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

Save ENERGY Now

Efficiency Opportunities in Data Centers September 3, 2009

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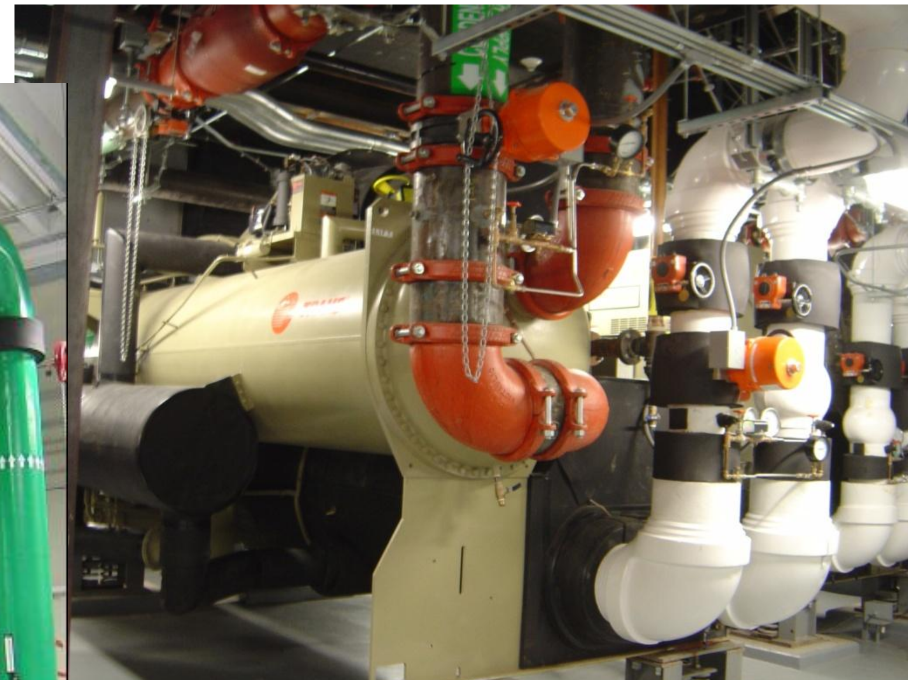
BERKELEY LAB

Think of Data Centers as INFORMATION FACTORIES…

- Data centers are energy intensive facilities
  - Server racks now designed for more than 25+ kW
  - Typical facility ~ 1MW, can be > 20 MW
  - Nationally 1.5% of US Electricity consumption in 2006
    - Projected to double in 5 years
  - Computing and storage are in growth mode

- Significant data center building boom
  - Power and cooling constraints in existing facilities
  - Building continues in down economy

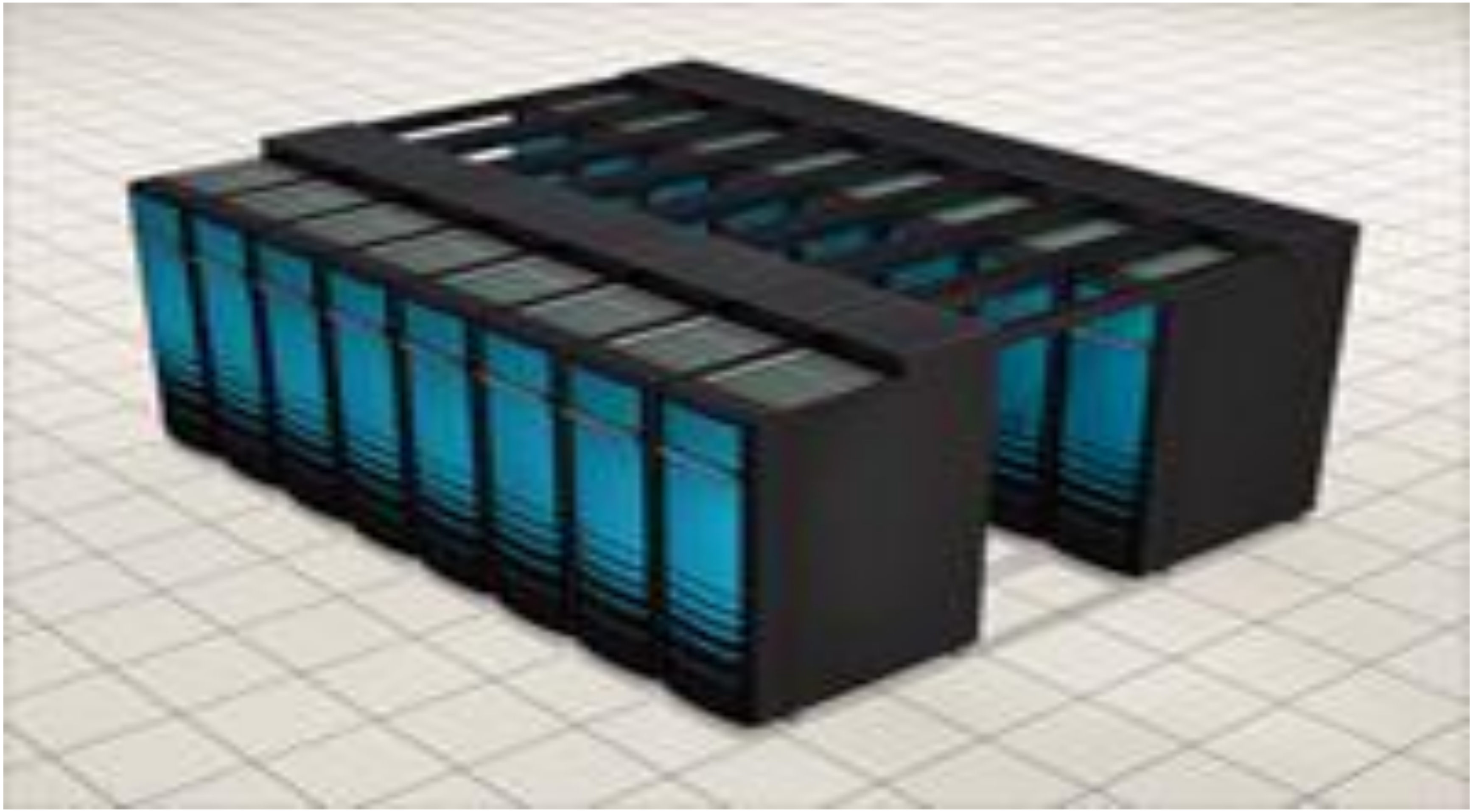
Data centers…
resemble large industrial facilities



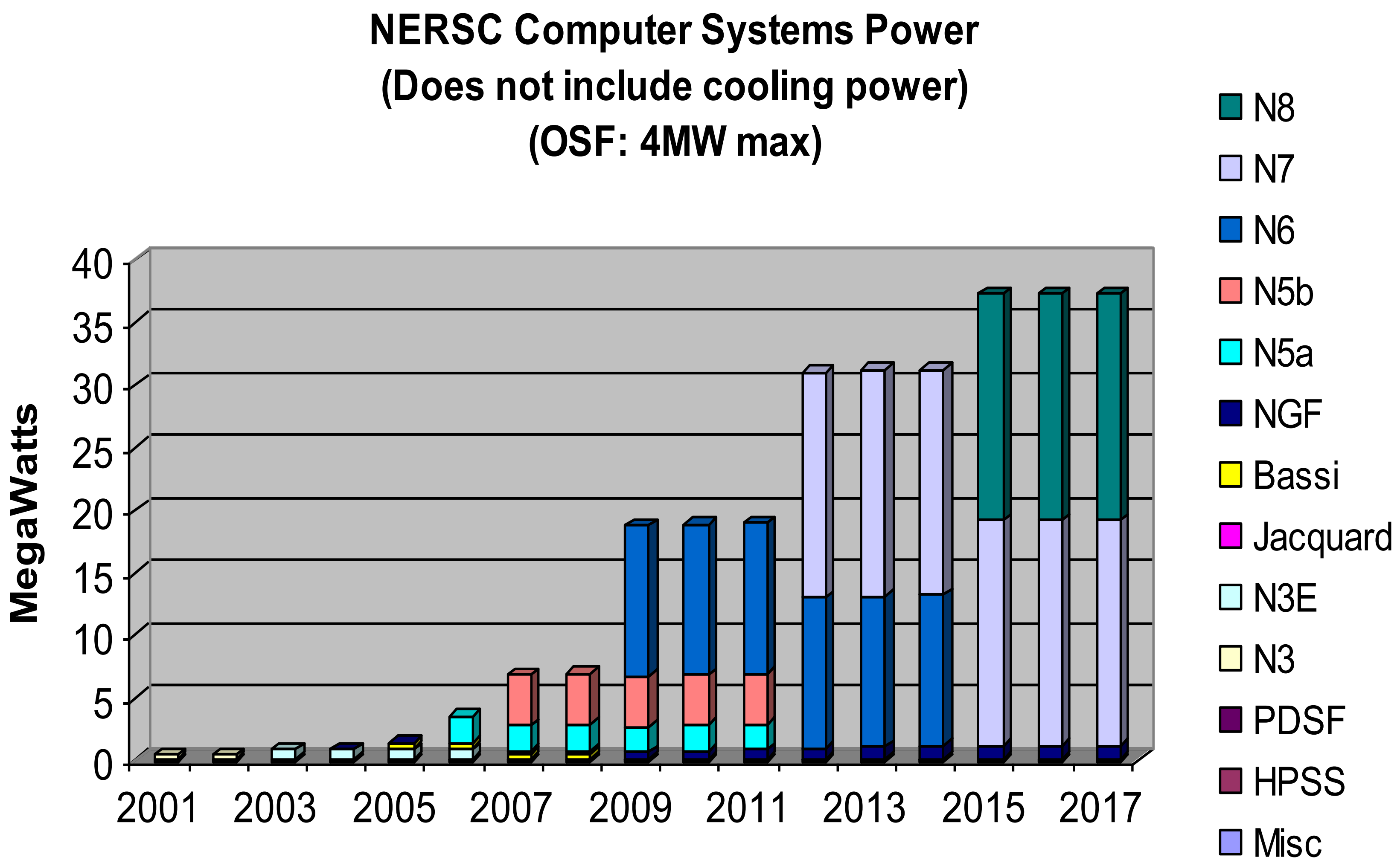

CONDENSER WATER RETURN

They also have specialized infrastructure

LBNL operates several data centers



LBNL super computer systems power:



Why best practices are important - the rising cost of ownership

- Cost of electricity and supporting infrastructure now surpasses the capital cost of IT equipment

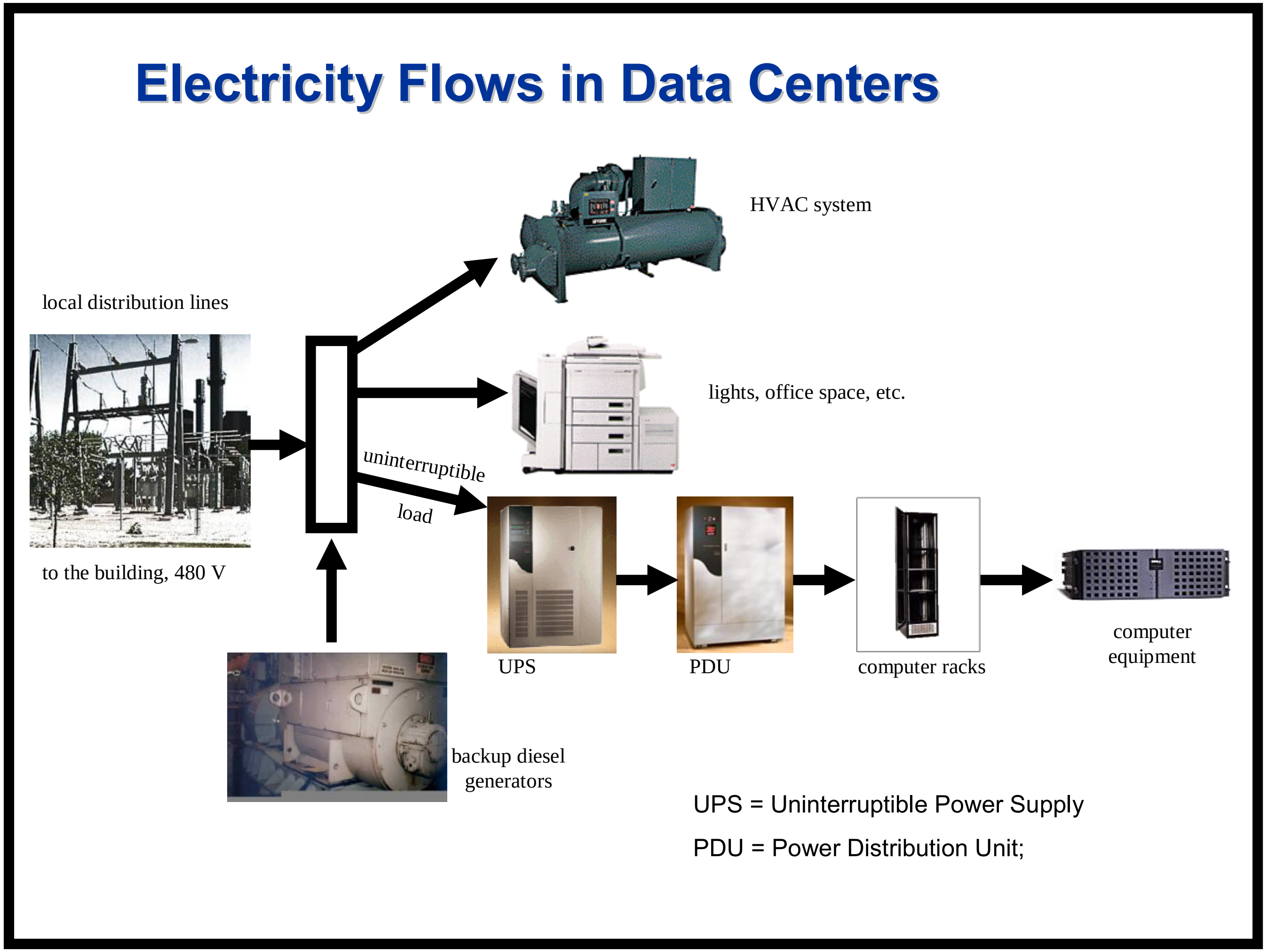
- Perverse incentives -- IT and facilities budgets are controlled in different parts of the organization

Source: The Uptime Institute, 2007

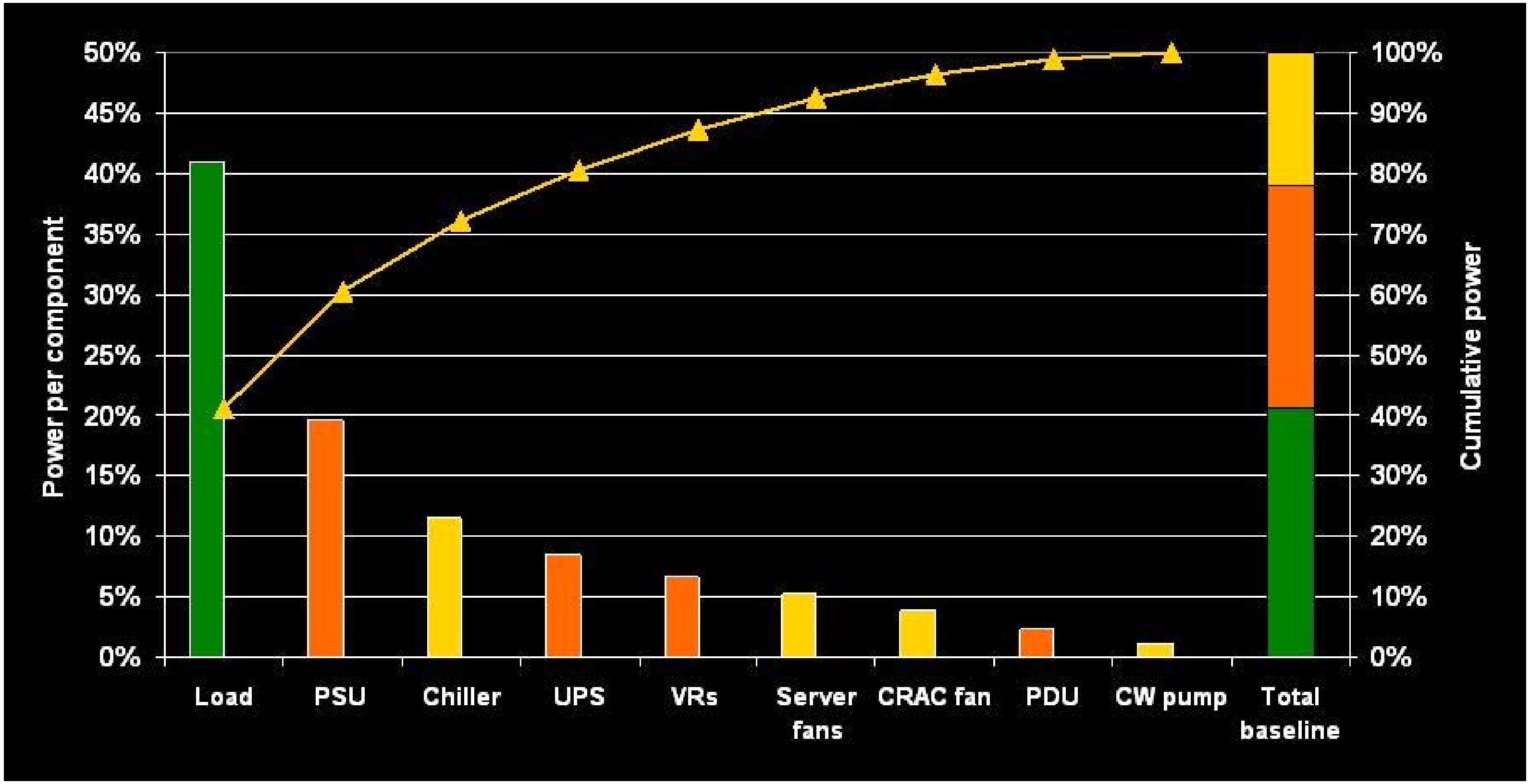
But are there potential savings?

- 20-40% savings are typically possible
- Aggressive strategies – better than 50% savings
- Paybacks are short – 1 to 3 years are common
- Potential to extend life and capacity of existing data center infrastructure but this also could allow for more IT equip – raising total energy use
- Most don’t know if their center is good or bad

Benchmarking energy end use



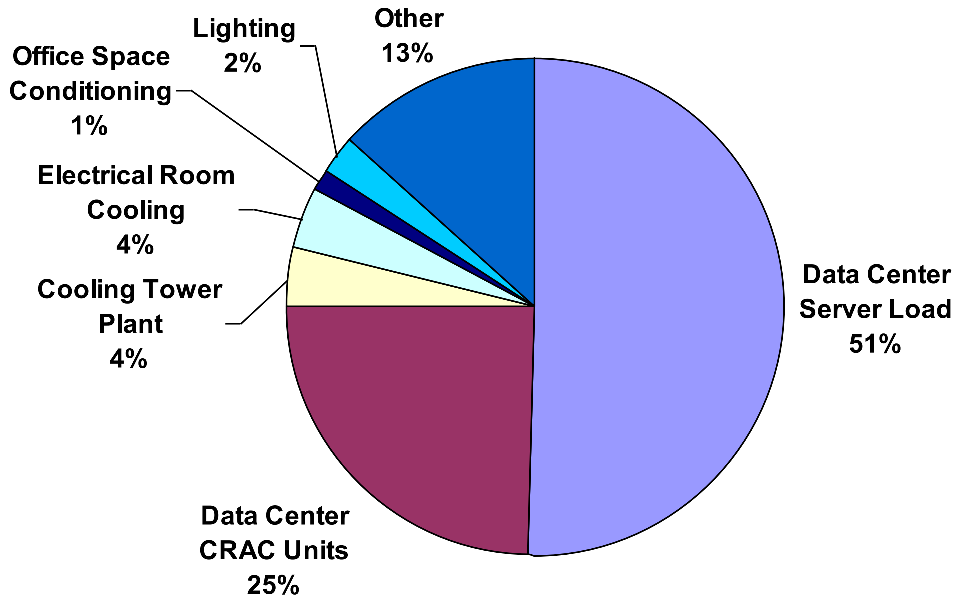
Electrical end use in one center

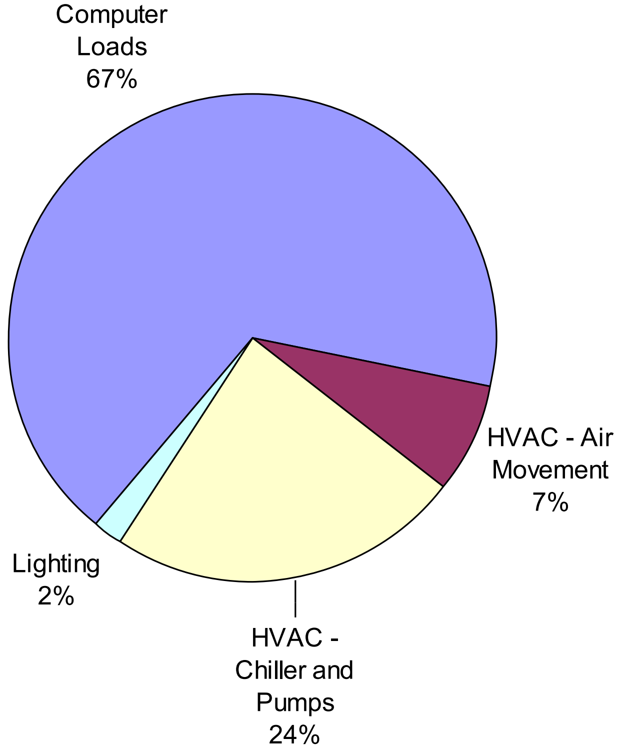


Courtesy of Michael Patterson, Intel Corporation

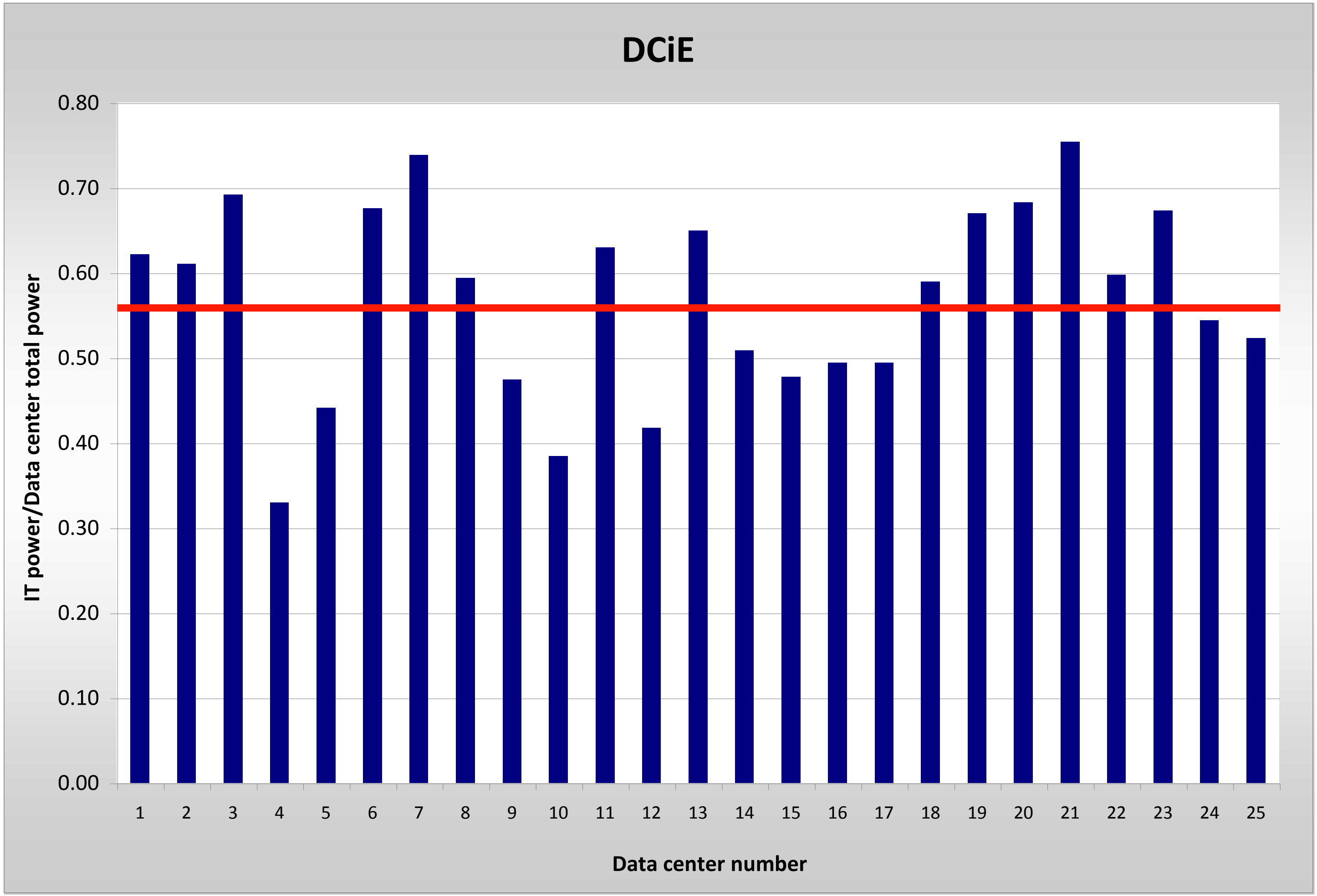
Your mileage will vary

The relative percentages of the energy doing computing varied considerably.





High level metric – IT/total



Average .57

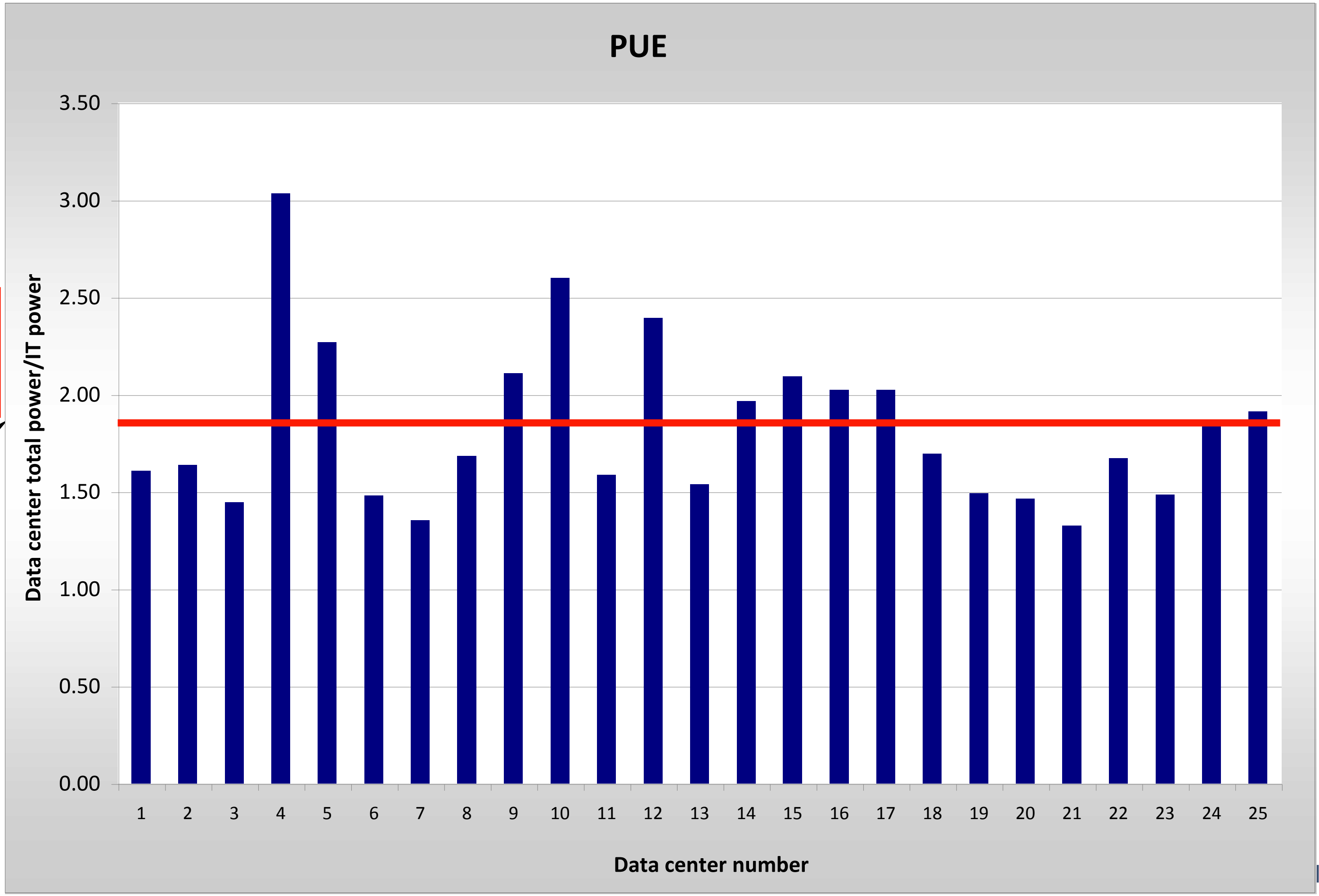
Higher is better

Source: LBNL

Inverse metric —total/IT (PUE)

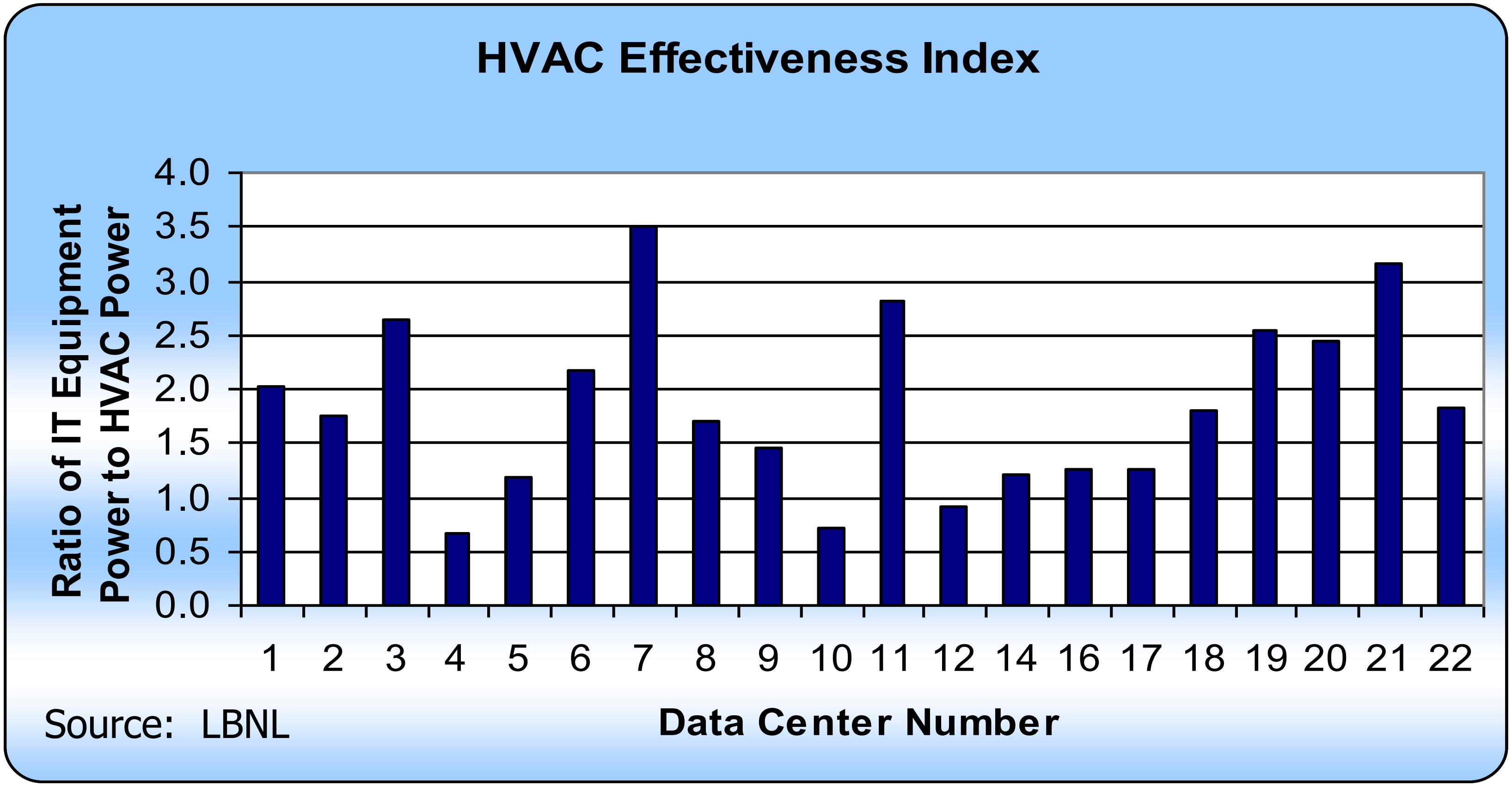
Average 1.83

Lower is better

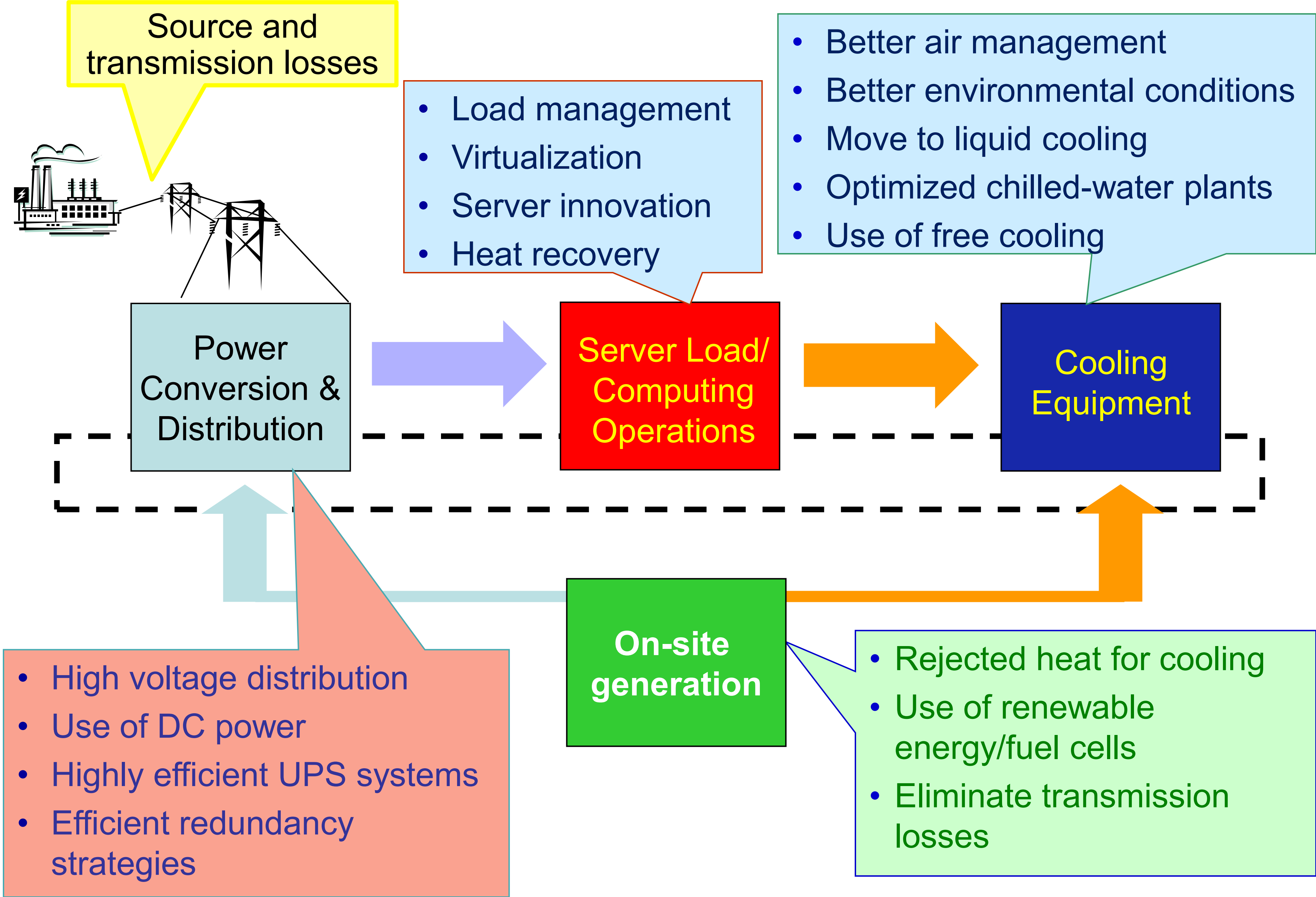


HVAC system effectiveness

We observed a wide variation in HVAC performance



Efficiency opportunities are everywhere



Data center efficiency opportunities

Benchmarking over 30 centers consistently lead to opportunities

No silver bullet

Lots of silver bb's

Many areas for improvement…

Cooling

- Air Management
- Free Cooling – air or water
- Environmental conditions
- Centralized Air Handlers
- Low Pressure Drop Systems
- Fan Efficiency
- Cooling Plant Optimization
- Direct Liquid Cooling
- Right sizing/redundancy
- Heat recovery
- Building envelope

Electrical

- UPS and transformer efficiency
- High voltage distribution
- Premium efficiency motors
- Use of DC power
- Standby generation
- Right sizing/redundancy
- Lighting – efficiency and controls
- On-site generation

IT

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

Use the DC Pro tool suite to identify opportunities

- Use the Profiling Tool to:
  - Establish DCIE baseline and improvement potential
  - Identify potential areas for improvement
  - Track progress in DCiE over time
- Use Assessment tools to evaluate improvement measures in more in-depth
  - Suite of tools address various areas of data center
  - Provides savings for efficiency actions
  - Assessment tool development is in progress
  - Not an investment grade audit

DC Pro tools

High Level Profiling Tool

- Overall energy performance (baseline) of data center
- Performance of systems (infrastructure & IT) compared to benchmarks
- Prioritized list of energy efficiency actions and their savings, in terms of energy cost ($), source energy (Btu), and carbon emissions (Mtons)
- Points to more detailed system tools

IT Module

- Servers
- Storage
- Network
- Software

Cooling

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

Air Management

- hot cold separation
- environmental conditions

Electrical Systems

- UPS
- Transformers
- Lighting
- Standby gen.

On-Site Gen

- Renewables
- use of waste heat

Where to focus to improve efficiency? Best practice opportunities

- IT equipment – reduce the load at the source
- Environmental conditions – most centers are not optimal
- Free cooling – many locations can employ free cooling
- UPS and PDU efficiency – efficient power conversions
- Air Management – enables efficiency measures
- Humidity Control – a common problem in data centers

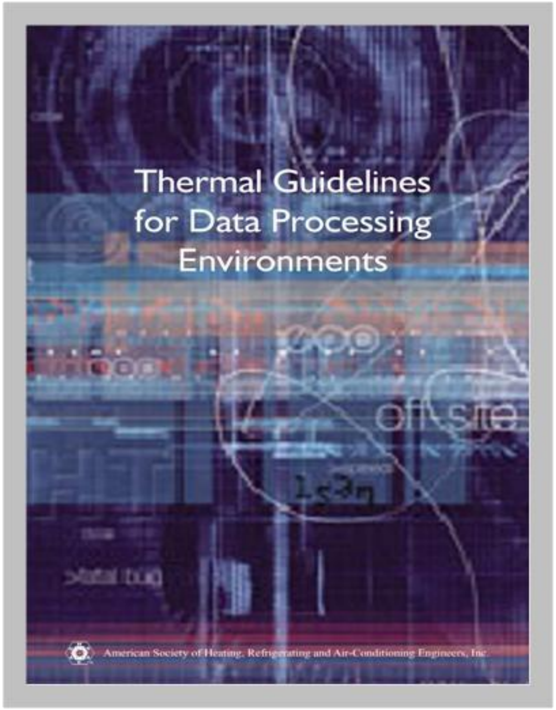
IT Equipment

- Specify Energy Star Servers
- Power Supplies
  - Investigate need for redundancy
  - Specify highly efficient power supplies
- Enable power management
- Virtualization – many applications on each computer increasing processor utilization
- Storage options
  - De-duplication
  - Reduce spinning discs
- Environmental conditions – see manufacturers recommendations for temperature and humidity

IT equipment power supply efficiency

Environmental Conditions

- Most centers are over cooled and have humidity control issues
- ASHRAE and IT equipment manufacturers have established recommended and allowable conditions for air delivered to the intake of the computing equipment
- Some manufacturers design for even harsher conditions
- Design for computer comfort – not people comfort
- Most data center computer room air conditioners are controlling the air returning to the unit



Environmental conditions

- Prior to ASHRAE's Thermal Guidelines, there were NO published multi-vendor or vendor neutral temperature and humidity guidelines.
- Perceptions today lead many data centers to operate much cooler than necessary; often less than 68 °F.
- ASHRAE's Thermal Guidelines have a RECOMMENDED temperature range of 18 °C (64.4 °F) to 27 °C (80.6 °F).
- The Recommended Range is a "statement of reliability" which means that operating within the range is safe.
- Although this wider band may feel strange, it is endorsed by IT manufacturers and can potentially enable SIGNIFICANT energy savings such as the use of economizers.

Table 2.1 - Equipment Environment Specifications							
Class	Product Powered 'On' - 2008 Recommended Environmental Envelope						
	Dry Bulb Temperature ^{o}C (^{o}F)		% Relative Humidity		Recommended Dew Point ^{o}C (^{o}F)		Max Rate of Change ^{o}C (^{o}F) / hr
	Allowable	Recommended	Allowable	Recommended	Minimum	Maximum	
1	15 to 32 (59 to 90)	18 to 27 (64 to 81)	20 to 80	Max. 60	5.5 (42)	15 (59)	5 (9)
2	10 to 35 (50 to 95)	18 to 27 (64 to 81)	20 to 80	Max. 60	5.5 (42)	15 (59)	5 (9)
3	5 to 35 (41 to 95)	NA	8 to 80	NA	NA	28 (82)	NA
4	5 to 40 (41 to 104)	NA	8 to 80	NA	NA	28 (82)	NA

Environmental Specifications are based on a maximum elevation of 3,050 meters
(10,000 feet)

Free cooling

- An Economizer is an HVAC device used to reduce energy consumption by leveraging environmental temperature differences to achieve efficiency improvements.

- Translation -
  - Air side - open the window
  - Water side - use cooling towers and heat exchanger and turn off chillers
  - Other economizer configurations

Where can I do free cooling?

The Green Grid Organization produced a tool to show the available hours for free cooling in the US by zip code

http://www.thegreengrid.org/en/sitecore/content/Global/Content/Tools/NAmericanFreeCoolingTool.aspx

the green grid™
get connected to efficient IT

Free-Cooling Estimated Savings

US/CANADA LOCATION (ZIP CODE): 73034

DEGREES IN: ○ FAHRENHEIT ◉ CELSIUS

ALLOW MIXING OF SUPPLY AND RETURN AIR ☑

ALLOW HUMIDIFICATION ☑

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

CALCULATE

RESET FORM

HELP

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

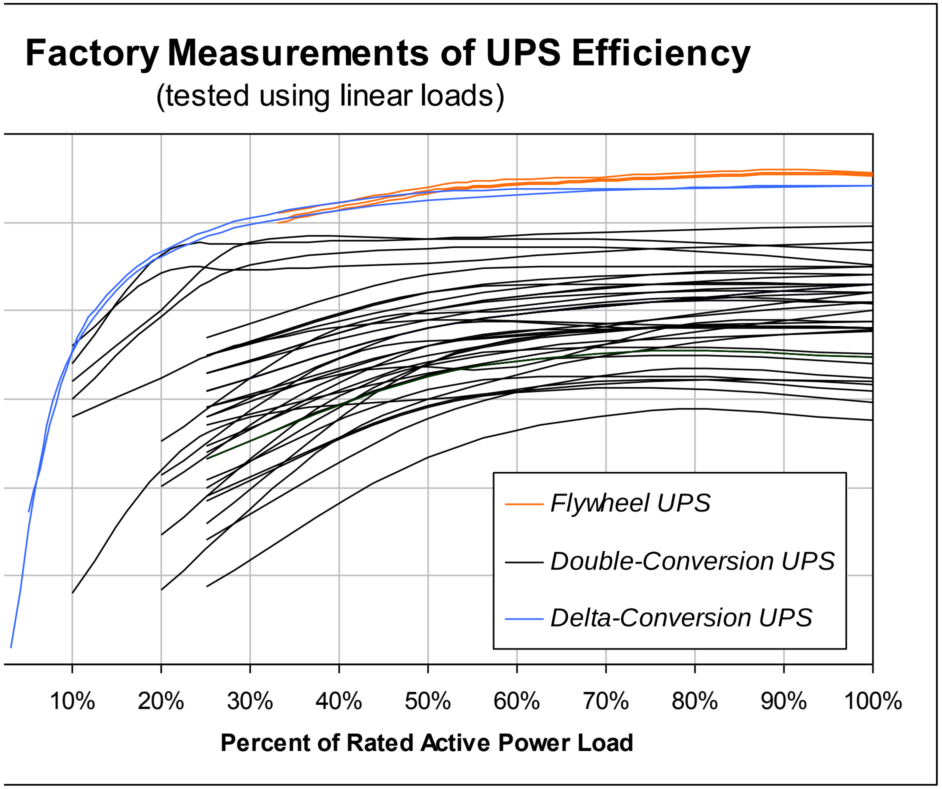
HOURS MEETING CRITERIA FOR FREE-AIR COOLING:

ESTIMATED SAVINGS USING FREE-AIR COOLING:

HOURS MEETING CRITERIA FOR WATER SIDE ECONOMIZER:

UPS systems, transformers, and PDUs efficiency

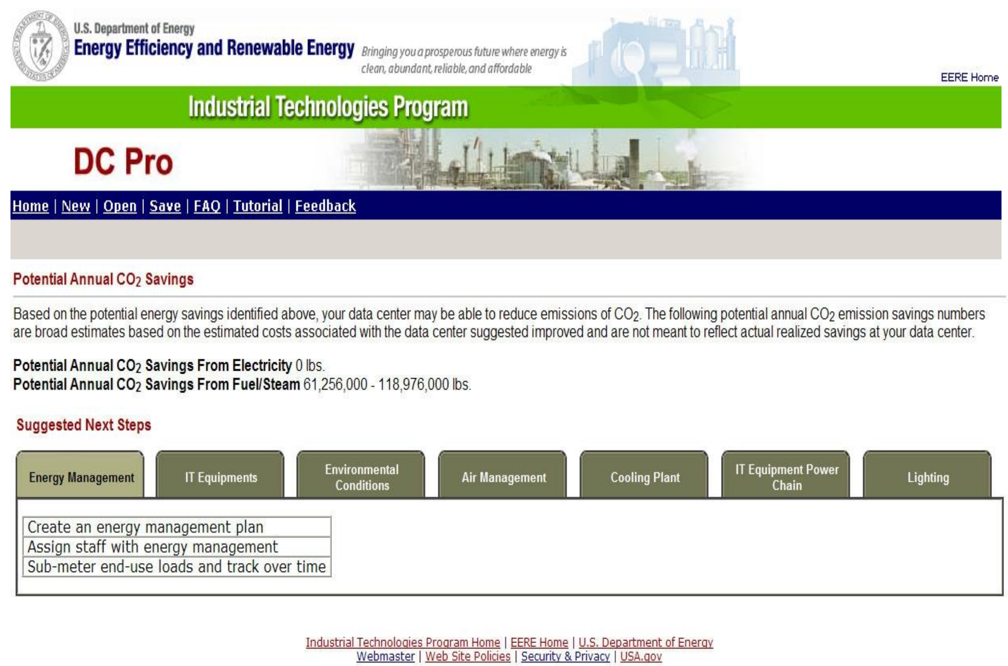
- Efficiencies vary with system design, equipment, and load
- Redundancies will always impact efficiency



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



Electrical Distribution Assessment tool

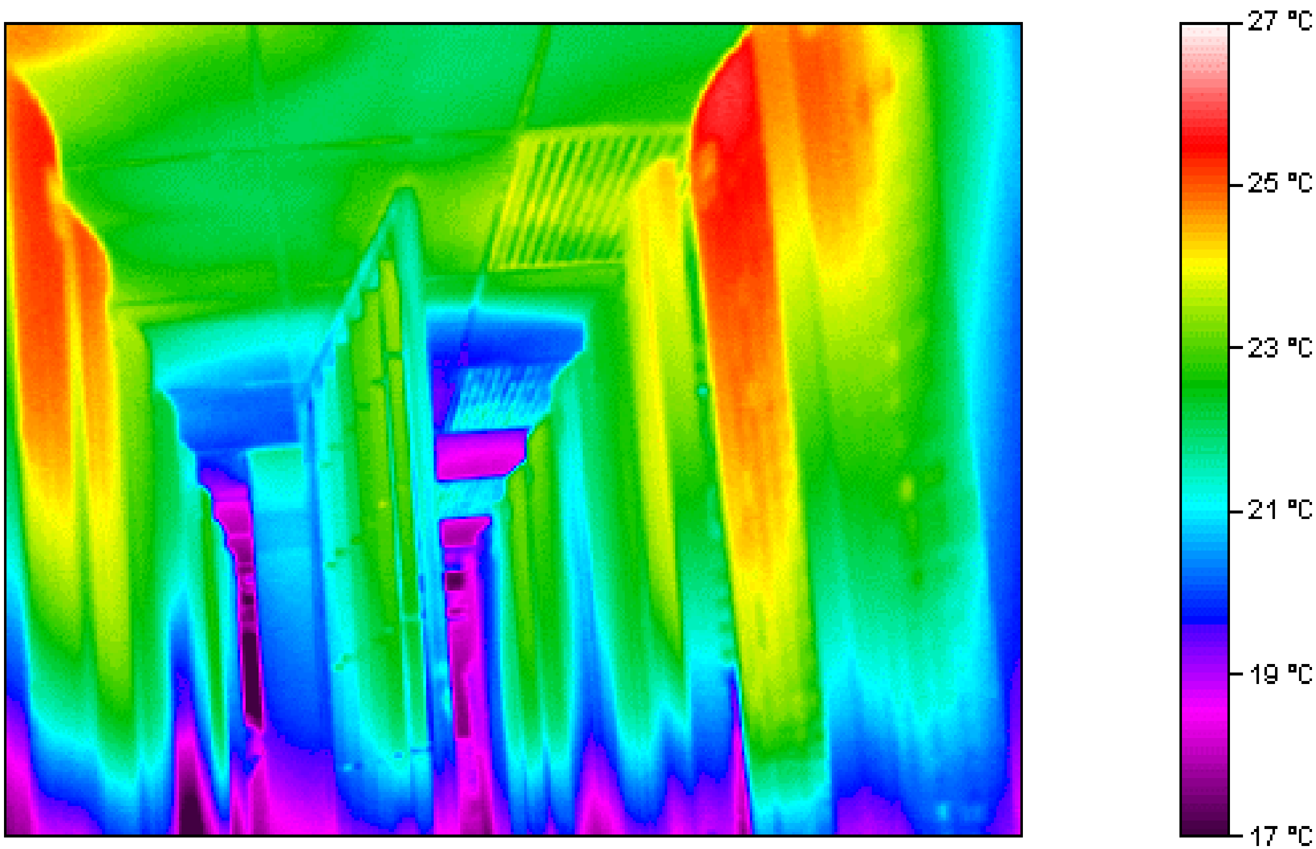
- An Excel assessment tool is available for trial use
- Tool quantifies potential savings
- More in-depth questions to analyze options

Air Management

- Short circuiting of air is common in most data centers
- Getting the right amount of air delivered to the intakes of the IT equipment is the goal
- To achieve this careful attention to air paths is required
- When measures are in place, savings come about in two ways:
  1. Airflow can be reduced resulting in fan energy savings
  2. High temperature return allows coils to be more efficient

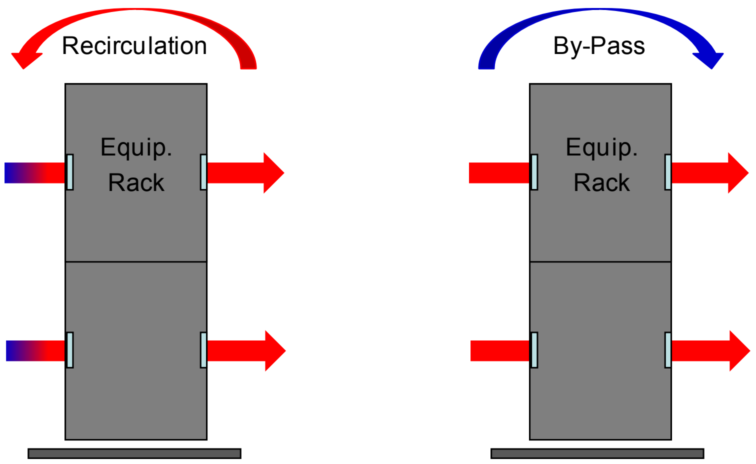
Visualize the problem

Infrared thermography

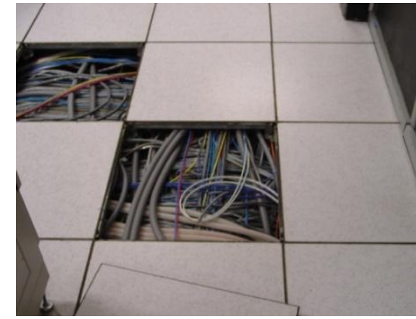


Aspects of Air Management

The goal of Air Management is always to minimize mixing of hot and cold air streams. Minimizing air *recirculation* of hot air and minimizing *by-pass* of cold air. Both measures can result in energy savings and better thermal conditions.



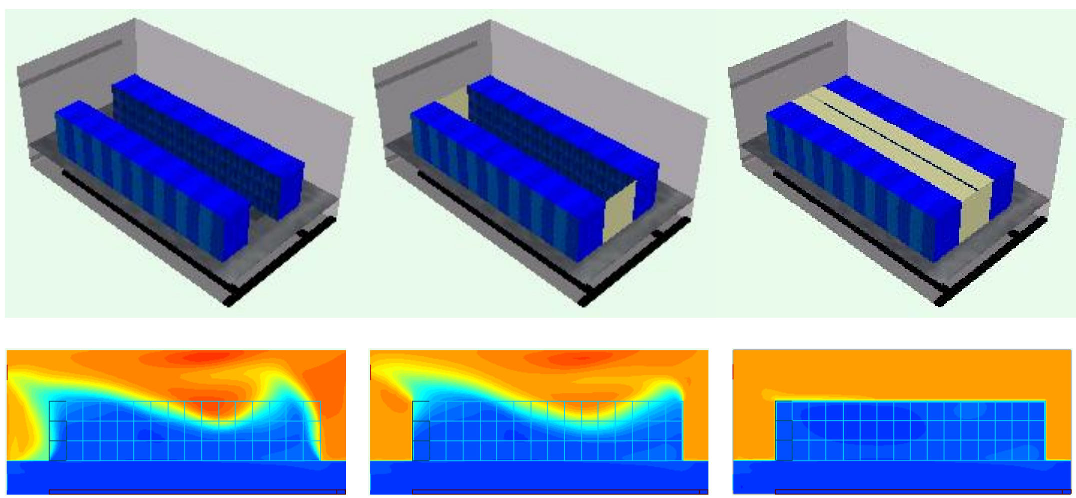
Typical Air Management Issues



- Height (volume) of raised floor
- Obstructions in raised floor or in cabinets
- Placement of air handlers
- Bypass through racks – use blanking plates
- Raised floor leakage
- Data center envelope leakage
- Oversupply of air to cold aisle – cold air spills out of cold aisle and mixes with hot
- Undersupply of air to cold aisle – cold air does not reach all the IT equipment which draws hot air from hot aisle
- Separation of hot return streams

Enhance Separation of Hot/Cold Air

Physical barriers can be used to enhance the separation of hot and cold air. The placement of barriers must take into account fire codes. Enclosed aisles permit higher supply and return temperatures.



Open Semi-enclosed Enclosed

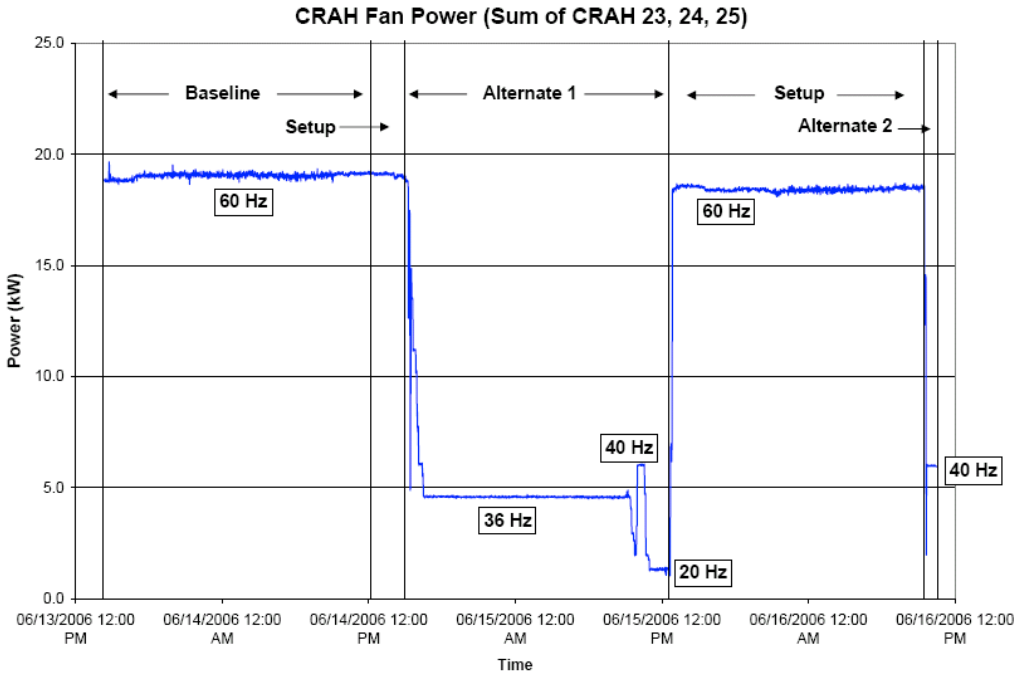
Graphics courtesy of ANCIS Incorporated

Fan Energy Savings with variable speed fans

If mixing of cold supply air with hot return air can be eliminated (enclosure), fan speed can be reduced.

Fan energy savings of 70-80% are not common with variable air volume (VAV) fans.

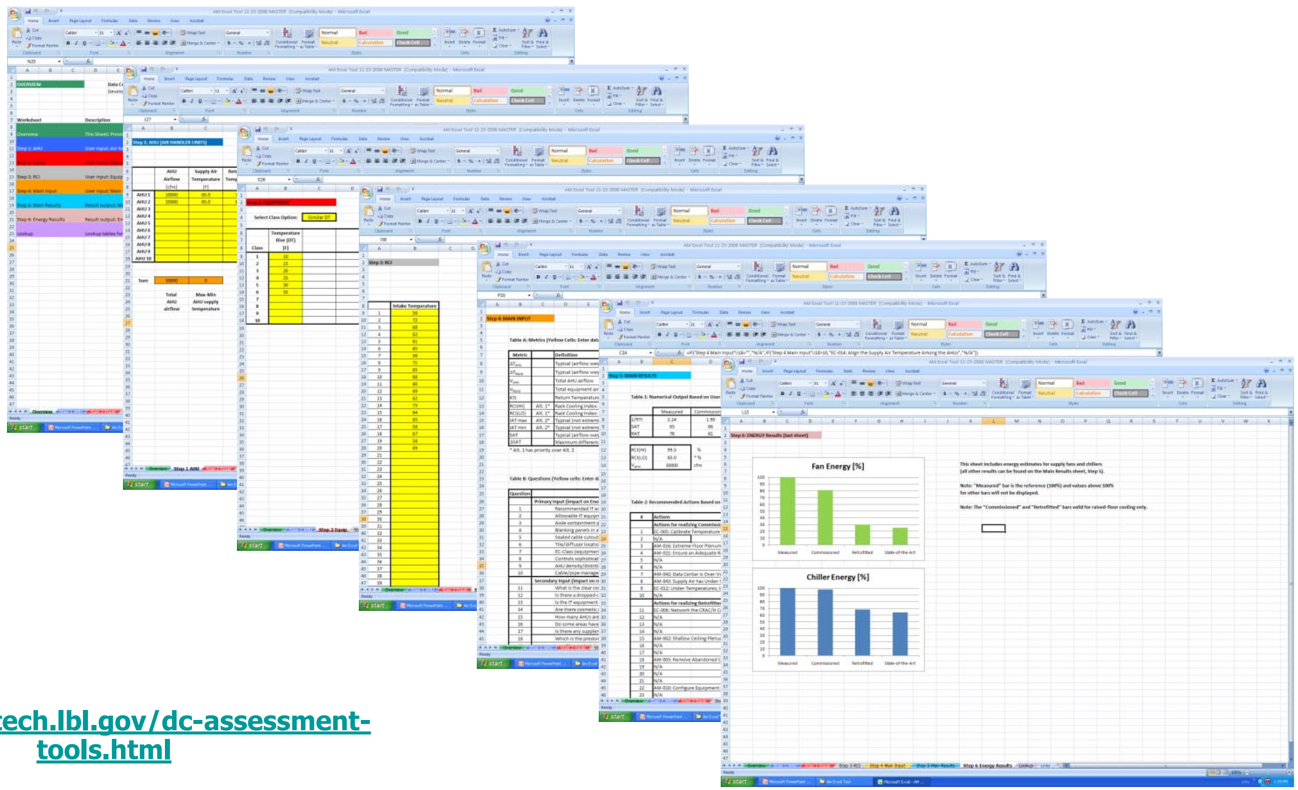
The power input to a fan is proportional to the cube of the speed of the device.



Without Enclosure **With Enclosure** **Without Enclosure**

DOE Air-Management Energy Assessment Tool

The Air Management-Tool is an Excel tool and is available for evaluating air-management opportunities.



http://hightech.lbl.gov/dc-assessment-tools.html

Humidity Control

- Data centers have a history of energy waste due to humidification.
- This is a legacy issue that has been perpetuated. Concerns were over electrostatic discharge on the low end (less than 20% RH) and contamination acceleration on the high end (greater than 80% RH).
- Modern equipment does not require tight humidity control. Use ASHRAE recommendations or vendor data.
- Control humidity for make-up air and not in the space. Relative humidity varies throughout the space as does temperature.

Links for more information

DOE EERE Technical Assistance Project:
http://apps1.eere.energy.gov/wip/tap.cfm

DOE Website: Sign up to stay up to date on new developments
www.eere.energy.gov/datacenters

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

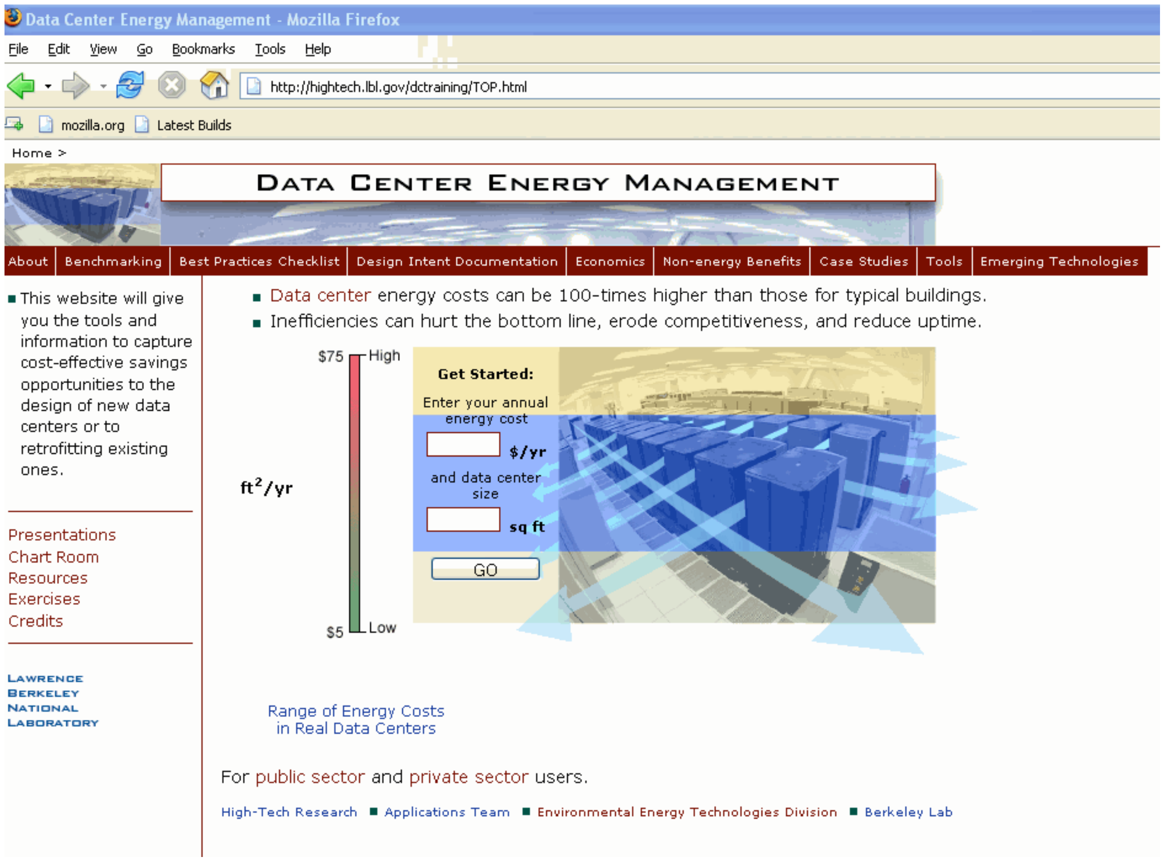
ASHRAE Data Center technical guidebooks
http://tc99.ashraetcs.org/

The Green Grid Association: White papers on metrics
http://www.thegreengrid.org/gg_content/

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

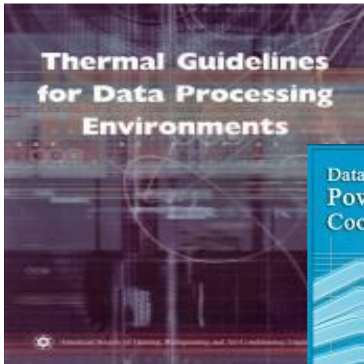
Uptime Institute white papers
www.uptimeinstitute.org

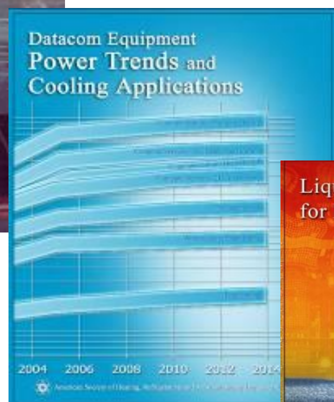
Web based training resource

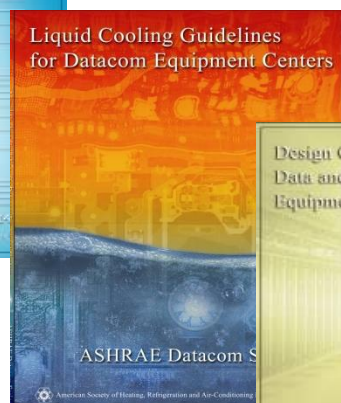


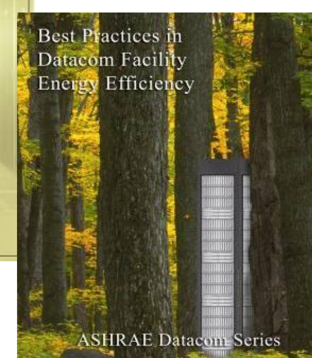
http://hightech.lbl.gov/dctraining/TOP.html

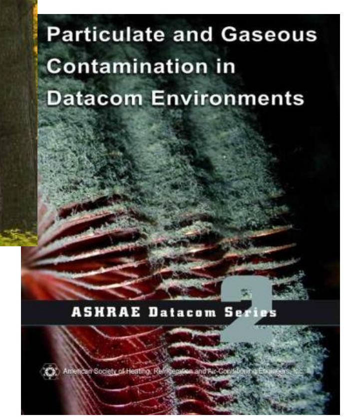
ASHRAE Datacom series



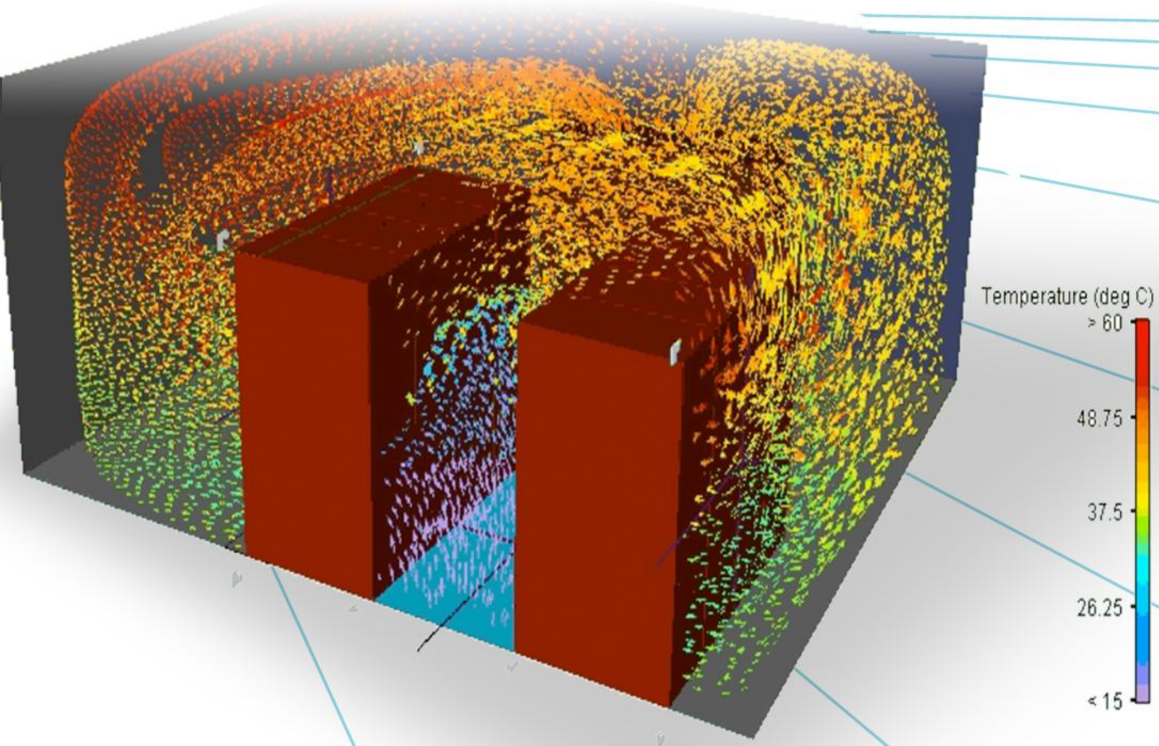








Order from http://tc99.ashraetcs.org/



Questions/discussion

Microsoft’s data center in a tent

http://www.datacenterknowledge.com/archives/2008/09/22/new-from-microsoft-data-centers-in-tents/

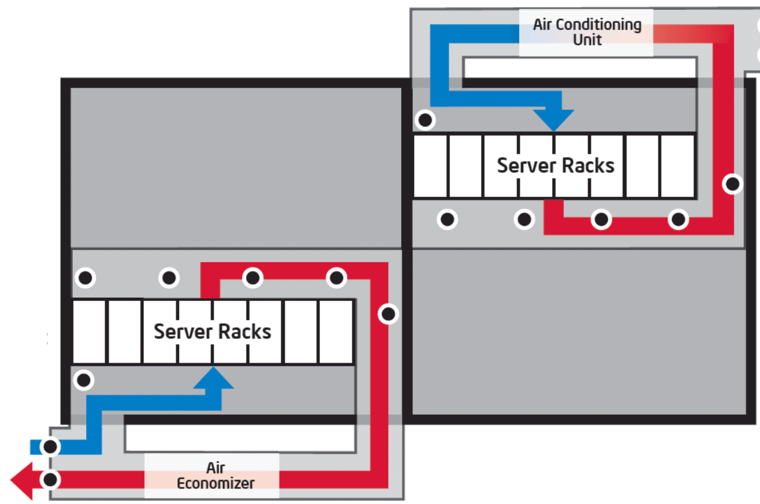
“Inside the tent, we had five HP DL585s running Sandra from November 2007 to June 2008 and we had **ZERO failures** or 100% uptime. In the meantime, there have been a few anecdotal incidents:

- Water dripped from the tent onto the rack. The server continued to run without incident.
- A windstorm blew a section of the fence onto the rack. Again, the servers continued to run.
- An itinerant leaf was sucked onto the server fascia. The server still ran without incident.”

And from Intel a side-by-side comparison

Intel conducted a 10-month test to evaluate the impact of using only outside air to cool a high-density data center, even as temperatures ranged between 64 and 92 degrees and the servers were covered with dust.

- Intel's result: "We observed no consistent increase in server failur rates as a result of the greater variation in temperature and humidity, and the decrease in air quality," Intel's Don Atwood and John Miner write in their white paper. "This suggests that existing assumptions about the need to closely regulate these factors bear further scrutiny



See http://www.datacenterknowledge.com/archives/2008/09/18/intel-servers-do-fine-with-outside-air/