

How to Save Money In Your Small Data Center

Dale Sartor, P.E.


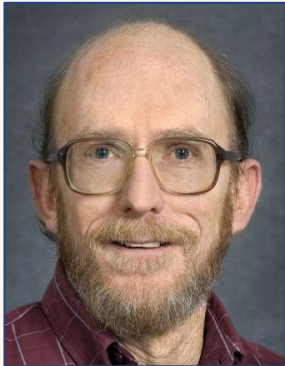
Steve Greenberg, P.E.

Lawrence Berkeley National Laboratory

DATE 08/20/2018



Today's Presenters

Name		Organization
Dale Sartor, P.E.	 A portrait of Dale Sartor, P.E., a man with curly grey hair and a mustache, wearing a grey zip-up sweater over a white shirt and dark tie. He is pointing his right index finger upwards.	LBNL
Steve Greenberg, P.E.	 A portrait of Steve Greenberg, P.E., a man with a beard and glasses, wearing a red and white plaid shirt. He is smiling slightly.	LBNL

Download Presentation - Verify

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



Agenda

- Why small data centers are important
- Simplest Measures
 - Information Technology (IT)
 - Cooling
 - Electrical distribution
- Still simple, a little more work
 - IT refresh and virtualization
- Break
- Higher-level investment, but very cost-effective
 - Move data center functions elsewhere
 - Implement IT and infrastructure power monitoring
 - Capital upgrades to cooling system
- Training for IT and Facility Staff
- Resources

Why Small Data Centers are Important

- Definition: “Small” is less than 5,000 square feet of computer floor
- Have nearly half of the total servers
- Use 40 billion kWh/yr in the US (~\$4 billion)
- Embedded data centers often dominate the entire building’s energy use even though they are a small fraction of the total floor area
- Have challenges in terms of good management:
 - Typically no one person in charge, and no one’s full-time job
 - Security risks
 - Computing and supporting infrastructure energy not monitored
- Have large energy-saving opportunities, typically 20 – 40%. 30% savings would result in ~\$1 billion per year in savings, across US data center industry.
- Not exempt from Data Center Optimization Initiative

Data Center Optimization Initiative (DCOI)

Specific goals for data centers:

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

Run by OMB and GSA

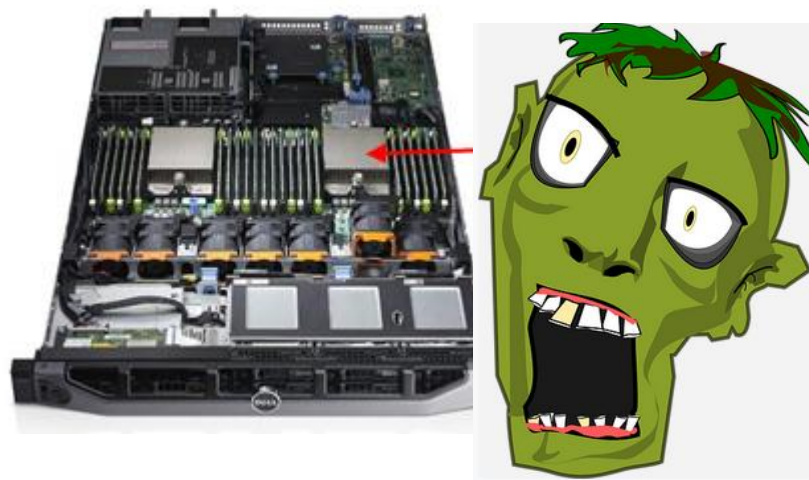
<https://datacenters.cio.gov/>

Simplest Measures

- Turn off unused servers
- Improve server power management
- Improve air management
- Increase temperature setpoints toward the high end of the range set by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE)
- Turn off active humidity control
- Minimize requirements for Uninterruptible Power Supplies (UPS)

Turn off unused servers

- Known as “comatose” or “zombie” servers: they do no useful work, but use
 - Power
 - Space
 - Cooling
- Estimated 20-30% of servers are comatose
- An idle server uses
 - ~50% of full-load power (100% utilization)
 - ~75% of typical load power (25% utilization)



What to do:

- Establish and maintain a list of what's running on each machine
- Shut down unused servers

Improve server power management

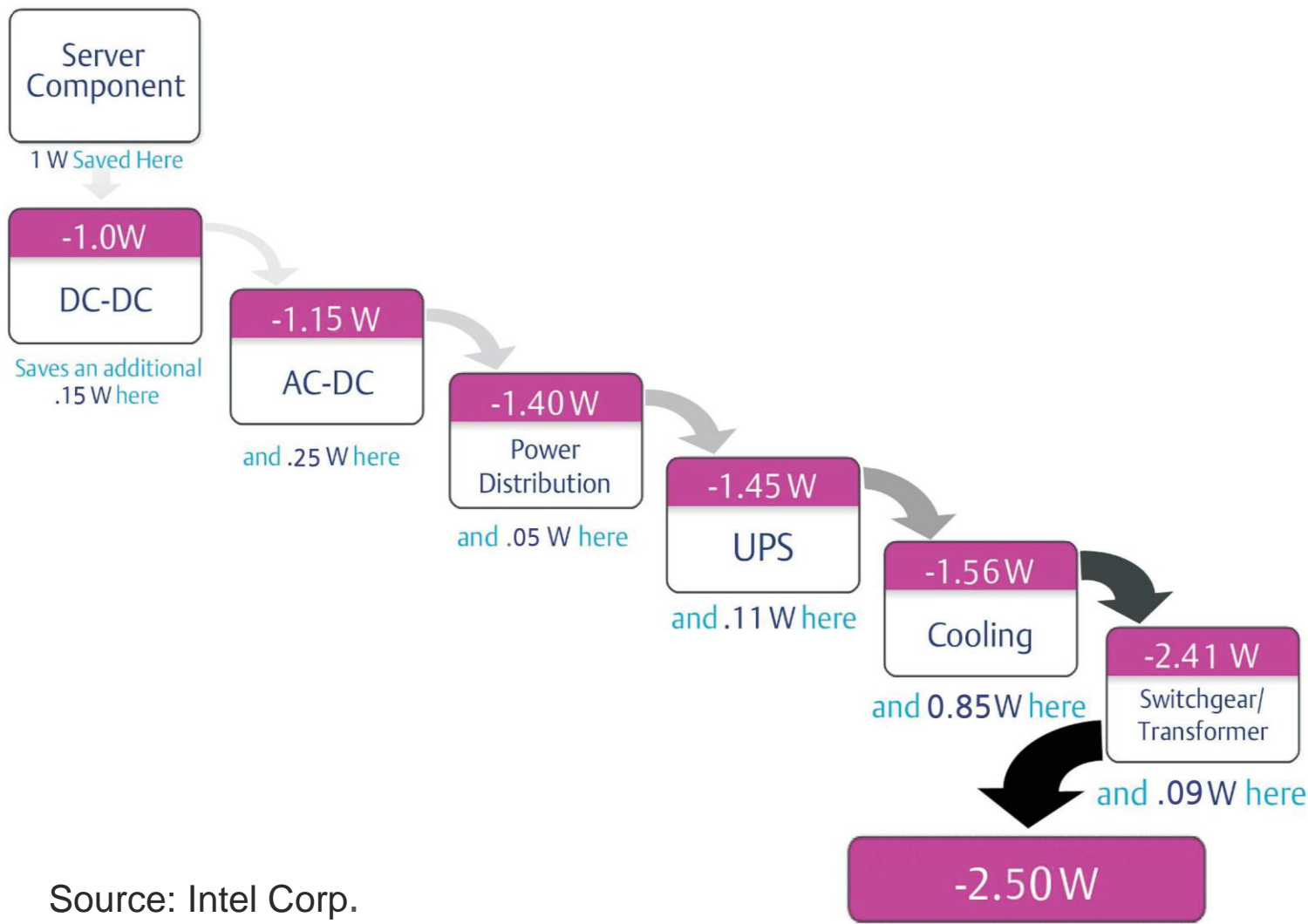
- Most servers are shipped with power management turned on
- Most servers in use have power management turned off

What to do:

- Check power management settings and enable
 - Processor
 - OS (Operating System)
/hypervisor
 - BIOS (Basic Input/
Output System)



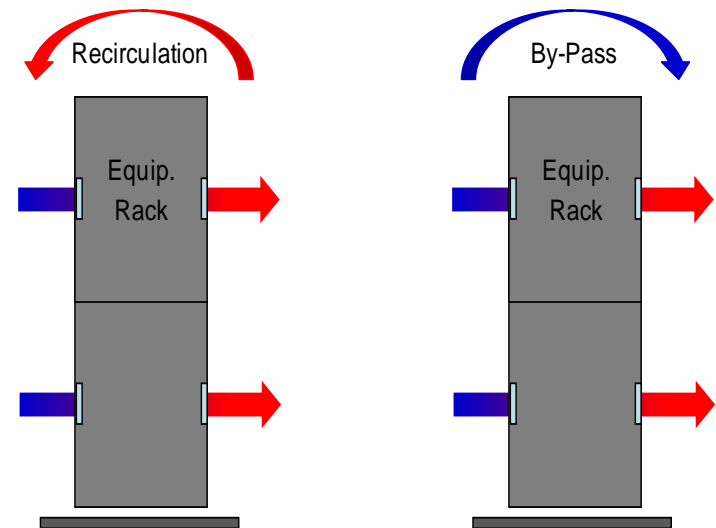
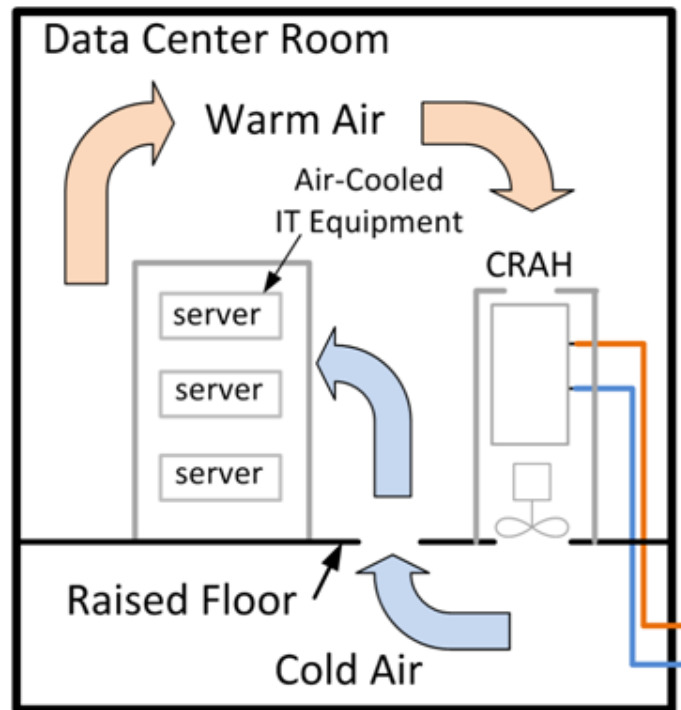
Actual Saving of One Watt Saved at the IT Equipment



Source: Intel Corp.

Improve air management

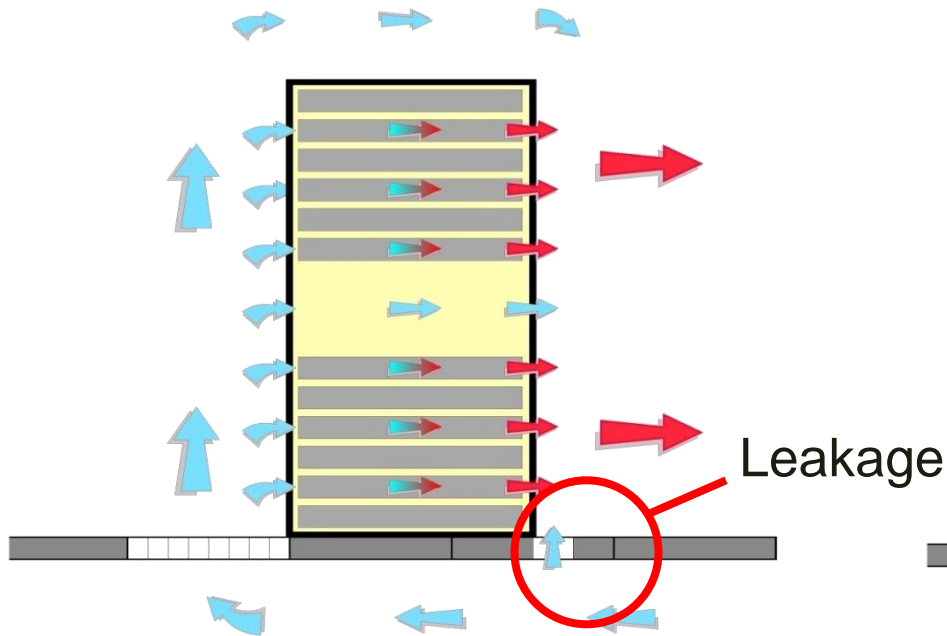
- Cool supply air *ideally* gets from cooling equipment to the Information Technology (IT) inlet without mixing with hot discharge air
- Hot discharge air *ideally* returns from the IT exhaust to the cooling equipment without mixing with the cool supply air



Note: CRAH (Computer Room Air Handler) is the cooling equipment

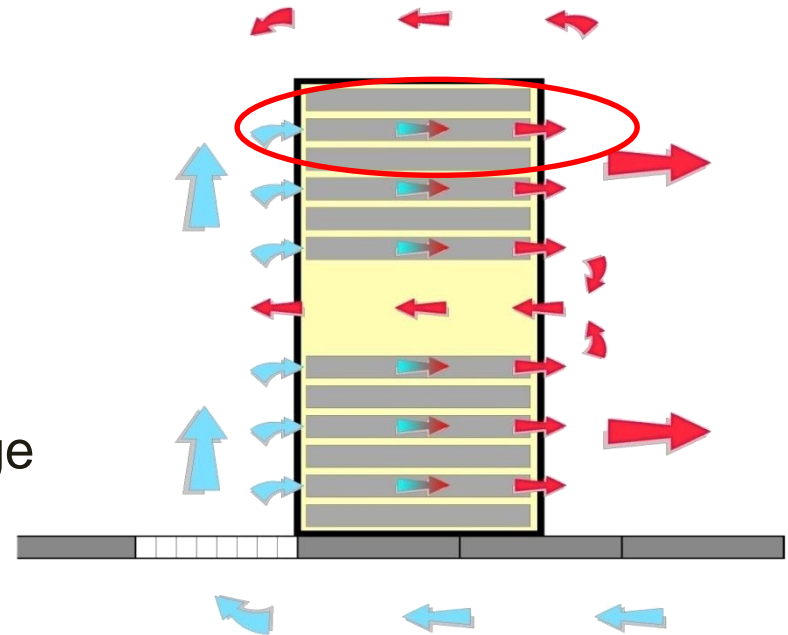
Reduce By-Pass and Recirculation Air

Bypass Air / Short-Circuiting



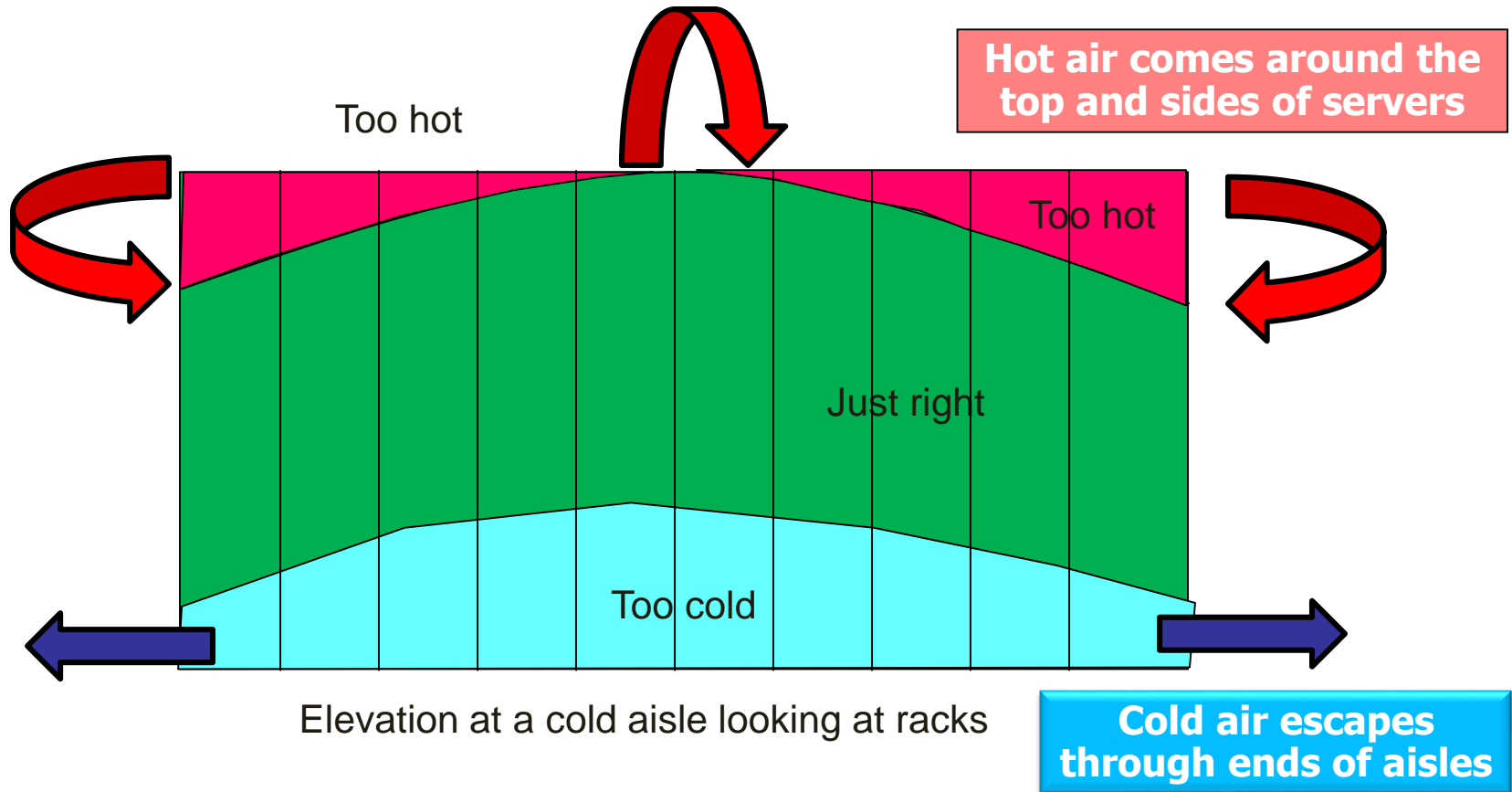
Wastes fan energy as well as cooling energy and capacity

Recirculation



Increases inlet temperature to servers

Typical Temperature Profile with Under-floor Supply



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.

Improve air management, con't

What to do:

- Clear the desired air path (e.g. abandoned and cluttered cables)
- Block the undesirable air paths
 - Within and between racks
 - Cable and conduit cutouts from under floor and into ceiling plenum
 - Rack tops and row ends



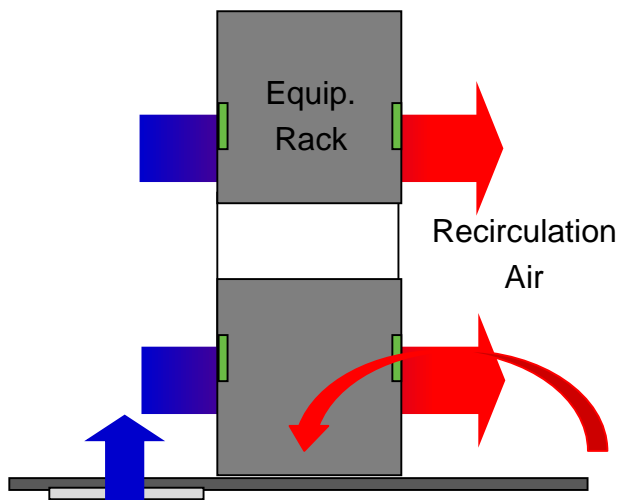
Benefits:

Pictures courtesy of ANCIS Incorporated

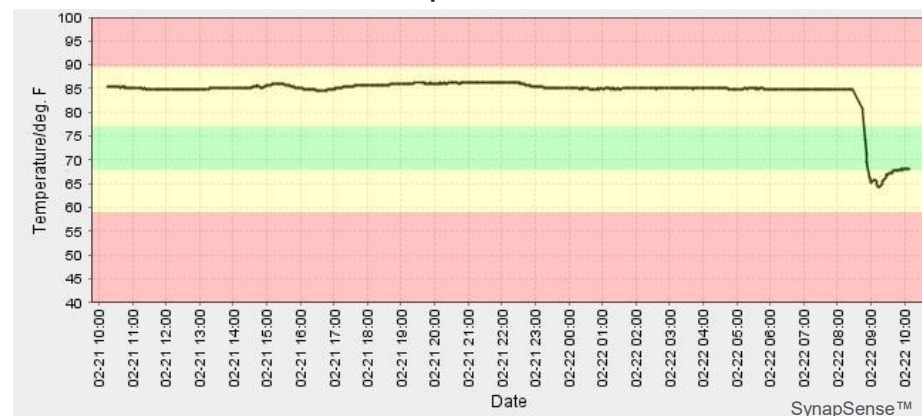
- Allows increased supply air temperature (reduced cooling energy)
- Allows reduced air flow (reduced fan energy)

Air Management: Blanking Panels

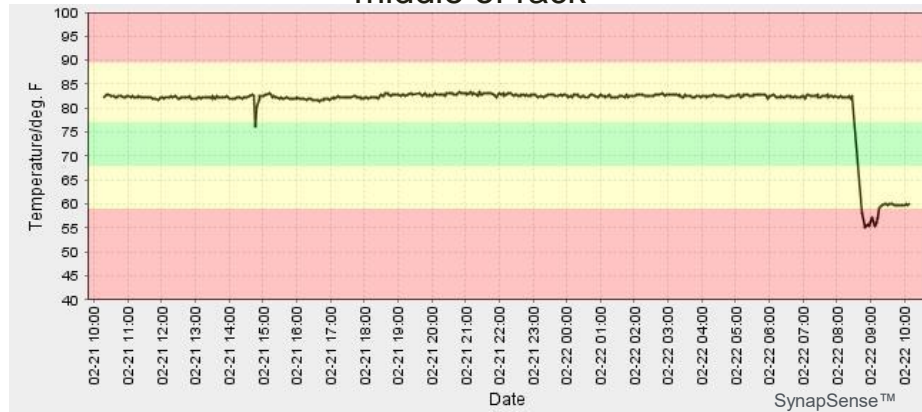
- Any opening will degrade the separation of hot and cold air
- Maintain blanking panels
 - One 12" blanking panel reduced temperature $\sim 20^{\circ}\text{F}$



top of rack

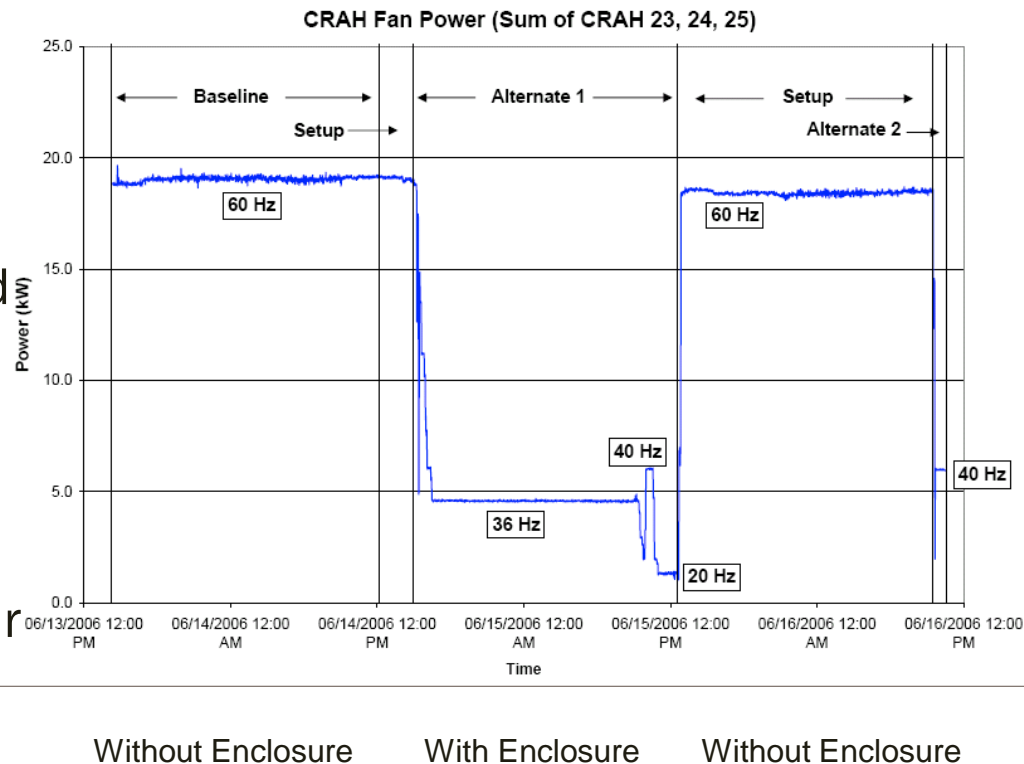


middle of rack



Air Management: Fan Energy Savings

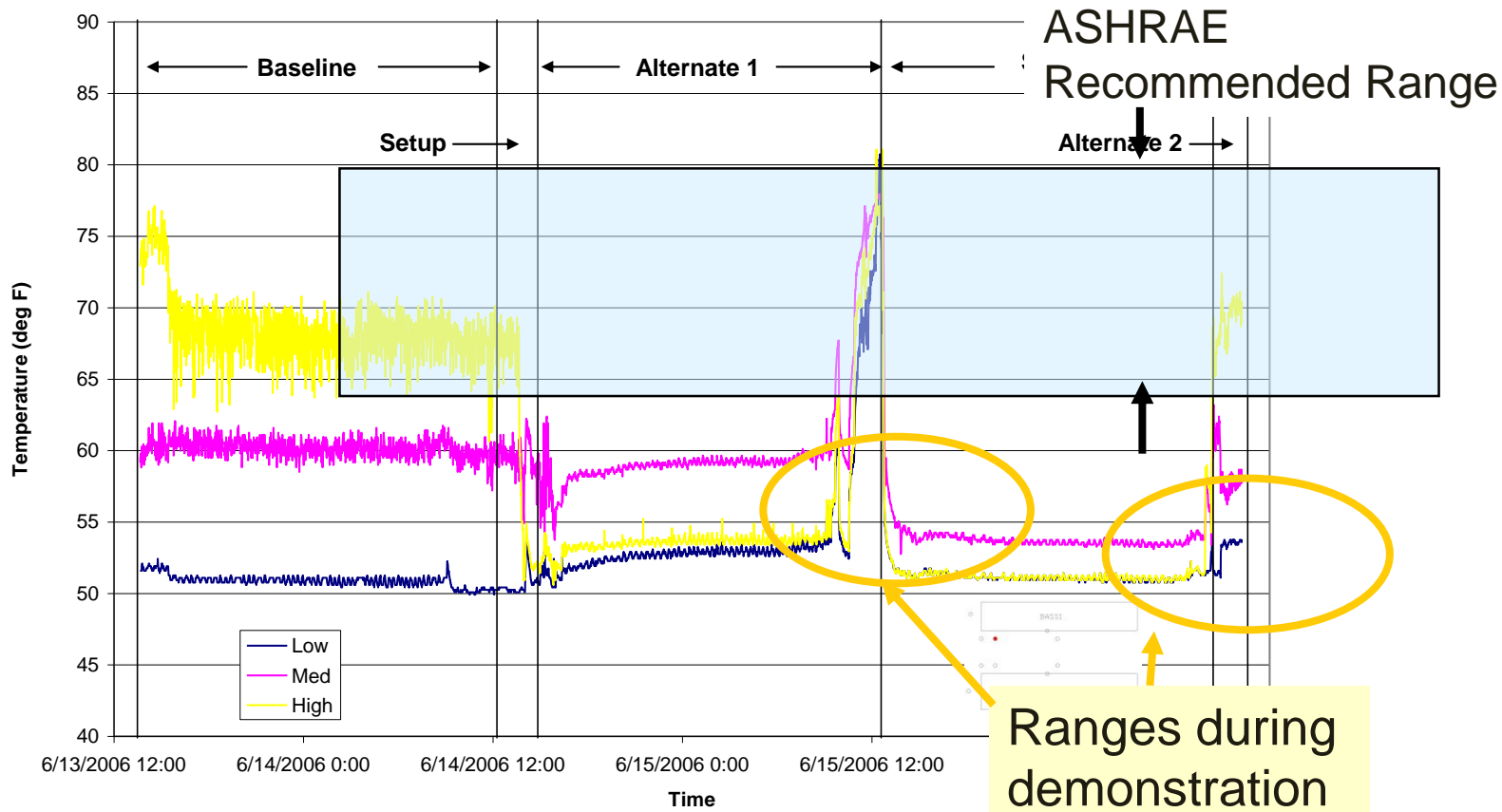
- Isolation significantly reduces bypass air, which in turn allows reduction of supply airflow
- Fan speed can be reduced, and fan power is proportional to nearly the cube of the flow
- Fan energy savings of 70%–80% is possible with variable air volume (VAV) fans



LBNL Air Management Demonstration

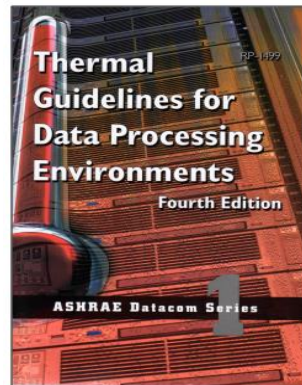
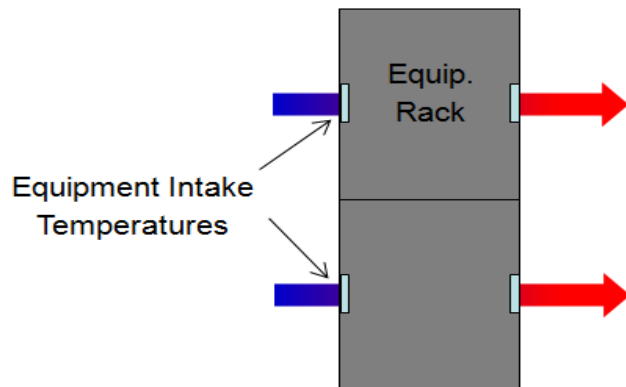
Better airflow management permits warmer supply temperatures!

Cold Aisle NW - PGE12813

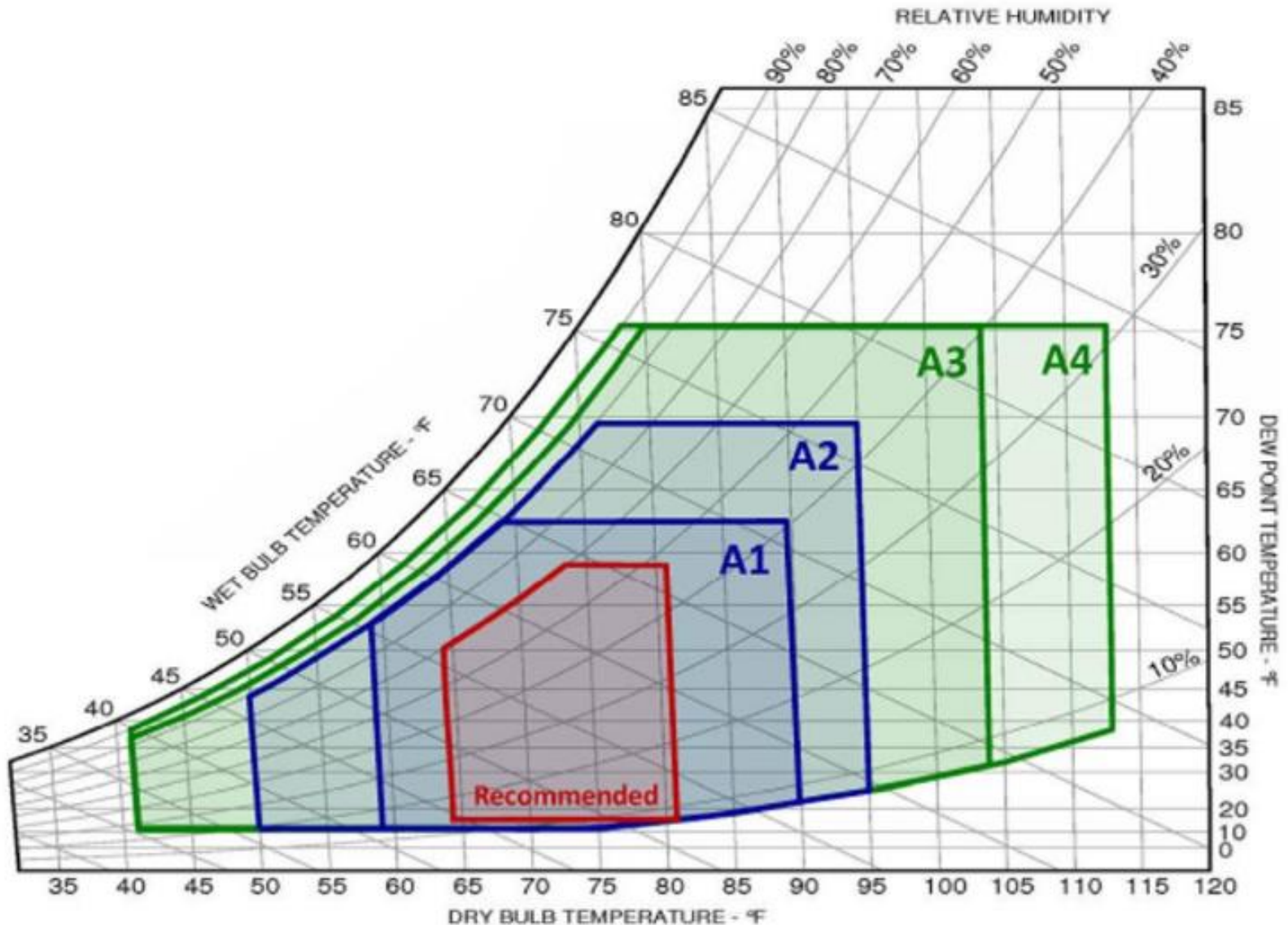


Increase air temperature setpoints toward the high end of the ASHRAE range

- IT *inlet* temperature is what matters
- ASHRAE ranges:
 - Recommended range (rounded): 65 to 80° F
 - Allowable ranges (A1 - A4): 59 to 90° F (A1) ... 41 to 113° F (A4)
- NOT the same as the temperature setpoint for the CRAC (Computer Room Air Conditioner) or CRAH (Computer Room Air Handler), especially for units controlled on return air
- Ensure good air management first before changing control setpoints to avoid hotspots
- Enables savings in chiller or CRAC compressor energy



2015 ASHRAE Temperature and Humidity Ranges

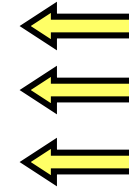


Turn off active humidity control

- Wider ASHRAE range (as of 2015, and retroactive) means that little if any control is required
- Recommended range: 15.8° to 59° F dewpoint temperature (a measure of absolute humidity) and 60% RH (relative humidity) at the IT inlet
- CRACs and CRAHs are often set
 - to 45-55% RH (much too tight)
 - based on the return air (rather than IT inlet or supply air)
- **Adjusting setpoints or turning off humidity control results in:**
 - Humidification savings
 - Dehumidification savings
 - Often both
 - 28% cooling savings at LBNL - eliminated humidity control

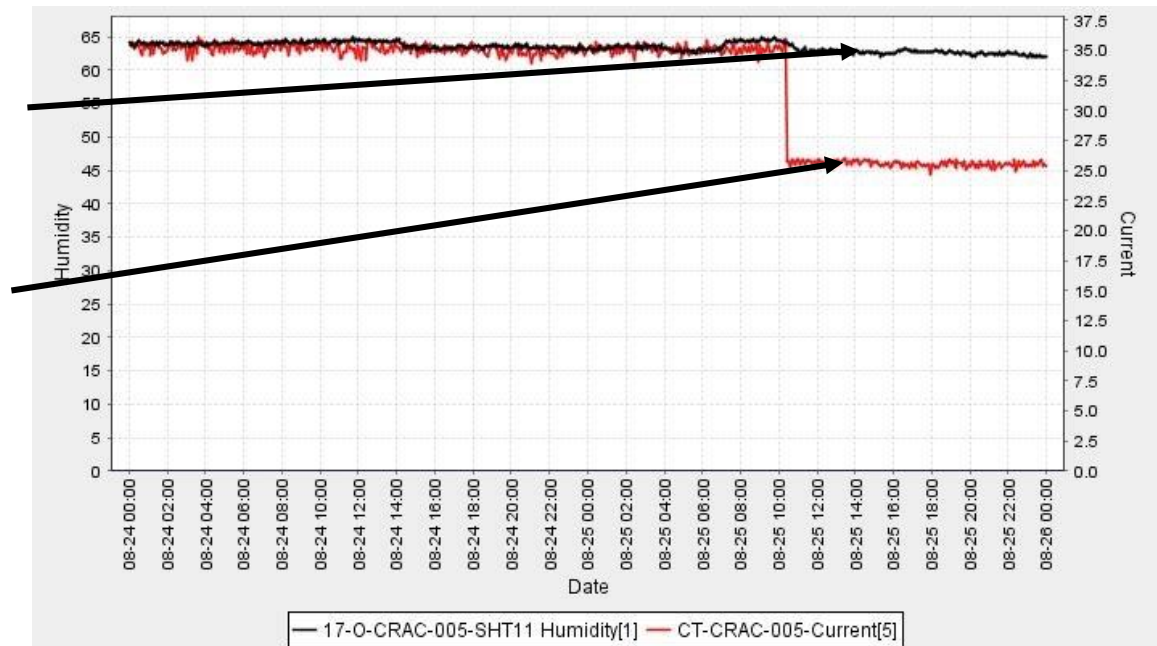
The Cost of Unnecessary Humidification

	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC010	77.5	32.8	46.1	68	45.0	45.9	Cooling
AC011	78.9	31.4	46.1	70	43.0	46.6	Cooling & Humidification
Min	72.8	27.5	46.1	55.0	32.0	37.2	
Max	84.0	38.5	47.2	76.0	51.0	50.2	
Avg	79.2	31.7	46.4	68.8	43.5	45.5	

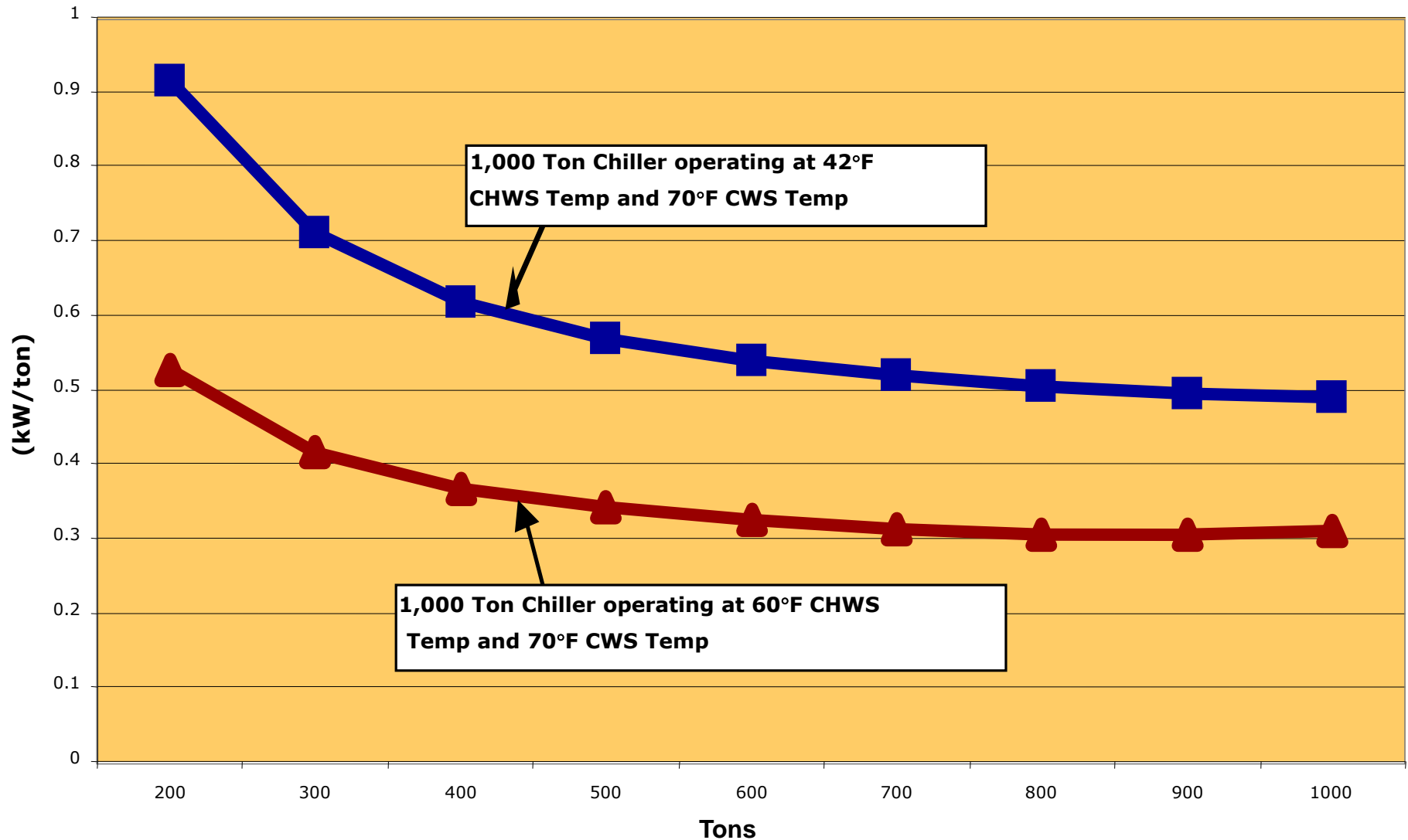


Humidity down 2%

CRAC power down 28%



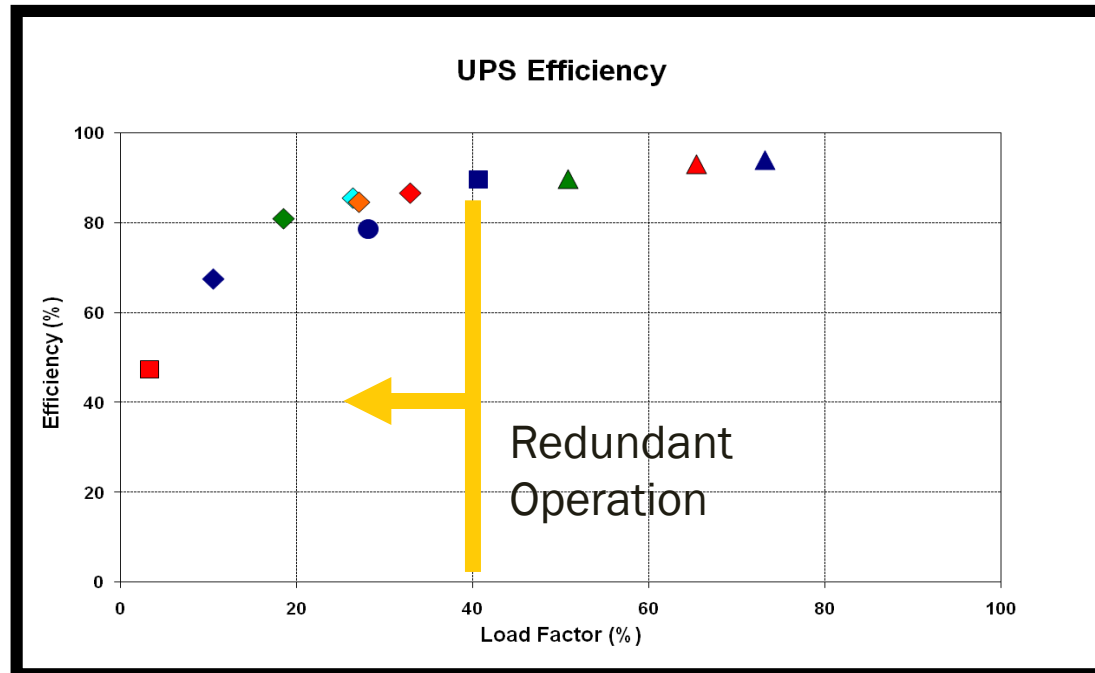
Increase Temperature of Chilled Water



Data provided by York International Corporation

Minimize Uninterruptible Power Supply (UPS) requirements

- Unnecessary redundancy leads to inefficiency
- Many applications can be shut down and restarted without adverse effects
- Critical applications should be considered for moving to a larger data center or the cloud
- Analyze UPS needs
 - Minimize number and size
 - Use ENERGY STAR UPS units
 - Use Eco-mode
 - Savings can range from ~10 - 50% of IT load



Source: LBNL Benchmarking study

Questions



Still simple, a little more work

- Refresh the oldest IT equipment with new high-efficiency equipment
- Consolidate and virtualize applications

Refresh the oldest IT equipment with new high-efficiency equipment

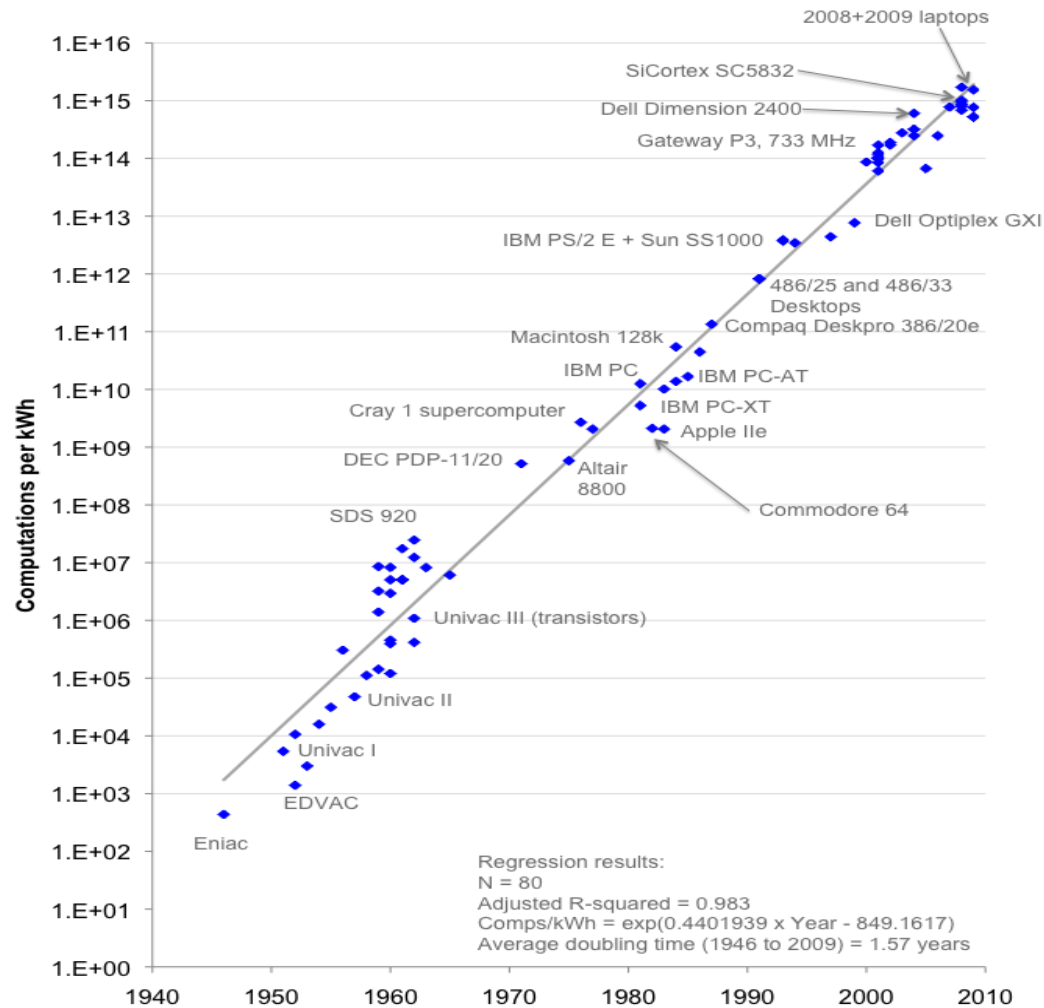
- New equipment is more powerful and gets more computing per watt plus better power management
- More virtualization potential
- Energy and software cost savings typically justifies a faster refresh rate

What to do – Procure:

- **ENERGY STAR**
 - Servers
 - Networking equipment
 - Storage
- **Solid-state drives (vs. hard disks)**
- **80-Plus power supplies (ENERGY STAR requirement)**
 - ~5-20% savings possible with more efficient power supplies

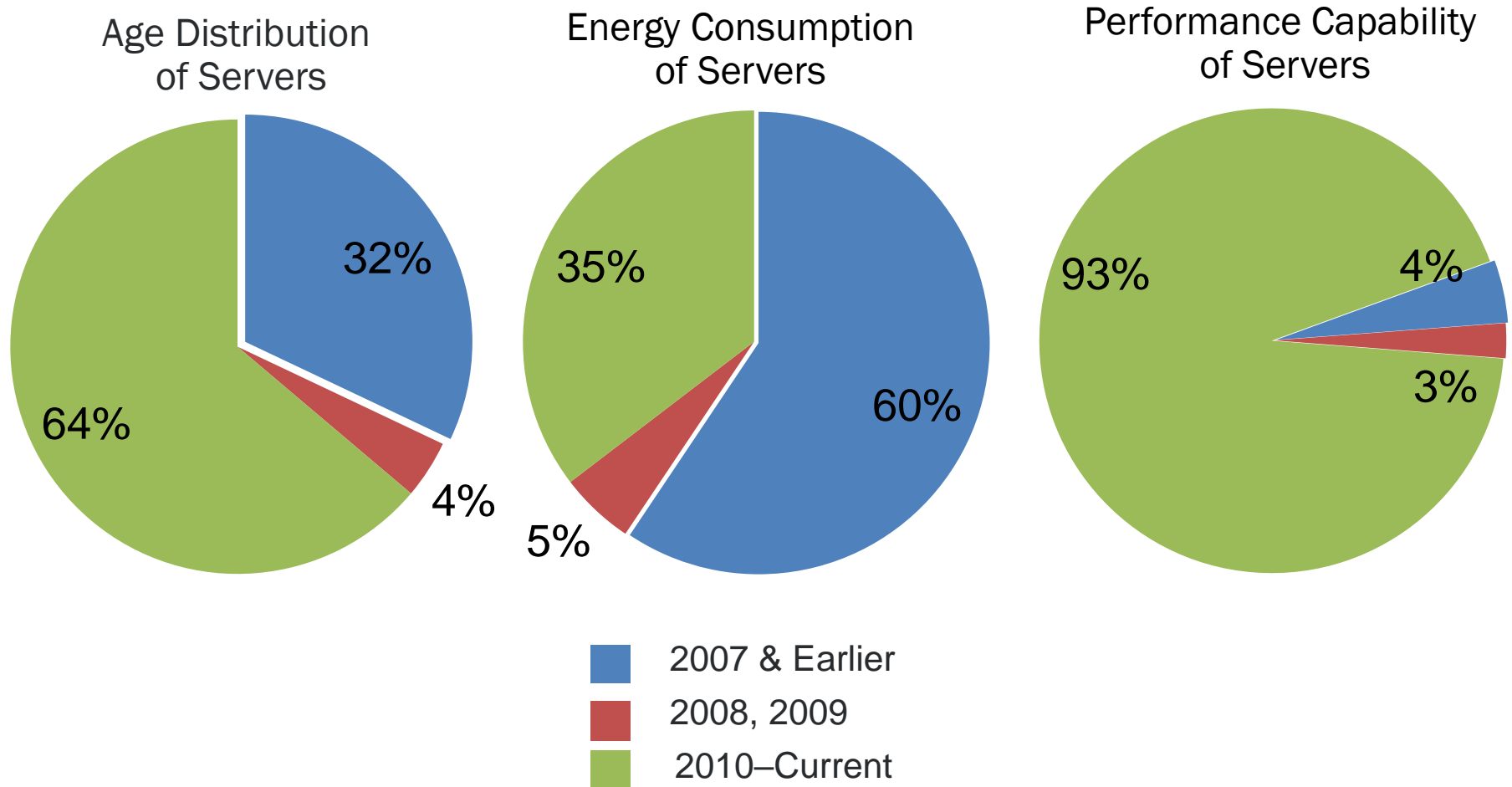


Computing Efficiency Increases 100x Every Decade



Source: Koomey et al. 2011

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



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

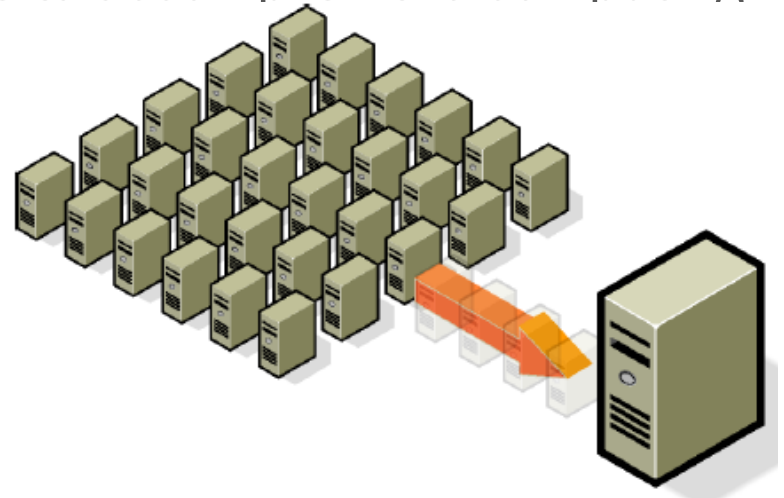
Use Efficient Power Supplies

80 PLUS Certification Levels

Level of Certification	Efficiency at Rated Load					
	115V Internal Non-Redundant			230V Internal Redundant		
	20%	50%	100%	20%	50%	100%
80 PLUS	80%	80%	80%	n/a	n/a	n/a
80 PLUS Bronze	82%	85%	82%	81%	85%	81%
80 PLUS Silver	85%	88%	85%	85%	89%	85%
80 PLUS Gold	87%	90%	87%	88%	92%	88%
80 PLUS Platinum	90%	92%	89%	90%	94%	91%
80 PLUS Titanium	92%	94%	90%	94%	96%	91%

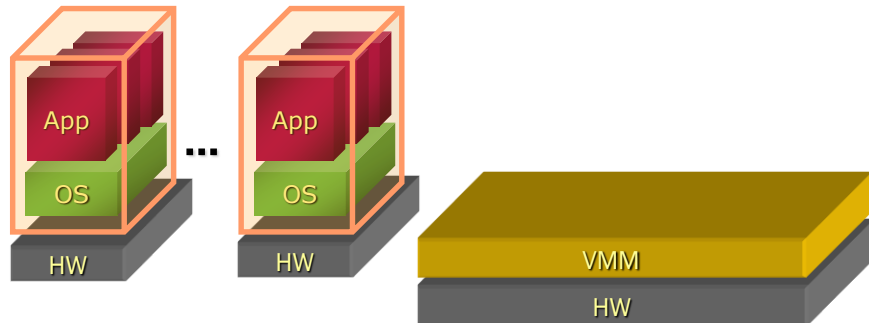
Consolidate and virtualize applications

- Most servers operate with very low utilization (5-15% on average)
- Servers at typical loads (5-15% utilization) use roughly 75% of average peak power
- **Big opportunities:**
 - Virtualization (running multiple software applications on one physical machine)
 - Consolidation (using fewer machines to accomplish the computing task)
- Energy savings from power and cooling reductions
- Space savings



Virtualization : Workload provisioning

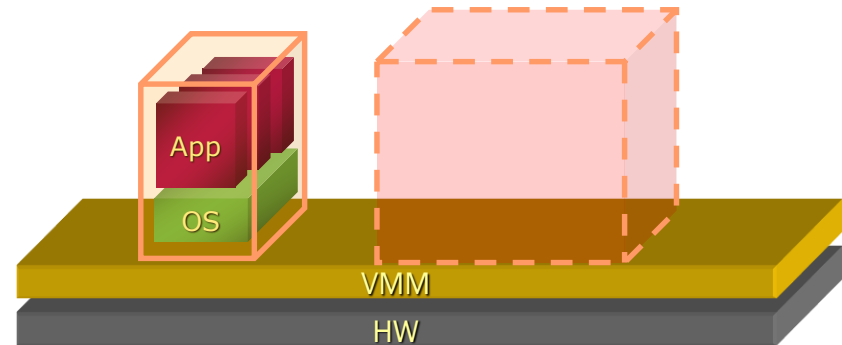
Server Consolidation



10:1 in many cases

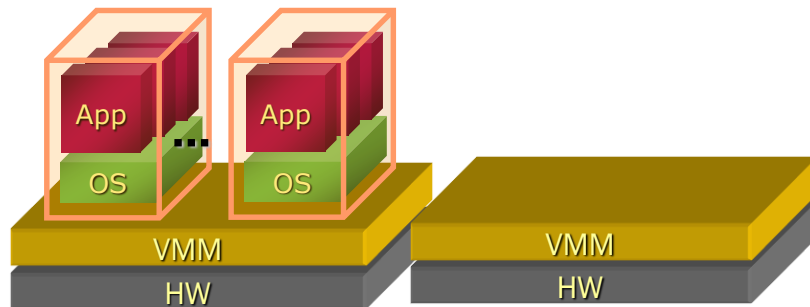
R&D

Production



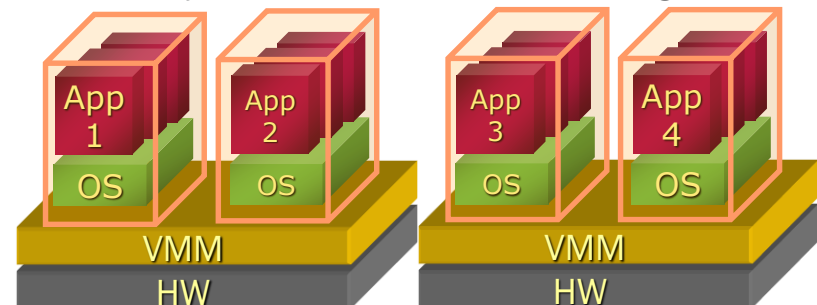
**Enables rapid deployment,
reducing number of idle, staged servers**

Disaster Recovery



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

Dynamic Load Balancing



CPU Usage



**Balancing
utilization with
head room**

CPU Usage



Questions



Higher-Level Investment, but Very Cost-Effective

- Move applications and/or hardware to higher-efficiency internal or external data center or to the cloud
- Implement IT and infrastructure power monitoring
- Install Variable-Speed Drives on cooling system fans
- Install rack and/or row-level cooling
- Use air-side economizer
- Implement dedicated room cooling (vs. using central building cooling)

Move to higher-efficiency internal or external data center or to the cloud

- Energy savings typically possible by moving applications or machines to
 - Larger data center
 - Co-location center
 - The cloud
- Better security
- Better redundancy
- Better efficiency
- In evaluating options, consider
 - Mandates
 - Moving cost
 - Total ongoing cost of staying vs. moving



Implement IT and infrastructure power monitoring

- Doesn't save energy by itself, but it informs the process
- Track performance of power and cooling systems and monitor IT
- Power Usage Effectiveness (PUE) as a metric
 - Ratio of total data center energy to IT energy
 - Measure of infrastructure energy overhead
 - Over 2.0—large opportunity
 - Under 1.5—good
 - Under 1.2—excellent
- Data Center Metering Webinar and Resource Guide
 - Guide: datacenters.lbl.gov/resources/data-center-metering-and-resource-guide
 - Webinar slides: datacenters.lbl.gov/resources/data-center-metering-and-power-usage



Data Center Metering and Resource Guide

FEBRUARY 2017

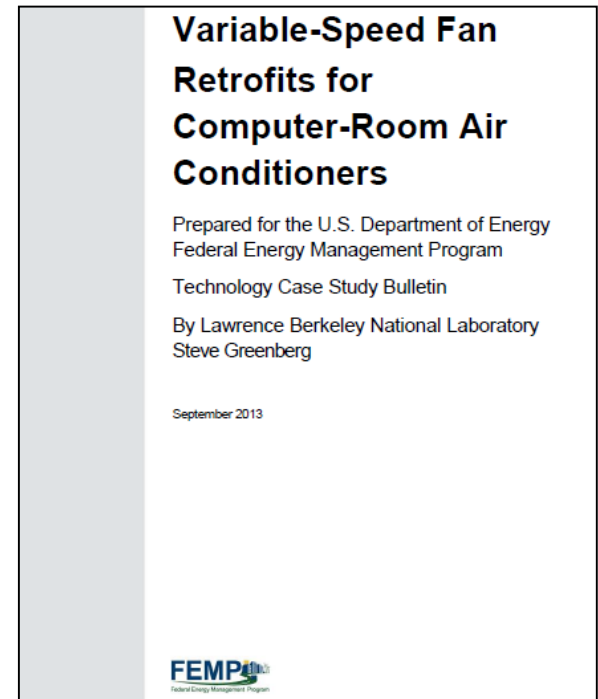
U.S. DEPARTMENT OF
ENERGY



Install Variable-Speed Drives on cooling system fans

- CRACs or CRAHs typically have constant-speed fans
- Air flows are typically higher than needed, especially once air management is improved
- 20% air flow reduction results in ~50% savings in fan energy
- 22-32% overall cooling system savings in FEMP case studies:

datacenters.lbl.gov/resources/variable-speed-fan-retrofits-computer-room-air-conditioners



Install rack and/or row-level cooling

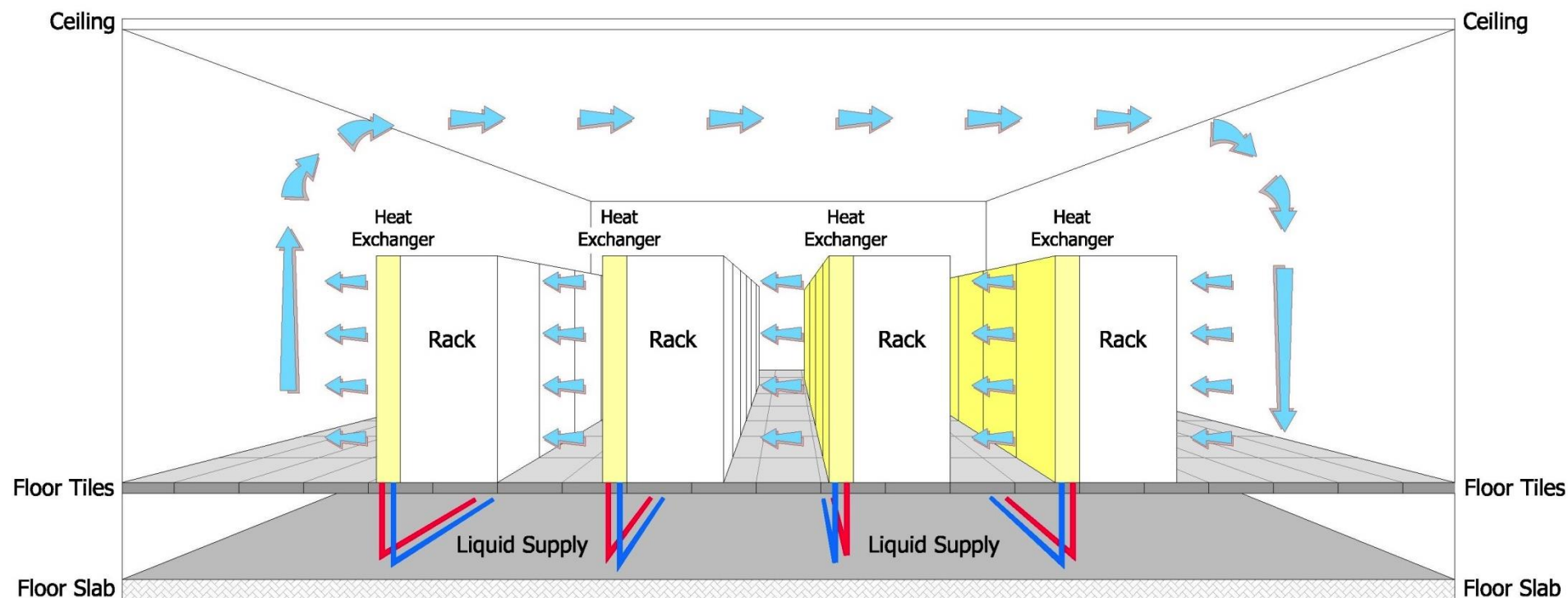
- Applicable when racks are being replaced or newly installed
- Moves cooling closer to the heat source (Closer = More Efficient)
- Various types
 - In-row
 - Rear-door (shown)
 - In-rack



Benefits:

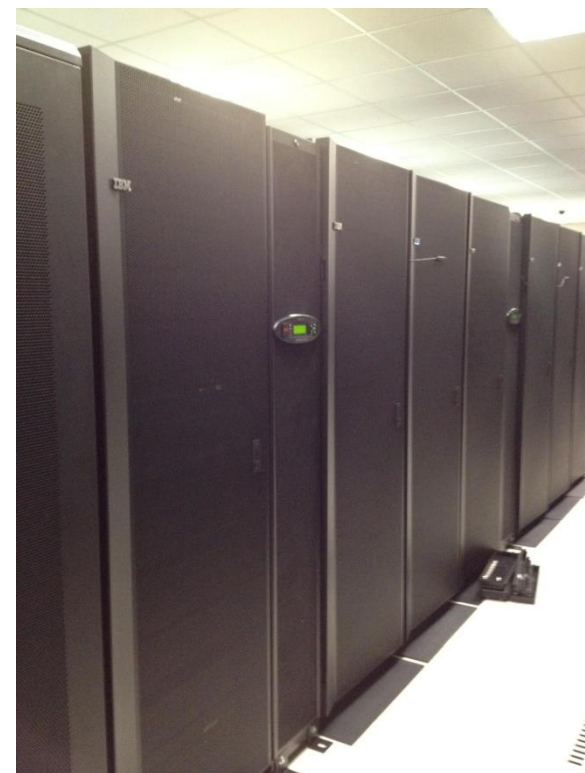
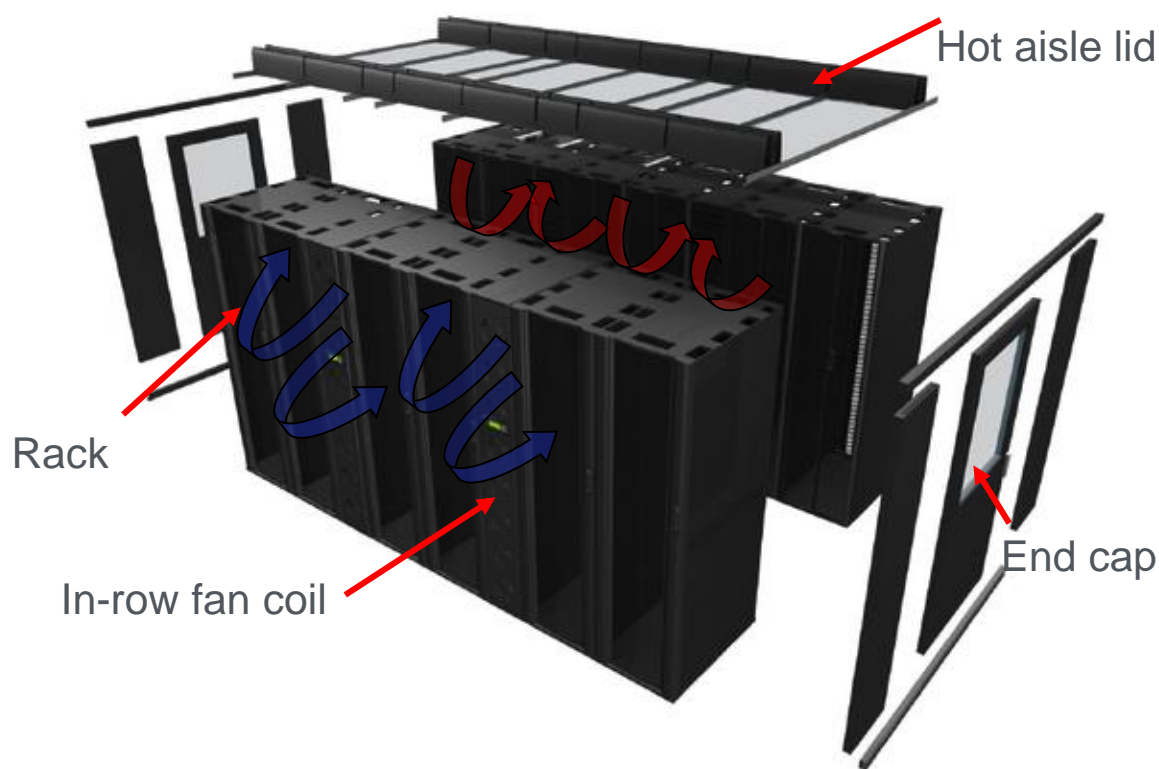
- Closer cooling system is more efficient and so generates less heat that needs to be removed
- Higher chilled water temperature:
 - Makes the cooling plant more efficient
 - Allows “free cooling” for more of the year (water-side economizer)

Rack-Mounted Heat Exchangers (“Rear Doors”)



In-Row Cooling System

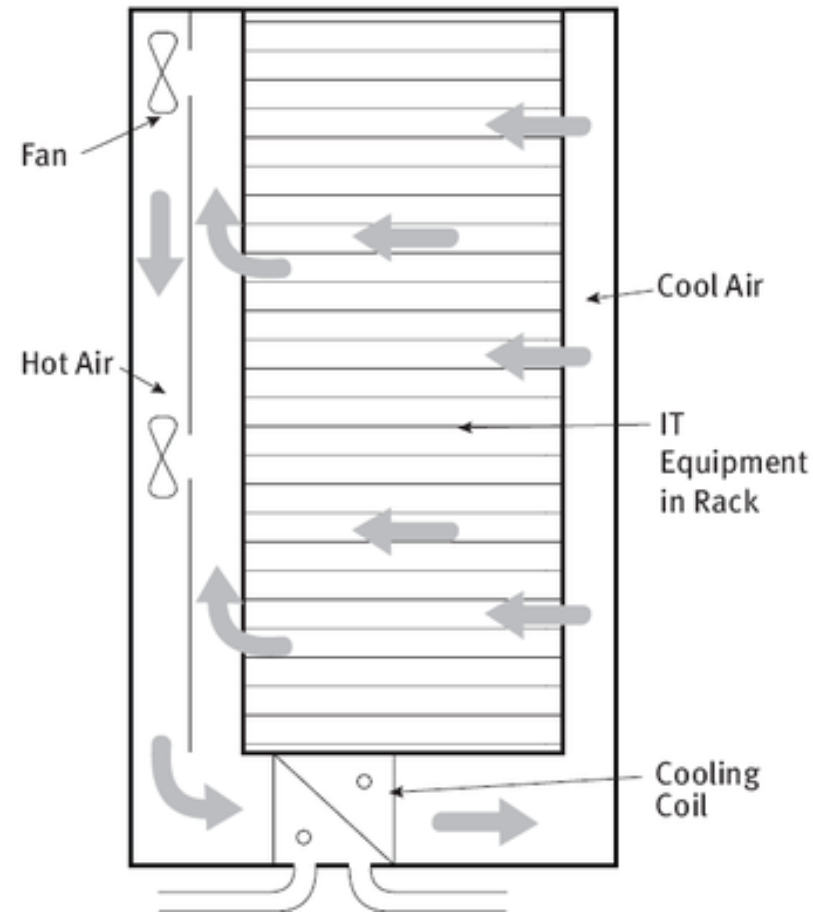
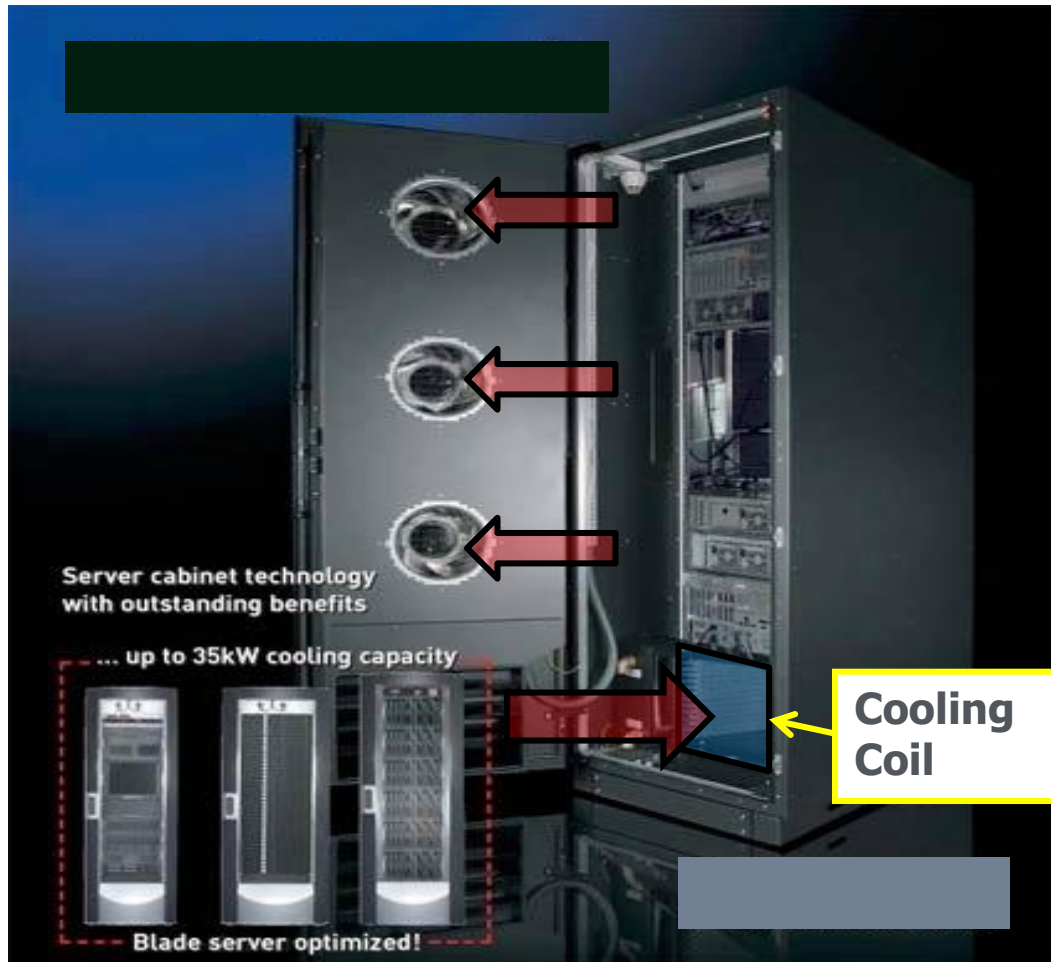
With hot aisle containment, the general data center space is neutral (75°F–80°F).



© APC, reprinted with permission

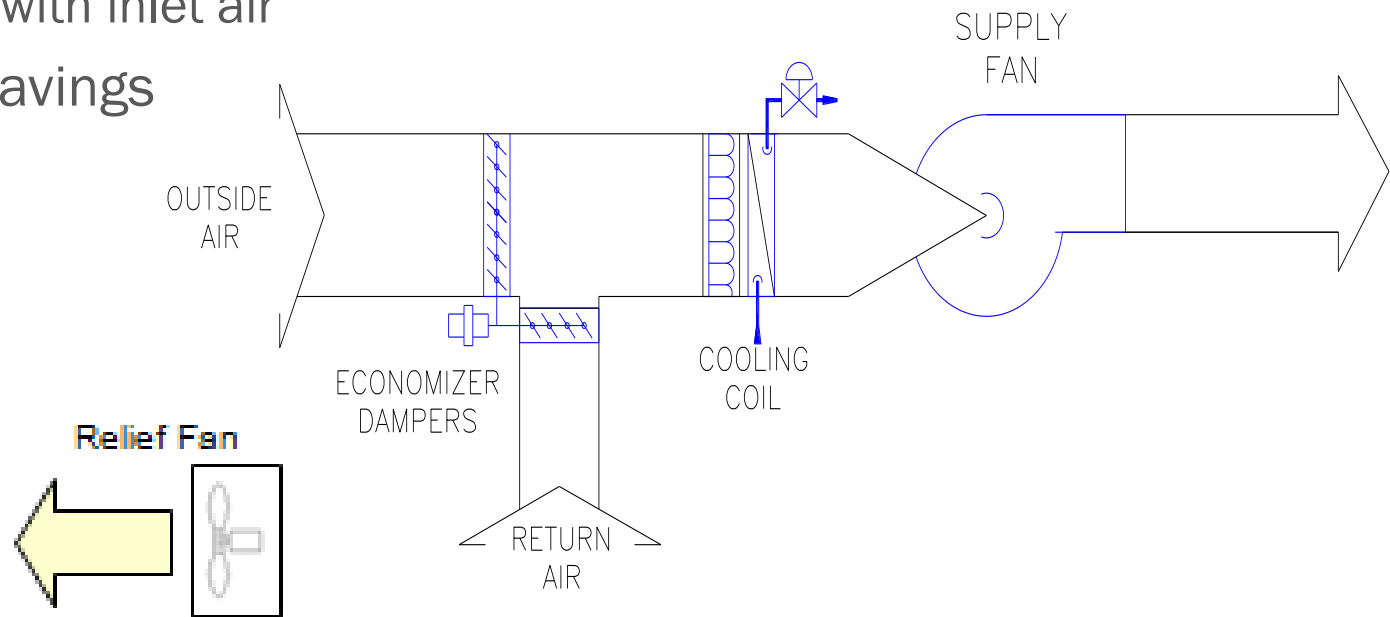
In-Rack Liquid Cooling

Racks with integral coils and full containment:



Use an air-side economizer

- Uses outside air when conditions are suitable
- Needs outside wall or roof for adequate access to large airflow
- Can be
 - air-handling unit
 - CRAC or CRAH with outside air capability
 - Exhaust fan with inlet air
- Large energy savings from reduced operation of cooling compressor



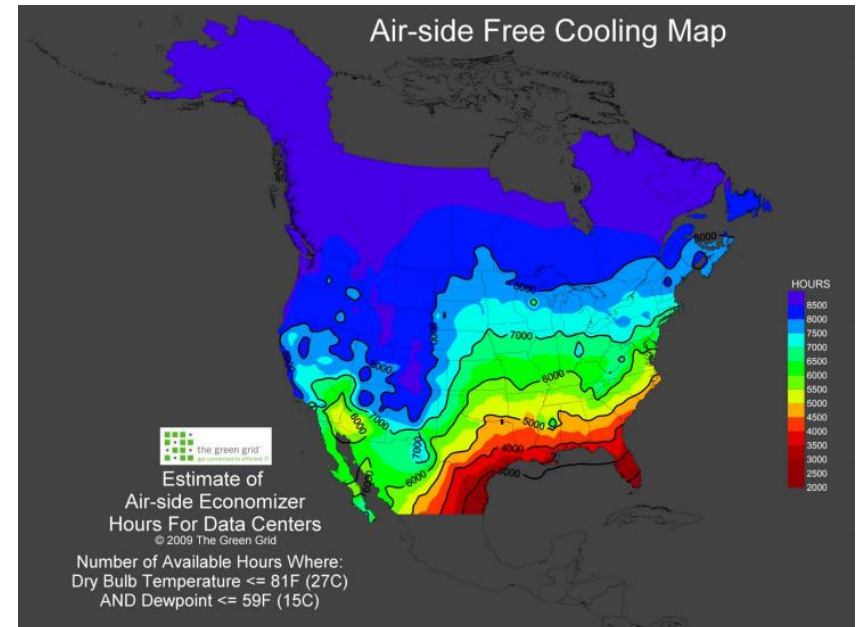
Outside Air (Air-Side) Economizers

Advantages

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

Potential Issues

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



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

Use a Water-Side Economizer

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

No or
minimum
compressor
cooling



Cooling tower and HX = Water-side Economizer



Economizers: The Green Grid Tool



Free-Cooling Estimated Savings

US/CANADA LOCATION (ZIP CODE):

DEGREES IN: ☐ FAHRENHEIT
☒ CELSIUS

ALLOW MIXING OF SUPPLY AND RETURN AIR ☒

ALLOW HUMIDIFICATION ☒

	MAX LIMIT	MIN LIMIT
DRYBULB TEMP THRESHOLD (DEG): ?	<input type="text" value="27.0"/>	<input type="text" value="NONE"/>
DEWPOINT TEMP THRESHOLD (DEG): ?	<input type="text" value="15.0"/>	<input type="text" value="NONE"/>
REL. HUMIDITY THRESHOLD (%): ?	<input type="text" value="NONE"/>	
DESIRED CHILLED WATER TEMP (DEG): ?	<input type="text" value="13.0"/>	
COOLING SYSTEM APPROACH TEMP (DEG): ?	<input type="text" value="3.0"/>	
DATA CENTER IT POWER (kW): ?	<input type="text" value="1000"/>	
POWER USAGE EFFECTIVENESS (PUE): ?	<input type="text" value="1.6"/>	
TOTAL FACILITY POWER (kW): ?	<input type="text" value="1600"/>	
OVERHEAD POWER (kW): ?	<input type="text" value="600"/>	
PERCENT OF OVERHEAD POWER FOR COOLING SYSTEM (%): ?	<input type="text" value="80"/>	% <input type="text" value="480"/> kW
PERCENT OF COOLING SYSTEM POWER FOR CHILLER (%): ?	<input type="text" value="40"/>	% <input type="text" value="192"/> kW
PERCENT OF COOLING SYSTEM POWER FOR TOWER (%): ?	<input type="text" value="40"/>	% <input type="text" value="192"/> kW

HOURS MEETING CRITERIA FOR FREE-AIR COOLING:

ESTIMATED SAVINGS USING FREE-AIR COOLING:

HOURS MEETING CRITERIA FOR WATER SIDE ECONOMIZER:

Implement dedicated room cooling (vs. using central building cooling)

- Dedicated unit allows main building system and plant to operate on normally occupied schedule instead of continuously
 - Allows for cooling operations independent from rest of the building
 - A small, imbedded data center can cause a central plant to operate when the rest of the building doesn't require it

What to do:

- Use high-efficiency unit - high SEER (Seasonal Energy Efficiency Ratio)
- Specify outside-air economizer
- Control based on IT inlet temperature



Sources of Training for Facilities and IT Staff

- Utility companies
- ASHRAE: www.ashrae.org
- Federal Energy Management Program (FEMP):
<http://eere.energy.gov/femp/training>
- Center of Expertise for Energy Efficiency in Data Centers
- Data Center Energy Practitioner
 - Required by the Data Center Optimization Initiative
 - datacenters.lbl.gov/dcep

Data Center Energy Practitioner (DCEP) Program

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

Key objective:

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

Target groups include:

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

Resources

- Small Data Center Guide:

[betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Better Buildings Data Center Accelerator - Small Data Center Energy Savings Guide.pdf](https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Better%20Buildings%20Data%20Center%20Accelerator%20-%20Small%20Data%20Center%20Energy%20Savings%20Guide.pdf)



Small Data Centers, Big Energy Savings: An Introduction for Owners and Operators

FINAL REPORT

APRIL 2017

U.S. DEPARTMENT OF
ENERGY

More Resources

DOE Better Buildings

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



Federal Energy Management Program

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



EPA

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



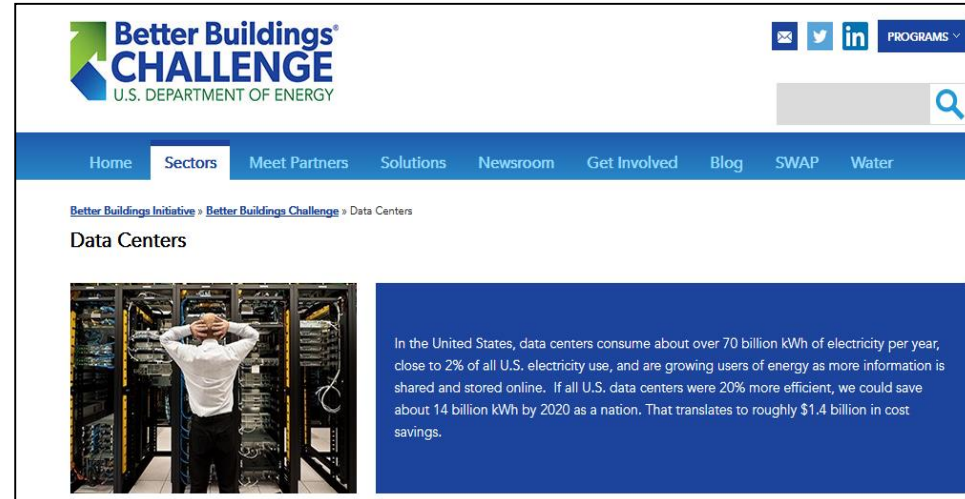
Industry

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



More Resources

Better Buildings Solutions Center:
betterbuildingssolutioncenter.energy.gov/challenge/sector/data-centers



Center of Expertise for Energy
Efficiency in Data Centers:
datacenters.lbl.gov



Resources: Center of Expertise (CoE)



**CENTER OF
EXPERTISE**
FOR ENERGY EFFICIENCY IN DATA CENTERS

SEARCH



[HOME](#) [ABOUT](#) [TECHNOLOGIES](#) [ACTIVITIES](#) [RESOURCES](#) [CONTACT US](#) [ADMIN](#)

"While information technology (IT) is improving the efficiency of government, energy use in data centers is growing at a significantly faster rate than any other building segment..."



The Department of Energy-led CENTER of EXPERTISE demonstrates national leadership in decreasing the energy use of data centers. The Center partners with key influential public and private stakeholders. It also supplies know-how, tools, best practices, analyses, and the introduction of technologies to assist Federal agencies with implementing policies and developing data center energy efficiency projects.

Better Buildings Data Center Partners

Program requires participating Federal agencies and other data center owners to establish an efficiency goal for their data centers, and to report and improve upon their performance through metrics such as Power Usage Effectiveness (PUE).

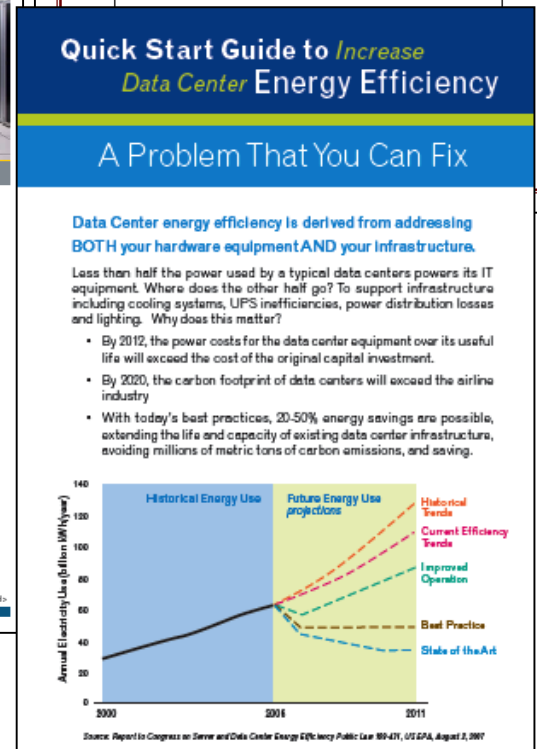
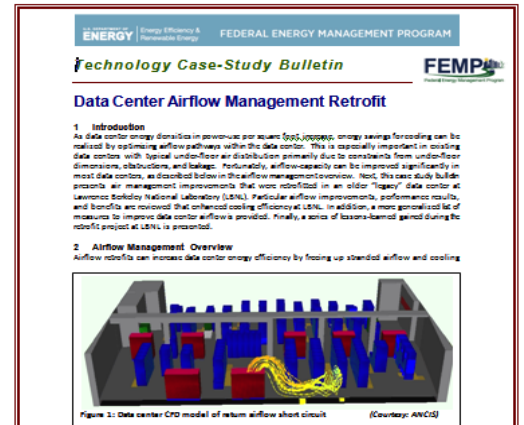
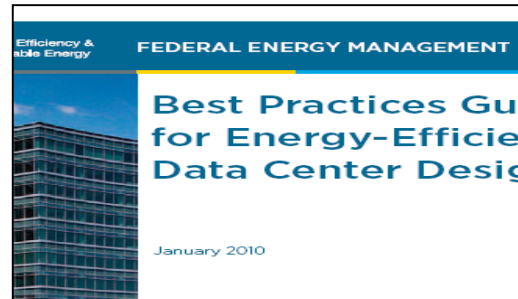
Measure and Manage

LBL and FEMP perform ongoing work with industry groups to assemble cost-effective, customer-friendly approaches to enable data center stakeholders to measure and manage the energy performance of their data center over time.

<https://datacenters.lbl.gov/>

Data Center Resources

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



Resources, con't.

- DOE Air Management Tools
datacenters.lbl.gov/tools/5-air-management-tools
- Humidity Control in Data Centers
datacenters.lbl.gov/resources/Humidity-Control-Data-Centers
- Data Center Metering and Resource Guide
datacenters.lbl.gov/resources/data-center-metering-and-resource-guide
- Variable-Speed Fan Retrofits for Computer-Room Air Conditioners
- Case study of 3 small data centers
datacenters.lbl.gov/resources/variable-speed-fan-retrofits-computer-room-air-conditioners
- Data Center Optimization Initiative (OMB): <https://datacenters.cio.gov/>
- ENERGY STAR Equipment: energystar.gov/products/office_equipment/

Summary

- Why small data centers are important
- Simplest Measures
 - Turn off unused servers
 - Improve server power management
 - Improve air management
 - Increase temperature setpoints toward the high end of the range set by the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE)
 - Turn off active humidity control
 - Minimize requirements for Uninterruptible Power Supplies (UPS)

Summary, con't

- Still simple, a little more work
 - Refresh the oldest IT equipment with new high-efficiency equipment
 - Consolidate and virtualize applications
- Higher-level investment, but very cost-effective
 - Move applications and/or hardware to higher-efficiency internal or external data center or to the cloud
 - Implement IT and infrastructure power monitoring
 - Install Variable-Speed Drives on cooling system fans
 - Install rack and/or row-level cooling
 - Use air-side or water-side economizer
 - Implement dedicated room cooling (vs. using central building cooling)
- Training for IT and Facility Staff
- Resources

Questions



Contact Information

Dale Sartor, P.E.

DASartor@LBL.gov

(510) 486-5988



Steve Greenberg, P.E.

SEGreenberg@lbl.gov

(510) 486-6971



Lawrence Berkeley National Laboratory

MS 90-3111

University of California

Berkeley, CA 94720

<https://datacenters.lbl.gov/>

