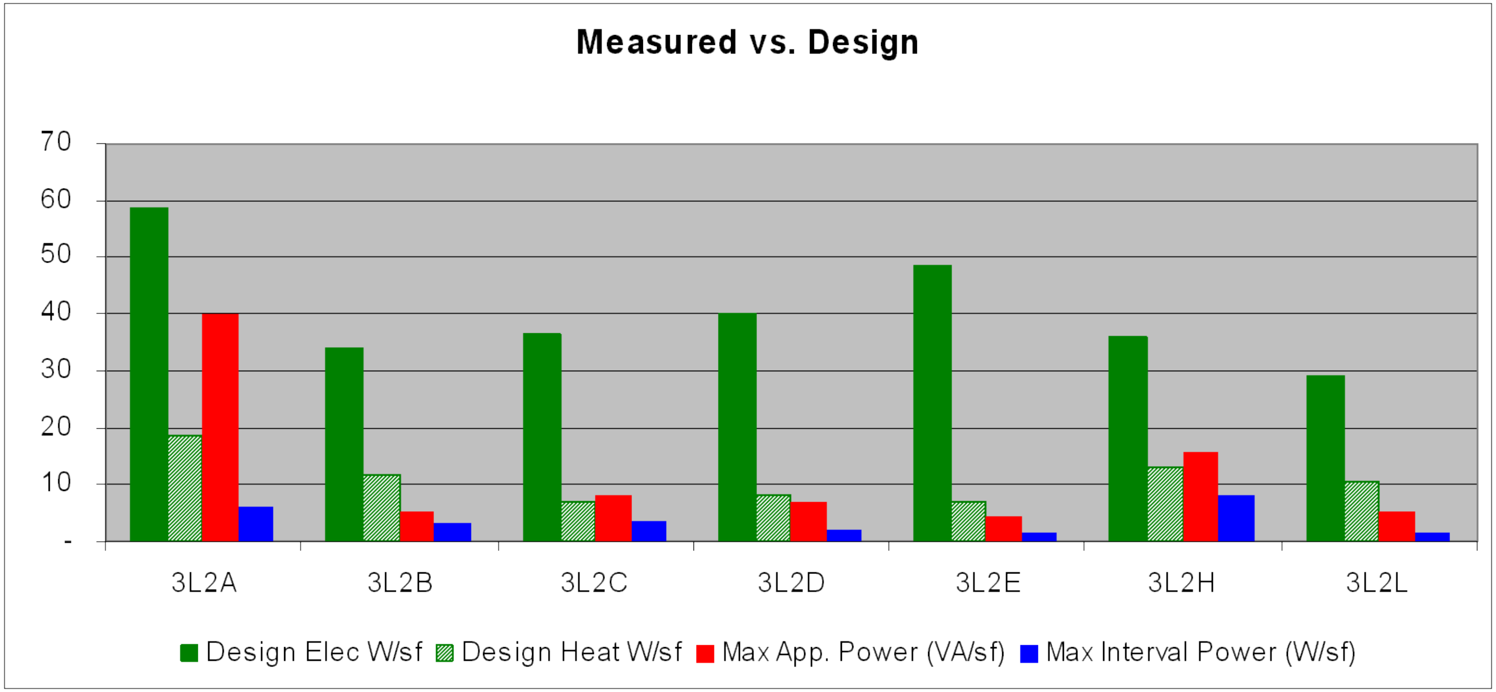
Source: J. Weale, P. Rumsey, D. Sartor, L. E. Lock, “Laboratory Low-Pressure Drop Design,” ASHRAE Journal, August 2002.

#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**

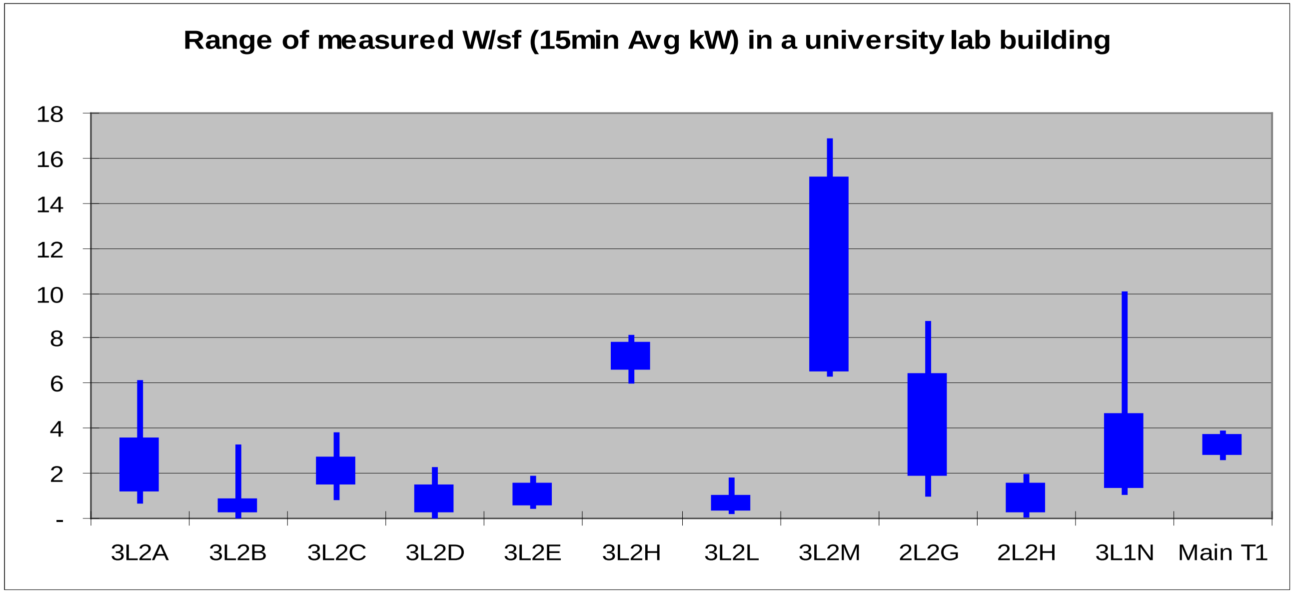
Measured vs. Design – UC Davis Case Study

- **Significant over-sizing not unusual**



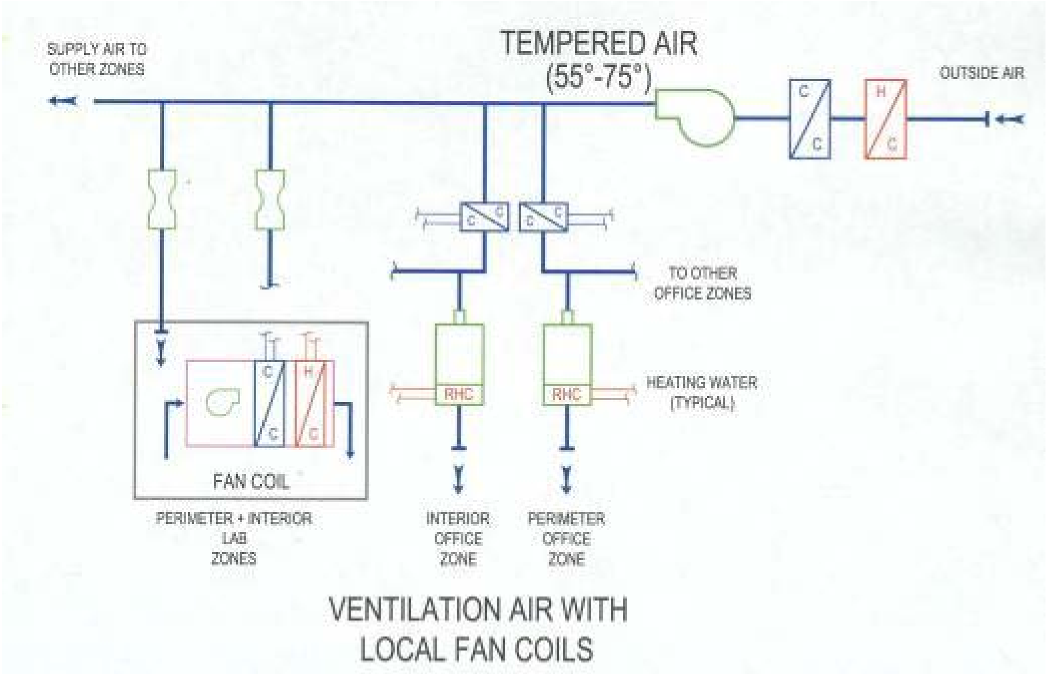
#5 Just Say No to Reheat

- **Reheat (simultaneous heating and cooling) causes major energy use in labs**
  – High-load areas require lower supply air temperature, so reheat occurs in other spaces



System Alternatives to Minimize Reheat

- Ventilation air with zone coils
- Ventilation air with fan coils
- Ventilation air with radiant cooling
- Ventilation air with inductive cooling coils (chilled beam)



Optimize Thermal Environment

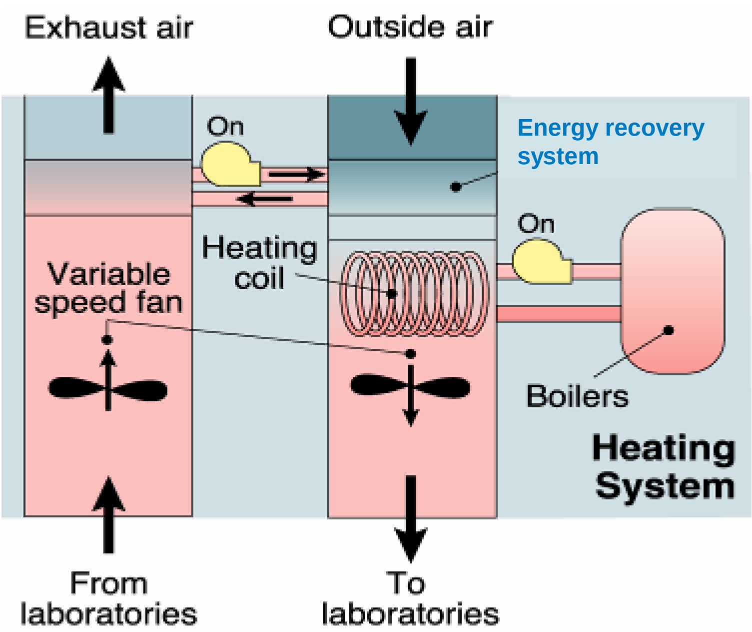
- **Global Ecology Center, Stanford University**
  - Main labs: 73 F +/- 5F
  - Highest intensity equipment (freezers, etc.)in dedicated warehouse:
    55F - 95F
  - Tight-tolerance equipment in separate room:
    70 F +/- 1F
- **Additional 17% savings over 41% CA Title 24 savings**

Source: EHDD Architecture

#6 Use energy recovery in most climates

➢Energy Recovery

- **Factors that improve energy recovery economics include:**
  - Colder climates (e.g. more than 3,000 heating degree-days)
  - High exhaust rates
  - High utility rates
- **Consider impact of increase pressure drop due to energy recovery devices in airflow.**
- **Evaporative cooling in exhaust stream can increase cooling energy-recovery without adding moisture to supply air.**

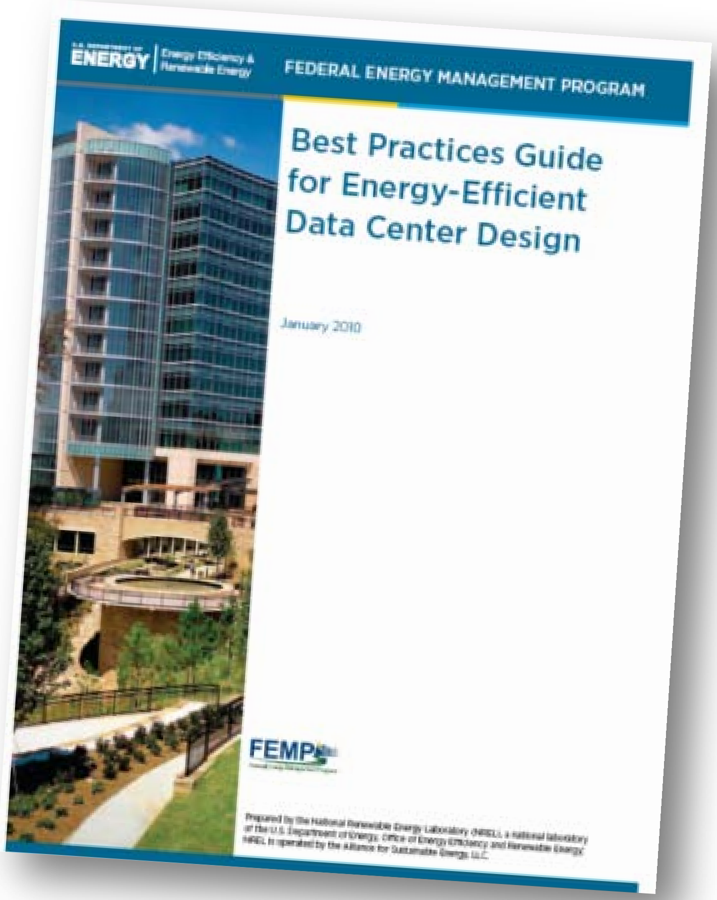


Data Center Energy

- **Data centers are energy intensive facilities**
  - Server racks now designed for more than 25+ kW
  - Surging demand for data storage
  - Typical facility ~ 1MW, can be > 20 MW
  - 1.5% of US Electricity consumption
  - Projected to double in next 5 years
- **Significant data center building boom**
  - Power and cooling constraints in existing facilities

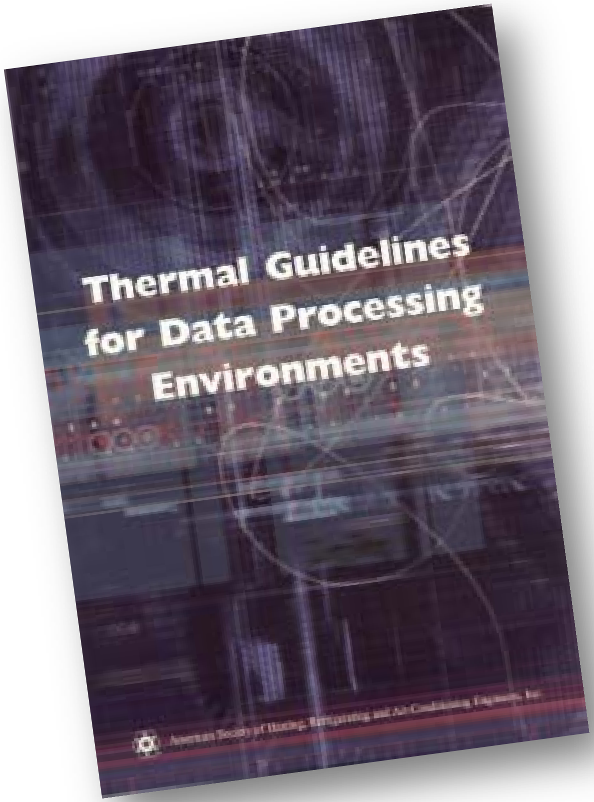
BPG Table of Contents

- Summary
- Background
- Information Technology Systems
- Environmental Conditions
- Air Management
- Cooling Systems
- Electrical Systems
- Other Opportunities for Energy Efficient Design
- Data Center Metrics & Benchmarking



Environmental Conditions

- Data Center equipment's environmental conditions should fall within the ranges established by ASHRAE as published in the Thermal Guidelines book.



Environmental Specifications (°F)

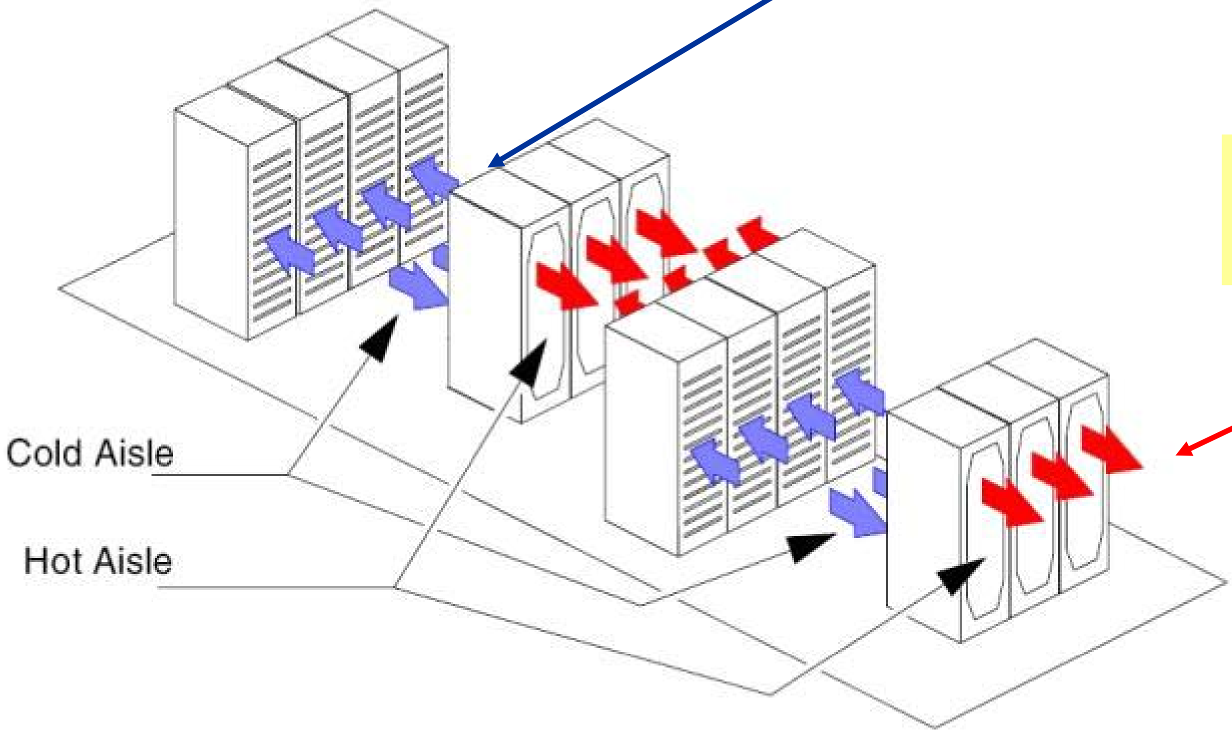
(@ Equipment Intake)	Recommended	Allowable
Temperature Data Centers ASHRAE	65° – 80°F	59° – 90°F (A1) 41° – 113°F (A4)
Humidity (RH) Data Centers ASHRAE	42°F DP – 60% or 59°F DP	20% – 80% & 63°F DP

ASHRAE Reference: ASHRAE (2008), (2011)

Equipment Environmental Specification

<u>Air Inlet</u> to IT Equipment **is** the important specification to meet

Outlet temperature is *not* important to IT Equipment

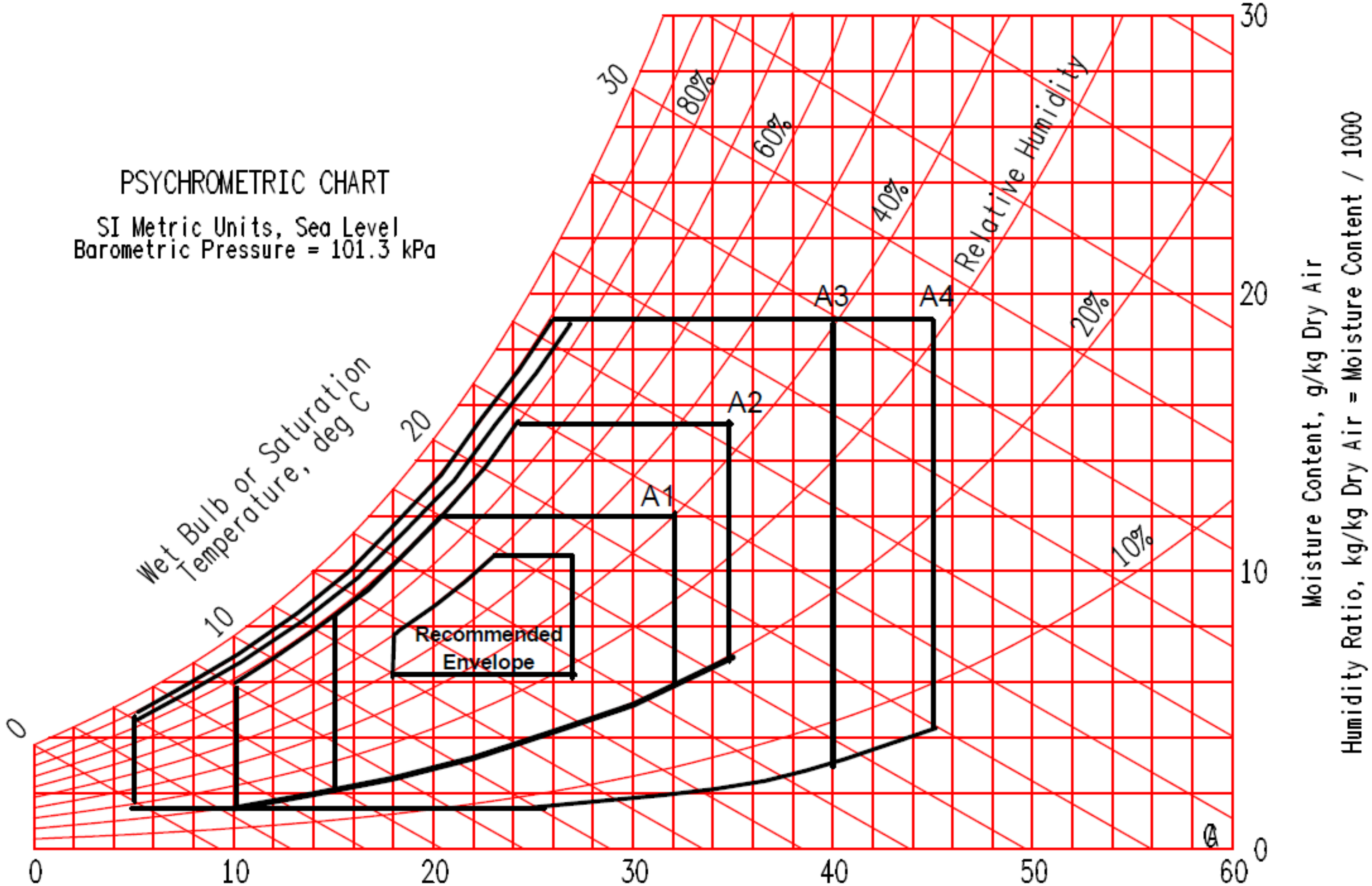


2011 ASHRAE Thermal Guidelines

Classes (a)	Equipment Environmental Specifications							
	Product Operations (b)(c)					Product Power Off (c) (d)		
	Dry-Bulb Temperature (˚F) (e) (g)	Humidity Range, non-Condensing (h) (i)	Maximum Dew Point (˚F)	Maximum Elevation (f)	Maximum Rate of Change(˚F/hr) (f)	Dry-Bulb Temperature (˚F)	Relative Humidity (%)	Maximum Dew Point (˚F)
Recommended (Applies to all A classes; individual data centers can choose to expand this range based upon the analysis described in this document)								
A1 to A4	64.4 to 80.6	41.9°F DP to 60% RH and 59°F DP						
Allowable								
A1	59 to 89.6	20 to 80% RH	62.6	10,000	9/36	41 to 113	8 to 80	80.6
A2	50 to 95	20 to 80% RH	69.8	10,000	9/36	41 to 113	8 to 80	80.6
A3	41 to 104	10.4˚F DP & 8% RH to 85% RH	75.2	10,000	9/36	41 to 113	8 to 85	80.6
A4	41 to 113	10.4˚F DP & 8% RH to 90% RH	75.2	10,000	9/36	41 to 113	8 to 90	80.6
B	41 to 95	8% RH to 80% RH	82.4	10,000	NA	41 to 113	8 to 80	84.2
C	41 to 104	8% RH to 80% RH	82.4	10,000	NA	41 to 113	8 to 80	84.2

2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance. White paper prepared by ASHRAE Technical Committee TC 9.9

2011 ASHRAE allowable ranges



Dry Bulb Temperature

Estimated Savings

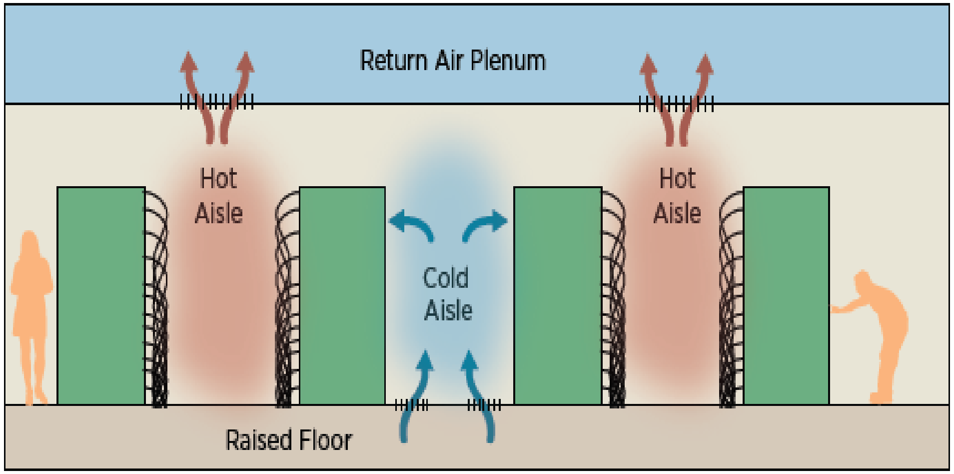
Baseline

System	DX Cooling with no economizer
Load	1 ton of cooling, constant year-round
Efficiency (COP)	3
Total Energy (kWh/yr)	10,270

	Recommended Range		Allowable Range	
Results	Hours	Energy (kWh)	Hours	Energy (kWh)
Zone1: DX Cooling Only	25	8	2	1
Zone2: Multistage Indirect Evap. + DX (H80)	26	16	4	3
Zone3: Multistage Indirect Evap. Only	3	1	0	0
Zone4: Evap. Cooler Only	867	97	510	57
Zone5: Evap. Cooler + Economizer	6055	417	1656	99
Zone6: Economizer Only	994	0	4079	0
Zone7: 100% Outside Air	790	0	2509	0
Total	***8,760***	***538***	***8,760***	***160***
Estimated % Savings	*-*	***95%***	*-*	***98%***

Improve Air Management

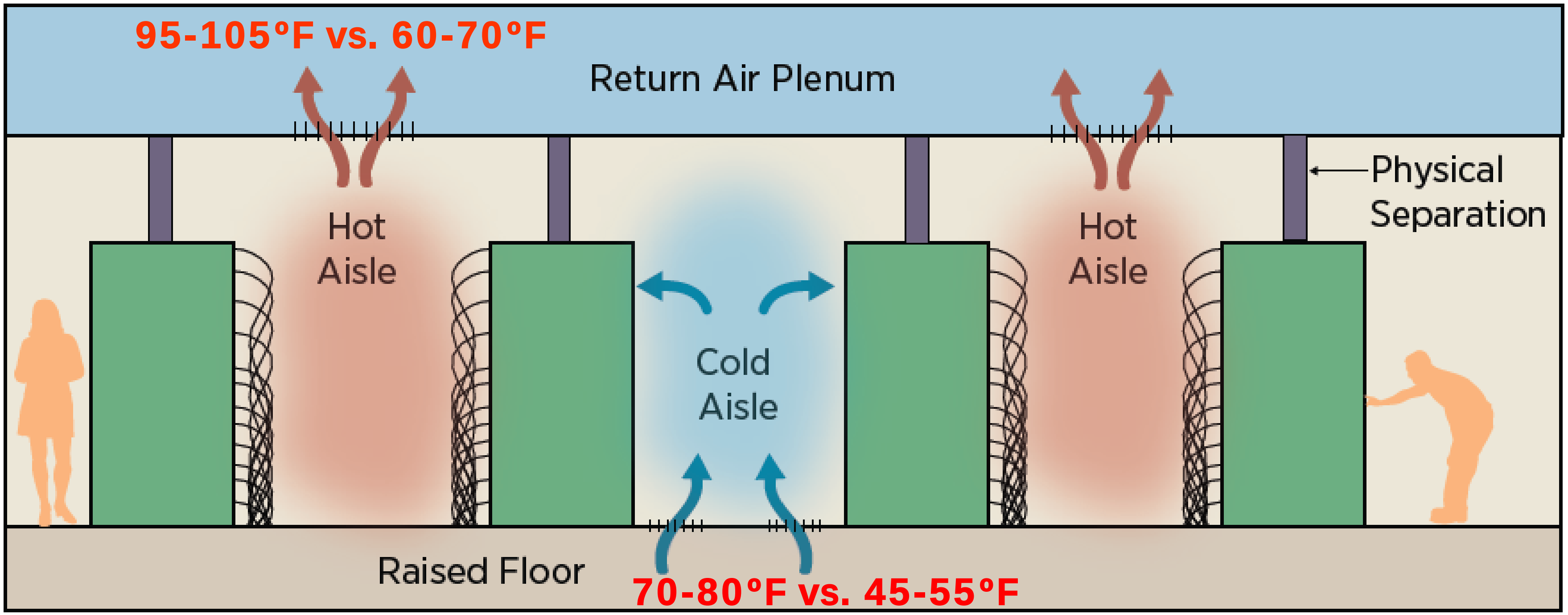
- **Typically, more air circulated than required**
- **Air mixing and short circuiting leads to:**
  - Low supply temperature
  - Low Delta T
- **Use hot and cold aisles**
- **Improve isolation of hot and cold aisles**
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling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



Source: http://www1.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf

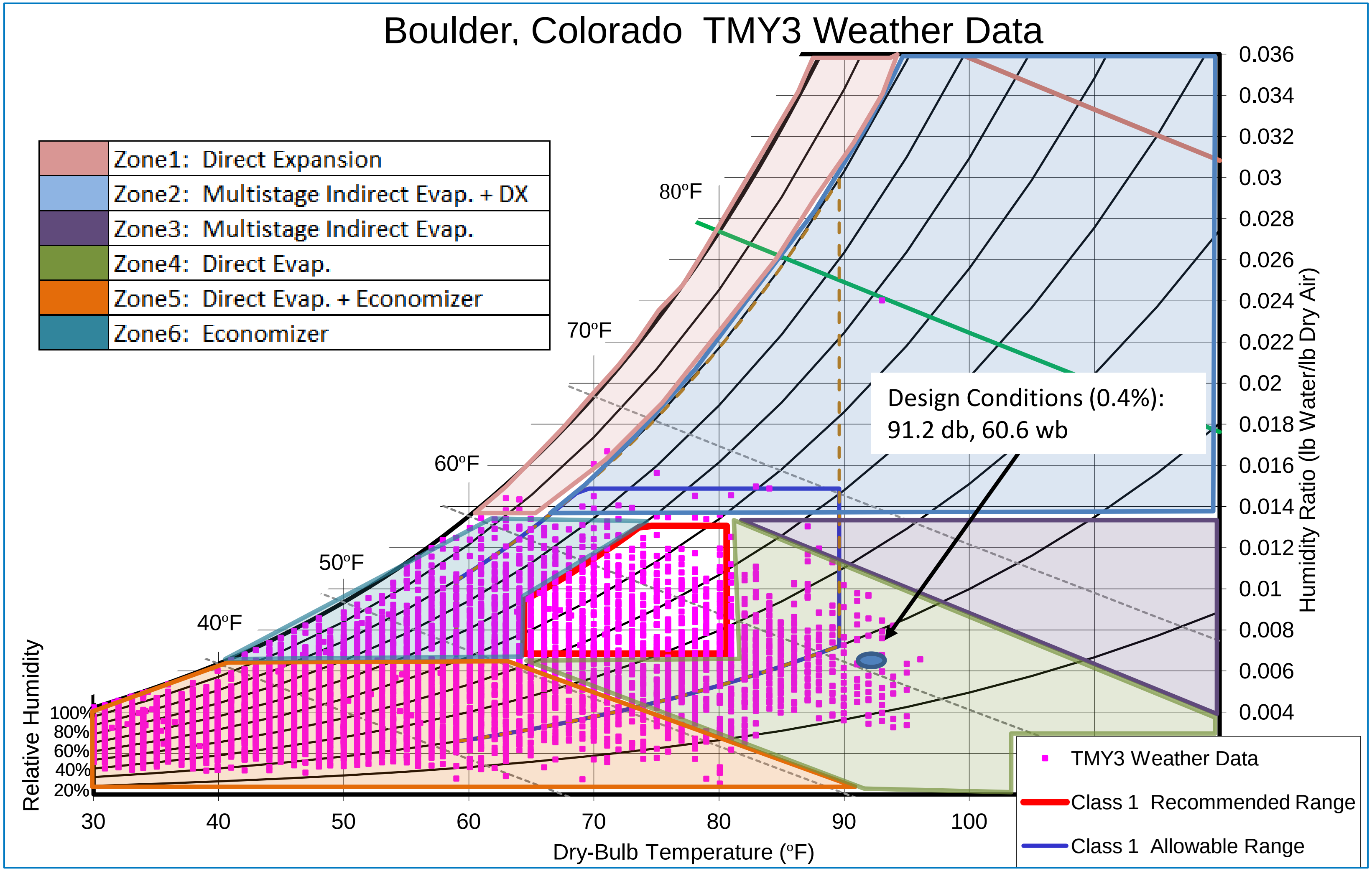
Hot aisle / cold aisle configuration decreases mixing of intake & exhaust air, promoting efficiency.

Isolate Cold and Hot Aisles



Source: http://www1.eere.energy.gov/femp/pdfs/eedatacenterbestpractices.pdf

Psychrometric Bin Analysis



Adding Air Curtains for Hot/Cold Isolation

Photo used with permission from the National Snow and Ice Data Center. http://www.nrel.gov/docs/fy12osti/53939.pdf

2011 ASHRAE Liquid Cooling Guidelines

Table A-1: 2011 ASHRAE Liquid Cooled Guidelines (SI Version in Main Body)

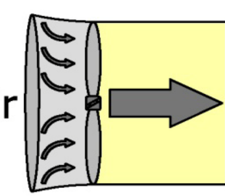
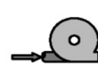
	Typical Infrastructure Design		
Liquid Cooling Classes	**Main Cooling Equipment**	**Supplemental Cooling Equipment**	**Facility Supply Water Temp(F)**
W1(see Figure A-a)	Chiller/Cooling Tower	Water-side Economizer (w drycooler or cooling tower)	35.6-62.6
W2(see Figure A-a)			35.6-80.6
W3(see Figure A-a)	Cooling Tower	Chiller	35.6-89.6
W4(see Figure A-b)	Water-side Economizer (w drycooler or cooling tower)	N/A	35.6-113.0
W5(see Figure A-c) See Operational Characteristics	Building Heating System	Cooling Tower	>113.0

NREL ESIF HPC (HP hardware) using 75 F supply, 113 F return –W4/W5

Liquid Cooling – Overview

Water and other liquids (dielectrics, glycols and refrigerants) may be used for heat removal.

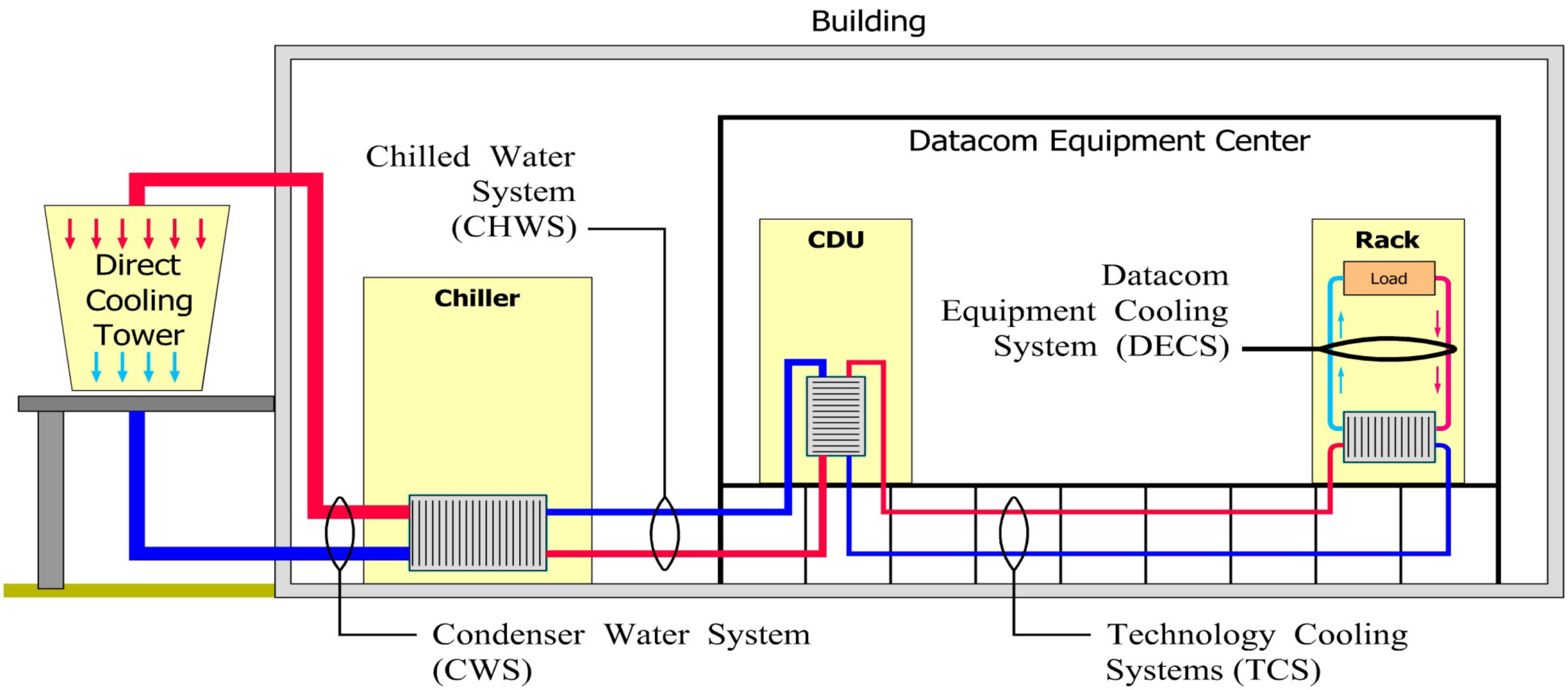
- Liquids typically use LESS transport energy
  (14.36 Air to Water Horsepower ratio for example below).
- Liquid-to-liquid heat exchangers have closer approach temps than
  Liquid-to-air (coils), yielding increased economizer hours.

Heat Transfer		Resultant Energy Requirements			
Rate	ΔT	Heat Transfer Medium	Fluid Flow Rate	Conduit Size	Theoretical Horsepower
10 Tons	12°F	Forced Air 	9217 cfm	34" Ø	3.63 Hp
		Water 	20 gpm	2" Ø	.25 Hp

Moving to liquid cooling designs

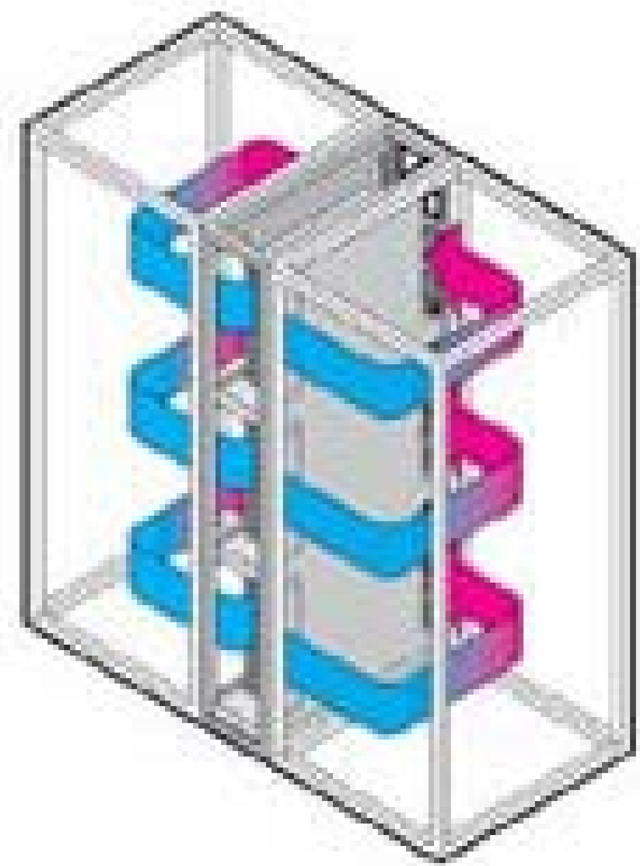
- As server heat densities rise, liquid heat removal solutions become more appropriate.
- Heat removal efficiency increases as the liquid gets closer to the source of heat.
- Liquids can provide cooling with higher temperature coolant.
- Liquids also offer the potential for better re-use of waste heat.

Liquid Cooling – Systems / Loops



Liquid Cooling Systems / Loops within a Data Center

In-Row Cooling

Graphics courtesy of Rittal

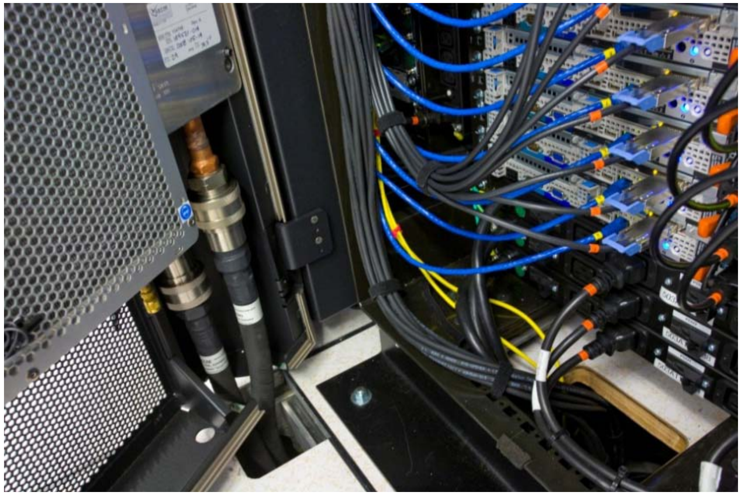
Rear-Door Liquid Cooling

Rear Door (open)

Inside rack RDHx, open 90°

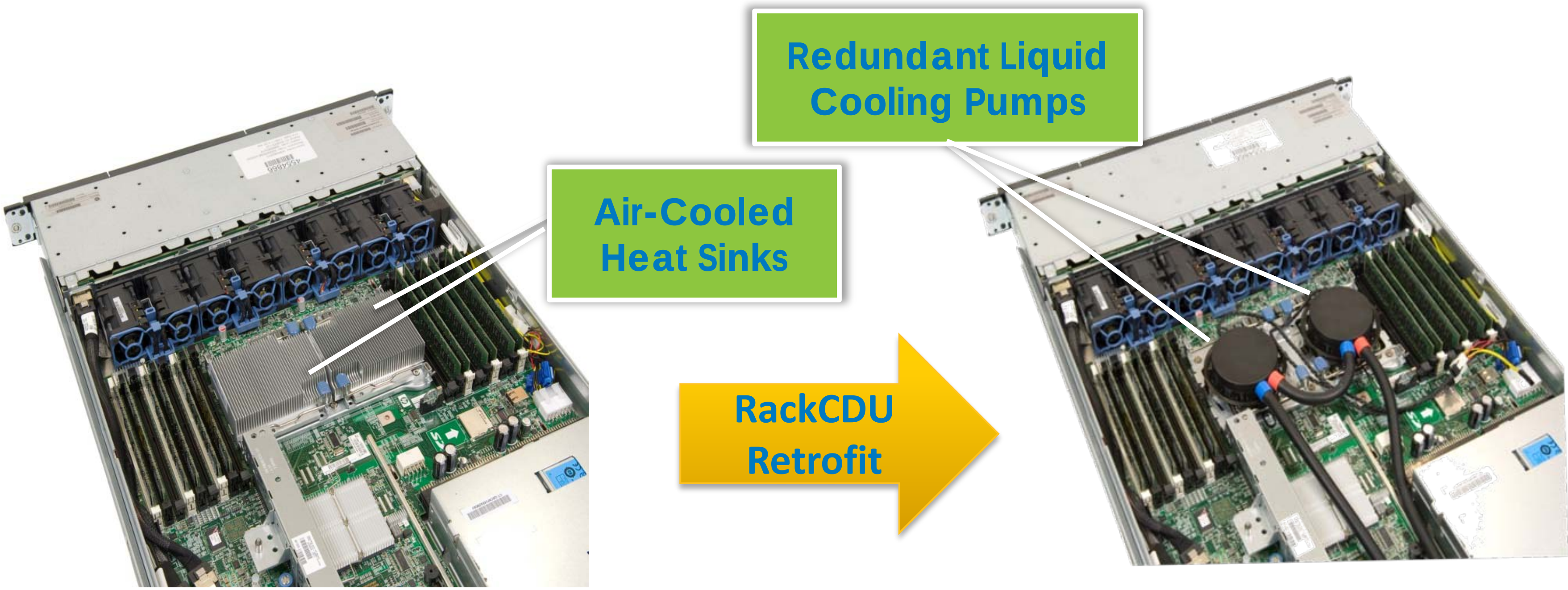
Rear Doors (closed)

Liquid Cooling Connections



Server Component Liquid Cooling

Within a server, most of the heat is concentrated in a small number of areas



- CPUs, GPUs and memory generate **60-80%** of data center heat-load
- RackCDU cools these components directly, **bypassing the CRAC entirely**

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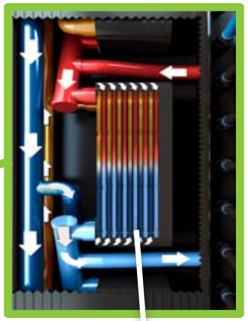
RackCDUTM “Hot-Spot” Liquid Cooling

RackCDU™ brings liquid coolant directly to the hottest components

- Redundant mini-pumps ensure reliability
- Low-pressure, low-volume mini-loops and factory sealed design eliminate risk of leaks
- Servers are physically separated facilty water (prevents leaks; maximizes performance)

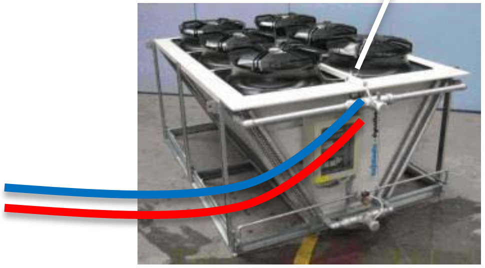


Liquid-to-Liquid HEX

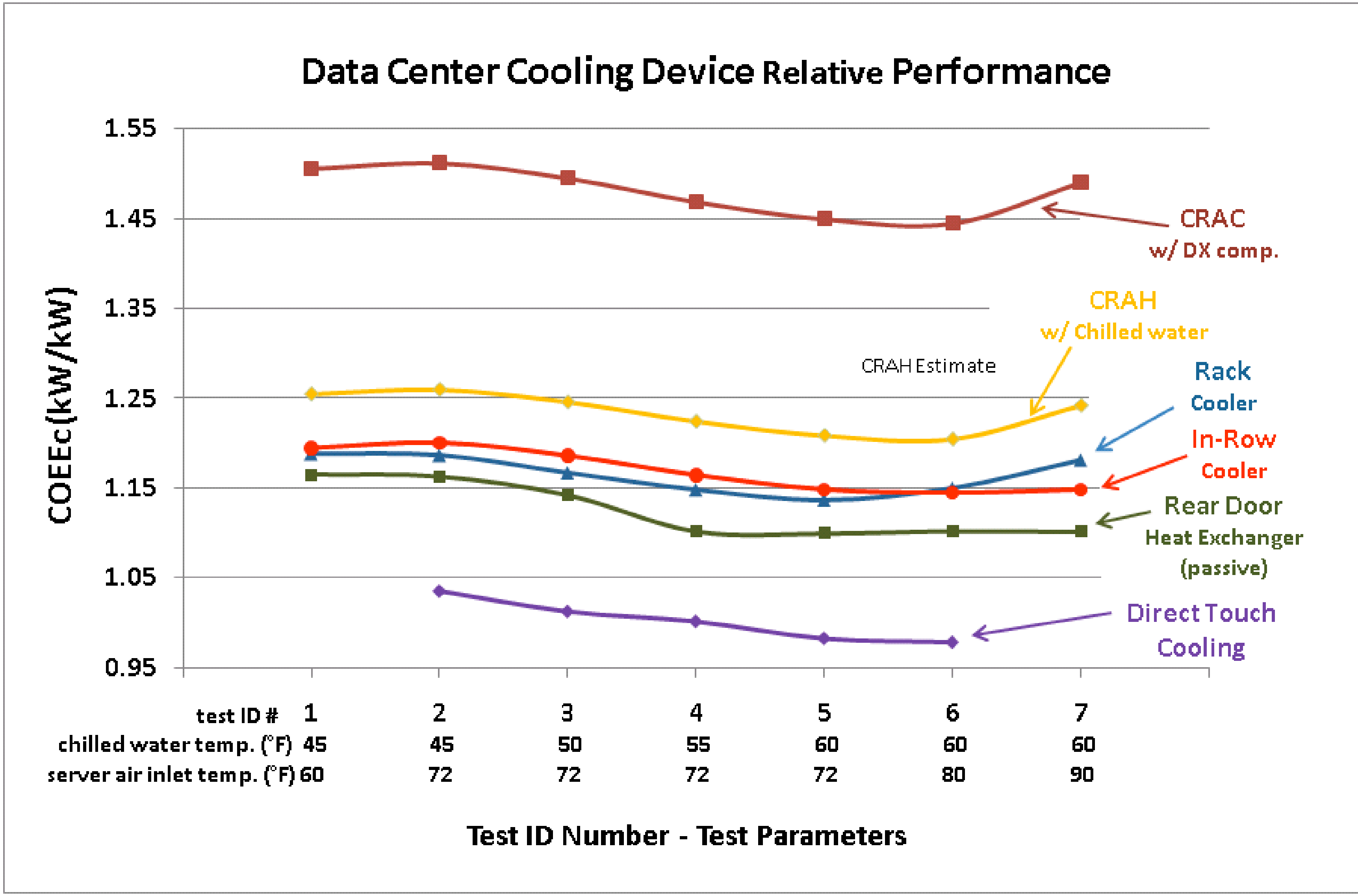
Cooling Loop

Rack Extension

Outdoor Dry Cooler



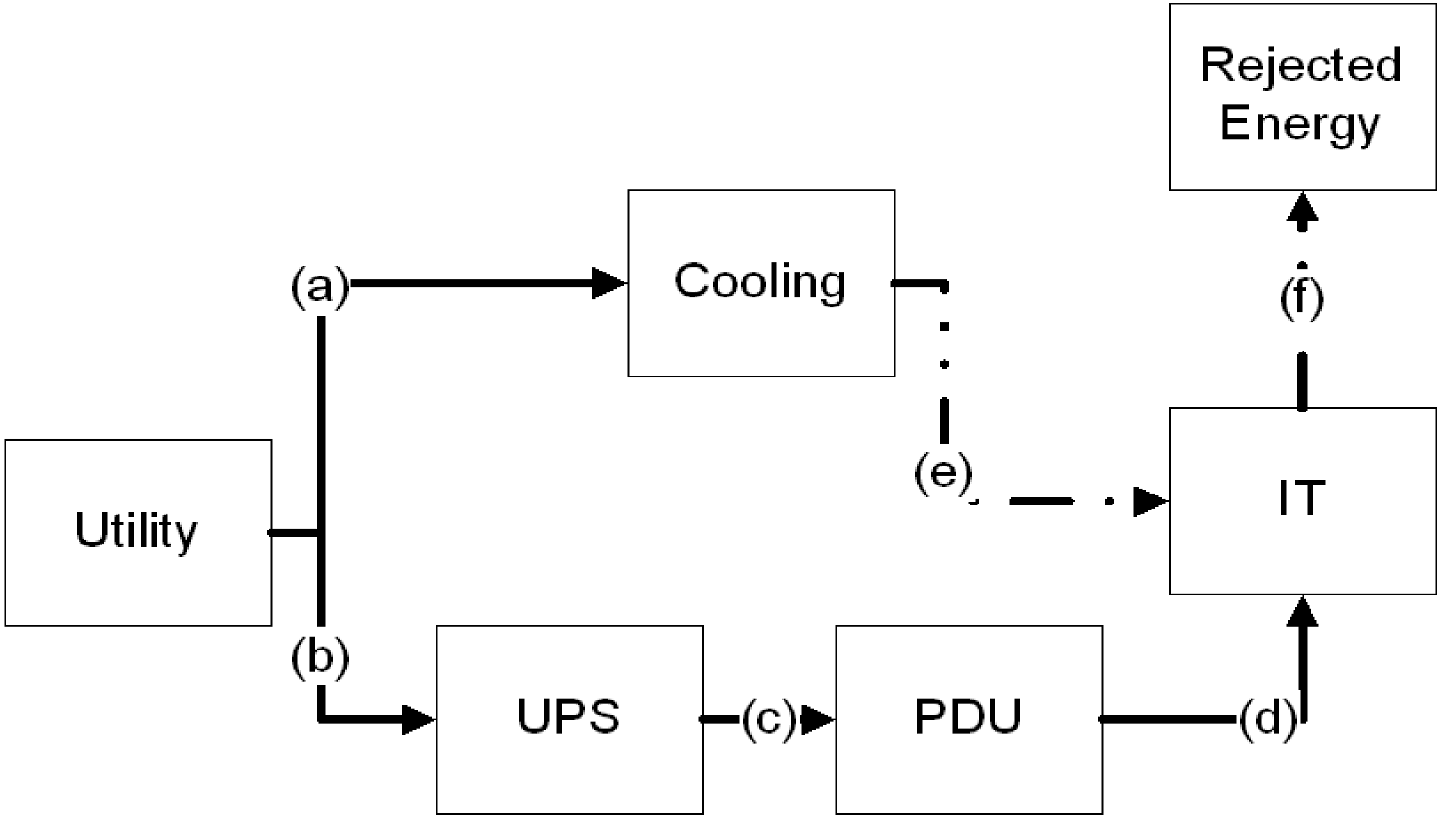
“Chill-off 2” evaluation of close-coupled cooling solutions



Cooling Takeaways…

- Use a central plant (e.g. chiller/CRAHs) vs. CRAC units
- Use centralized controls on CRAC/CRAH units to prevent simultaneous humidifying and dehumidifying.
- Move to liquid cooling (room, row, rack, chip)
- Consider VSDs on fans, pumps, chillers, and towers
- Use air- or water-side economizers.
- Expand humidity range and improve humidity control (or disconnect).

PUE – simple and effective



$$PUE = \frac{Total\ Energy}{IT\ Energy} = \frac{Cooling + PowerDistribution + Misc + IT}{IT} = \frac{a+b}{d}$$

“I am re-using waste heat from my data center on another part of my site and my PUE is 0.8!”

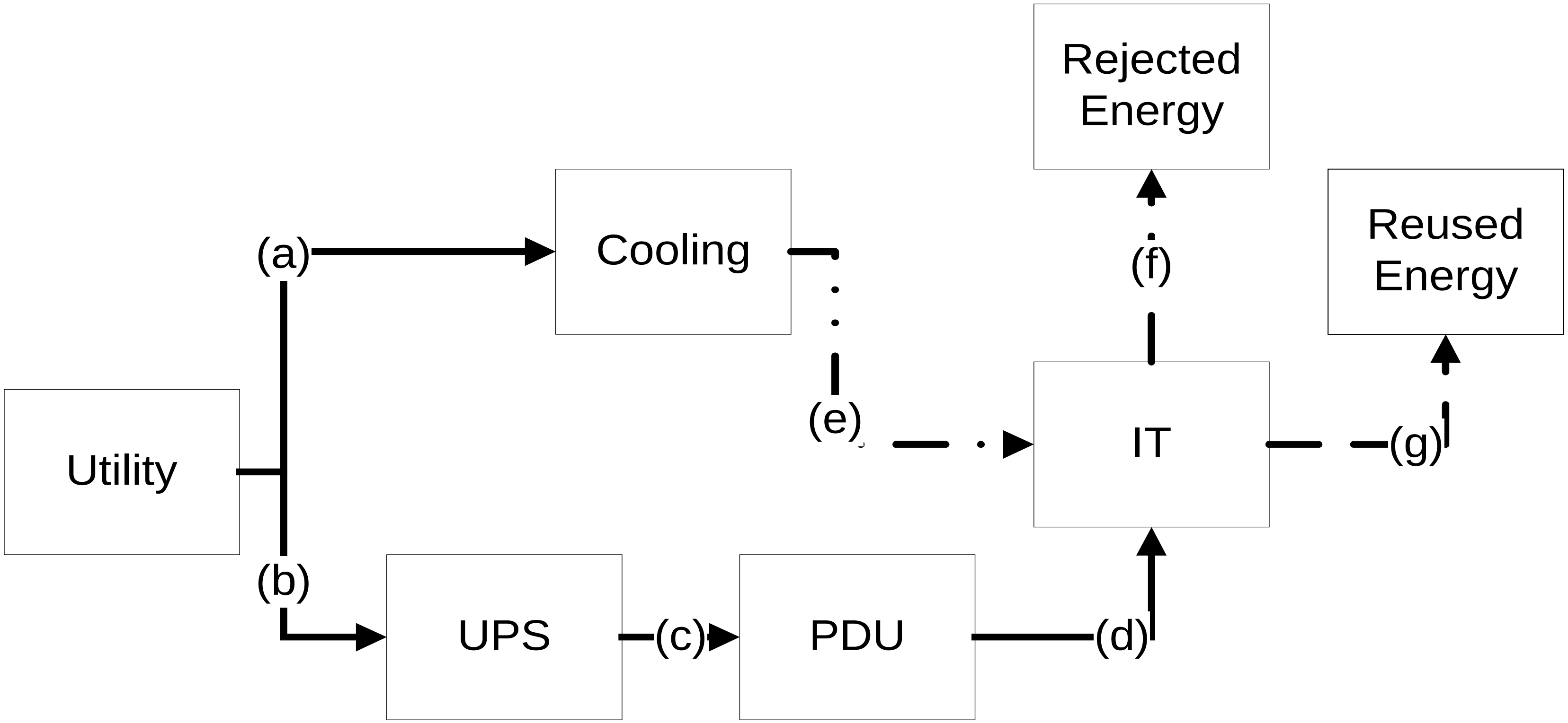
“I am re-using waste heat from my data center on another part of my site and my PUE is 0.8!”

ASHRAE & friends (DOE, EPA, TGG, 7x24, etc..) do not allow reused energy in PUE & PUE is always >1.0

Another metric has been developed by The Green Grid +; ERE – Energy Reuse Effectiveness

http://www.thegreengrid.org/en/Global/Content/white-papers/ERE

ERE – adds energy reuse



$$ERE = \frac{Total\ Energy - Reuse\ Energy}{IT\ Energy}$$

$$= \frac{Cooling + PowerDistribution + Misc + IT - Reuse}{IT} = \frac{a + b - g}{d}$$

Stennis Data Center

- Huge energy consumption
- Energy use = 52,010,100 kWh/yr in FY11
- PUE = 2.0

Homeland Security

What we did

- Traveled to Stennis for one week with an NREL team.
- Team identified financially viable energy and renewable energy projects.
- Team developed a site-specific action plan for implementing measures.

Savings at Data Centers

Results: The team identified 15 energy conservation measures in 5 categories:

- UPS upgrades
- HVAC systems
- Lighting upgrades
- IT environment improvements
- Renewable energy additions

Homeland Security

Cost Savings

Bundle Package	Total Cost ($)	Energy Savings (kWh/year)	Cost Savings ($/year)	Simple Payback (years)
All ECMs without PV system	$3,050,027	19,531,494	$1,367,205	2.2
All ECMs including PV system	$9,743,777	$22,038,905	$1,542,723	6.3

Energy Conservation Measures

1. Reduce the IT load - Virtualization & Consolidation (up to 80% reduction)
2. Implement contained hot aisle and cold aisle layout
   - Curtains, equipment configuration, blank panels, cable entrance/exit ports,
3. Install economizer (air or water) and evaporative cooling (direct or indirect)
4. Raise discharge air temperature. Install VFD's on all computer room air conditioning (CRAC) fans (if used) and network the controls
5. Reuse data center waste heat if possible
6. Raise the chilled water (if used) set-point
   - Increasing chiller water temperature by 1°F reduces chiller energy use by 1.4%
7. Install high efficiency equipment including UPS, power supplies, etc.
8. Move chilled water as close to server as possible (direct liquid cooling)
9. Consider centralized high efficiency water cooled chiller plant
   - Air-cooled = 2.9 COP, water-cooled = 7.8 COP

Questions?

RSF II
21 kBtu/ft2
$246/ft2 construction cost

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