Data Center Efficiency Workshop

GovEnergy, Cincinnati

August 7, 2011

Presented by: Dale Sartor, P.E.

(Version: 8/2/11)

AGENDA

Morning

- Introductions to course and instructors
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions

Lunch On your own

Afternoon

- Airflow management
- Cooling systems
- Electrical systems
- Summary and Takeaways

Data Center Efficiency Workshop: Introduction

Presented by: Dale Sartor, P.E.

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

FEMP
Federal Energy Management Program

GSA

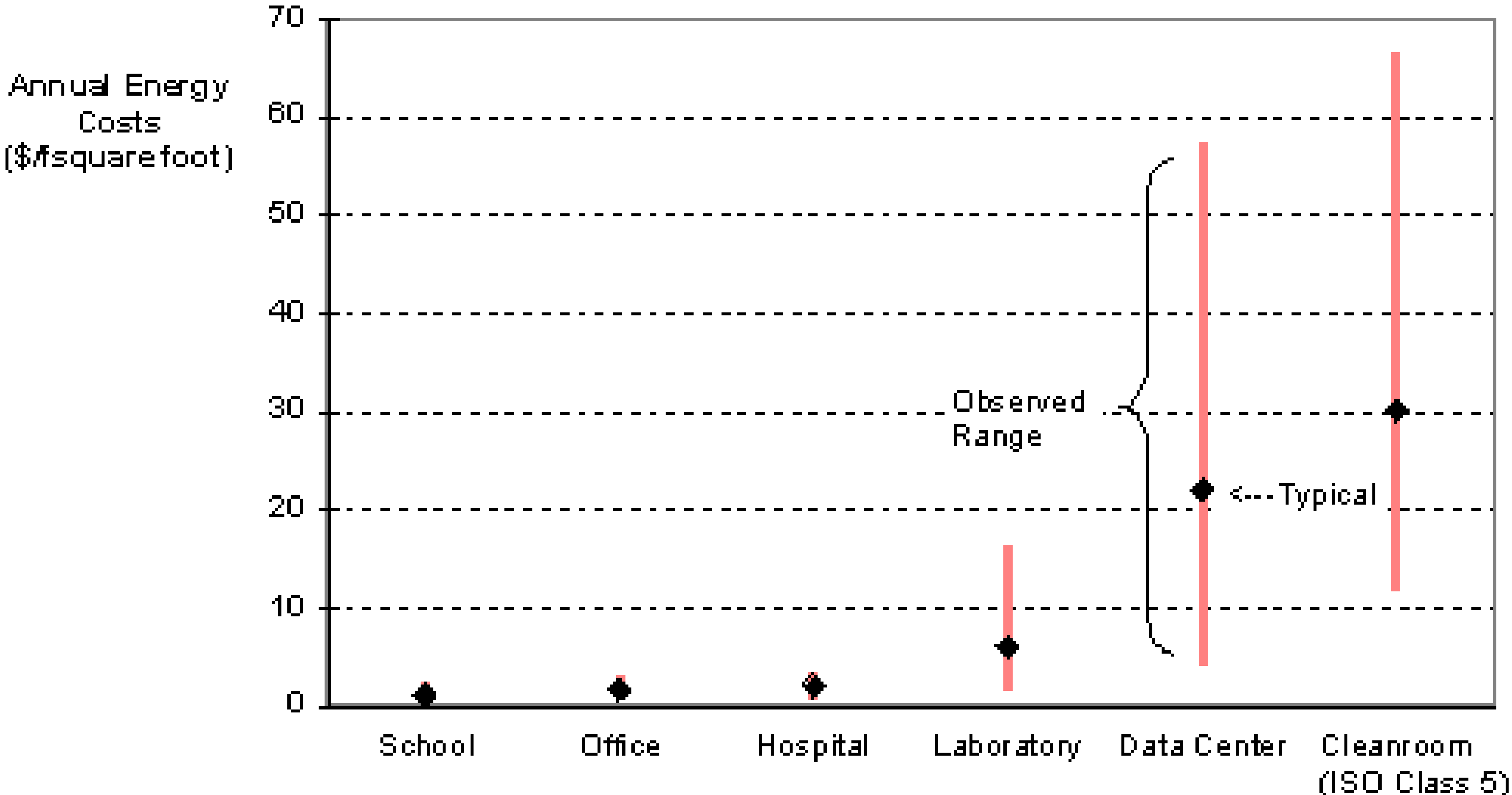
Workshop Learning Objectives

- Provide background on data center efficiency
- Raise awareness of efficiency opportunities
- Provide overview of Federal Data Center Programs/resources
- Develop common understanding between IT and Facility staff
- Group interaction for common issues and solutions

High Tech Buildings are Energy Hogs

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

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

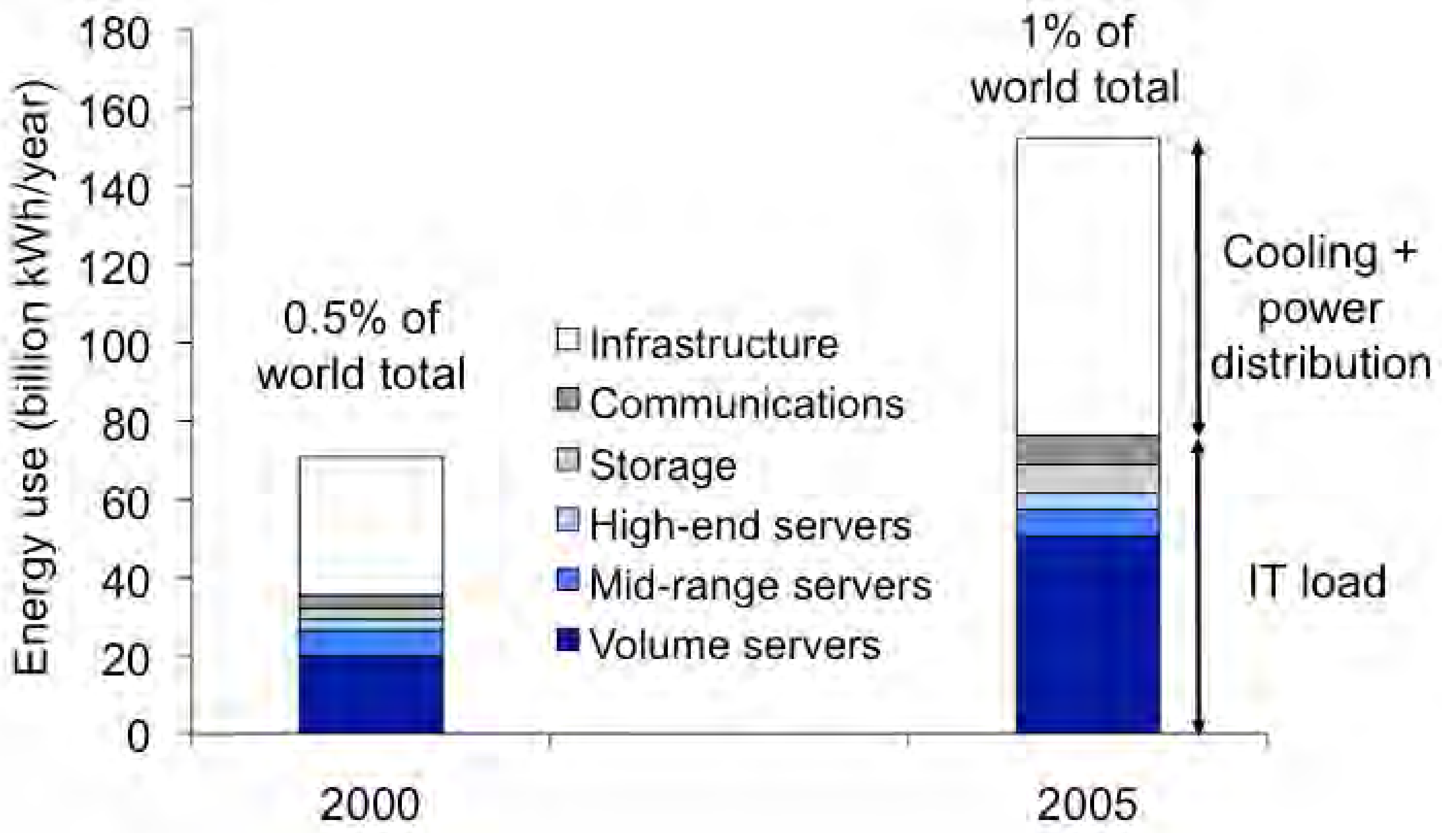


Data Center Energy

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

World Data Center Electricity Use - 2000 and 2005

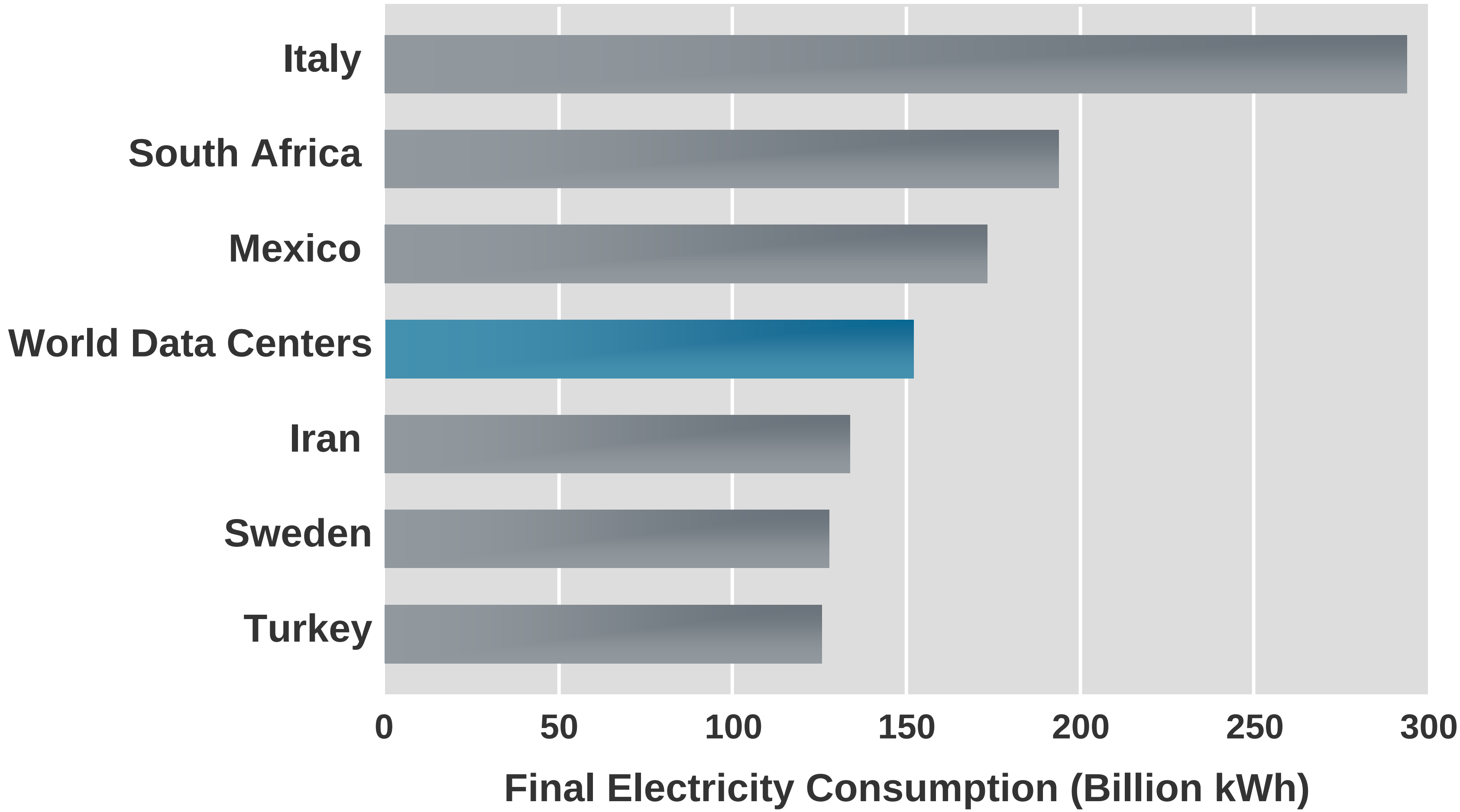
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Source: Koomey 2008

How much is 152B kWh?

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



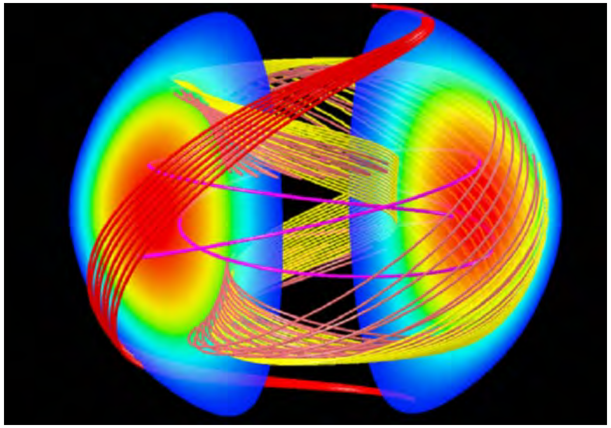
Source for country data in 2005: International Energy Agency, *World Energy Balances* (2007 edition)

The Rising Cost of Ownership

- 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

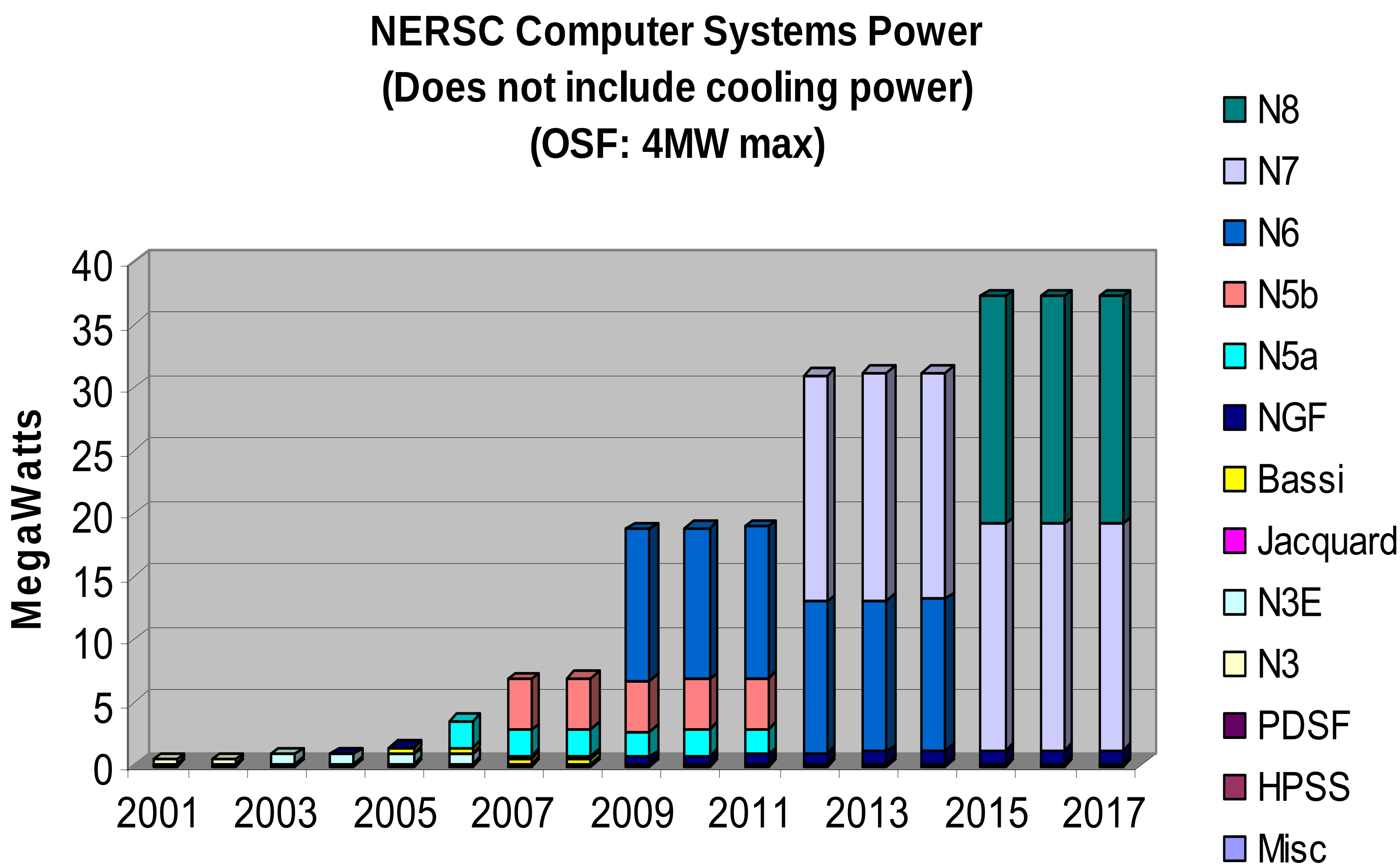


We also research energy efficiency opportunity and work on various deployment programs

LBNL Feels the Pain!

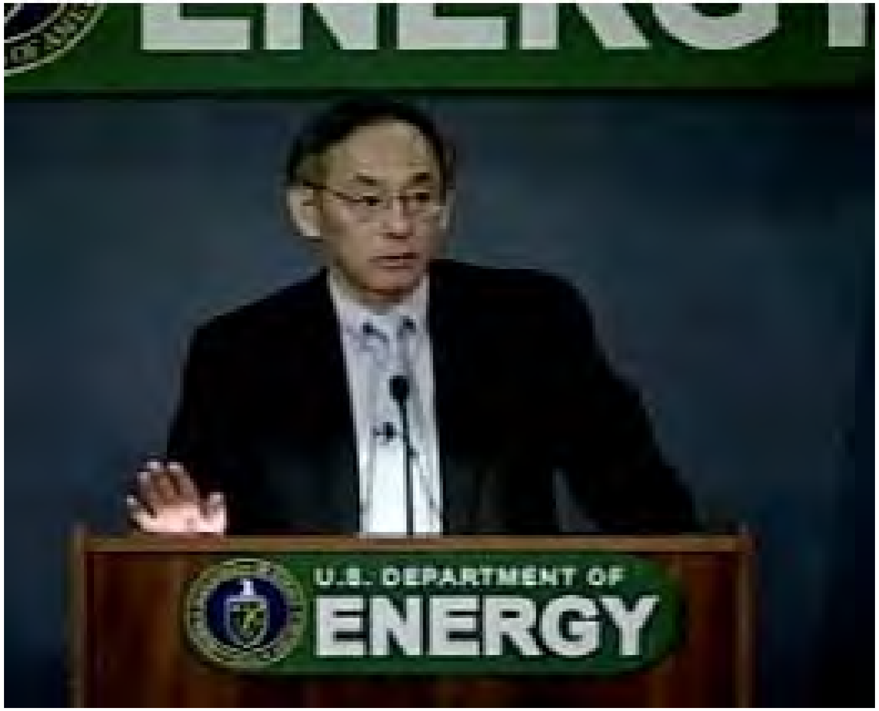
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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



First, a Few Words from our Leader

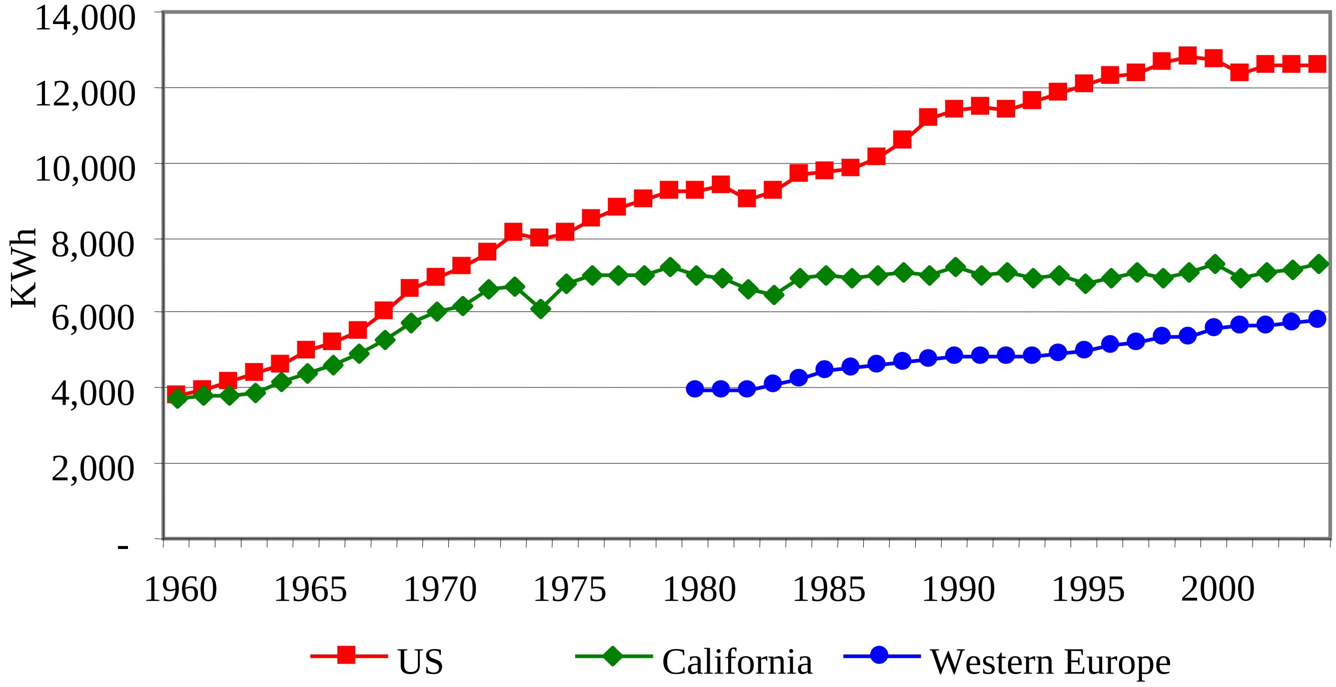
- "We're certainly in a mess right now."
- "The environment... is the reason I joined the Dept of Energy."
- "We simply cannot fail."



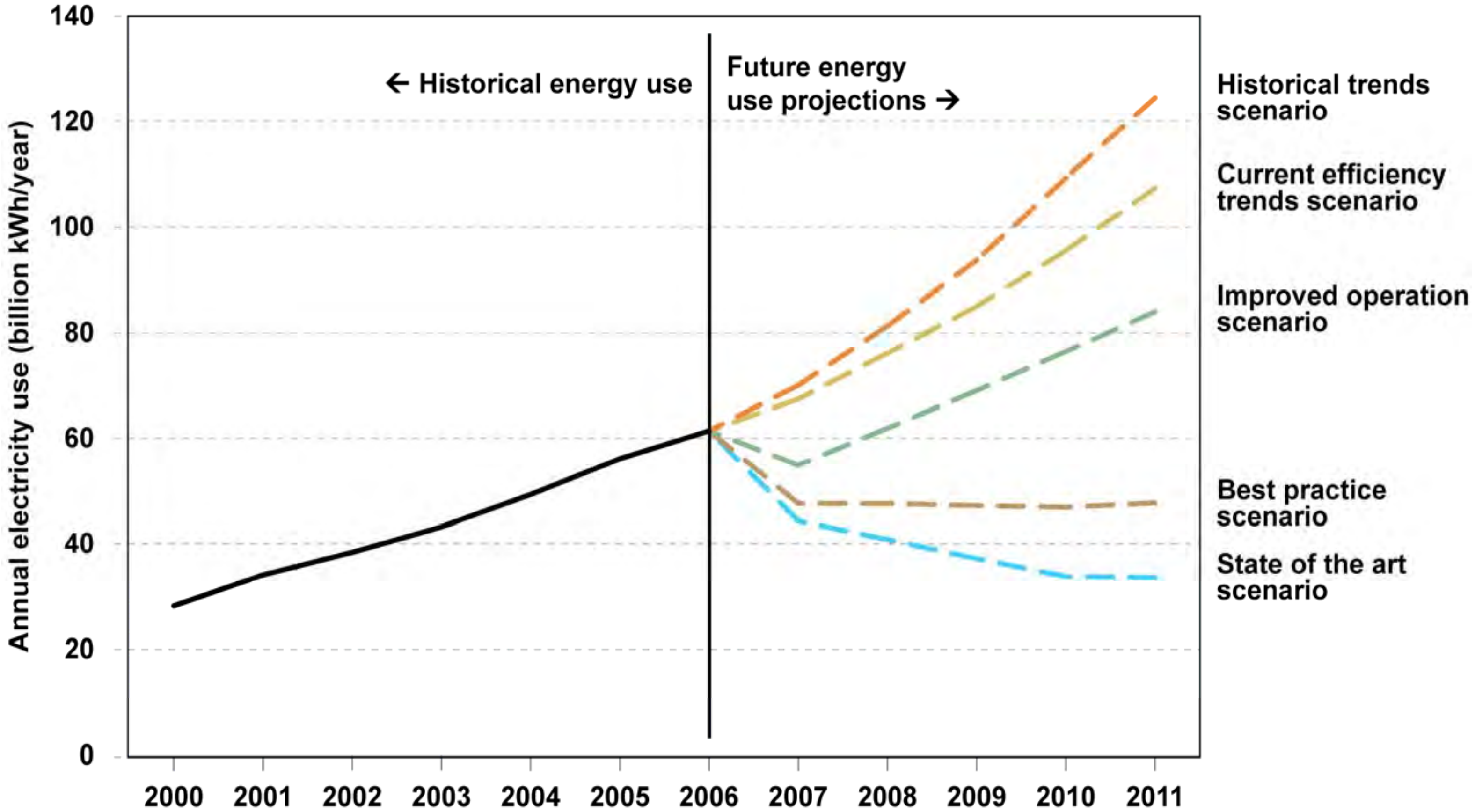
Source: Secretary Chu's address to DOE staff 1/22/09

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

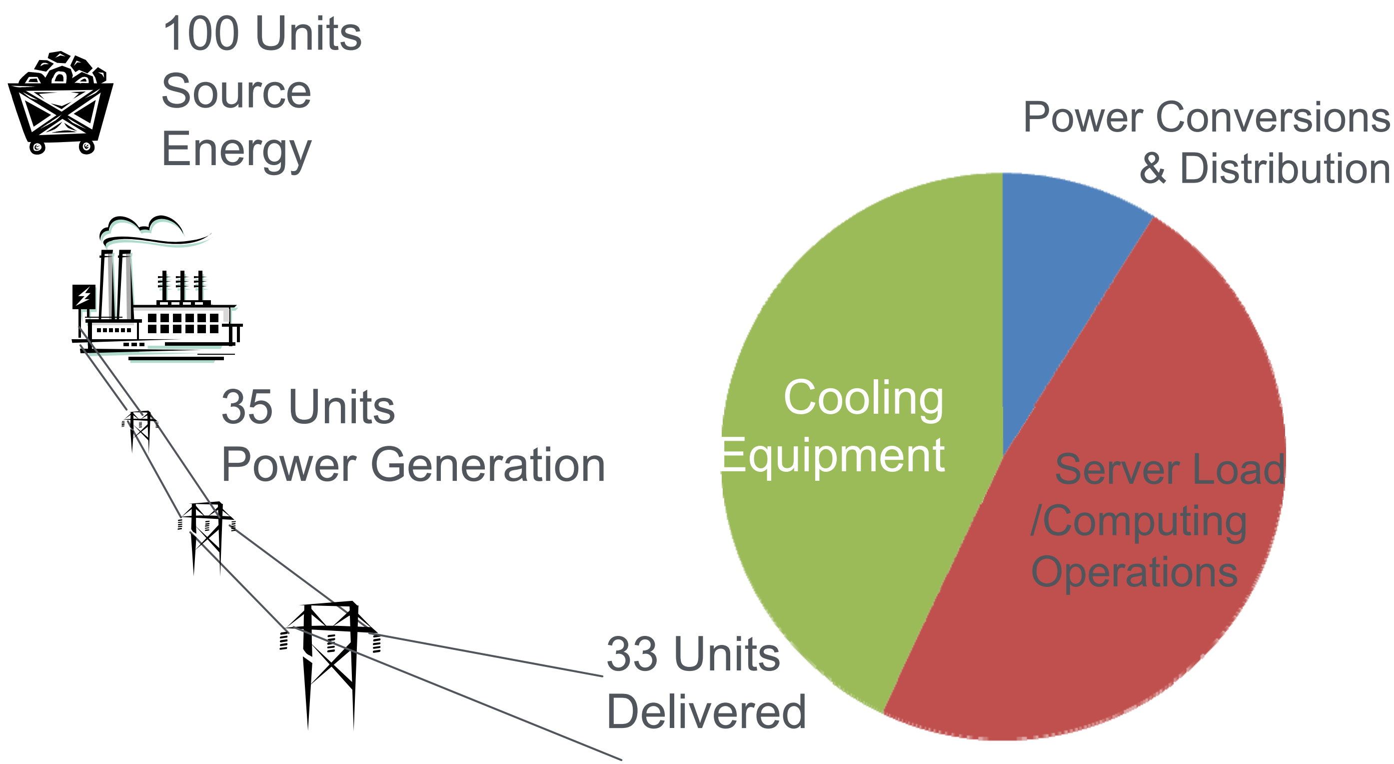


EPA Report to Congress 2008

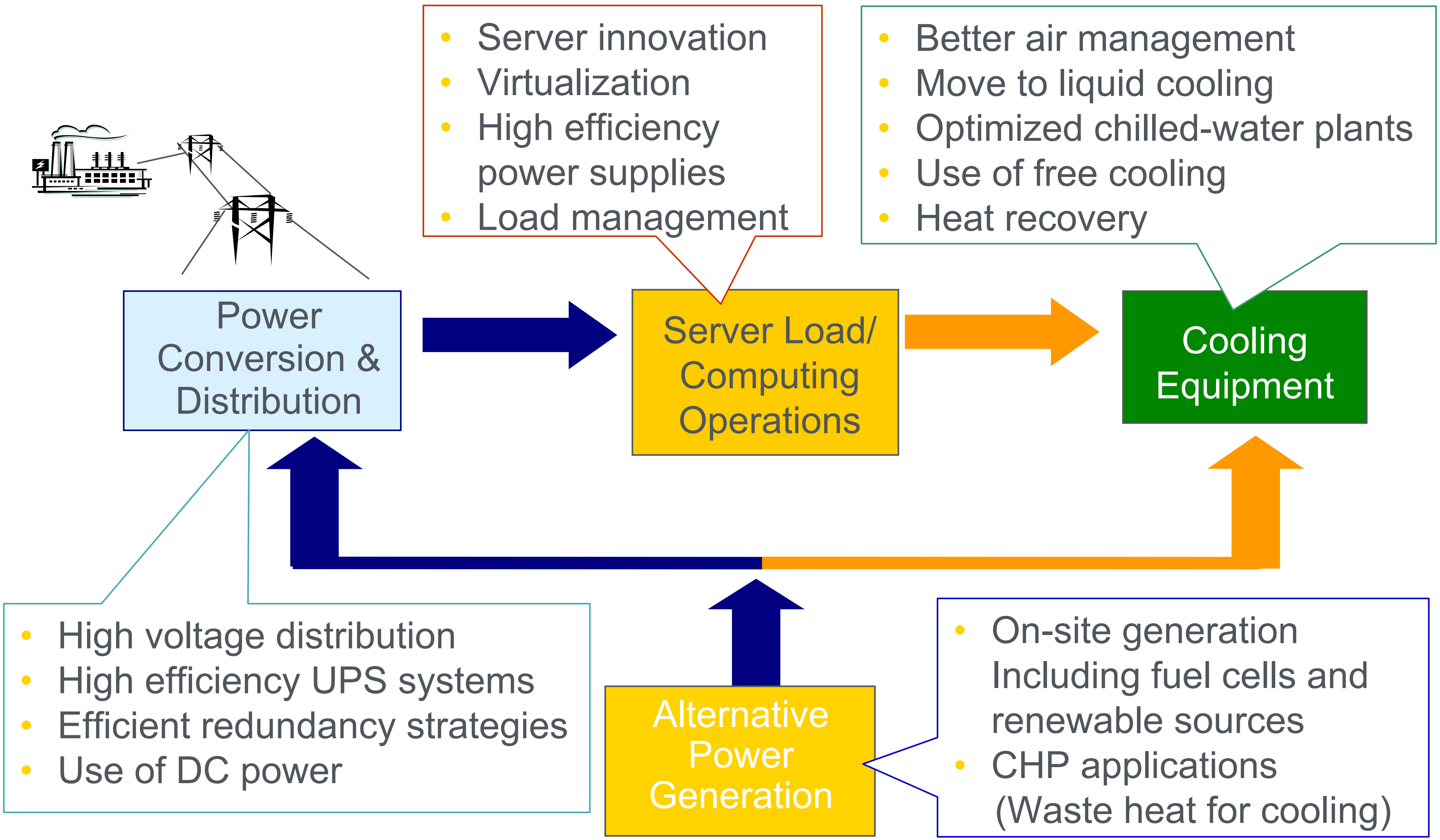
Data Center Energy Efficiency = 15% (or less)

(Energy Efficiency = Useful computation / Total Source Energy)

Typical Data Center Energy End Use



Energy Efficiency Opportunities



Potential Benefits of Data Center Energy Efficiency

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

Challenging Conventional Wisdom: Game Changers

- 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

Federal Programs/Resources

Industrial Technologies Program

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

Save ENERGY Now

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

Industry

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

EPA

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

Department of Energy (DOE) Data Center Initiatives

Develops tools and resources to make data centers more efficient throughout the United States

Participants:

- DOE Federal Energy Management Program (FEMP)
- DOE Sustainability Performance Office (SPO)
- DOE Industrial Technologies Program's (ITP) *Save Energy Now*
- In partnership with ENERGY STAR, GSA, The Green Grid, ASHRAE, and other industry partnerships

FEMP MISSION

FEMP Facilitates the Federal Government's implementation of sound, cost-effective energy management & investment practices to enhance the nation's energy security & environmental stewardship.

Federal agencies have been instructed to...

- Reduce facility energy intensity
- Increase renewable energy use
- Reduce water consumption intensity
- Purchase EPEAT and FEMP-designated products
- Meter and benchmark facilities
- Consolidate data center facilities wherever possible

FEMP Support for Data Center Energy Efficiency

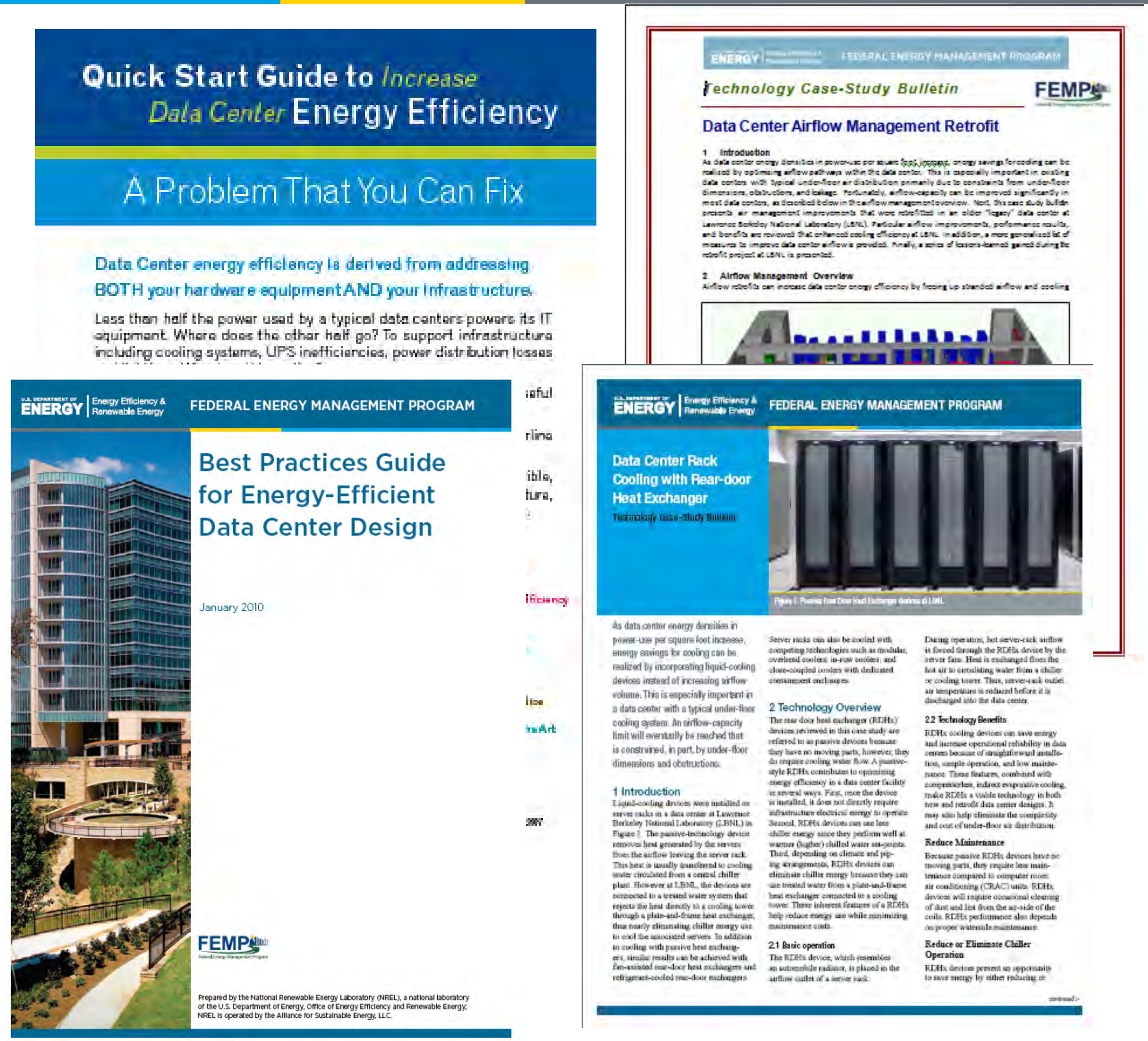
FEMP in partnership with GSA and other agencies supports data center efficiency in the Federal sector:

- **Technical Assistance**
  - Implementation of DC Pro Tool Suite for benchmarking and assessments
  - Project planning and early design
  - Technology demonstration projects
- **Training**
  - Webinars
  - Workshops
- **Development of tools and resources**
- **Access to funding sources**
  - Energy savings performance contracts
  - Utility energy savings contracts
- **Federal Energy Management Program awards**

Federal Data Center Resources

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

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



Data Center Working Groups

The Federal Partnership for Green Data Centers

- **An Inter-Agency forum to exchange ideas, develop policy guidance & tools to improve data center performance**

High Performance Computing Working Group

- **A forum for sharing information on best practices in scientific computing**
- **Includes members from the public and private sectors**

FEMP/GSA Partnership

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

Quick Start Guide

To Increase Your Data Center Energy Efficiency

5 Five More Best Practices

Optimize the Central Plant

Typically, a central cooling plant and air handlers are more efficient than distributed air conditioning units. Begin with an efficient water cooled variable speed chiller, add high-efficiency air handlers, low-pressure drop components, and finish with an integrated control system that minimizes unnecessary dehumidification and simultaneous heating and cooling.

Use temperature resets to allow use of medium-temperature water "chilled" (55 degrees Fahrenheit or higher). Warmer chilled water improves chiller plant efficiency and eliminates the need for the chiller during many hours of operation (tower cooling only).

Free Cooling

Can you design your building for free cooling? Can you retrofit outside air supply? Can you retrofit a water side economizer (use cooling tower to pre-cool return "chilled" water)? It is all about humidity and temperature.

Right Sizing

When the ultimate load is uncertain, data center cooling systems are often oversized and operate at inefficient part loads. Therefore, it makes sense to pre-install fixed elements such as ducts and pipes, but design for modular growth of the mechanical equipment. Include variable speed fans, pumps and compressors. Right size all your plant equipment—overbuilding in advance of actual needs makes many subsystems operate inefficiently.

Use Liquid Cooling of Racks and Computers

Since water is 3500 times more effective than air on a volume basis, it cools servers and appliances more efficiently than air conditioning! Today, you can purchase liquid cooled racks. Manufacturers are prototyping liquid-cooled computers as well.

People are Key

Facilities and IT staff bring different perspectives to create better solutions when it comes to data center energy efficiency. Ask your counterpart to lunch so you can begin to learn about their challenges and explain your own.

This Guide is funded by U.S. General Services Administration and U.S. Department of Energy's Federal Energy Management Program

GSA FEMP

6 What Can You Really Achieve?

Save energy now.

Improve Design and Operations Processes

- Benchmark existing facilities
- Document design intent
- Introduce energy optimization early in the design process
- Use life-cycle total cost of ownership analysis
- Re-commission as a regular part of maintenance
- Encourage IT and facilities people to work together

More Information

You can learn more about these topics at the following URLs:

- Air management
- Right-sizing
- Central plant optimization
- Efficient air handling
- Free cooling
- Humidity control
- Server efficiency (see Energy Star®)
- Liquid cooling
- Improving power chain
- UPSs and equipment power supplies
- On-site generation
- Designing, measuring & optimizing processes

Useful Websites:

Sign up here to stay up to date on the DOE website:
www.eere.energy.gov/datacenters

Energy Star® Program:
www.energystar.gov/index.cfm?c=prod_development.server_efficiency

Lawrence Berkeley National Laboratory (LBNL):
http://hightech.lbl.gov/datacenters.html

LBNL Best Practices Guidelines (cooling, power, IT systems):
http://hightech.lbl.gov/datacenters-bpg.html

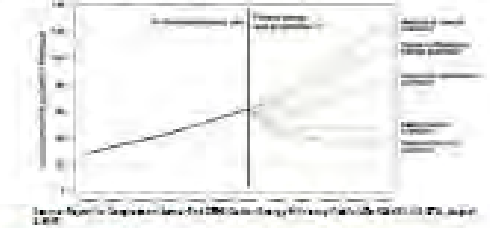
ASHRAE Data Center technical guidebooks:
http://tc99.ashraetcs.org

1 We have a problem that we can fix.

- The energy used by a single rack of the emerging generation of servers (25kW plus air-conditioning) each year (and associated air-conditioning) is equivalent to the energy required to drive an average car (25 miles per gallon) coast-to-coast about 100 times. (Source: Evan Mills, Lawrence Berkeley Lab, 2006)
- Electric bill could exceed the cost of IT equipment over its useful life. 20-40% savings are typically possible; aggressive strategies can yield better than 50% savings.

We make choices every day that affect our carbon footprint. As the chart below shows, we are choosing how much effort we will exert in order to decrease our data center carbon footprint.

Data Center energy efficiency is derived from addressing BOTH your hardware equipment AND your infrastructure.



High Level Facility Metrics

Both PUE (Power Usage Effectiveness) and DCiE (Data Center Infrastructure Efficiency) are accepted measures of overall data center efficiency.

DOE's *SEN* program provides tools and resources to help data center 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 to identify and reduce operating costs, and regain data center infrastructure capacity
- **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**

Save ENERGY Now

- *Products*
- DC Pro tool Suite (Assessment protocols and tools)
- Training curriculum
- Data center energy practitioner program
- Case studies
- Technology R&D and demonstrations

Market Delivery

- 200 Energy Practitioners
    - Suppliers
    - Engineering firms
    - Utilities
- Associations and technical Organizations

Data Center Results

- 10 billion kWh per year saved
- 3,000 people trained on tools and assessment protocols
- 1,500 data centers improve energy efficiency > 25%
- 200 data centers improve energy efficiency >50%

DOE DC Pro Tool Suite

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

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

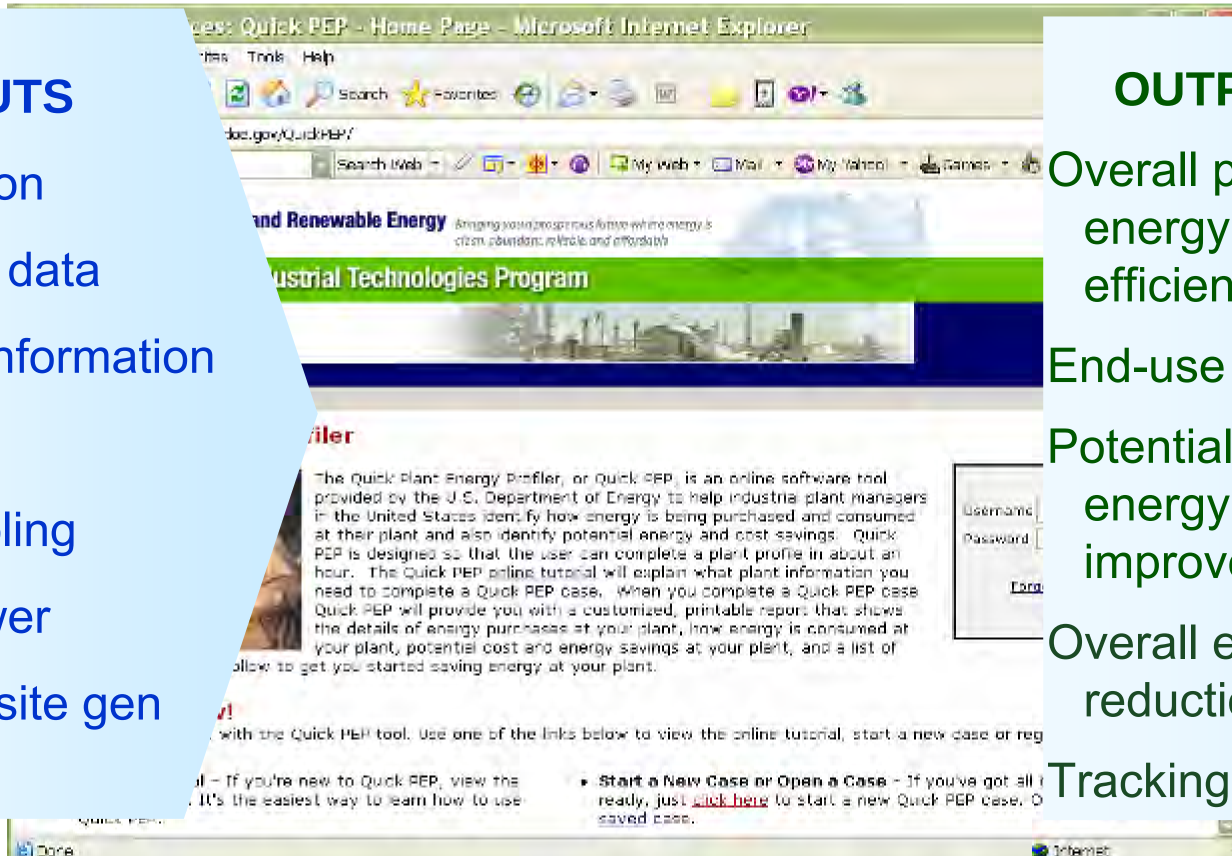
Cooling

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

On-line Profiling Tool

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

Save ENERGY Now



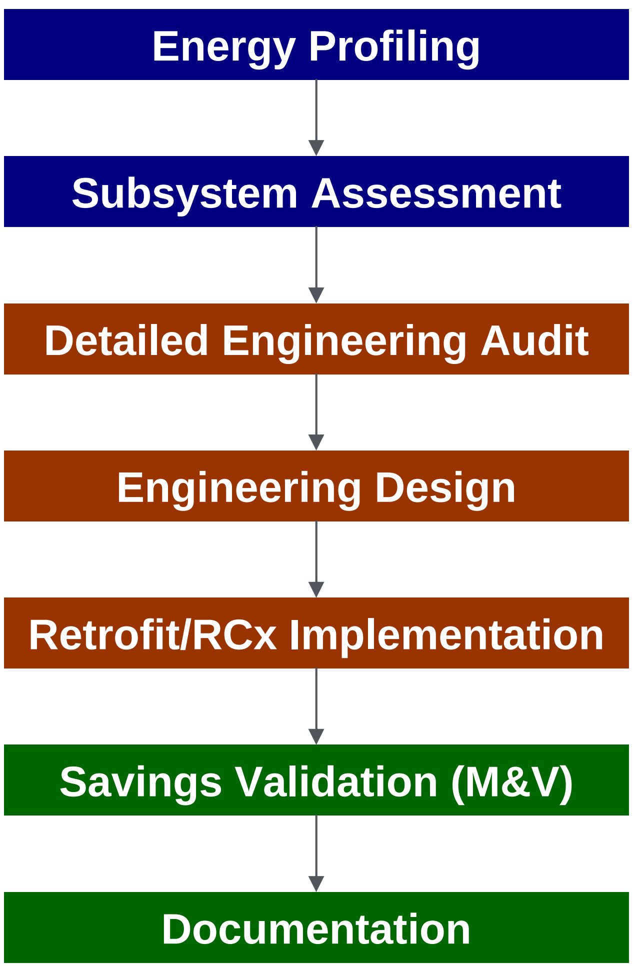
INPUTS

- Description
- Utility bill data
- System information
  - IT
  - Cooling
  - Power
  - On-site gen

OUTPUTS

- Overall picture of energy use and efficiency
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential
- Tracking capability

Steps to Saving Energy:



- Assessments conducted by owners and engineering firms using DOE tools
- Tools provide uniform metrics and approach

- Audits, design and implementation by engineering firms and contractors

- M&V by site personnel and eng firms
- DOE tools used to document results, track performance improvements, and disseminate best practices

Partnering with industry DOE has developed a certificate process leading to energy practitioners qualified to evaluate energy consumption and efficiency opportunities in Data Centers.

Key objective:

- Raise the standards of those involved in energy assessments
- Provide repeatability and credibility of assessment recommendations.

Target groups include:

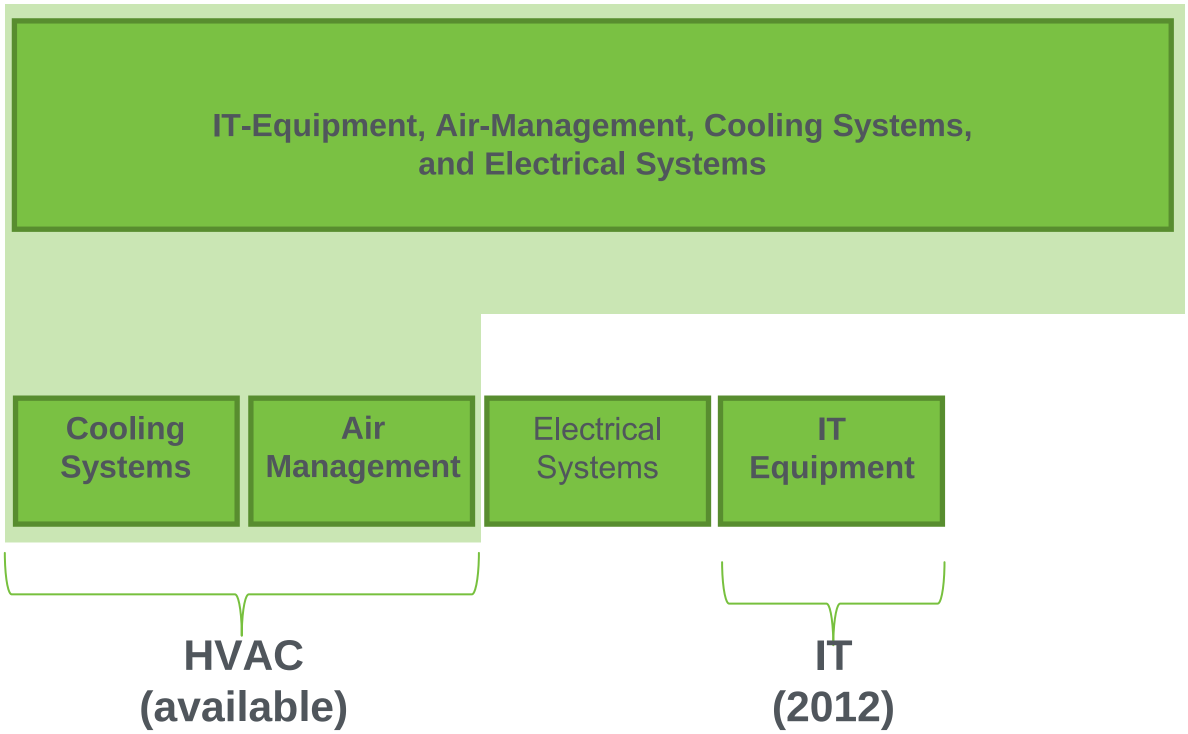
- Data Center personnel (in-house experts)
- Consulting professionals (for-fee consultants)

33

Training & Certificate Disciplines/Levels/Tracks

<u>Level 1 Generalist:</u>
Prequalification, Training and Exam on All Disciplines
+ Assessment Process
+ DC Pro Profiling Tool

<u>Level 2 Specialist:</u>
Prequalification, Training and Exam on Select Disciplines
+ Assessment Process
+ DC Pro System Assessment Tools



<u>Two Tracks:</u>
- Certificate track (training + exam)
- Training track (training only)

What is ENERGY STAR?

A voluntary public-private partnership program

- Buildings
- Products

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
- Evaluating enterprise data storage, UPS, and networking equipment for Energy STAR product specs

Resources

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

FEMP Federal Energy Management Program

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

BERKELEY LAB

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

ENERGY STAR

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

Save ENERGY Now ®

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


Questions?

Energy metrics and benchmarking

Presented by: Dale Sartor, PE

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

FEMP
Federal Energy Management Program

GSA

AGENDA

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

Morning

- Introductions to course and instructors
- **Performance metrics and benchmarking**
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions

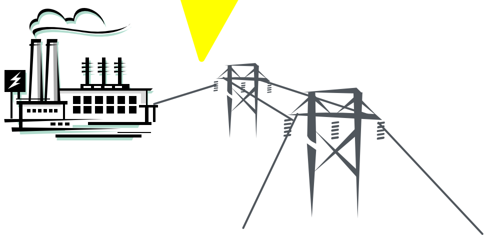
Lunch On your own

Afternoon

- Airflow management
- Cooling systems
- Electrical systems
- Summary and Takeaways

Efficiency opportunities are everywhere

Source and transmission losses



- Power management
- Virtualization
- Server innovation
- Heat recovery

- **Better air management**
- **Better environmental conditions**
- **Move to liquid cooling**
- **Optimized chilled-water plants**
- **Use of free cooling**
- **Reuse of waste heat**

Power Conversion & Distribution

Server Load/ Computing Operations

Cooling Equipment

On-site generation

- High voltage distribution
- Use of DC power
- Highly efficient UPS systems
- Efficient redundancy strategies

- Rejected heat for cooling
- Use of renewable energy/fuel cells
- Eliminate transmission losses

Energy metrics and benchmarking

Where does all of the energy go?

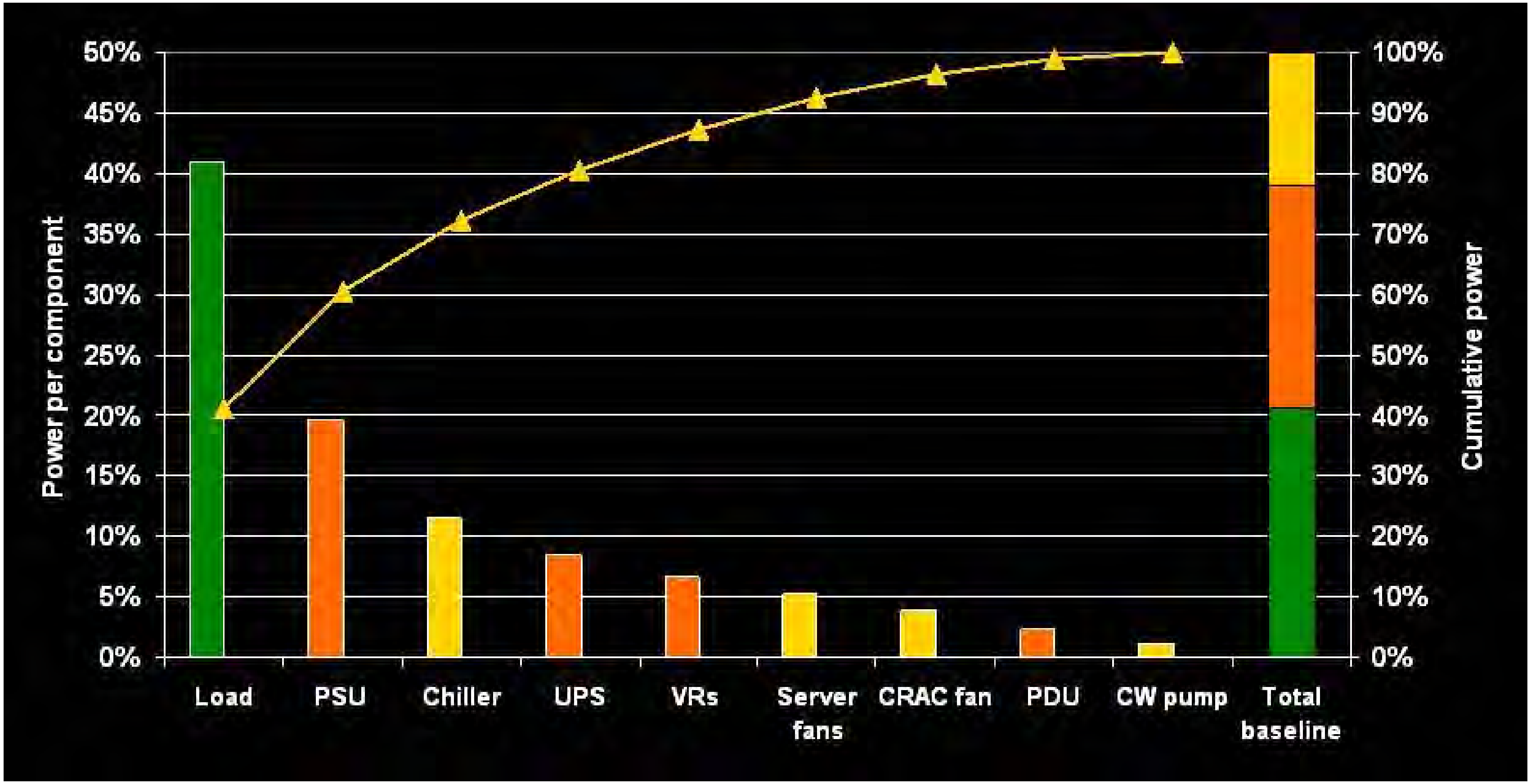
- Consider an energy monitoring and control system

How efficient is the data center?

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

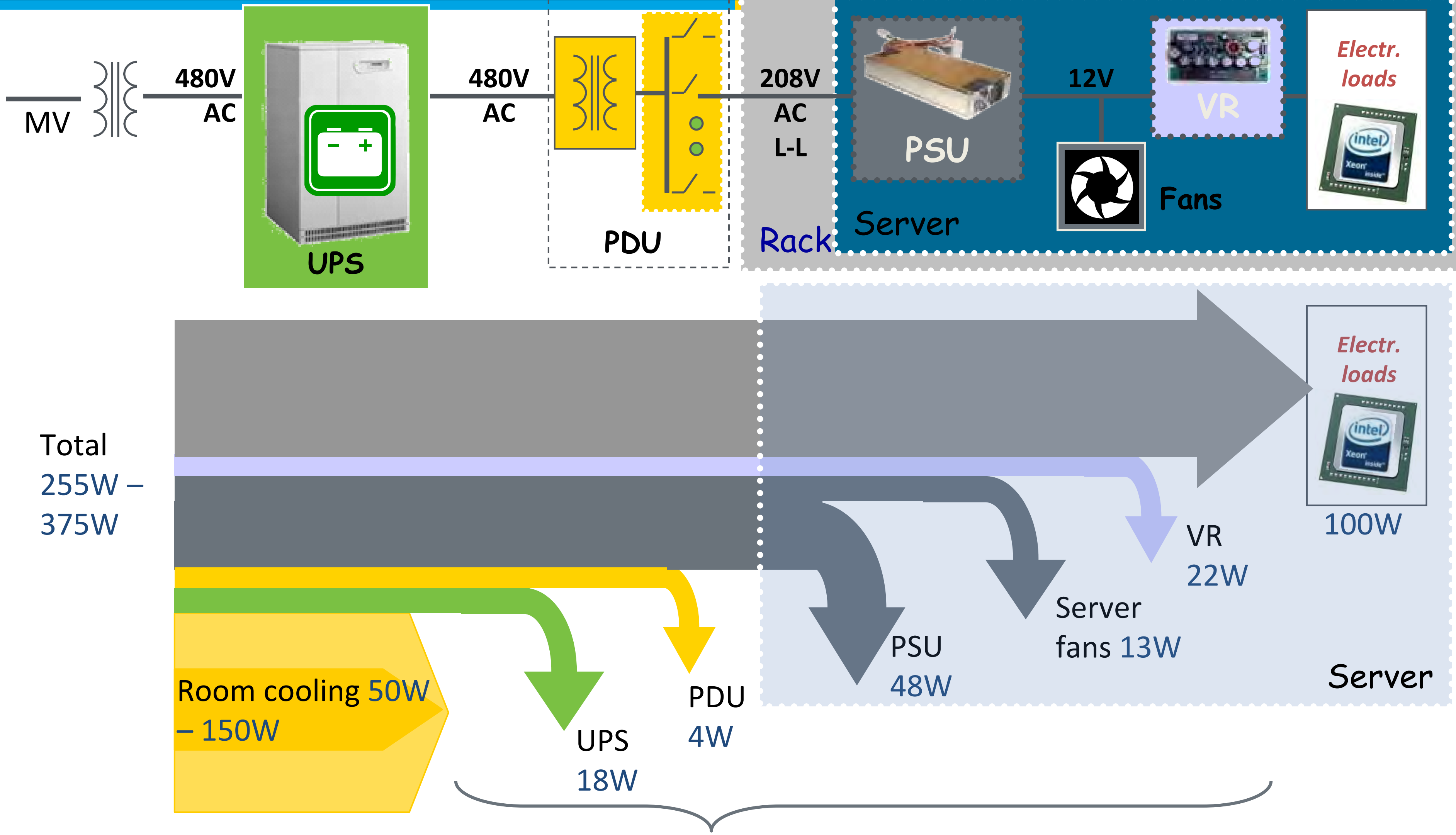
Electricity use in data centers

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



Courtesy of Michael Patterson, Intel Corporation

Power distribution – in a typical US data center today



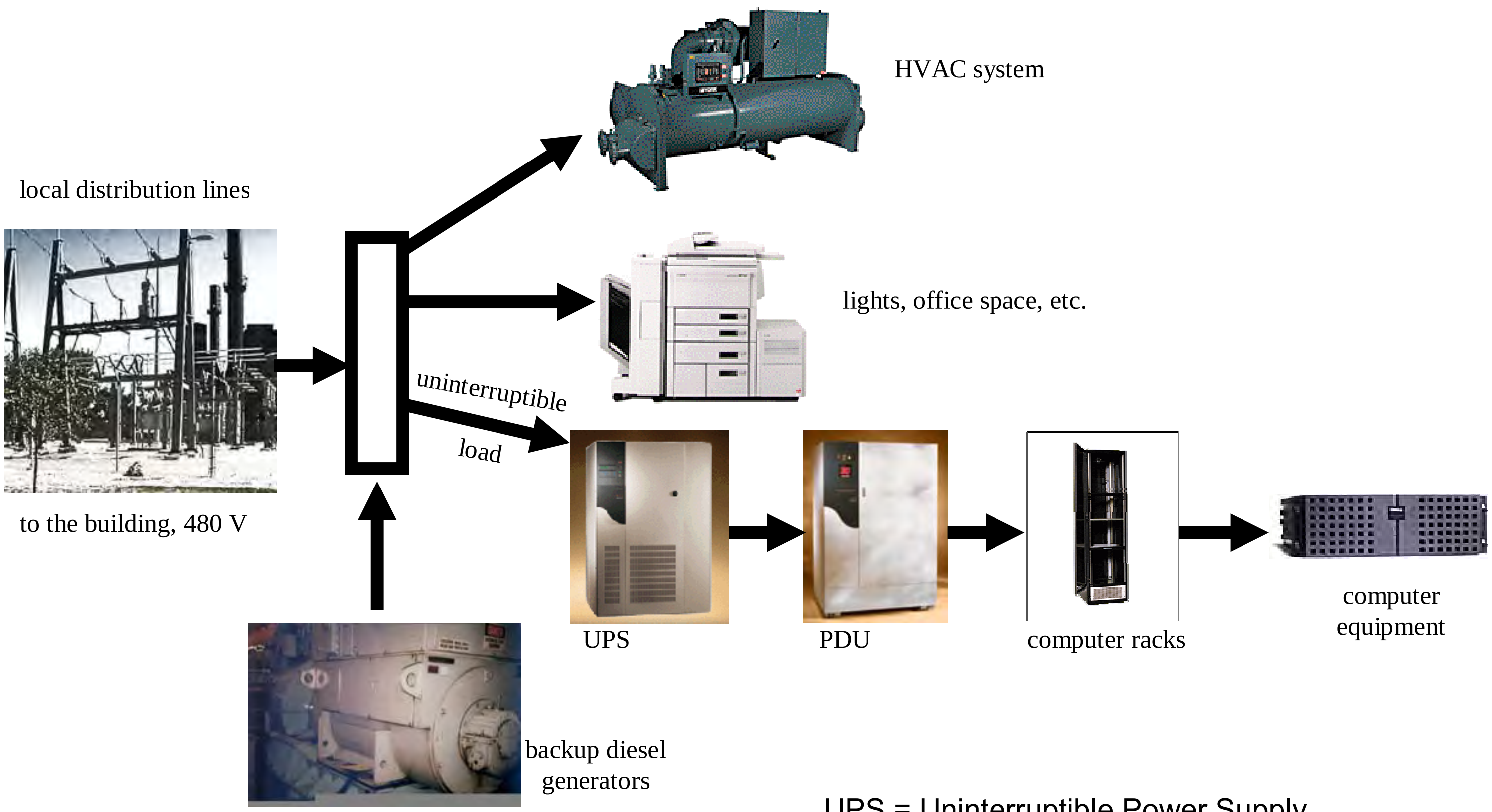
~50% of power lost in power distribution

Benchmarking for Energy Performance Improvement:

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

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

Electricity Flows in Data Centers



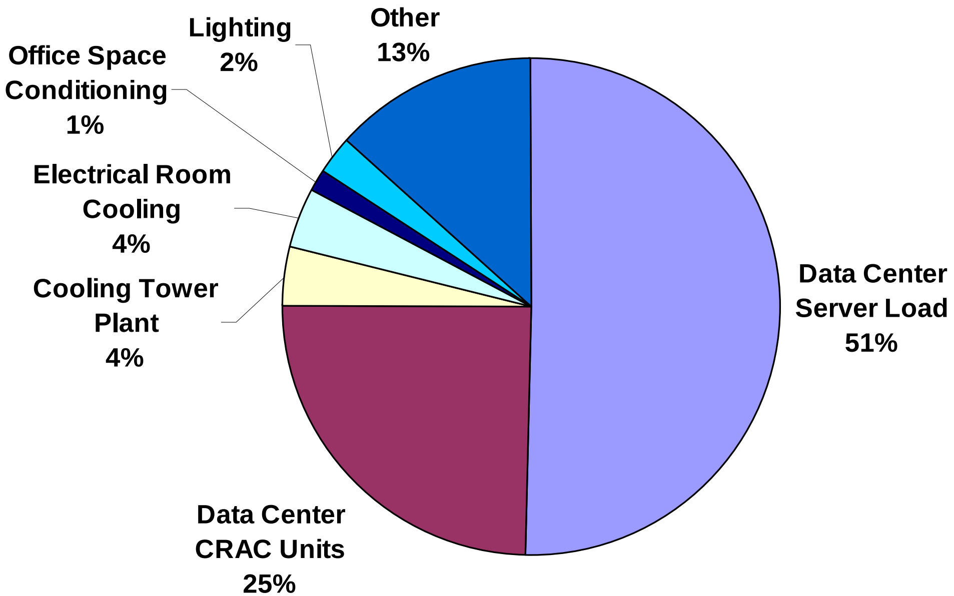
UPS = Uninterruptible Power Supply

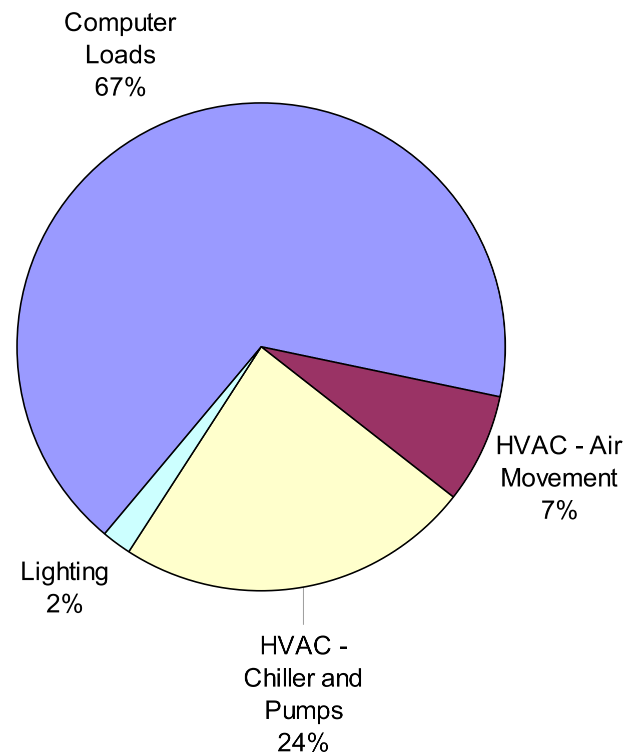
PDU = Power Distribution Unit;

Your Mileage Will Vary

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

The relative percentages of the energy doing computing varies considerably.

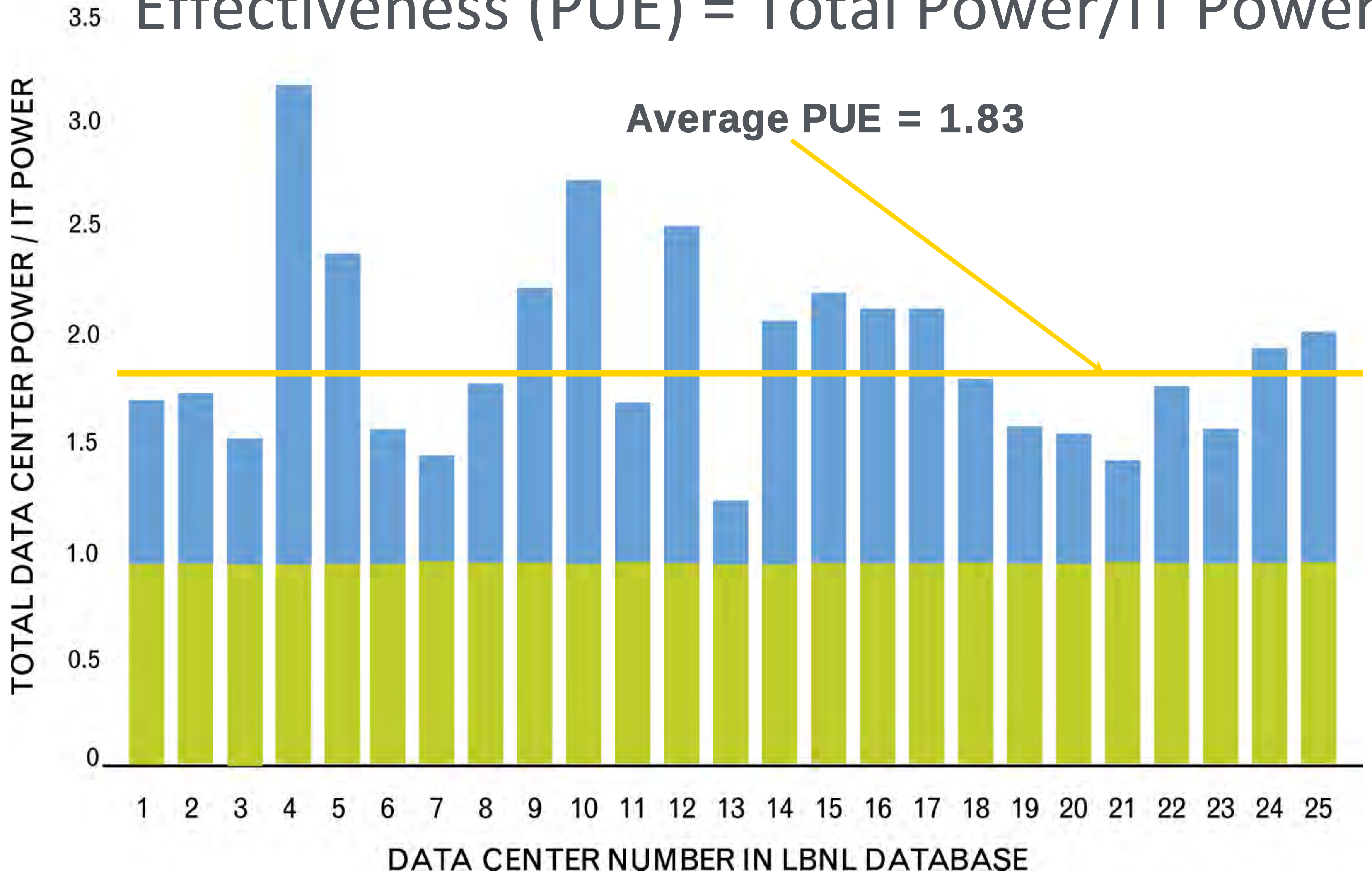




Benchmarks obtained by LBNL

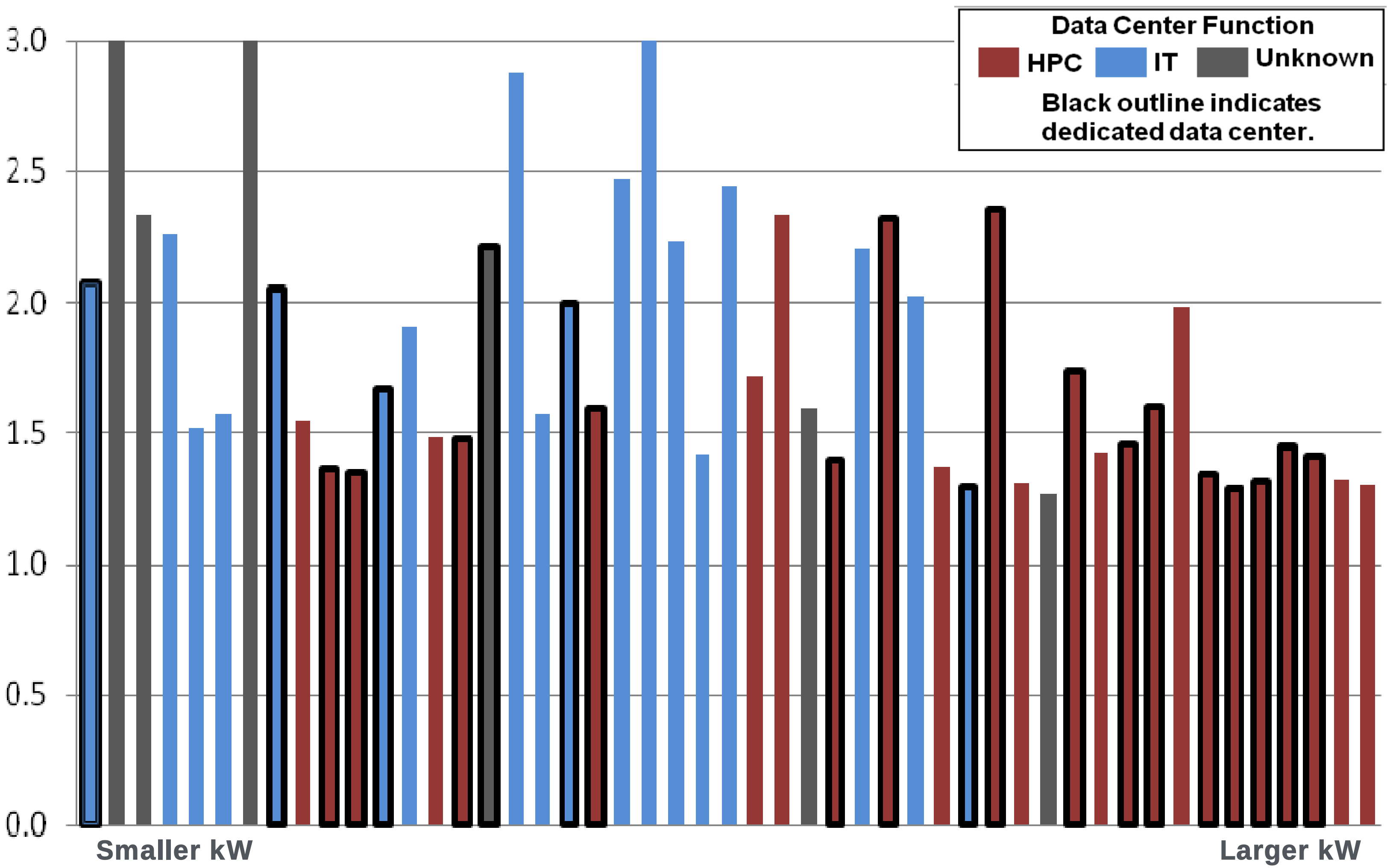
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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

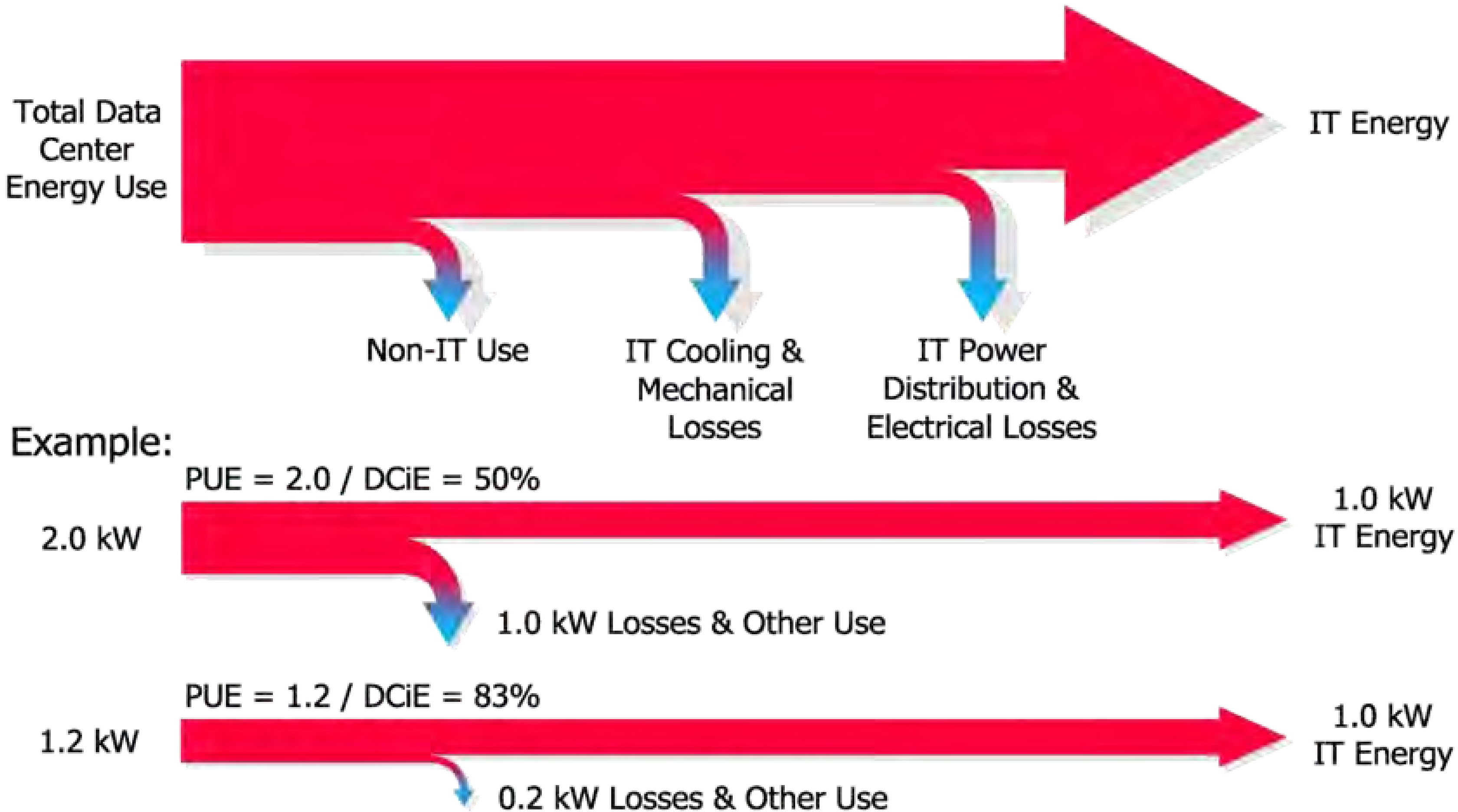


PUE of DOE Data Centers

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



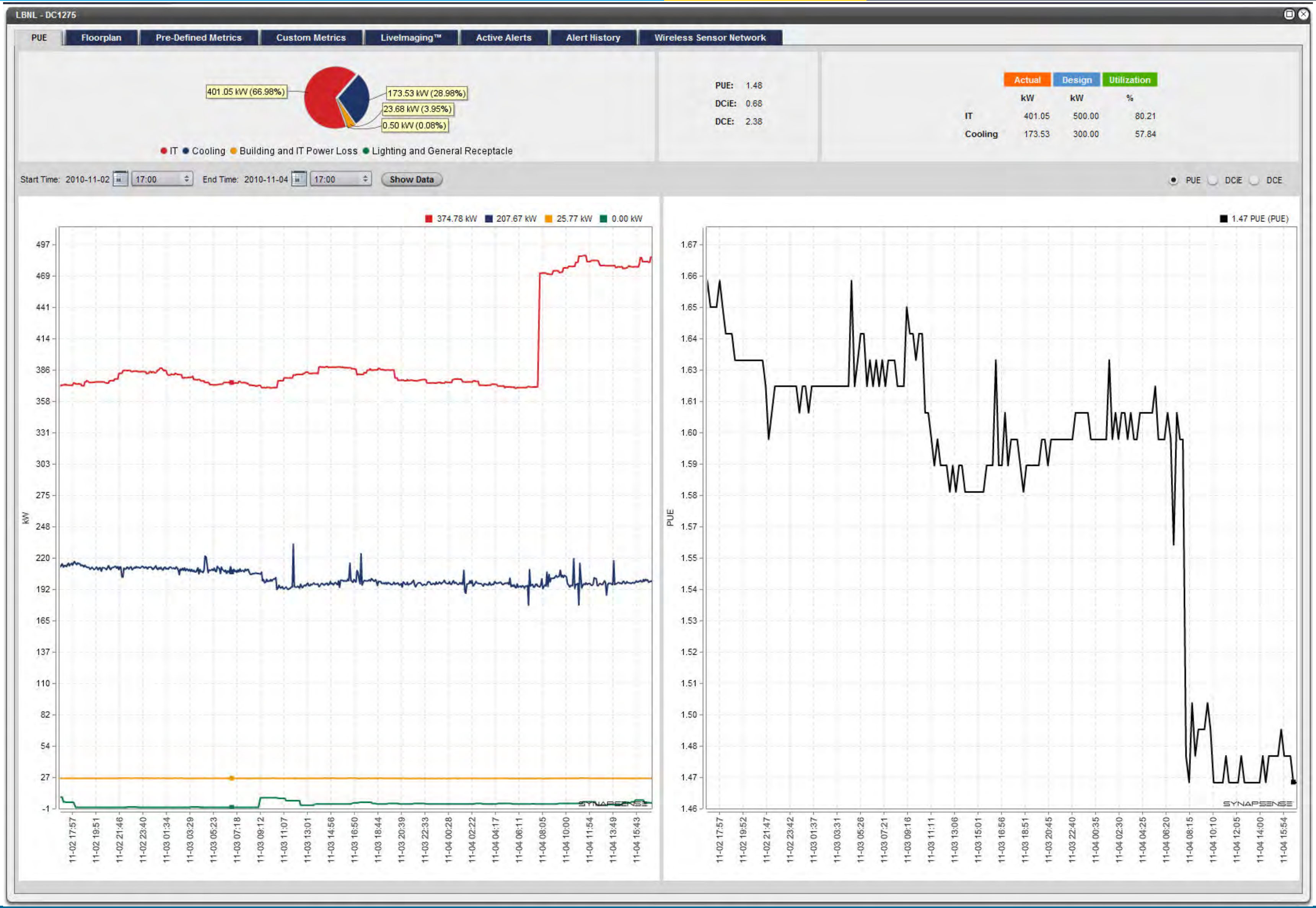
PUE and Energy Savings



<u>40% Energy Savings</u> going from PUE = 2.0 to 1.2

Real-time PUE Display

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



PUE Calculation Diagram

Other Data Center Metrics:

- Watts per square foot, Watts per rack
- Power distribution: UPS efficiency, IT power supply efficiency
  - Uptime: IT Hardware Power Overhead Multiplier (ITac/ITdc)
- HVAC
  - IT total/HVAC total
  - 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)/ITΔT
- Lighting watts/square foot

Metrics & Benchmarking

Power Usage Effectiveness

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

Standard	Good	Better
2.0	1.4	1.1

Airflow Efficiency

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

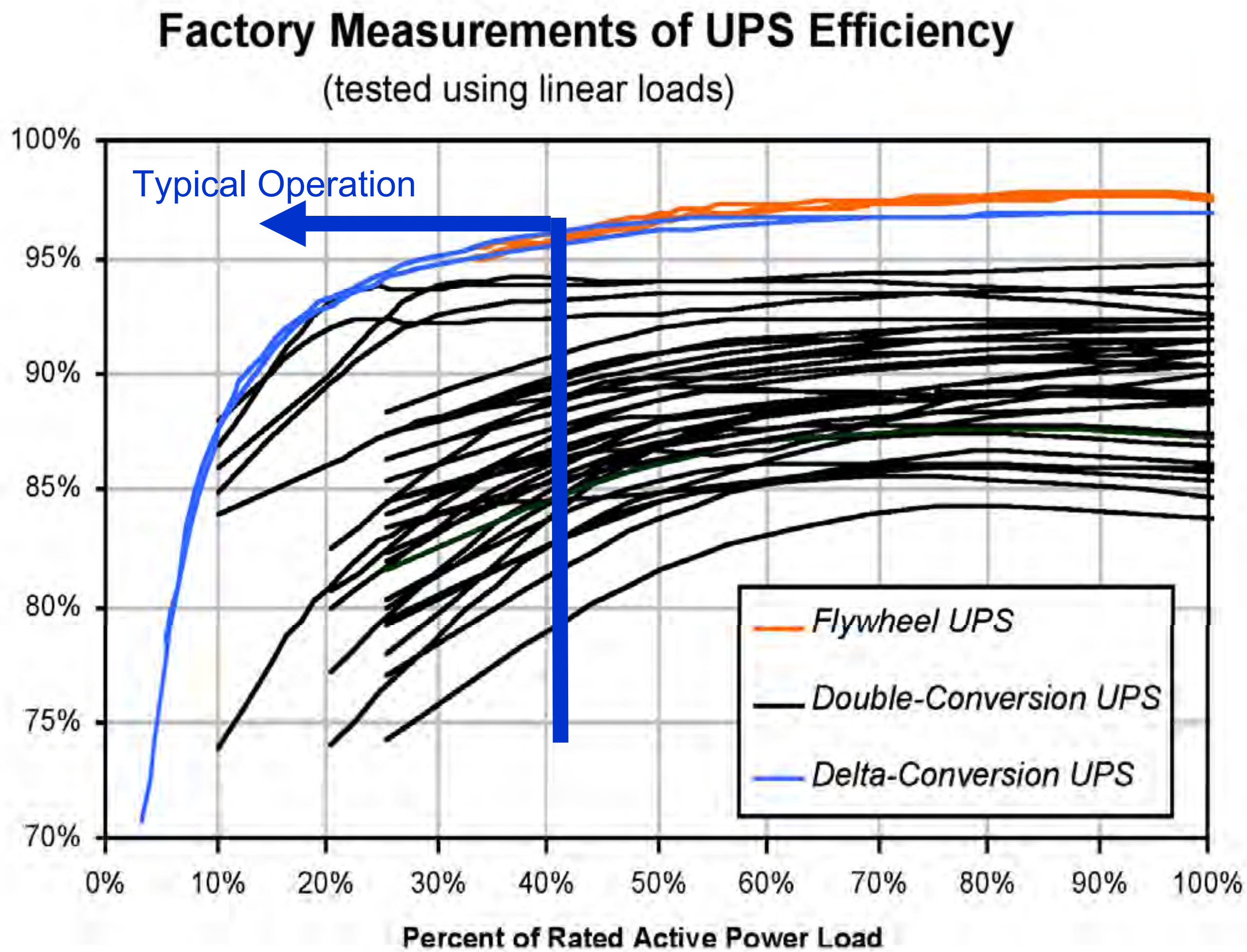
Standard	Good	Better
1.25W/cfm	0.75 W/cfm	0.5 kW/cfm

Cooling System Efficiency

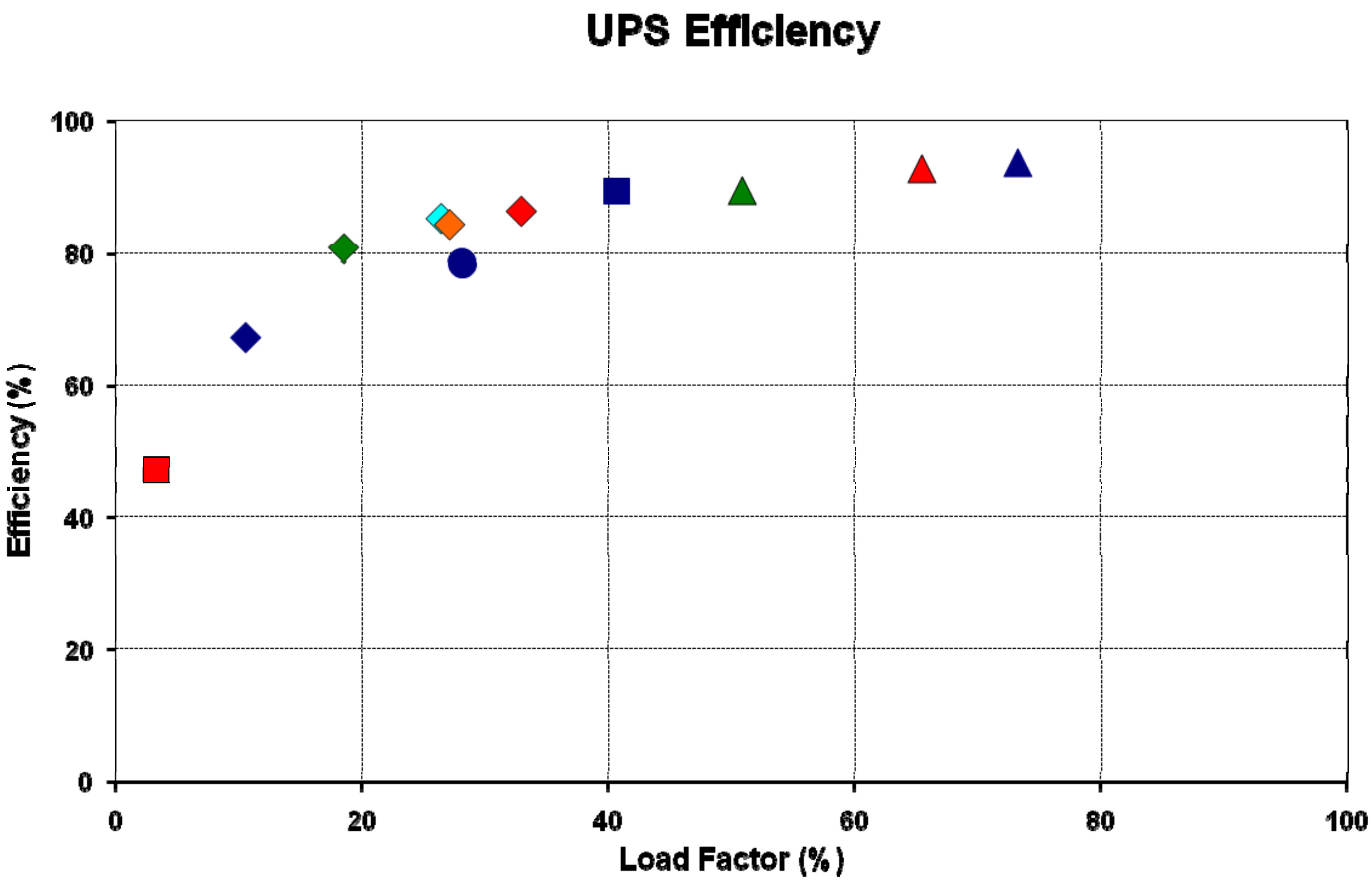
$$\frac{\text{Average Cooling System Power (kW)}}{\text{Average Cooling Load (ton)}}$$

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

UPS factory measurements

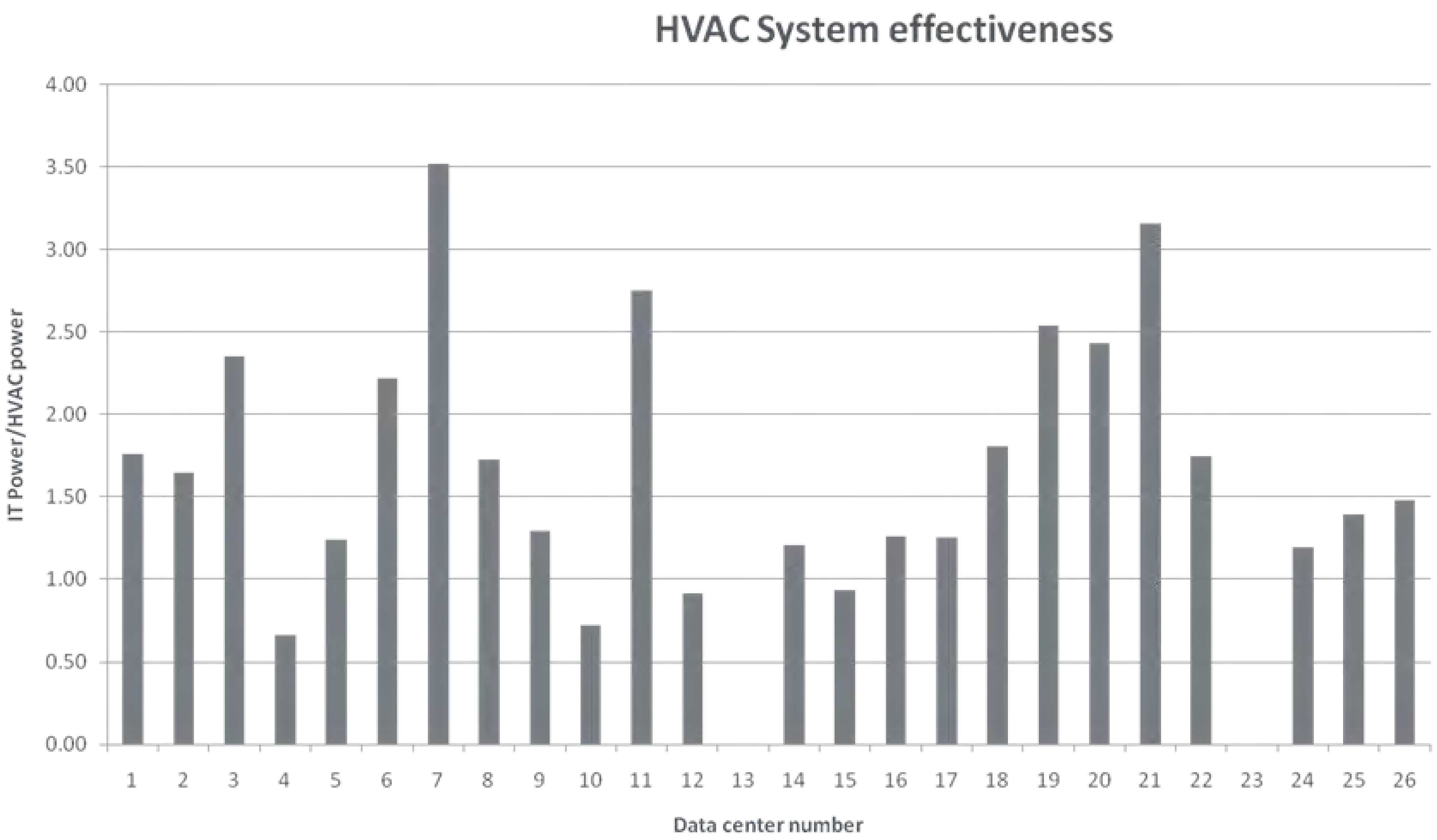


Benchmarked UPS performance



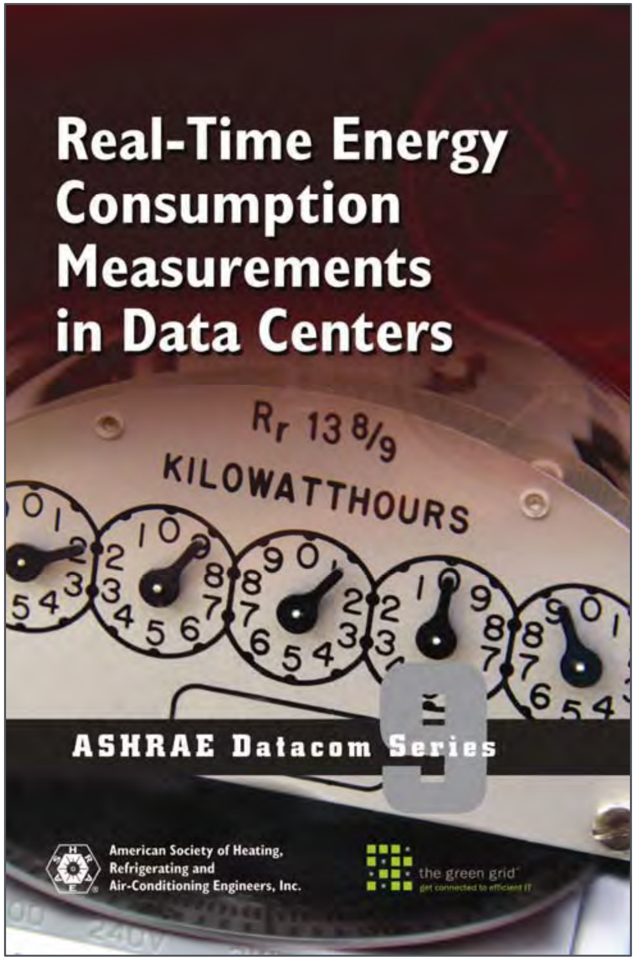
HVAC Effectiveness

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



ASHRAE / Green Grid Measurements Book

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



- **Chapter 1** – Introduction
- **Chapter 2** – How, What, & Where To Measure
- **Chapter 3** – Measurement Devices
- **Chapter 4** – Measurement Collection Systems…
- **Chapter 5** – Air Handlers
- **Chapter 6** – Computer Room Units
- **Chapter 7** – Pumps
- **Chapter 8** – Cooling Towers
- **Chapter 9** – Chillers
- **Chapter 10** – Heat Exchangers
- **Chapter 11** – Introduction To Critical Power Distribution
- **Chapter 12** – Upstream Critical Power Distribution
- **Chapter 13** – Uninterruptible Power Supply (UPS)
- **Chapter 14** – Computer Room Transformer & PDU
- **Chapter 15** – Compute & Storage Systems
- **Chapter 16** – Networking Systems
- **Appendices A – F**

DOE DC Pro Tool Suite

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

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 Excel 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

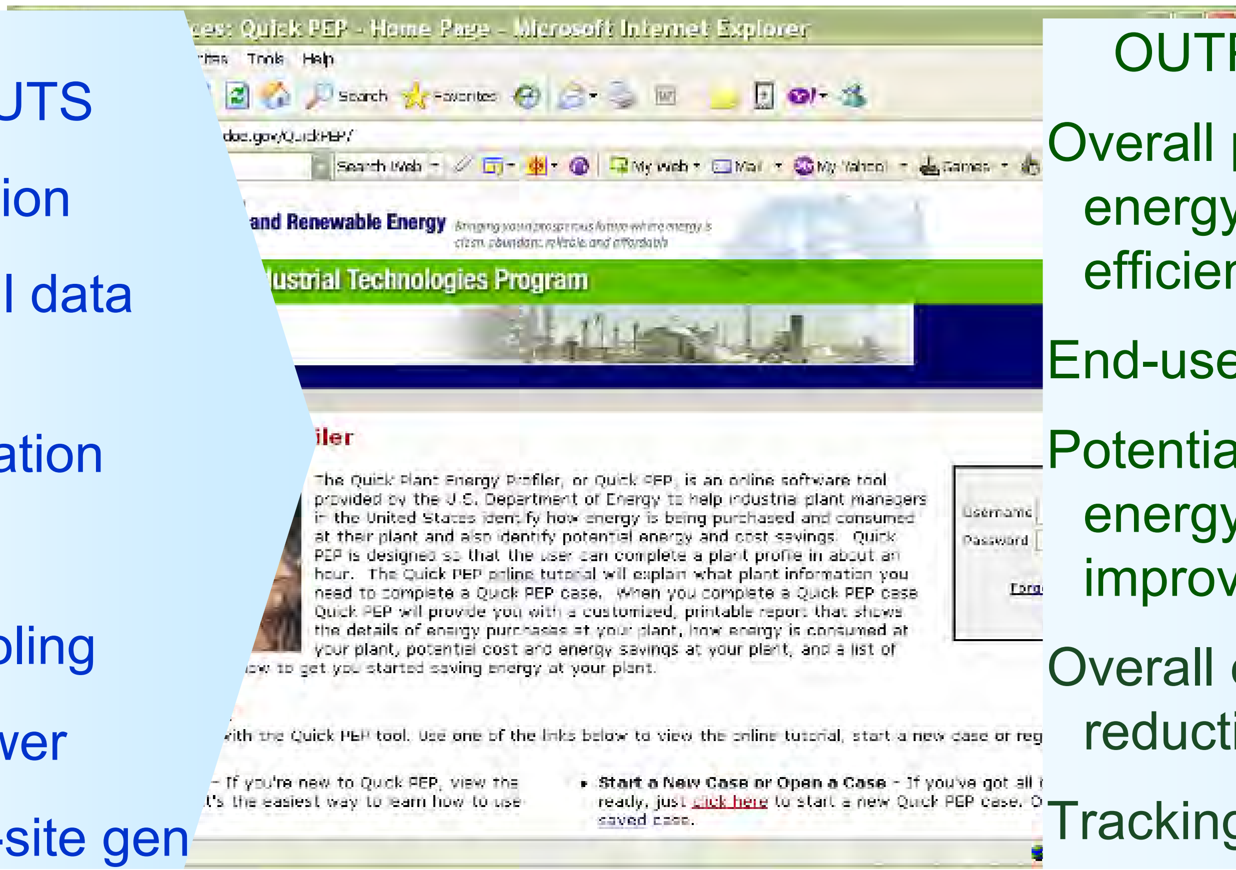
Save Energy Now on-line profiling tool "Data Center Pro"

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

Save ENERGY Now

INPUTS

- Description
- Utility bill data
- System information
  - IT
  - Cooling
  - Power
  - On-site gen



OUTPUTS

- Overall picture of energy use and efficiency
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential
- Tracking capability

Example of DC Pro Recommendations

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

List of Actions (for the Electric Distribution System)

- Avoid lightly loaded UPS systems
- Use high efficiency MV and LV transformers
- Reduce the number of transformers upstream and downstream of the UPS
- Locate transformers outside the data center
- Use 480 V instead of 208 V static switches (STS)
- Specify high-efficiency power supplies
- Eliminate redundant power supplies
- Supply DC voltage to IT rack

61

DC Pro Output

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

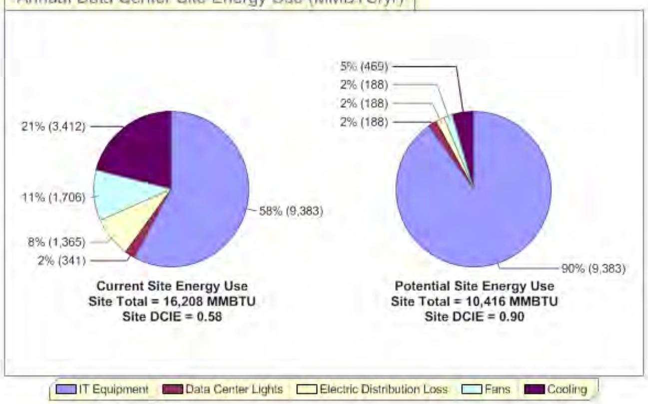
File Edit View History Bookmarks Tools Help

Potential Annual Energy Savings Suggested Next Steps

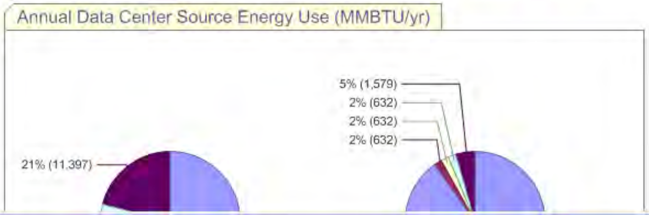
The following chart and data table summarize your data center's potential annual energy savings by breakout catergory.
NOTE: The energy and money savings listed below are only estimates based on the data you entered and the estimated costs associated with the data center suggested improved. Your actual savings will vary.

Breakout Category	Current Energy Use				Potential Energy Use				Potential Savings (Site Energy)		
	Site Energy		Source Energy		Site Energy		Source Energy				
	MMBTU/yr	%	MMBTU/yr	%	MMBTU/yr	%	MMBTU/yr	%	MMBTU/yr	%	$
IT Equipment	9,383	58%	31,341	58%	9,383	90%	31,575	90%	0	0%	$ 0.00
Data Center Lights	341	2%	1,140	2%	188	2%	632	2%	154	1%	$ 4,736.84
Electric Distribution Losses	1,365	8%	4,559	8%	188	2%	632	2%	1,177	7%	$ 36,315.79
Fans	1,706	11%	5,698	11%	188	2%	632	2%	1,518	9%	$ 46,842.11
Cooling	3,412	21%	11,397	21%	469	5%	1,579	5%	2,943	18%	$ 90,789.47
Total	16,208	100%	54,134	100%	10,416	100%	35,048	100%	5,792	36%	$ 178,684.21
DCIE		0.58		0.58		0.90		0.90			

Annual Data Center Site Energy Use (MMBTU/yr)



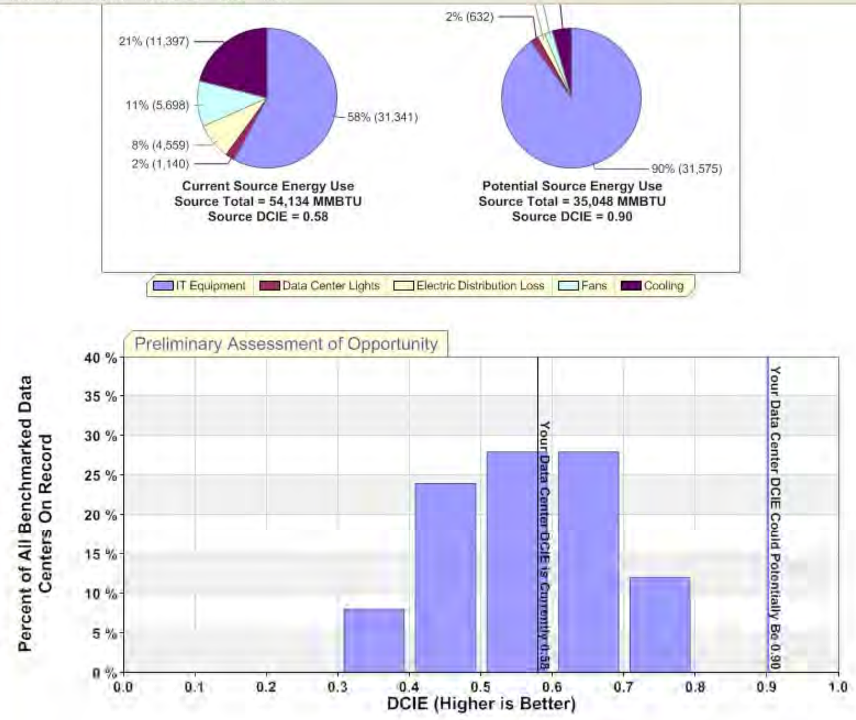
Annual Data Center Source Energy Use (MMBTU/yr)



DC Pro Output

DCPro Report - Mozilla Firefox

File Edit View History Bookmarks Tools Help



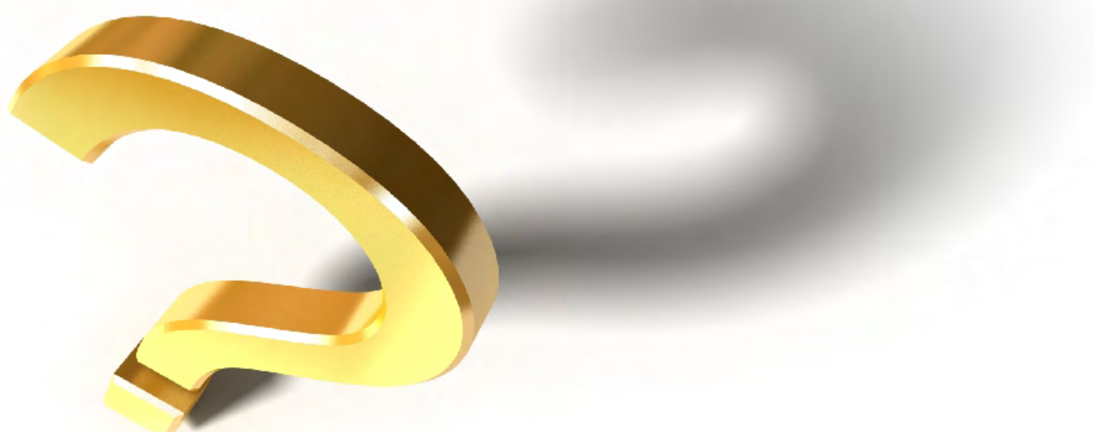
Potential Annual CO_2 Savings

Based on the potential energy savings identified above, your data center may be able to reduce emissions of CO_2. The following potential annual CO_2 emission savings numbers are broad estimates based on the estimated costs associated with the data center suggested improved and are not meant to reflect actual realized savings at your data center.

Potential Annual CO_2 Savings From Electricity 5,792.11 lbs.
Potential Annual CO_2 Savings From Fuel/Steam 1,696,576.17lbs

Previous | Save & Continue

Questions?



IT Systems Efficiency

Presented by: Dale Sartor, PE

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

FEMP
Federal Energy Management Program

GSA

AGENDA

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

Morning

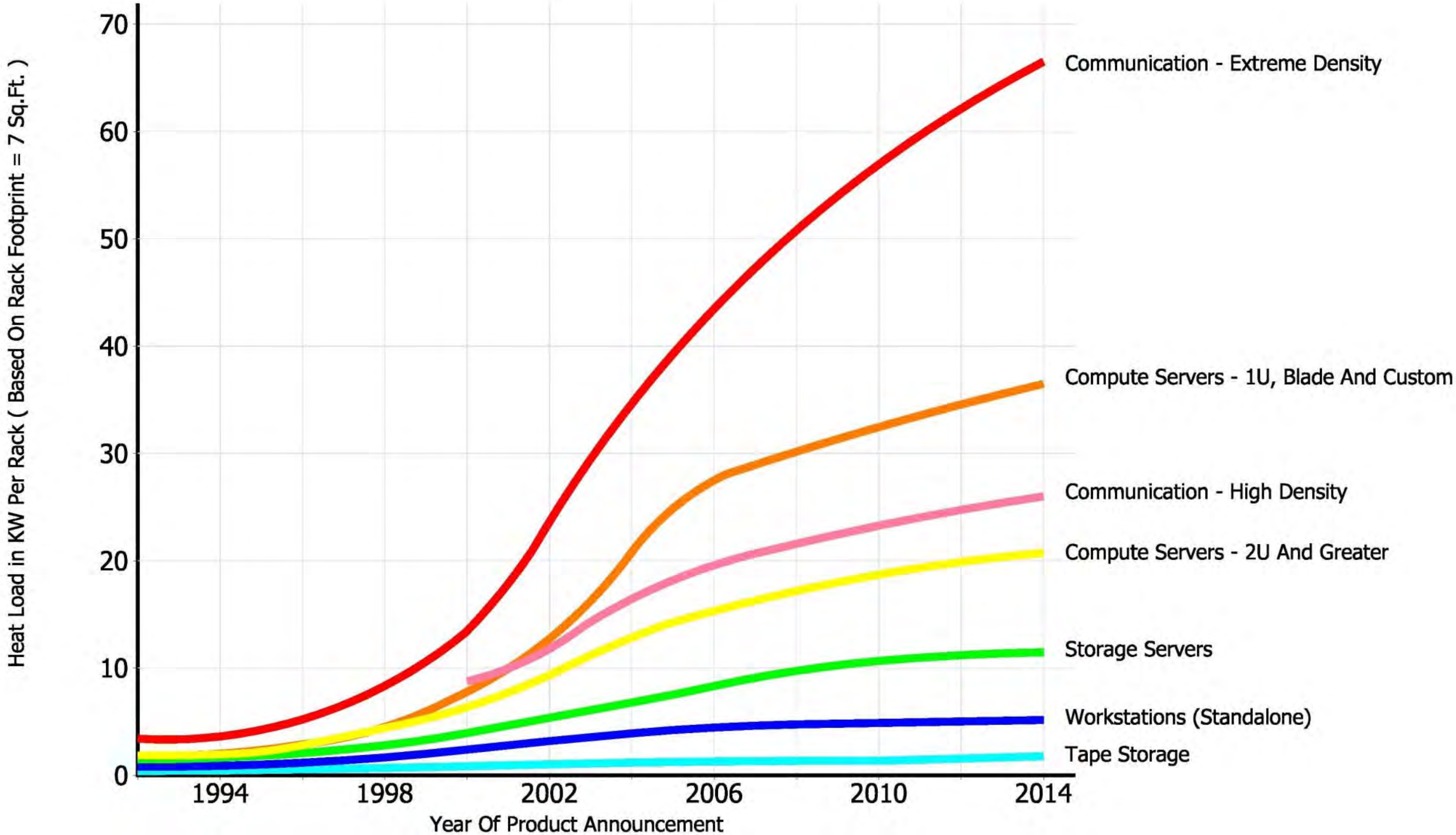
- Introductions to course and instructors
- Performance metrics and benchmarking
- **IT equipment and software efficiency**
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions

Lunch On your own

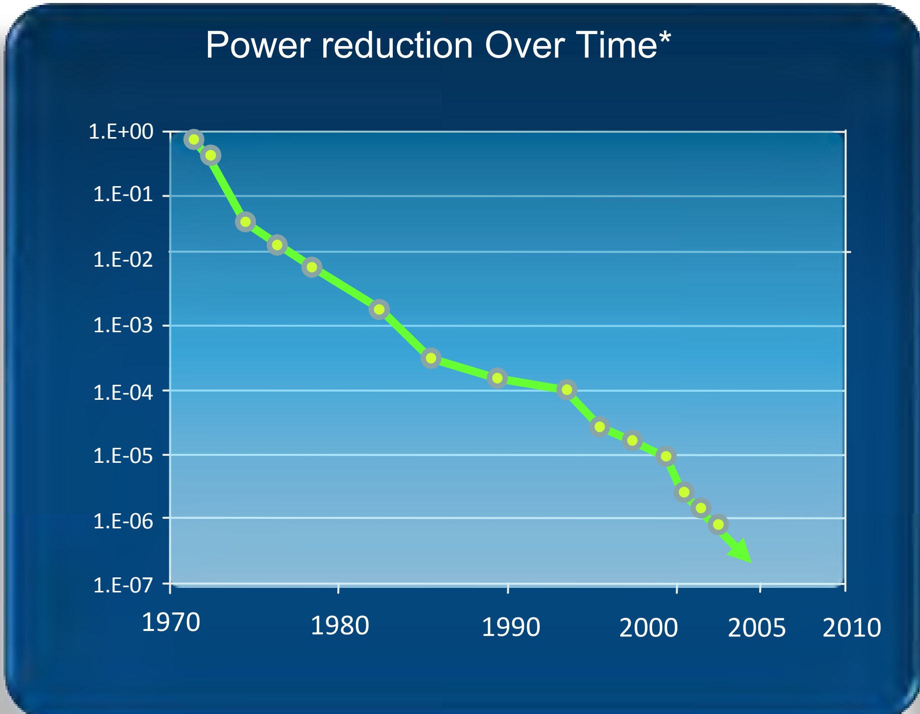
Afternoon

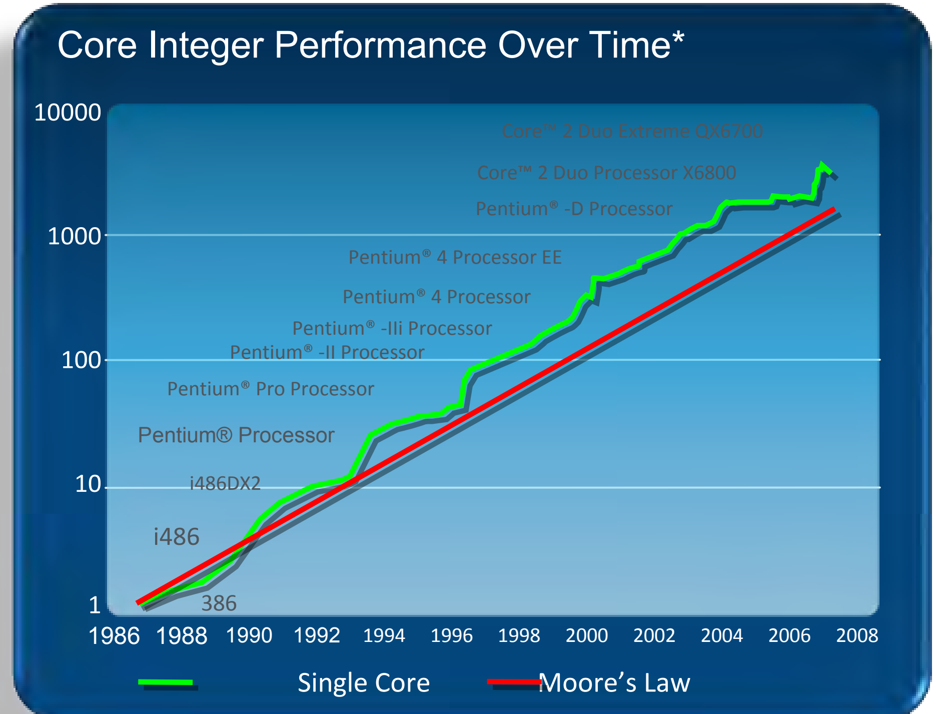
- Airflow management
- Cooling systems
- Electrical systems
- Summary and Takeaways

Server & Component Power Trends – kW/Rack



Moore's Law = Miniaturization = Continuous Chip-level Energy Efficiency Improvements, from 1 year to the next





- Every year, Moore's Law drives smaller, more energy-efficient transistors
- 1 million x factor reduction in energy/transistor over 30+ years
- Smaller, faster transistors = faster AND more efficient chips

Source: Intel Corp.

IT System Efficiency

Servers

- Choose *variable speed fans*
- Enable *power management capabilities*!
- Use EnergyStar® Servers

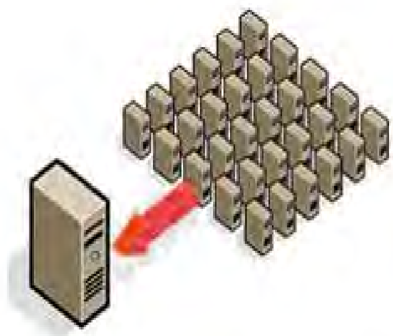
Power Supplies

- Optimal load level: 40-60%
- Reconsider Redundancy
- 80 PLUS Program offers certification of efficient power supplies

Storage Devices

- Take superfluous data offline
- Use thin provisioning technology

Consolidation



- Group hardware with similar heat load densities
- Practice virtualization

IT systems issues

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

- Predicting IT loads
  - Over sizing, at least initially, is common
  - Over estimating of IT loads can lead to inefficiencies in electrical and mechanical systems (and higher capital costs)
- IT loads can be controlled
  - Server efficiency
    - Power supply efficiency
    - Redundancy options
    - Low power modes
    - Fan energy
    - Liquid cooling
  - Software efficiency
  - Virtualization, MAID, etc.
  - Redundancy and back-up power
- Reducing IT load has a multiplier effect
- Setting environmental conditions is an opportunity

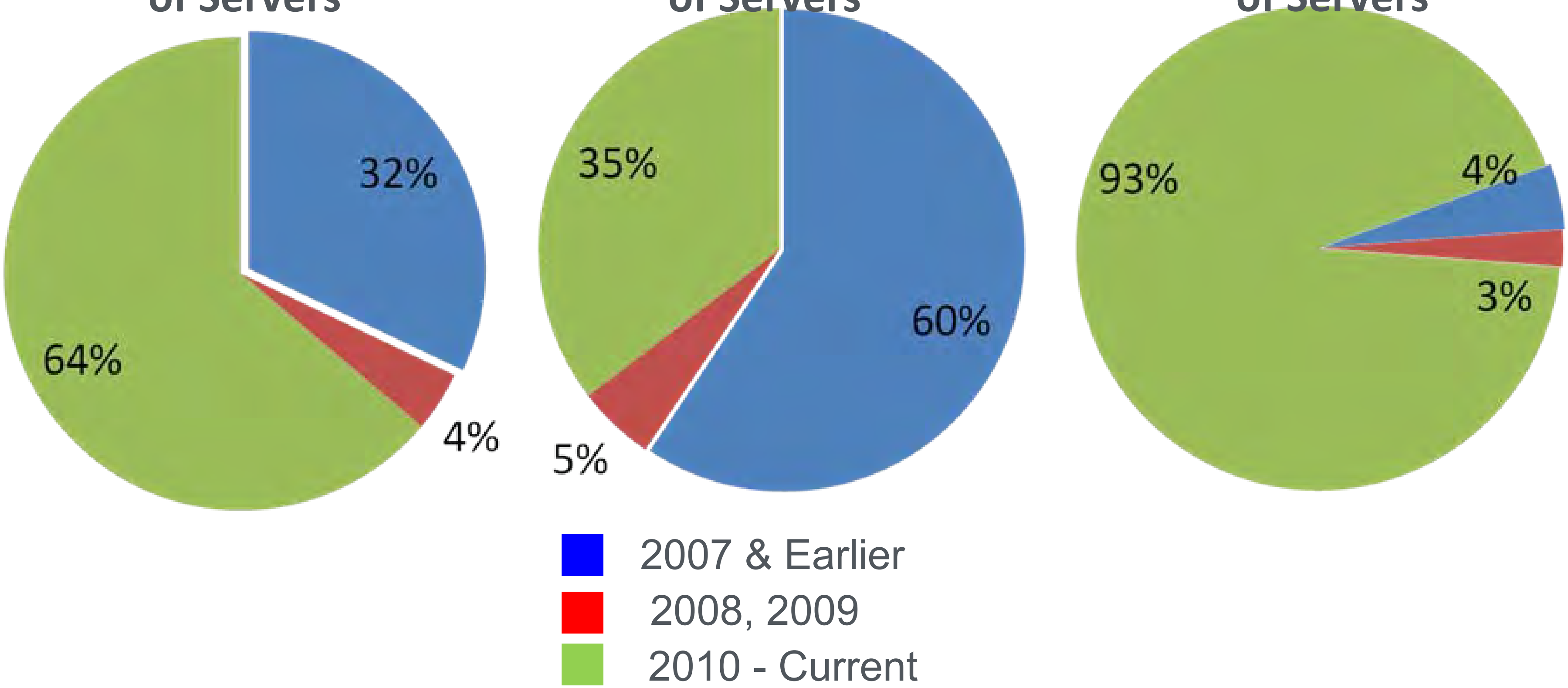
SLA - Service Level Agreements – Definition

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

- **An SLA is an agreement describing the level of service expected by a customer from a supplier** (can be the IT dept. and the facilities dept).
  - Increases understanding, awareness and results
  - Commonly used in colocation types of data centers but can also be established between two departments in the same organization
  - Can establish environmental conditions and expected efficiencies
- **SLAs lay out the metrics used to measure the service**
  - Define and resolve issues regarding boundary conditions between IT equipment and the facility infrastructure / environment supporting it (power, cooling, maintenance, redundancy, etc.)

IT equipment Performance

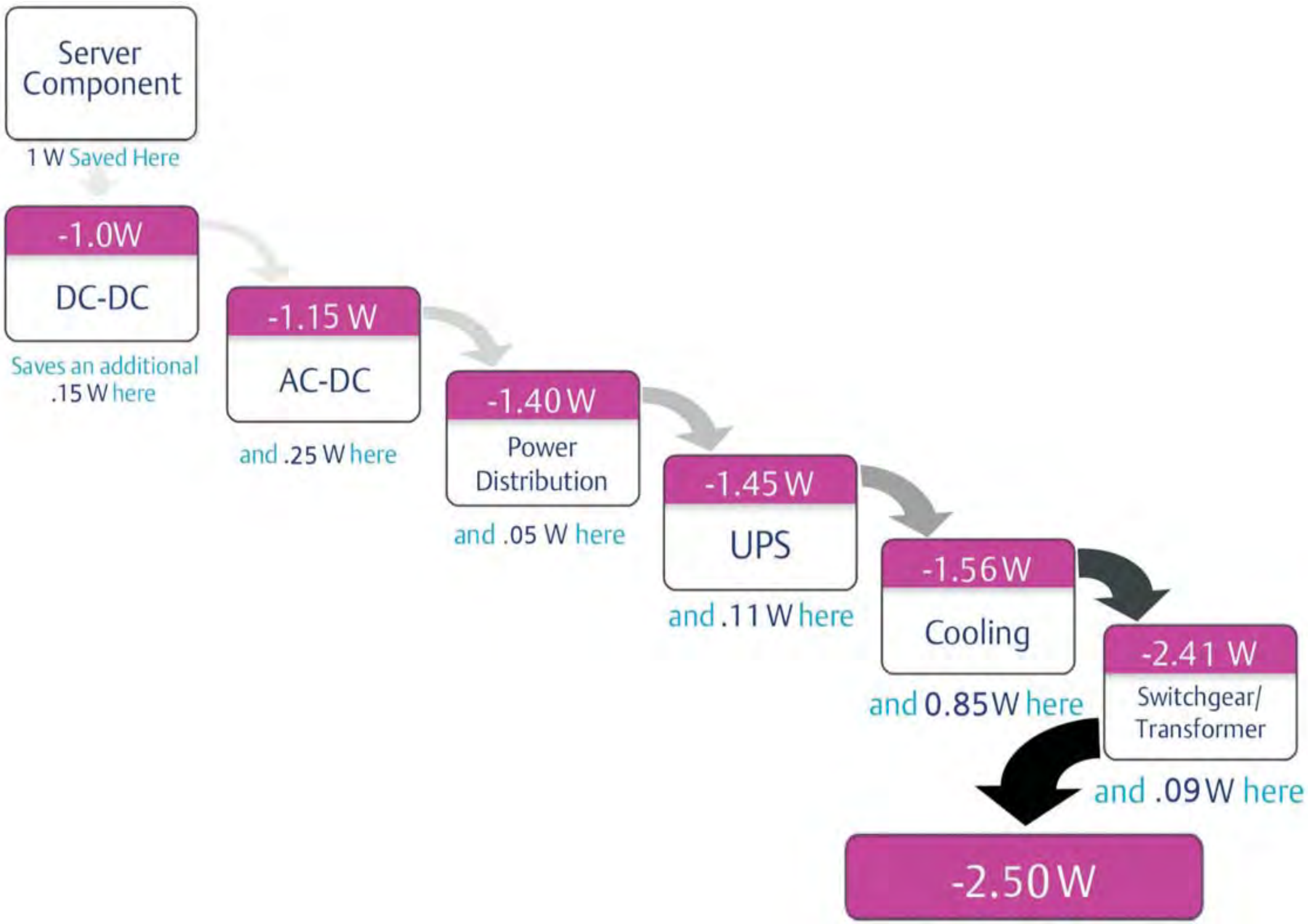
Age Distribution of Servers | Energy Consumption of Servers | Performance Capability of Servers



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

The value of one watt saved at the IT equipment

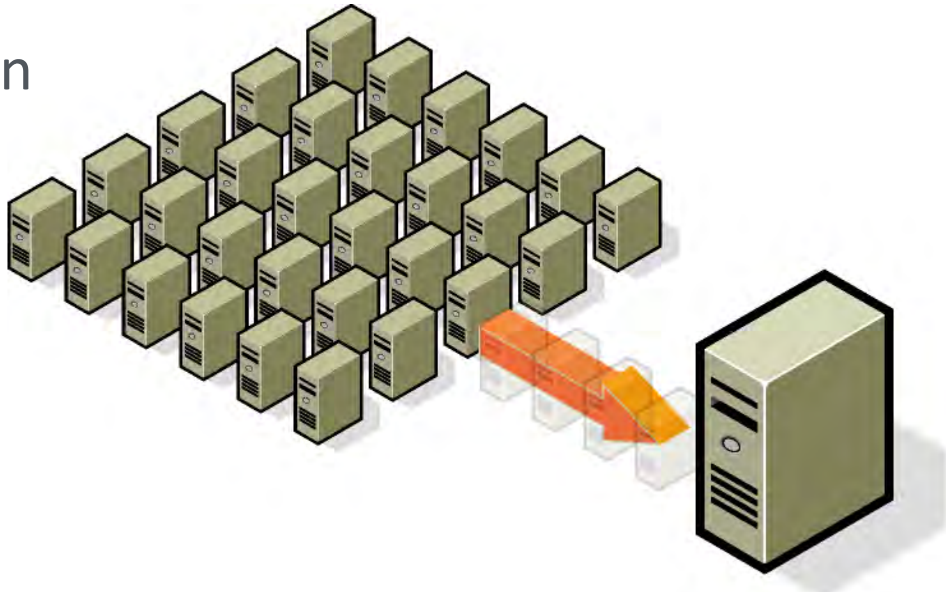


Selected IT Systems Energy Best Practices

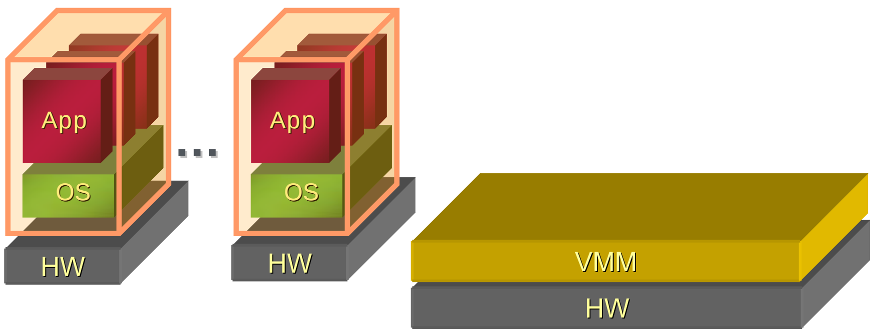
1. Server and Storage Virtualization and Consolidation
2. Power Supply Efficiency
3. IT Asset Management & Disposal
4. Cloud Computing
5. IT Systems Energy Audits

Virtualization

- Run many “virtual” machines on a single “physical” machine
- Developed in the 1960s to achieve better utilization & efficiency
- Can consolidate underutilized physical machines, increasing utilization
- Energy saved by shutting down or eliminated by underutilized machines
- Virtualization is hardware and operating system independent.

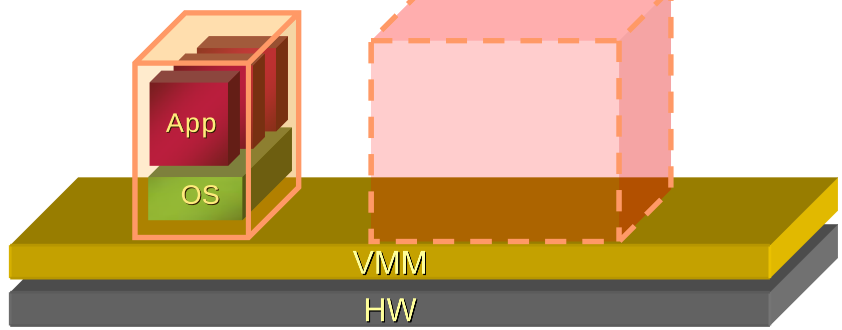


Server Consolidation



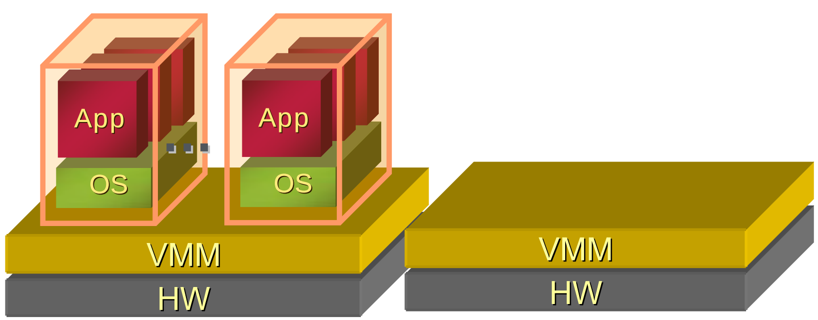
10:1 in many cases

R&D Production



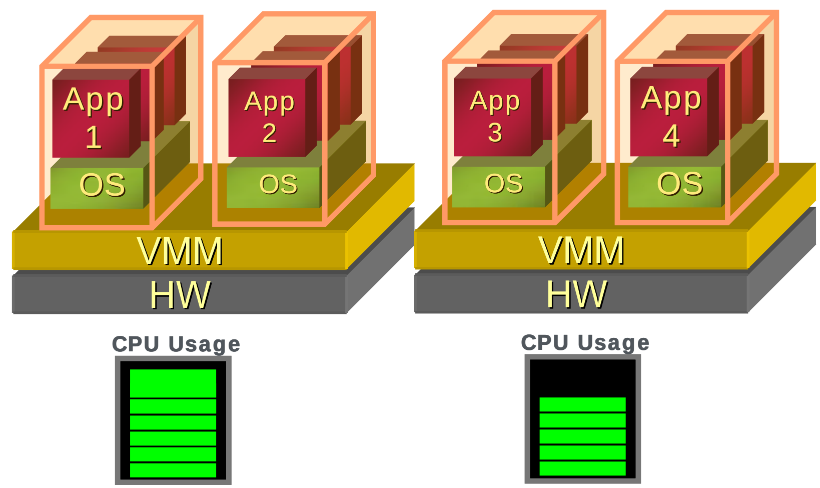
Enables rapid deployment, reducing number of idle, staged servers

Disaster Recovery



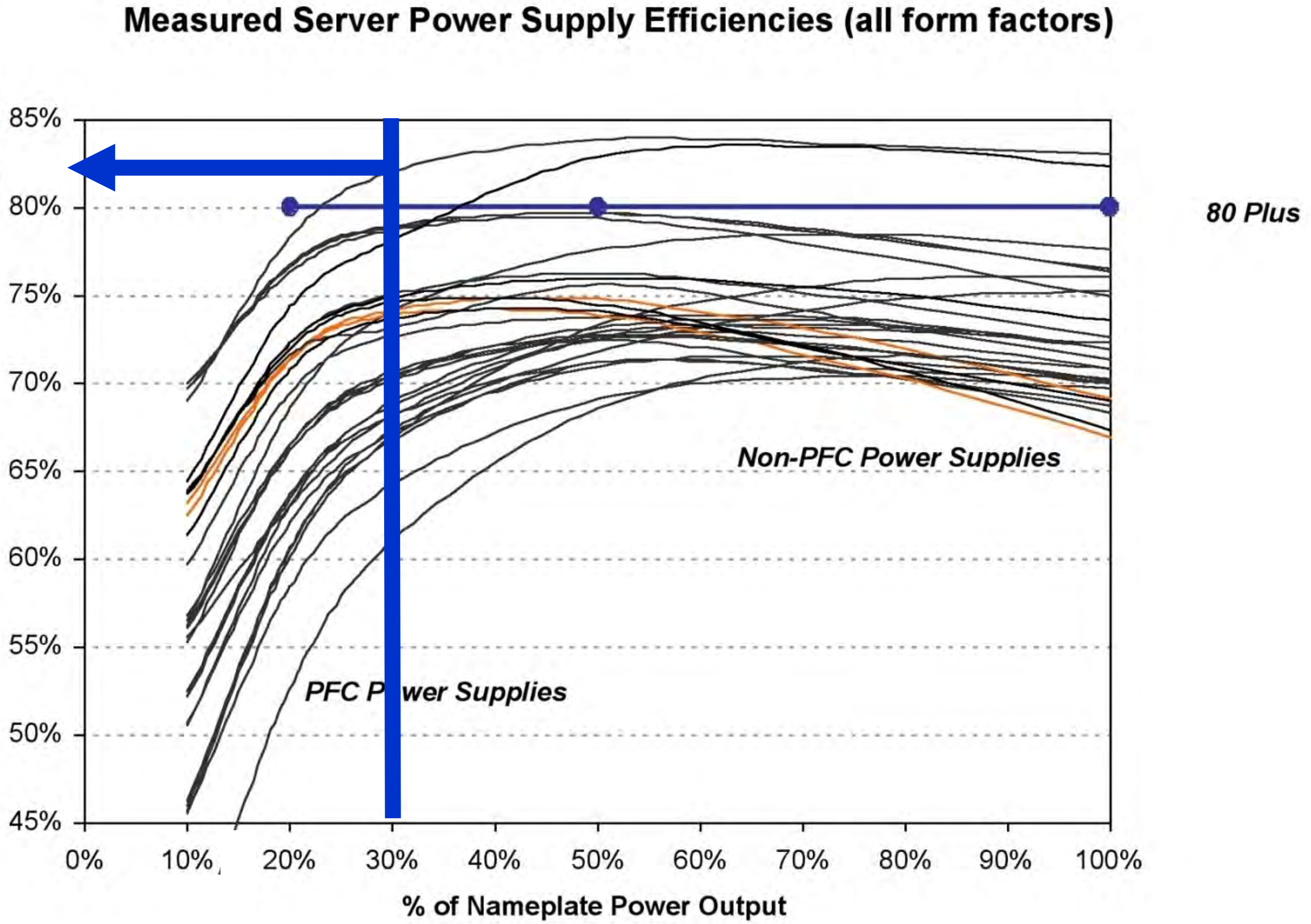
- Upholding high-levels of business continuity
  - One Standby for many production servers

Dynamic Load Balancing



Balancing utilization with head room

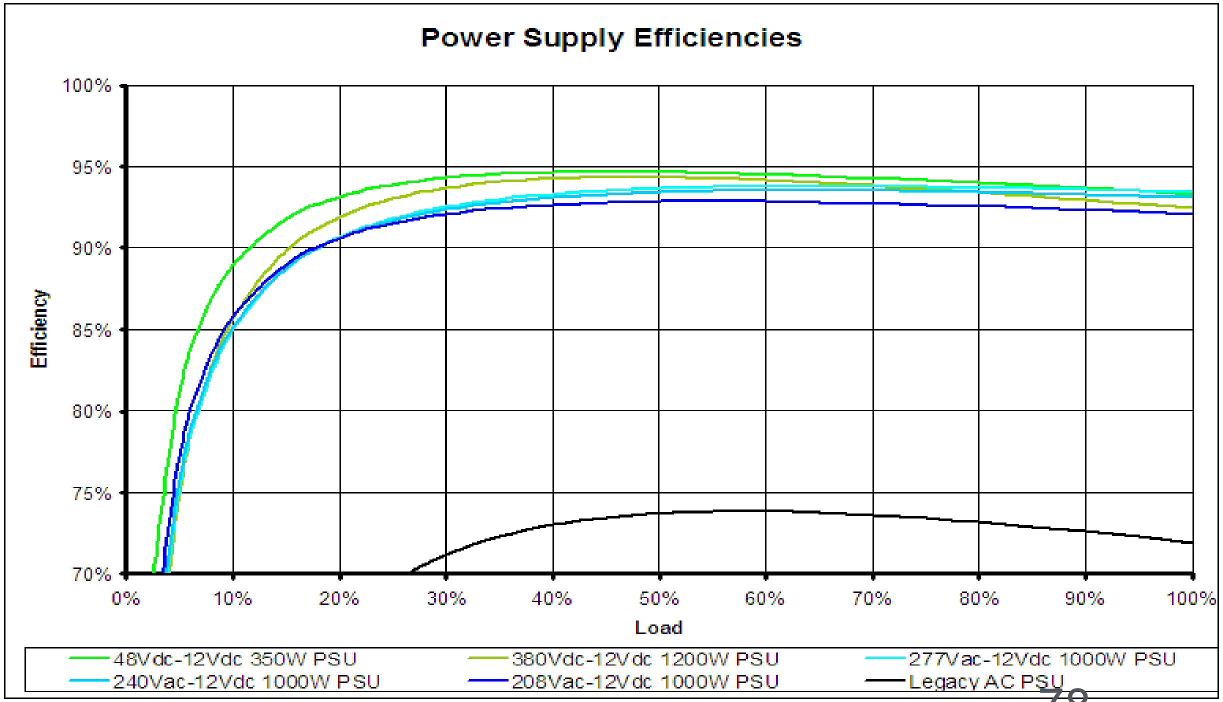
LBNL/EPRI measured power supply efficiency



Power Supply Units

Power supplies are most efficient in the mid-range of their performance curves. Ensure power supplies are appropriate for the anticipated load. Power supply redundancy: operation is lower on the efficiency curve. Using Energy Star or Climate Savers power supplies will improve efficiencies.

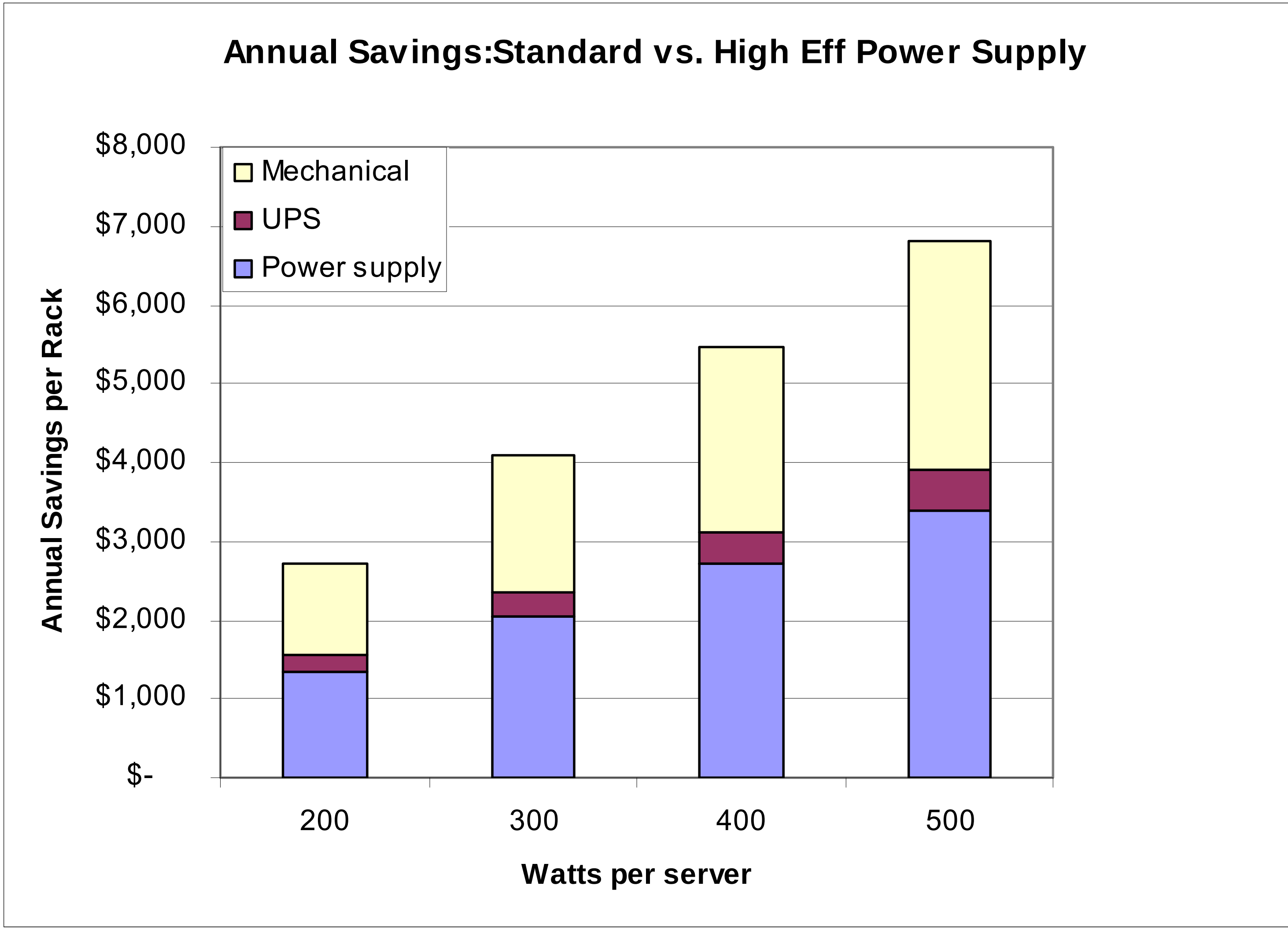
Source: The Green Grid



78

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%


Annual Savings:Standard vs. High Eff Power Supply
Annual Savings per Rack
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
Mechanical
UPS
Power supply
200
300
400
500
Watts per server

The value of high efficiency power supplies

1 Watt at CPU

= 1.25 Watts at entry to server (80% efficient power supply)

= 1.56 Watts at entry to UPS (80% efficient UPS)

= 2.5 Watts including cooling (2.0 PUE)

= 22 kWh per year

= $2.20 per year (assuming $0.10/kWh)

= $6 of infrastructure cost (assuming $6/W)

- **Total Cost of Ownership (TCO) Perspective = $12.60 (assuming three year life of server)**
- **Typical added cost of 80 plus power supply $3 - $5.**
- **Typical value - $170 (assumes 15 Watts saved at power supply)**

$$\text{Energy} \quad \frac{15w \times 2.0PUE \times \$0.10/kw \times 8{,}760hrs/yr}{1{,}000w/kW} \times 3yrs \approx \$80$$

$$\text{Infrastructure } 15\text{w} \times \$6\text{/watt} = \$90$$

$$\text{Total } \$80 + \$90 = \$170$$

IT Decommissioning

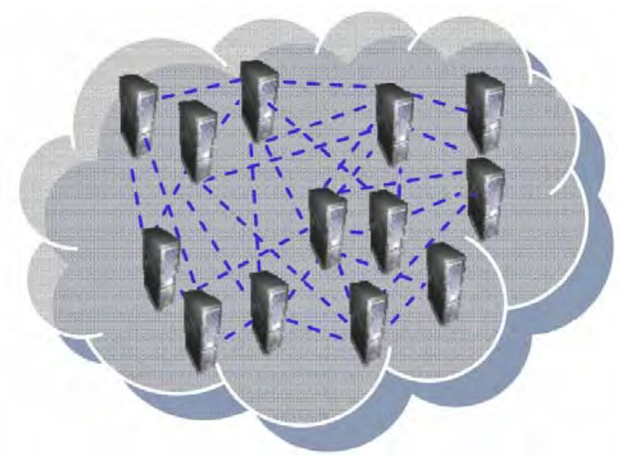
- **According to Uptime Institute, 15-30% of servers are on and consuming energy but serve no useful purpose**
- **Some decommissioning goals include:**
  - Regular inventory and monitoring
  - Offline idle or unassigned equipment
  - Identify low utilized hardware - consolidate
  - Remove leftover hardware from unfinished projects
  - Retire legacy hardware especially following refresh
- **PHYSICALLY RETIRE AN INEFFICIENT OR UNUSED SYSTEM.**
- **DO NOT PUSH THE PROBLEM ELSEWHERE.**

Cloud Computing

- Dynamically scalable resources that are provided over the internet.
  - Infrastructure as a Service (IaaS): Managed hardware to host OS and applications
  - Platform as a Service (PaaS): Managed OS to host applications
  - Software as a Service (SaaS): Applications accessed through a web-browser.
- Decreases the need for localized resources and avoids capital expenditures by renting IT usage managed by a third party.

Cloud Computing – Impact on Utilization

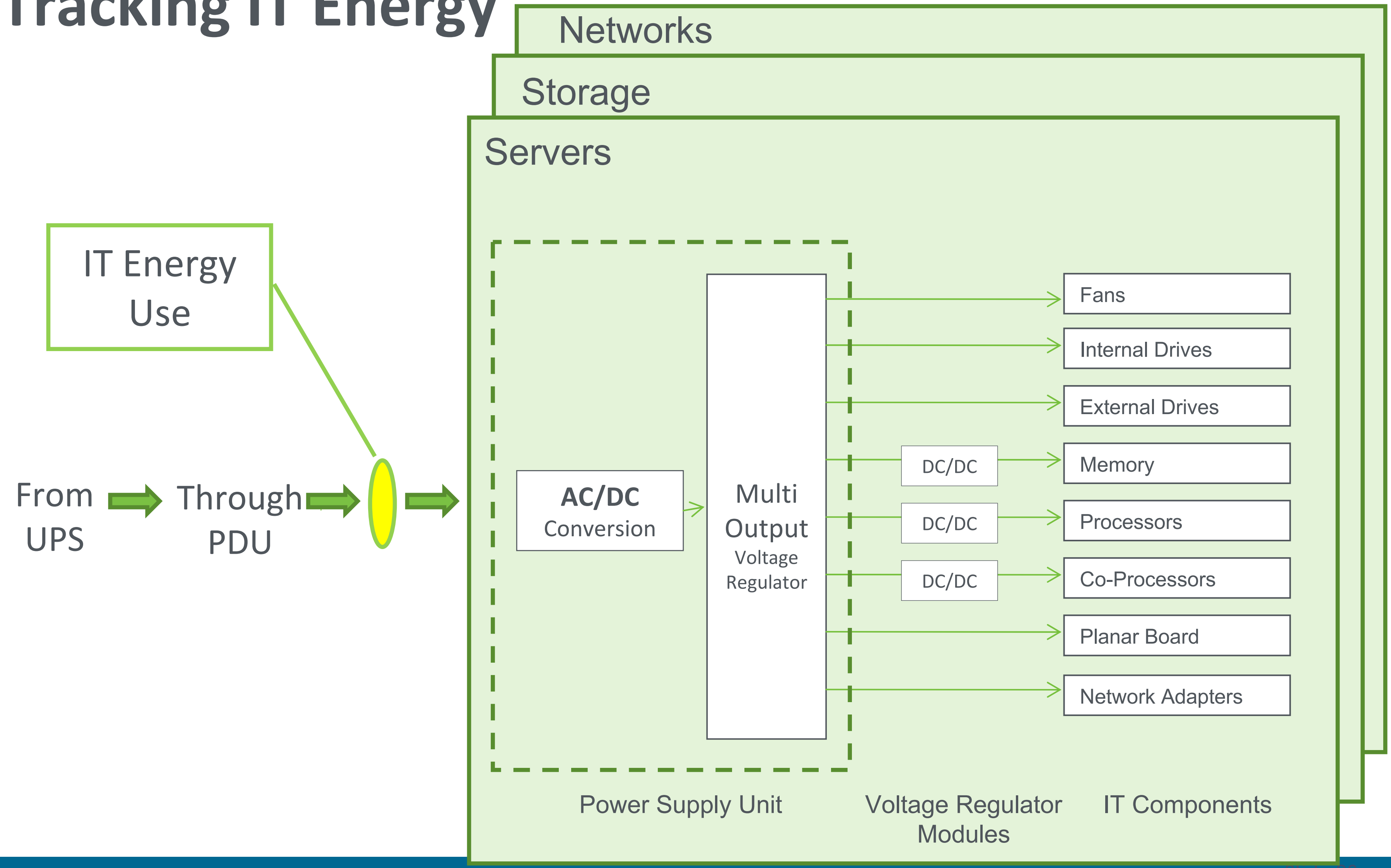
- Workstations used 8 hours / workday with 12% utilization = **3% total utilization**
- A cloud can be used 24/7 with 80% load = **80% total utilization**
- Virtualized cloud computing increases overall efficiency by:
  - Balancing out different application peak loads
  - Higher utilization
  - Shutting down unused servers to dynamically right size
  - Decreasing hardware requirements of workstation
  - Better managed systems
  - Better facility efficiency



IT Systems Energy Assessments

- Covers:
  - Workload
  - IT Power Management
  - IT Cooling
  - IT Systems Management
- Automated tools available
  - Wide range of sophistication and features
- DC Pro Assessment tool in development
  - Recommended actions to improve energy performance
  - Estimate of potential energy savings

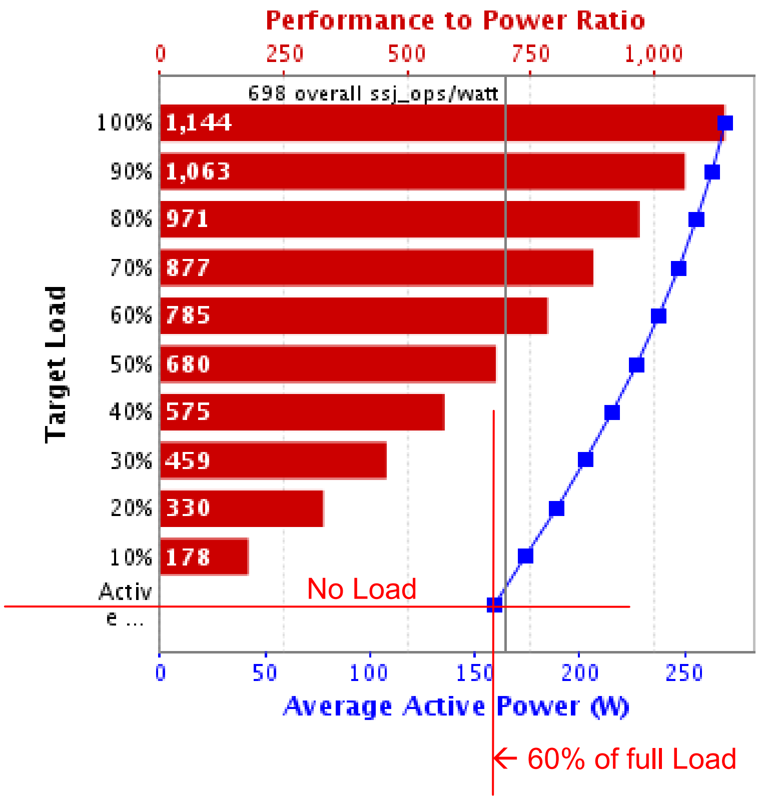
Tracking IT Energy



IT Energy Use Patterns: Servers

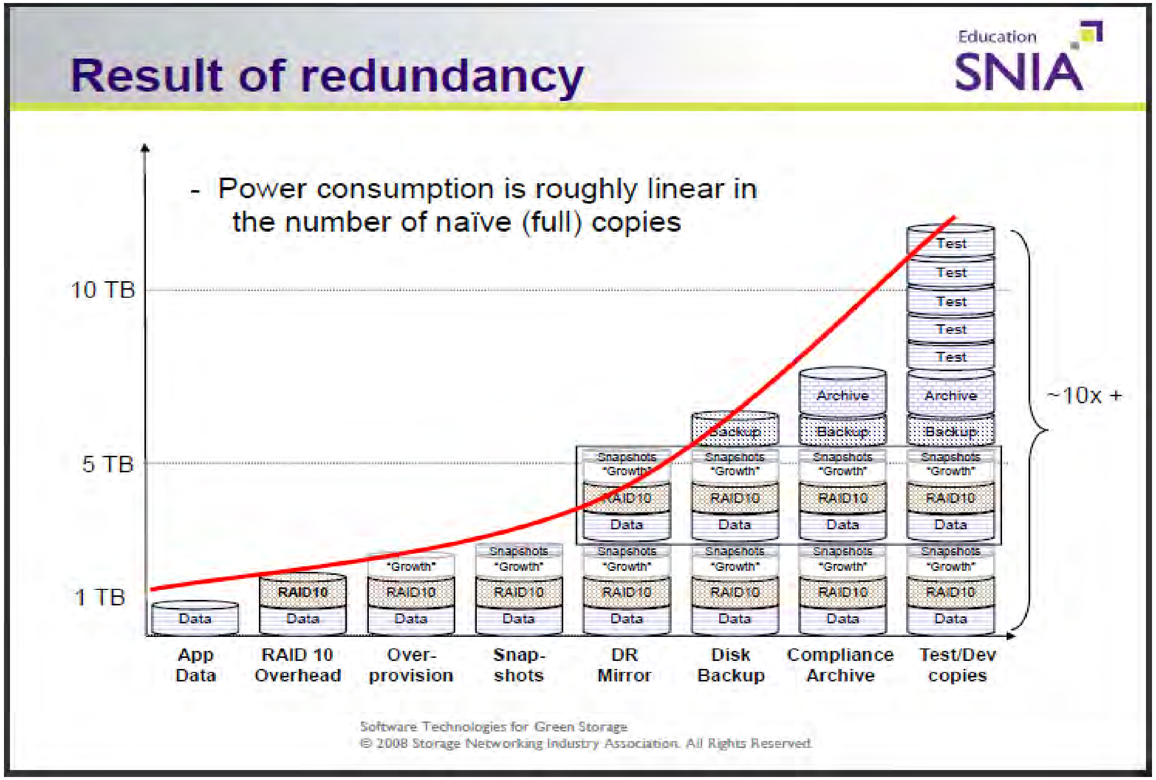
Idle servers consume as much as 50-60% of power @ full load as shown in SpecPower Benchmarks.

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



IT Energy Use Patterns: Storage Systems

Power consumption is roughly linear to the number of storage modules used. Storage redundancy needs to be rationalized and right-sized to avoid rapid scale up in size and power consumption. De-duplication is a strategy to eliminate unnecessary copies.

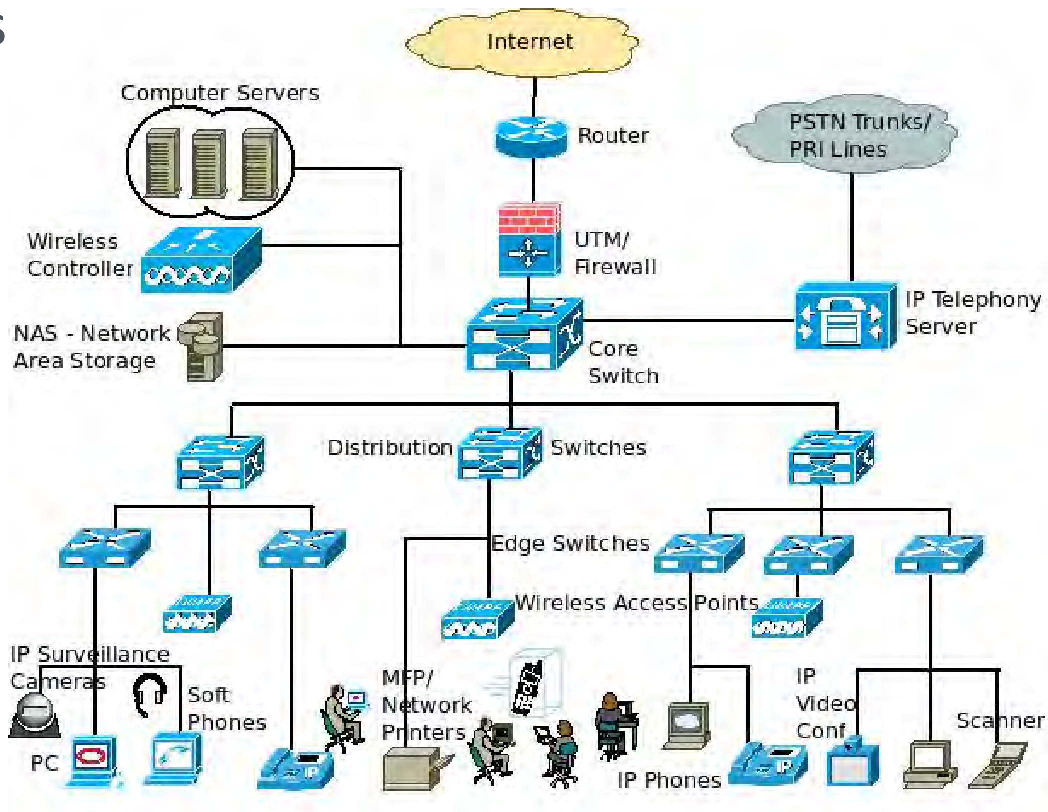


Network Equipment Energy

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

Network Devices

- An integral part of a Data Center
- Consumes significant energy in a Data Center
- Types of Network Devices
  - Hubs
  - Switches
  - Firewall
  - Wireless Access Points



Network Equipment Energy Consumption

Network Devices Benchmarking Research by HP demonstrated the following:

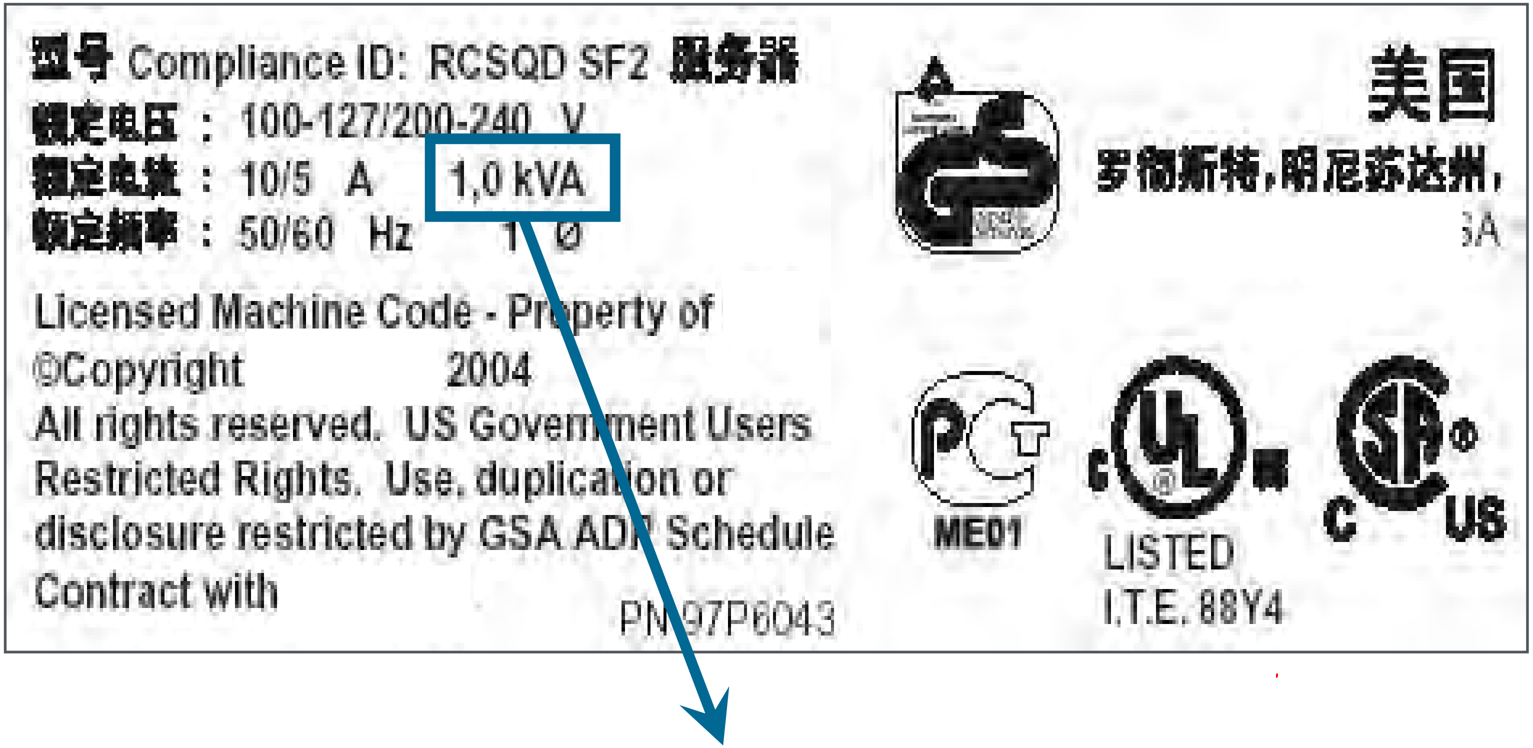
- Energy usage proportional to data speed
  - 1 Gbps consumes more energy than 100 Mbps
  - Energy consumption is independent of packet size
  - Consolidate under utilized network ports to save energy
- Core switches
  - Energy consumption proportional to active ports in a card, and the number of cards
  - Disable ports and line cards when not in use
  - Consolidate to fewer line cards using most if not all ports
- In small switches (less than 48 ports) no significant relation between power consumption and the number of active ports
  - Uses same power whether 1 or all ports are active

Thermal Report – Example: Generic Server

Configuration		Condition				
Description	Model	Typical Heat Release	Airflow			
			Nominal		Max. (@ 35°C)	
		Watts @ 120V	cfm	(m^3/h)	cfm	(m^3/h)
Minimum	1-way 1.5 GHz Processor 16GB memory	420	26	44	40	68
Full	2-way 1.65 GHz Processor Max. memory	600	30	51	45	76
Typical	1-way 1.65 GHz Processor 16GB memory	450	26	44	40	68

Note: Most new server fans are variable speed

Thermal Report – Comparison to Nameplate



ASHRAE thermal report – 420 to **600** W

References and Resources

Server System Infrastructure
Managing Component Interfaces

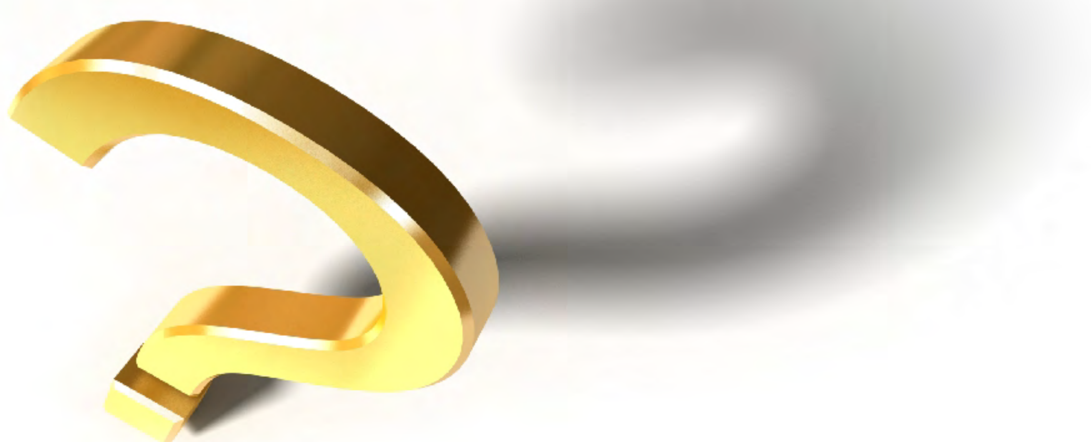
- www.ssiforums.org
- www.80plus.org
- www.climatesaverscomputing.org
- http://tc99.ashraetcs.org/

80 PLUS

climate savers computing

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

Presented by: Geoffrey Bell, PE

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

FEMP
Federal Energy Management Program

GSA

AGENDA

Morning

- Introductions to course and instructors
- Performance metrics and benchmarking
- IT equipment and software efficiency
- **Use IT to save IT (monitoring and dashboards)**
- Data center environmental conditions

Lunch On your own

Afternoon

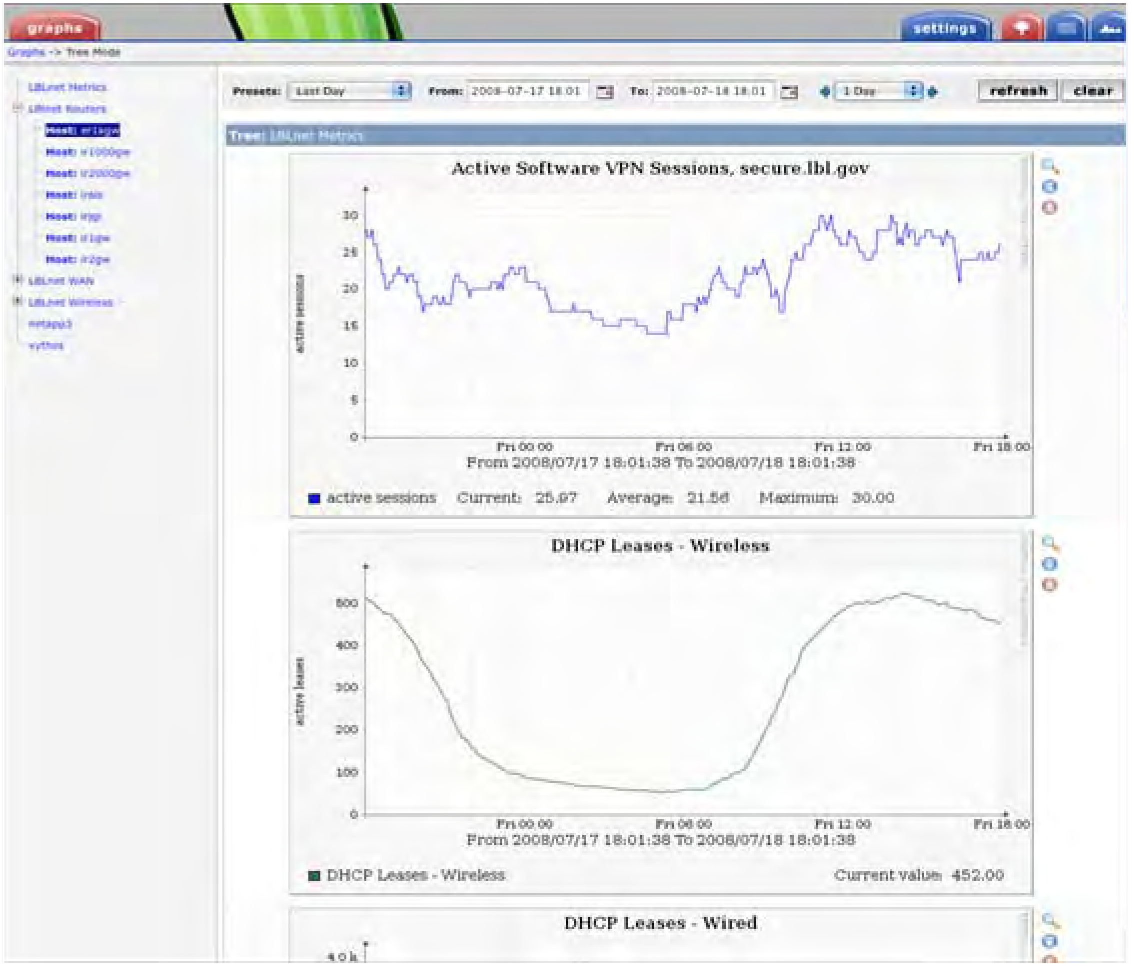
- Airflow management
- Cooling systems
- Electrical systems
- Summary and Takeaways

Use IT to Save Energy in IT:

- Most operators lack visibility into their data center environment
- We can't manage what we don't measure
- Provide the same level of monitoring and visualization of the physical space as we have for the IT environment
- Measure and track performance metrics
- Spot problems before they result in high energy cost or down time

The Importance of Visualization

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



Monitoring Data Center Infrastructure

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

- ✓ LBNL installed a wireless sensor network
  - Monitoring over 700 points.
  - Sensing temperature, humidity, under-floor pressure, current
- ✓ Provided a detailed understanding of environmental conditions in the data center
  - Produces real-time and historical graphs
  - Achieved a baseline database

- ❖ Emerging technology transfer a success!
  - Verifying, "You can't control or manage what you don't measure."

LBNL Wireless sensor installation

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

- Provides a mesh sensor network
- Non-invasive installation.
- Includes 2 internal & 6 external sensors per node.
- Measures temperature, humidity, pressure, and current.
- Can also measure liquid flow, liquid presence, and particle count.
- Air management and other tasks now based on empirical data, not intuition

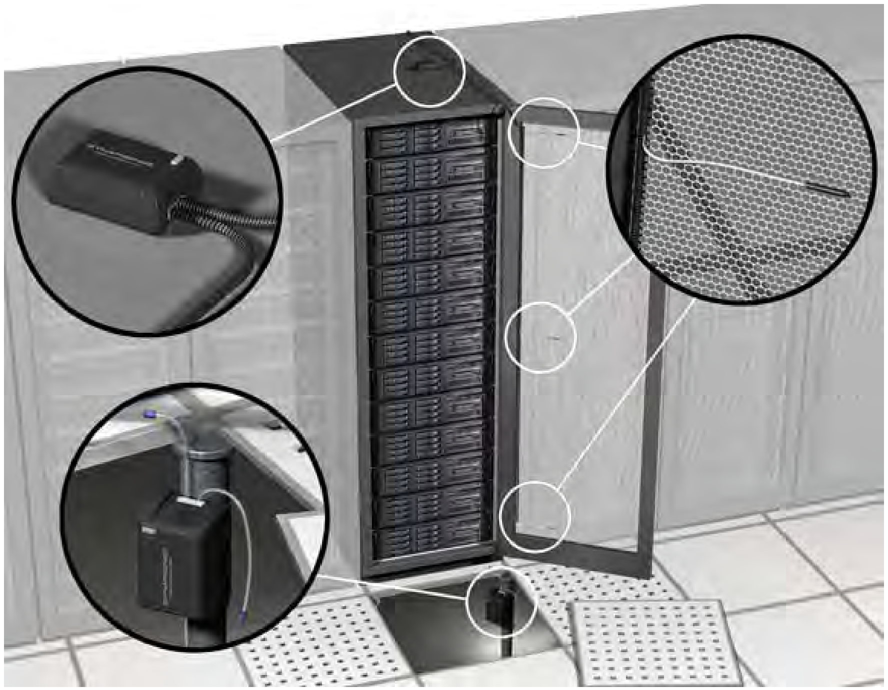
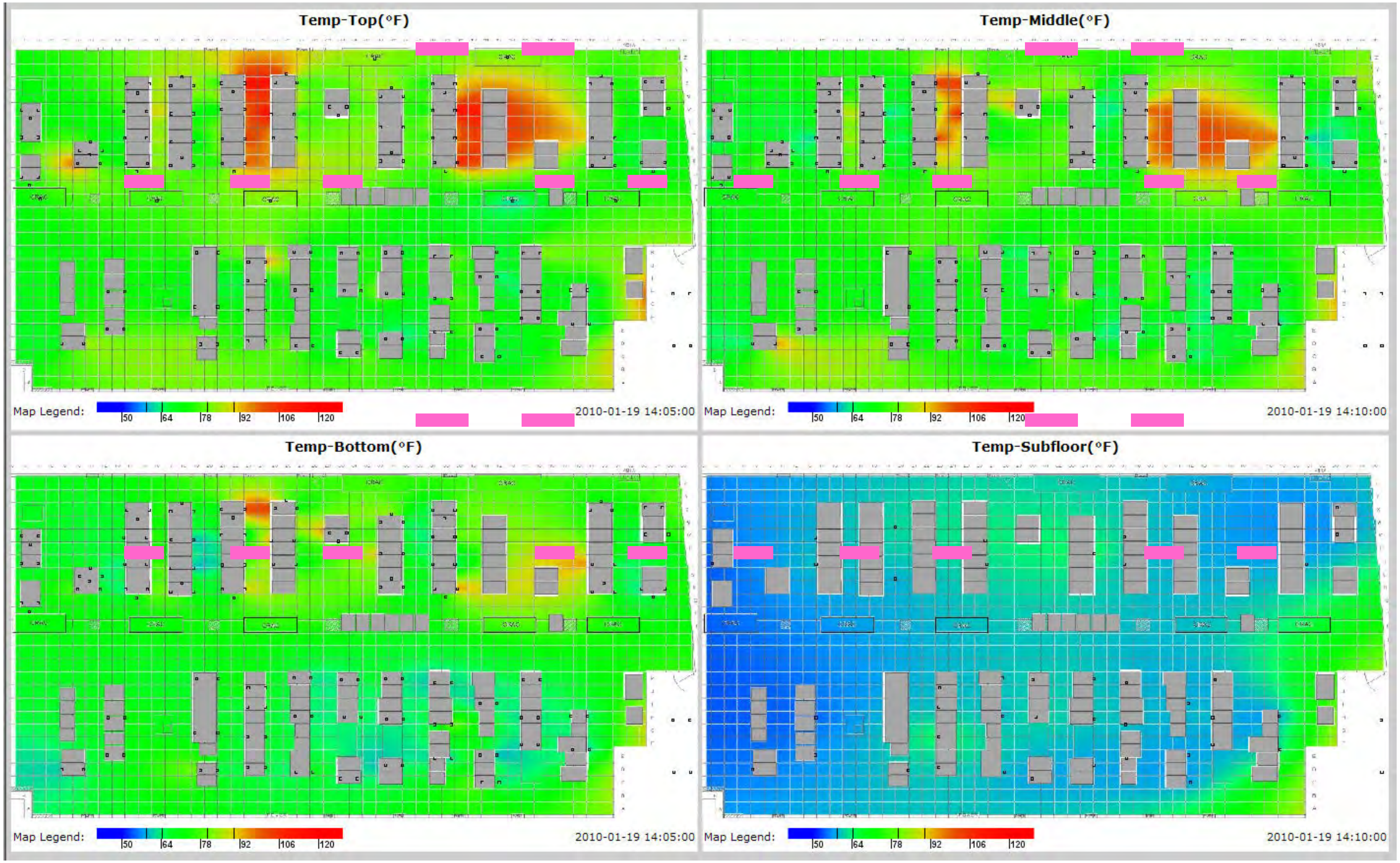


Image: SynapSense

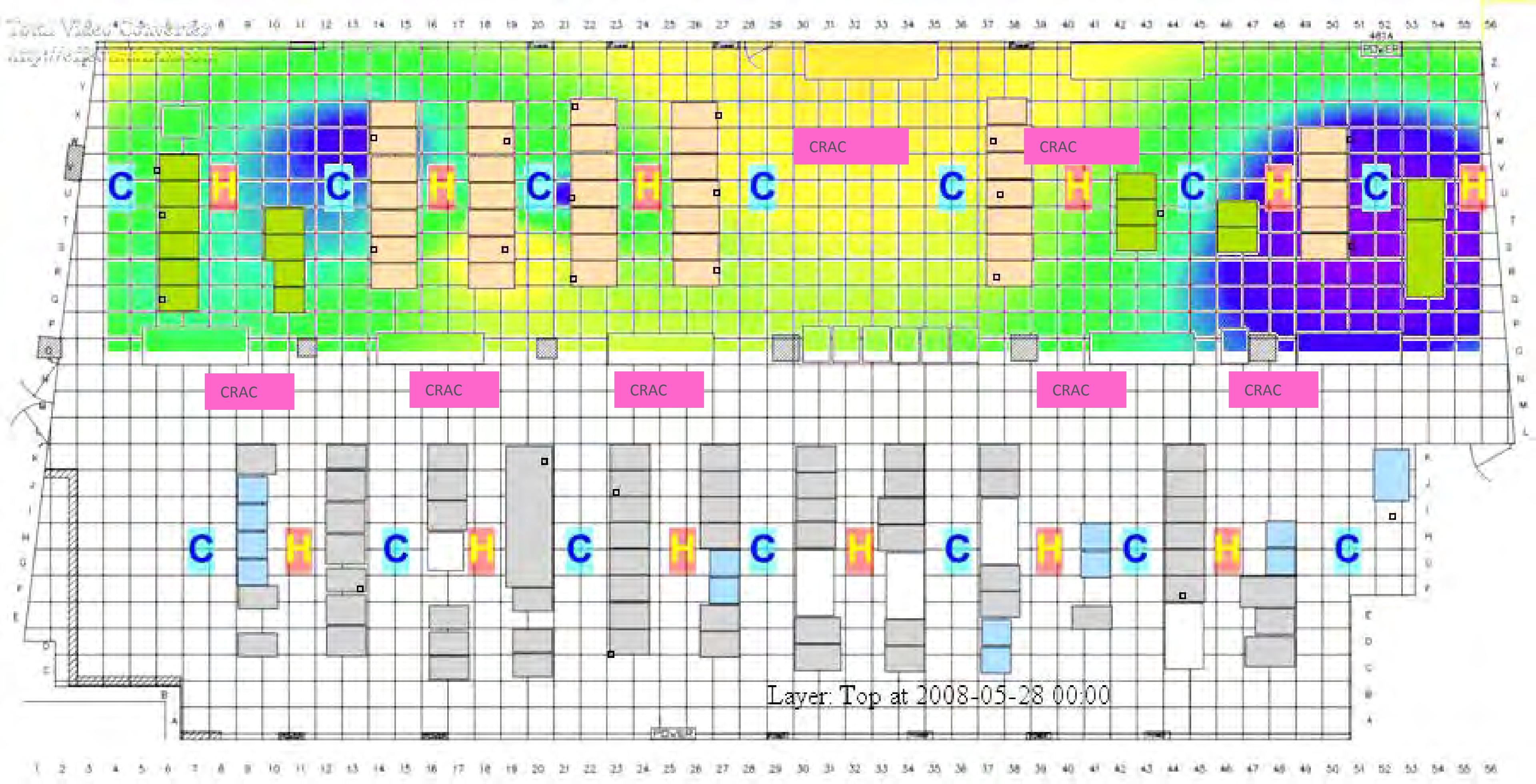
Real-time temperature visualization by level

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



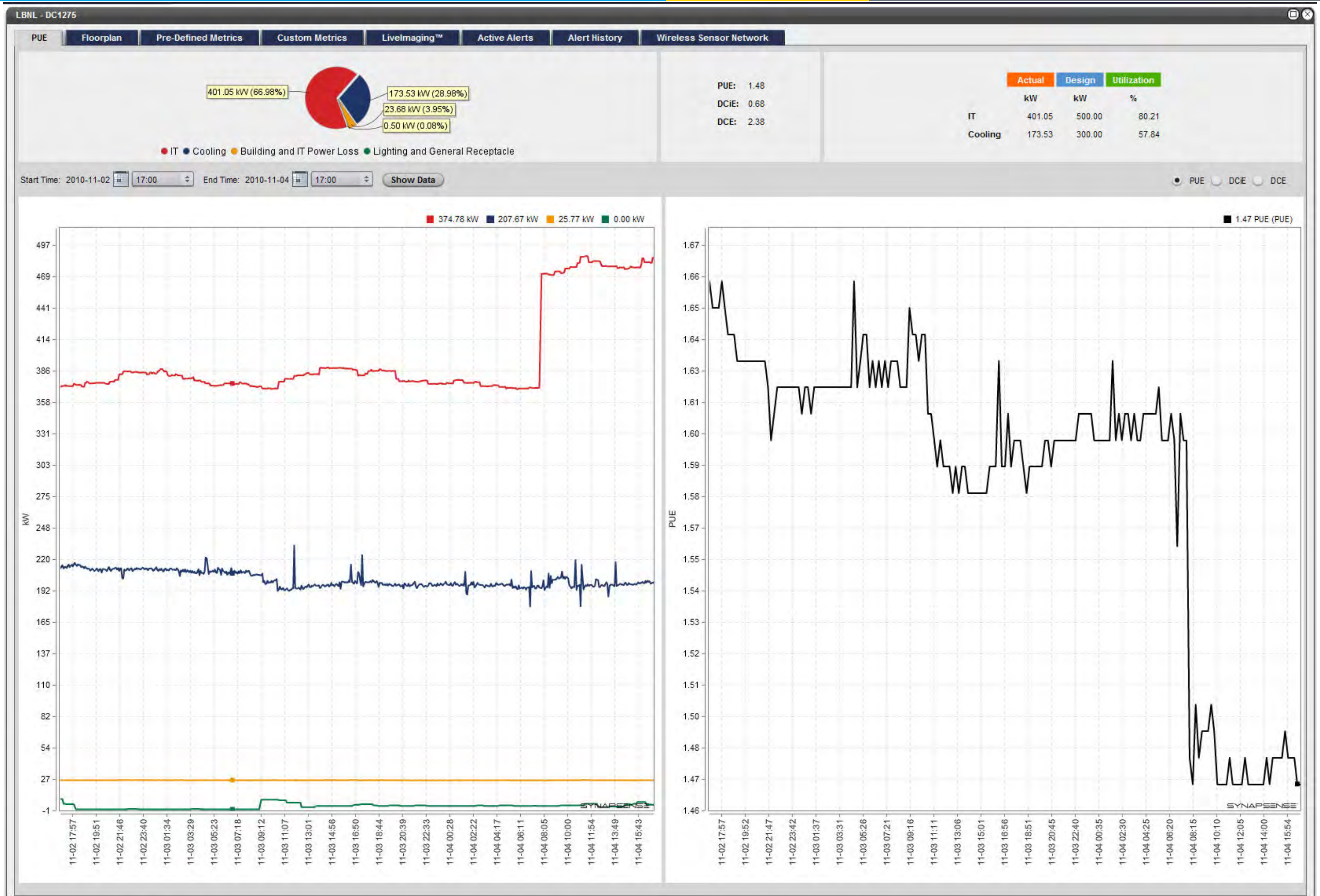
Provided heat-map movies…

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



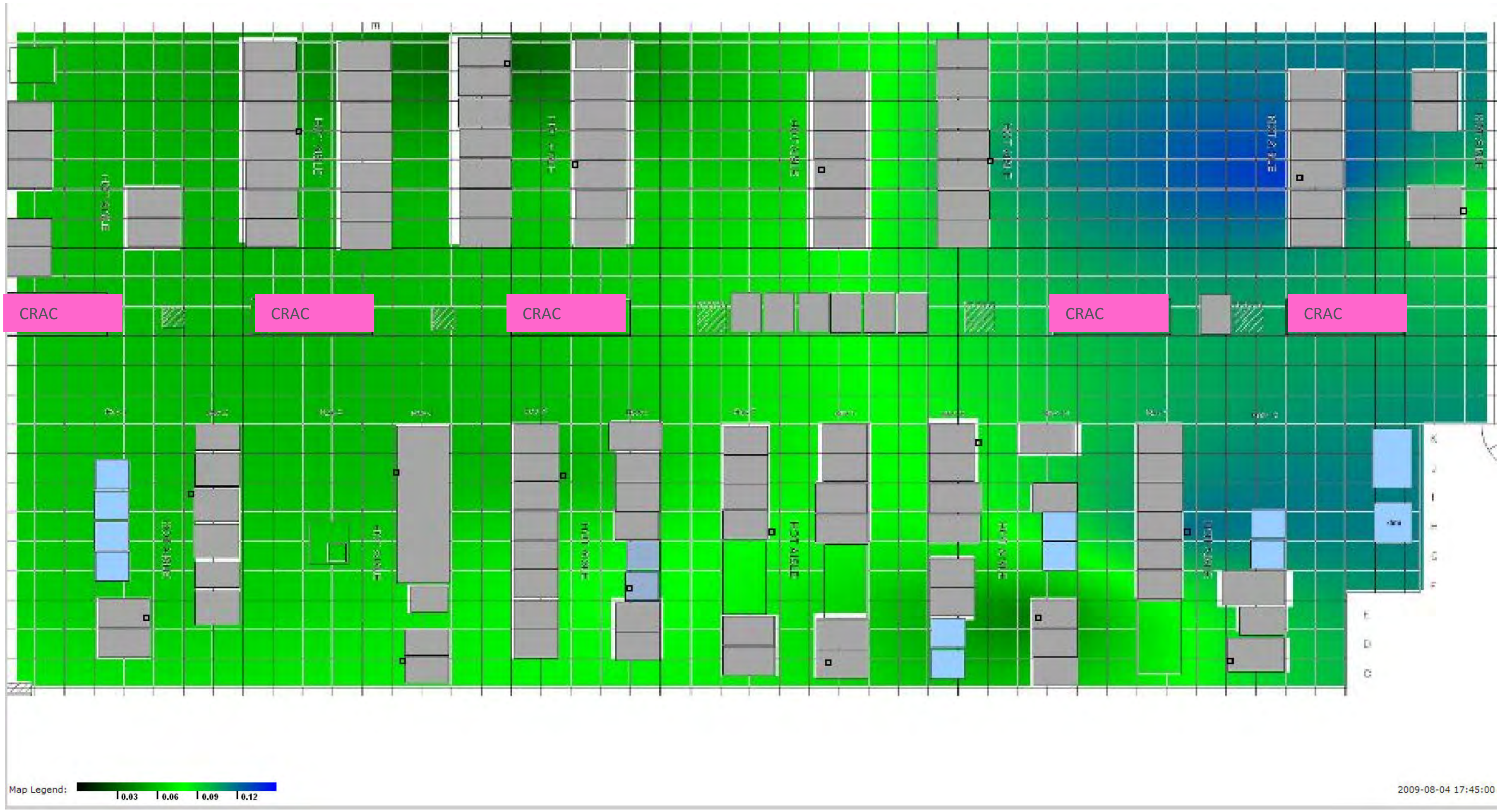
Real-time PUE Display

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



Displayed Under-floor pressure map…

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

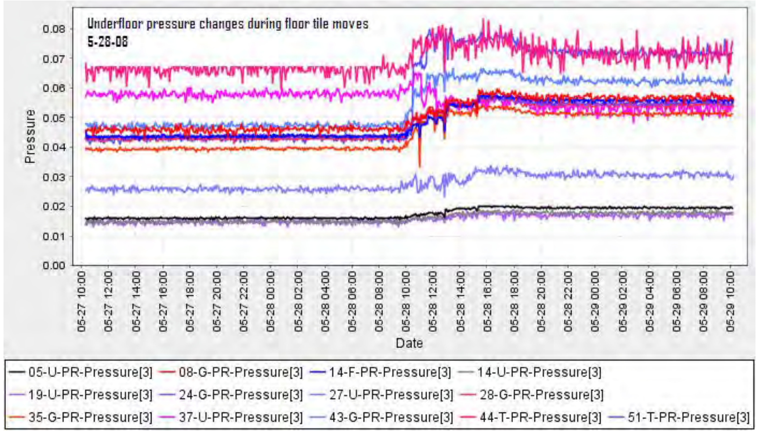


Provided real-time feedback; helped floor-tile tuning

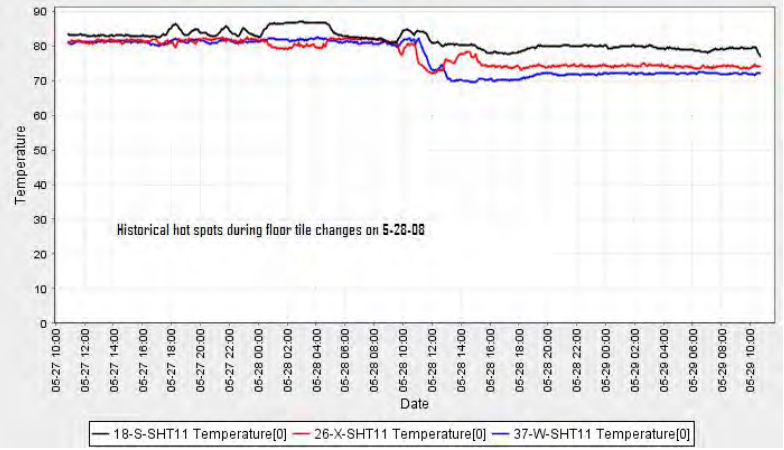
- ✓ Results in real-time.
- ✓ Removed guesswork by monitoring and using visualization tool.

- ➢ Verified that when airflow optimized,
  - – under-floor pressure increases.
  - – rack-top temperatures decreases.

Under-Floor Pressure



Rack-Top Temperatures



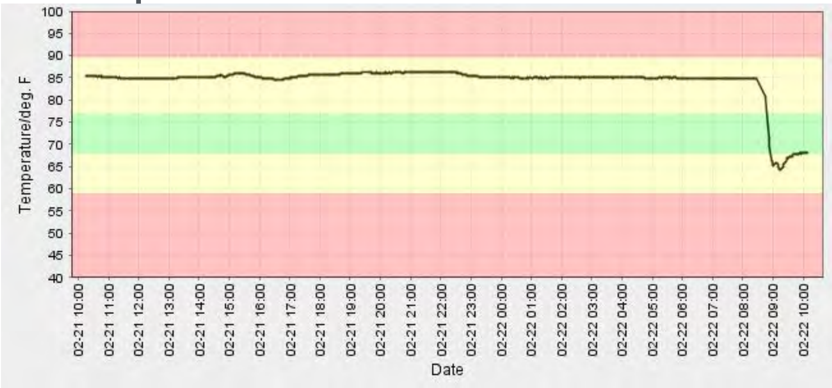
Demonstrated server-rack tuning from blanking plates

Charts show effect of adding one 12” blanking panel to the middle of a server rack…

Conclusions:

- ✓ Use blanking panels.
- ✓ Eliminate leaks in floor
- ✓ Manage floor tile permeability

Top of rack

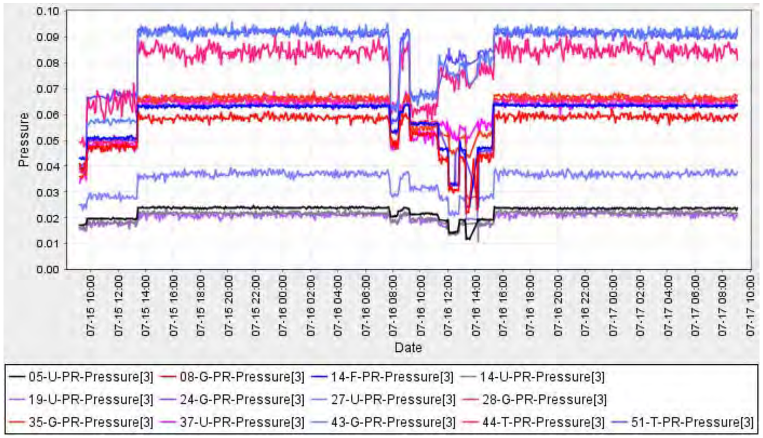


Middle of rack

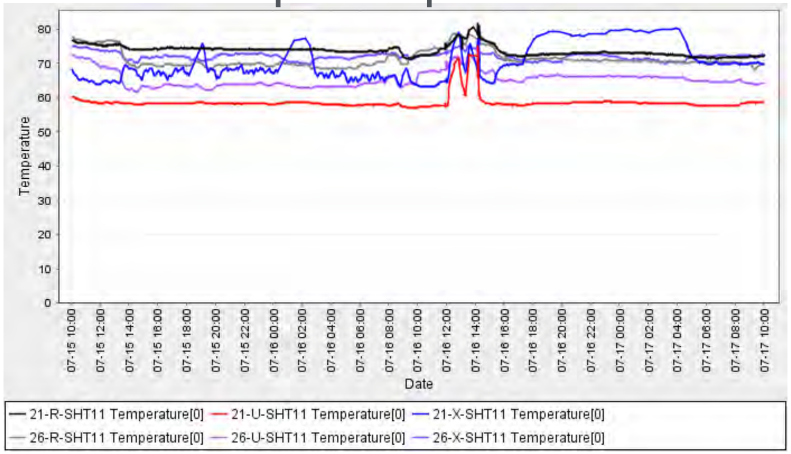
Determined relative CRAC cooling energy impact

- Turned off each CRAC in turn, for service.
- Monitored resulting hot spots during maintenance.
- Identified non-critical CRAC units.
- Enhanced knowledge of data center redundancy.
- Turned off unnecessary CRAC units to save energy.

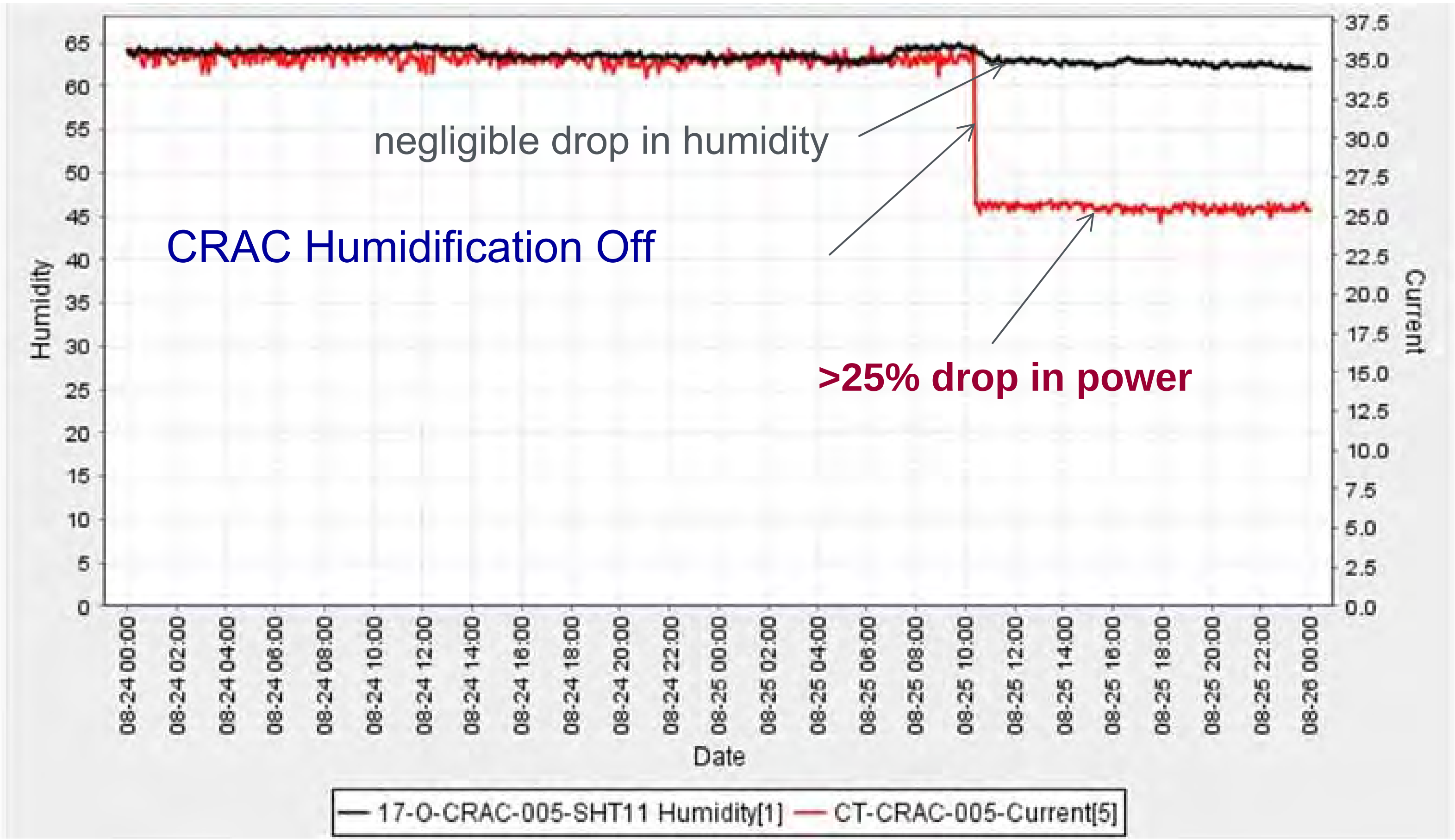
Under-Floor Pressure



Rack-Top Temperatures

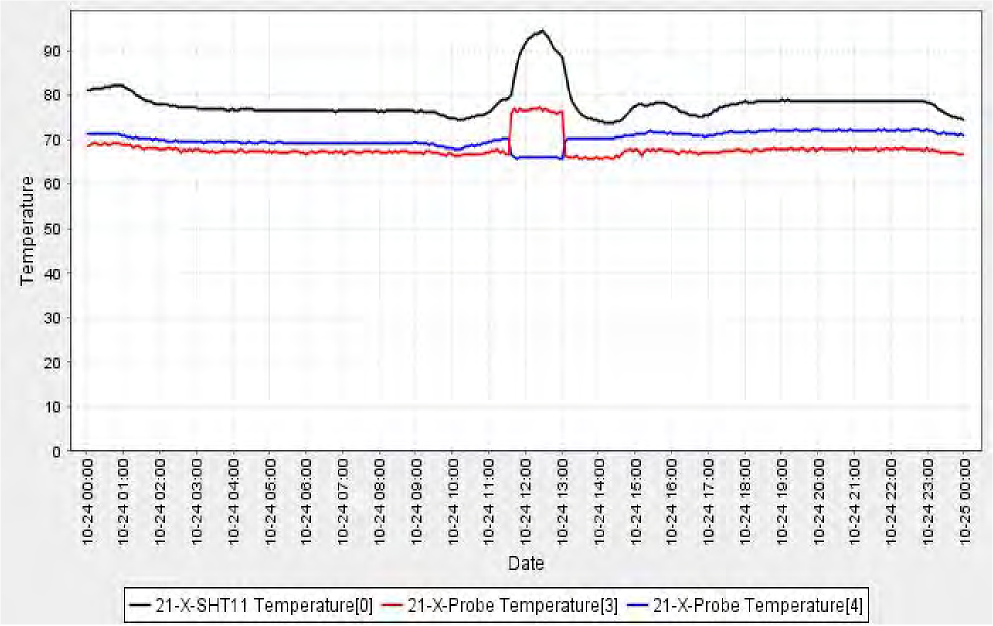


Analyzed humidity control



Feedback continues to help: Note impact of IT cart!

Real-time feedback identified cold aisle air flow obstruction!



Franchise Tax Board (FTB) Data Center: Summary

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

Description:

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

Challenges:

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

Solution:

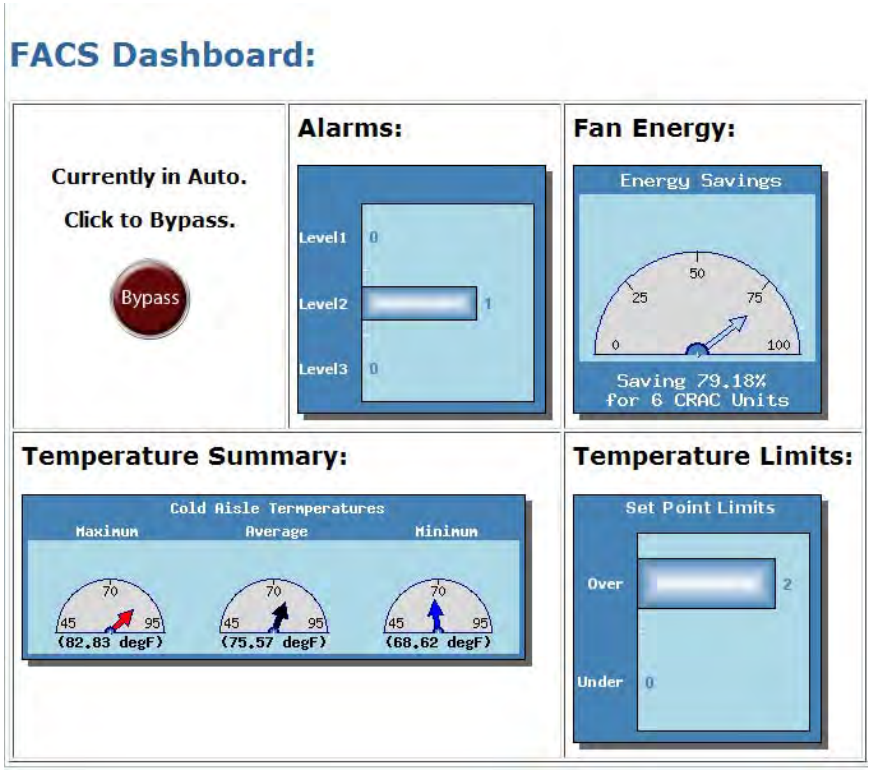
- Intelligent supervisory control software with inlet air sensing

FTB Project Tasks:

- Establish baseline
- Adjust floor tiles
- Install Variable Frequency Drives (VFDs)
- Install supervisory control software
- Isolate hot-aisles
- Blank racks

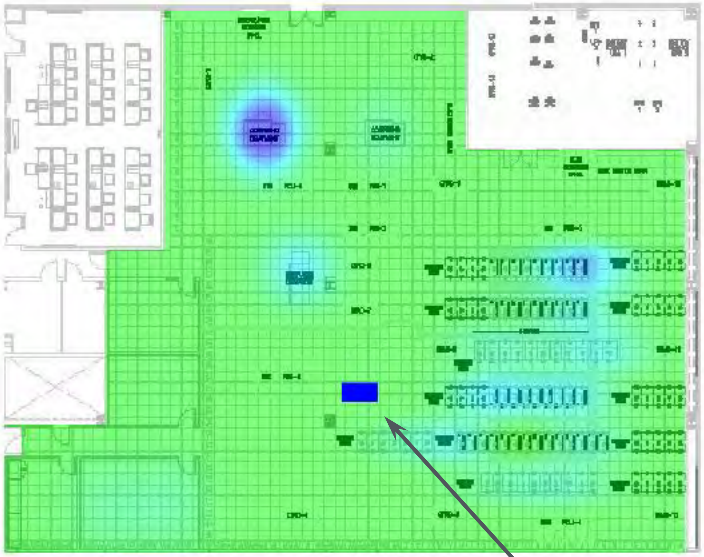
FTB Wireless Sensor Network

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

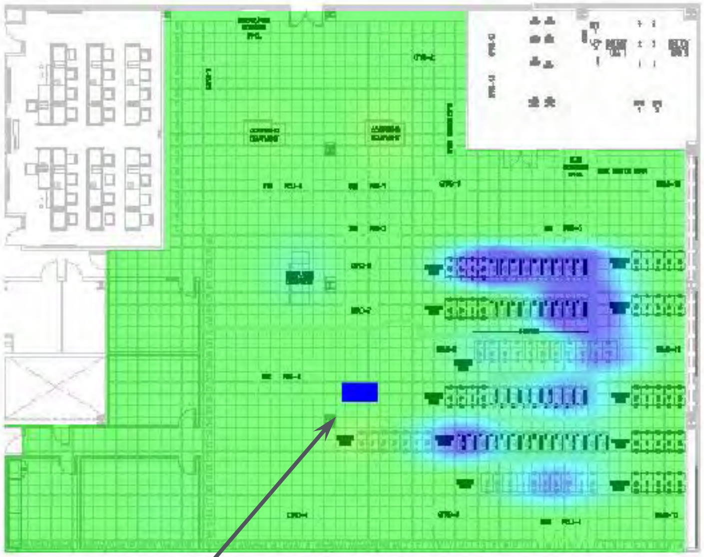


WSN Smart software: learns about curtains

CRAH 3 influence at start

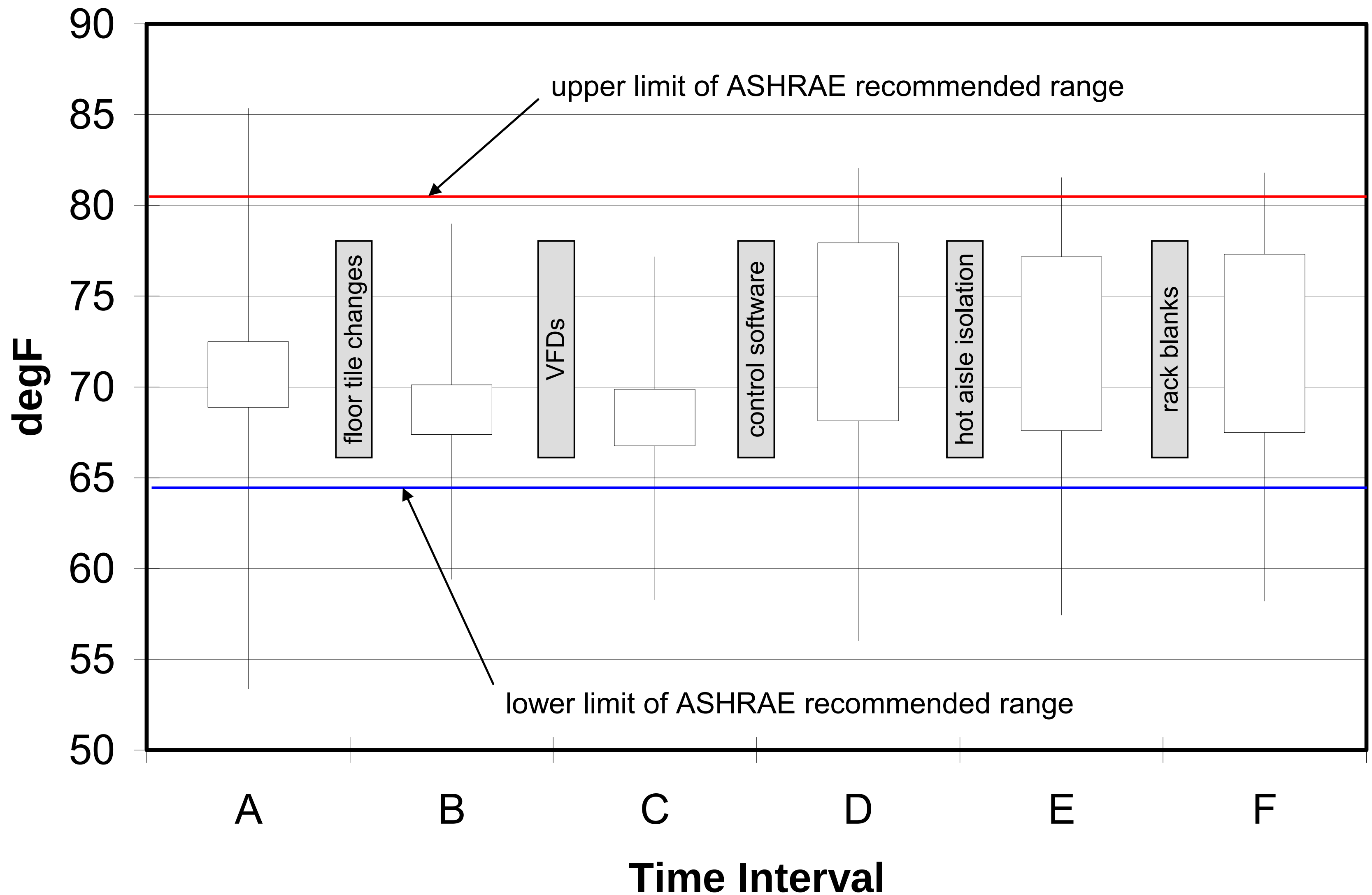


CRAH 3 influence after curtains



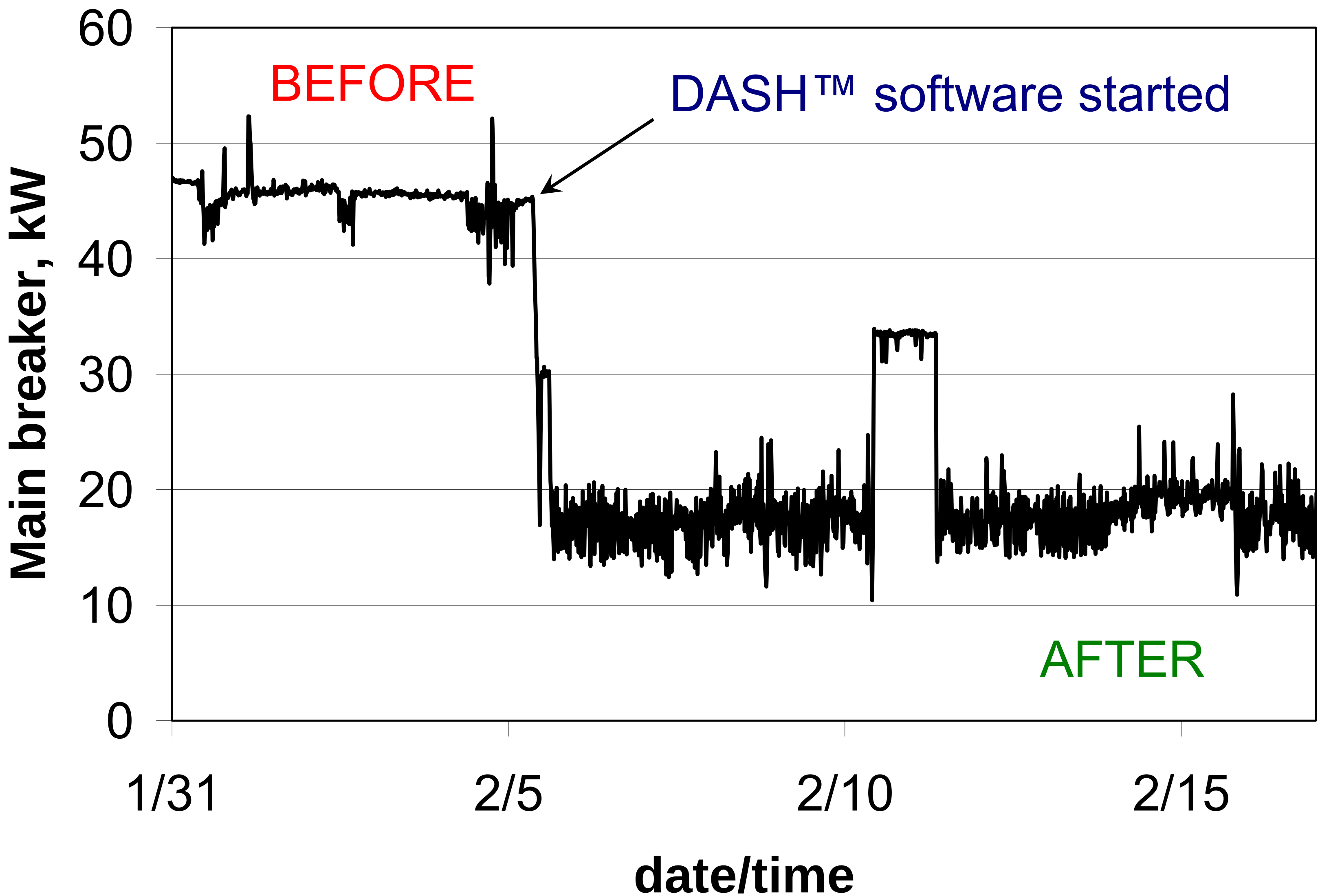
CRAH-03

WSN provided effect on cold-aisle temperatures:

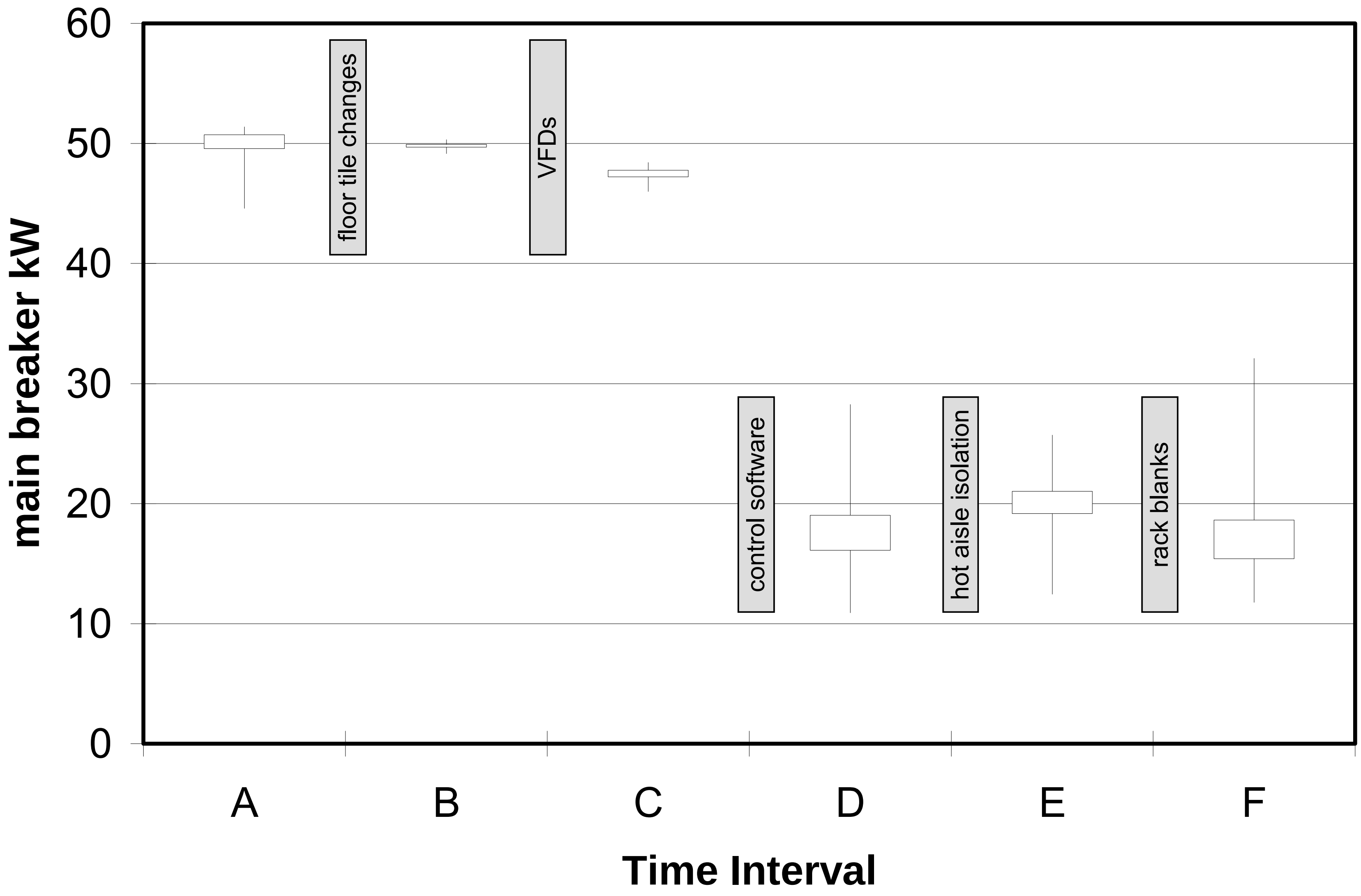


WSN software = Dramatic Energy Reduction…

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



WSN provided feedback on CRAH Power reduction



Cost-Benefit analysis:

- Total project cost-benefit
  - Cost: $134,057
  - Savings: $42,772
  - Payback: 3.1 years

- DASH cost-benefit (sensors and software)
  - Cost: $56,824
  - Savings: $30,564
  - Payback: 1.9 years

Something new:
How would you like to…

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

- **Reduce costs**
  by saving energy…

AND

- **Increase reliability**
  by better managing your assets…

Interested?

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

Background:

❖ Typically, data center cooling devices use return air temperature sensors as the primary control-variable to adjust supply air temperature to the data center.

➢ **Promotes** energy inefficiency; a single-point, “open loop” control method without feedback.

➢ **Blends** server return air temperature; does not provide any specific information about a server’s temperature or health.

Guideline and Technology Evolution:

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

- **ASHRAE Guidelines:**
  Server manufacturers have agreed; main operational parameter is server inlet air temperature.

- **Intelligent Platform Management Interface (IPMI):**
  Server inlet air temperature is monitored and available from ICT manageability network, either IPMI or SNMP (simple network management protocol).

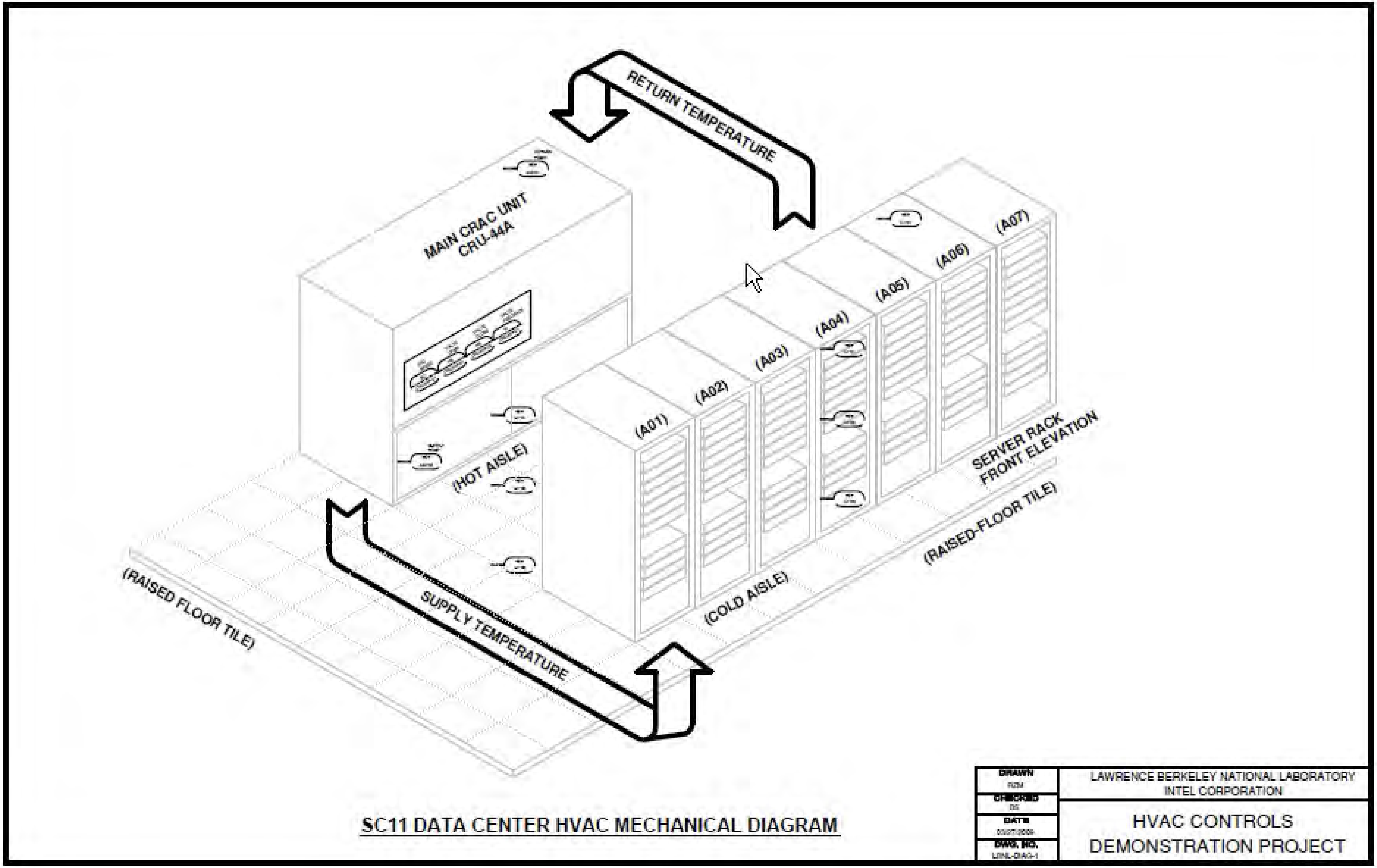
Demonstration Project: Results…

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

- **Demonstrated** and **Validated** successfully that computer servers can:
  - ✓ provide temperature information to a facility management system (FMS)
  - ✓ subsequently have the FMS determine and provide operating setpoint(s) for cooling system operations.

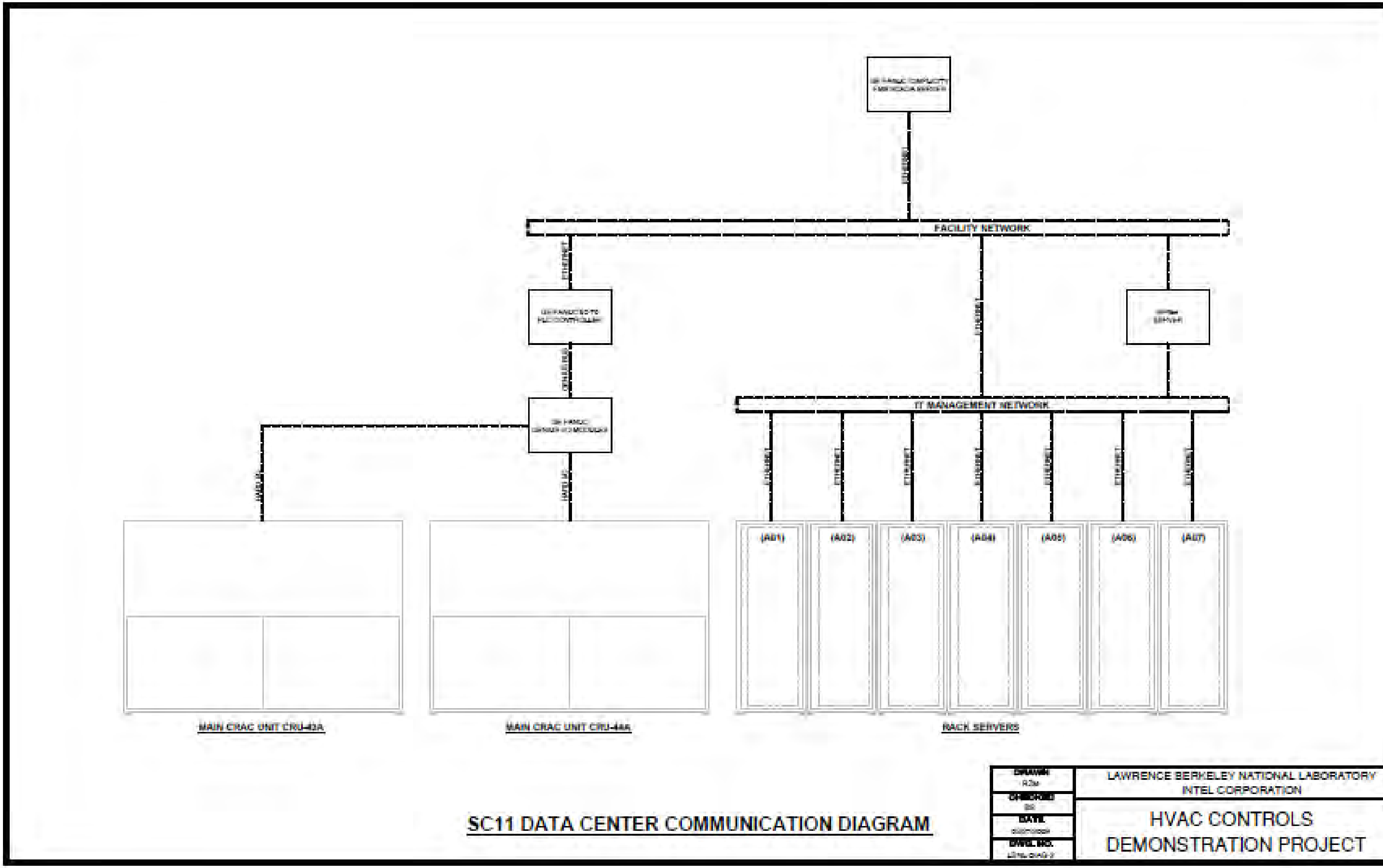
- **Completed** effective two-way communications and closed-loop control without significant interruption or reconfiguration of the ICT or FMS devices.

Intel Data Center HVAC:



Intel Data Center IT/server Communication

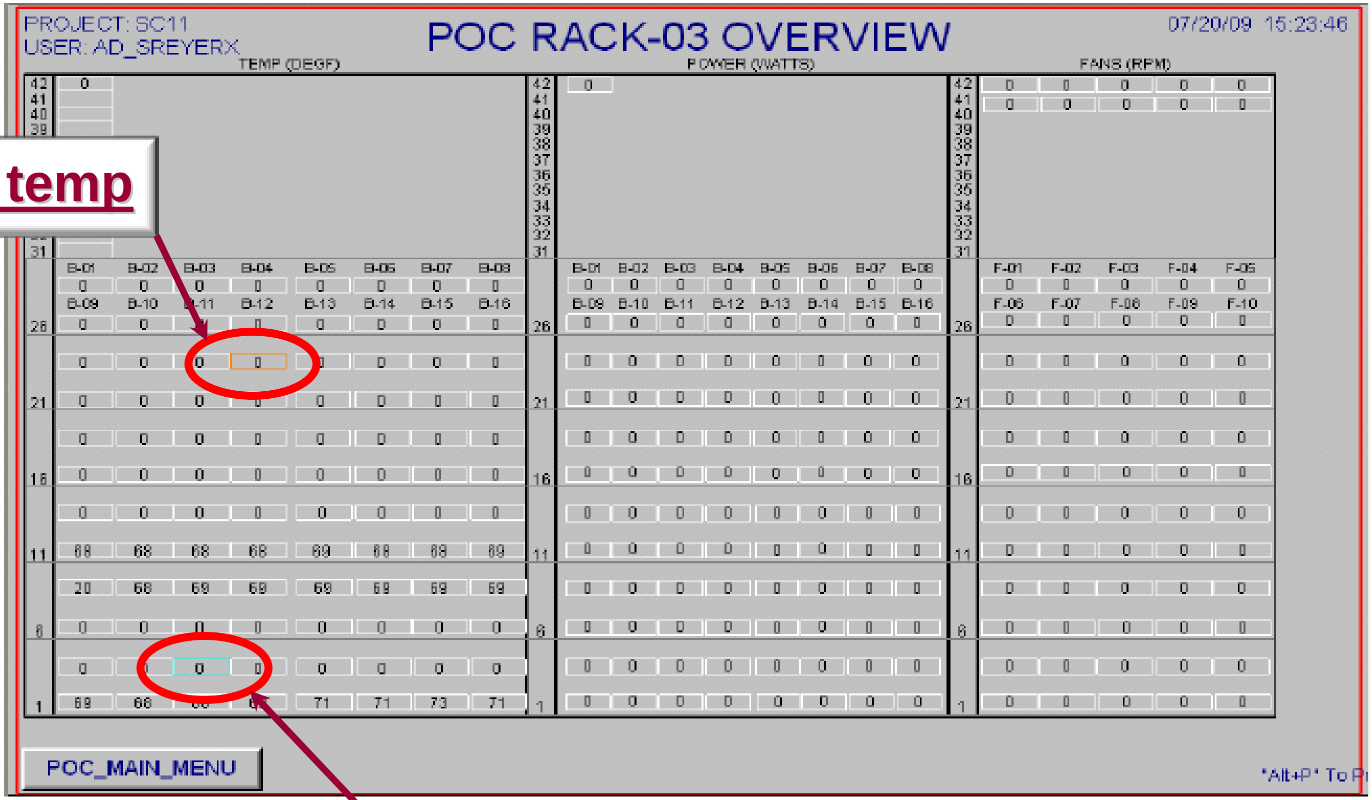
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Selected servers for BAS control input

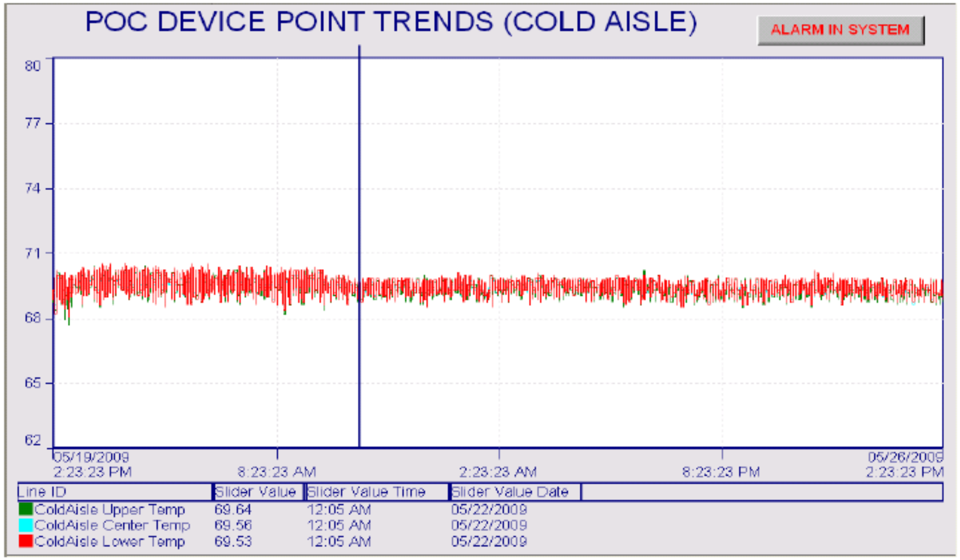
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

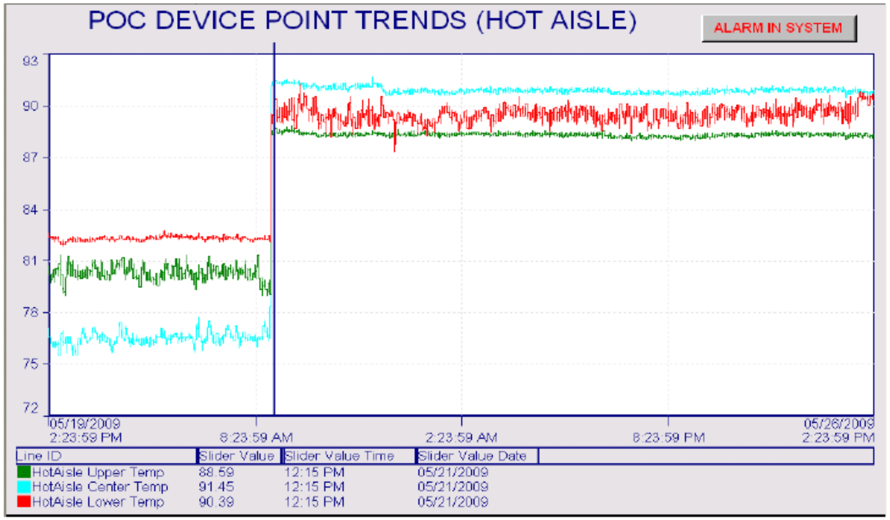
Higher server temp



Lower server temp

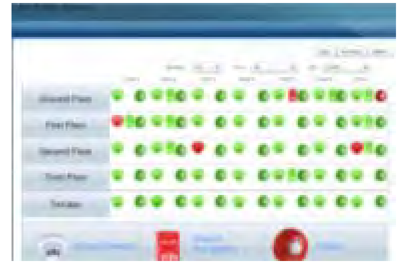
Server Inlet & Leaving Air Temperatures



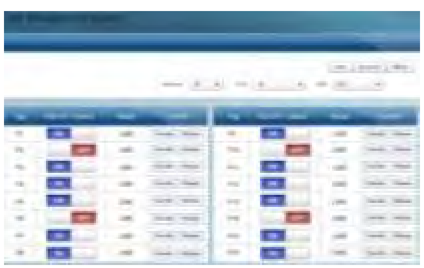


Dashboards



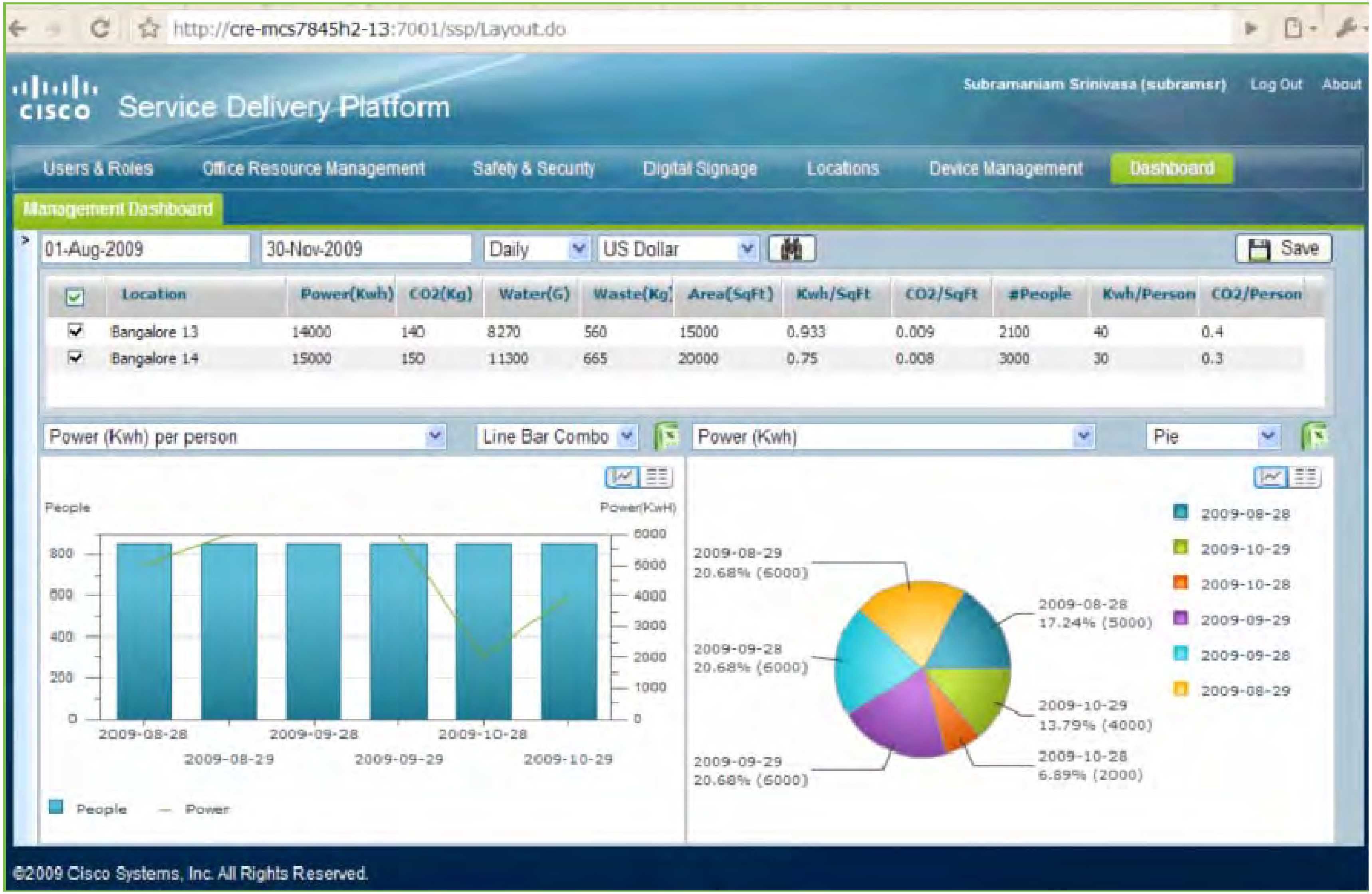



Dashboards can display multiple system's information for monitoring and maintaining data center performance and health.



Dashboard example…

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



Summary

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

- Evaluate monitoring systems to enhance real-time efficiency.
- Use on-board server temperature sensors to control cooling system.
- Install dashboards to manage and sustain energy efficiency.

Questions?

Environmental Conditions

Presented by: Dale Sartor, PE

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

FEMP
Federal Energy Management Program

GSA

AGENDA

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

Morning

- Introductions to course and instructors
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- **Data center environmental conditions**

Lunch On your own

Afternoon

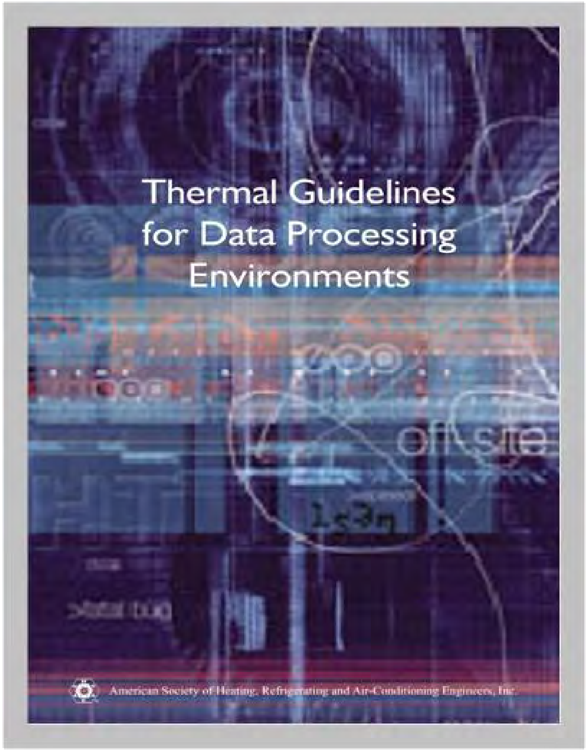
- Airflow management
- Cooling systems
- Electrical systems
- Summary and Takeaways

What are the main HVAC Energy Drivers?

- IT Load
- Climate
- **Room temperature and humidity**

Environmental Conditions

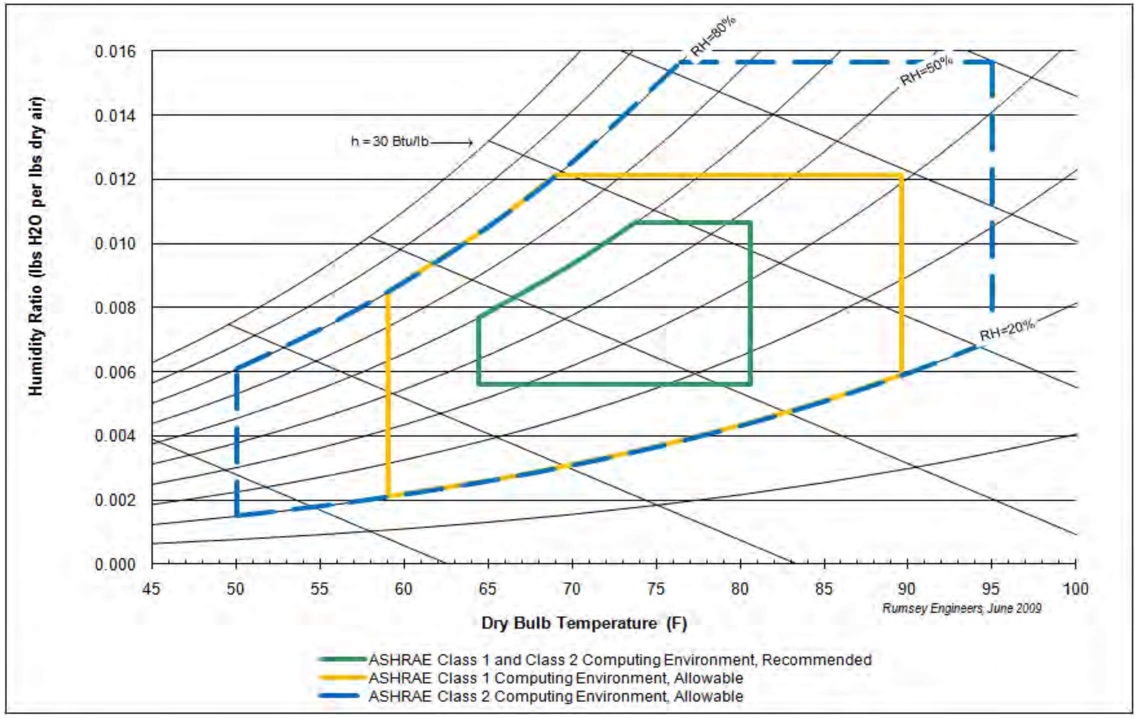
- Most data centers are over-cooled and have humidity control issues
- ASHRAE and IT equipment manufacturers established recommended and allowable conditions for air delivered to the intake of the computing equipment
- There is a lot of misunderstanding about cooling requirements for IT equipment
- The IT equipment manufacturers developed the guidelines with ASHRAE and **recently agreed to even broader ranges of temperature and humidity**

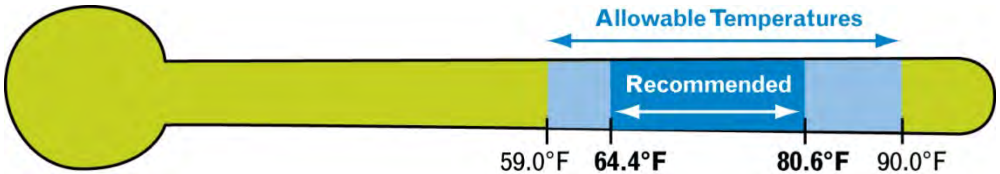


Environmental Conditions

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

- Use ASHRAE Recommended and Allowable ranges of temperature and humidity





Environmental Conditions

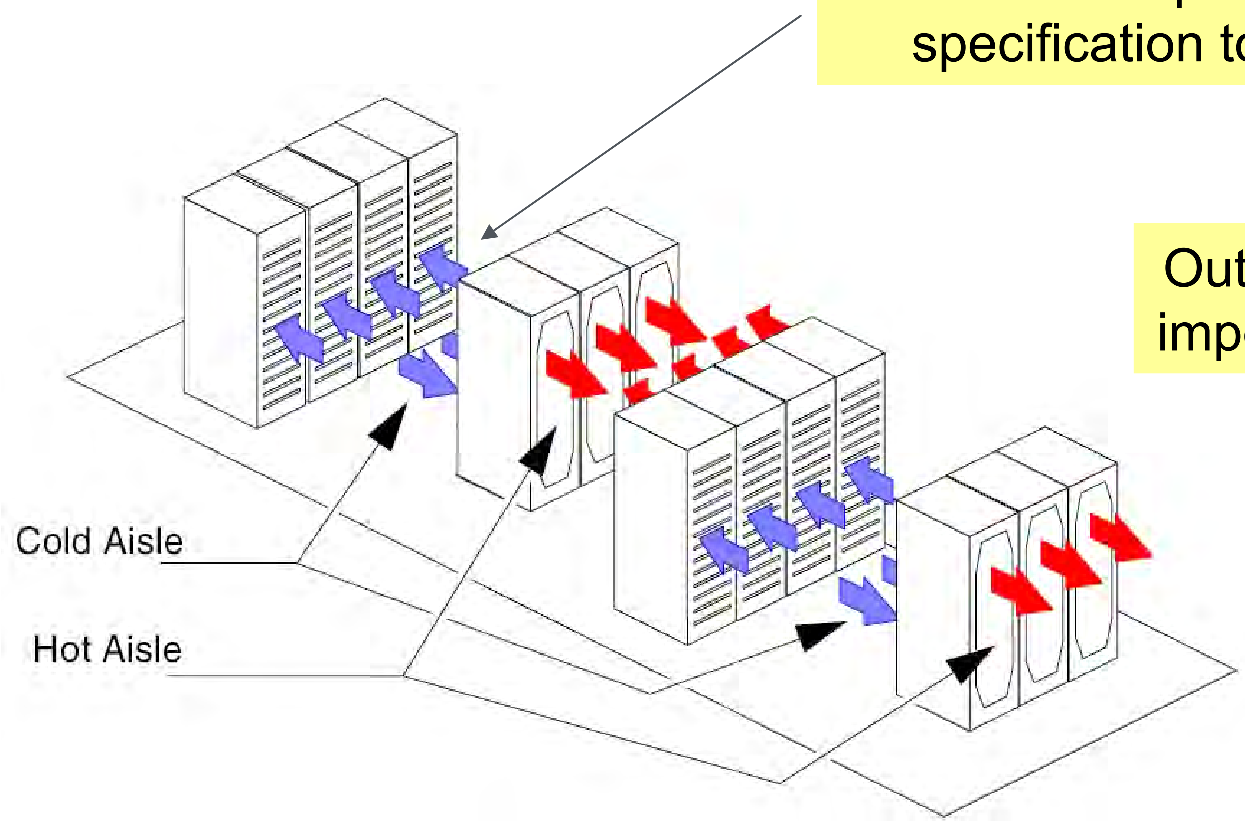
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- ASHRAE's Thermal Guidelines provide a common understanding for IT and facility staff.
- ASHRAE's Thermal Guidelines have a recommended temperature range of 18 ℃ to 27 ℃ (80.6°F) and allowable ranges much higher.
- Endorsed by IT manufacturers and enable large energy savings - especially when using economizers.
- **New ASHRAE white paper**
  - **Further broadens the allowable ranges**
  - **Provides more justification for operation above recommended limits**
  - **Six classes of equipment identified with wider allowable ranges from 32° C to 45° C (113°F)**

Equipment environmental specification

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

Outlet temperature is not important to IT Equipment



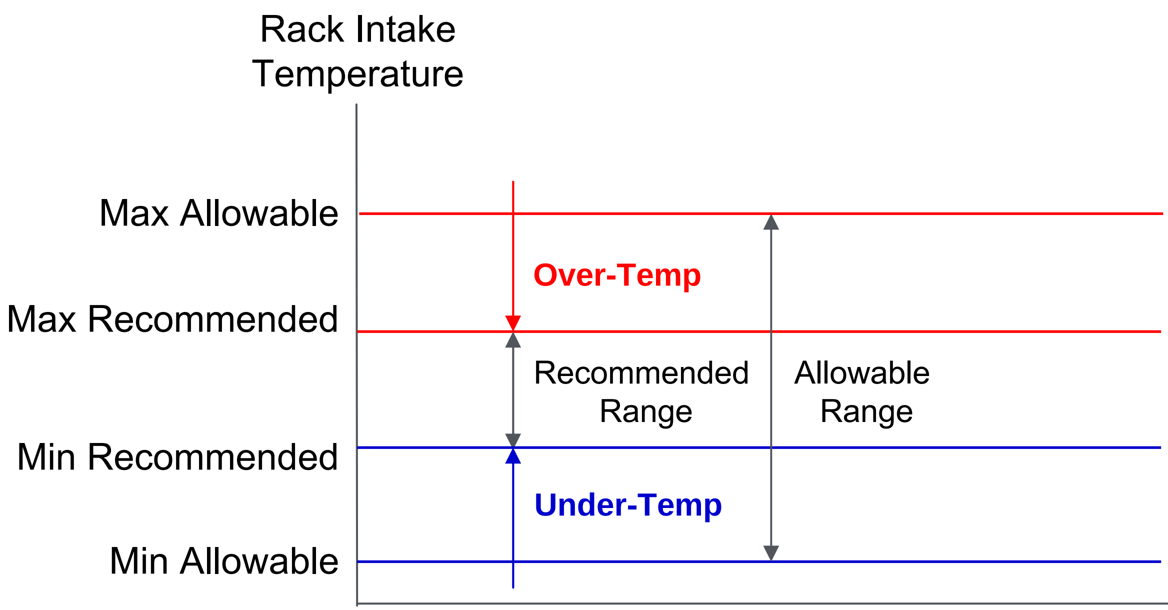
Key Nomenclature

Recommended range (statement of reliability):

Preferred facility operation; most values should be within this range.

Allowable range (statement of functionality):

Robustness of equipment; no values should be outside this range.



138

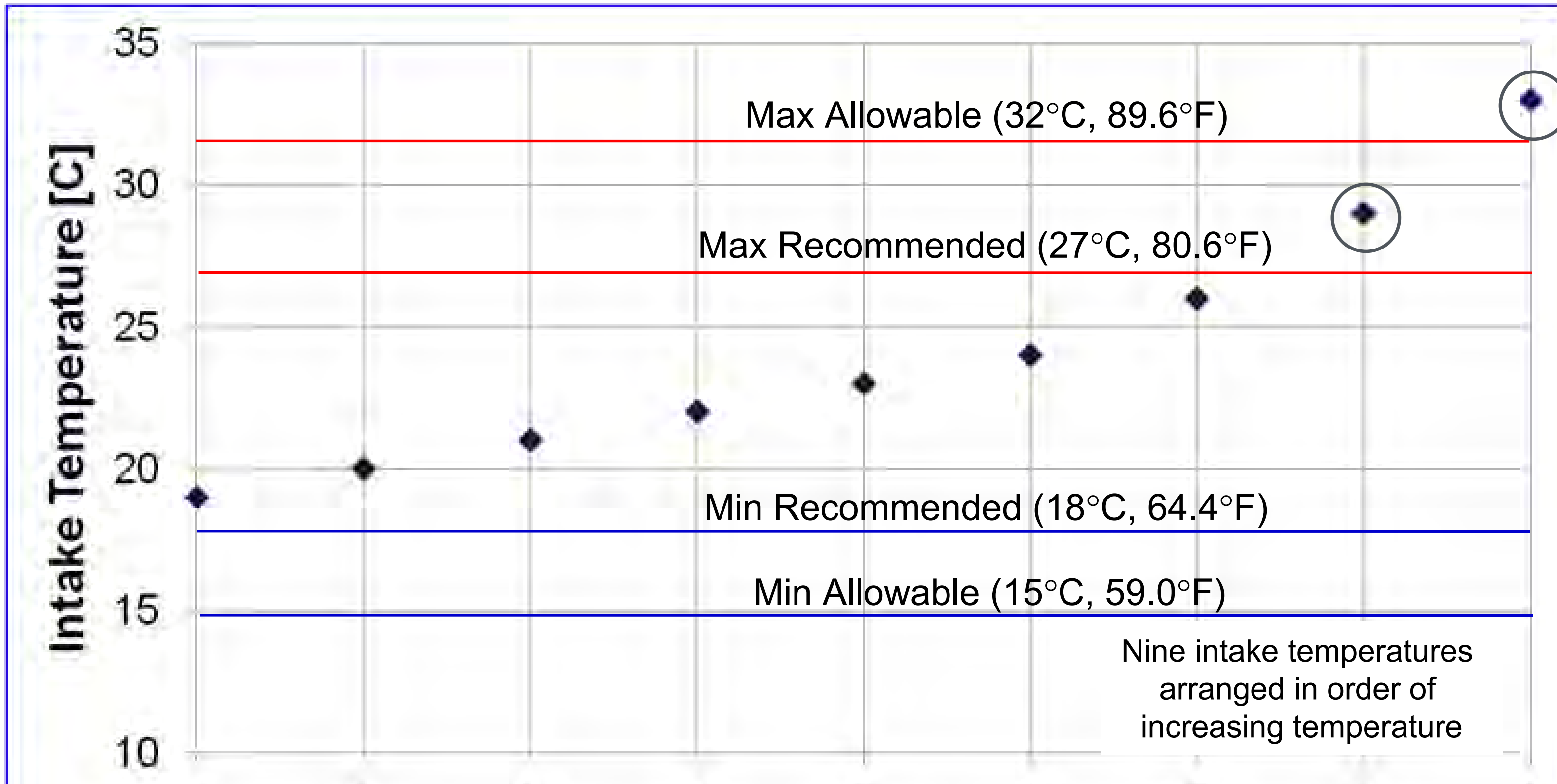
Purpose of the Ranges

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.

- Human comfort should be a secondary consideration in data centers.

Example: Determining Compliance



Two intake temps above the max recommended temp: 29° and 33°C.
One intake temp above the max allowable temperature: 33°C.

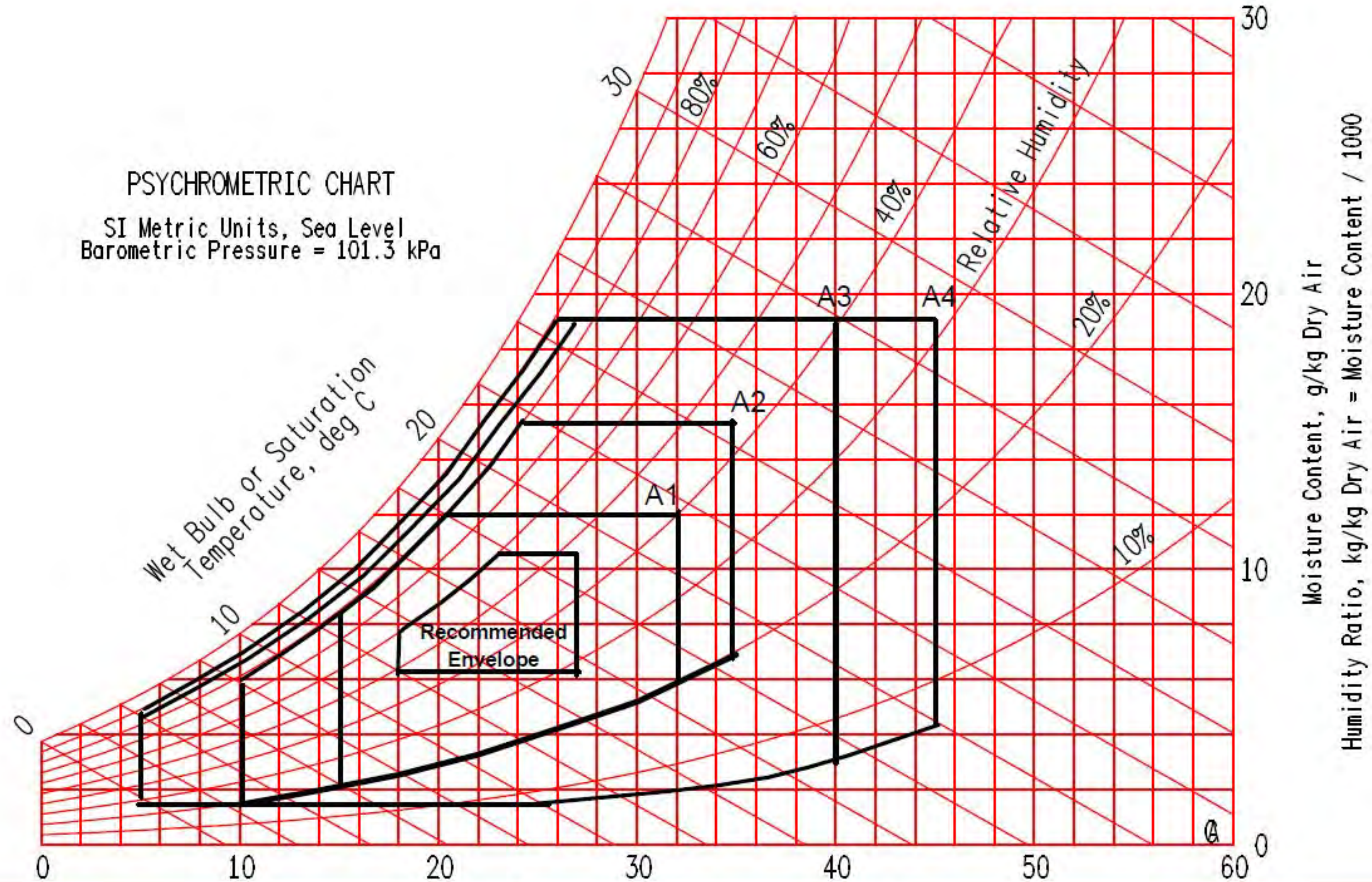
2011 ASHRAE Thermal Guidelines

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

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)
Recommended (Applies to all A classes; individual data centers can choose to expand this range based upon the analysis described in this document)								
A1 to A4	18 to 27	5.5ºC DP to 60% RH and 15ºC DP						
Allowable								
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

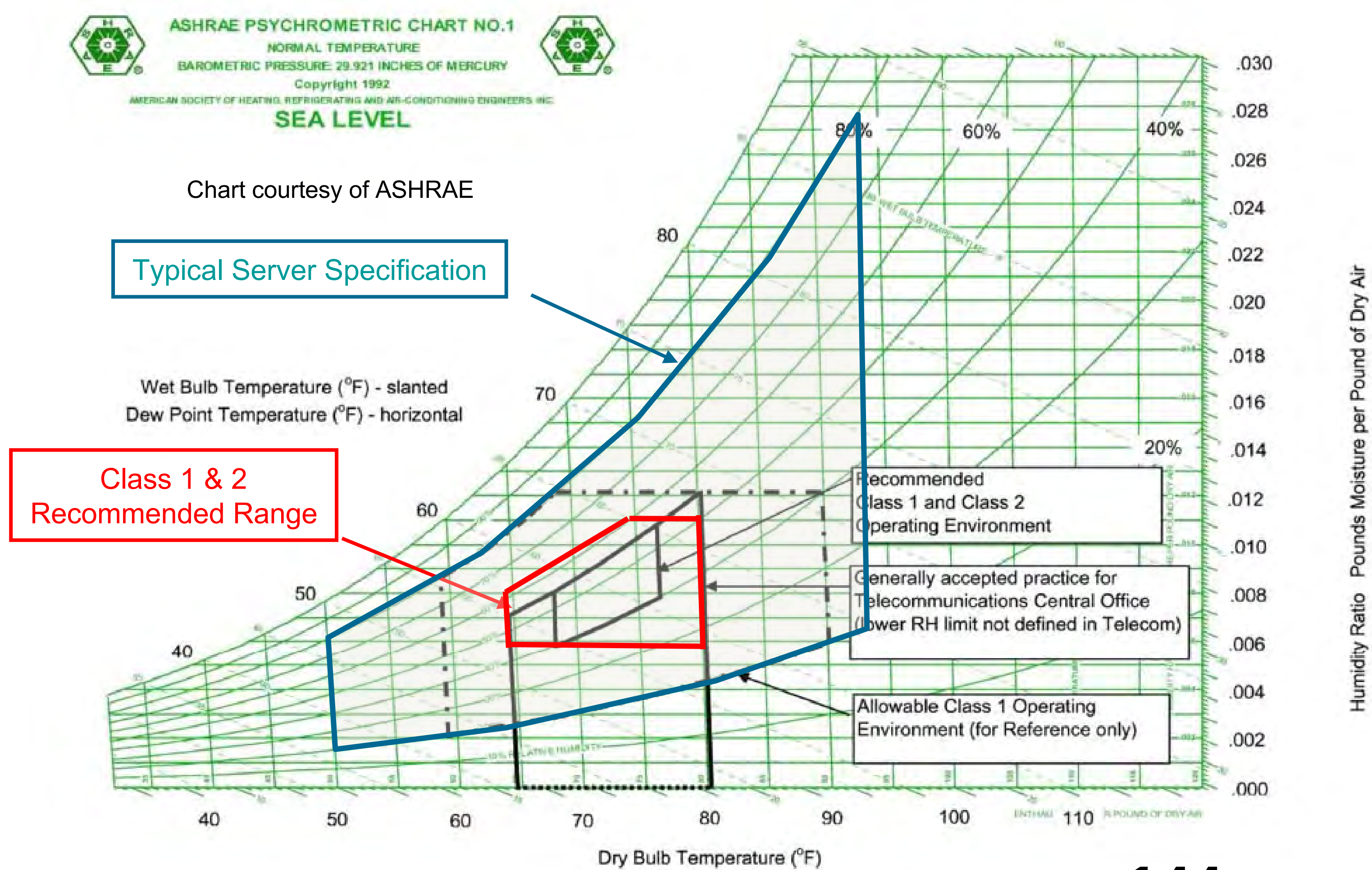


Dry Bulb Temperature

ASHRAE 2011 White Paper key conclusion considering potential for increased failures at higher 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."

Server Specs Generally Exceed ASHRAE Ranges



144

Example server specification

Environmental

Temperature:

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

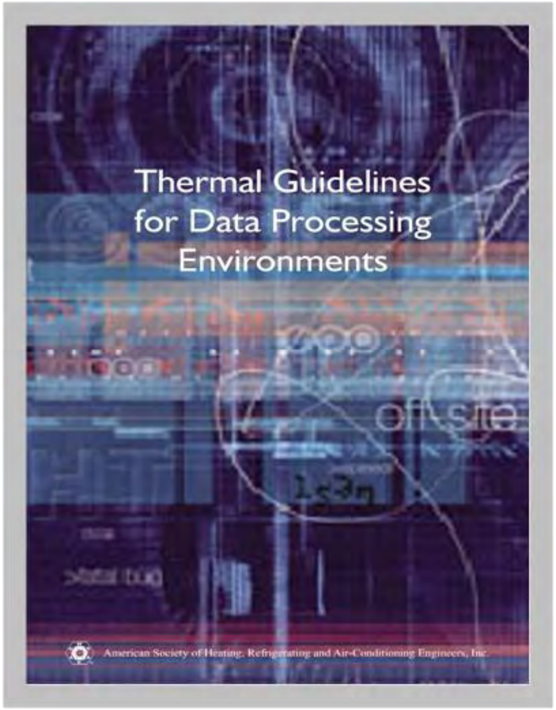
Relative humidity

- 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)

- Some manufacturers design for even harsher conditions.
- Facilities should be designed for IT equipment comfort – not people comfort.
- If the data center is cold there is an efficiency opportunity.
- Most data center computer room air conditioners are controlling the temperature <u>returning</u> to the unit – this needs to change.
- Perceptions lead many data centers to operate much cooler than necessary; often less than 68 °F at the inlet to IT equipment.



Temperature Rate-of-Change Specifications

(@ Equipment Intake)	Maximum
Data Centers ASHRAE	20°C/hr
Telecom Centers NEBS	96.1°C/hr

Very large differences in temperature rate-of-change. The NEBS specification was developed by estimating the potential gradients in case of cooling outages.

ASHRAE Reference: ASHRAE (2011); NEBS References: Telcordia (2001, 2002, and 2006)

Humidity Control

- **Design Conditions**
  - Maintain inlet conditions to the electronic equipment to the recommended ASHRAE Thermal Guideline between 41.9° F dew-point and 59° F dew-point and 60% RH or manufacturer's requirements.
  - Use dew-point control, NOT %RH.
  - The need for any humidity control needs more study.
- **Eliminate dehumidification, if possible**
  - High humidity is usually limited by cooling coil dew-point temperature.
- **Use more efficient means of dehumidification**
  - Control make-up air humidity and turn off CRAC humidification control

High Humidity Limit Issues

– Some contaminants (hydroscopic salts) with high humidity can deposit and bridge across circuits over time
– Operating with high humidity (>60%) in an environment with high concentrations of particulates could therefore 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.

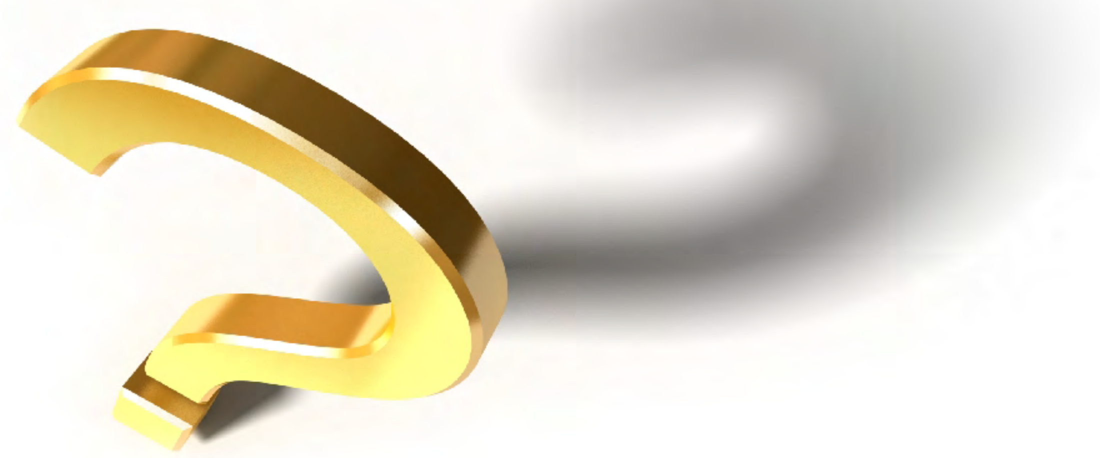
Low Humidity Limit Issues - Electrostatic discharge

- Industry practices
  - Telecom has no lower limit (personnel grounding)
  - 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 grounding
- Recommended equipment
  - Grounding wrist straps
  - Grounded plate for cables
  - Grounded flooring

Liquid Cooling Guidelines

- ASHRAE developing a white paper for liquid cooling
- A High Performance Computer (HPC) user group led by LBNL also developing recommended liquid cooling temperatures
- Attempting to harmonize the two
- HPC user group's goal is to provide liquid cooling without compressor cooling (no chillers) through cooling towers or dry coolers

Questions?



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

Airflow Management

Effective Application and Use in Data Centers

Presented by: Geoffrey C. Bell, PE

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

FEMP
Federal Energy Management Program

GSA

AGENDA

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

Morning

- Introductions to course and instructors
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions

Lunch On your own

Afternoon

- **Airflow management**
- Cooling systems
- Electrical systems
- Summary and Takeaways

It was cold but hot spots were everywhere

Fans were used to redirect air

High flow tiles reduced air pressure

Airflow Management

What are the benefits of hot- and cold-aisles?

How does air flow in a data center?

- **Detect airflow mixing and short-circuits**
- **Discover airflow Identify hot spots**

What can be done to improve under-floor air distribution?

- **Manage under-floor pressurization**
- **Relocate supply tiles to cold aisles**
- **Select and optimize supply tiles**

Isolate hot and cold aisles

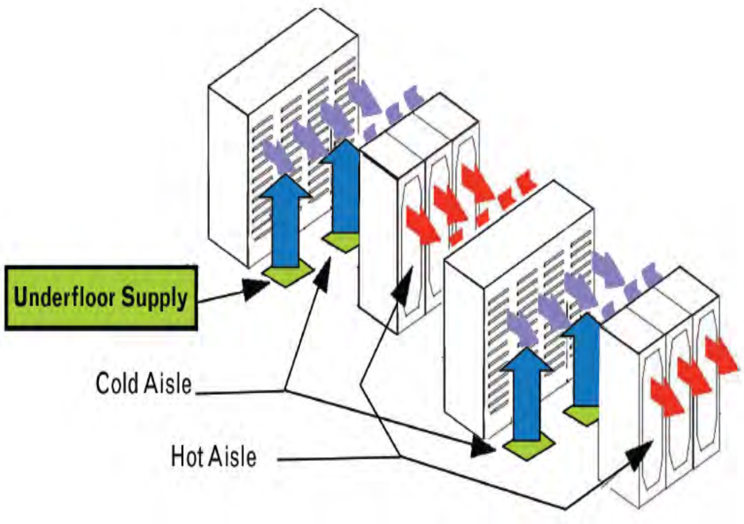
What alternatives to under-floor air distribution increase efficiency?

- **Overhead cooling**
- **In-row and rack cooling**

Air Management

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

- 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.

What are the benefits of hot- and cold-aisles?

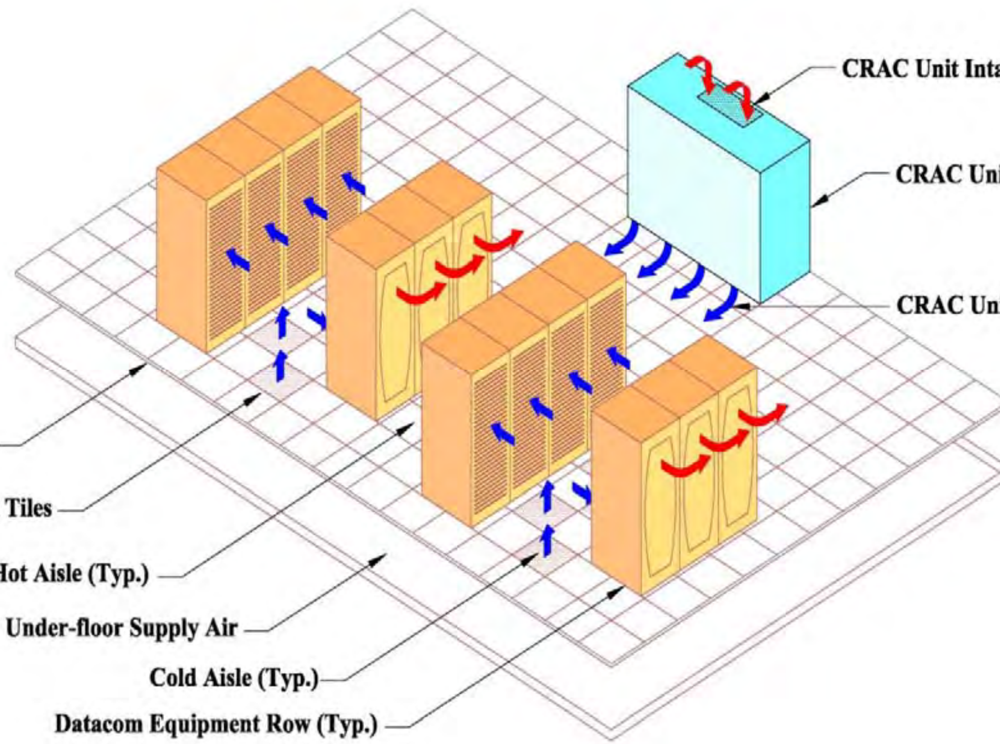
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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

Preparation:
✓Arranging racks with alternating hot and cold aisles.

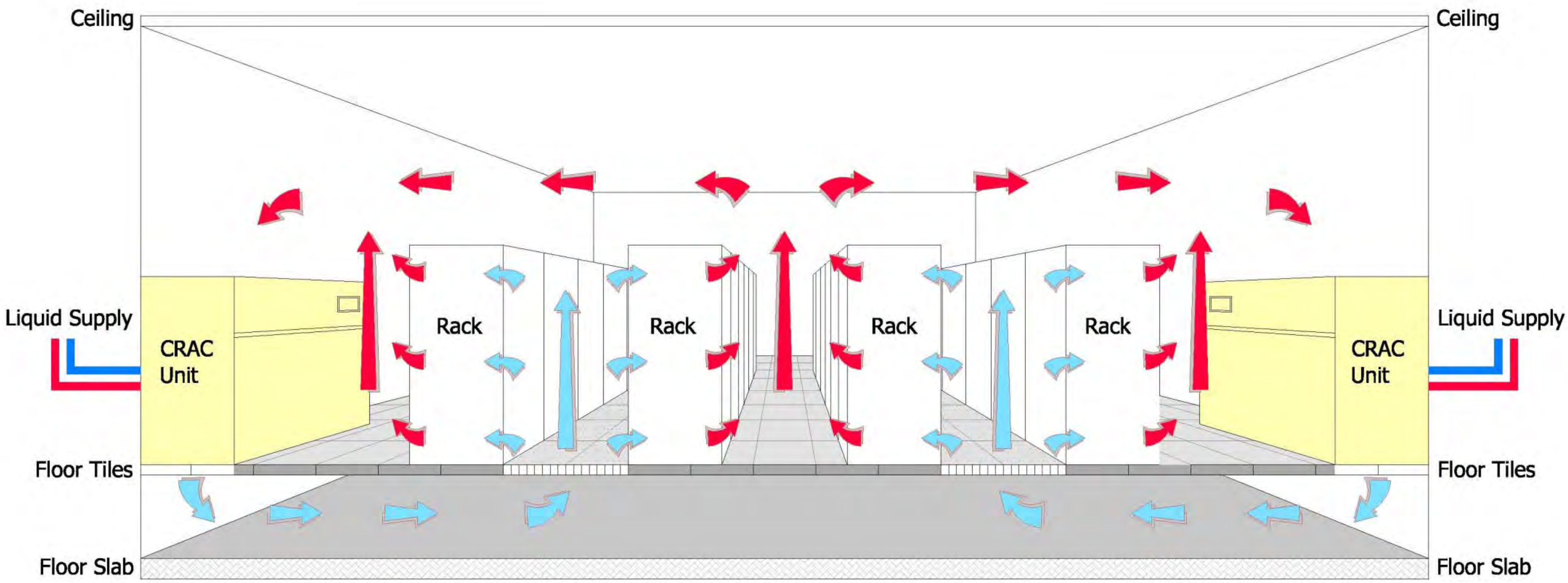
✓Supply cold air to front of facing servers.

✓Hot exhaust air exits into rear aisles.



Graphics courtesy of DLB Associates

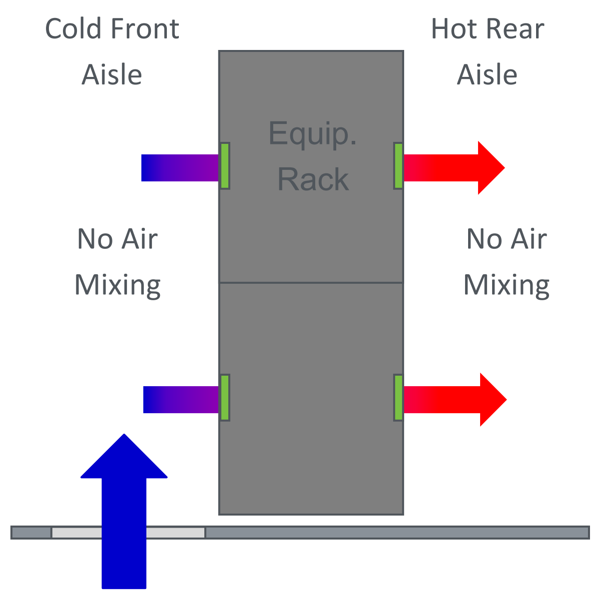
Typical Vertical Under Floor (VUF) Air–Distribution System



Cooling airflow is supplied to the equipment racks through perforated tiles via an under-floor distribution system that is connected to CRAC or CRAH units.

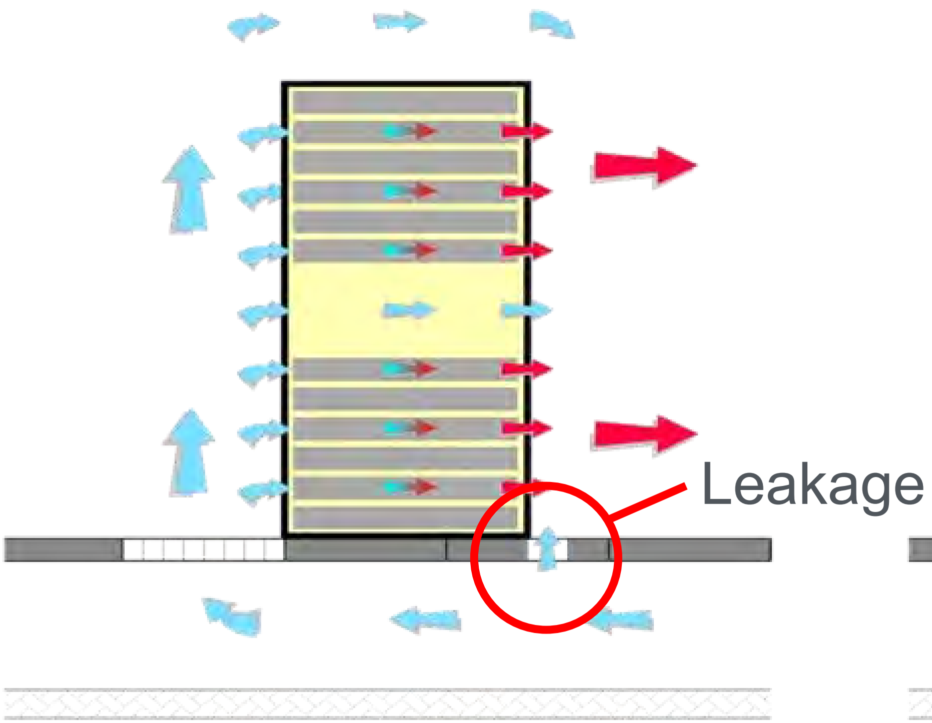
Separating Cold from Hot Airflow…

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



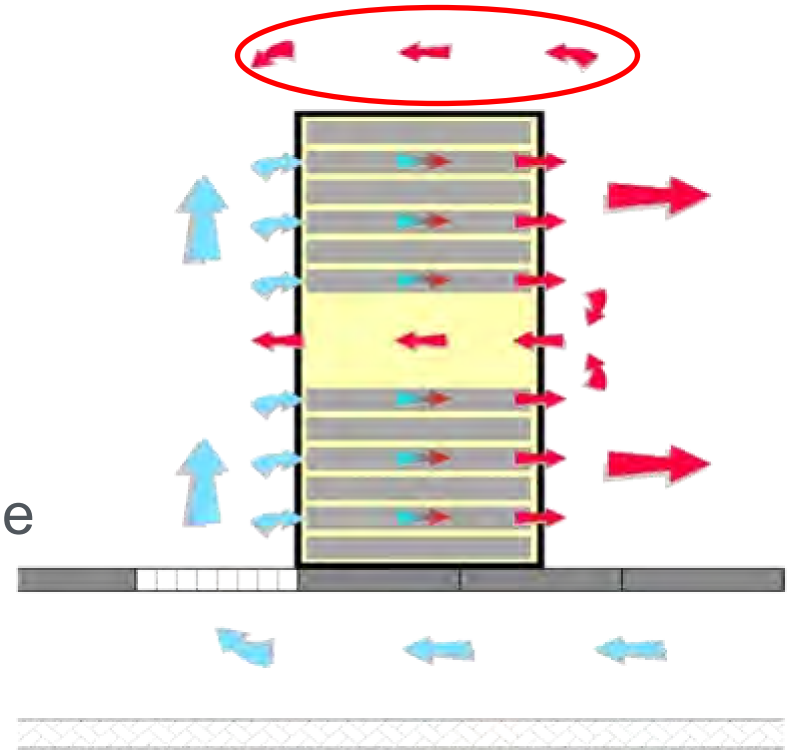
Reduce Bypass and Recirculation

Bypass Air / Short-Circuiting…



Wastes cooling capacity.

Recirculation…

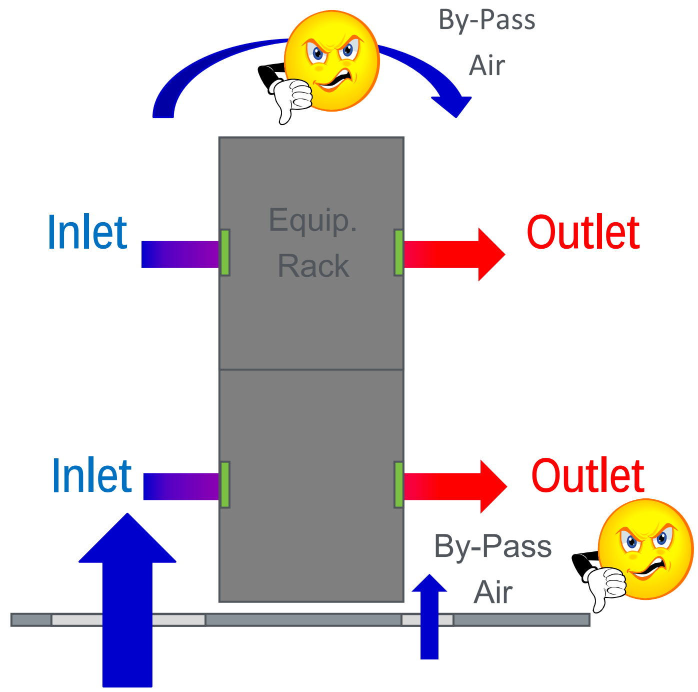


Increases inlet temperature to servers.

Bypass Air

Some common causes:

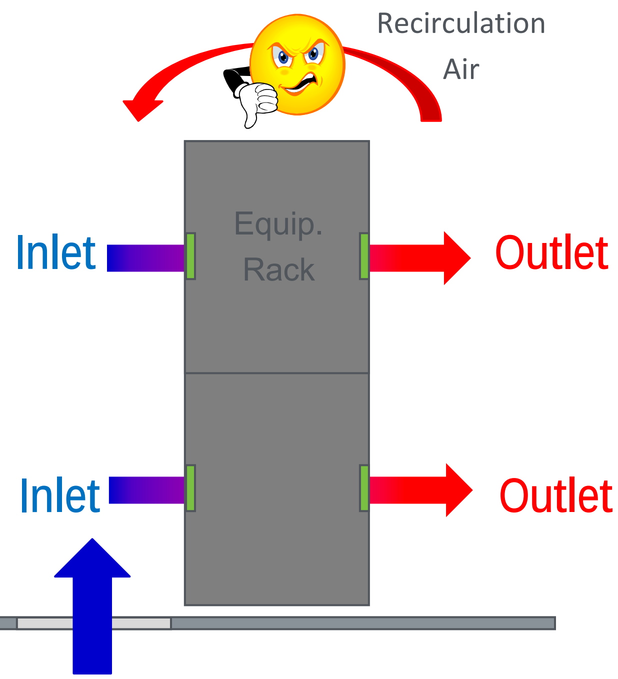
- Too much supply airflow
- Misplaced perforated tiles
- Leaky cable penetrations
- Too high tile exit velocity



Recirculation Air

Some common causes:

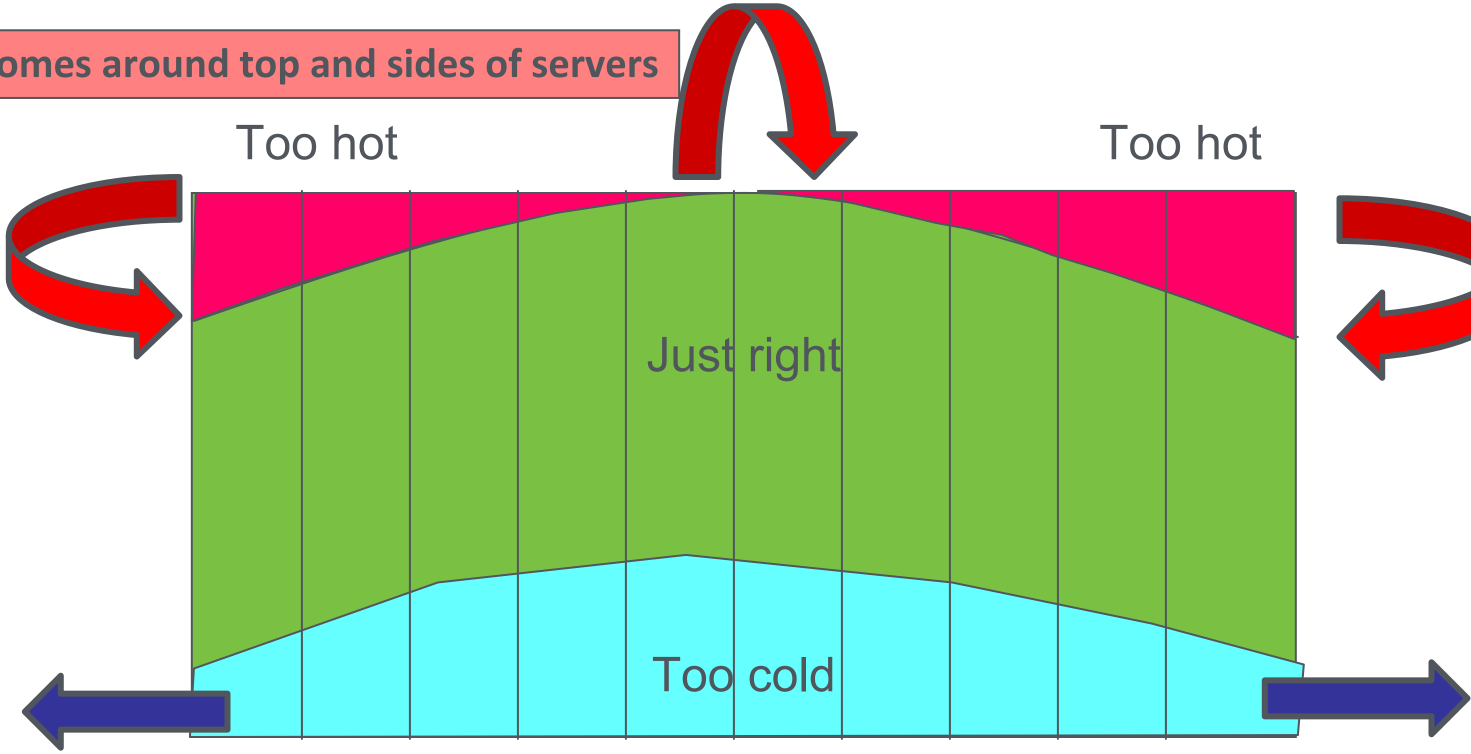
- Too little supply airflow
- Lack of blanking panels
- Gaps between racks
- Short equipment rows



Typical temperature profile with under-floor supply

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

Hot air comes around top and sides of servers



Cold air escapes through ends of aisles

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

What can done to improve under-floor air distribution?

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

Goals:

- **Manage under-floor pressurization**
- **Improve Airflow Distribution**

Tasks…

✓ Maintain Raised-Floor Seals

✓ Manage Blanking Panels

✓ Reduce Cable Congestion

✓ Resolve Airflow Balancing

- – Select tiles with care

✓ Evaluate Perforated Floor Tiles

- – Relocate supply tiles to cold aisles

Manage under-floor pressure

- **In theory, a raised under-floor plenum is at a single static pressure that results in even airflow throughout the data center.**
- **In practice, significant pressure variations within the plenum from:**
  - Air leaks.
  - Cables and congestion in the floor plenum.
  - Increased velocity pressures near supply air fans.
  - Raised floor not tall enough.

➢ **Consequently, pressure variations result in:**
  - Non-uniform airflow distribution causing hot spots.
  - Potential reversed airflow (close to supply fan).

Improve Airflow Distribution

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

- **Poorly distributed air does not reach the intended location.**

- **Investigate**:
  - – Leaks such as unsealed raised floor cutouts and cable openings.
  - – Incorrectly located and sized air outlets and perforated floor tiles
  - ➢ Air outlets should ONLY be in cold aisles near active IT equipment.

Maintain Raised-Floor Seals

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

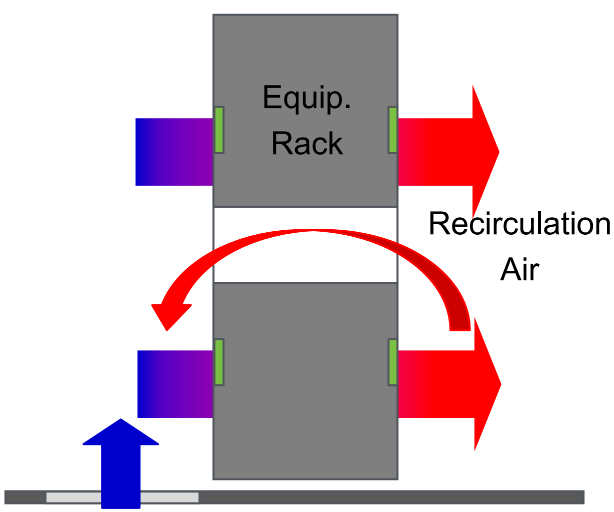
- Typically, a large fraction of cooling air is lost through leaks in the raised floor.

➢ Ensure a rigorous program maintains sealing of all potential leaks in the raised floor plenum.

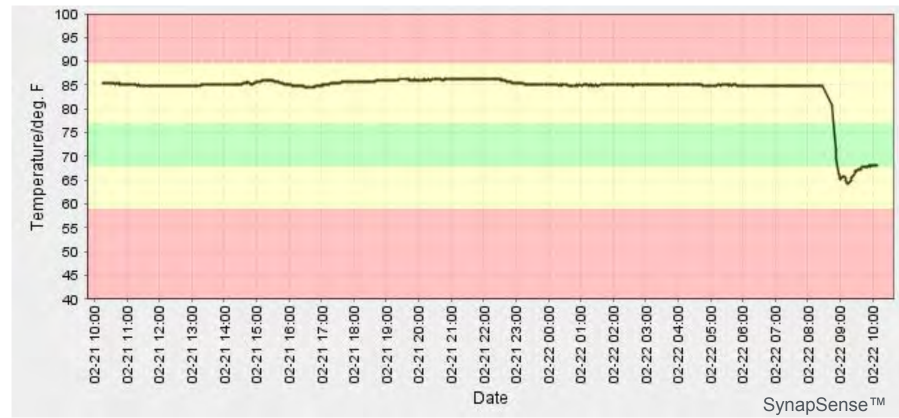
Unsealed cable penetration

Results: Blanking Panels

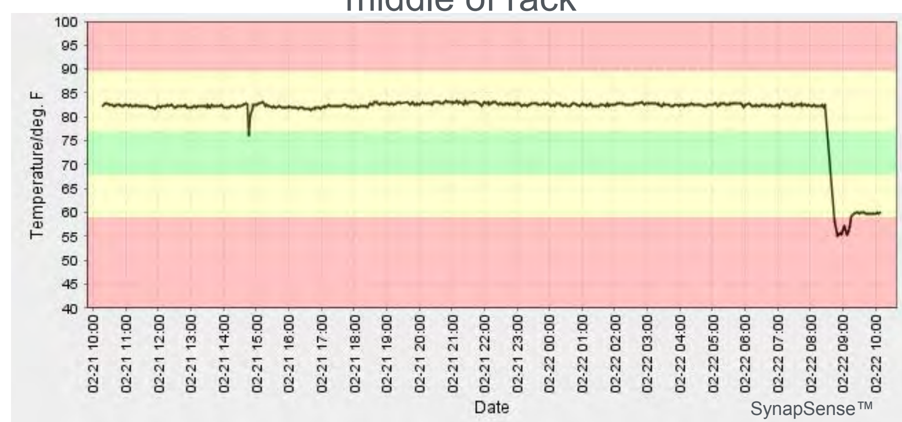
- One 12” blanking panel added
  - Temperature dropped ~20°
- Impact of other best practices confirmed
  - Eliminate leaks in floor
  - Improve air management



top of rack



middle of rack

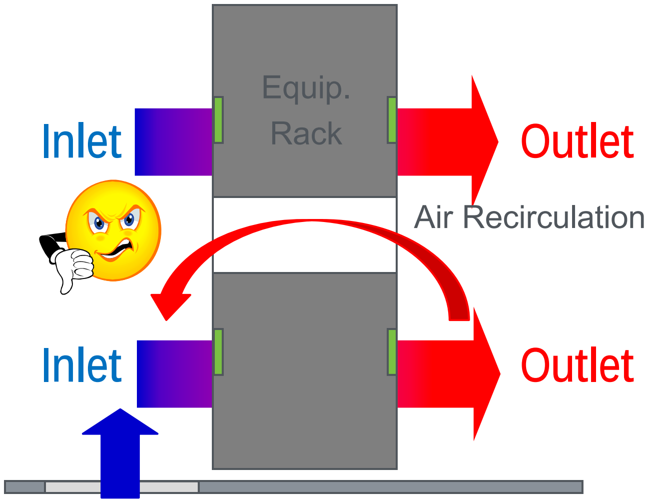


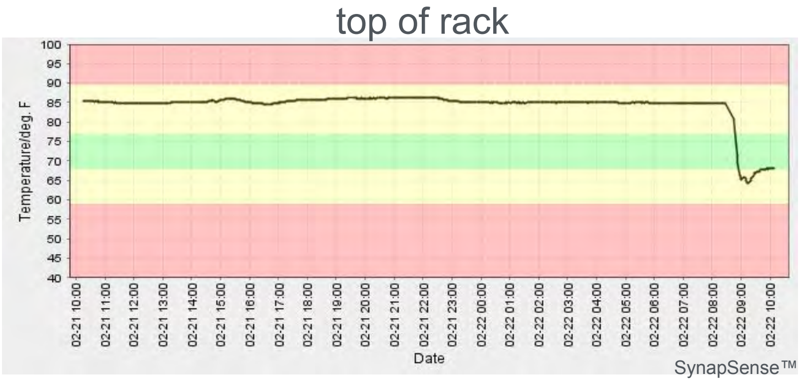
Manage Blanking Panels

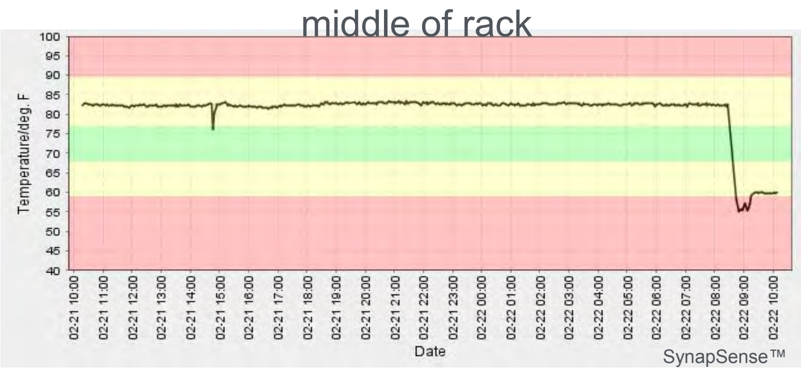
- Managing server blanking and side panels is very important.
- *Any* opening between the aisles will degrade the separation of hot and cold air.

➢ Ensure a rigorous program maintains server blanking and side panels.

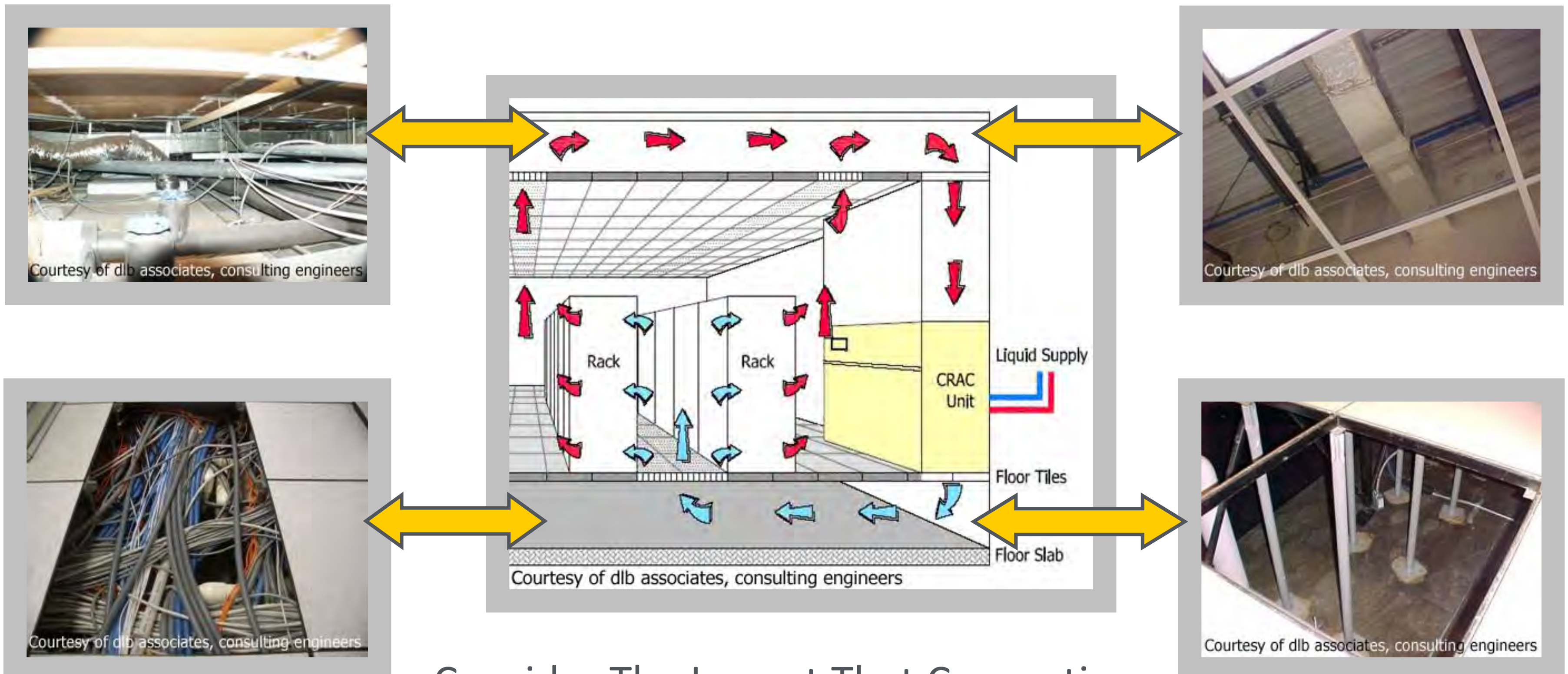
One 12” blanking panel added
Temperature dropped ~20°







Reduce Airflow Restrictions & Congestion



Consider The Impact That Congestion Has On The Airflow Patterns

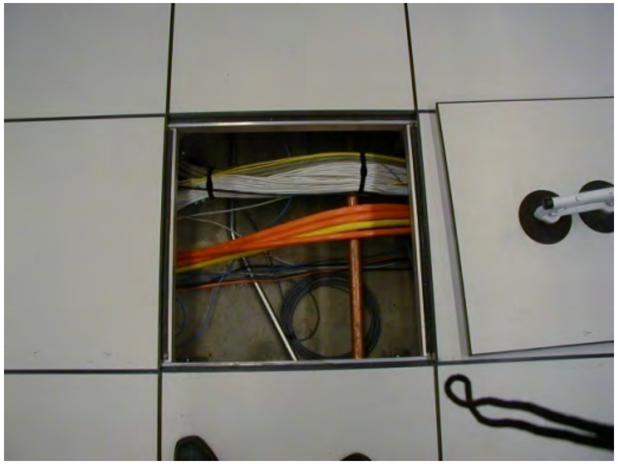
Congested Floor & Ceiling Cavities

Empty Floor & Ceiling Cavities

Reduce Cable Congestion

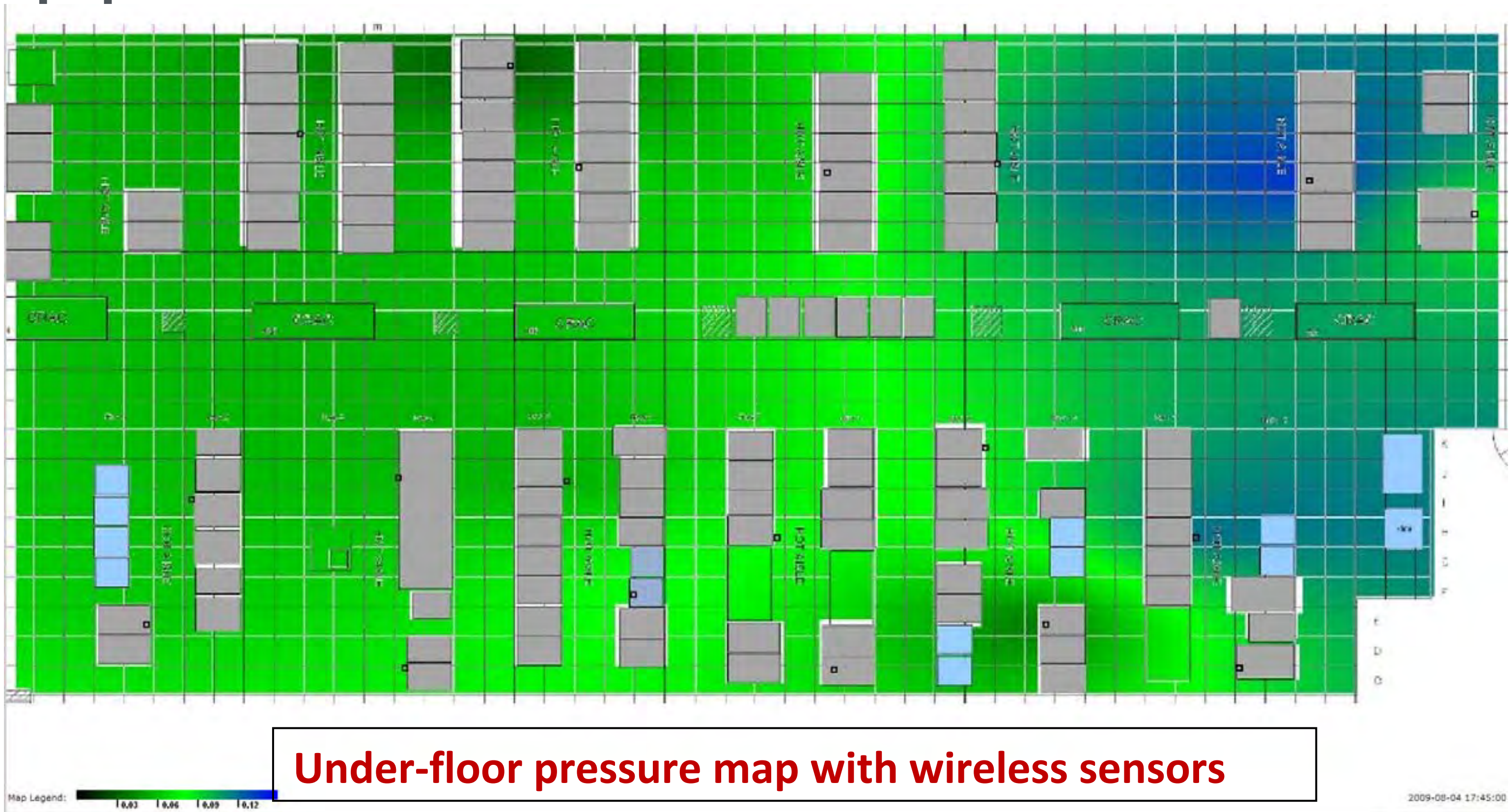
- Cable congestion sharply reduces airflow and degrades airflow distribution.
- No cable trays should be placed below perforated tiles.

➢ Generally, it is obvious when there is too much "*stuff*."



Resolve Airflow Balancing

- **BALANCING is required to optimize airflow.**
- **Measure & REBALANCE whenever new IT or HVAC equipment is installed.**



Under-floor pressure map with wireless sensors

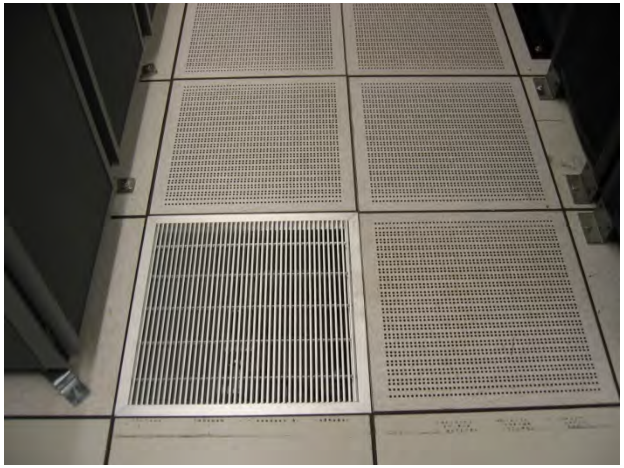
Evaluate Perforated Floor Tiles

- Locate perforated floor tiles *only* in cold aisles.
  - Do not locate perforated tiles in hot aisles; they are supposed to be hot.
- Too little or *too much* supply air may result in poor overall airflow distribution; see below.

Before

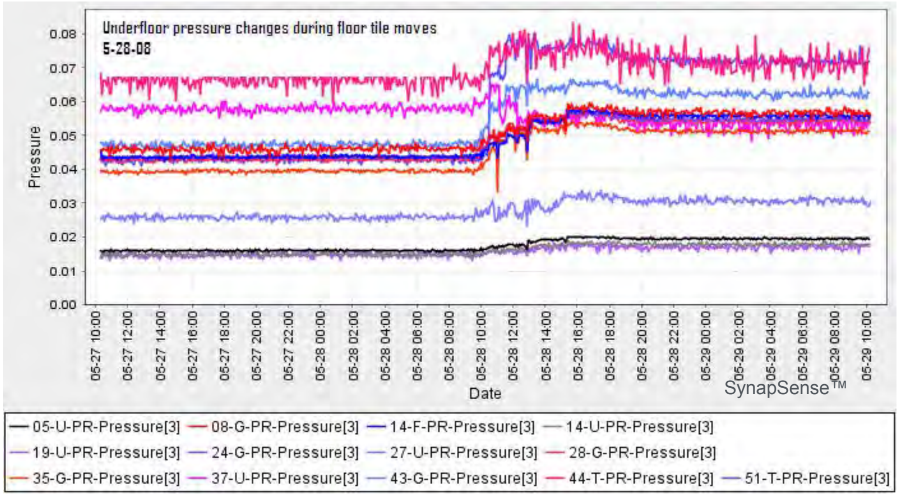
After

Results: Tune Floor Tiles

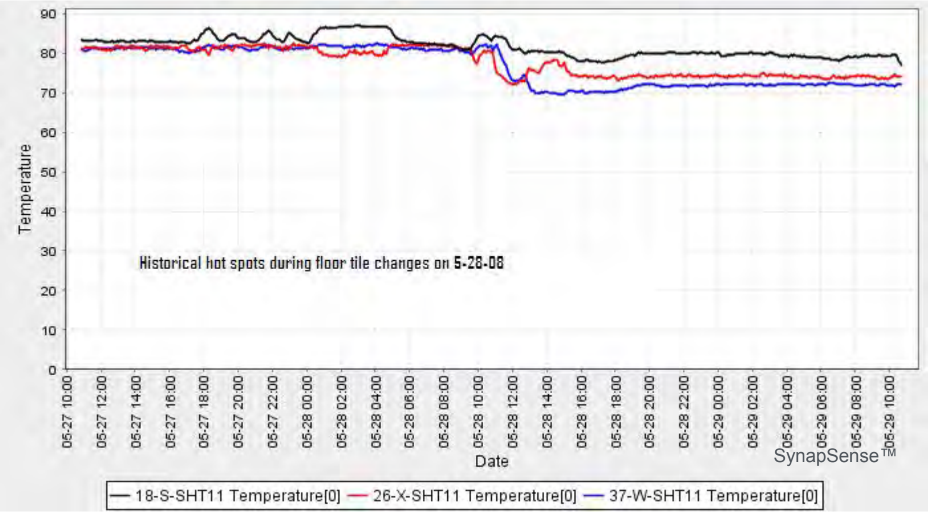


- Too many permeable floor tiles
- if airflow is optimized
  - under-floor pressure ↑
  - rack-top temperatures ↓
  - data center capacity increases
- Measurement and visualization assisted tuning process

under-floor pressures



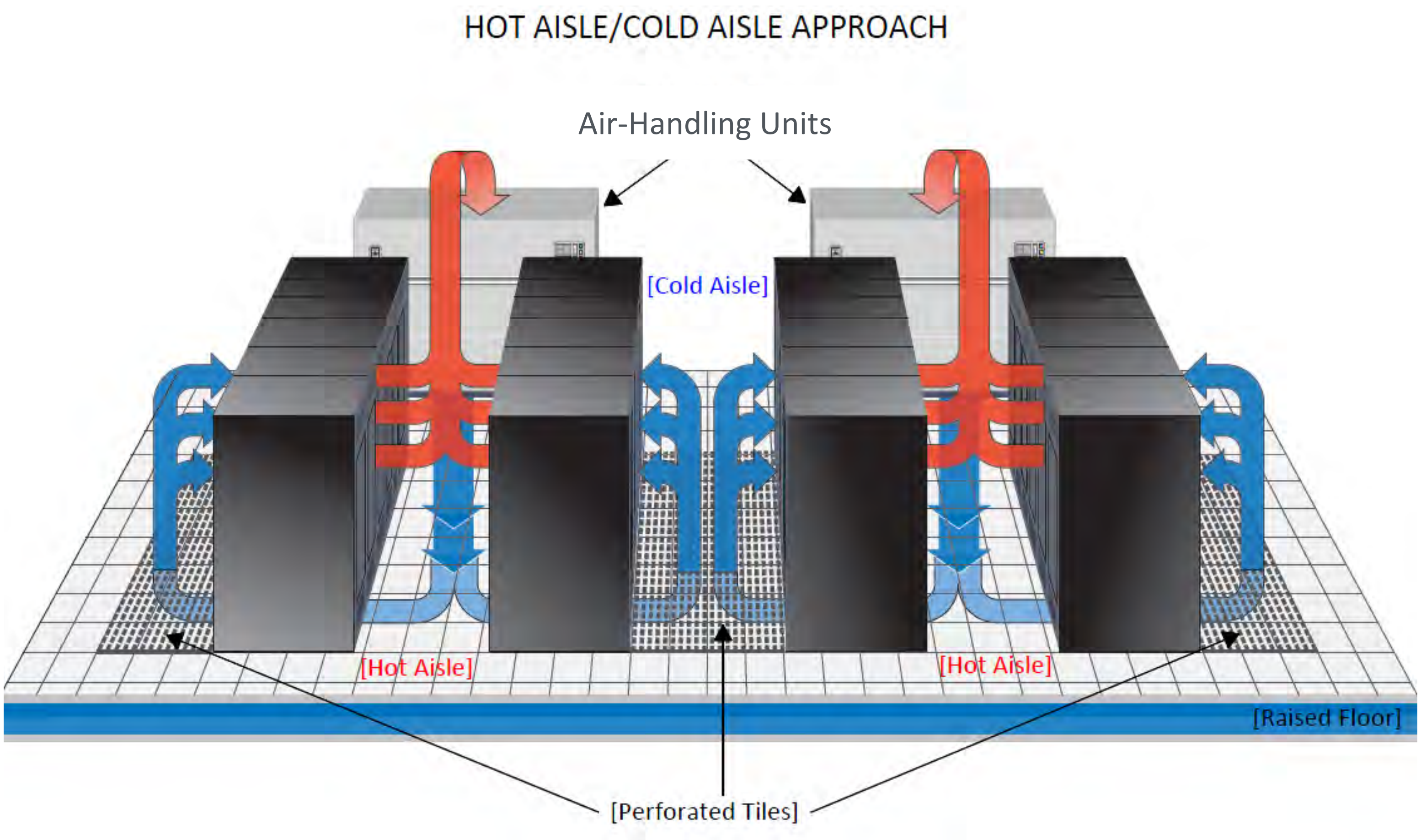
rack-top temperatures



Optimally Locate CRAC/CRAHs

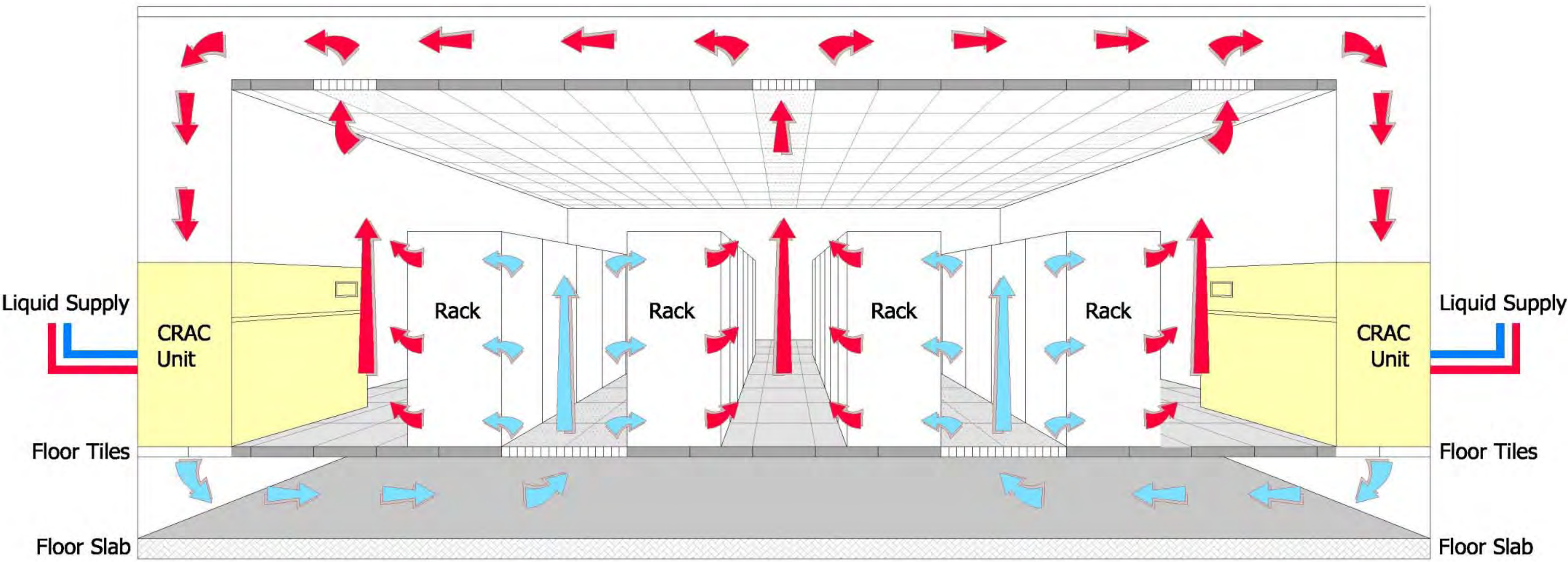
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Locate CRAC/CRAH units at ends of Hot Aisles



Next step: Air Distribution Return-Air Plenum

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



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 Plenum Connections

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

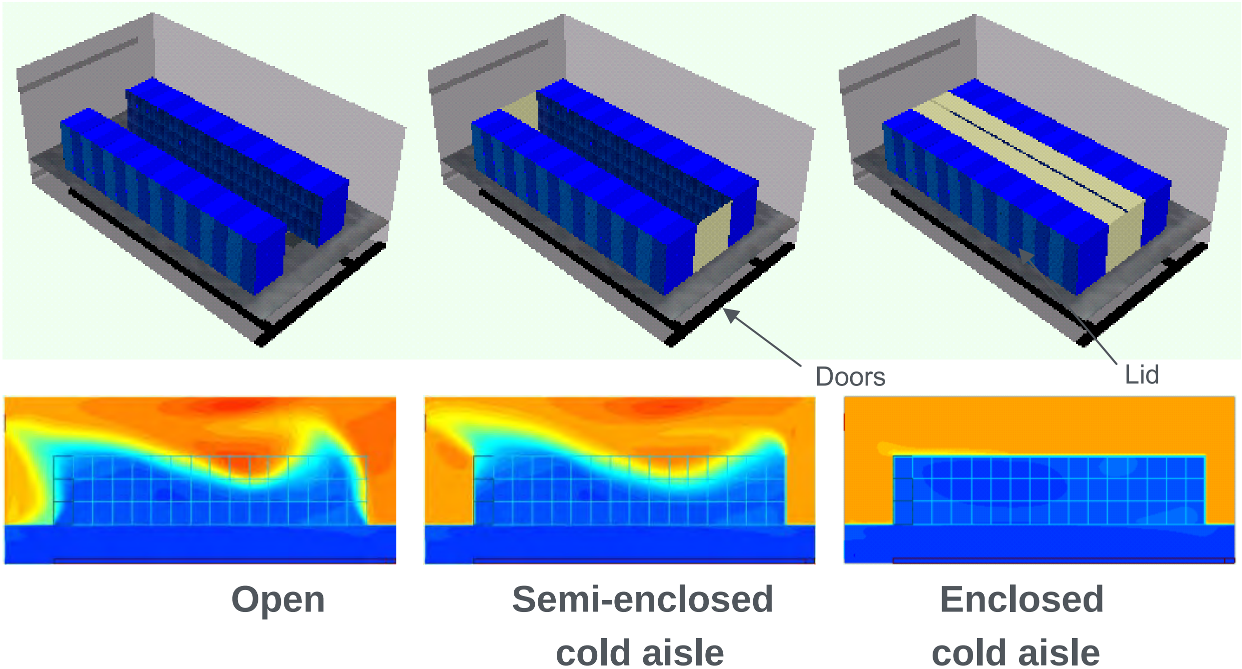
Return air duct on top of CRAC unit connects to the return air plenum.

Isolate Hot Return

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

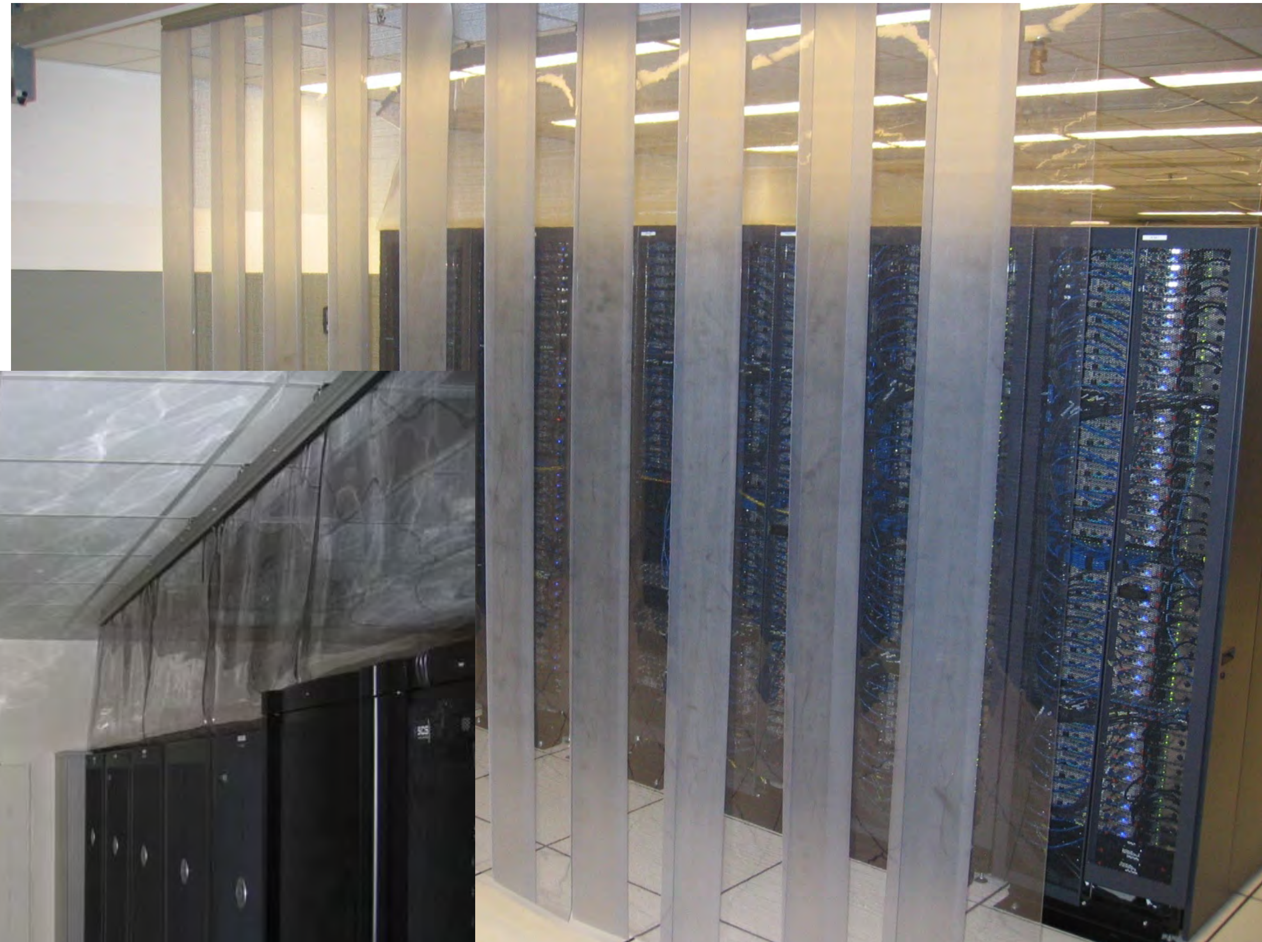
Other Isolation Options

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

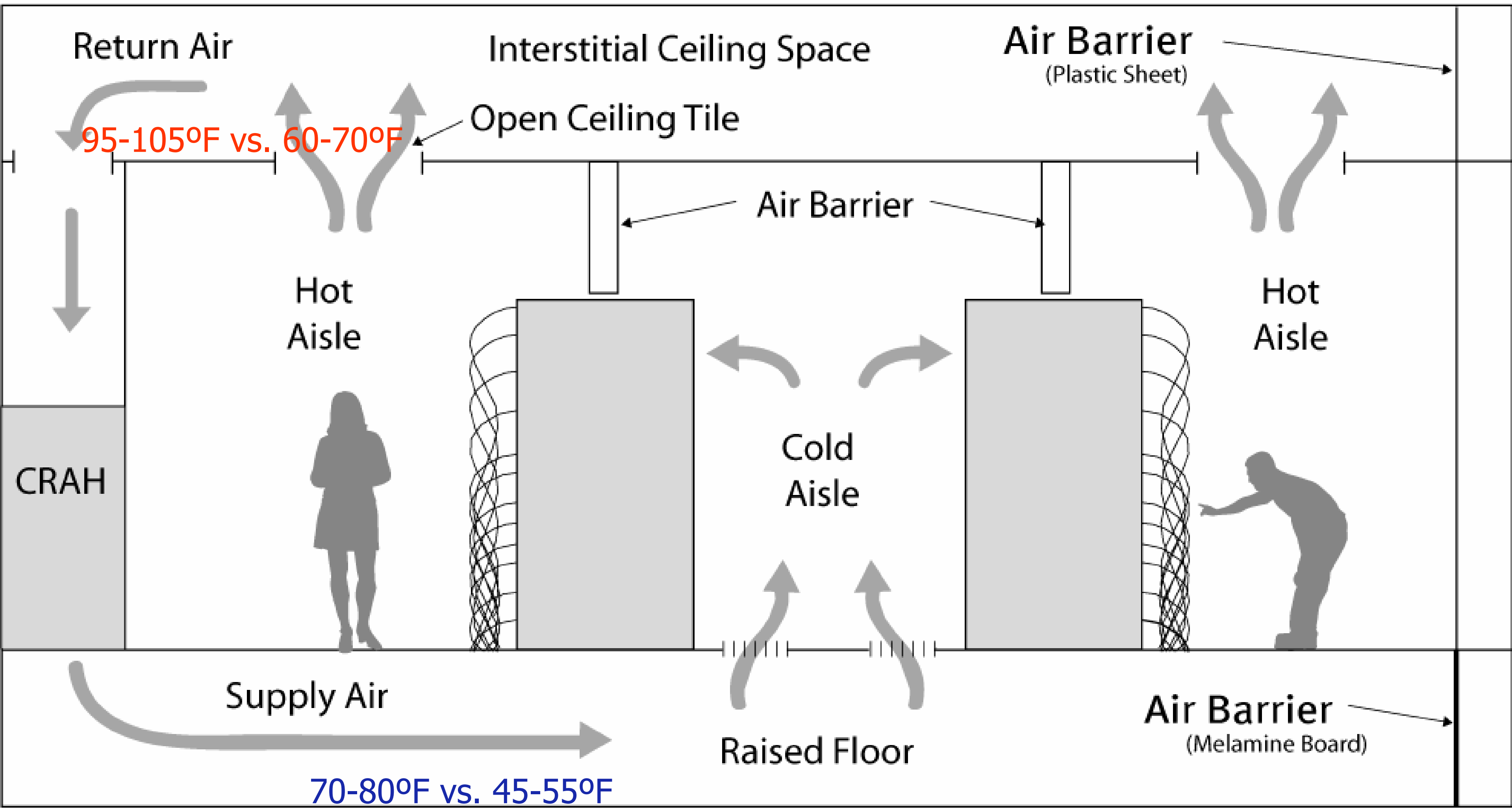


Adding Air Curtains for Hot/Cold Isolation

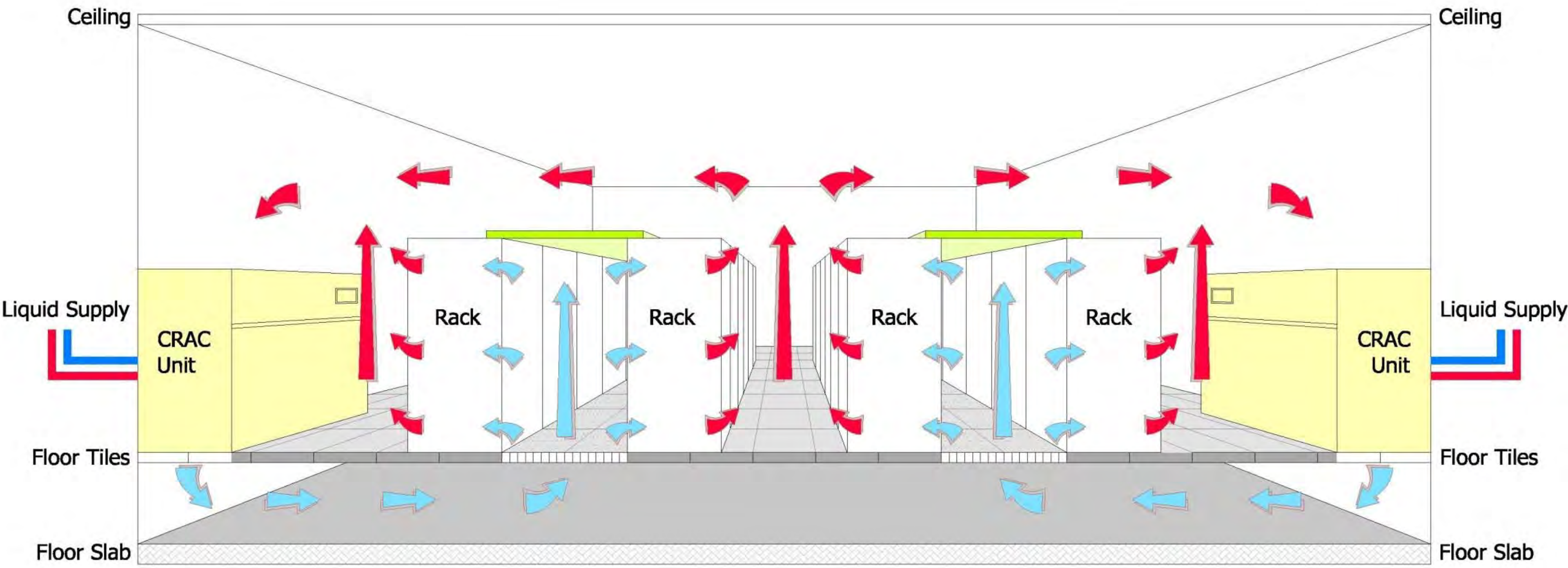
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Improve Air Management: Isolate Cold and Hot Aisles



Cold Aisle Airflow Containment Example

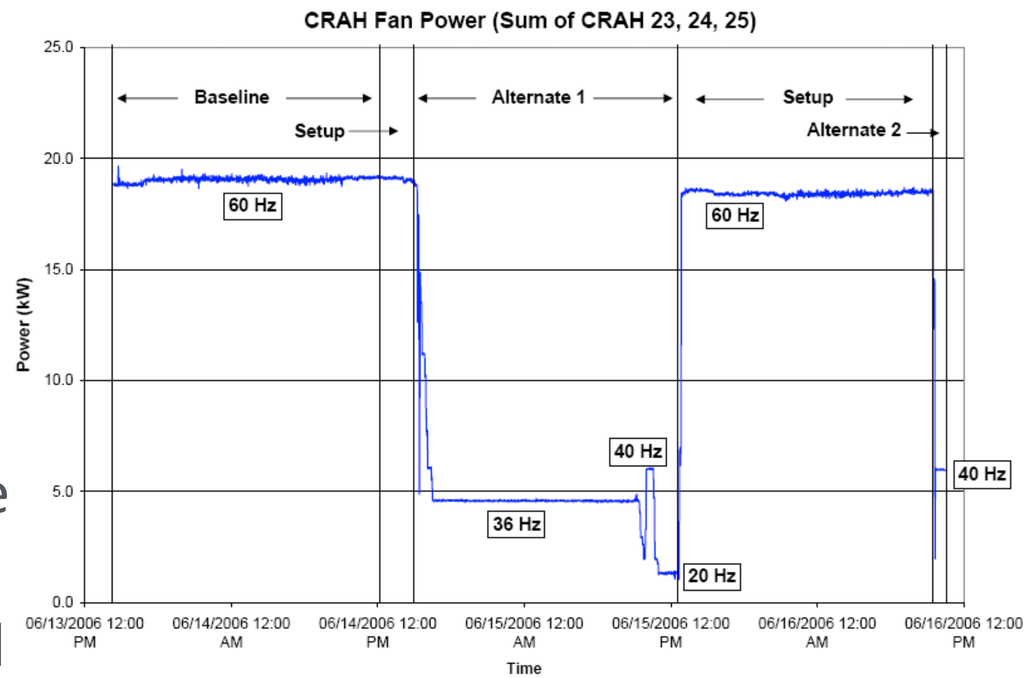


LBNL Cold Aisle Containment study achieved fan energy savings of ~ 75%

Fan Energy Savings

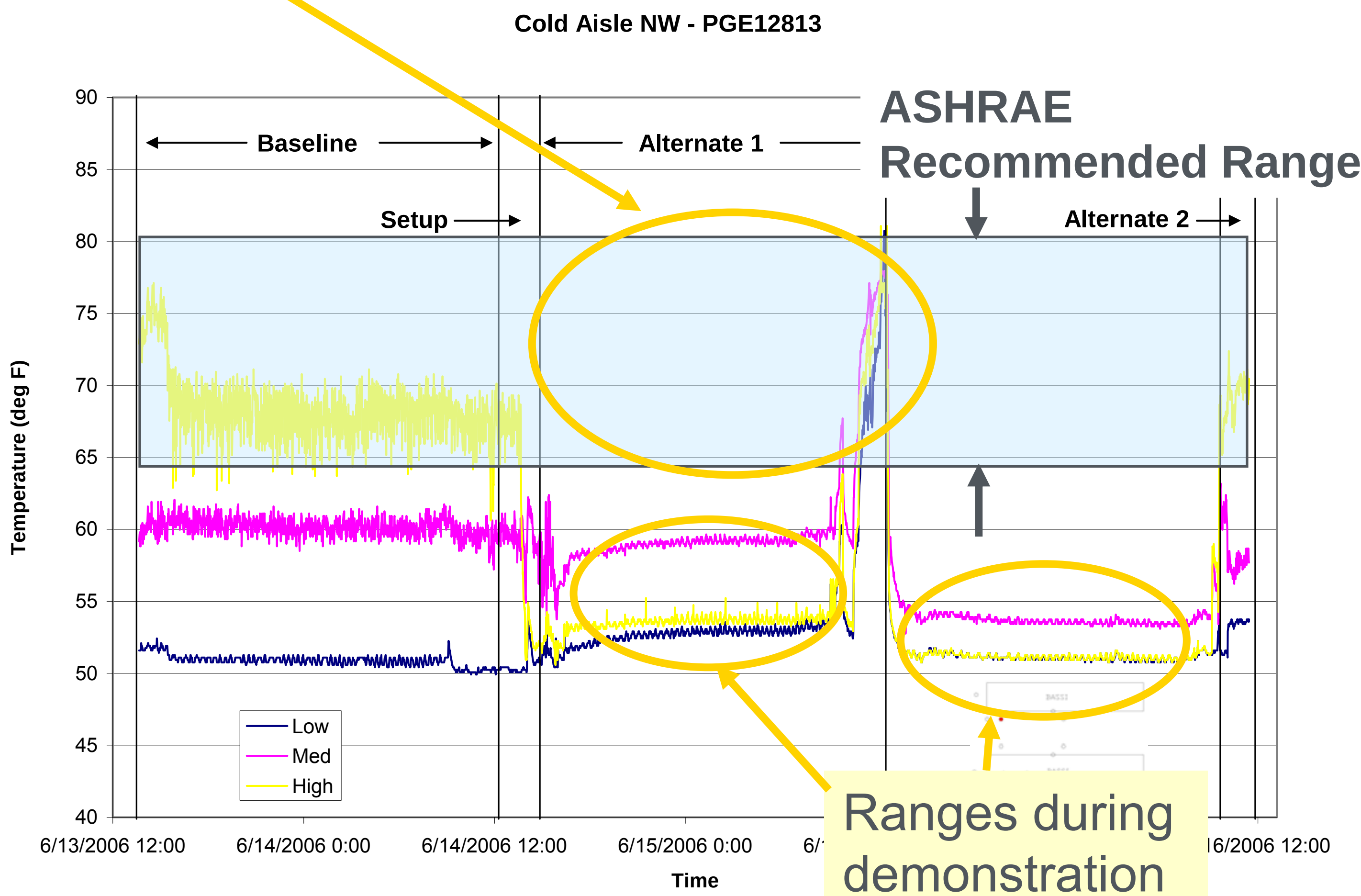
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Isolation can significantly reduce air mixing 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)

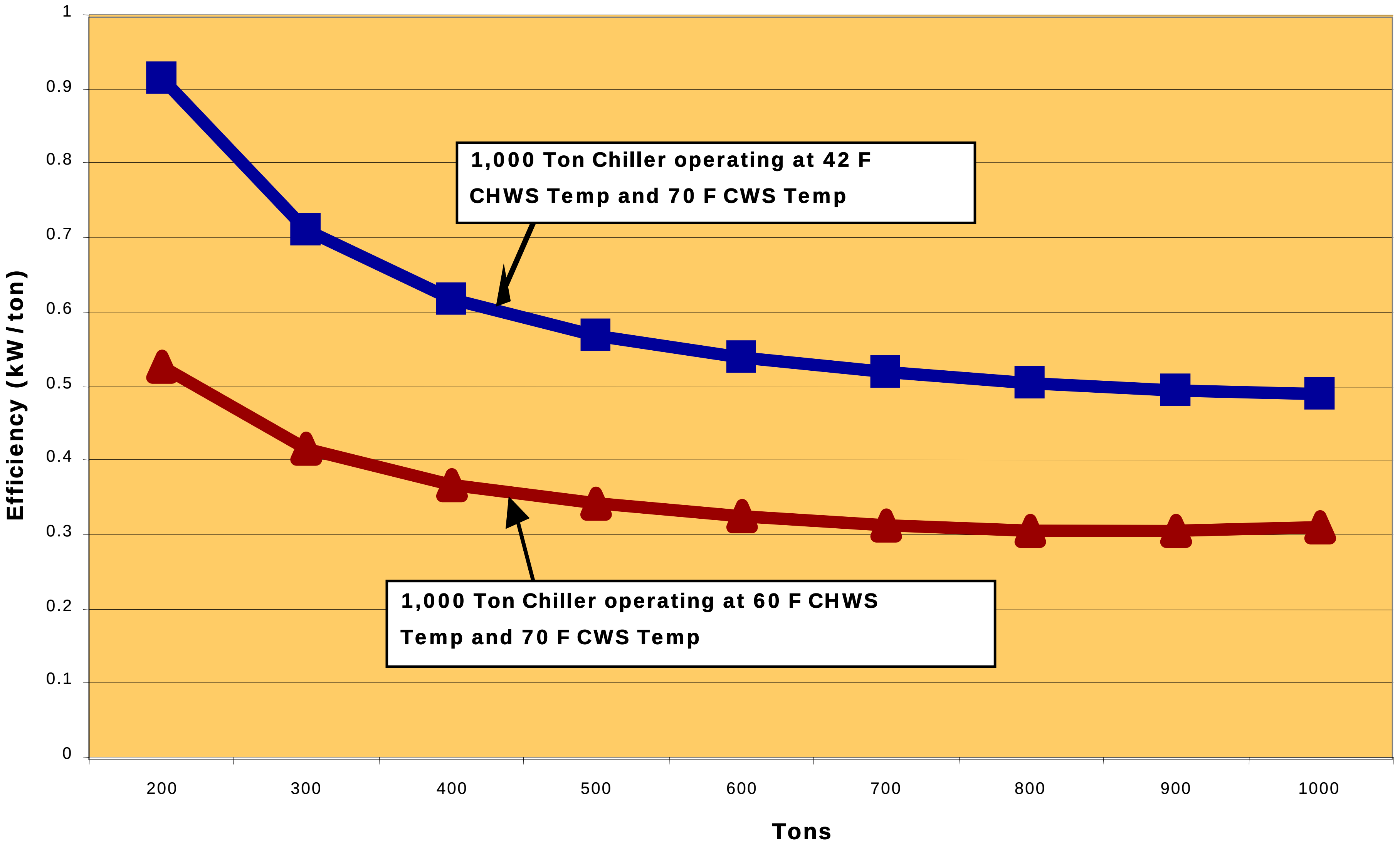


Without Enclosure With Enclosure Without Enclosure

Better airflow management permits warmer supply temperatures!



Cooling System Efficiencies Under Different Conditions:

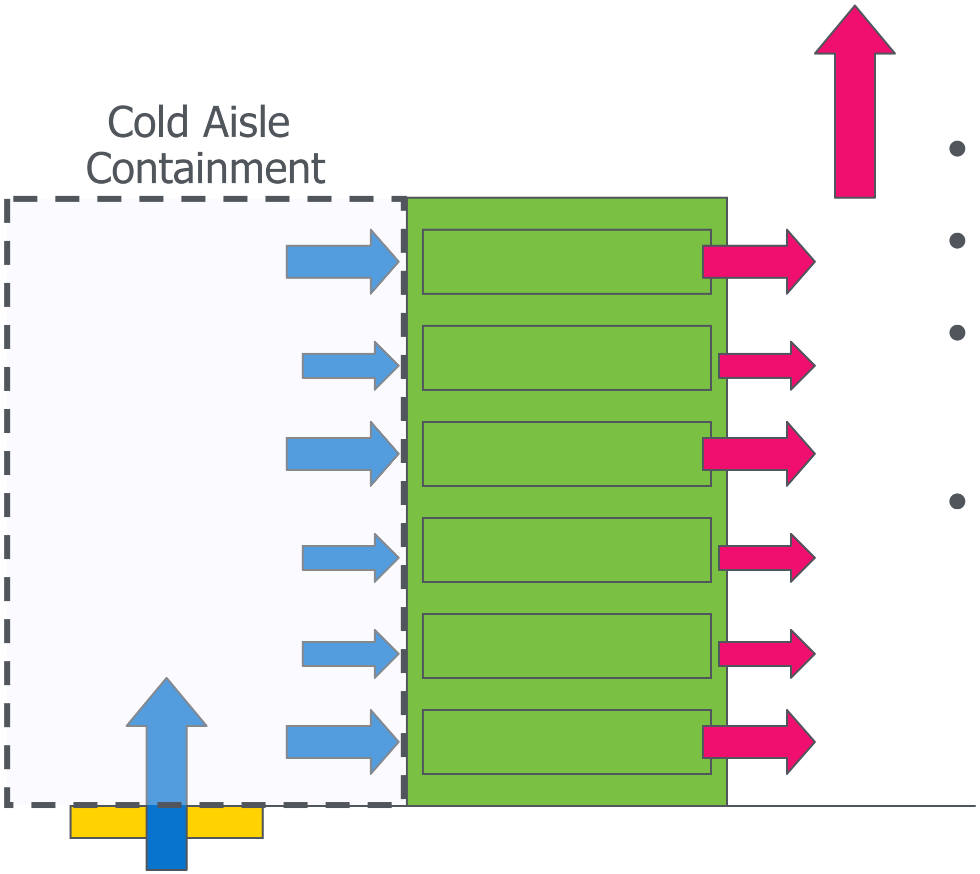


Data provided by York International Corporation.

Isolating hot or cold aisles

- Energy intensive IT equipment needs good isolation of “cold” inlet and “hot” discharge.
- Supply airflow can be reduced if no mixing 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 coil capacity increases with warmer air temperatures.

In a perfect world, variable flow supply, variable flow server fans and air containment



- Partial flow condition
- Best energy performance
- Hard to control with under-floor supply plenum
- Works best with aisle containment

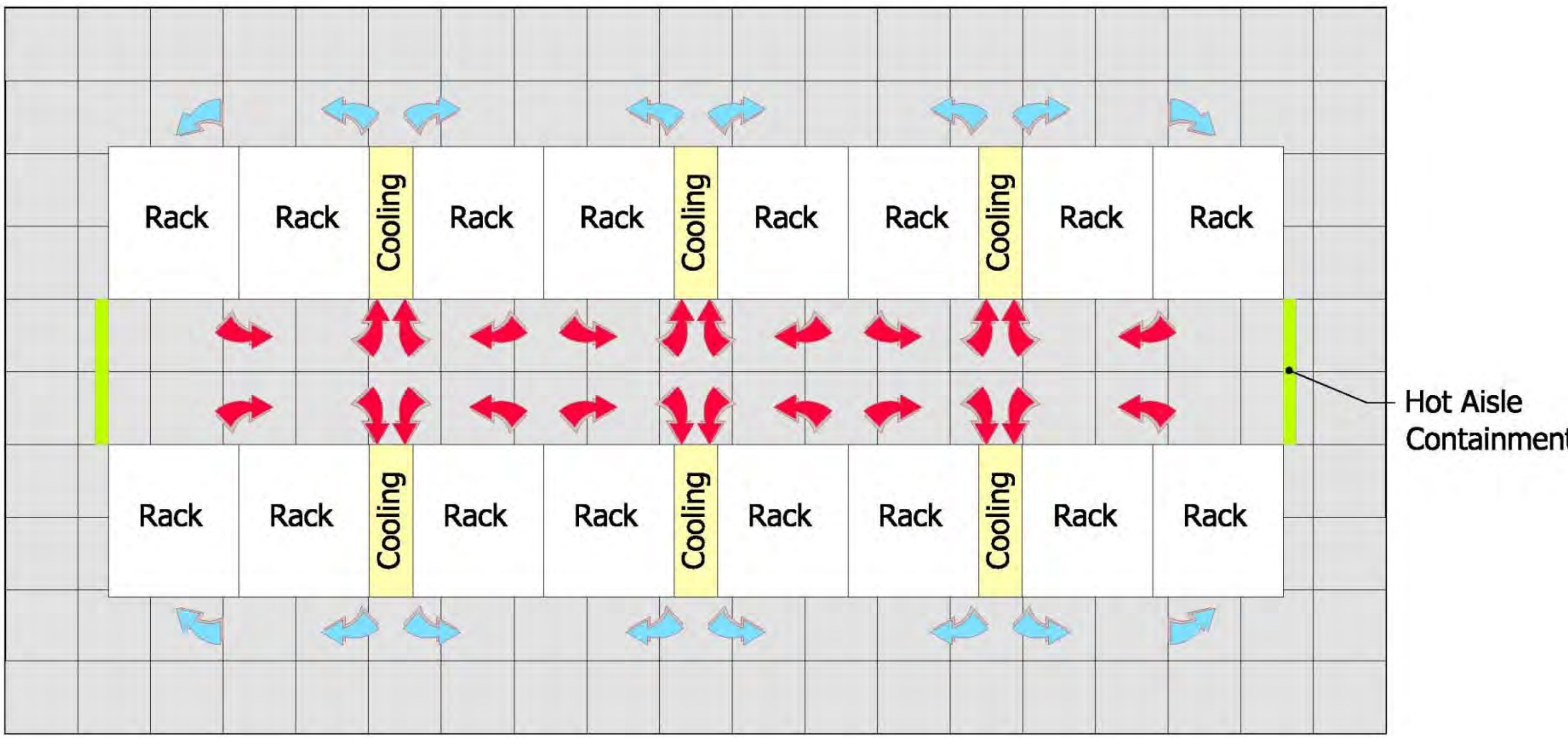
What alternatives to under-floor air distribution increase efficiency?

Localized air cooling systems with improved air management can be used to supplement or replace under-floor systems.

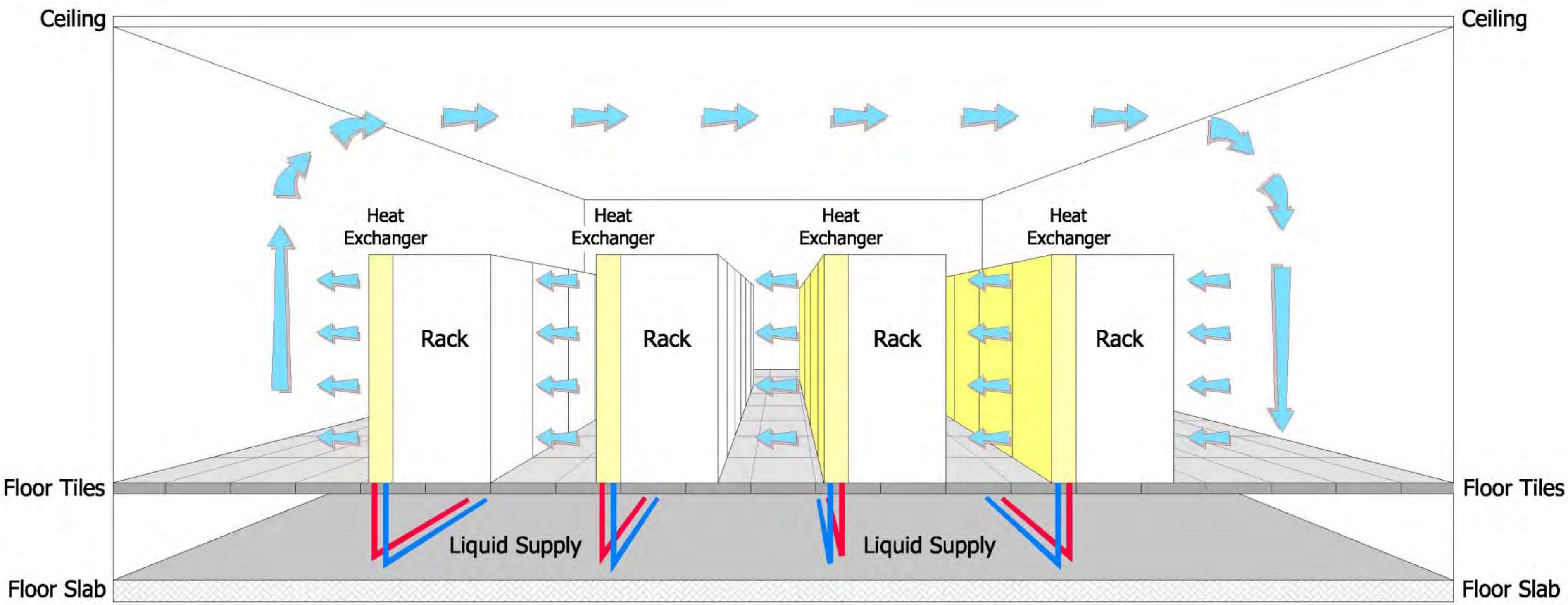
Examples include:

- **Row-based cooling units**
  - Cooling units placed in the rows of isolated servers.
- **Rack-Mounted heat exchangers**
  - Cool the hot exhaust air from the rack (prior to entering adjacent rack).
- **Overhead cooling units**
  - Cooling units placed over the cold aisles or servers.

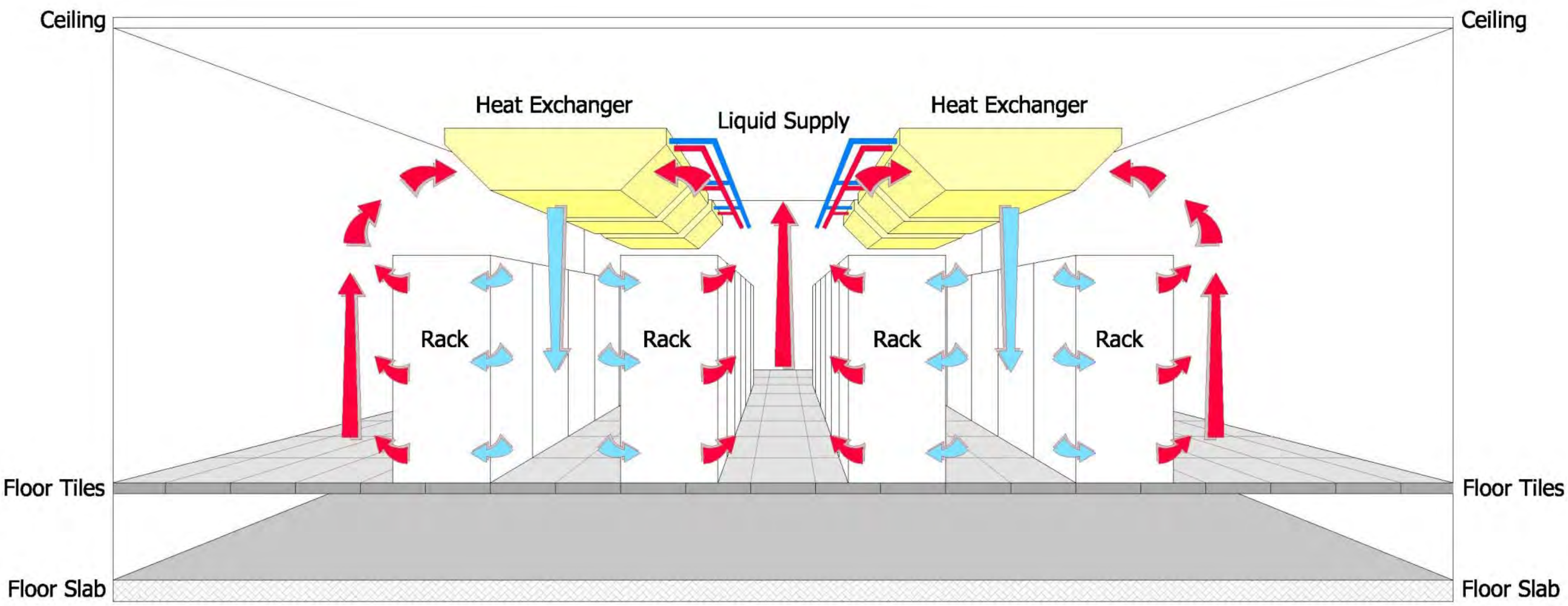
Air Distribution – Local Row-Based Cooling Units



Air Distribution – Rack-Mounted Heat Exchangers

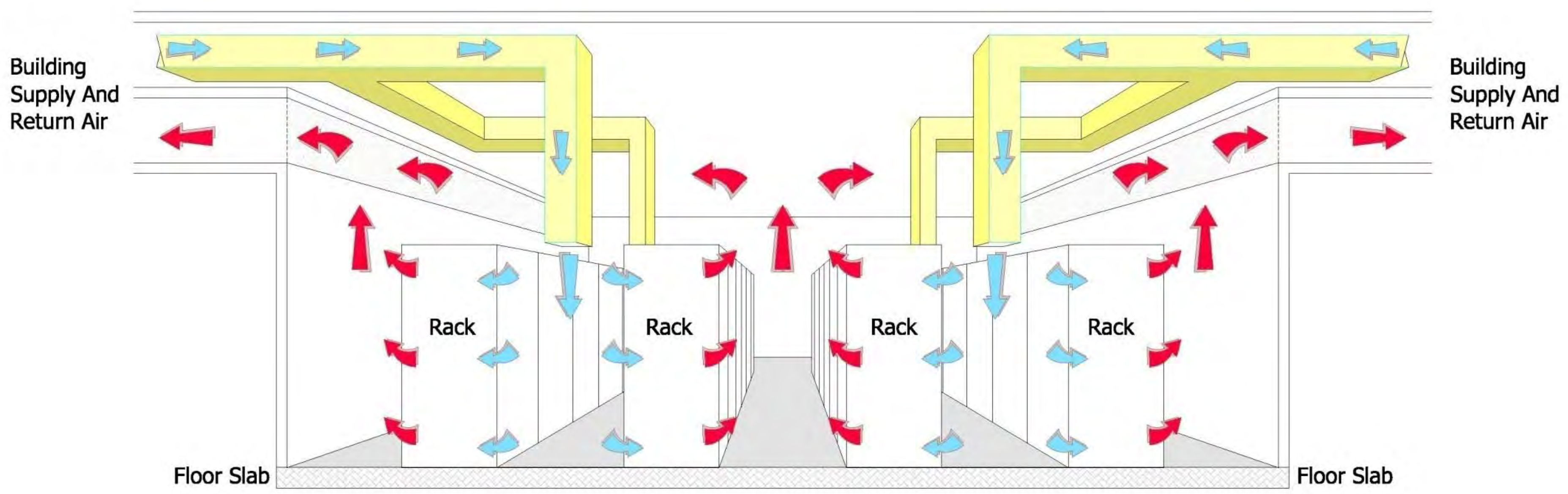


Air Distribution – Local Overhead Cooling Units



Air Distribution – Vertical Overhead (VOH) System

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

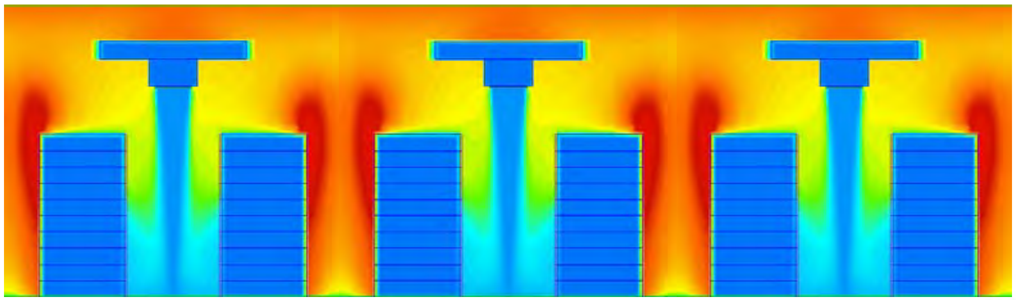


VOH, an alternative an under-floor air supply system:
Cooling airflow is supplied to the equipment racks through registers via an overhead ductwork system that is connected to air handlers.

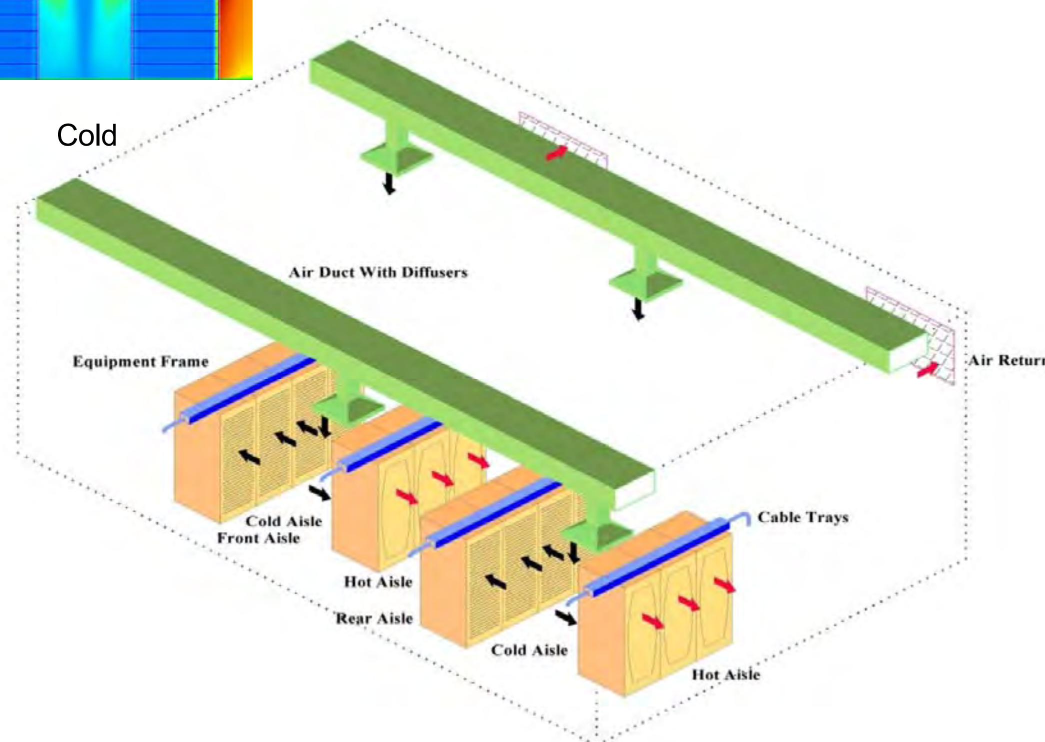
Hot and Cold Aisles from over-head cooling

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

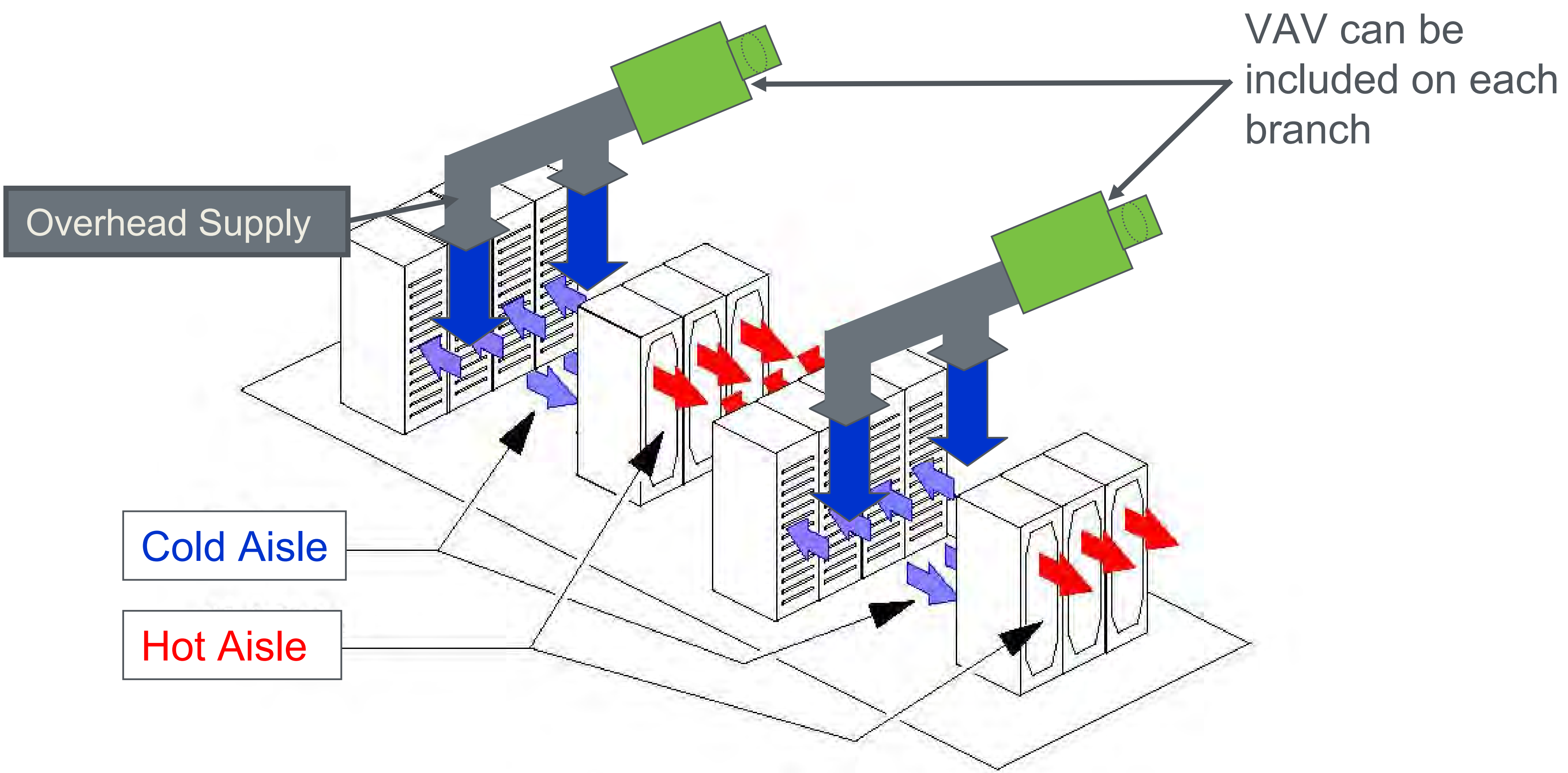
- Cross-section of hot and cold aisles



Cold Hot Cold Hot Cold



Overhead Supply Variable Air Volume (VAV)



Review: Airflow Management Basics

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

Basic air management techniques:

- Seal air leaks around floor tiles, cable penetrations, and short-circuit pathways; they are everywhere!
- Locate CRAC units at the end of the hot aisle to reduce short-circuiting from cold aisles.
- Prevent recirculation of hot air by installing blanking panels at all open rack locations and within racks.
- Manage floor tiles - do not put perforated tiles in the hot aisle.
- Use return air plenums and duct the returns of cooling units to draw the warmest air from the top of the hot aisles.
- Install airflow barriers to isolation and contain hot aisle and cold aisle.

The Bottom line…$

Energy Savings Achieved at DOE Savannah River Site (SRS)
from basic retro-commissioning effort that:

1 Eliminated electric reheat.

2 Turned off humidification devices.

3 Tuned floor tile airflow.

4 Turned off three CRAC units.

Total estimated savings = ~1,400,000 kWh/year

Retro-Cx cost at SRS

Engineering consultant: preliminary, on-site, and follow-up work including data measurements and retrieval. SRS on-site facilities personnel and engineering support.

Total estimated cost = ~$25,000.

Simple Payback at SRS

Estimated, at $0.045/kWh = **2.5 months**.

Questions ?

Cooling systems

Removing heat from data centers

Presented by: Geoffrey C. Bell, PE

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

FEMP
Federal Energy Management Program

GSA

AGENDA

Morning

- Introductions to course and instructors
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions

Lunch On your own

Afternoon

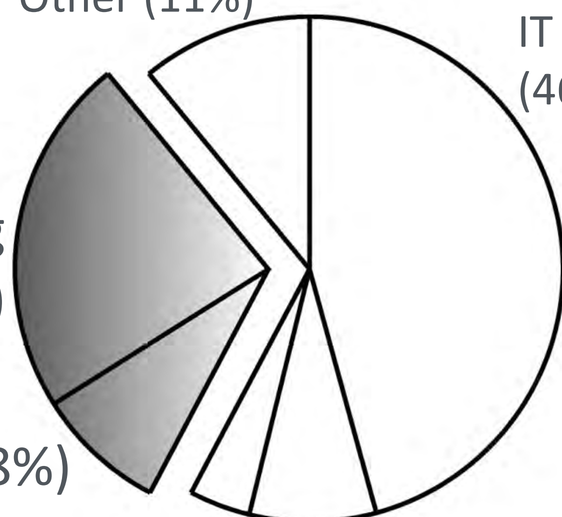
- Airflow management
- **Cooling systems**
- Electrical systems
- Summary and Takeaways

Benefits of Operating at Higher Data Center Air Temperatures

The connection between air management and the cooling system:

- ✓ Improved DX CRAC unit efficiencies
- ✓ Increased CRAC/CRAH cooling coil capacity
- ✓ Higher allowable chilled-water supply temperature which improves chiller efficiency
- ✓ More hours for air-side and water-side free cooling
- ✓ Lower humidification/dehumidification energy.

Data Center Cooling Energy



Typical Data Center Power Allocation

Source: LBNL

Typical Power for Cooling

HVAC Cooling	23%
HVAC Fans	8%
TOTAL	31%

How is data center cooling achieved?

What are methods to increase cooling energy efficiency?

- Chillers vs. computer room air conditioners (CRACs)
- Liquid cooling (to the room, row, rack, chip)
- Install variable speed chillers, pumps, and fans
- Optimize chiller plant
- Optimize humidity control

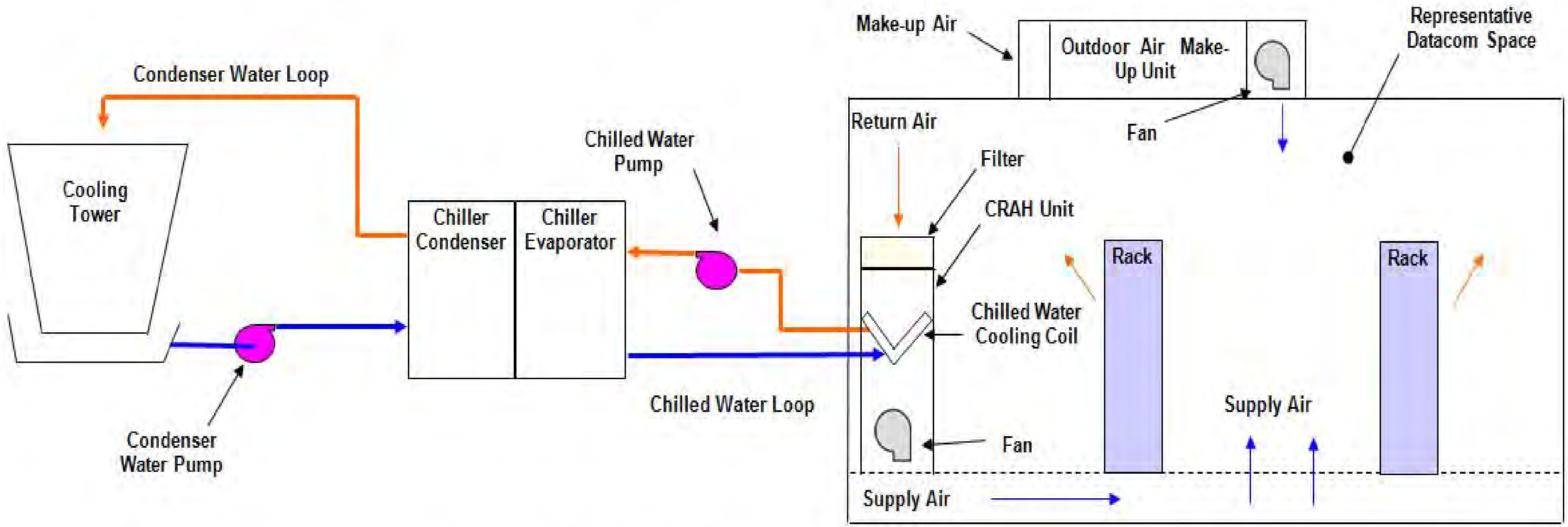
What is compressorless cooling?

- Use outside air for cooling [air-side economizer]
- Install evaporative (direct or indirect) cooling
- Evaluate water-side economizers

HVAC Systems Overview

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

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

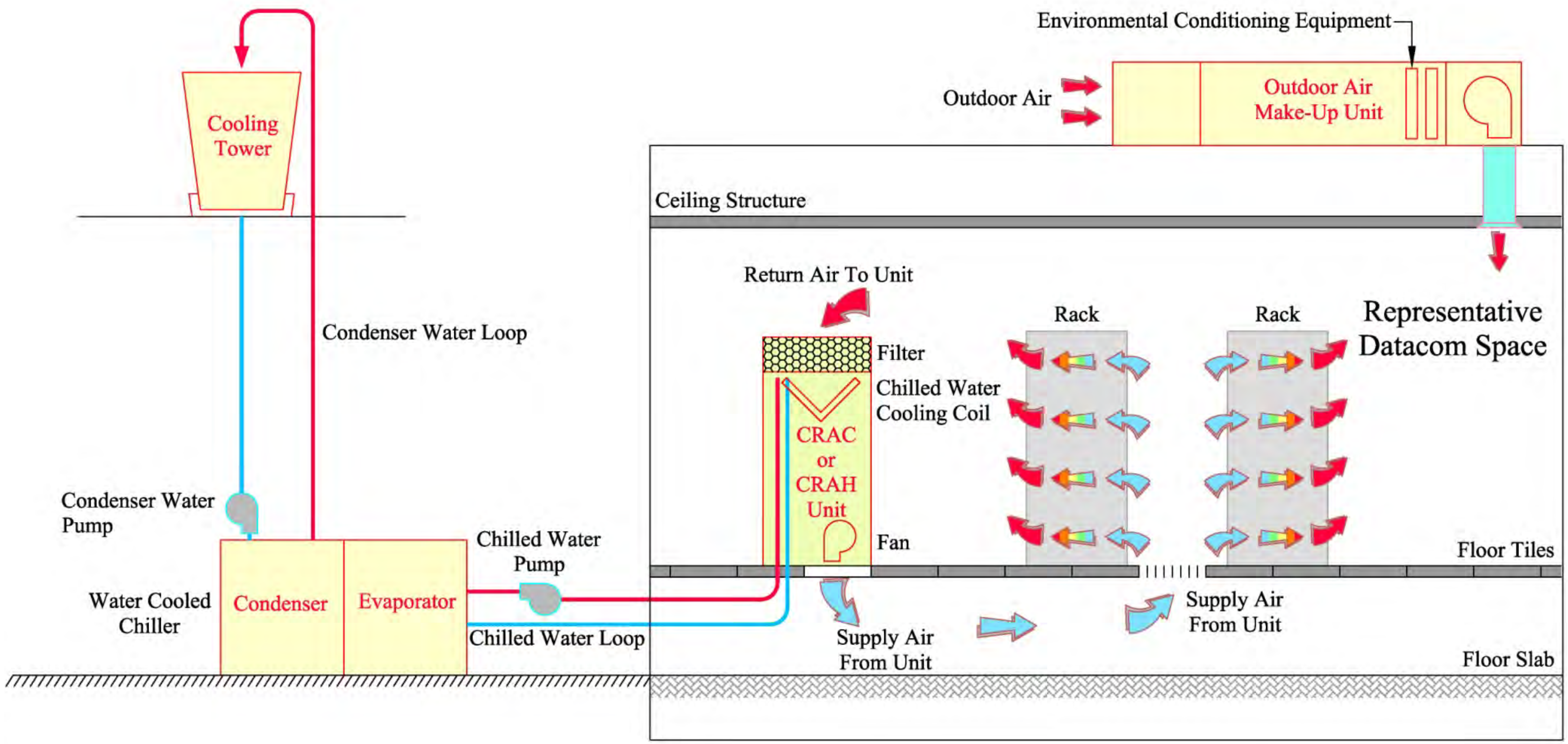
- Liquid Cooling
- Central AHU
- CRAH Unit (shown)
- CRAC Unit (DX)

Distribution Alternatives

High Eff

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

Low Eff

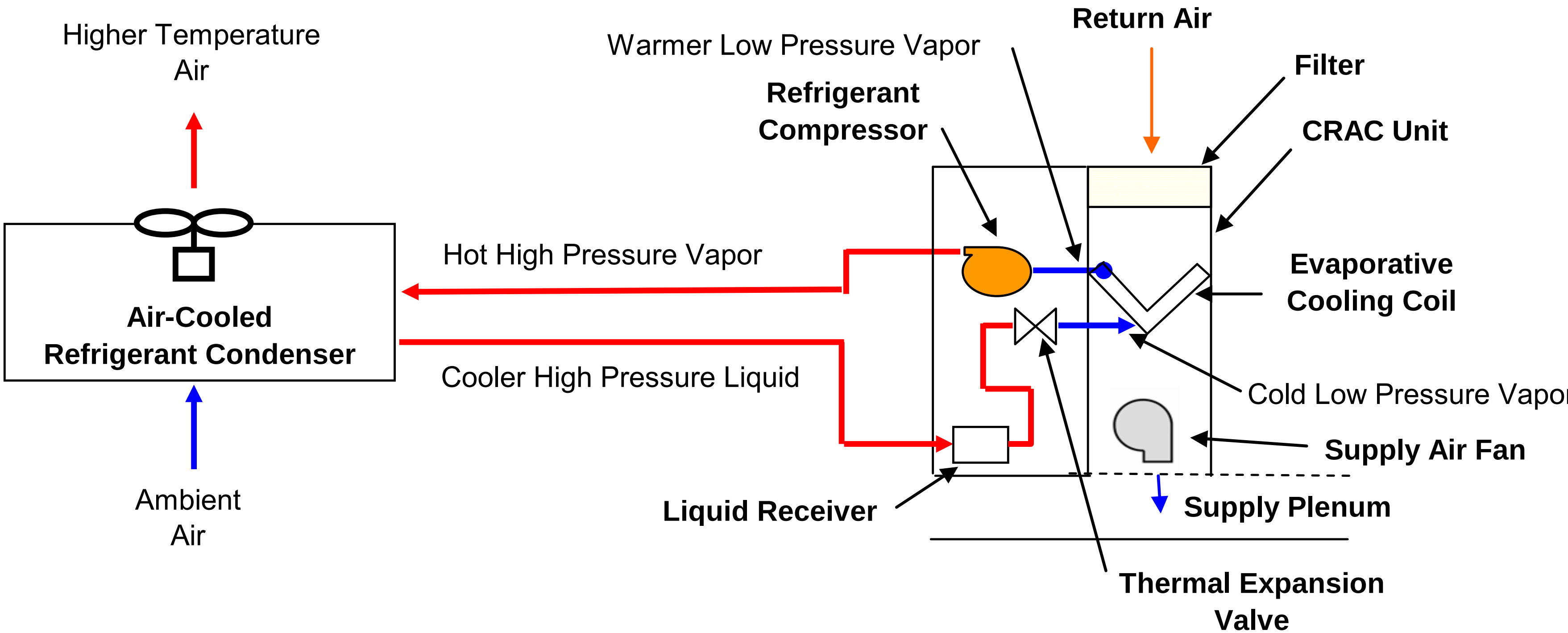


There are energy saving opportunities in each piece to the Cooling System
Critical to select efficient equipment (24/7 operation often at partial load).

Computer Room Air Conditioners and Air Handlers (CRAC & CRAHs)

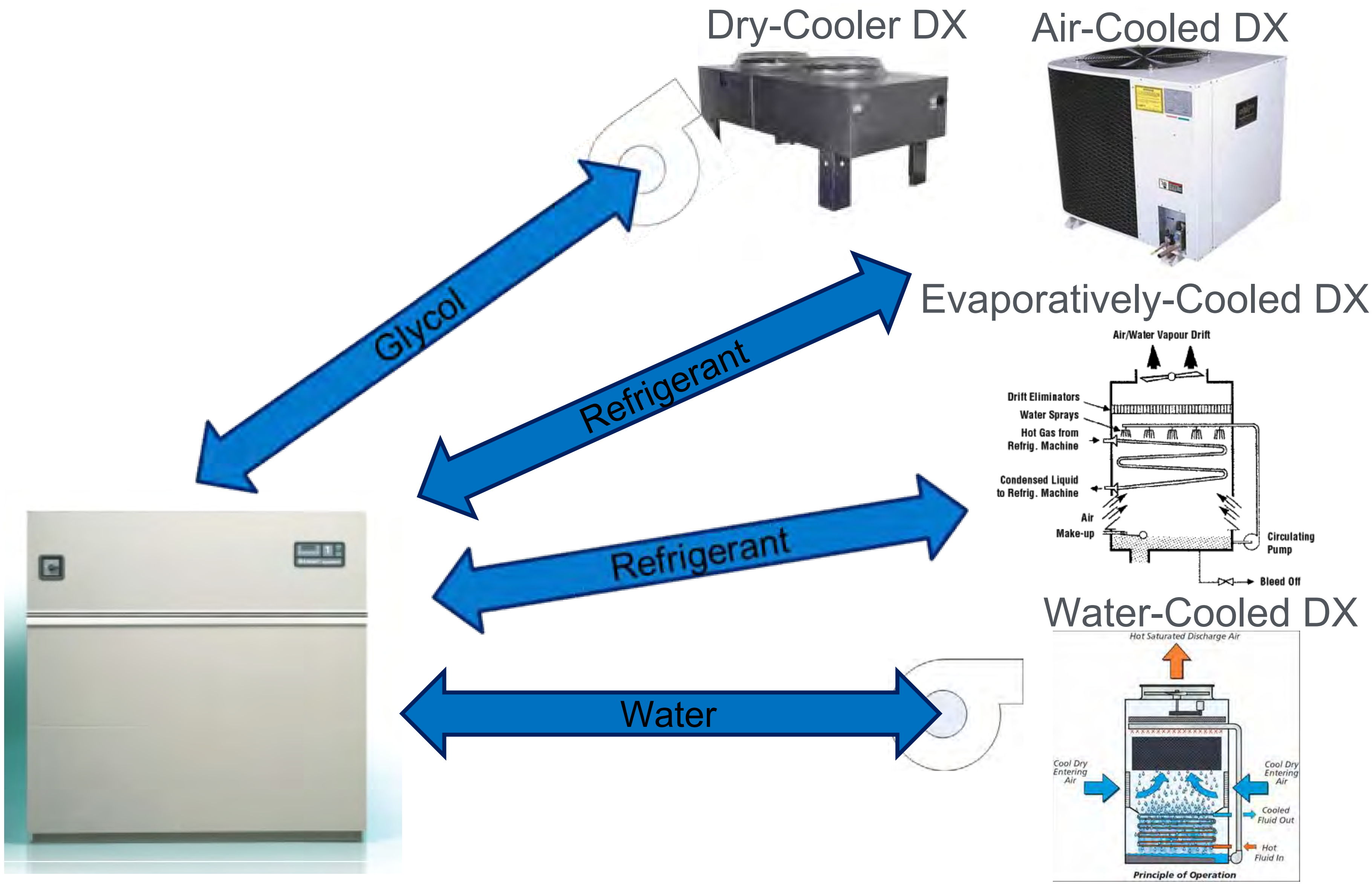
- **DX/CRAC units**
  - Contain a fan, DX cooling coil and a refrigerant compressor
  - The compressor may be cooled by:
    - An air-cooled condenser
    - Water from a cooling tower or dry-cooler
- **Air Handler/CRAH units**
  - Contain a fan and chilled water cooling coil
  - Typically in larger facilities with a central chiller plant
- **Both units often equipped with humidifiers and reheat for dehumidification**
- **Often independently controlled**

Typical Air-Cooled CRAC Unit

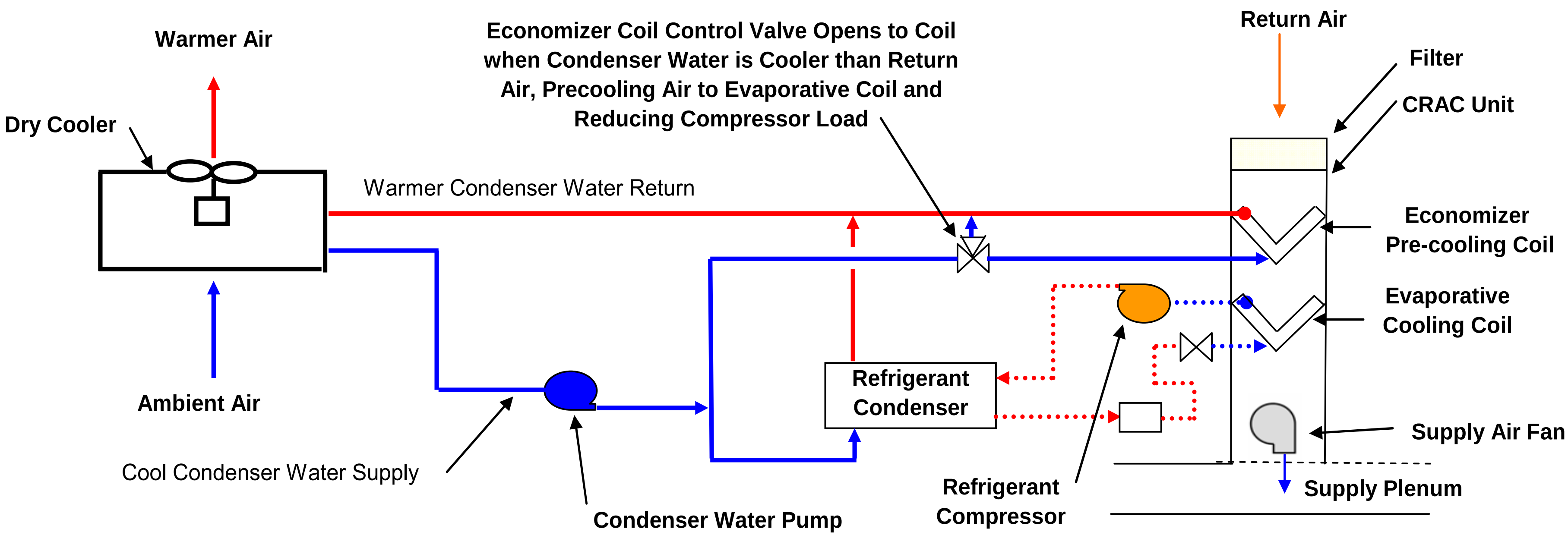


Courtesy of ASHRAE

DX (or AC) units reject heat outside…



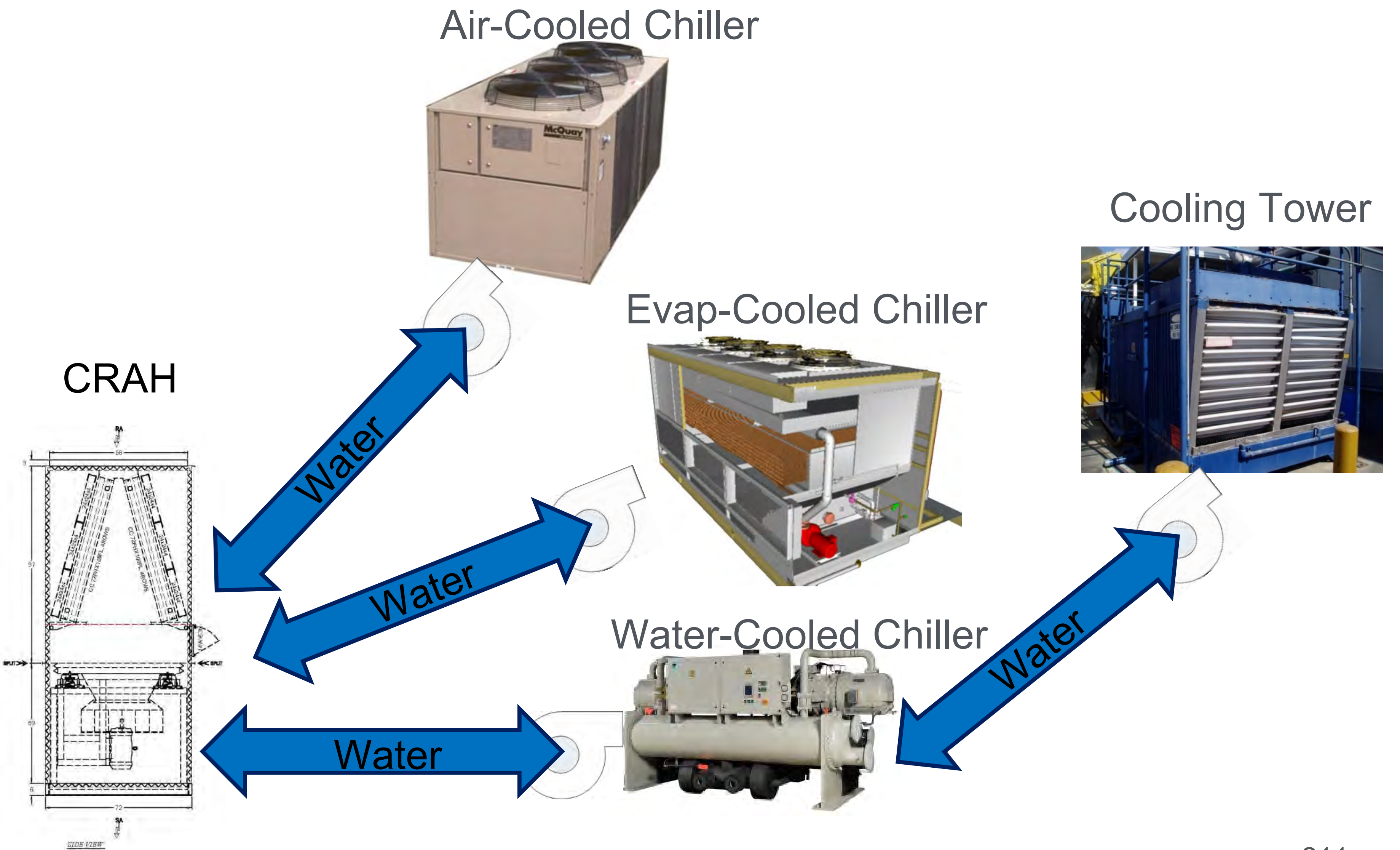
Dry-Cooler DX with Optional Economizer Coil



• • • • • Dotted lines refer to refrigerant flow

Courtesy of ASHRAE

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



211

Moving to liquid cooling

- Many options available
- As heat densities rise liquid solutions are becoming more attractive
- The closer the liquid gets to the heat source, the more efficient it can become
- Liquids can provide cooling with higher temperature coolant
- Liquids also offer the potential for better re-use of waste heat

Why Liquid Cooling?

Volumetric heat capacity comparison

Water

=

Air

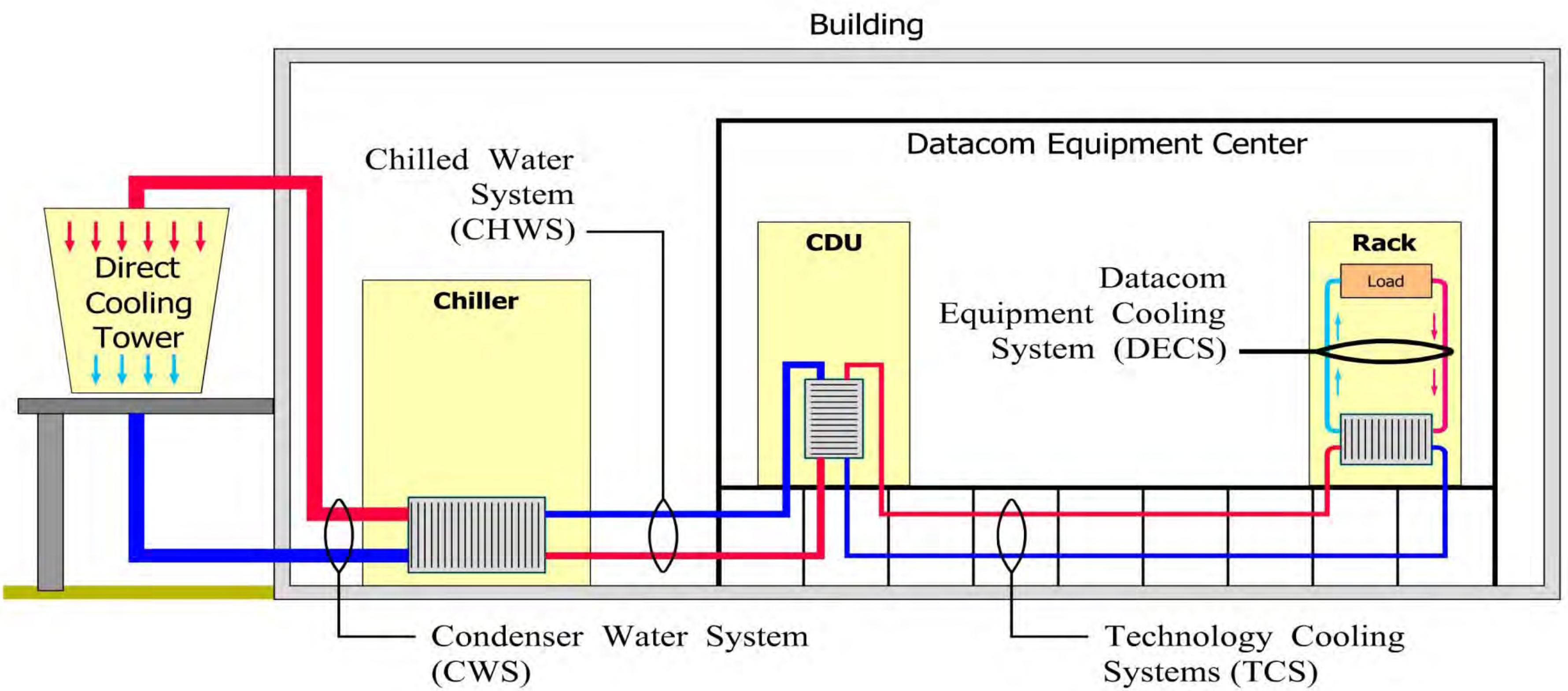
Liquid Cooling – Overview

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

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

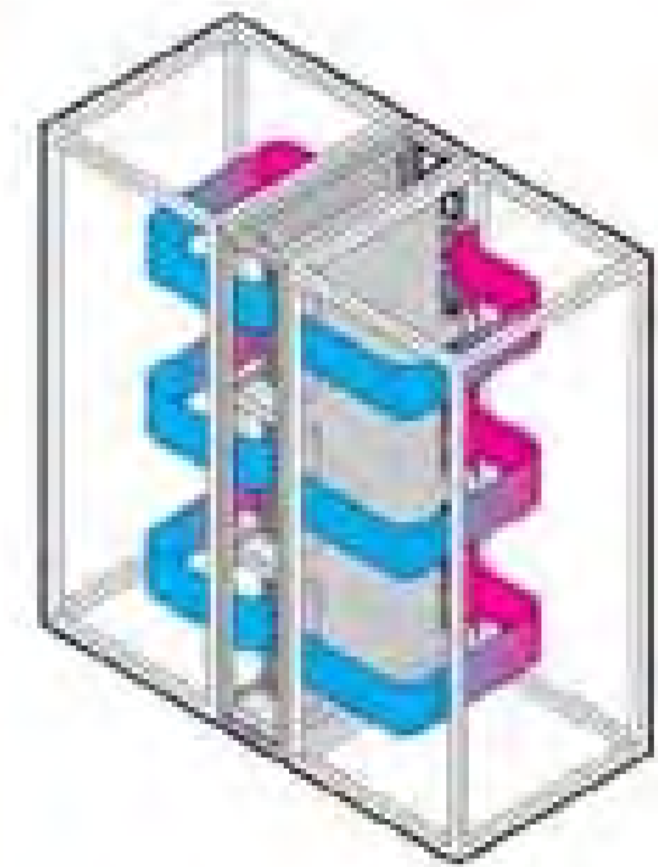
Heat Transfer		Resultant Energy Requirements			
Rate	ΔT	Heat Transfer Medium	Fluid Flow Rate	Conduit Size	Theoretical Horsepower
10 Tons	12°F	Forced Air	9217 cfm	34" Ø	3.63 Hp
		Water	20 gpm	2" Ø	.25 Hp

Liquid Cooling – Systems / Loops



Liquid Cooling Systems / Loops within a Data Center

In-Row Cooling

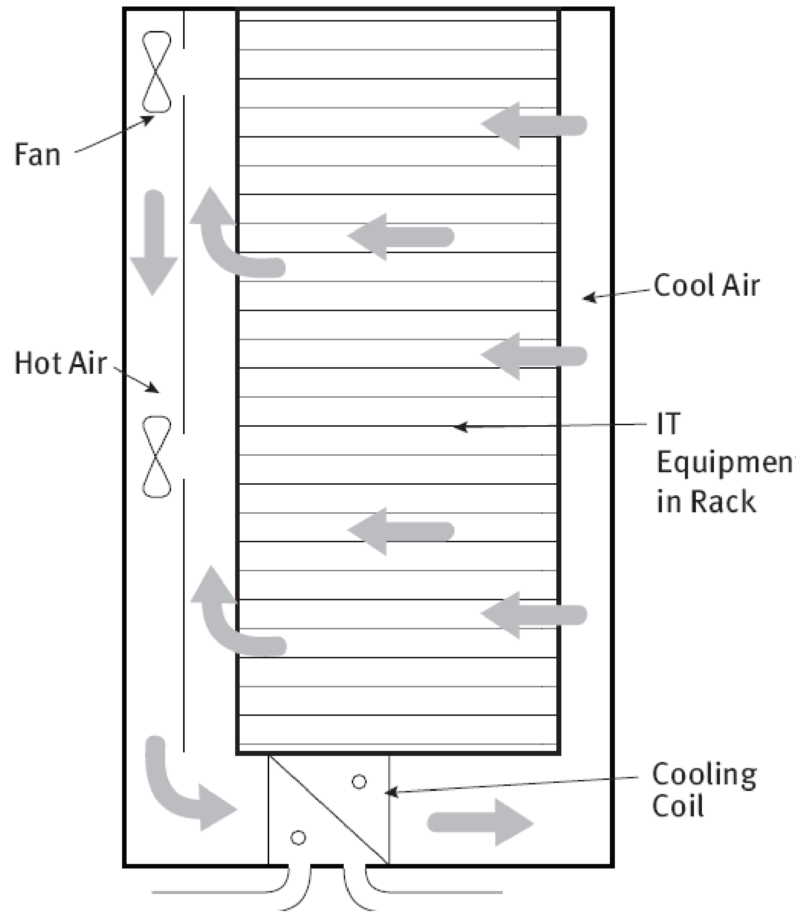


Graphics courtesy of Rittal

In rack liquid cooling

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

Racks with integral coils and full containment



Rear-Door Liquid Cooling

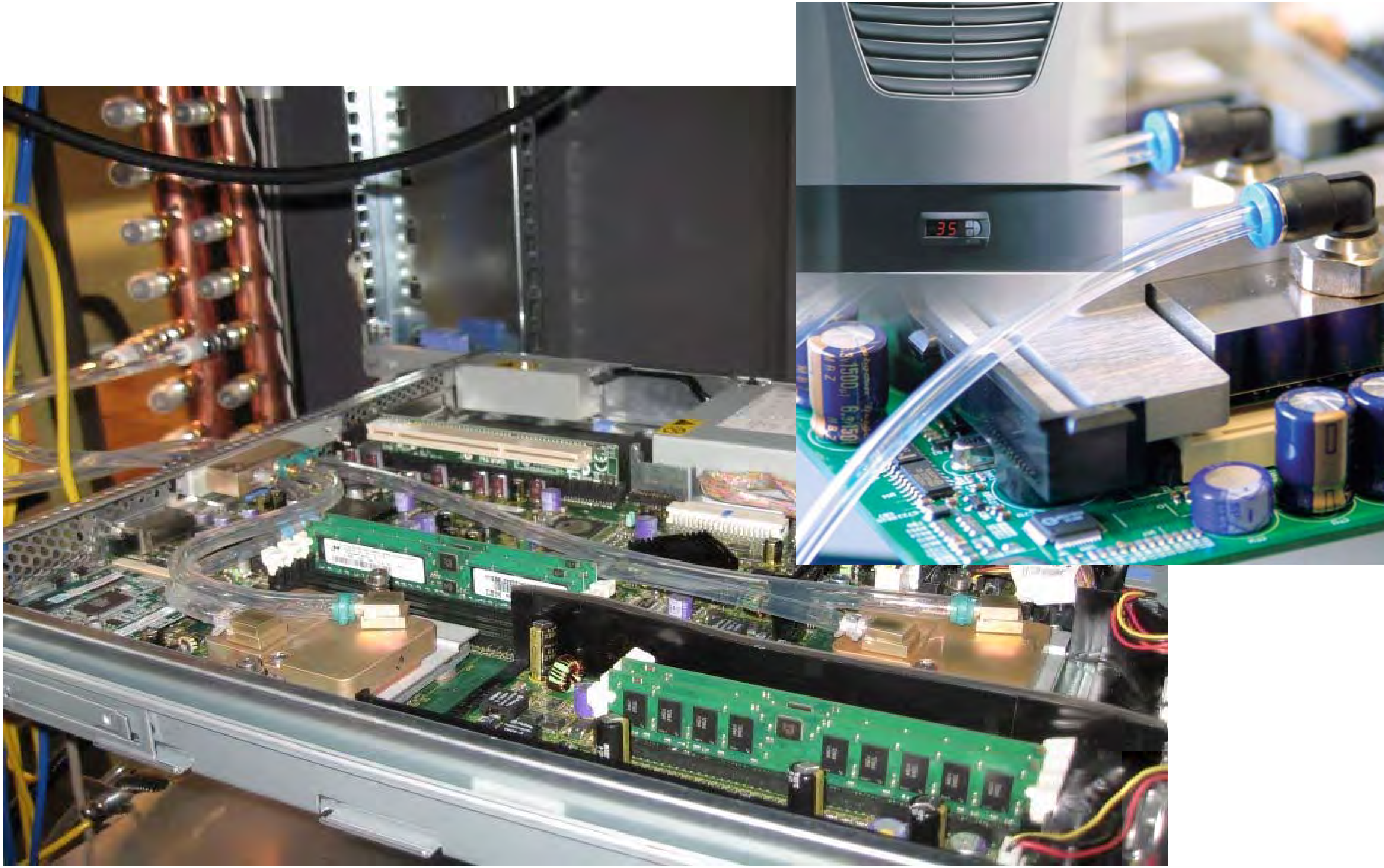
Rear Door (open)

Inside rack RDHx, open 90°

Rear Doors (closed)

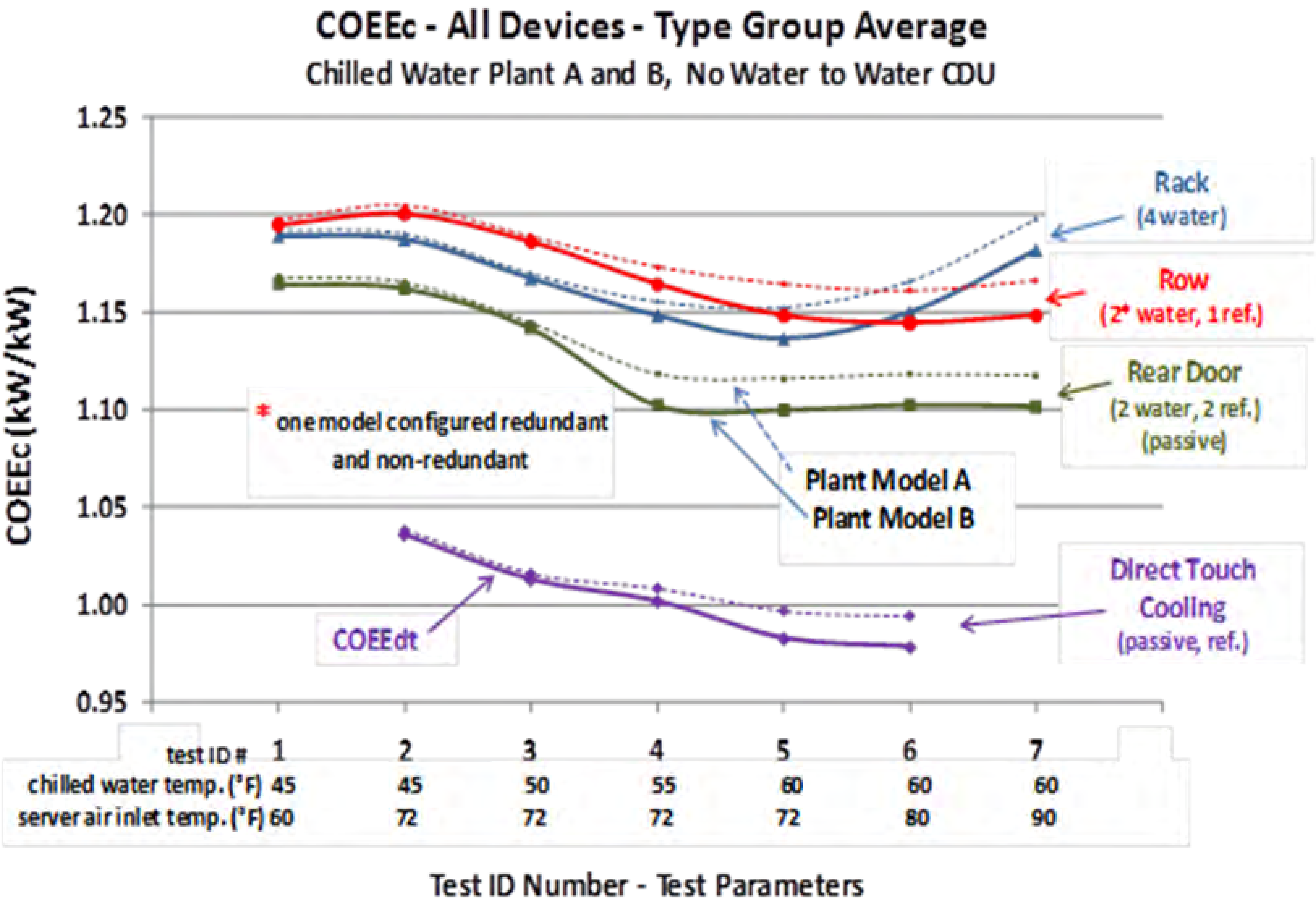
Liquid Cooling Connections

On Board Cooling



"Chill-off 2" evaluation of modular cooling

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



Optimizing Plant Energy Usage

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

- **Have a plant (vs. distributed cooling)**
- **Right size**
  - Design for high part-load efficiency
- **Chillers (have one)**
  - Type, efficiency, size, VSD
- **Cooling Towers (size for "free" cooling)**
  - Fan type, efficiency, approach, range, speed control, flow turndown
- **Chilled Water Pumps**
  - Arrangement, flow rate (delta-T), pressure drop, VSD
- **Condenser Water Pumps**
  - Flow rate (delta-T), pressure drop
- **Air Handling Units (fewer larger fans and motors better)**
  - Coil sizing, air-side pressure drop, water-side pressure drop
- **Integrate controls and monitor efficiency of all primary components**

Use Variable Speed Drives (VSDs)

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

Design cooling systems for dynamic loads. Install VSD's to control compressors, fans, and pumps. For example:

- **Fan Capacity:** Air flow (CFM) is proportional to speed (RPM) of fan
- **Fan Power:** Power (HP) is proportional to [speed (RPM) of fan]^3

Fan Power at Varying Air Flow						
Air Flow	**100%**	**90%**	**80%**	**70%**	**60%**	**50%**
Fan Speed	**100%**	**90%**	**80%**	**70%**	**60%**	**50%**
Fan Power	**100%**	**73%**	**51%**	**34%**	**22%**	**13%**

Varying the fan speed to match the required air flow can provide a SIGNIFICANT reduction in energy consumption during PART-LOAD conditions

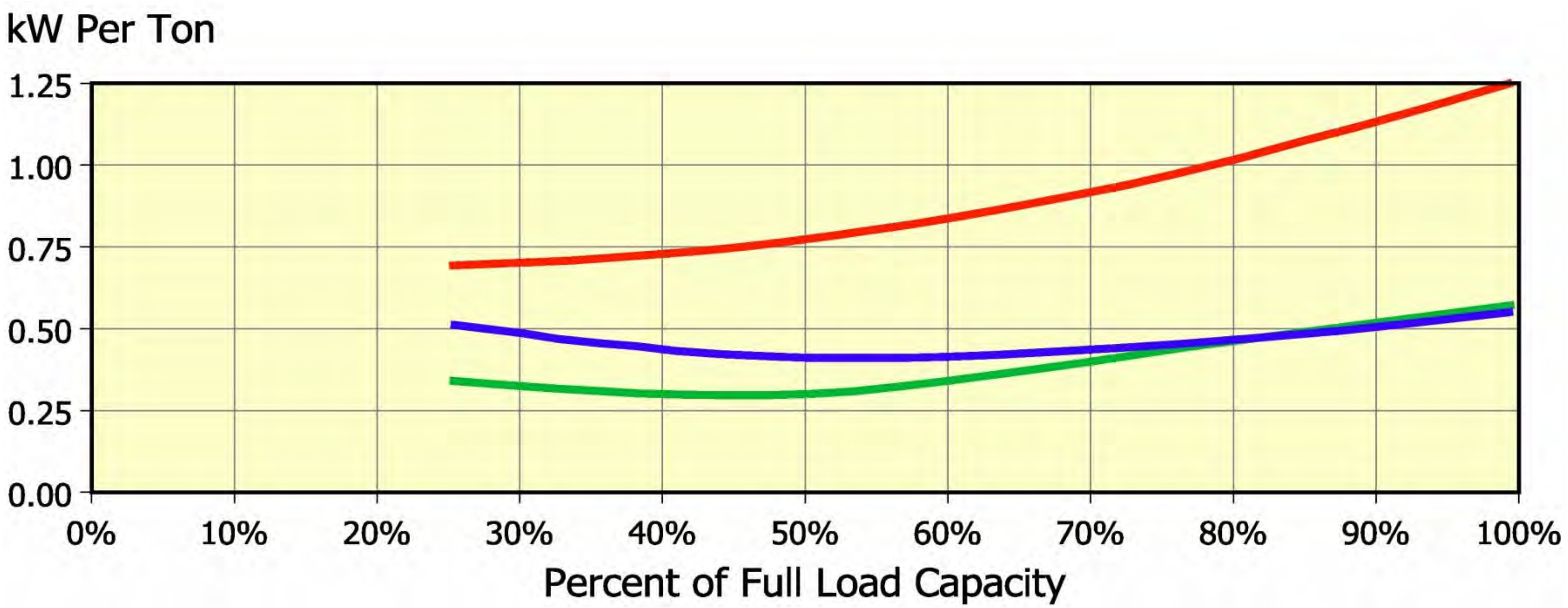
Optimizing Chiller Efficiency

- Consider replacing chillers that are older than 5 years or in poor condition.
- Design for high part load efficiency (e.g. modular with VSD)
- Decrease the entering condenser water temperature
- Raise chilled-water supply temperature
- Recalibrate chilled-water temperature sensors.

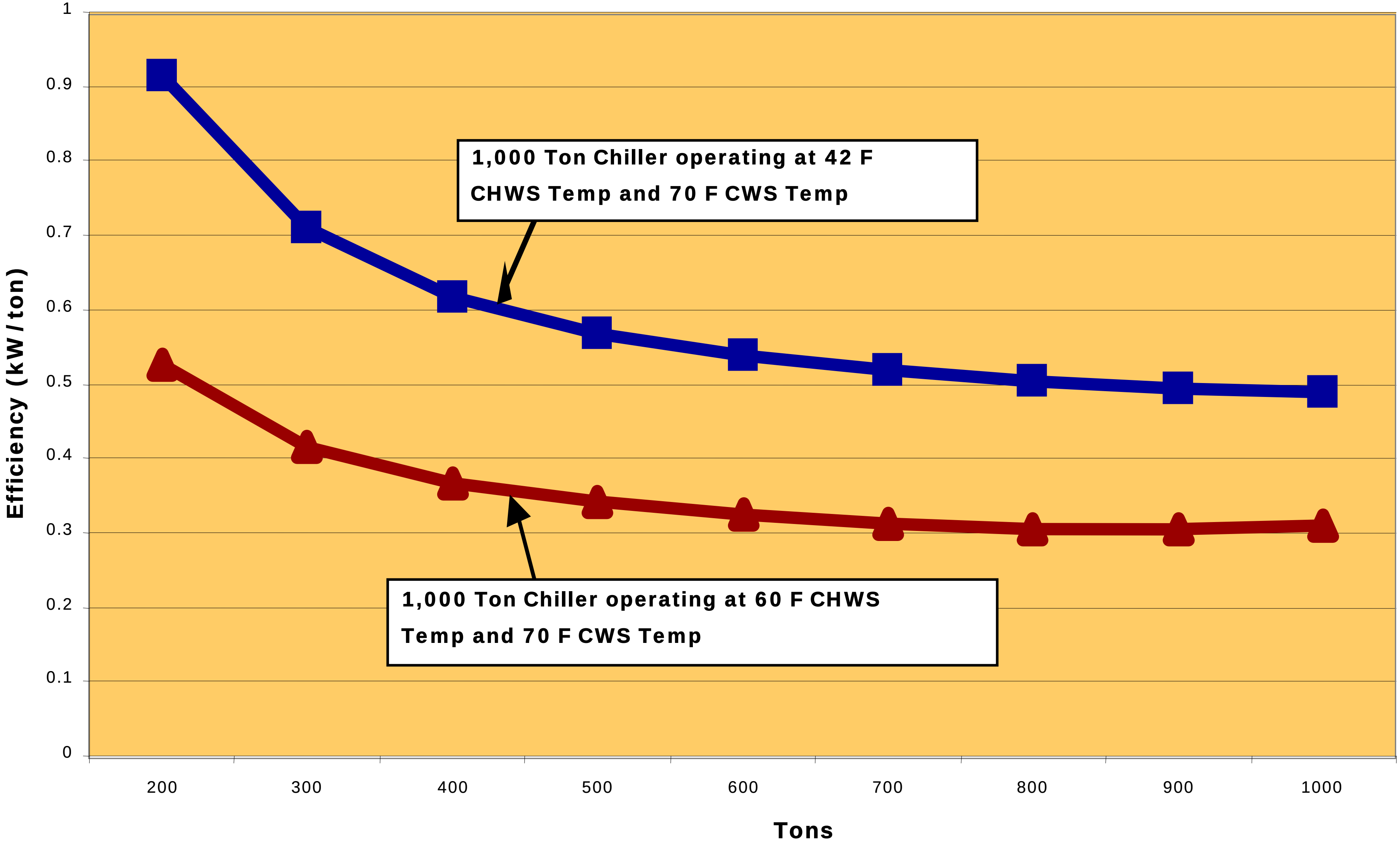
Cooling Equipment – Chiller Sizing & Selection

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

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



Increase Temperature of Chiller Plant



Data provided by York International Corporation.

Optimizing Cooling Tower Efficiency

- Add VSDs (variable speed drives) to cooling tower fans.
- Operate cooling towers in parallel
- Recalibrate condenser water temperature sensors.

Optimizing Pump Efficiency

- Convert all 3-way chilled-water valves to 2-way.
- Install VSDs.
- Remove any triple-duty valves or balancing valves on pumps.

Improve Humidity Control:

- Eliminate inadvertent dehumidification
  - Computer load is sensible only
- Use ASHRAE allowable RH and temperature
  - Many manufacturers allow even wider humidity range
- Eliminate equipment fighting
  - Coordinate controls

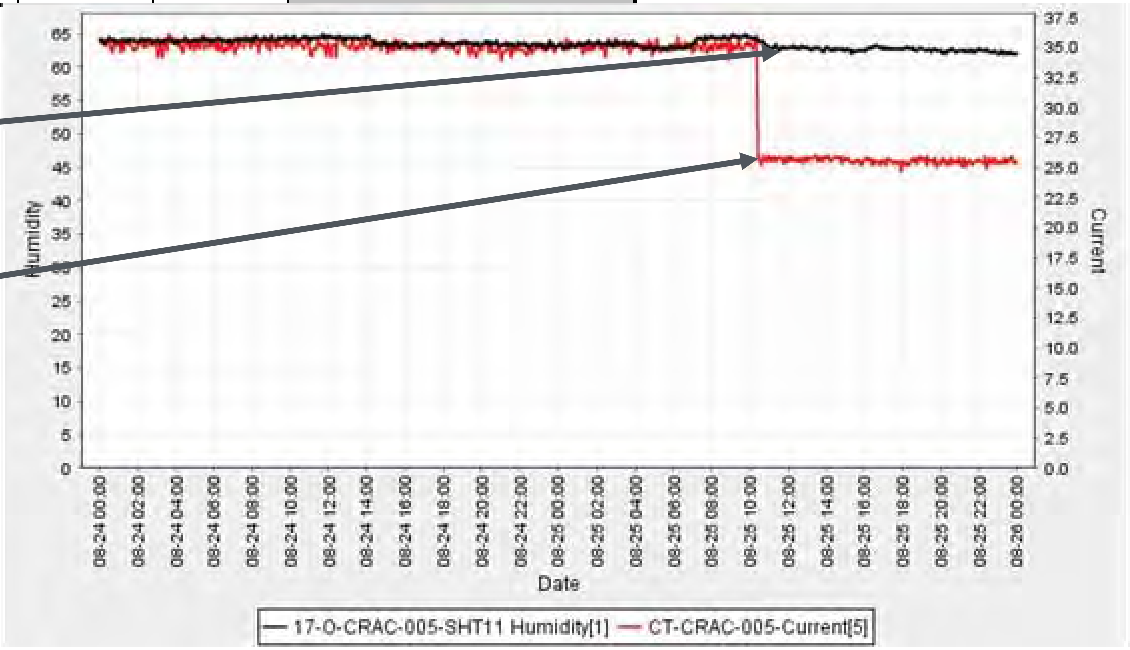
Cost of Unnecessary Humidification

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

	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 Free Cooling:

Cooling without Compressors:

- Outside-Air Economizers
- Water-side Economizers

- ➢ Let’s get rid of chillers in data centers
- ➢ Large savings

Outside-Air Economizers

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

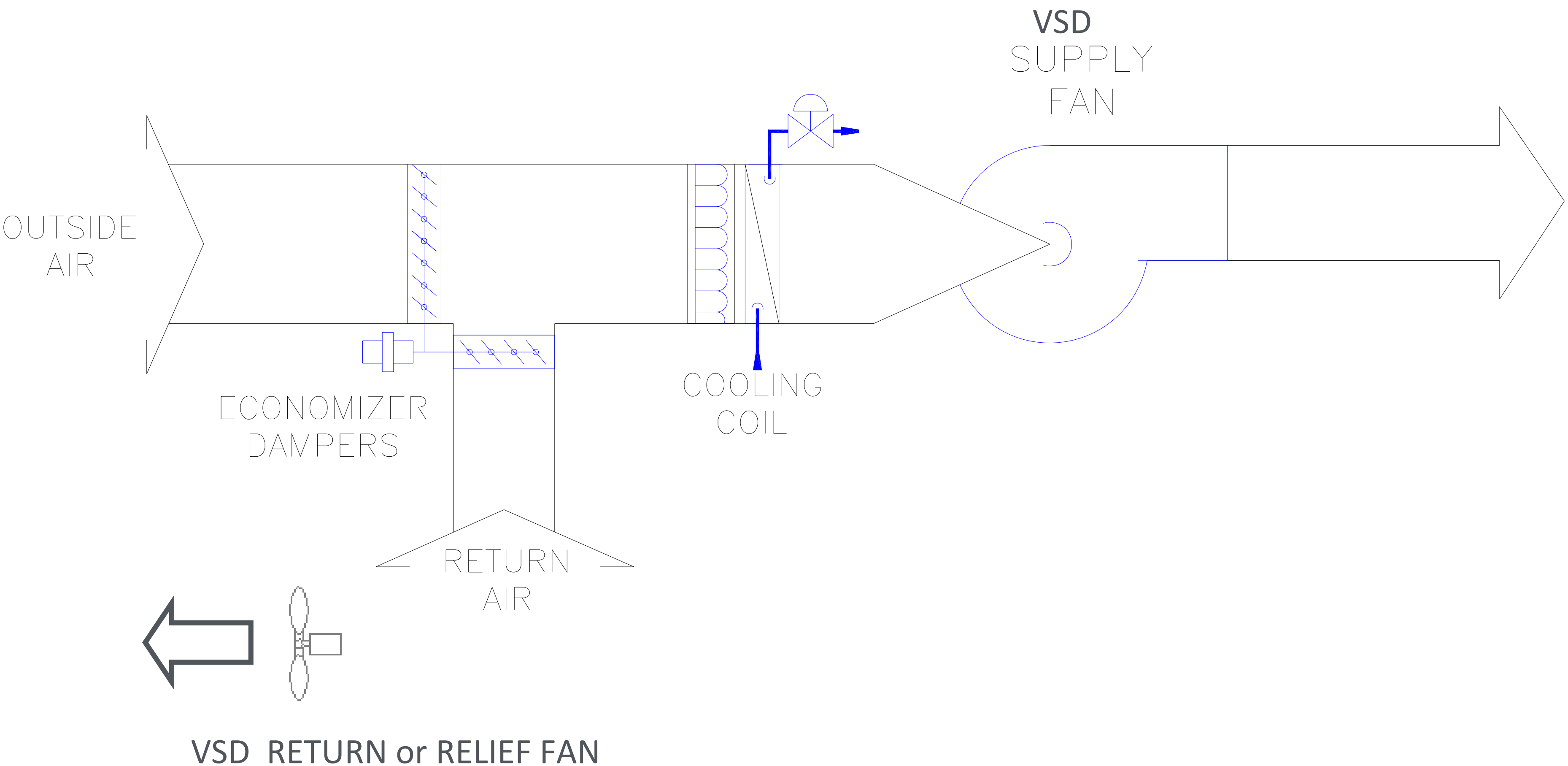
Advantages

- Lower energy use
- Added reliability (backup in the event of cooling system failure)

Potential Issues

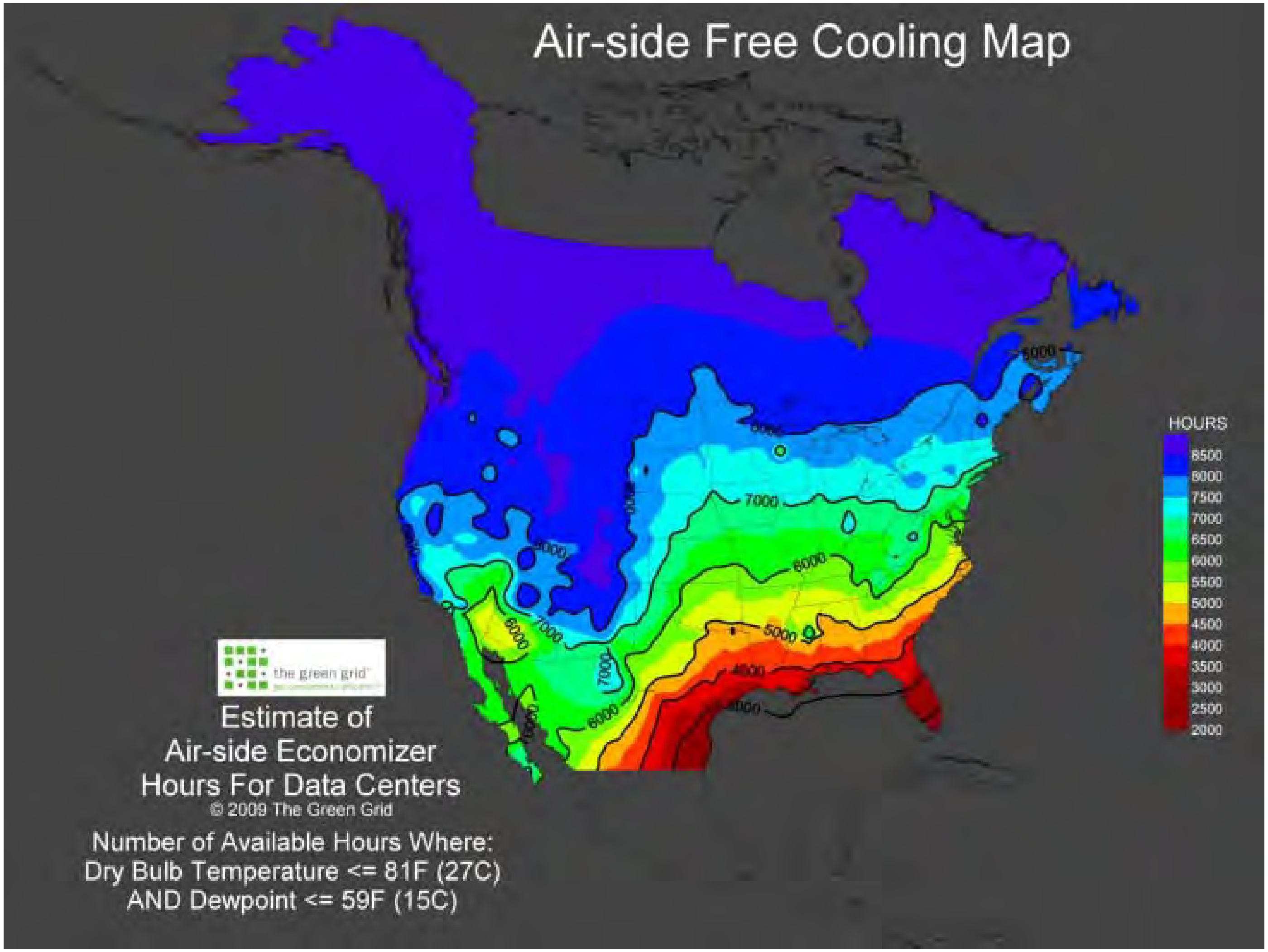
- Space
- Contaminants (not a concern with adequate filtration)
- Need low dew-point switch if used with humidification
- Shutdown if smoke is outside data center.

Outside-Air Economizer



Air-Side Economizer – Free Cooling Hours

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



Map Courtesy of The Green Grid

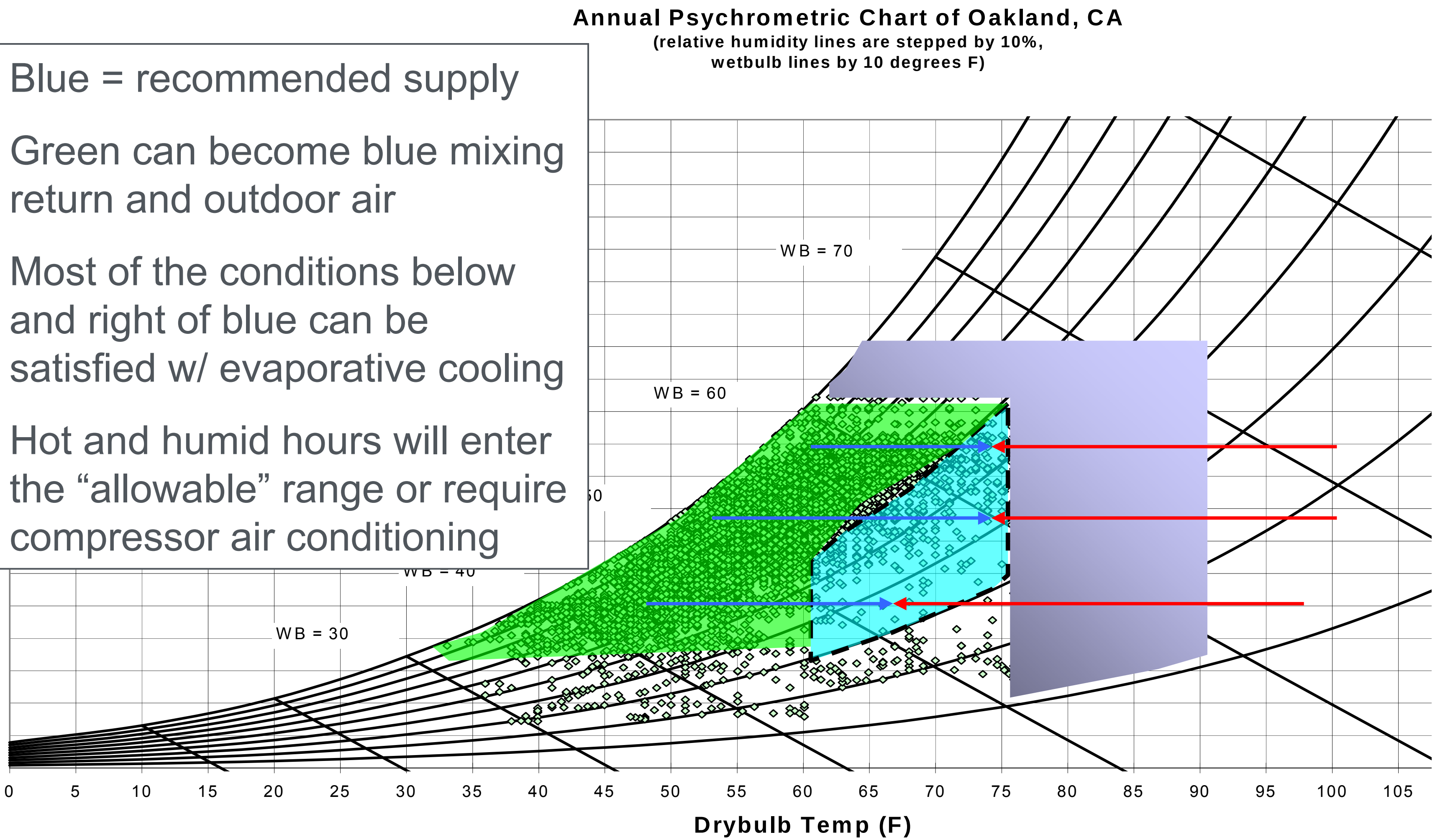
http://cooling.thegreengrid.org/namerica/WEB_APP/calc_index.html

UC's Computational Research and Theory (CRT) Facility

Free Cooling – Outside Air Based

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

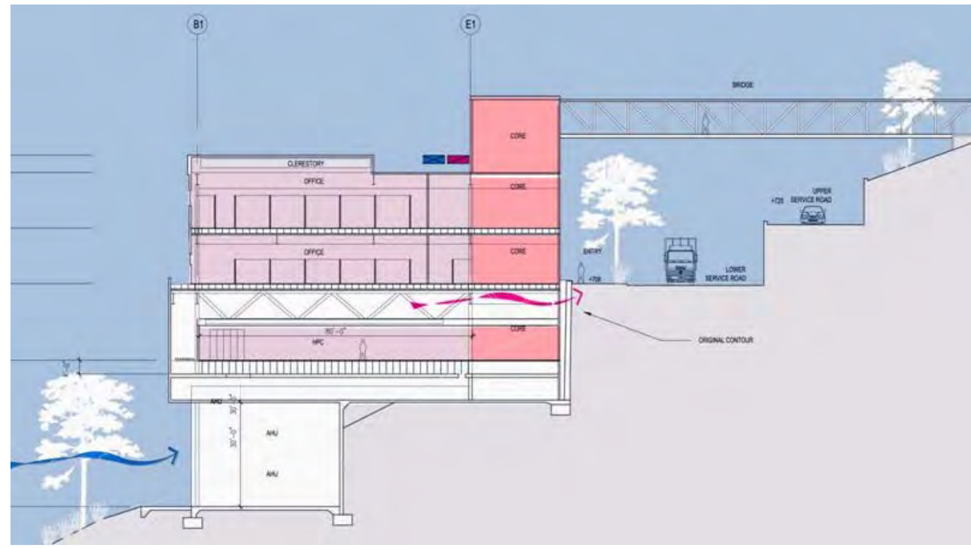
1. Blue = recommended supply
2. Green can become blue mixing return and outdoor air
3. Most of the conditions below and right of blue can be satisfied w/ evaporative cooling
4. Hot and humid hours will enter the “allowable” range or require compressor air conditioning



System Design Approach:

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

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



<u>Hours of Operation</u>

Mode 1	100% Economiser	2207	hrs
Mode 2	OA + RA	5957	hrs
Mode 3	Humidification	45	hrs
Mode 4	Humid + CH cooling	38	hrs
Mode 5	CH only	513	hrs
total		8760	hrs

Water Cooling: Four-pipe System

- Closed-loop treated cooling water from cooling towers (via heat exchanger)
- Chilled water from chillers
- Allows multiple temperature feeds at server locations
- Headers, valves and caps for modularity and flexibility

Predicted CRT Performance:

- PUE of 1.1 based on annual energy

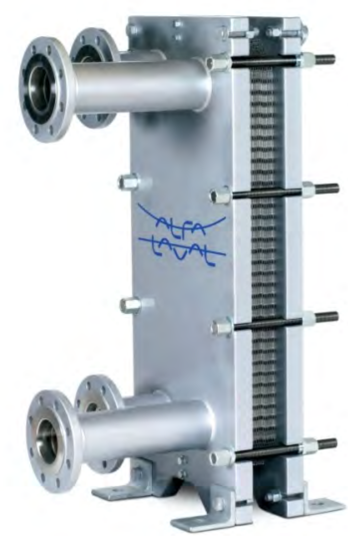
Water-Side Economizers

Advantages

- Very cost effective in cool and dry climates
- Often easier retrofit
- Added reliability (backup in the event of chiller failure).

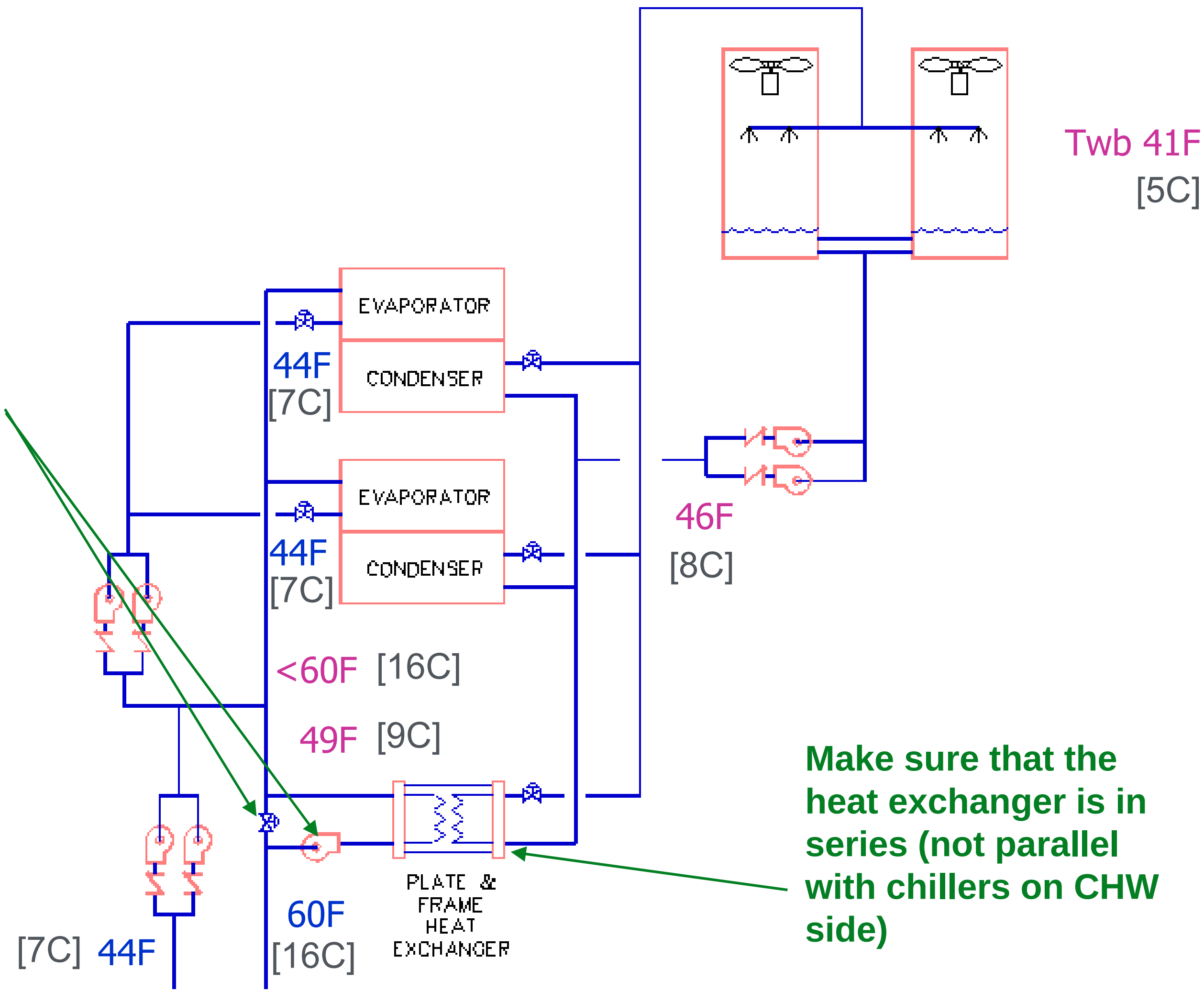
Potential Issues

- Heat exchanger should be in series (not parallel) with chillers
- Works best with high delta-T (warm CHWR temperatures).



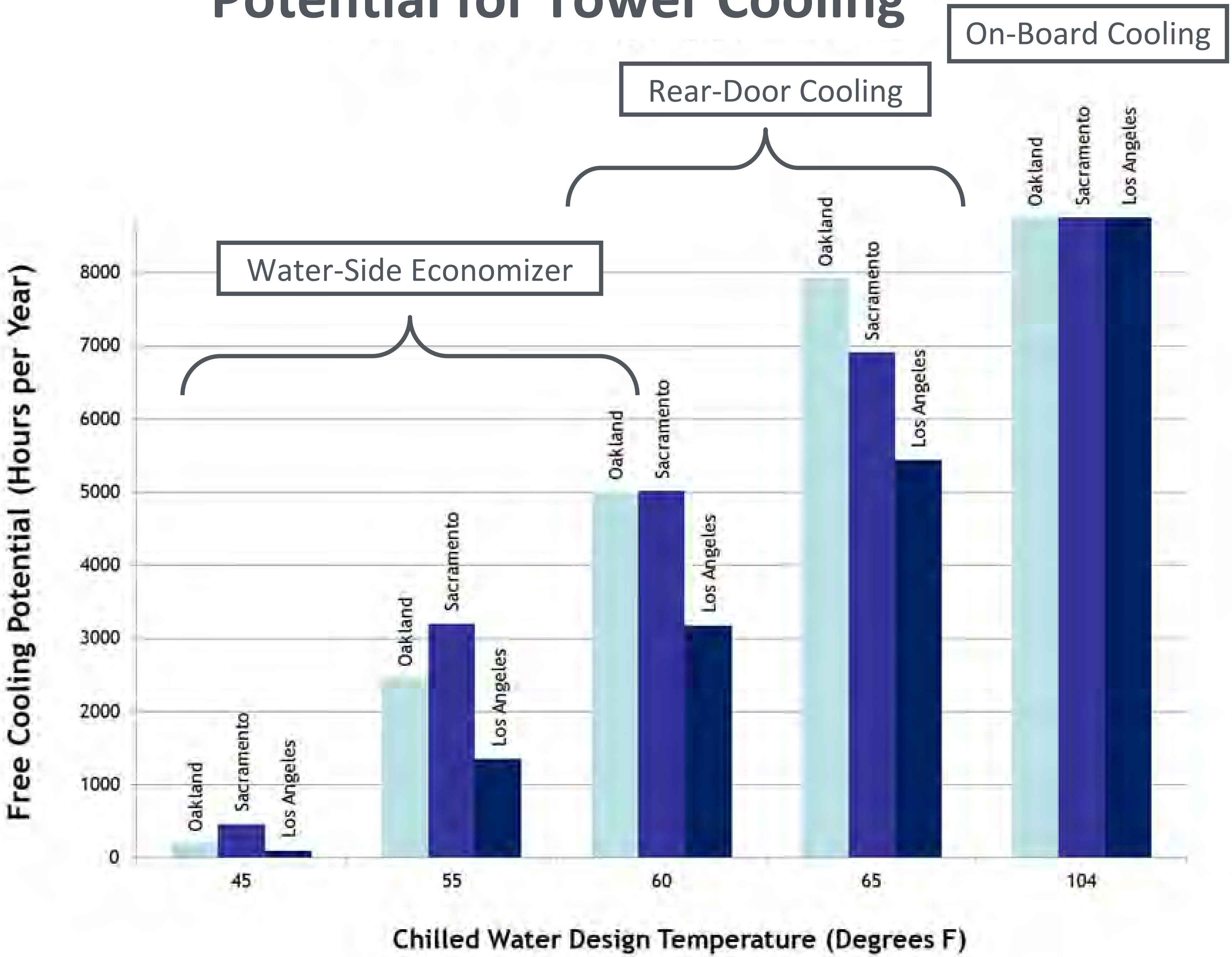
Integrated Water-Side Economizer

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)

Potential for Tower Cooling



LBNL Example: Rear Door Cooling

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

- 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.

Cooling Takeaways…

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

References and Resources

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

- ASHRAE Datacom Series www.ashrae.com
- LBNL http://hightech.lbl.gov/datacenters.html
- Uptime http://www.uptimeinstitute.org

Questions?

Electrical Systems

Presented by: Dale Sartor, PE

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

FEMP
Federal Energy Management Program

GSA

AGENDA

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

Morning

- Introductions to course and instructors
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions

Lunch On your own

Afternoon

- Airflow management
- Cooling systems
- **Electrical systems**
- Summary and Takeaways

Electrical Distribution 101

- 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 saves capital cost (conductor size is smaller)
- Uninterruptible power supply (UPS), transformer, and PDU efficiencies vary – carefully review
- Efficiency of power supplies in IT equipment varies
- Lowering distribution losses also lowers cooling loads

Electrical systems sizing

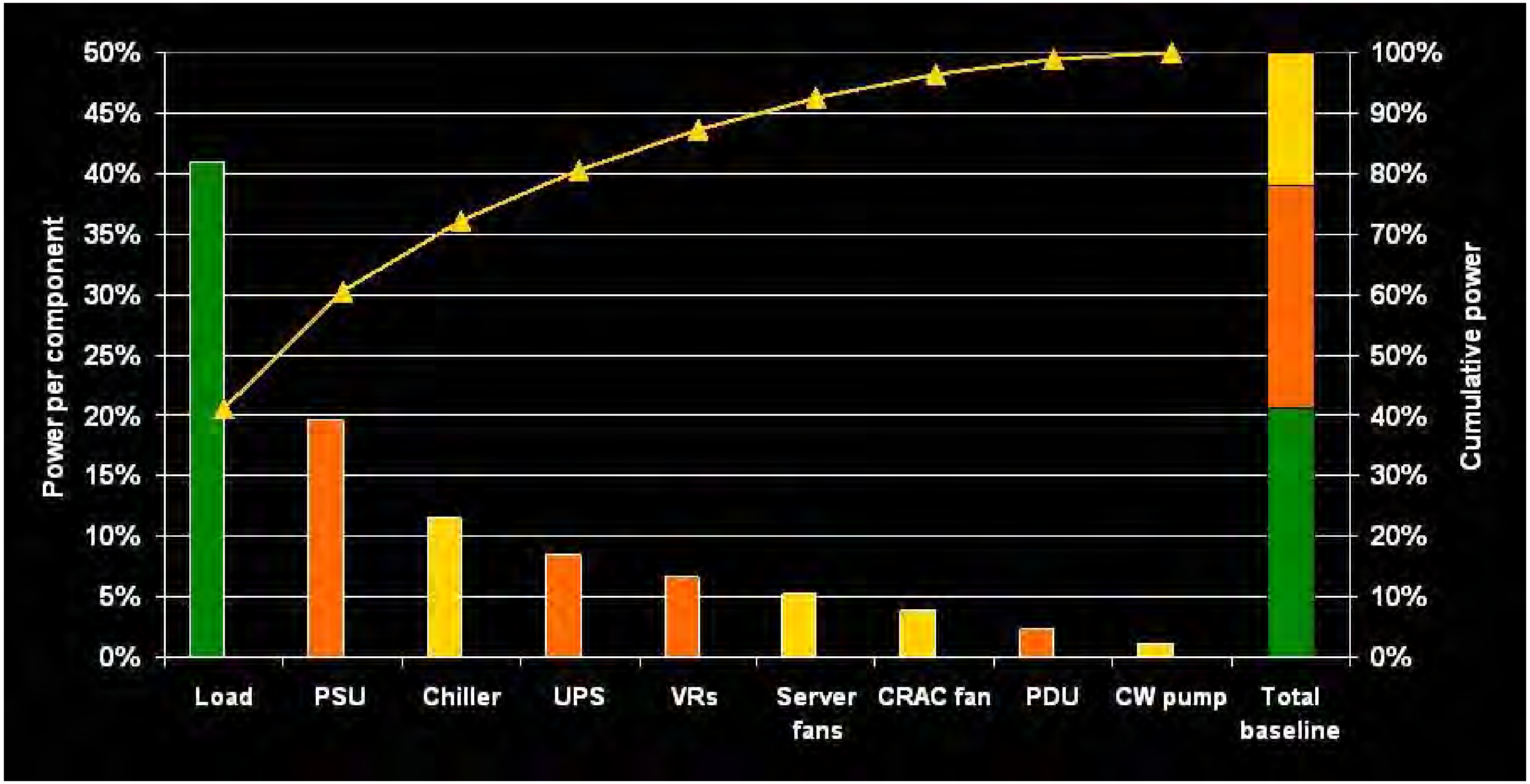
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- IT Design Load historically was typically based on IT Nameplate load rating plus future growth. In many cases the IT equipment is not known when the data center is designed. Problem – actual IT loads are <25% of nameplate

- IT load was determined on a Watts/sf basis Problem –IT loads are now concentrated

- UPS systems are sized for IT load plus 20-50% Problem – load was already oversized

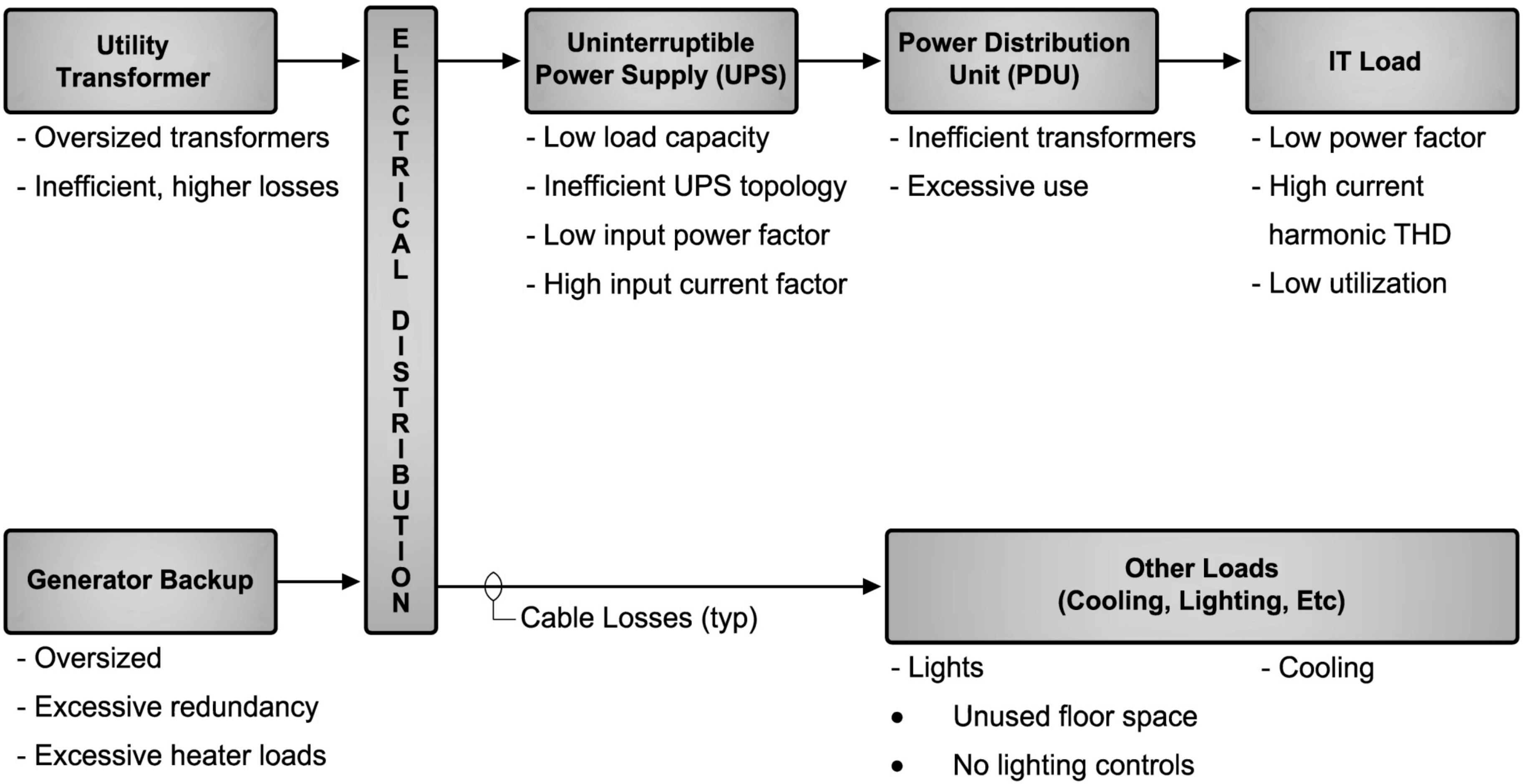
Electrical system end use – Orange bars



Courtesy of Michael Patterson, Intel Corporation

Electrical Systems – Points of Energy Inefficiency

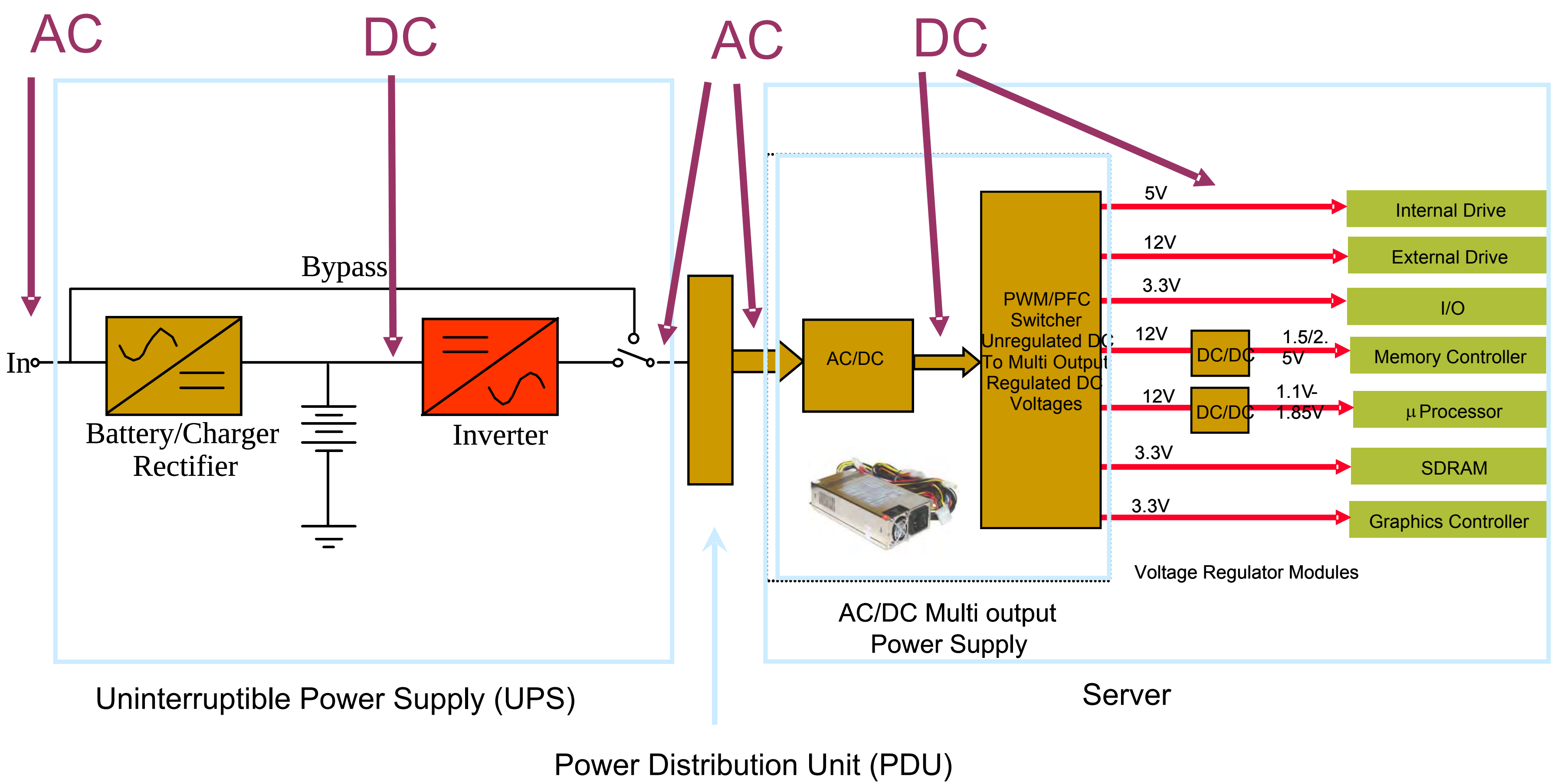
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



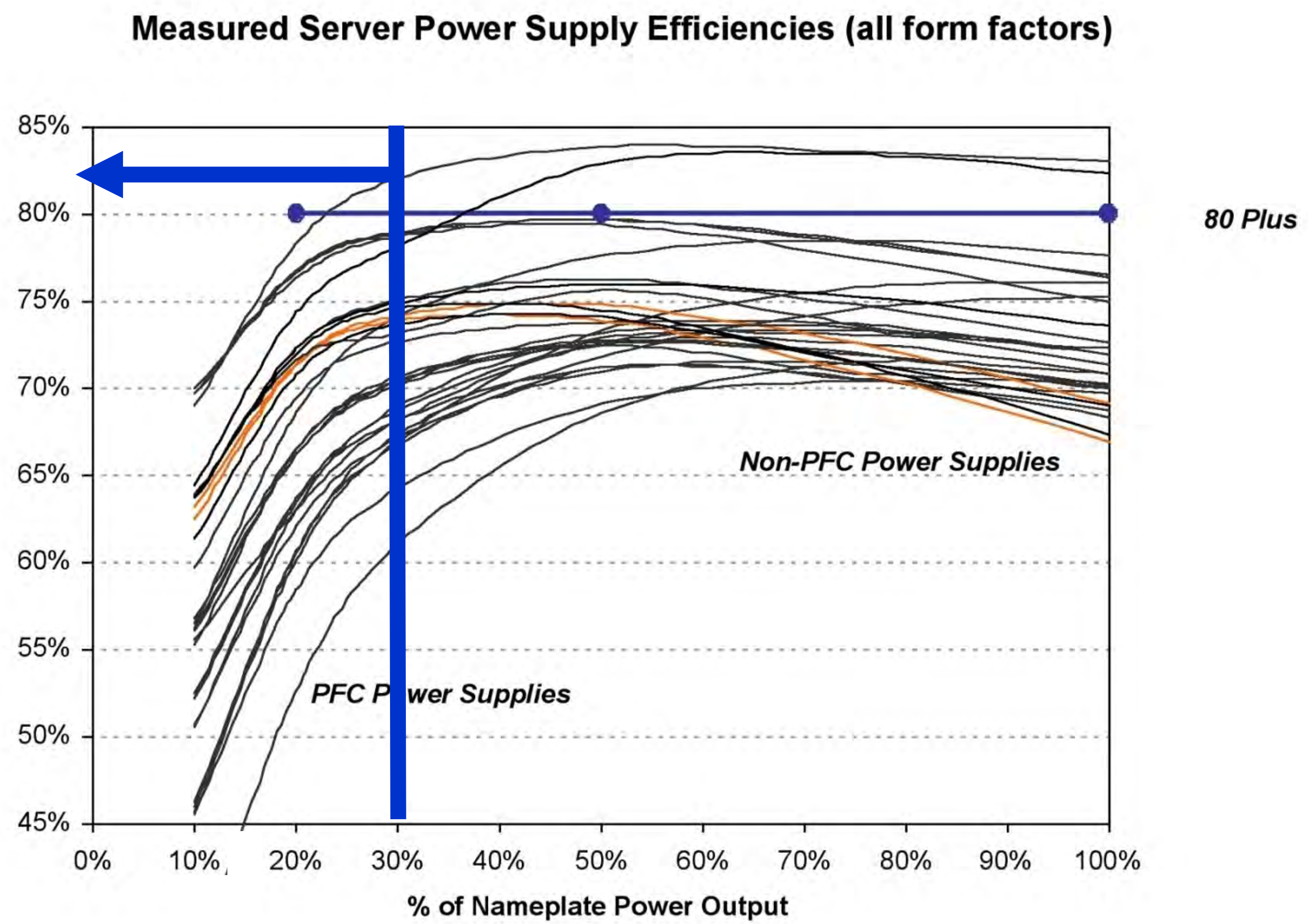
Reduce electrical distribution conversion losses:

- Choose UPSs with high efficiency (low losses) throughout their expected operating range. UPS efficiency varies by model and topology.
  - Line-interactive or flywheel UPS efficiency can vary from 95-98%
  - Double conversion UPS efficiency can be 86-95%
  - Lightly loaded UPS systems are typically much less efficient
- Redundancy should be used only to the required level. (N+1 is much different than 2N)
- Select high efficiency transformers including those in Power Distribution Units (PDUs)
- Distribute high voltage AC or DC power to the point of use.

From utility power to the chip – multiple electrical power conversions

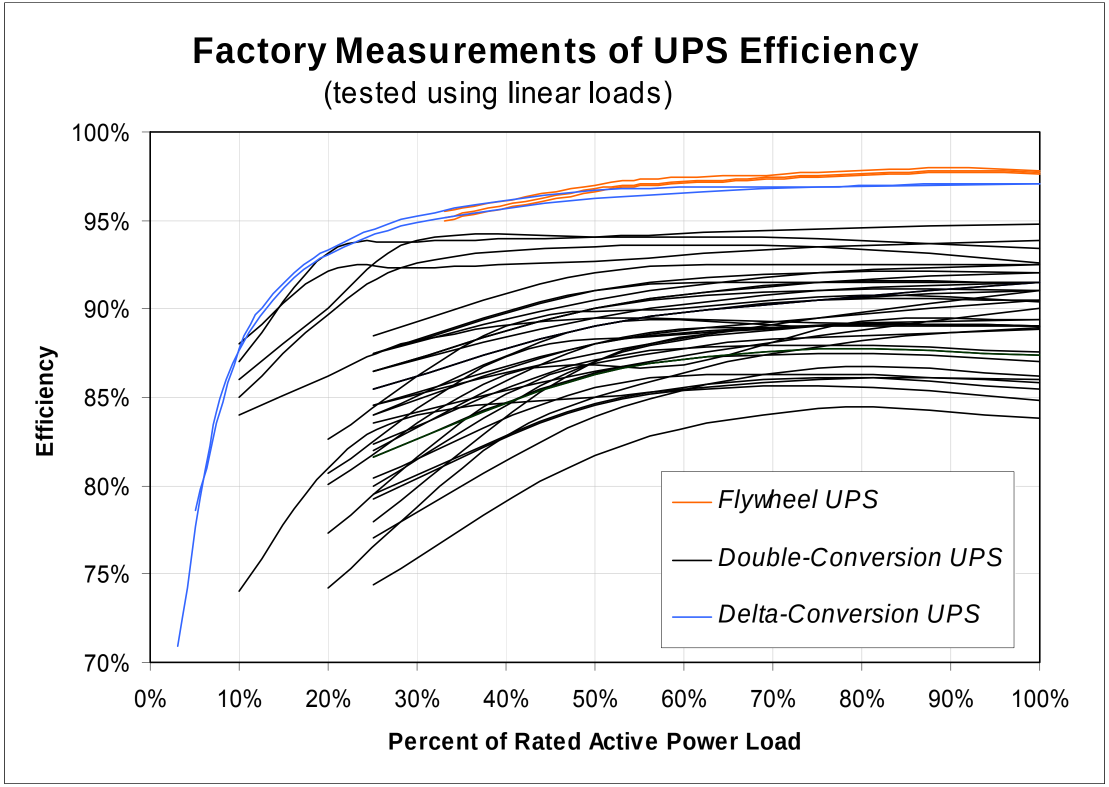


LBNL/EPRI measured power supply efficiency

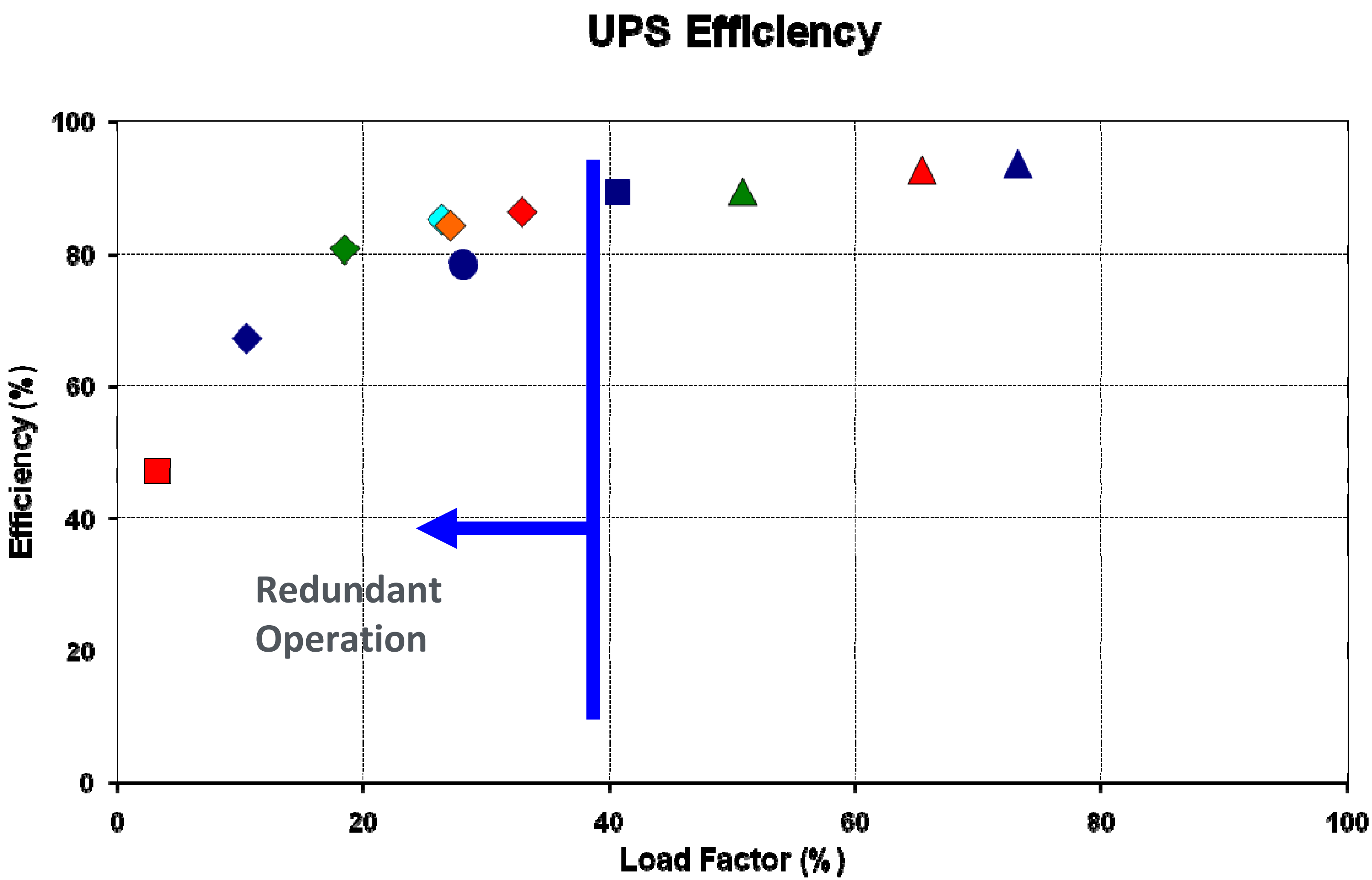


UPS, transformer, and PDU efficiency

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

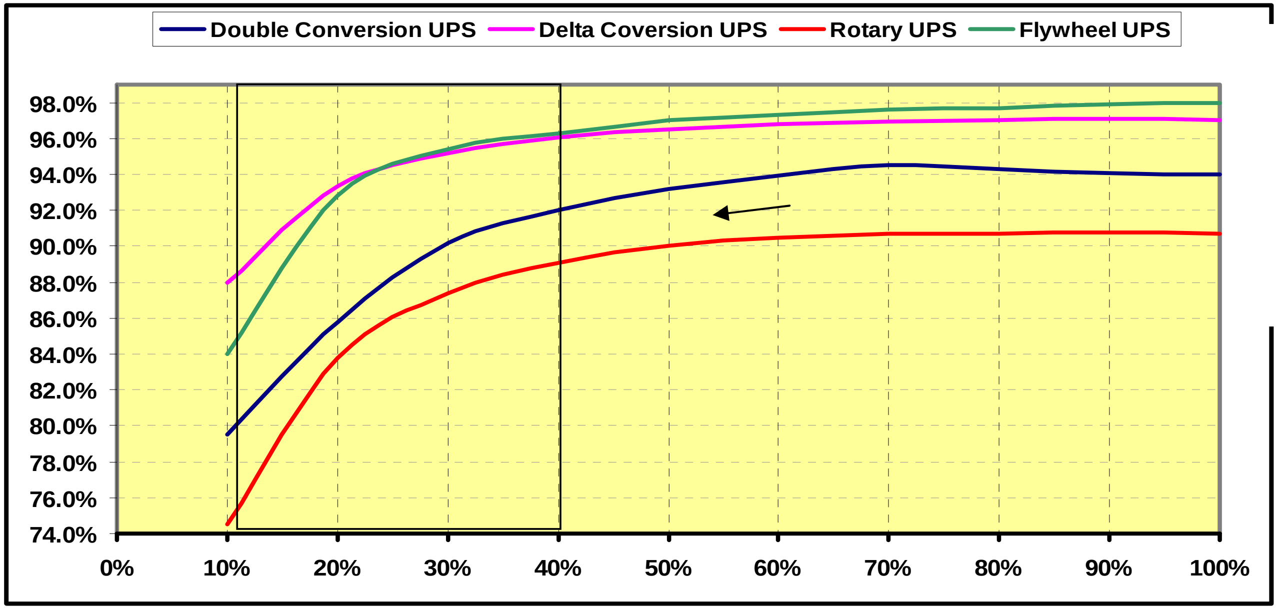


Measured UPS efficiency



Managing UPS load capacity

Example: 10% difference in UPS efficiency per 1000 kW IT load results in approximately 900 MWhr of Energy saving per year and approx $400K of energy saving over 5 years.

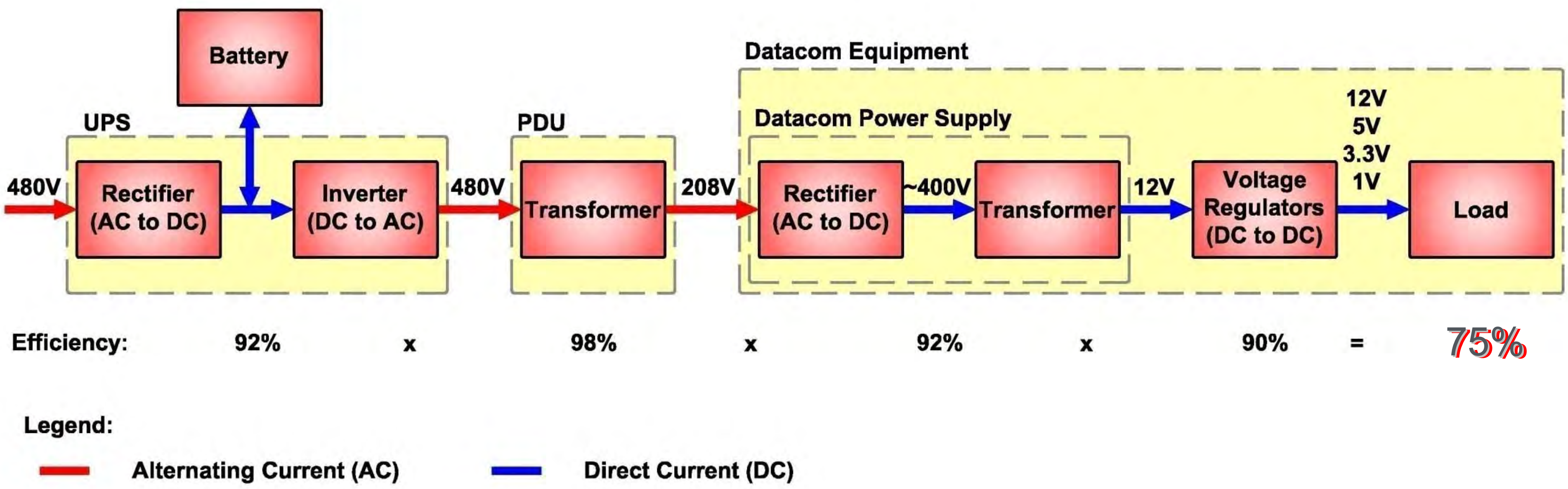


Most UPS units in N or N+X configuration operate at 10% to 40% load capacity

Electrical systems – Losses

Losses are compounded as power flows downstream:

- Components in series can dramatically lower the overall efficiency.
- This example shows only three/fourths of the power actually reaches the load.

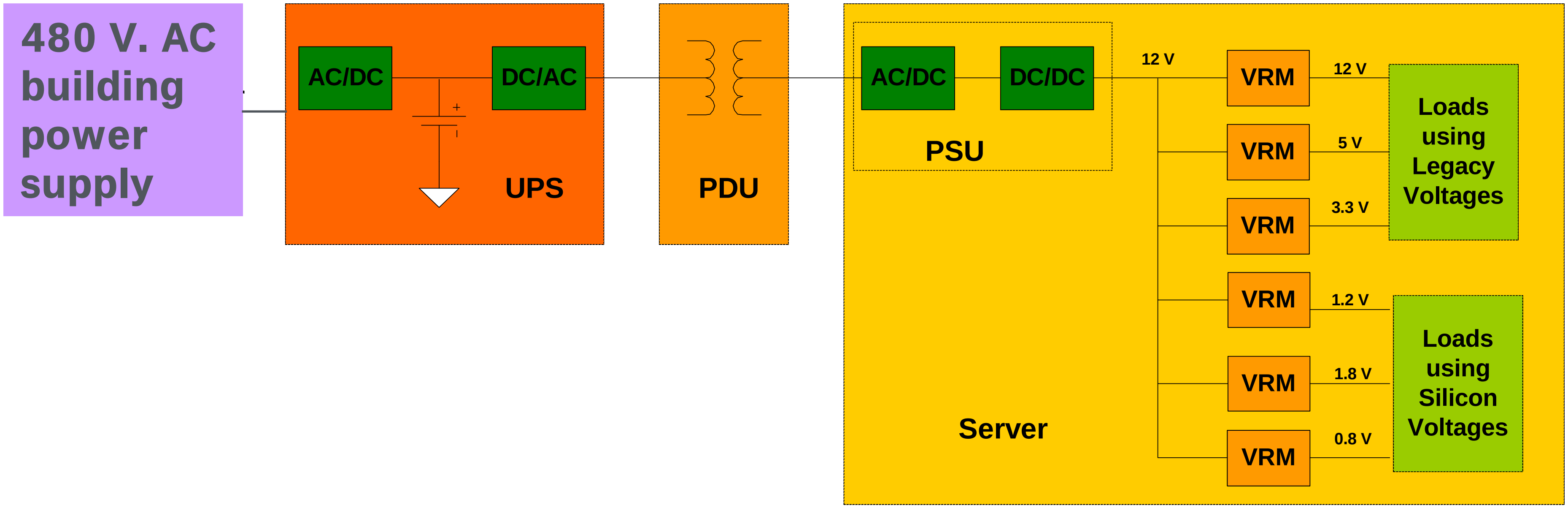


Redundancy

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

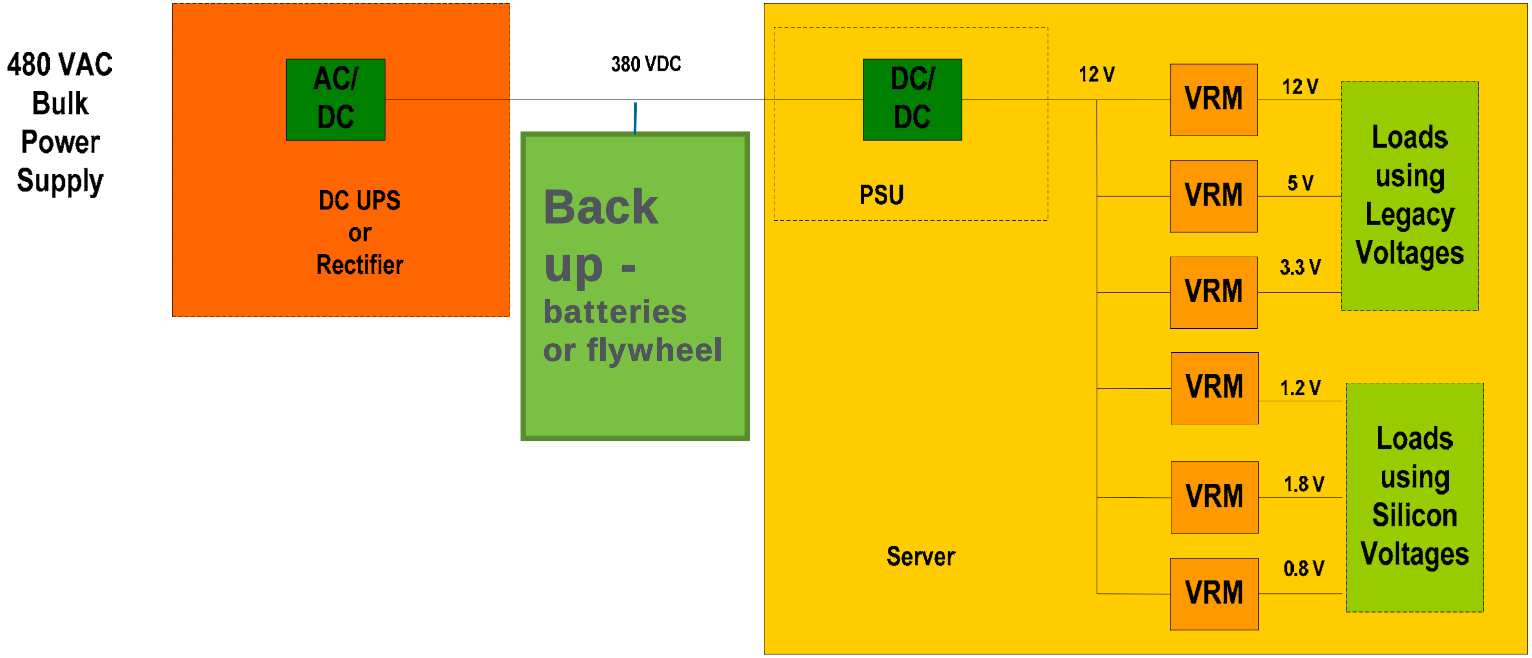
- Understand what redundancy costs and what it gets you – is it worth it?
- Does everything need the same level?
- Different strategies have different energy penalties (e.g. 2N vs. N+1)
- It's possible to more fully load UPS systems and achieve desired redundancy
- Redundancy in electrical distribution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

"Today's" AC distribution



380V. DC power distribution

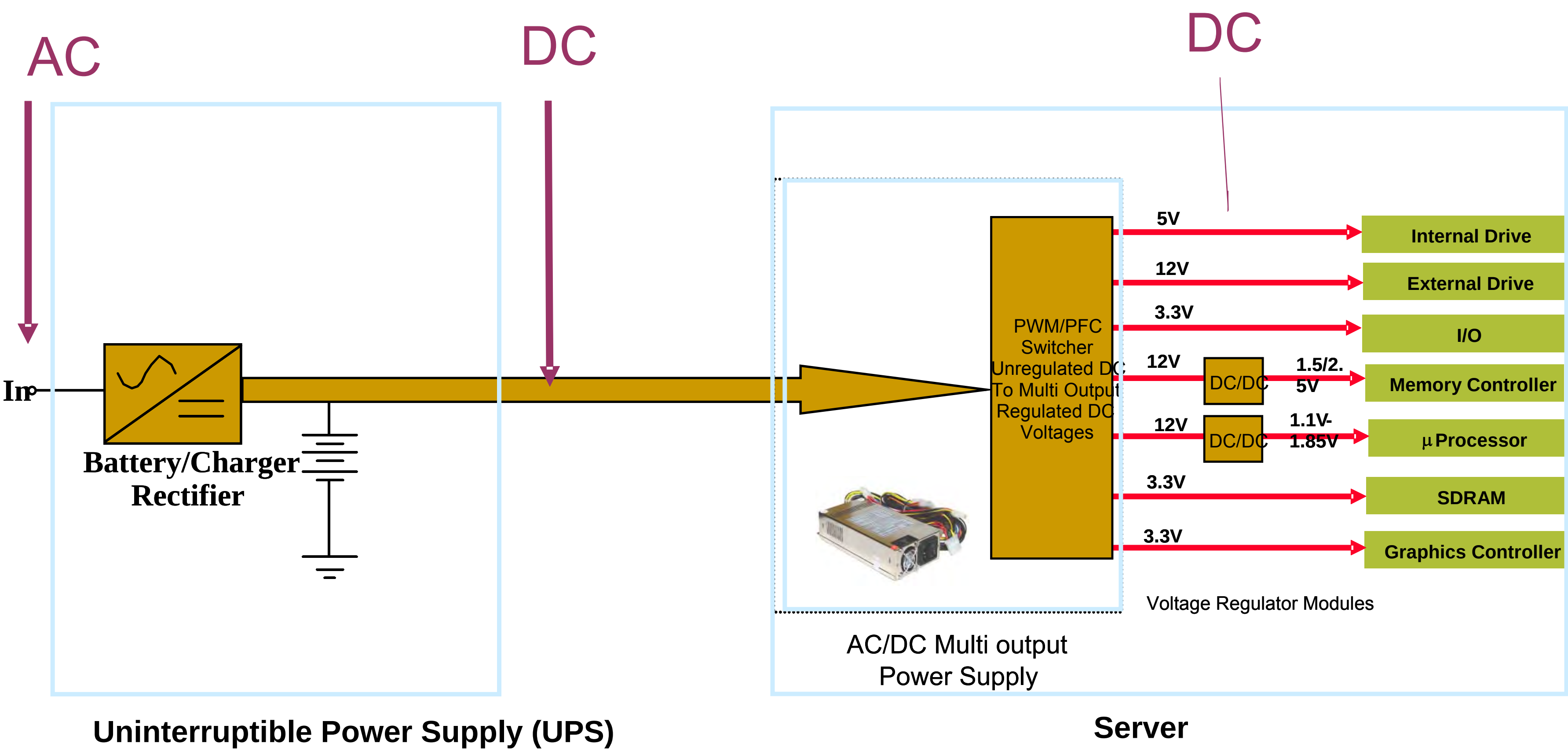
DC power can eliminate several stages of conversion and could be used for lighting, easy tie in of variable speed drives, and renewable energy sources.



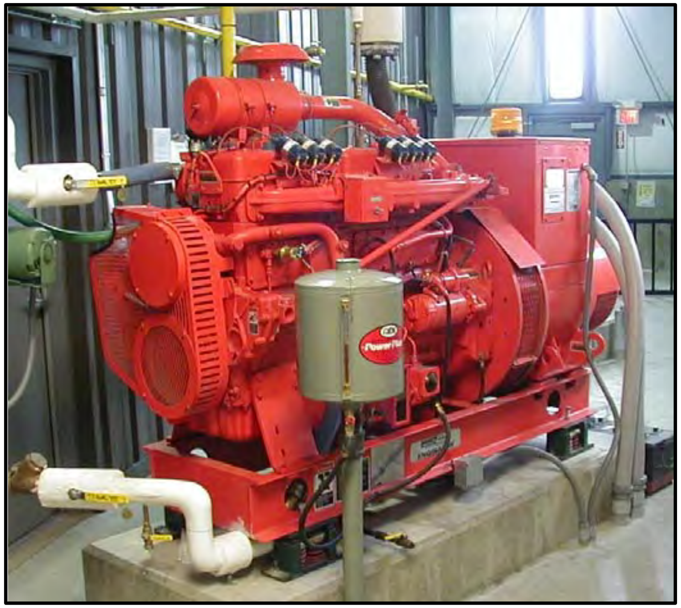
Edison was right

380V DC – (actually 350-400V)

Eliminates multiple electrical power conversions

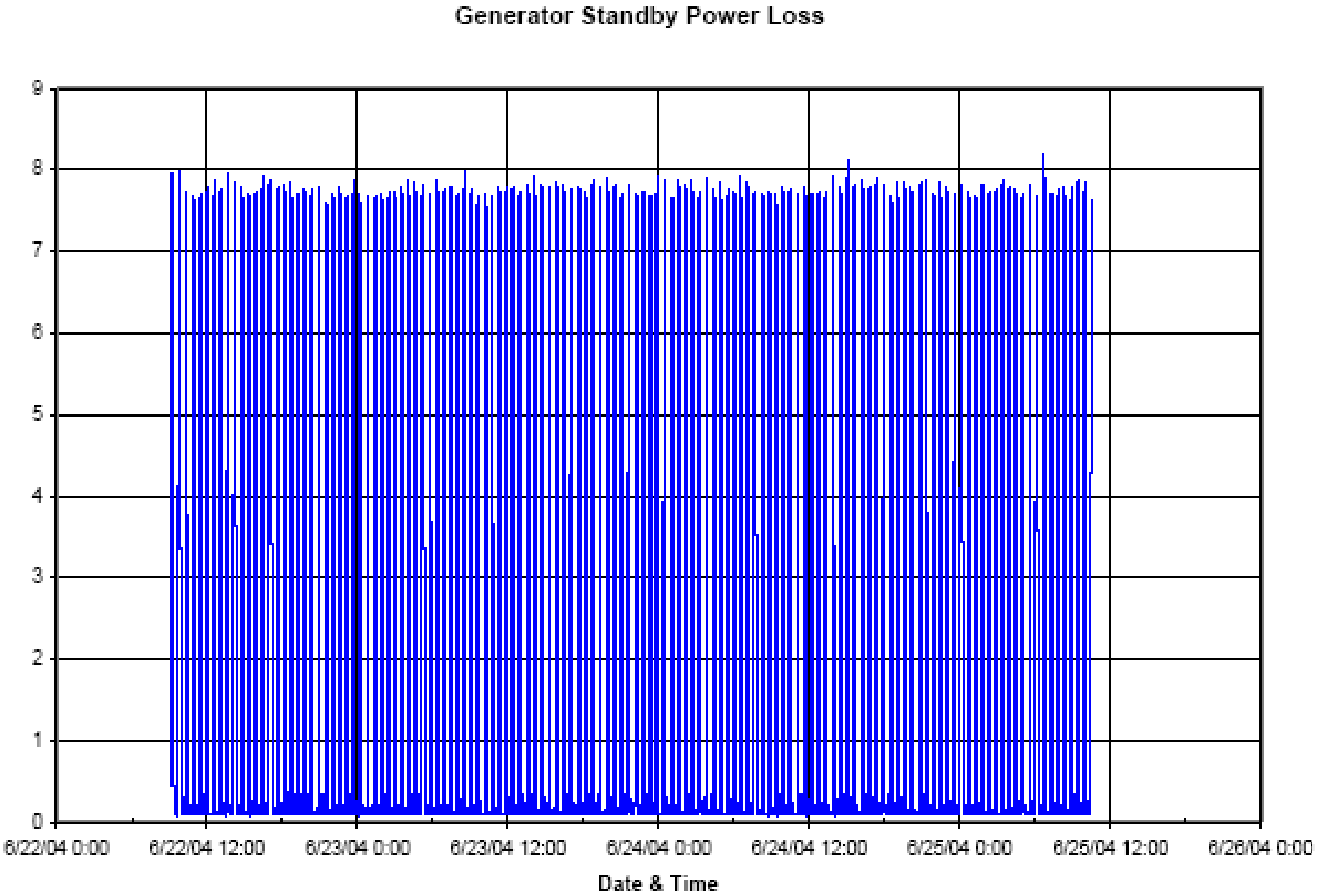


Standby generation loss



- Losses
  - Heaters
  - Battery chargers
  - Transfer switches
  - Fuel management systems
- Opportunities to reduce or eliminate losses
- Heaters (many operating hours) use more electricity than the generator produces (few operating hours)
  - Check with generator manufacturer on how to reduce the energy consumption of block heaters (e.g. temperature settings and control)
- Right-sizing of stand-by generation
- Consider redundancy options

Standby generator heater



Data center lighting

- 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

Motors and Drives

- Since most cooling system equipment operates continuously, premium efficiency motors should be specified everywhere
- As mentioned in the cooling sections, variable speed drives should be used
  - Chillers
  - Pumps
  - Air handler fans
  - Cooling tower fans

Key Takeaways

- Choose highly efficient components
- Every power conversion (AC-DC, DC-AC, AC-AC, DC-DC) decreases overall efficiency and creates heat
- Efficiency decreases when systems are lightly loaded
- Distributing higher voltage reduces the number of power conversions and reduces capital cost (conductor size is smaller)
- Direct Current (DC) systems can reduce conversion losses
- Consider the minimum redundancy required

Questions?

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

Workshop Summary

Best Practices and Trends

Presented by: Dale Sartor, PE

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

FEMP Federal Energy Management Program

GSA

AGENDA

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

Morning

- Introductions to course and instructors
- Performance metrics and benchmarking
- IT equipment and software efficiency
- Use IT to save IT (monitoring and dashboards)
- Data center environmental conditions

Lunch On your own

Afternoon

- Airflow management
- Cooling systems
- Electrical systems
- **Summary and Takeaways**

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!

More to Come

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

Next Steps for LBNL's Legacy Data Center

- Integrate CRAC controls with wireless monitoring system
  - Demand based resets of pressure and temperature
- 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)

Data Center Best Practices

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

Measure and Benchmark Energy Use

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

Identify IT Opportunities

- Specify efficient servers (incl. power supplies)
- Virtualize
- Refresh IT equipment, and decommission unused equipment

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.

Manage Airflow

- Implement hot and cold aisles
- Fix leaks
  - Use blanking plates and panels.
  - Consolidate and seal cable penetrations.
- Manage floor tiles
  - Eliminate floor openings in hot aisles.
  - Evaluate tile perforations and balancing.
  - Match under-floor airflow to IT equipment needs.
- Isolate hot and cold airstreams.
  - Optimize airflow with return air plenum.

Optimize Environmental Conditions

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

Evaluate Cooling Options

- Use centralized cooling system
- Maximize central cooling plant efficiency
- Provide liquid-based heat removal
- Compressorless cooling
  - Install integrated water-side economizer
  - Implement outside air economizer

Data Center Best Practices

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

Improve Electrical Efficiency

- Select efficient UPS systems and topography
- Examine redundancy levels
- Increase voltage distribution and reduce conversions
- Control or eliminate standby generator block heaters
- Lighting controls

Implement Standard Energy Efficiency Measures

- Install premium efficiency motors
- Use occupancy sensors to control lighting.
- Upgrade building automation control system
  - Integrate CRAC controls
- Variable speed everywhere
- Optimize cooling tower efficiency

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

New Data Center Design Trends

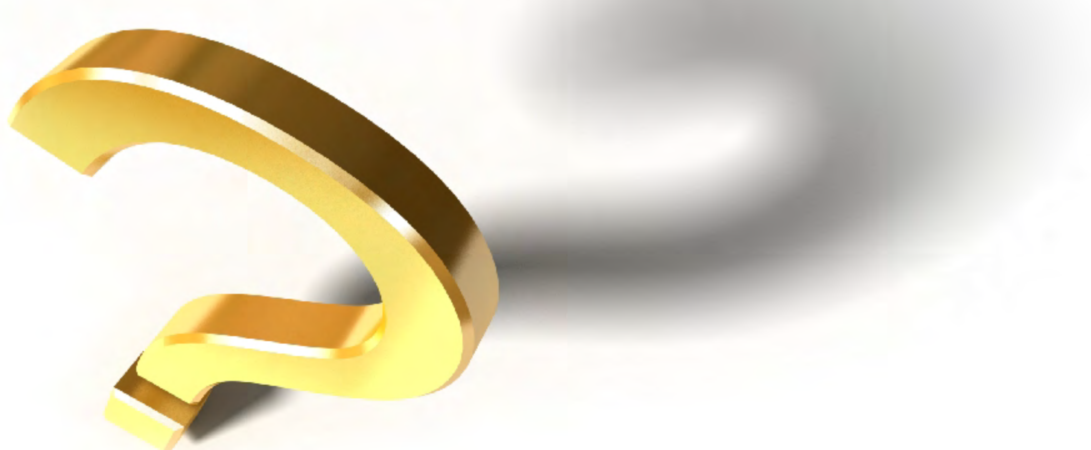
- Document Design intent, commission, and provide training
- Set and track performance goals
- Use life-cycle total cost of ownership analysis
- Design for variable loads
- Design for hot and cold isolation and warmer operation
- Design for outside air economizer and warm liquid cooling
- Consider redundancy in the network rather than in the data center
- Use DC power to servers and higher voltage AC
- Reuse server waste-heat
- Minimize lighting during unoccupied periods
- Evaluate alternative data center locations
- Consider clean on-site power

Legacy Data Center Opportunities

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

- Virtualize server operations [power-down unused servers]
- Implement hot and cold aisles and good air management
  - Seal air leaks [esp. within racks and around cabling]
  - Install blanking plates
- Increase room set-point temperature
- Coordinate existing CRAC/CRAH operations
- Eliminate reheat and humidification
- Install variable speed supply fans
- Maintenance (eat your spinach)
  - Hot and cold separation – e.g. blanking panels and cable penetrations
  - CRAC units (and all mechanical systems)
  - Controls (incl. sensor calibration)

Questions?



Contact Information…

Lawrence Berkeley National Laboratory
A-Team
Energy Efficient Building Design Applications

Dale Sartor, P.E.

510.486.5988

DASartor@lbl.gov

Geoffrey C. Bell, P.E.

510.486.4626

GCBell@lbl.gov