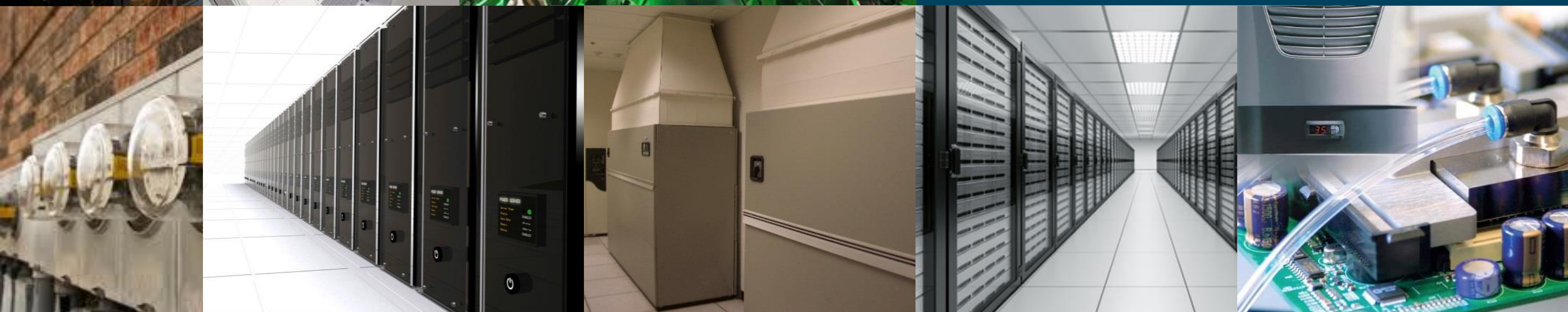
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Better Buildings, Better Data Centers: Applying Best Practices

California Higher Education Sustainability Conference
U.C. Santa Barbara
June 26, 2016

Dale Sartor, P.E.

Lawrence Berkeley National Laboratory

FEMP
Federal Energy Management Program

Version: 06/20/17

Download Presentation

This Presentation is Available for download at:

http://datacenterworkshop.lbl.gov/

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

Agenda

- Introduction
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Data center environmental conditions
- Break
- Air management
- Cooling systems (part 1)
- Break
- Cooling systems (part 2)
- Electrical systems
- Use IT to manage IT (Monitoring and integrated controls)
- Resources and workshop summary

Learning Objectives

- Understand why data center energy use is a concern
- Identify and define key data center energy performance metrics (e.g., power usage effectiveness [PUE])
- Understand standards for monitoring, analytics, and reporting
- Understand best practices for data center energy efficiency
- Understand the need to integrate acquisition, IT, and facilities to optimize energy performance

Challenging Conventional Wisdom: Game Changers

Conventional Approach

- All data centers are “mission critical”
- 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

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

Introduction

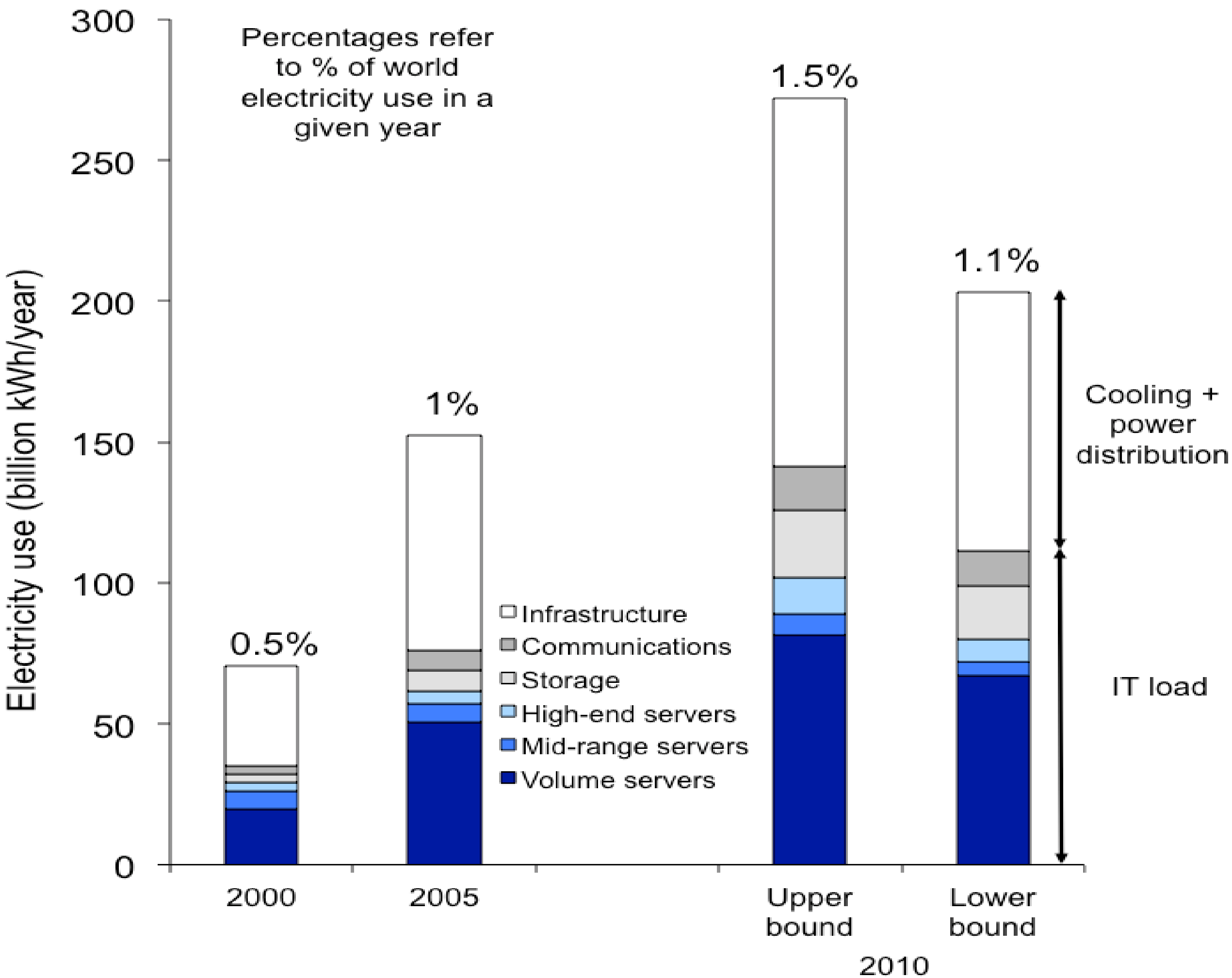
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Data centers are energy-intensive facilities

- 10 to 100 times more energy intensive than an office building
- Some server racks now designed for more than 30 kW
- Surging demand for data storage
- 1.8% of U.S. electricity consumption
- Power and cooling constraints in existing facilities

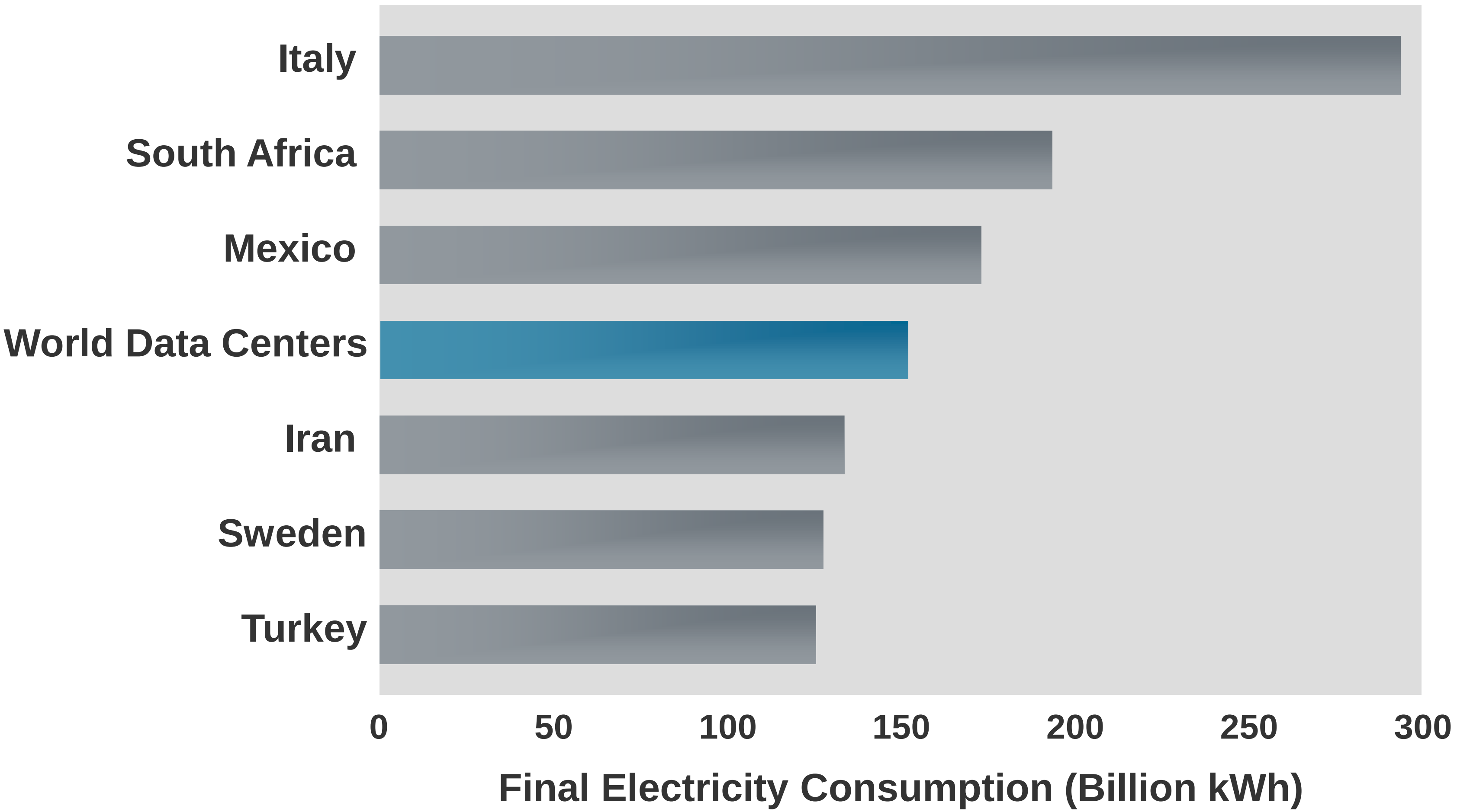
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Global Data Center Electricity Use



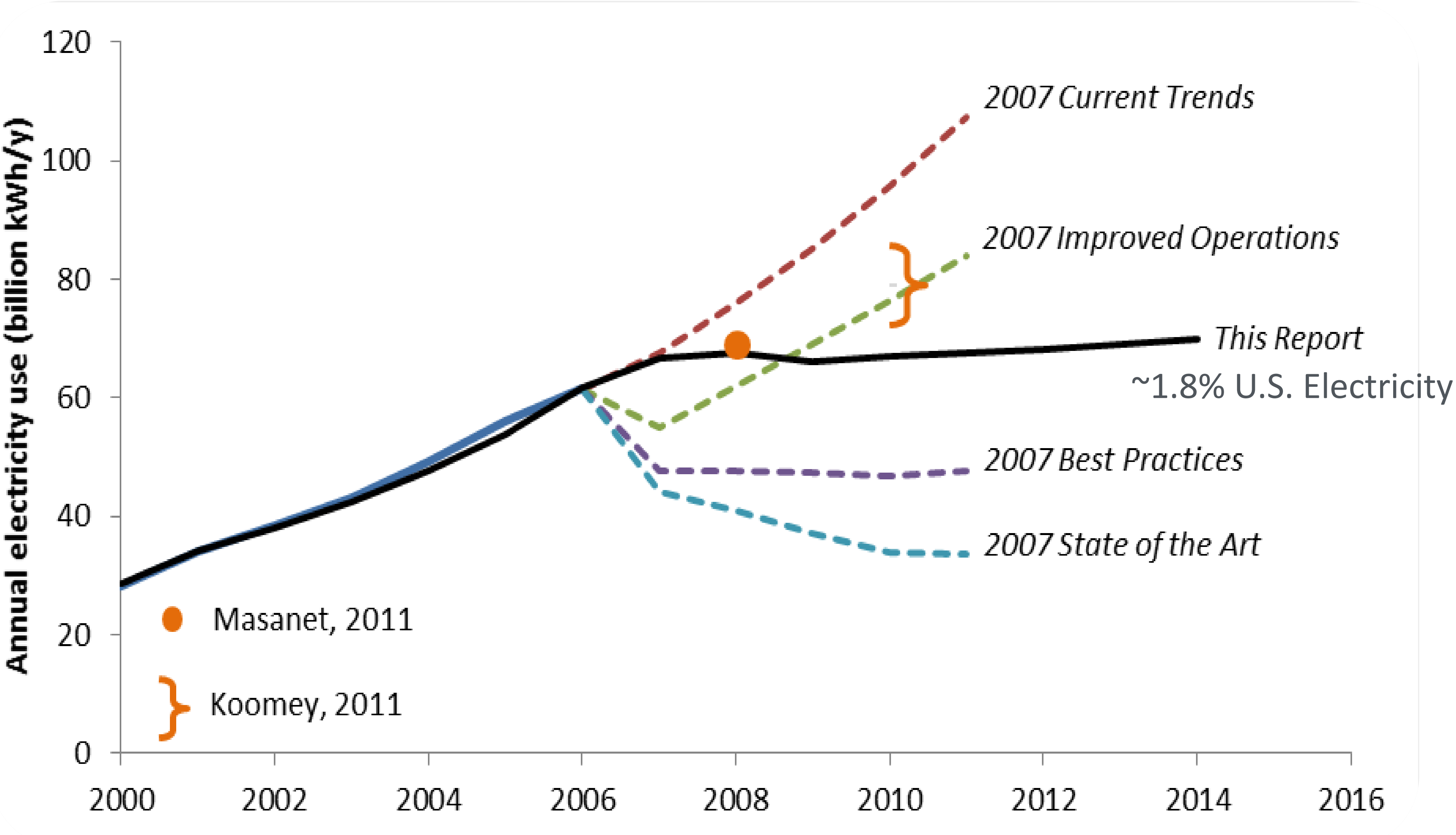
Source: Koomey 2011

How Much is 152B kWh?



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

US Data Center Energy Usage Reports (2007 & 2016)



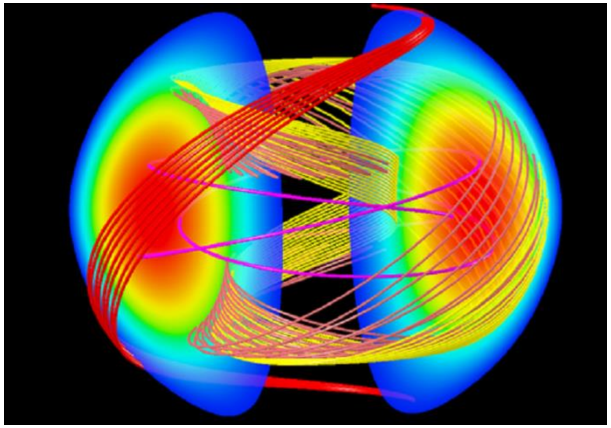
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Data Center Energy

- Demand for computing power is growing fast but so is energy efficiency gains
- Cost of electricity for IT equipment and supporting infrastructure surpasses the capital cost of IT equipment
- Perverse incentives: IT and facility costs are paid by separate departments/accounts

Lawrence Berkeley National Laboratory (LBNL)

- Operates large systems along with legacy equipment

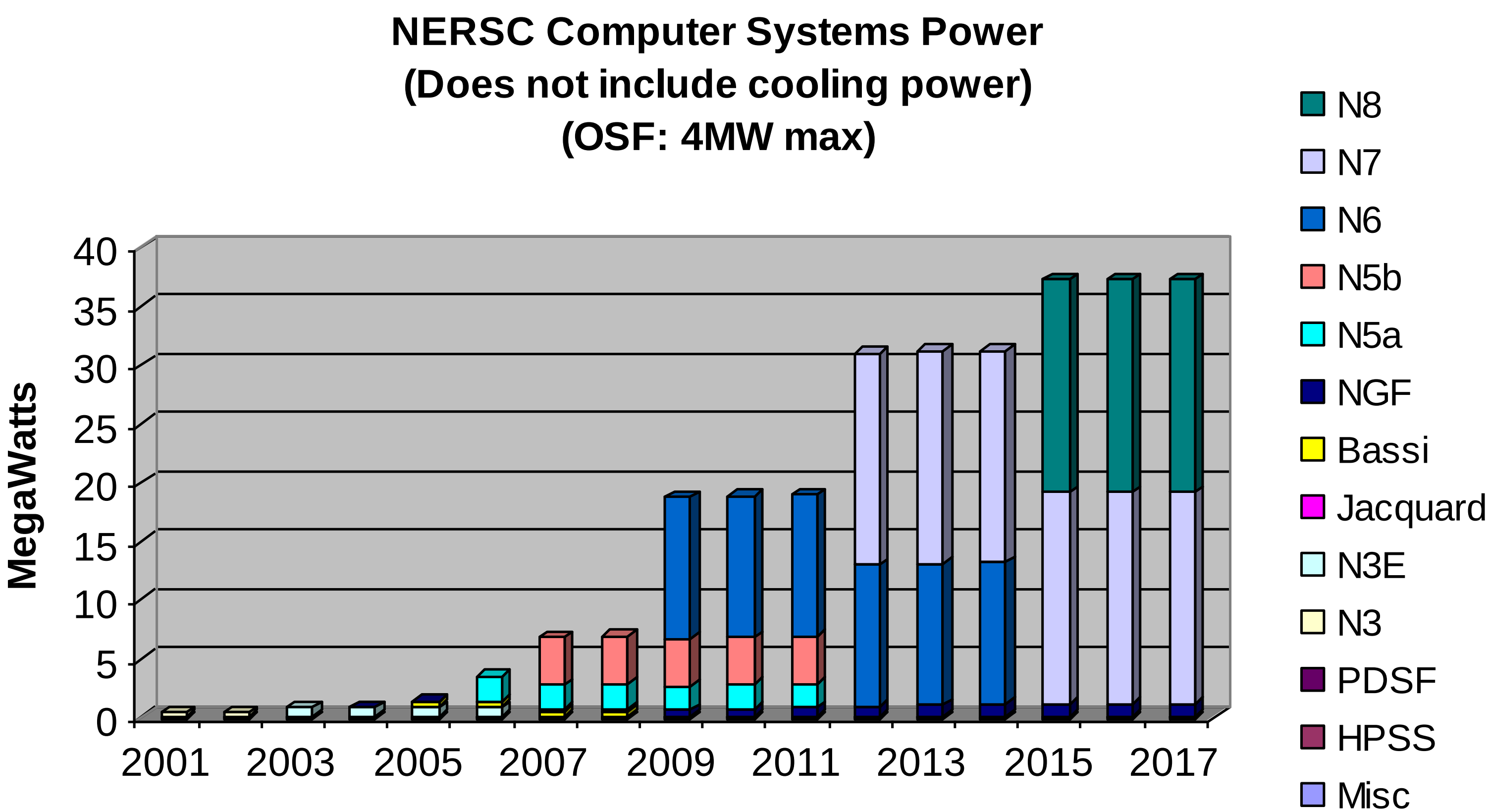


- We also research energy-efficiency opportunities and work on various deployment programs

LBNL Feels the Pain!

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

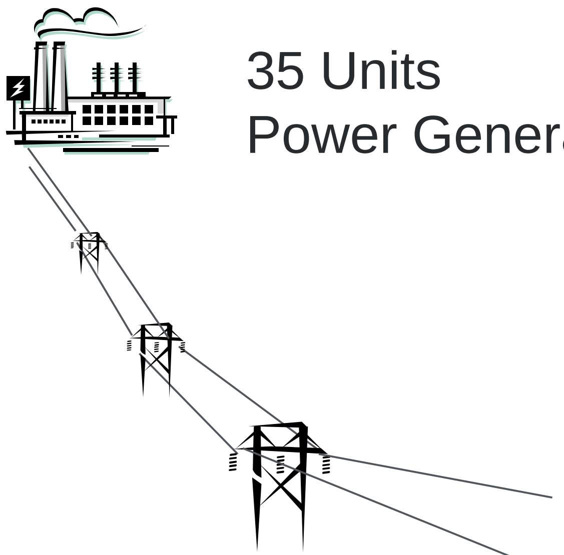
LBNL Super Computer Systems Power



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

Typical Data Center Energy Efficiency ~ 15%

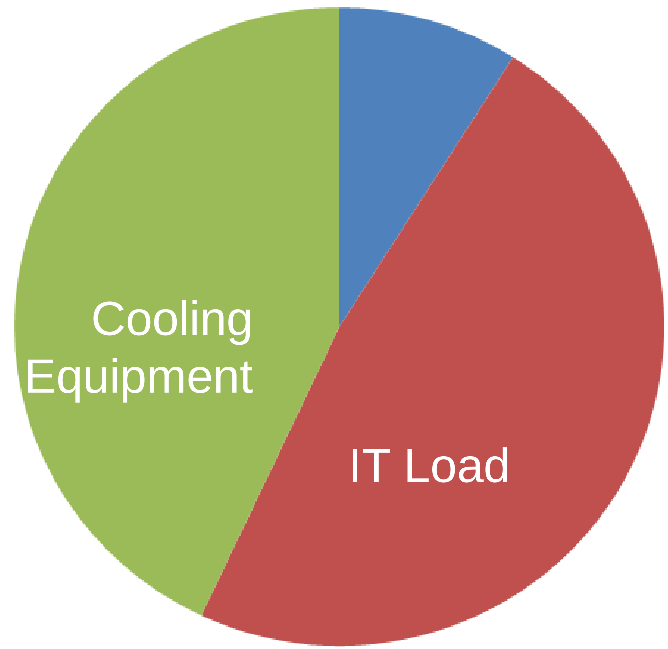
100 Units
Source
Energy



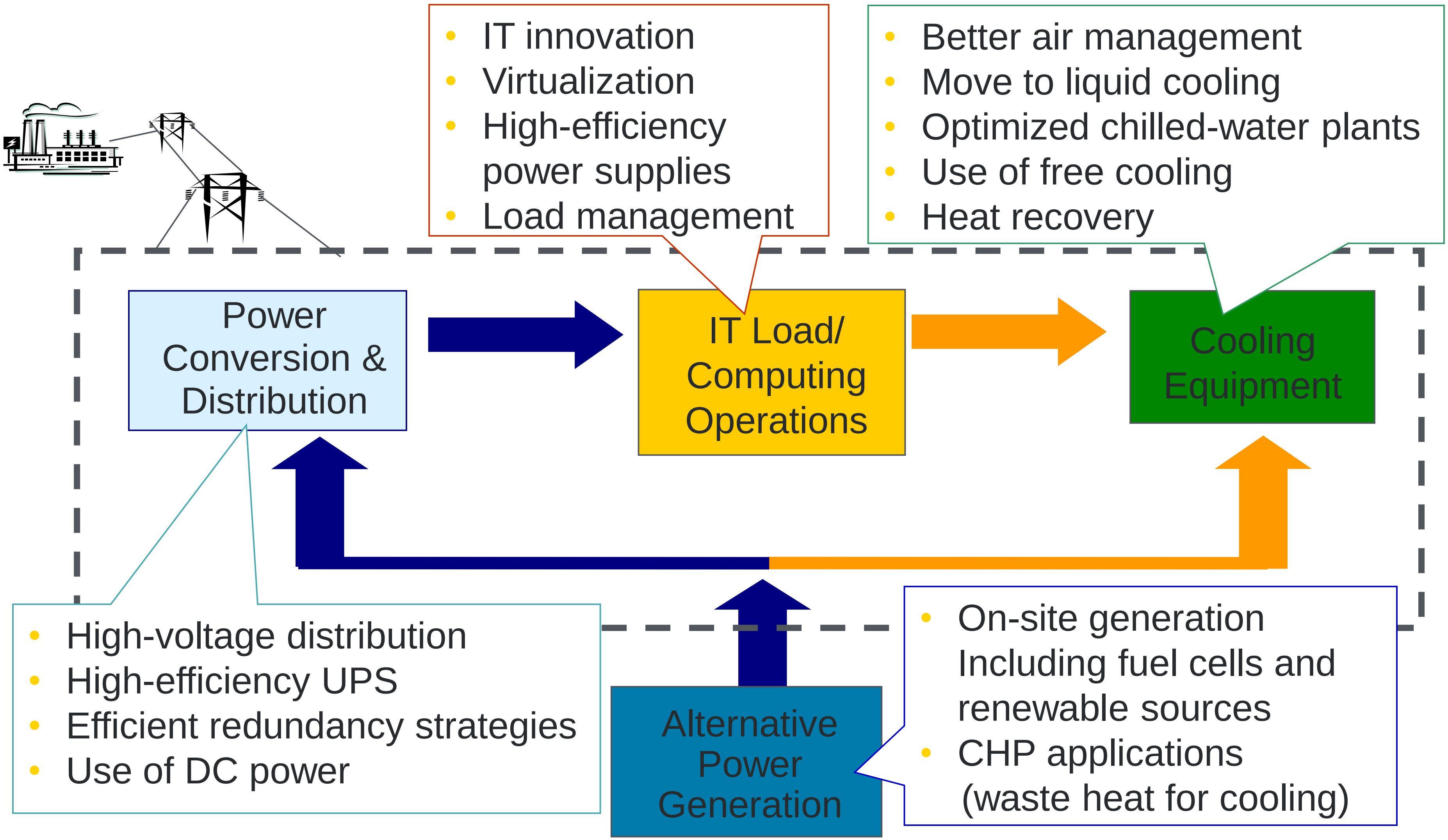
35 Units
Power Generation

33 Units
Delivered

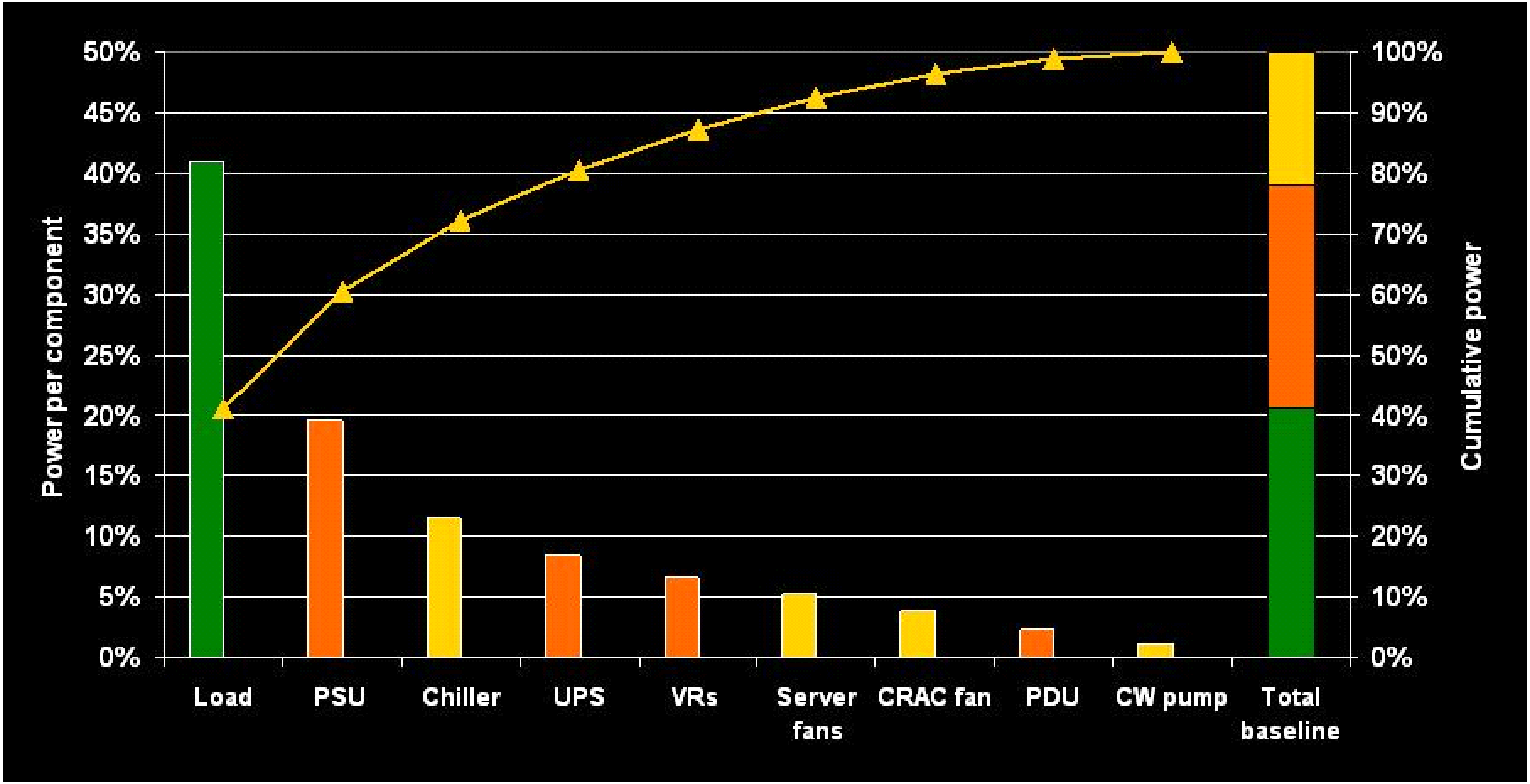
Power
Conversions
& Distribution



Energy Efficiency Opportunities



Electricity End Use in Data Centers



Courtesy of Michael Patterson, Intel Corporation

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

Benefits of Higher Data Center Efficiencies

- Typical savings: 20%–40%
- Aggressive Savings: 50%+
- Extend life of infrastructure
- But is my data center efficient?

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

Executive Order 13693: The New Fed Driver

Specific goals for data centers:

- Promote energy optimization, efficiency, and performance
- Installing and monitoring advanced energy meters in all data centers by fiscal year 2018
- Establishing a Power Usage Effectiveness (PUE) target of 1.2 to 1.4 for new data centers and less than 1.5 for existing data centers.

Other related goals:

- Reduce building energy 2.5% per year per sq.ft.
- Increase clean and renewable energy (to 25 & 30%)
- Reduce water consumption 2% per year per sq.ft.
- Energy Star or FEMP designated acquisitions.

Questions

Performance Metrics and Benchmarking

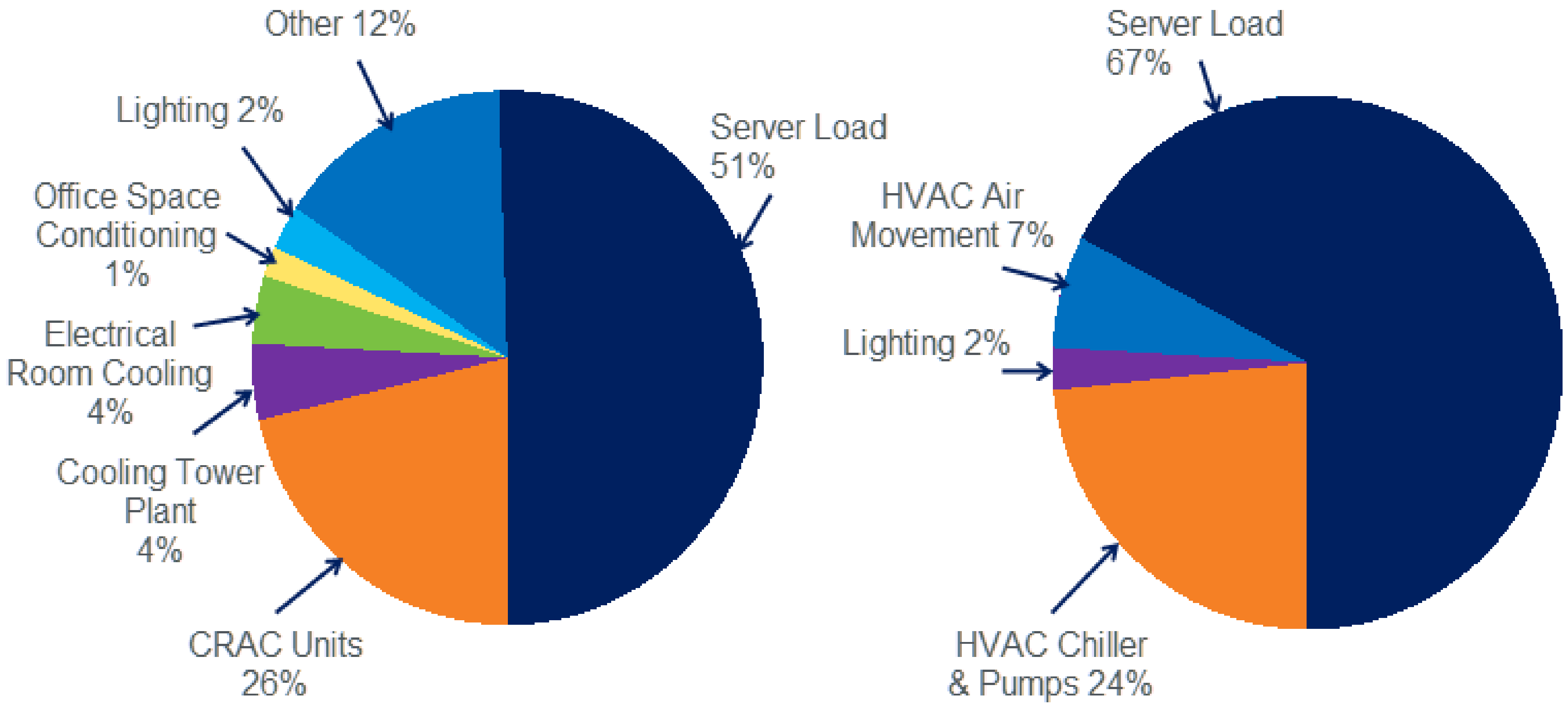
Benchmark Energy Performance

- Compare to peers
  - Wide variation
- Identify opportunities
- Identify best practices
- Track performance
  - Can’t manage what isn’t measured.

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

Your Mileage Will Vary

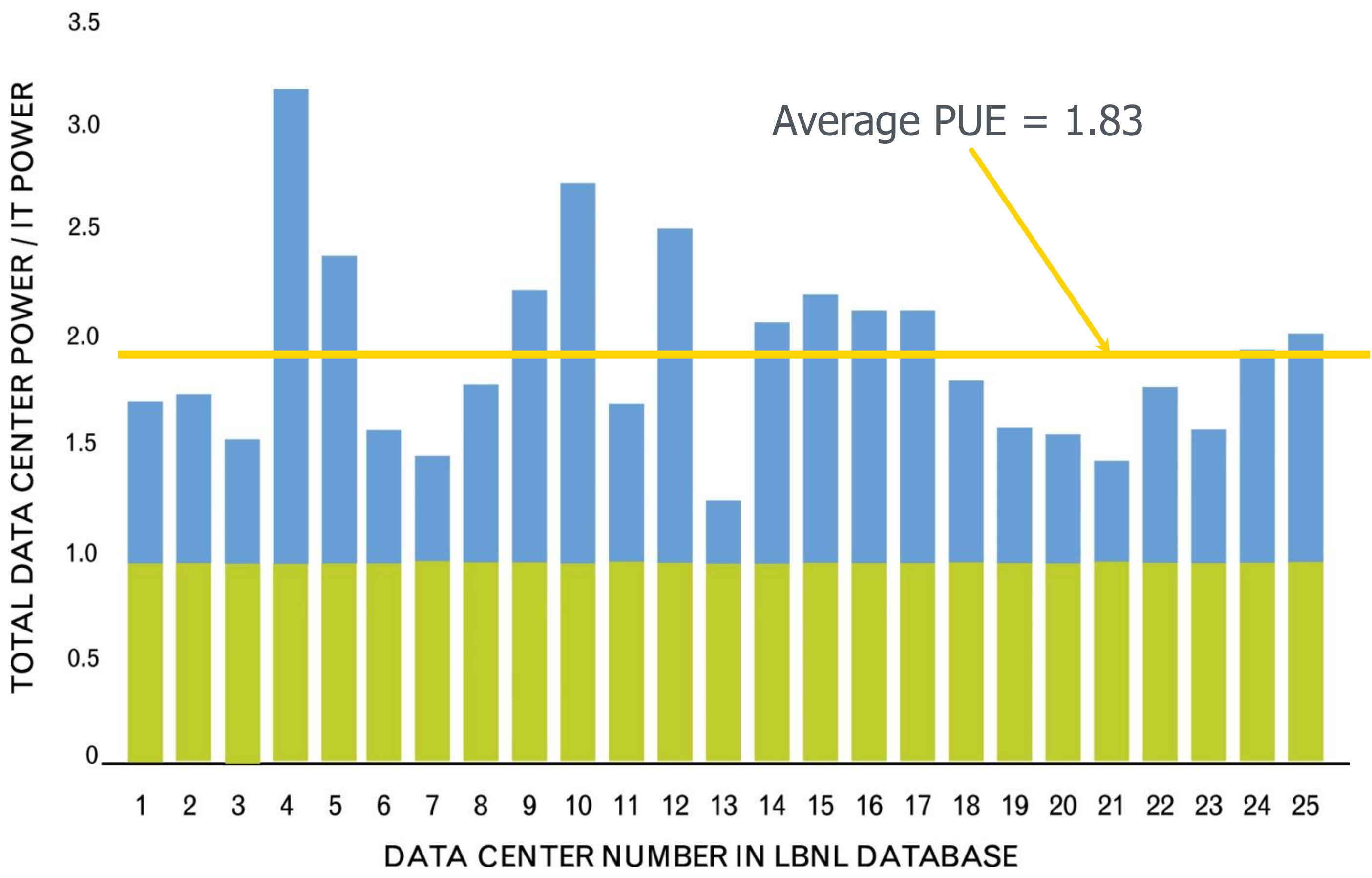
The relative percentages of energy actually doing computing varies considerably.



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

Benchmarks Obtained by LBNL

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



Example PUE Values

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)	1.06

Slide Courtesy Mike Patterson, Intel

PUE Calculation Diagram

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

PUE Measurement Categories Recommended by The GreenGrid (TGG) Task Force

Table 1: PUE measurement categories recommended by this task force.

	PUE Category 0*	PUE Category 1	PUE Category 2	PUE Category 3
IT energy measurement location	UPS output	UPS output	PDU output	IT equipment input
Definition of IT energy	Peak IT electric demand	IT annual energy	IT annual energy	IT annual energy
Definition of Total energy	Peak Total electric demand	Total annual energy	Total annual energy	Total annual energy

*For PUE Category 0 the measurements are electric demand (kW).

Courtesy of TGG

Energy Metrics and Benchmarking

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

Other Data Center Metrics

- Watts per square foot, watts per rack
- Power distribution: UPS efficiency, IT power supply efficiency
- HVAC
  - Fan watts/cubic feet per minute (cfm)
  - Pump watts/gallons per minute (gpm)
  - Chiller plant (or chiller or overall HVAC) kW/ton
- Air Management
  - Rack Cooling Index (RCI = measure of temperature compliance)
  - Return Temperature Index (RTI = (RAT-SAT)/deltaT$_{IT}$)
- Lighting watts/square foot

Metrics and Benchmarking

Power Usage Effectiveness

$$PUE = \frac{Total\ Facility\ Energy}{IT\ Equipment\ Energy}$$

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

Source: LBNL Programing Guide

Best Practices Based on Benchmark Results

- IT equipment and software efficiency
- Optimize environmental conditions
- Manage airflow
- Efficient cooling options
  - Free cooling
  - Humidity control
  - Liquid cooling
- Improve power chain
- Use IT to save energy in IT

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

Questions

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

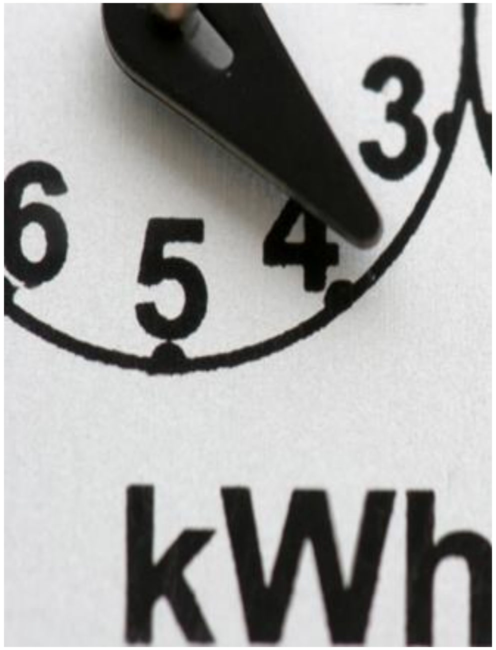
IT Equipment and Software Efficiency

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

IT Equipment Load Can Be Controlled

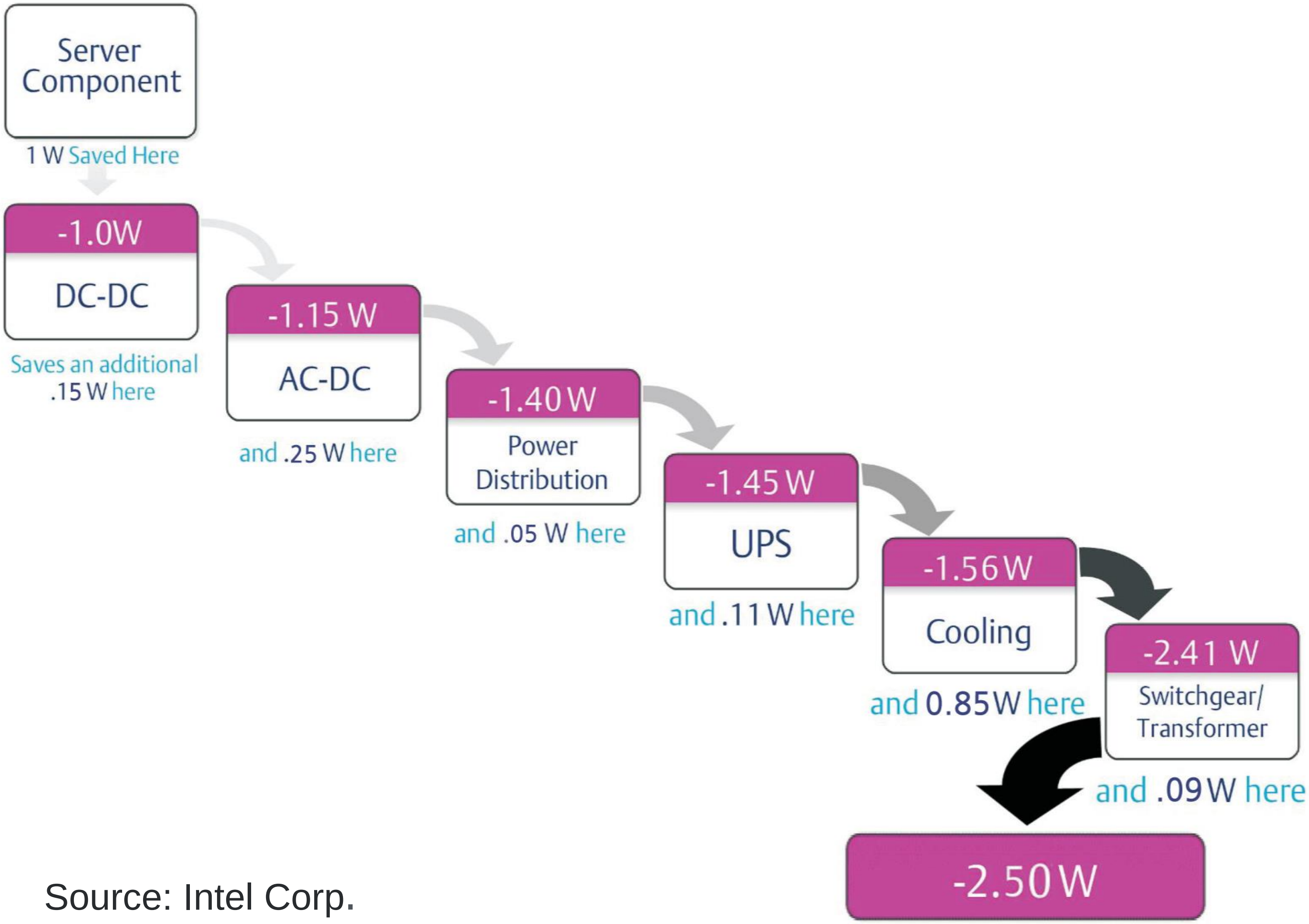
Computations per Watt is improving

- Consolidation
- Server efficiency (Use ENERGY STAR servers)
  - Flops per Watt
  - Efficient power supplies and less redundancy.
- Software efficiency
  - Virtualize for higher utilization
  - Data storage management.
- Enable power management (e.g., sleep mode)
- Reducing IT load has a <u>multiplier effect</u>
  - Savings in infrastructure energy depends on PUE



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

Actual Saving of One Watt Saved at the IT Equipment

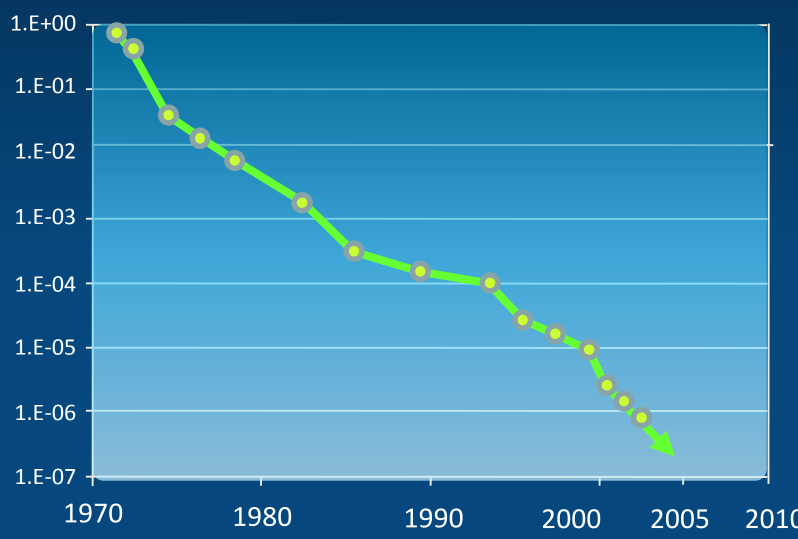


Source: Intel Corp.

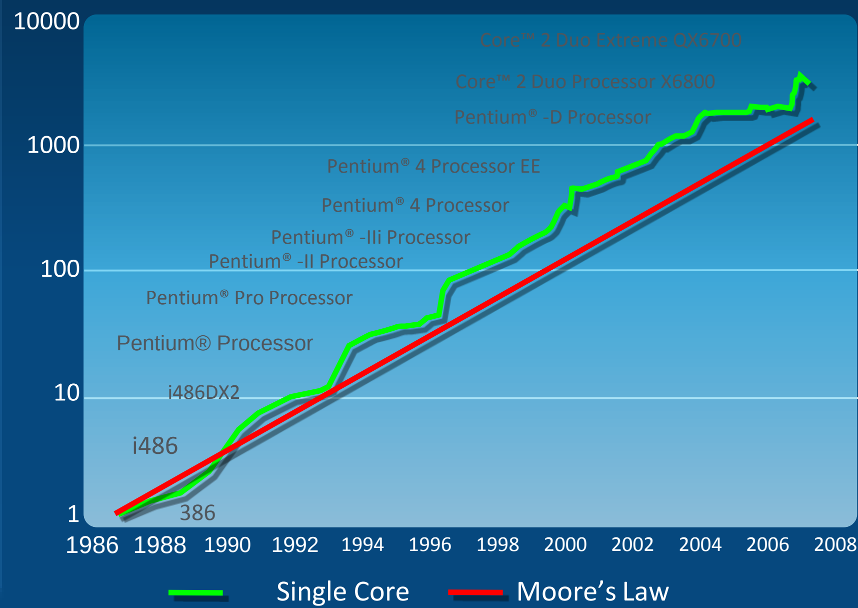
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Moore’s Law

Power Reduction Over Time*



Core Integer Performance Over Time*

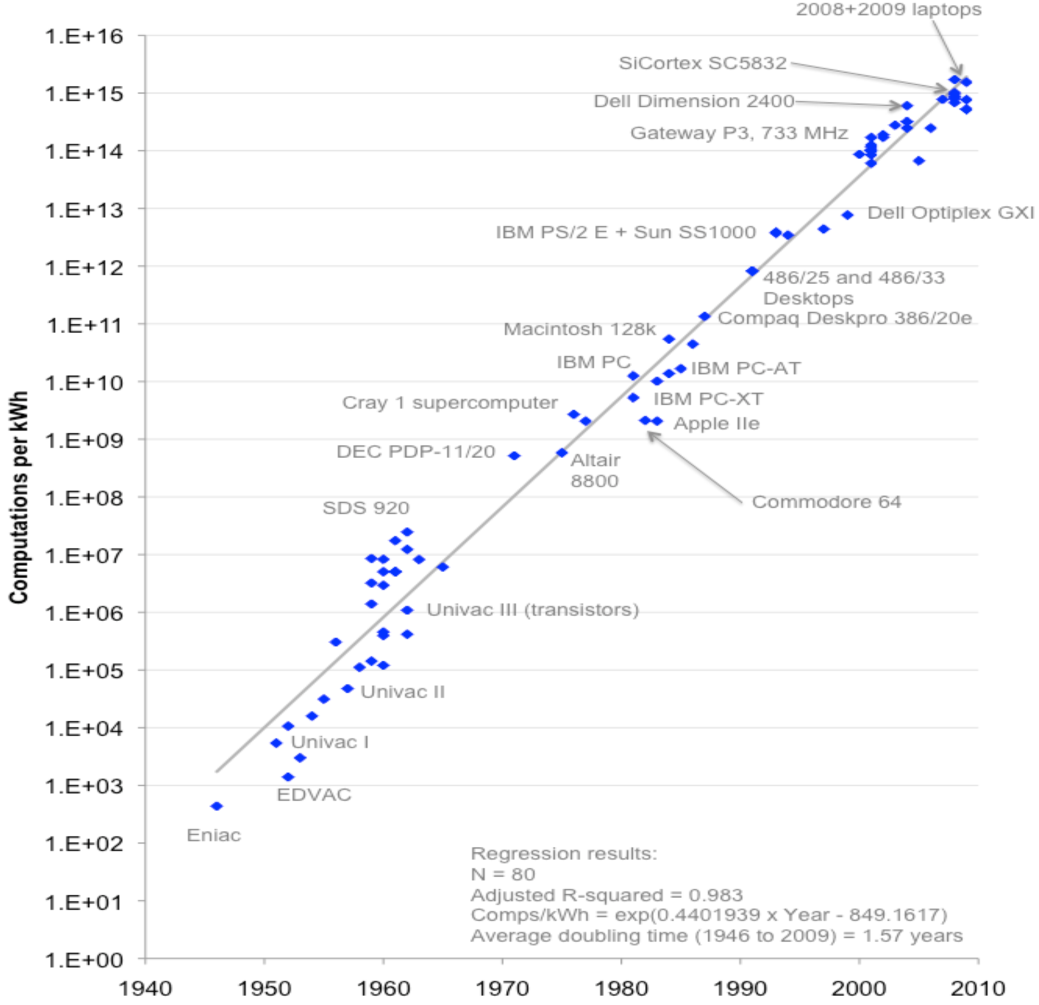


- Every year brings smaller, more energy-efficient transistors
- Miniaturization reduced transistor size 1 million times over 30 years
- Benefits: Smaller, faster transistors => faster AND more energy-efficient chips

Source: Intel Corporate Technology Group

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

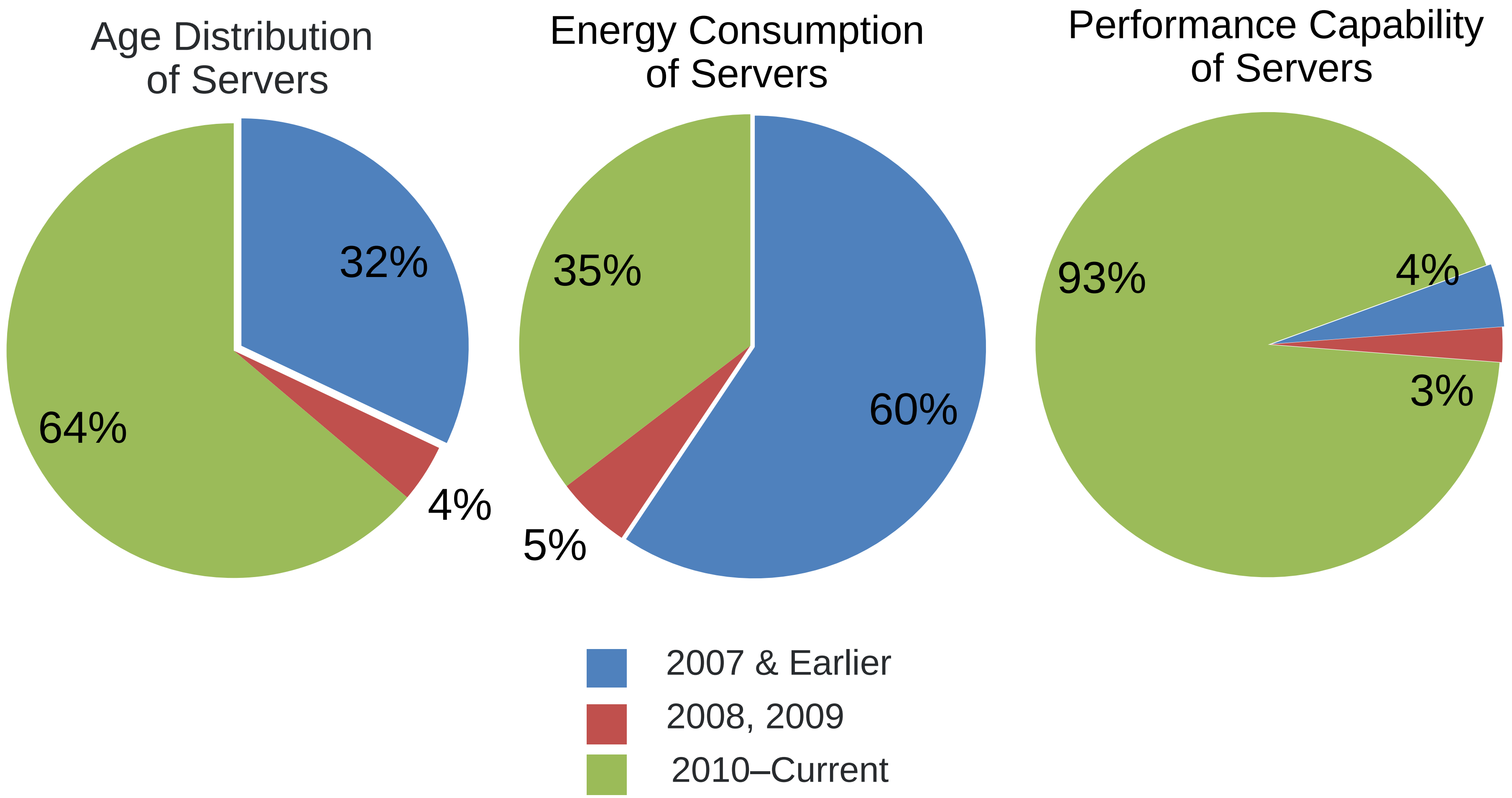
Computing Efficiency Increases 100x Every Decade



Source: Koomey et al. 2011

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

Old servers consume 60% of energy, but deliver only 4% of performance capability



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

Decommission Unused Servers

- Physically Retire Inefficient or Unused Systems

- The Uptime Institute reported 15%–30% of servers are on but not being used

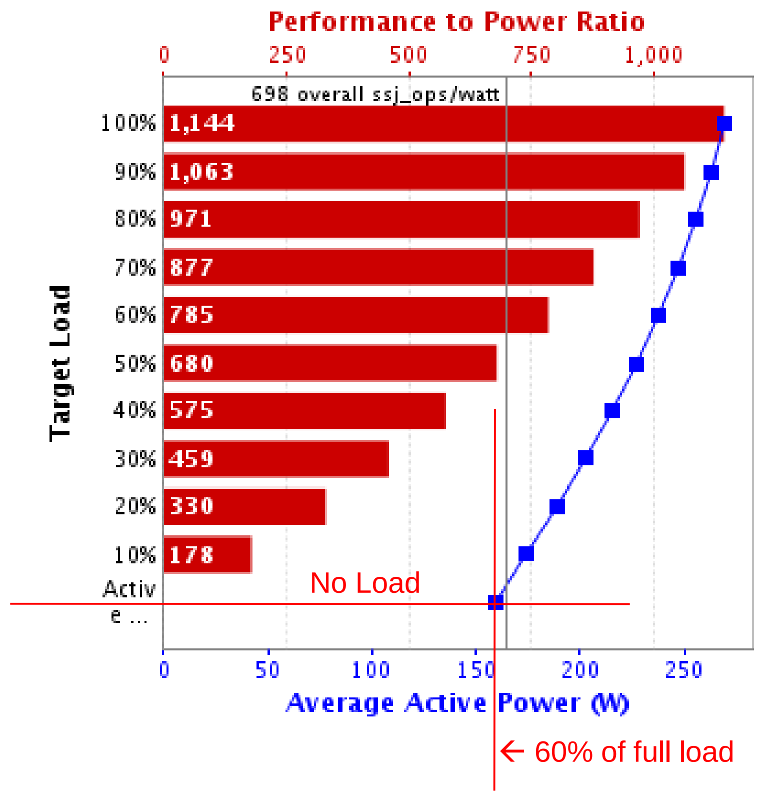
- Decommissioning process includes:
  - Regularly inventory and monitoring
  - Consolidate/retire poorly utilized hardware

IT Energy Use Patterns: Servers

Idle servers consume as much as 50%–60% of power at full load.

Benchmark Results Summary

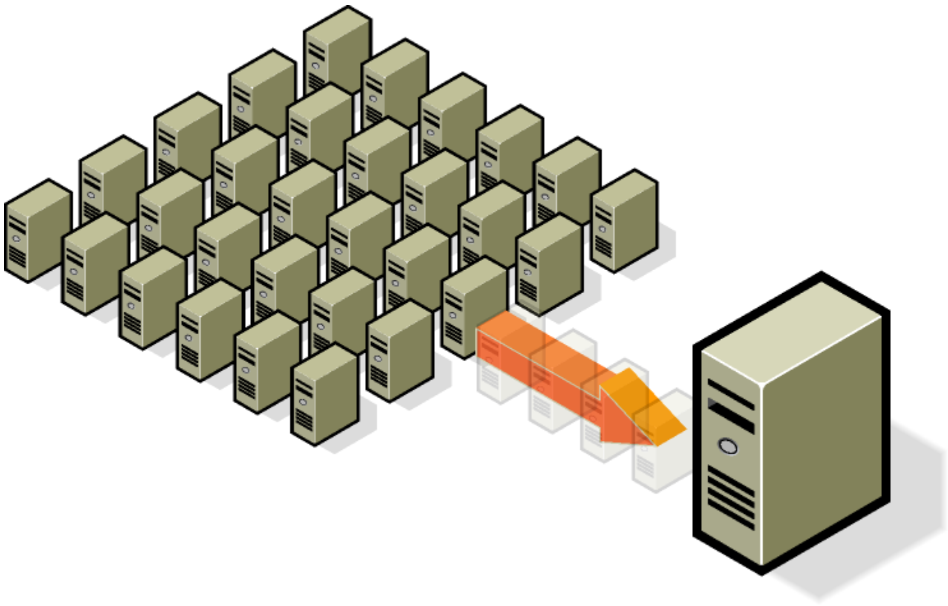
Performance			Power	
Target Load	Actual Load	ssj_ops	Average Active Power (W)	Performance to Power Ratio
100%	99.2%	308,022	269	1,144
90%	90.2%	280,134	264	1,063
80%	80.0%	248,304	256	971
70%	69.9%	217,096	247	877
60%	60.1%	186,594	238	785
50%	49.6%	154,075	227	680
40%	39.9%	123,805	215	575
30%	29.9%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



Source: SpecPower Benchmarks

Virtualize and Consolidate Servers & Storage

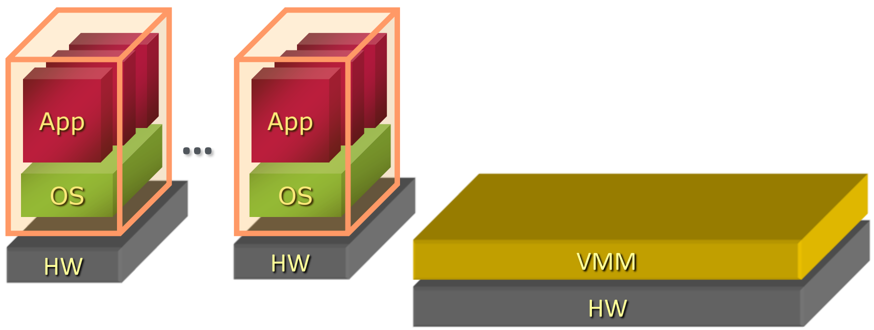
- Run many “virtual” machines on a single “physical” machine
- Consolidate underutilized physical machines, increasing utilization
- Energy is saved by shutting down underutilized machines.



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

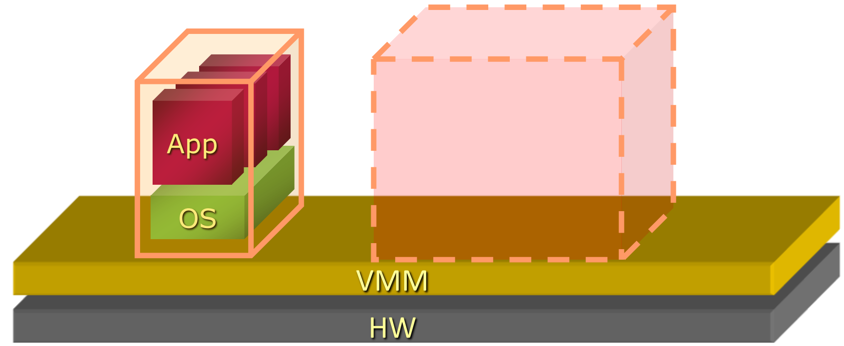
Virtualization : Workload provisioning

Server Consolidation



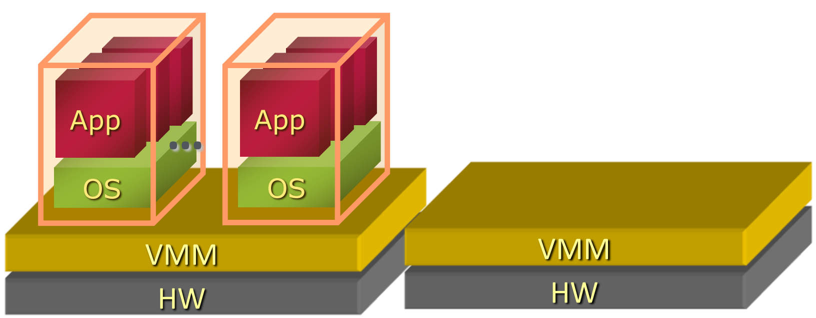
10:1 in many cases

R&D Production



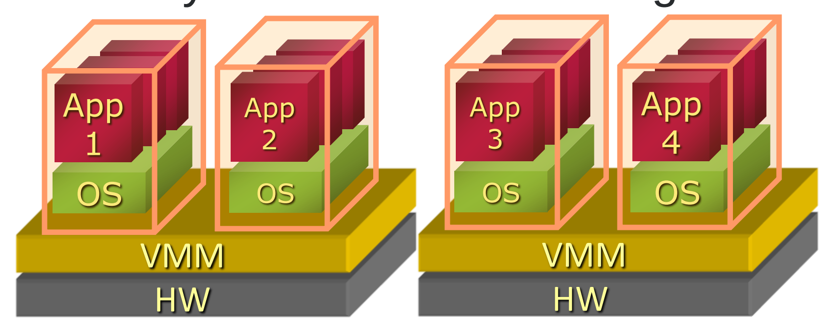
Enables rapid deployment, reducing number of idle, staged servers

Disaster Recovery

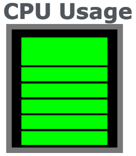


Upholding high-levels of business continuity. One Standby for many production servers.

Dynamic Load Balancing

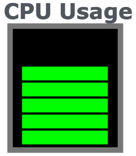


CPU Usage



Balancing utilization with head room

CPU Usage

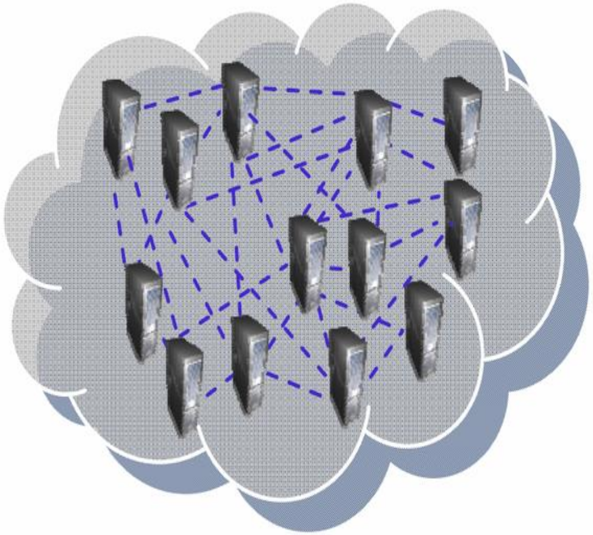


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Cloud Computing

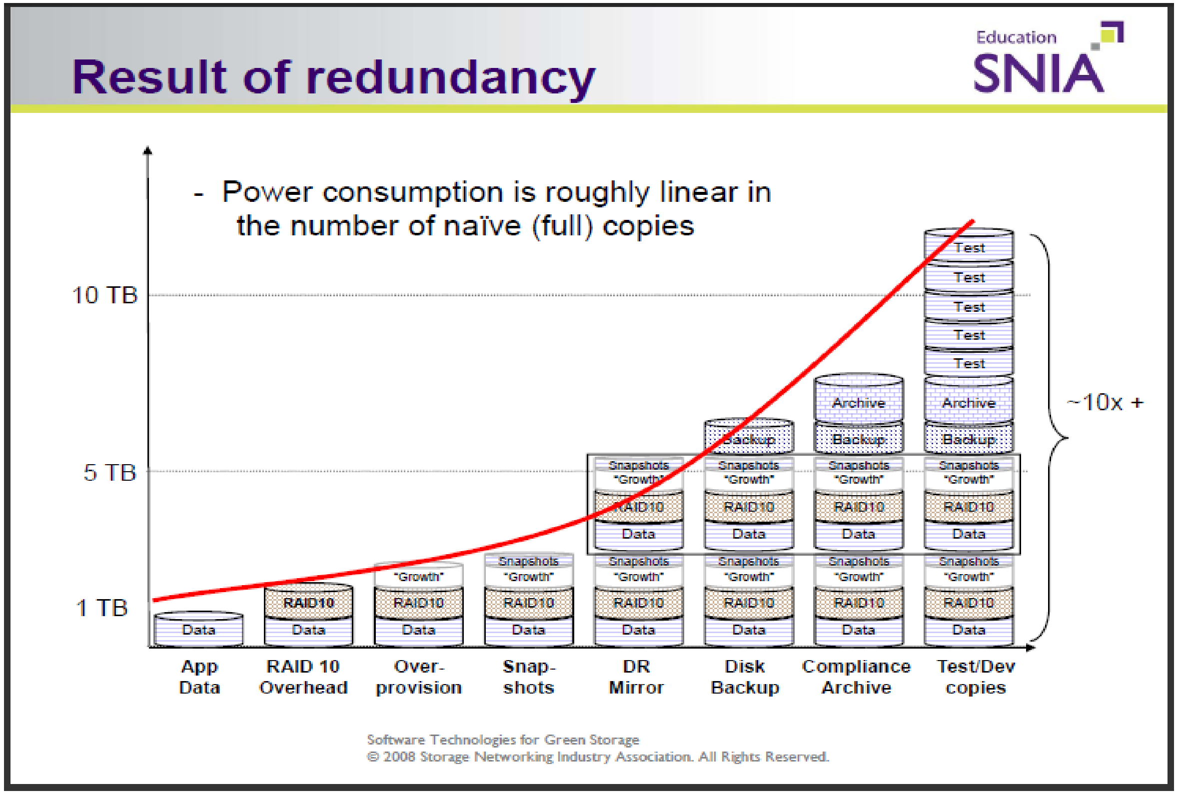
Virtualized cloud computing can:

- Provide dynamically scalable resources over the Internet
- Be internal or external
- Balance different application peak loads
- Typically achieve high utilization rates



Data Storage Systems and Energy

- Growing demand
- Power roughly linear to storage modules
- Storage redundancy significantly increases energy
- Consider lower-energy hierarchal storage
- Storage de-duplication - eliminate unnecessary copies



IT System Efficiency Review

Servers

- Enable power management capabilities!
- Use ENERGY STAR® Servers

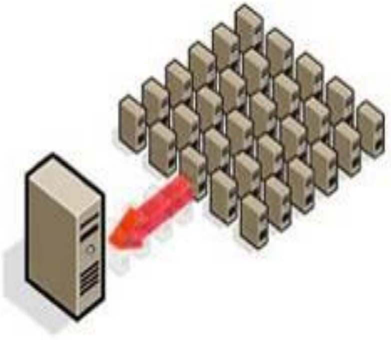
Power Supplies

- 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

Questions

Environmental Conditions

Environmental Conditions

What are the main HVAC Energy Drivers?

- IT Load
- Climate
- System Design
- Room temperature and humidity
  - Most data centers are overcooled and have too strict of a humidity control
  - Human comfort should not be a driver

Safe Temperature Limits

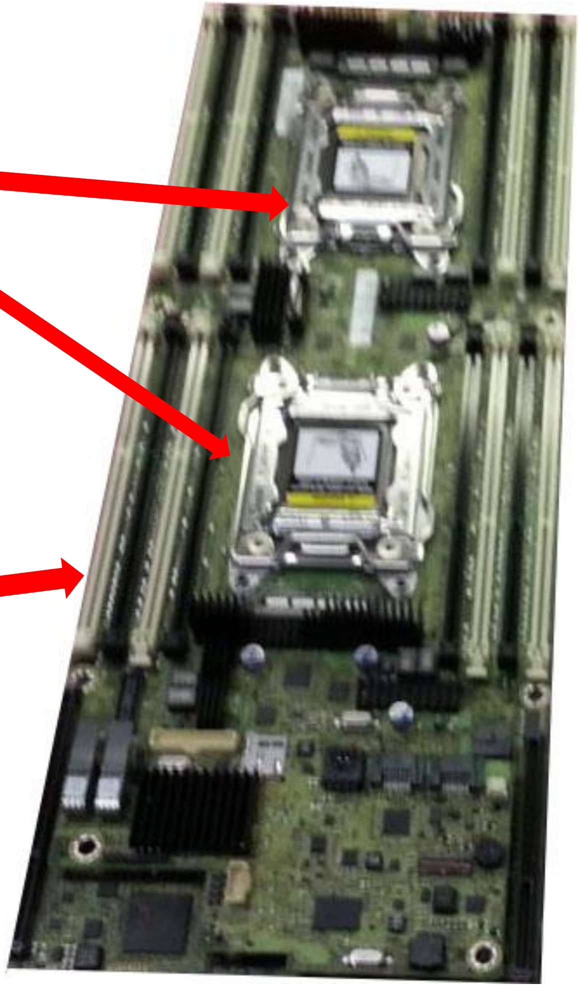
CPUs
~65C
(149F)

GPUs

~75C
(167F)

Memory

~85C
(185F)

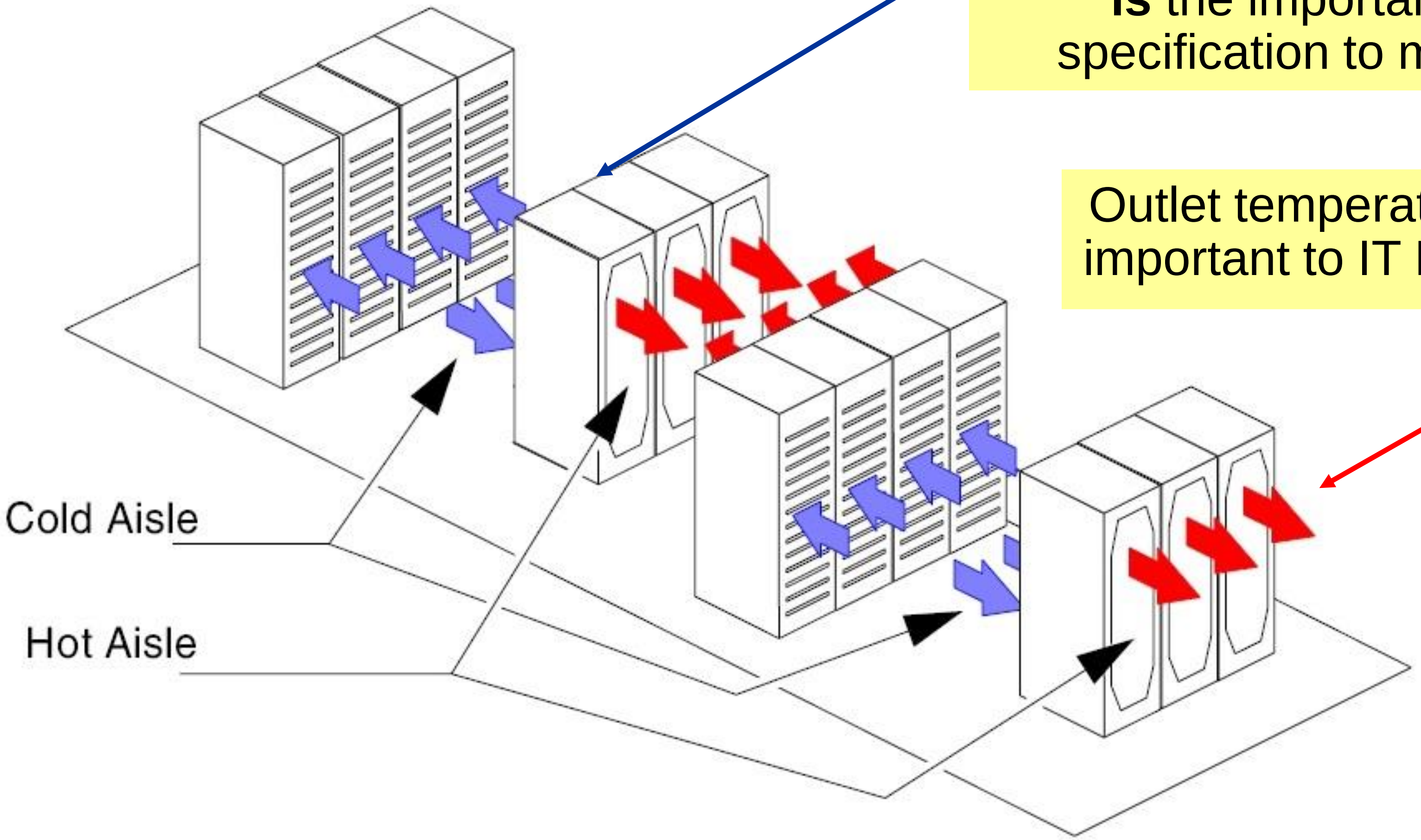


So why do we need jackets in many data centers?

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

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

Equipment Environmental Specification



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

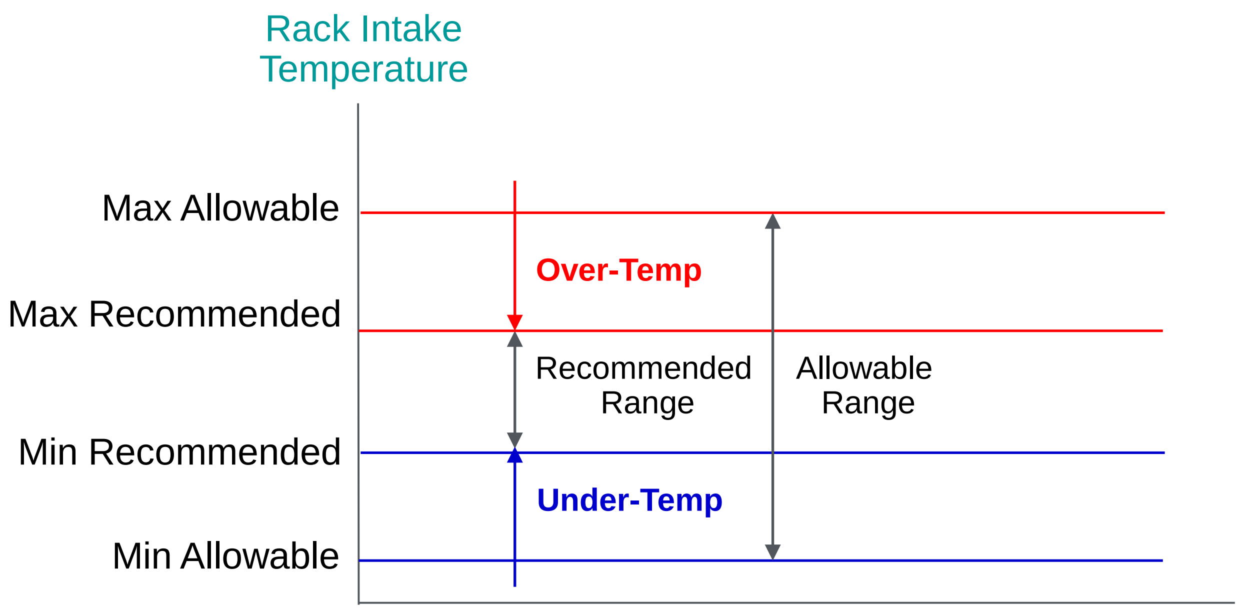
Outlet temperature is *not* important to IT Equipment

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

Key Nomenclature

- 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.

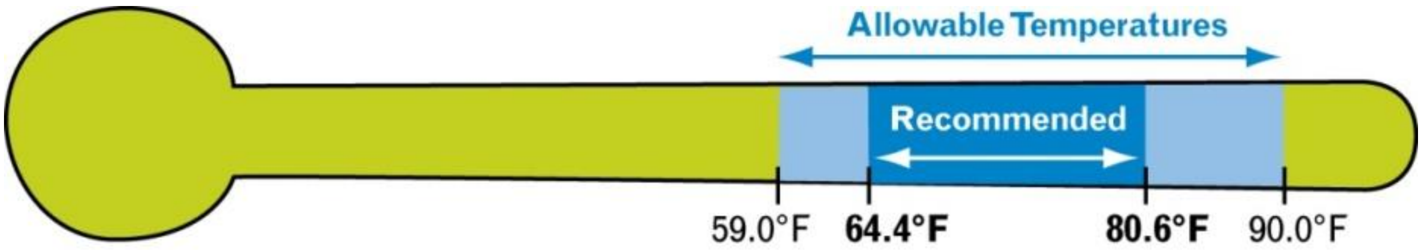
- The allowable range is a statement of functionality. These are the boundaries where IT manufacturers test their equipment to verify that the equipment will function.



ASHRAE Thermal Guidelines

- Default <u>recommended</u> range = 64.4 - 80.6F
- Provides guidance for operating above the default upper limit

- Default <u>allowable</u> range = 59.0 – 89.6F (Class A1)
- Six classes with allowable ranges up to 113.0F



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

Recommended Data Center Environmental Conditions

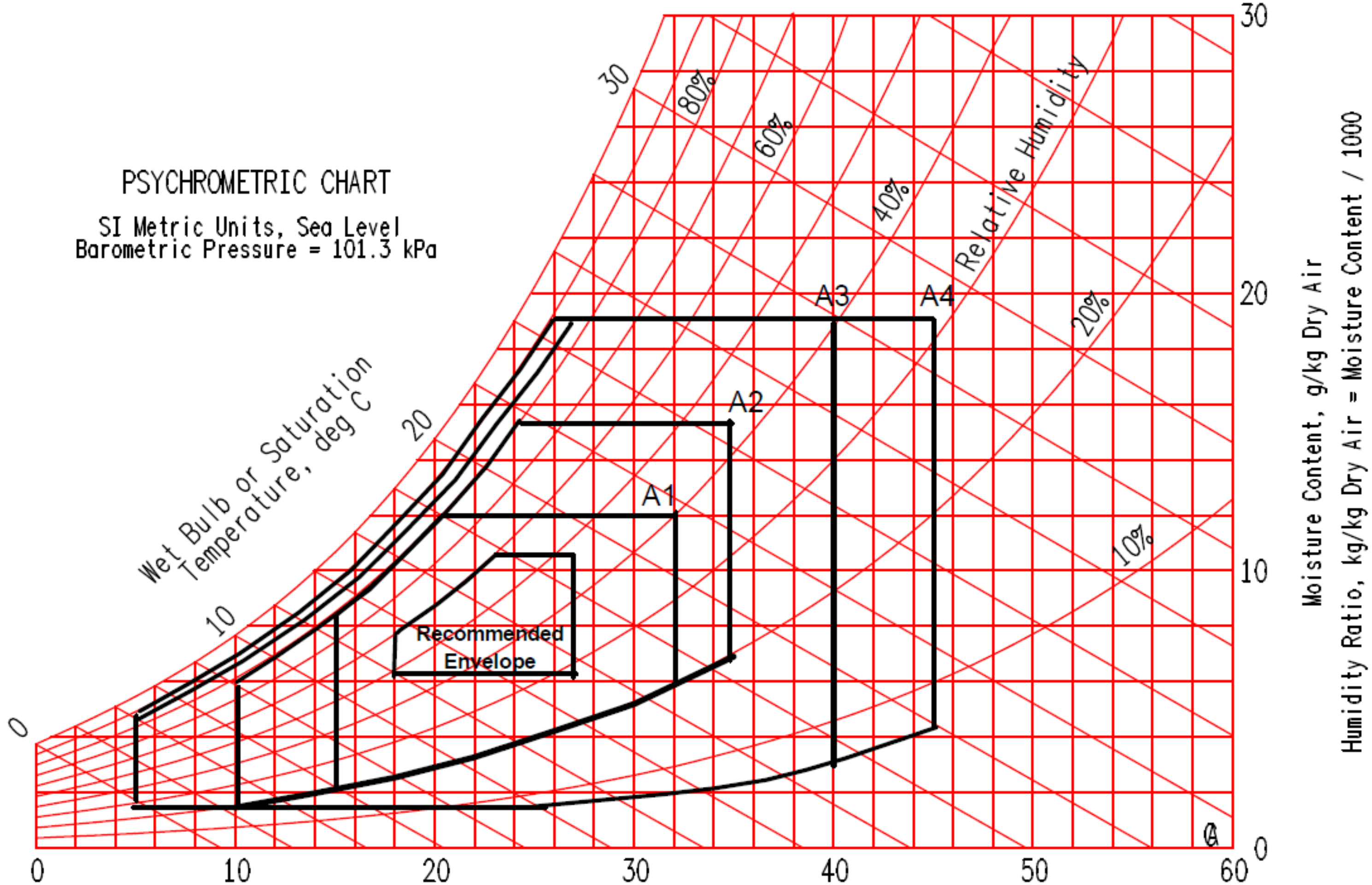
ASHRAE 2011:

ITE Environment – 2011 Environment Specifications Table (Partial)

Class (Previous)	Class (Current)	Dry Bulb (°F)	Humidity Range	Max Dew Point (°F)	Max Elevation (ft)	Max Rate of Change (°F / hr)
Recommended						
1 & 2	A1 to A4	64.4 to 80.6	41.9°F DP to 60% RH & 59°F DP	N/A		
Allowable						
1	A1	59 to 89.6	20% to 80% RH	62.6	10,000	9* / 36
2	A2	50 to 95	20% to 80% RH	69.8	10,000	9* / 36
N/A	A3	41 to 104	10.4°F DP & 8% RH to 85% RH	75.2	10,000	9* / 36
N/A	A4	41 to 113	10.4°F DP & 8% RH to 90% RH	75.2	10,000	9* / 36

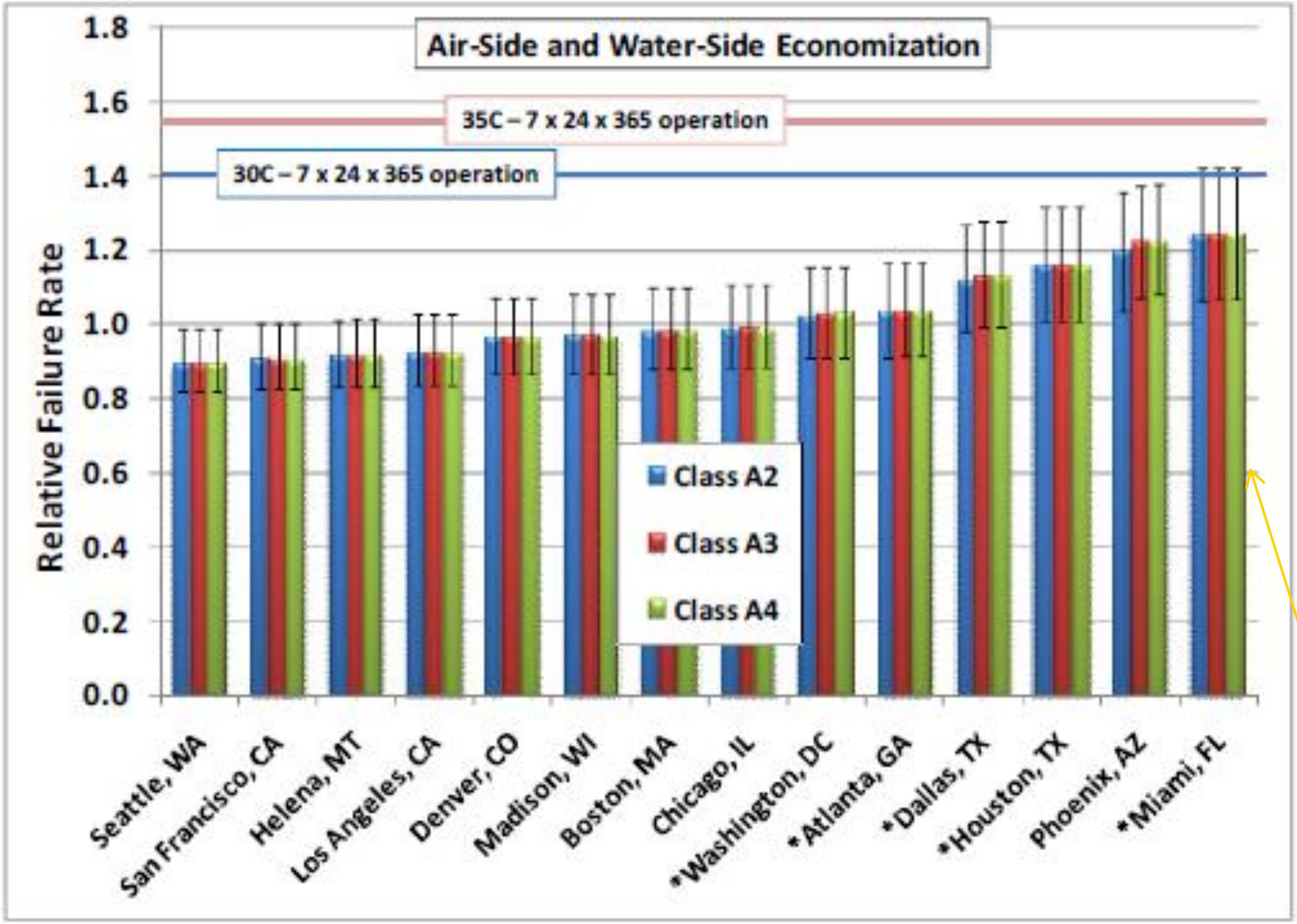
* More stringent rate of change for tape drives

2011 ASHRAE Allowable Ranges



Dry Bulb Temperature

Thermal Conditions Are Less Relevant



Source: ASHRAE

If 4 failures per 1,000 servers incorporates warmer temperatures, and the relative failure. Rate is 1.2, then the expected failure rate would be 5 failures per 1,000 servers.

2011 ASHRAE Thermal Guidelines

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

"For a majority of U.S. 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 (68°F)."

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

ASHRAE Liquid Cooling Guidelines

- ASHRAE and a DOE High Performance Computer (HPC) user group developed guidance

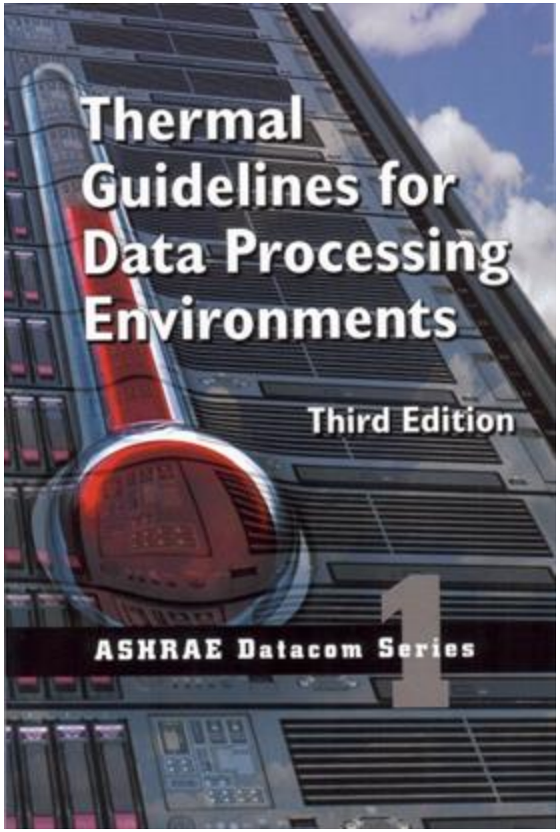
- Three temperature standards defined based on three mechanical system configurations:
  - Chilled water provided by a chiller (with or without a “tower side economizer”)
  - Cooling water provided by a cooling tower with possible chiller backup
  - Cooling water provided by a dry cooler with possible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

ASHRAE Liquid Cooling Guidelines

Liquid Cooling Class	Main Cooling Equipment	Supplemental Cooling Equipment	Building Supplied Liquid Cooling 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 Conditions Review

- Most computer room air conditioners (CRACs) are controlled based on the <u>return</u> 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's "default" Class A1
- Design Data Centers for IT equipment performance, *not people comfort*
- **Address air management issues first**



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

Questions

Air Management

The Early Days at LBNL

It was cold, but hot spots were everywhere:

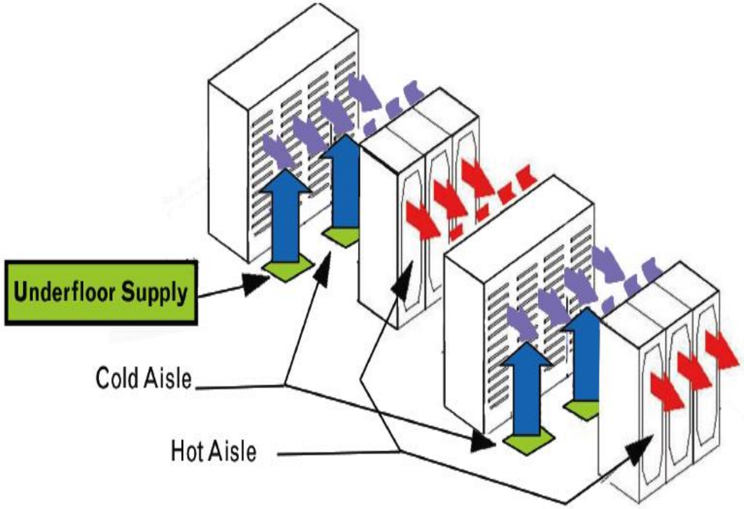
Fans were used to redirect air

High-flow tiles reduced air pressure

Air Management

- Problems:
  - By-pass air
  - Re-circulation air
- Solution:
  - Air Management

- Use hot and cold aisles
- Improve isolation of hot and cold aisles
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity

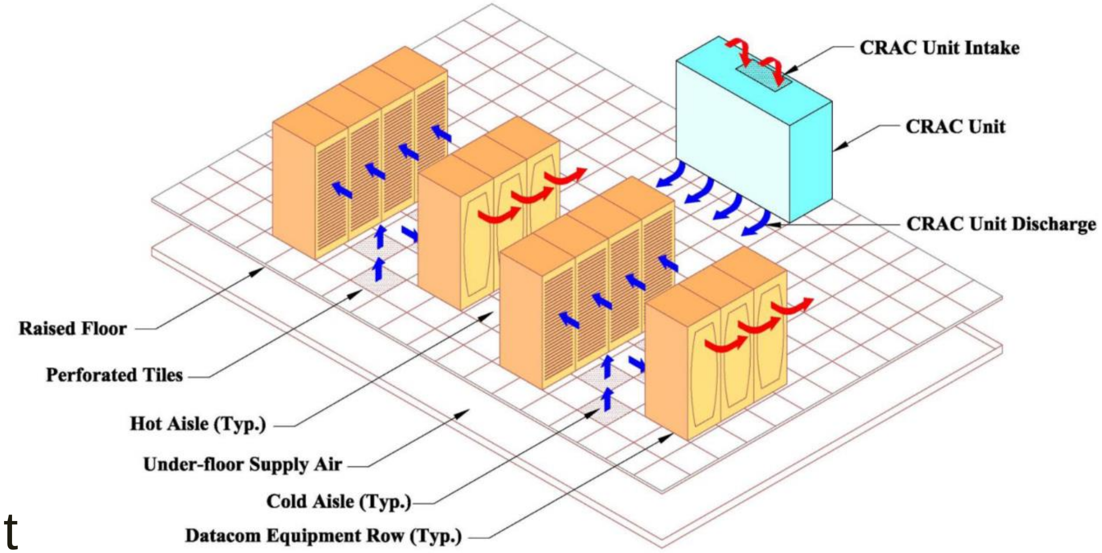


Hot aisle/cold aisle configuration decreases mixing of intake and exhaust air, promoting efficiency.

Hot- and Cold-aisles

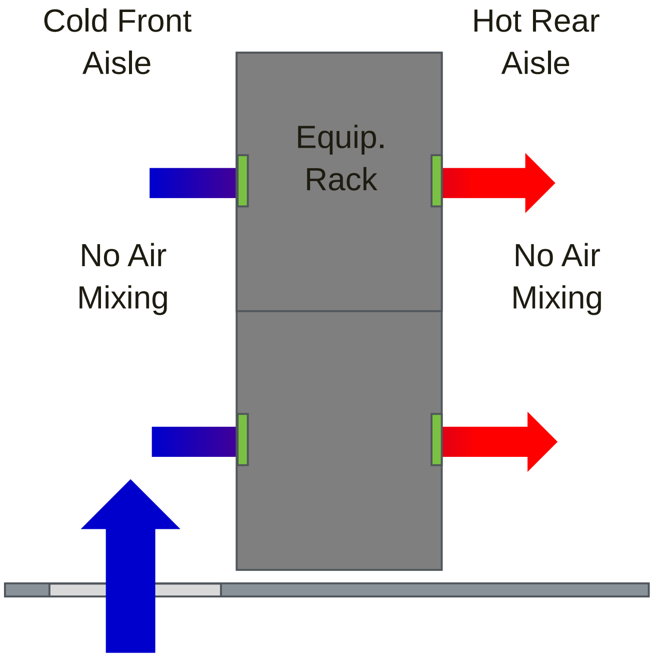
- Improves equipment intake air conditions by separating cold from hot airflow

- Preparation
  – Arrange racks with alternating hot and cold aisles
  – Supply cold air to front of facing servers. Hot exhaust air exits into rear aisles.



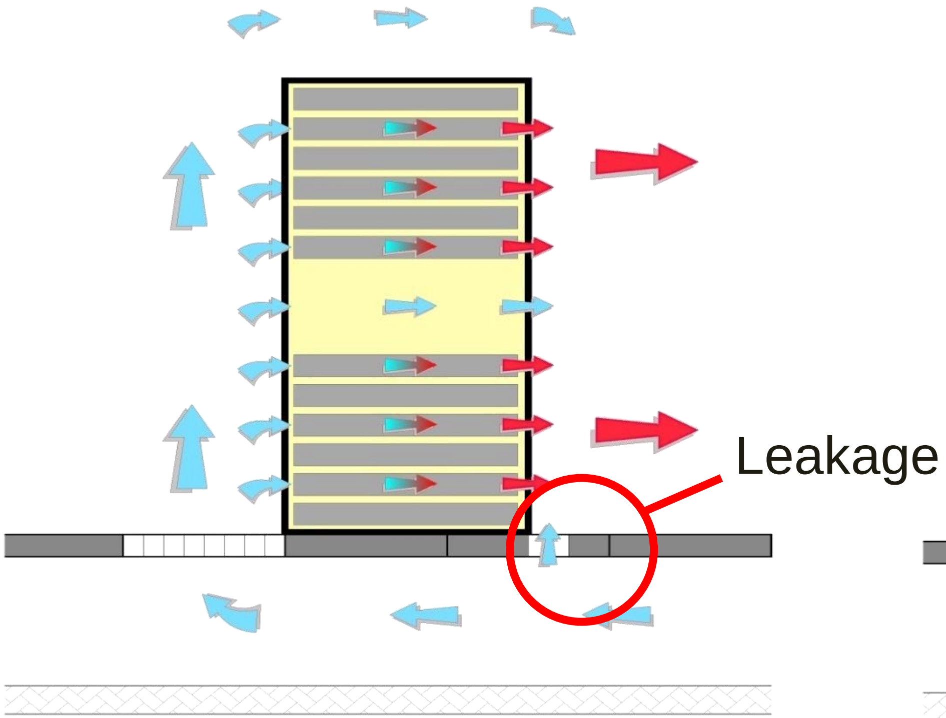
Separating Cold from Hot Airflow

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



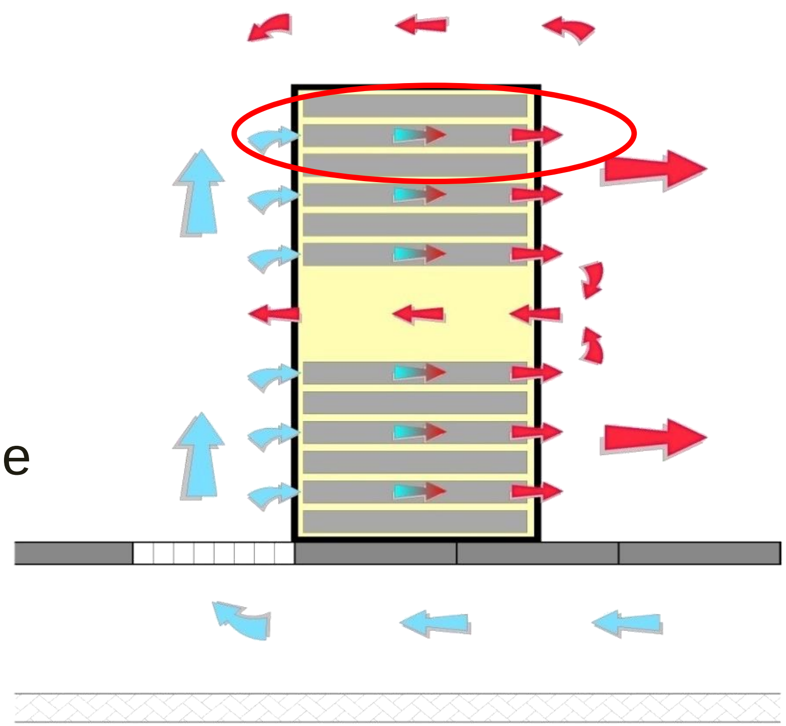
Reduce By-Pass and Recirculation Air

Bypass Air / Short-Circuiting



Wastes fan energy as well as cooling energy and capacity

Recirculation

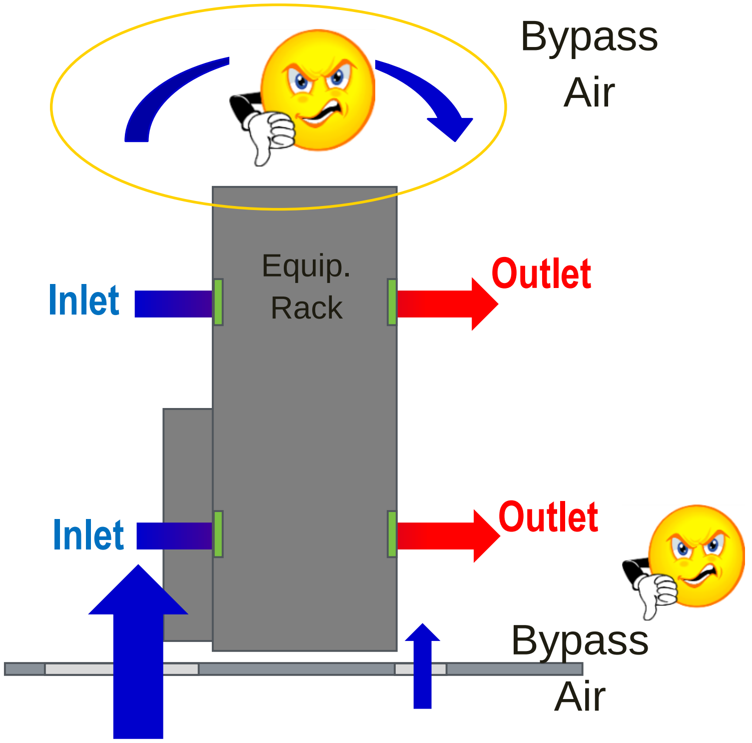


Increases inlet temperature to servers

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

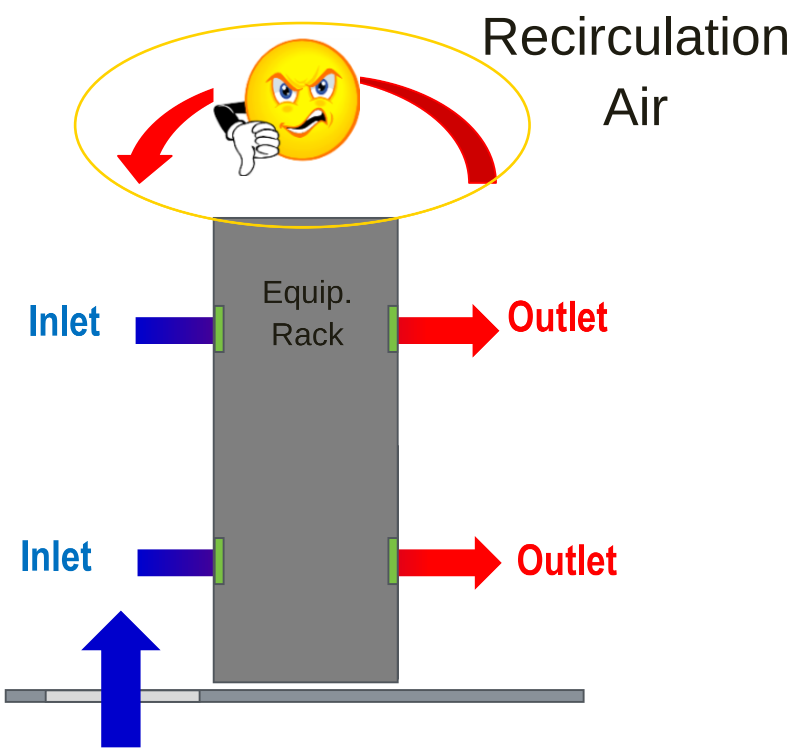
Bypass Air - Common Causes

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



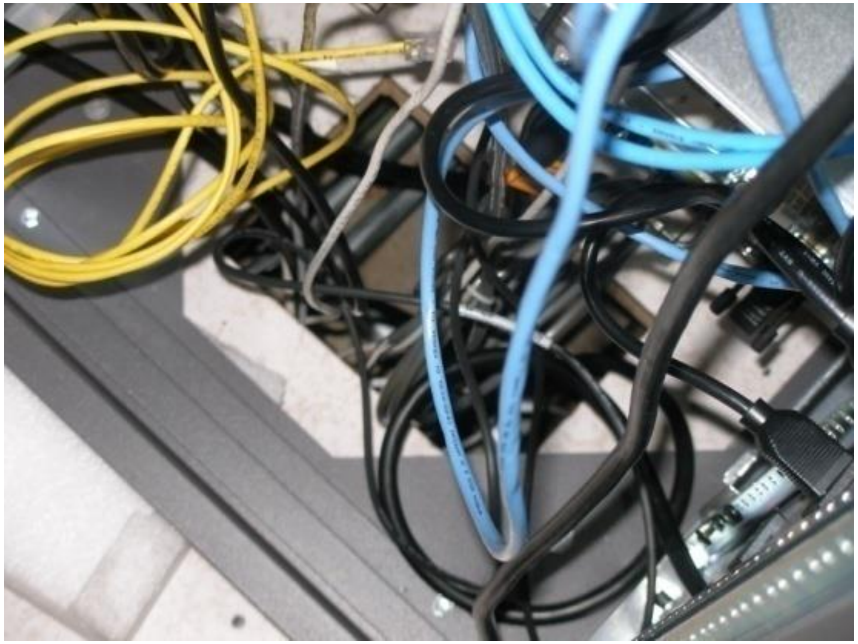
Recirculation Air - Common Causes

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



Maintaining Raised-Floor Seals

Maintain seals of all potential leaks in the raised floor plenum



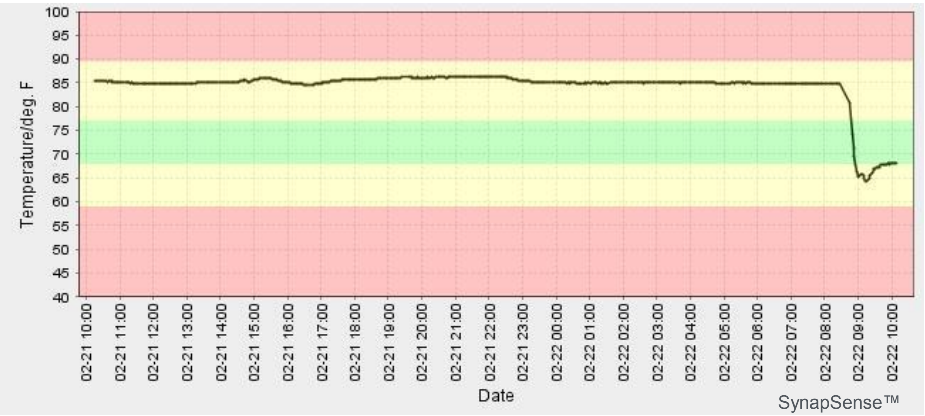
Unsealed cable penetration (inside rack)

Sealed cable penetration

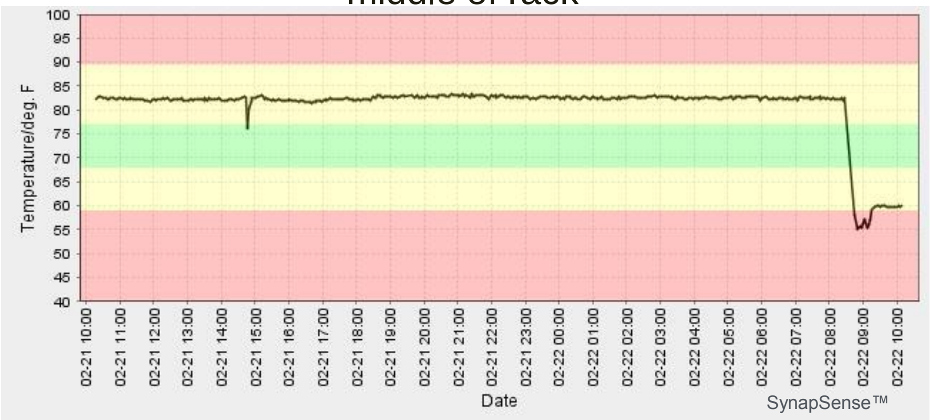
Managing Blanking Panels

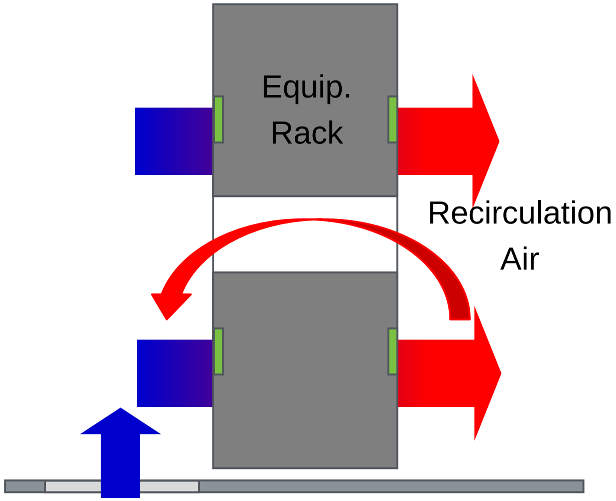
- Any opening will degrade the separation of hot and cold air
- Maintain blanking panels
  - One 12" blanking panel reduced temperature ~20°F

top of rack

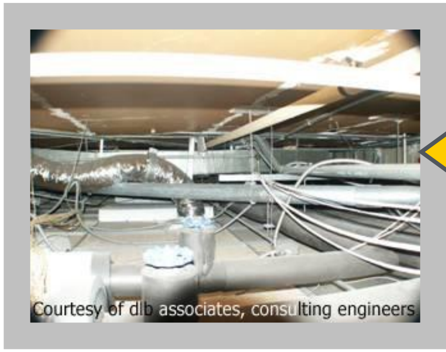


middle of rack

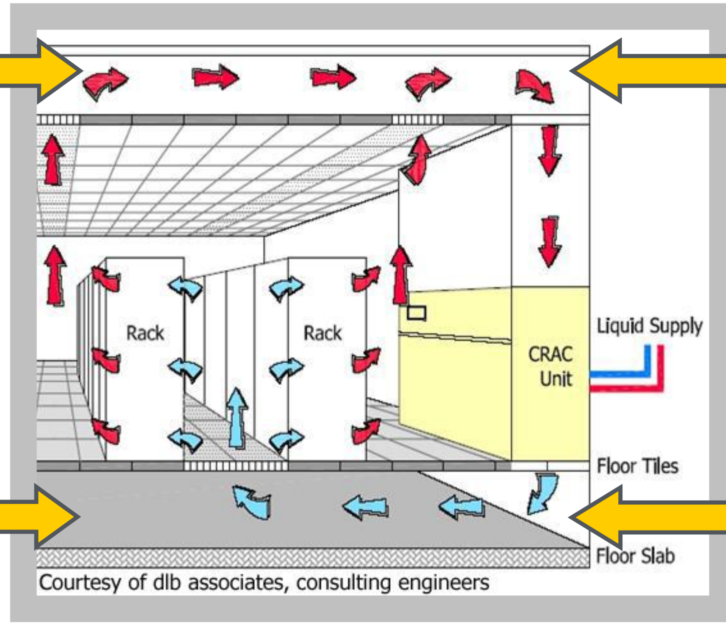




Reduce Airflow Restrictions & Congestion



Congested Floor & Ceiling Cavities

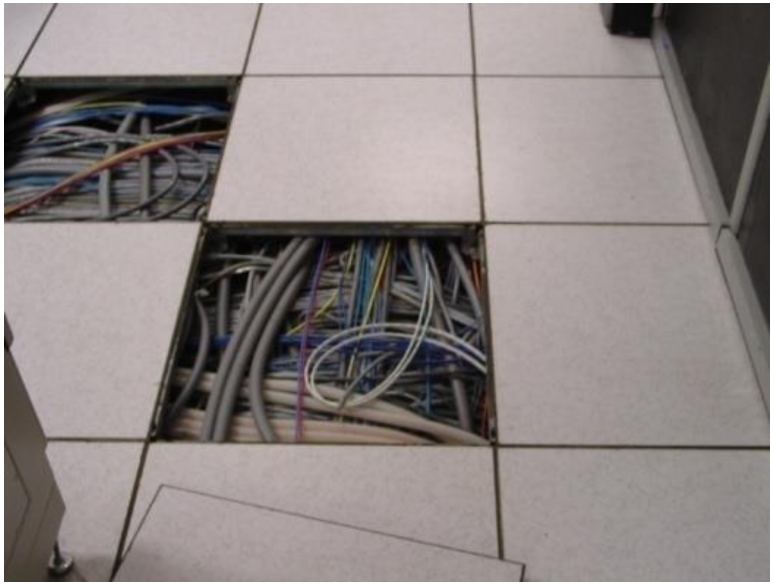


Consider the Impact that Congestion Has on the Airflow Patterns

Empty Floor & Ceiling Cavities

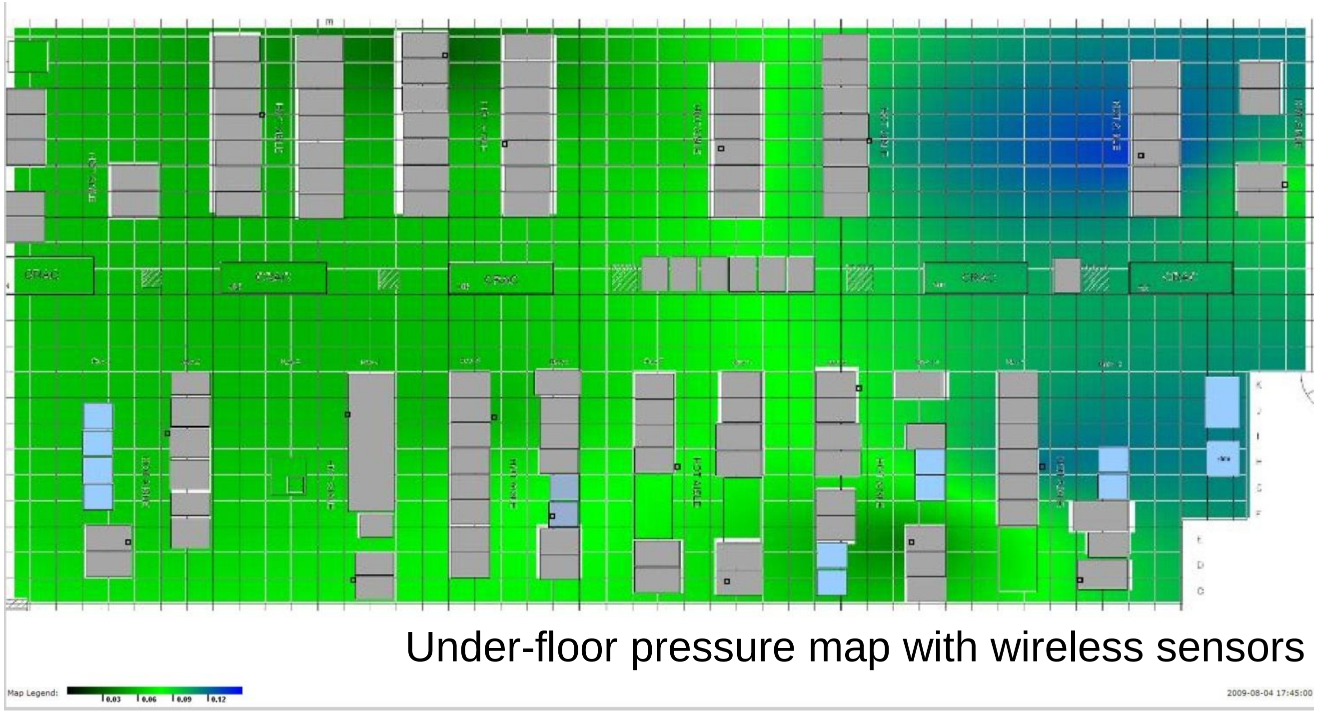
Reduce Cable Congestion

- 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*”



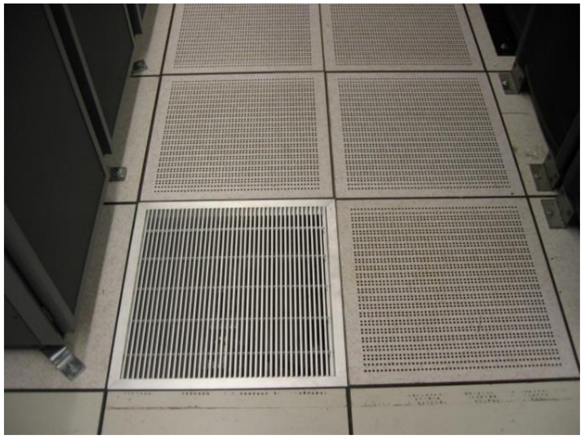
Resolve Airflow Balancing

- <u>Balancing</u> is required to optimize airflow
- Rebalance with new IT or HVAC equipment
- Place perforated floor tiles *only* in cold aisles

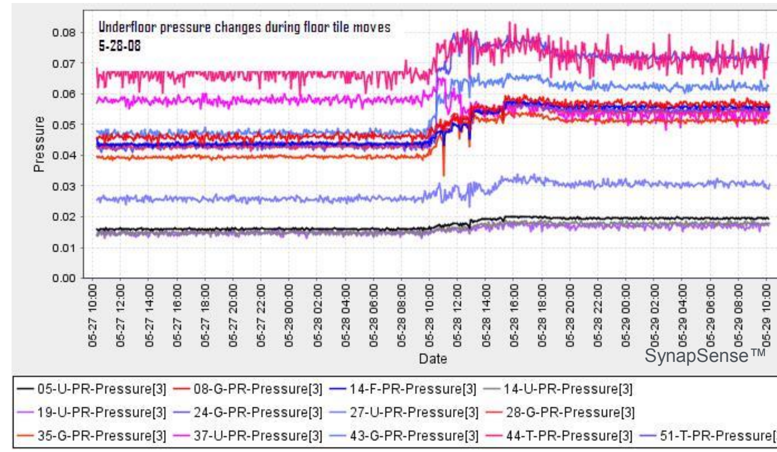


Under-floor pressure map with wireless sensors

Results: Tune Floor Tiles

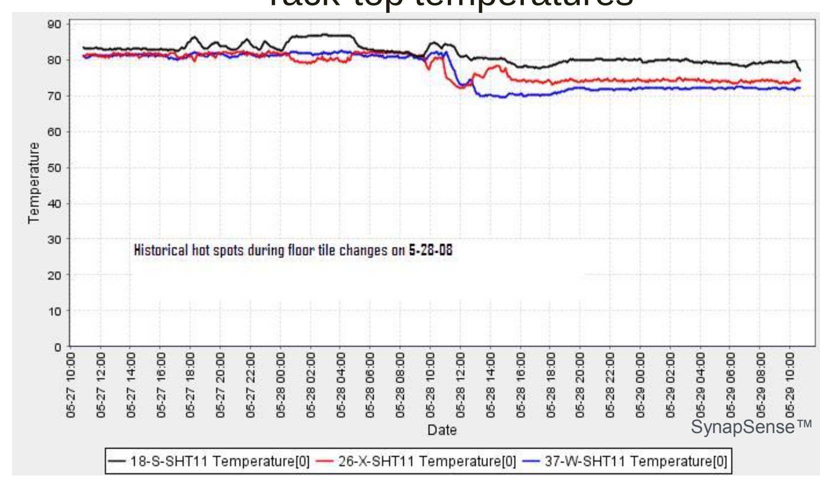


under-floor pressures



- Too many permeable floor tiles
- If airflow is optimized
  - under-floor pressure ↑
  - rack-top temperatures ↓
  - data center capacity increases
- Measurement and visualization assisted the tuning process

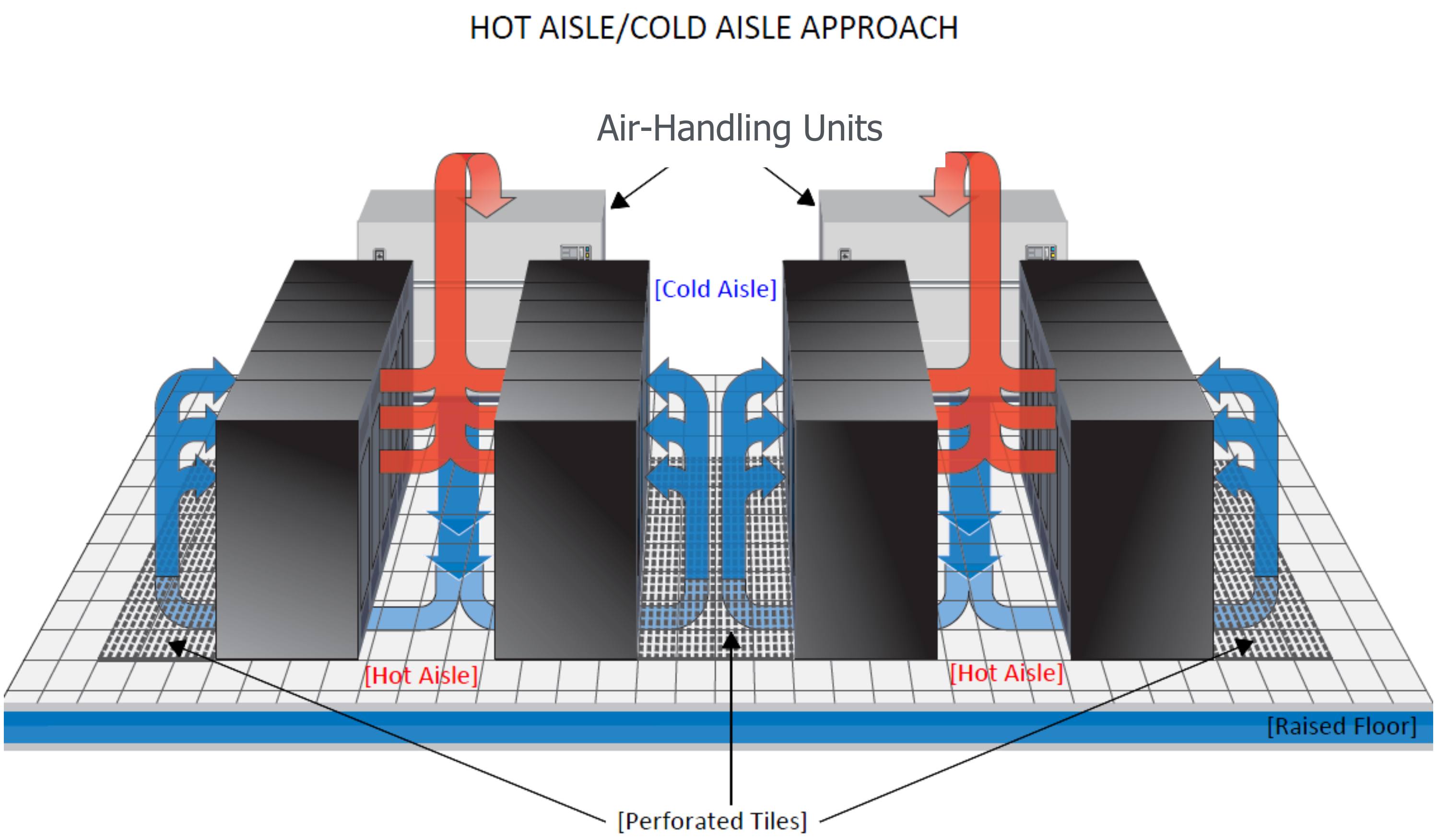
rack-top temperatures



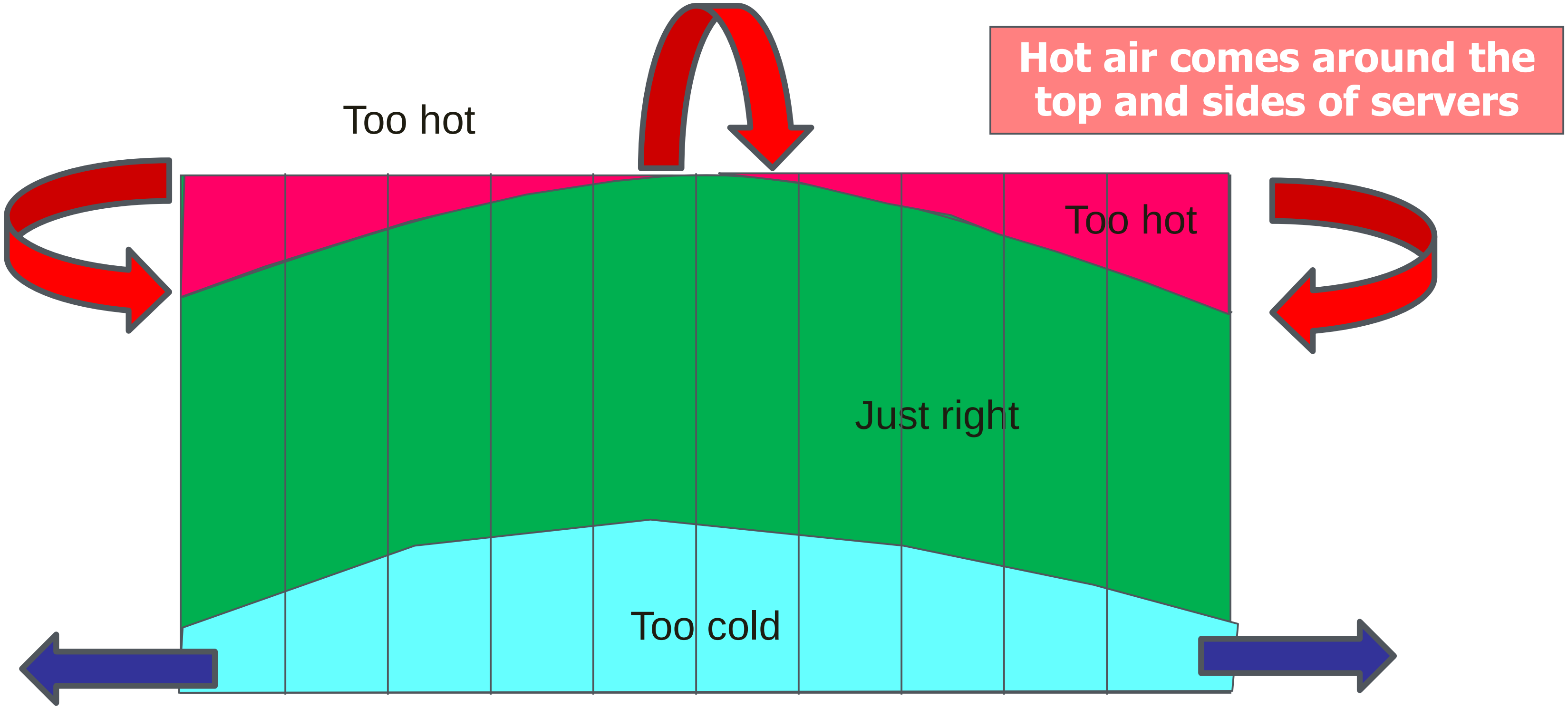
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Optimally Locate CRAC/CRAHs

At ends of hot aisles to minimize mixing of hot return:



Typical Temperature Profile with Under-floor Supply

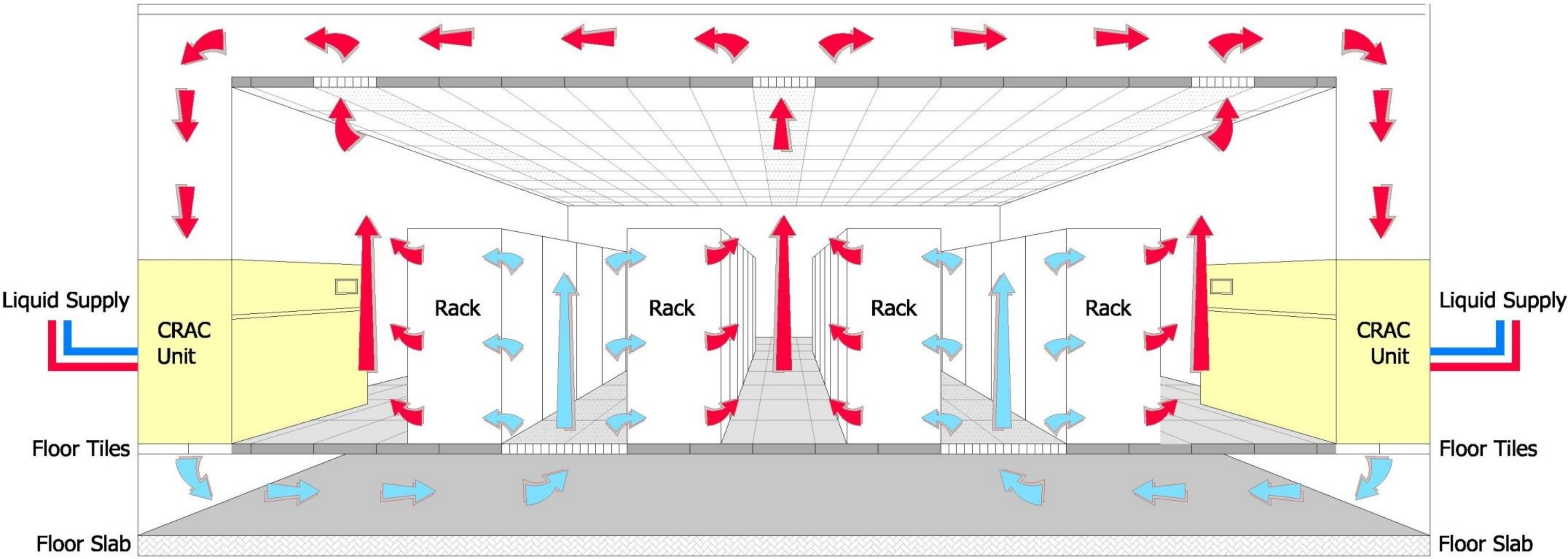


Elevation at a cold aisle looking at racks

Cold air escapes through ends of aisles

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



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

LBNL Improved Air Management

- Overhead plenum converted to hot-air return (A)
- CRAC intakes extended to overhead plenum (B)
- Return registers placed over hot aisle (C)

Before

After

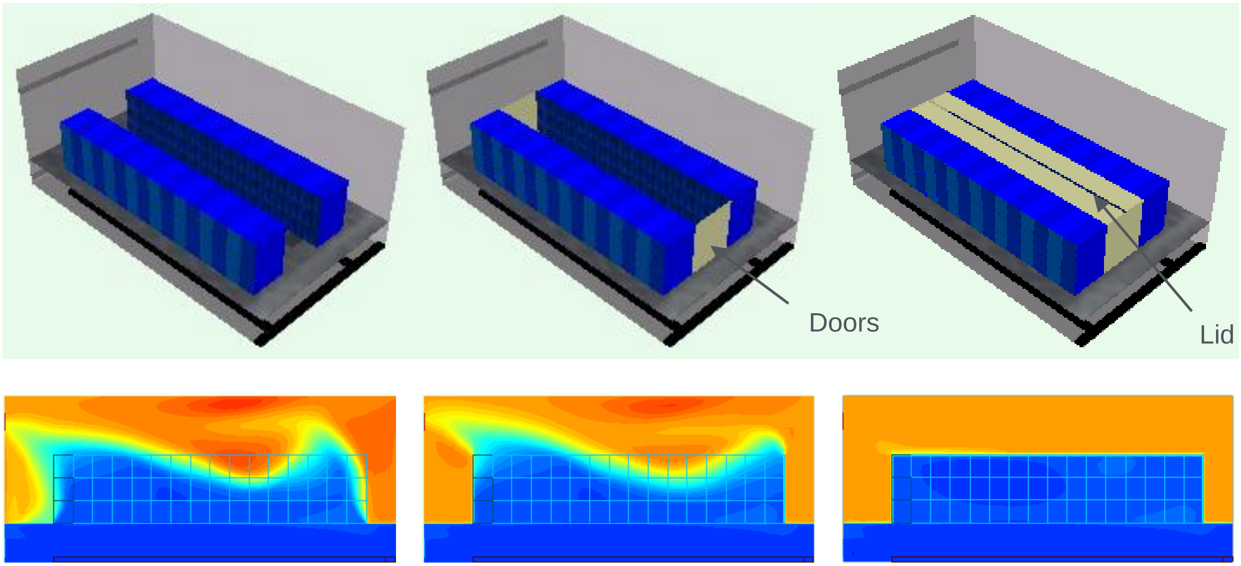
Return-Air Plenum Connections

Isolate return air at CRAC/CRAH:

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

Enhanced Isolation Options

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



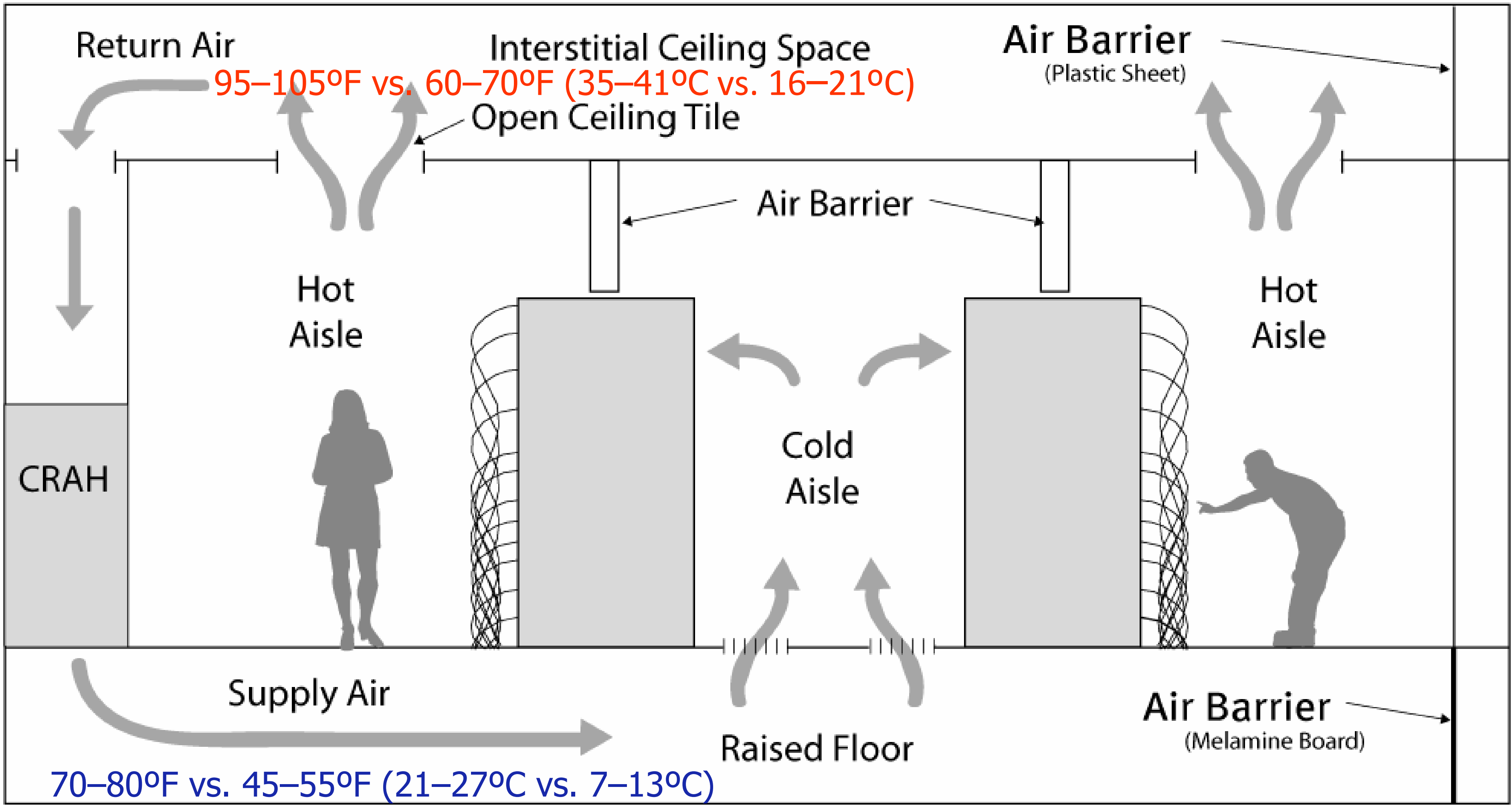
Open | **Semi-enclosed cold aisle** | **Enclosed cold aisle**

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

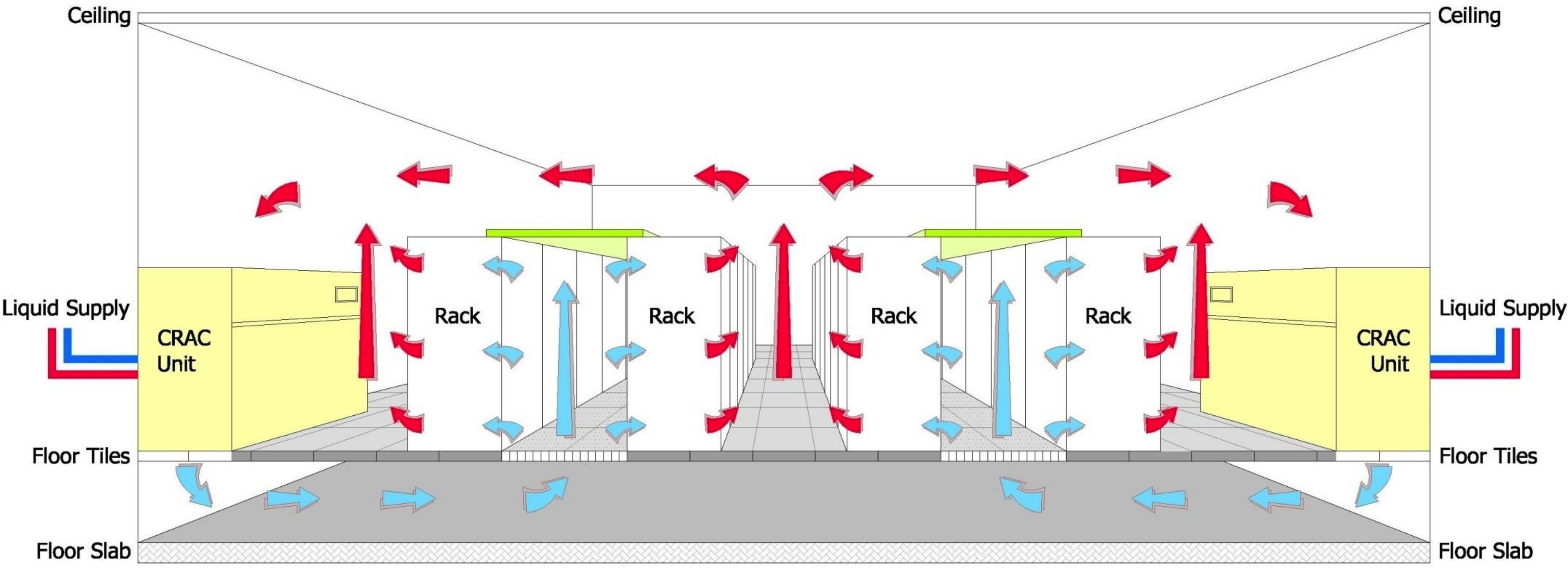
Adding Air Curtains for Hot/Cold Isolation

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

Air Management: Separate Cold and Hot Air



Cold Aisle Airflow Containment Example

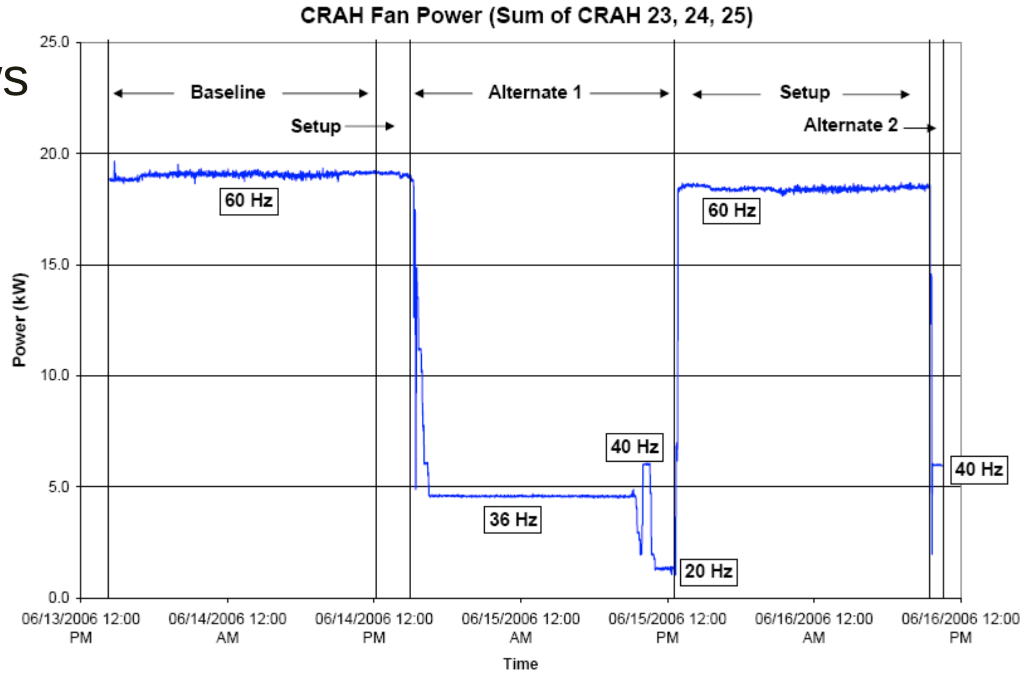


LBNL's Cold Aisle Containment study achieved fan energy savings of ~75%

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

Fan Energy Savings

- Isolation significantly reduces bypass air, which in turn allows reduction of supply airflow
- Fan speed can be reduced, and fan power is proportional to nearly the cube of the flow
- Fan energy savings of 70%–80% is possible with variable air volume (VAV) fans

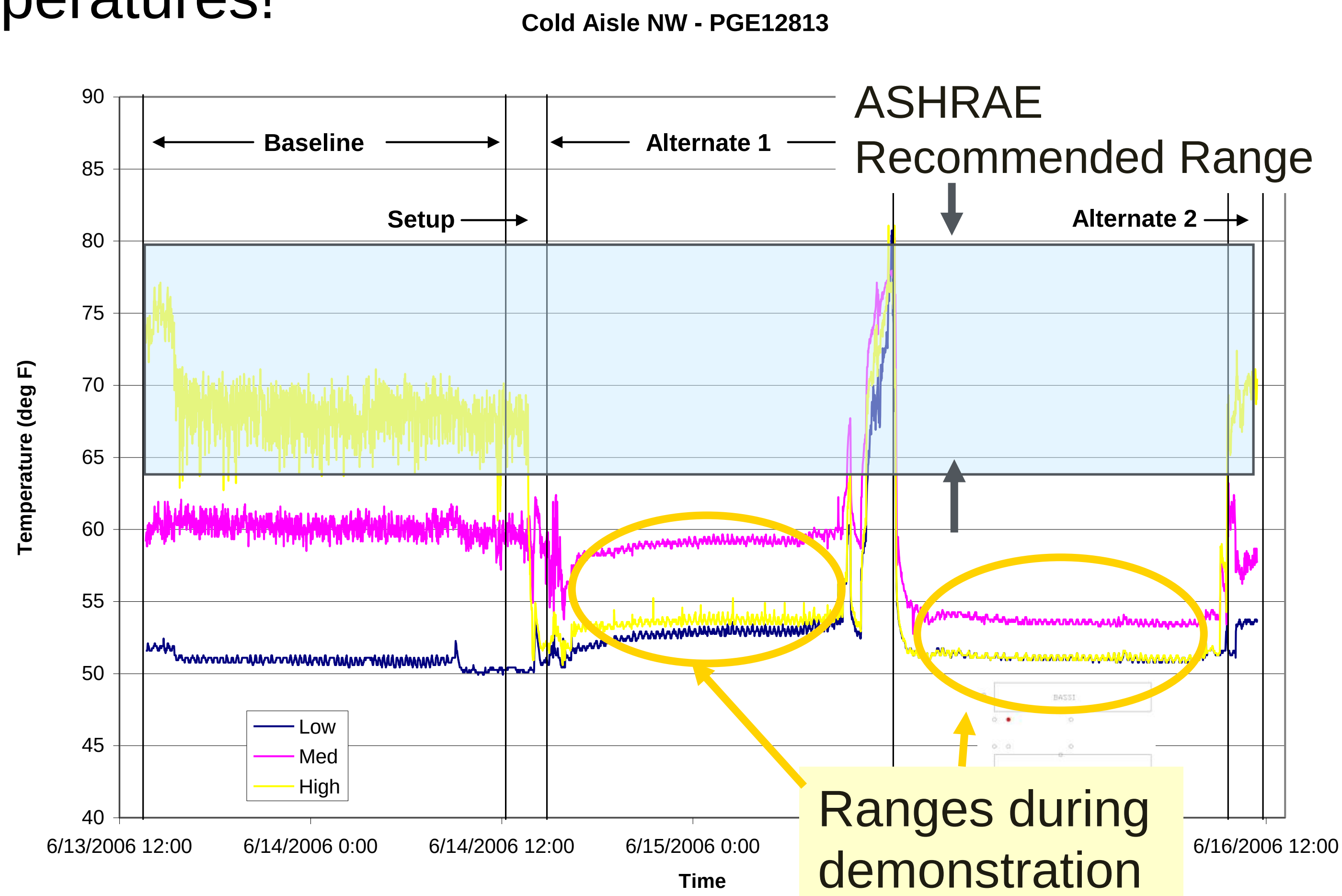


Without Enclosure | With Enclosure | Without Enclosure

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

LBNL Air Management Demonstration

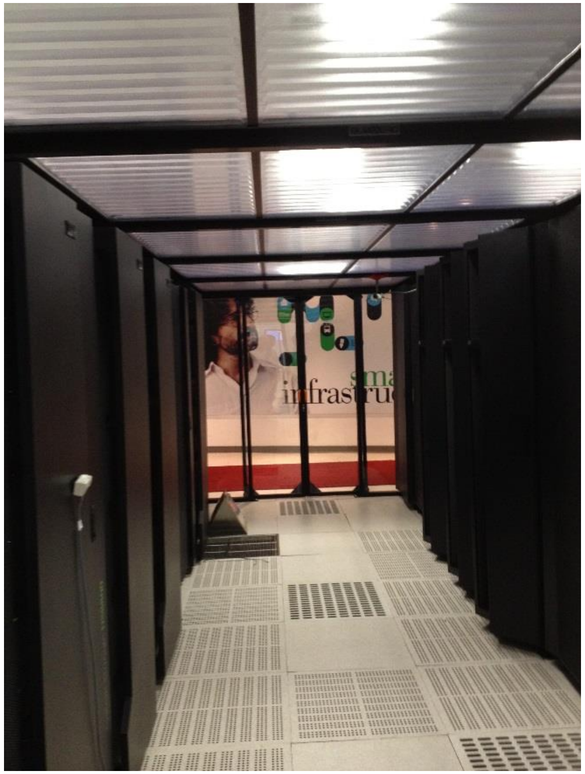
Better airflow management permits warmer supply temperatures!

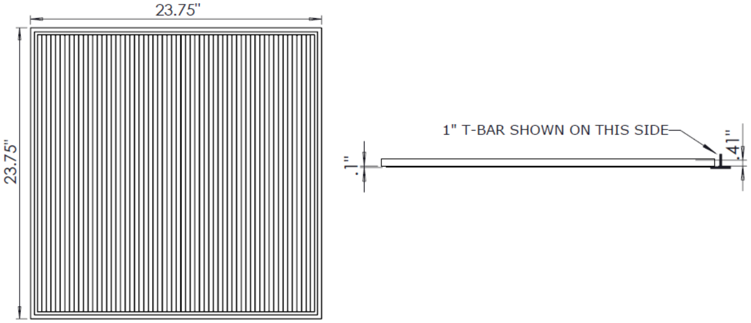


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Hot and Cold Aisle Containment

Subzero Cold Aisle Containment





Ceilume Heat Shrink Tiles

APC Hot Aisle Containment
(with in-row cooling)

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

LBNL Air Management Improvement Effort

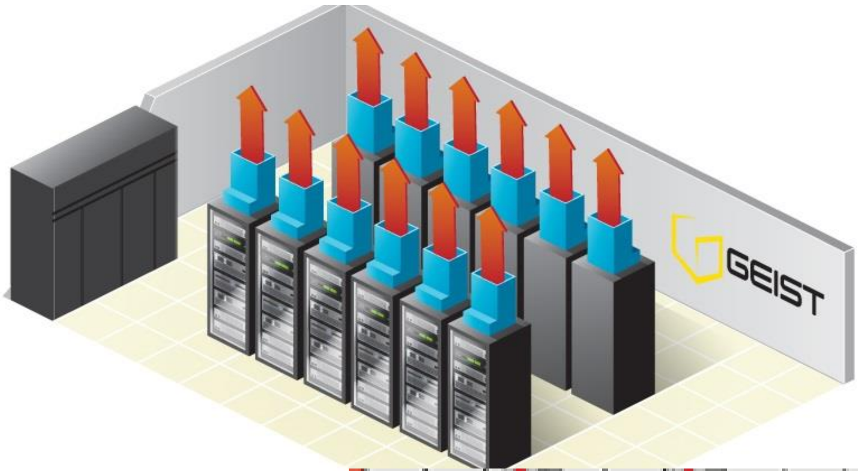
- Perform CFD modeling
- Deploy a wireless monitoring system
- Identify opportunities for improvement
  - Enforce hot aisle/cold aisle arrangement
  - Use blanking panels
  - Improve airflow and under-floor pressure by tuning floor tiles
  - Reduce mixing and short circuits
  - Convert overhead plenum to return
  - Extend CRAC intakes into overhead plenum
  - Add air curtains to improve isolation.

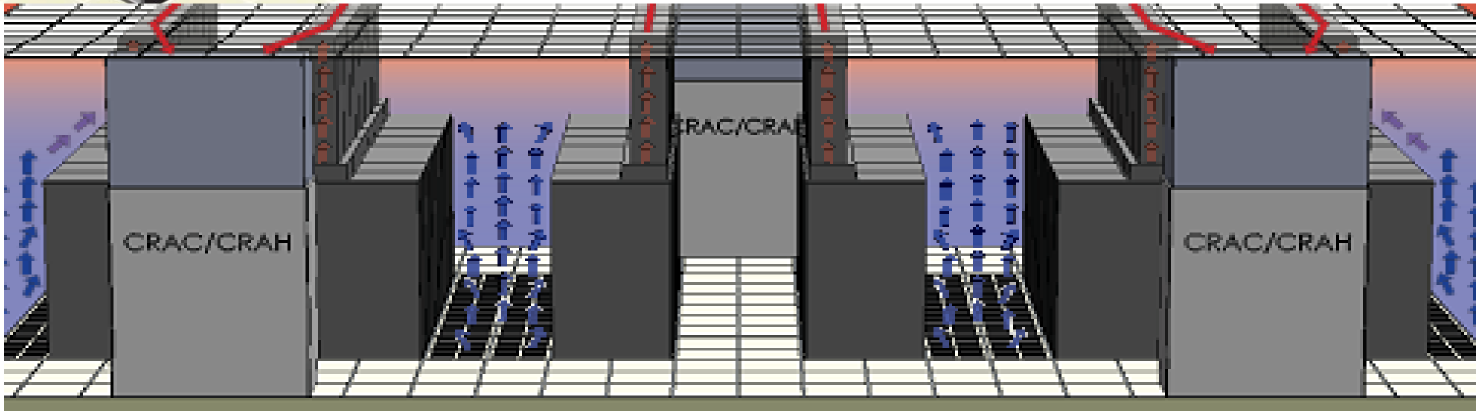
Isolated Hot Return

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

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

Cabinet/Row Containment





eist'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 slab environments
Data center floor becomes a cold aisle providing comfortable working conditions
1:1 airflow balance makes cooling over-provision unnecessary

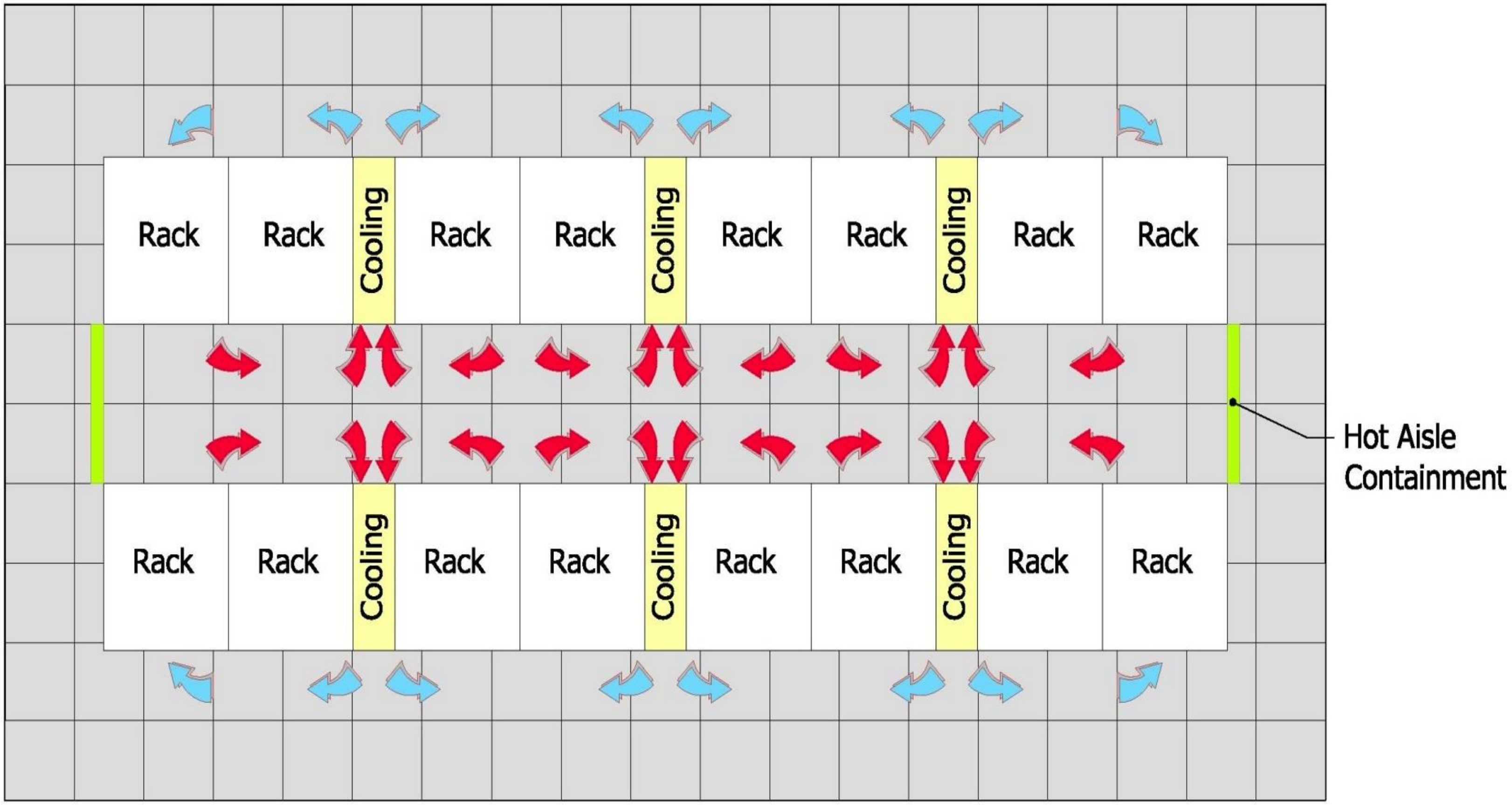
Isolating Hot and Cold Aisles Summary

- Energy intensive IT equipment needs good isolation of “cold” intake and “hot” exhaust
- Supply airflow can be reduced if no bypass occurs (assuming VFD fans)
- Supply temperature can be raised if air is delivered without mixing
- Chillers and economizers are more efficient with warmer return air temperatures
- Cooling and raised-floor capacity increase with air management

Efficient Alternatives to Under-Floor Air Distribution

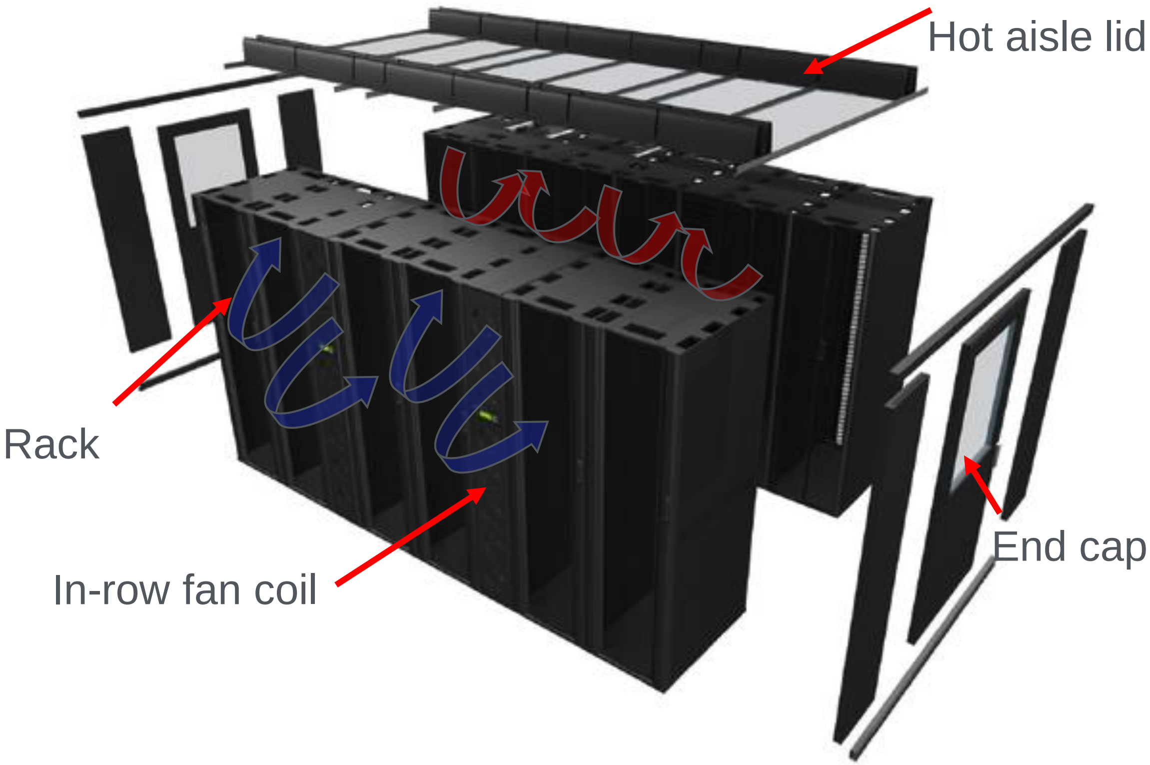
- Localized air cooling systems with hot and cold isolation can supplement or replace under-floor systems
- Examples
  - Row-based cooling units
  - Rack-mounted heat exchangers
- Both options "pre-engineer" hot and cold isolation

Example - Local In-Row Based Cooling

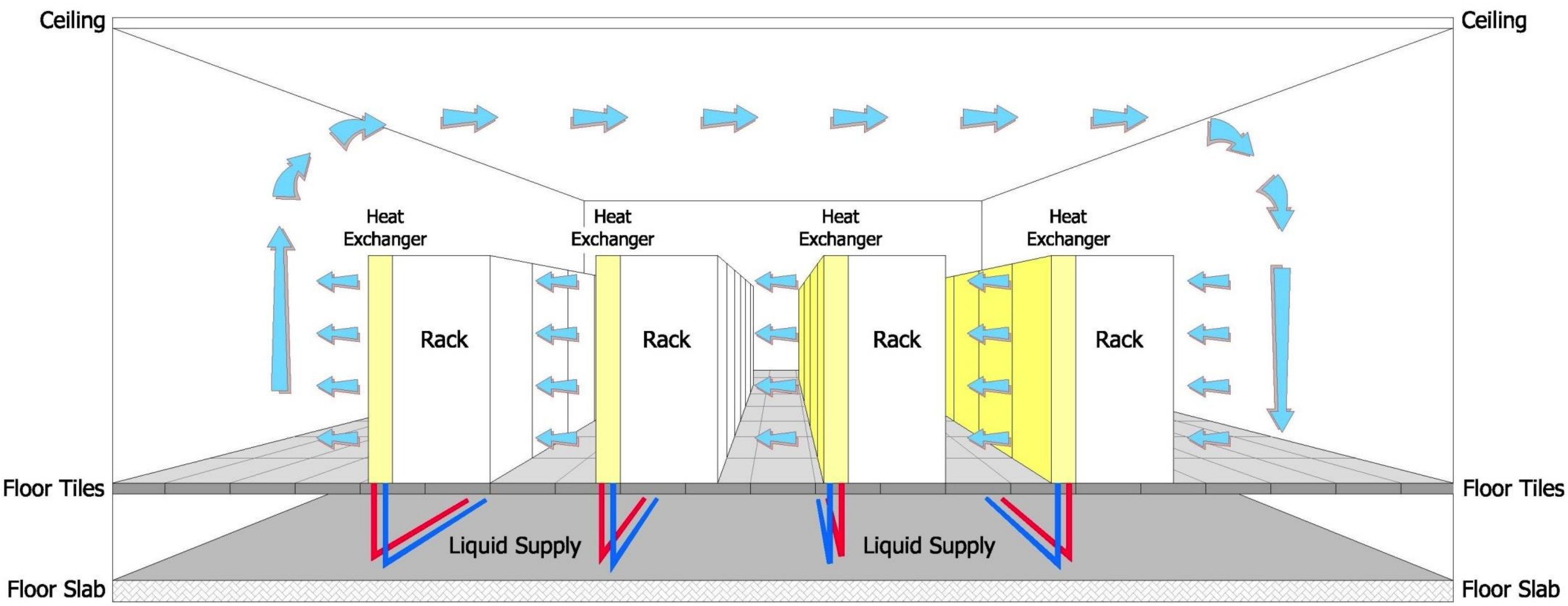


In-Row Cooling System

With hot aisle containment, the general data center space is neutral (75°F–80°F).



Rack-Mounted Heat Exchangers ("Rear Doors")



Airflow Management Review

Air management techniques:

- Seal air leaks in floor (e.g., cable penetrations)
- Prevent recirculation with blanking panels in racks and between 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%+
- Supply air temperature can be raised
  - Chiller efficiency improves
  - Greater opportunity for economizer operation ("free" cooling)
- Cooling and raised-floor capacity increases.

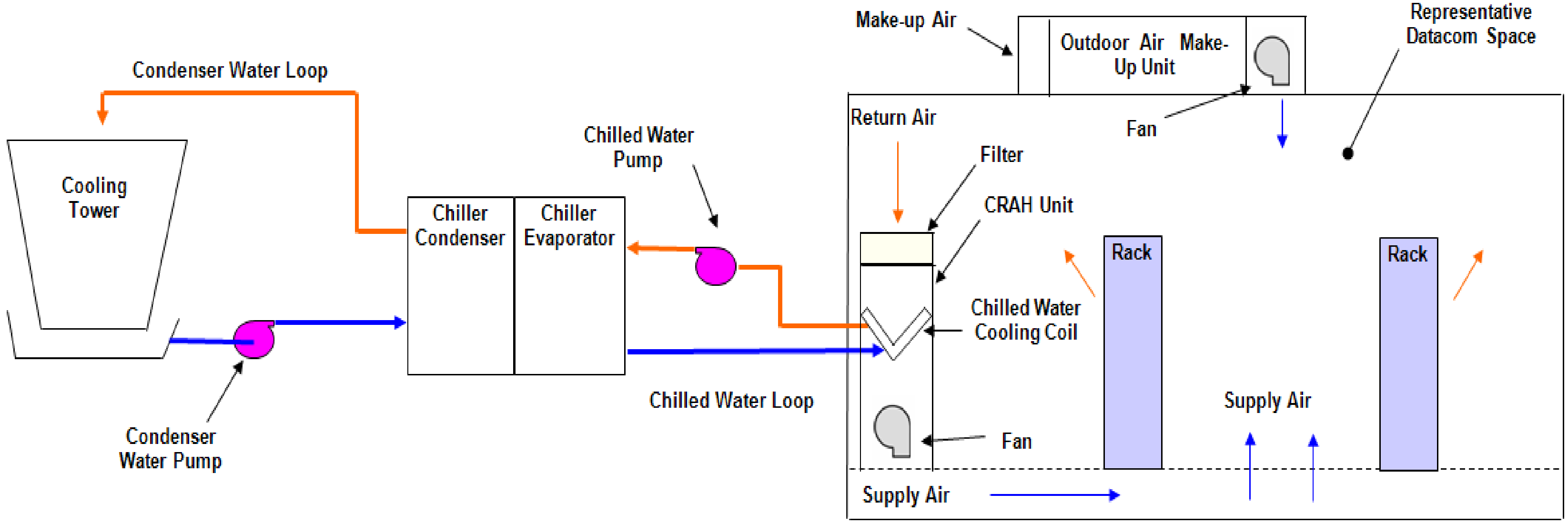
Questions

Cooling Systems

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

HVAC Systems Overview

Heat Rejection | Cooling Plant | Cooling Distribution



Heat Rejection Alternatives:

High Eff

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

Low Eff

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

High Eff

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

Low Eff

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

CRAC units

- Fan, direct expansion (DX) coil
- Refrigerant compressor

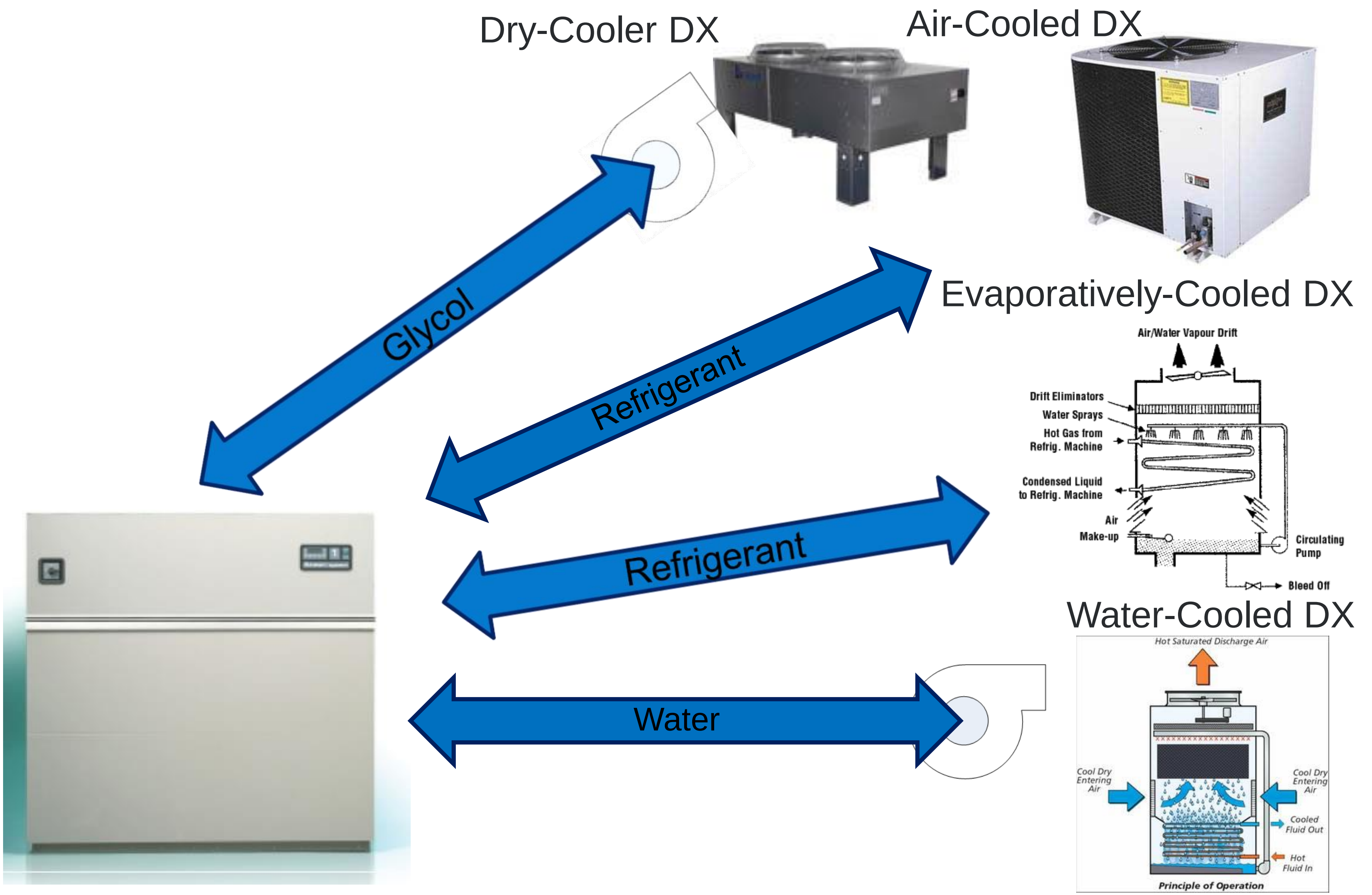
CRAH units

- Fan and chilled water coil
- Typically in larger facilities with a chiller plant

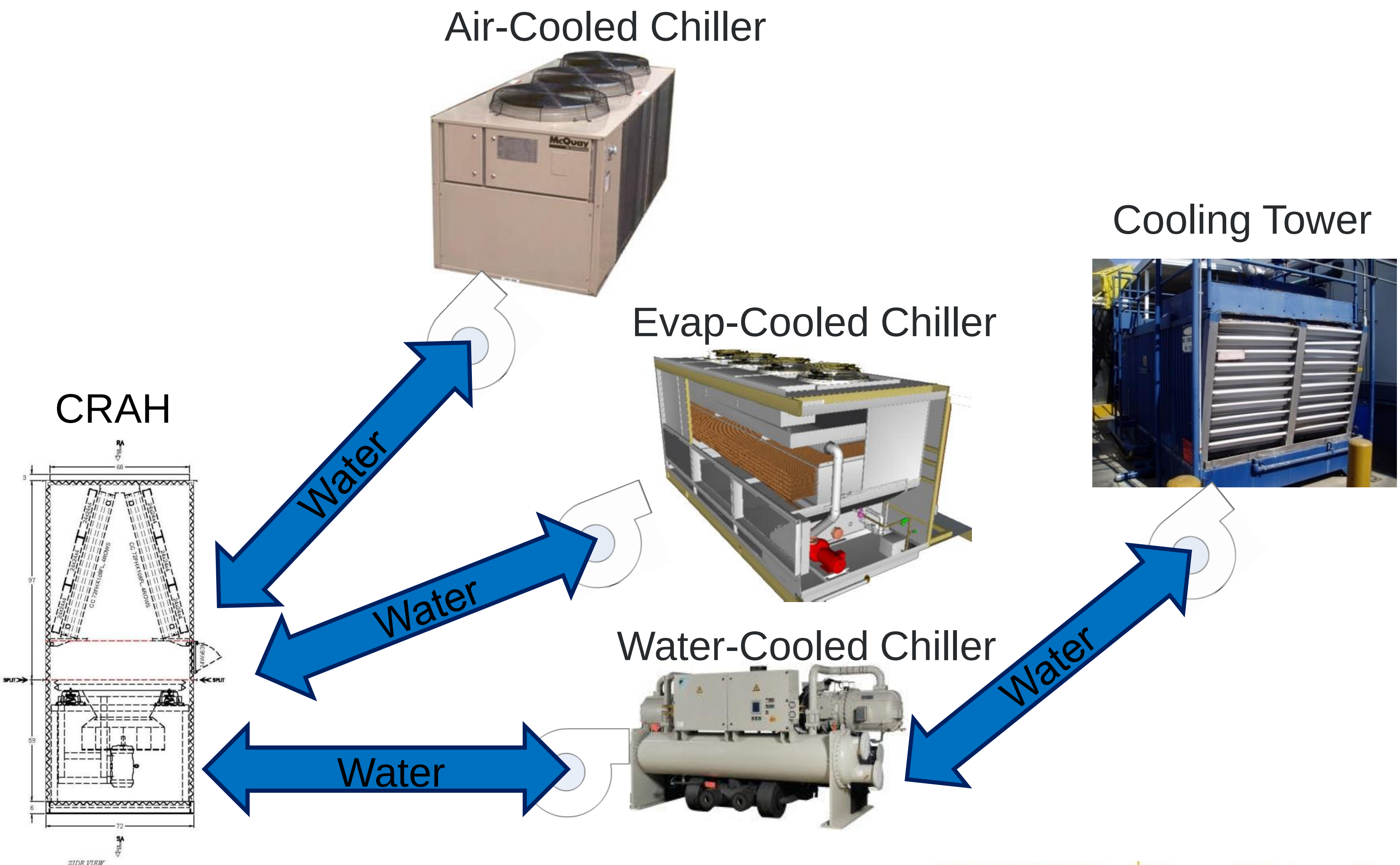
Both

- Often equipped with humidifiers and reheat for dehumidification
- Often independently controlled
  - Tight ranges and poor calibration may lead to in-fighting among units

DX (or AC) units reject heat outside

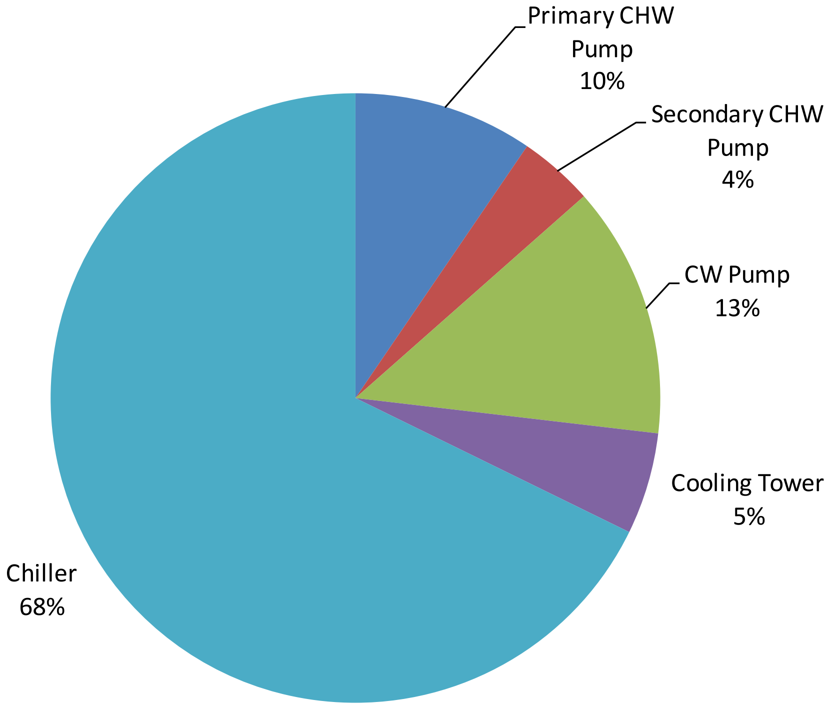


Computer Room Air Handling (CRAH) units using Chilled-Water



Optimize the Chiller Plant

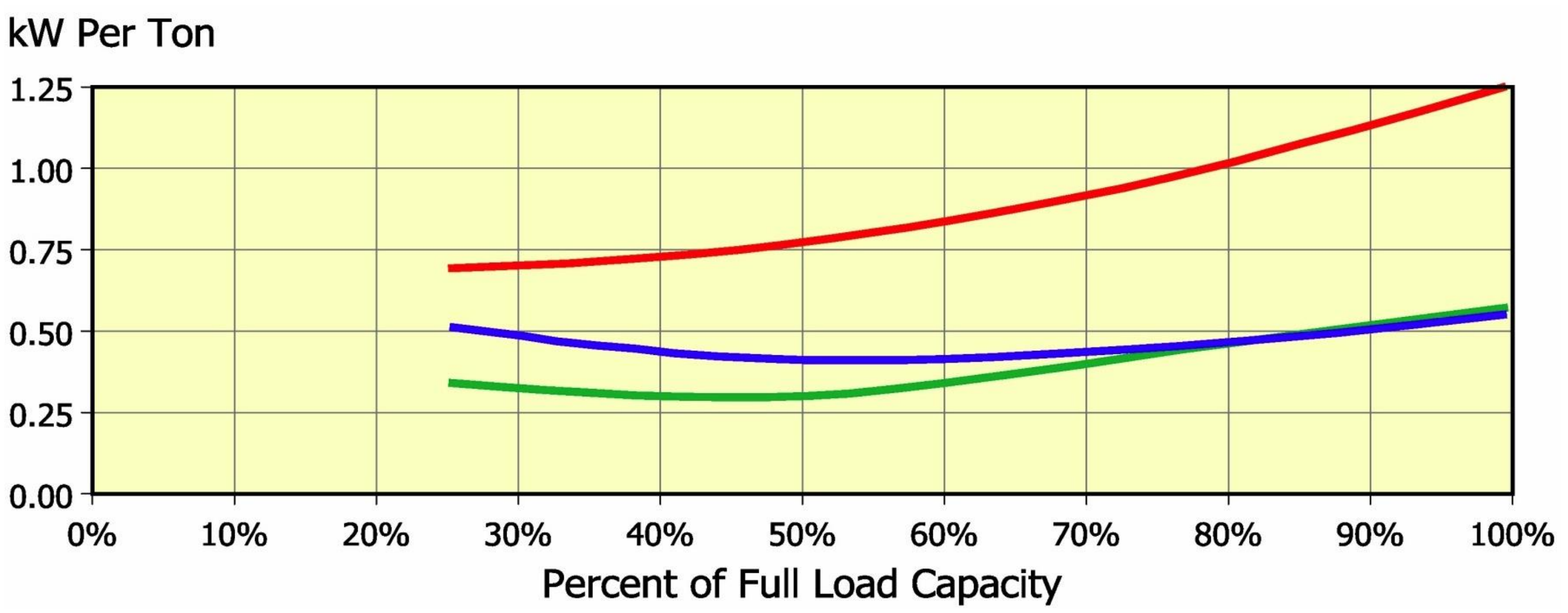
- Have a plant (vs. distributed cooling)
- Use “warm” water cooling (multi-loop)
- Size cooling towers for “free” cooling
- Integrate controls and monitor efficiency of all primary components
- Thermal storage
- Utilize variable speed drives “everywhere”:
  - Fans
  - Pumps
  - Towers
  - Chillers



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

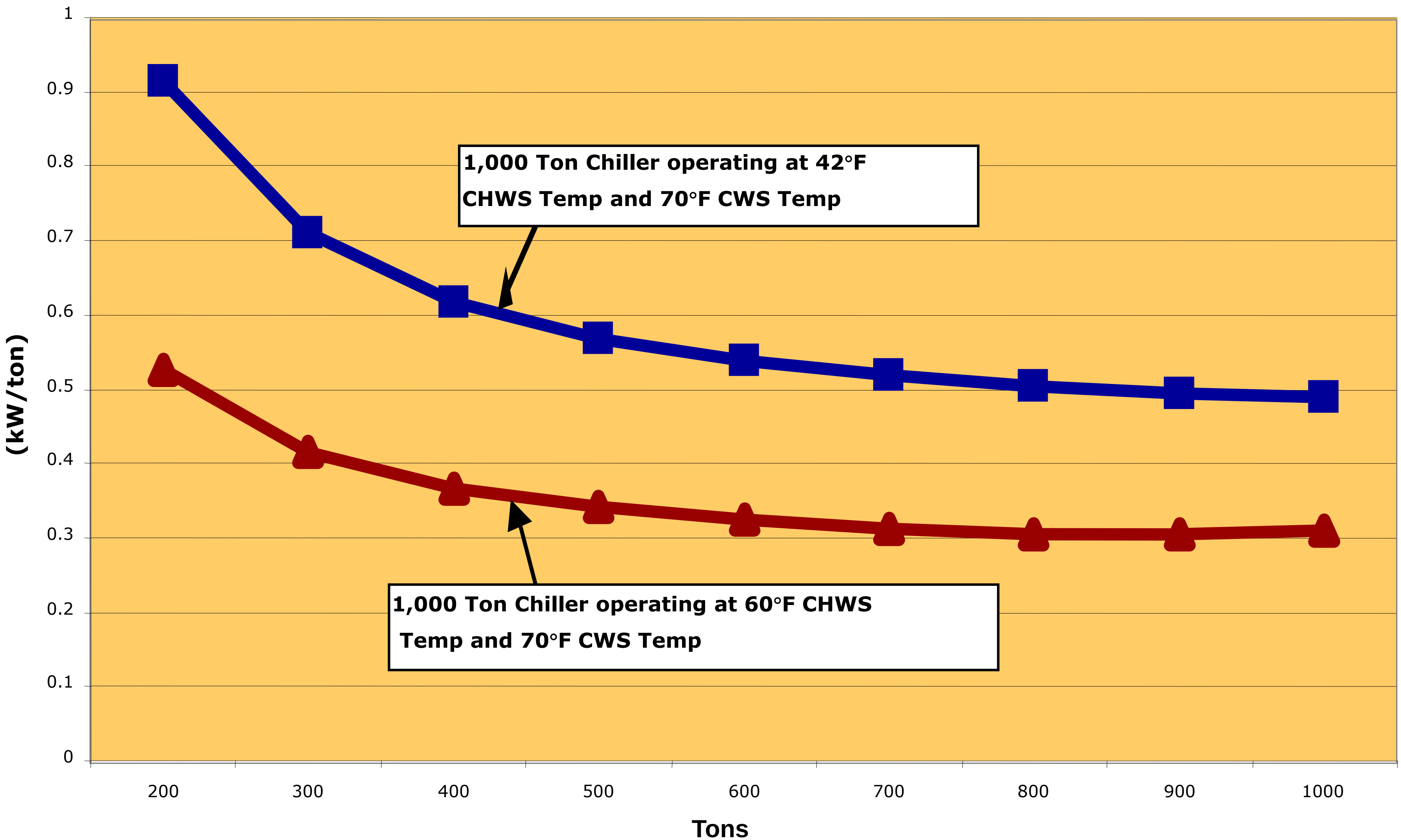
Select Efficient Chillers

Chiller	Compressor kW / ton			
	25%	50%	75%	100%
400-Ton Air Cooled	0.69	0.77	0.96	1.25
1,200-Ton Water Cooled w/o VFD	0.51	0.41	0.45	0.55
1,200-Ton Water Cooled with a VFD	0.34	0.30	0.43	0.57



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

Increase Temperature of Chilled Water



Data provided by York International Corporation

Moving (Back) to Liquid Cooling

- As heat densities rise, liquid solutions become more attractive
- Volumetric heat capacity comparison

(1.5 m^3)

Water

=

(5,380 m^3)

Air

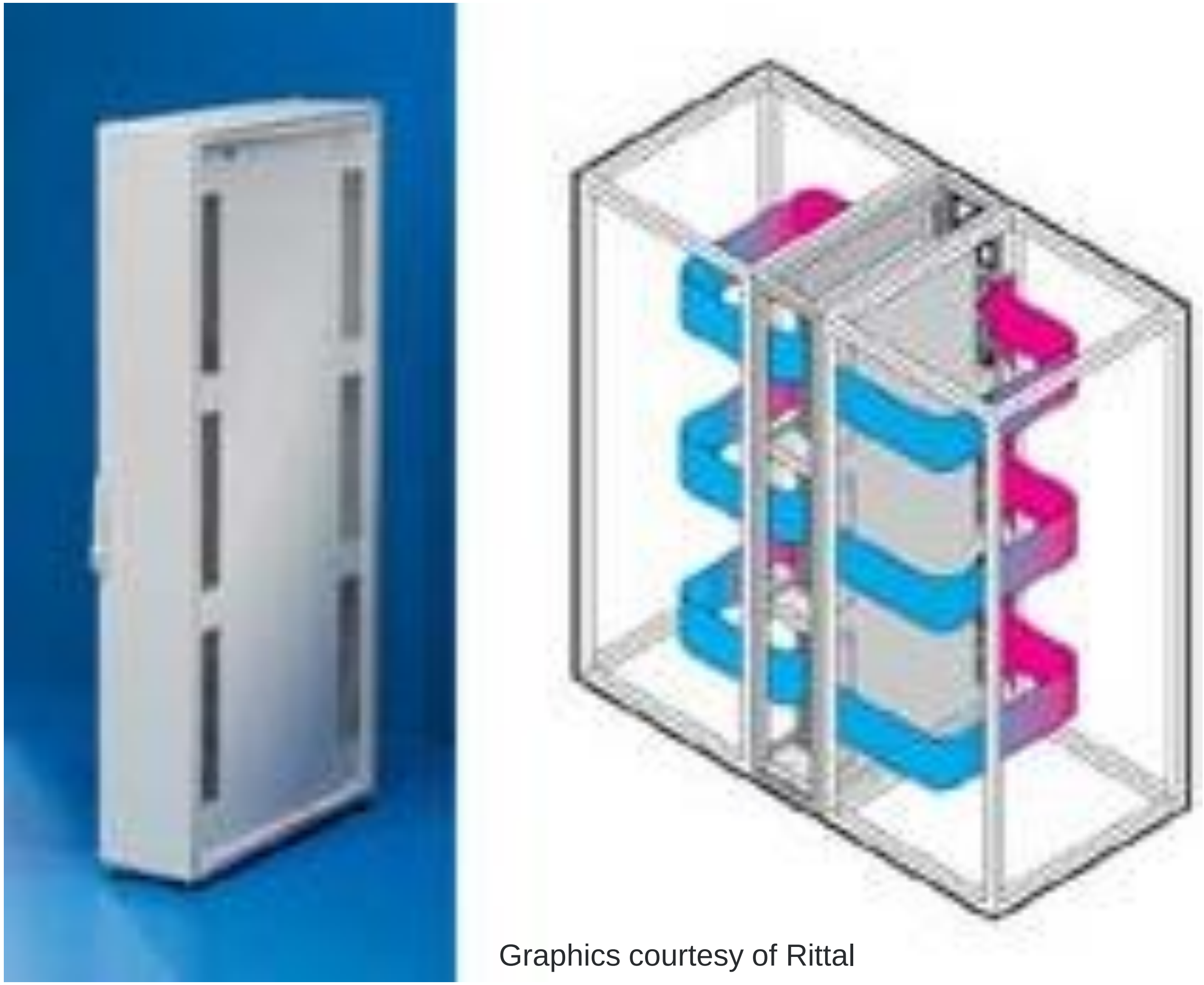
Why Liquid Cooling?

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

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

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

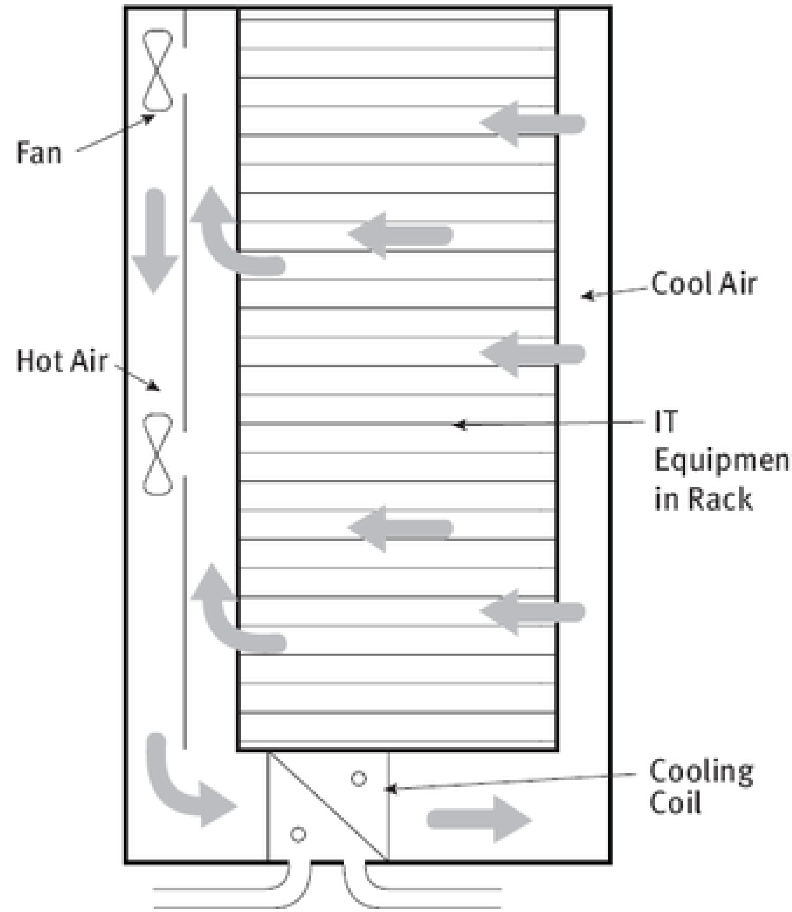
In-Row Liquid Cooling



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

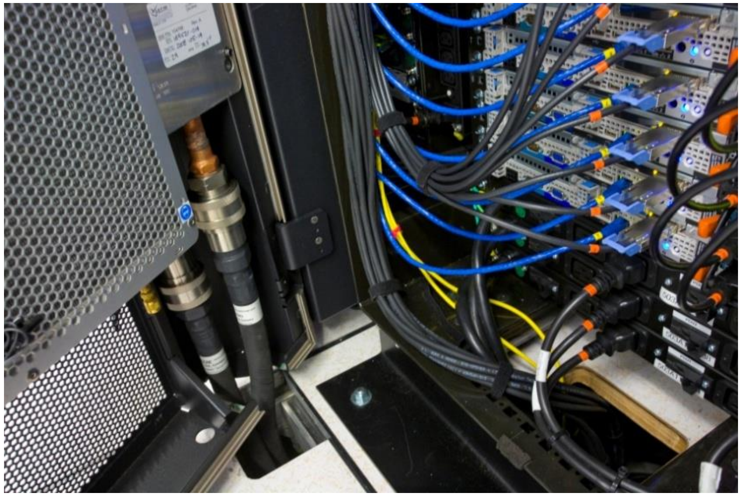
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Rear-Door Liquid Cooling

Inside rack RDHx, open 90°

Rear Doors (closed)

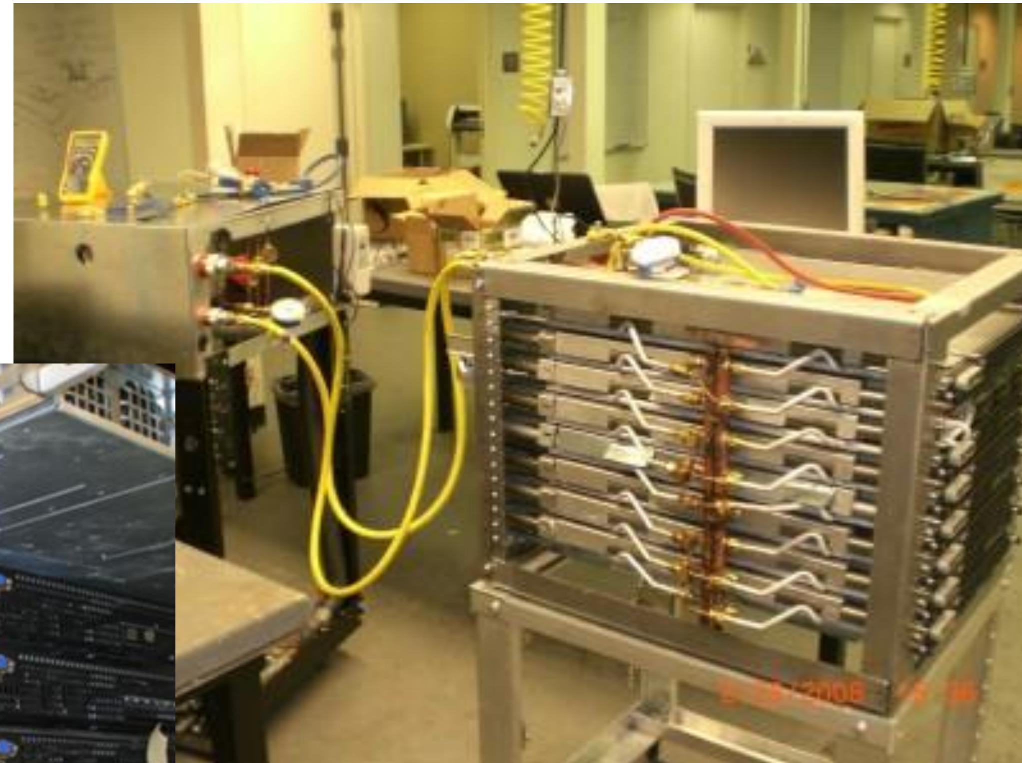
Liquid Cooling Connections



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

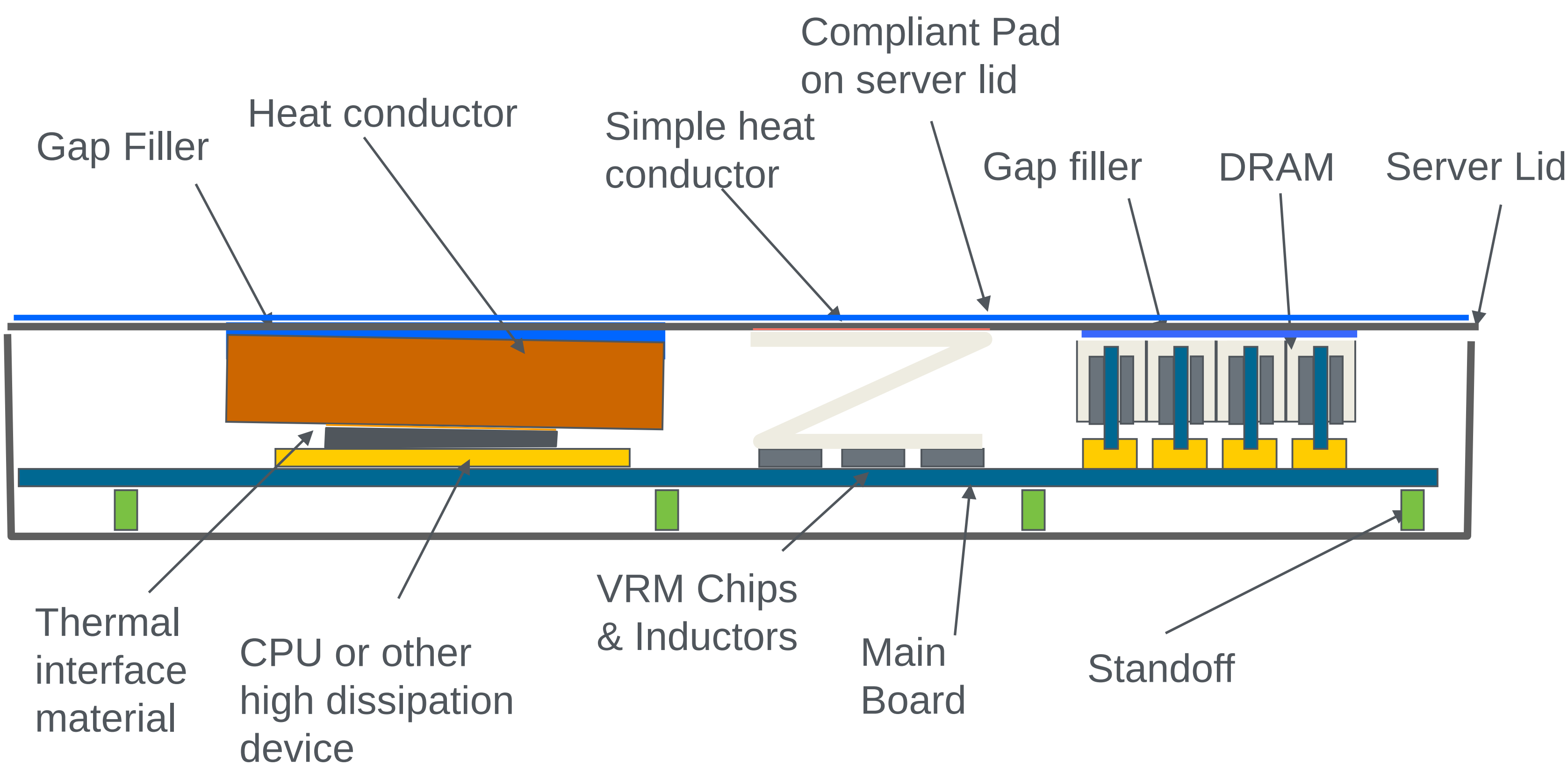
Liquid On-Board Cooling

- Clustered Systems design
- Conducting heat to a cold plate containing refrigerant



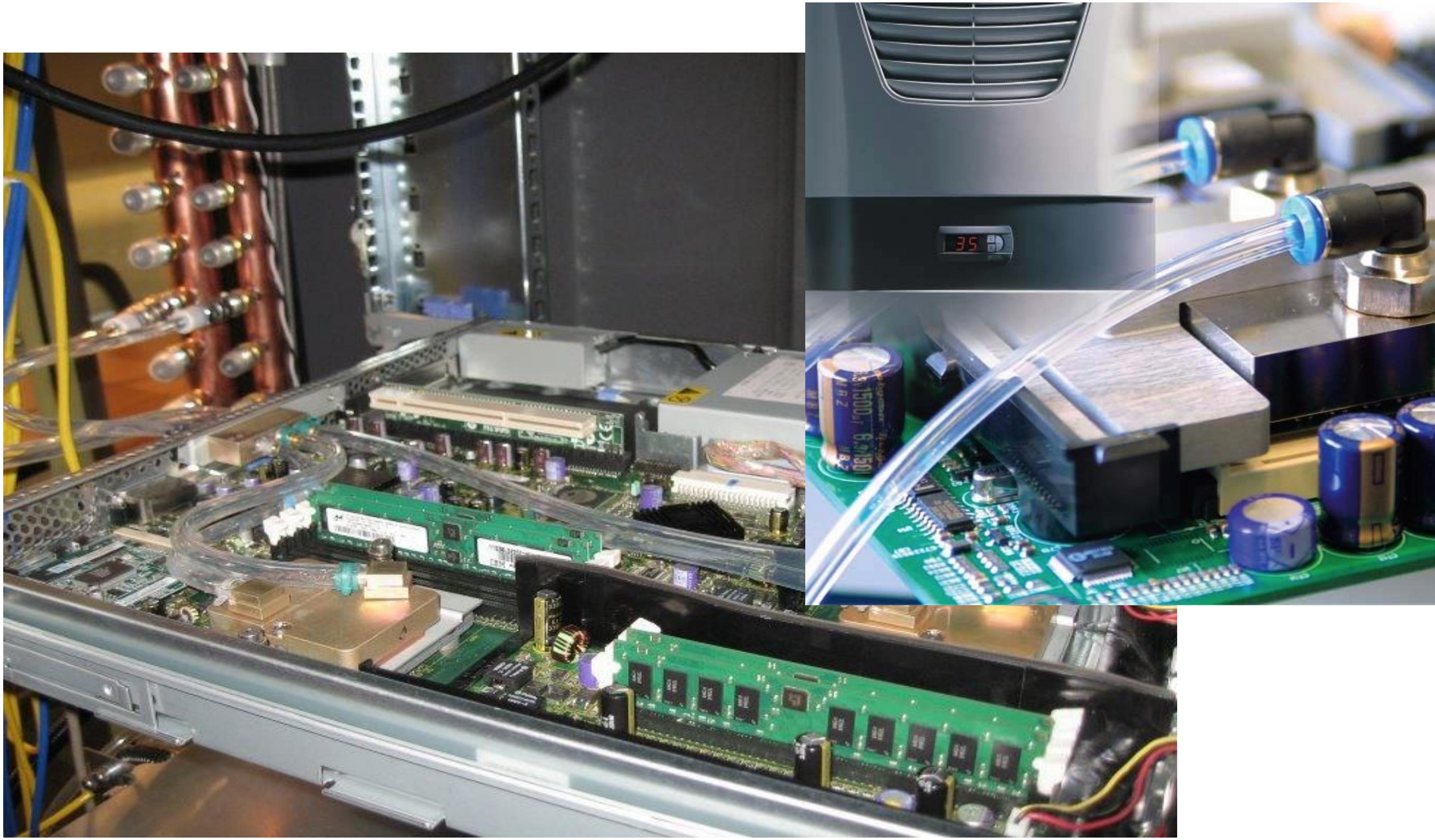
Liquid On-Board Cooling

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



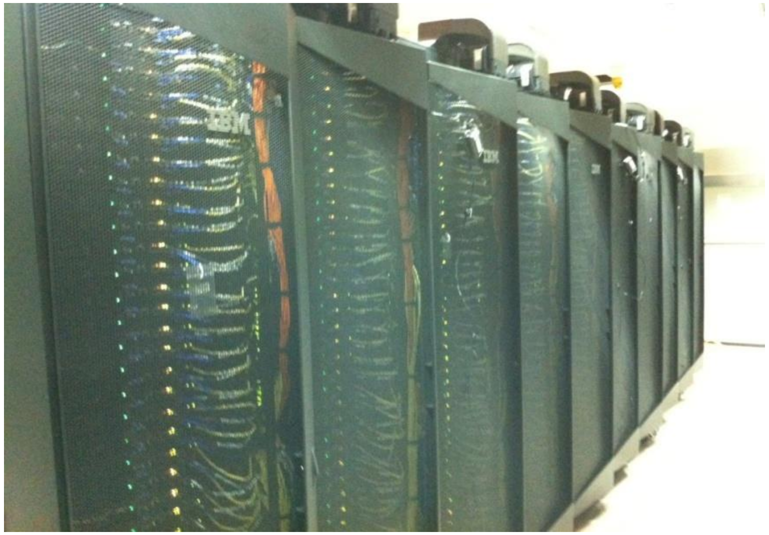
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Liquid On-Board Cooling

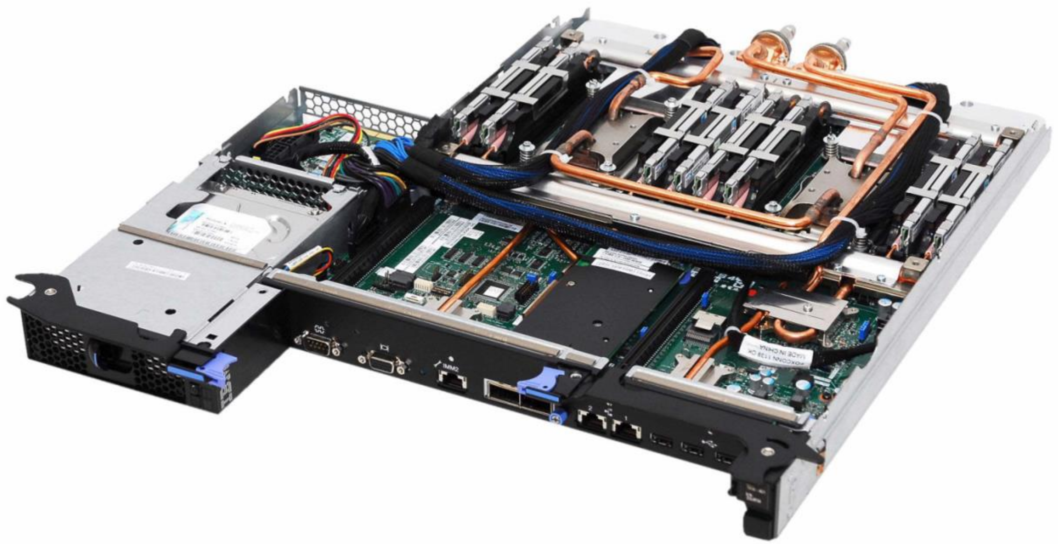


Maui HPC Center Warm Water Cooling

IBM System x iDataPlex



90% water cooled, 10% air cooled

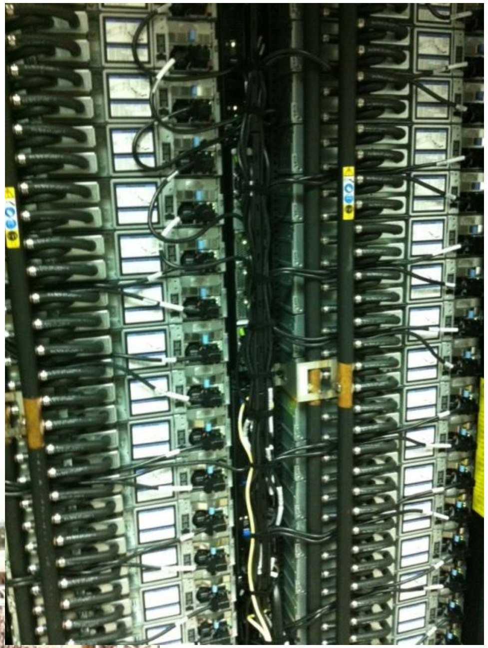


Water inside

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

MHPCC Water Cooling, continued

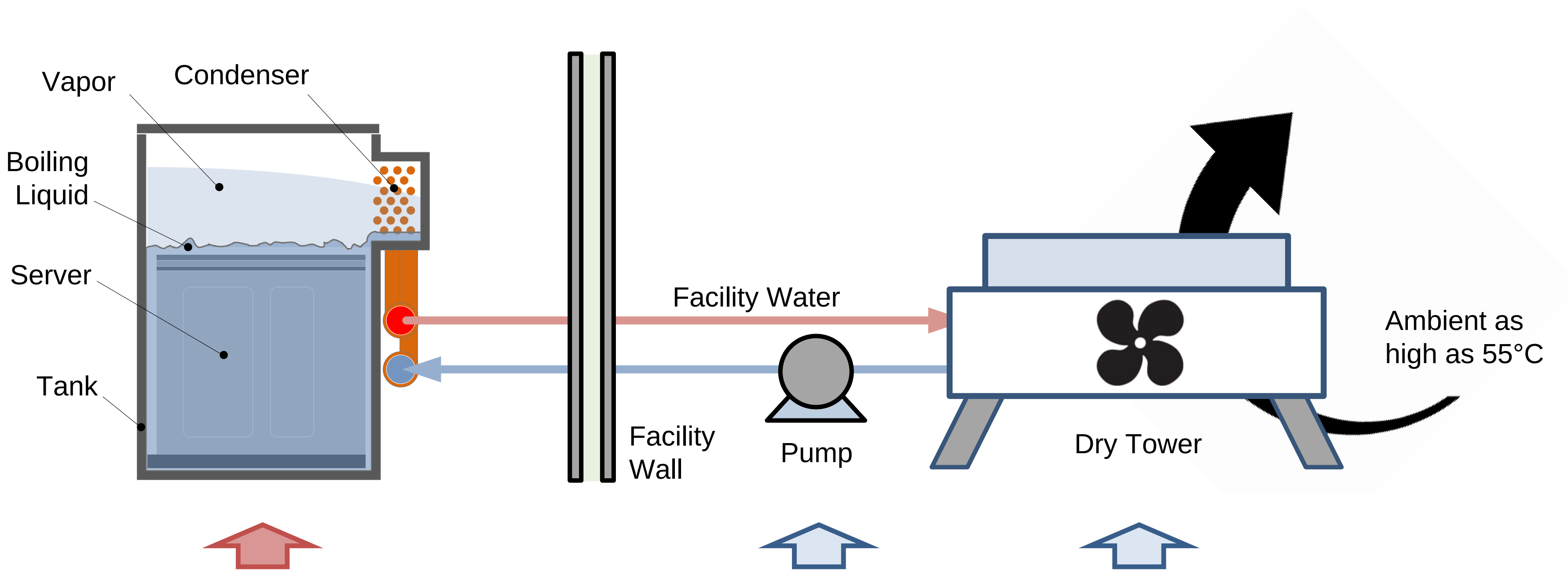
Water piping behind the servers



Cooling water temperature as high as 44°C

Dry Coolers, 10 kW each
compared to 100 kW Chillers

Liquid Immersion Cooling Demonstration



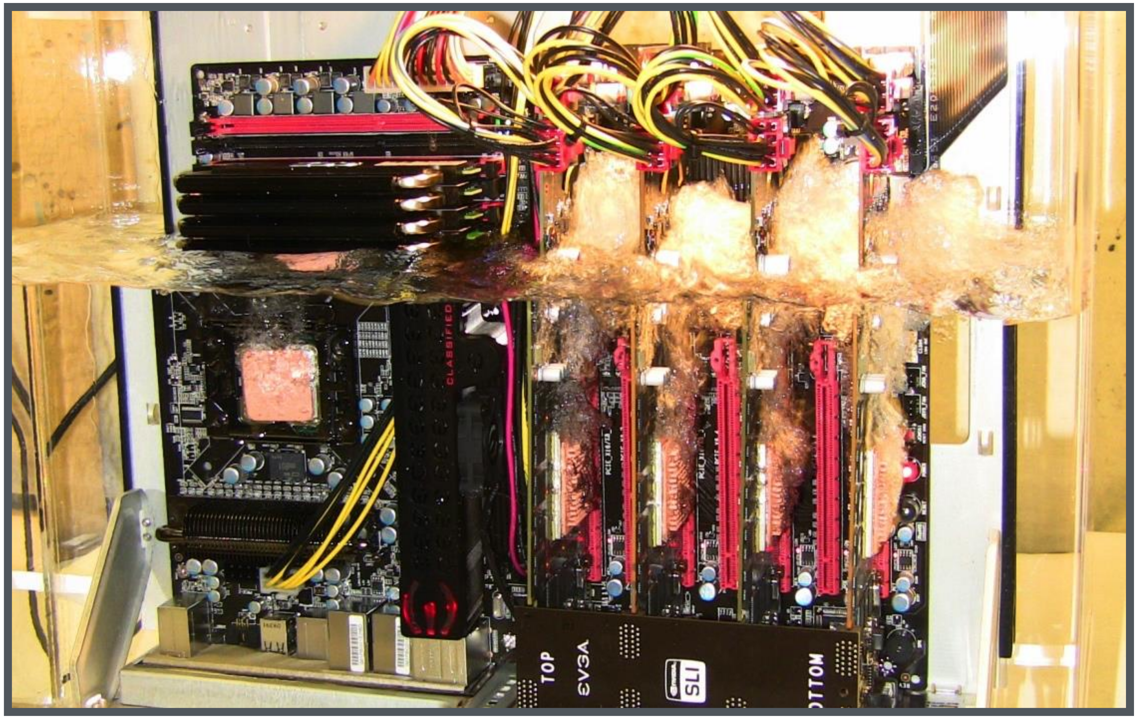
IT Power

Cooling Power = Pump + Fan

No longer requirements:

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

Phase Change of Dielectric Fluid Removes Heat Efficiently

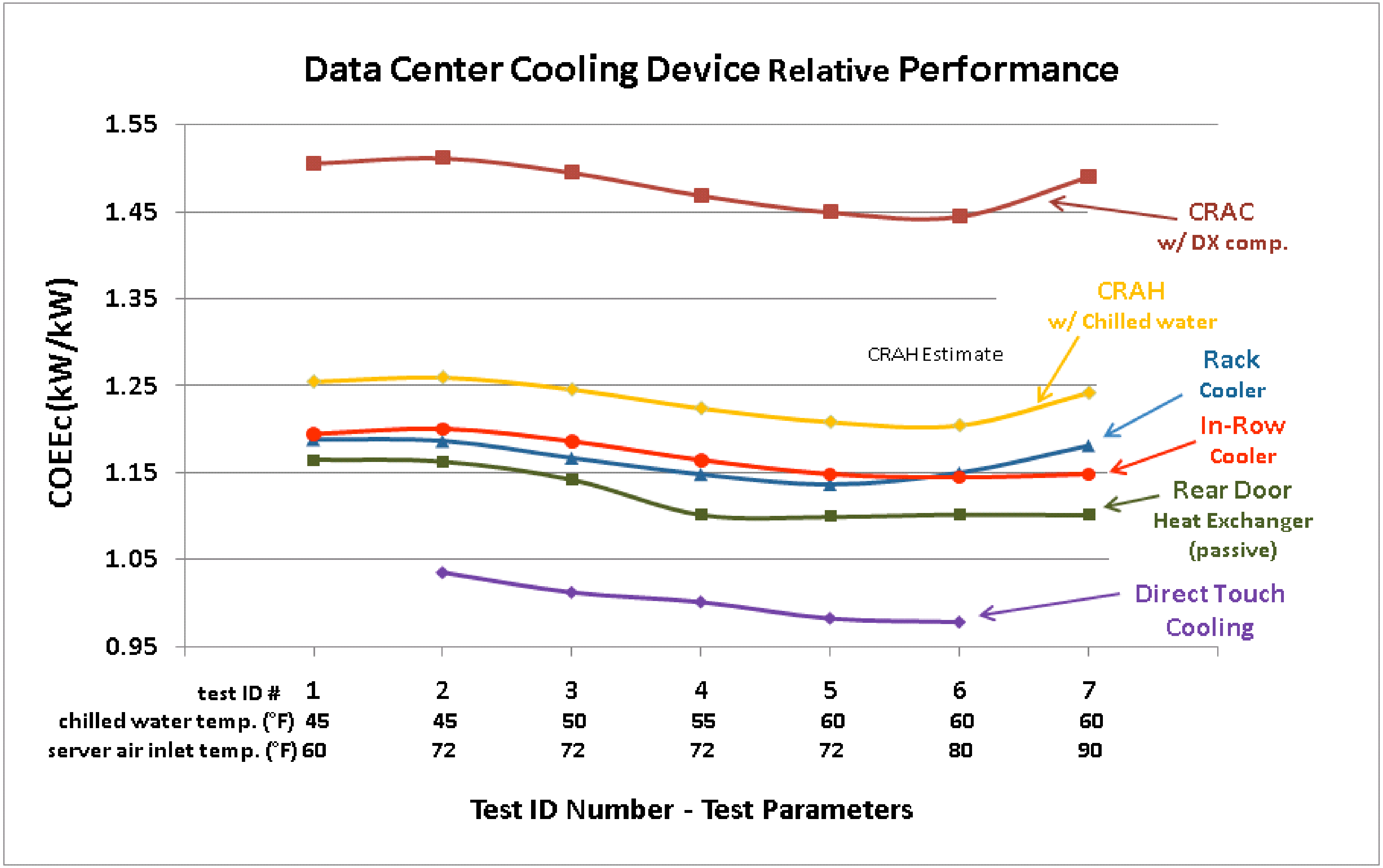


Computer in glass tank

3M Corp.
4 server system

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

“Chill-Off 2” Evaluation of Liquid Cooling Solutions



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

Use “Free” Cooling

Cooling without Compressors:

- Outside Air Economizers
- Water-Side Economizers

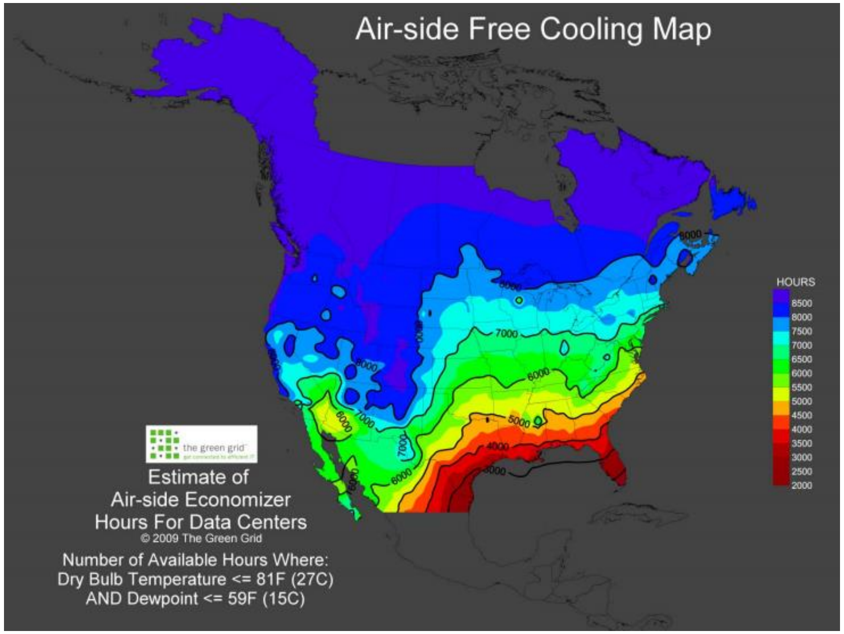
Outside Air (Air-Side) Economizers

Advantages

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

Potential Issues

- Space (retrofit projects difficult)
- Outside dust
  - Not a concern with MERV 13 filters
- Outside gaseous contaminants
  - Not widespread
  - Impacts normally cooled data centers as well
- Shutdown or bypass if smoke or other contaminant is outside data center



http://cooling.thegreengrid.org/namerica/WEB_APP/calc_index.html

The Green Grid Tool

the green grid™
get connected to efficient IT

Free-Cooling Estimated Savings

US/CANADA LOCATION (ZIP CODE): 73034

DEGREES IN: ○ FAHRENHEIT ◉ CELSIUS

ALLOW MIXING OF SUPPLY AND RETURN AIR ☑

ALLOW HUMIDIFICATION ☑

	MAX LIMIT	MIN LIMIT
DRYBULB TEMP THRESHOLD (DEG): ?	27.0	NONE
DEWPOINT TEMP THRESHOLD (DEG): ?	15.0	NONE
REL. HUMIDITY THRESHOLD (%): ?	NONE	
DESIRED CHILLED WATER TEMP (DEG): ?	13.0	
COOLING SYSTEM APPROACH TEMP (DEG): ?	3.0	

CALCULATE

RESET FORM

HELP

DATA CENTER IT POWER (KW): ?	1000			
POWER USAGE EFFECTIVENESS (PUE): ?	1.6			
TOTAL FACILITY POWER (KW): ?	1600			
OVERHEAD POWER (KW): ?	600			
PERCENT OF OVERHEAD POWER FOR COOLING SYSTEM (%): ?	80	%	480	KW
PERCENT OF COOLING SYSTEM POWER FOR CHILLER (%): ?	40	%	192	KW
PERCENT OF COOLING SYSTEM POWER FOR TOWER (%): ?	40	%	192	KW

HOURS MEETING CRITERIA FOR FREE-AIR COOLING:

ESTIMATED SAVINGS USING FREE-AIR COOLING:

HOURS MEETING CRITERIA FOR WATER SIDE ECONOMIZER:

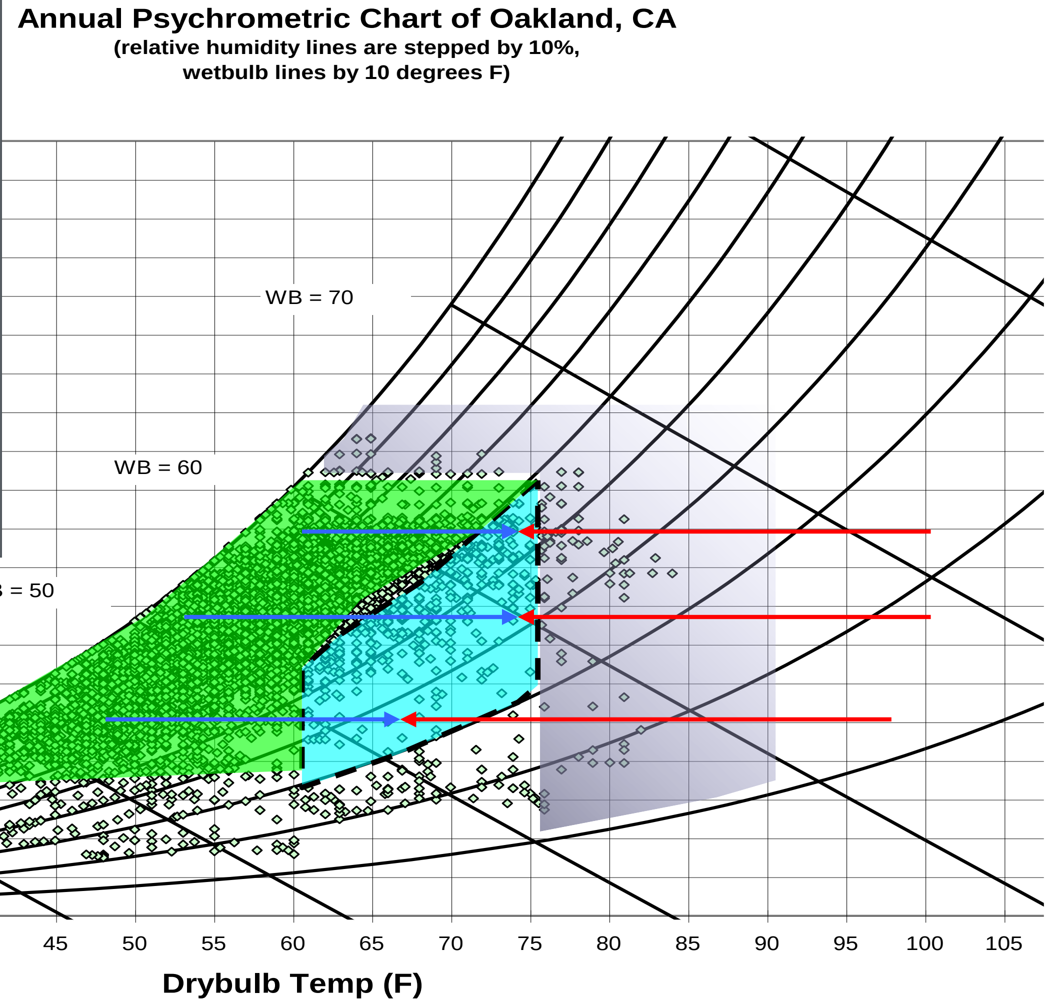
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

LBNL's Computational Research and Theory (CRT) Facility

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

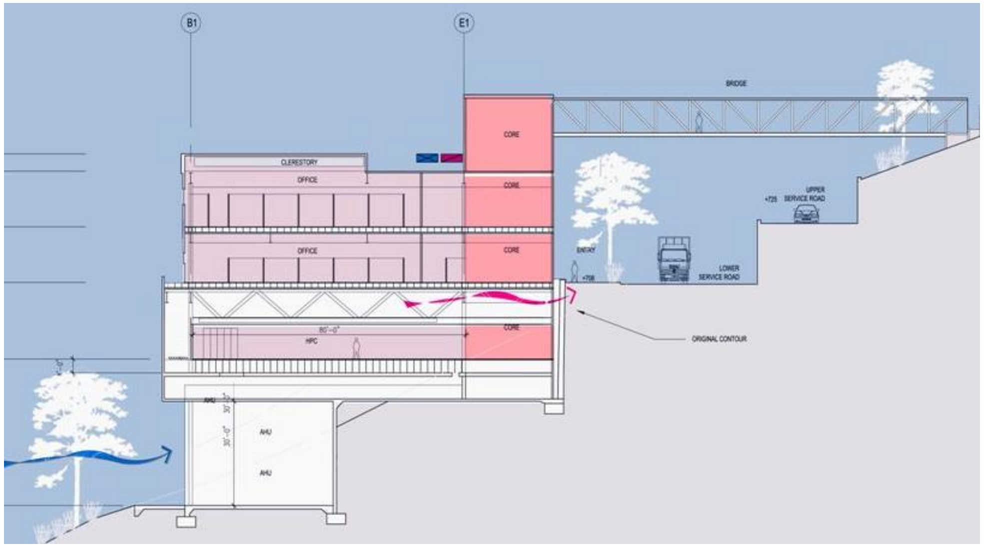
Free Cooling: Outside Air-Based

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 with evaporative cooling.
4. Hot and humid hours will enter the "allowable" range or require compressor air conditioning.



LBNL Computational Research and Theory (CRT) System Design Approach

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



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

Water-Side Economizers

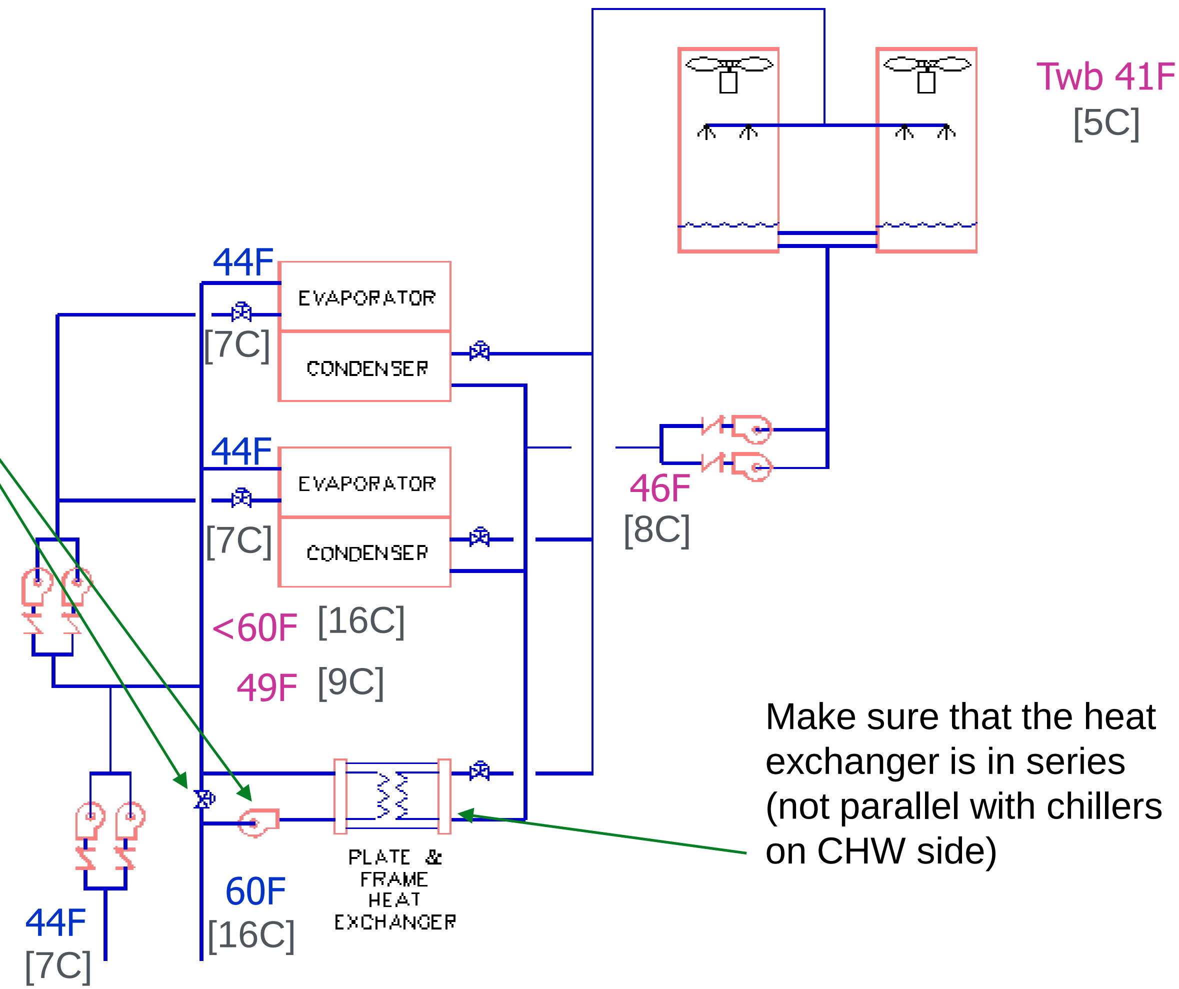
- Easier retrofit
- Added reliability (backup in case of chiller failure)
- No contamination issues
- Put in series with chiller
- Uses tower or dry cooler

No or minimum compressor cooling

Cooling tower and HX = Water-side Economizer

Integrated Water-Side Economizer

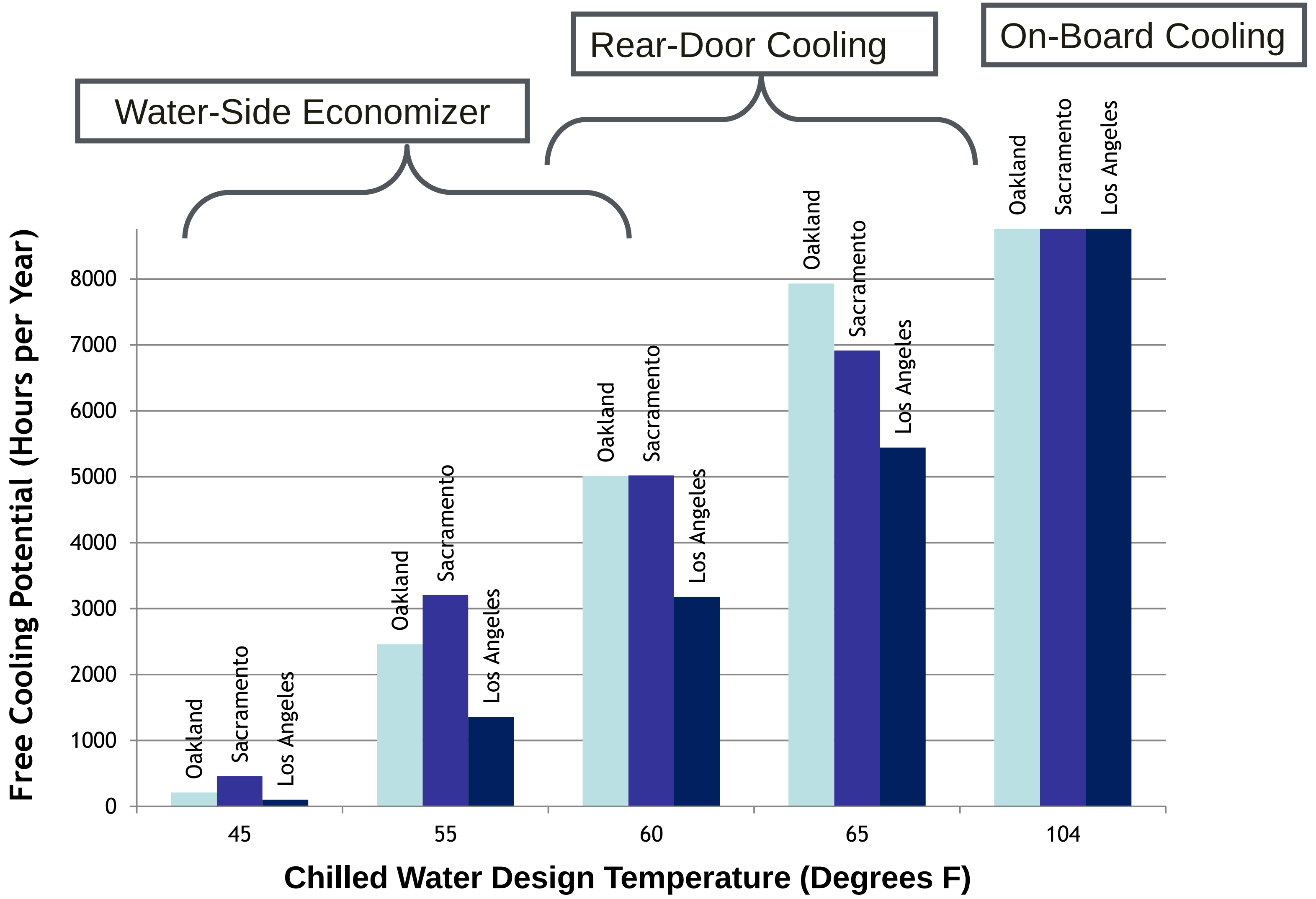
You can use either a control valve or pump



Make sure that the heat exchanger is in series (not parallel with chillers on CHW side)

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

Potential for Tower Cooling



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

LBNL 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

Re-Use of Waste Heat

- Heat from a data center can be used for:
  - Heating adjacent offices directly
  - Preheating make-up air (e.g., “run around coil” for adjacent laboratories)
- Use a heat pump to elevate temperature
  - Waste heat from LBNL ALS servers captured with rear door coolers feed a heat pump that provides hot water for reheat coils
- Warm-water cooled computers are used to heat:
  - Greenhouses, swimming pools, and district heating systems in Europe

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

Improve Humidity Control

- Eliminate inadvertent dehumidification
  - Computer heat load is sensible only
- Use ASHRAE allowable RH and temperature ranges
  - Many manufacturers allow even wider ranges
- Defeat equipment “fighting”
  - Coordinate controls (central)
  - Disconnect and only control humidity of makeup air, or
  - Control with one CRAC/CRAH unit
- Entirely disconnect (many have)

High-Humidity Limit Issues

- Contaminants (e.g., hydroscopic salts)
- Gaseous contamination
  - More study is needed in this area; however, few locations have such condition
- Particulates
  - Normal building filtration is effective in removing “enough” particulates

Low-Humidity Limit Issues

Electrostatic Discharge (ESD)

- 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.

Not to Worry

Server Performance Specifications Generally Exceed ASHRAE Ranges.

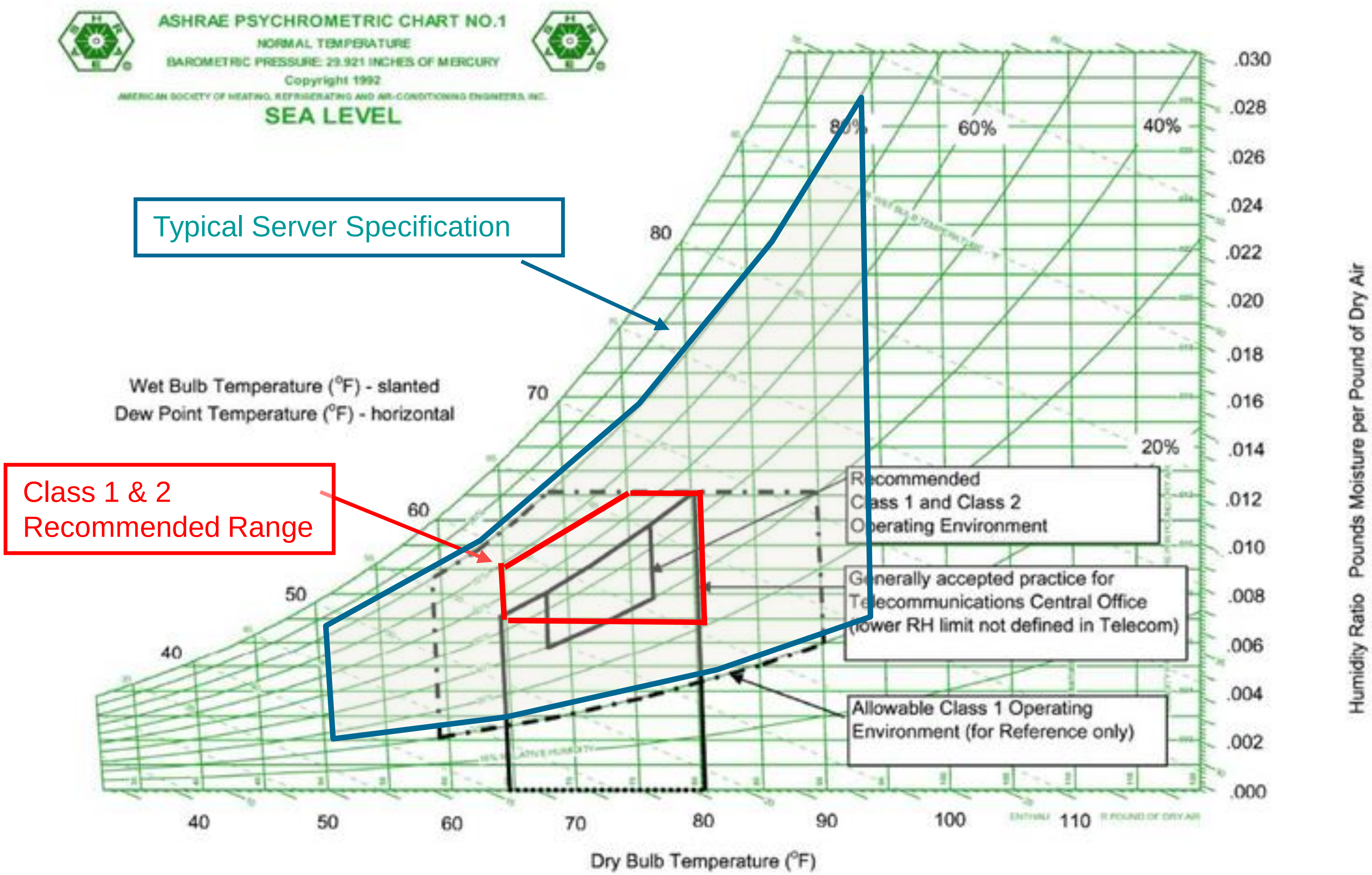


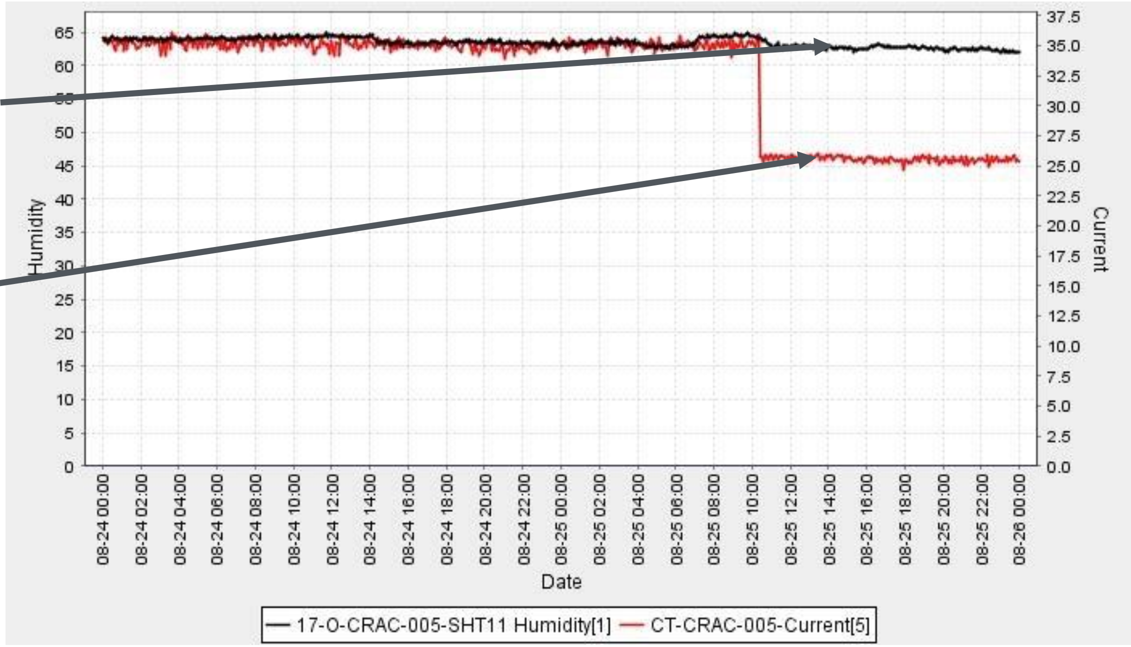
Chart courtesy of ASHRAE

The Cost of Unnecessary Humidification

	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC010	77.5	32.8	46.1	68	45.0	45.9	Cooling
AC011	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%



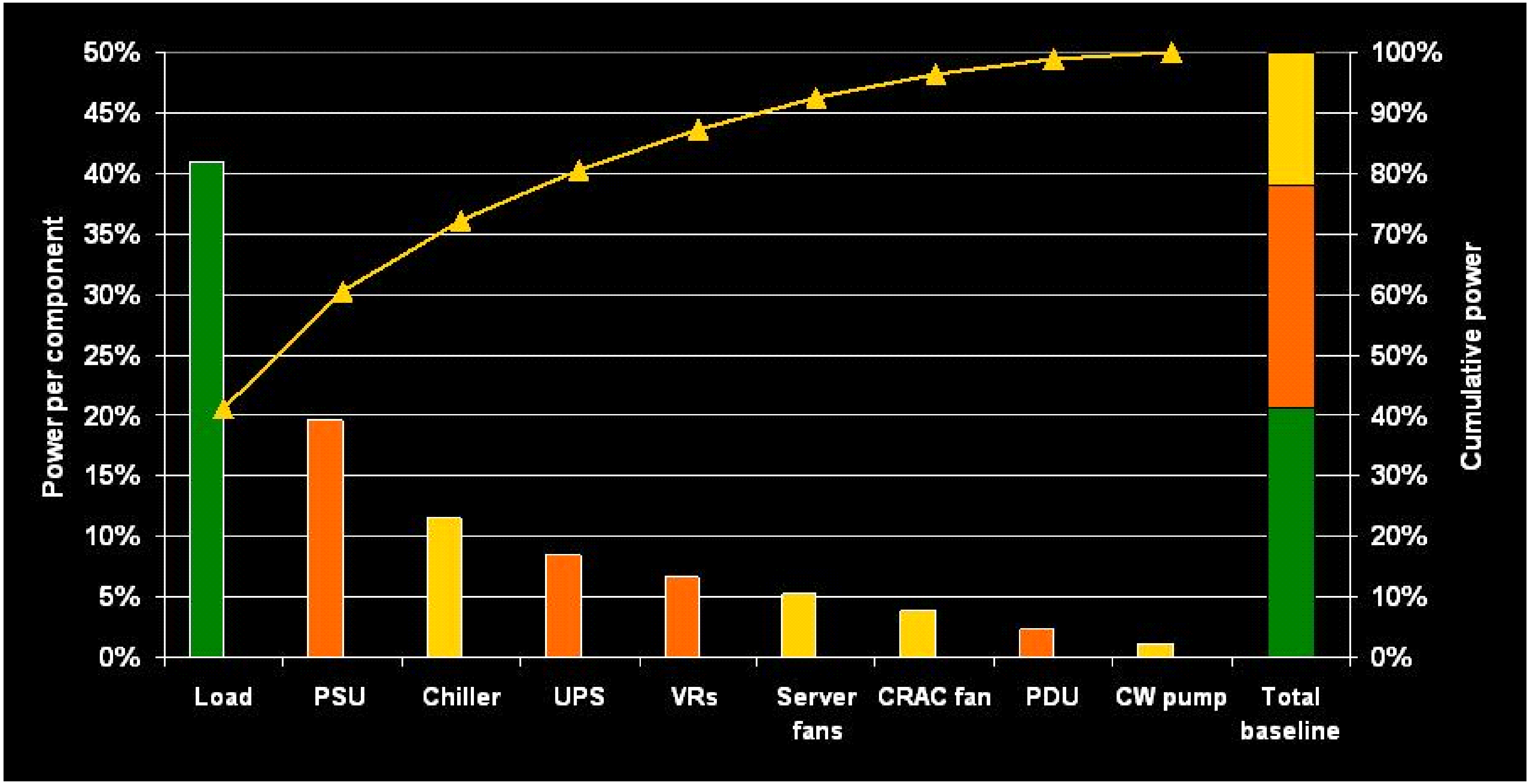
Cooling Review

- 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

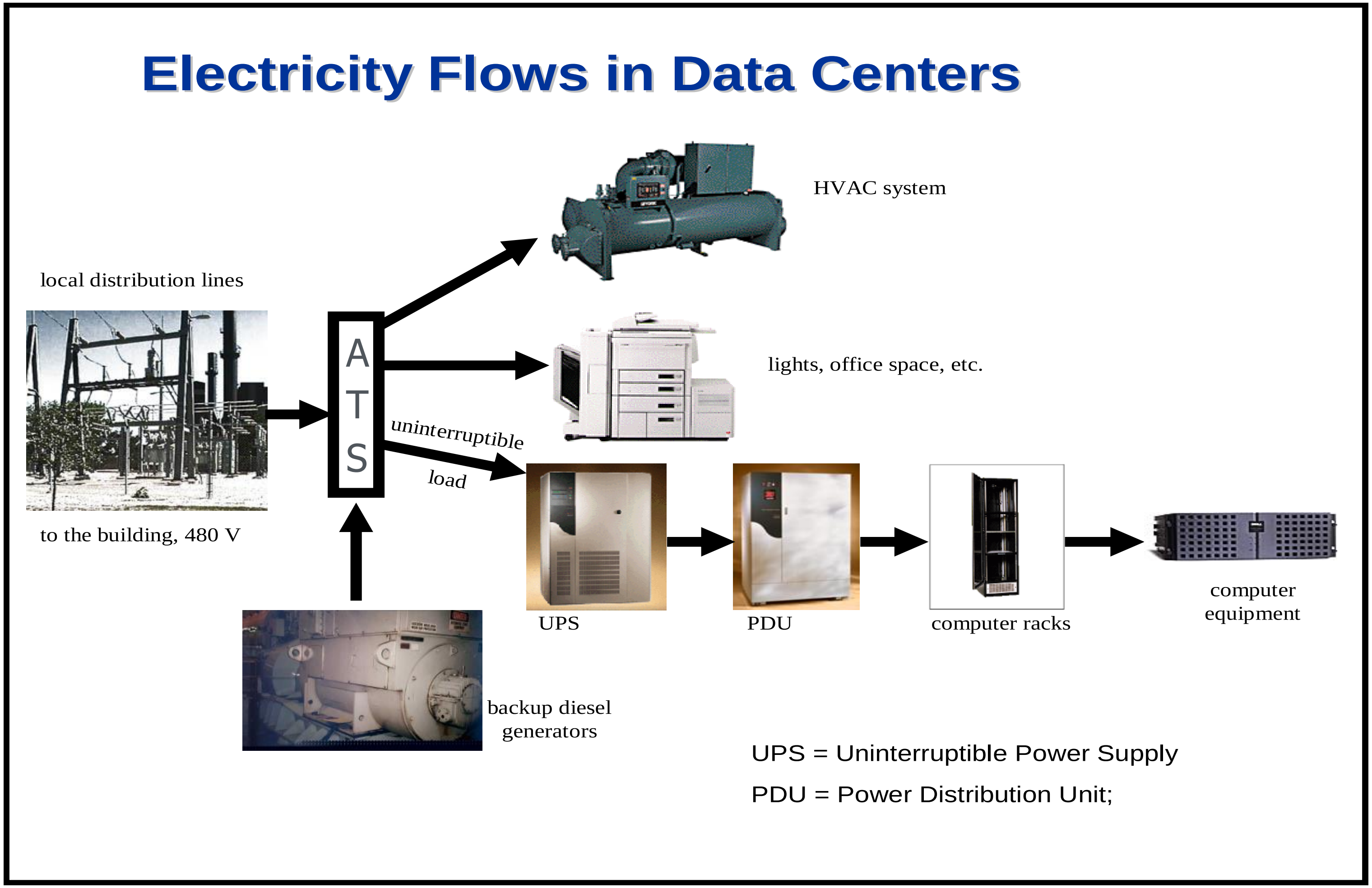
Electrical Systems

Electrical System End Use – Orange Bars



Courtesy of Michael Patterson, Intel Corporation

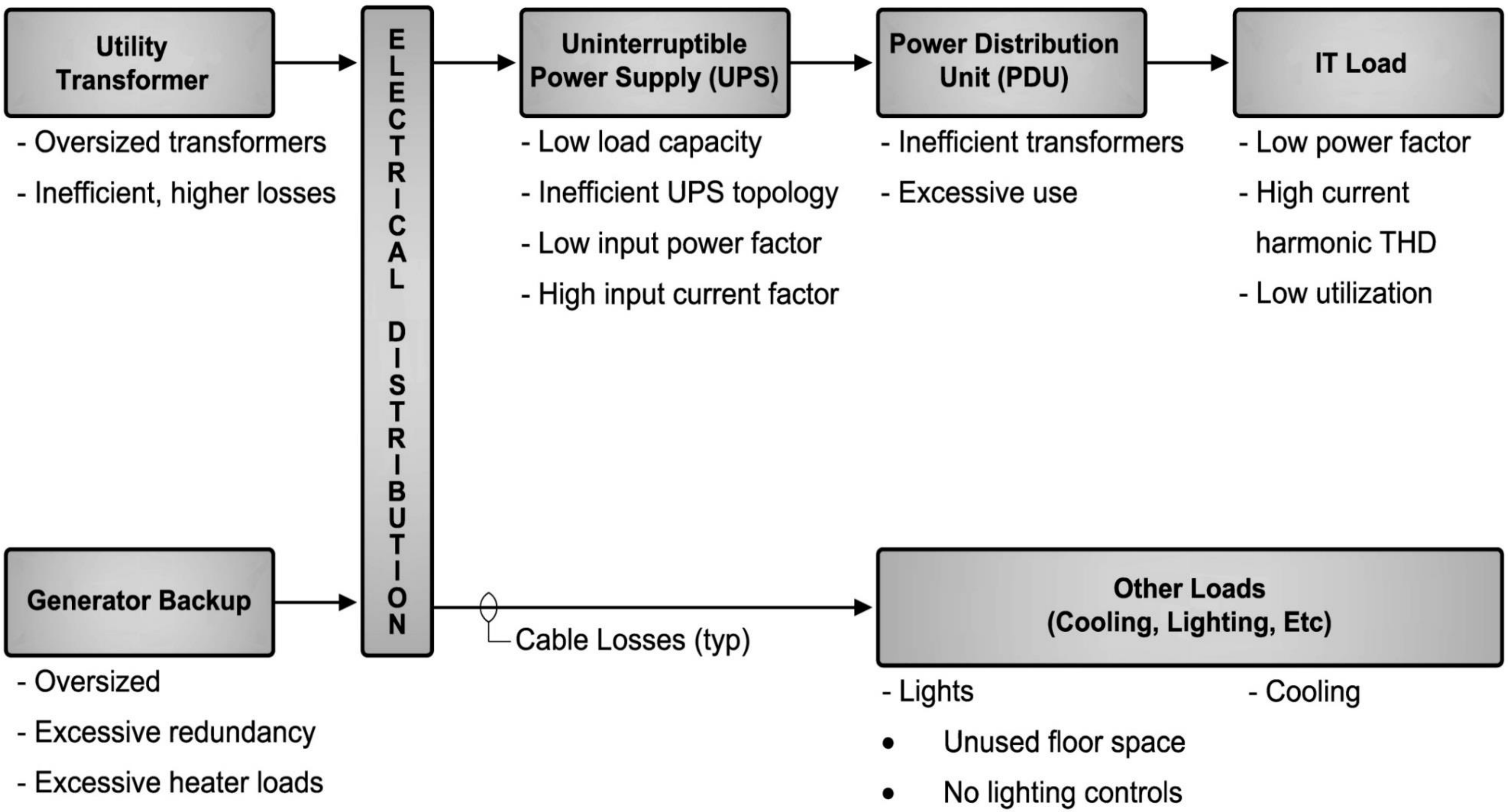
Power Chain Conversions Losses



Electrical Distribution

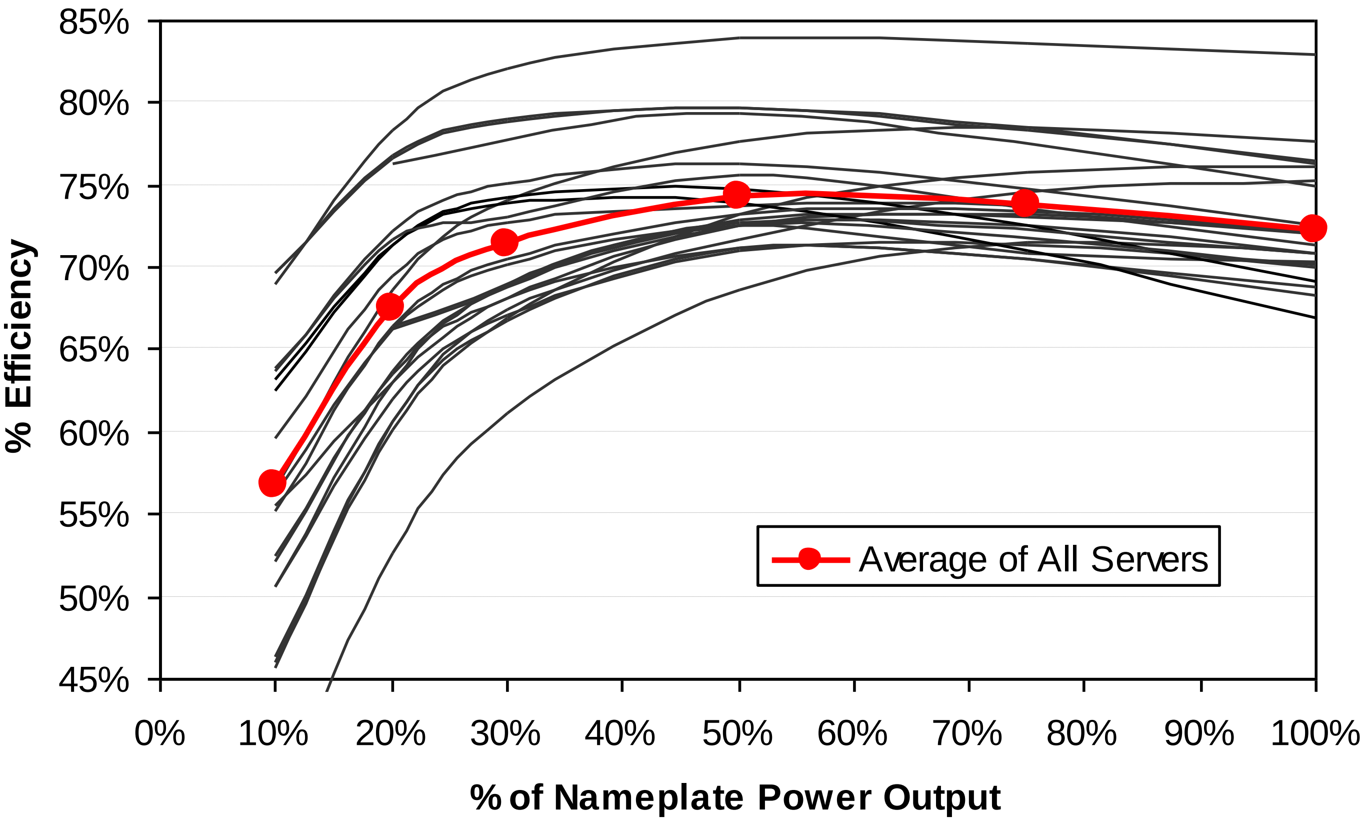
- Every power conversion (AC-DC, DC-AC, AC-AC) loses some energy and creates heat
- Efficiency decreases when systems are lightly loaded
- Distributing higher voltage is more efficient and can save capital cost (conductor size is smaller)
- Power supply, uninterruptible power supply (UPS), transformer,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

Electrical System Points of Losses



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

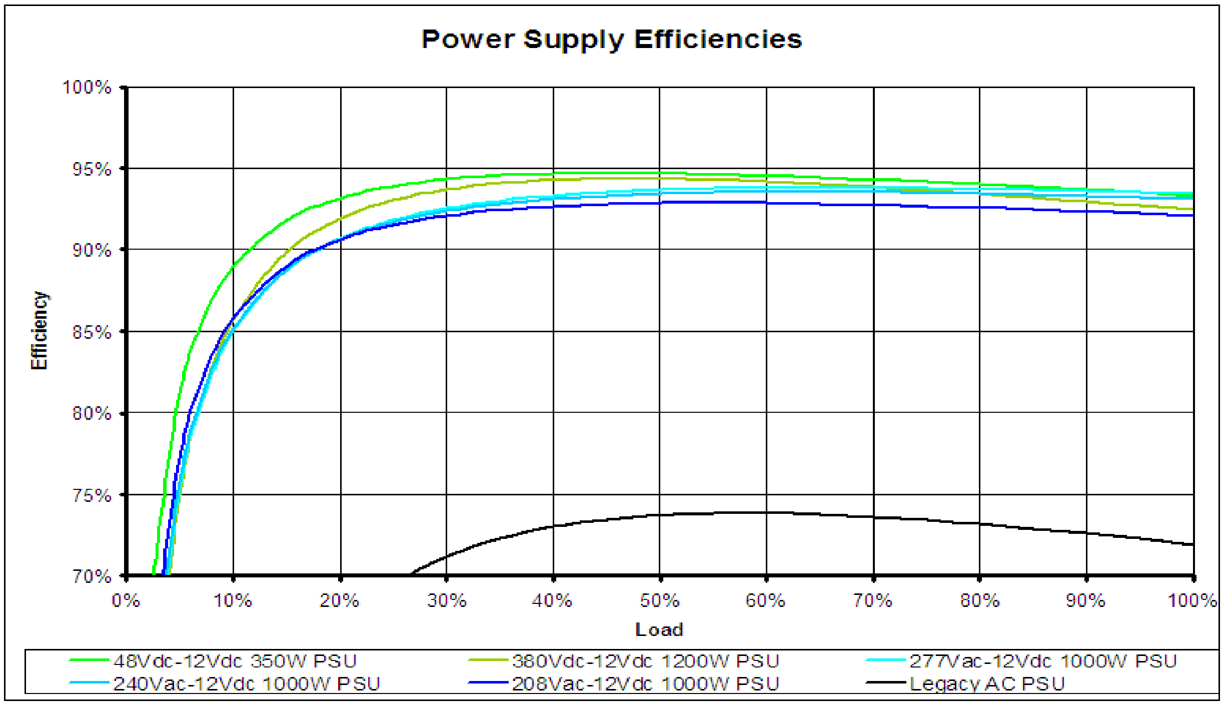
Select/Configure Power Supplies for Greater Efficiency



Source: LBNL and EPRI study

Use Efficient Power Supplies

- 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

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

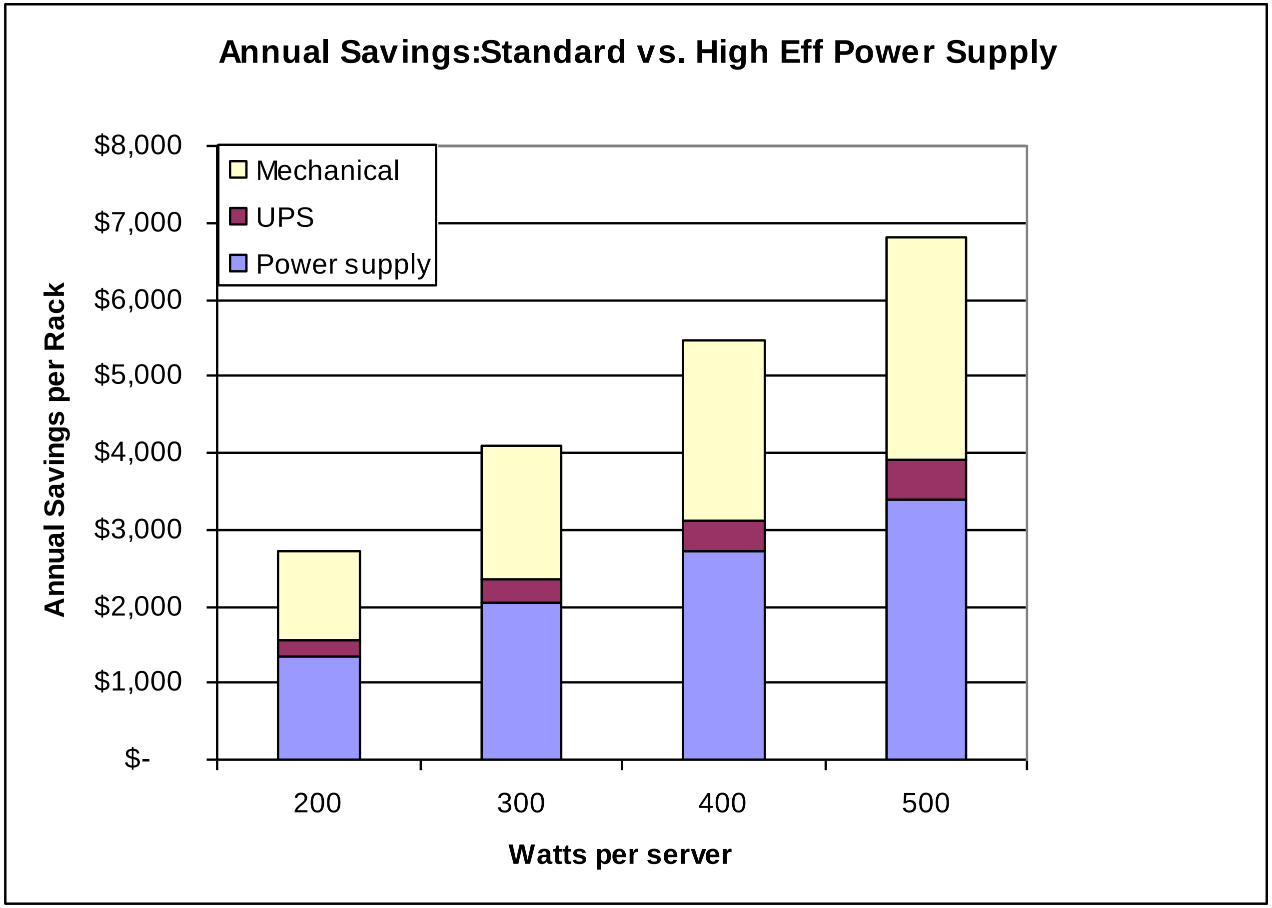
Use Efficient Power Supplies

80 PLUS Certification Levels

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

Use Efficient Power Supplies

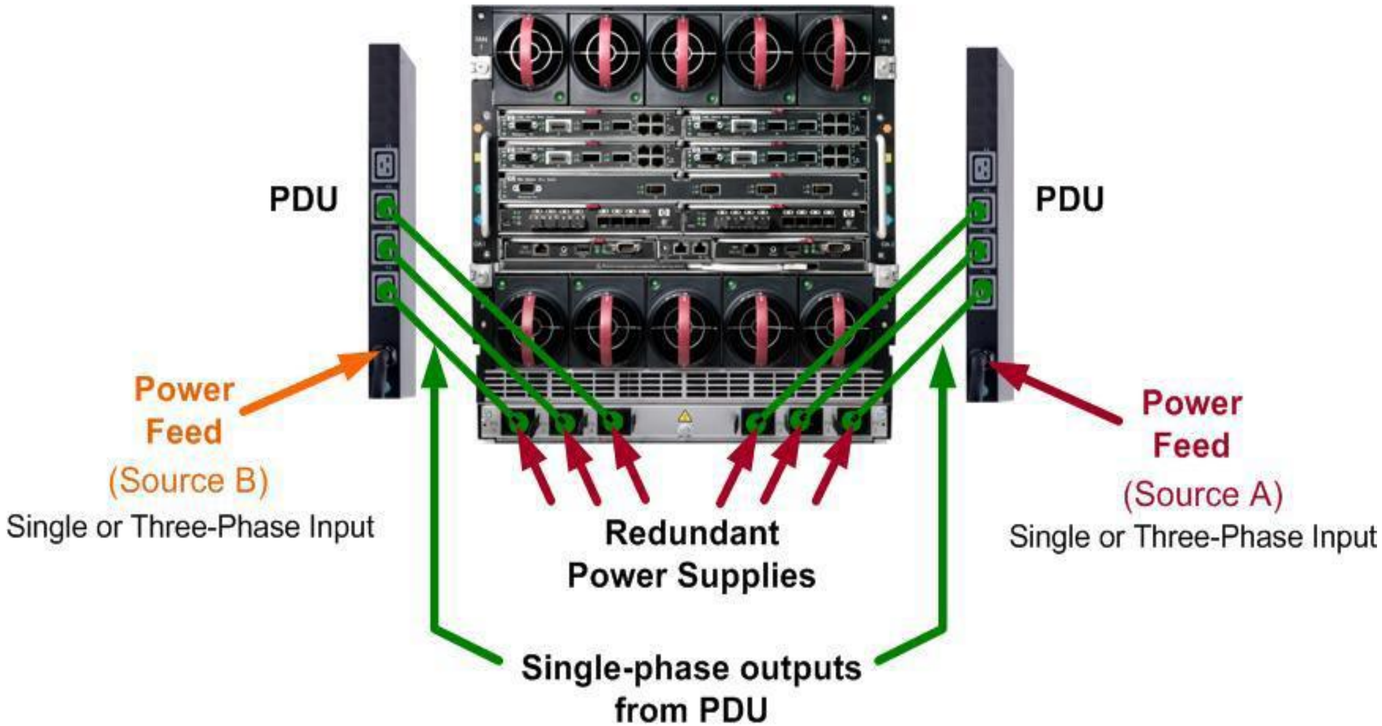
Power supply savings add up



Source: Integral Group

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

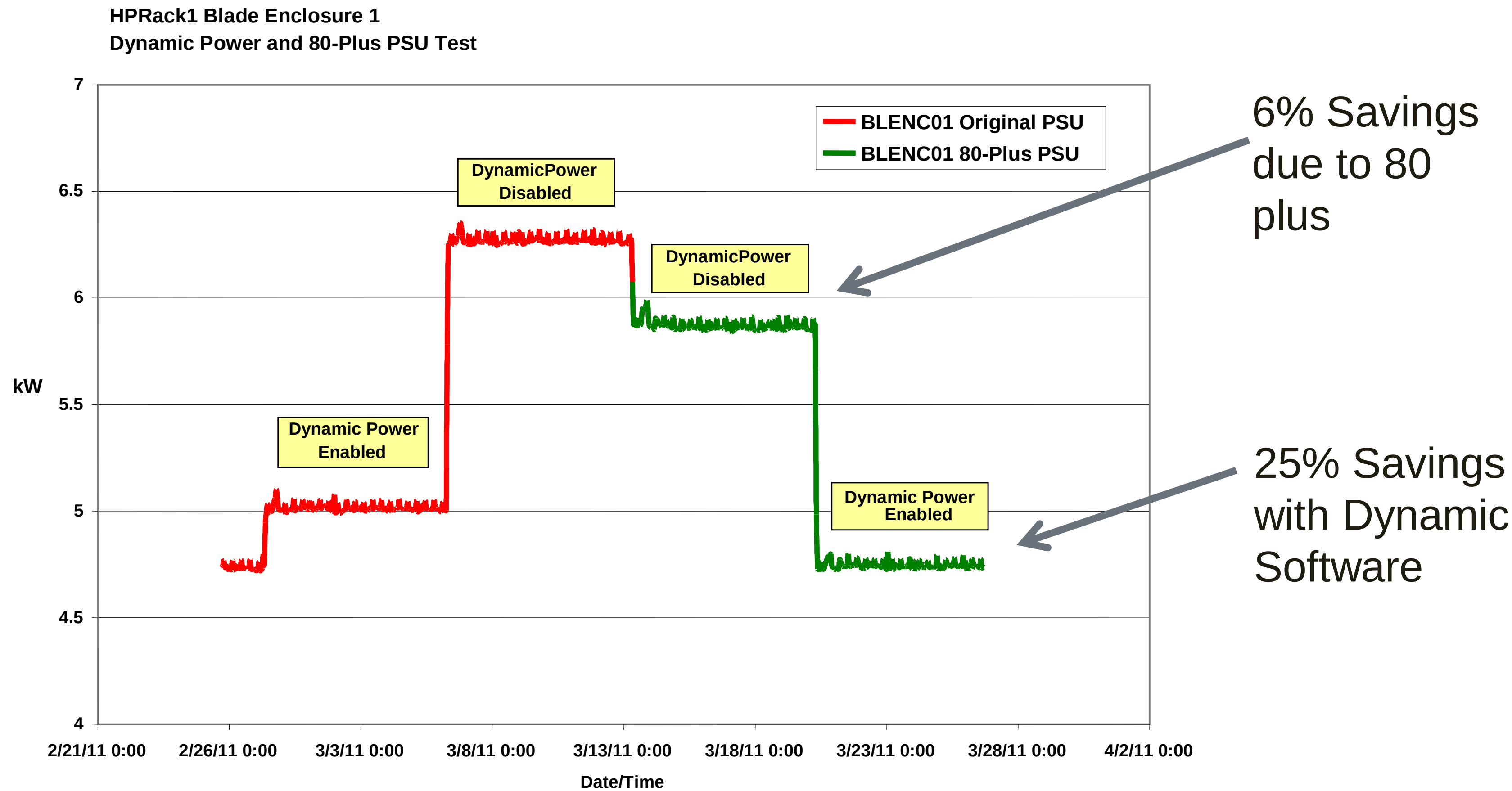
The 80 Plus Program Drives Efficiency Improvements



- An Electric Power Research Institute (EPRI) case study illustrated the savings

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

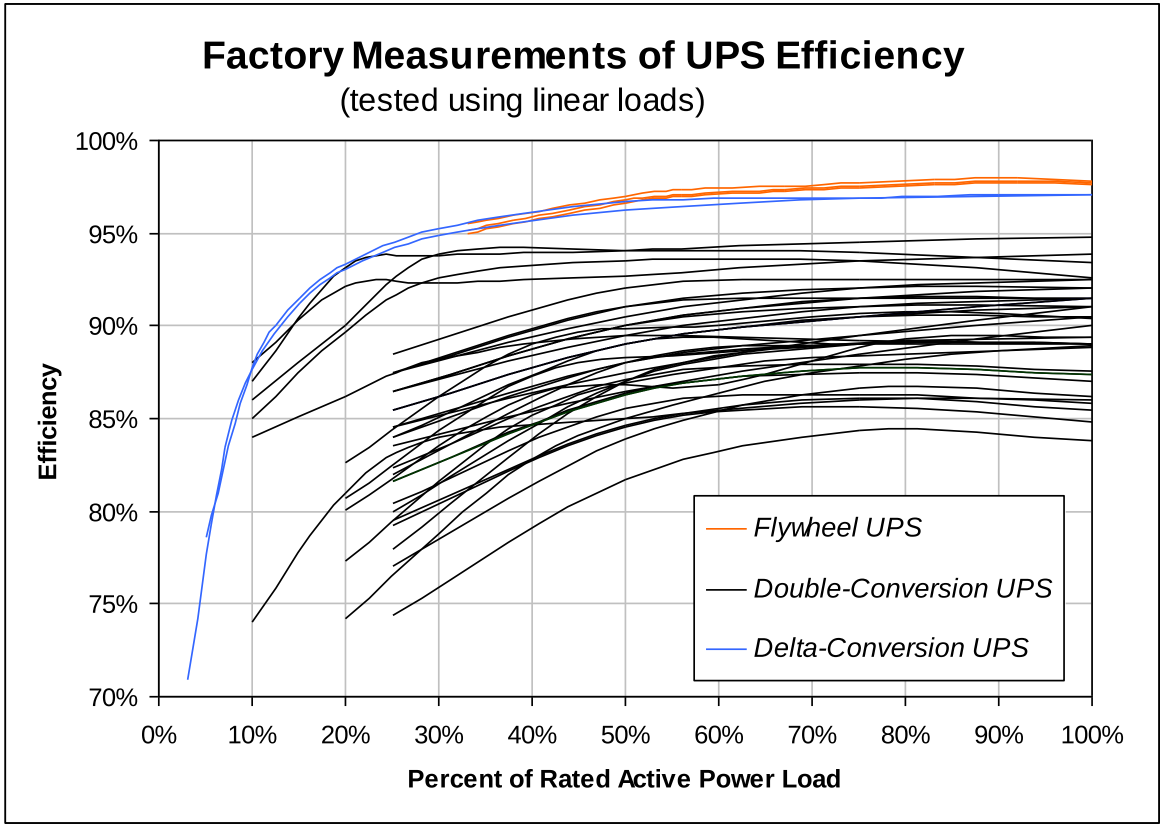
Upgraded Power Supplies and Controls



- Dynamic power software turns off redundant power supplies when not needed

UPS, Transformer, and PDU Efficiency

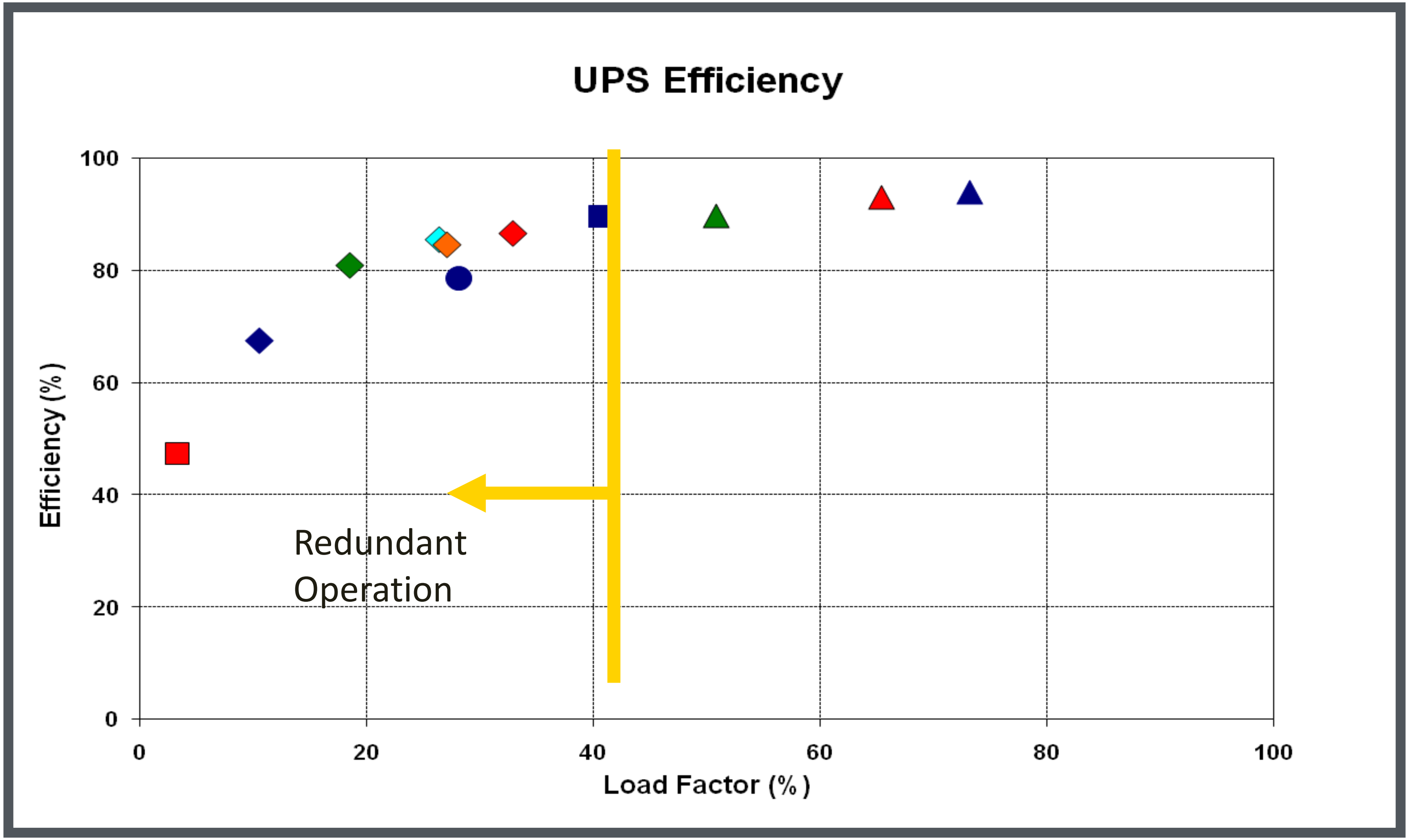
- Efficiencies vary with system design, equipment, and load
- Redundancies impact efficiency



Source: LBNL and EPRI study

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

Measured UPS Efficiency



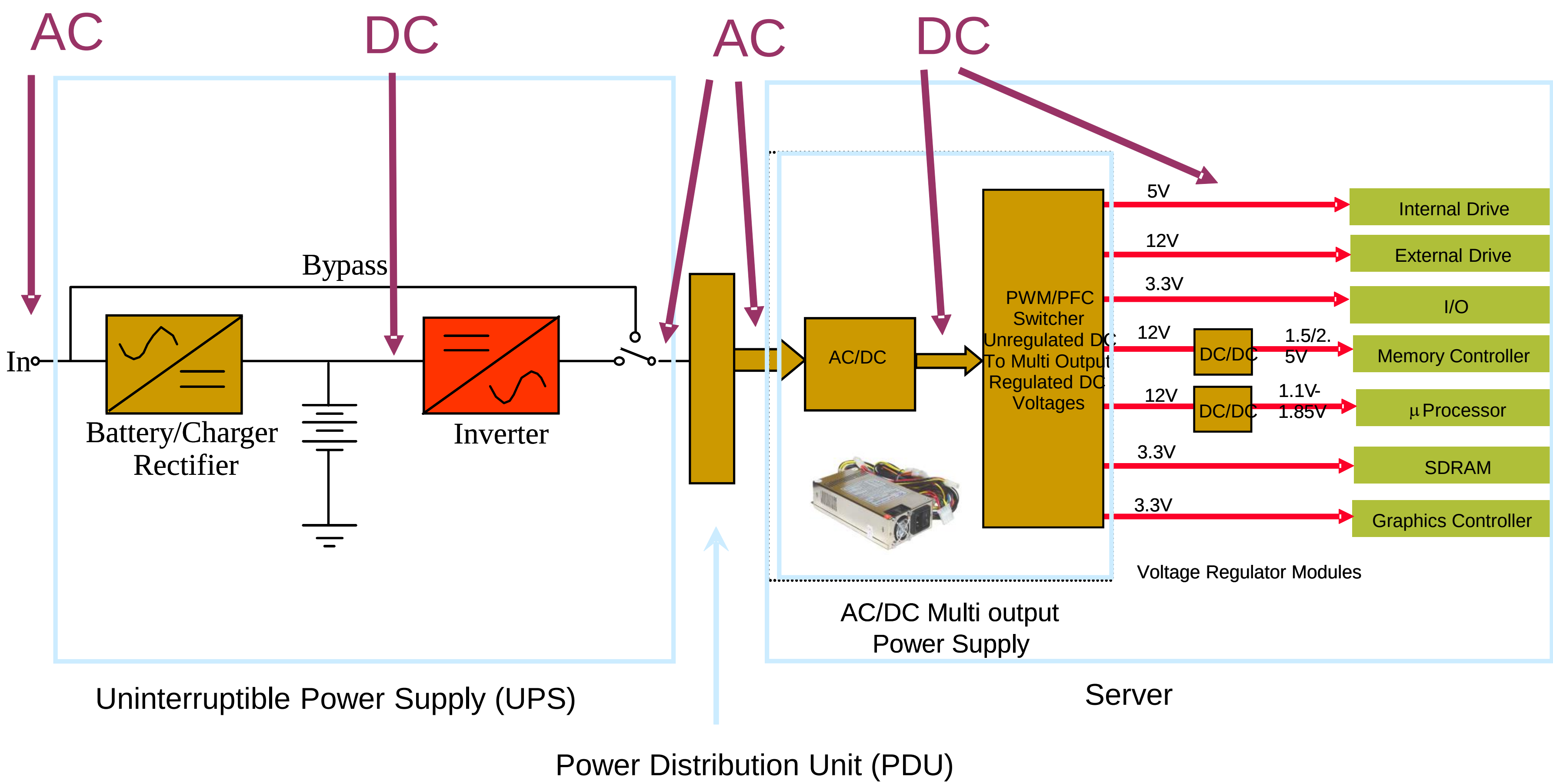
Source: LBNL Benchmarking study

Understand What Redundancy Costs

- Different strategies have different energy penalties (e.g., 2N vs. N+1)
- Redundancy in electrical distribution puts you down the efficiency curve
- Does everything need the same level?
- Establish redundancy in the network rather than in the data center

From Utility Power to the Chip

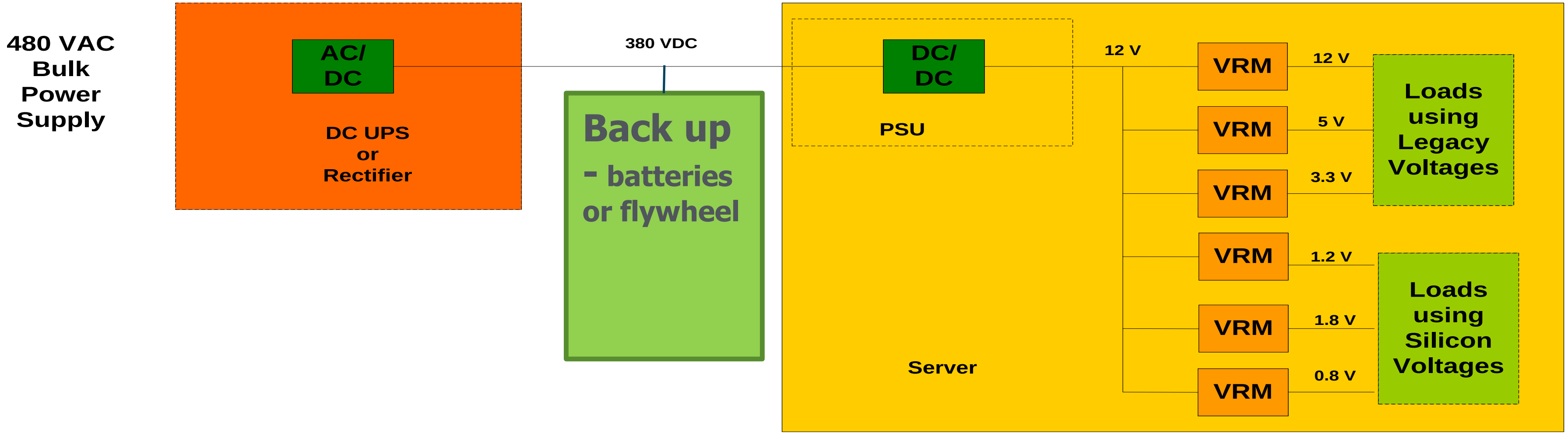
Multiple Electrical Power Conversions:



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

Emerging Technology: DC Distribution

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



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

Standby Generation Loss

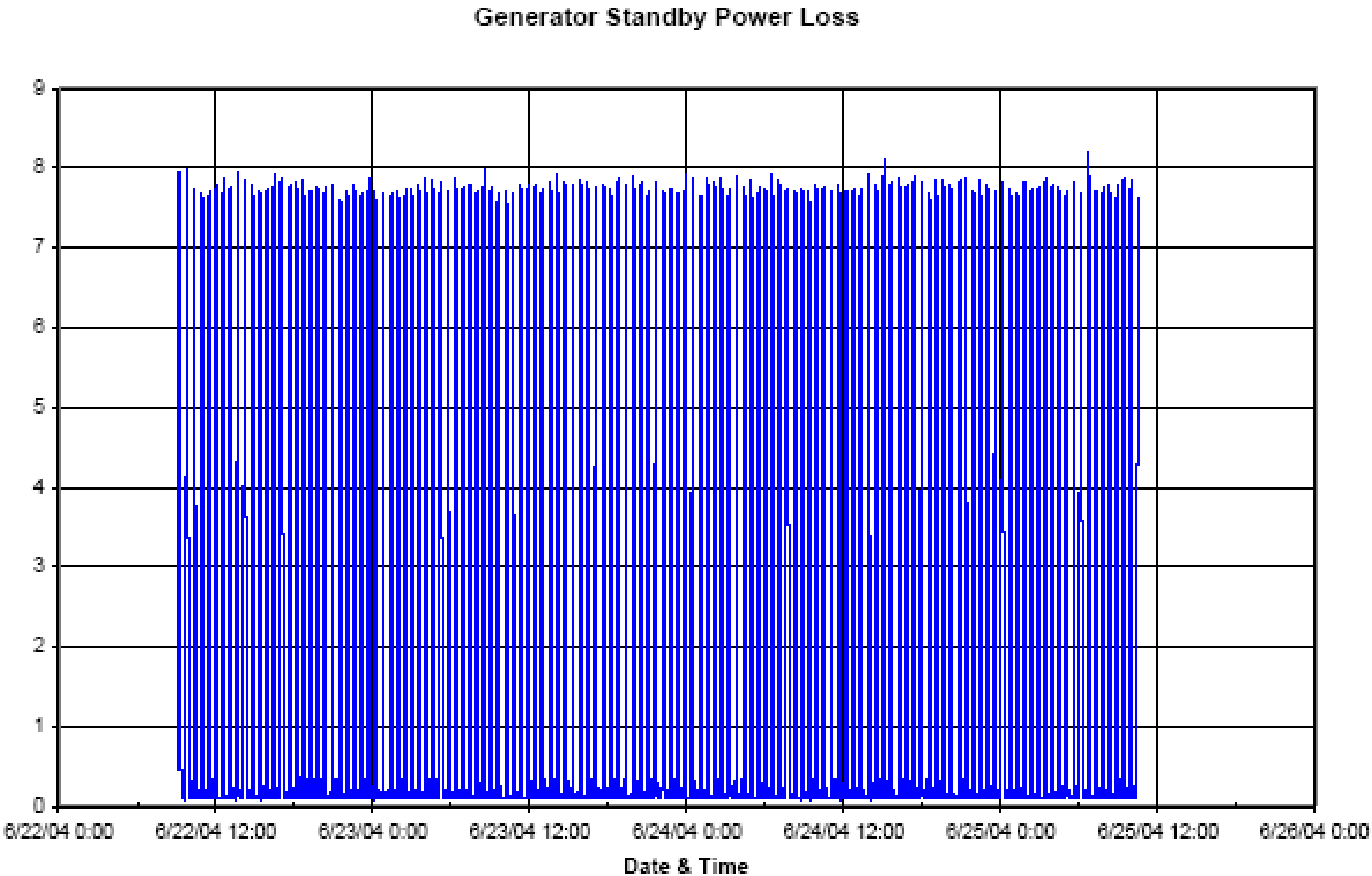
- Standby generators typically use more energy than they will ever generate

- Several Load Sources
  - Heaters
  - Battery chargers
  - Transfer switches
  - Fuel management systems

- Reduce or eliminate heating, batteries, and chargers. Check with the manufacturer for temperature and control requirements.

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

Standby Generator Heater



Source: LBNL

Data Center Lighting

- Lights are on and nobody's home
  - Switch off lights in unused/unoccupied areas or rooms (UPS, Battery, SwitchGear, 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

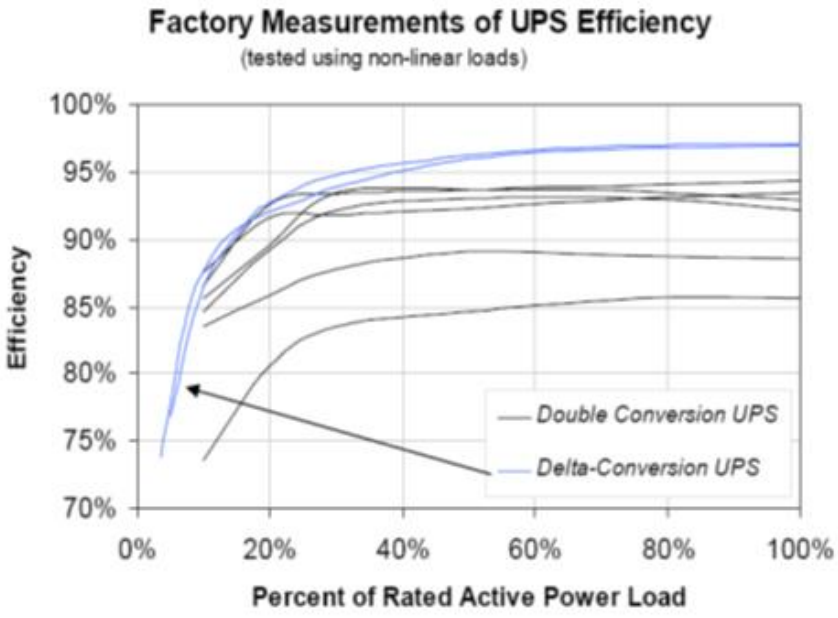
Motors and Drives

- Since most cooling system equipment operates continuously, premium efficiency motors should be specified everywhere

- Variable speed drives should be used for:
  - Chillers
  - Pumps
  - Air handler fans
  - Cooling tower fans

Improving the LBNL Power Chain

- Increase distribution voltage
  - NERSC going to 480 volts to the racks
- Improve equipment power supplies
  - Avoid redundancy unless needed
- Improve UPS
  - LBNL uses minimal UPS
  - Selected to minimize losses



Source: LBNL and EPRI study

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

Electrical Systems Review

- Choose highly efficient components and configurations
- Reduce power conversion (AC-DC, DC-AC, AC-AC, and DC-DC)
- Consider the minimum redundancy required, as efficiency decreases when systems are lightly loaded
- Redundancy in the network not the data center

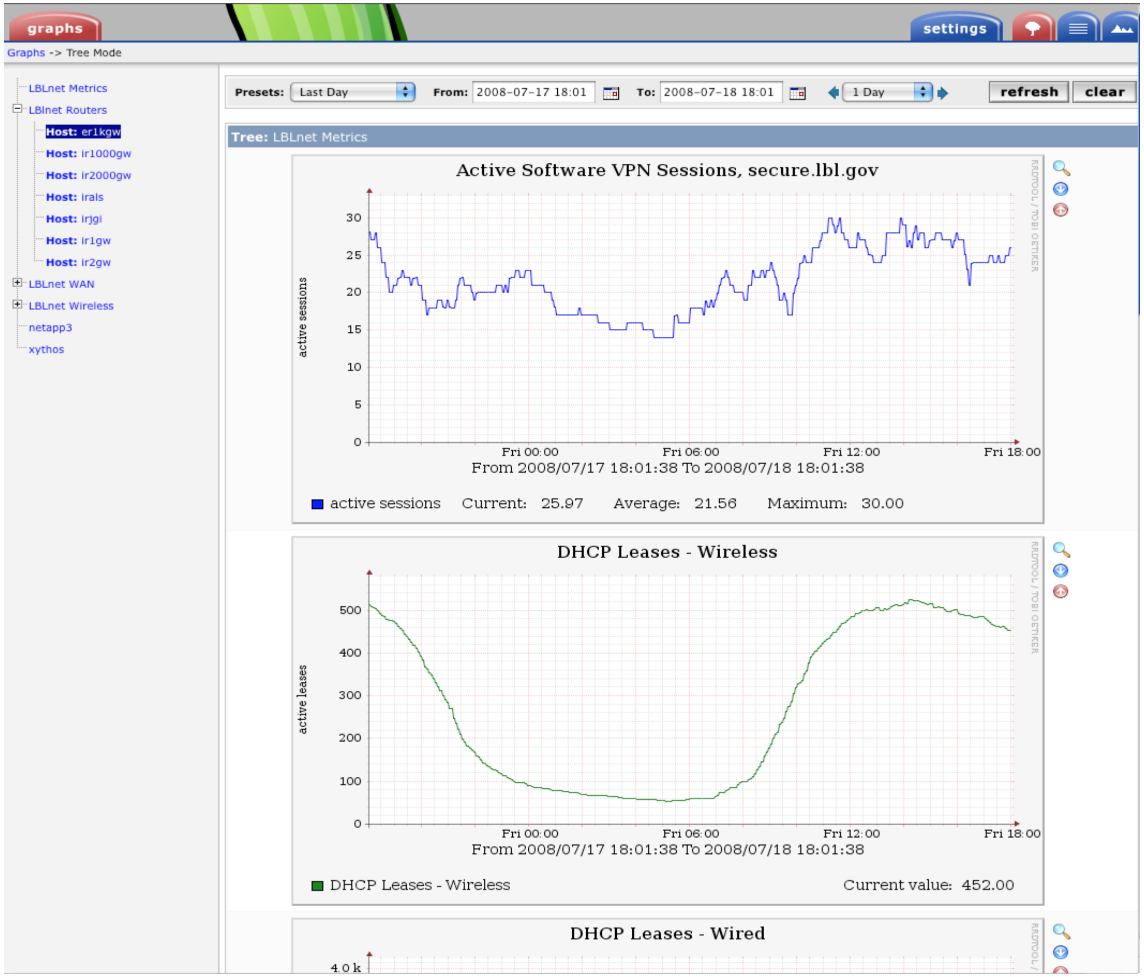
Questions

Using IT to Manage IT

Application of IT in Data Centers for Energy Efficiency

The Importance of Converting Data to Information

- 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
- Operators can't manage what they don't measure.



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

Using IT to Save Energy in IT

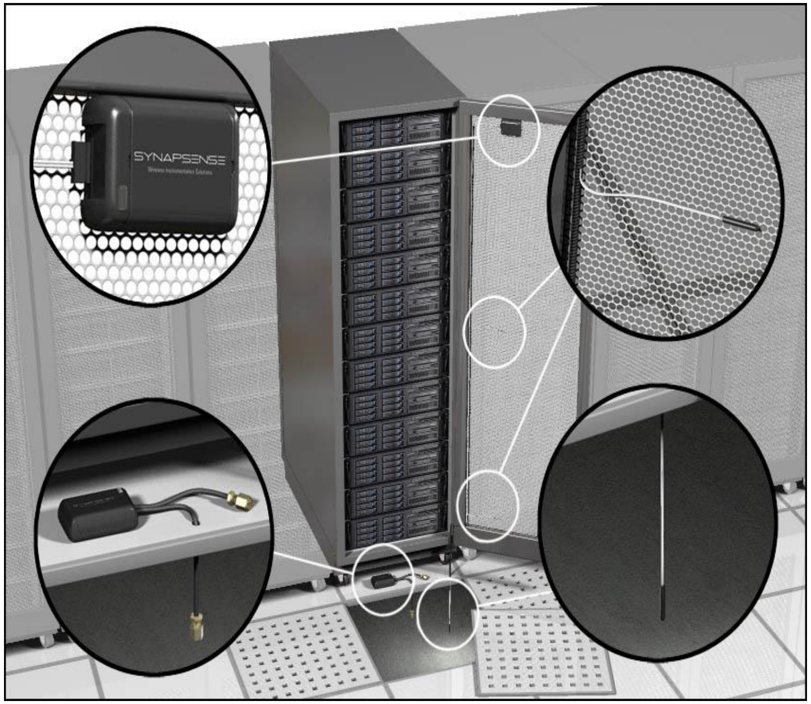
- Goals for an Energy Information System:
  - Provide the same level of monitoring and visualization of the physical space that exists for monitoring the IT environment
  - Measure and track performance
  - Spot problems before they result in high energy cost or down time

- May be part of a broader Data Center Infrastructure Management (DCIM) system

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

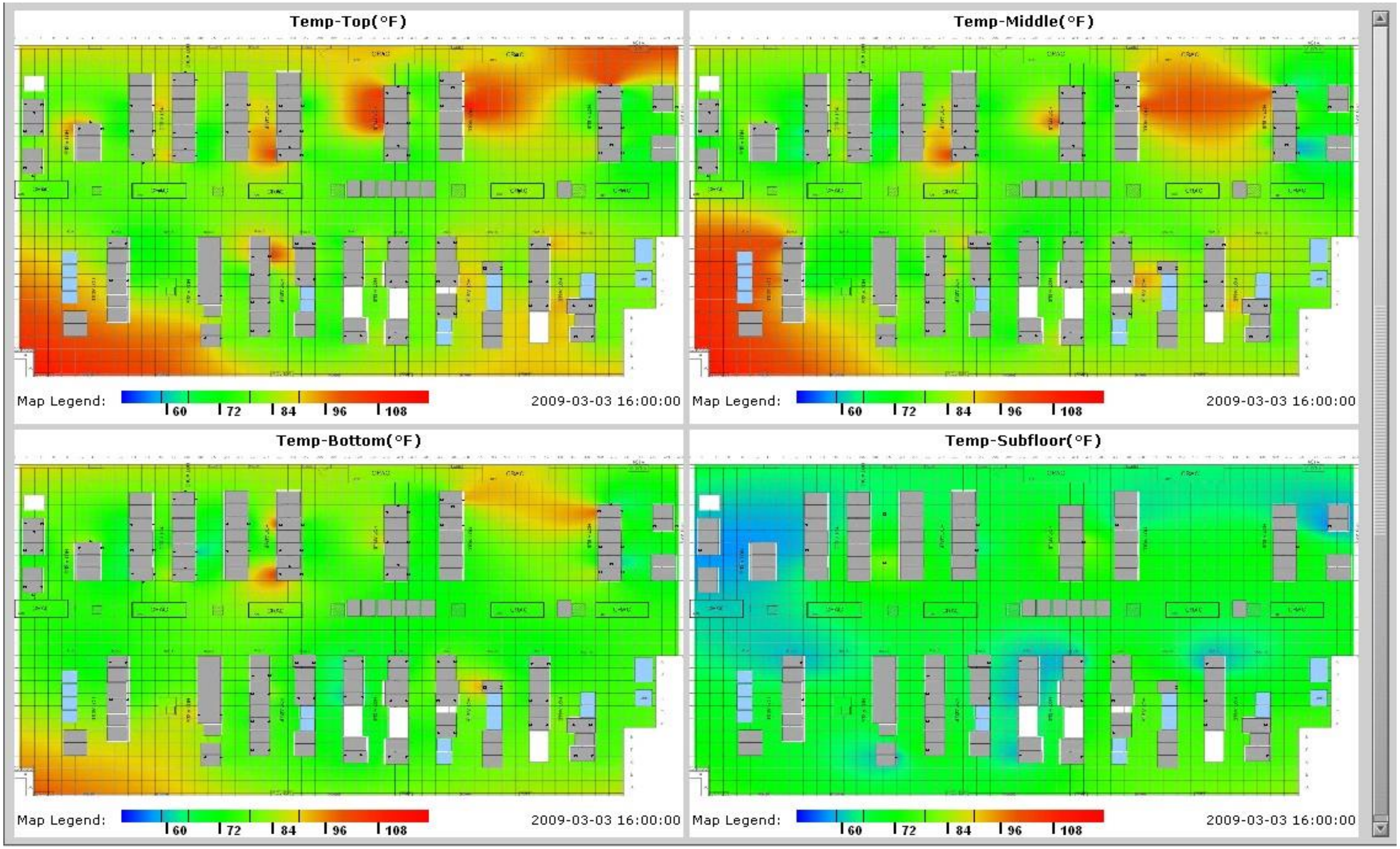
LBNL Wireless Sensor Installation

- 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



Source: SynapSense

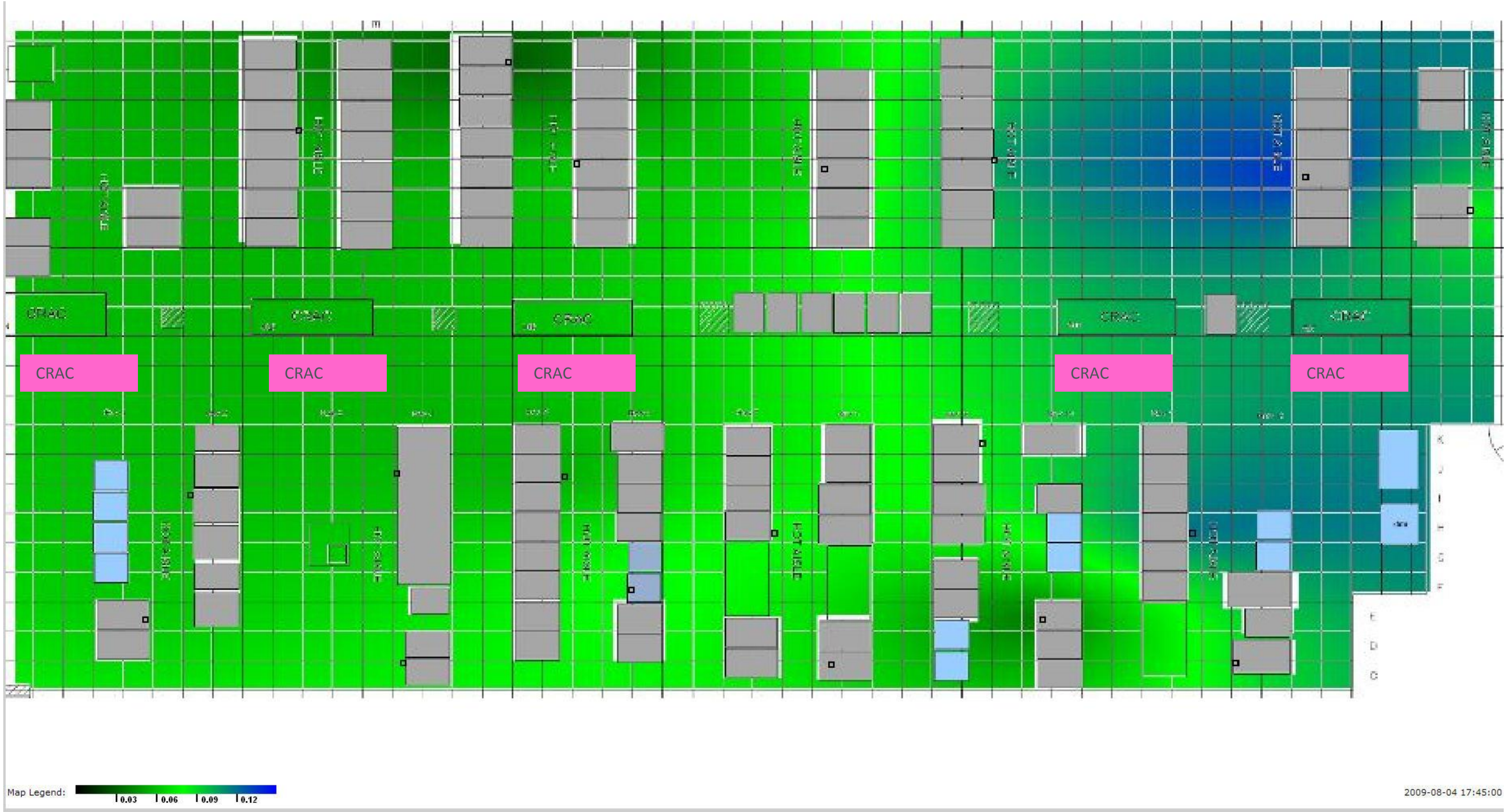
Communicating/Presenting Data



SynapSense™

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

Displayed Under-floor Pressure Map

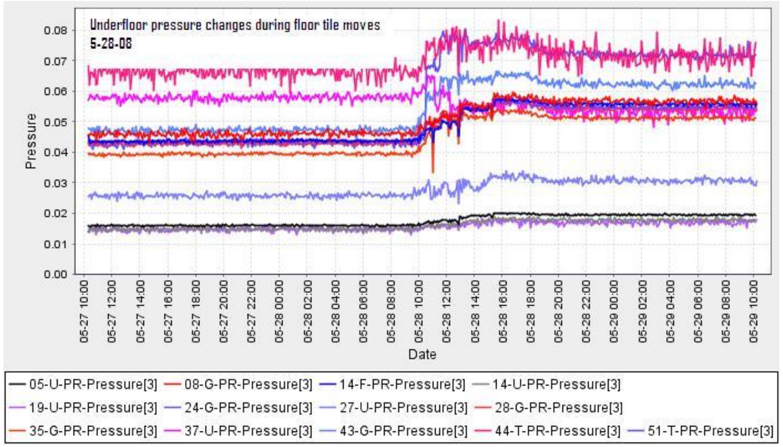


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

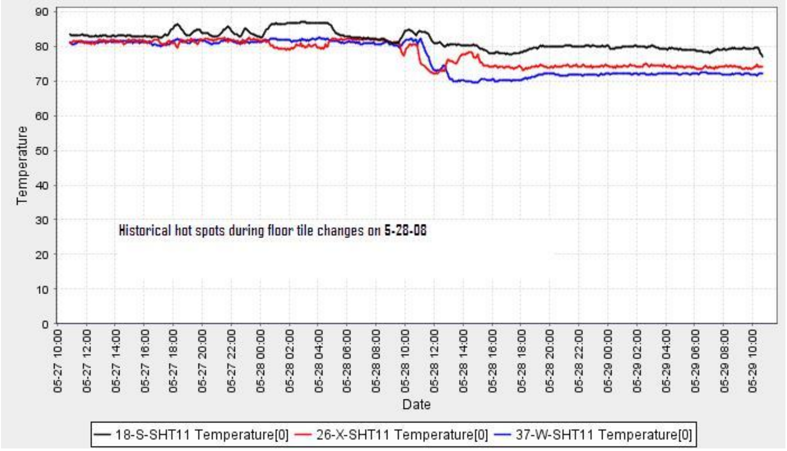
Provides Real-Time Feedback

- Removed guesswork by monitoring and using visualization tools
  - Floor tile tuning

Under-Floor Pressure



Rack-Top Temperatures

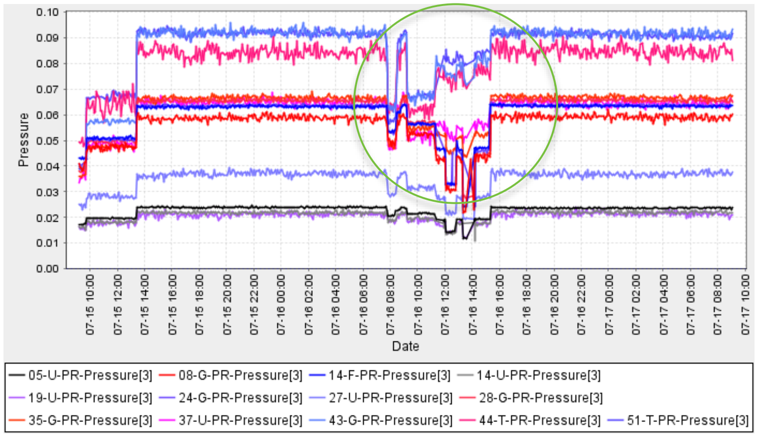


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

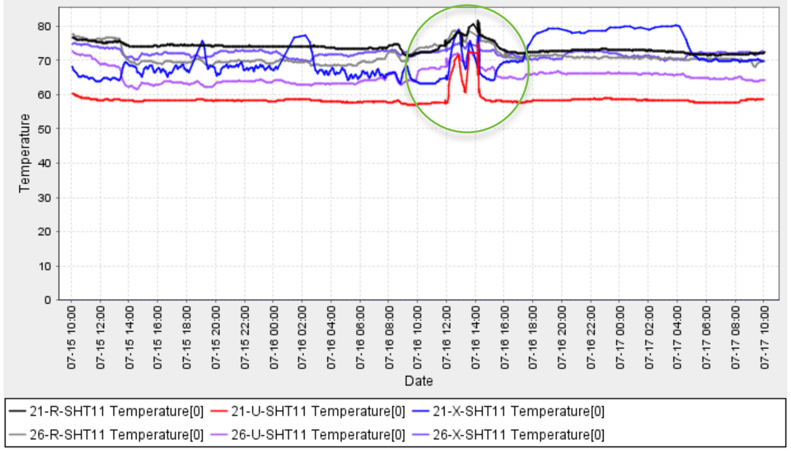
Provides Real-Time Feedback

- Determined relative CRAC cooling impact
- Enhanced knowledge of data center redundancy
- Turned off unnecessary CRAC units to save energy

Under-Floor Pressure

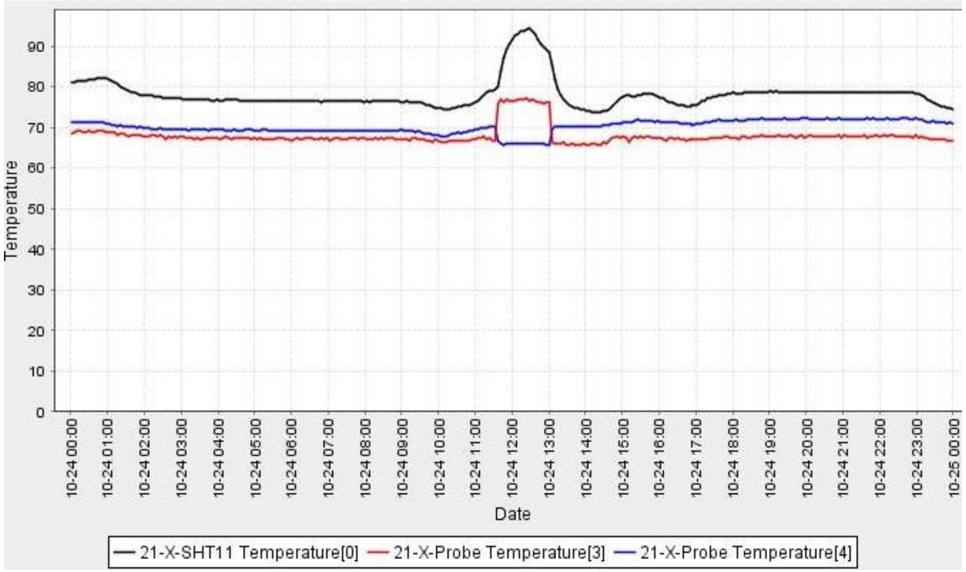


Rack-Top Temperatures

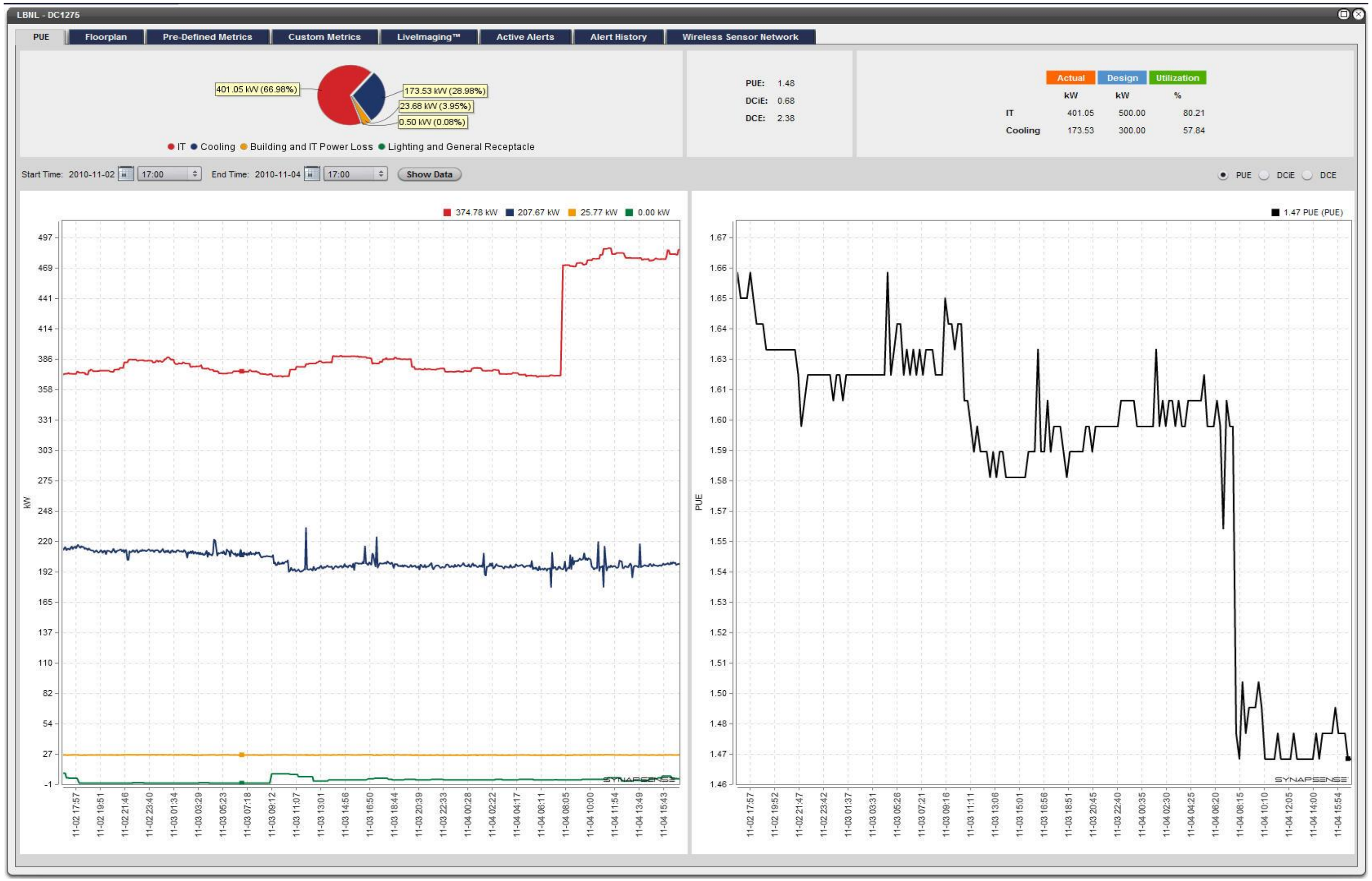


Feedback Continues to Help

- 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

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

Franchise Tax Board (FTB) Case Study

Description

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

Challenges

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

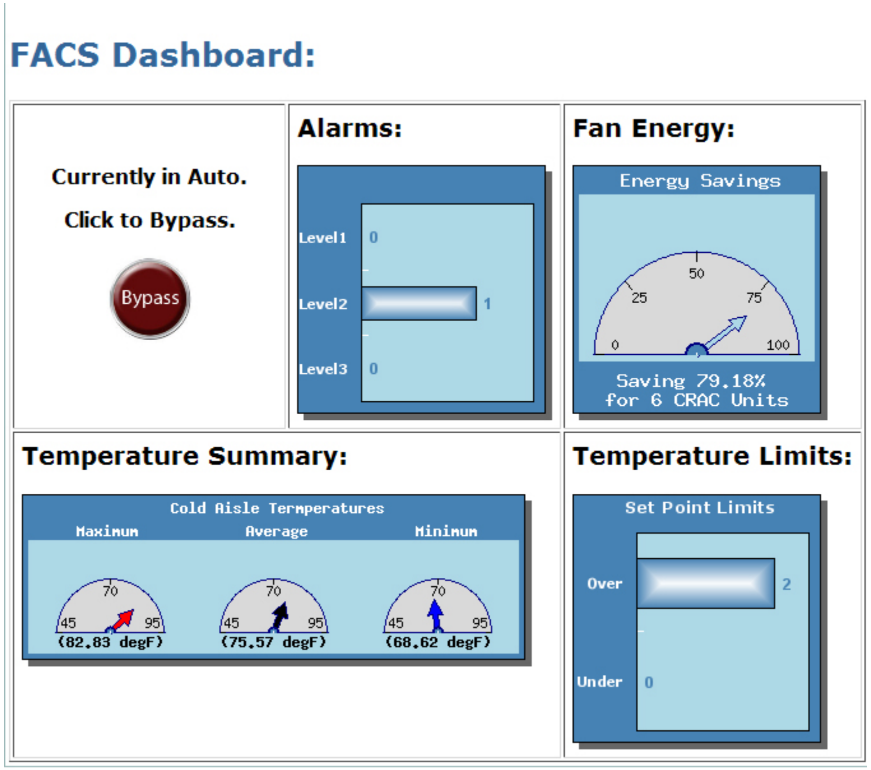
Solution

- Intelligent supervisory control software with rack intake temperature sensing

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

FTB Wireless Sensor Network (WSN)

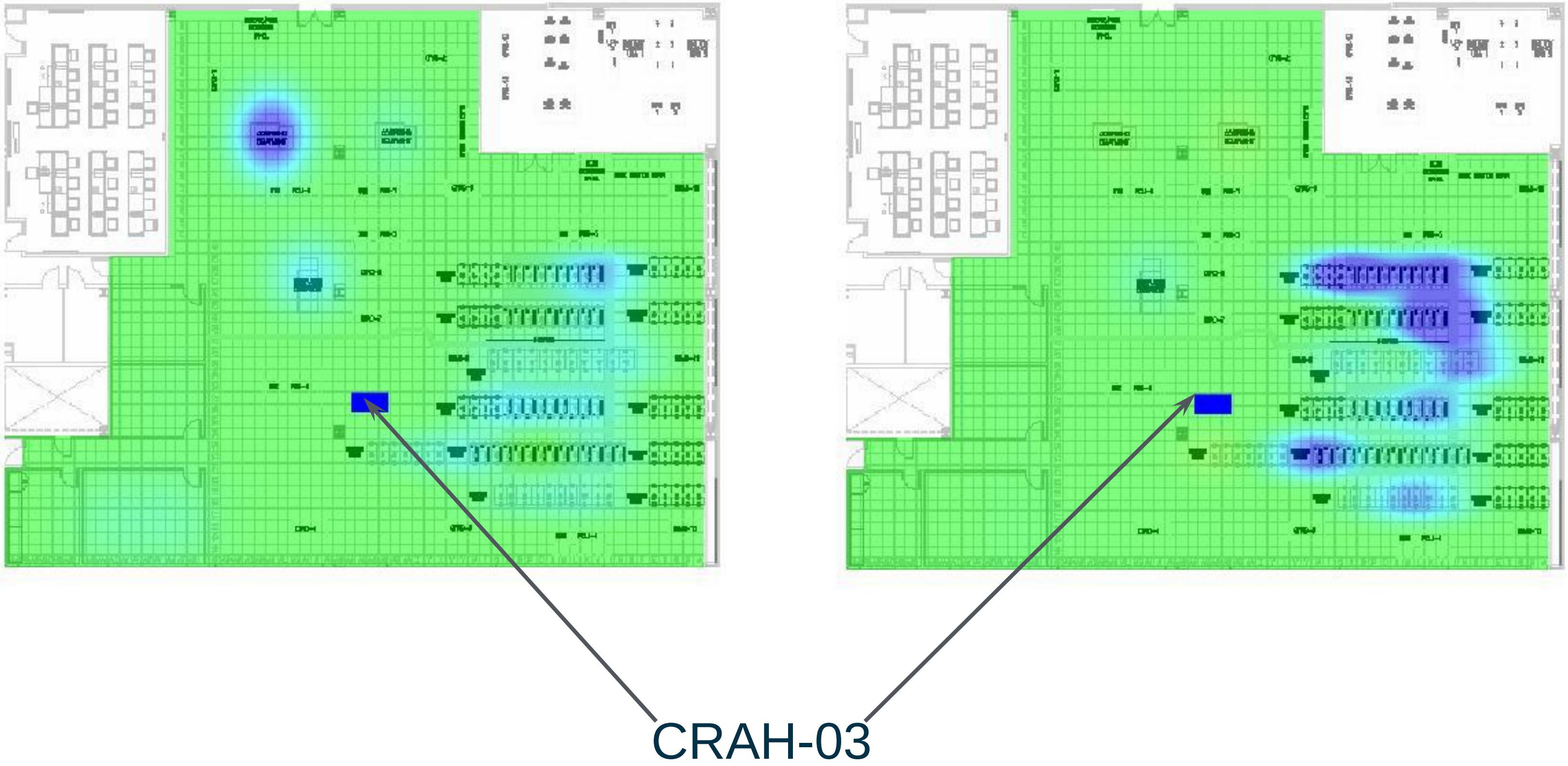
- WSN included 50 wireless temperature sensors (Dust Networks radios)
- Intelligent control software



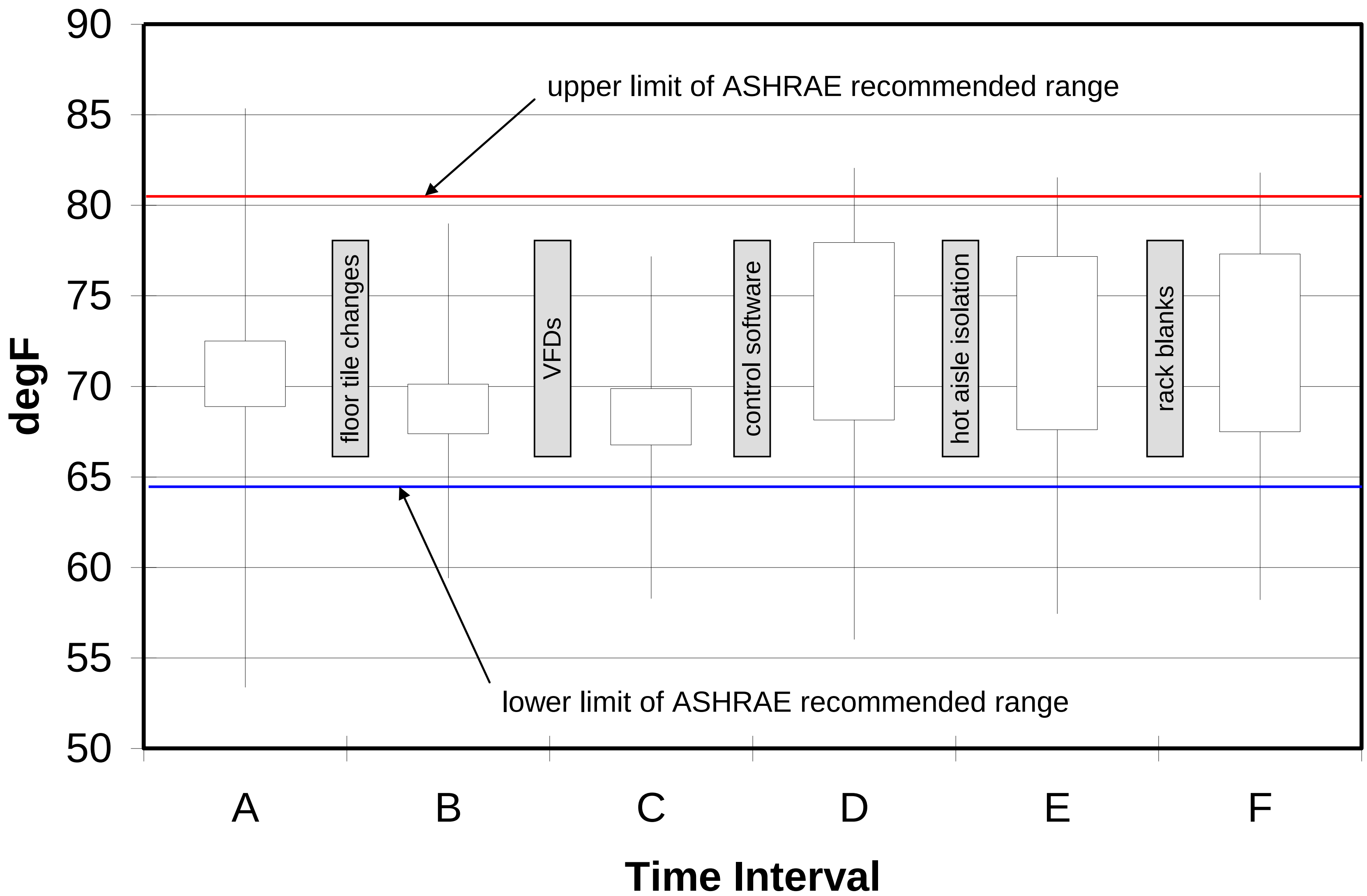
WSN Smart Software: Learns About Curtains

CRAH 3 influence at start

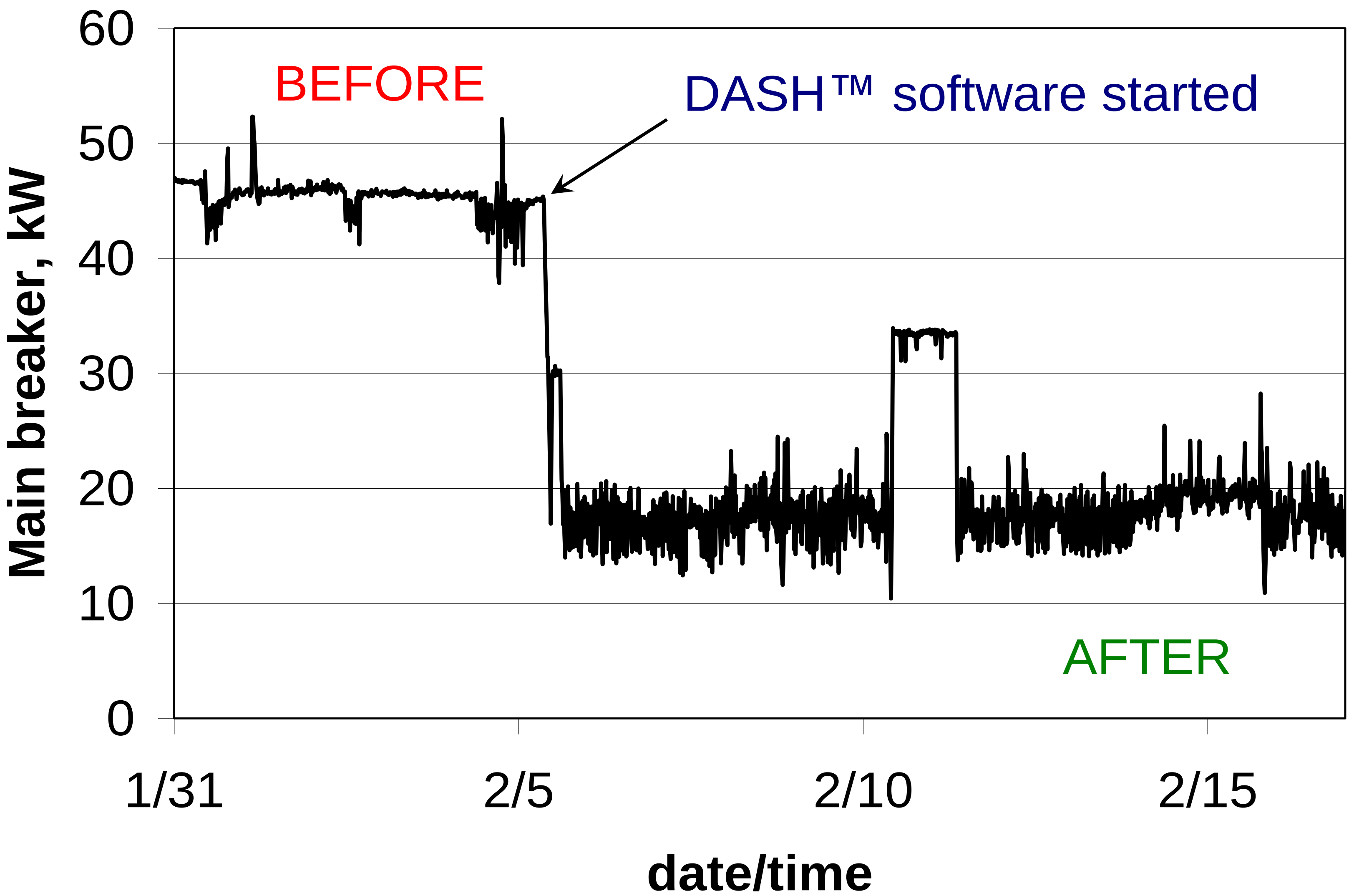
CRAH 3 influence after curtains



WSN Tracked Cold-aisle Temperatures



WSN Software = Dramatic Energy Reduction



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

Cost-Benefit Analysis

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

An Emerging Technology

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

- Typically, data center cooling uses *return air temperature* for control
  - Optimum control difficult
  - ASHRAE and IT manufacturers recommend use of inlet air temp

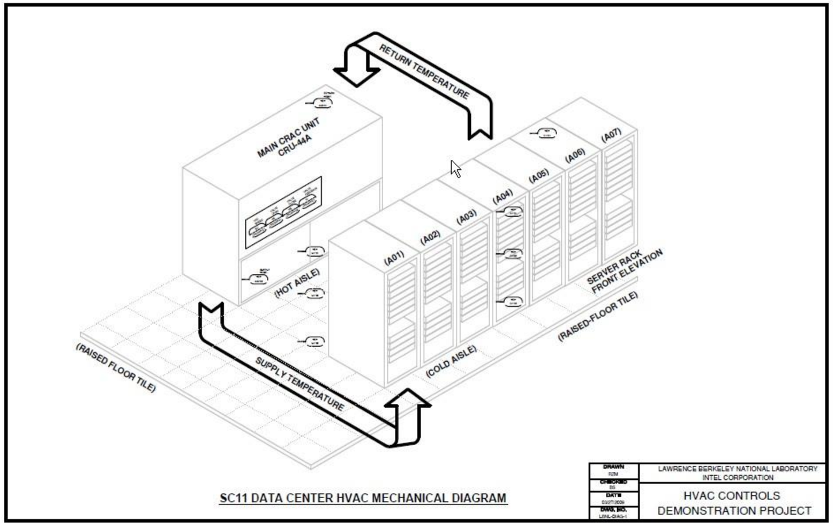
- IT equipment has multiple temperature sensors

- Information from these sensors is available on the IT network.

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

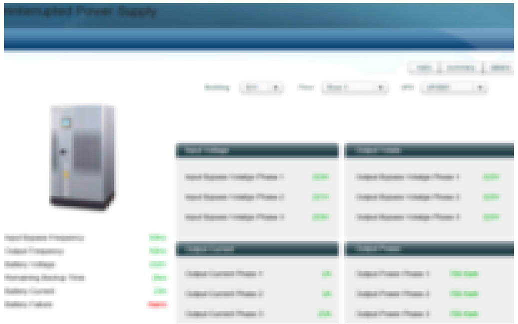
Intel Demonstration

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



Energy Information System Dashboards

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



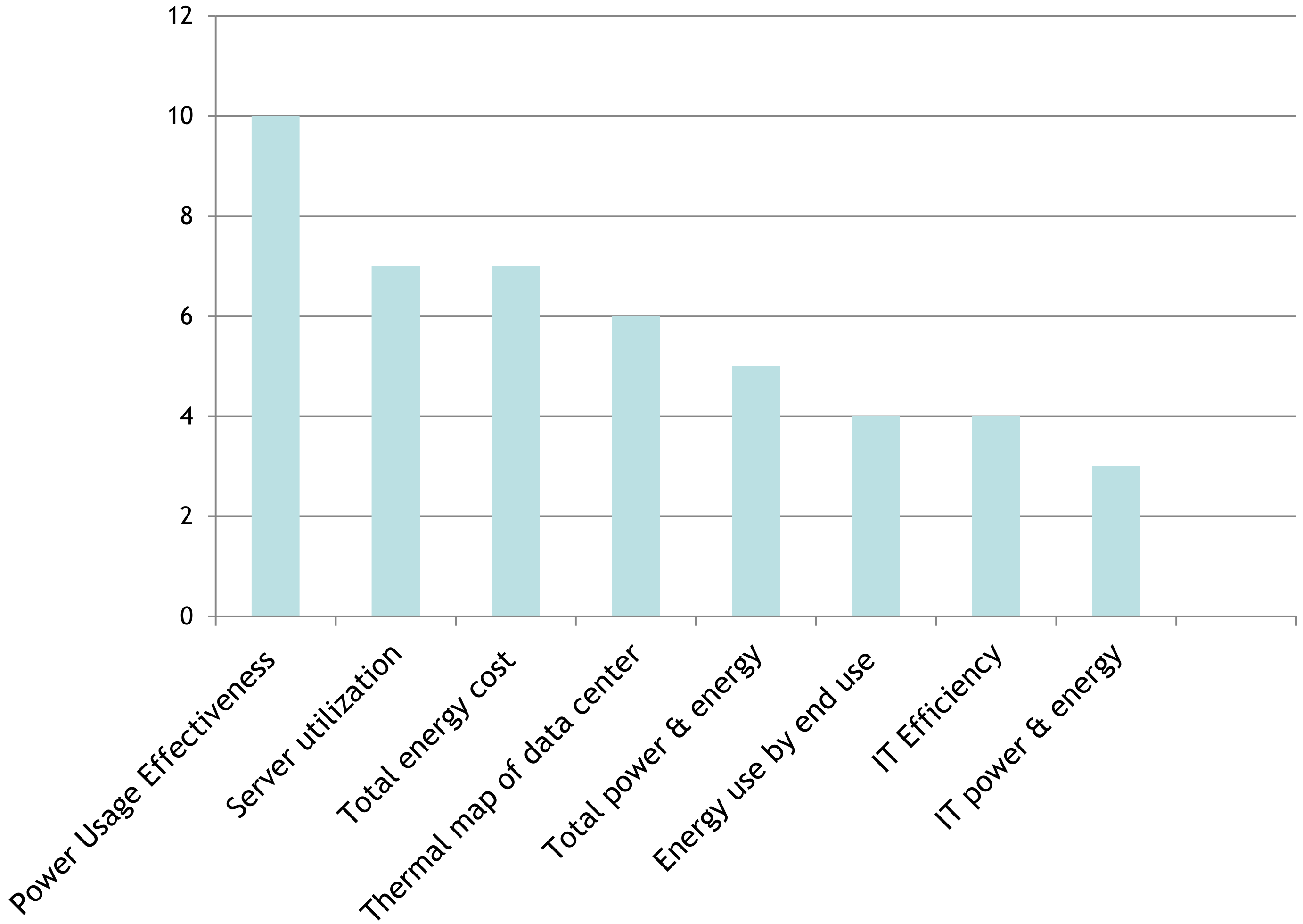
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Why Dashboards?

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

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

Highest Staff-Chosen Metrics for Dashboards

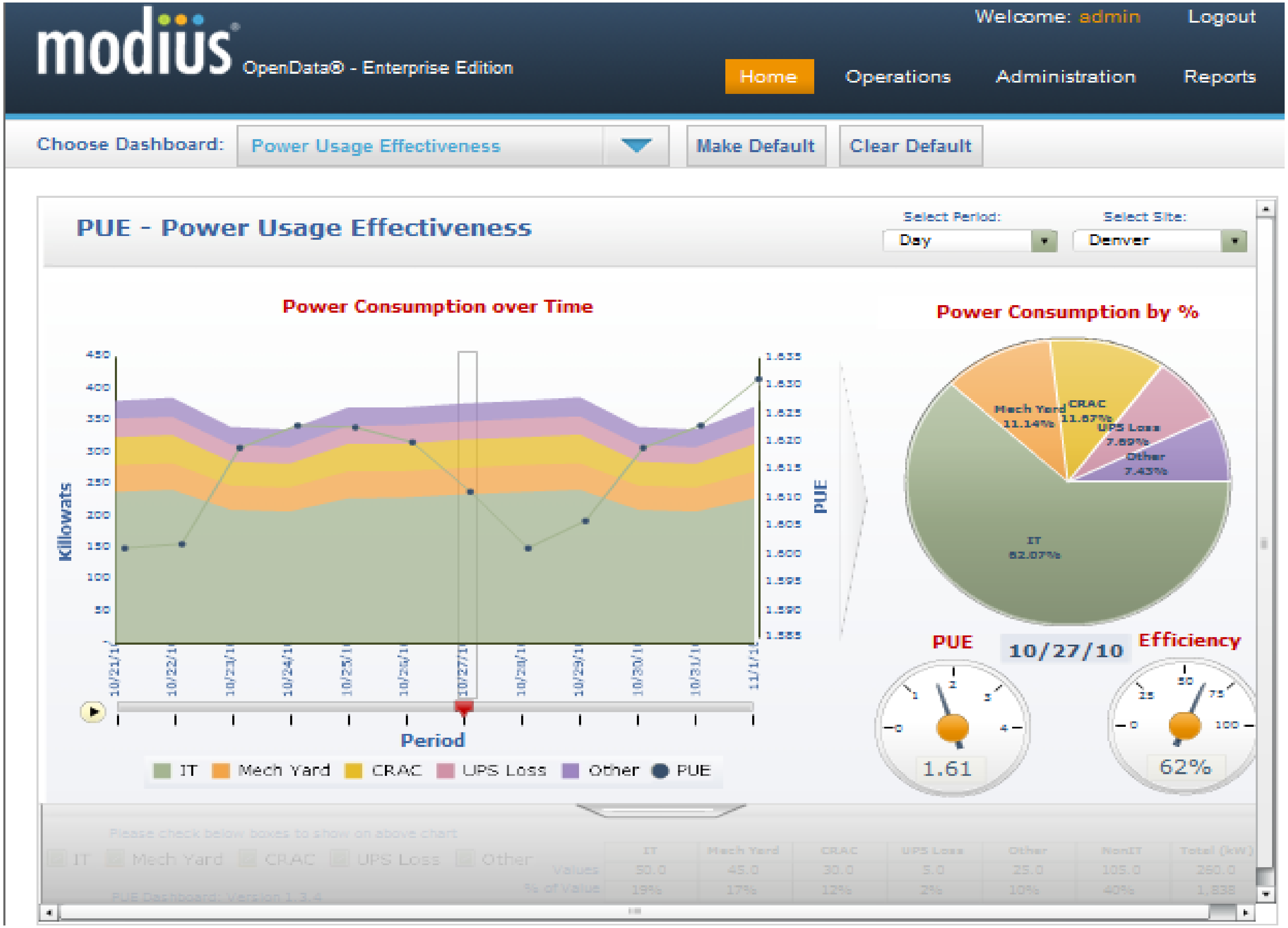


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Key Performance Metrics

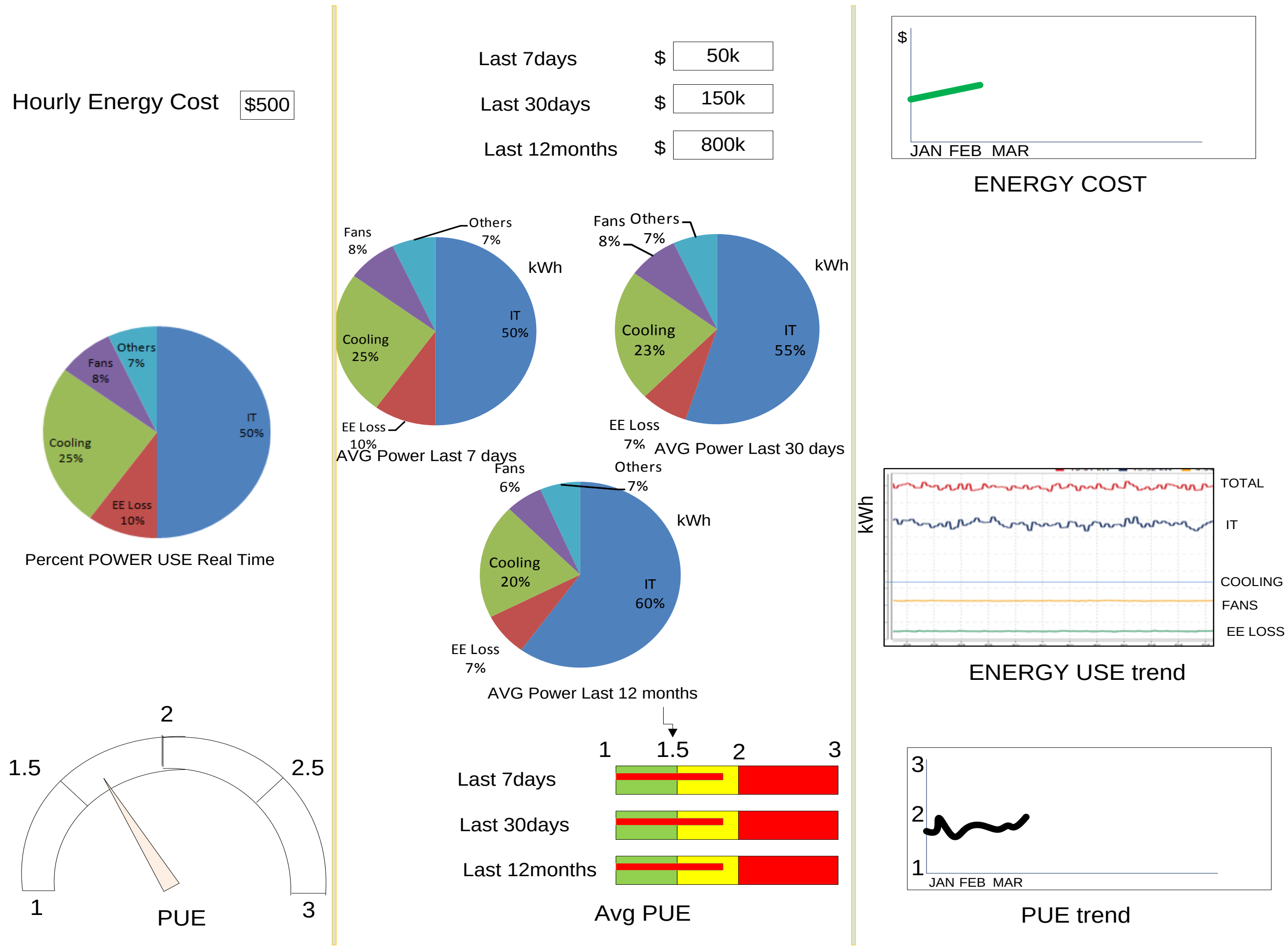
- Power Usage Effectiveness (PUE)
- Energy Cost
- Energy Use by end-use
- Electrical distribution efficiency
- Cooling efficiency
- Environmental map
- IT utilization

Dashboard and Reporting

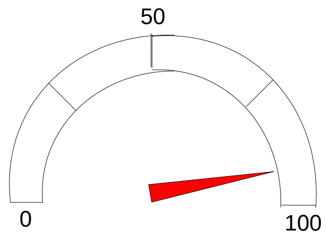


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

High-Level Energy Performance Dashboard



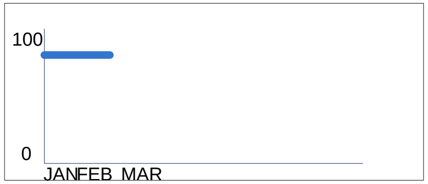
Facility Manager’s Dashboard (added)



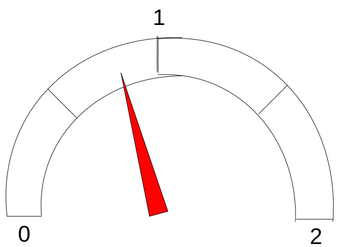
ELEC DIST EFFICIENCY

WEEK TO DATE	90	%
MONTH TO DATE	90	%
YEAR TO DATE	90	%

AVG ELEC DIST EFFICIENCY



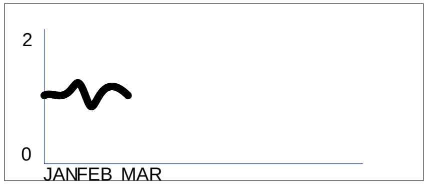
ELEC DIST EFFICIENCY



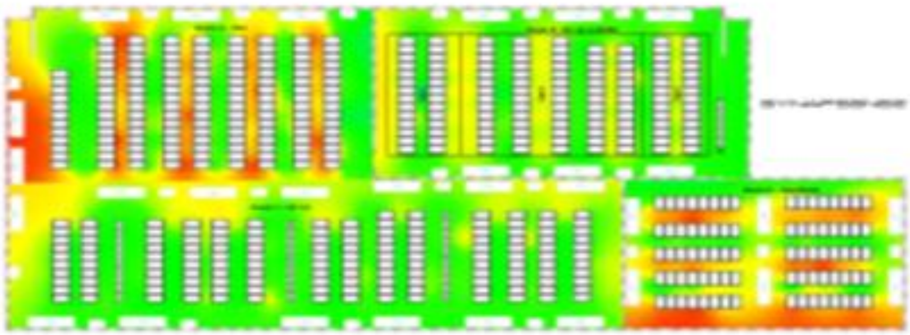
COOLING EFFICIENCY

WEEK TO DATE	.8	kW/ton
MONTH TO DATE	.8	kW/ton
YEAR TO DATE	.8	kW/ton

AVG COOLING EFFICIENCY



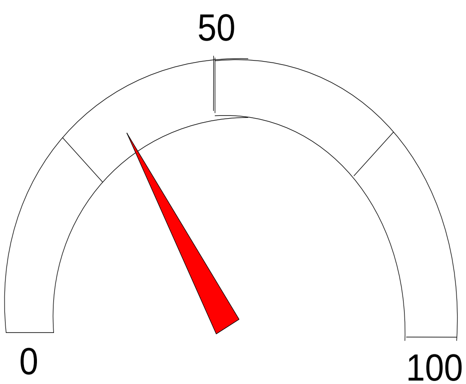
COOLING EFFICIENCY



Thermal Map

IT Manager's Dashboard

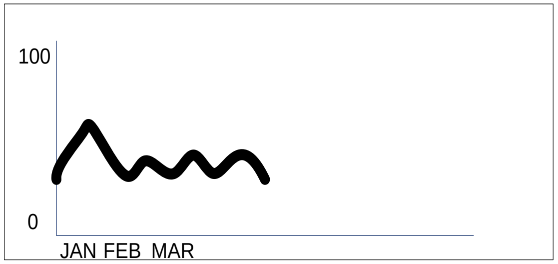
A third dashboard is recommended for the IT manager:



IT UTILIZATION

Last 7days	35	%
Last 30days	35	%
Last 12months	35	%

AVG IT UTILIZATION



IT utilization trend

End-to-End Management with DCIM

Courtesy of Cormant Inc.

Use IT to Manage IT: Summary

- Evaluate monitoring systems to enhance operations and controls

- Install dashboards to manage and sustain energy efficiency

Questions

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

Resources

Resources

DOE Better Buildings

- Tool suite & metrics for base-lining
- Training
- Showcase case studies
- Recognition of high energy savers

Federal Energy Management Program

- Workshops
- Federal case studies
- Federal policy guidance
- Information exchange & outreach
- Qualified specialists
- Technical assistance

EPA

- Metrics
- Server, UPS, network equipment performance rating & ENERGY STAR label
- Data center benchmarking

Industry

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

Center of Expertise (CoE)

https://datacenters.lbl.gov/

Data Center Resources

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

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

Federal Energy Management Program (FEMP)

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

- DC Pro Software and Assessment 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
- Data Center Energy Practitioner (DCEP) certificate program
  - Qualification of professionals to evaluate energy efficiency opportunities in data centers http://datacenters.lbl.gov/dcep

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

Data Center Software Tool Suite

High-Level Online Profiling Tool (DC Pro v.3)

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

System Assessment Tools

Air Management

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

Electrical Systems

- UPS
- PDU
- Transformers
- Lighting
- Standby genset

Future Tools

- HVAC
- IT

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

Data Center Energy Practitioner (DCEP) Program

U.S. DOE certificate process for energy practitioners qualified to assess energy consumption and energy efficiency opportunities in data centers.

Key objective:
- Raise the standard of energy assessors
- Greater repeatability/credibility of recommendations

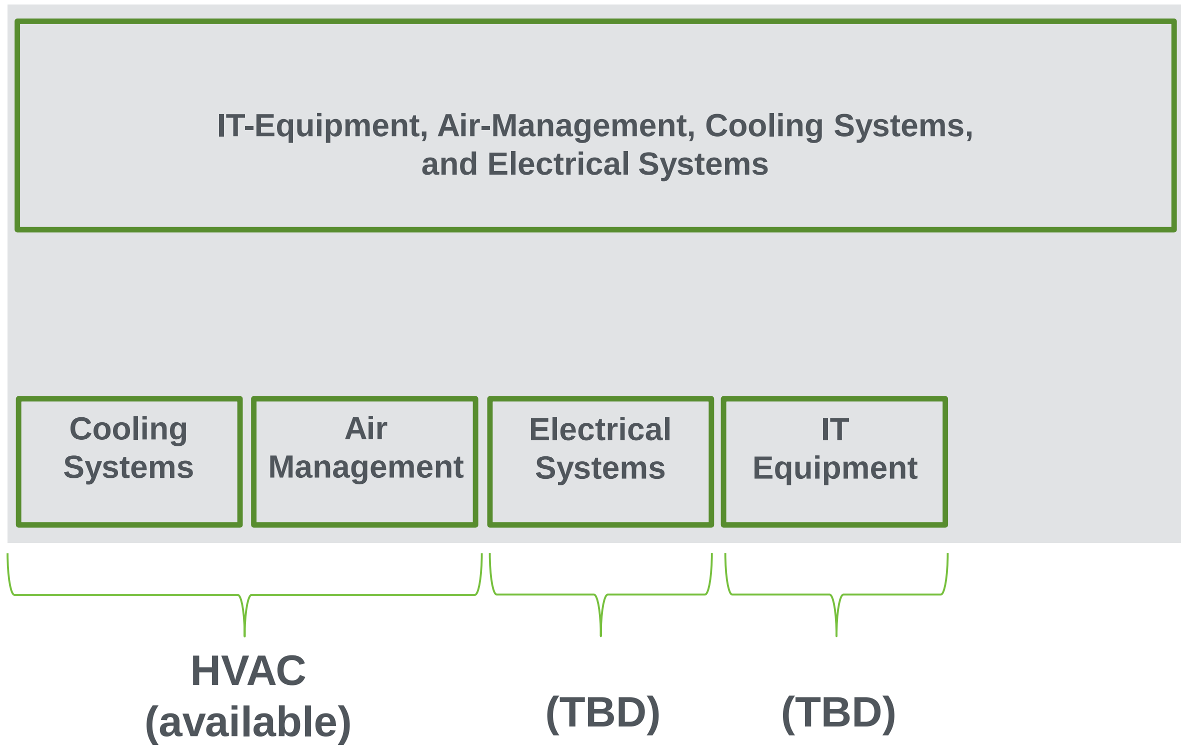
Target groups include:
- Data center personnel (in-house experts)
- Consulting professionals (for-fee consultants)

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

Training & Certificate Disciplines, Levels, and Tracks

<u>**Level 1 "Generalist" (1-day):**</u>
Pre-qualifications, Training/Exam on All Disciplines
+ Assessment Process
+ DC Pro Profiling Tool

<u>**Level 2 "Specialist" (2-day):**</u>
Pre-qualifications, Training/Exam on Select Disciplines
+ Assessment Process
+ System Assessment Tool



There is also a "Training Track": Training only (no pre-qualifications and no exam)

DCEP Training Organizations

- DCEP training is delivered by six training organizations:
- The training organizations:
  - license training and exam content from U.S. DOE
  - provide training/exams
  - issue certificates
- Access up-to-date program information and complete training schedule at U.S. DOE Center of Expertise for Energy Efficiency in Data Centers: http://datacenters.lbl.gov/dcep

Energy Star

- A voluntary public-private partnership program
  - Buildings (including data centers)
  - Products (including IT equipment)

ENERGY STAR

Energy Star Data Center Activities

- 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, UPSs, storage, and networking equipment

Resources

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

http://datacenters.lbl.gov/

http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

https://datacenters.lbl.gov/better-buildings-data-center-partners

Questions

Workshop Summary

Best Practices

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

Summary

- A data center uses 10-100 times more energy than an office building per sq.ft.
- There are federal mandates and requirements related to energy efficiency in data centers
- Integration of acquisition, IT, and facilities optimizes energy performance
- Key data center energy performance metrics assist in benchmarking data centers
- Monitoring, analytics, and reporting should be standard practice.

Data Center Best Practices Summary

1. Measure and Benchmark Energy Use
2. Identify IT Opportunities, and modify procurement processes to align with the procurement policy
3. Optimize Environmental Conditions
4. Manage Airflow (Air Management)
5. Evaluate Cooling Options
6. Improve Electrical Efficiency
7. Use IT to Control IT

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
- Implement acquisition systems to assure efficient products are purchased
- Increase utilization rates
- Consider redundancy in the network rather than in the data center

3. Optimize Environmental Conditions

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

4. Manage Airflow

- Implement hot and cold aisles
- Seal leaks
- Manage floor tiles
- Isolate hot and cold air streams

5. Evaluate Cooling Options

- Use centralized cooling system
- Maximize central cooling plant efficiency
- Provide liquid-based heat removal
- Compressorless cooling (“free” cooling)

6. Improve Electrical Efficiency

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

7. Use IT to Control IT Energy

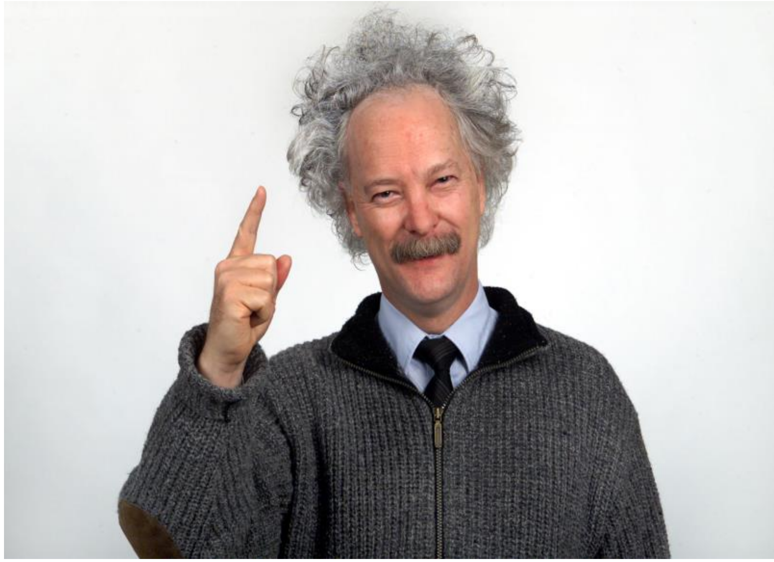
- Evaluate monitoring systems to enhance real-time management and efficiency
- Use visualization tools (e.g., thermal maps)
- Install dashboards to manage and sustain energy efficiency

Most importantly

Get IT and Facilities people talking and working together as a team!

Questions

Contact Information



Dale Sartor, P.E.

DASartor@LBL.gov

(510) 486-5988

Lawrence Berkeley National Laboratory

MS 90-3111

University of California

Berkeley, CA 94720

https://datacenters.lbl.gov/

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

BERKELEY LAB