

# Best Practices for Data Center Energy Efficiency Workshop

Hosted by Data Center Dynamics  
New Delhi  
Septyember 5, 2013

Presented by:

Dale Sartor, P.E.

Applications Team Leader, Building Technologies  
Lawrence Berkeley National Laboratory

(Version: 08/10/13)



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



This Presentation is Available for download at:  
<http://datacenterworkshop.lbl.gov/>



- Introduction
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions
- Airflow management
- Cooling systems
- Electrical systems
- Resources
- Workshop summary

## Conventional Approach

- Data centers need to be cool and controlled to tight humidity ranges
- Data centers need raised floors for cold air distribution
- Data centers require highly redundant building infrastructure

## Need Holistic Approach

- IT and Facilities Partnership



## Introduction

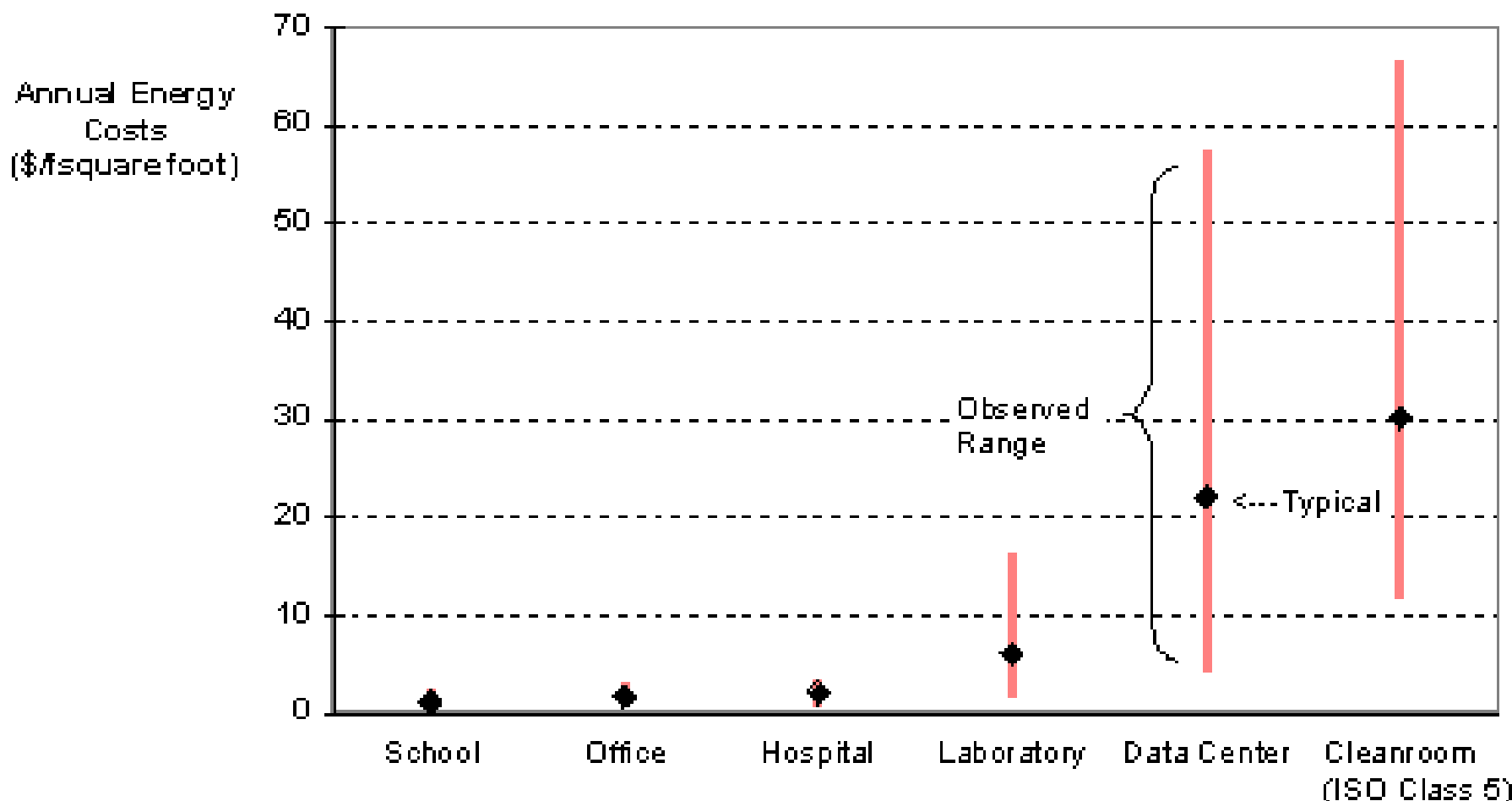


U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



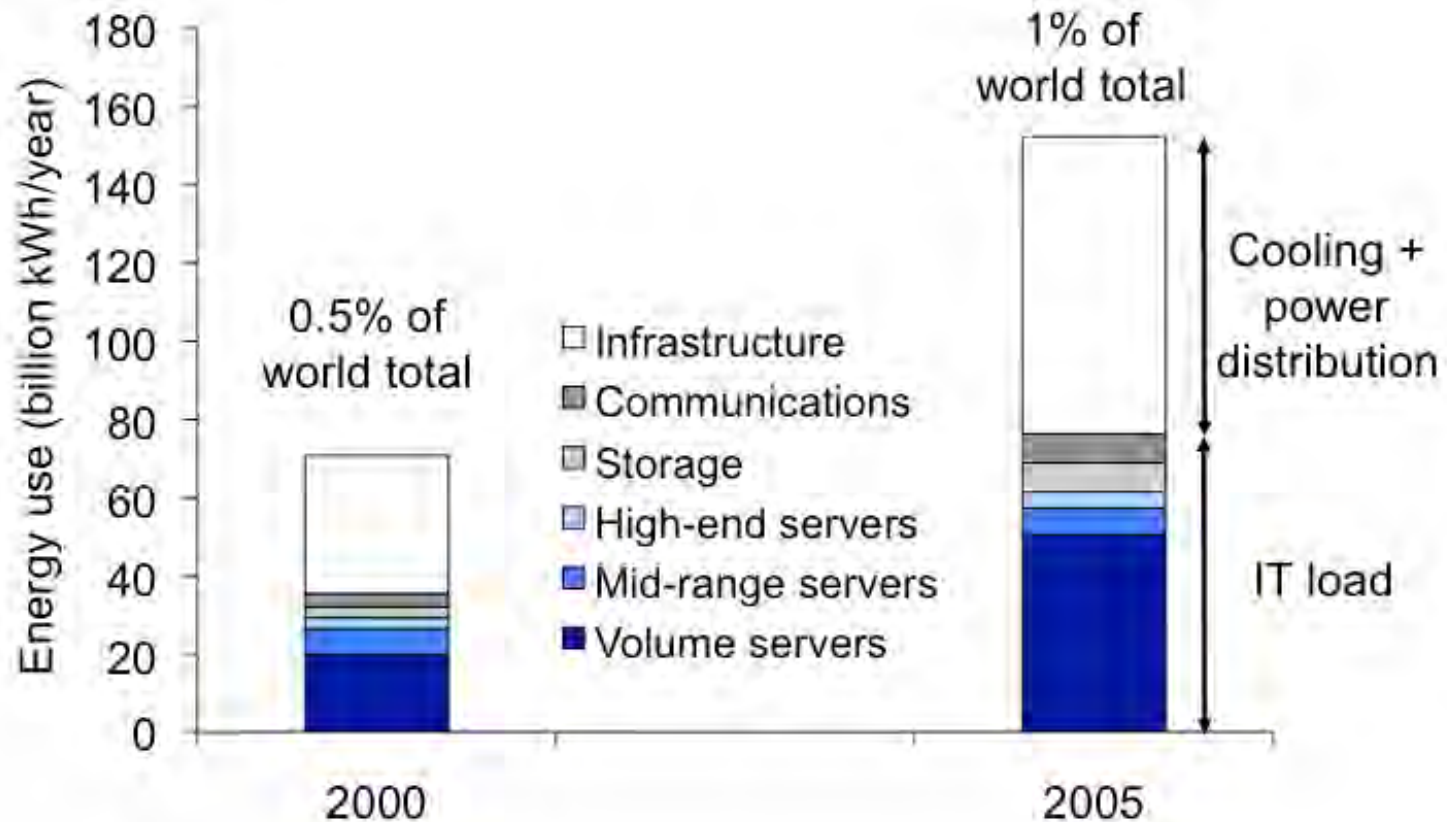
- **Provide background on data center efficiency**
- **Raise awareness of efficiency opportunities**
- **Develop common understanding between IT and Facility staff**
- **Review of data center efficiency resources**
- **Group interaction for common issues and solutions**

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



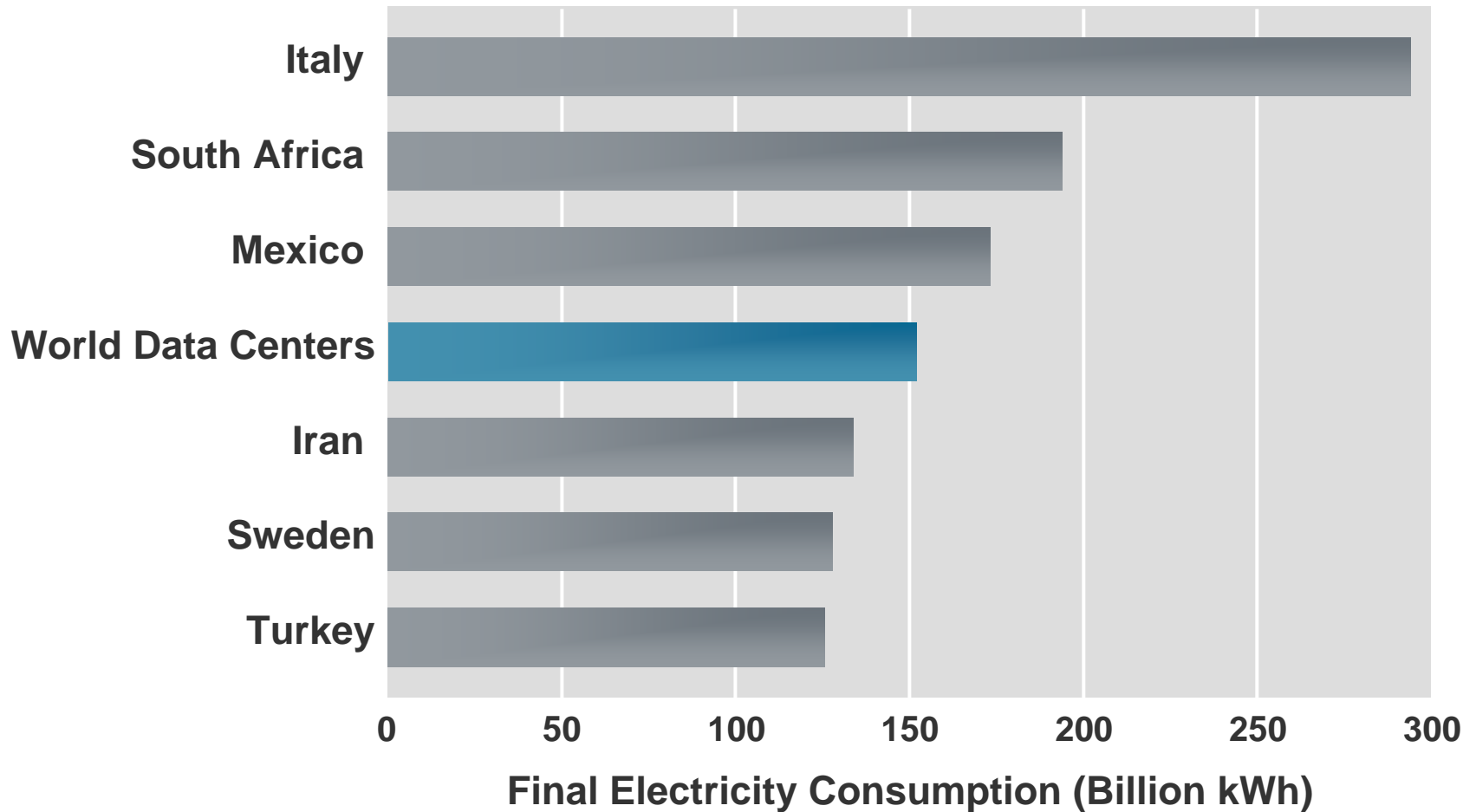
- Data centers are energy intensive facilities
  - 10 to 100 times more energy intensive than an office
  - Server racks now designed for more than 25+ kW
  - Surging demand for data storage
  - 2% of US Electricity consumption
  - Projected to double in next 5 years
  - Power and cooling constraints in existing facilities

# World Data Center Electricity Use - 2000 and 2005



Source: Koomey 2008

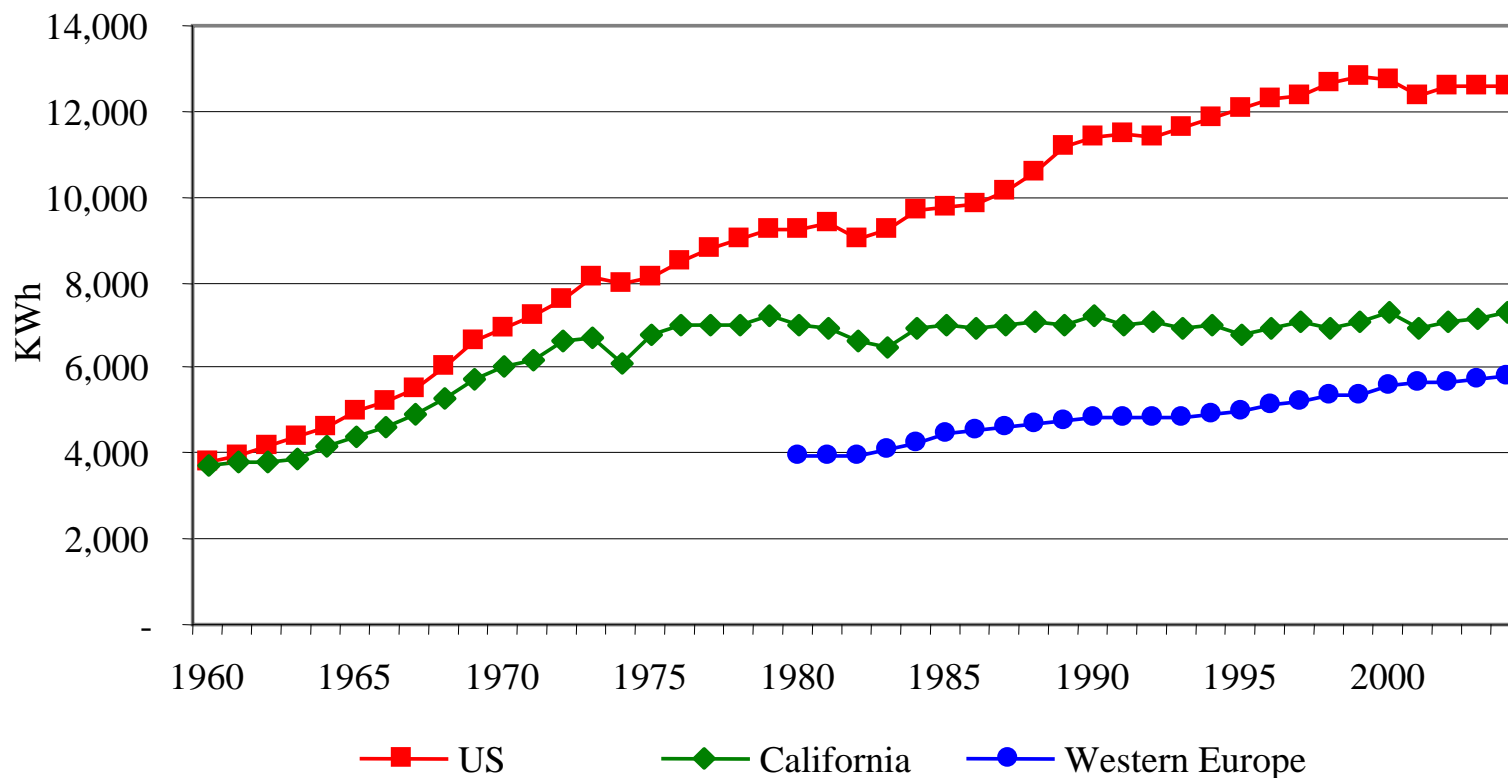
# How Much is 152B kWh?



Source for country data in 2005: International Energy Agency, *World Energy Balances* (2007 edition)

# Aggressive Programs Make a Difference

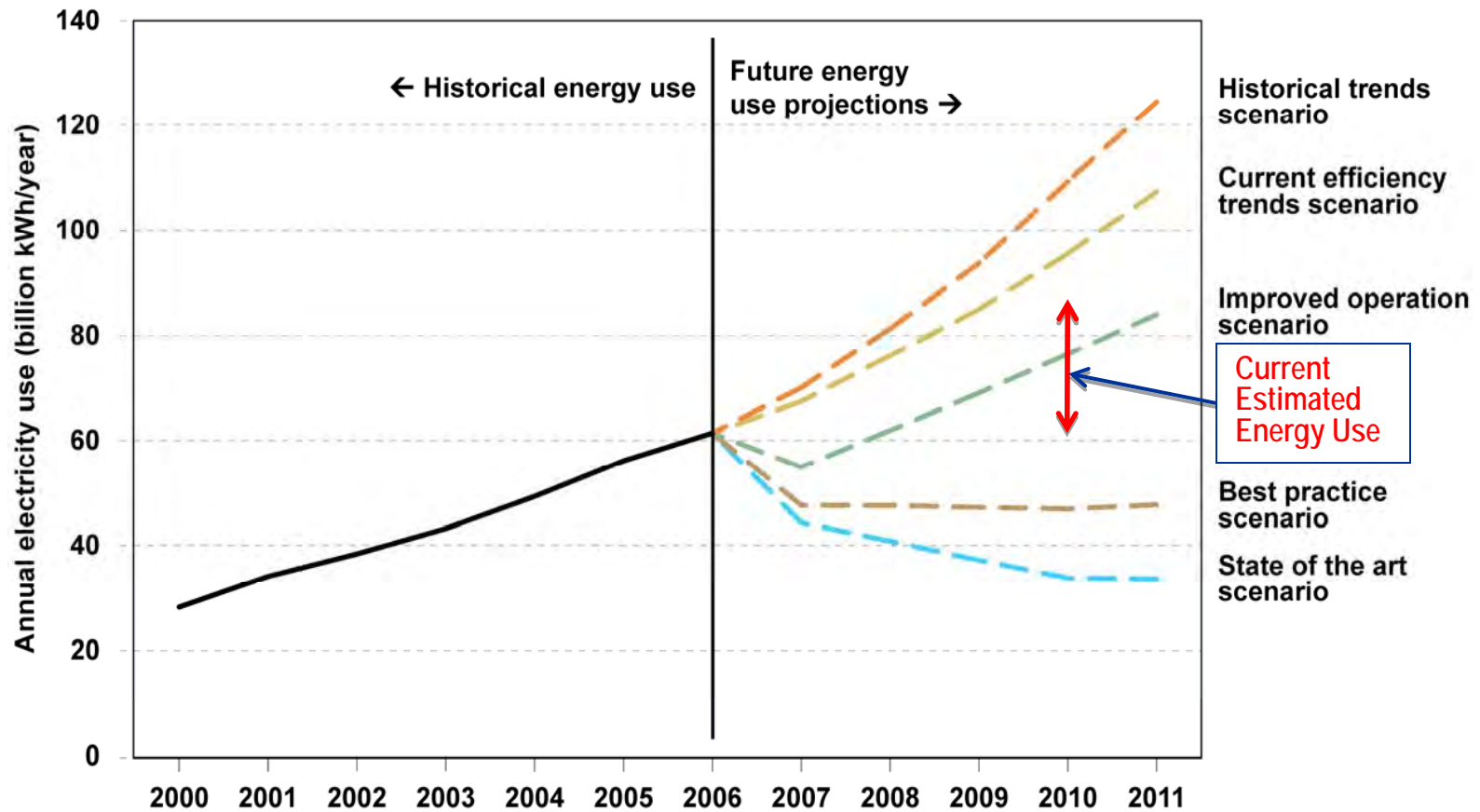
Energy efficiency programs have helped keep per capita electricity consumption in California flat over the past 30 years



# Projected Data Center Energy Use

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

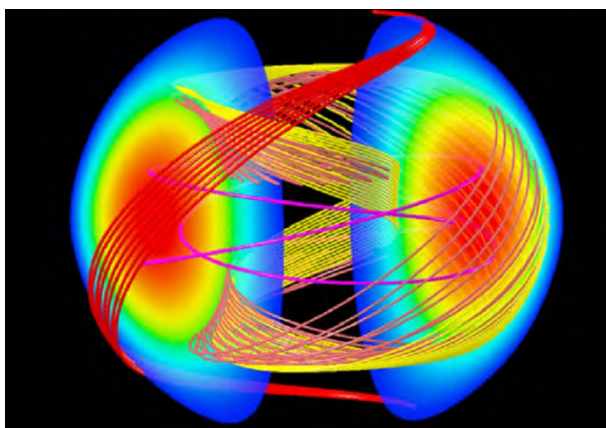


EPA Report to Congress 2008

- From 2000 – 2006, computing performance increased 25x but energy efficiency only 8x
  - Amount of power consumed per \$1,000 of servers purchased has increased 4x
- Cost of electricity and supporting infrastructure now surpassing capital cost of IT equipment
- Perverse incentives -- IT and facilities costs separate

Source: The Uptime Institute, 2007

## LBNL operates large systems along with legacy systems

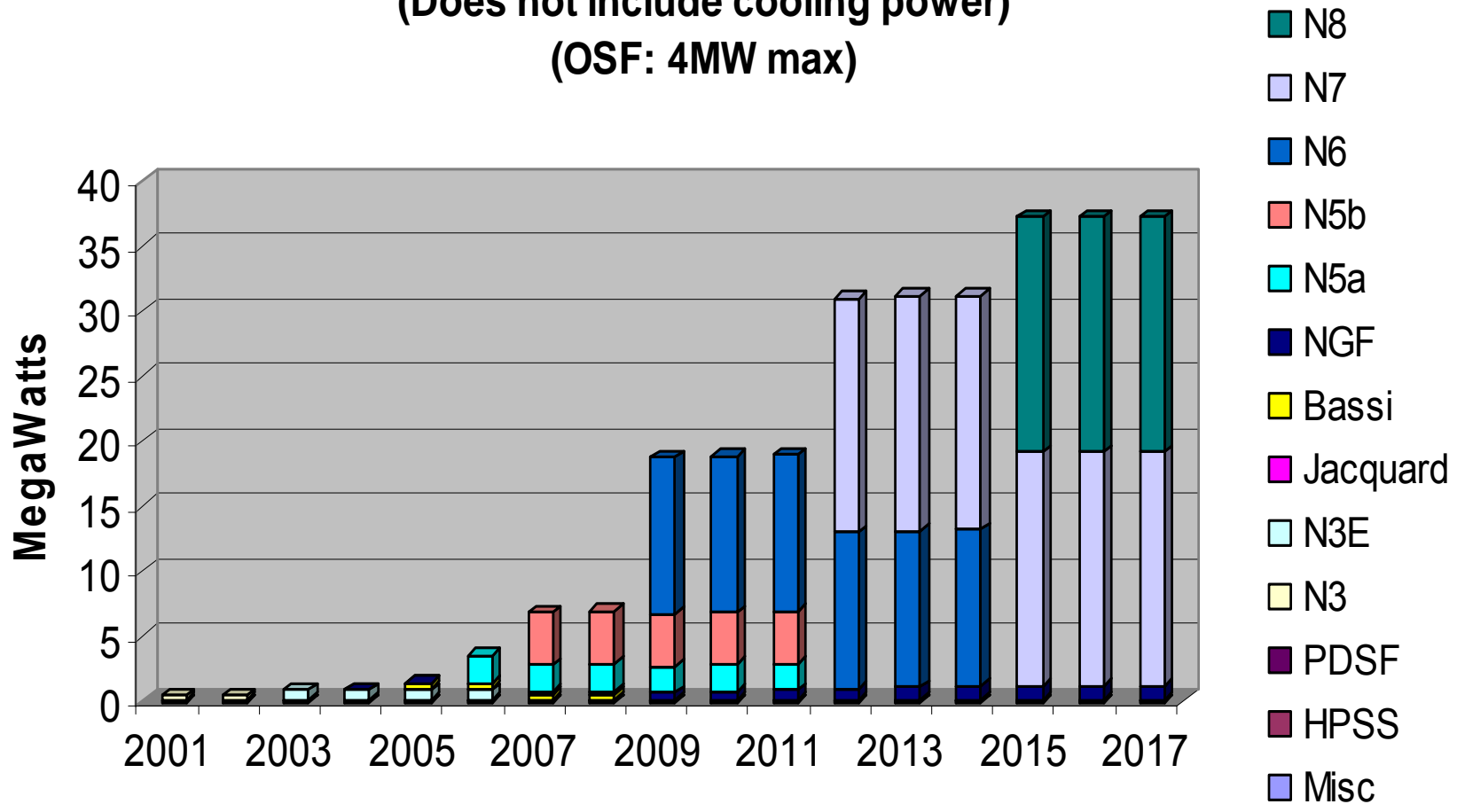


We also research energy efficiency opportunity and work on various deployment programs

# LBNL Feels the Pain!

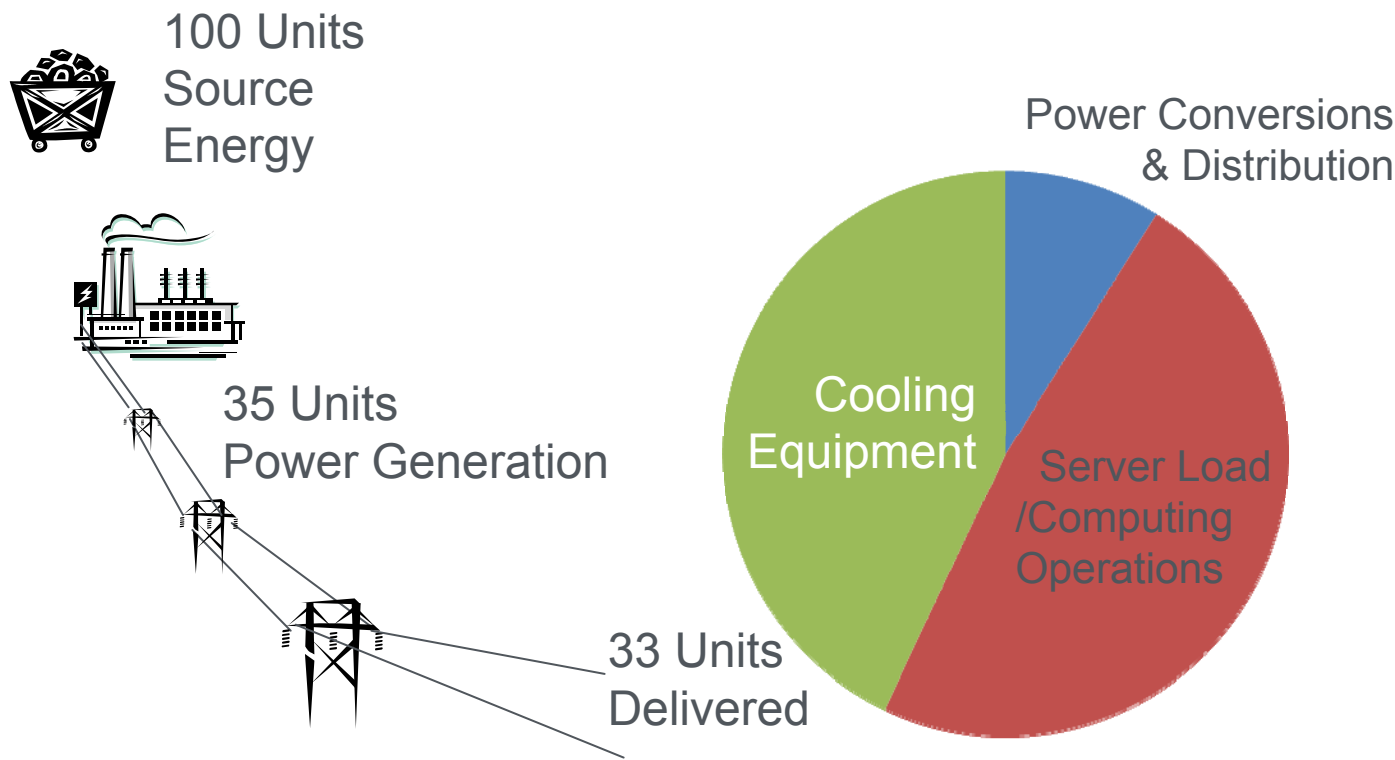


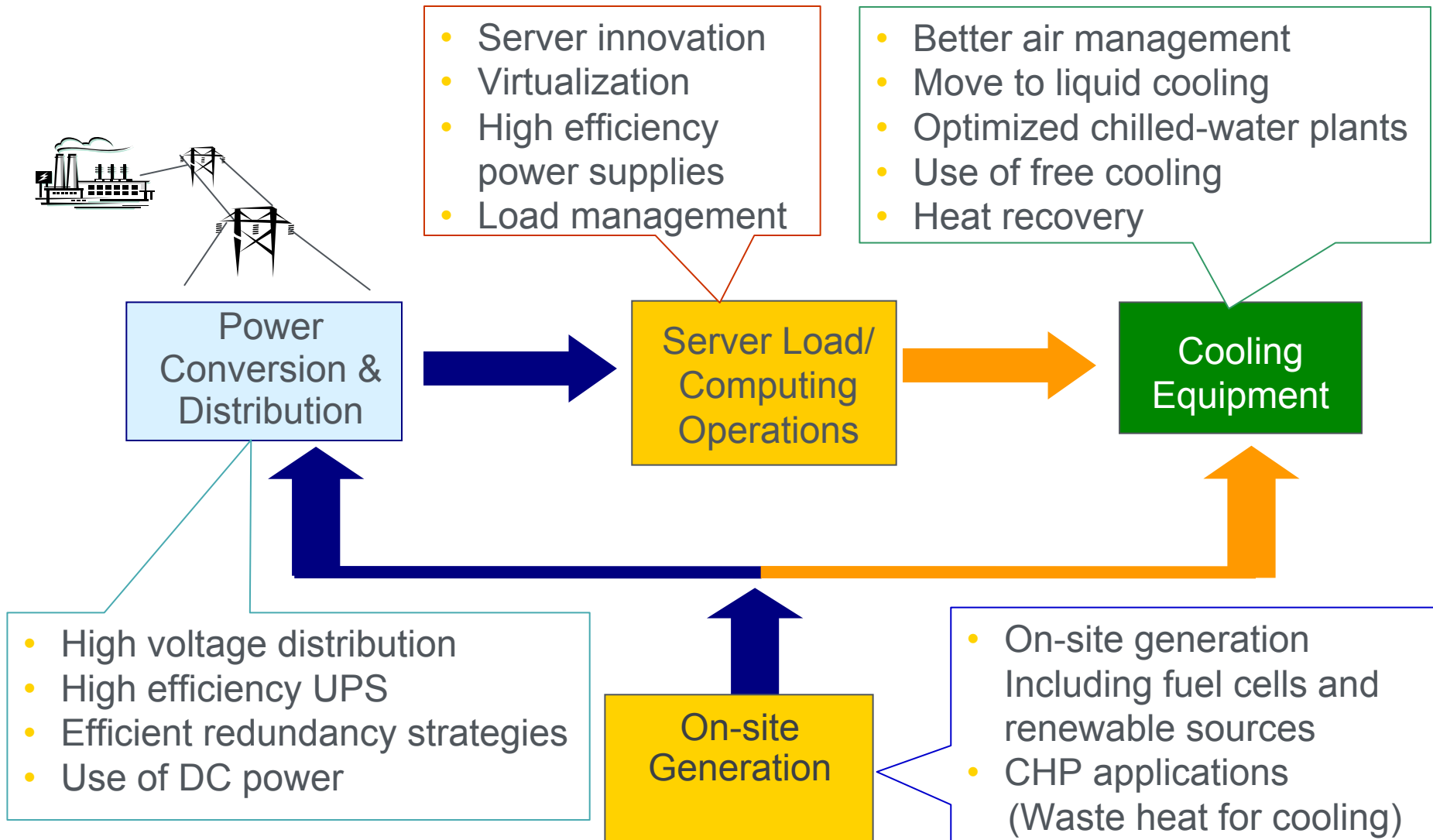
NERSC Computer Systems Power  
 (Does not include cooling power)  
 (OSF: 4MW max)



Energy Efficiency = Useful computation / Total Source Energy

Typical Data Center Energy End Use





# Potential Benefits of Data Center Energy Efficiency

- 20-40% savings typical
- Aggressive strategies can yield 50+% savings
- Extend life and capacity of infrastructures



# Questions?



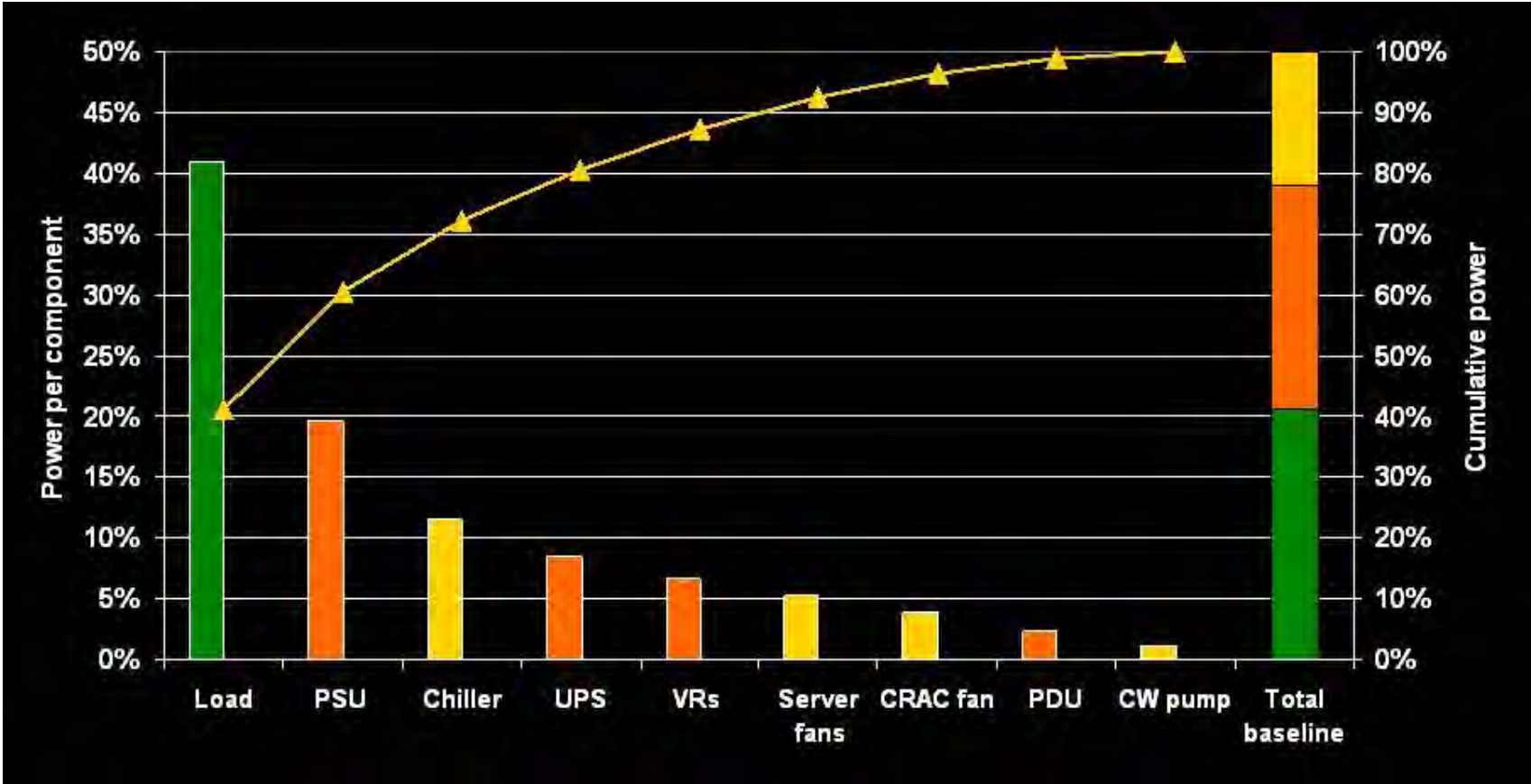


## Performance metrics and benchmarking



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**





Courtesy of Michael Patterson, Intel Corporation

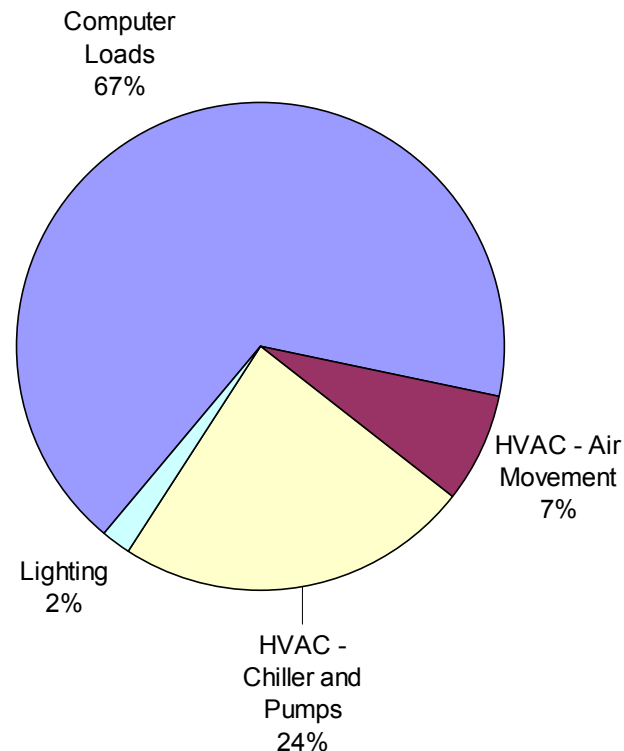
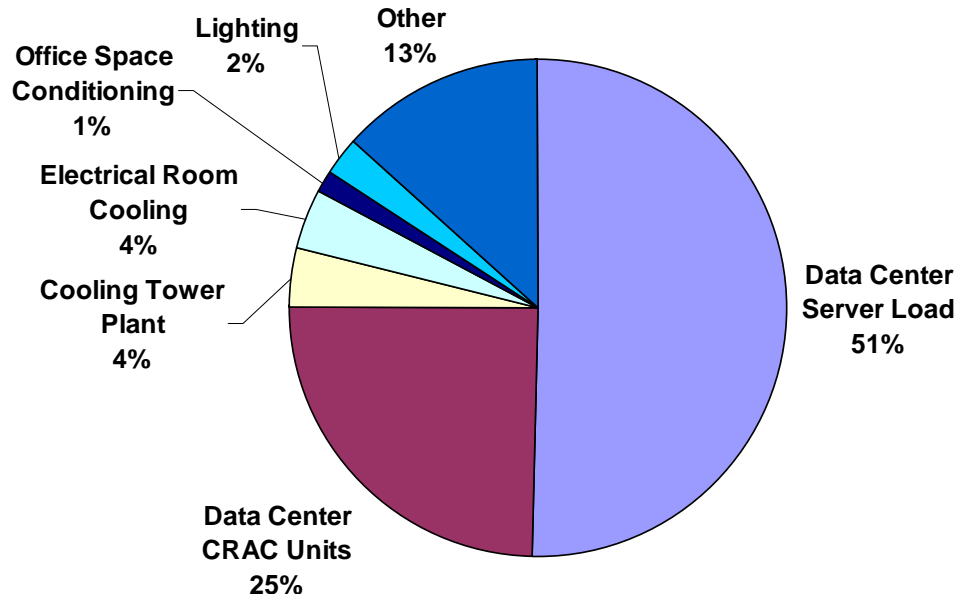
# Benchmarking for Energy Performance Improvement:

- Energy benchmarking can allow performance tracking and comparison to peers
- LBNL conducted studies of over 30 data centers:
  - Wide variation in performance
  - Identified best practices
- Can't manage what isn't measured

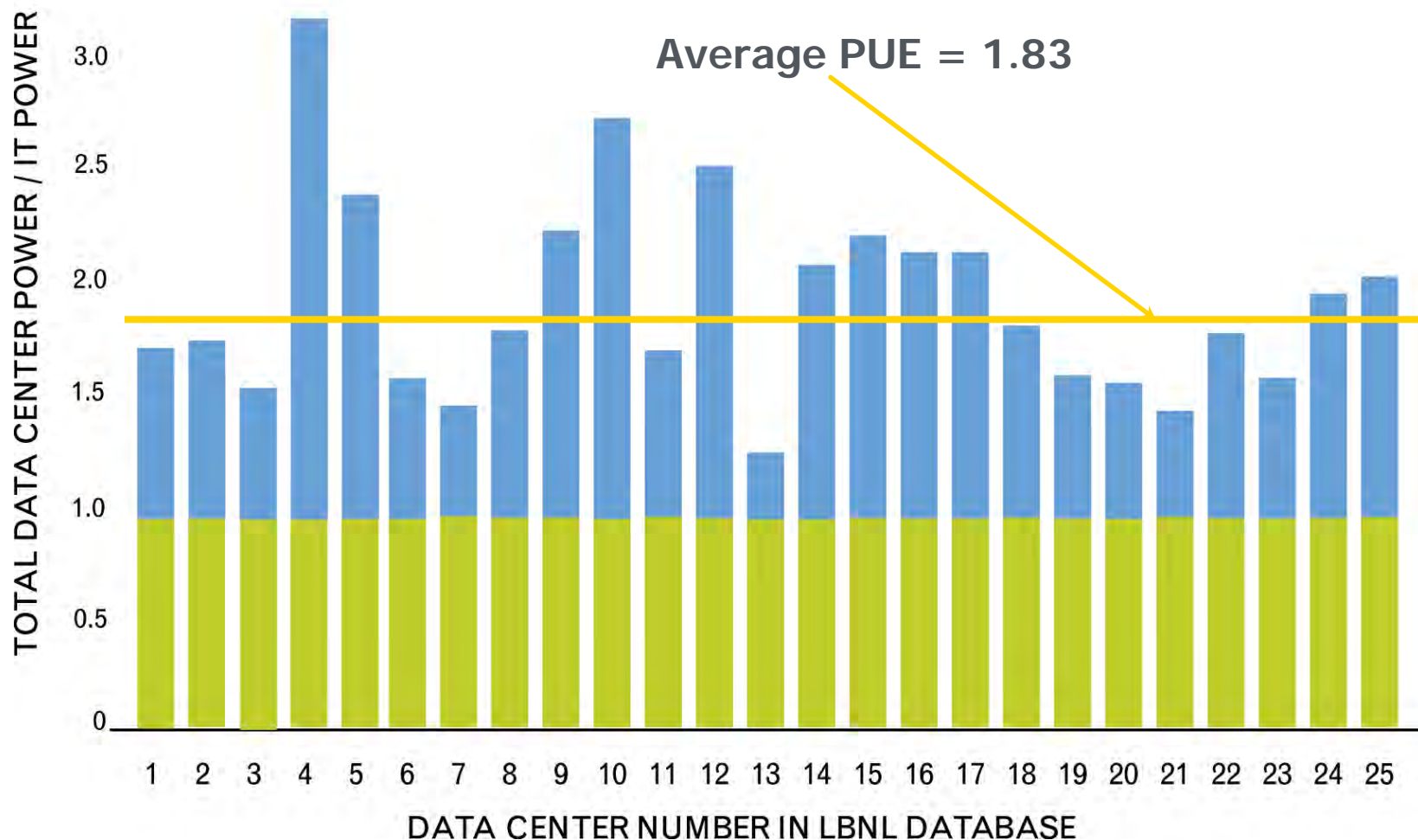


# Your Mileage Will Vary

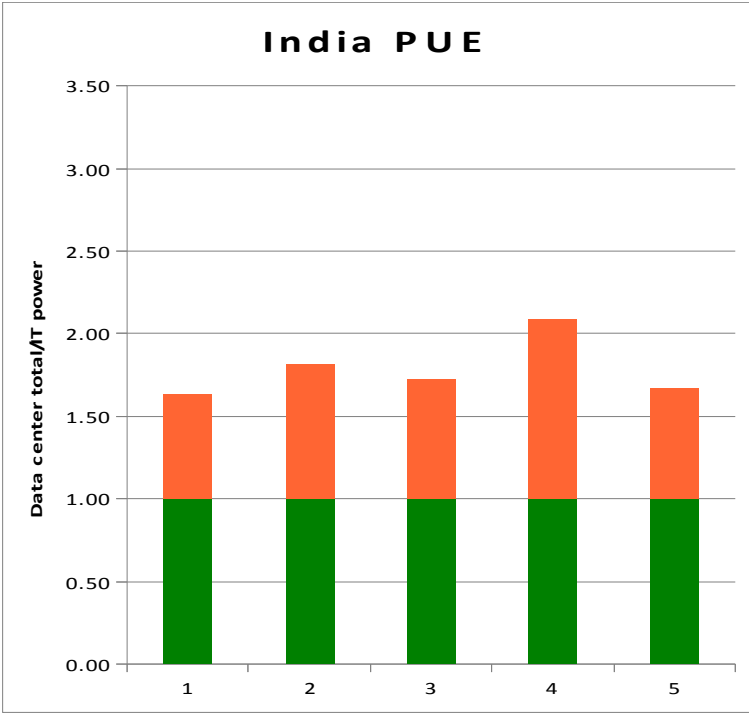
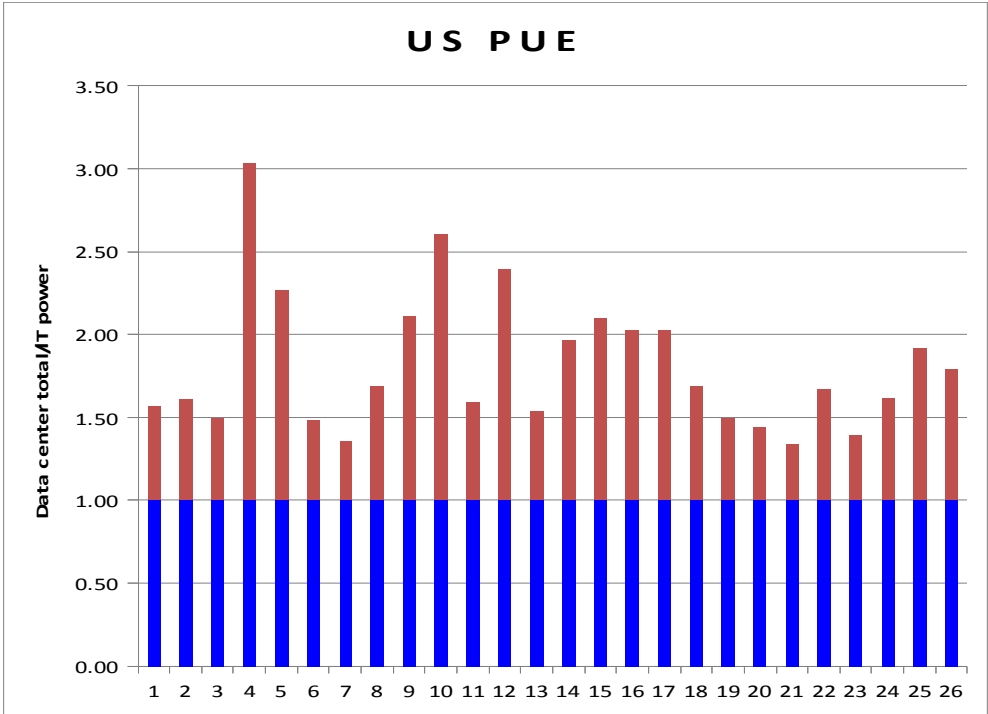
The relative percentages of the energy doing computing varies considerably.



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



# Power Usage Effectiveness (PUE)



## Thanks To:

- Intel
- Hewlett Packard
- APC
- Maruti
- Texas Instruments

More Needed!

PUEs: Reported & Calculated	PUE
EPA Energy Star Average	1.91
Intel Jones Farm, Hillsboro	1.41
T-Systems & Intel DC2020 Test Lab, Munich	1.24
Google	1.16
Leibniz Supercomputing Centre (LRZ)	1.15
National Center for Atmospheric Research (NCAR)	1.10
Yahoo, Lockport	1.08
Facebook, Prineville	1.07
National Renewable Energy Laboratory (NREL)	<b>1.06</b>

Slide Courtesy Mike Patterson, Intel

- **Key Metrics:**
  - PUE and partial PUEs (e.g. HVAC, Electrical distribution)
  - Utilization
  - Energy Reuse (ERF)
- **The future: Computational Metrics (e.g. peak flops per Watt; transactions/Watt)**

- Watts per square foot, Watts per rack
- Power distribution: UPS efficiency, IT power supply efficiency
  - Uptime: IT Hardware Power Overhead Multiplier ( $IT_{ac}/IT_{dc}$ )
- HVAC
  - Fan watts/cfm
  - Pump watts/gpm
  - Chiller plant (or chiller or overall HVAC) kW/ton
- Air Management
  - Rack cooling index (fraction of IT within recommended temperature range)
  - Return temperature index  $(RAT-SAT)/IT\Delta T$
- Lighting watts/square foot

## Power Usage Effectiveness

$$PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

Standard	Good	Better
2.0	1.4	1.1

## Airflow Efficiency

$$\frac{\text{Total Fan Power (W)}}{\text{Total Fan Airflow (cfm)}}$$

Standard	Good	Better
1.25W/cfm	0.75 W/cfm	0.5 kW/cfm

## Cooling System Efficiency

$$\frac{\text{Average Cooling System Power (kW)}}{\text{Average Cooling Load (ton)}}$$

Standard	Good	Better
1.1 kW/ton	0.8 kW/ton	0.6 kW/ton

# Questions?





## IT Equipment and Software Efficiency

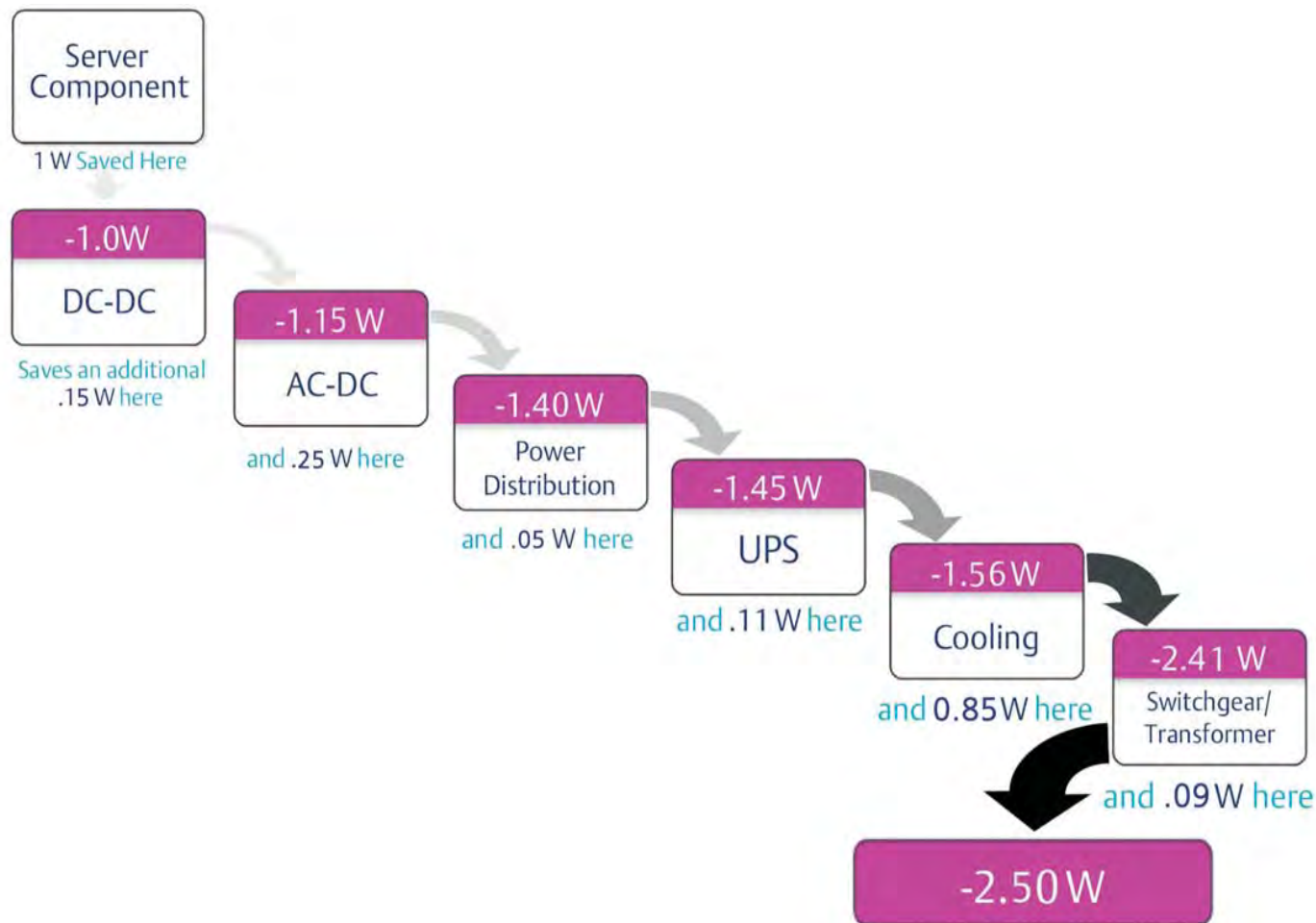


U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**

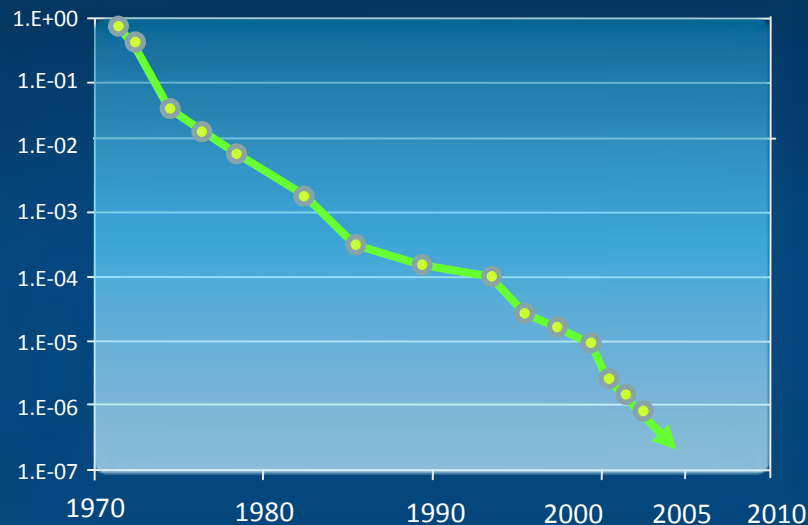


# IT Server Performance - Saving a Watt...

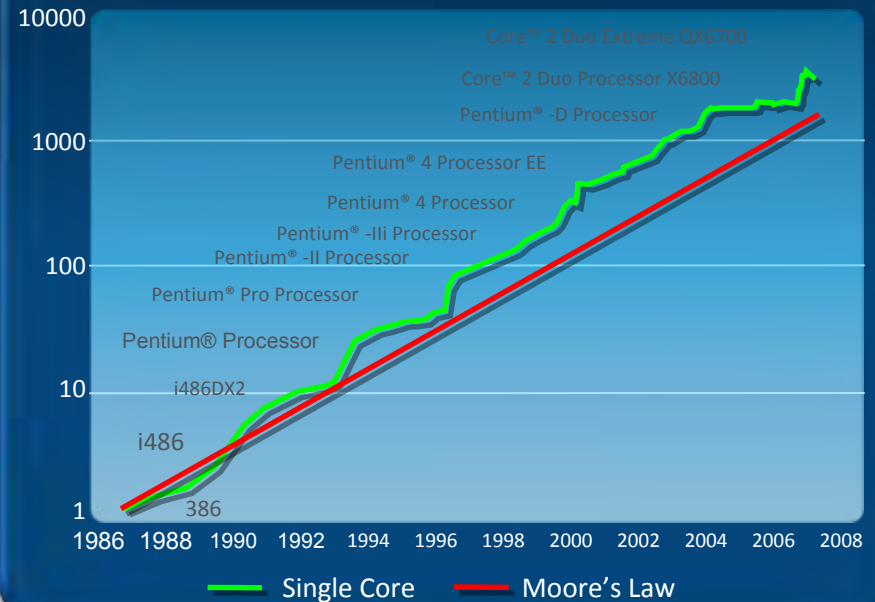
## The value of one watt saved at the IT equipment



Power reduction Over Time\*



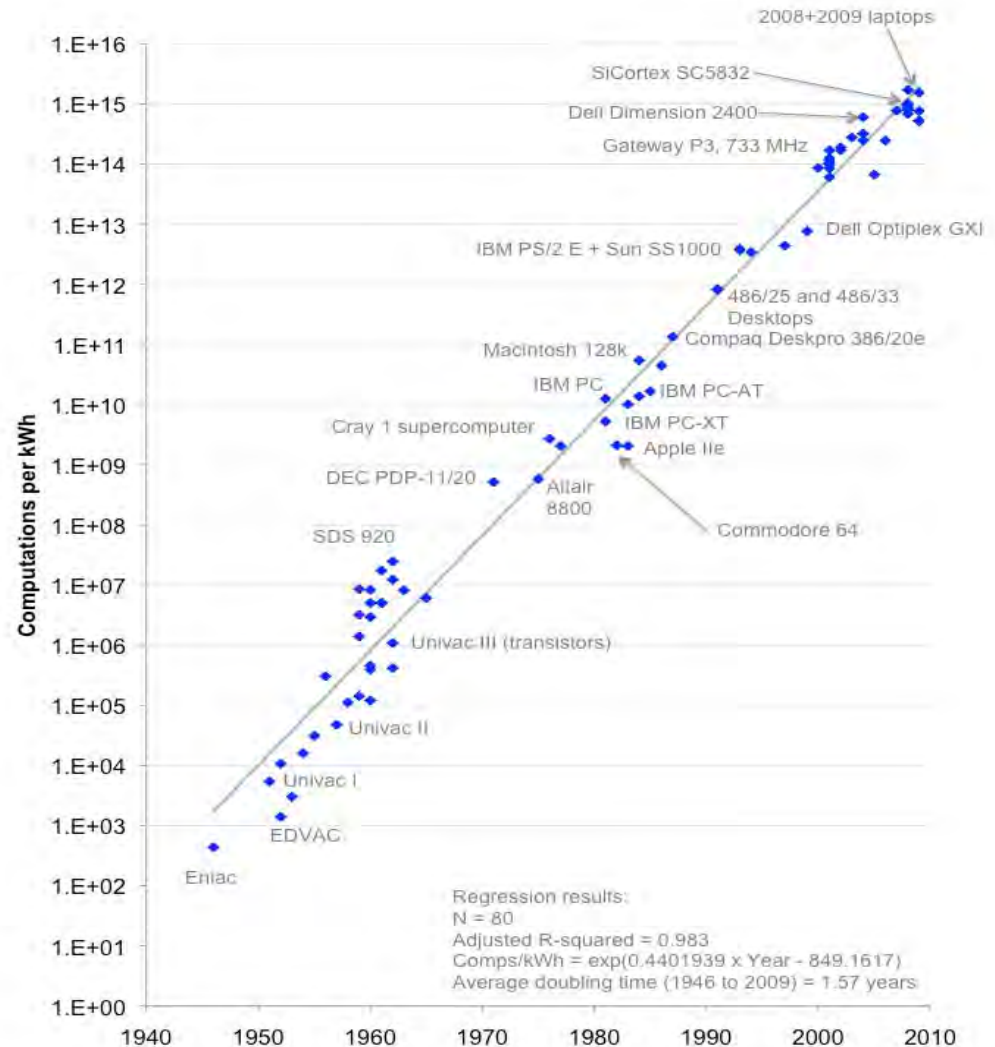
Core Integer Performance Over Time\*



- Every year Moore's Law is followed, smaller, more energy-efficient transistors result
- Miniaturization provides 1 million times reduction in energy/transistor size over 30+ years.
- Benefits: Smaller, faster transistors => faster AND more energy-efficient chips.

Source: Intel Corp.

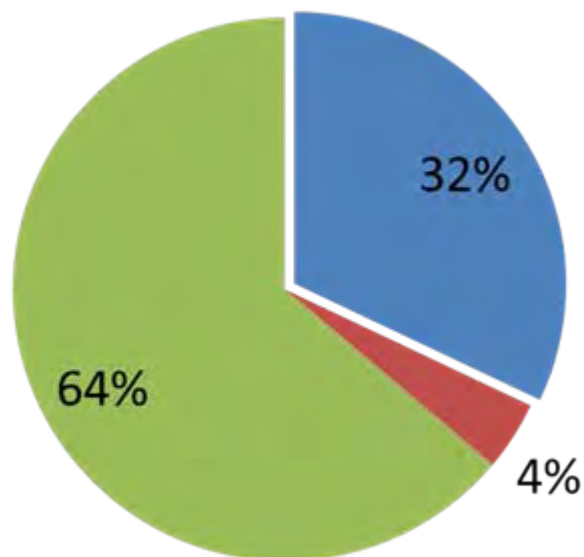
# Computing Efficiency Increases 100x Every Decade



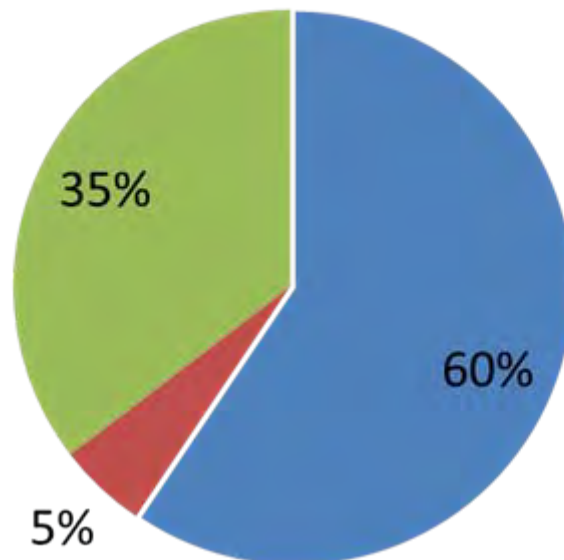
Source: Koomey et al. 2011

# IT Equipment Age and Performance

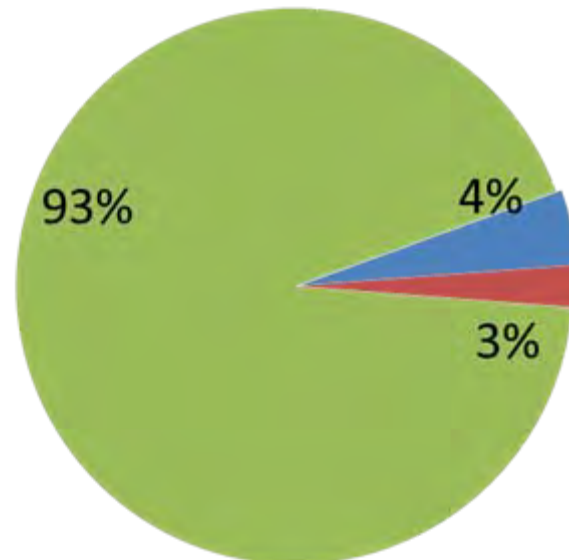
Age Distribution  
of Servers



Energy Consumption  
of Servers



Performance Capability  
of Servers



Old Servers consume 60% of Energy, but deliver only 4% of Performance Capability.

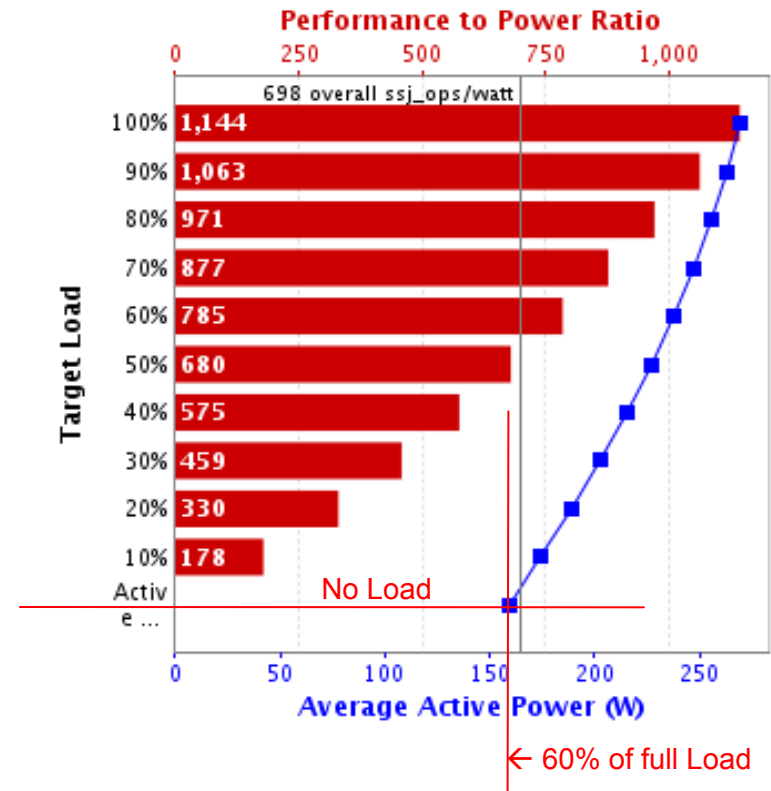
Data collected recently at a Fortune 100 company; courtesy of John Kuzma and William Carter, Intel

# Perform IT System Energy Assessments

## IT Energy Use Patterns: Servers

Idle servers consume as much as 50-60% of power @ full load as shown in SpecPower Benchmarks.

Performance			Power	Performance to Power Ratio
Target Load	Actual Load	ssj_ops	Average Active Power (W)	
100%	99.2%	308,022	269	1,144
90%	90.2%	280,134	264	1,063
80%	80.0%	248,304	256	971
70%	69.9%	217,096	247	877
60%	60.1%	186,594	238	785
50%	49.6%	154,075	227	680
40%	39.9%	123,805	215	575
30%	29.9%	92,944	203	459
20%	20.1%	62,364	189	330
10%	10.0%	31,049	174	178
Active Idle		0	160	0
$\Sigma \text{ssj\_ops} / \Sigma \text{power} =$				698

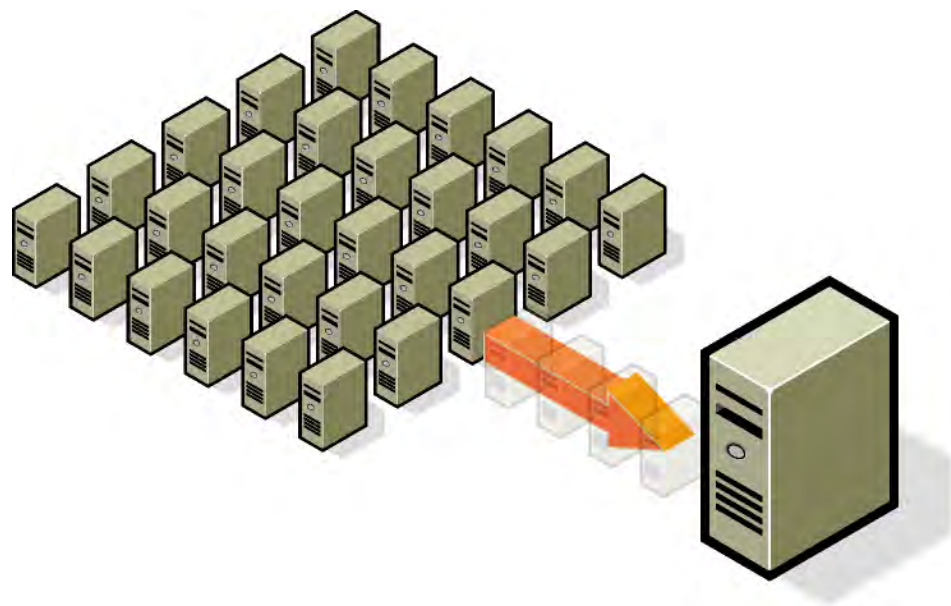


## PHYSICALLY RETIRE AN INEFFICIENT OR UNUSED SYSTEM

- **Uptime Institute reported 15-30% of servers are on but not being used**
- **Decommissioning goals include:**
  - Regularly inventory and monitor
  - Consolidate/retire poorly utilized hardware

# Virtualize and Consolidate Servers and Storage

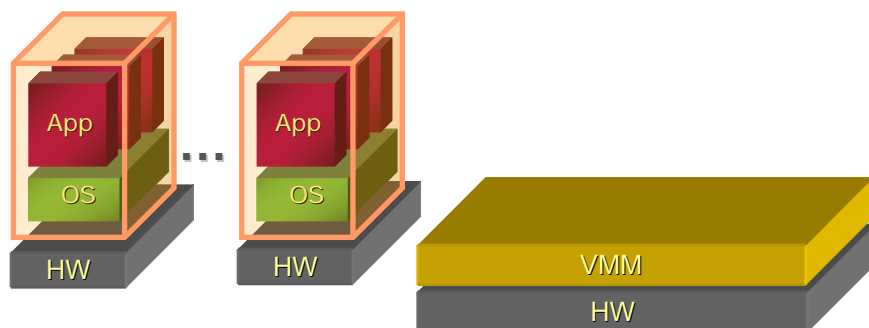
- Run many “virtual” machines on a single “physical” machine
- Consolidate underutilized physical machines, increasing utilization
- Energy saved by shutting down underutilized machines



# Virtualize and Consolidate Servers and Storage

## Virtualization: Workload provisioning

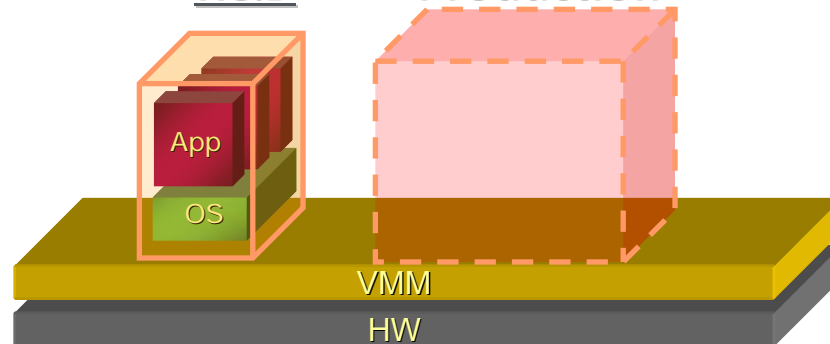
### Server Consolidation



10:1 in many cases

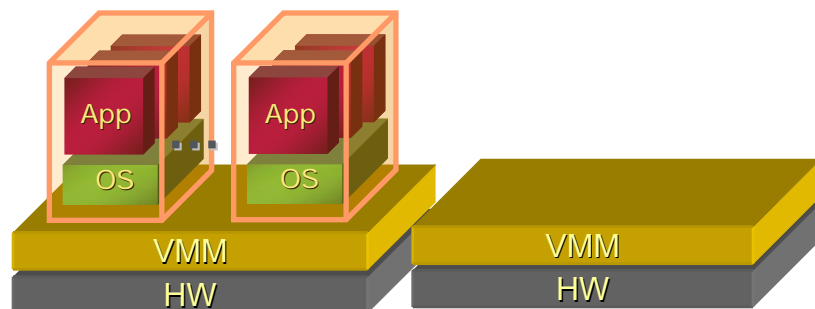
### R&D

### Production



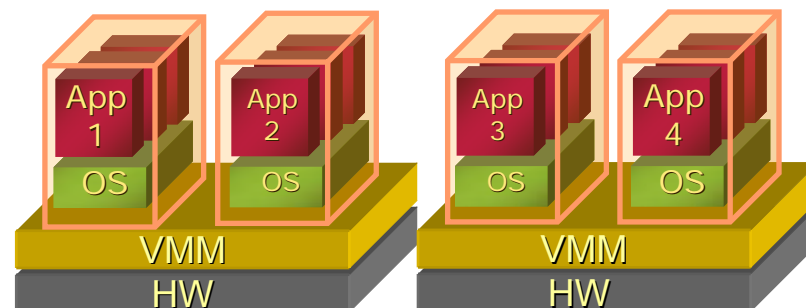
Enables rapid deployment,  
reducing number of idle, staged servers

### Disaster Recovery



- Upholding high-levels of business continuity
- One Standby for many production servers

### Dynamic Load Balancing



CPU Usage



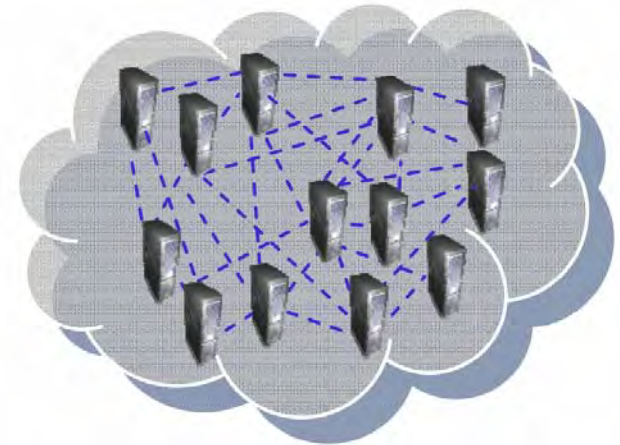
CPU Usage



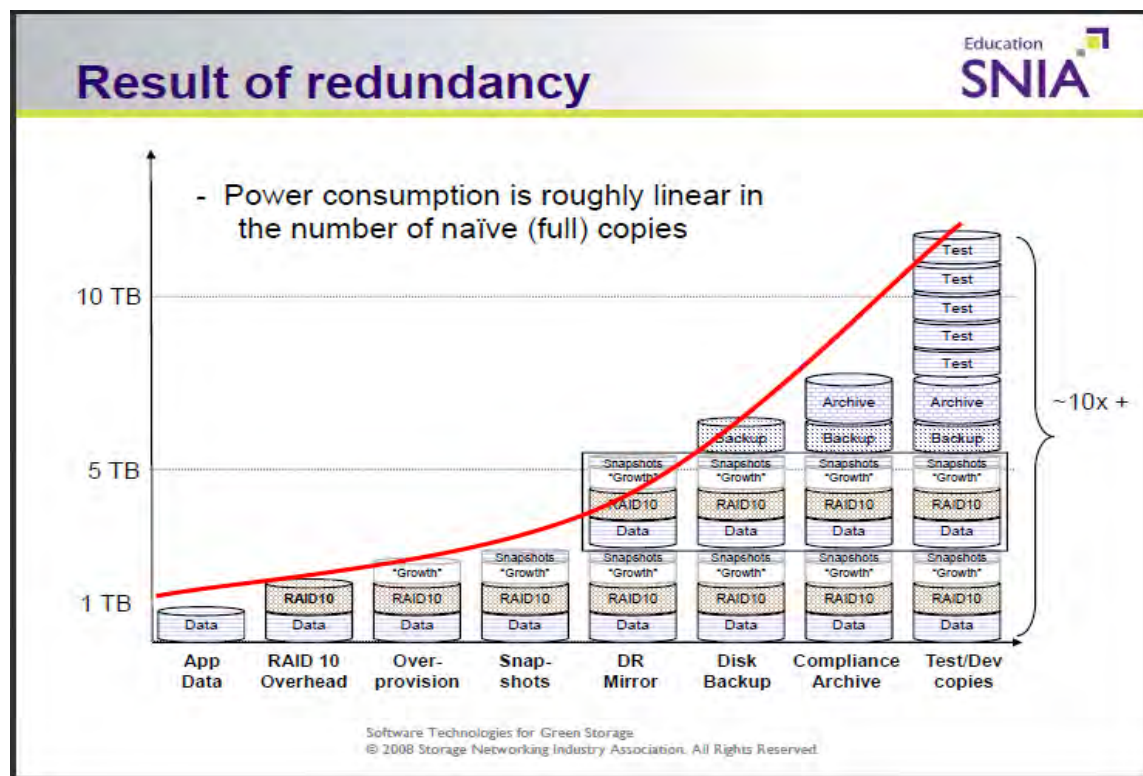
Balancing utilization with head room

## Virtualized cloud computing can provide...

- Dynamically scalable resources over the internet
- Can be internal or external
- Can balance different application peak loads
- Typically achieves high utilization rates

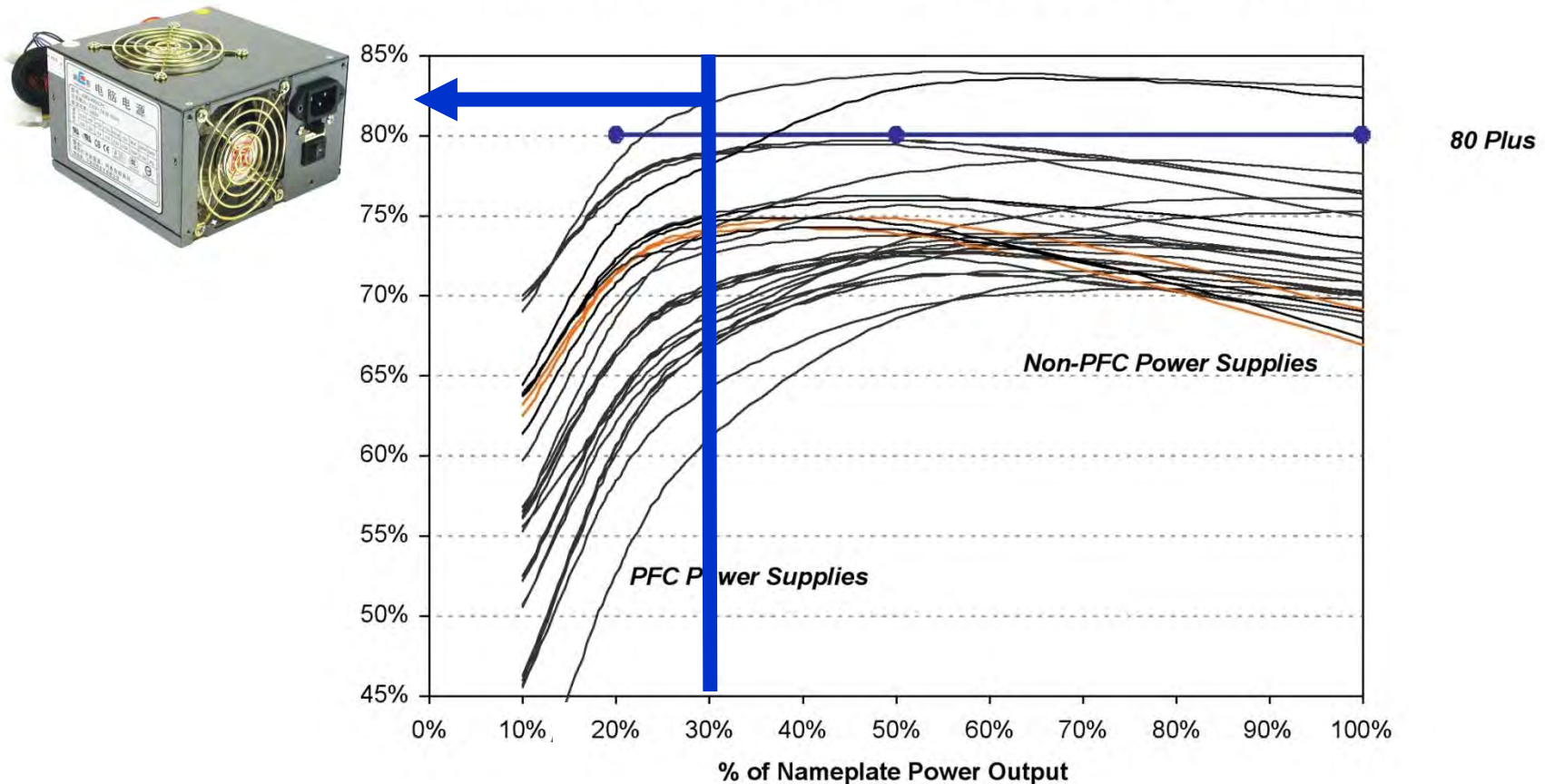


- Power roughly linear to storage modules
- Storage redundancy significantly increases energy
- Consider lower energy hierarchal storage
- Storage De-duplication - Eliminate unnecessary copies



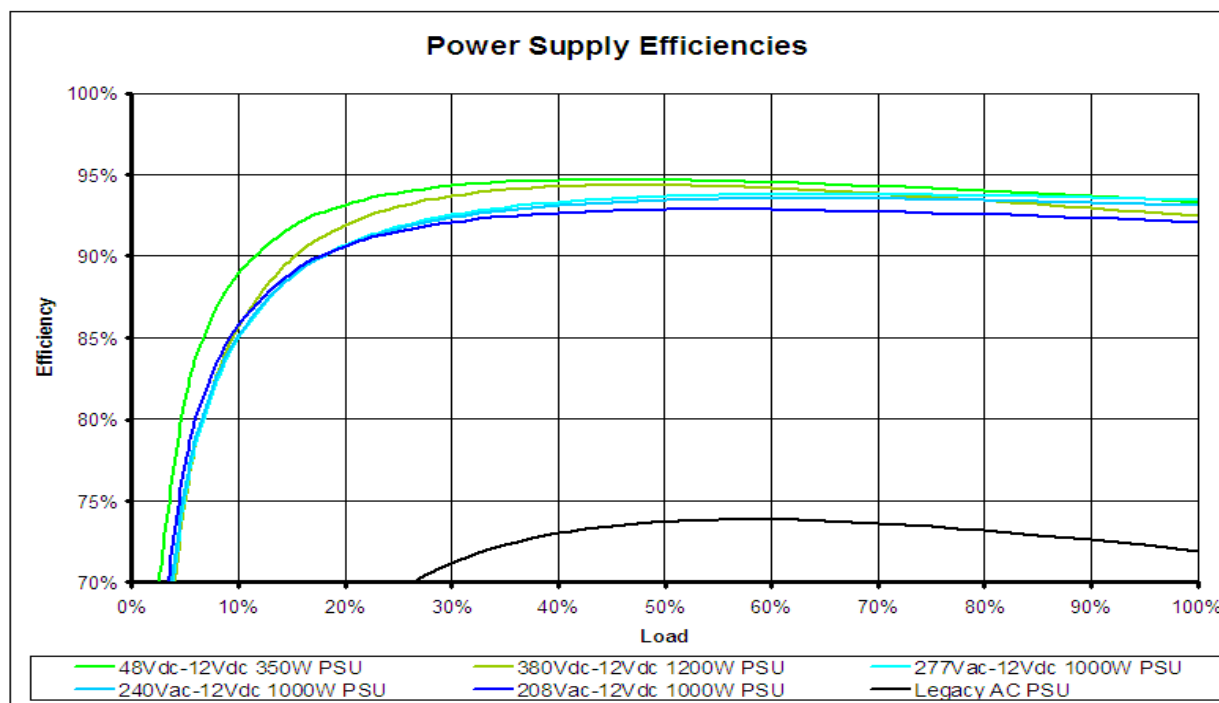
## LBLN/EPRI measured power supply efficiency

Measured Server Power Supply Efficiencies (all form factors)



## Power Supply Units

- Most efficient in the mid-range of performance curves
- Right-size for load
- Power supply redundancy puts operation lower on the curve
- Use Energy Star or Climate Savers power supplies

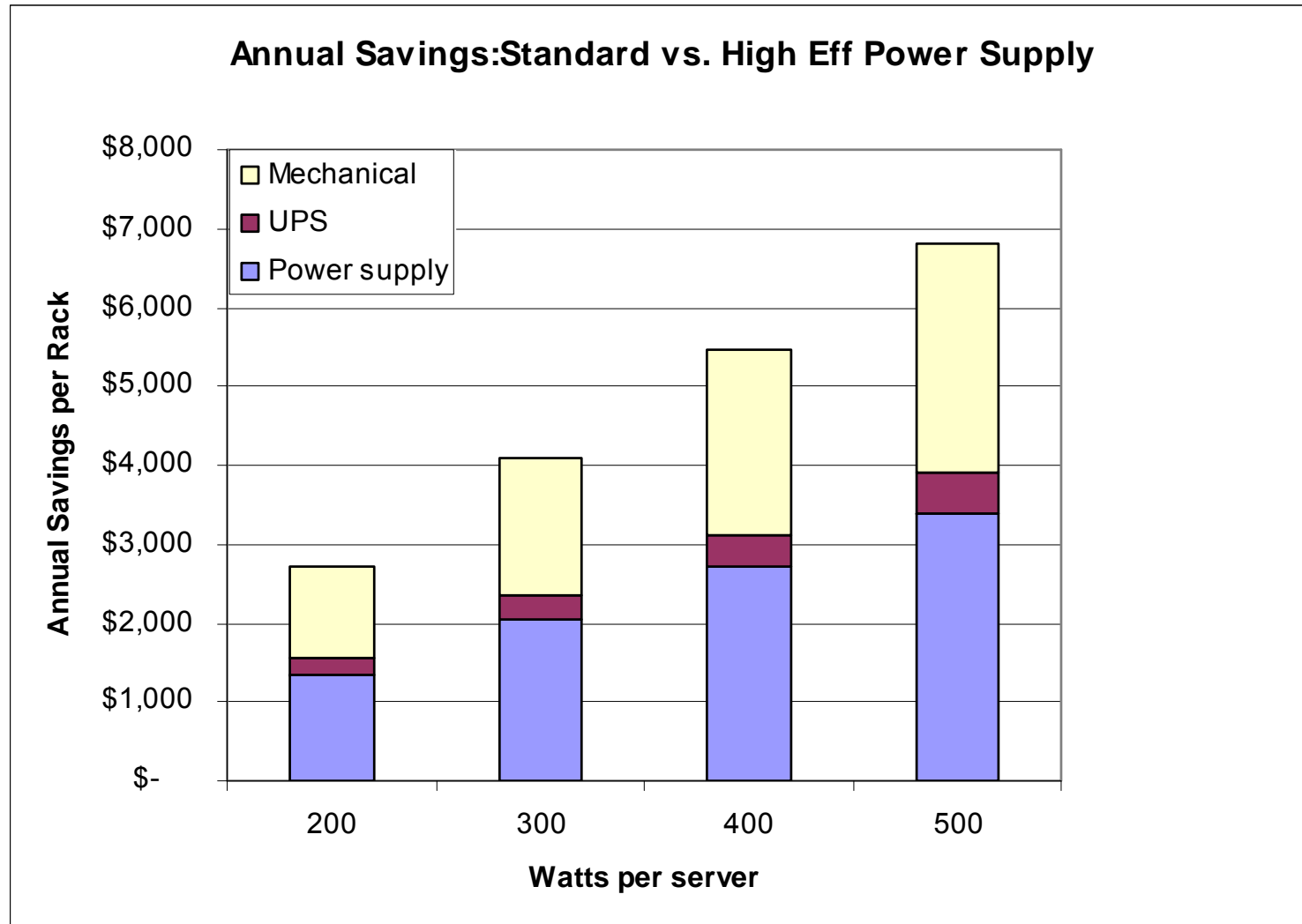


Source: The Green Grid

## 80 PLUS Certification Levels

Level of Certification	Efficiency at Rated Load					
	115V Internal Non-Redundant			230V Internal Redundant		
	20%	50%	100%	20%	50%	100%
<b>80 PLUS</b>	80%	80%	80%	n/a	n/a	n/a
<b>80 PLUS Bronze</b>	82%	85%	82%	81%	85%	81%
<b>80 PLUS Silver</b>	85%	88%	85%	85%	89%	85%
<b>80 PLUS Gold</b>	87%	90%	87%	88%	92%	88%
<b>80 PLUS Platinum</b>	n/a	n/a	n/a	90%	94%	91%

## Power supply savings add up...



# IT System Efficiency Summary...

## Servers



- Enable *power management capabilities!*
- Use EnergyStar® Servers

## Power Supplies



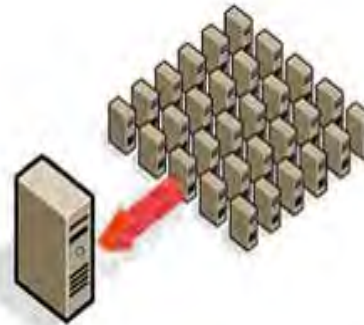
- Reconsider Redundancy
- Use 80 PLUS or Climate Savers products

## Storage Devices



- Take superfluous data offline
- Use thin provisioning technology
- De-duplicate

## Consolidation



- Use virtualization
- Consider cloud services

## Server System Infrastructure

*Managing Component Interfaces*

- [www.ssiforums.org](http://www.ssiforums.org)
- [www.80plus.org](http://www.80plus.org)
- [www.climatesaverscomputing.org](http://www.climatesaverscomputing.org)
- <http://tc99.ashraetcs.org/>



**ASHRAE**  
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.  
**ASHRAE Technical Committee 9.9**



# Questions?





## Using IT to Manage IT

Innovative Application of IT in Data Centers for Energy Efficiency



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**

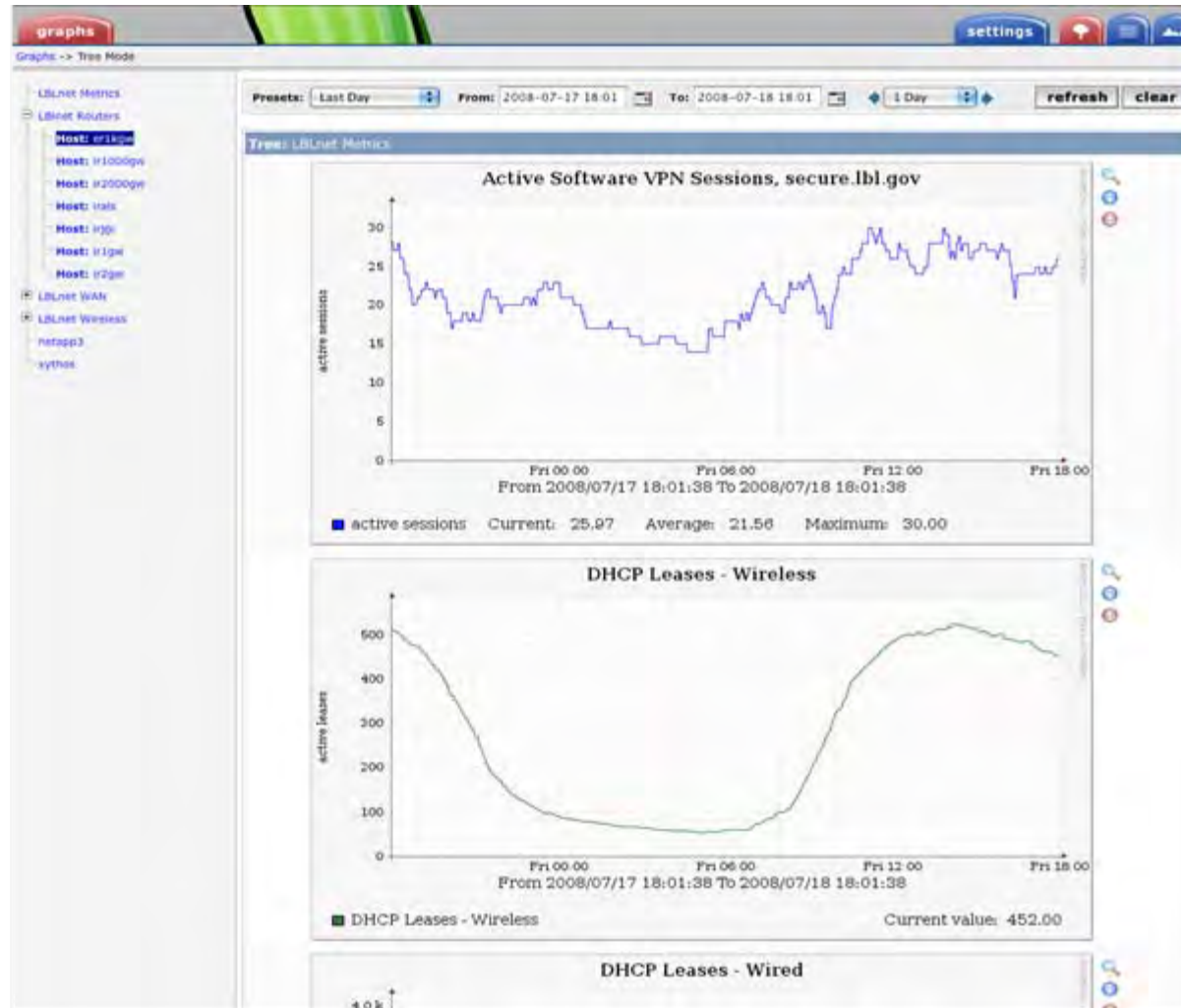


## Using IT to Save Energy in IT:

- Most operators lack “visibility” into their data center environment.
- An operator can’t manage what they don’t measure.
- Goals:
  - Provide the same level of monitoring and visualization of the physical space that exists for monitoring the IT environment.
  - Measure and track performance metrics.
  - Spot problems before they result in high energy cost or down time.

# The Importance of Visualization

- IT Systems & network administrators have tools for visualization.
- Useful for debugging, benchmarking, capacity planning, forensics.
- Data center facility managers have had comparatively poor visualization tools.



- ✓ LBNL installed 800+ point sensor network.
- ✓ Measures:
  - Temperature
  - Humidity
  - Pressure (under floor)
  - Electrical power
- ✓ Presents real-time feedback and historic tracking
- ✓ Optimize based on empirical data, not intuition.

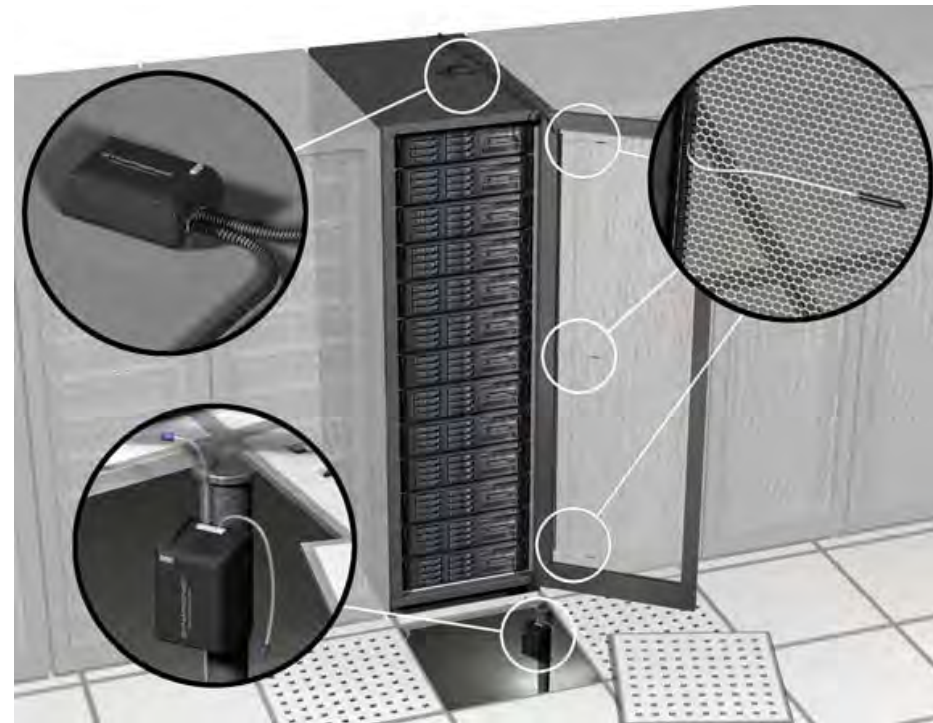
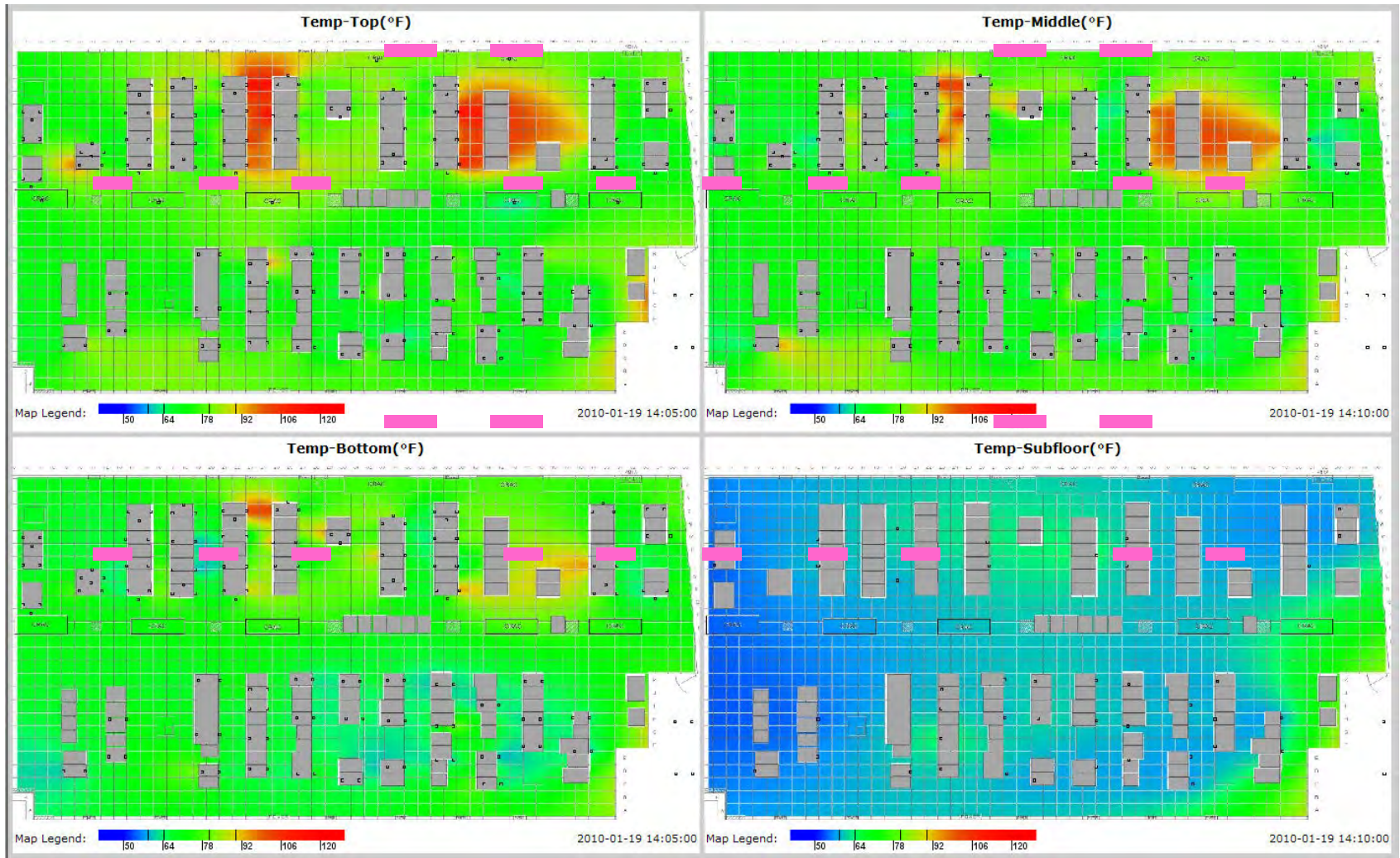
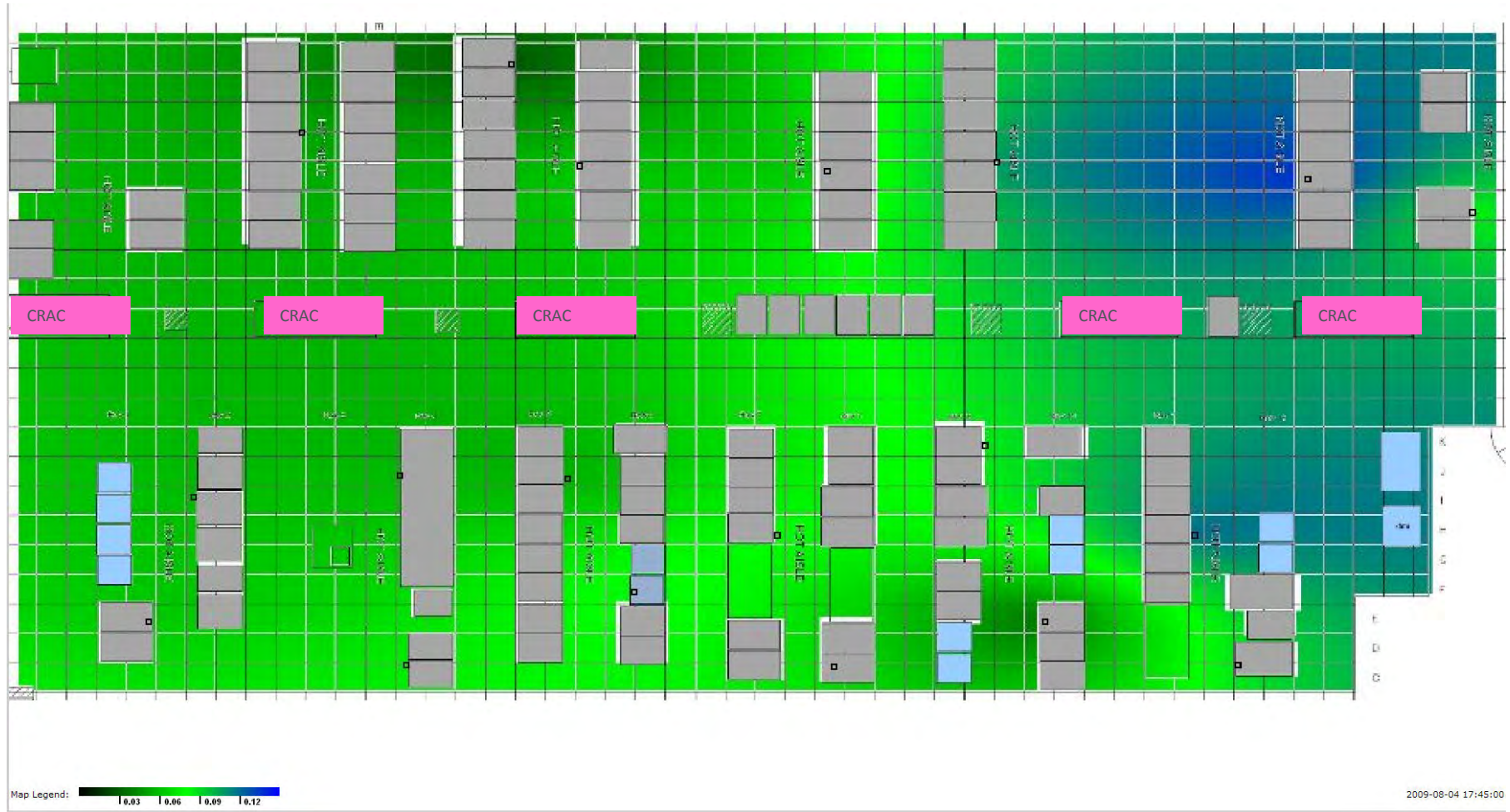


Image: SynapSense

# Real-time Temperature Visualization by Level



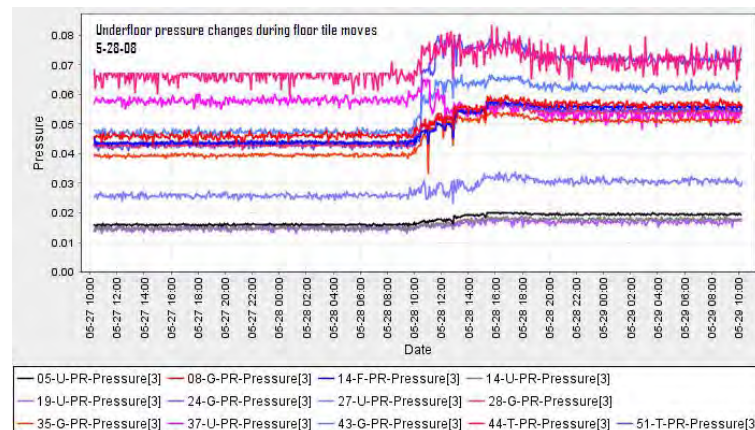
# Displayed Under-floor Pressure Map...



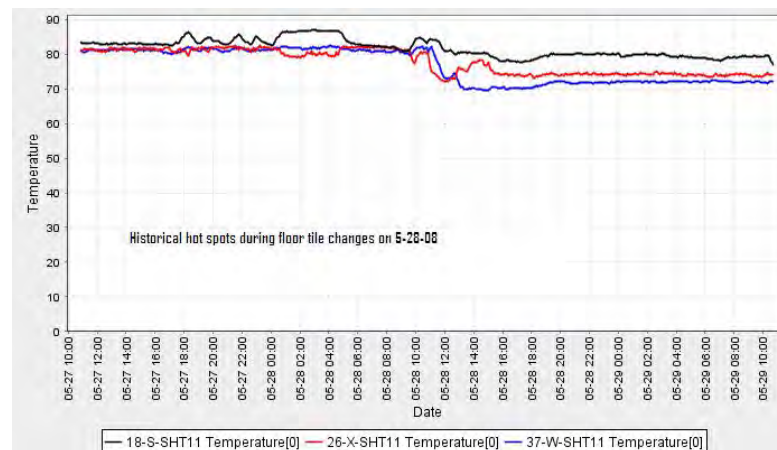
# Provided Real-time Feedback During Floor-tile Tuning

- ✓ Removed guesswork by monitoring and using visualization tool.

## Under-Floor Pressure



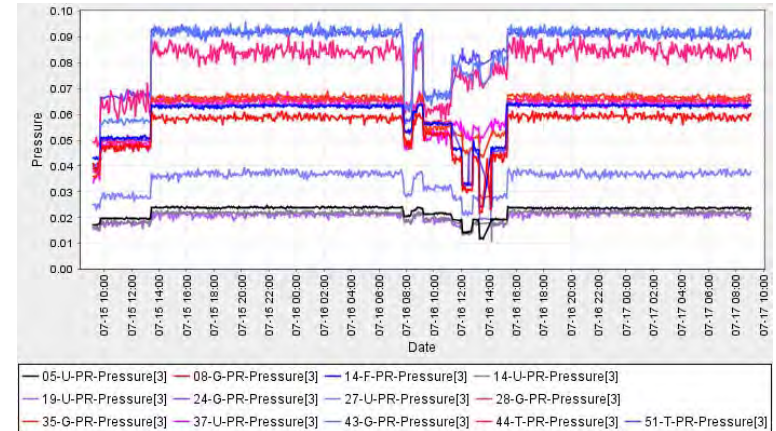
## Rack-Top Temperatures



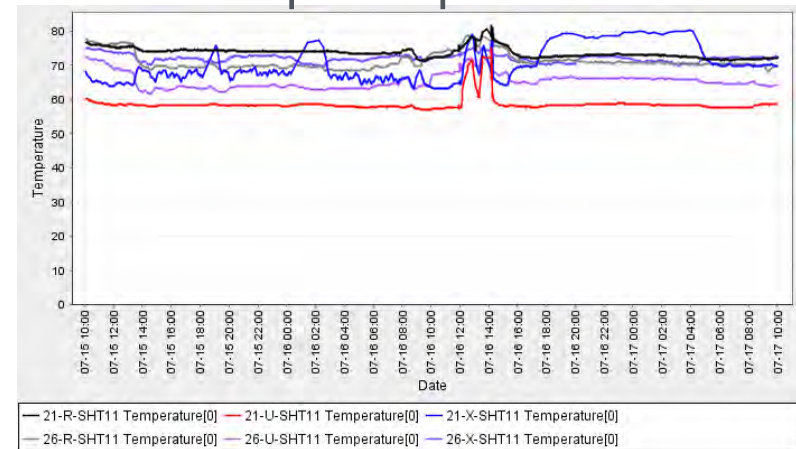
# Determined Relative CRAC Cooling Energy Impact

- Enhanced knowledge of data center redundancy.
- Turned off unnecessary CRAC units to save energy.

## Under-Floor Pressure

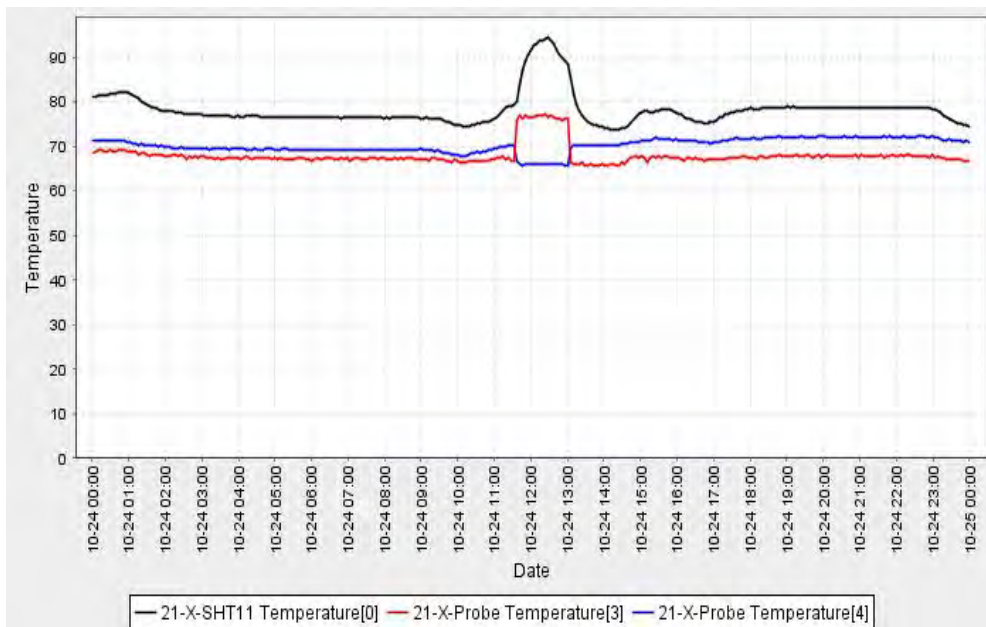


## Rack-Top Temperatures



# Feedback Continues to Help: Note impact of IT cart!

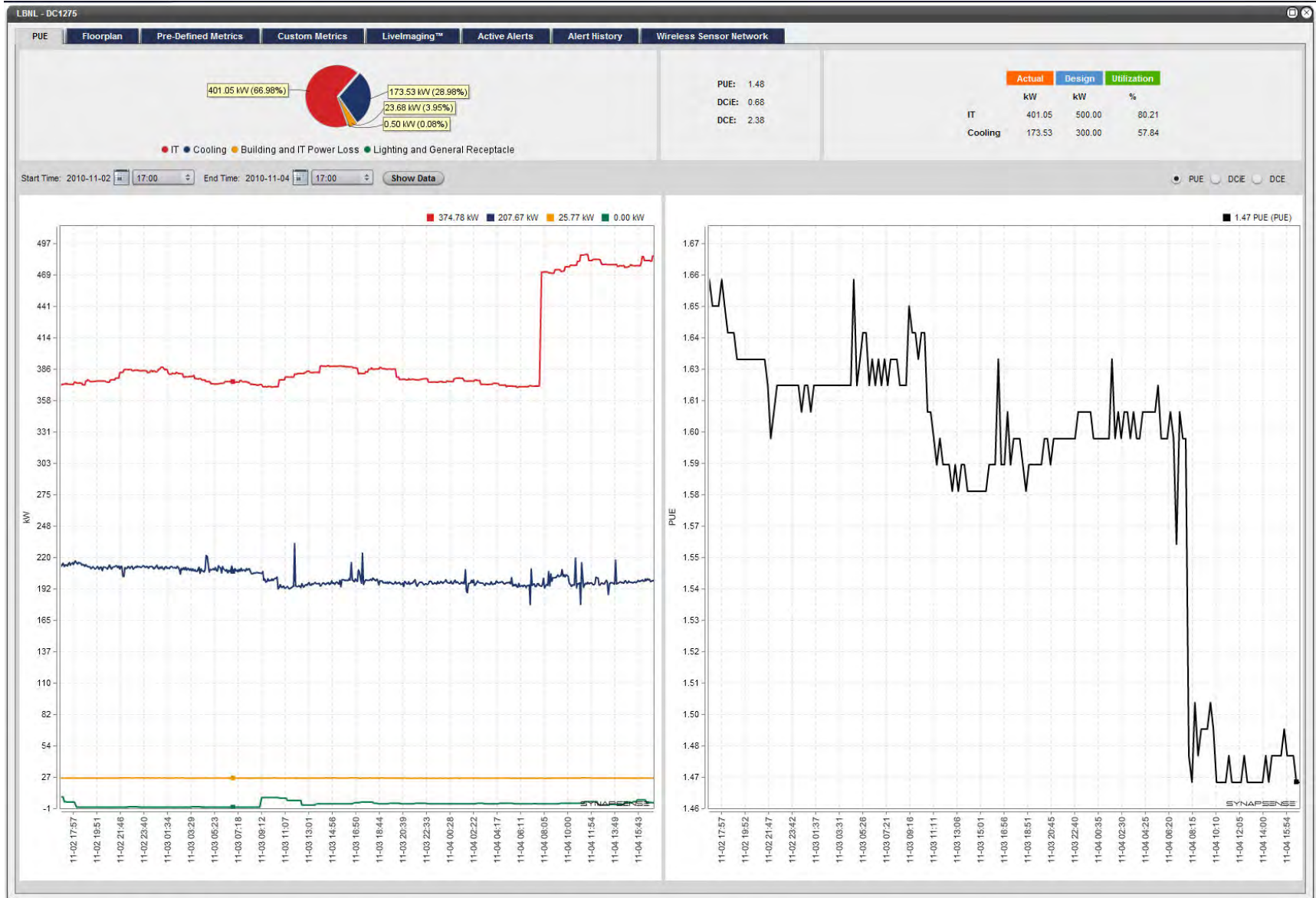
Real-time feedback identified  
cold aisle air flow obstruction!



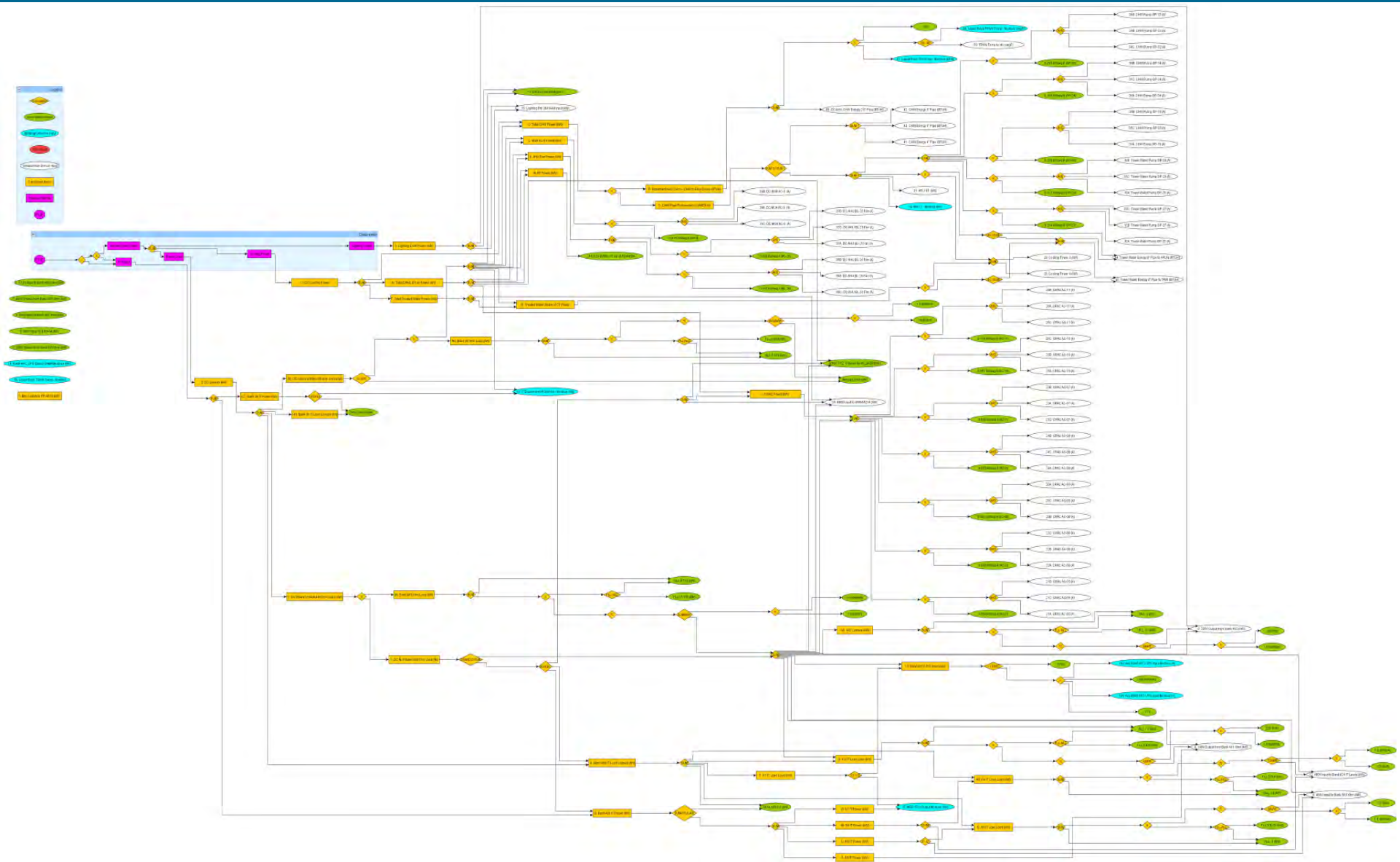
# Real-time PUE Display

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy



# PUE Calculation Diagram



# Franchise Tax Board (FTB) Case Study

## Description:

- 10,000 Sq Ft
- 12 CRAH cooling units
- 135 kW load

## Challenges:

- Over-provisioned
- History of fighting
- Manual shutoff not successful

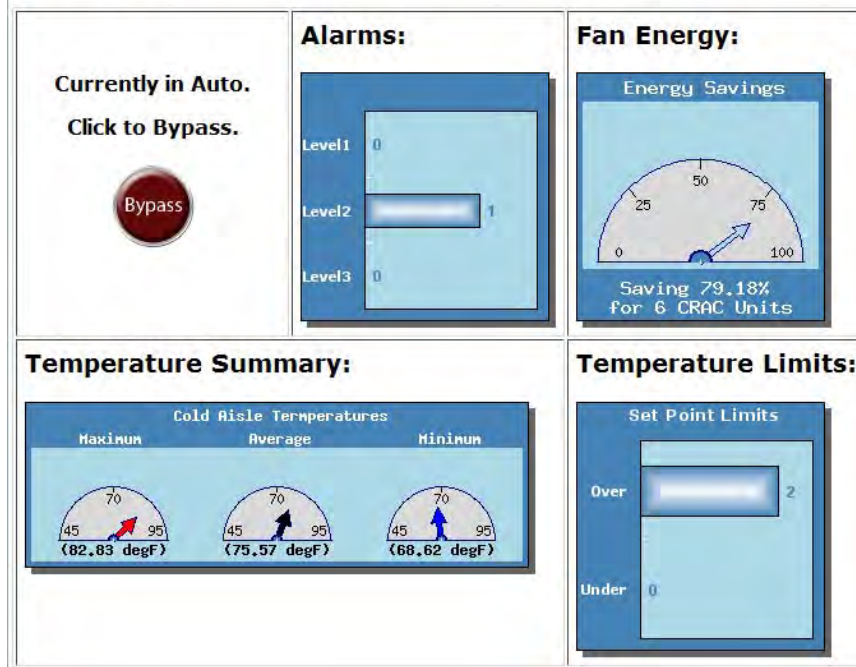
## Solution:

- Intelligent supervisory control software with inlet air sensing



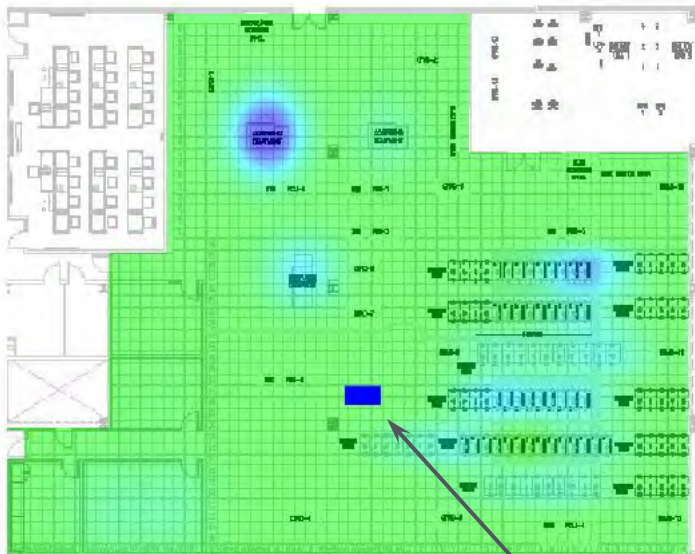
- WSN included 50 wireless temperature sensors (Dust Networks radios)
- Intelligent control software

## FACS Dashboard:

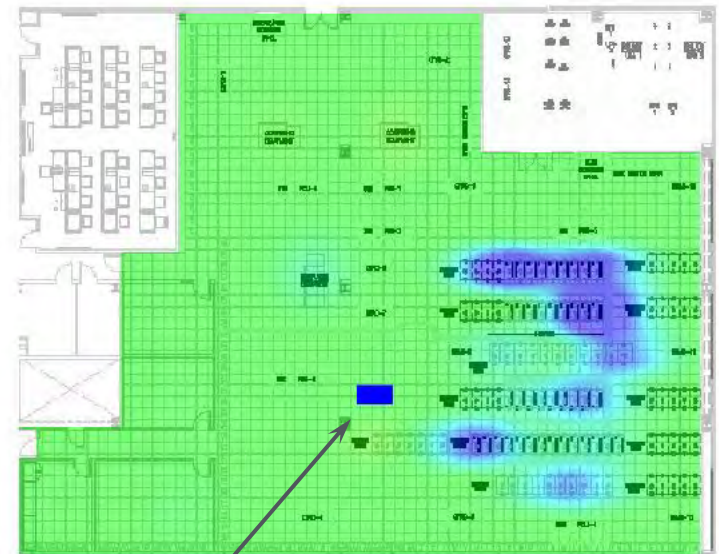


# WSN Smart Software: learns about curtains

CRAH 3 influence at start

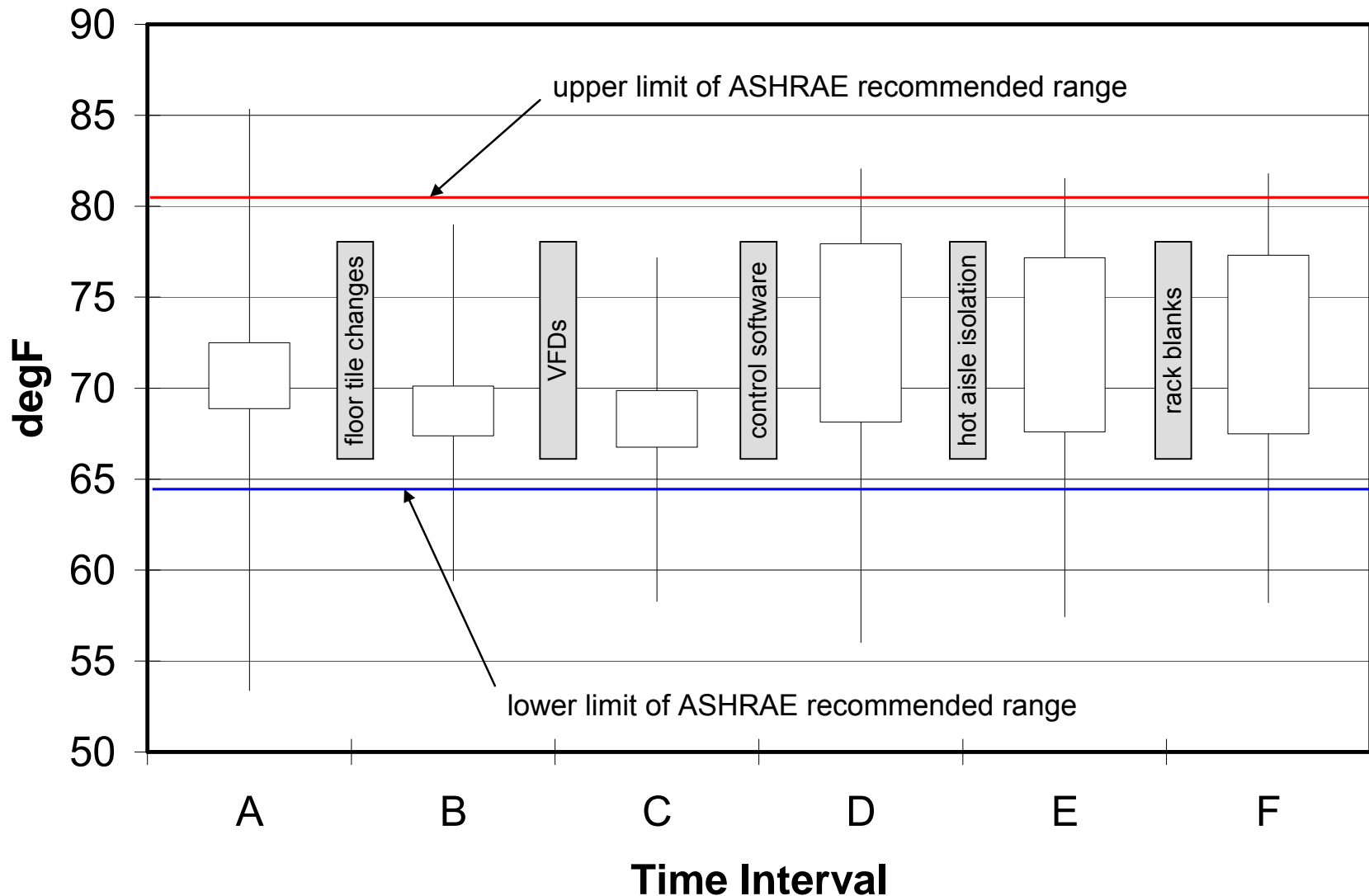


CRAH 3 influence after curtains

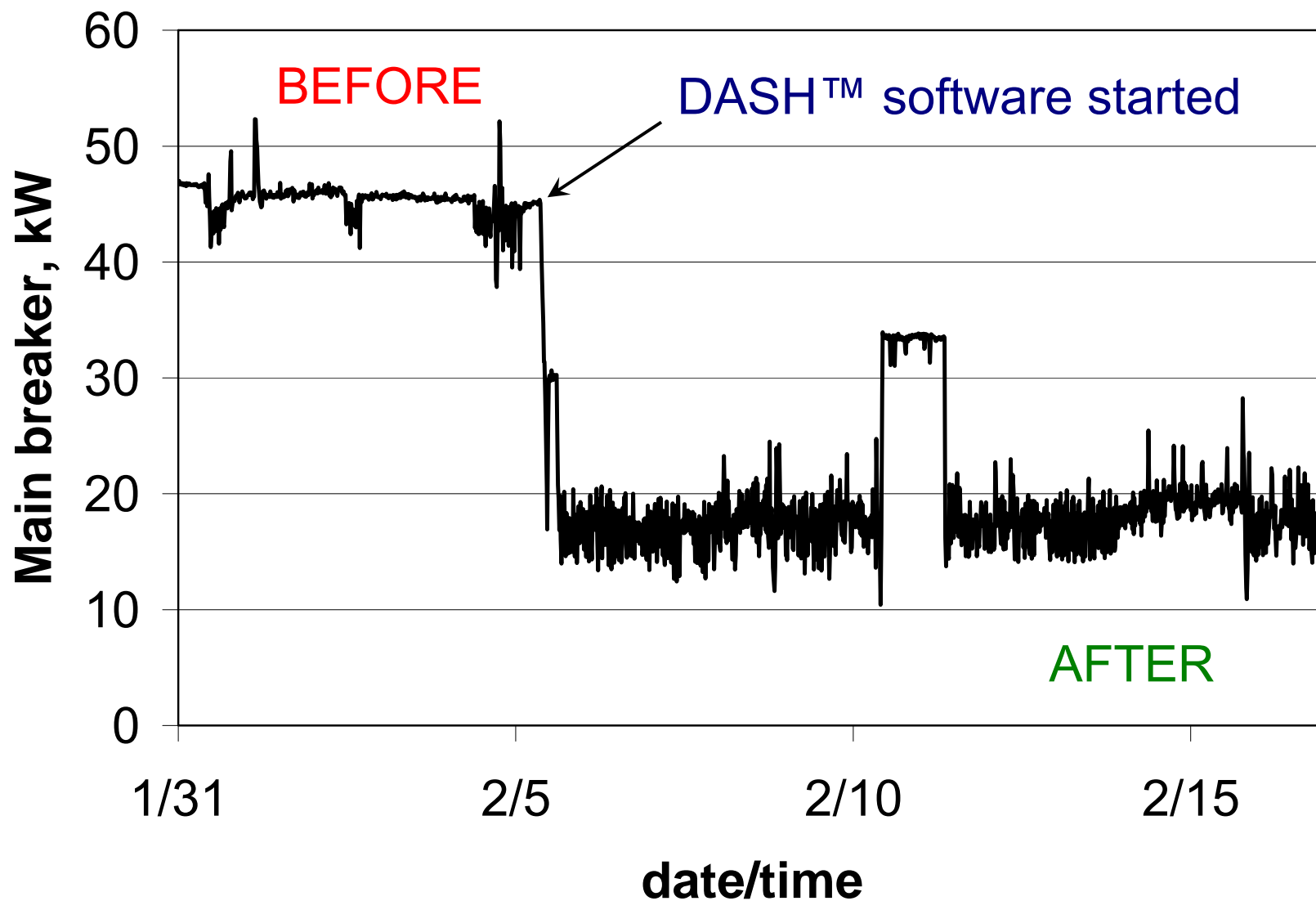


CRAH-03

# WSN Provided Effect on Cold-aisle Temperatures:



# WSN Software = Dramatic Energy Reduction...

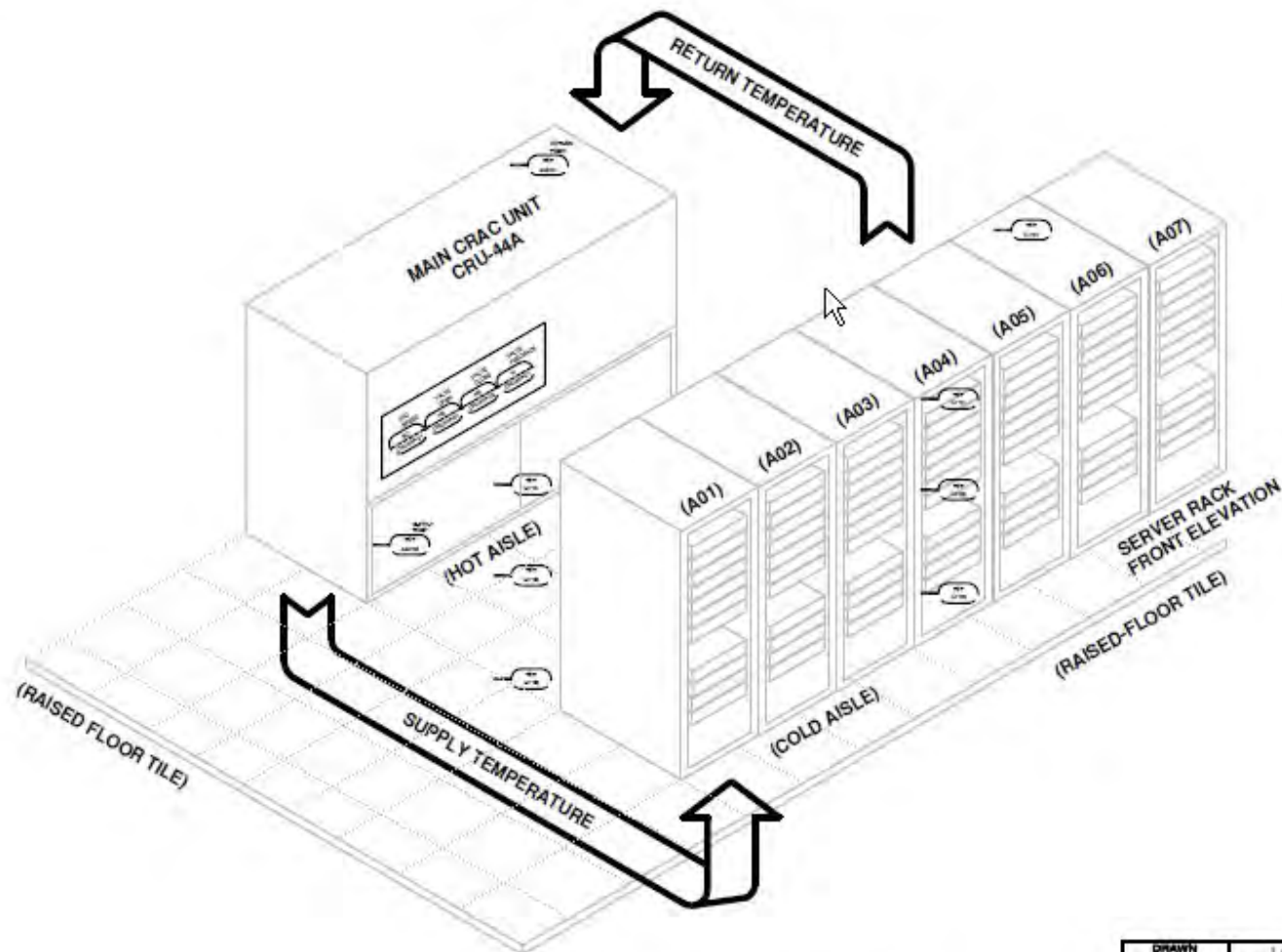


- DASH cost-benefit (sensors and software)
  - Cost: \$56,824
  - Savings: \$30,564
  - Payback: 1.9 years
- Total project cost-benefit
  - Cost: \$134,057
  - Savings: \$42,772
  - Payback: 3.1 years

## Control data center air conditioning using the *built-in* IT server-equipment temperature sensors

- **Typically**, data center cooling uses *return air temperature* as the primary control-variable
  - ASHRAE and IT manufacturers agree IT equipment inlet air temperature is the key parameter
  - Optimum control difficult
- IT equipment has multiple sensors used to protect itself by adjusting internal fans, clock speeds, etc.
- One such sensor is typically located at the air inlet to the IT equipment - monitoring intake conditions
- Information from these sensors is available on the IT network





**SC11 DATA CENTER HVAC MECHANICAL DIAGRAM**

DRAWN RJM	LAWRENCE BERKELEY NATIONAL LABORATORY INTEL CORPORATION
CHECKED DS	
DATE 03/07/2006	HVAC CONTROLS DEMONSTRATION PROJECT
DWG. NO. LBNL-DIAG-1	

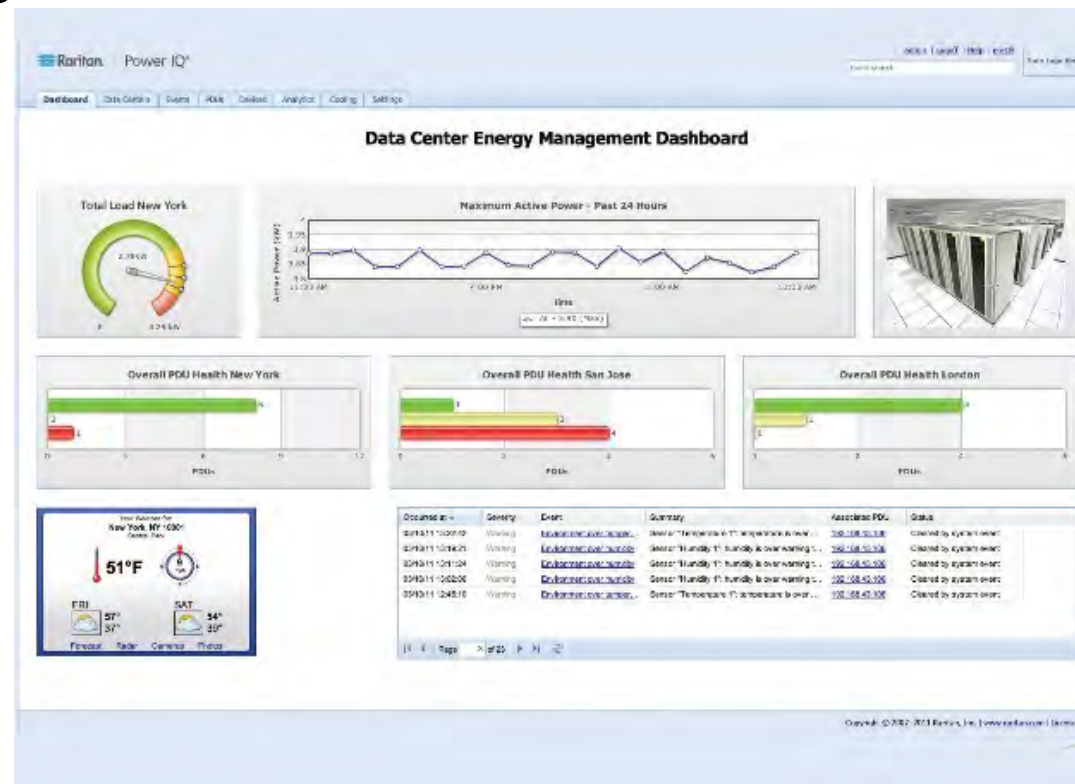
- Demonstration showed:
  - Servers can provide temperature data to facilities control system
  - Given server inlet temperature, facility controls improved temperature control and efficiency
  - Effective communications and control accomplished without significant interruption or reconfiguration of systems

Dashboards can display multiple systems' information for monitoring and maintaining data center performance

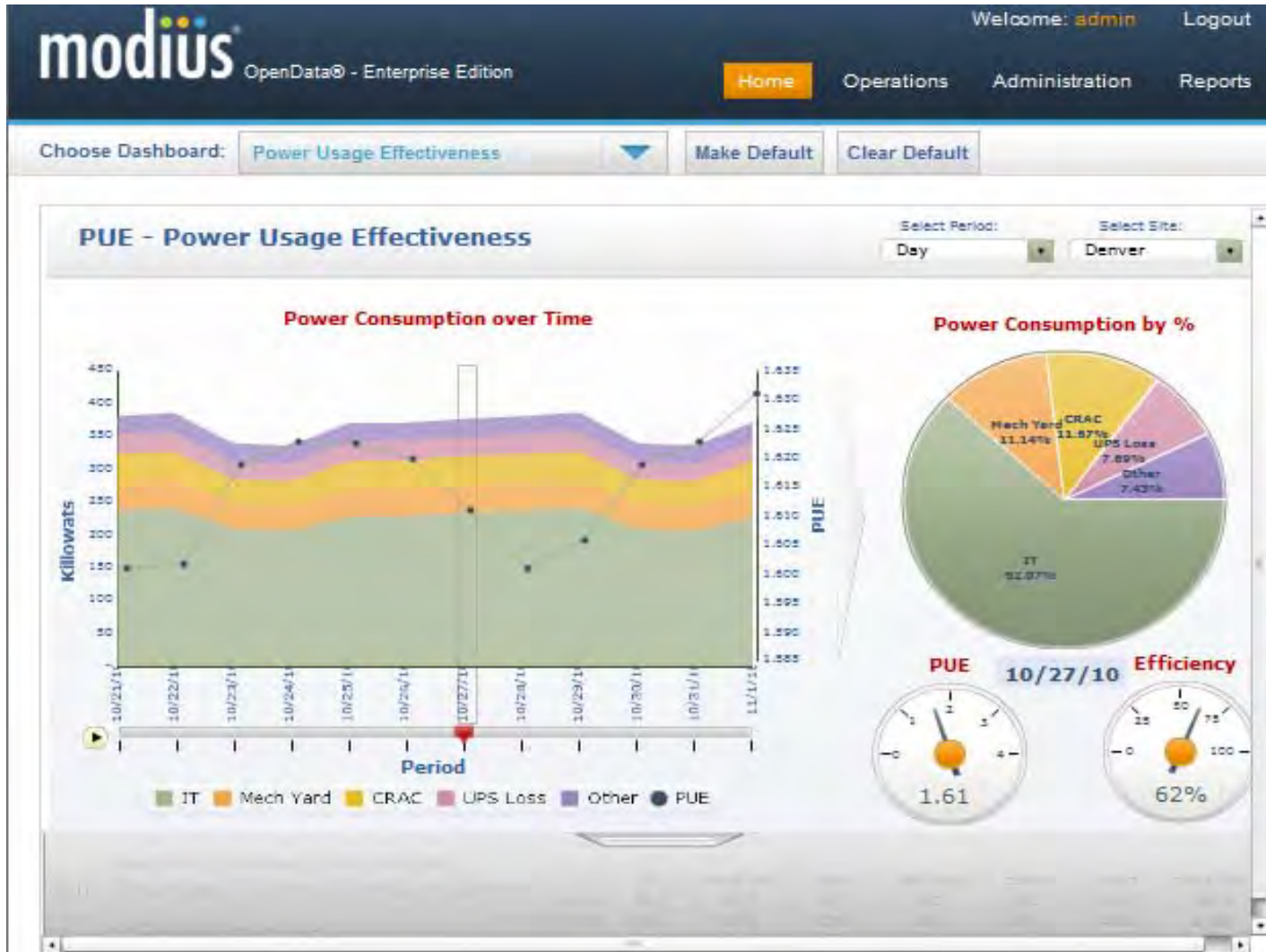


# Why Dashboards?

- Provide IT and HVAC system performance at a glance
- Identify operational problems
- Baseline energy use and benchmark performance
- View effects of changes
- Share information and inform integrated decisions



# Another Dashboard Example...



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



- **Evaluate monitoring systems to enhance operations and controls**
- **Install dashboards to manage and sustain energy efficiency.**

# Questions?





## Environmental Conditions



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



## What are the main HVAC Energy Drivers?

- IT Load
- Climate
- **Room temperature and humidity**
  - Most data centers are overcooled and have humidity control issues
  - Human comfort should not be a driver

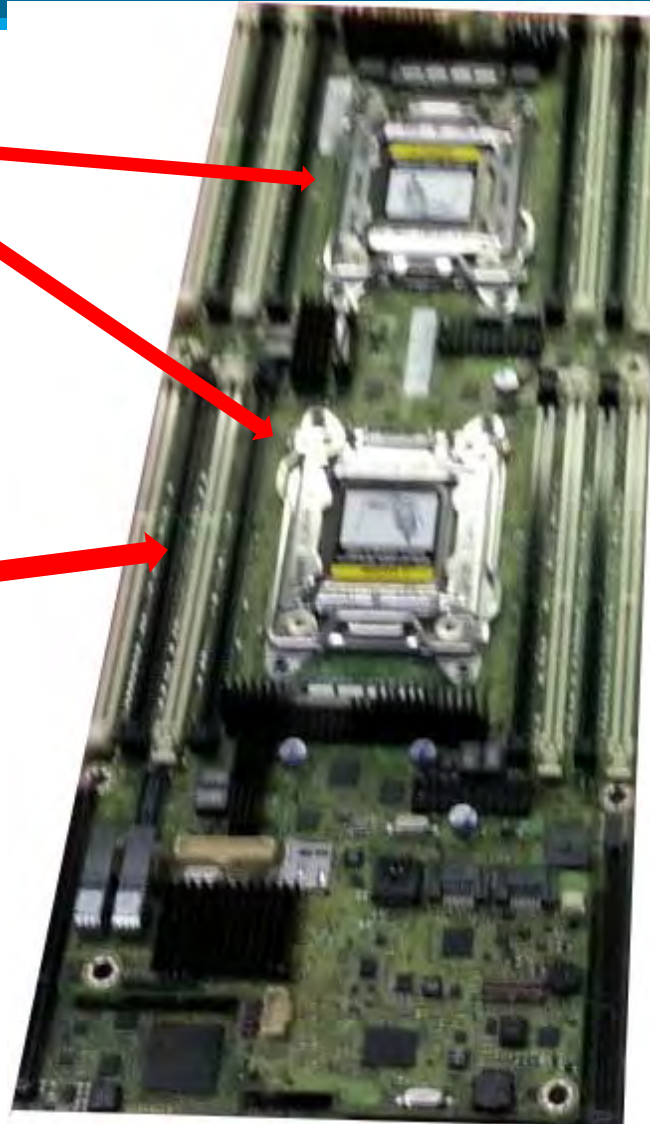
# Safe Temperature Limits

CPU

~65C  
(149F)

Memory

~85C  
(185F)



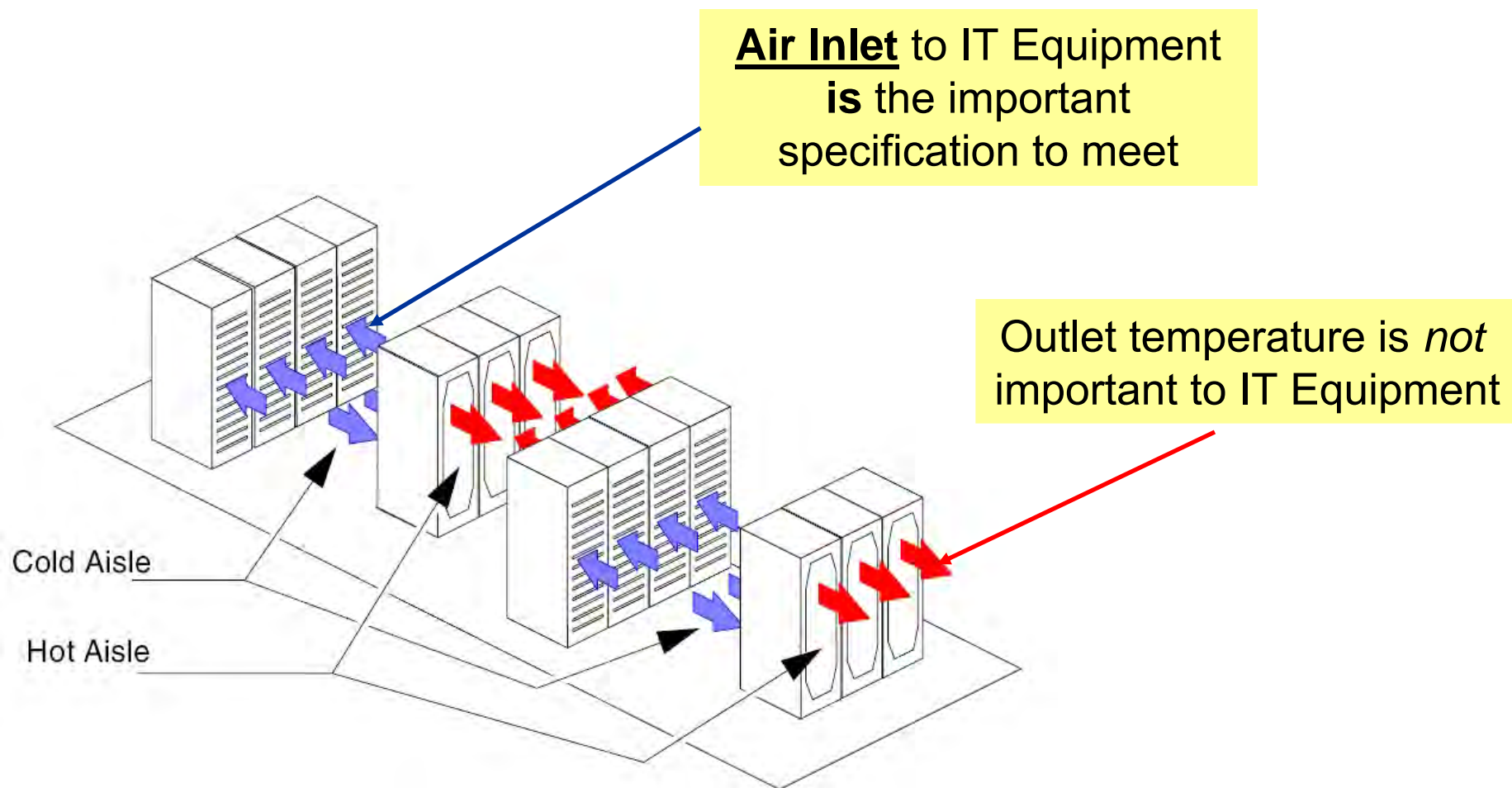
GPU

~75C  
(167F)

So why do we  
need jackets in  
data centers?

CPU, GPU & Memory, represent ~75-90% of heat load ...

# Equipment Environmental Specification



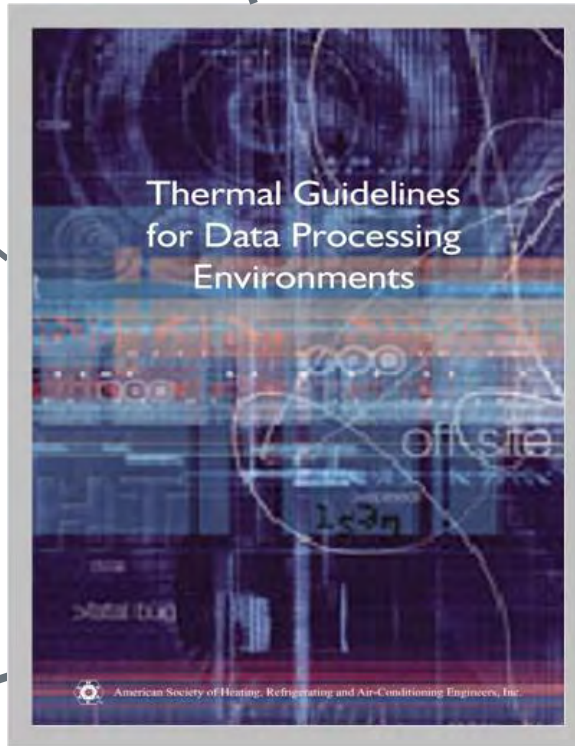
# ASHRAE Thermal Guidelines

## The defacto standard in the industry

Provides common understanding between IT and facility staff.

Developed with IT manufacturers

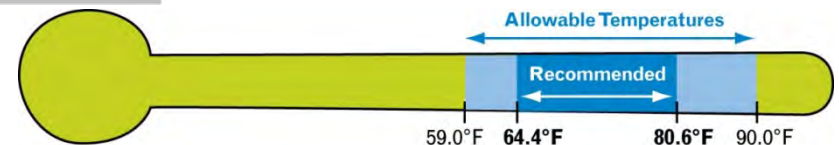
Recommends temperature range up to 80.6°F with “allowable” much higher.



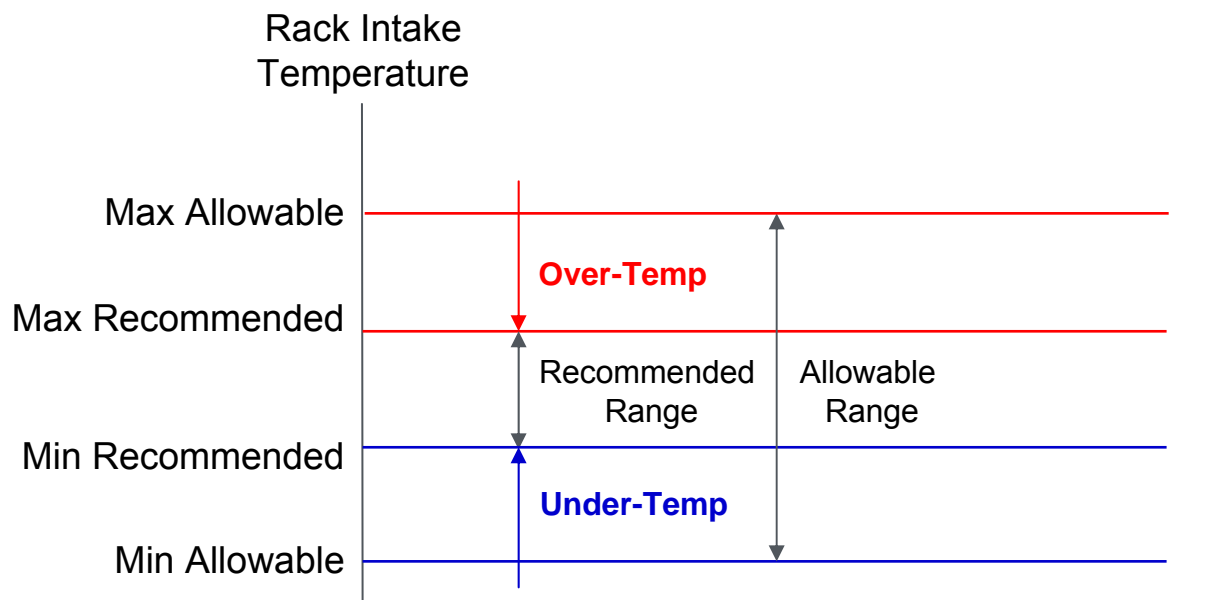
Six classes of equipment identified with wider allowable ranges to 45° C (113°F).

Provides more justification for operating above the recommended limits

Provides wider humidity ranges



- ❖ The recommended range is a statement of reliability. For extended periods of time, the IT manufacturers recommend that data centers maintain their environment within these boundaries.
- ❖ The allowable range is a statement of functionality. These are the boundaries where IT manufacturers test their equipment to verify that the equipment will function.

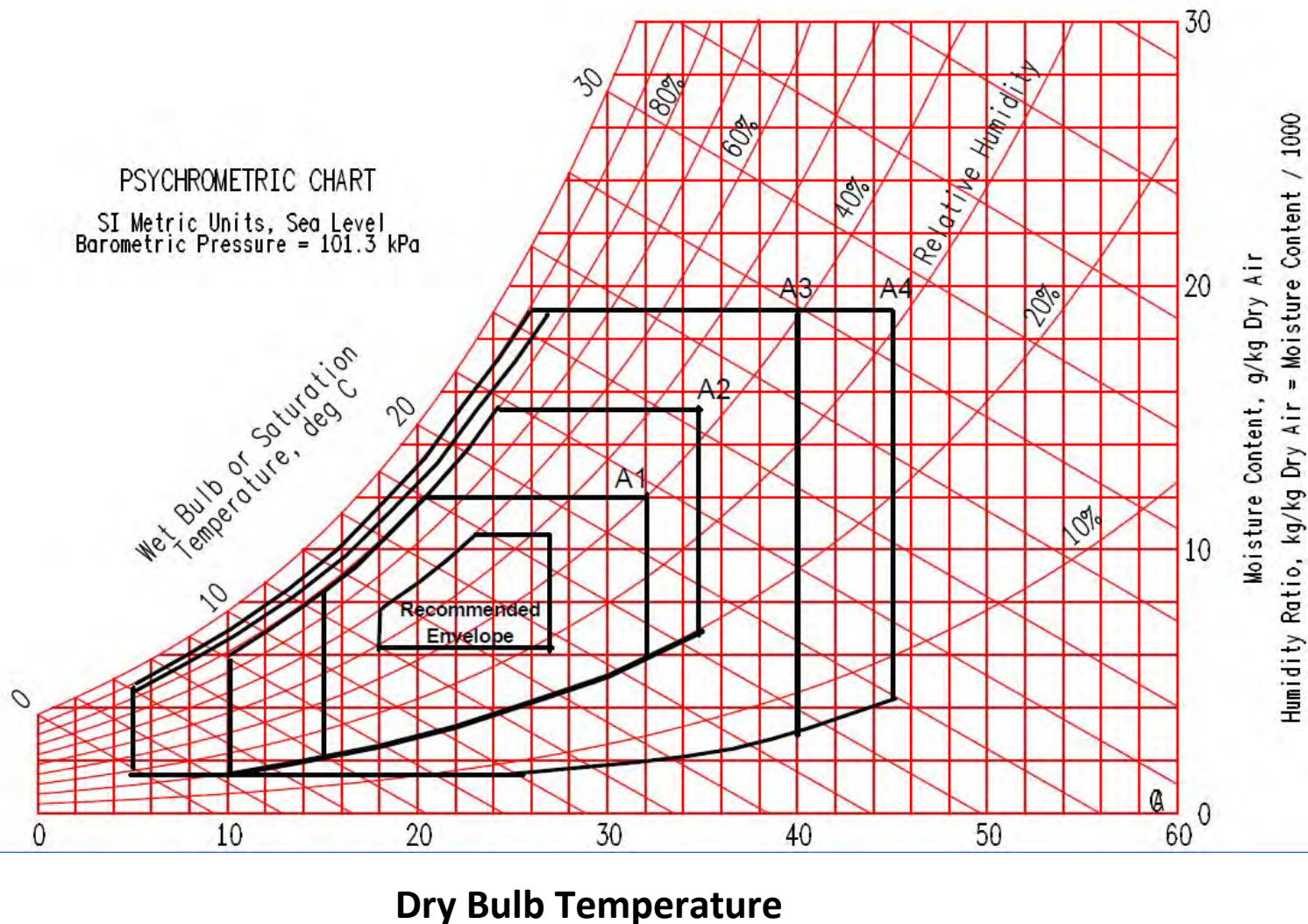


# 2011 ASHRAE Thermal Guidelines

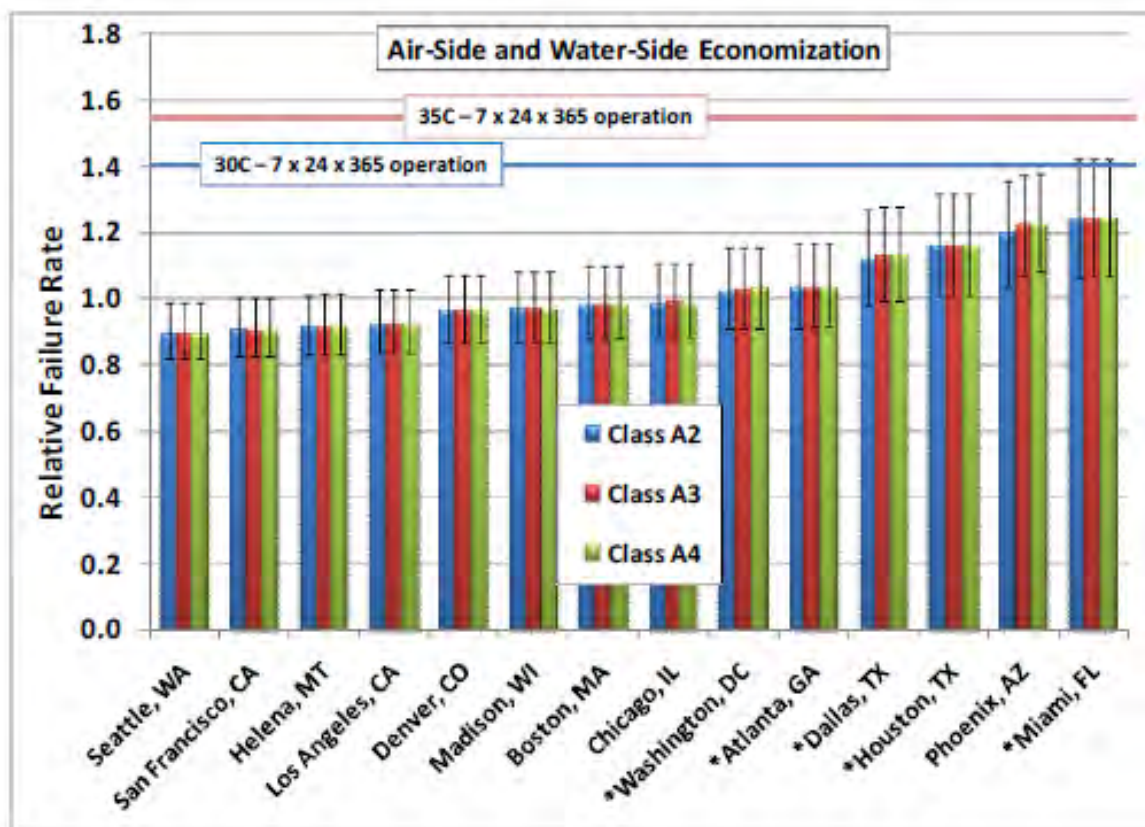
Classes (a)	Equipment Environmental Specifications							
	Product Operations (b)(c)					Product Power Off (c) (d)		
	Dry-Bulb Temperature (°C) (e) (g)	Humidity Range, non-Condensing (h) (i)	Maximum Dew Point (°C)	Maximum Elevation (m)	Maximum Rate of Change (°C/hr) (f)	Dry-Bulb Temperature (°C)	Relative Humidity (%)	Maximum Dew Point (°C)
<b>Recommended</b> (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	18 to 27	5.5°C DP to 60% RH and 15°C DP						
<b>Allowable</b>								
A1	15 to 32	20% to 80% RH	17	3050	5/20	5 to 45	8 to 80	27
A2	10 to 35	20% to 80% RH	21	3050	5/20	5 to 45	8 to 80	27
A3	5 to 40	-12°C DP & 8% RH to 85% RH	24	3050	5/20	5 to 45	8 to 85	27
A4	5 to 45	-12°C DP & 8% RH to 90% RH	24	3050	5/20	5 to 45	8 to 90	27
B	5 to 35	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29
C	5 to 40	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29

**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



# Thermal conditions are less relevant today



“...the *relative failure rate* shows the expected increase in the number of failed servers, not the percentage of total servers failing; e.g. if a data center that experiences 4 failures per 1000 servers incorporates warmer temperatures and the relative failure rate is 1.2, then the expected failure rate would be 5 failures per 1000 servers.”

## **ASHRAE's key conclusion when considering potential for increased failures at higher (allowable) temperatures:**

“For a majority of US and European cities, the air-side and water-side economizer projections show failure rates that are very comparable to a traditional data center run at a steady state temperature of 20°C.”

ASHRAE and a DOE High Performance Computer (HPC) user group have developing a white paper for liquid cooling

- Three temperature standards defined based on three mechanical system configurations:
  - Chilled water provided by a chiller (with or without a “tower side economizer”)
  - Cooling water provided a cooling tower with possible chiller backup
  - Cooling water provided by a dry cooler with possible backup using evaporation

# Summary Recommended Limits

Liquid Cooling Class	Main Cooling Equipment	Supplemental Cooling Equipment	Building Supplied Cooling Liquid Maximum Temperature
L1	Cooling Tower and Chiller	Not Needed	17°C (63°F)
L2	Cooling Tower	Chiller	32°C (89°F)
L3	Dry Cooler	Spray Dry Cooler, or Chiller	43°C (110°F)



## Environmental

### Temperature:

- Operating: 10° to 35°C (50° to 95°F)
- Storage: -40° to 65°C (-40° to 149°F)

### Relative humidity

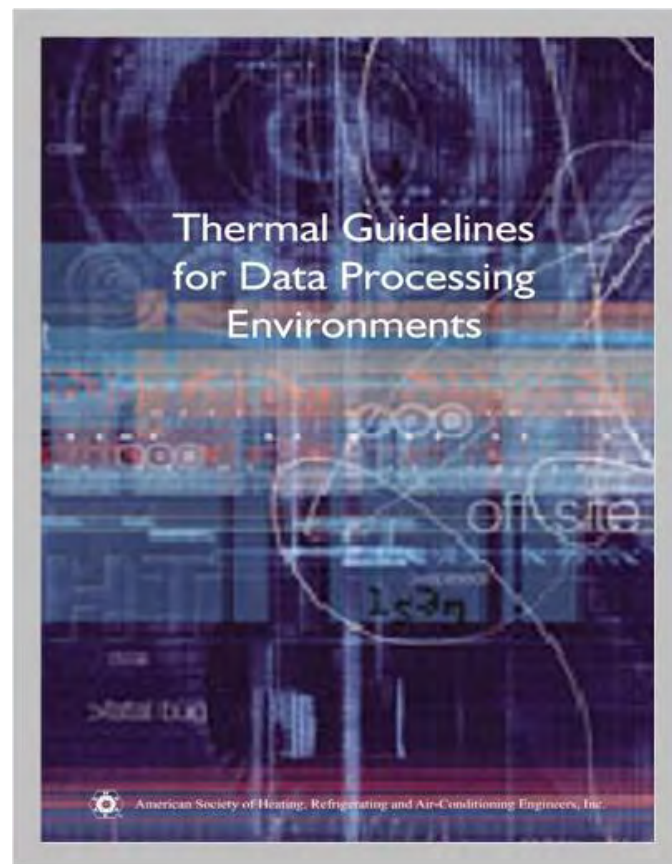
- Operating: 20% to 80% (non-condensing)
- Storage: 5% to 95% (non-condensing)

### Altitude

- Operating: -15 to 3048 m (-50 to 10,000 ft)
- Storage: -15 to 10,668 m (-50 to 35,000 ft)

# Environmental Conditions: Summary

- Most computer room air conditioners (CRACs) are controlled based on the return air temperature – *this needs to change*
- A cold data center = efficiency opportunity
- Perceptions, based on old technology lead to cold data centers with tight humidity ranges – *this needs to change.*
- Many IT manufacturers design for harsher conditions than ASHRAE guidelines
- Design Data Centers for IT equipment performance - *not people comfort.*
- **Address air management issues first**



# Questions?





# Airflow Management



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



# Air Management: The Early Days at LBNL

**It was cold but hot spots were everywhere**

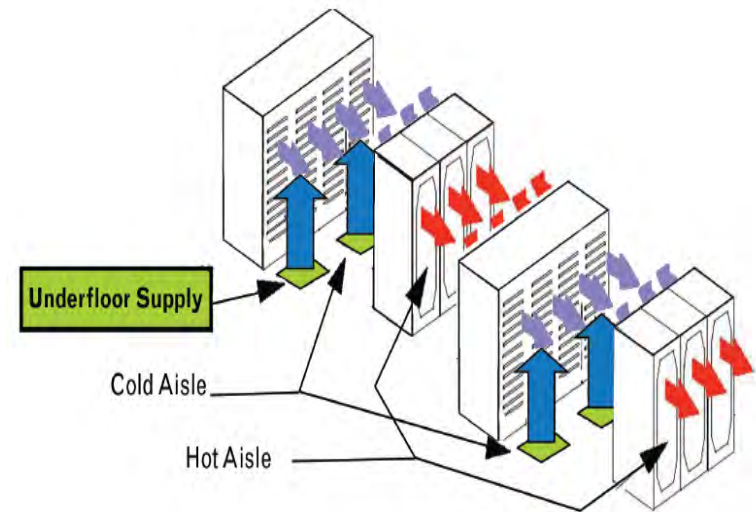


**Fans were used to redirect air**

**High flow tiles reduced air pressure**



- 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



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

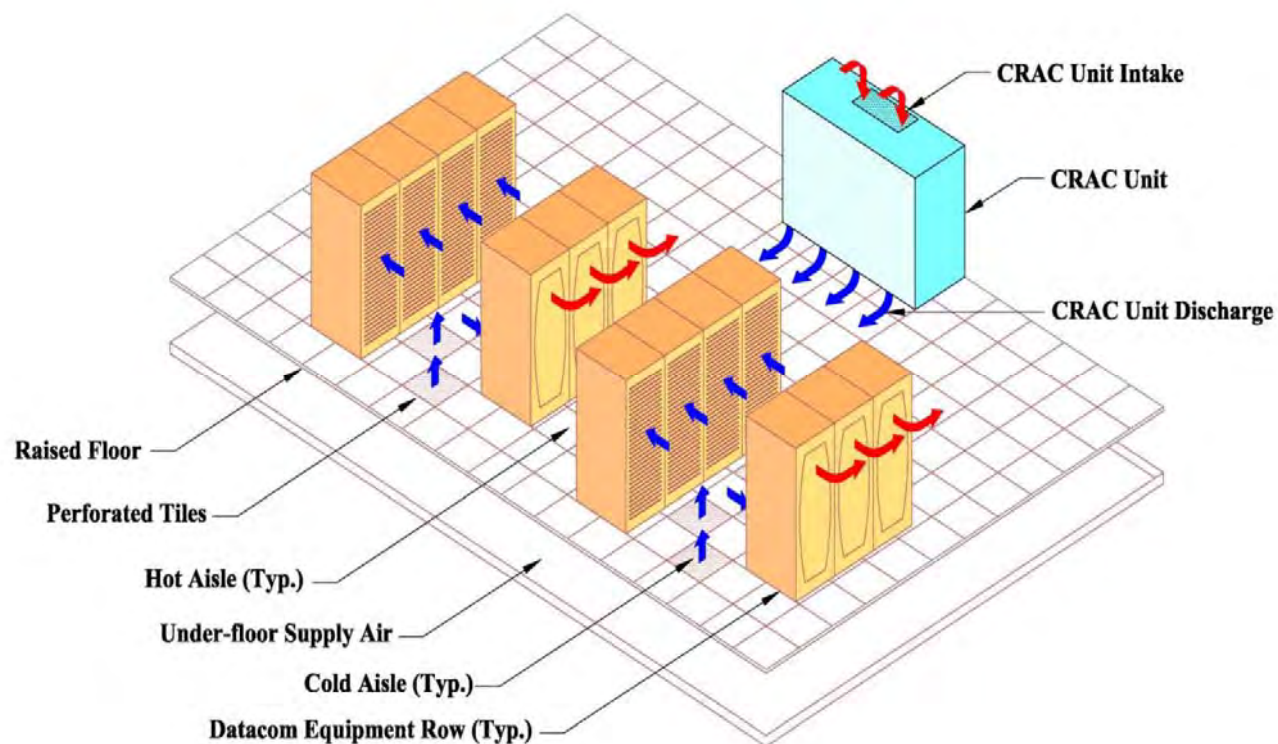
## ➤ Improves equipment intake air conditions by separating cold from hot airflow.

Preparation:

- ✓ Arranging racks with alternating hot and cold aisles.

- ✓ Supply cold air to front of facing servers.

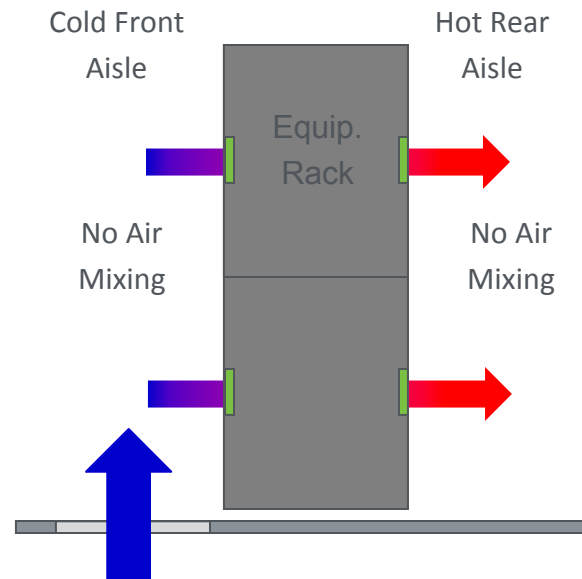
- ✓ Hot exhaust air exits into rear aisles.



Graphics courtesy of DLB Associates

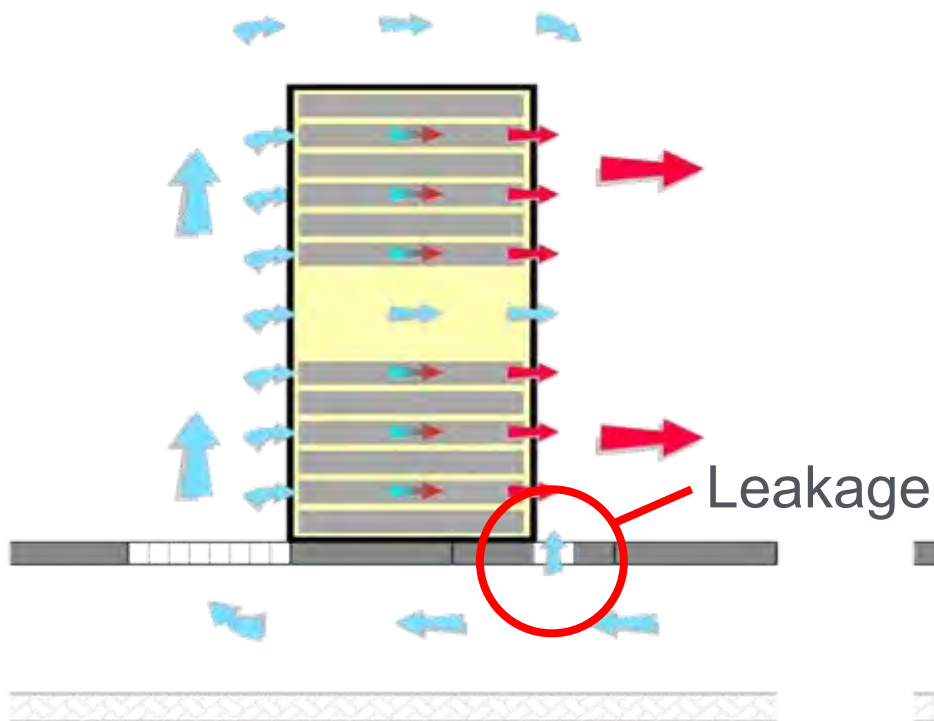
# Separating Cold from Hot Airflow...

- Supply cold air as close to rack inlet as possible.
- Reduce mixing with ambient air and hot rack exhaust
- Flow air from the cold front aisle to the rear hot aisle



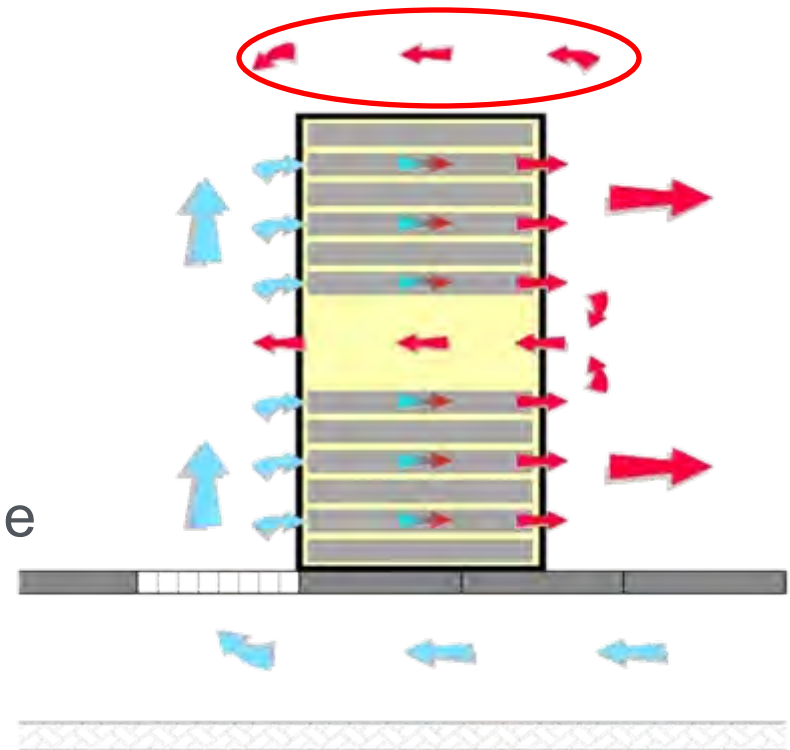
# Reduce Bypass and Recirculation

## Bypass Air / Short-Circuiting...



Wastes cooling capacity.

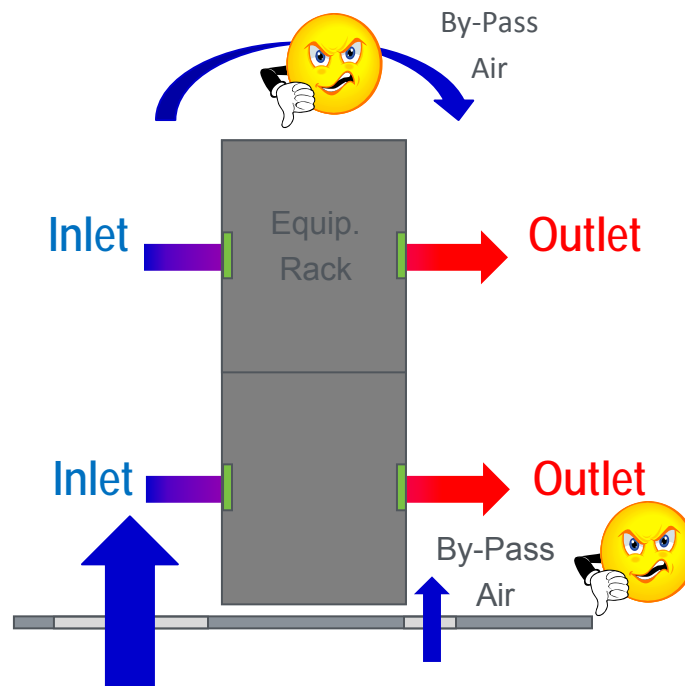
## Recirculation...



Increases inlet temperature to servers.

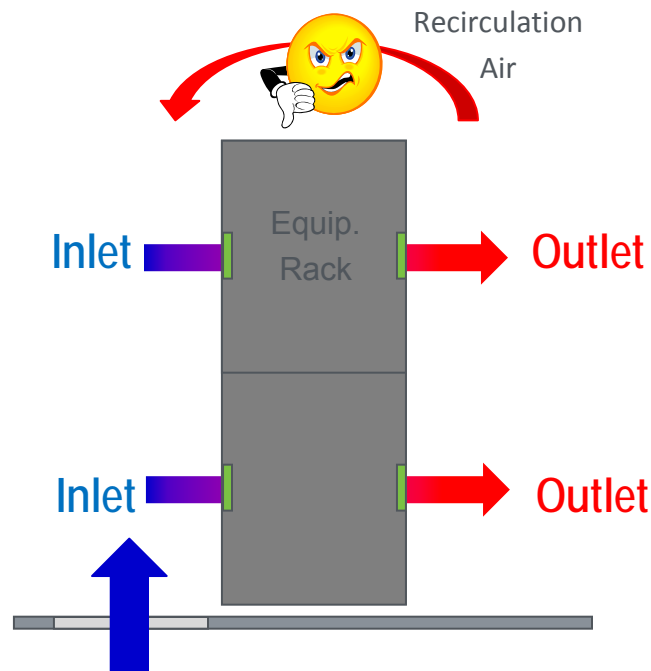
## Some common causes:

- Too much supply airflow
- Misplaced perforated tiles
- Leaky cable penetrations
- Too high tile exit velocity

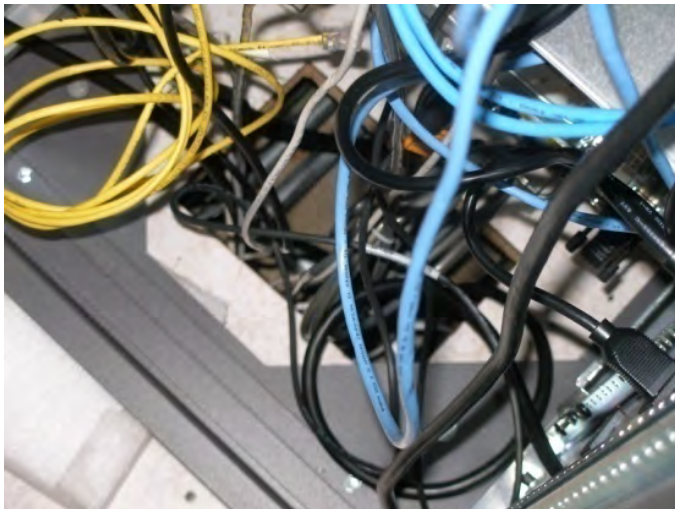


## Some common causes:

- Too little supply airflow
- Lack of blanking panels
- Gaps between racks
- Short equipment rows



Maintain sealing of all potential leaks in the raised floor plenum.



**Unsealed cable penetration**



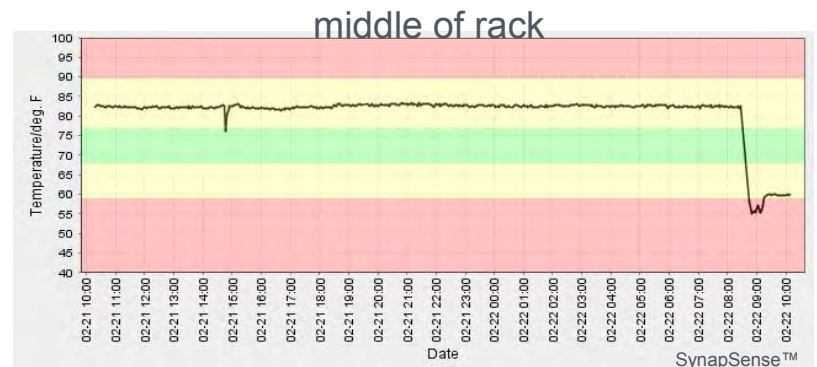
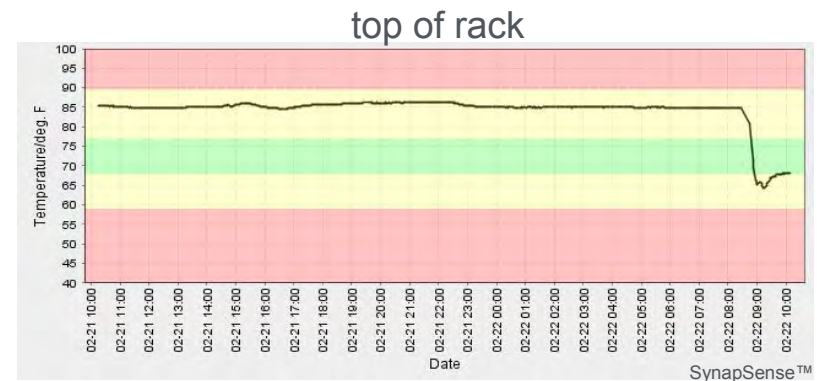
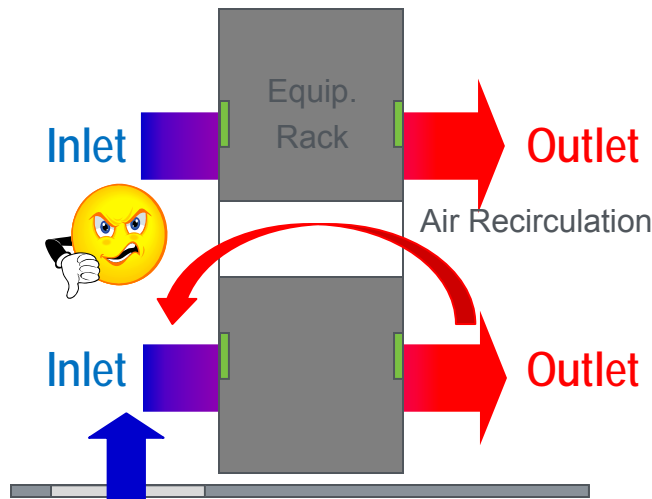
**Sealed cable penetration**

# Manage Blanking Panels

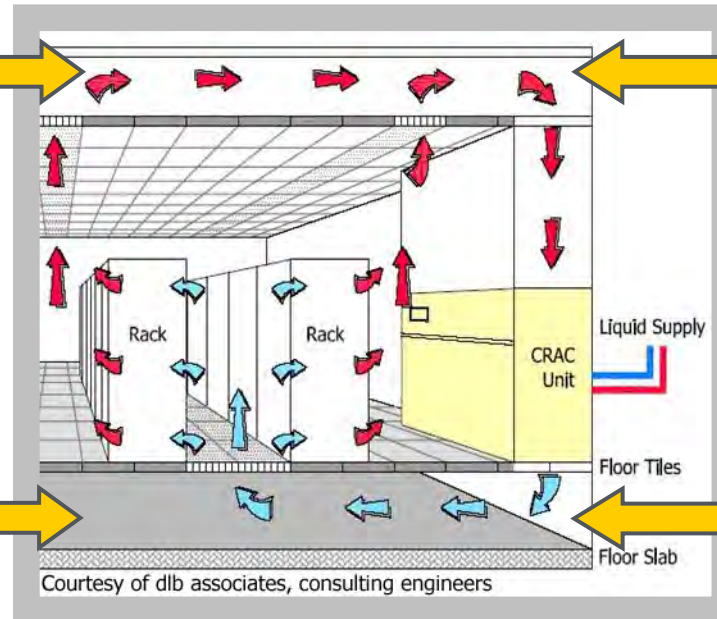
Any opening will degrade the separation of hot and cold air

- maintain server blanking and side panels.

One 12" blanking panel added  
Temperature dropped ~20°



# Reduce Airflow Restrictions & Congestion



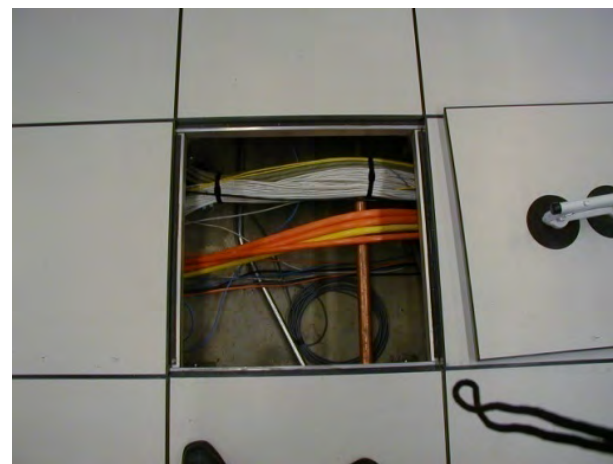
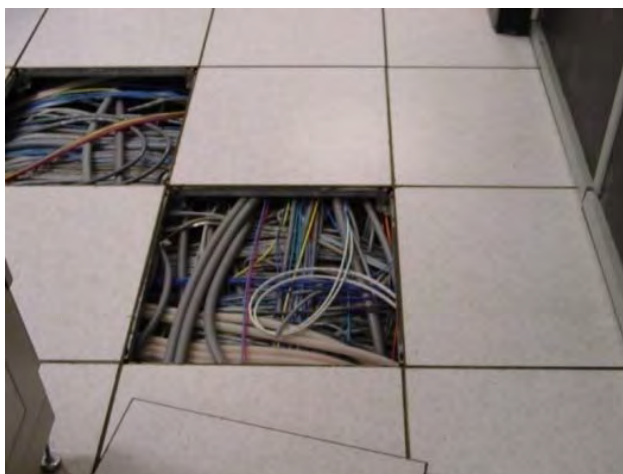
Consider The Impact That Congestion  
Has On The Airflow Patterns

**Congested Floor &  
Ceiling Cavities**

**Empty Floor &  
Ceiling Cavities**

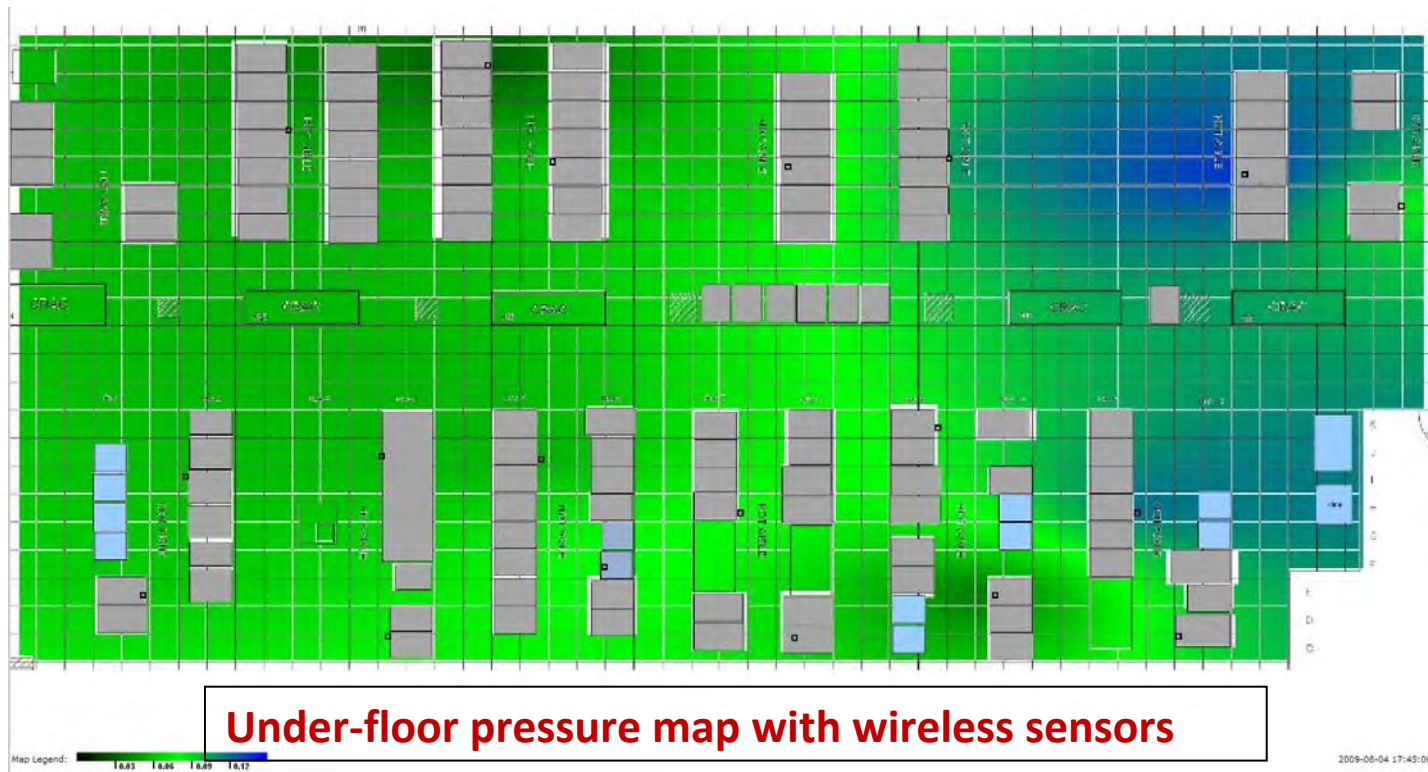
# Reduce Cable Congestion

- Cable congestion sharply reduces airflow and degrades airflow distribution.
- No cable trays should be placed below perforated tiles.
- Generally, it is obvious when there is too much “*stuff*.”

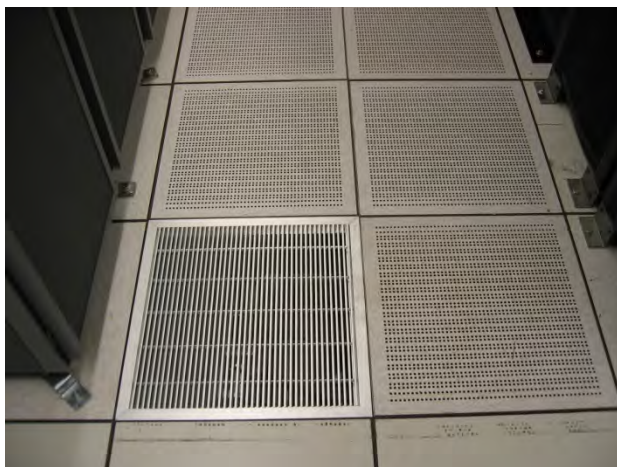


# Resolve Airflow Balancing

- BALANCING is required to optimize airflow.
- Rebalance with new IT or HVAC equipment
- Locate perforated floor tiles *only* in cold aisles

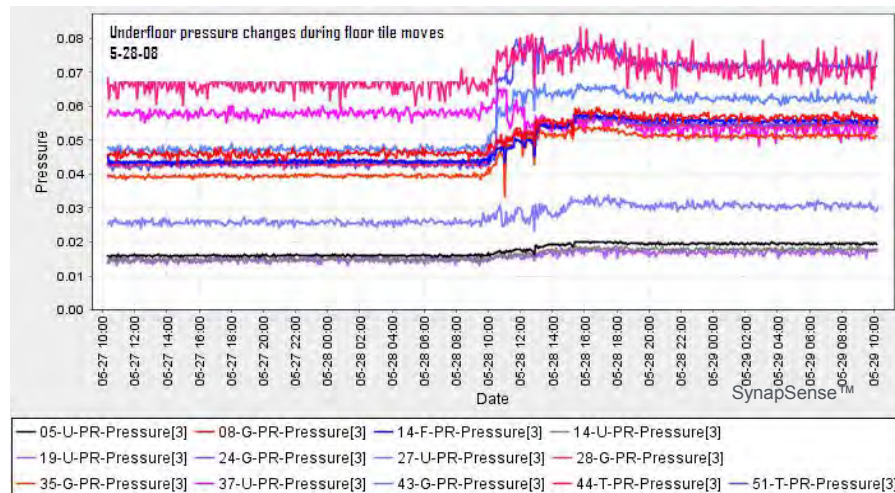


# Results: Tune Floor Tiles

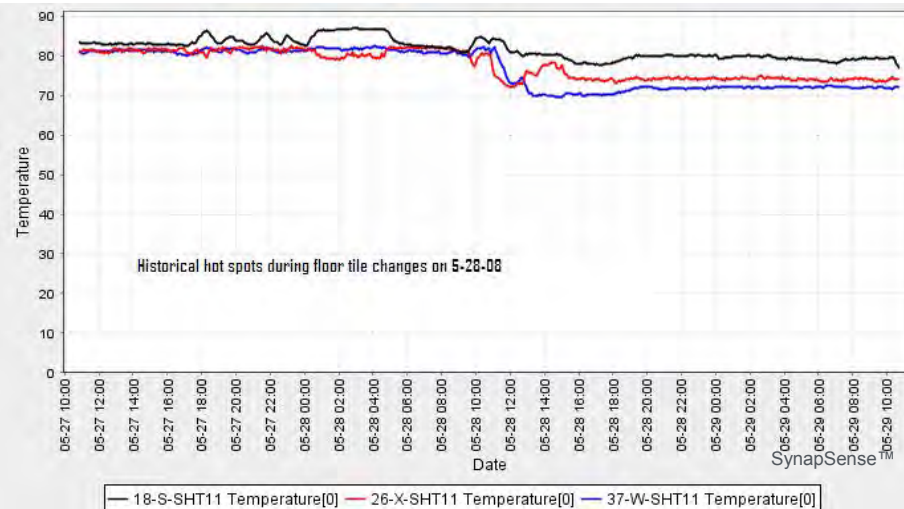


- Too many permeable floor tiles
- if airflow is optimized
  - under-floor pressure up ☐
  - rack-top temperatures down ☐
  - data center capacity increases
- Measurement and visualization assisted tuning process

under-floor pressures

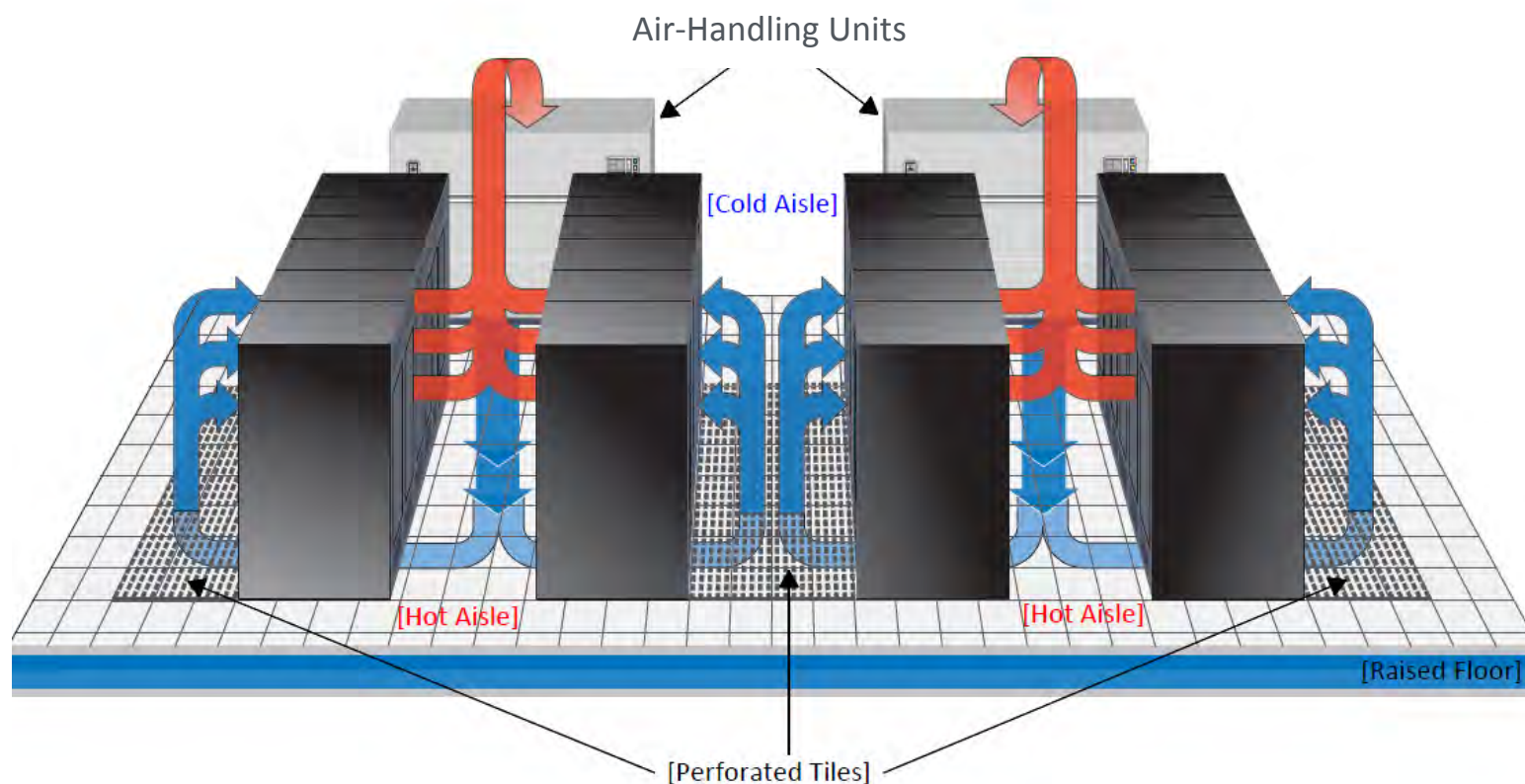


rack-top temperatures

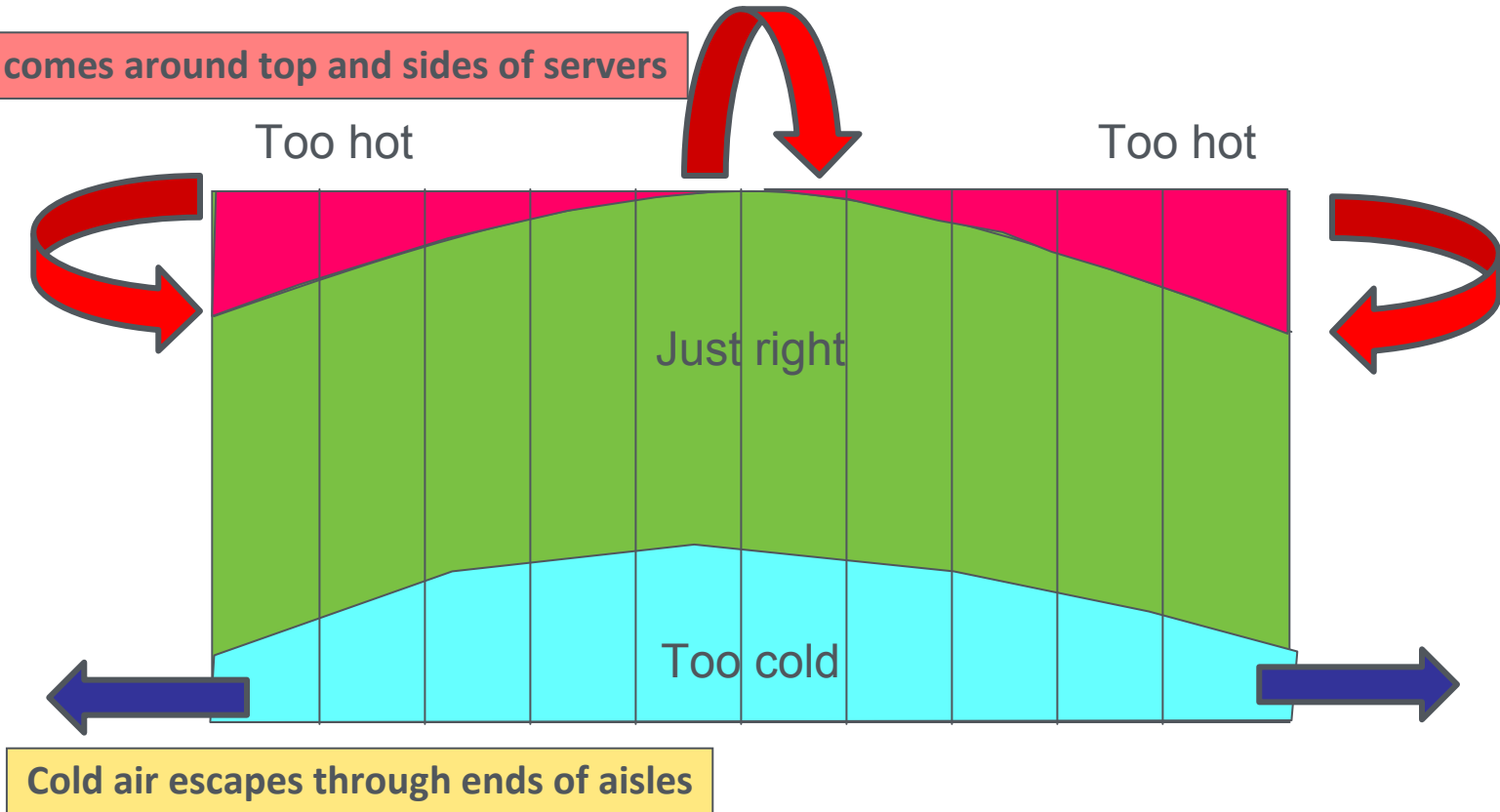


## Locate CRAC/CRAH units at ends of Hot Aisles

### HOT AISLE/COLD AISLE APPROACH



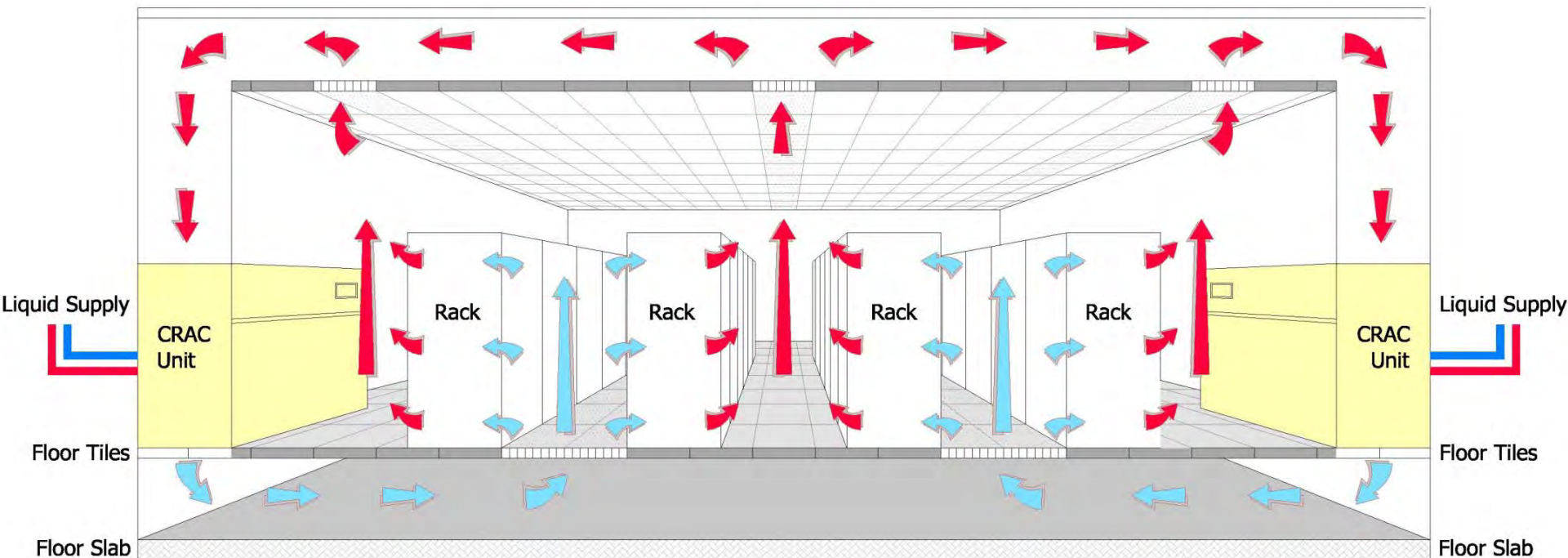
# Typical Temperature Profile with Under-floor Supply



Elevation at a cold aisle looking at racks

*There are numerous references in ASHRAE. See for example V. Sorell et al; "Comparison of Overhead and Underfloor Air Delivery Systems in a Data Center Environment Using CFD Modeling"; ASHRAE Symposium Paper DE-05-11-5; 2005*

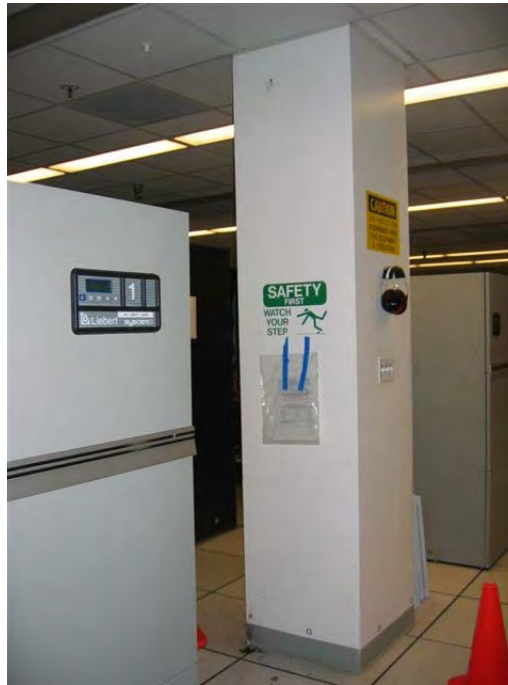
# Next step: Air Distribution Return-Air Plenum



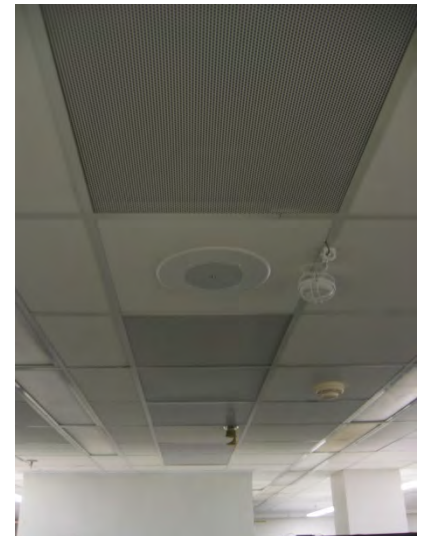
# Return Air Plenum

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

Before



After





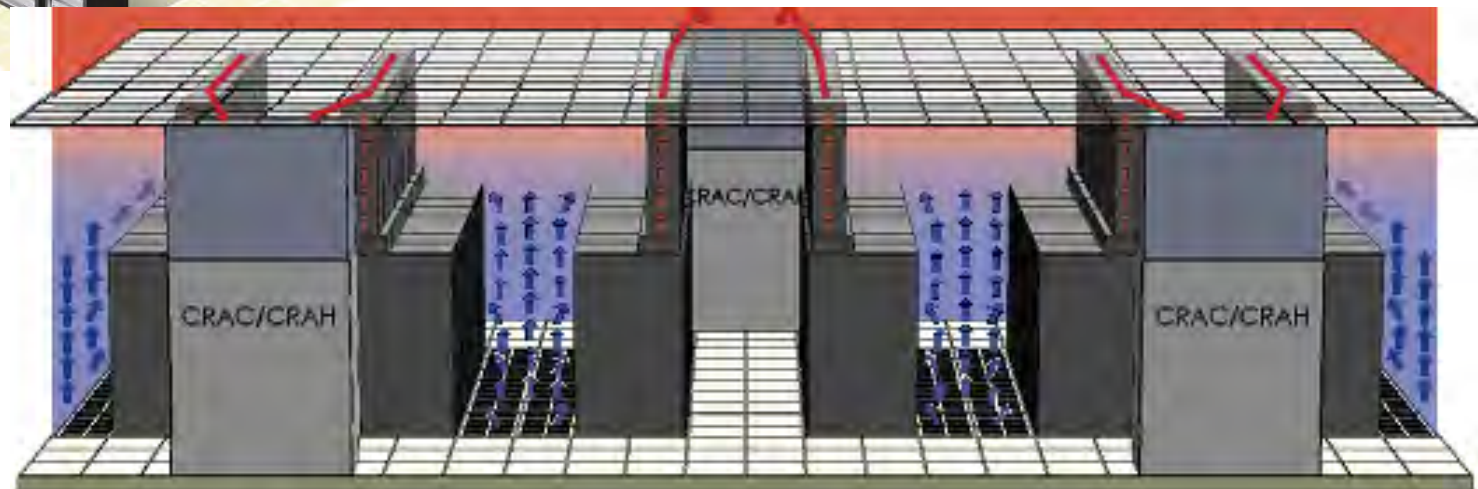
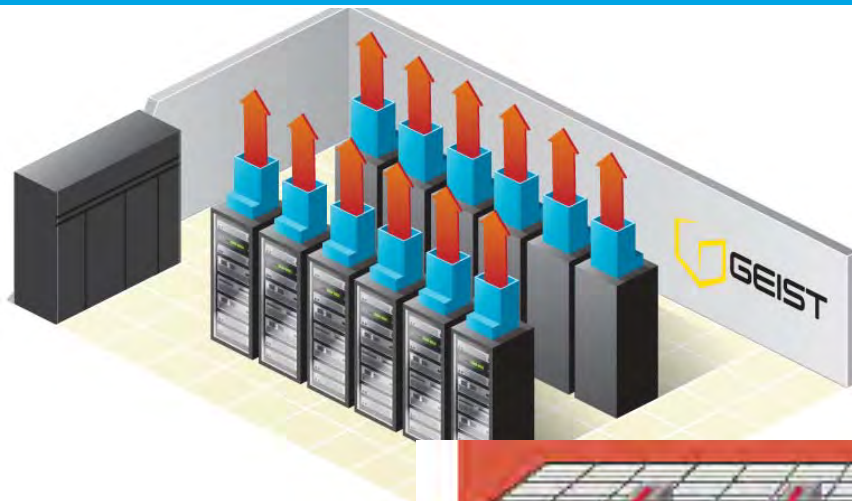
**Return air duct on top of CRAC unit connects to the return air plenum.**

# Isolate Hot Return



Duct on top of each rack connects to the return air plenum.

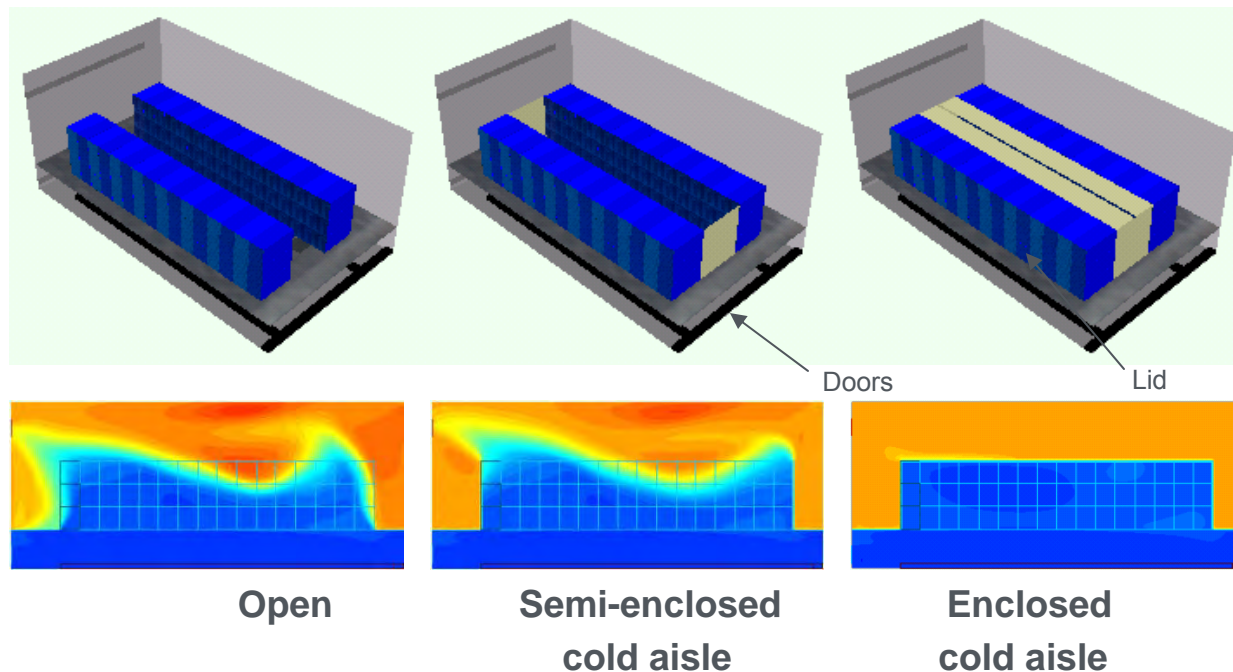
# Cabinet/row containment



## geist's **ACTIVE CABINET** or **ROW BASED** containment method

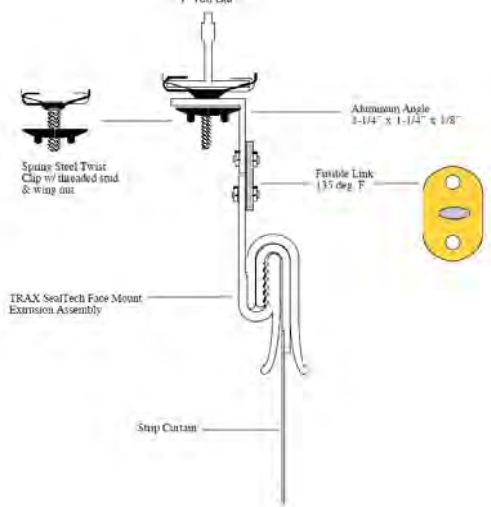
- + No hot air mixing, no wrap around heating, NO HOT SPOTS
- + Actively balances return airflow to server usage
- + Complete hot air separation enabling highest CRAC/CRAH return air temperatures
- + Eliminates raised floor pressure balancing issues making it suitable for lab environments
- + Data center floor becomes a cold aisle providing comfortable working conditions
- + 1:1 airflow balance makes cooling over-provision unnecessary

- ✓ Physical barriers enhance separate hot and cold airflow.
- ✓ Barriers placement must comply with fire codes.
- ✓ Curtains, doors, or lids have been used successfully.

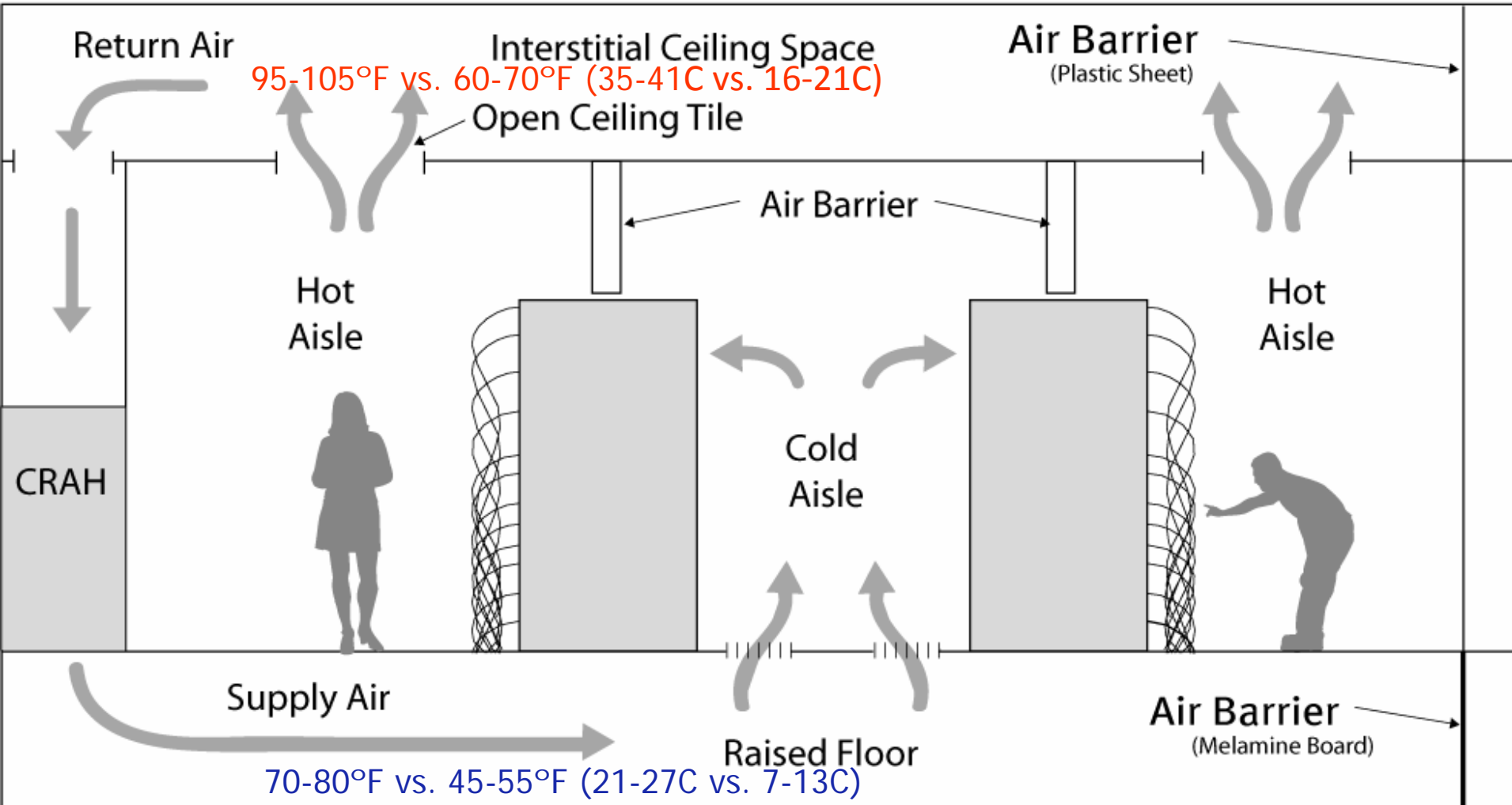


# Adding Air Curtains for Hot/Cold Isolation

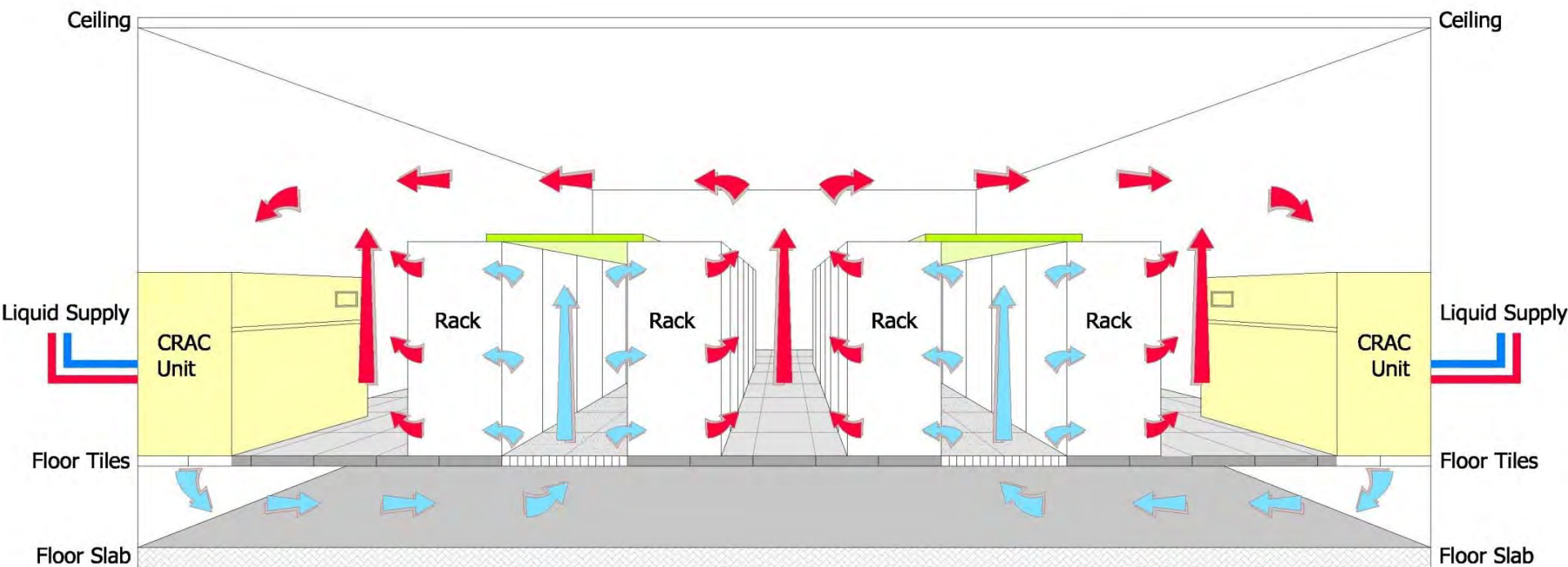
## CoolShield or Trax SealTech



# Isolate Cold and Hot Aisles



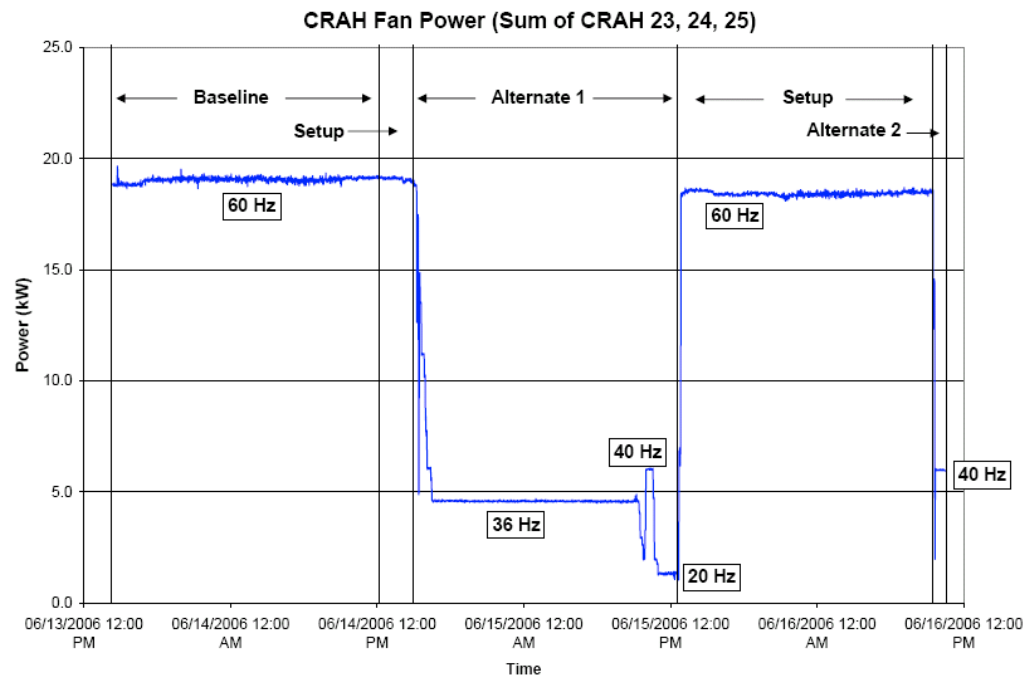
# Cold Aisle Airflow Containment Example



**LBL Cold Aisle Containment study achieved fan energy savings of ~ 75%**

# Fan Energy Savings

- Isolation can significantly reduce air bypass and hence flow
- Fan speed can be reduced and fan power is proportional to the cube of the flow.
- Fan energy savings of 70-80% is possible with variable air volume (VAV) fans in CRAH/CRAC units (or central AHUs)

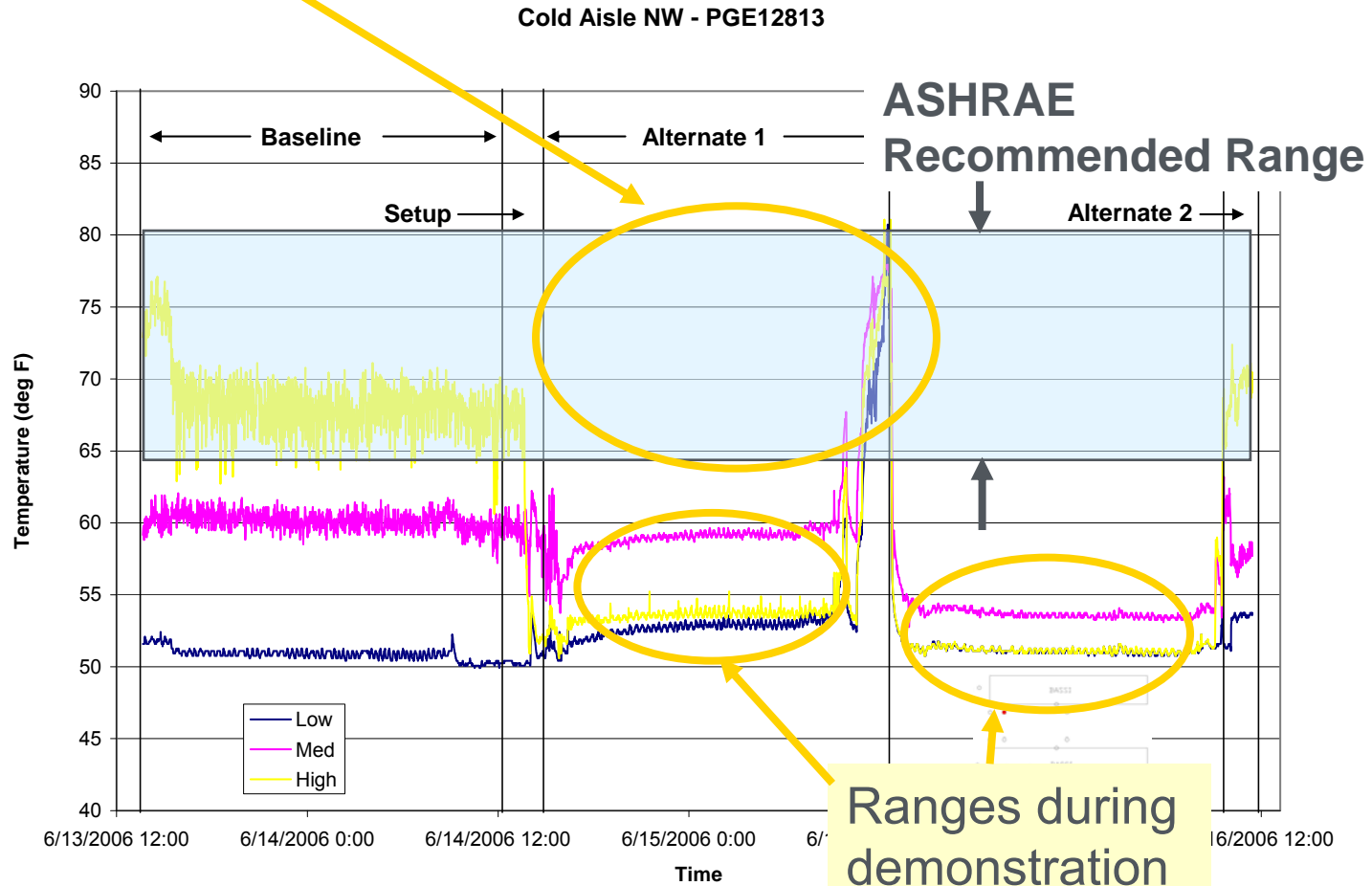


Without Enclosure

With Enclosure

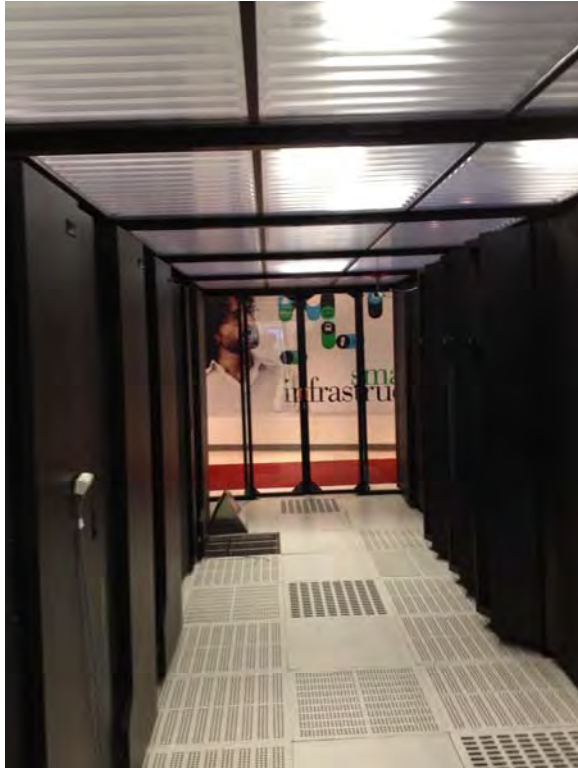
Without Enclosure

Better airflow management permits warmer supply temperatures!

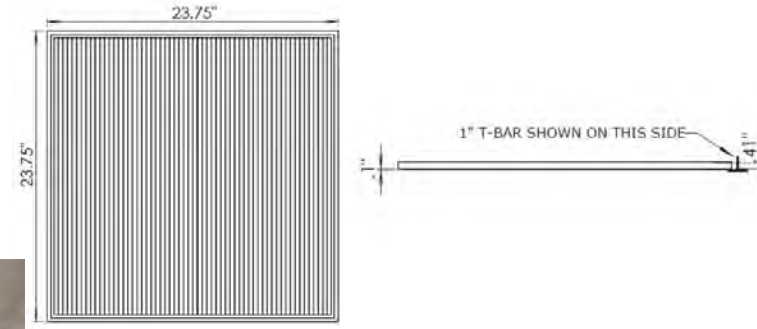


# Hot and Cold Aisle Containment

## Subzero Cold Aisle Containment



APC Hot Aisle Containment  
(with in-row cooling)



Ceilume Heat Shrink Tiles



# Isolating Hot and Cold Aisles Summary

- Energy intensive IT equipment needs good isolation of “cold” inlet and “hot” discharge.
- Supply airflow can be reduced if no bypass occurs.
- Overall temperature can be raised if air is delivered without mixing.
- Cooling systems and economizers use less energy with warmer return air temperatures.
- Cooling capacity increases with warmer air temperatures.

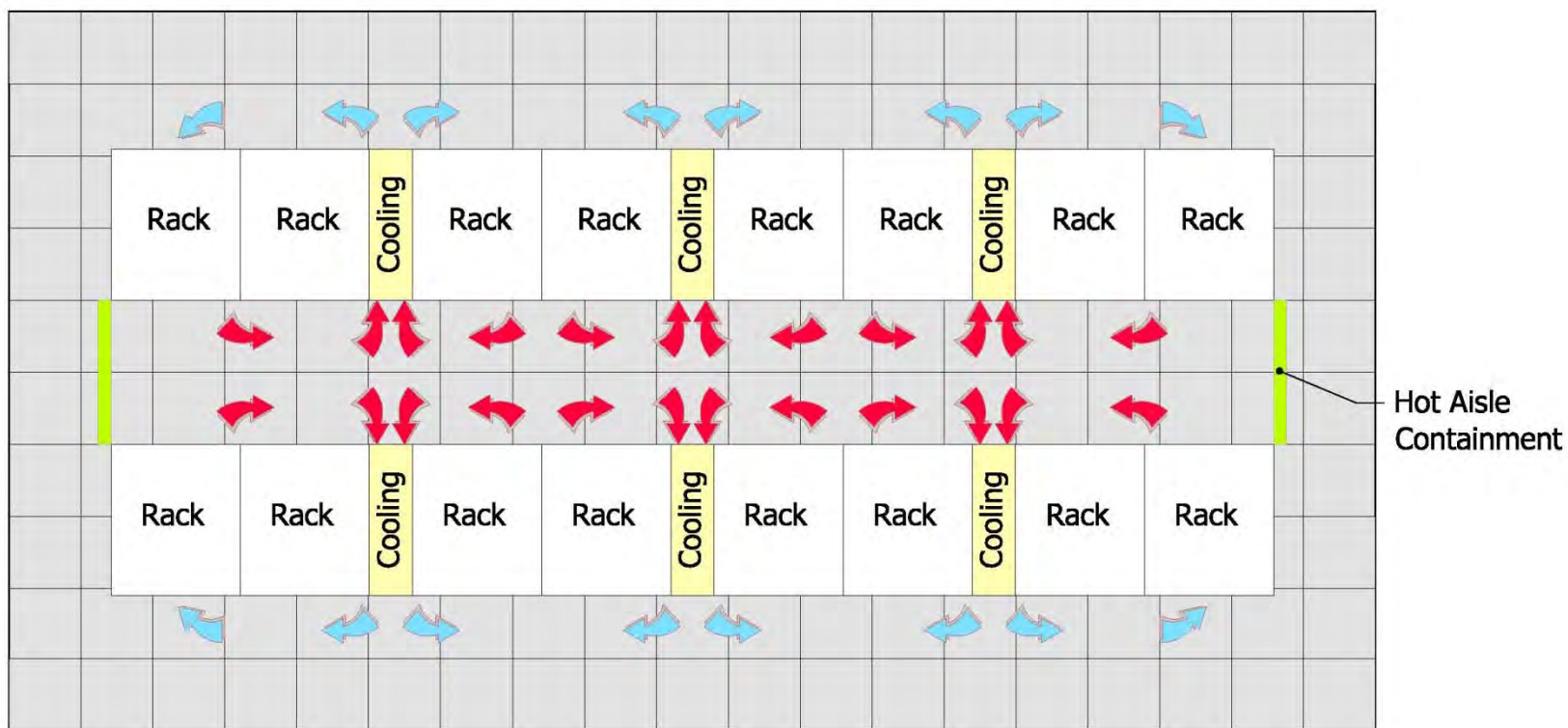
**Localized air cooling systems with hot and cold isolation can supplement or replace under-floor systems (raised floor not required!)**

Examples include:

- **Row-based cooling units**
- **Rack-mounted heat exchangers**

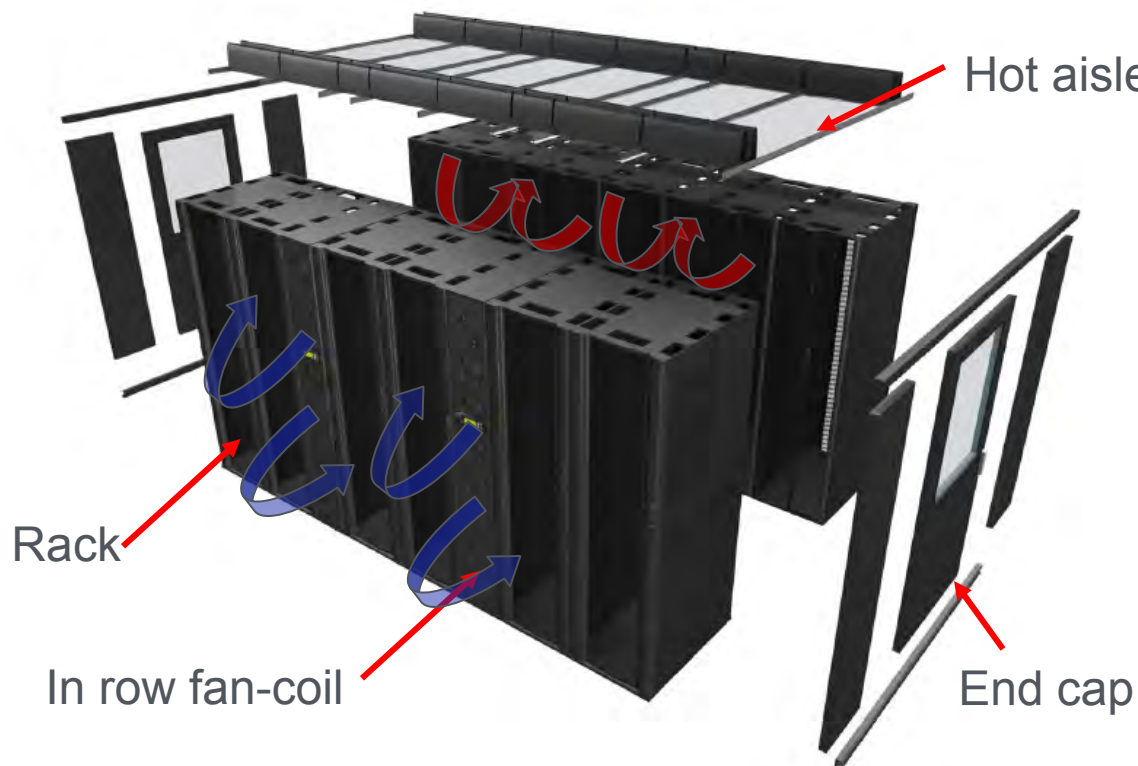
**Both options “Pre-engineer” hot and cold isolation**

# Example – Local Row-Based Cooling Units



# In-row cooling system

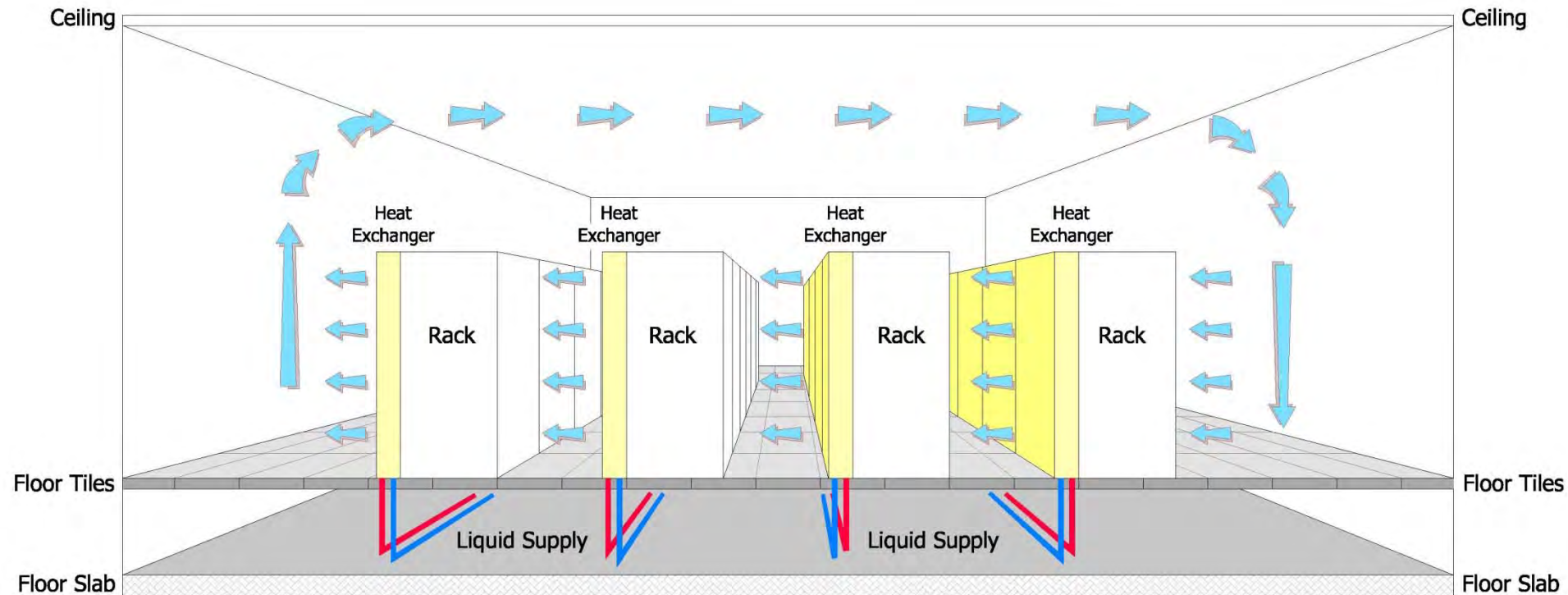
With hot aisle containment, the general data center is neutral (75-80F)



© APC reprinted with permission



# Air Distribution – Rack-Mounted Heat Exchangers



## **Air management techniques:**

- Seal air leaks in floor (e.g. cable penetrations)
- Prevent recirculation with blanking panels in racks
- Manage floor tiles (e.g. no perforated tiles in hot aisle)
- Improve isolation of hot and cold air (e.g. return air plenum, curtains, or complete isolation)

## **Impact of good isolation:**

- Supply airflow reduced
  - Fan savings up to 75%+
- Overall temperature can be raised
  - Cooling systems efficiency improves
  - Greater opportunity for economizer (“free” cooling)
- Cooling capacity increases

# Questions?





## Cooling systems



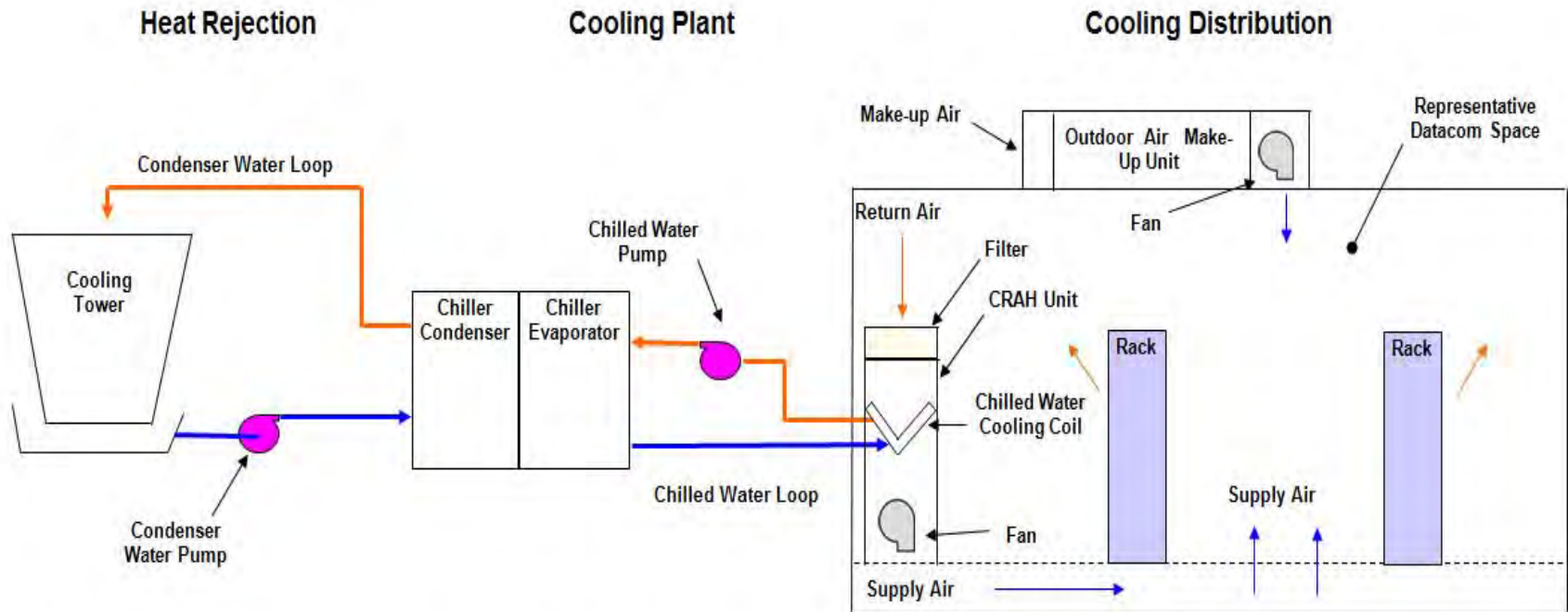
U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



## Linking good air management and an optimized cooling system:

- ✓ Improved efficiencies
- ✓ Increased cooling capacity
- ✓ More hours for air-side and water-side free cooling
- ✓ Lower humidification/dehumidification energy
- ✓ Reduced fan energy

# HVAC Systems Overview



## Heat Rejection Alternatives:



- Water Cooled Direct (shown)
- Water Cooled Indirect (with HX)
- Evaporatively Cooled
- Air Cooled
- Dry Cooler (Air Cooled with Glycol)

## Cooling Plant Alternatives:

- Water-Side Economizer (HX)
- Chiller (shown)
- Direct Expansion (DX)

## Terminal Unit Alternatives

- Liquid Cooling
- Central AHU
- CRAH Unit (shown)
- CRAC Unit (DX)

## Distribution Alternatives

- On Board
- In Rack
- In Row
- Overhead Air
- Underfloor Air (Shown)

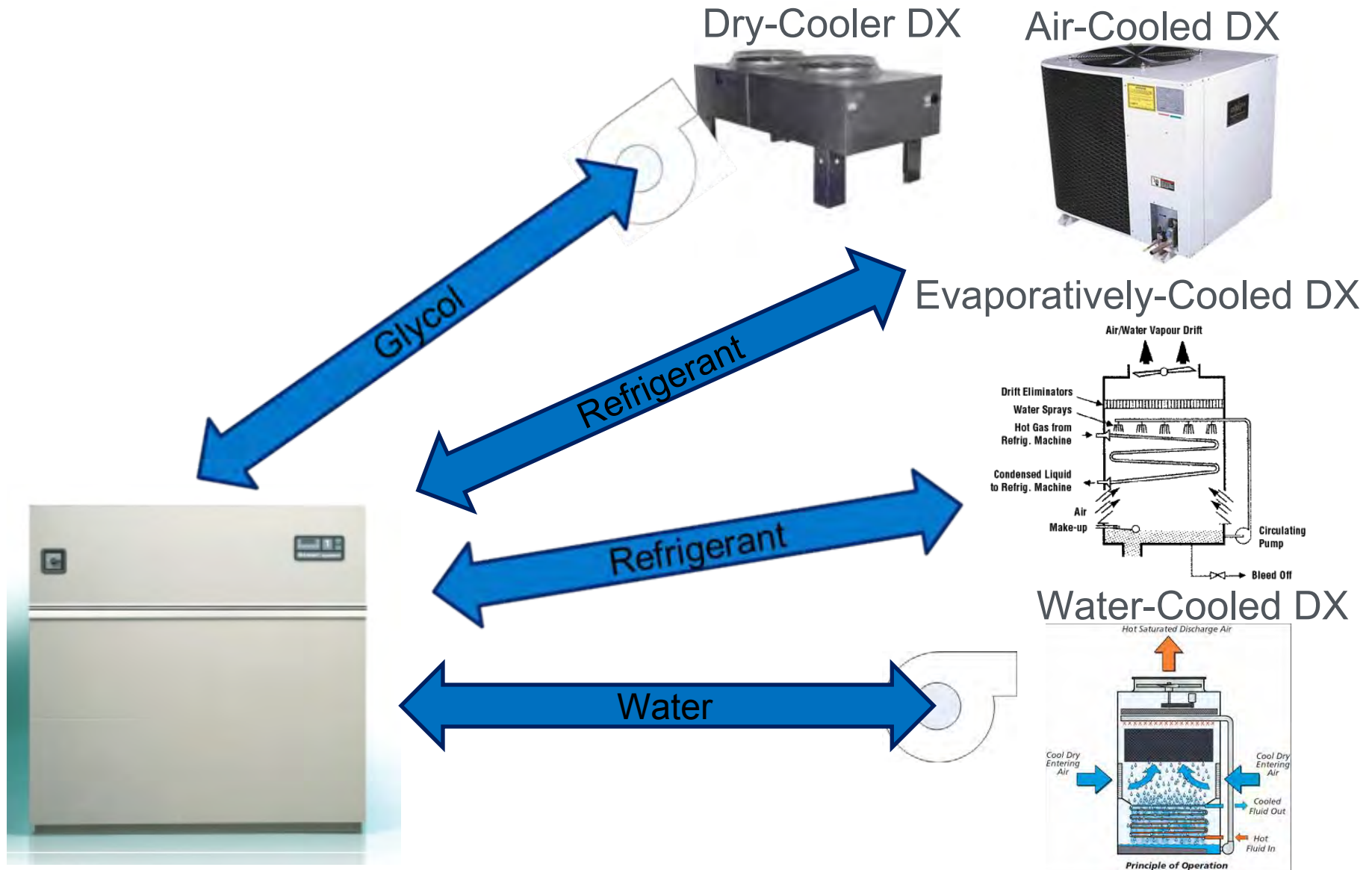


# Computer Room Air Conditioners (CRACs) and Air Handlers (CRAHs)

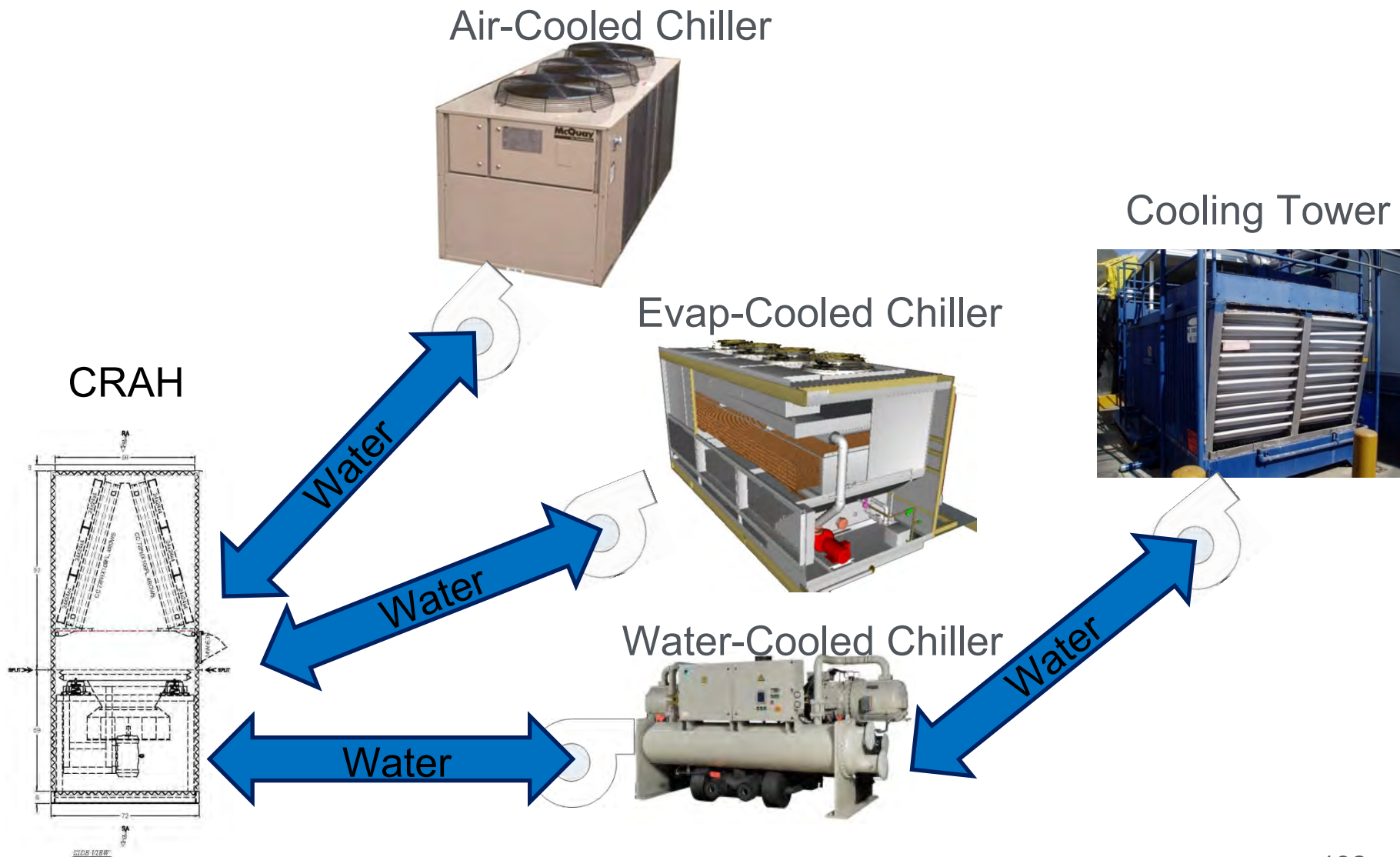
- **CRAC units**
  - Fan, direct expansion (DX) coil, and refrigerant compressor.
- **CRAH units**
  - Fan and chilled water coil
  - Typically in larger facilities with a chiller plant
- **Both often equipped with humidifiers and reheat for dehumidification**
- **Often independently controlled**
  - Tight ranges and poor calibration lead to fighting



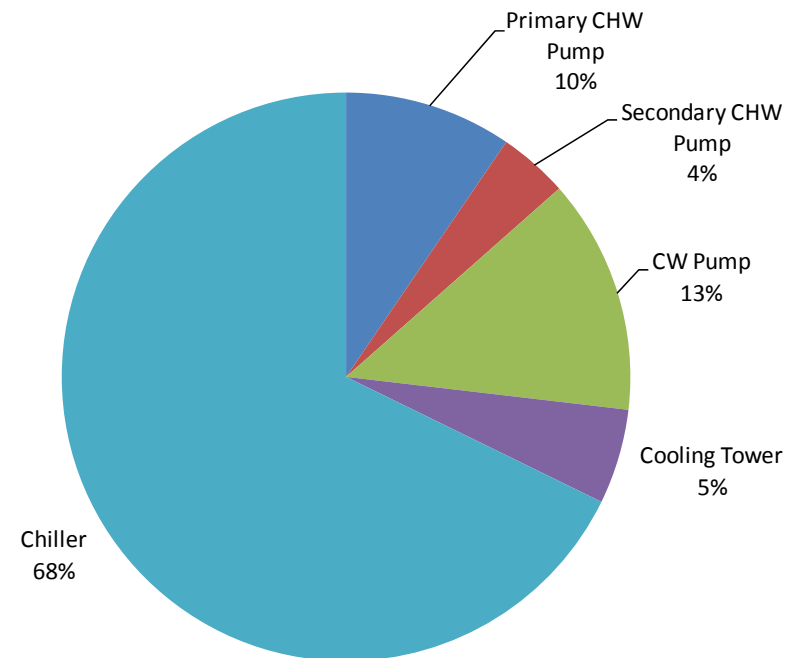
# DX (or AC) units reject heat outside...



# Computer Room Air Handling (CRAH) units using Chilled-Water



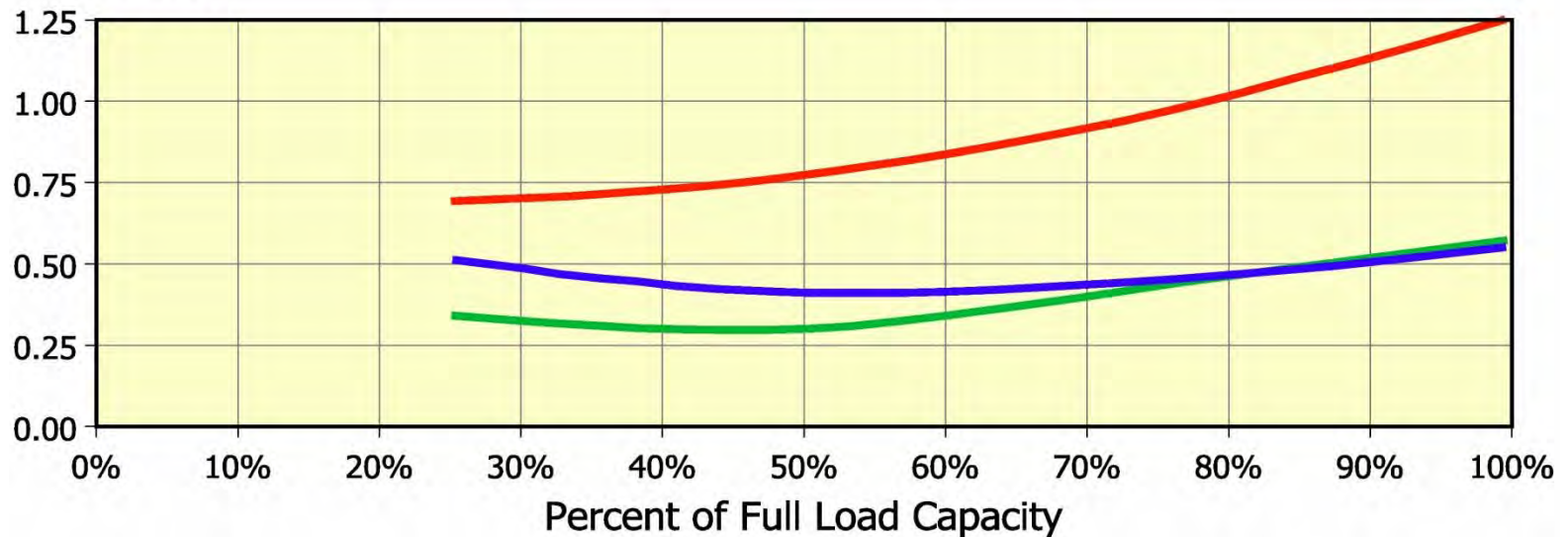
- Have a plant (vs. distributed cooling)
- Use “warm” water cooling (multi-loop)
- Size cooling towers for “free” cooling
- Integrate controls and monitor efficiency of all primary components
- Thermal storage
- Utilize variable speed drives on:
  - Fans
  - Pumps
  - Towers
  - Chillers



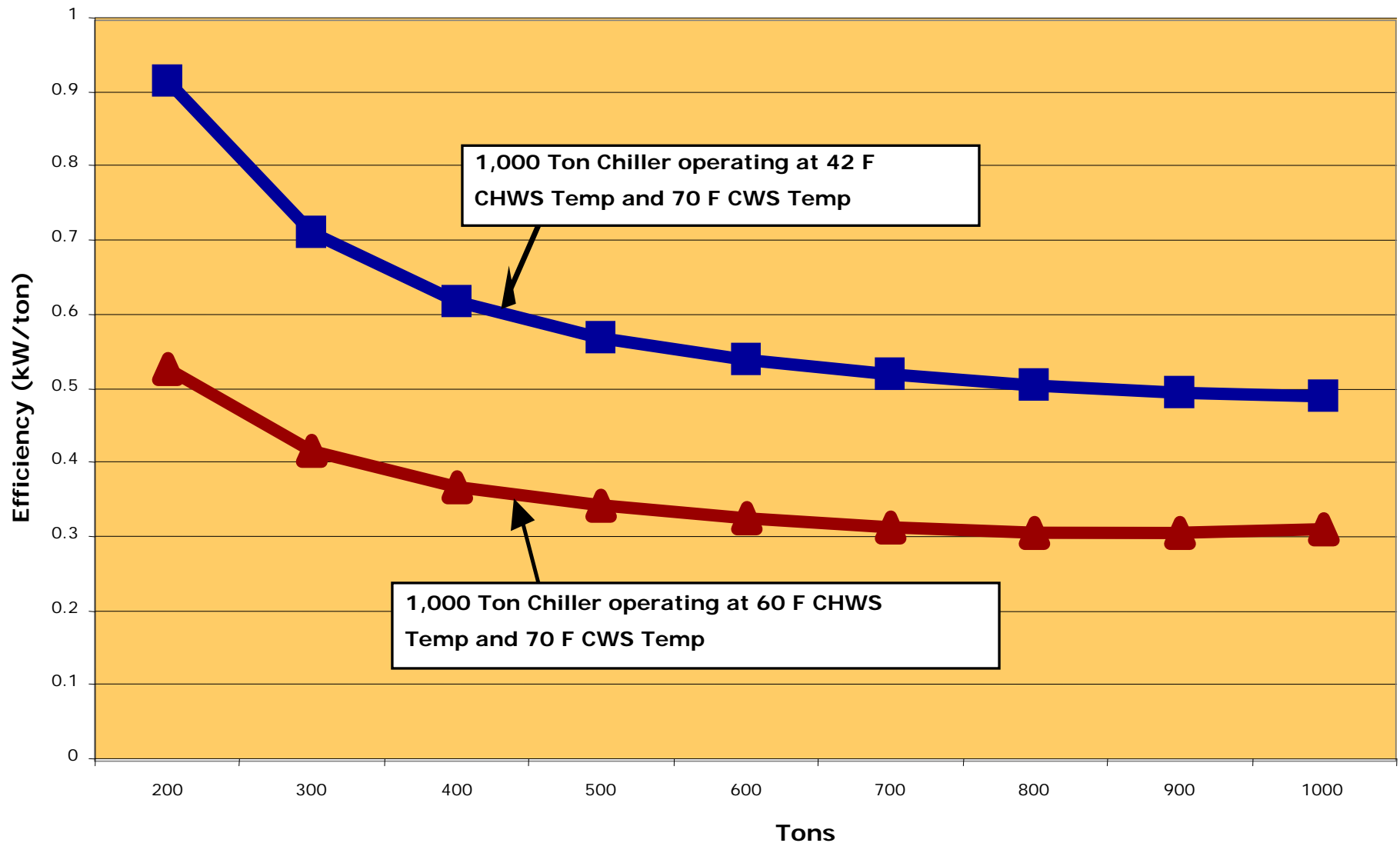
# Select Efficient Chillers

Chiller	Compressor kW / ton			
	25%	50%	75%	100%
400 Ton Air Cooled	0.69	0.77	0.96	1.25
1200 Ton Water Cooled w/o VFD	0.51	0.41	0.45	0.55
1200 Ton Water Cooled with a VFD	0.34	0.30	0.43	0.57

kW Per Ton



# Increase Temperature of Chiller Plant



Data provided by York International Corporation.

As heat densities rise, liquid solutions become more attractive:

## Volumetric heat capacity comparison



400 Gallon pool  
[1.5 m<sup>3</sup>]

Water

=



[5380 m<sup>3</sup>]

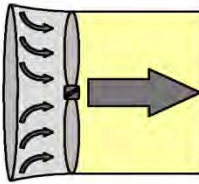

~ 190,000 cubic foot blimp

GOODYEAR

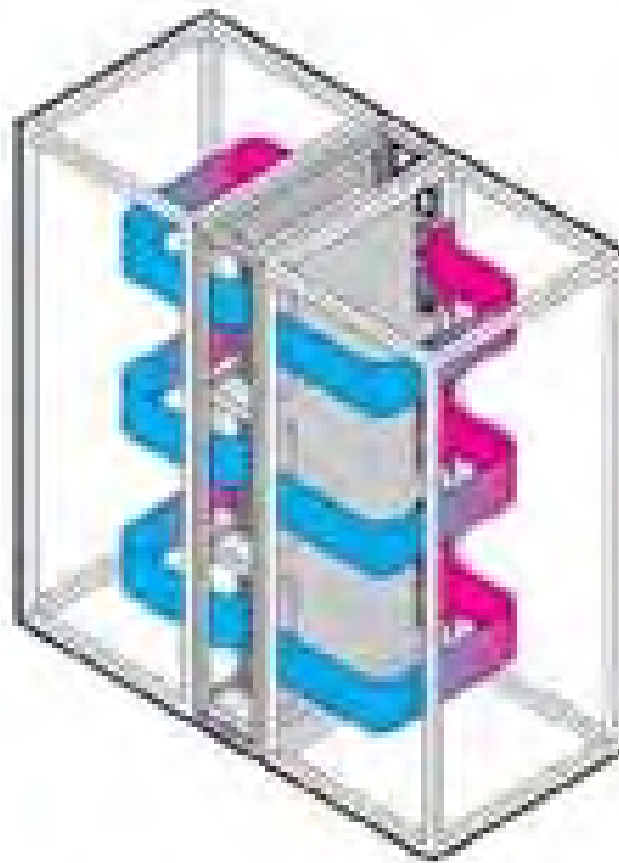
Air

# Why Liquid Cooling?

- Heat removal efficiency increases as liquid gets closer to the heat source
- Liquids can provide cooling with higher temperature coolant
  - Improved cooling efficiency
  - Increased economizer hours
  - Greater potential use of waste heat
- Reduced transport energy:

Heat Transfer		Resultant Energy Requirements			
Rate	$\Delta T$	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

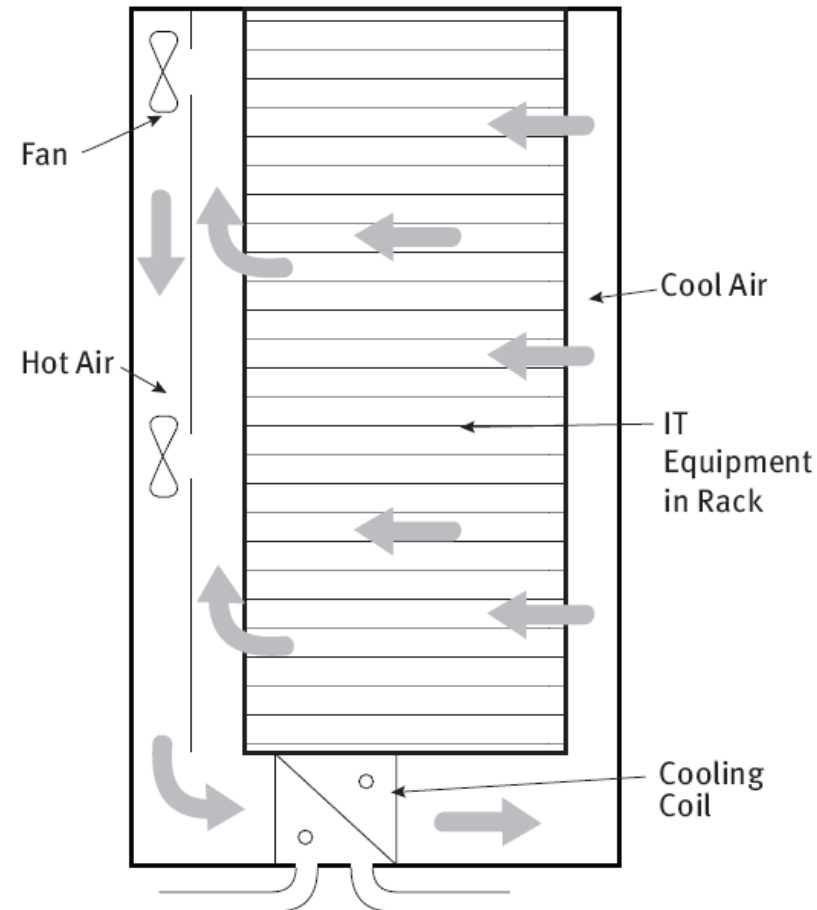
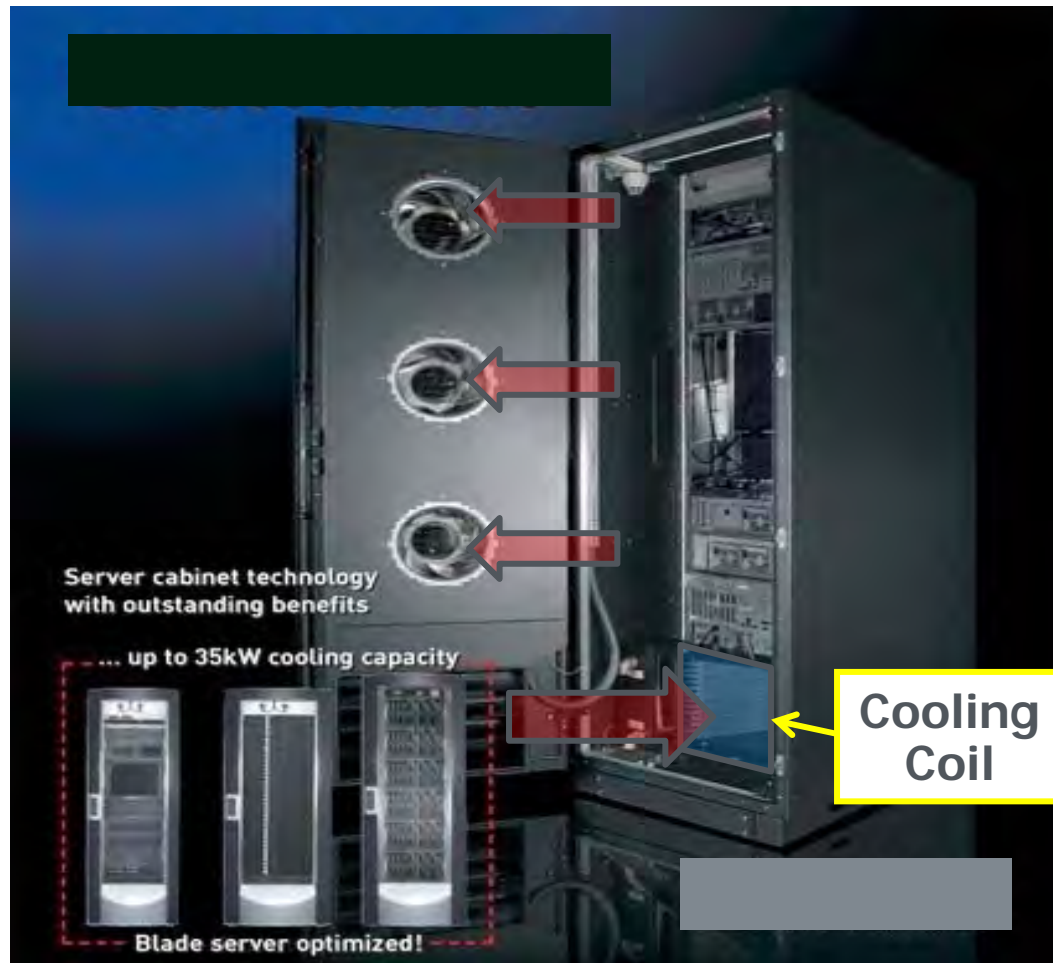
# In-Row Liquid Cooling



*Graphics courtesy of Rittal*

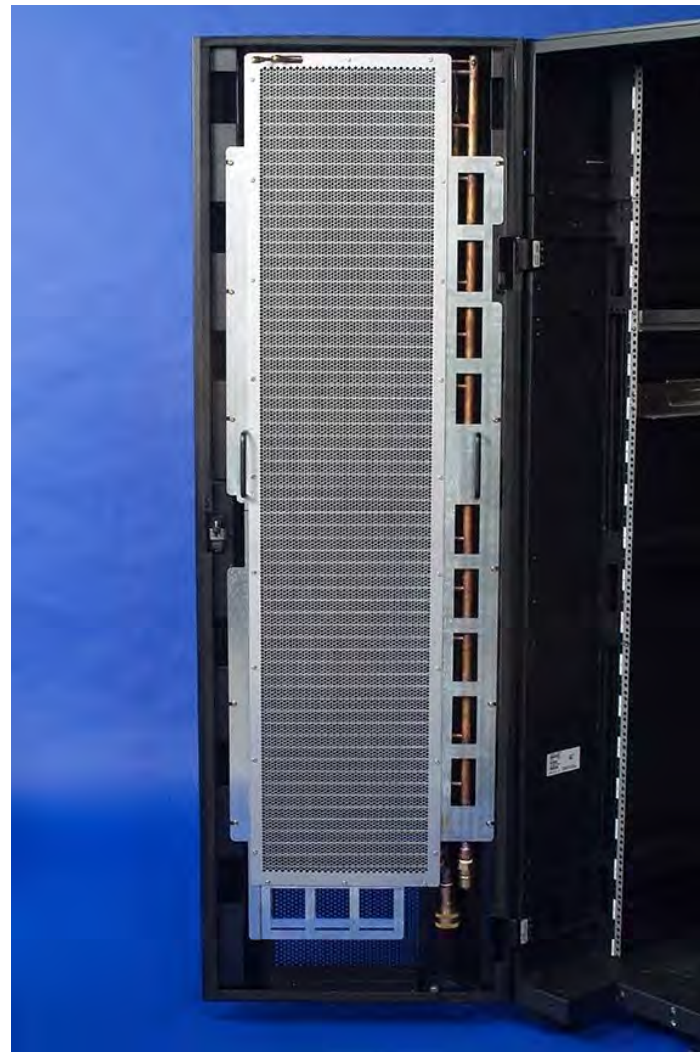
# In Rack Liquid Cooling

Racks with integral coils and full containment



# Rear Door Heat Exchanger

- Passive technology: relies on server fans for airflow
- Can use chilled or higher temperature water for cooling



*Photo courtesy of Vette*

# Rear-Door Liquid Cooling

Rear Door (open)

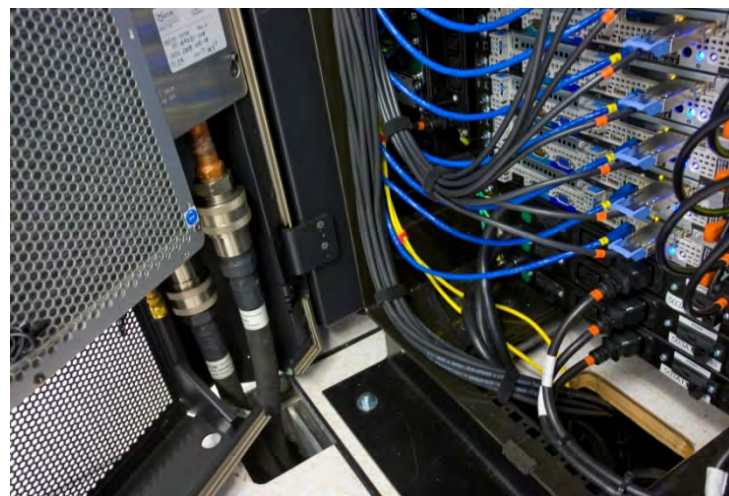


Inside rack RDHx, open 90°

Rear Doors (closed)



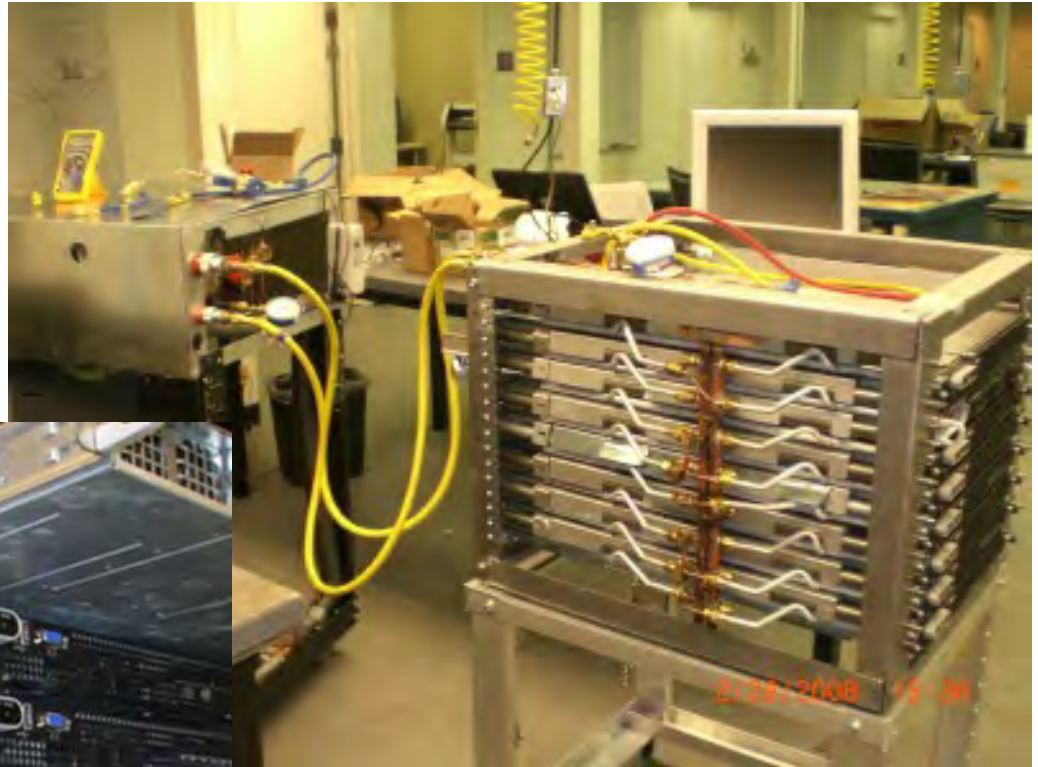
Liquid Cooling Connections



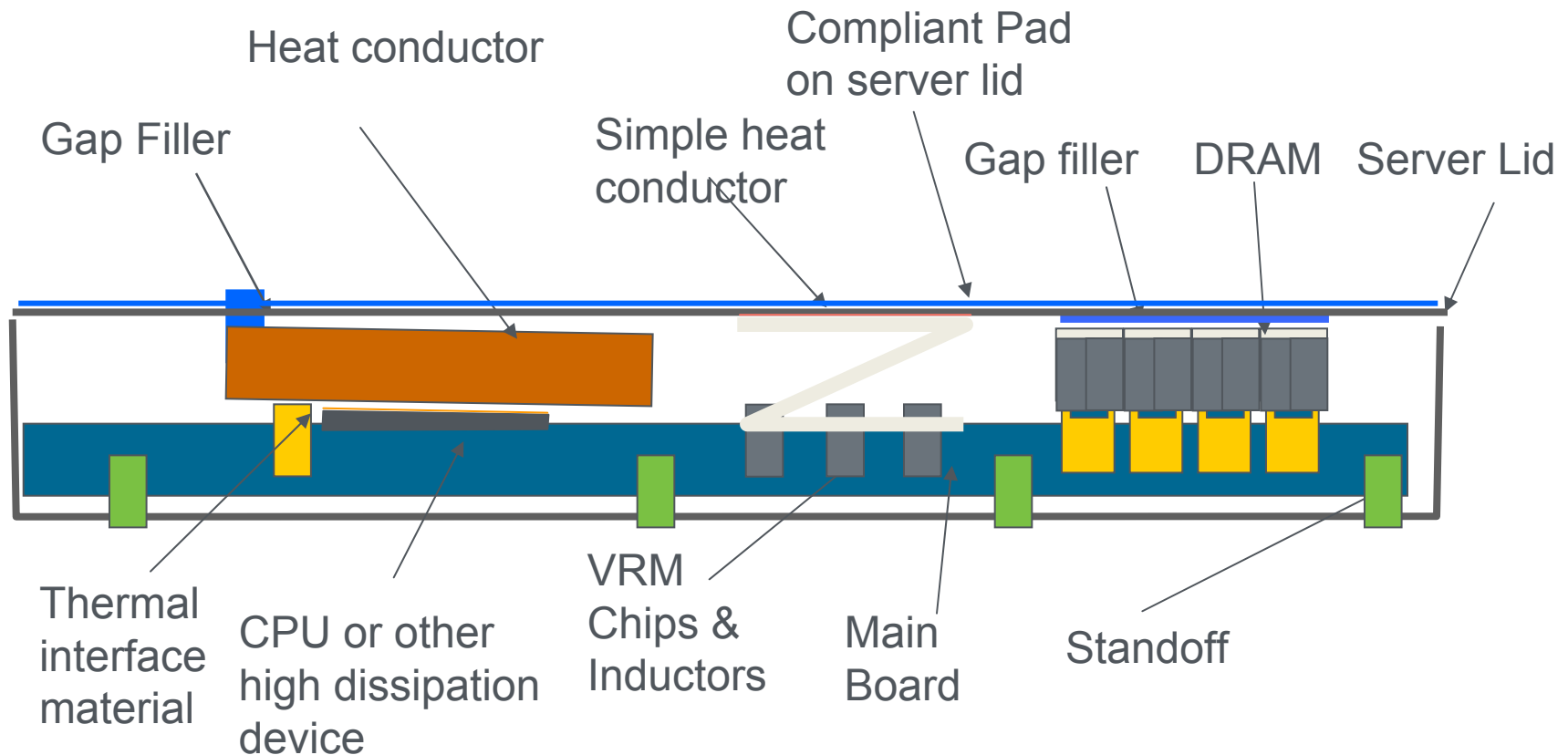
# Direct touch cooling

Clustered Systems design

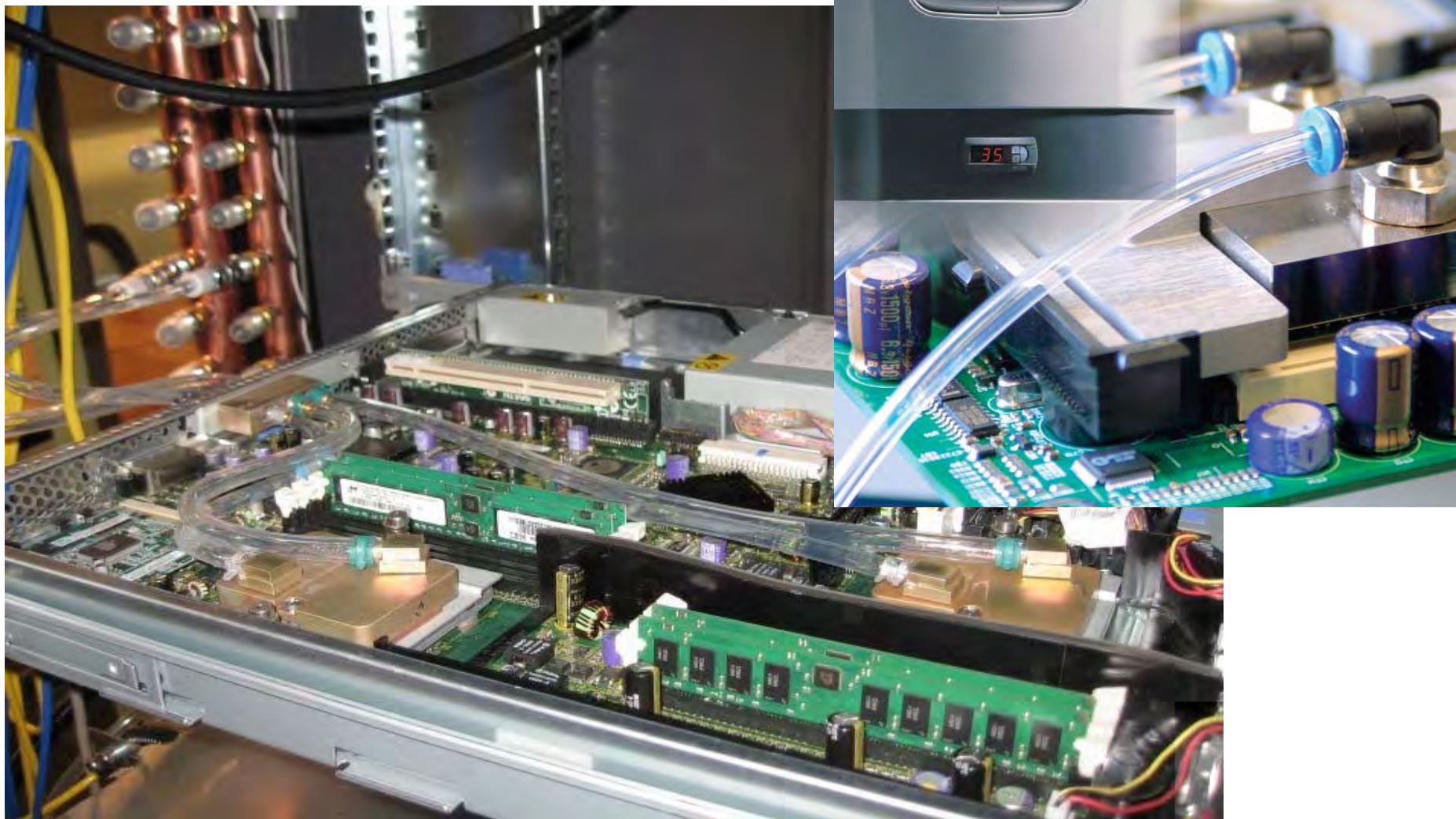
Conducting heat to a cold plate containing refrigerant



- Server fans are removed
- Heat risers connect to top plate which has a micro channel heat exchanger



# On Board Cooling

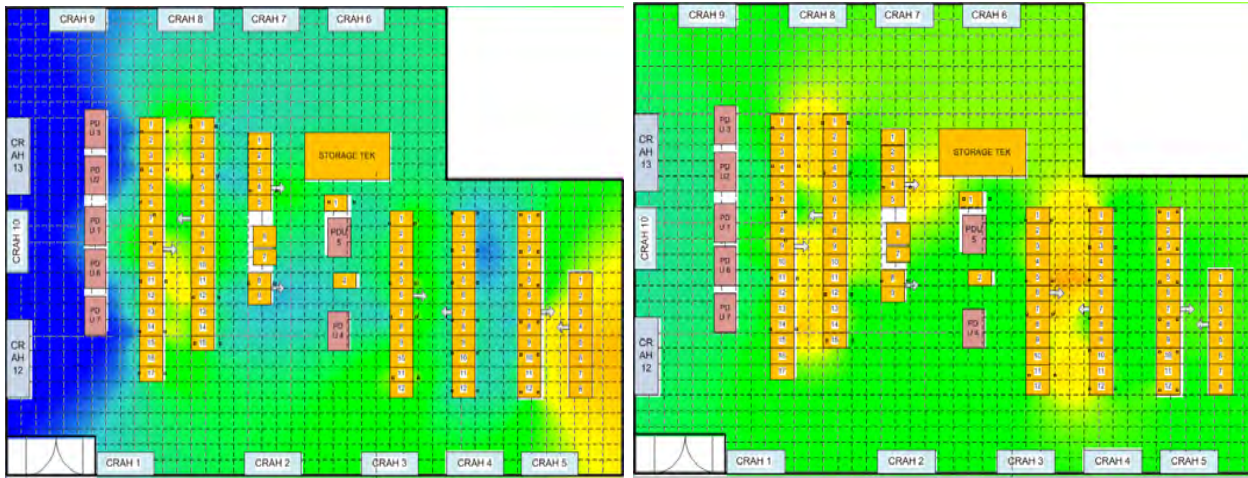


# Maui High Performance Computing Center

- Increased air intake temperature
- Turned off 3 CRAHs
- Saved almost \$300,000 annually

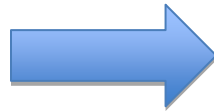
Then:

- Installed dry coolers for water cooled system
- Will save additional \$200,000 annually
- 6 times more compute

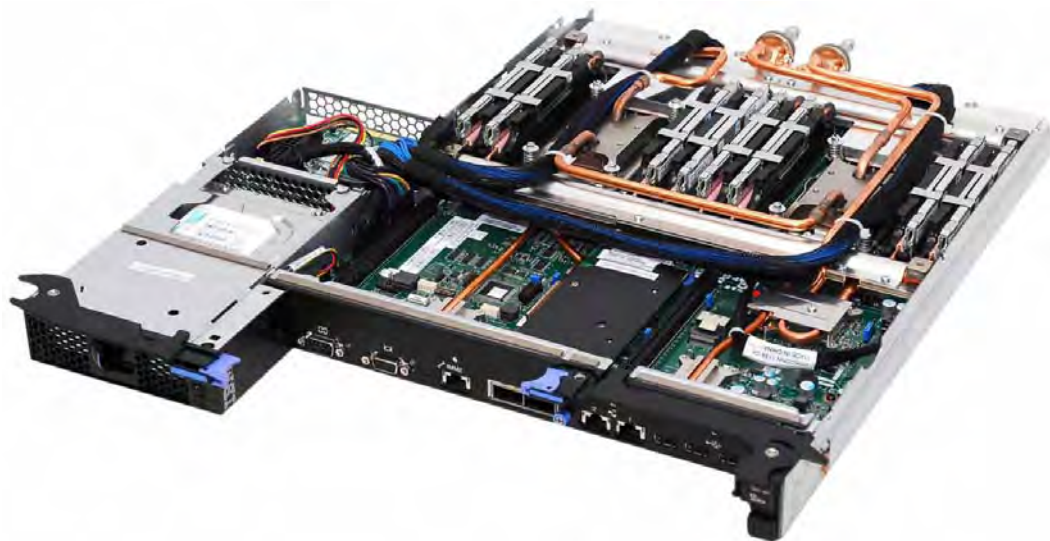


# Maui HPC Center Warm Water Cooling

IBM Riptide



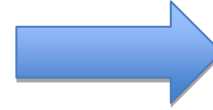
- 91% water cooled, 9% air cooled



Water inside

# MHPCC Water Cooling, continued

Water Piping Behind the servers

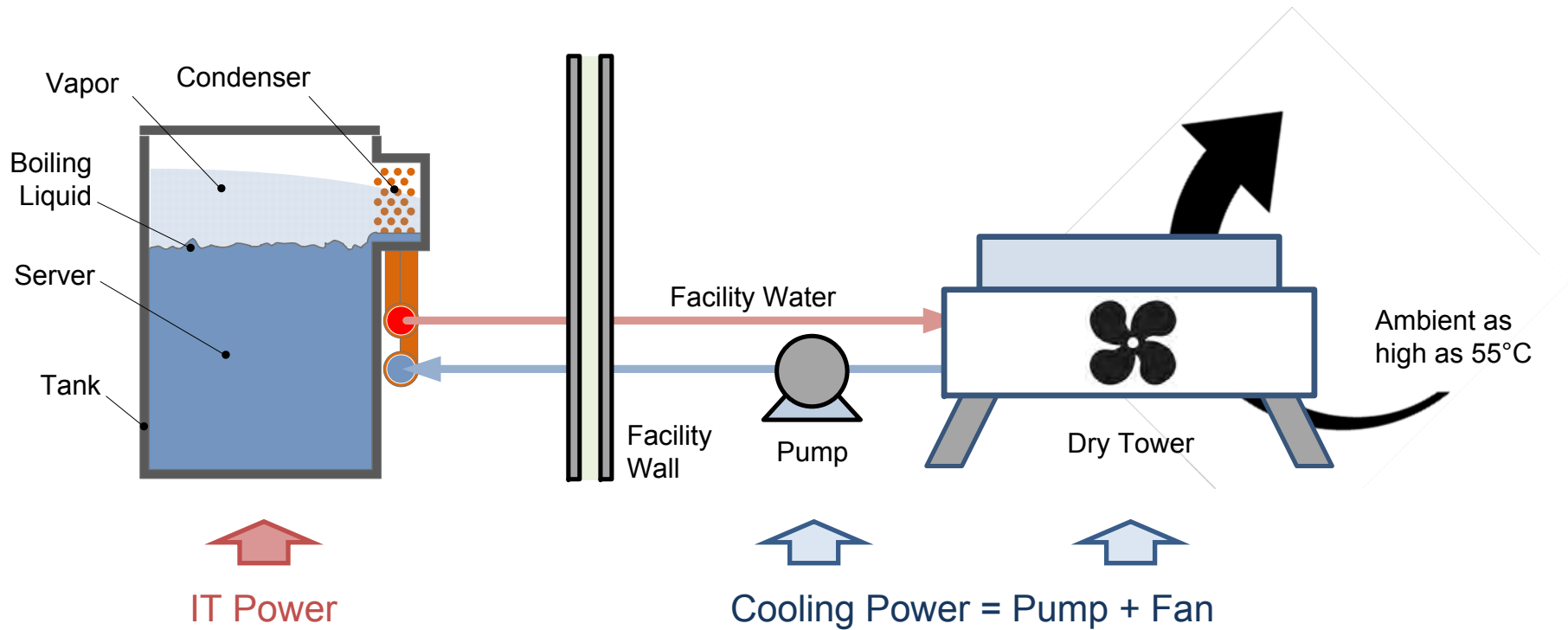


- Cooling water temperature as high as 44° C

Dry Coolers, 10kW each  
compared to 100kW Chillers



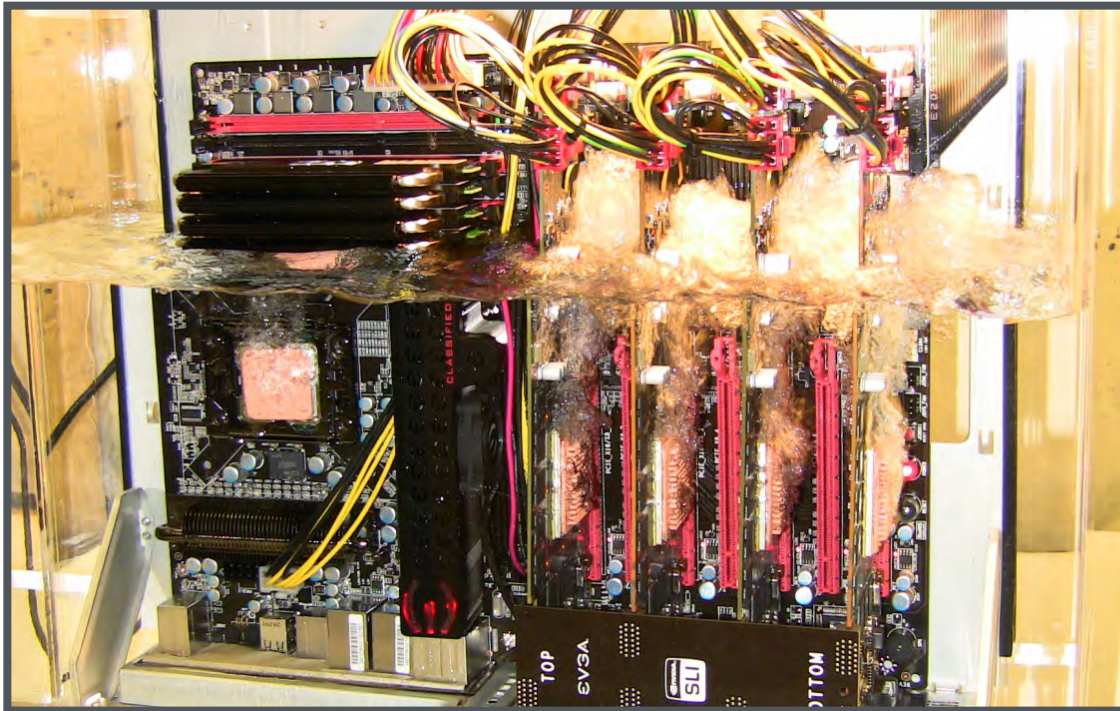
# Liquid immersion cooling demonstration



**No longer requires:**

- chillers
- cooling towers
- water use
- raised floors
- computer room air conditioners
- earplugs!

# Phase change of dielectric fluid removes heat efficiently



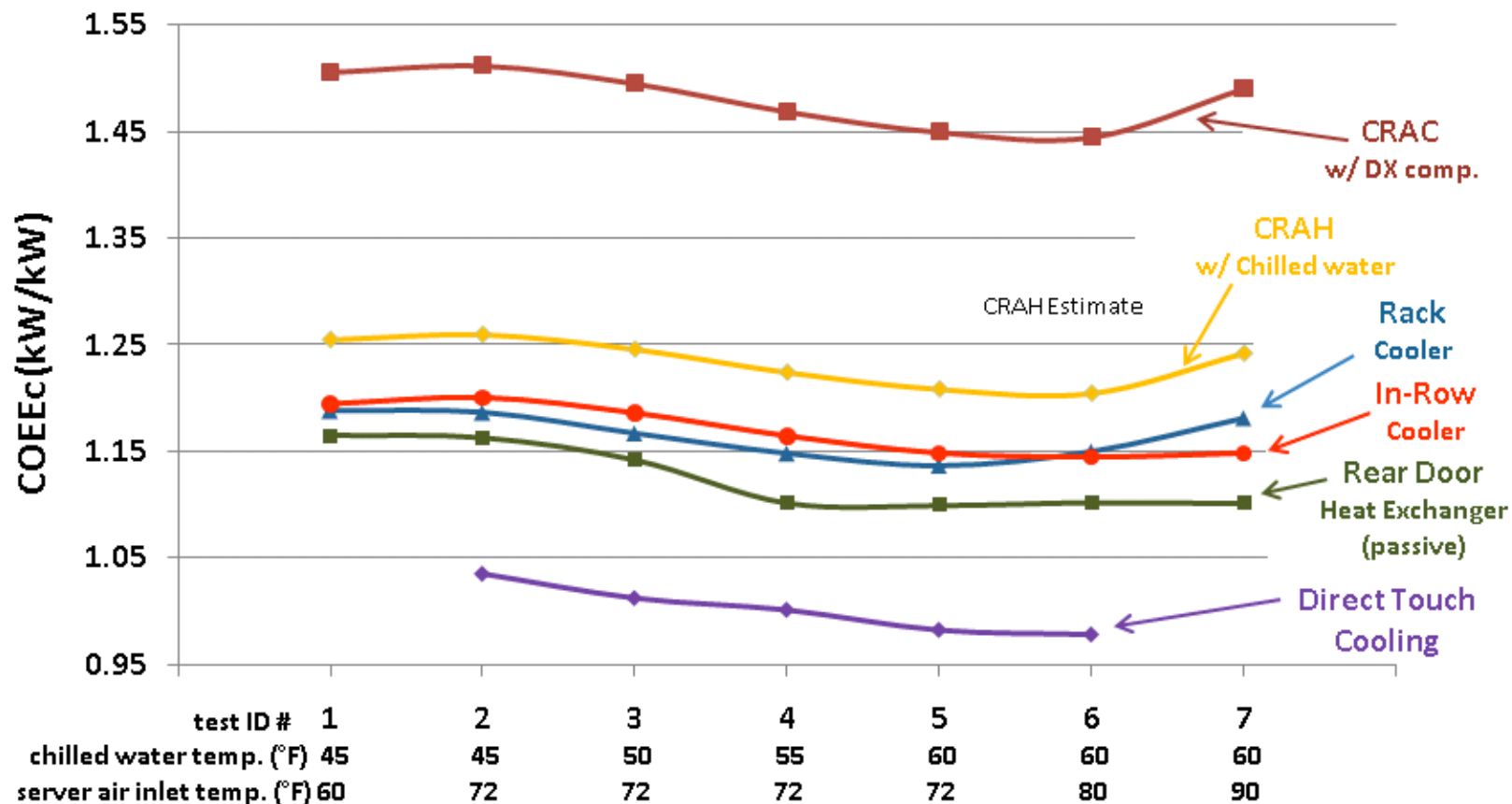
Computer in glass tank



3M Corp.  
4 server system

# “Chill-off 2” Evaluation of Liquid Cooling Solutions

## Data Center Cooling Device Relative Performance



# Use Free Cooling:

## Cooling without Compressors:

- Outside-Air Economizers
- Water-side Economizers
- Let's get rid of chillers in data centers

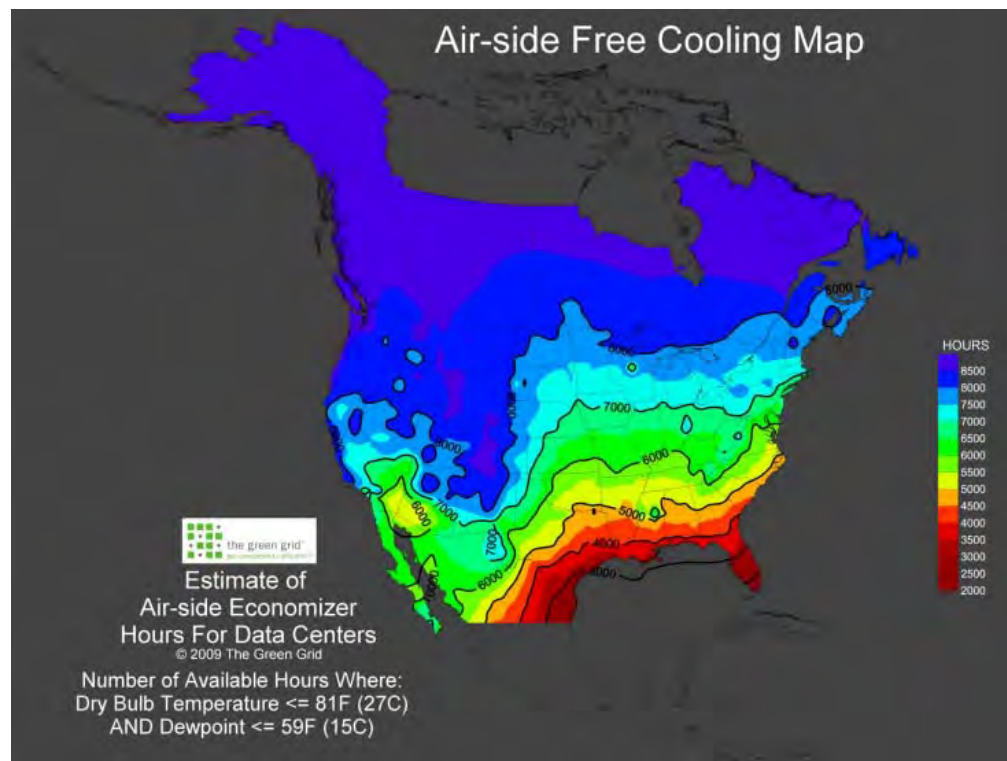


## Advantages

- Lower energy use
- Added reliability (backup for cooling system)

## Potential Issues

- Space.
- Dust
  - Not a concern with Merv 13 filters
- Gaseous contaminants
  - Not widespread
  - Impacts normally cooled data centers as well
- Shutdown or bypass if smoke is outside data center.



[http://cooling.thegreengrid.org/namerica/WEB\\_APP/calc\\_index.html](http://cooling.thegreengrid.org/namerica/WEB_APP/calc_index.html)



## Free-Cooling Estimated Savings

US/CANADA LOCATION (ZIP CODE):

DEGREES IN: ☐ FAHRENHEIT  
☒ CELSIUS

ALLOW MIXING OF SUPPLY AND RETURN AIR ☒

ALLOW HUMIDIFICATION ☒

	MAX LIMIT	MIN LIMIT
DRYBULB TEMP THRESHOLD (DEG): ?	<input type="text" value="27.0"/>	<input type="text" value="NONE"/>
DEWPOINT TEMP THRESHOLD (DEG): ?	<input type="text" value="15.0"/>	<input type="text" value="NONE"/>
REL. HUMIDITY THRESHOLD (%): ?	<input type="text" value="NONE"/>	
DESIRED CHILLED WATER TEMP (DEG): ?	<input type="text" value="13.0"/>	
COOLING SYSTEM APPROACH TEMP (DEG): ?	<input type="text" value="3.0"/>	

DATA CENTER IT POWER (kW): ?	<input type="text" value="1000"/>		
POWER USAGE EFFECTIVENESS (PUE): ?	<input type="text" value="1.6"/>		
TOTAL FACILITY POWER (kW): ?	<input type="text" value="1600"/>		
OVERHEAD POWER (kW): ?	<input type="text" value="600"/>		
PERCENT OF OVERHEAD POWER FOR COOLING SYSTEM (%): ?	<input type="text" value="80"/>	%	<input type="text" value="480"/> kW
PERCENT OF COOLING SYSTEM POWER FOR CHILLER (%): ?	<input type="text" value="40"/>	%	<input type="text" value="192"/> kW
PERCENT OF COOLING SYSTEM POWER FOR TOWER (%): ?	<input type="text" value="40"/>	%	<input type="text" value="192"/> kW

HOURS MEETING CRITERIA FOR FREE-AIR COOLING:

ESTIMATED SAVINGS USING FREE-AIR COOLING:

HOURS MEETING CRITERIA FOR WATER SIDE ECONOMIZER:

# *UC's Computational Research and Theory (CRT) Facility*

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

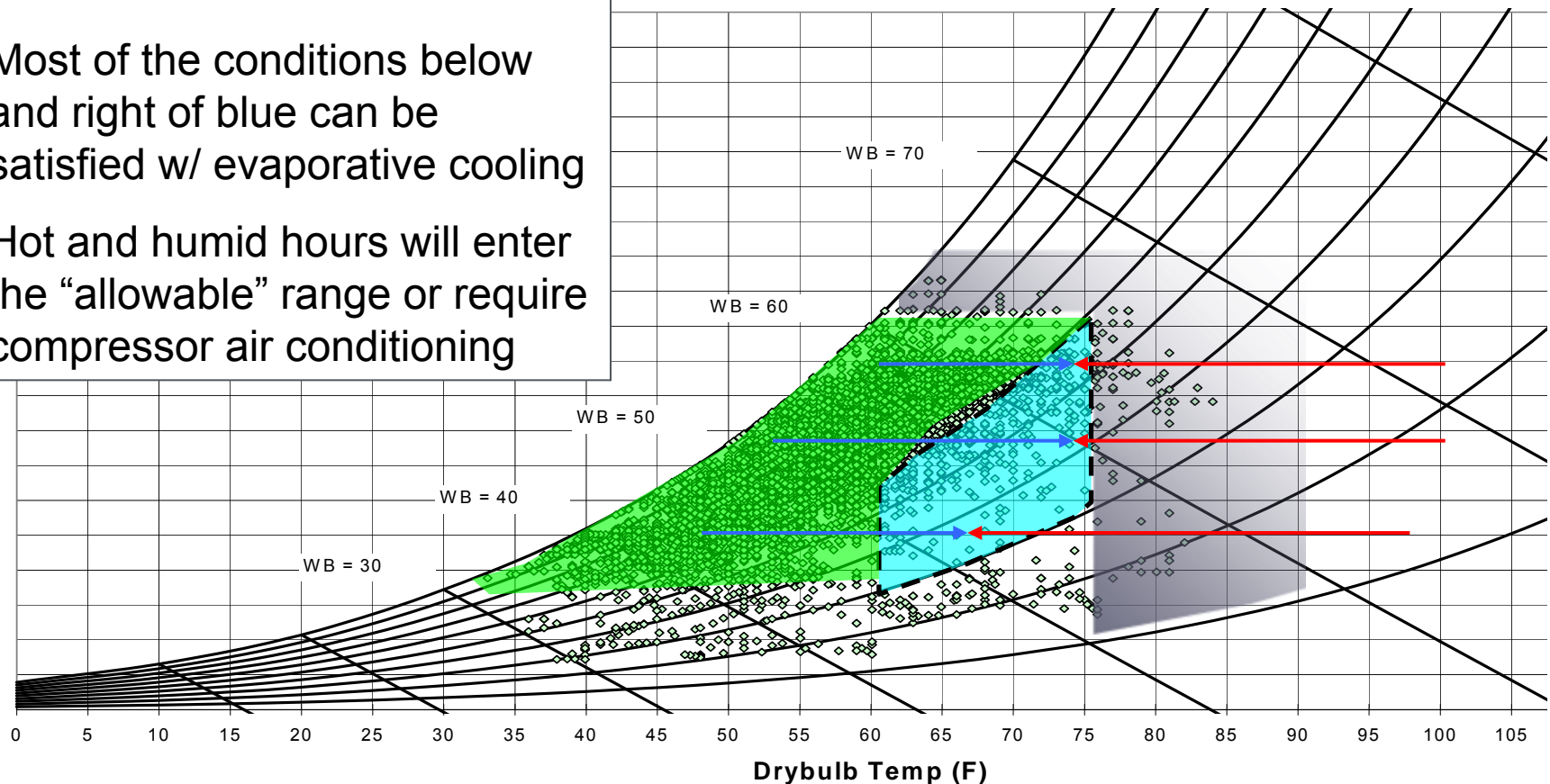


# Free Cooling – Outside Air Based

1. Blue = recommended supply
2. Green can become blue mixing return and outdoor air
3. Most of the conditions below and right of blue can be satisfied w/ evaporative cooling
4. Hot and humid hours will enter the “allowable” range or require compressor air conditioning

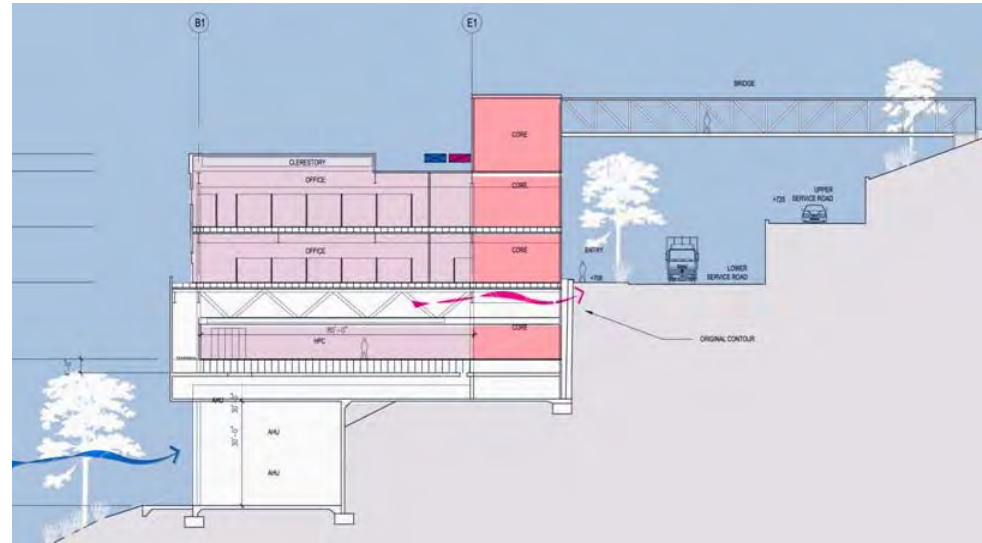
**Annual Psychrometric Chart of Oakland, CA**

(relative humidity lines are stepped by 10%,  
wetbulb lines by 10 degrees F)



# System Design Approach:

- Air-Side Economizer (93% of hours)
- Direct Evaporative Cooling for Humidification/ pre-cooling
- Low Pressure-Drop Design (1.5" total static peak)



## Hours of Operation

Mode 1

Mode 2

Mode 3

Mode 4

Mode 5

total

100% Economiser

OA + RA

Humidification

Humid + CH cooling

CH only

2207 hrs

5957 hrs

45 hrs

38 hrs

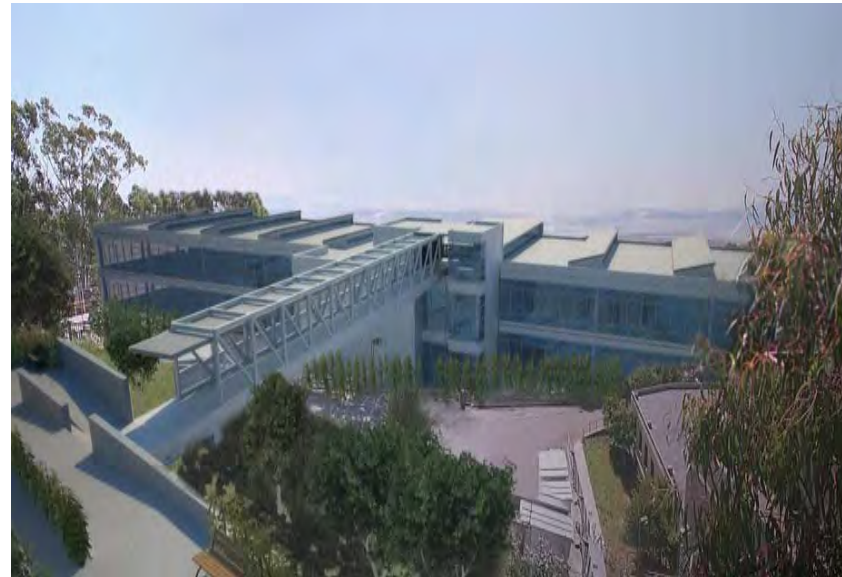
513 hrs

8760 hrs

- Tower side economizer
- Four pipe system
- Waste heat reuse
- Headers, valves and caps for modularity and flexibility

## Predicted CRT Performance:

- Annual PUE = 1.1

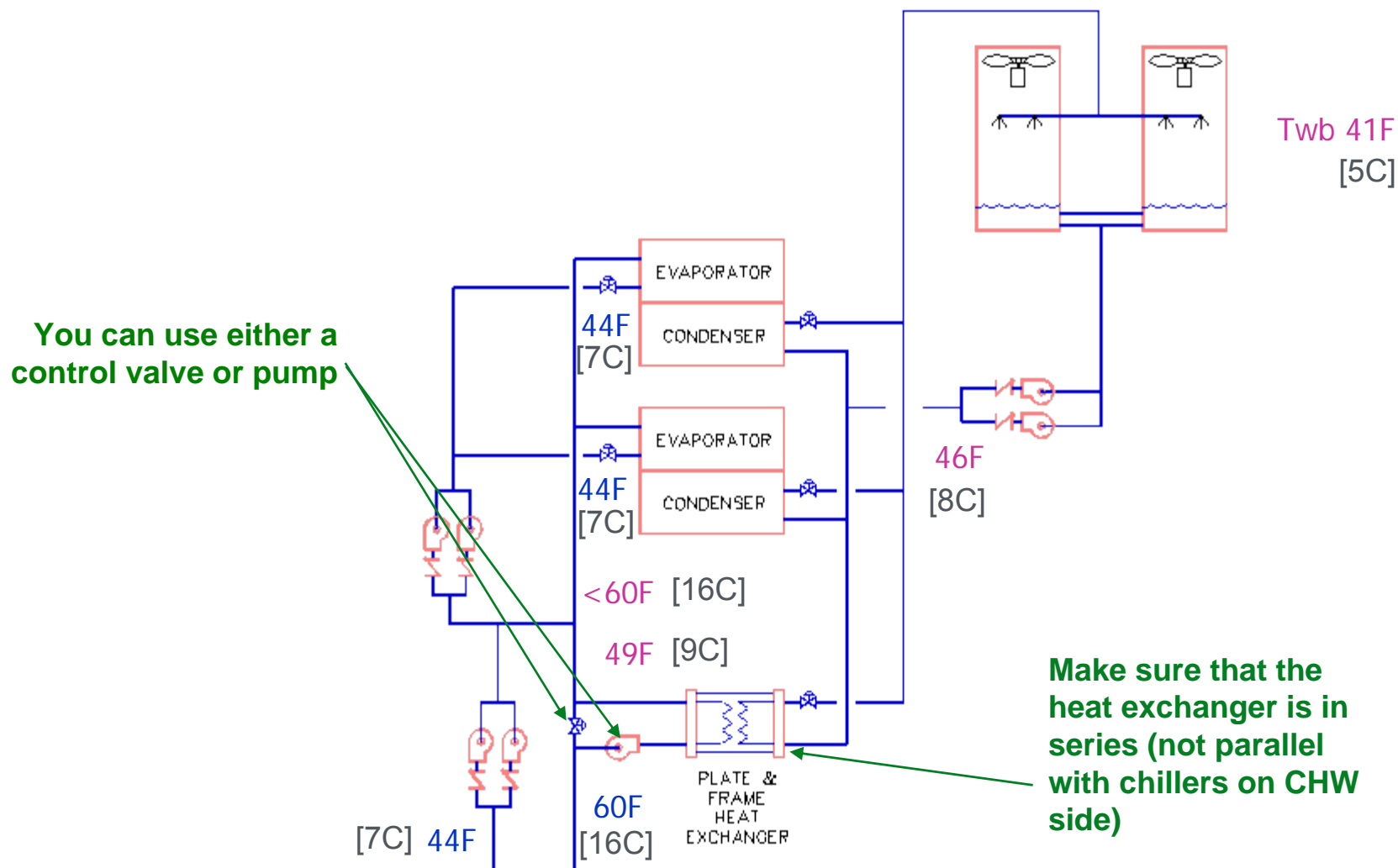


## Advantages

- Cost effective in cool and dry climates
- Often easier retrofit
- Added reliability (backup in the event of chiller failure).
- No contamination questions

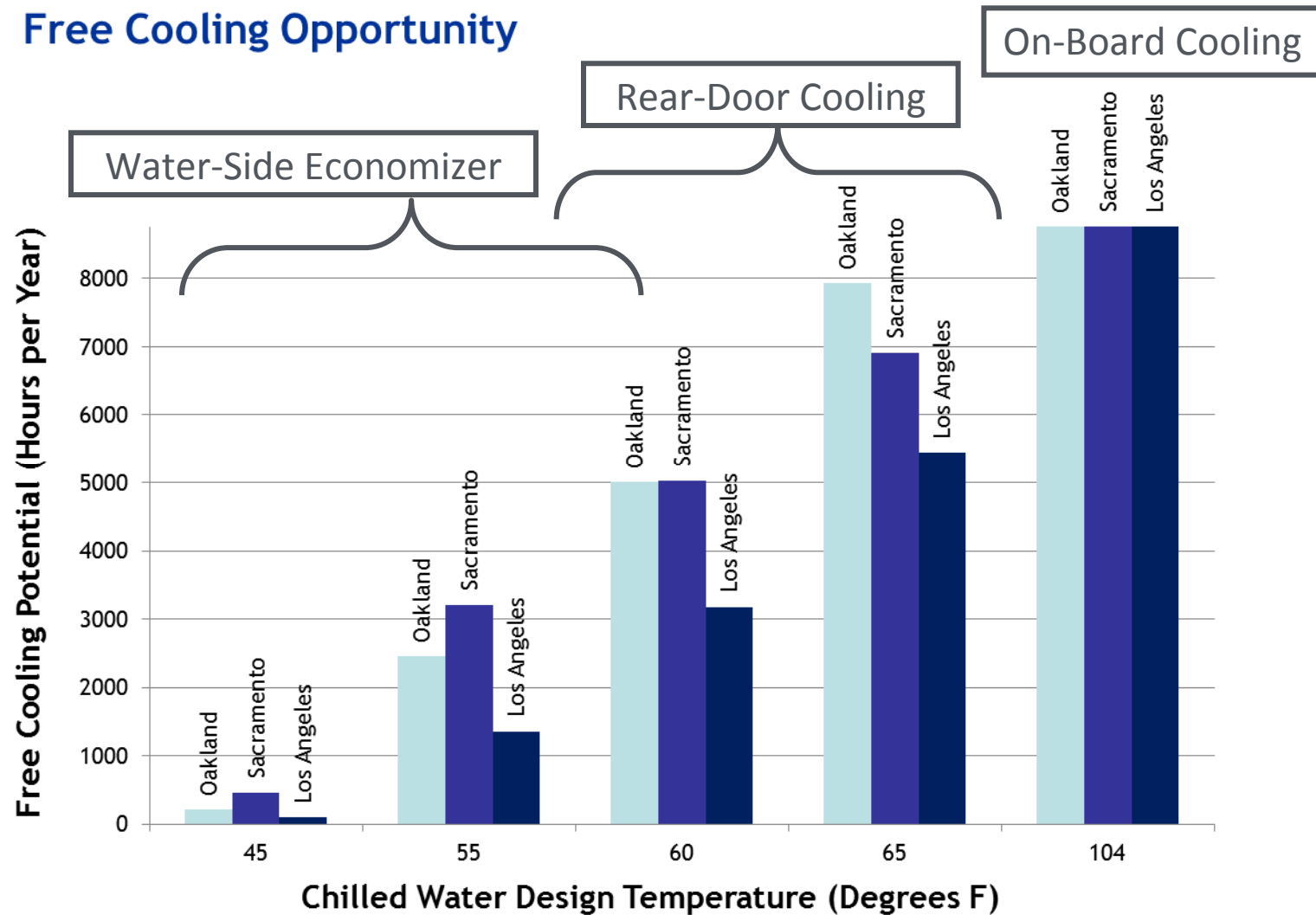


# Integrated Water-Side Economizer



# Potential for Tower Cooling

## Free Cooling Opportunity



# LBL Example: Rear Door Cooling

- Used instead of adding CRAC units
- Rear door water cooling with tower-only (or central chiller plant in series).
  - Both options significantly more efficient than existing direct expansion (DX) CRAC units.



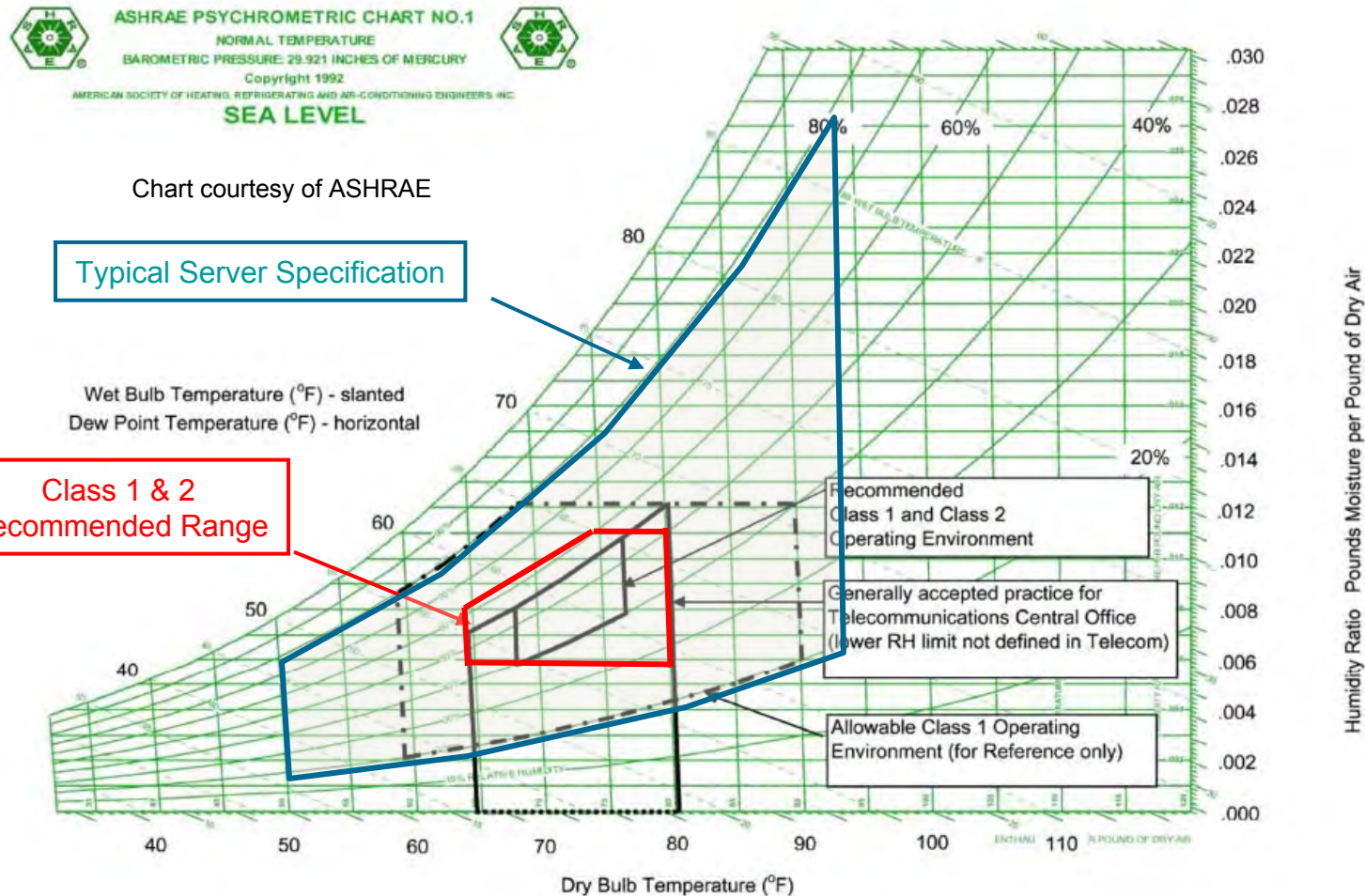
- Eliminate inadvertent dehumidification
  - Computer load is sensible only
- Use ASHRAE allowable humidity ranges
  - Maintain inlet conditions between 41.9° F dew-point and 59° F dew-point and 60% RH or manufacturer's requirements (many manufacturers allow even wider humidity range).
  - Use dew-point control, NOT %RH.
- Defeat equipment fighting
  - Coordinate controls
- Disconnect and only control humidity of makeup air or one CRAC/CRAH unit
- Entirely disconnect (many have!)

- Some contaminants (hygroscopic salts) with high humidity can deposit and bridge across circuits
- Operating with high humidity (>60%) in an environment with high concentrations of particulates could be a problem.
- **Normal building filtration is effective in removing particulates**
- Operating with high humidity (>60%) in areas with gaseous contamination could cause problems. More study is needed in this area, however few locations have such conditions.

## Electrostatic discharge

- Industry practices
  - Telecom has no lower limit (personnel grounding expected)
  - Electrostatic Discharge Association removed humidity control as a primary ESD control measure in ESD/ANSI S20.20
  - IT equipment is qualified to withstand ESD and it is grounded
  - Many centers eliminate humidification with no adverse effects
- Recommended procedures
  - Personnel grounding
  - Cable and floor grounding

## Server Performance Specifications Generally Exceed ASHRAE Ranges

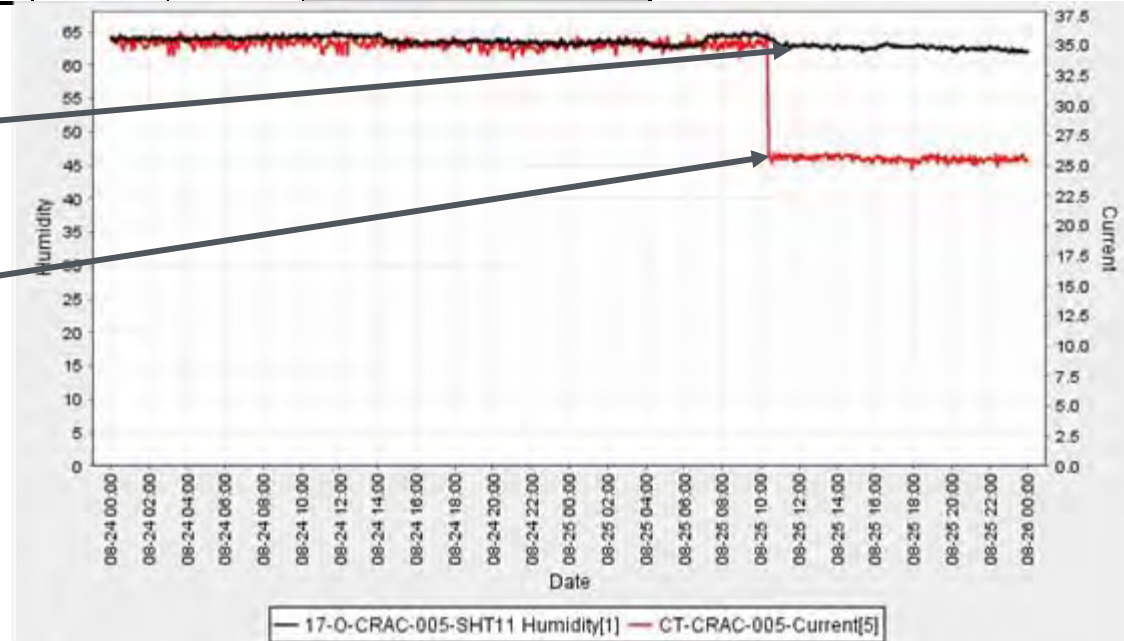


# Cost of Unnecessary Humidity Control

	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	

Humidity down ~2%

CRAC power down 28%



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

# Questions?





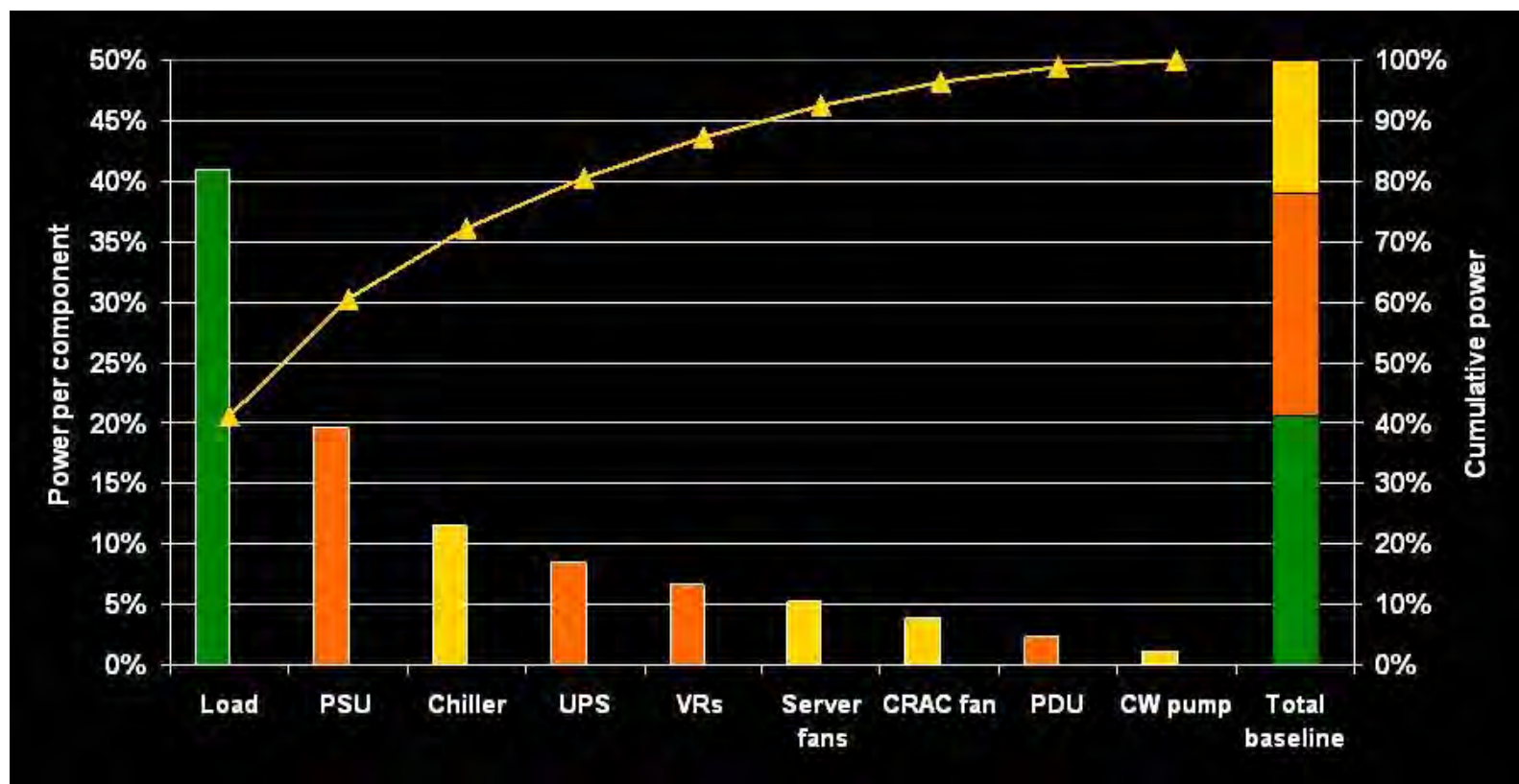
## Electrical Systems



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



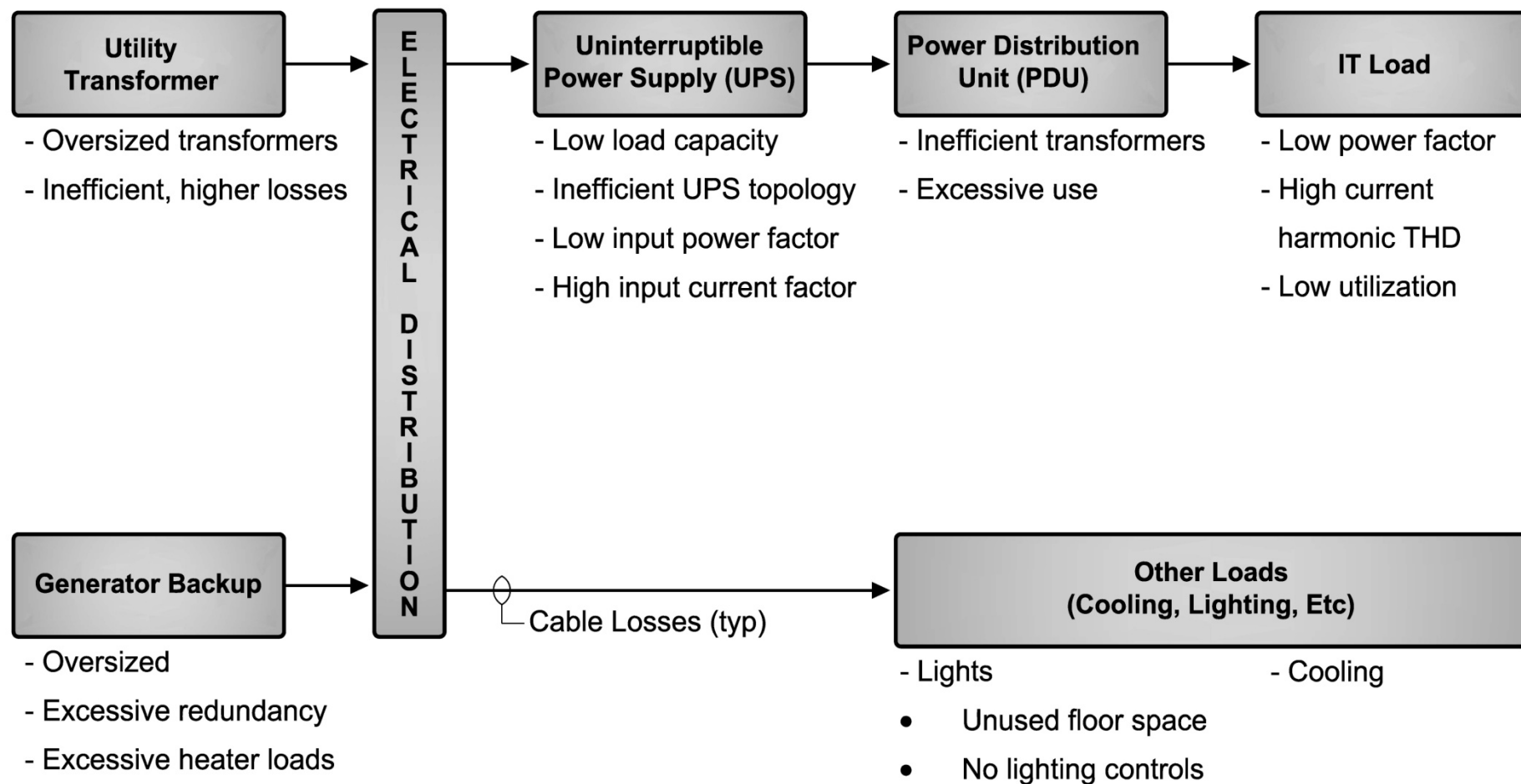
# Electrical system end use – Orange bars



Courtesy of Michael Patterson, Intel Corporation

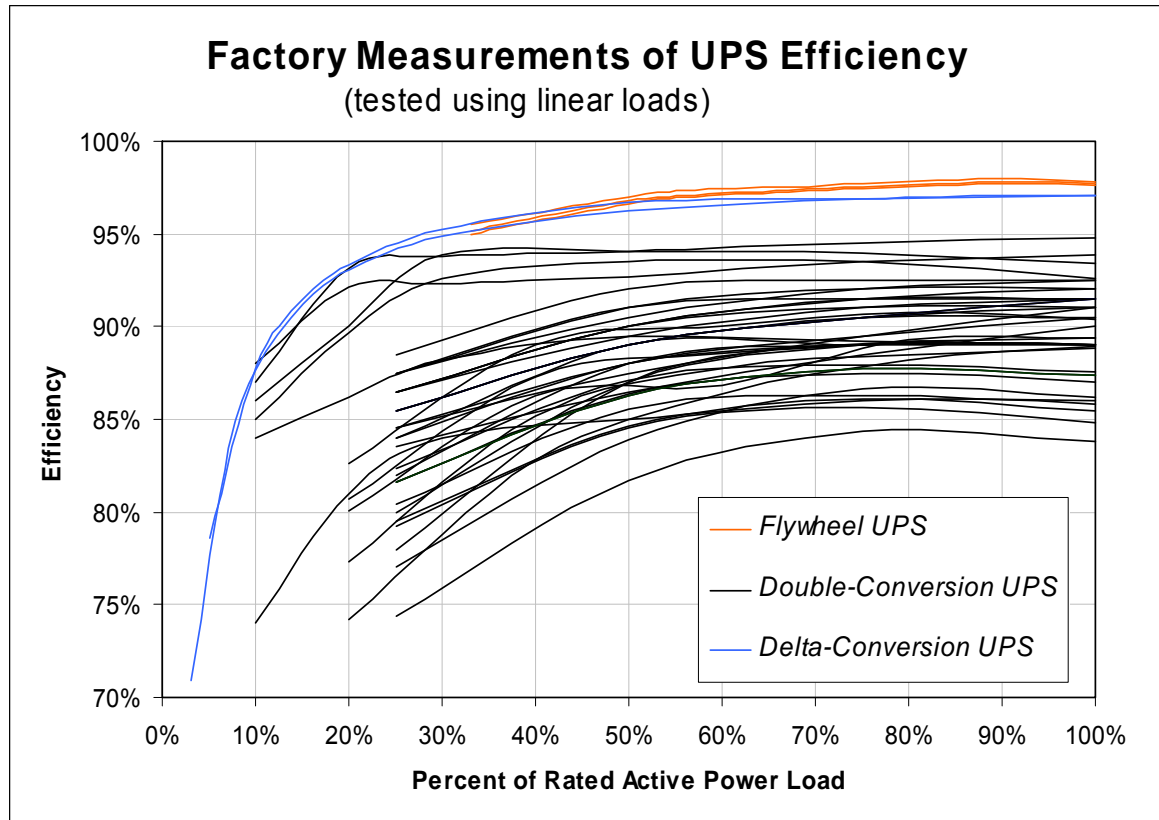
- Every power conversion (AC-DC, DC-AC, AC-AC) loses some energy and creates heat
- Efficiency decreases when systems are lightly loaded
- Distributing higher voltage is more efficient and can save capital cost (conductor size is smaller)
- Power supply, uninterruptible power supply (UPS), transformer, and PDU efficiency varies – carefully select
- Lowering distribution losses also lowers cooling loads

# Electrical Systems – Points of Energy Inefficiency

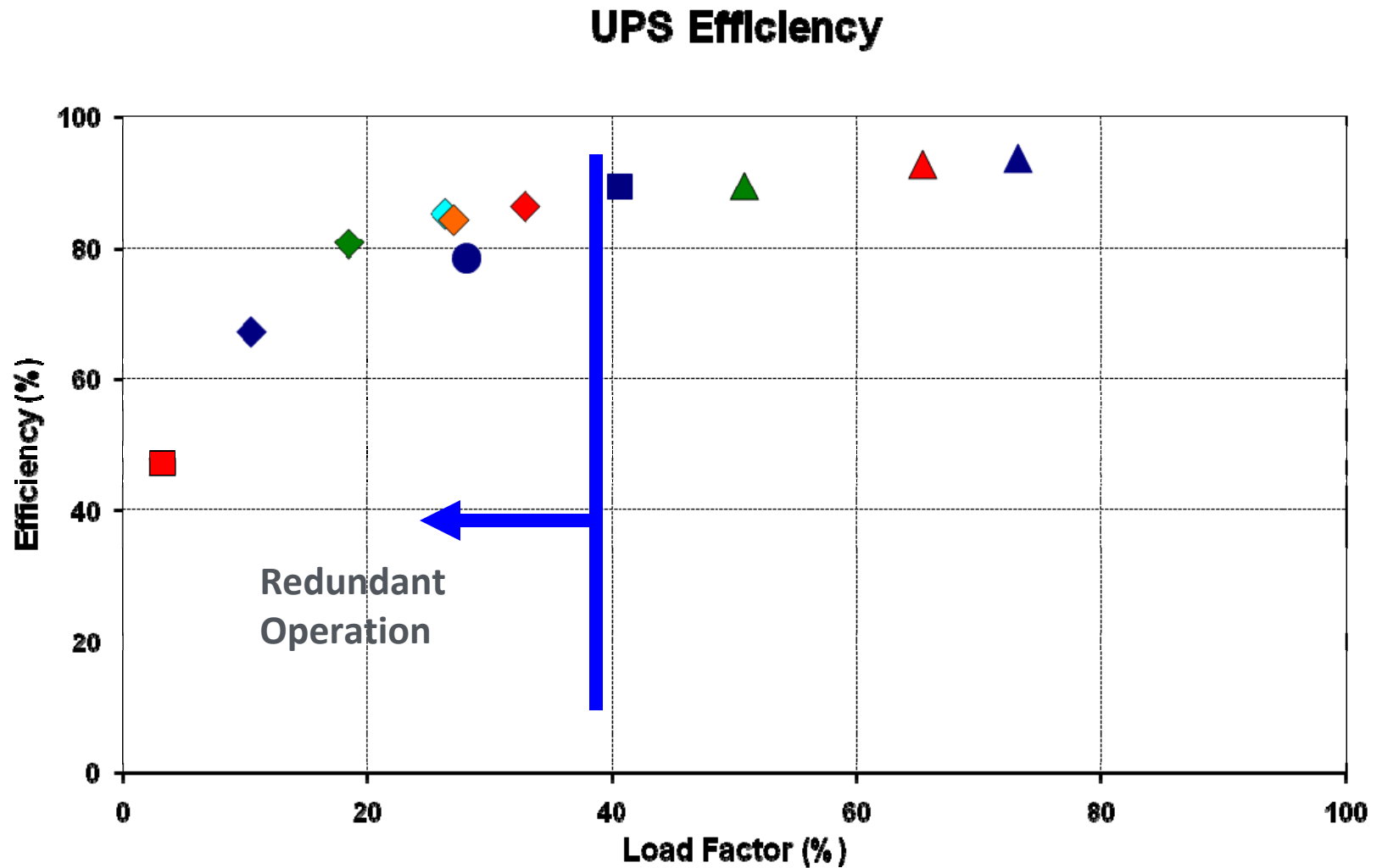


# UPS, Transformer, & PDU Efficiency

- Efficiencies vary with system design, equipment, and load
- Redundancies impact efficiency

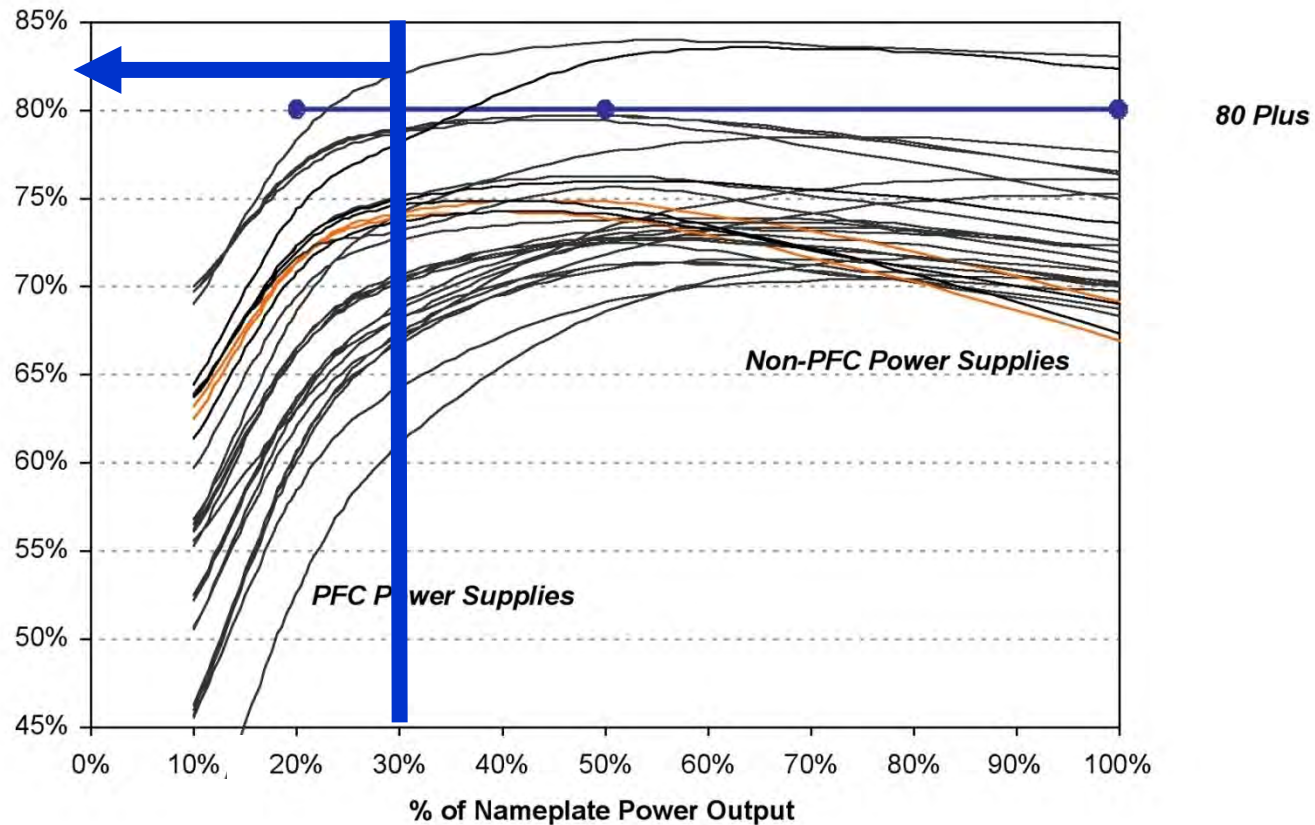


# Measured UPS efficiency

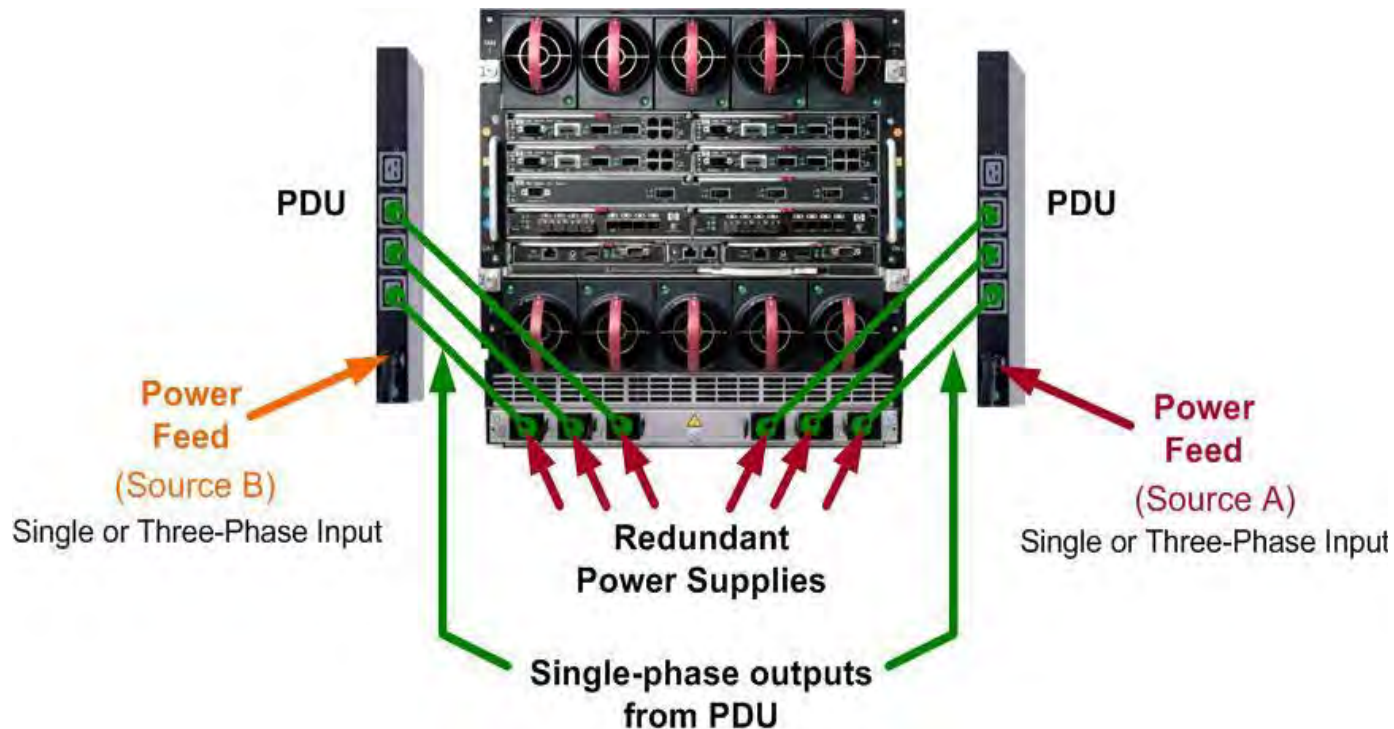


# LBNL/EPRI Measured Power Supply Efficiency

Measured Server Power Supply Efficiencies (all form factors)

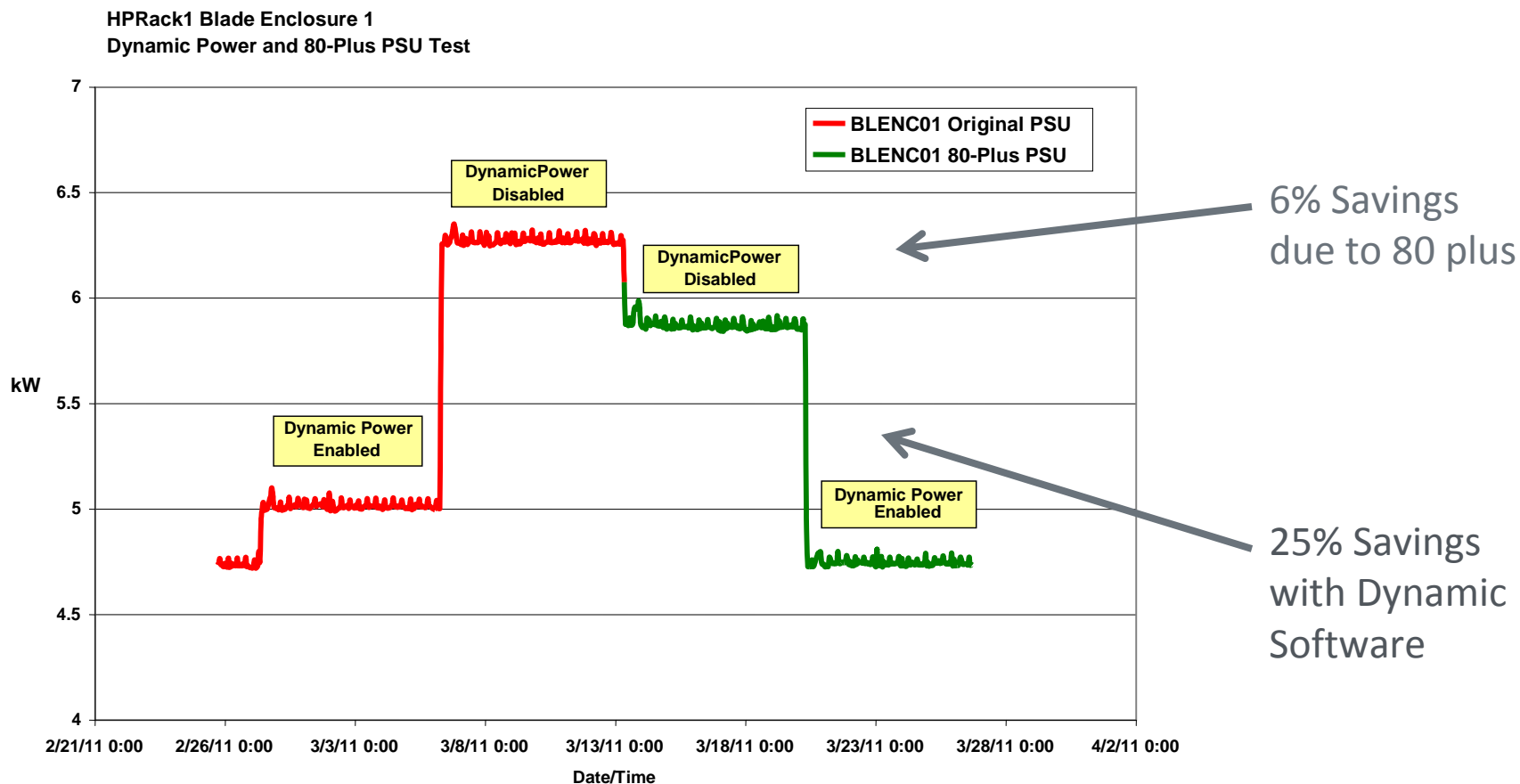


# The 80 Plus program drives efficiency improvement



An Electric Power Research Institute case study illustrated the savings

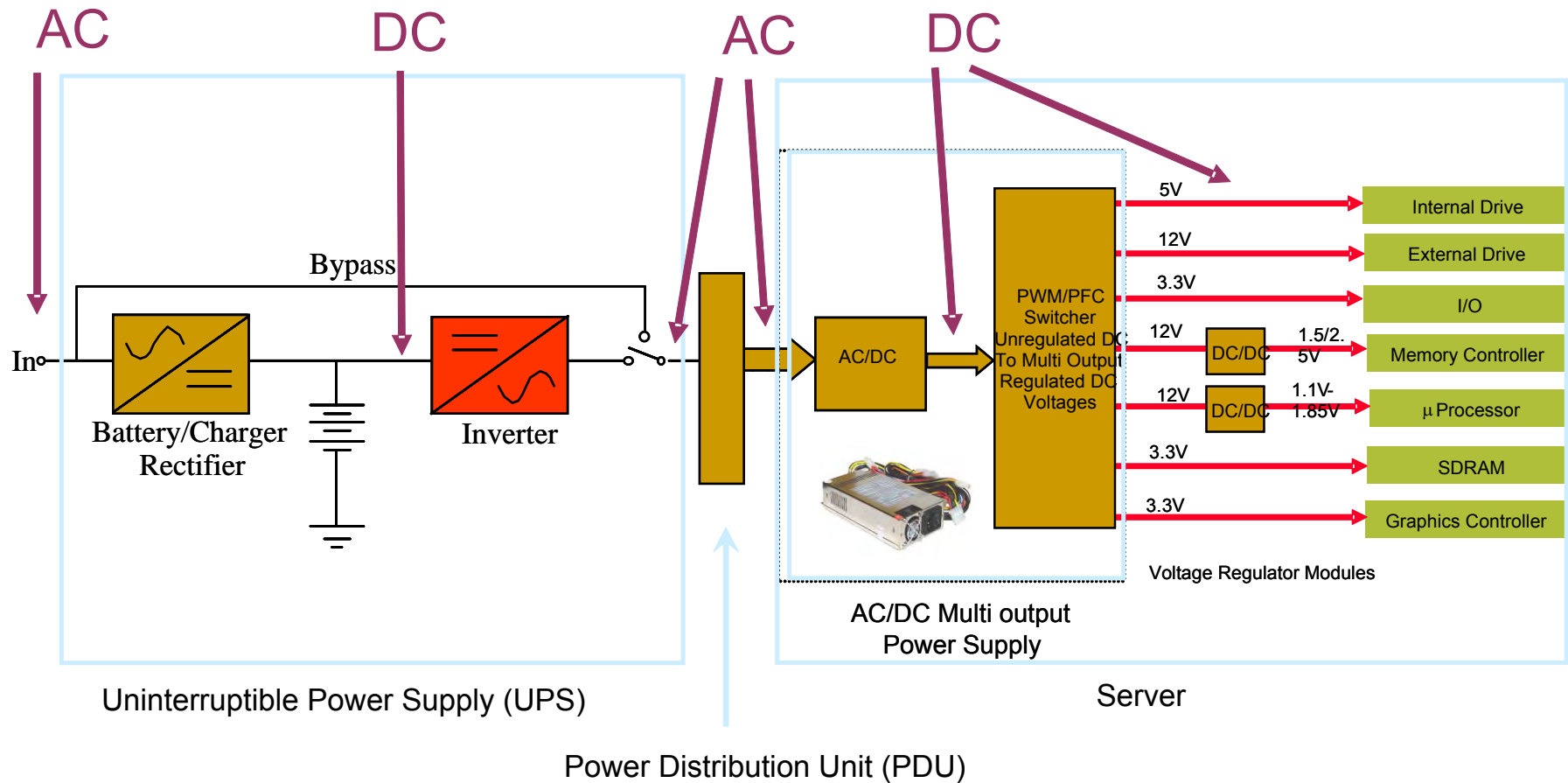
# Upgraded power supplies



Dynamic power software turns off redundant power supplies when not needed

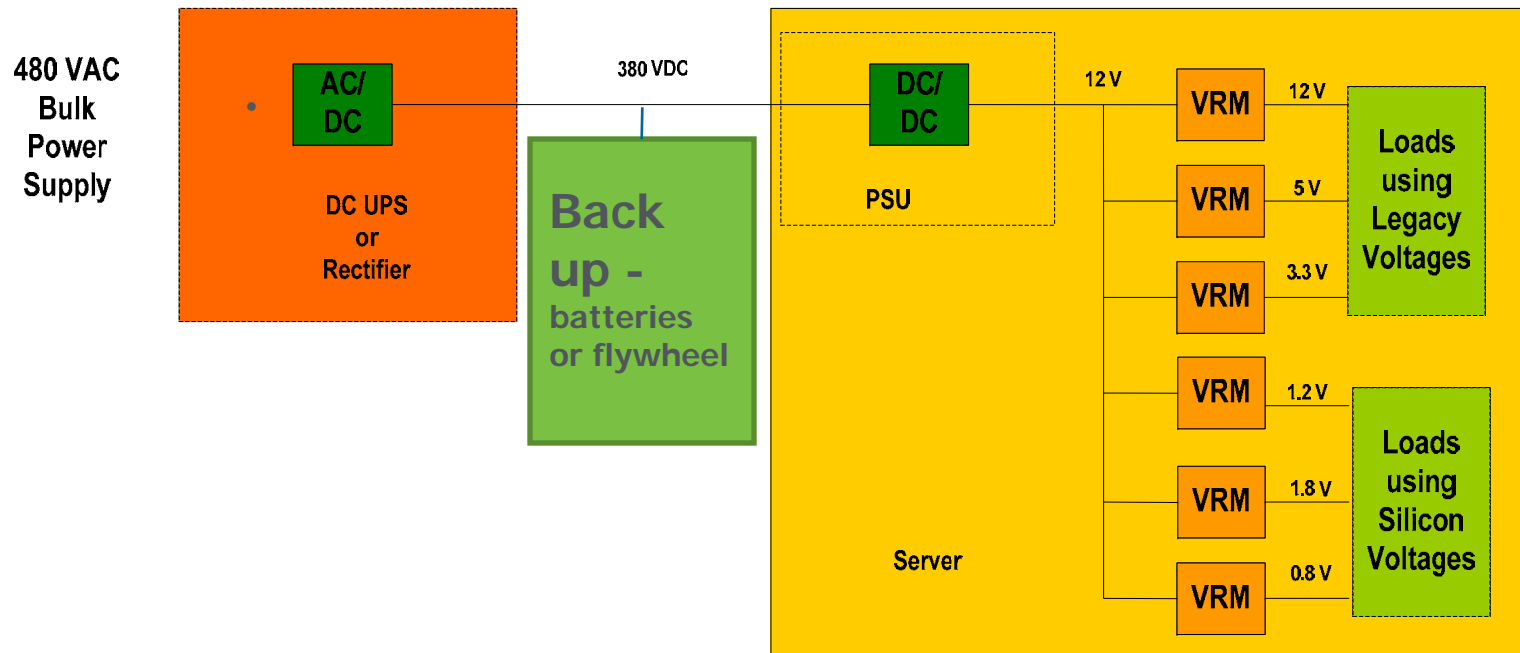
- Understand what redundancy costs and what it gets you – is it worth it?
- Does everything need the same level?
- Different strategies have different energy penalties (e.g.  $2N$  vs.  $N+1$ )
- It's possible to more fully load UPS systems and achieve desired redundancy
- Redundancy in electrical distribution puts you down the efficiency curve
- Redundancy in the network vs. data center

# From Utility Power to the Chip— Multiple Electrical Power Conversions



## 380V. DC power distribution

- Eliminate several conversions
- Also use for lighting, and variable speed drives
- Use with on-site generation including renewable energy sources



# Standby generation loss

**Standby generators typically use more energy than they will ever generate**

## Several load sources

Heaters

Battery chargers

Transfer switches

Fuel management systems

Reduce or eliminate heating, batteries,  
and chargers – check with manufacturer  
for temperature and control

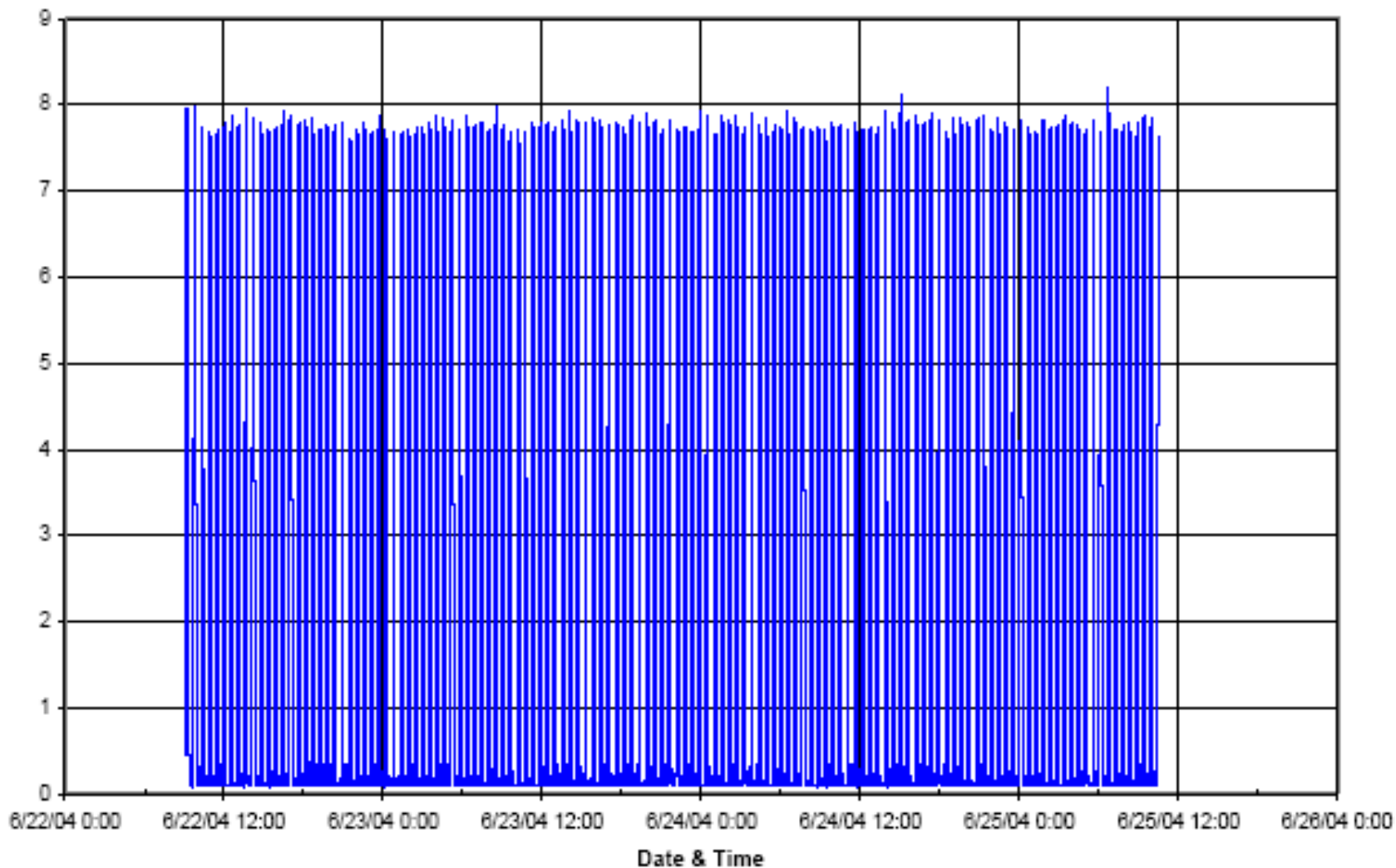


## Other options:

- Right-sizing of stand-by generation
- Consider redundancy options

# Standby generator heater

Generator Standby Power Loss



- Lights are on and nobody's home
  - Switch off lights in unused/unoccupied areas or rooms (UPS, Battery, S/Gear, etc)
  - Lighting controls such as occupancy sensors are well proven
- Small relative benefit but easy to accomplish – also saves HVAC energy
- Use energy efficient lighting
- Lights should be located over the aisles



- Since most cooling system equipment operates continuously, premium efficiency motors should be specified everywhere
- Variable speed drives should be used
  - Chillers
  - Pumps
  - Air handler fans
  - Cooling tower fans

- **Choose highly efficient components and configurations**
- **Reduce power conversion (AC-DC, DC-AC, AC-AC, DC-DC)**
- **Consider the minimum redundancy required as efficiency decreases when systems are lightly loaded**
- **Use higher voltage**

# Questions?





## Resources



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



## Advanced Manufacturing Office

- Tool suite & metrics for baselining
- Training
- Qualified specialists
- Case studies
- Recognition of high energy savers
- R&D - technology development



## Federal Energy Management Program

- Workshops
- Federal case studies
- Federal policy guidance
- Information exchange & outreach
- Access to financing opportunities
- Technical assistance



## GSA

- Workshops
- Quick Start Efficiency Guide
- Technical Assistance



## EPA

- Metrics
- Server performance rating & ENERGY STAR label
- Data center benchmarking



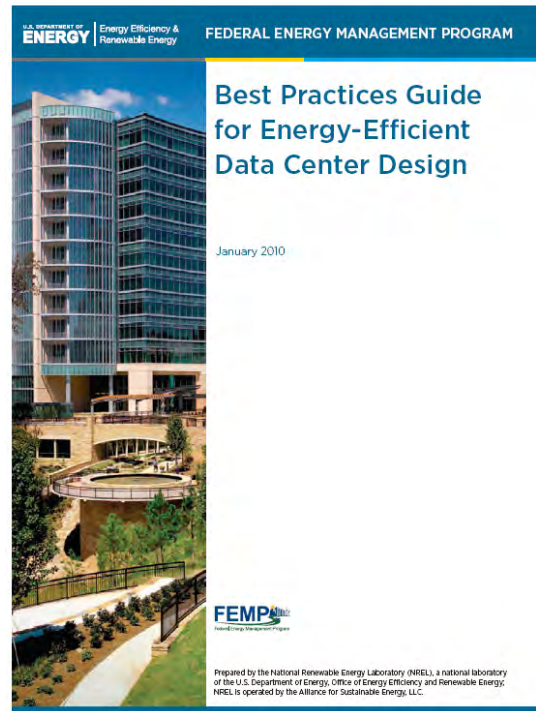
## Industry

- Tools
- Metrics
- Training
- Best practice information
- Best-in-Class guidelines
- IT work productivity standard



# Resources from DOE Federal Energy Management Program (FEMP)

- Best Practices Guide
- Benchmarking Guide
- Data Center Programming Guide
- Technology Case Study Bulletins
- Procurement Specifications
- Report Templates
- Process Manuals
- Quick-Start Guide



As data center energy densities in power-use per square foot increase, energy savings for cooling can be realized by incorporating liquid-cooling devices instead of increasing airflow volume. This is especially important in a data center with a typical under-floor cooling system.

Server racks can also be cooled with competing technologies such as modular, overhead coolers, server coolers, and closed-circuit coolers with dedicated containment enclosures.

During operation, hot server-rack airflow is forced through the RDHs device by the server fans. Hot air is exchanged from the hot air to circulating water from a chiller or cooling tower. Then, server-rack outlet air temperature is reduced before it is discharged into the data center.

2 Technology Overview  
The covered data center is located at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL).



1 Introduction  
As data center energy densities in power-use per square foot increase, energy savings for cooling can be realized by optimizing airflow pathways within the data center. This is especially important in existing data centers with typical under-floor air distribution primarily due to constraints from under-floor dimensions, obstructions, and leakage. Individually, airflow capacity can be improved significantly in most data centers, as described below in the airflow management overview. Next, this case study bulletin presents air management improvements that were retrofitted in an older "legacy" data center at Lawrence Berkeley National Laboratory (LBNL). Particular airflow improvements, performance results, and benefits are reviewed that enhanced cooling efficiency at LBNL. In addition, a more generalized list of measures to improve data center airflow is provided. Finally, a series of lessons learned gained during the retrofit project at LBNL is presented.

2 Airflow Management Overview  
Airflow retrofits can increase data center energy efficiency by freeing up stranded airflow and cooling capacity.

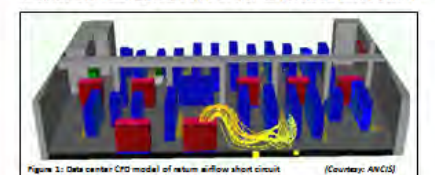


Figure 1: Data center CFD model of return airflow short circuit (Courtesy: ANSYS)

supply, and make it available for future needs. Effective implementation requires information technologies (IT) staff, in-house facilities technicians, and engineering consultants working collaboratively. Together they can identify airflow deficiencies, develop solutions, and implement fixes and upgrades.

## DOE's AMO data center program provides tools and resources to help owners and operators:

- **DC Pro Software Tool Suite**
  - Tools to define baseline energy use and identify energy-saving opportunities
- **Information products**
  - Manuals, case studies, and other resources
- **End-user awareness training**
  - Workshops in conjunction with ASHRAE
- **Data Center Energy Practitioner (DCEP) certificate program**
  - Qualification of professionals to evaluate energy efficiency opportunities
- **Research, development, and demonstration of advanced technologies**

## High-Level On-Line Profiling and Tracking Tool

- Overall efficiency (Power Usage Effectiveness [PUE])
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential

## In-Depth Assessment Tools → Savings

### Air Management

- Hot/cold separation
- Environmental conditions
- RCI and RTI

### Electrical Systems

- UPS
- PDU
- Transformers
- Lighting
- Standby gen.

### IT-Equipment

- Servers
- Storage & networking
- Software

### Cooling

- Air handlers/conditioners
- Chillers, pumps, fans
- Free cooling

**A certificate process for energy practitioners qualified to evaluate energy consumption and efficiency opportunities in Data Centers.**

**Key objective:**

- Raise the standards of assessors
- Provide greater repeatability and credibility of recommendations.

**Target groups include:**

- Data Center personnel (in-house experts)
- Consulting professionals (for-fee consultants)

## Training & Certificate Disciplines/Levels/Tracks

### Level 1 Generalist:

Prequalification,  
Training and Exam on  
All Disciplines  
+ Assessment Process  
+ DC Pro Profiling Tool

IT-Equipment, Air-Management, Cooling Systems,  
and Electrical Systems

### Level 2 Specialist:

Prequalification,  
Training and Exam on  
Select Disciplines  
+ Assessment Process  
+ DC Pro System  
Assessment Tools

Cooling  
Systems

Air  
Management

Electrical  
Systems

IT  
Equipment

HVAC  
(available)

IT  
(2012)

### Two Tracks:

- Certificate track (training + exam)
- Training track (training only)

**DCEP training is delivered by Professional Training Organizations that were selected through a competitive process**



<http://www.cdcdp.com/dcep.php>



<http://www.datacenterdynamics.com/training/course-types/doe-certified-energy-professional>

The PTO(s):

- license training and exam content from DOE
- provide training/exams
- issue certificates.

A voluntary public-private partnership program

- Buildings
- Products



- ENERGY STAR Datacenter Rating Tool
  - Build on existing ENERGY STAR platform with similar methodology (1-100 scale)
  - Usable for both stand-alone and data centers housed within another buildings
  - Assess performance at building level to explain how a building performs, not why it performs a certain way
  - ENERGY STAR label to data centers with a rating of 75+
  - Rating based on data center infrastructure efficiency
    - Ideal metric would be measure of useful work/energy use.
    - Industry still discussing how to define useful work.
- Energy STAR specification for servers and UPSs
- Evaluating enterprise data storage, and networking equipment for Energy STAR product specs





[http://www1.eere.energy.gov/femp/program/data\\_center.html](http://www1.eere.energy.gov/femp/program/data_center.html)



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



[http://www.energystar.gov/index.cfm?c=prod\\_development.server\\_efficiency](http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency)



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

# Questions?





# Workshop Summary

## Best Practices



U.S. Department of Energy  
**Energy Efficiency and Renewable Energy**



## LBNL's Legacy Data Center:

- Increased IT load
  - >50% (~180kW) increase with virtually no increase in infrastructure energy use
- Raised room temperature 8+ degrees
- AC unit turned off
  - (1) 15 ton now used as backup
- Decreased PUE from 1.65 to 1.45
  - 30% reduction in infrastructure energy
- More to come!

## Next Steps for LBNL's Legacy Data Center

- Integrate CRAC controls with wireless monitoring system
- Retrofit CRACs w/ VSD
  - Small VAV turndown, yields big energy savings
- Improve containment (overcome curtain problems)
- Increase liquid cooling (HP in-rack, and APC in-row)
- Increase free cooling (incl. tower upgrade)

1. Measure and Benchmark Energy Use
2. Identify IT Opportunities
3. Use IT to Control IT
4. Manage Airflow
5. Optimize Environmental Conditions
6. Evaluate Cooling Options
7. Improve Electrical Efficiency
8. Implement Energy Efficiency Measures

## 1. Measure and Benchmark Energy Use

- Use metrics to measure efficiency
- Benchmark performance
- Establish continual improvement goals

## 2. Identify IT Opportunities

- Specify efficient servers (incl. power supplies)
- Virtualize
- Refresh IT equipment
- Turn off unused equipment.

## 3. Use IT to Control IT Energy

- Evaluate monitoring systems to enhance real-time management and efficiency.
- Use visualization tools (e.g. thermal maps).
- Install dashboards to manage and sustain energy efficiency.

## 4. Manage Airflow

- Implement hot and cold aisles
- Fix leaks
- Manage floor tiles
- Isolate hot and cold airstreams.

## 5. Optimize Environmental Conditions

- Follow ASHRAE guidelines or manufacturer specifications
- Operate to maximum ASHRAE recommended range.
- Anticipate servers will occasionally operate in allowable range.
- Minimize or eliminate humidity control

## 6. Evaluate Cooling Options

- Use centralized cooling system
- Maximize central cooling plant efficiency
- Provide liquid-based heat removal
- Compressorless cooling

## 7. Improve Electrical Efficiency

- Select efficient UPS systems and topography
- Examine redundancy levels
- Increase voltage distribution and reduce conversions

## 8. Implement Standard Energy Efficiency Measures

- Install premium efficiency motors
- Upgrade building automation control system
  - Integrate CRAC controls
- Variable speed everywhere
- Optimize cooling tower efficiency

***Most importantly...***

Get IT and Facilities People  
Talking and working  
together as a team!!!

# Questions?



# Contact Information:

Dale Sartor, P.E.  
Lawrence Berkeley National Laboratory  
Applications Team  
MS 90-3111  
University of California  
Berkeley, CA 94720

[DSartor@LBL.gov](mailto:DSartor@LBL.gov)  
(510) 486-5988  
<http://Ateam.LBL.gov>

