DOE's Better Buildings Data Center Partnerships

Applying Best Practices to meet the Challenge

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FEMP
Federal Energy Management Program

Learning Outcomes

By attending this session, attendees will:

- Understand the data center challenge from DOE
- Gain knowledge of available services and resources for data center efficiency
- Understand how to base-line and implement continuous improvement process to improve the efficiency of data centers
- Gather details of specific best practice solutions through a lens of practicality

Outline

- Data Center Energy Context
- Performance metrics and Benchmarking
- Applying Best Practices – LBNL case study
- Resources to Get Started

Challenging Conventional Wisdom: Game Changers

Conventional Approach

- 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

Data Center Energy

- Data centers are energy intensive facilities
  - 10 to 100 times more energy intensive than an office
  - Server racks now designed for more than 25+ kW
  - Surging demand for data storage
  - 2% of US Electricity consumption
  - 10.5% 2000 – 2010 nationwide annual electricity growth rate
    - Even though computational energy efficiency increasing rapidly
  - Power and cooling constraints in existing facilities
  - Cost of electricity and supporting infrastructure now surpassing capital cost of IT equipment
  - Perverse incentives -- IT and facilities costs separate

Potential Benefits of Energy Efficiency

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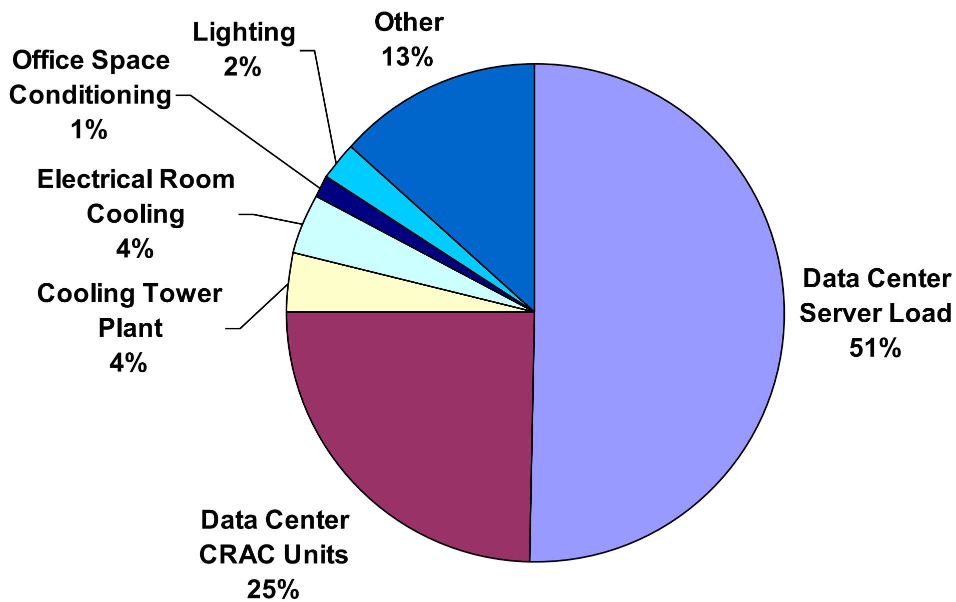
- 20-40% savings & high ROI typical
- Aggressive strategies can yield 50+ % savings
- Extend life and capacity of infrastructures
- But is mine good or bad?

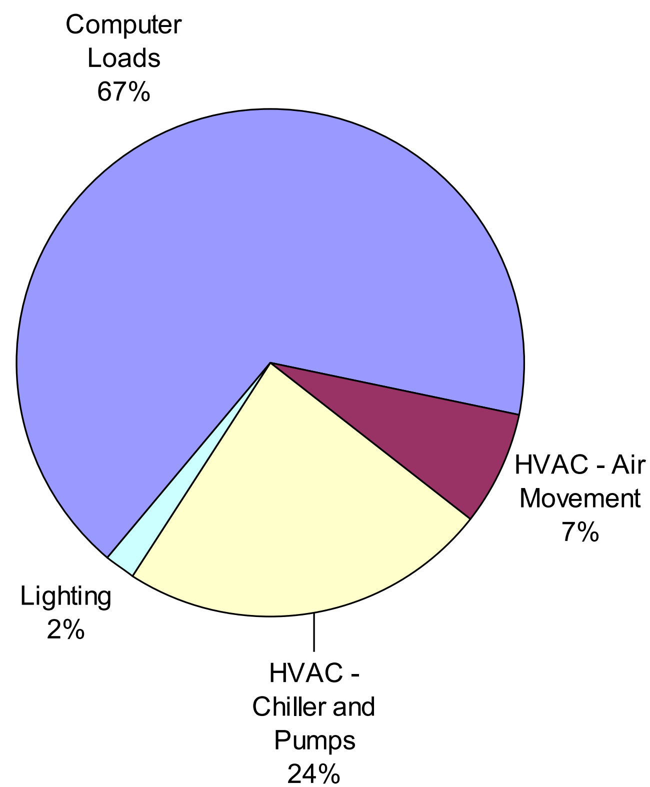
Benchmark Energy Performance

- Compare to peers
  - Wide variation
- Identify best practices
- ID opportunities
- Track performance
  - Can’t manage what isn’t measured

Your Mileage Will Vary

- The relative percentages of the energy actually doing computing varied considerably





High Level Metric: PUE

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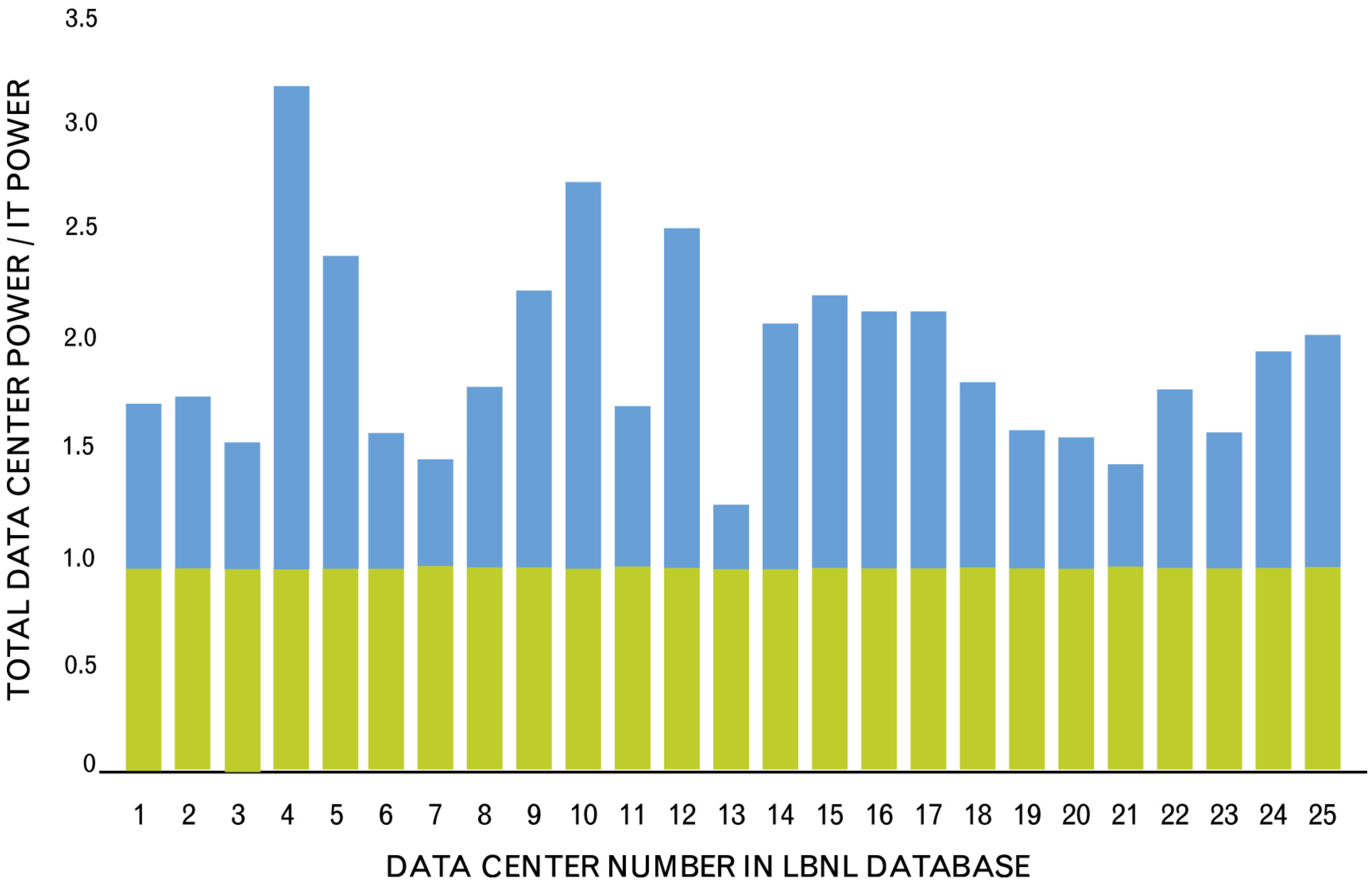
Power Utilization Effectiveness (PUE) = Total Power/IT Power

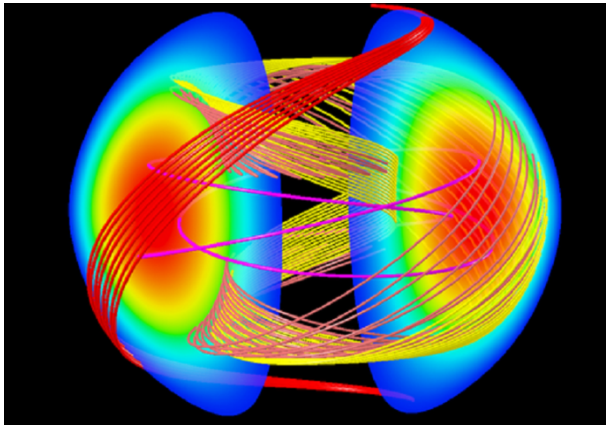


High Level Metric

PUEs: Reported & Calculated	PUE
EPA Energy Star Average	1.91
Intel Jones Farm, Hillsboro	1.41
T-Systems & Intel DC2020 Test Lab, Munich	1.24
Google	1.16
Leibniz Supercomputing Centre (LRZ)	1.15
National Center for Atmospheric Research (NCAR)	1.10
Yahoo, Lockport	1.08
Facebook, Prineville	1.07
National Renewable Energy Laboratory (NREL)	**1.06**

Slide Courtesy Mike Patterson, Intel

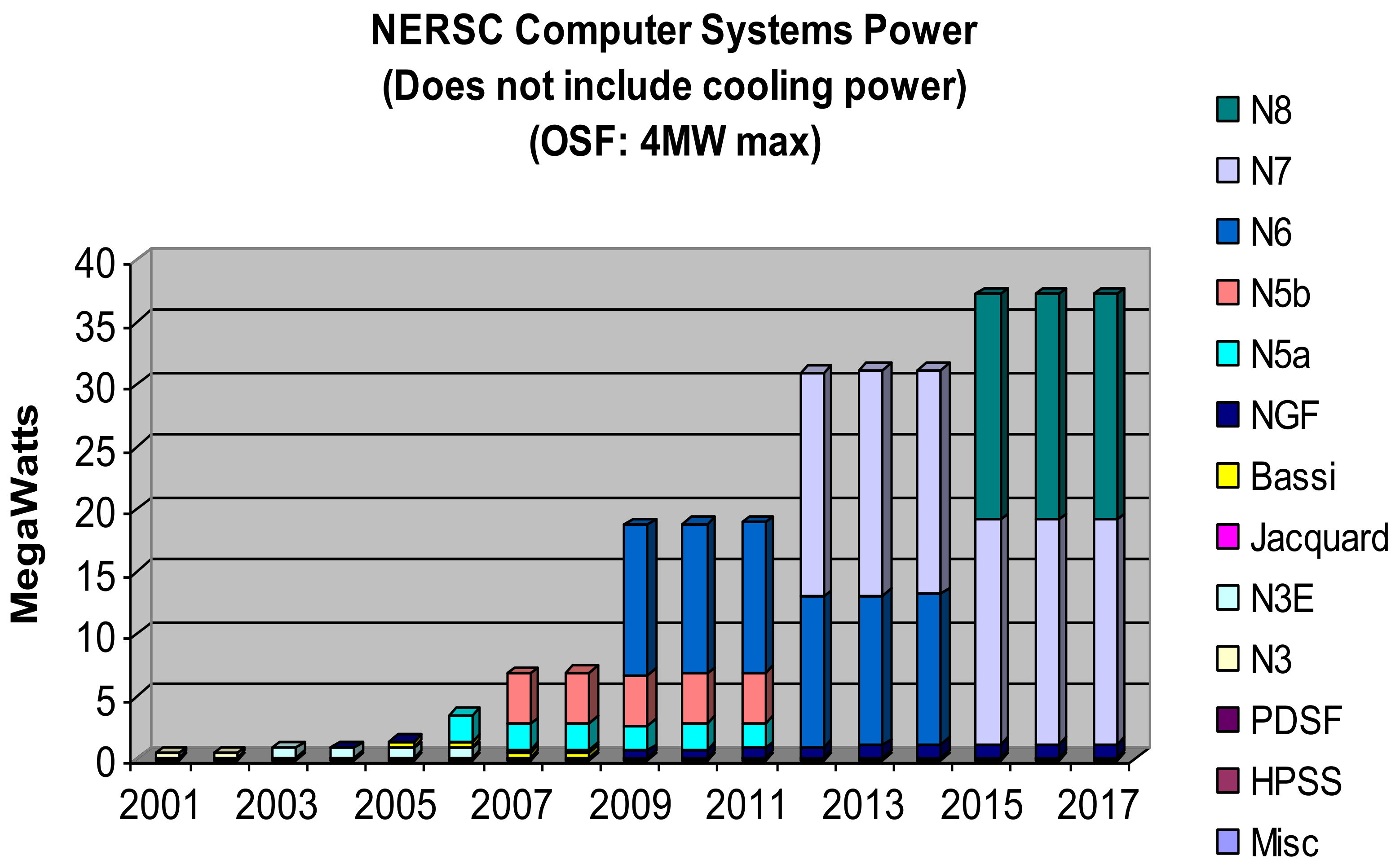
LBNL operates large systems along with legacy systems



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

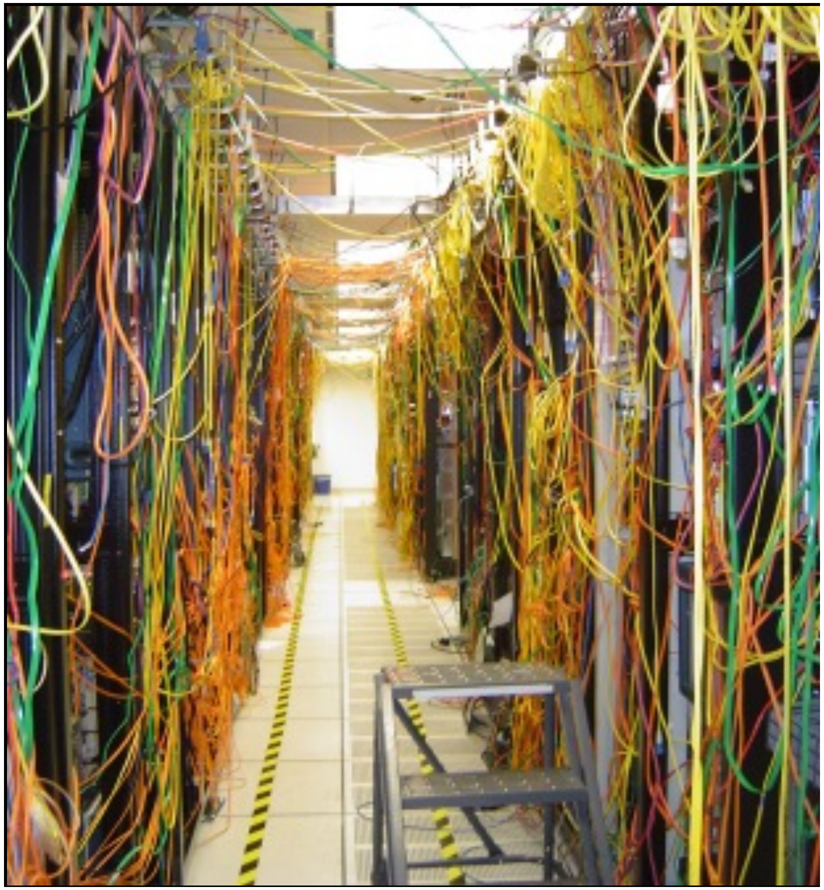
LBNL Feels the Pain!

LBNL Super Computer Systems Power



Applying Best Practices

- Measure and benchmark
- IT equipment efficiency
- Use IT to save energy in IT
- Environmental conditions
- Air management
- Cooling optimization
- Humidity control
- Improve power chain
- M&O processes



Applying Best Practices at LBNL

- Partnership between CIO, CS, and energy efficiency researchers, facilities
- Existing data centers relatively efficient
  - NERSC: PUE = 1.3 (1.4), takes advantage of central plant
  - 50B-1275: PUE = 1.45 (1.65), tower cooled CRACs
- Increased efficiency frees up needed “capacity”
- New data centers much better (PUE = 1.1)
- Leveraging data centers as test beds to create an impact beyond Berkeley Lab
- Working with vendors to develop new products and strategies

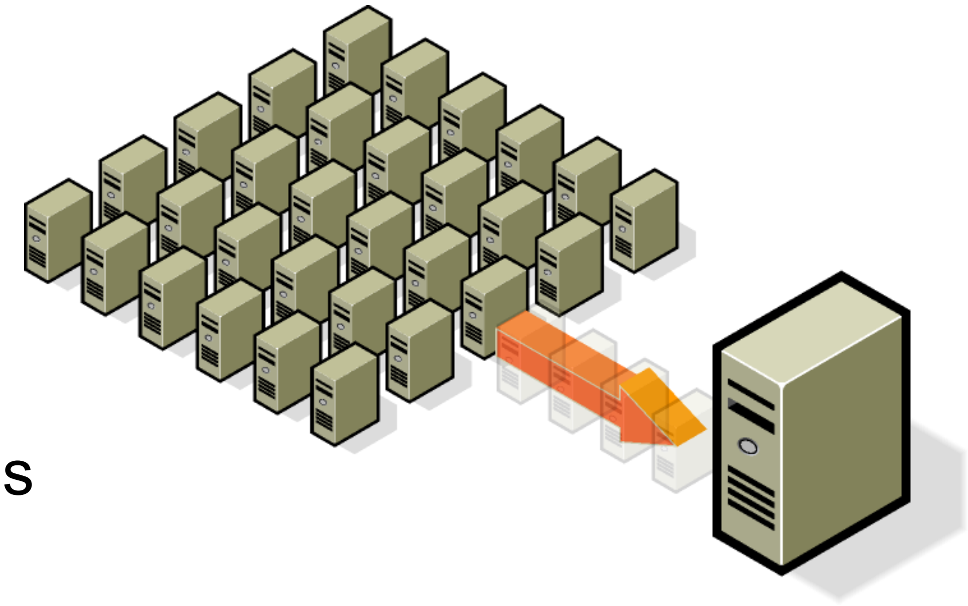
IT equipment load can be controlled:

Computations per Watt is improving, but computation demand is increasing even faster so overall energy is increasing. Lifetime electrical cost will soon exceed cost of IT equipment.

- Consolidation
- Server efficiency (Use Energy Star servers)
  - Flops per watt
  - Efficient power supplies and less redundancy
- Software efficiency:
  - Virtualize for higher utilization
  - Data storage management
- Enable power management
- Reducing IT load has a multiplier effect
  - Equivalent savings +/- in infrastructure

Virtualize and Consolidate Servers and Storage

- Run many “virtual” machines on a single “physical” machine
- Consolidate underutilized physical machines, increasing utilization
- Energy saved by shutting down underutilized machines



Virtualize and Consolidate Servers and Storage

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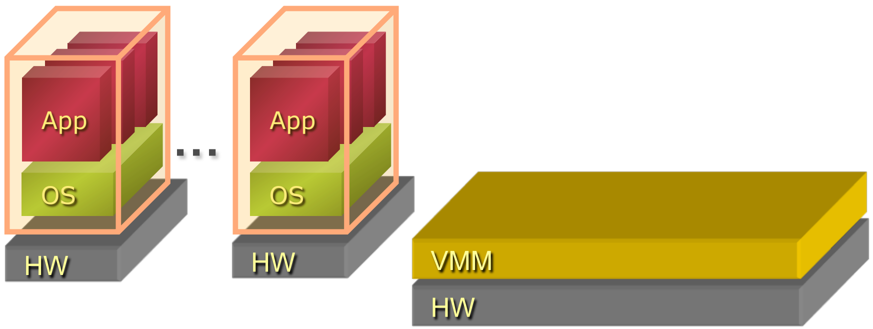
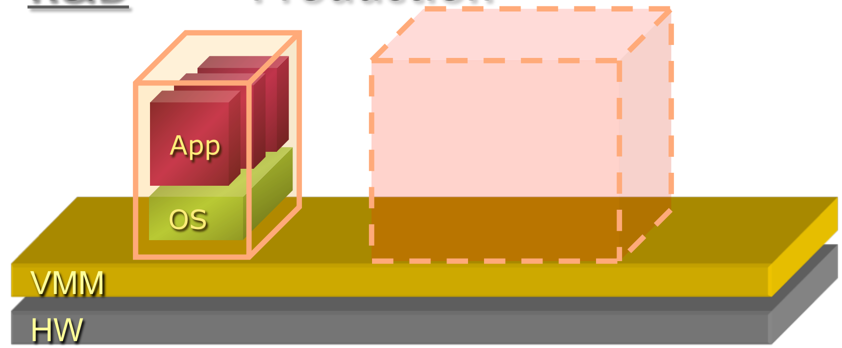
Server Consolidation



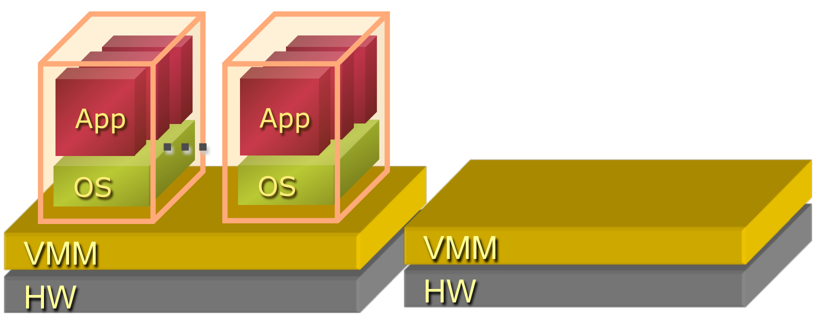
10:1 in many cases

R&D Production



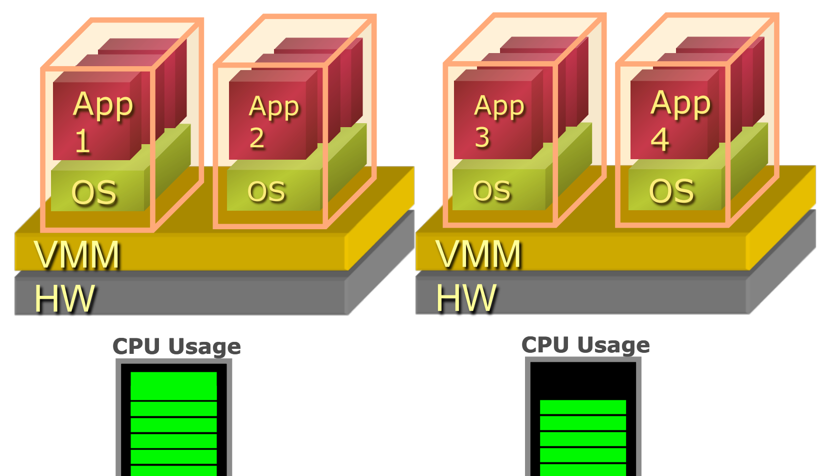
Enables rapid deployment,
reducing number of idle, staged servers

Disaster Recovery



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

Dynamic Load Balancing



Balancing utilization with head room

Using IT to Save Energy in IT

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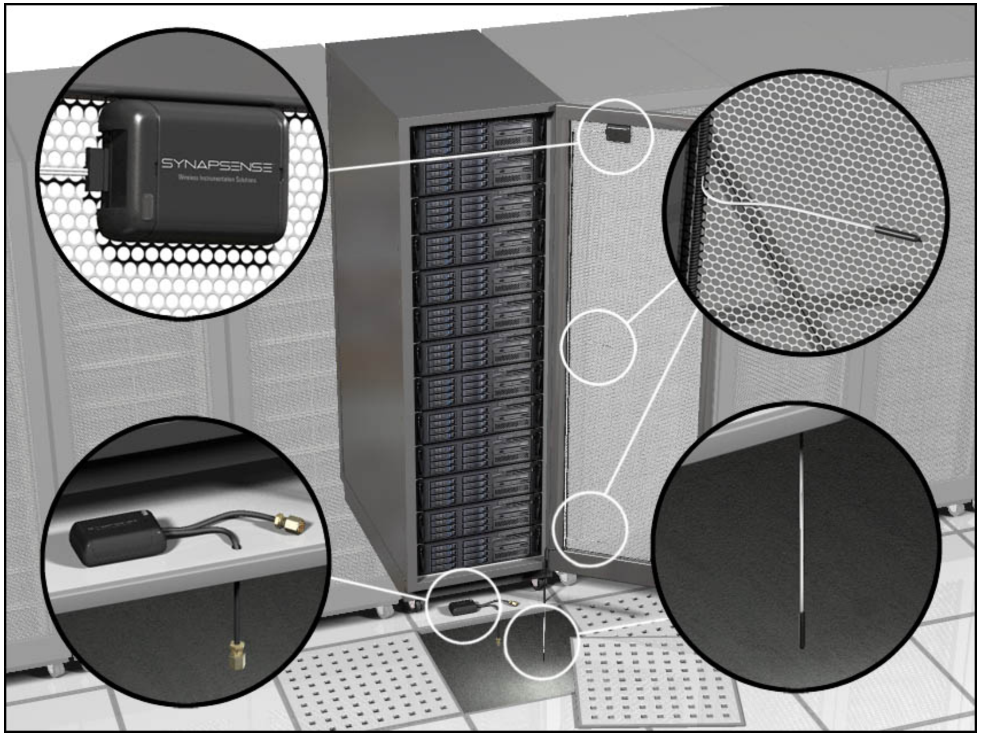
- Operators lack visibility into data center environment
- Provide same level of monitoring and visualization of the physical space as we have for the IT environment
- Measure and track performance
- Spot problems early
- 800 point SynapSense system
  - Temperature, humidity, under-floor pressure, current

LBNL Wireless Monitoring System



source: SynapSense

Visualization getting much better

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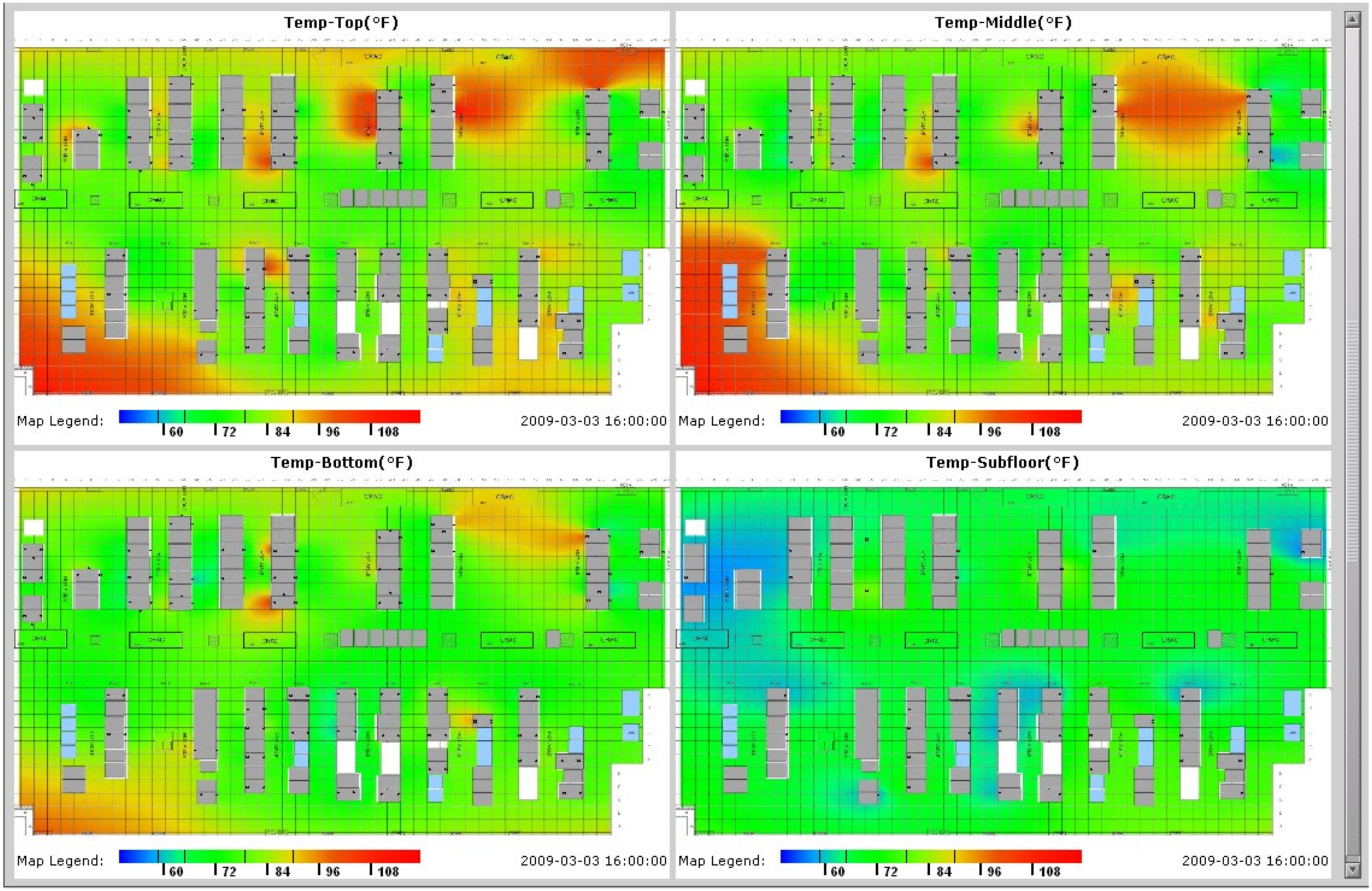
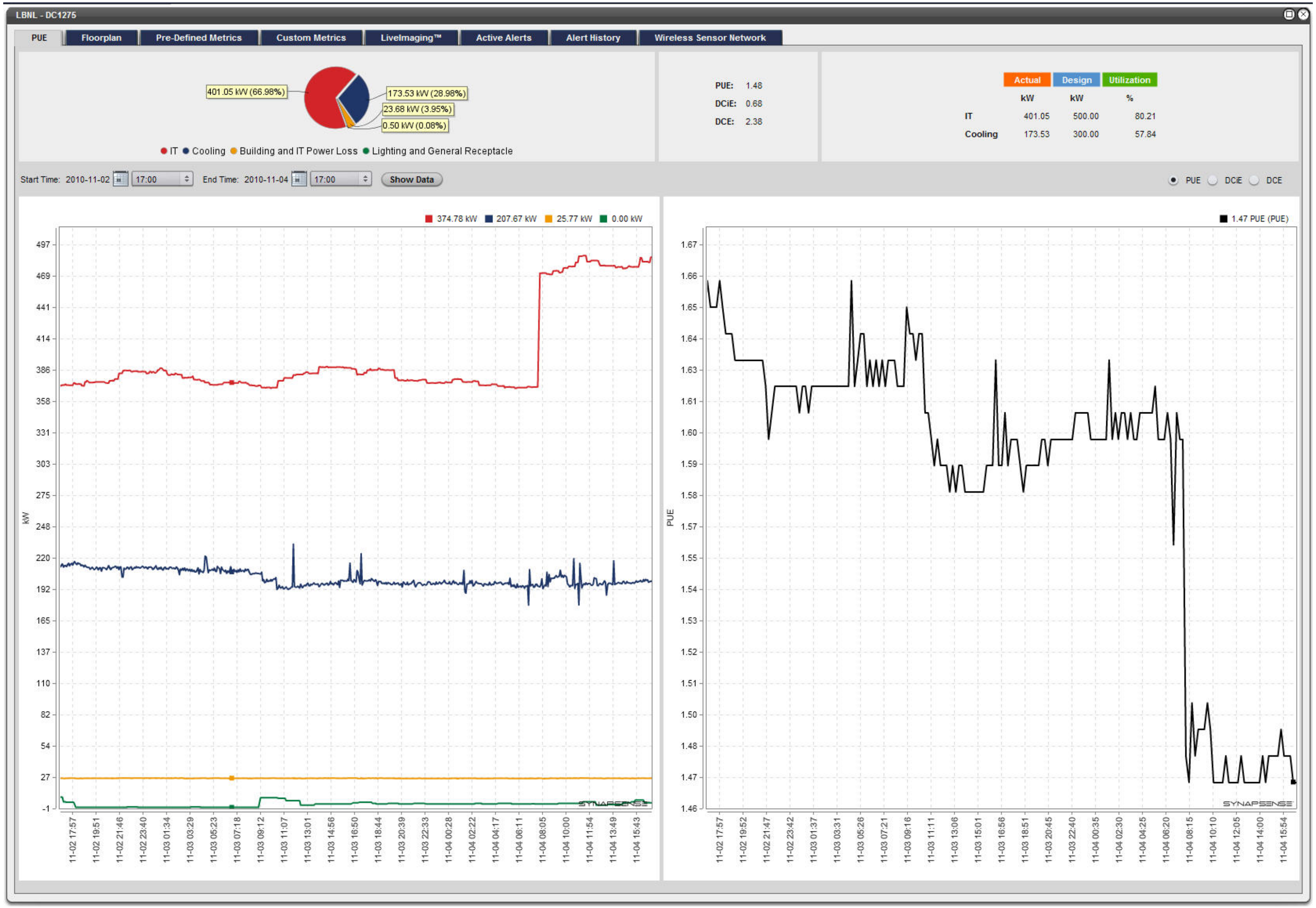


SynapSense™

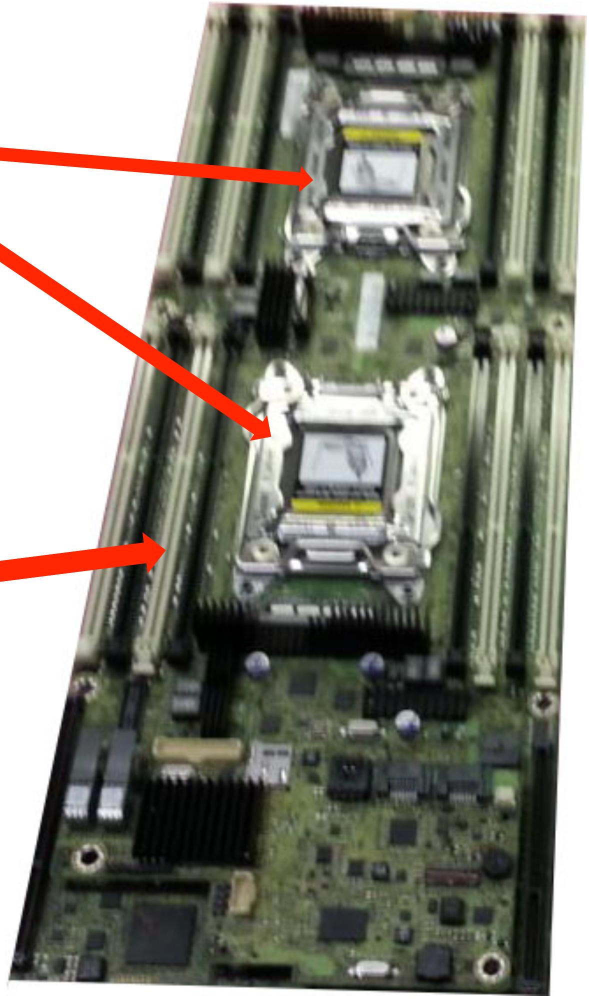
Real-time PUE Display



Environmental conditions: Safe Temperature Limits

CPUs
~65C
(149F)

Memory
~85C
(185F)



GPUs
~75C
(167F)

So why do we need jackets in data centers?

CPU, GPU & Memory, represent ~75-90% of heat load …

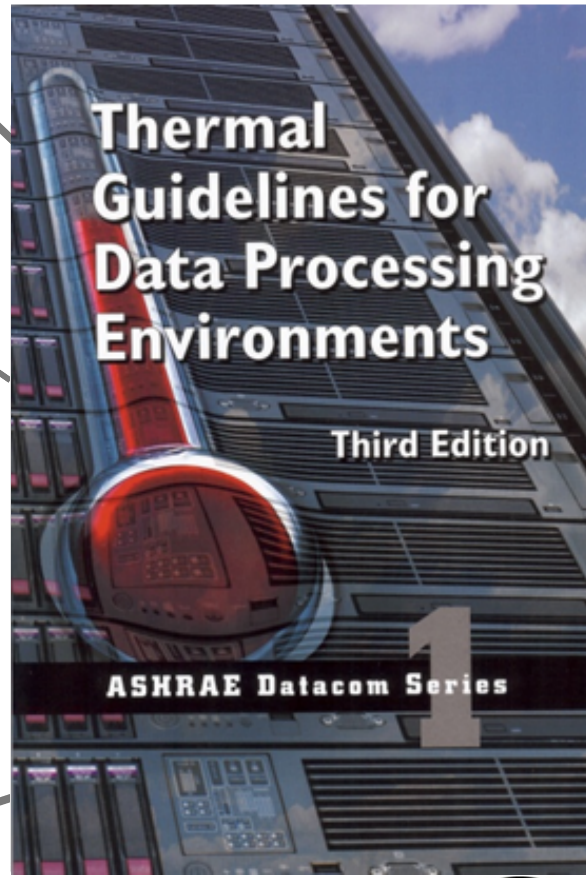
Slide courtesy of NREL

ASHRAE Thermal Guidelines
The defacto standard in the industry

Provides common understanding between IT and facility staff.

Developed with IT manufacturers

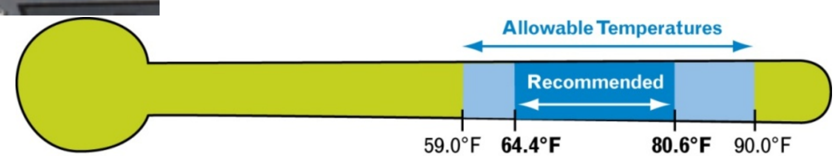
Recommends temperature range up to 80.6℉ with “allowable” much higher.



Six classes of equipment identified with wider allowable ranges to 45℃ (113℉).

Provides more justification for operating above the recommended limits

Provides wider humidity ranges



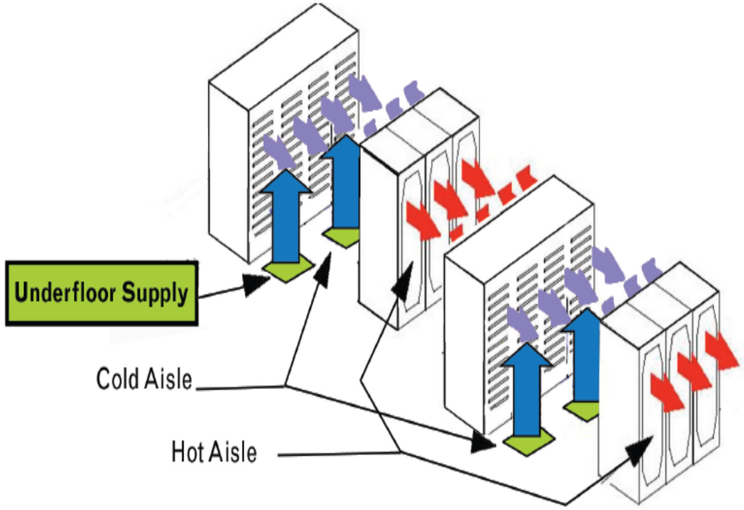
It was cold but hot spots were everywhere

Fans were used to redirect air

High flow tiles reduced air pressure

Air Management

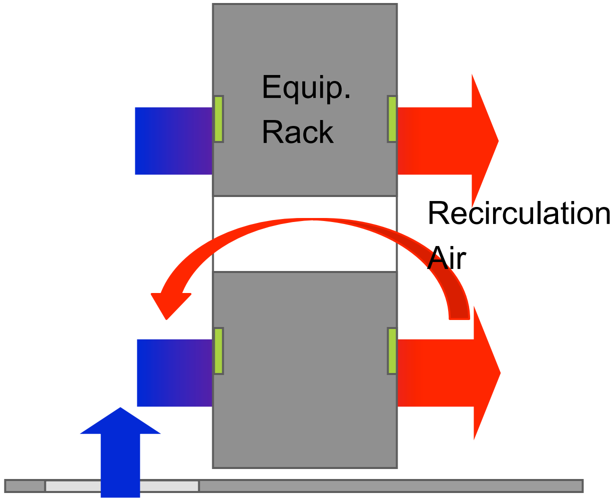
- Typically, more air circulated than required
- Air mixing and short circuiting leads to:
  - Low supply temperature
  - Low Delta T
- Use hot and cold aisles
- Improve isolation of hot and cold aisles
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity



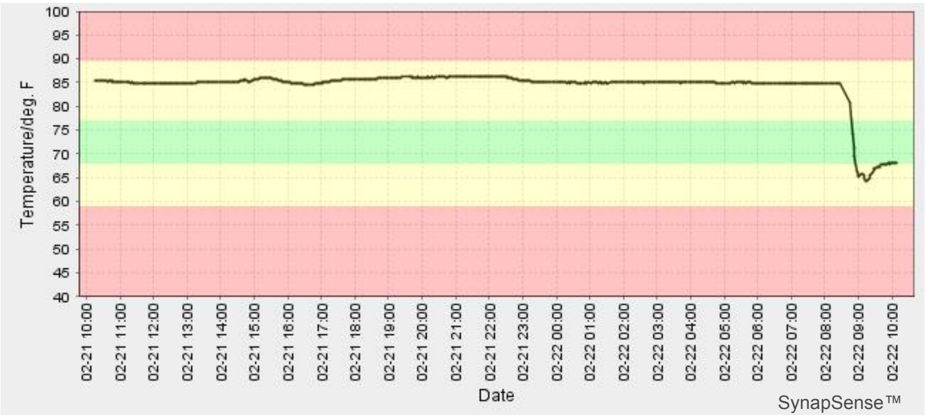
Hot aisle / cold aisle configuration decreases mixing of intake & exhaust air, promoting efficiency.

Results: Blanking Panels

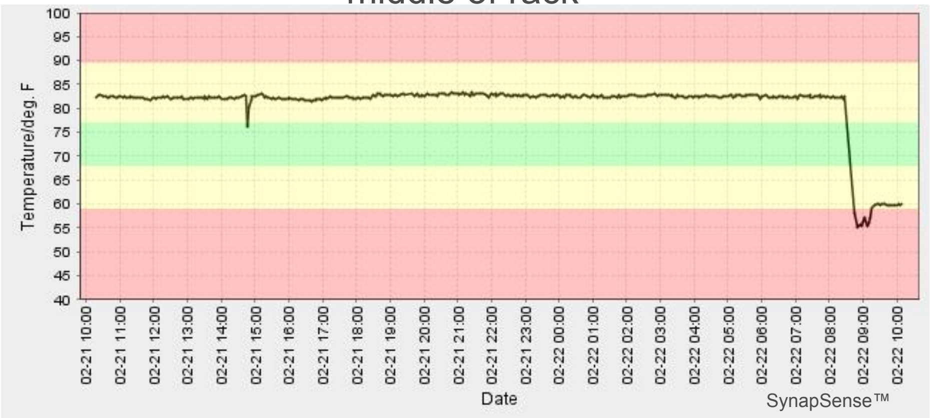
One 12 inch blanking panel reduced temperature ~20°F



top of rack



middle of rack



Results: Tune Floor Tiles

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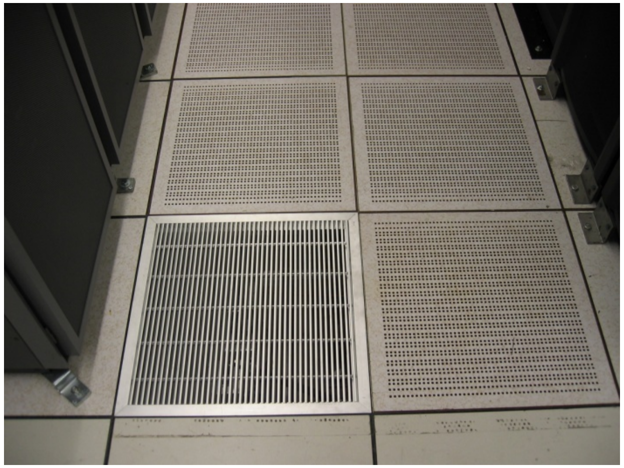
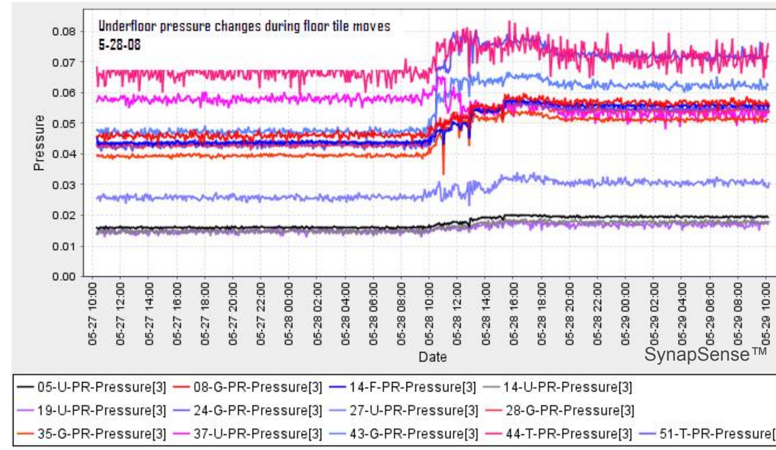
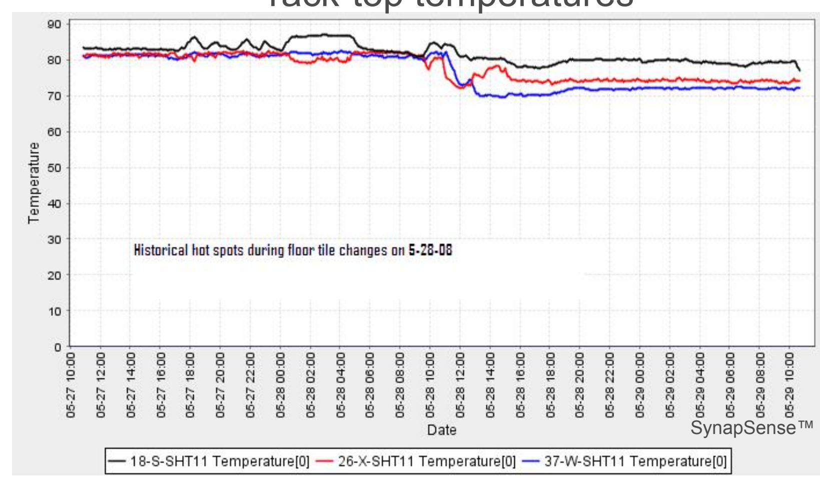


under-floor pressures



rack-top temperatures



- 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

Improve Air Management

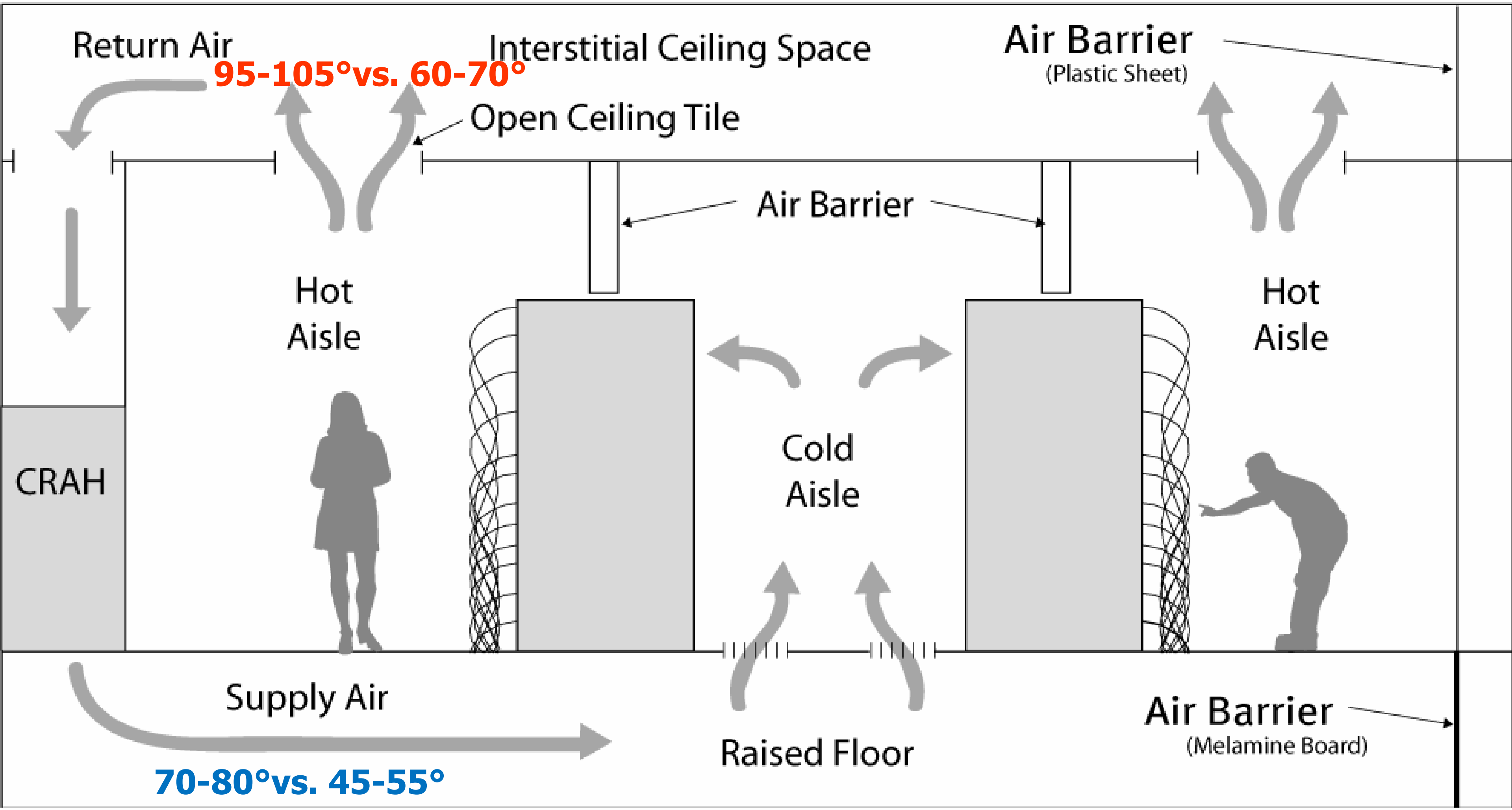
- Overhead plenum converted to hot-air return
- Return registers placed over hot aisle
- CRAC intakes extended to overhead

Before

After

Adding Air Curtains for Hot/Cold Isolation

Isolate Cold and Hot Aisles



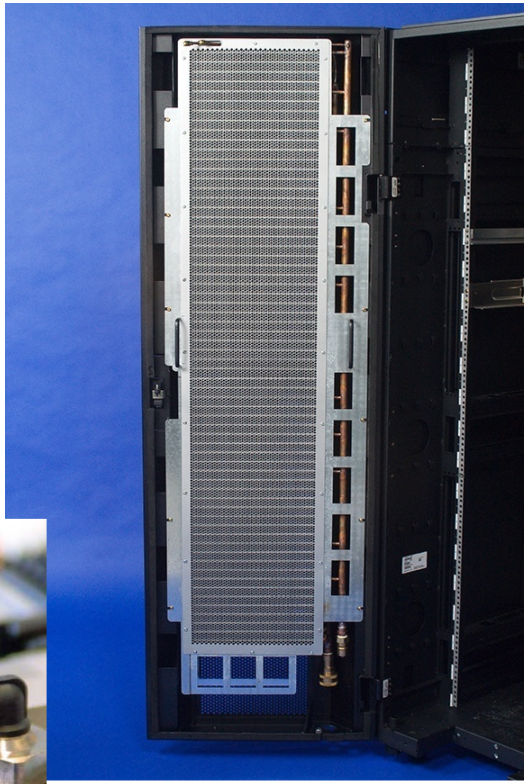
Cooling without Compressors

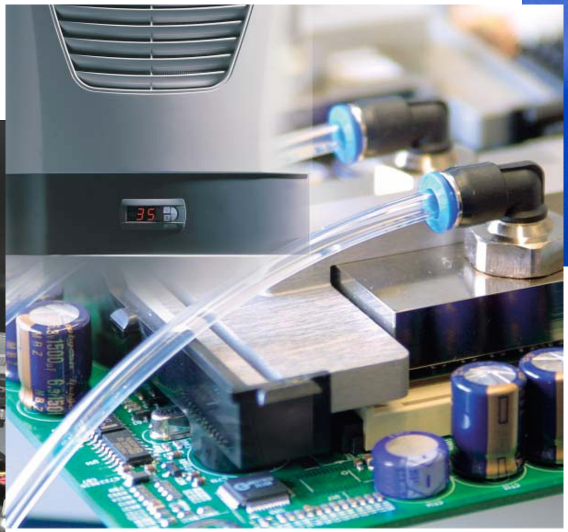
- Water-side Economizers
- Outside-Air Economizers

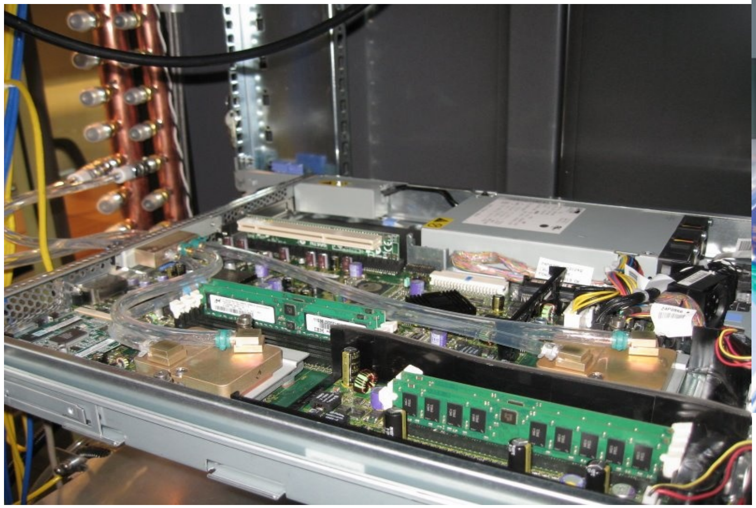
➢ Let's get rid of chillers in data centers

Liquid Based Cooling

- Liquid is much more efficient than air for heat transfer
- Efficiency improves the closer the liquid comes to the hear source (e.g. CPU)
- Most efficient data centers often don’t have raised floors!



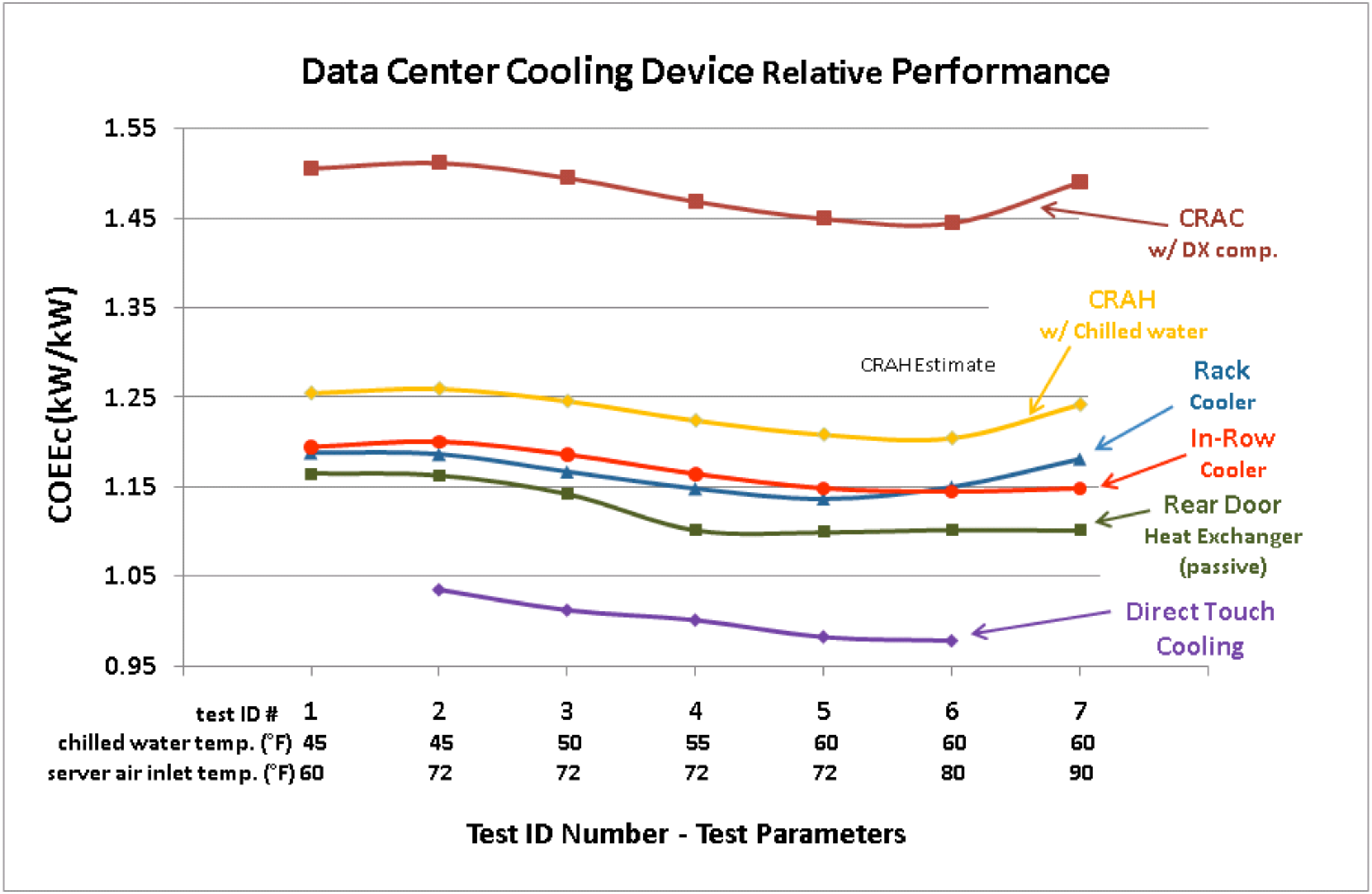




LBNL Example: Rear Door Cooling

- Used instead of adding CRAC units
- Cooling with tower-only or chiller assisted
  - Both options significantly more efficient than existing direct expansion (DX) CRAC units.

"Chill-off 2" evaluation of liquid cooling solutions



Improve Humidity Control

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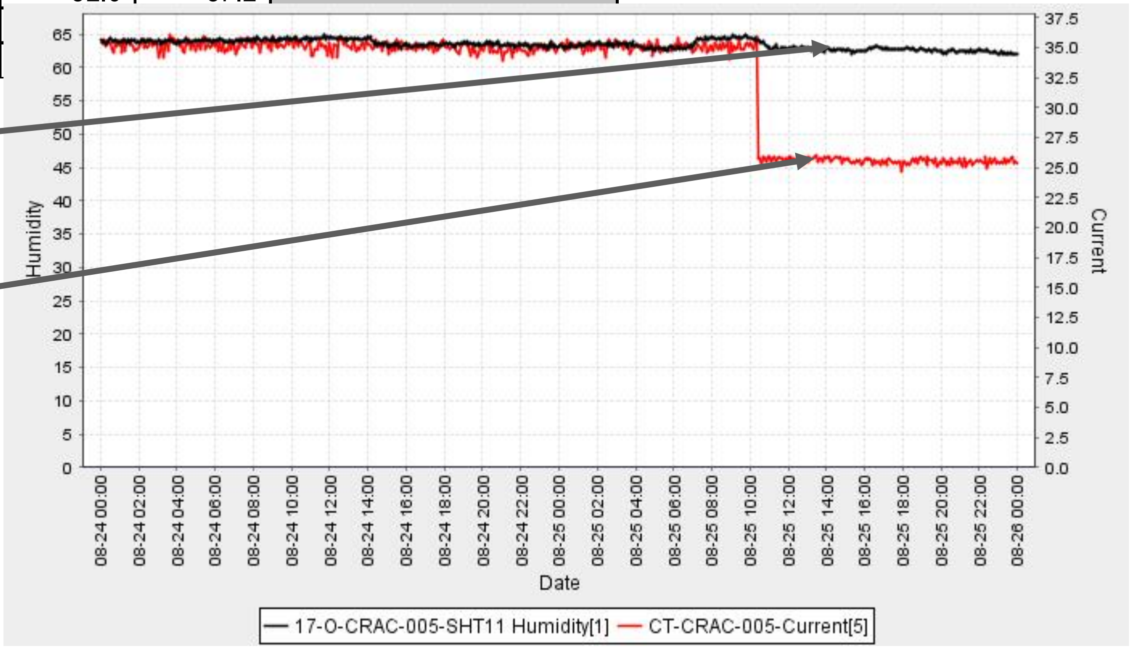
- Eliminate inadvertent dehumidification
  - Computer load is sensible only
- Use ASHRAE allowable RH and temperature
  - Many manufacturers allow even wider humidity range
- Defeat equipment fighting
  - Coordinate controls
  - Turn off

The Cost of Unnecessary Humidification

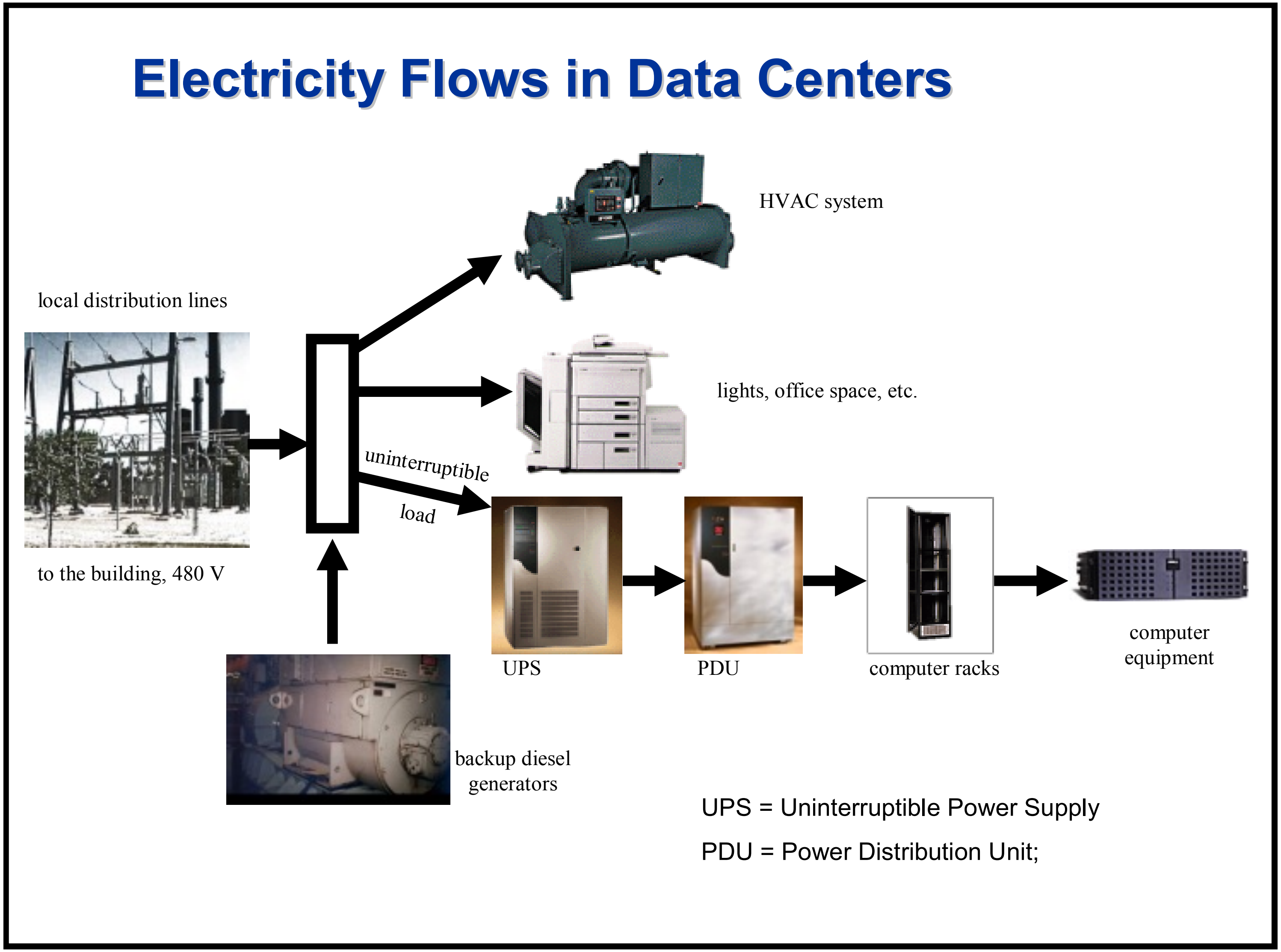
	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC 005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC 006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC 007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC 010	77.5	32.8	46.1	68	45.0	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			
Avg	79.2	31.7	46.4	68.8			

Humidity down 2%

CRAC power down 28%



Power Chain Conversions Waste Energy



Improving the Power Chain

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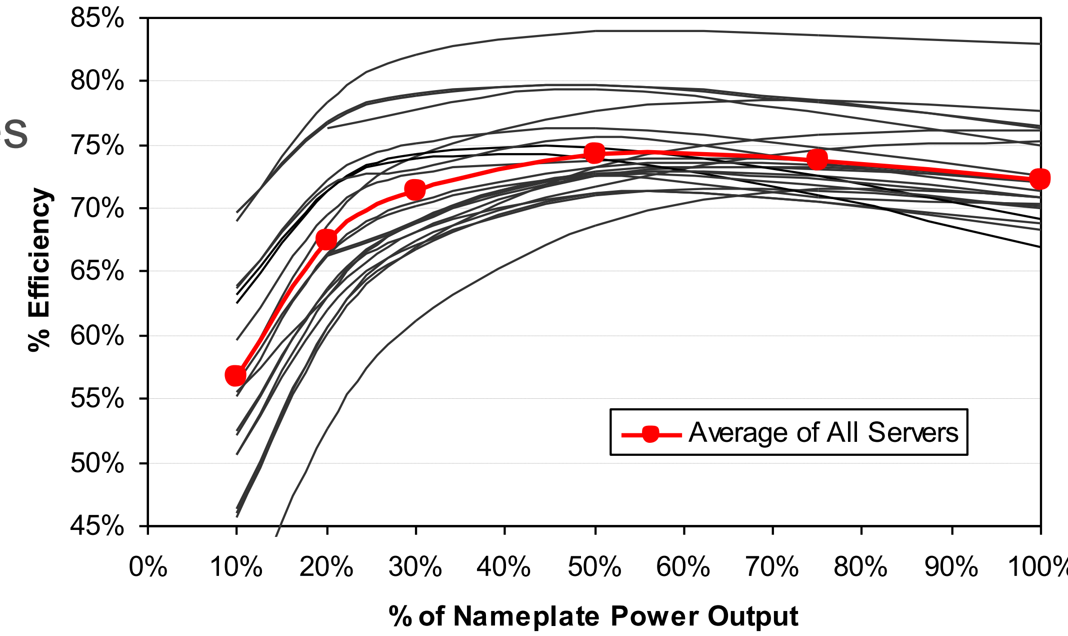
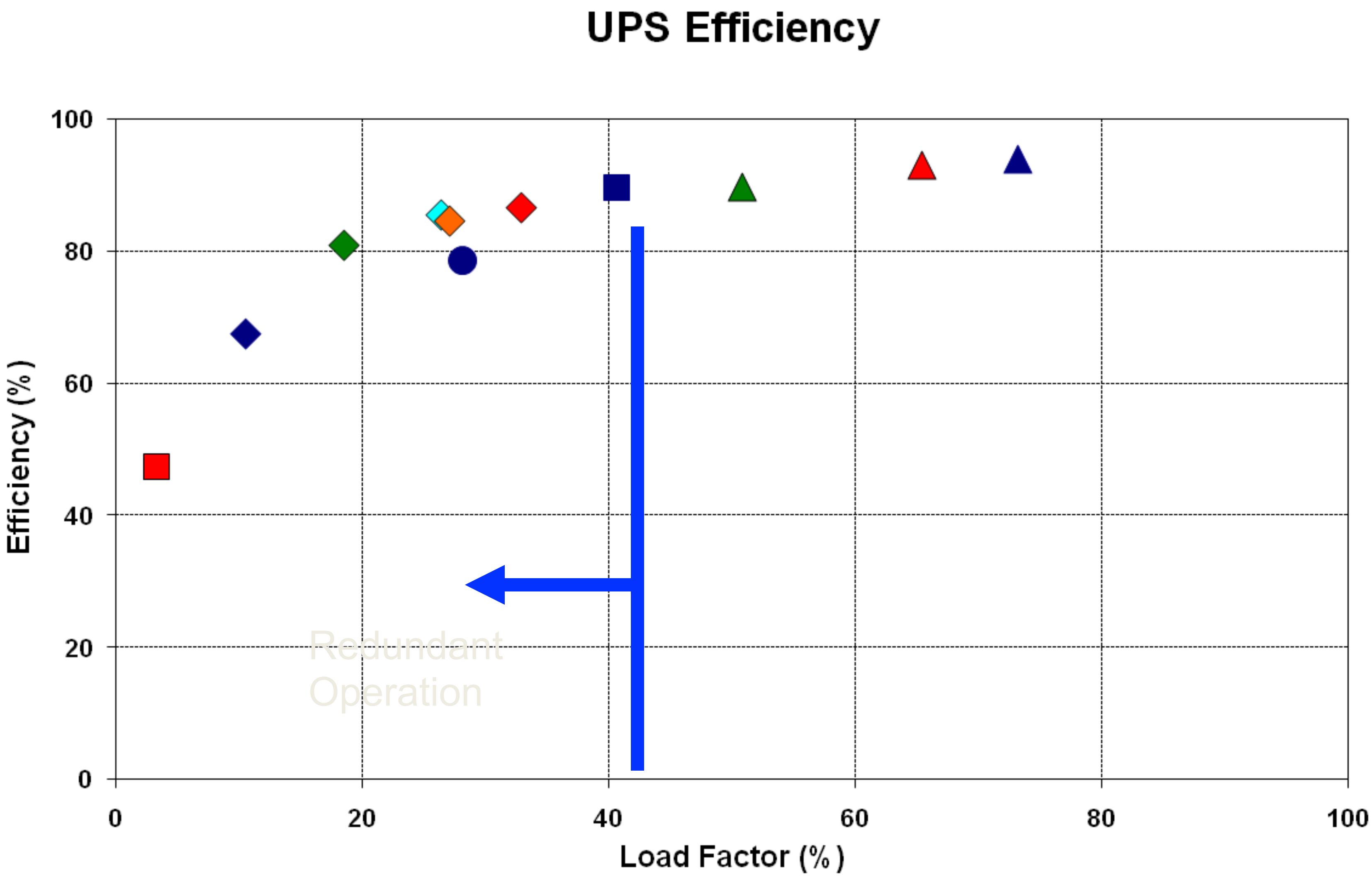
- Increase distribution voltage
  - NERSC going to 480 volts to the racks
- Improve equipment power supplies
  - Avoid redundancy unless needed
- Improve UPS
  - LBNL uses minimal UPS
  - Selected to minimize losses



Measured UPS Efficiency



Redundancy

- Understand what redundancy costs – is it worth it?
- Different strategies have different energy penalties (e.g. 2N vs. N+1)
- Redundancy in electrical distribution puts you down the efficiency curve
- Does everything need the same level?
- Redundancy in the network rather than in the data center
- LBNL minimizes use of redundant power supplies and size of UPS

Improve M&O Processes

- Get IT and Facilities people working together
- Use life-cycle total cost of ownership analysis
- Document design intent and provide training
- Benchmark and track existing facilities
- Eat your spinach (blanking panels, leaks, CRAC maintenance)
- Re-commission regularly as part of maintenance
- Keep an eye on emerging technologies (flywheel UPS, rack-level cooling, DC power) and work with vendors to improve efficiency

Results at LBNL's Legacy Data Center

- Increased IT load ~180kW
  - >50% increase with virtually no increase in infrastructure energy use
- Raised room temperature 9°F
- 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!

Best Practices Summary

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1. Measure and Benchmark Energy Use
2. Identify IT Equipment and Software Opportunities
3. Use IT to Monitor and Control IT
4. Optimize Environmental Conditions
5. Manage Airflow
6. Evaluate Cooling Options
7. Reconsider Humidity Control
8. Improve Electrical Efficiency
9. Implement Energy Efficient O&M

Most importantly…

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

- Ensure they know what each other is doing
- Consider impact of each on other, including energy costs

Resources to Get Started

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DOE Better Buildings

- Tool suite & metrics for baselining
- 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

DOE’s Center of Expertise

Datacenters.lbl.gov

CENTER OF EXPERTISE
FOR ENERGY EFFICIENCY IN DATA CENTERS

SEARCH

HOME ABOUT TECHNOLOGIES ACTIVITIES RESOURCES CONTACT US ADMIN

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

LBNL 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.

Available Resources

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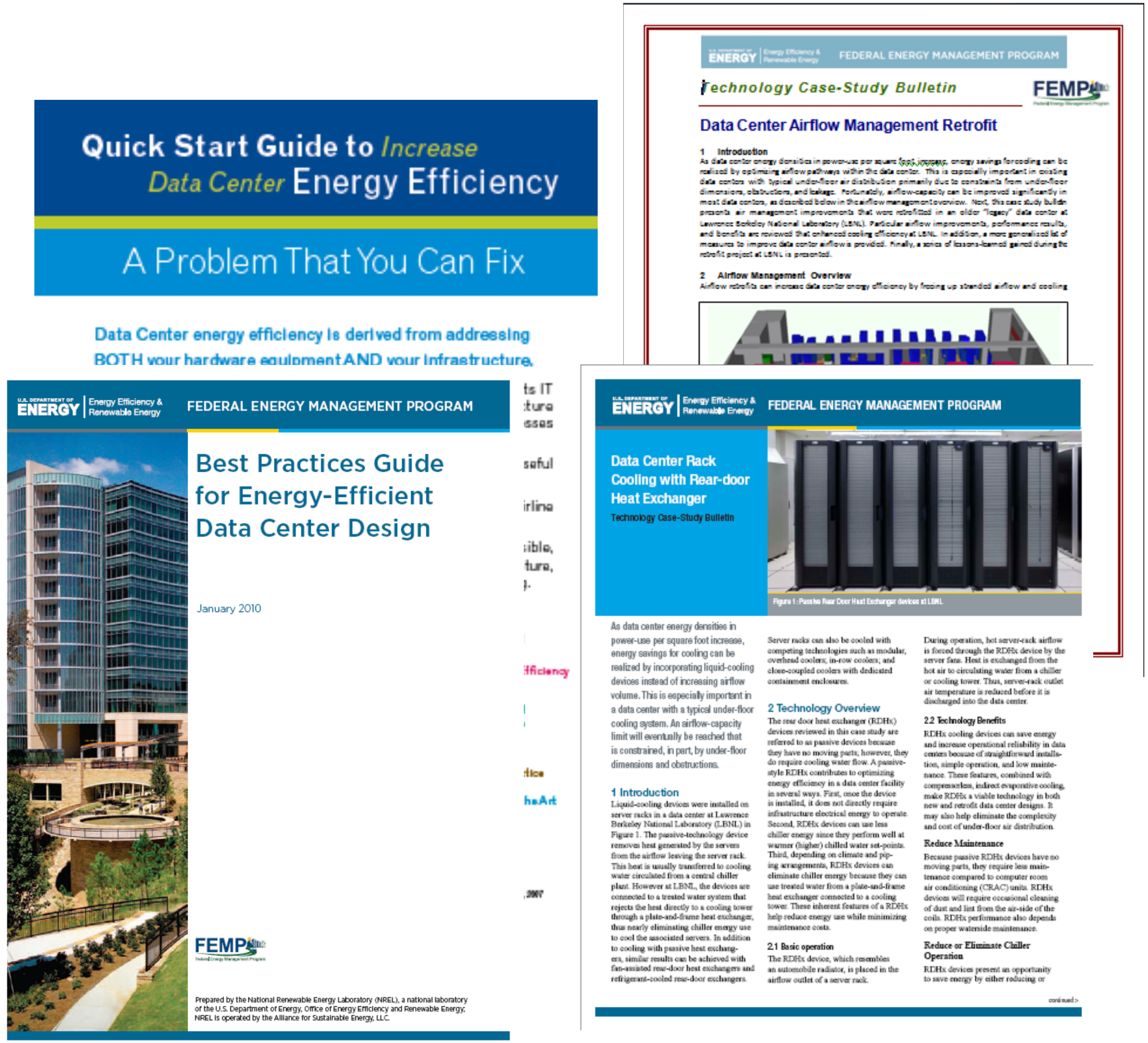
- Profiling Tool
- Assesment Tools
- Best Practices Guide
- Benchmarking Guide
- Data Center Programming Guide
- Technology Case Study Bulletins
- Procurement Specifications
- Report Templates
- Process Manuals
- Quick-Start Guide



DOE Data Center Tool Suite

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High-Level On-Line Profiling (DC Pro 3)

- 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

DC Pro Profiling Tool

INPUTS

- Description
- Utility bill data
- System information
  - IT
  - Cooling
  - Power

OUTPUTS

- Overall efficiency (PUE)
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential

http://datacenters.lbl.gov/dcpro/

Data Center Energy Practitioner (DCEP) Program

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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).

Delivery:
- 2 Levels (Generalist and Specialist)
- Delivered by CNET and Data Center Dynamics

datacenters.lbl.gov/dcep

Other Resources

http://energy.gov/eere/femp/data-center-energy-efficiency

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

Speaker Contact Information

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