AFCOM

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Advancing Data Center Professionals

Data Center Leadership
In the DOE Better Buildings Challenge
Applying Best Practices to meet the Challenge

Dale Sartor, PE
Lawrence Berkeley National Laboratory

Better Buildings U.S. DEPARTMENT OF ENERGY

BERKELEY LAB

U.S. DEPARTMENT OF ENERGY

Outline

- Data Center Energy Context
- Performance metrics and Benchmarking
- DOE Better Buildings Initiative and Data Center Partnerships
- Applying Best Practices
  - LBNL case study
- Resources to Get Started

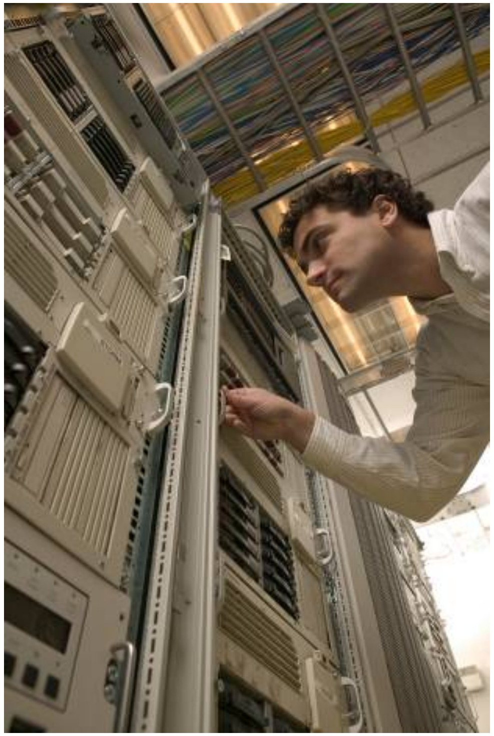
Data Center Energy Context

- 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
  - High energy growth despite computational efficiency gains
  - 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

Data Center Energy Context

Large opportunity

- Typical 20% to 40% savings with high ROIs
- Aggressive strategies can yield 50+% savings
- If all data centers were more efficient, we could save $2B annually; 20B kWh
- Extend life and capacity of infrastructure
- Reduced IT equipment requirements



Benchmark Energy Performance

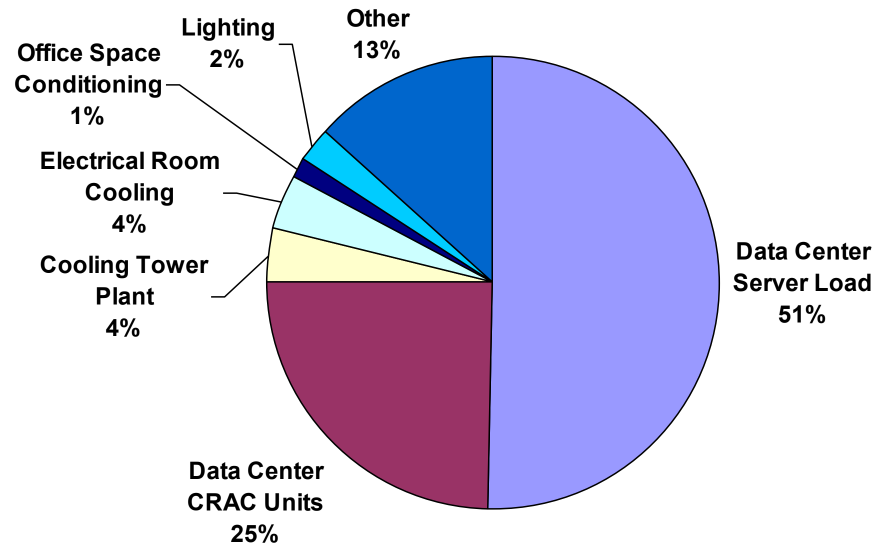
Is my data center good or bad?
Benchmark to:

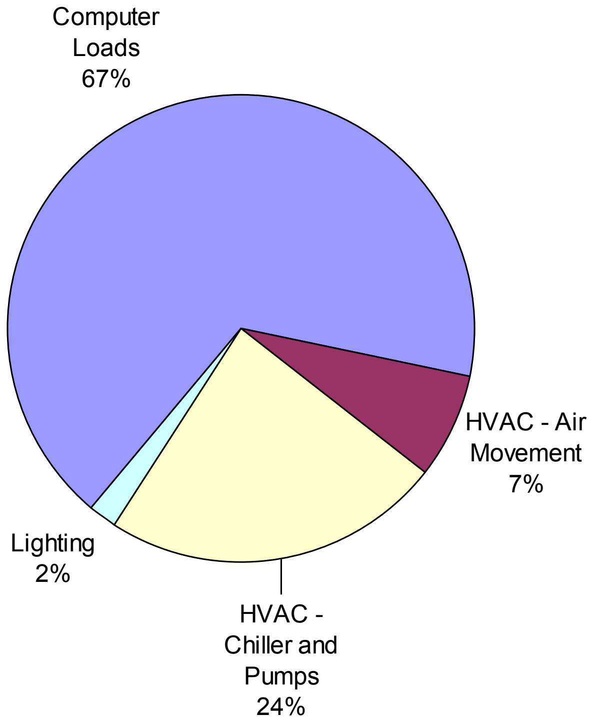
- Compare to peers
  - Wide variation
- Identify best practices
- Identify opportunities
- Track performance
  - Can’t manage what isn’t measured

Benchmarking Results

Your Mileage Will Vary

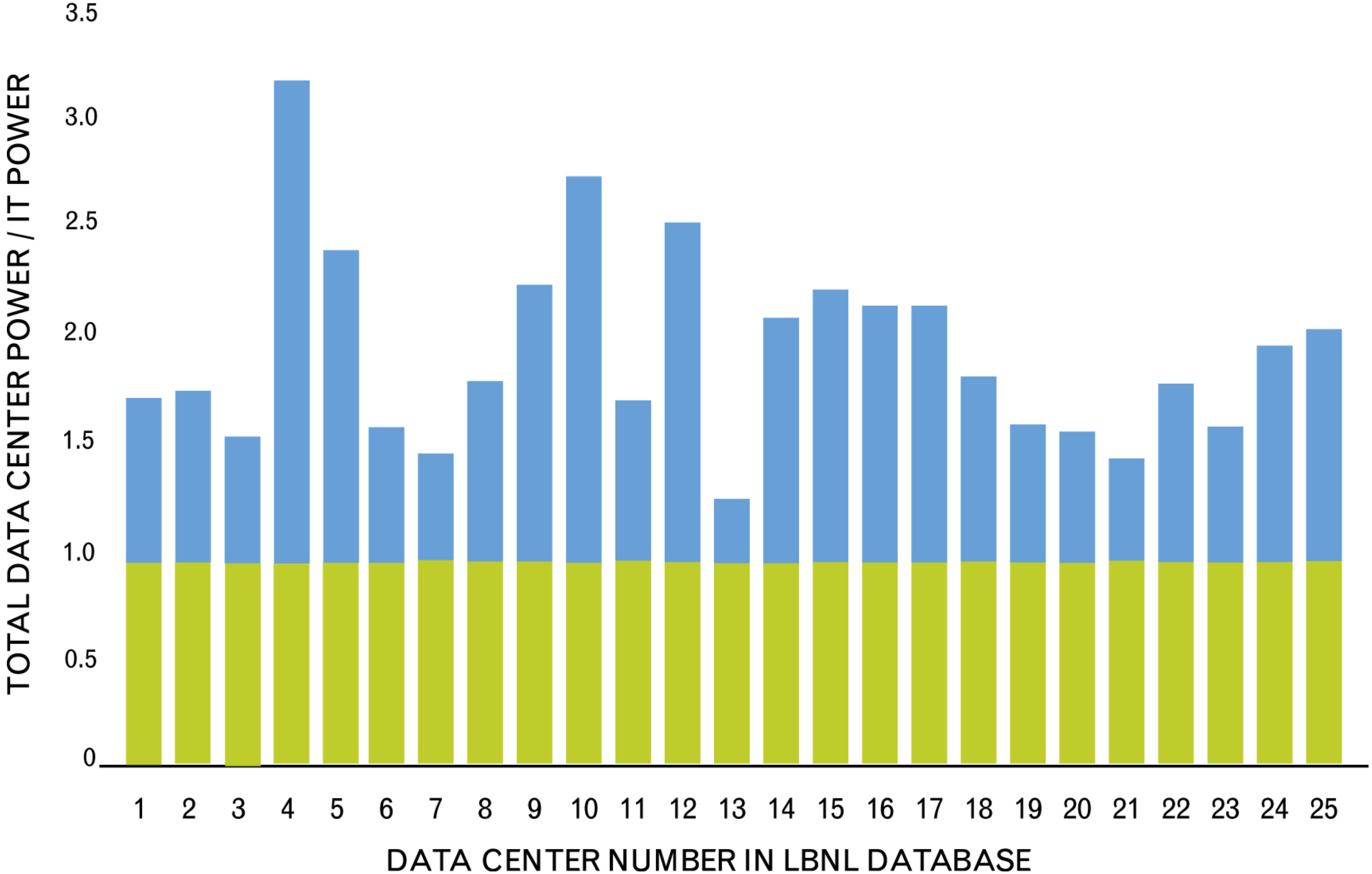
- The relative percentages of the energy actually doing computing varied considerably





High Level Metric: PUE

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

DOE's Better Buildings Challenge

Launched December 2011

Goals:

- Make commercial, industrial buildings & multifamily housing 20%+ more efficient in 10 years
- Save more than $80B for US organizations
- Create American jobs; improve energy security
- Mitigate impacts of climate change

How:

✓ Leadership
✓ Results
✓ Transparency
✓ Best Practice Models
✓ Recognition
✓ Catalyzing Action

Now 200+ Partners

Commercial, Industrial, Public, Private

Represent:

3+ Billion Square Feet

$2 Billion Private Financing

600+ Manufacturing plants

$2 B Federal Commitment

Data Center Partnerships

- DOE recently expanded the Better Buildings Challenge to include data centers; also added a new Data Center Accelerator
  - Federal Government, Public, and Private Sector leadership
  - 22 partners, over 90 MW committed todate
  - Unique opportunity– included in many other buildings
  - Small, medium and large data centers
  - Focus on infrastructure savings; ~50% of energy
  - Highlight innovative and replicable solutions, leaders

http://www4.eere.energy.gov/challenge/partners/data-centers

Data Centers Added To The BB Program

Organizations that own and or operate data centers can now partner with DOE to lead by example in one of two ways:

1. Better Buildings Challenge

Partners commit to reduce the energy intensity of their portfolio (including data centers) by at least 20% within 10 years and share their results.

2. Better Buildings Data Center Accelerator

Partners commit to reducing the infrastructure energy use of at least one data center (IT load ≥ 100 kW) by at least 25% within 5 years and share their results.

DOE agrees to:

- Provide technical expertise, communications support, and dedicated account manager
- Create networking opportunities to help Partners share best practices and innovative solutions
- Collaborate with Partners regularly
- Recognize Partners' progress and successes; highlight leadership

Focus On Infrastructure Improvements

- Infrastructure energy accounts for half or more in many data centers (less for hyper scale data centers)
- Improvement can be a challenging process to undertake, particularly in multi-use buildings
  - Metering and monitoring issues
  - Sizeable initial capital investment may be required
  - Need for cooperation between facilities and IT
- IT efficiency improves with each new generation of equipment
- The Better Buildings effort is focusing on building infrastructure at this time
  - DOE is open to working with partners to explore methods and metrics to address IT efficiency

Partner Participation Details

Process:

- Management commits to goal and forms team
- Baseline established (can be up to 3 years in past)
- Benchmark performance and develop plan
- Identify and implement efficiency measures
- Measure and track PUE performance
- Continuous improvement

How Will Data Be Tracked?

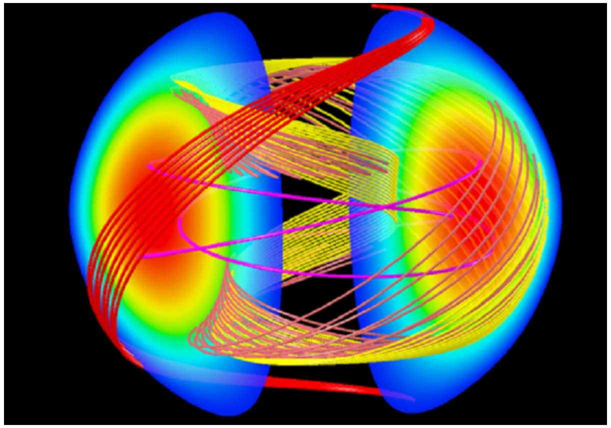
- DOE will collect data center PUE data annually through portfolio manager
  - $PUE = Total\ Data\ Center\ Facility\ Power\ or\ Energy / IT\ Equipment\ Power\ or\ Energy$
- DOE will calculate portfolio PUE-1 (infrastructure energy intensity) from the collected PUE data
  - $PUE - 1 = Total\ Data\ Center\ Facility\ Power\ or\ Energy / IT\ Equipment\ Power\ or\ Energy$ - 1
- Year by year and current vs. base year will be tracked for % change in PUE-1
  - % $Improvement = (Baseline\ PUE - 1) - (Current\ PUE - 1) / Baseline\ PUE - 1$
- Base year can go back as far as three years from joining

What If Current Metering Is Insufficient?

- If metering is not fully implemented when joining, partners may work with DOE to estimate a PUE baseline, with the goal of moving towards full metering for subsequent data submissions
- Partners must install metering as part of their participation, then track PUE using metered data

Applying Best Practices, an LBNL Case Study

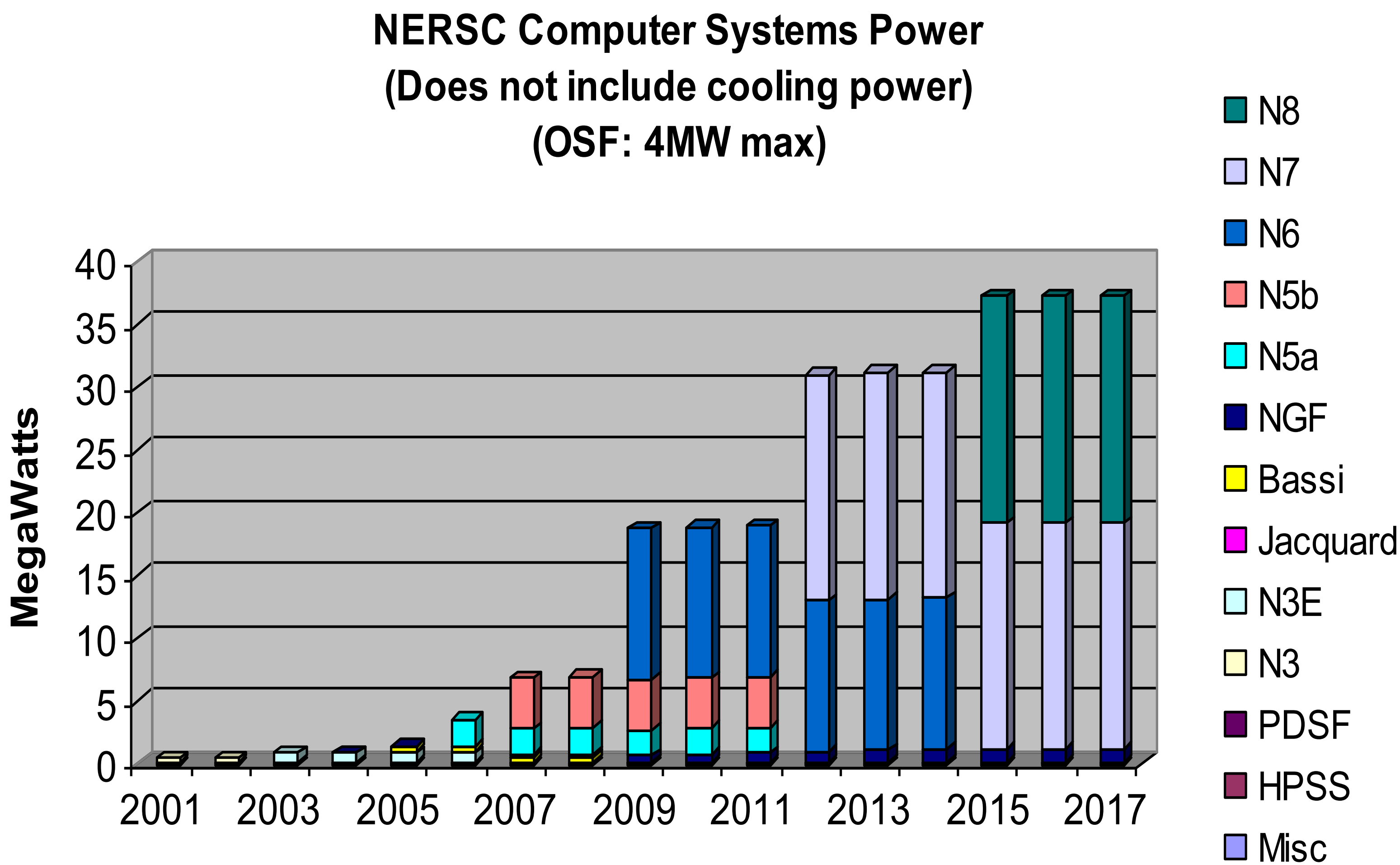
LBNL operates large systems along with legacy systems



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

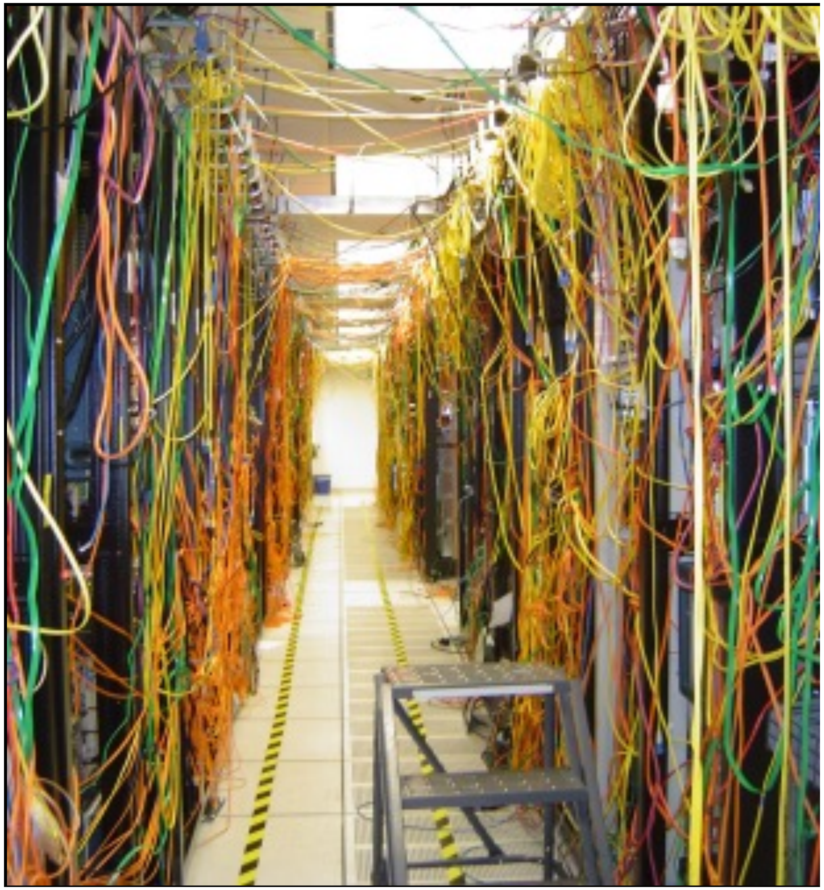
LBNL Feels the Pain!

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 and Software

IT equipment load can be controlled:

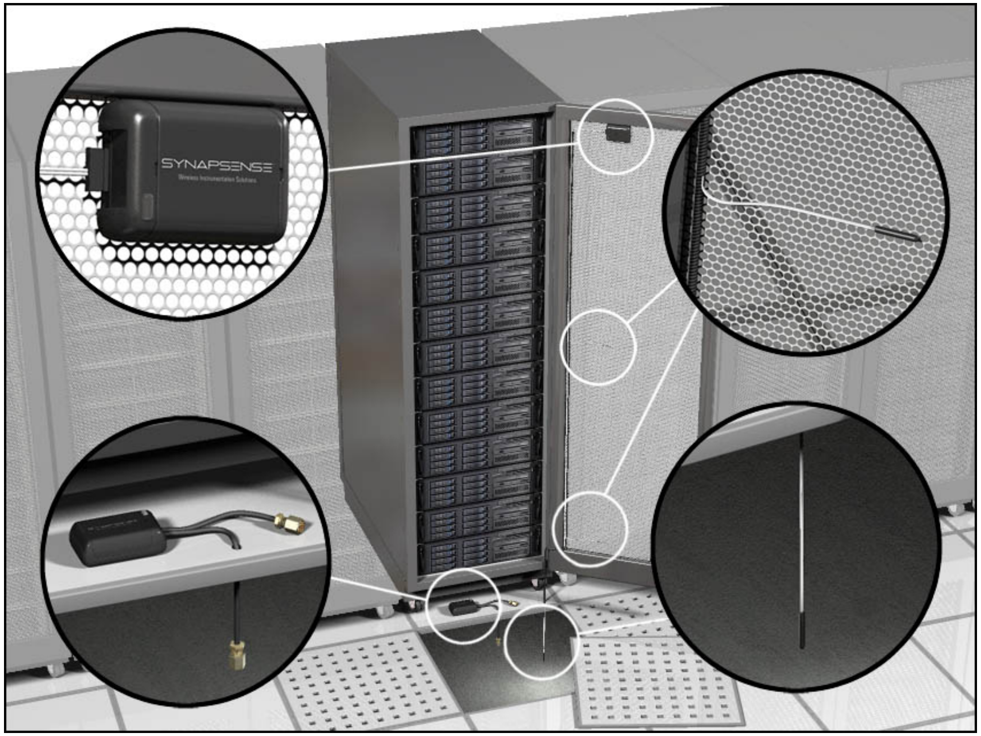
Computations per Watt is improving, but computation demand is increasing even faster so overall energy is increasing. Lifetime electrical cost will soon exceed cost of IT equipment.

- 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 <u>multiplier effect</u>
  - Equivalent savings +/- in infrastructure

Using IT to Save Energy in IT

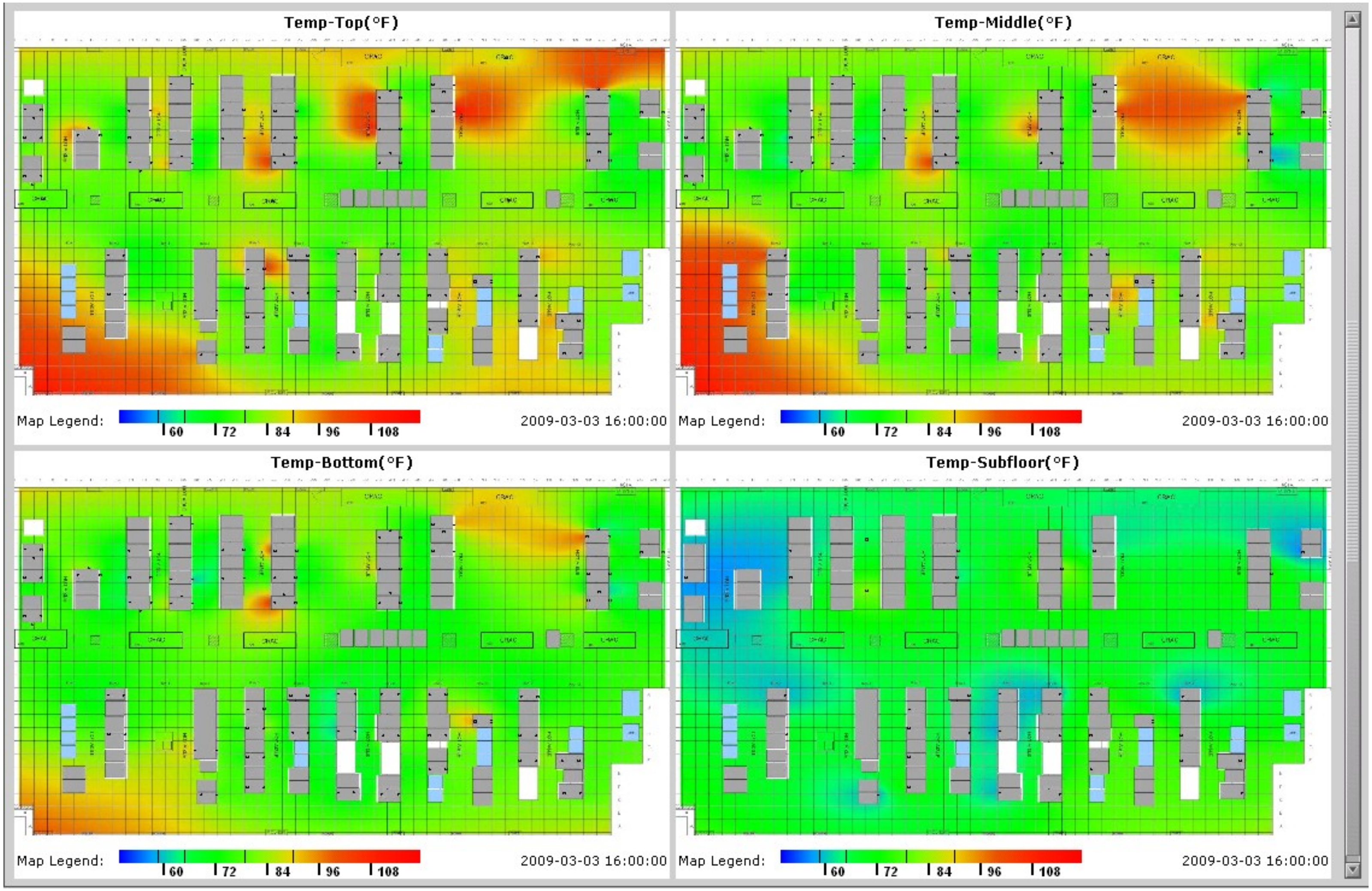
- Operators lack visibility into data center environment
- Provide same level of monitoring and visualization of the physical space as we have for the IT environment
- Measure and track performance
- Spot problems early
- 800 point SynapSense system
  - Temperature, humidity, under-floor pressure, current

LBNL Wireless Monitoring System

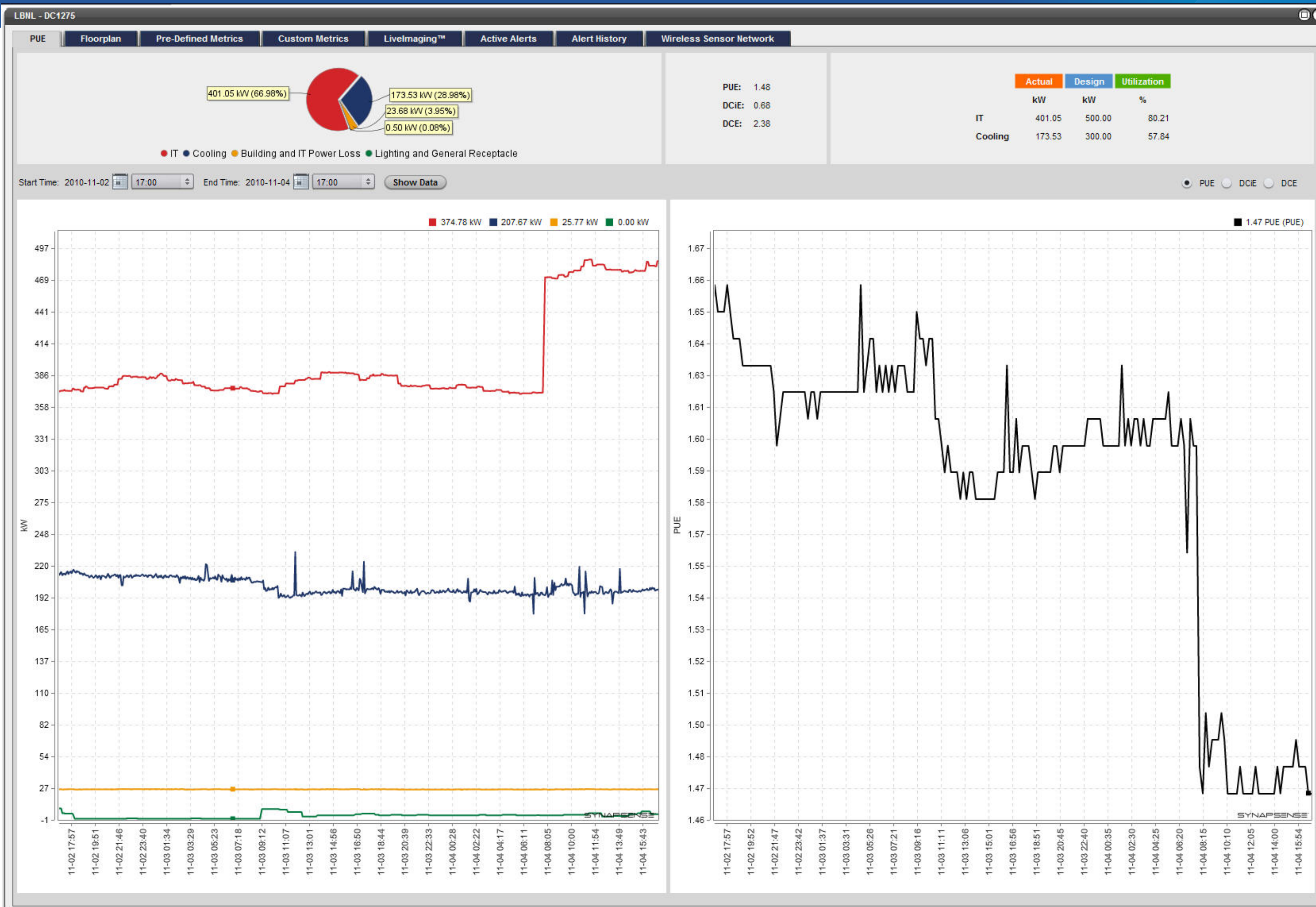


source: SynapSense

Visualization getting much better



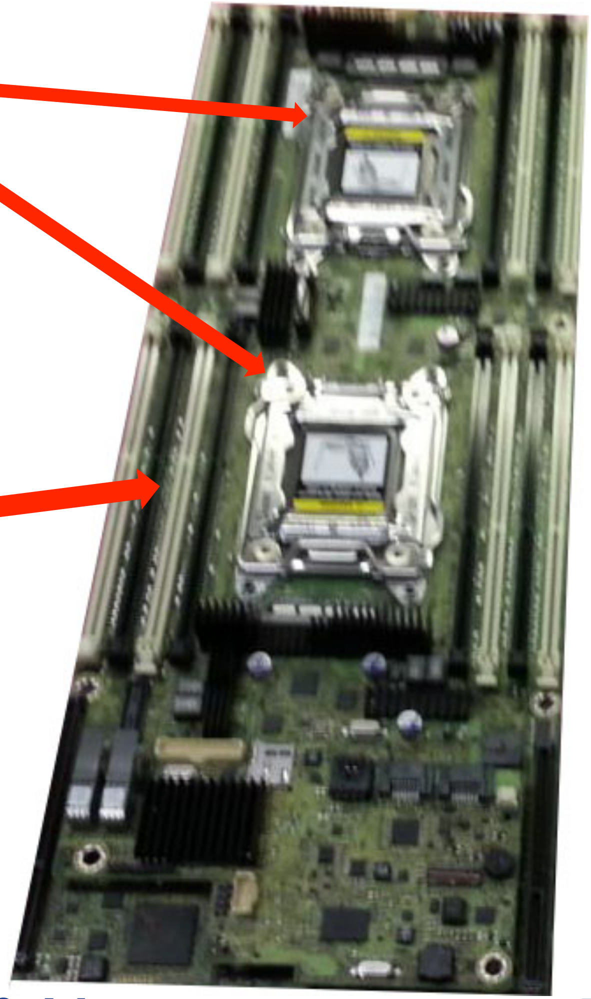
Real-time PUE Display



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

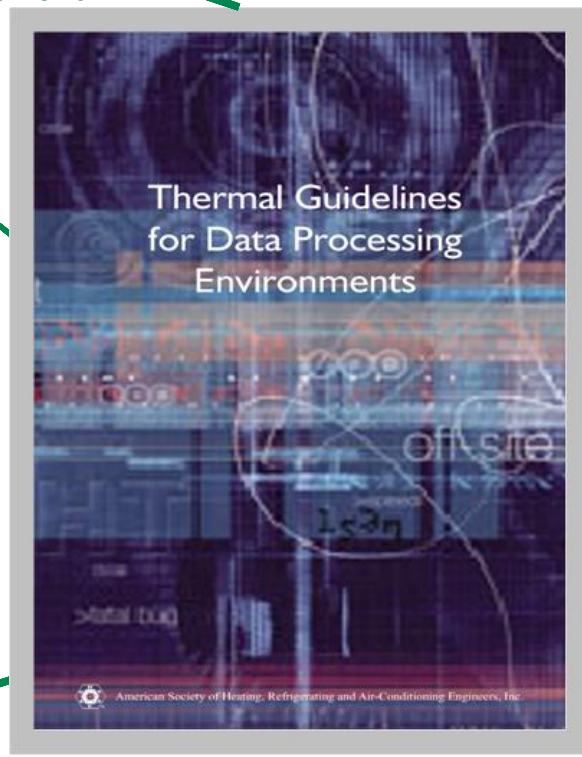
ASHRAE Thermal Guidelines

The defacto standard in the industry

Provides common understanding between IT and facility staff.

Developed with IT manufacturers

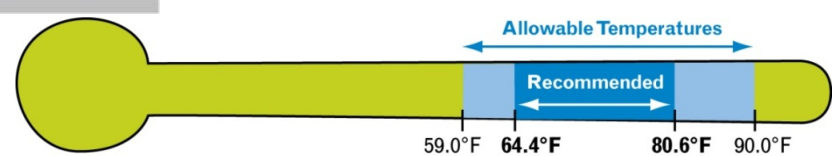
Recommends temperature range up to 80.6℉ with “allowable” much higher.



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

Provides more justification for operating above the recommended limits

Provides wider humidity ranges



Air Management: The Early Days

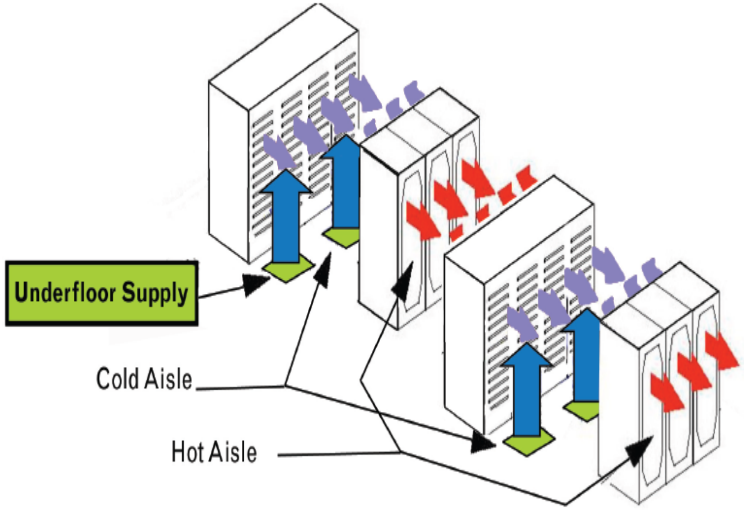
It was cold but hot spots were everywhere

Fans were used to redirect air

High flow tiles reduced air pressure

Air Management

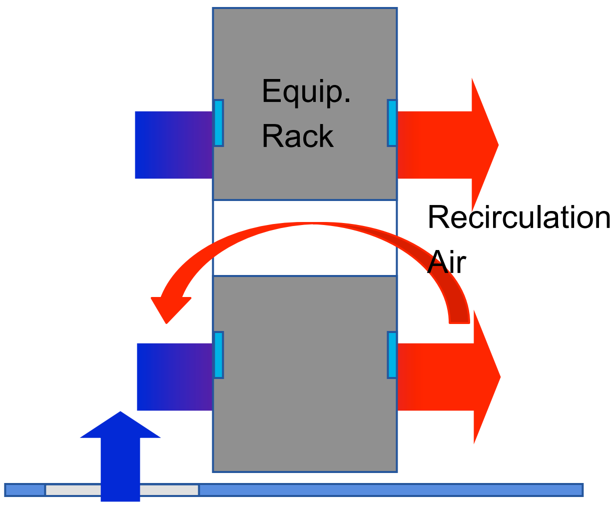
- Typically, more air circulated than required
- Air mixing and short circuiting leads to:
  - Low supply temperature
  - Low Delta T
- Use hot and cold aisles
- Improve isolation of hot and cold aisles
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity



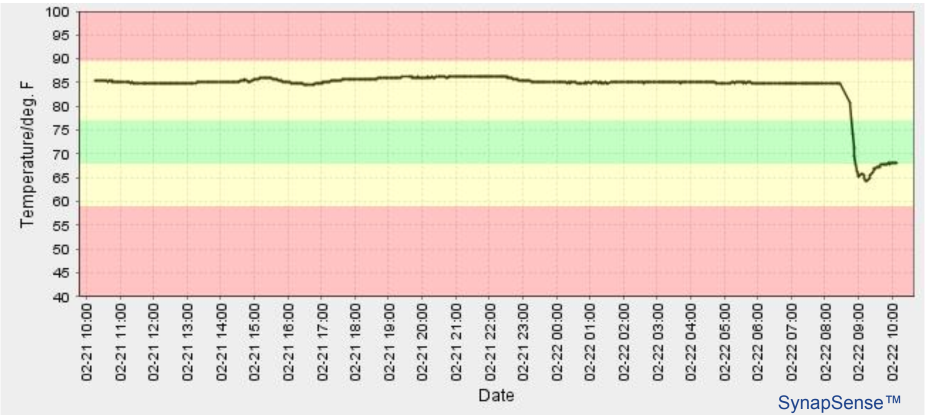
Hot aisle / cold aisle configuration decreases mixing of intake & exhaust air, promoting efficiency.

Results: Blanking Panels

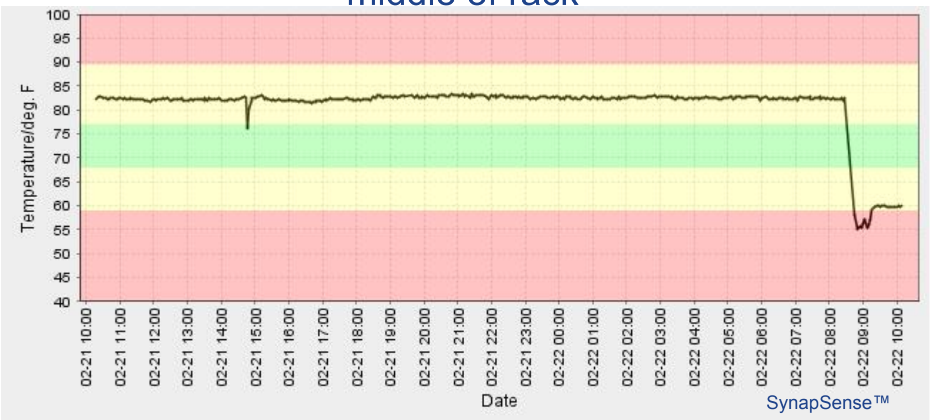
One 12 inch blanking panel reduced temperature ~20°F



top of rack

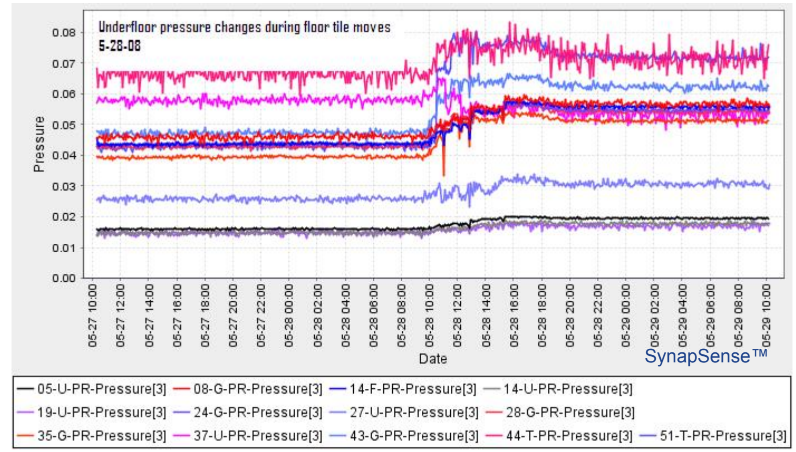


middle of rack

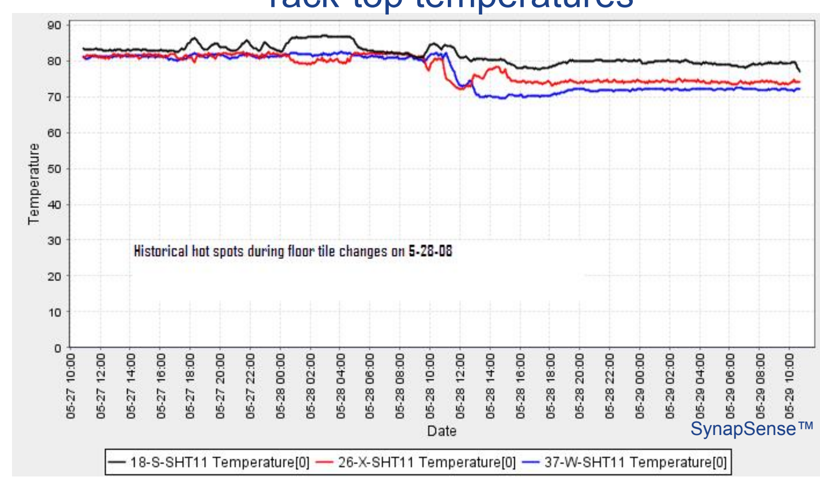


Results: Tune Floor Tiles

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

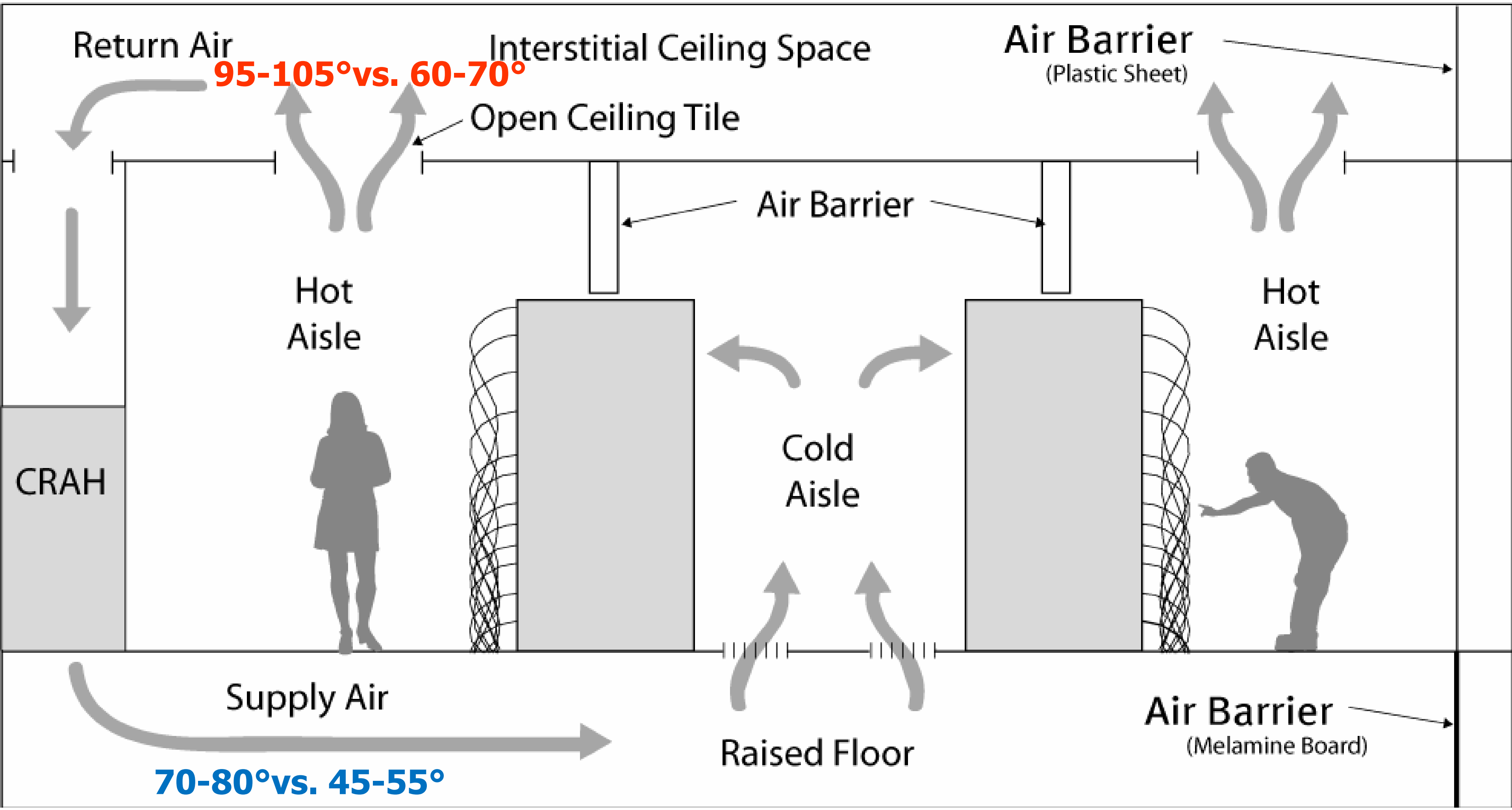
- Overhead plenum converted to hot-air return
- Return registers placed over hot aisle
- CRAC intakes extended to overhead

Before

After

Adding Air Curtains for Hot/Cold Isolation

Isolate Cold and Hot Aisles



Use Free Cooling

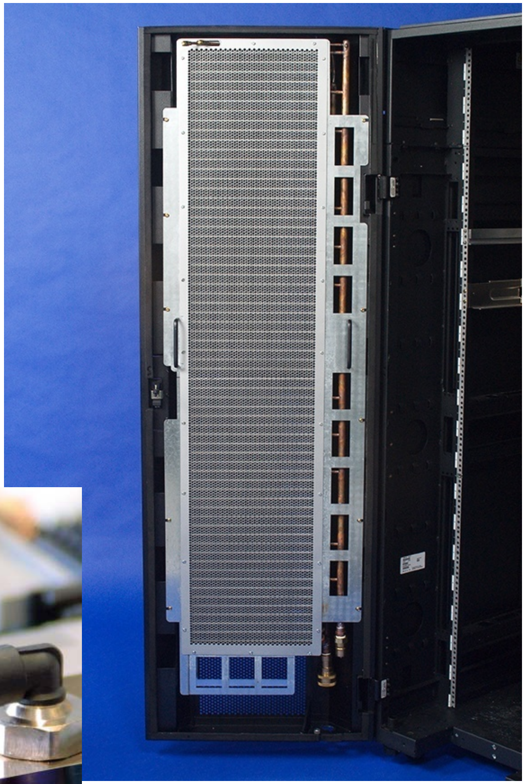
Cooling without Compressors

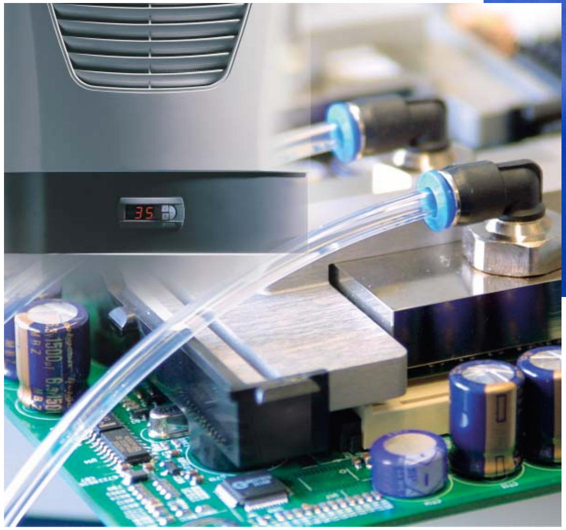
- Water-side Economizers
- Outside-Air Economizers

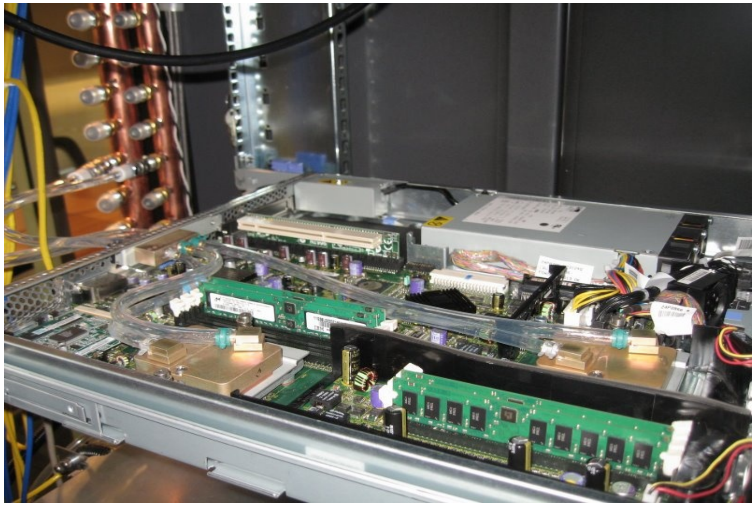
➢ Let's get rid of chillers in data centers

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!



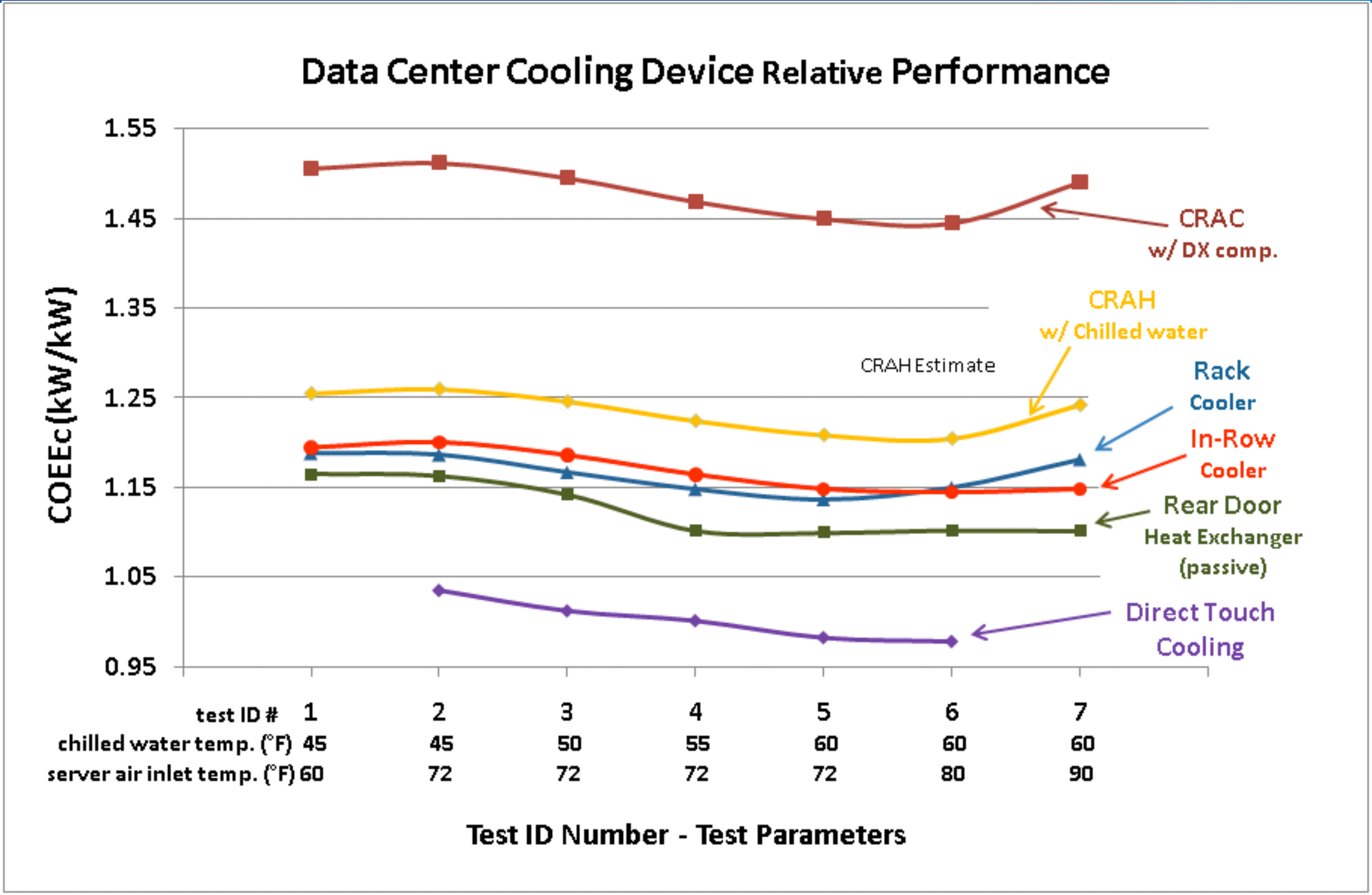




LBNL Example: Rear Door Cooling

- 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

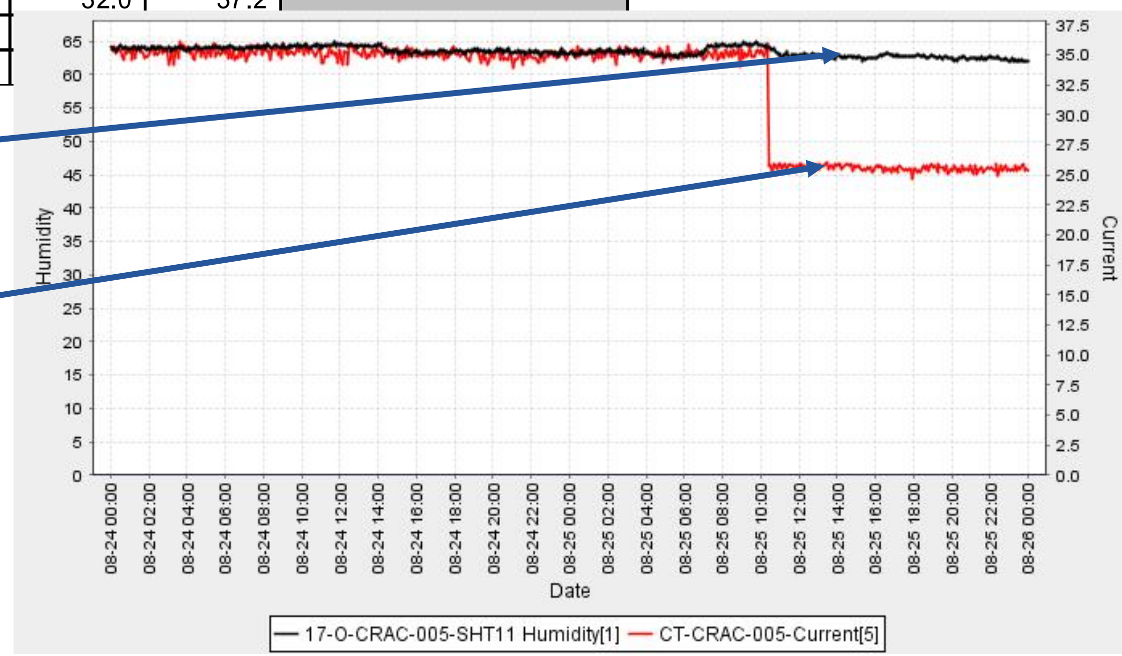
- Eliminate inadvertent dehumidification
  - Computer load is sensible only
- Use ASHRAE allowable RH and temperature
  - Many manufacturers allow even wider humidity range
- Eliminate equipment fighting
  - Coordinate controls
  - Turn off

The Cost of Unnecessary Humidification

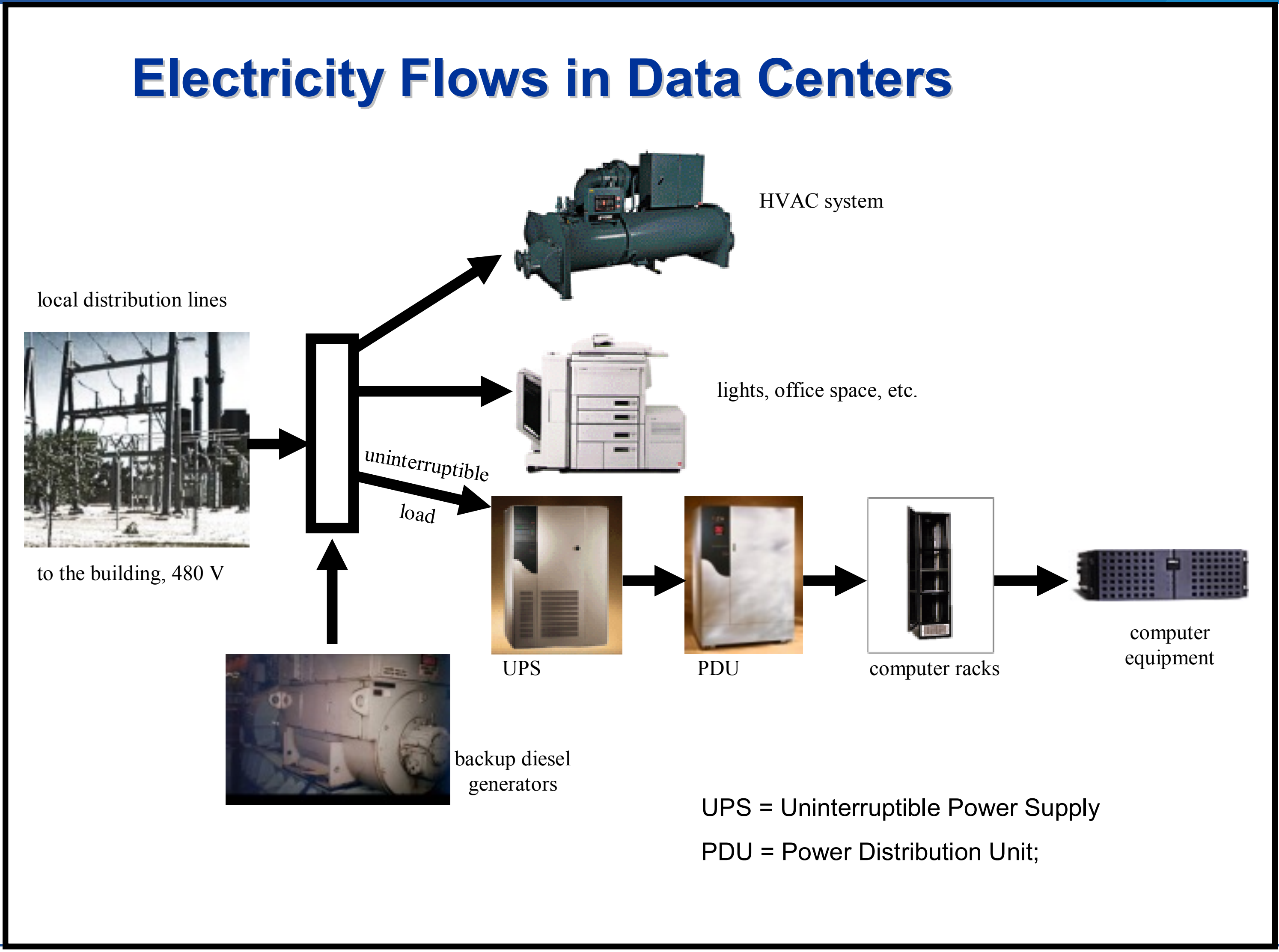
	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC 005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC 006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC 007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC 010	77.5	32.8	46.1	68	45.0	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 3%

CRAC power down 28%

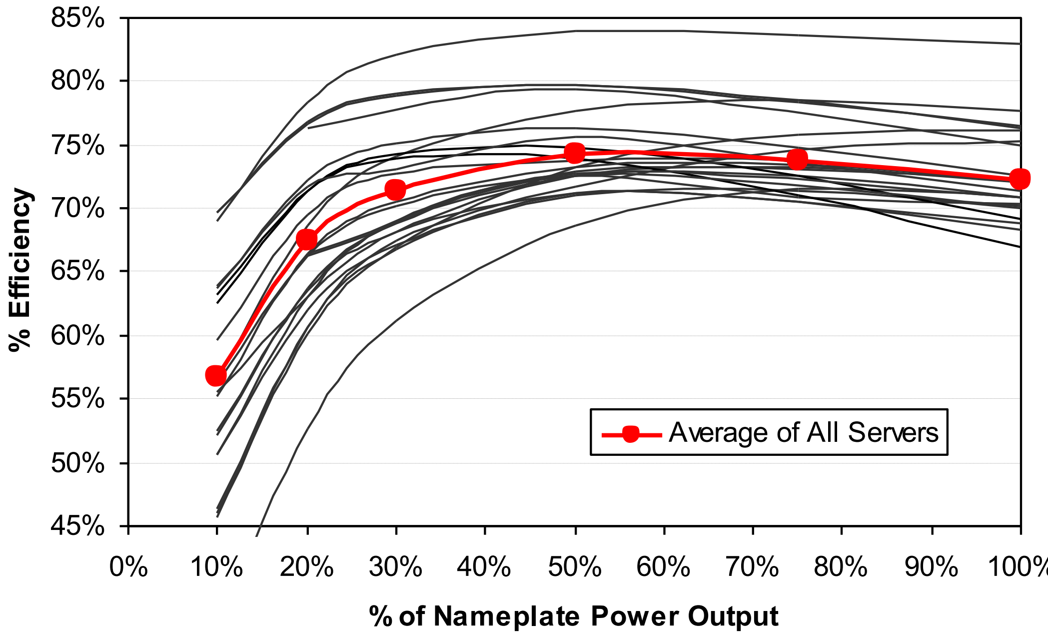


Power Chain Conversions Waste Energy

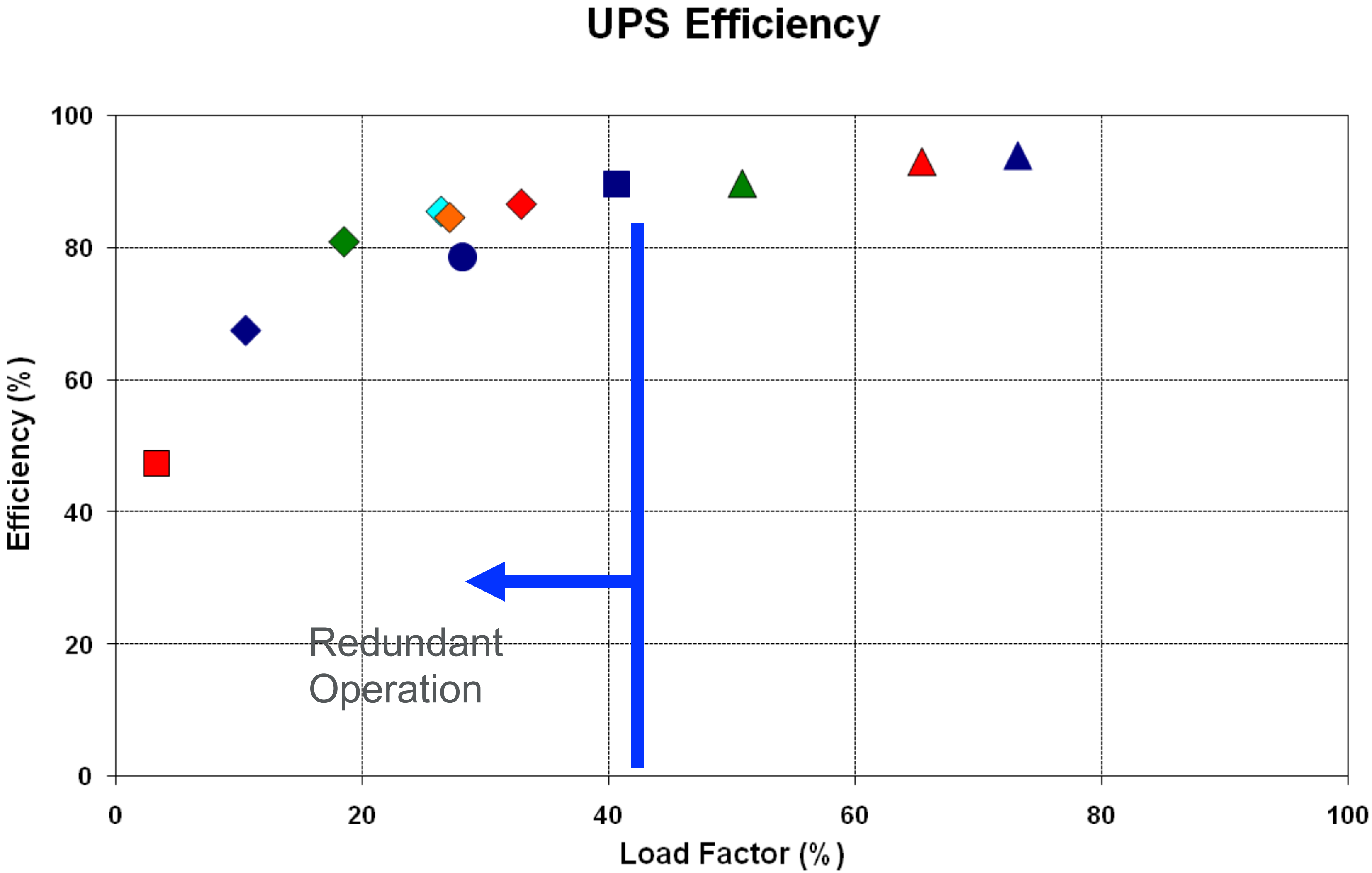


Improving the Power Chain

- 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
- 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 5°C
- 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

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

Data Center Best Practices

Most importantly…

Get IT and Facilities People Talking and working together as a <u>team</u>!!!

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

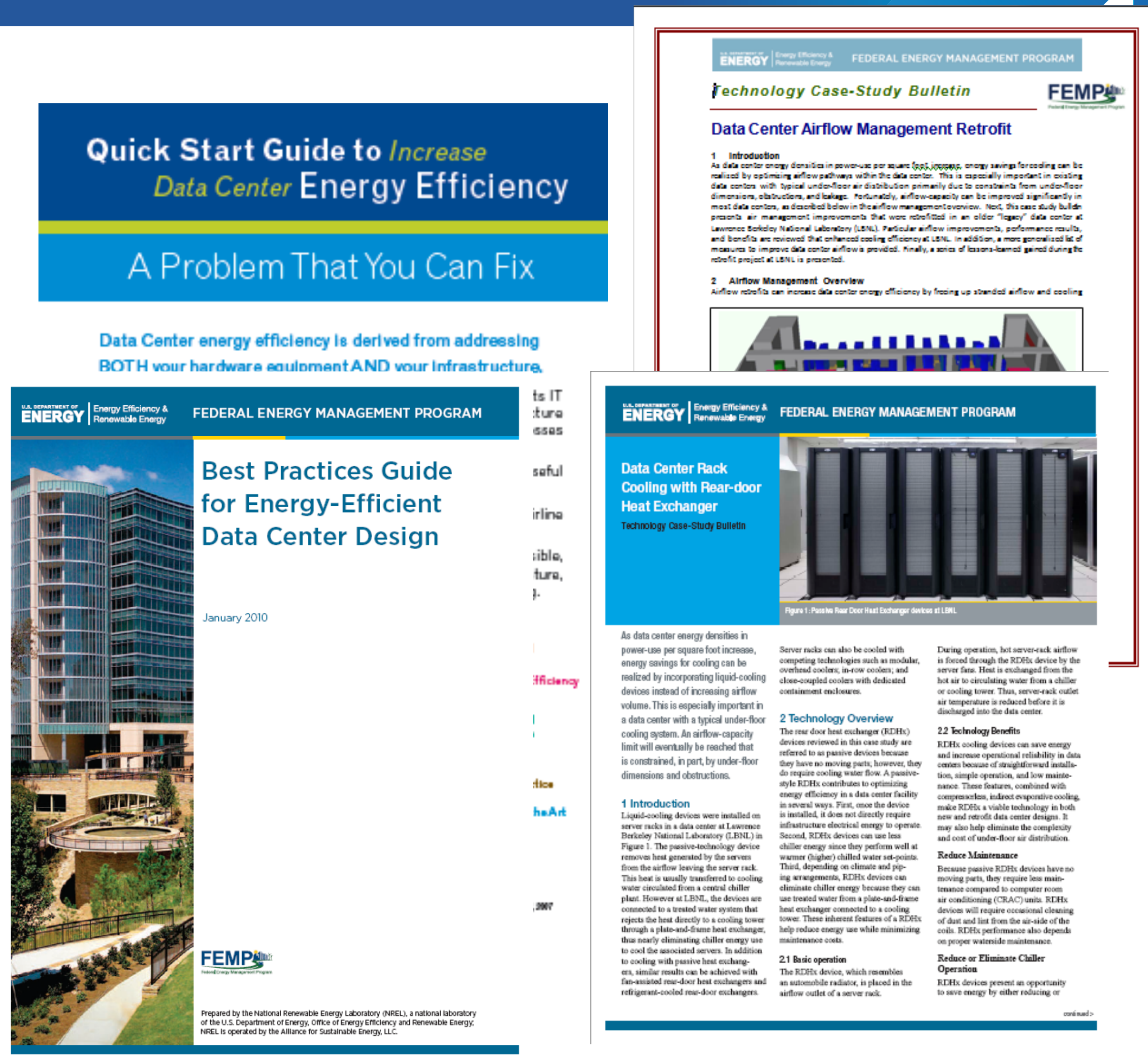
Resources to Get Started

DOE's Data Center Energy Efficiency Center of Expertise:

Datacenters.lbl.gov

Resources

- 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



FEMP Data Center Training Opportunities

Online Presentations:

- No cost, no travel
- Available 24/7
- Online, open-access courses
- Expert Instructors
- Self paced
- CEUs

AUTHORIZED IACET PROVIDER

Accredited Courses specifically on Data Centers:

- Advanced HVAC in High-Tech Buildings – Data Centers
- Advanced HVAC in High-Tech Buildings - Laboratories
- Labs, Data Centers, and High-Tech Facilities
- Achieving Energy-Efficient Data Centers with New ASHRAE Thermal Guidelines

Live Webinars (not IACET accredited)

- Data Center Profiler Tool Training

For more information visit: **http://femp.energy.gov/training**

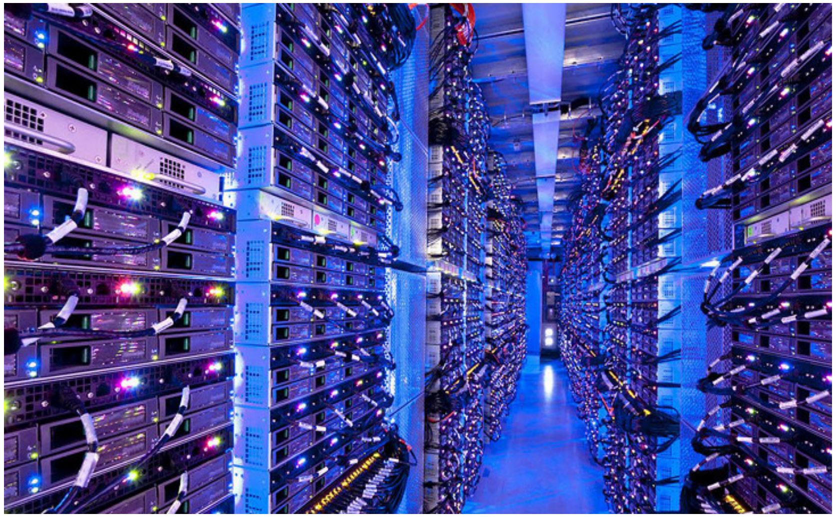
Data Center Energy Practitioner (DCEP) Program

- FEMP supported training to prepare students to perform accurate assessments
- Provided by Professional Training Organizations
- Regular offerings
- Registration Cost

http://datacenters.lbl.gov/dcep

Moving Forward Together

- Looking forward to working with you as a Better Buildings Partner
- Highlighting what is possible in data centers
- Voluntary partnership; welcomes feedback and input
- Better Buildings Summit, May 27-29, 2015
  - Registration is open



http://www4.eere.energy.gov/challenge/partners/data-centers

Data Center Partner Roster

Defense Information Systems Agency
Department of Veterans Affairs · United States of America
U.S. Justice Department · Drug Enforcement Administration
United States Environmental Protection Agency
Social Security Administration · USA
NASA
The Home Depot
ebay
Digital Realty
Data Center Solutions
facebook
Staples
that was easy®
Schneider Electric
Stanford University
CoreSite
Argonne National Laboratory
Michigan State University
NERSC
Berkeley Lab
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
EST. 1943
EMSL
NREL
National Renewable Energy Laboratory

Speaker Contact Information

Dale Sartor, P.E.
Lawrence Berkeley National Laboratory
MS 90-3111
University of California
Berkeley, CA 94720

BERKELEY LAB

DASartor@LBL.gov
(510) 486-5988
http://datacenters.lbl.gov/