Data Center
Energy Efficiency Opportunities
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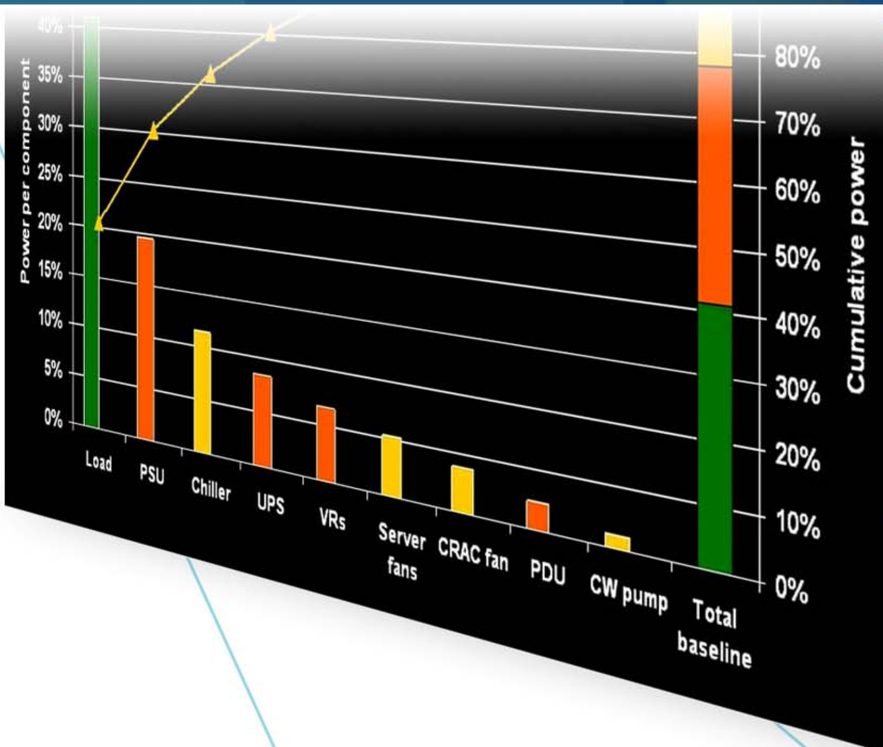
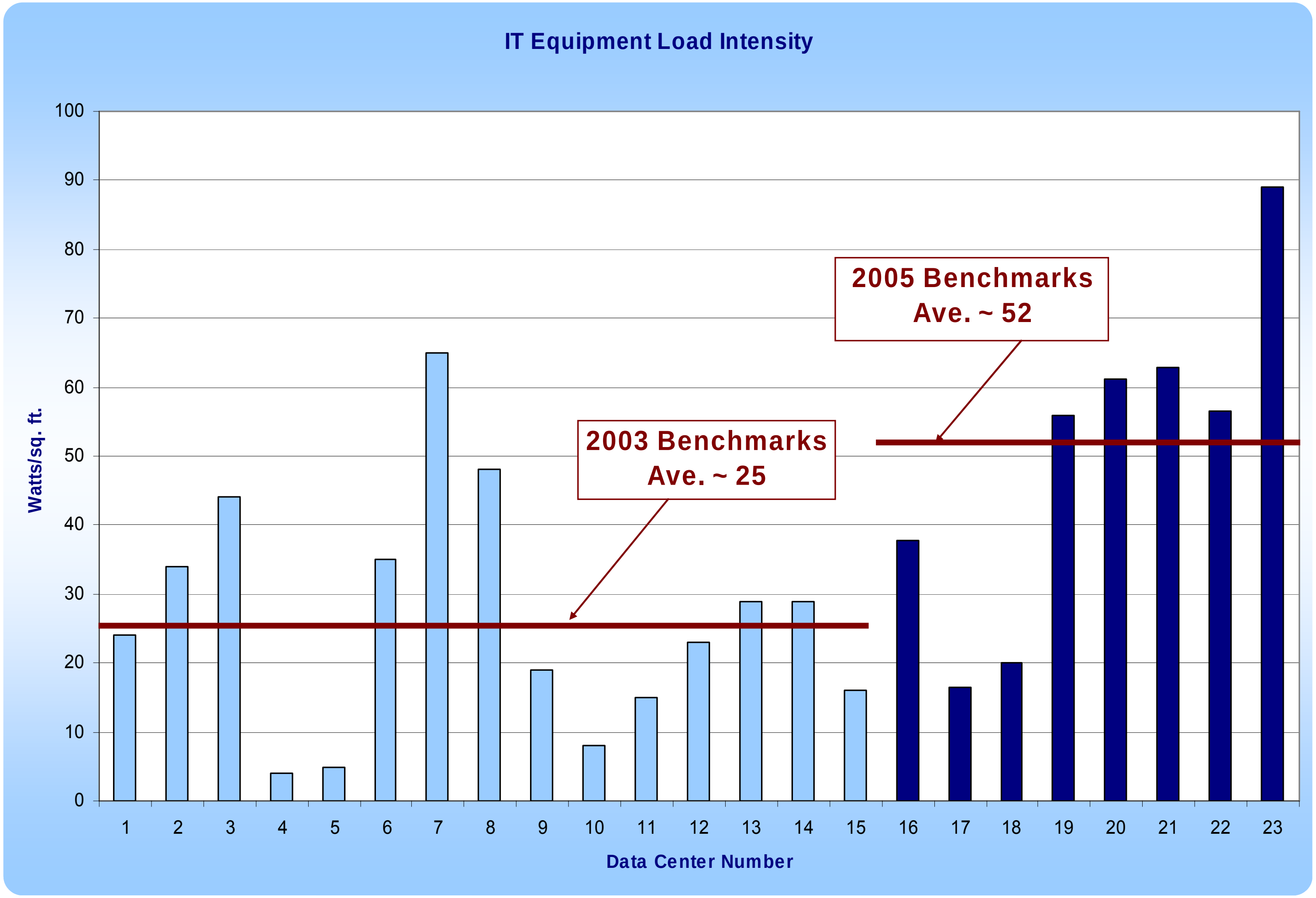
FEMP

Save ENERGY Now

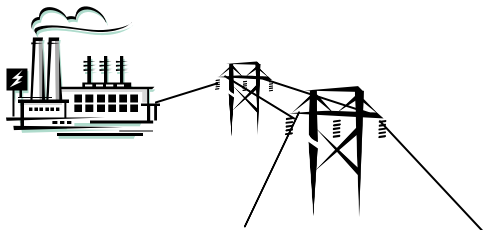


Benchmarking Data Center Energy Use

IT Equipment Load Density



Energy Efficiency Opportunities Are Everywhere



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

- Load management
- Server innovation

Power Conversion & Distribution

Server Load/ Computing Operations

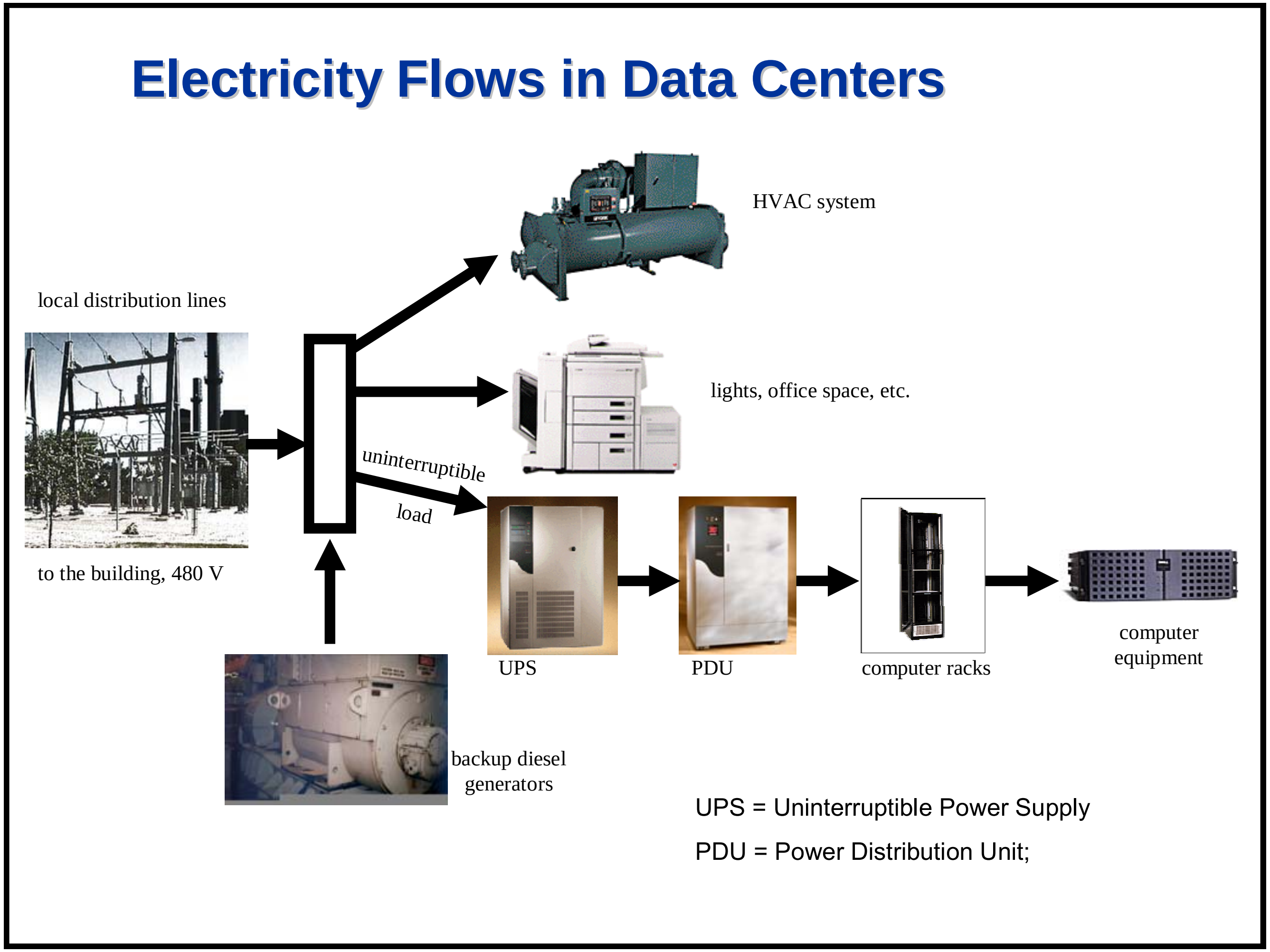
Cooling Equipment

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

Alternative Power Generation

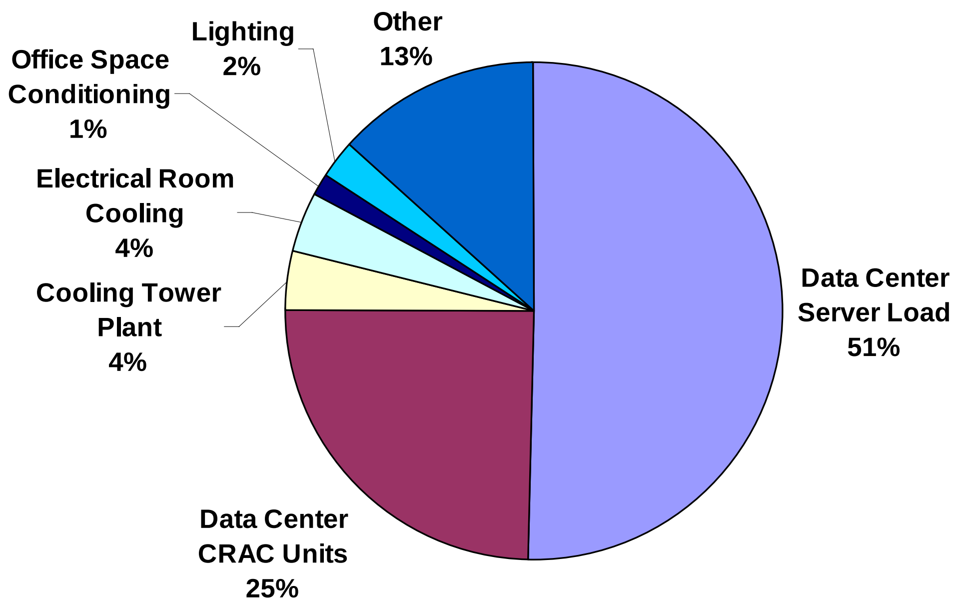
- On-site generation
- Waste heat for cooling
- Use of renewable energy/fuel cells

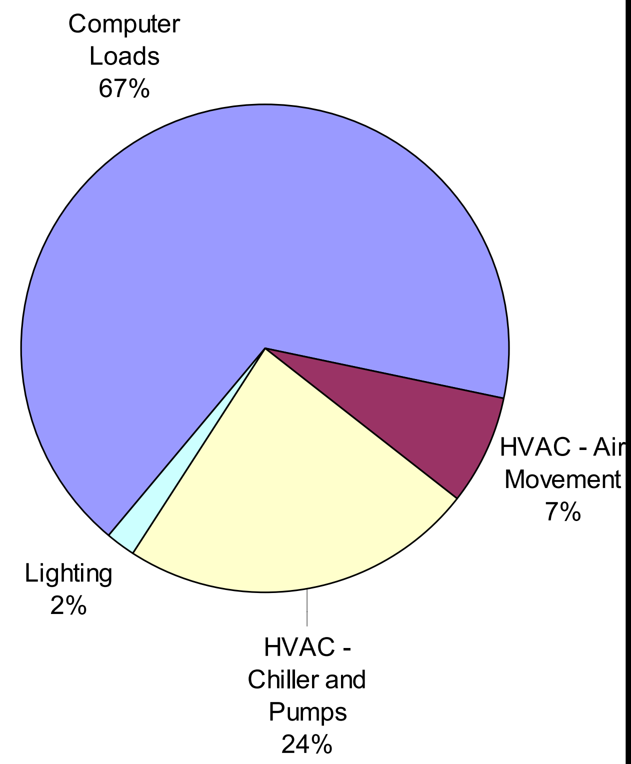
Benchmarking Energy End Use



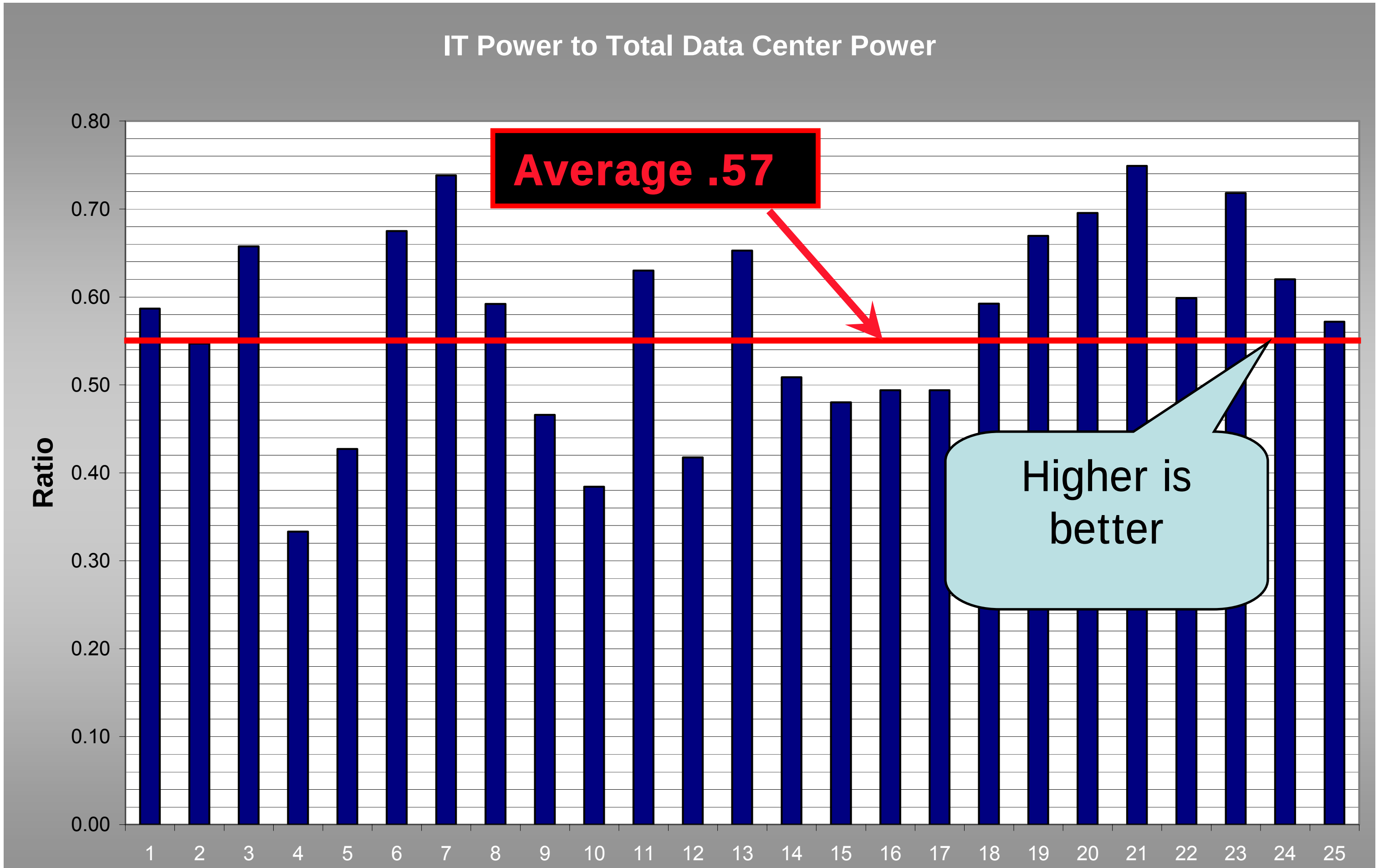
Performance Varies

The relative percentages of the energy doing computing varied considerably.



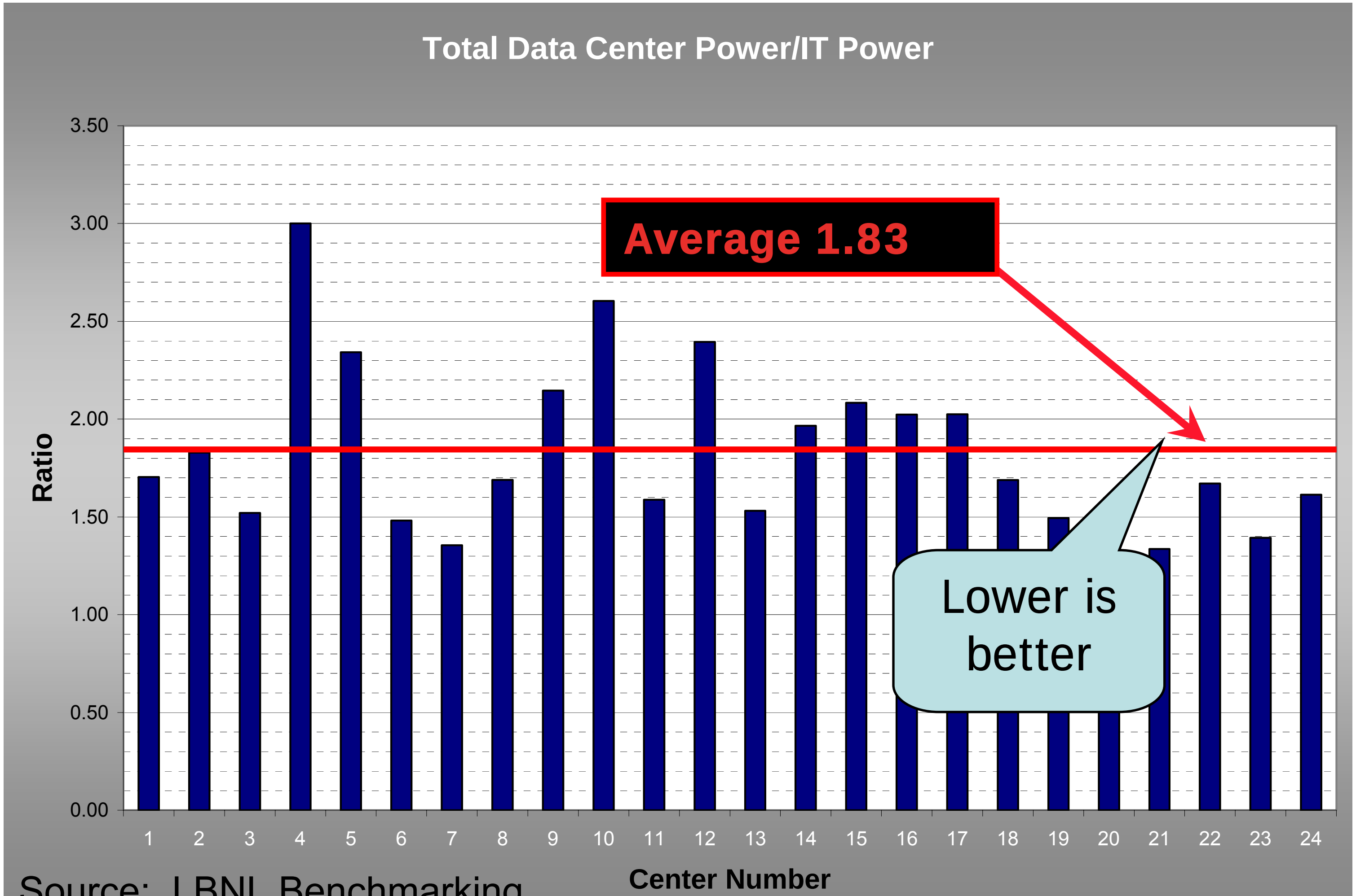


High Level Metric— DCiE
Ratio of Electricity Delivered to IT Equipment



Source: LBNL Benchmarking

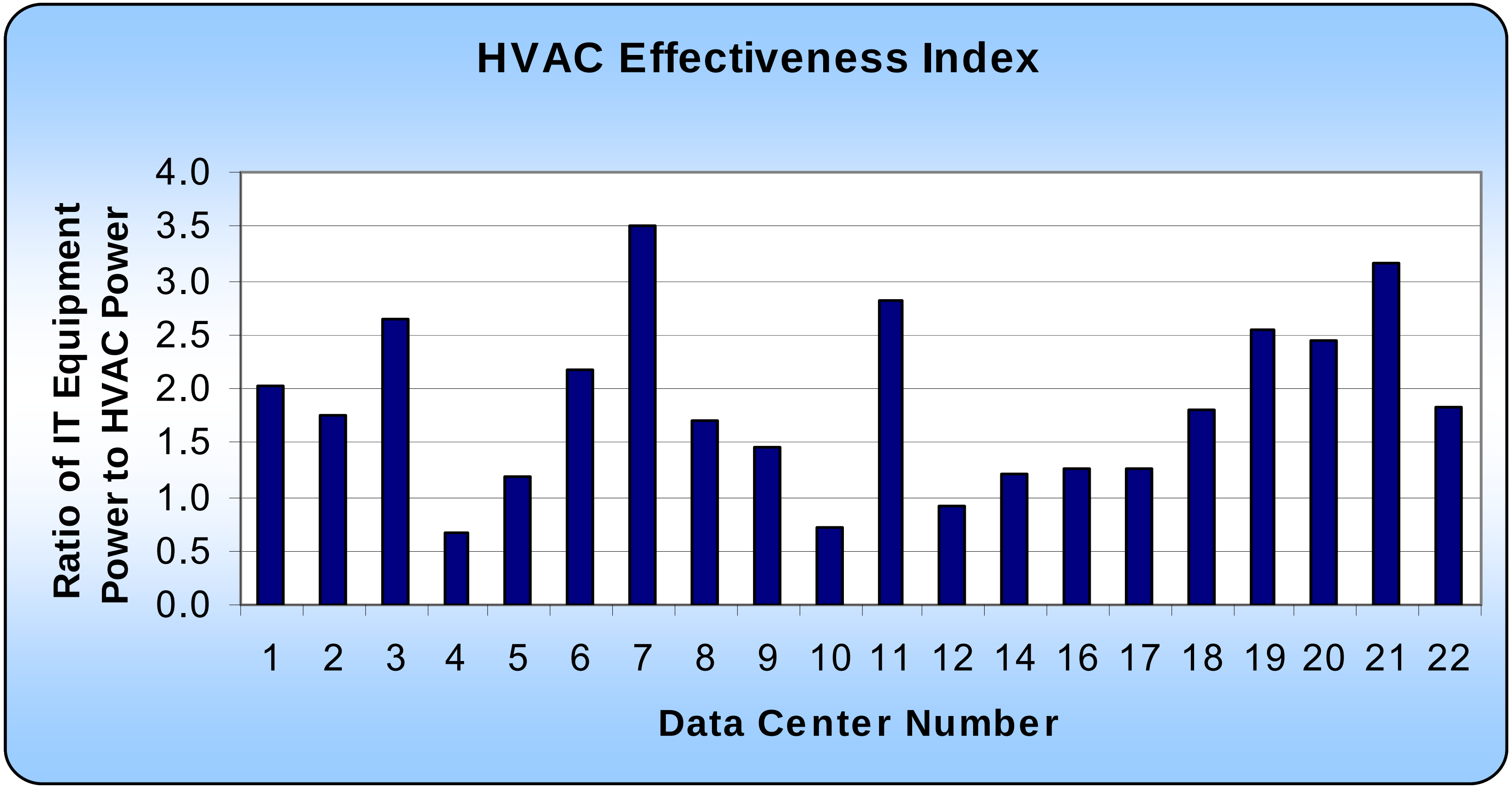
Alternate High Level Metric – PUE
Data Center Total / IT Equipment



Source: LBNL Benchmarking

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)/ITΔT

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

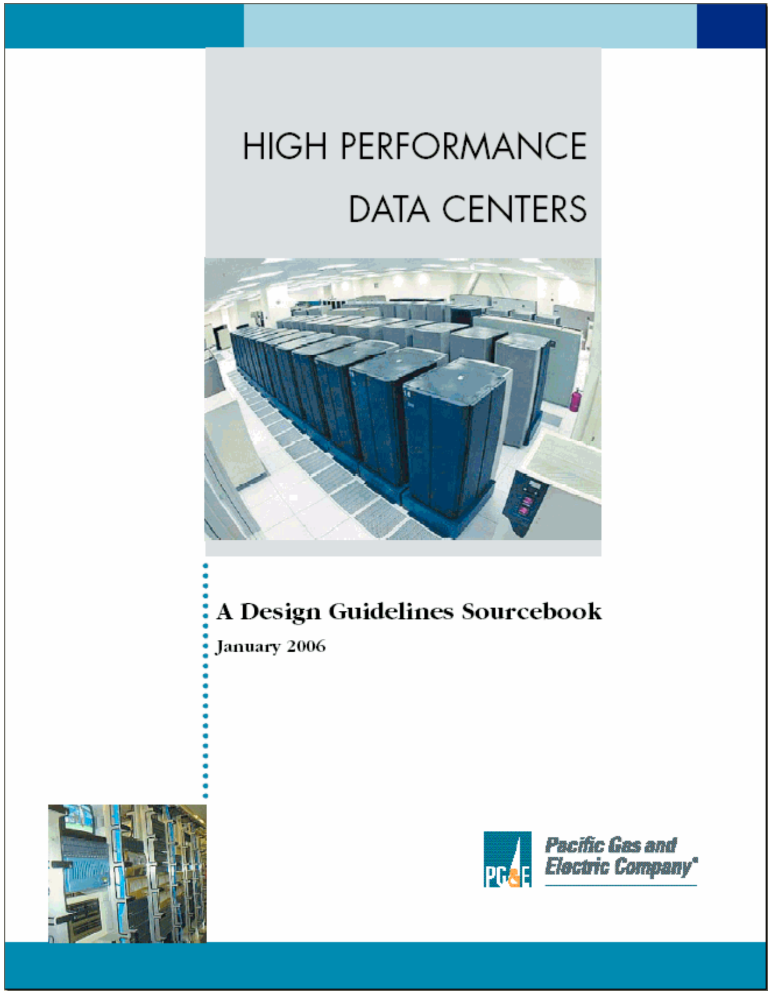
- Power supply efficiency
- Standby/sleep power modes
- IT equipment fans
- Virtualization
- Load shifting
- Storage options

Best Practices —
Cross-Cutting and Misc. Issues

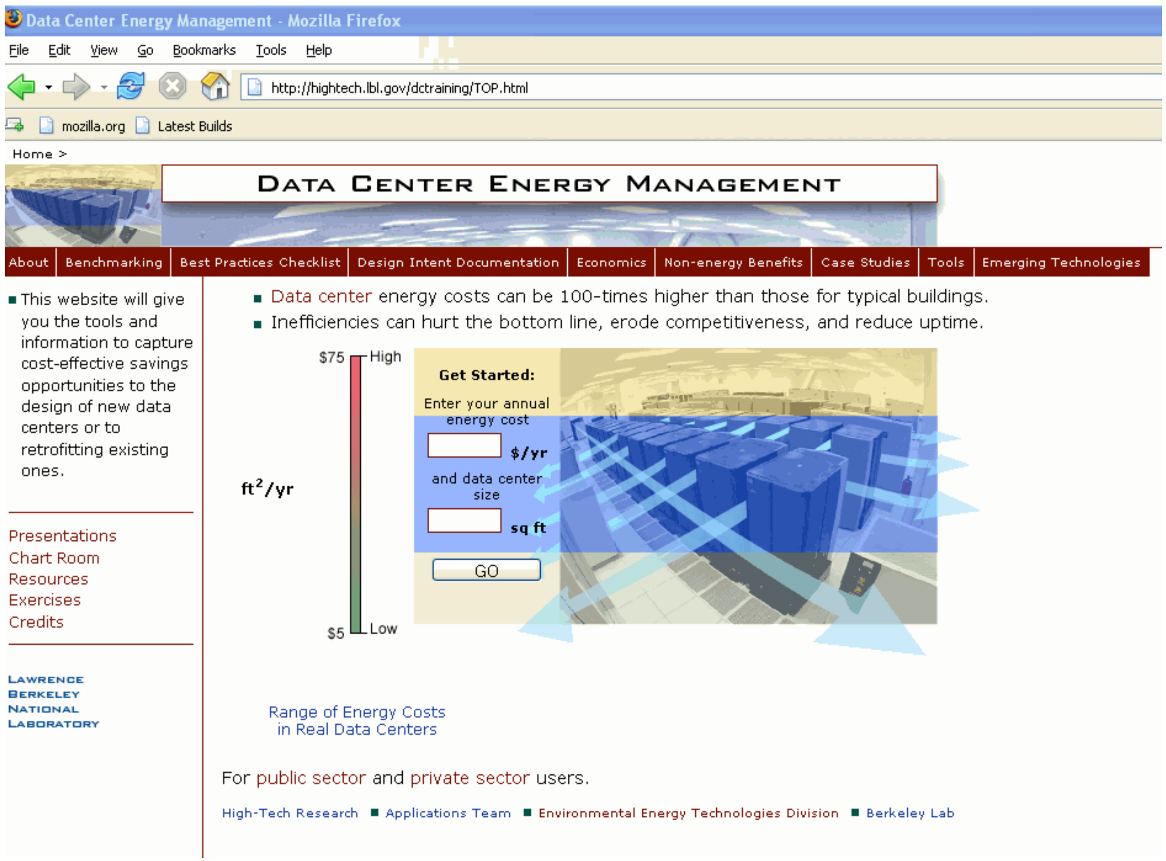
- Motor efficiency
- Right sizing
- Variable speed drives
- Lighting
- Maintenance
- Continuous Commissioning and Benchmarking
- Heat Recovery
- Building Envelope
- Redundancy Strategies

Design Guidelines for Ten Best Practices Were Developed

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



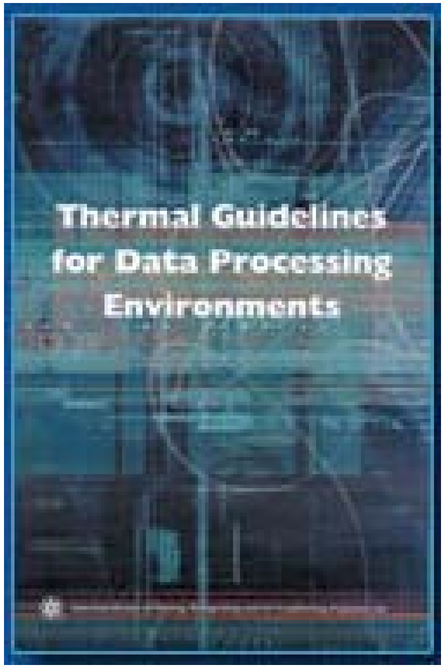
Design Guidance is Summarized in a Web Based Training Resource

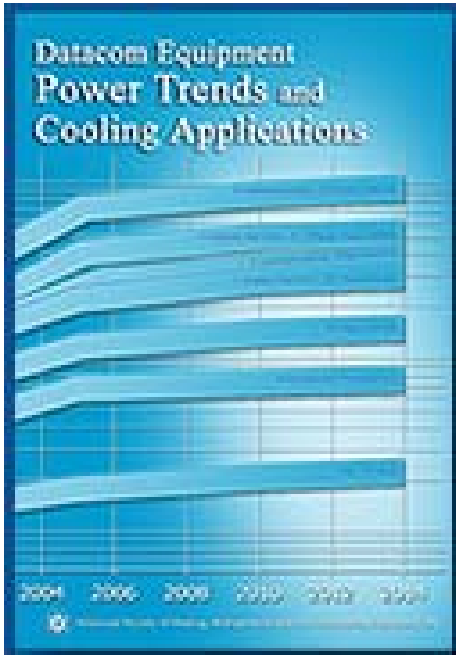


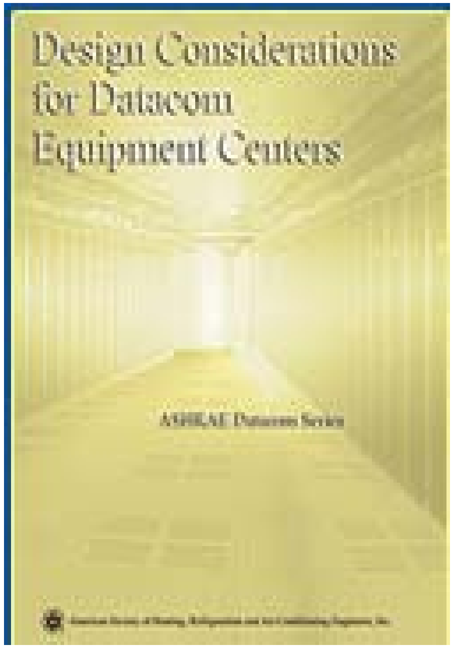
http://hightech.lbl.gov/dctraining/TOP.html

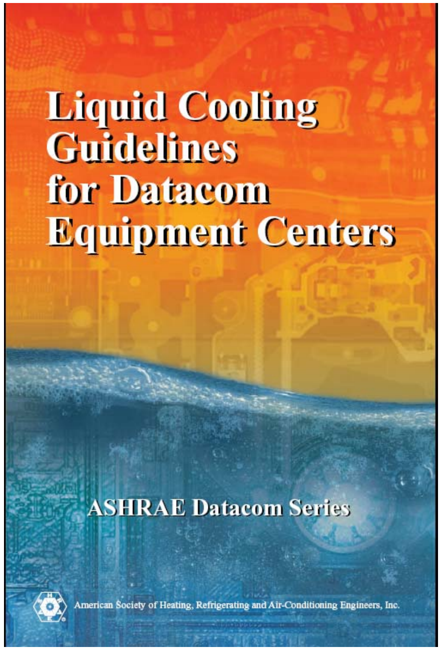
ASHRAE Resources

Six books published—
more in preparation







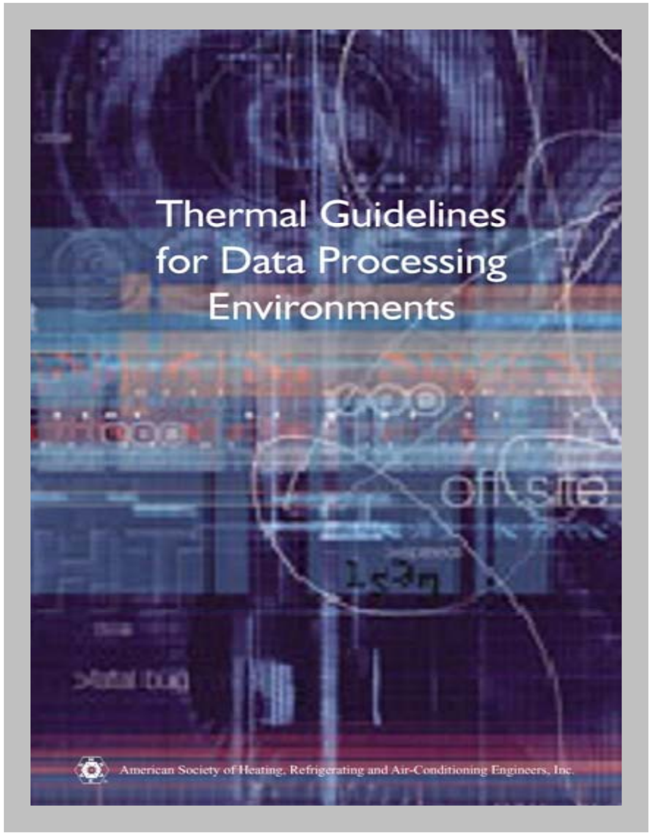


ASHRAE, Thermal Guidelines for Data Processing Environments, 2004, Datacom Equipment Power Trends and Cooling Applications, 2005, Design Considerations for Datacom Equipment Centers, 2005, Liquid Cooling Guidelines for Datacom Equipment Centers, 2006, © American Society of Heating, Refrigerating and 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

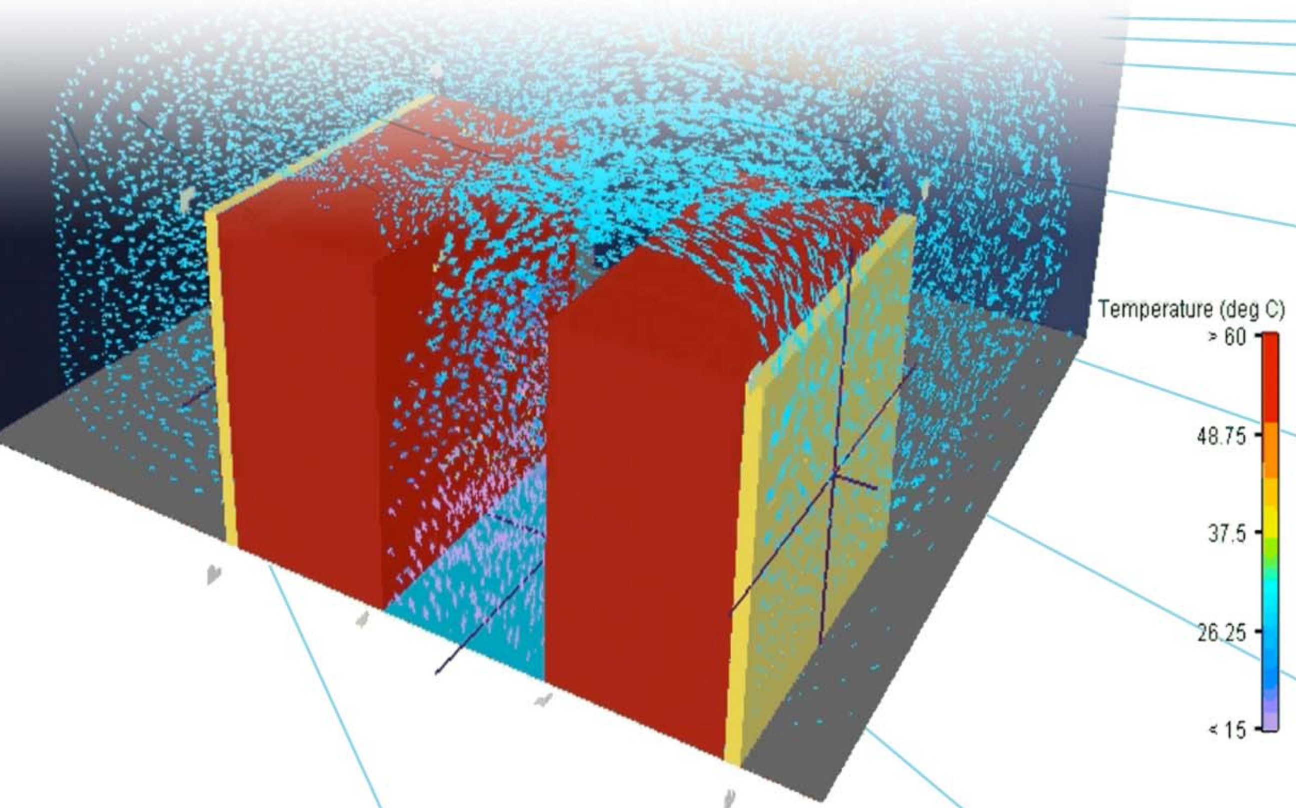


Design Conditions - at Inlet to IT Equipment

Table 2.1 Class 1, Class 2 and NEBS Design Conditions				
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]			

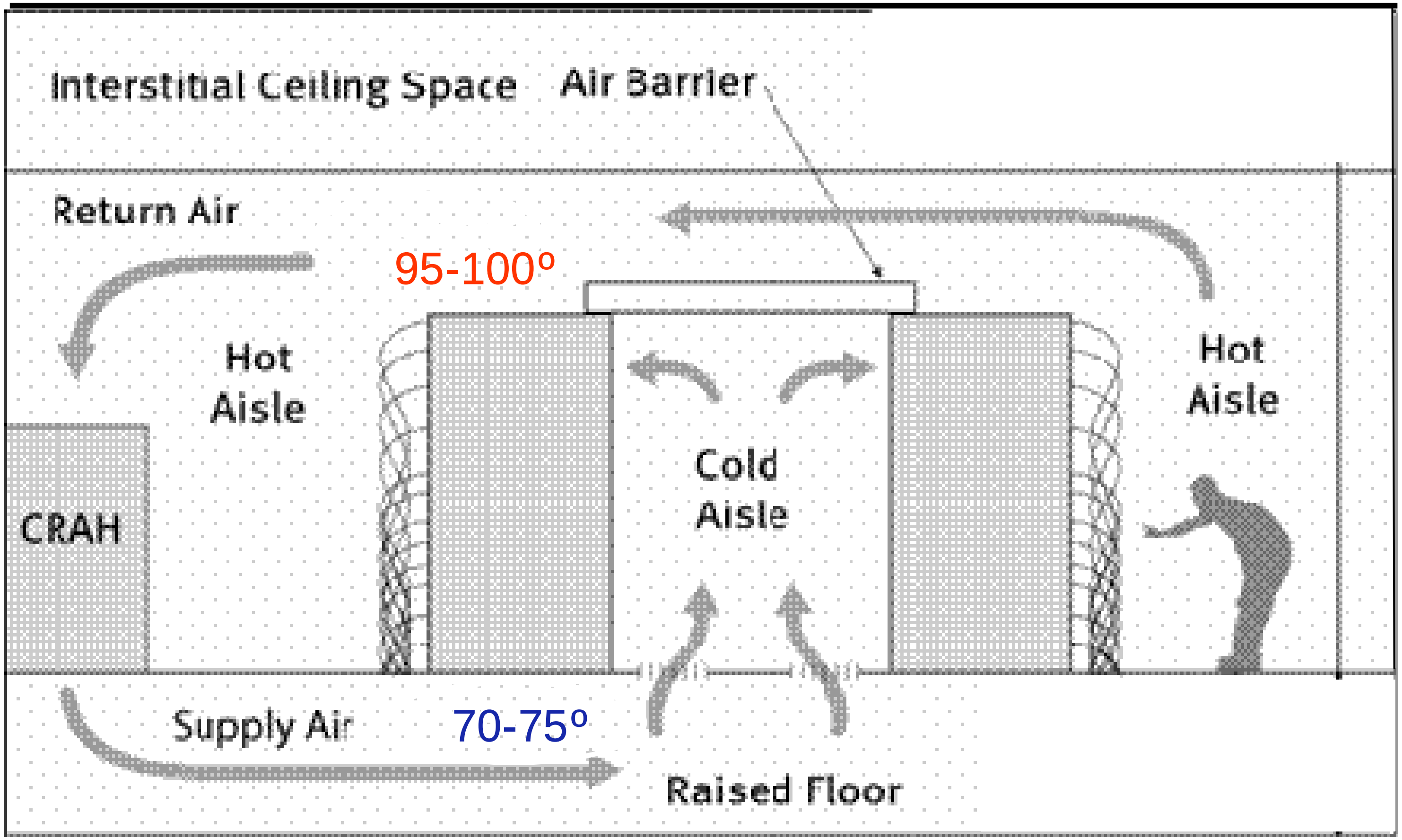
[a]These conditions are inlet conditions recommended in the ASHRAE Publication *Thermal Guidelines for Data Processing Environments* (ASHRAE, 2004).
[b]Percentage values per ASHRAE *Standard* 52.1 dust-spot efficiency test. MERV values per ASHRAE Standard 52.2. Refer to Table 8.4 of this publication for the correspondence between MERV, ASHRAE 52.1 & ASHRAE 52.2 Filtration Standards.
[c]Telecordia 2002 GR-63-CORE
[d]Telecordia 2001 GR-3028-CORE
[e]Generally accepted telecom practice. Telecom central offices are not generally humidified, but grounding of personnel is common practice to reduce ESD.
[f]Refer to Figure 2.2 for temperature derating with altitude

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



Demonstration projects

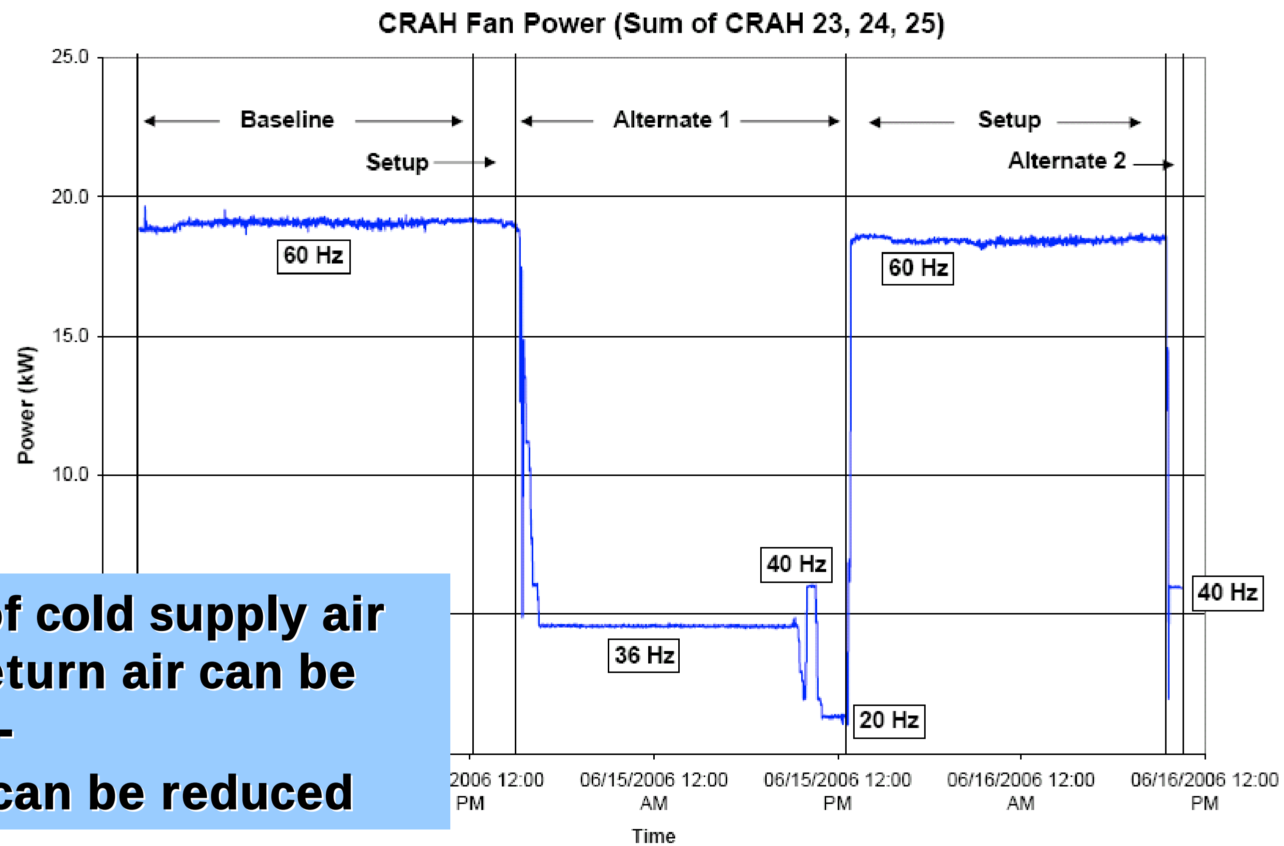
Best Scenario— Isolate Cold and Hot



Isolating Hot and Cold:

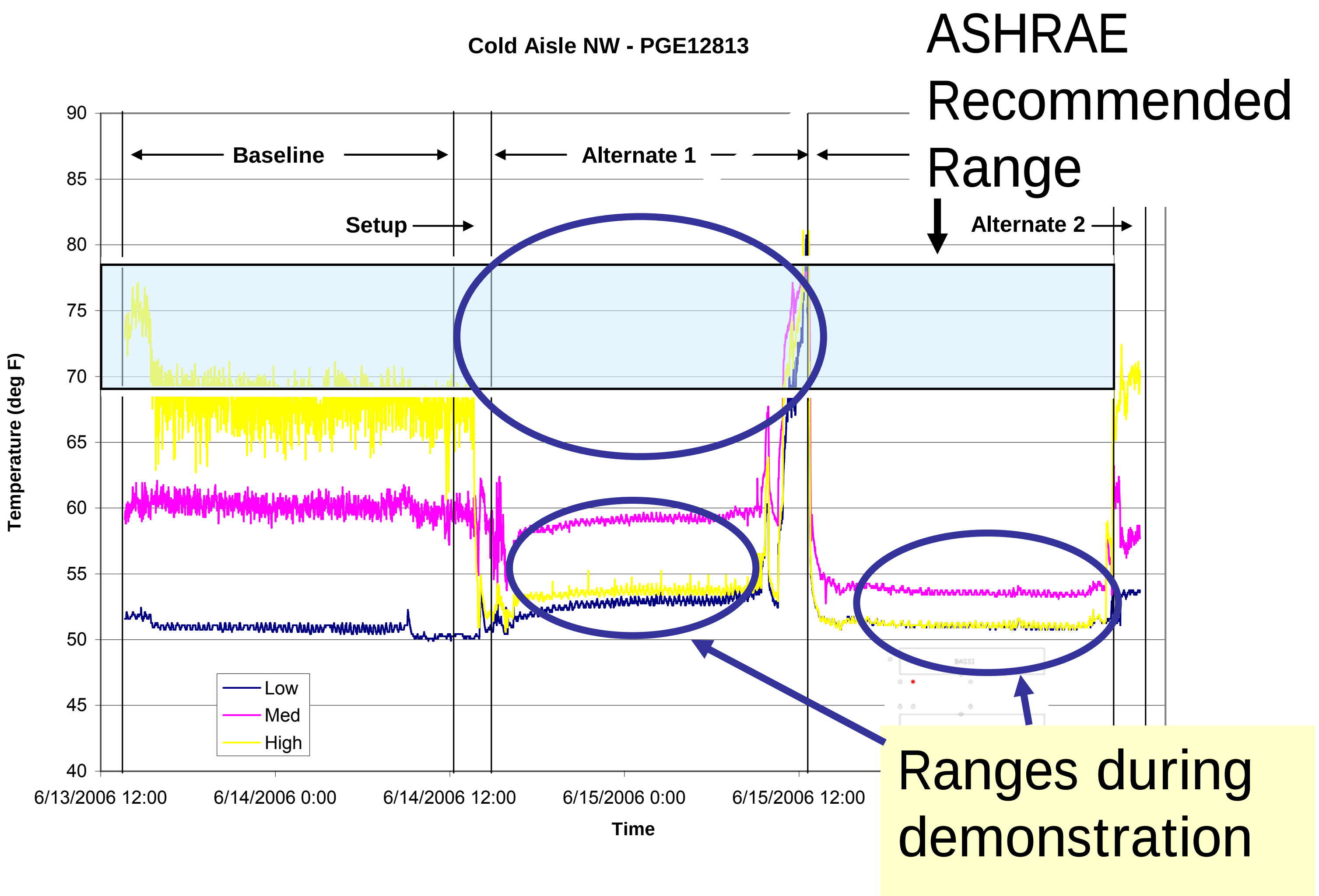
- Energy intensive IT equipment needs isolation of “cold” inlet and “hot” discharge
- Computer room air conditioner airflow can be reduced if no mixing of hot and cold occurs
- Overall temperature can be raised in the data center if air is delivered to equipment without mixing
- Coils and chillers are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

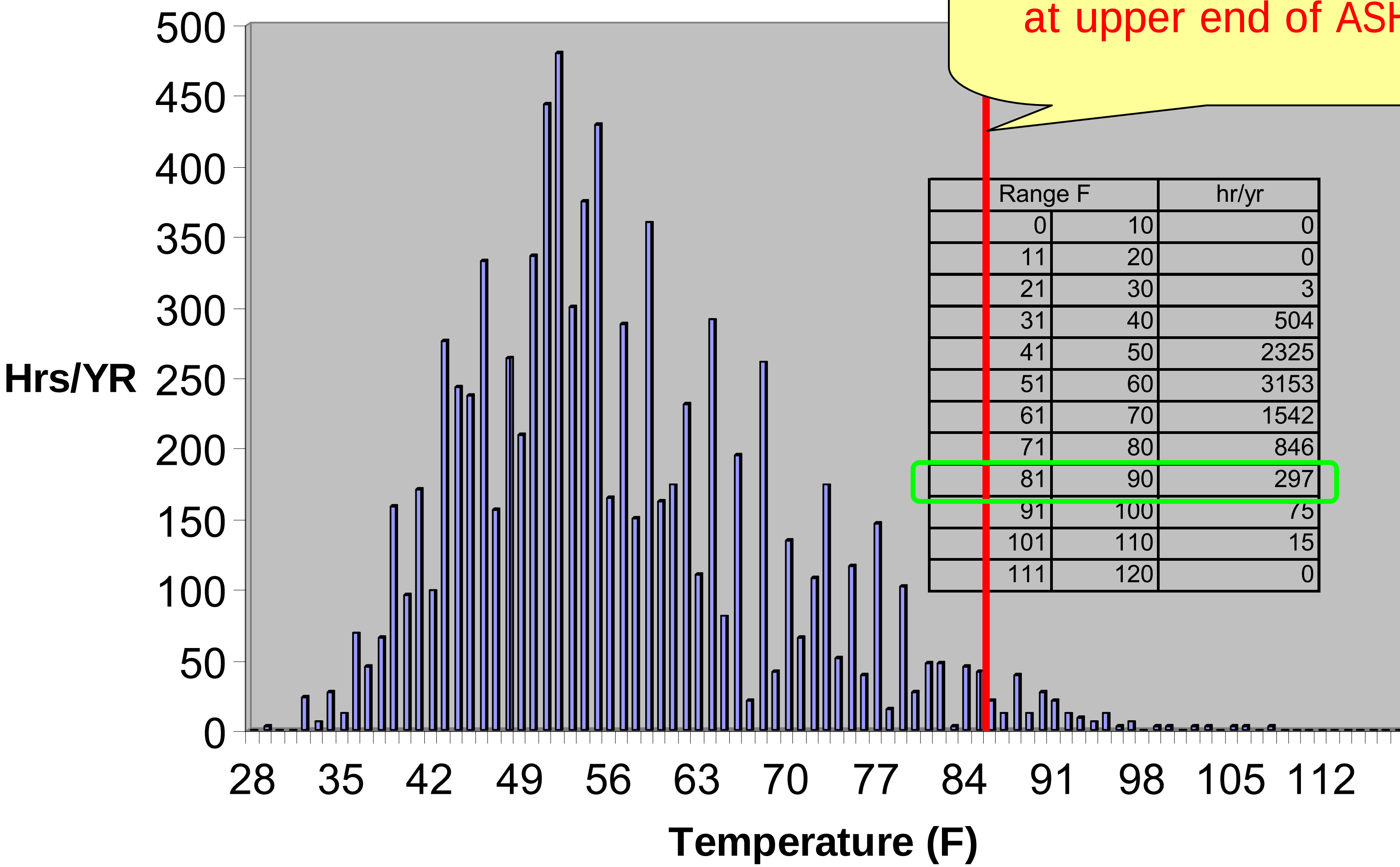


Encouraging use of Air Economizers

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

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

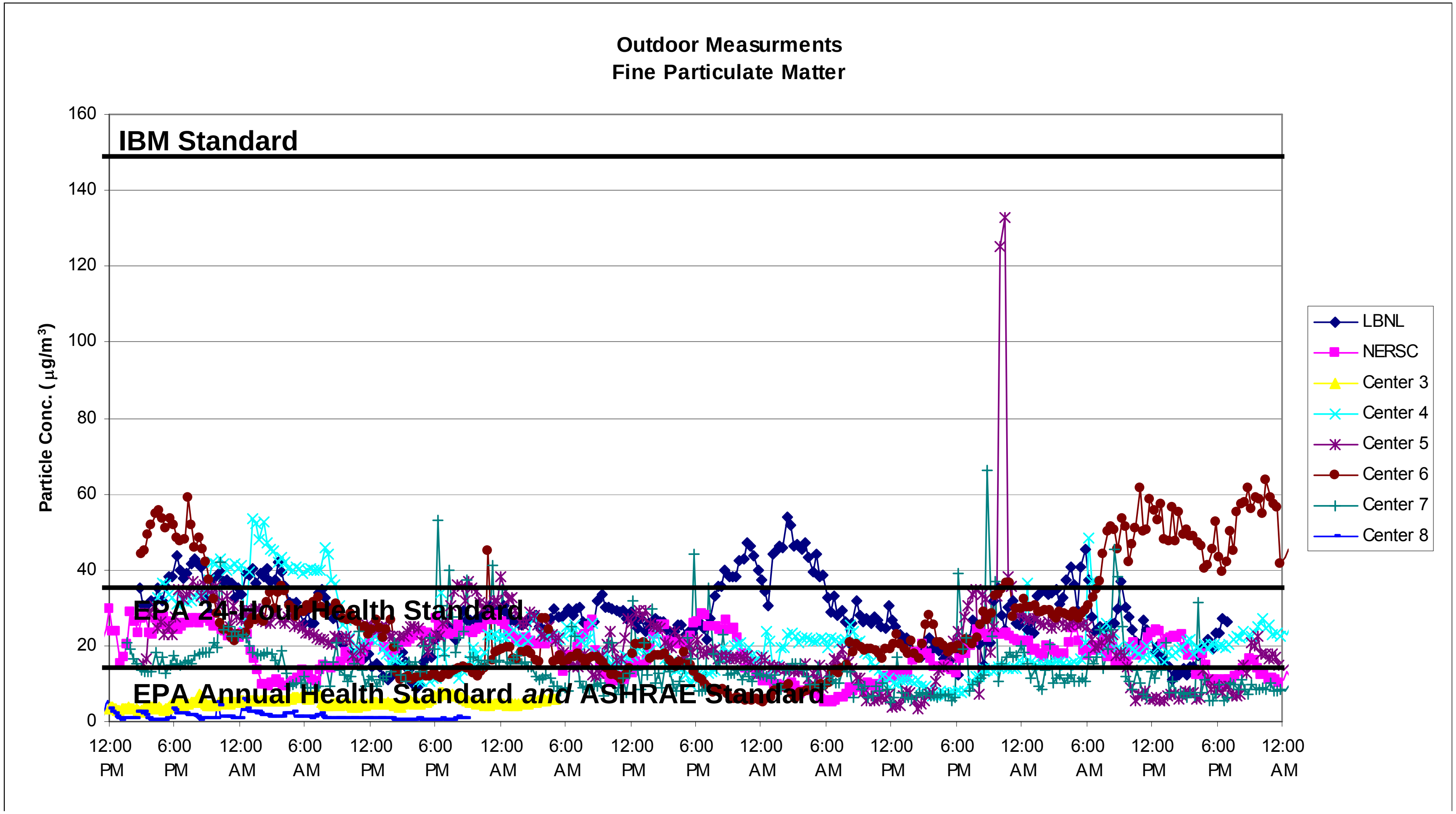
Berkeley Weather



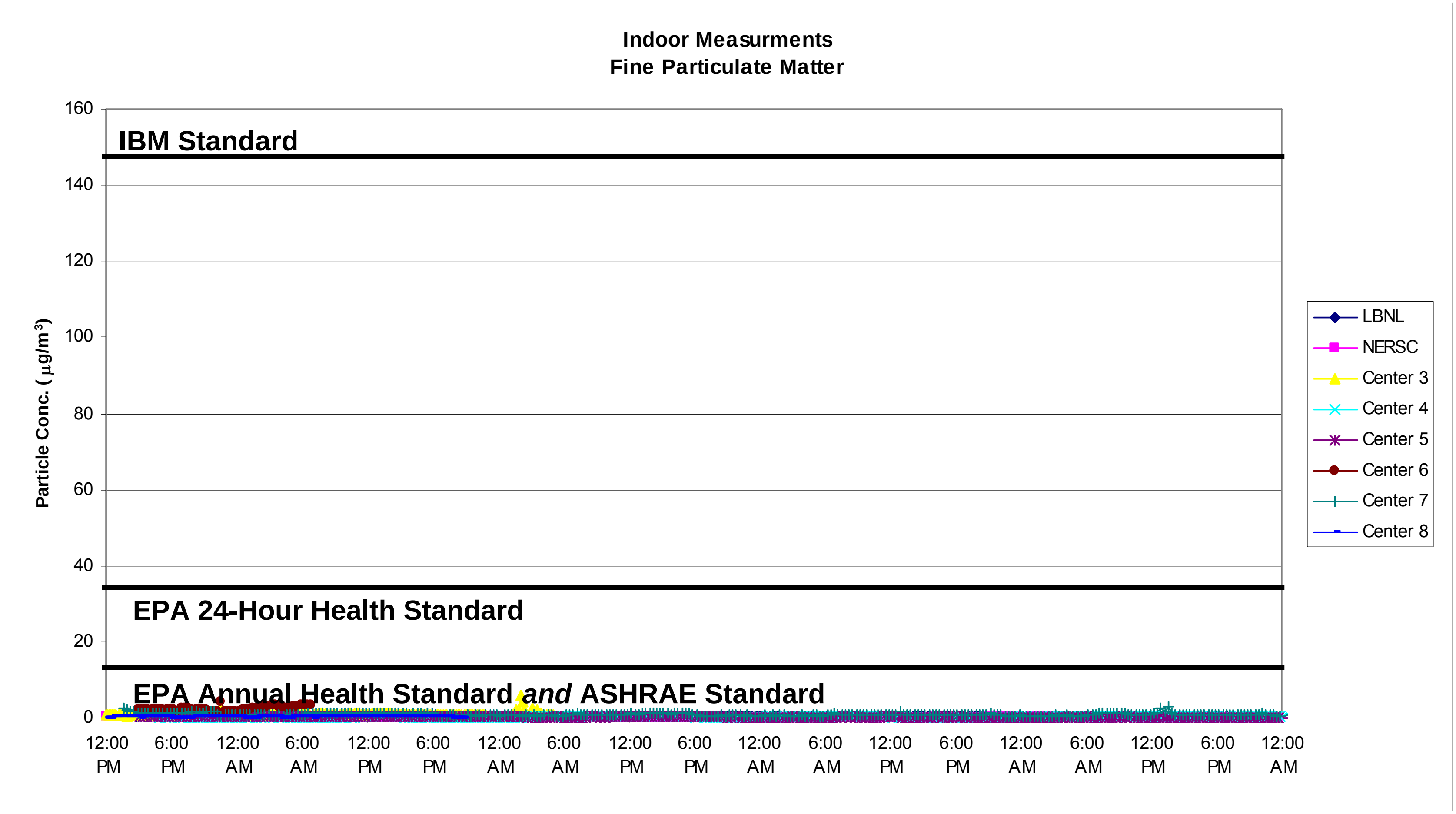
Inlet Temperature
at upper end of ASHRAE

Range F		hr/yr
0	10	0
11	20	0
21	30	3
31	40	504
41	50	2325
51	60	3153
61	70	1542
71	80	846
81	90	297
91	100	75
101	110	15
111	120	0

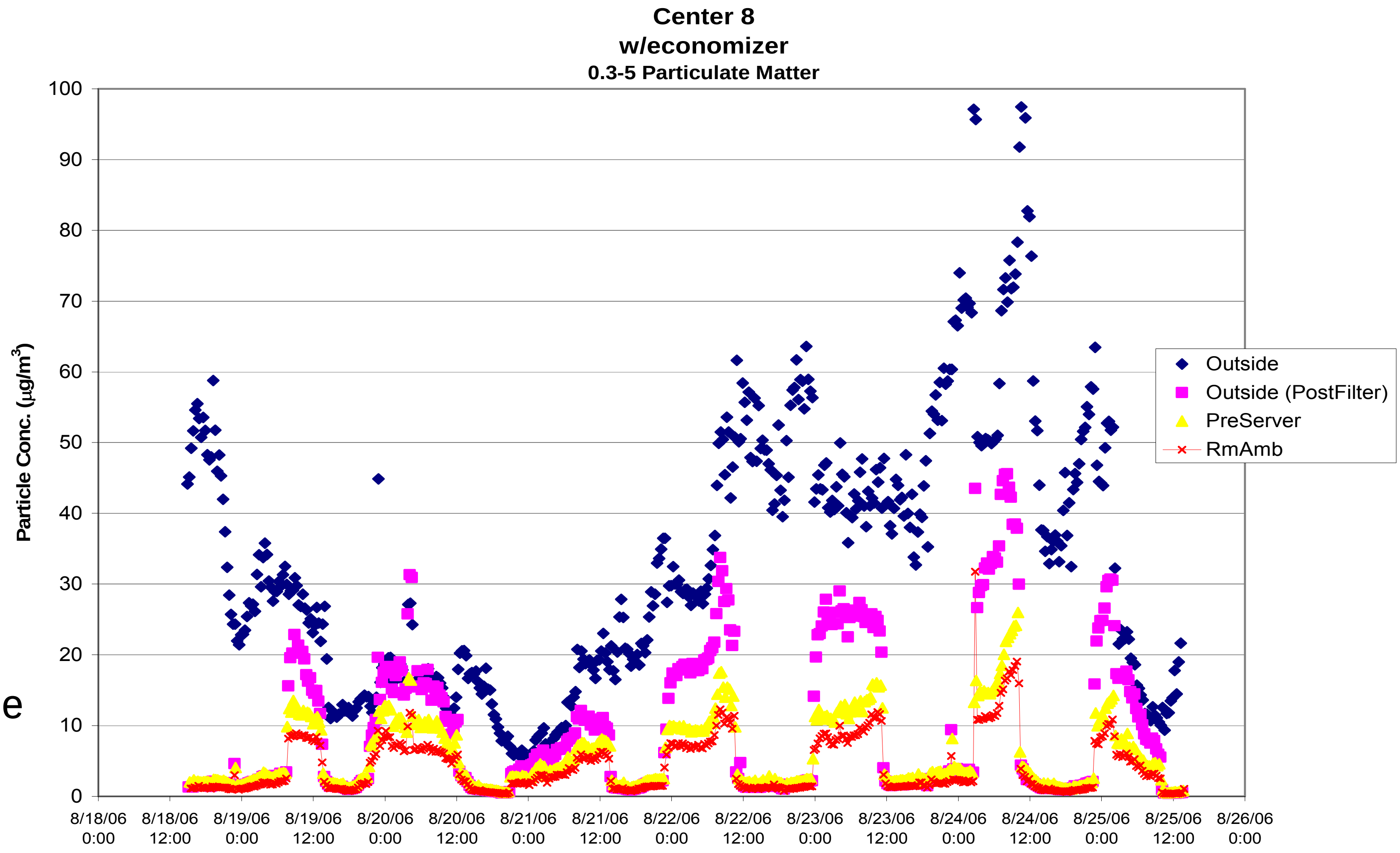
Outdoor measurements at 8 data centers



Measurements inside the centers



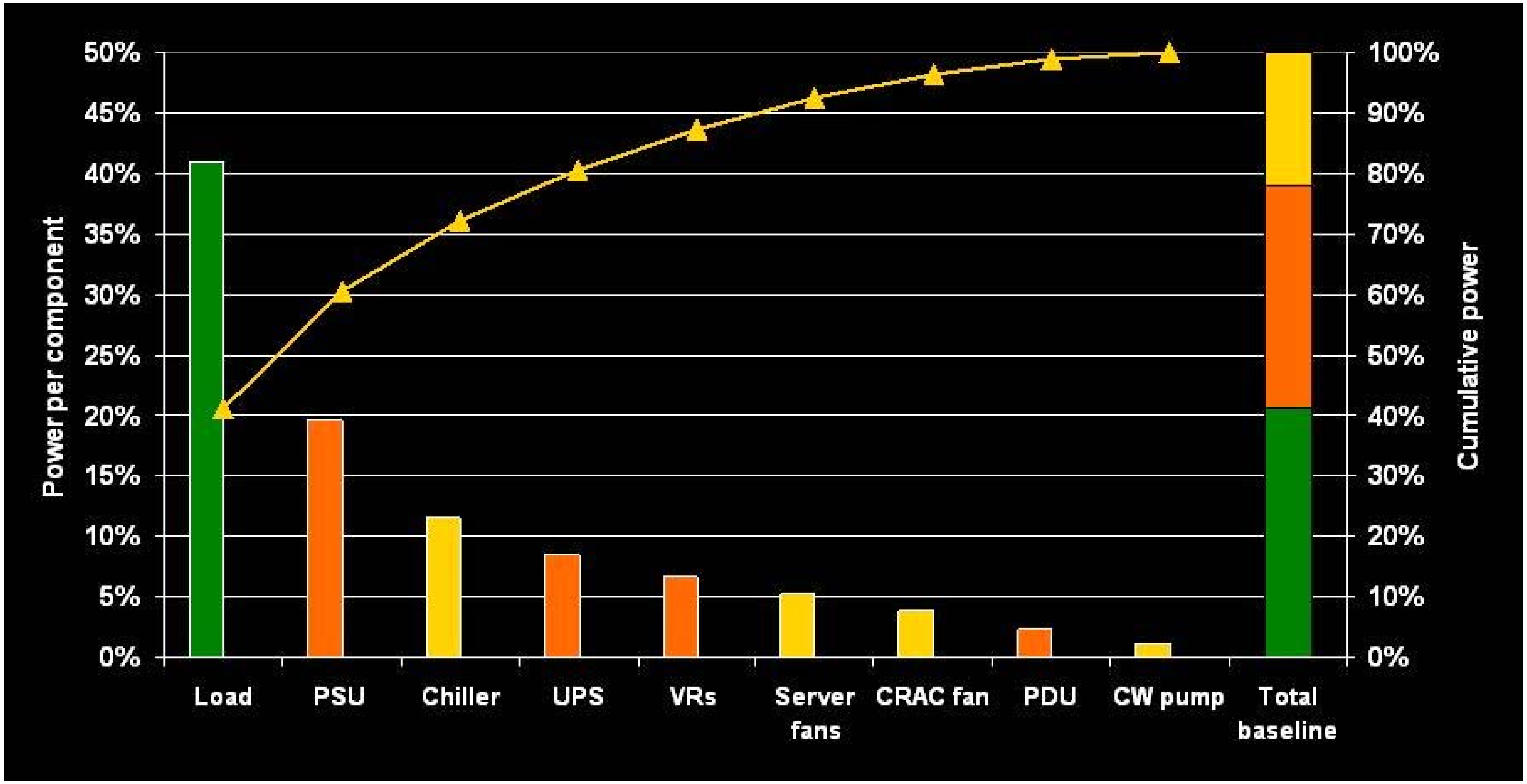
Data center w/economizer



Note Scale

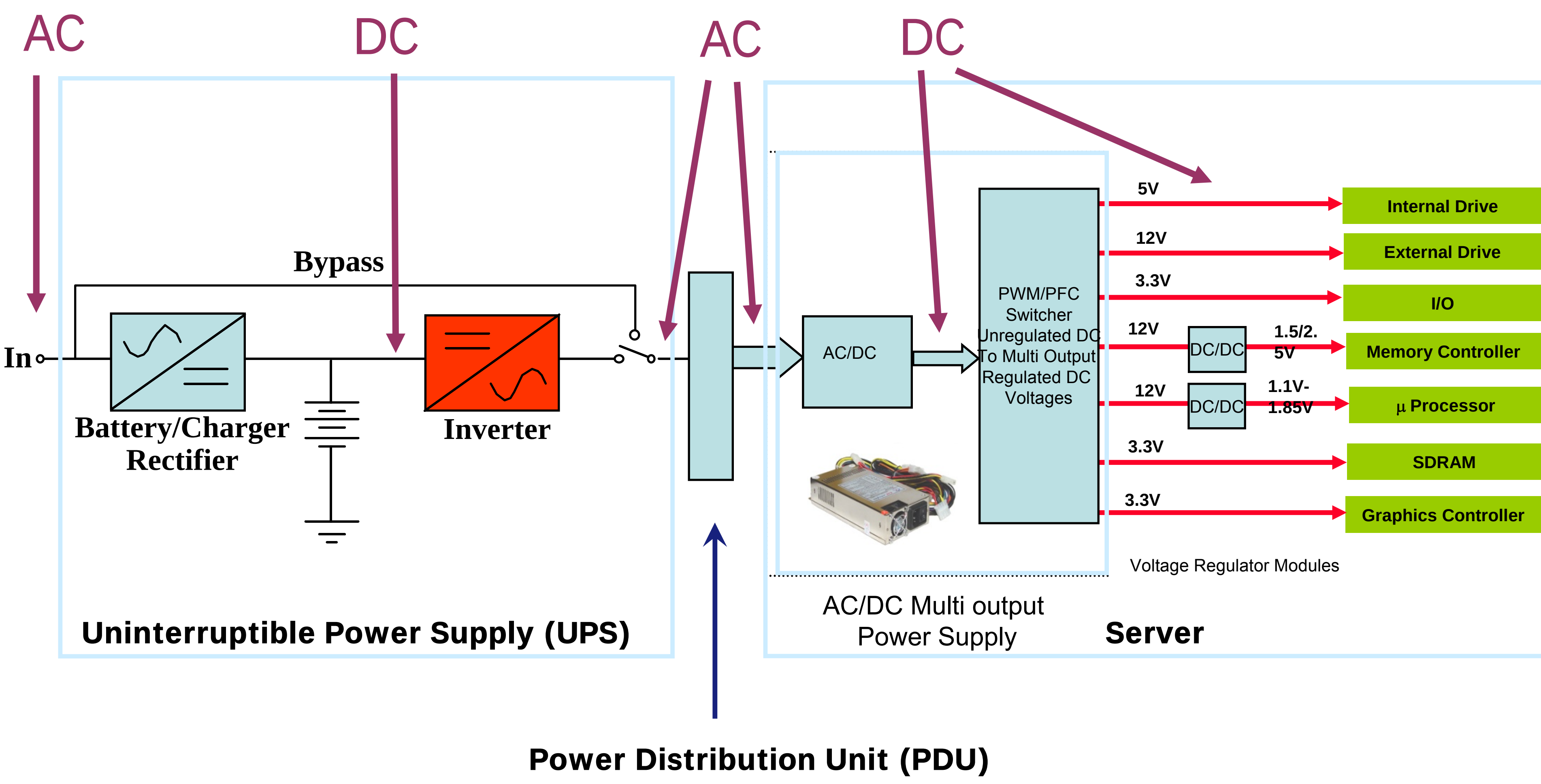
DC Power Demonstration

Overall Power Use in Data Centers



Courtesy of Michael Patterson, Intel Corporation

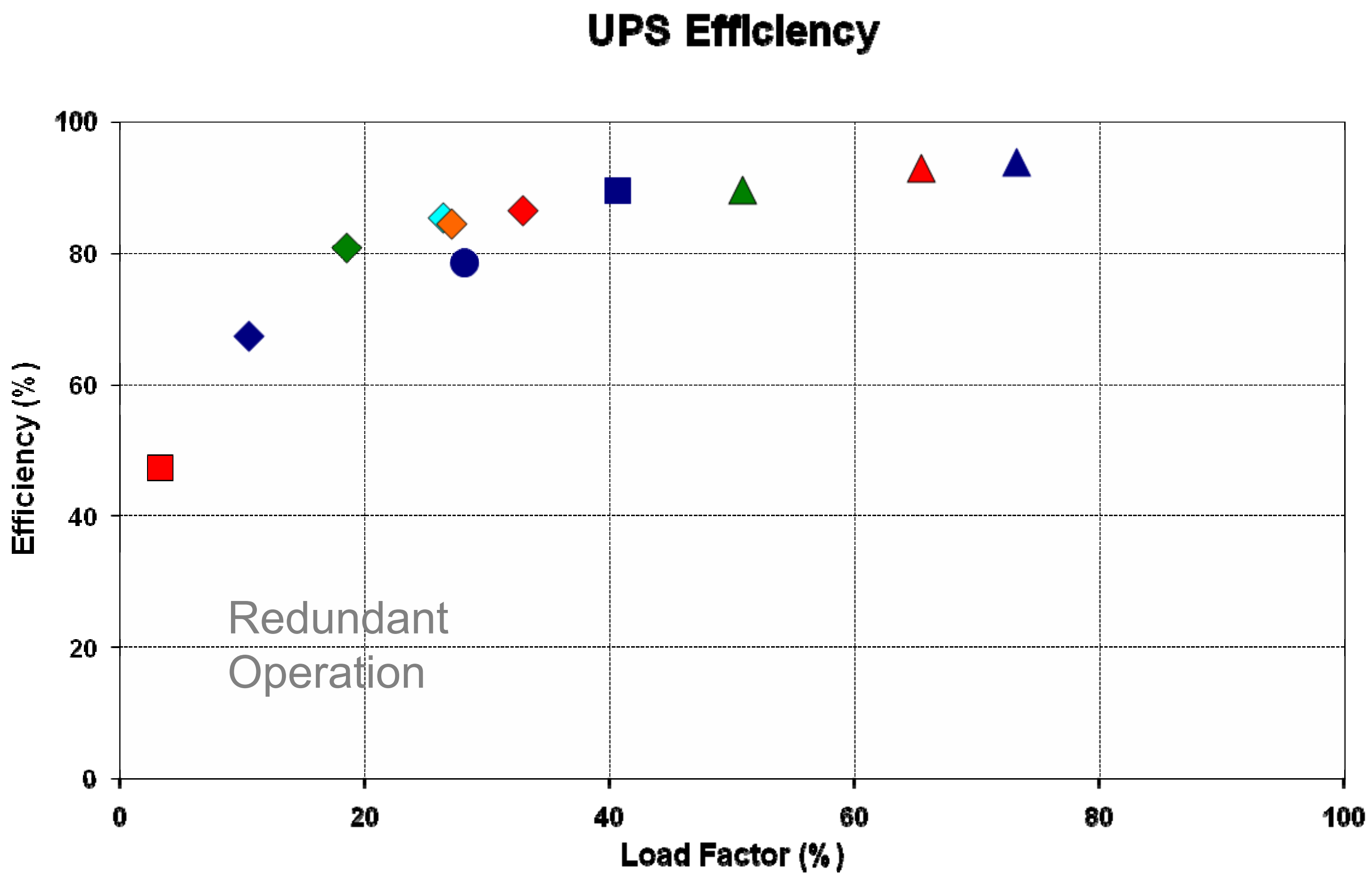
Data Center Power Conversions



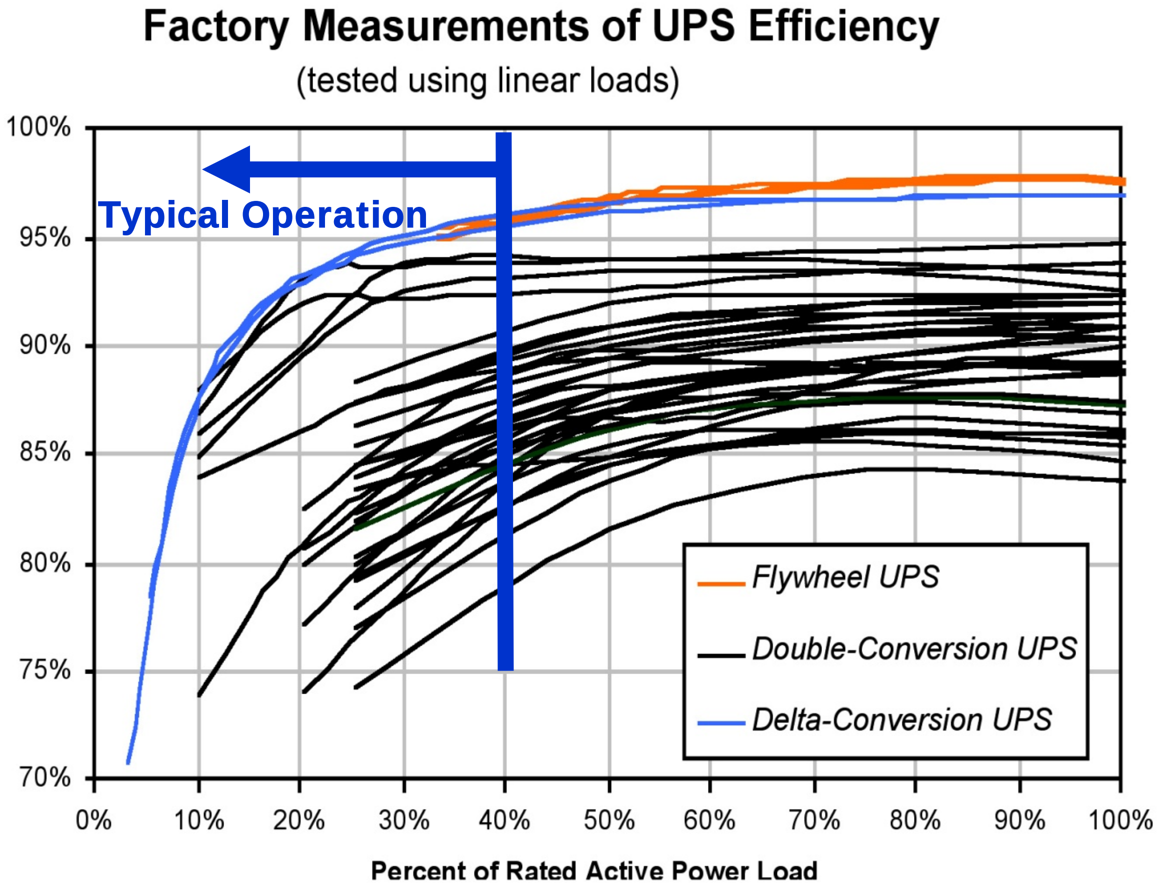
Electrical Distribution

- 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

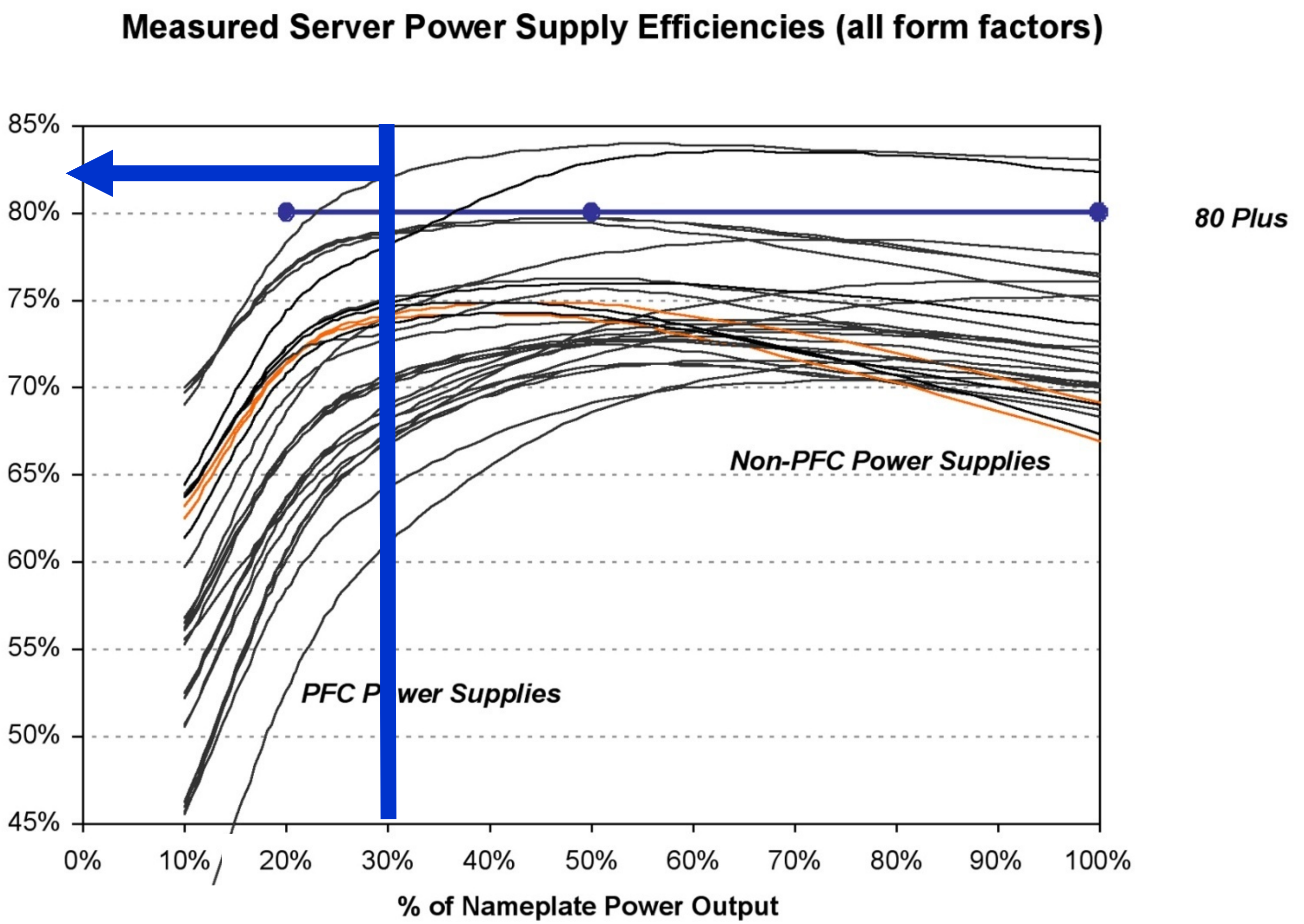
Measured UPS Efficiencies



UPS Factory Measurements

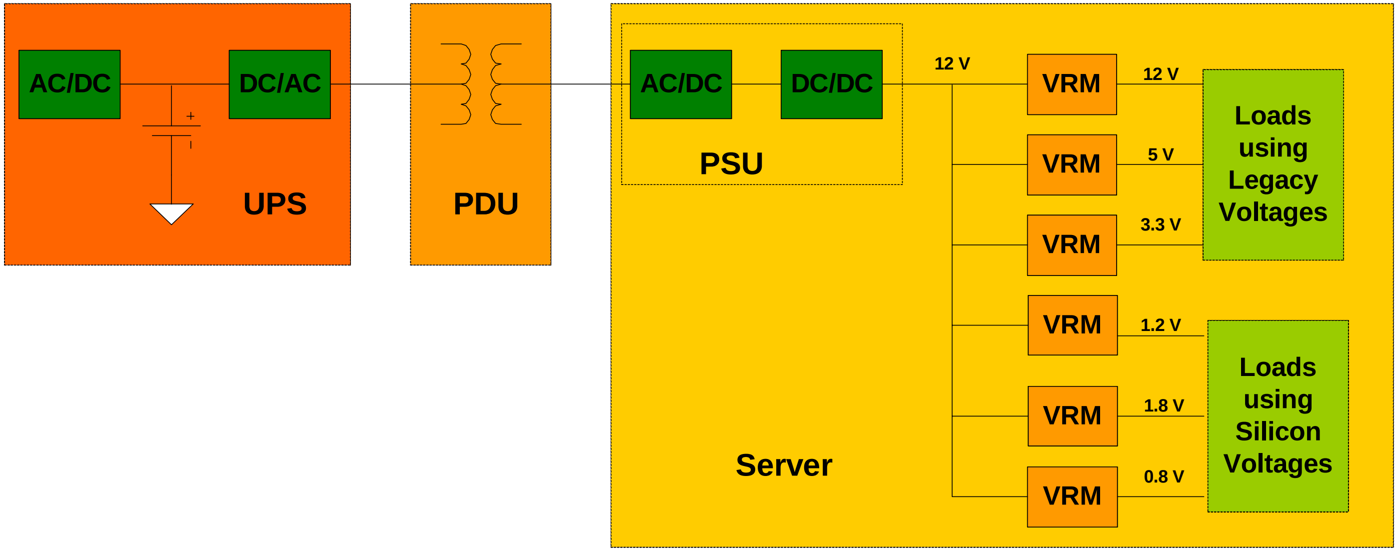


Measured Power Supply Efficiency

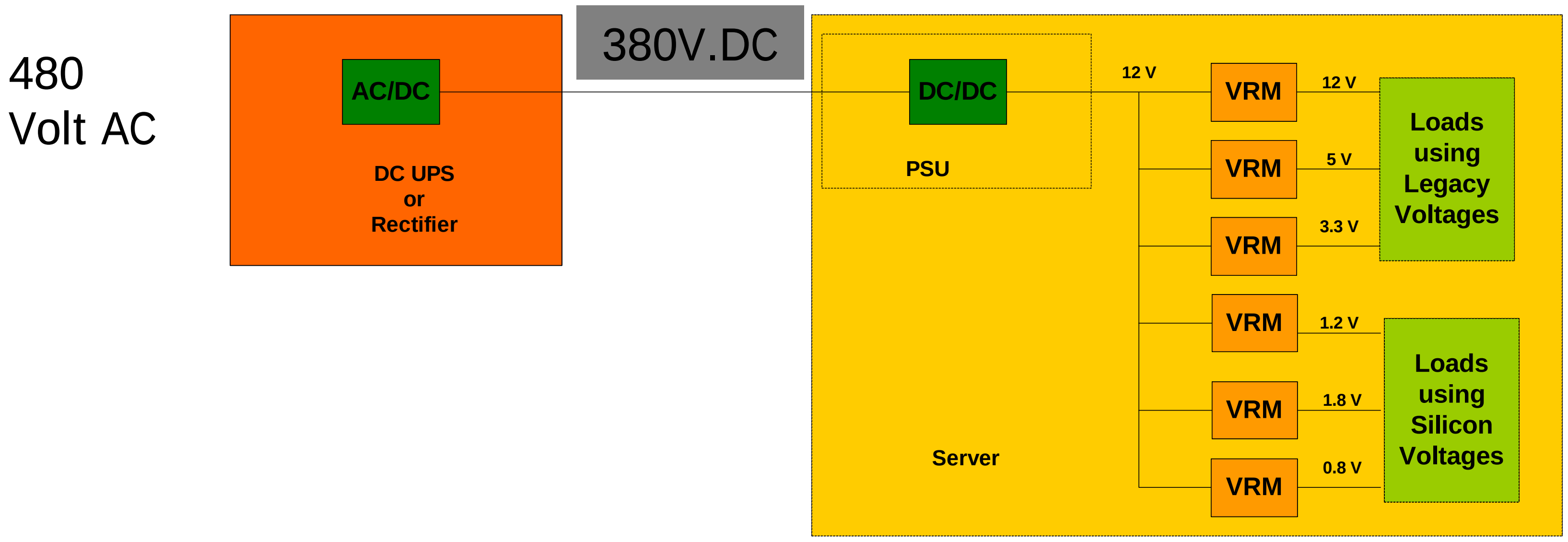


Typical AC Distribution Today

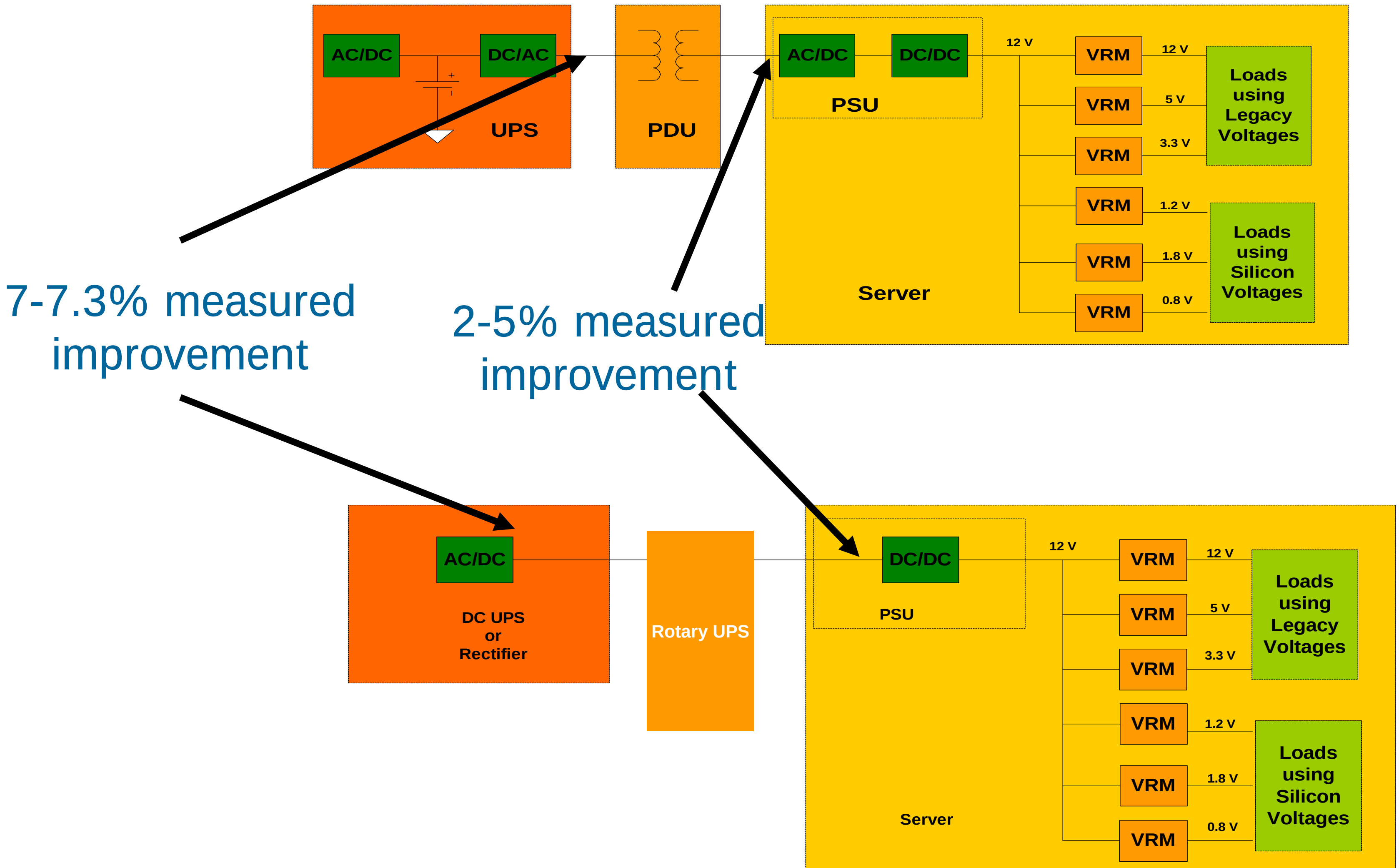
480
Volt AC



DC power distribution



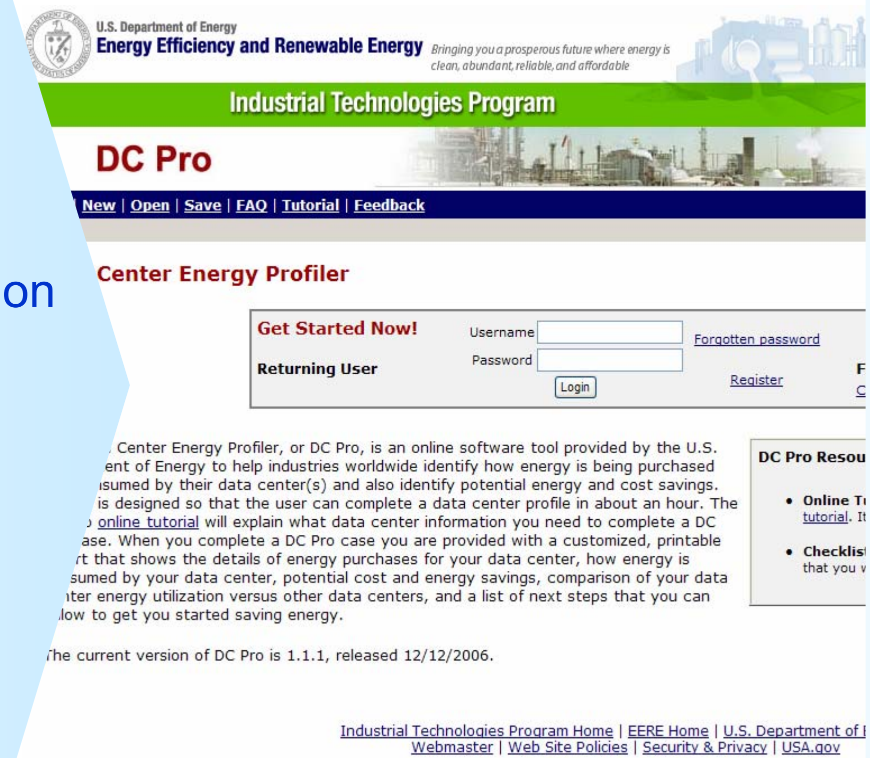
AC System Loss Compared to DC



"DC Pro" – Coming soon - An Online Tool

INPUTS

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



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

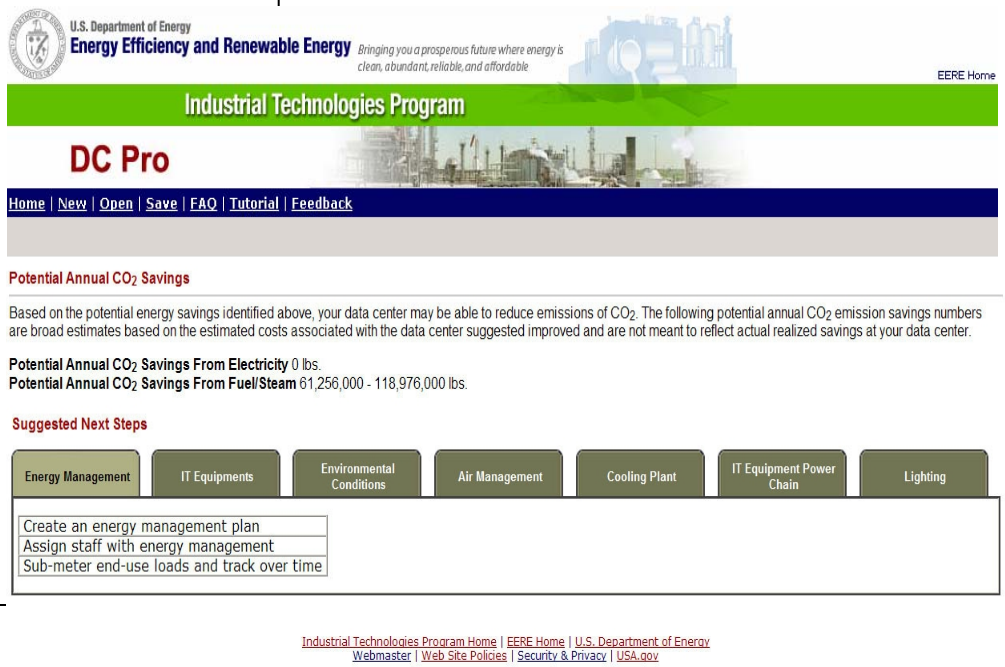
Energy Source

- 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 trans-formers upstream and down-stream 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



Save ENERGY Now

DOE Data Center program

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Information Tech. R&D program

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