



**Data Center
Energy Efficiency Opportunities
June 17, 2008**

OFEE Federal and Environmental Symposium West

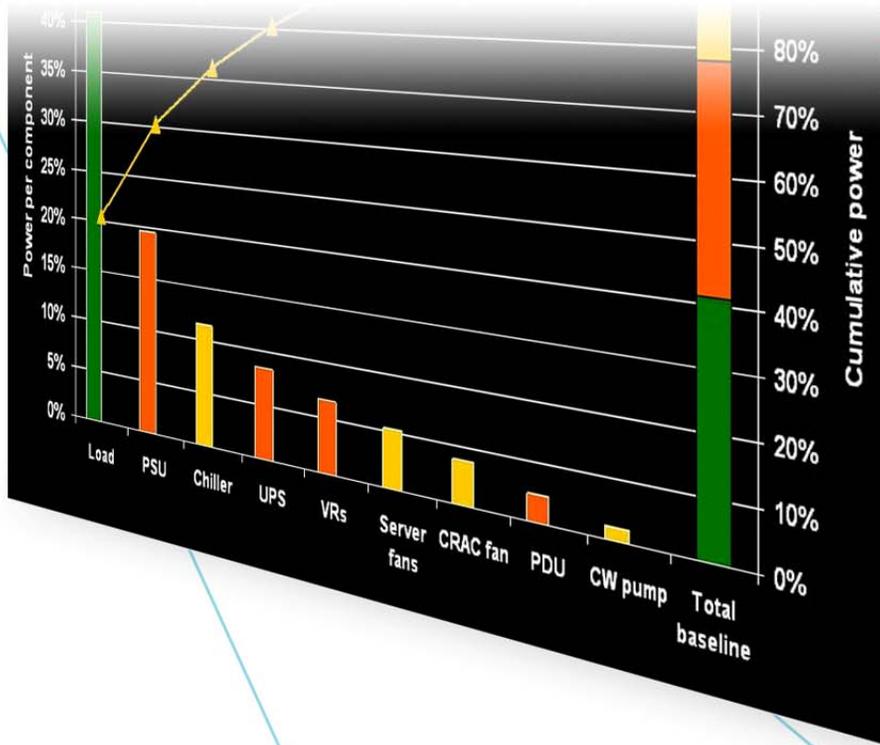
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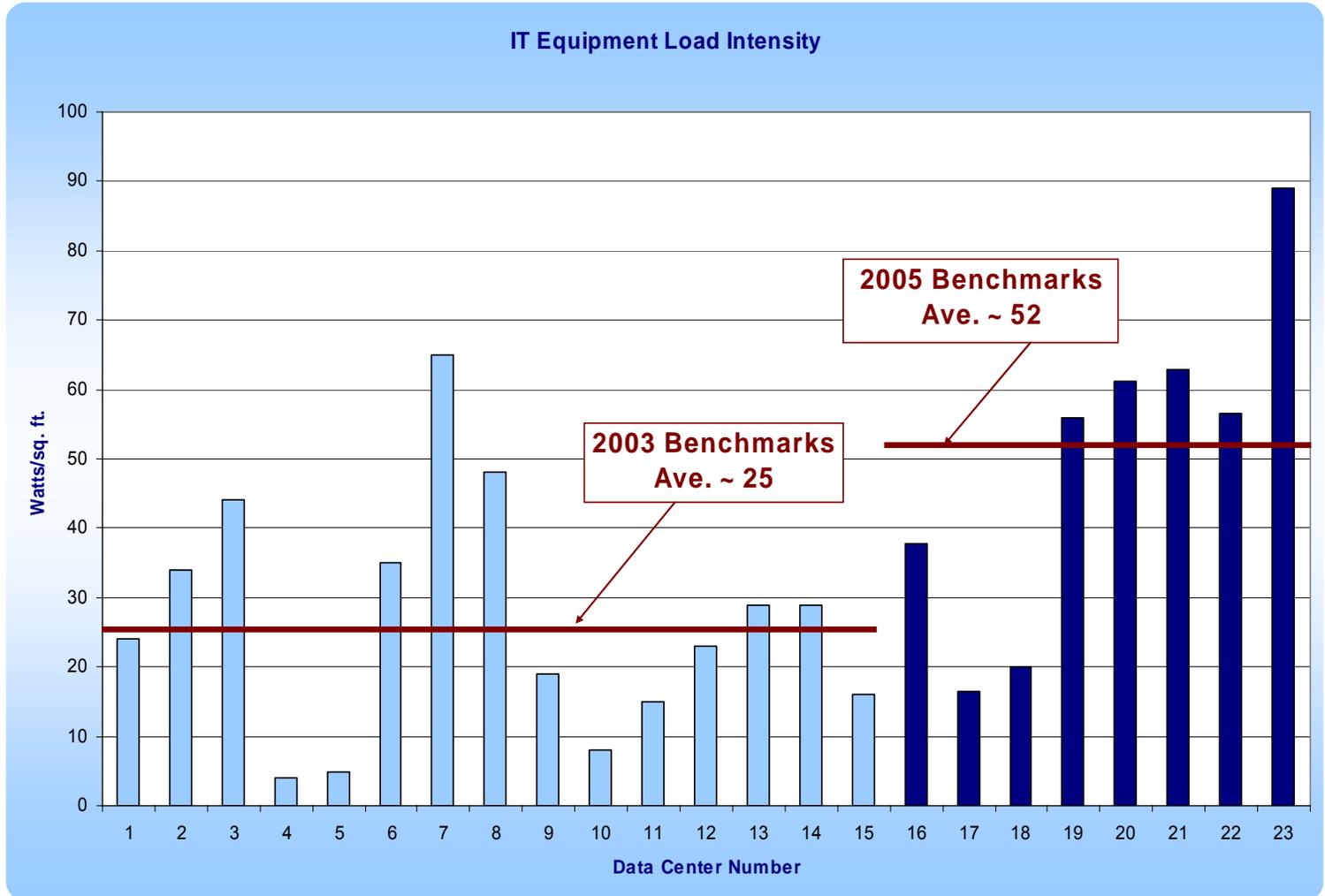
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Benchmarking Data Center Energy Use

IT Equipment Load Density



Energy Efficiency Opportunities Are Everywhere



Power Conversion & Distribution

- Load management
- Server innovation

Server Load/
Computing
Operations

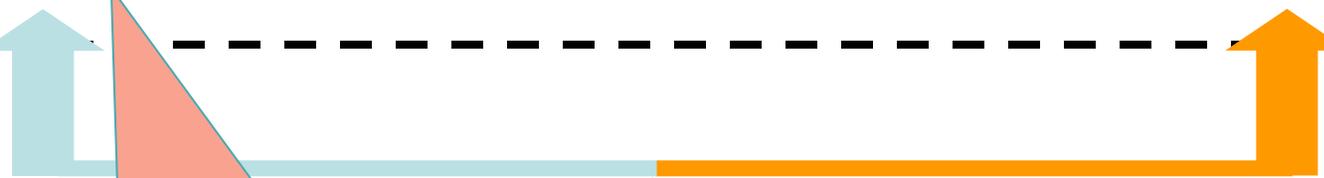
- Better air management
- Better environmental conditions
- Move to liquid cooling
- Optimized chilled-water plants
- Use of free cooling

Cooling
Equipment

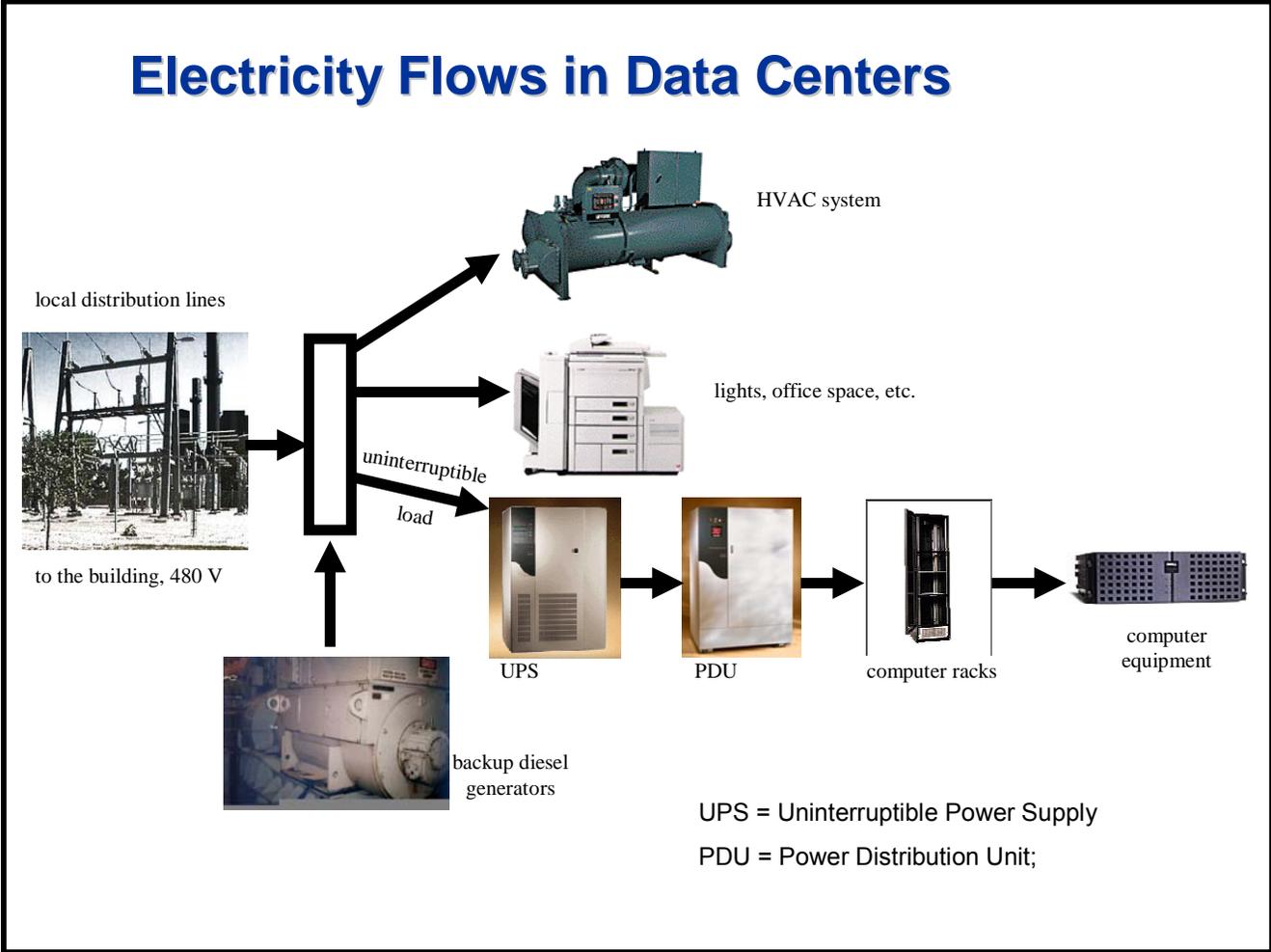
- High voltage distribution
- Use of DC power
- Highly efficient UPS systems
- Efficient redundancy strategies

Alternative
Power
Generation

- On-site generation
- Waste heat for cooling
- Use of renewable energy/fuel cells



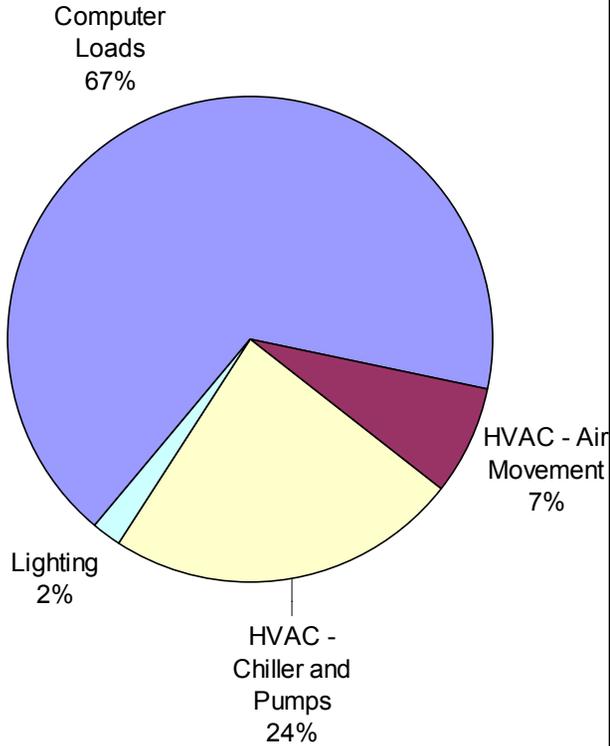
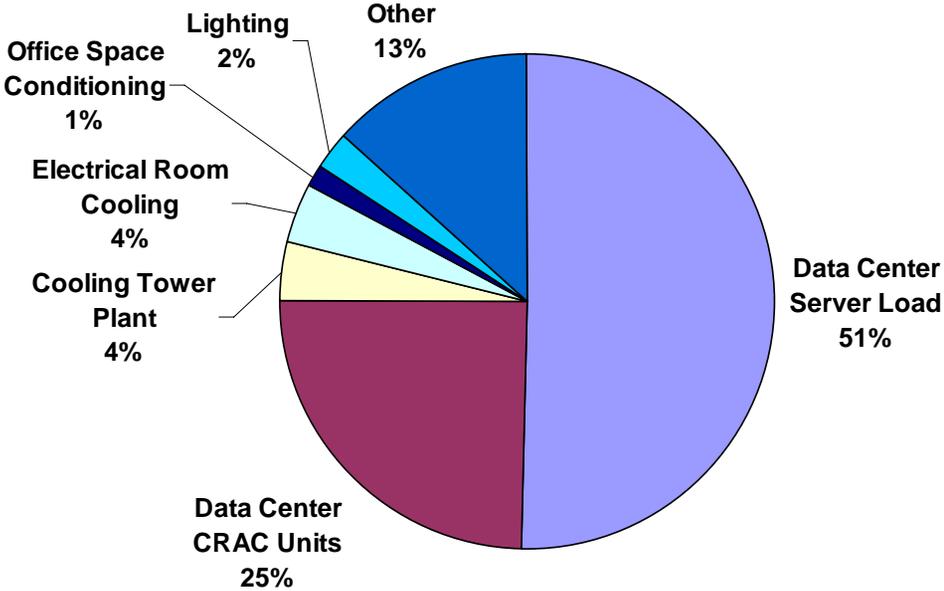
Benchmarking Energy End Use





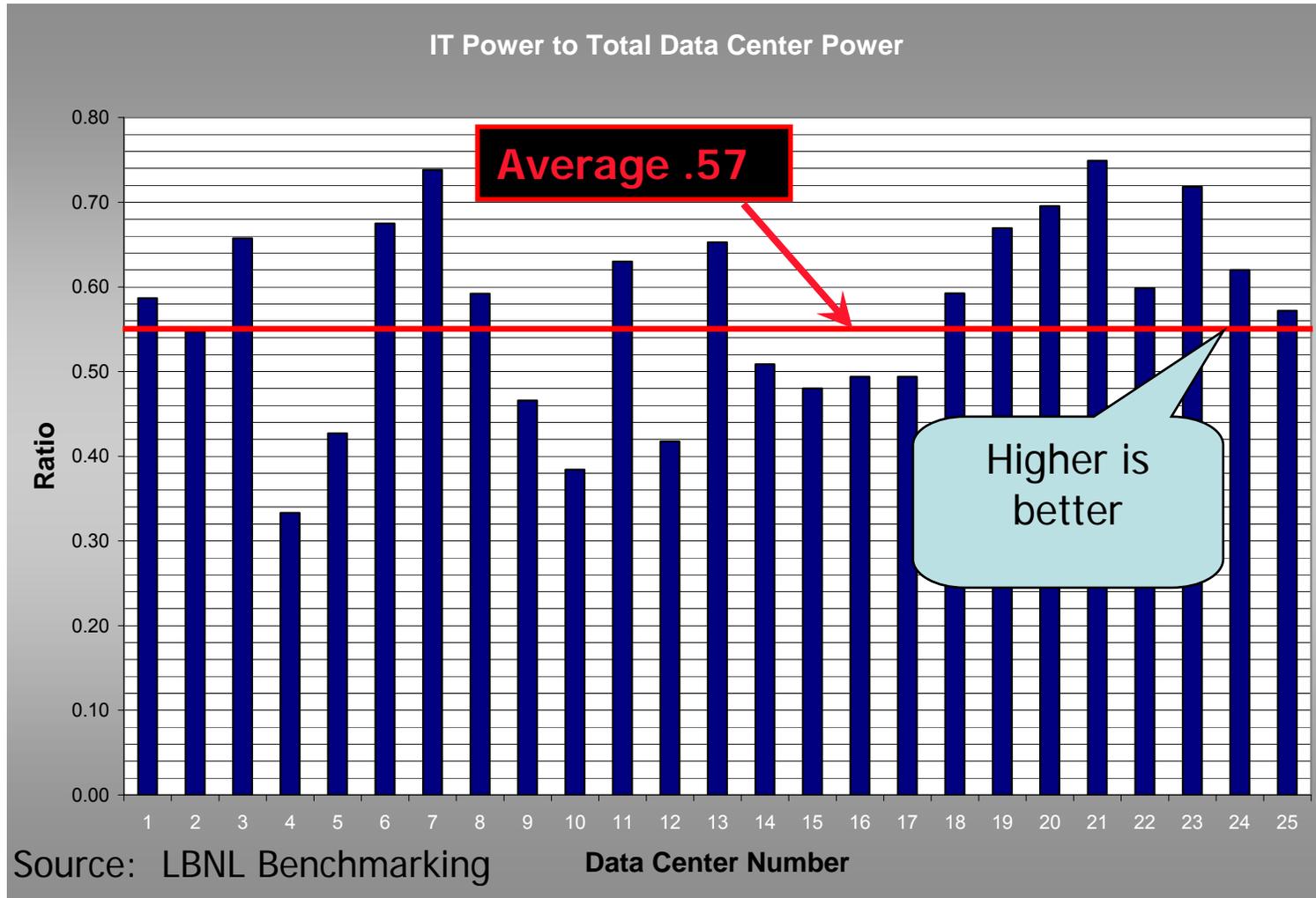
Performance Varies

The relative percentages of the energy doing computing varied considerably.

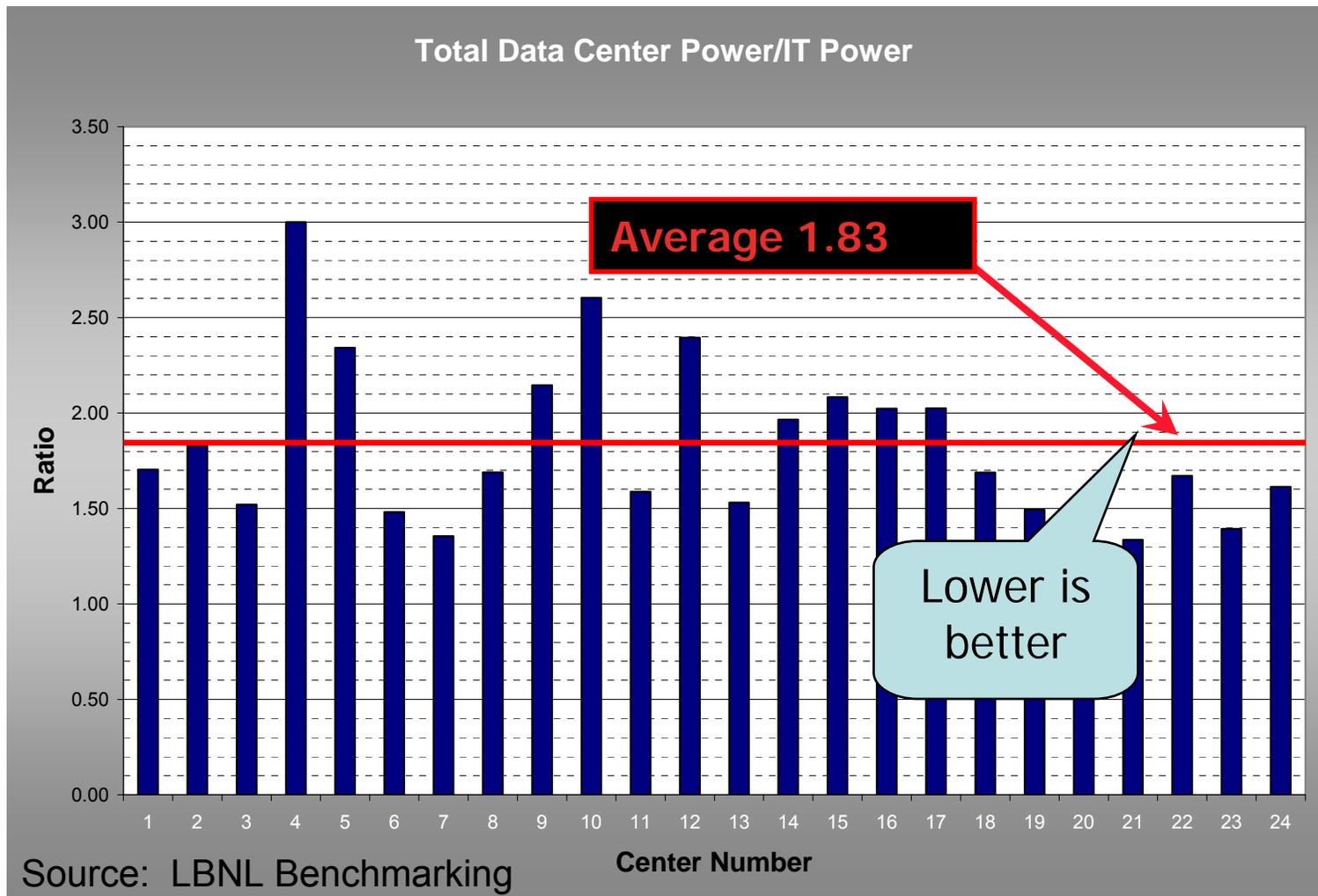


High Level Metric— DCiE

Ratio of Electricity Delivered to IT Equipment

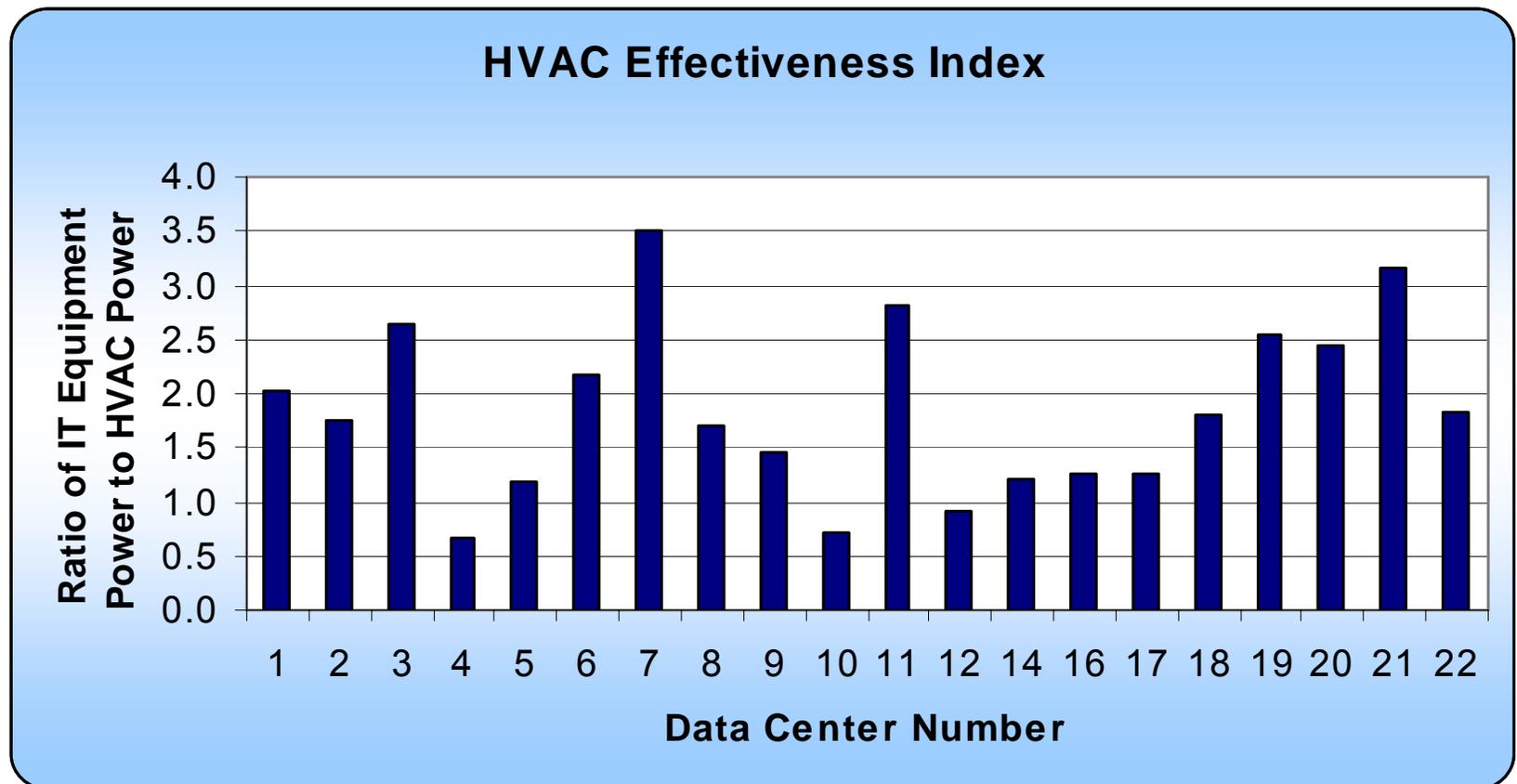


Alternate High Level Metric – PUE Data Center Total / IT Equipment



HVAC System Effectiveness

We observed a wide variation in HVAC performance





Other Data Center Metrics:

- Watts per square foot/Watts per rack
- Power distribution: UPS efficiency, PDU efficiency, IT power supply efficiency
- HVAC
 - IT total/HVAC total
 - Fan watts/cfm
 - Pump watts/gpm
 - Chiller plant (chiller or overall HVAC) kW/ton
- Lighting watts/square foot
- Rack cooling index (fraction of IT within recommended temperature range)
- Return temperature index $(RAT-SAT)/IT\Delta T$



IT equipment load can be controlled

- Consolidation
- Server efficiency
 - Flops per watt
 - Efficient power supplies
- Software efficiency (Virtualization, MAID, etc.)
- Power management
 - Low power modes
- Redundant power supplies
- Reducing IT load has a multiplier effect
 - Equivalent savings +/- in infrastructure



Benchmark Results Help Identify Best Practices

The ratio of IT equipment power to the total is an indicator of relative overall efficiency. Examination of individual systems and components in the centers that performed well helped to identify best practices.



Best HVAC Practices

- Air Management
- Air Economizers
- Humidification Control
- Centralized Air Handlers
- Low Pressure Drop Systems
- Fan Efficiency
- Cooling Plant Optimization
- Water Side Economizer
- Variable Speed Chillers
- Variable Speed Pumping
- Direct Liquid Cooling



Best Electrical Practices

- UPS systems
- Self-generation
- AC-DC distribution
- Standby generation



Best Practices and IT Equipment

- Power supply efficiency
- Standby/sleep power modes
- IT equipment fans
- Virtualization
- Load shifting
- Storage options

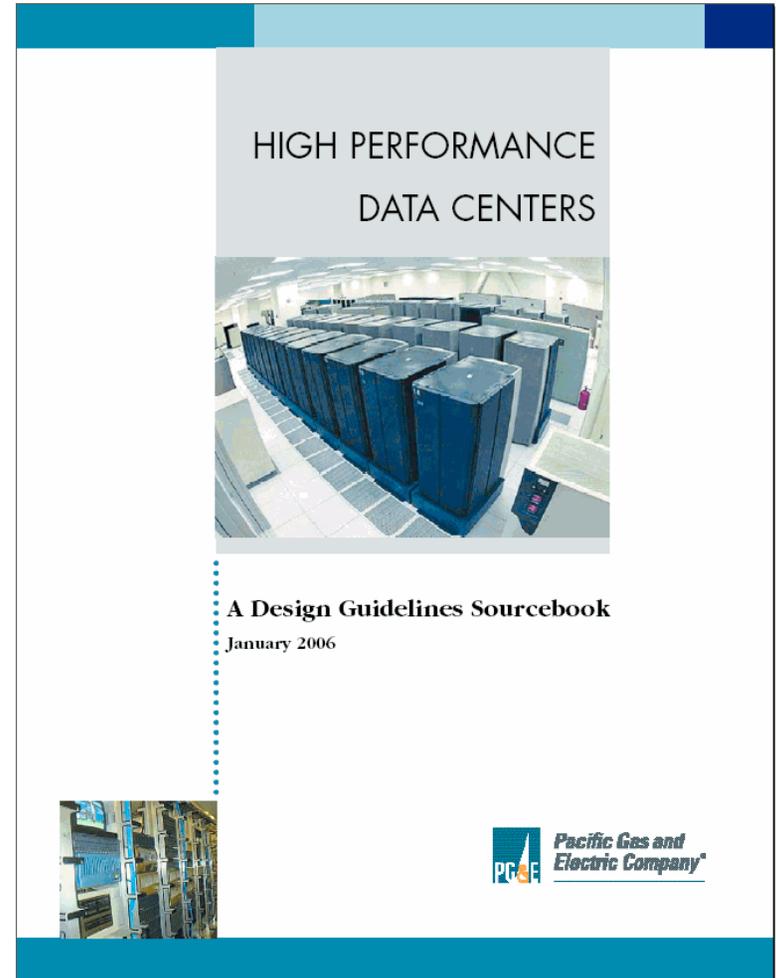


Best Practices — Cross-Cutting and Misc. Issues

- Motor efficiency
- Right sizing
- Variable speed drives
- Lighting
- Maintenance
- Continuous Commissioning and Benchmarking
- Heat Recovery
- Building Envelope
- Redundancy Strategies

Design Guidelines for Ten Best Practices Were Developed

Guides available through PG&E's Energy Design Resources, and LBNL Websites



Design Guidance is Summarized in a Web Based Training Resource

Data Center Energy Management - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://hightech.lbl.gov/dctraining/TOP.html

mozilla.org Latest Builds

Home >

DATA CENTER ENERGY MANAGEMENT

About Benchmarking Best Practices Checklist Design Intent Documentation Economics Non-energy Benefits Case Studies Tools Emerging Technologies

- This website will give you the tools and information to capture cost-effective savings opportunities to the design of new data centers or to retrofit existing ones.
- Data center energy costs can be 100-times higher than those for typical buildings.
- Inefficiencies can hurt the bottom line, erode competitiveness, and reduce uptime.

ft²/yr

\$75 High

\$5 Low

Get Started:
Enter your annual energy cost
 \$/yr
and data center size
 sq ft

Range of Energy Costs in Real Data Centers

For public sector and private sector users.

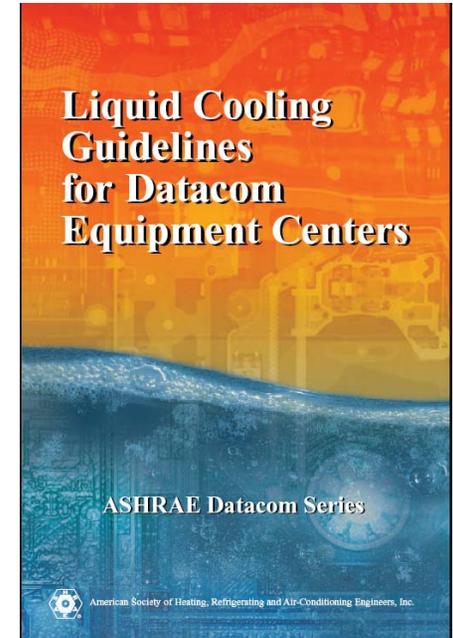
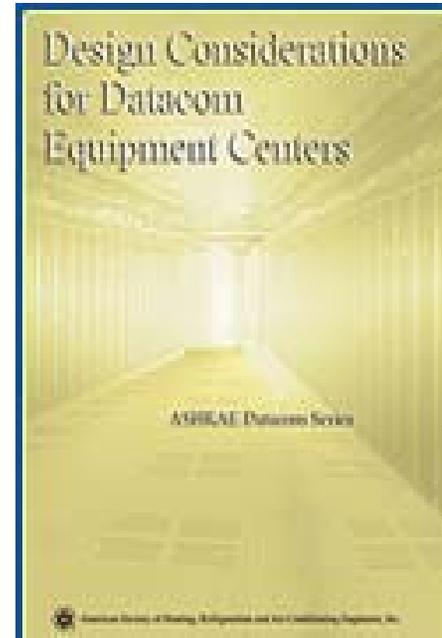
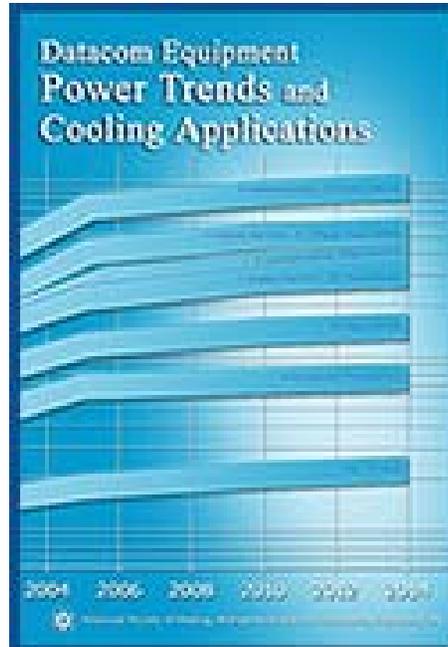
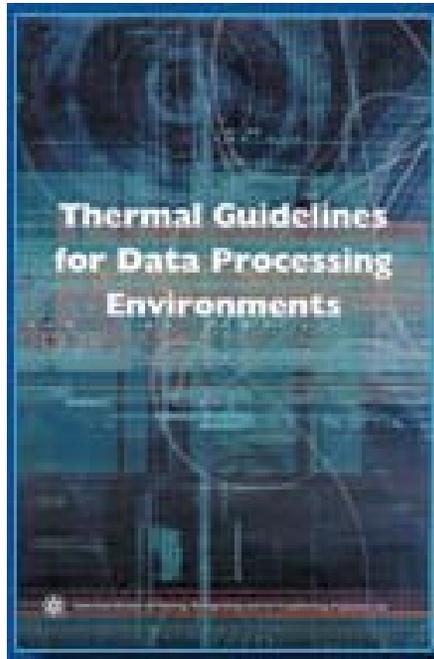
LAWRENCE BERKELEY NATIONAL LABORATORY

High-Tech Research ■ Applications Team ■ Environmental Energy Technologies Division ■ Berkeley Lab

<http://hightech.lbl.gov/dctraining/TOP.html>

ASHRAE Resources

Six books published—
more in preparation



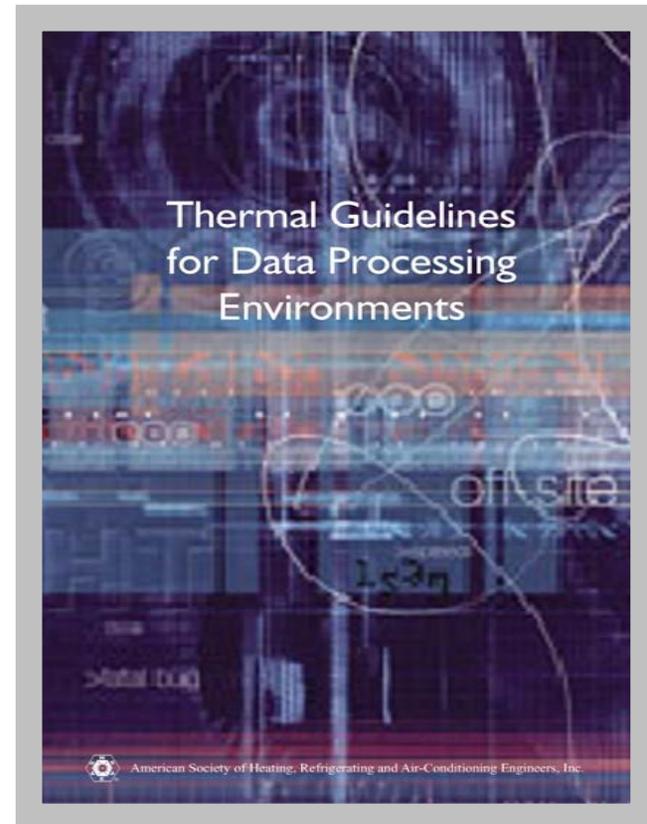
ASHRAE, Thermal Guidelines for Data Processing Environments, 2004, Datacom Equipment Power Trends and Cooling Applications, 2005, Design Considerations for Datacom Equipment Centers, 2005, Liquid Cooling Guidelines for Datacom Equipment Centers, 2006, © American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org

Order from <http://tc99.ashraetcs.org/>



Environmental Conditions

- ASHRAE - consensus from all major IT manufacturers on temperature and humidity conditions
- Recommended and Allowable ranges of temperature and humidity
- Air flow required

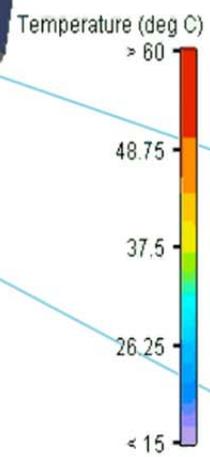
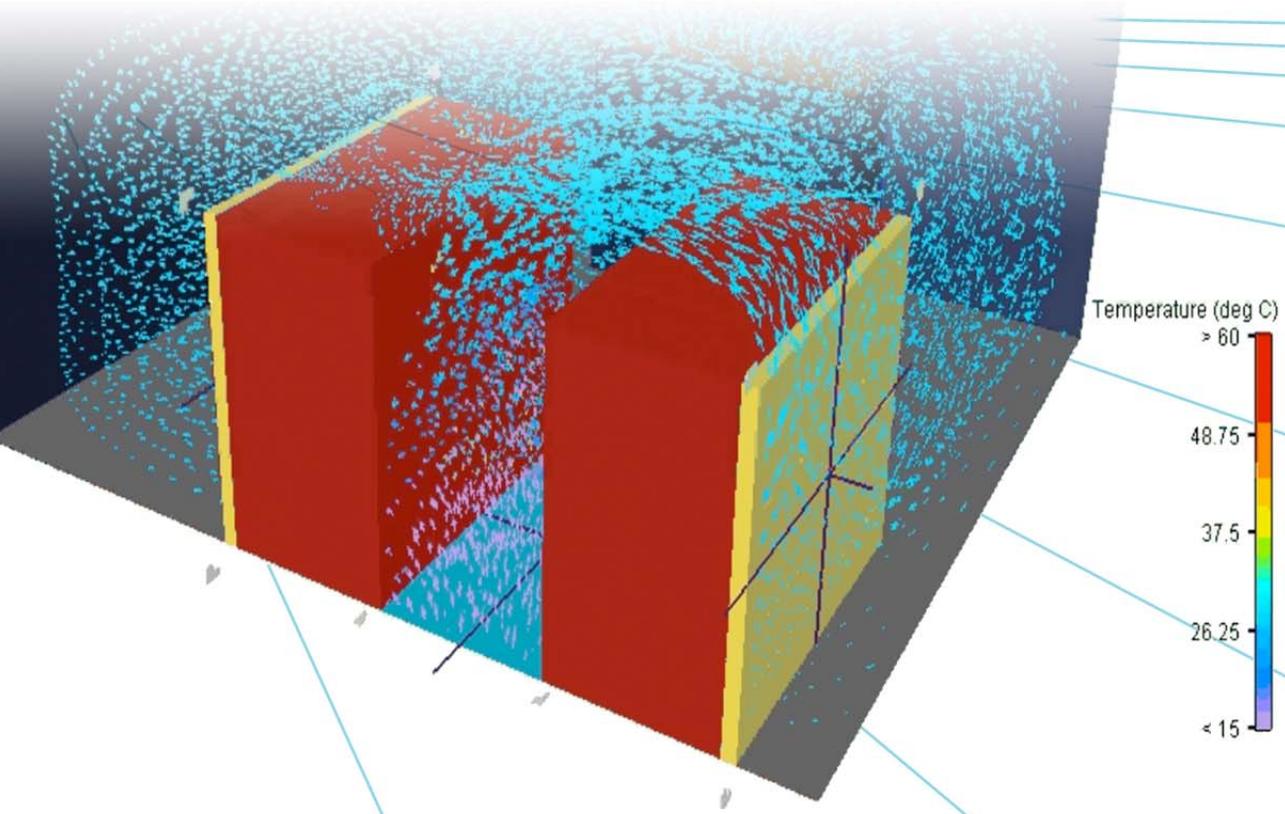


Design Conditions - at Inlet to IT Equipment

Condition	Class 1 / Class 2		NEBS	
	Allowable Level	Recommended Level	Allowable Level	Recommended Level
Temperature control range	59°F – 90°F ^{a,f} (Class 1) 50°F – 95°F ^{a,f} (Class 2)	68°F – 77°F ^a	41°F – 104°F ^{c,f}	65°F – 80°F ^d
Maximum temperature rate of change	9°F. per hour ^a		2.9°F/min. ^d	
Relative humidity control range	20% - 80% 63°F. Max Dewpoint ^a (Class 1) 70°F. Max Dewpoint ^a (Class 2)	40% - 55% ^a	5% to 85% 82°F Max Dewpoint ^c	Max 55% ^e
Filtration quality	65%, min. 30% ^b (MERV 11, min. MERV 8) ^b			

^aThese conditions are inlet conditions recommended in the ASHRAE Publication *Thermal Guidelines for Data Processing Environments* (ASHRAE, 2004).
^bPercentage values per ASHRAE *Standard* 52.1 dust-spot efficiency test. MERV values per ASHRAE Standard 52.2. Refer to Table 8.4 of this publication for the correspondence between MERV, ASHRAE 52.1 & ASHRAE 52.2 Filtration Standards.
^cTelecordia 2002 GR-63-CORE
^dTelecordia 2001 GR-3028-CORE
^eGenerally accepted telecom practice. Telecom central offices are not generally humidified, but grounding of personnel is common practice to reduce ESD.
^fRefer to Figure 2.2 for temperature derating with altitude

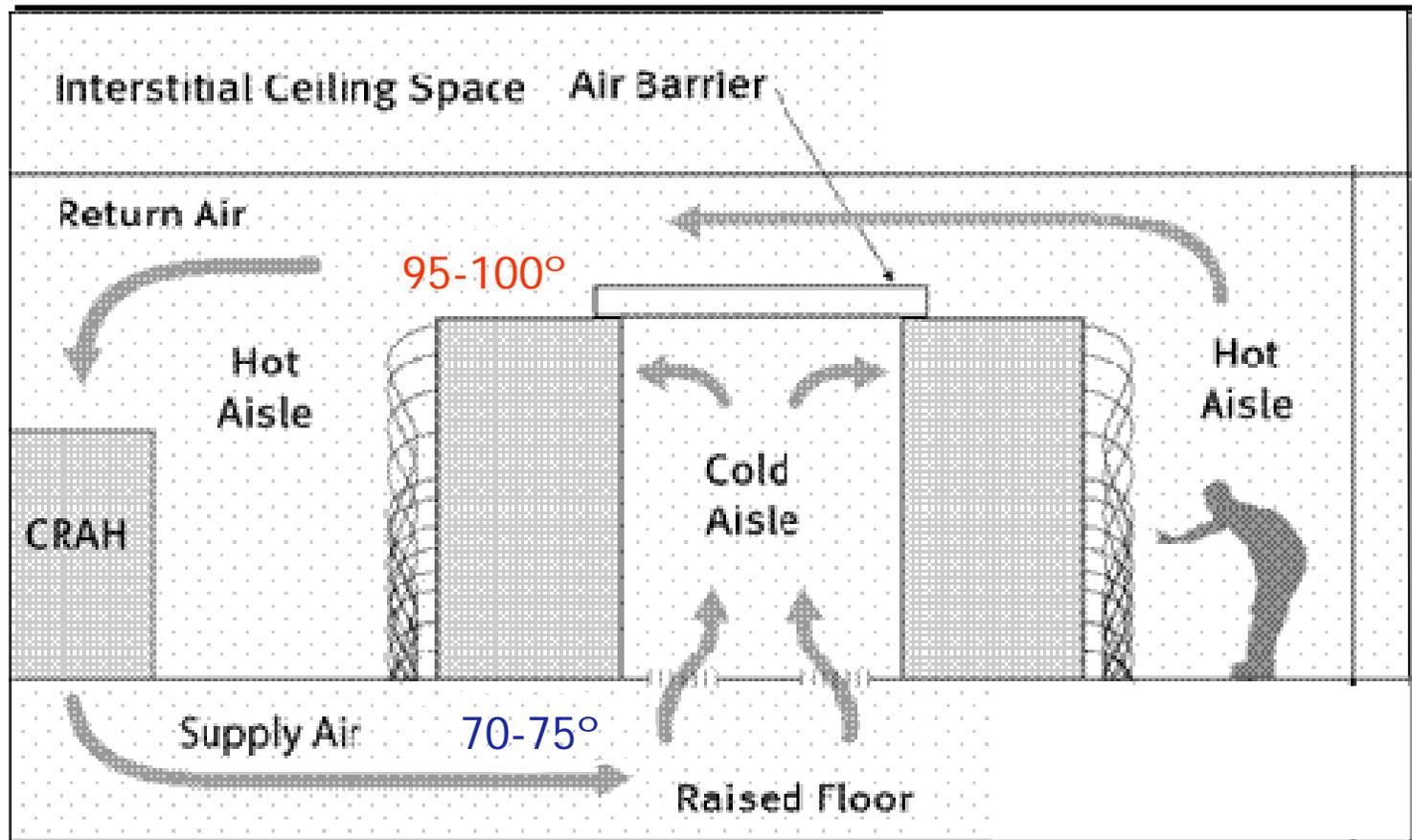
Note: ASHRAE is in the process of widening the recommended ranges



Demonstration projects



Best Scenario— Isolate Cold and Hot



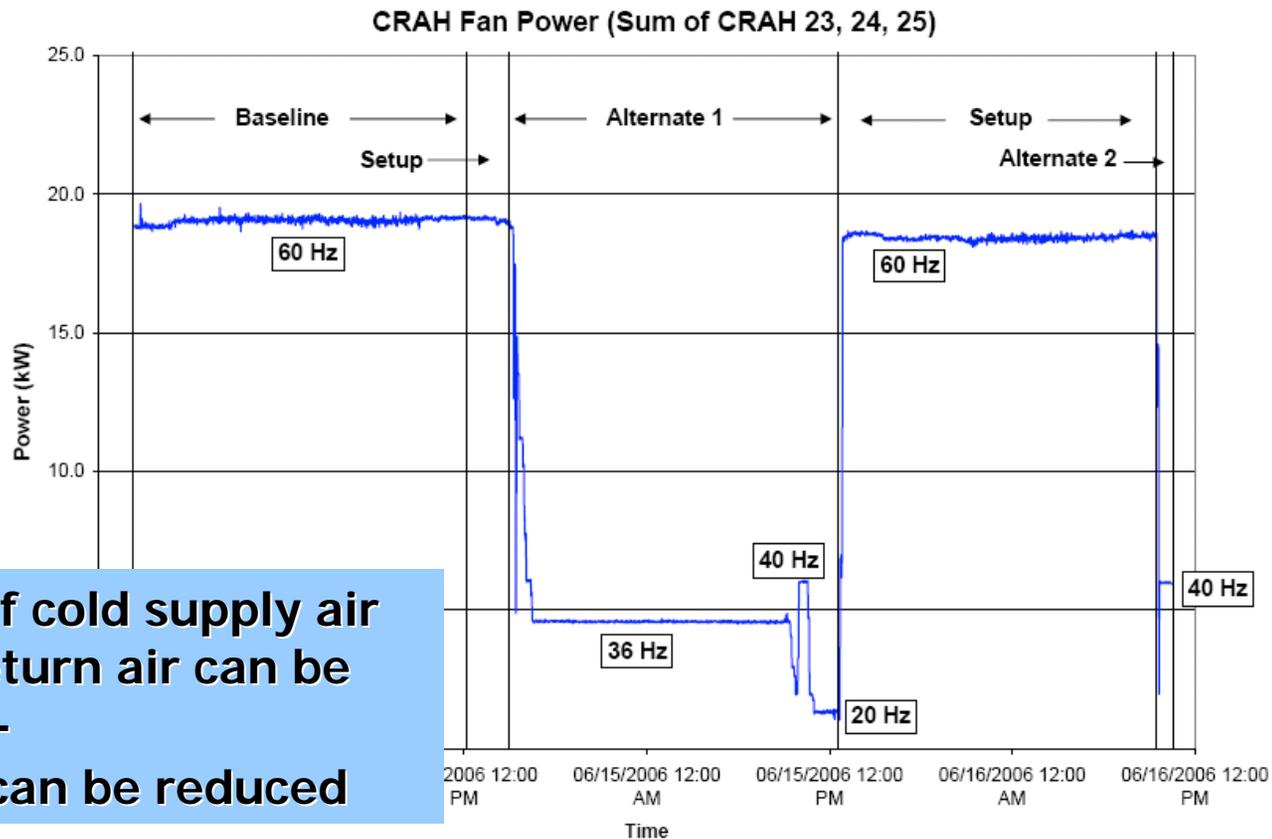


Isolating Hot and Cold:

- Energy intensive IT equipment needs isolation of “cold” inlet and “hot” discharge
- Computer room air conditioner airflow can be reduced if no mixing of hot and cold occurs
- Overall temperature can be raised in the data center if air is delivered to equipment without mixing
- Coils and chillers are more efficient with higher temperature differences



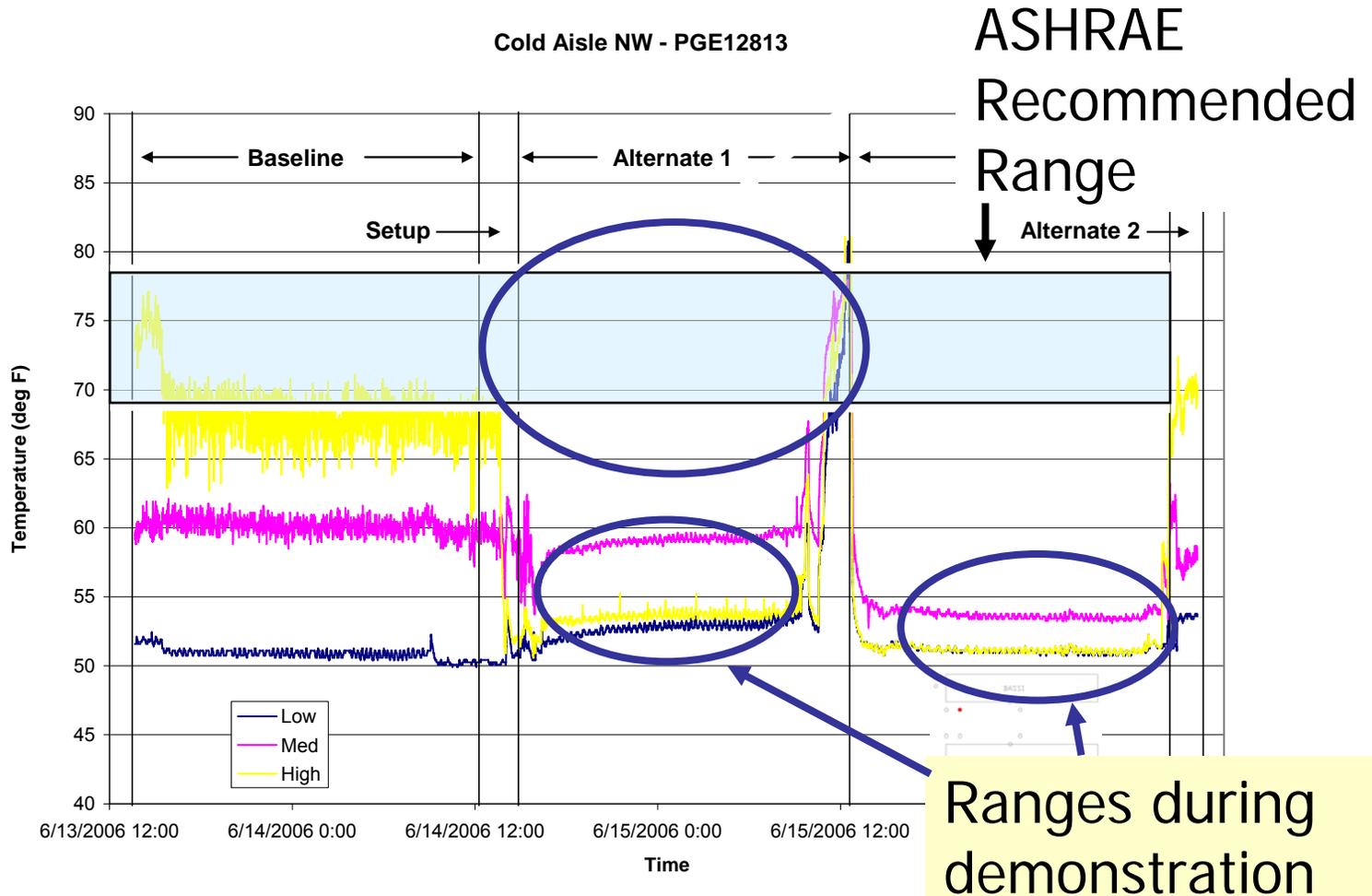
Fan Energy Savings – 75%



If mixing of cold supply air with hot return air can be eliminated- fan speed can be reduced



Better Temperature Control Can Allow Raising the Temperature in The Entire Center





Encouraging use of Air Economizers

Use of “Free Cooling” in many climates can be a big winner.

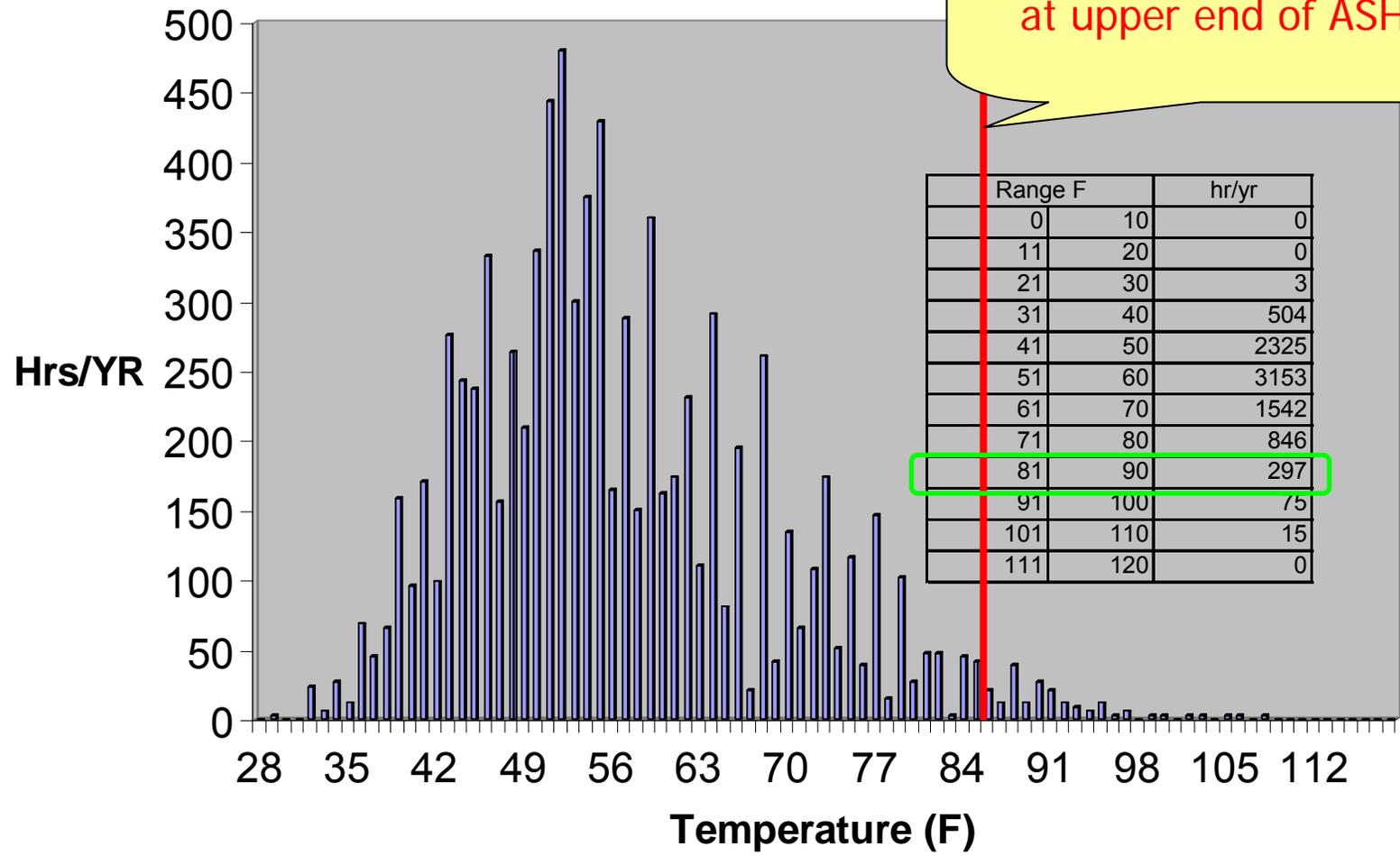
Overcoming concerns of contamination or loss of humidity control is a barrier.



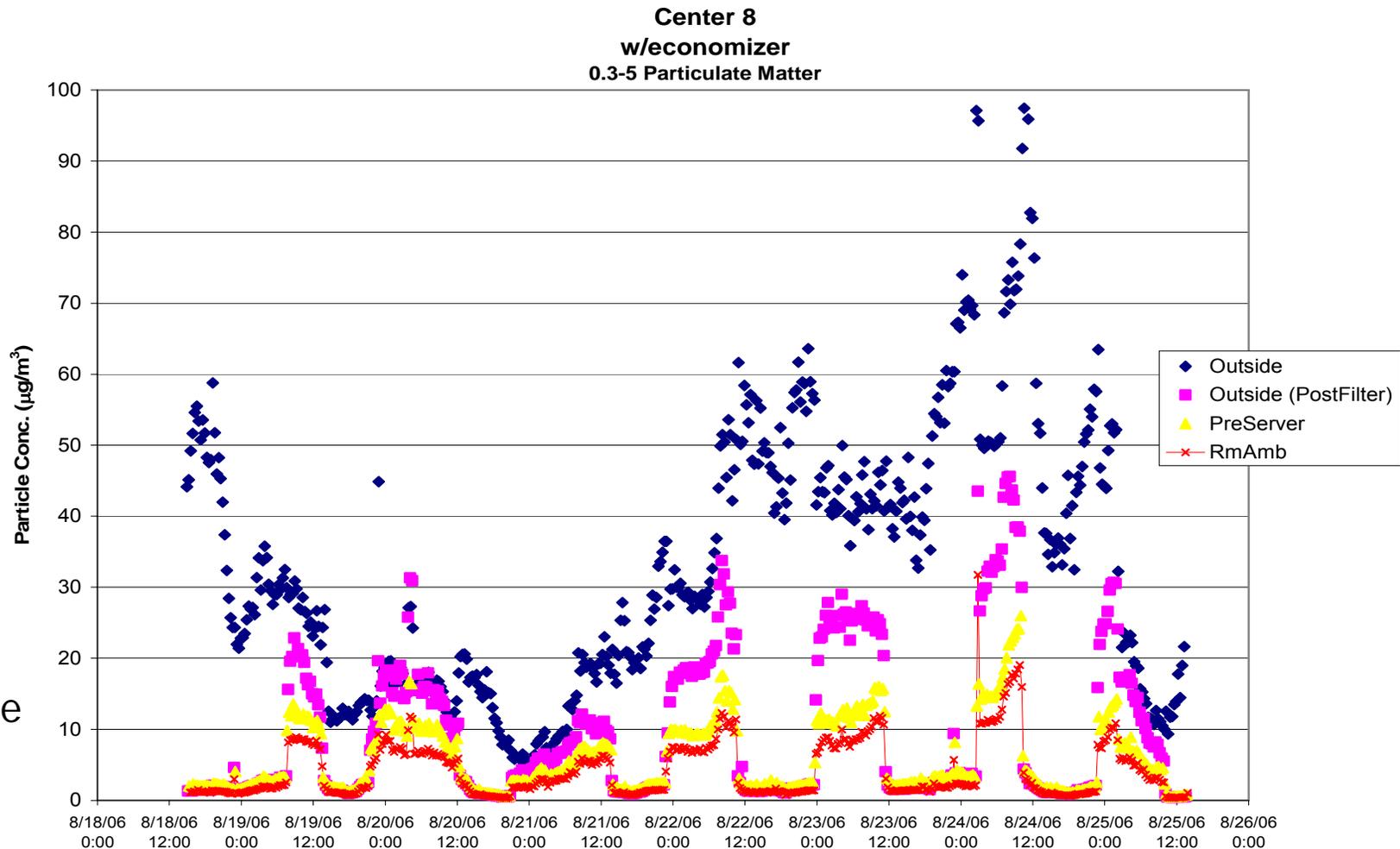


Berkeley Weather

Inlet Temperature
at upper end of ASHRAE



Data center w/economizer

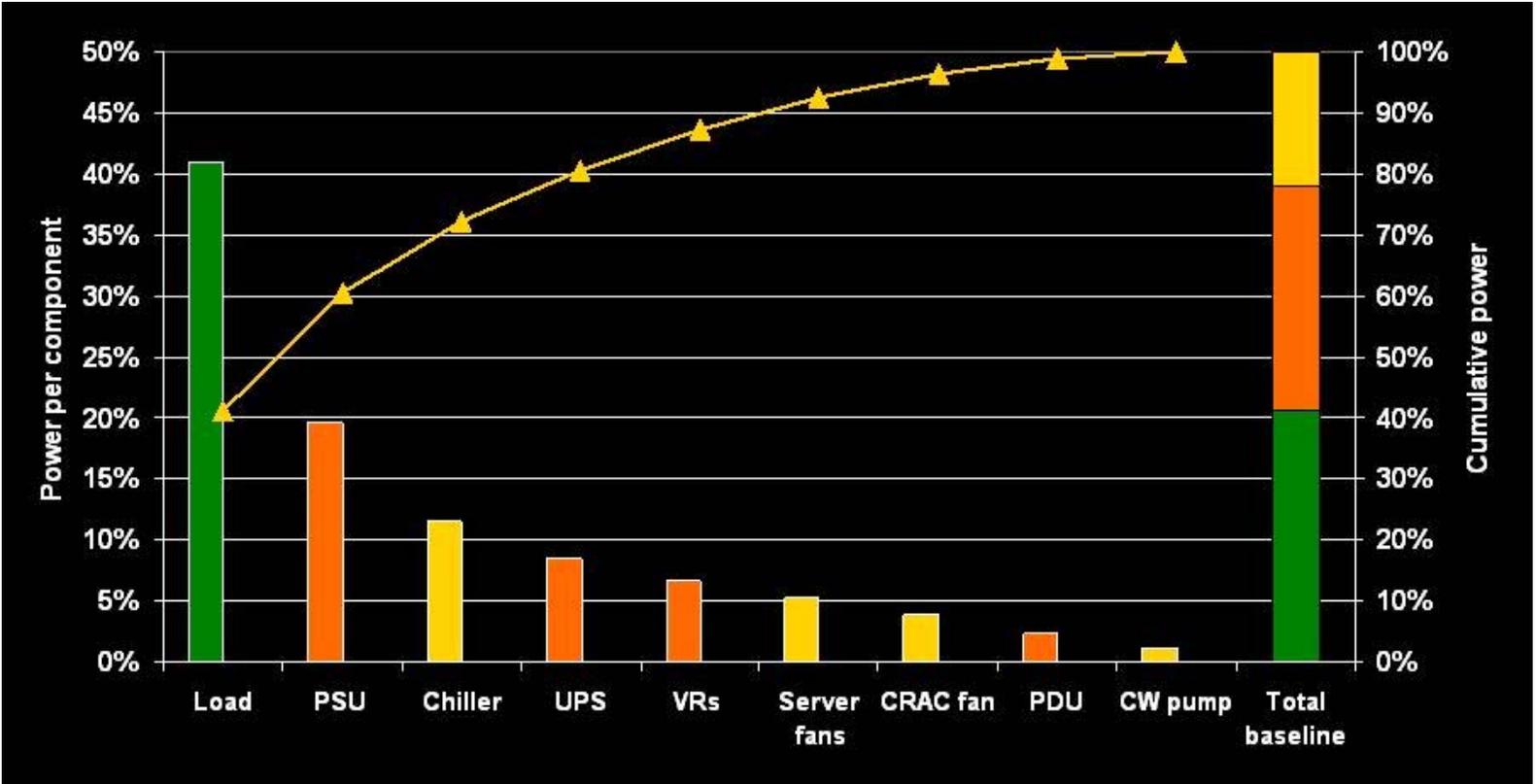




DC Power Demonstration

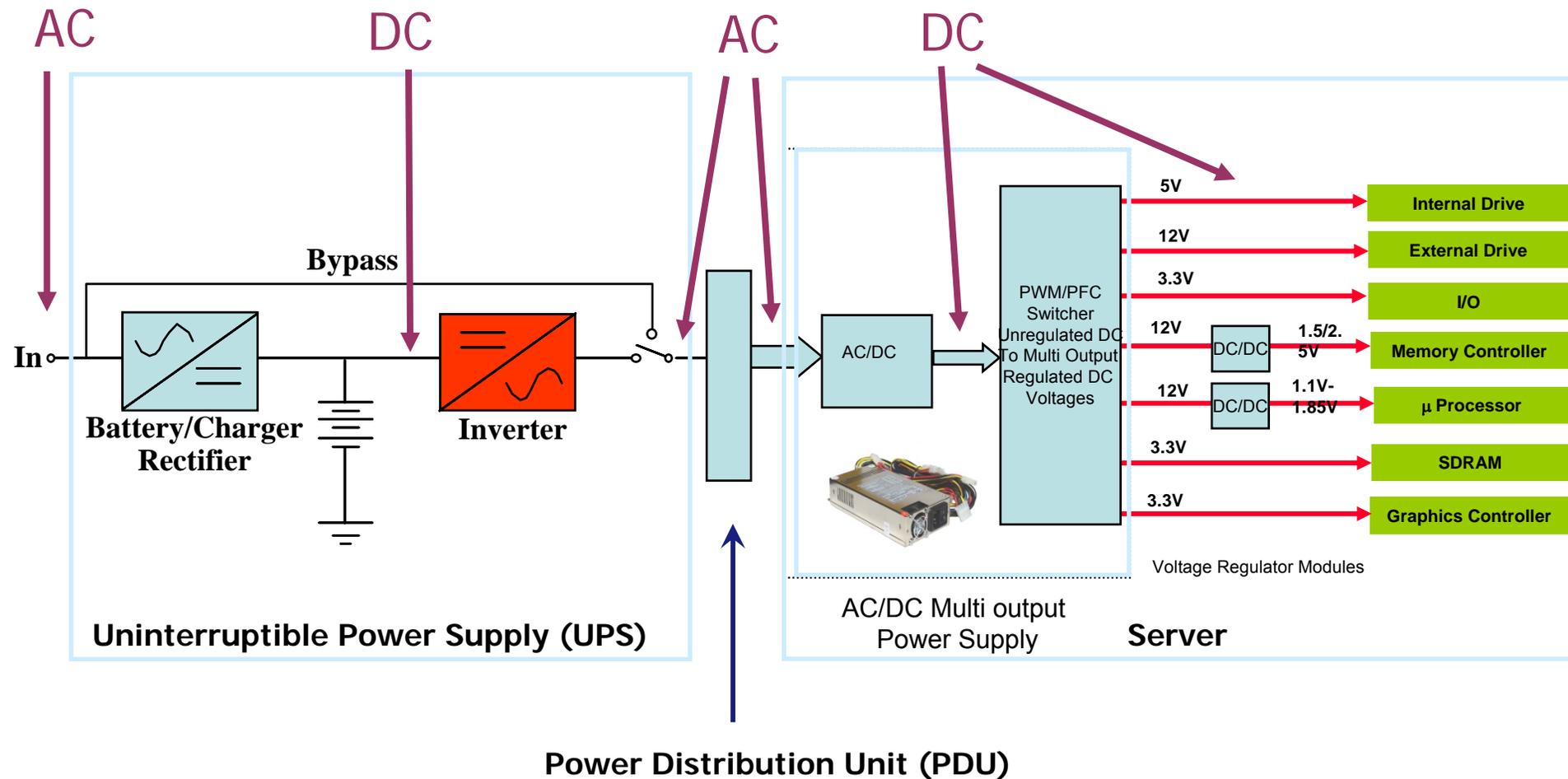


Overall Power Use in Data Centers



Courtesy of Michael Patterson, Intel Corporation

Data Center Power Conversions

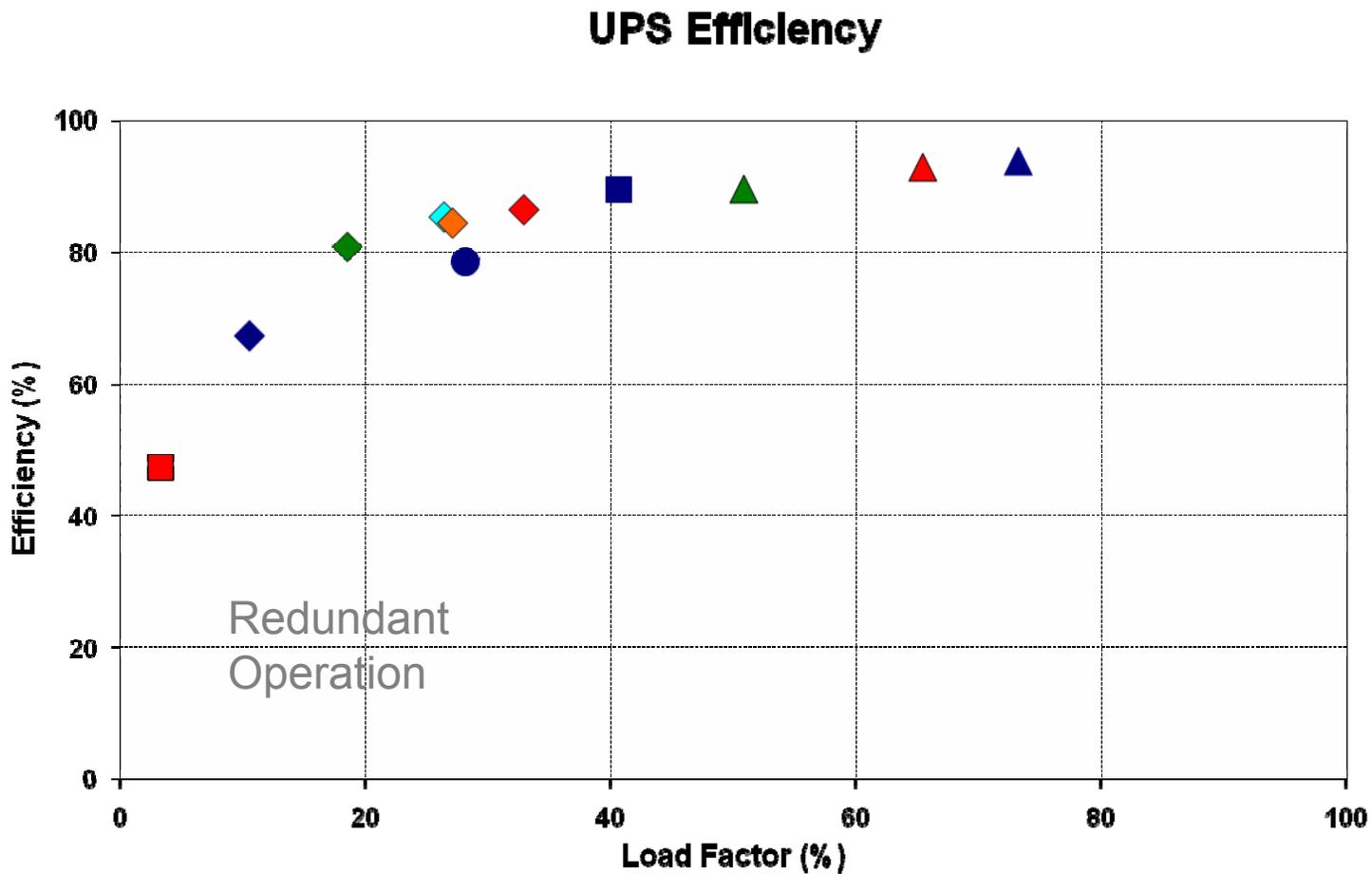




Electrical Distribution

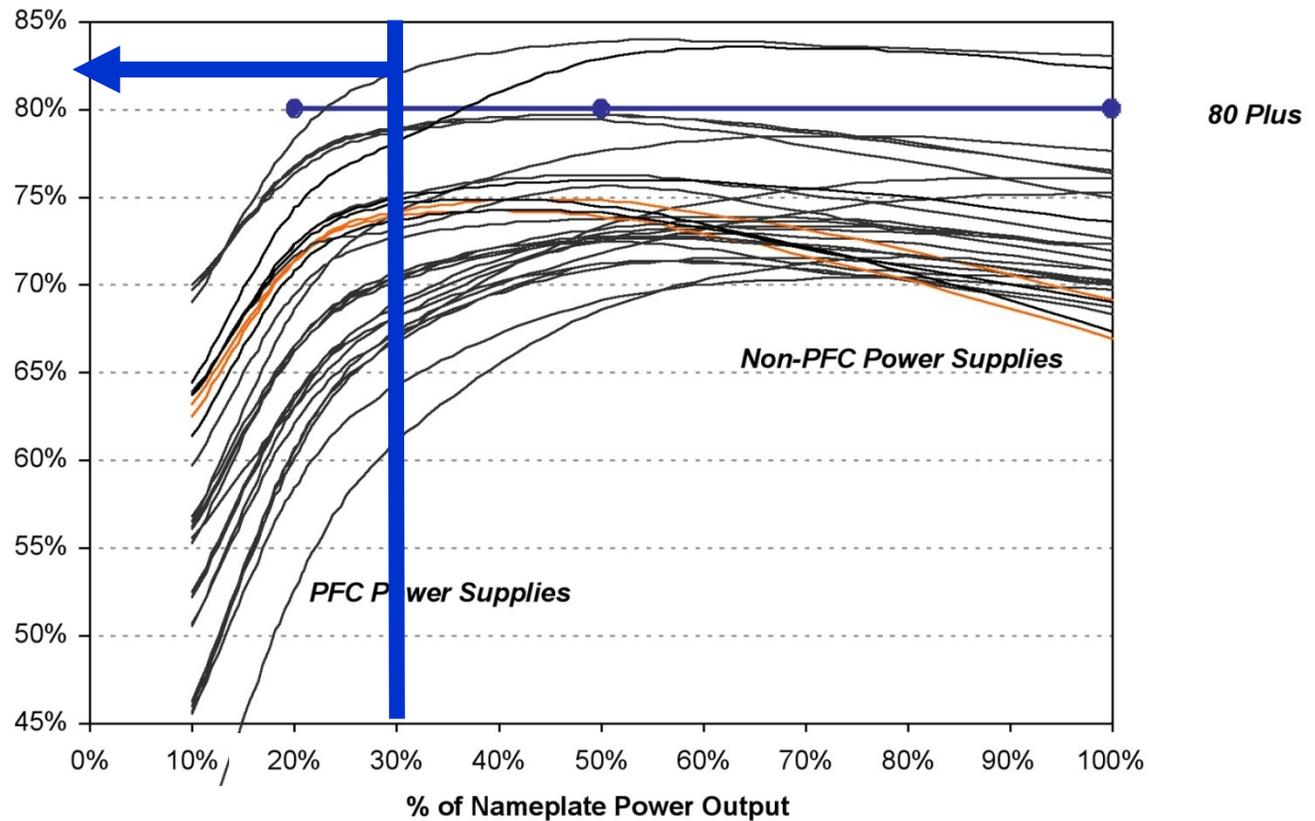
- Every power conversion (AC - DC, DC - AC, AC - AC) loses power, creating heat
- Distributing higher voltage is more efficient and saves capital cost (wire size is smaller)
- Uninterruptible power supplies (UPS's) efficiencies vary
- Efficiency of power supplies in computing equipment vary

Measured UPS Efficiencies



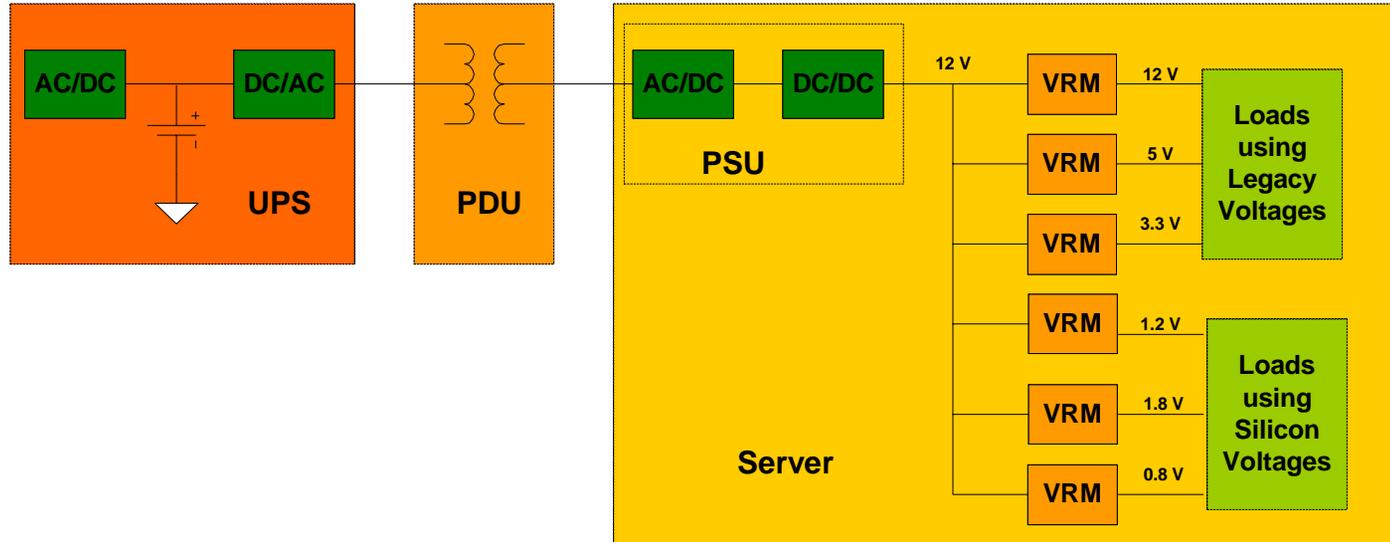
Measured Power Supply Efficiency

Measured Server Power Supply Efficiencies (all form factors)



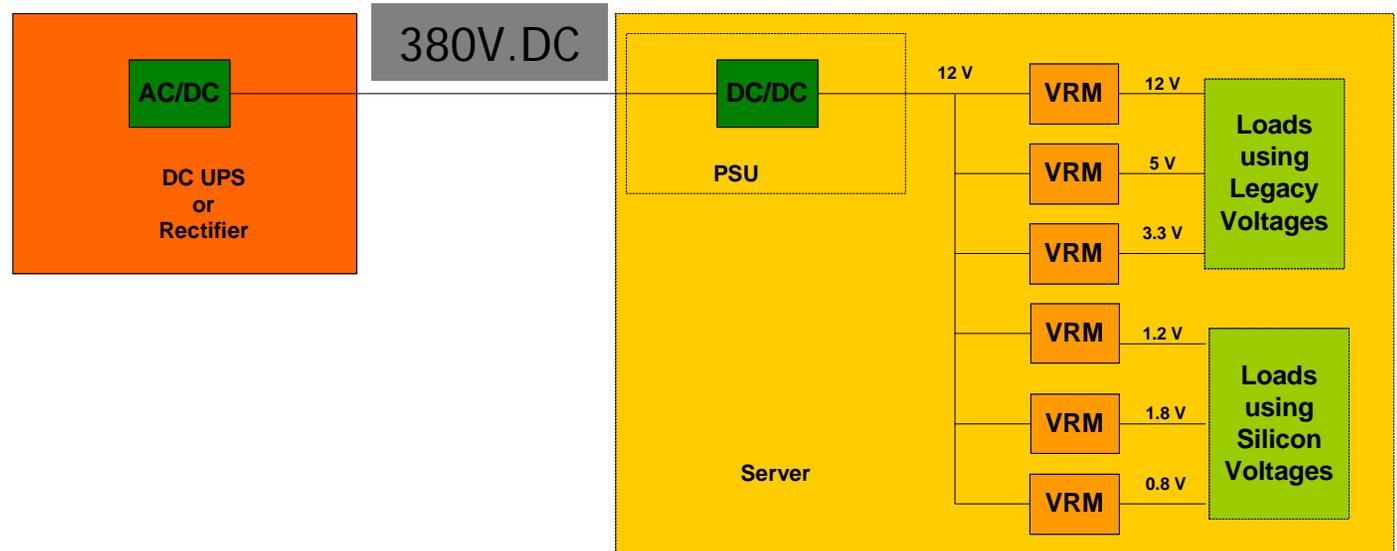
Typical AC Distribution Today

480
Volt AC



DC power distribution

480
Volt AC



AC System Loss Compared to DC



“DC Pro” – Coming soon - An Online Tool

INPUTS

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

The screenshot shows the DC Pro website interface. At the top, it features the U.S. Department of Energy logo and the text "Energy Efficiency and Renewable Energy" with the tagline "Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable". Below this is a green banner for the "Industrial Technologies Program". The main heading is "DC Pro" in red, with a navigation bar containing links for "New", "Open", "Save", "FAQ", "Tutorial", and "Feedback". The page title is "Center Energy Profiler". A login section titled "Get Started Now!" includes fields for "Username" and "Password", with links for "Forgotten password" and "Register". A "Login" button is also present. Below the login section, there is a paragraph of text describing the tool: "The Center Energy Profiler, or DC Pro, is an online software tool provided by the U.S. Department of Energy to help industries worldwide identify how energy is being purchased and consumed by their data center(s) and also identify potential energy and cost savings. The tool is designed so that the user can complete a data center profile in about an hour. The online tutorial will explain what data center information you need to complete a DC Pro case. When you complete a DC Pro case you are provided with a customized, printable report that shows the details of energy purchases for your data center, how energy is consumed by your data center, potential cost and energy savings, comparison of your data center energy utilization versus other data centers, and a list of next steps that you can follow to get you started saving energy." A "DC Pro Resources" sidebar lists "Online Tutorial" and "Checklist". At the bottom, it states "The current version of DC Pro is 1.1.1.1, released 12/12/2006." and provides links for "Industrial Technologies Program Home", "EERE Home", "U.S. Department of Energy", "Webmaster", "Web Site Policies", "Security & Privacy", and "USA.gov".

OUTPUTS

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



"DC Pro" Key Elements

Data Center Performance

- Overall energy performance (baseline) of data center
- Performance of IT & infrastructure subsystems compared to benchmarks
- Potential areas for efficiency improvement
- Energy cost (\$), source energy (Btu), and carbon emissions (Mtons)



IT Module

- Servers
- Storage & networking hardware
- Software



Cooling

- Chillers
- CRAC units
- Fan power



Power Systems

- UPS
- Distribution



Energy Source

- Source of power
- Distributed generation
- Cost per kWh
- Backup power

Example “DC Pro” Recommendations

List of Actions (for 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



The screenshot displays the DC Pro web application interface. At the top, it features the U.S. Department of Energy logo and the text "Energy Efficiency and Renewable Energy" with the tagline "Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable". Below this is a green banner for the "Industrial Technologies Program" and a red "DC Pro" header. A navigation bar includes links for Home, New, Open, Save, FAQ, Tutorial, and Feedback. The main content area shows "Potential Annual CO₂ Savings" based on potential energy savings identified, with a note that these are broad estimates. It lists "Potential Annual CO₂ Savings From Electricity 0 lbs." and "Potential Annual CO₂ Savings From Fuel/Steam 61,256,000 - 118,976,000 lbs." Below this, a "Suggested Next Steps" section contains a row of buttons for Energy Management, IT Equipments, Environmental Conditions, Air Management, Cooling Plant, IT Equipment Power Chain, and Lighting. A table under Energy Management lists: "Create an energy management plan", "Assign staff with energy management", and "Sub-meter end-use loads and track over time".



Save ENERGY Now

DOE Data Center program

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Information Tech. R&D program

Gideon Varga

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websites:

<http://hightech.lbl.gov/datacenters/>
www.EERE.energy.gov/datacenters