


Applying Data Center Energy Efficiency Best Practices

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FEMP Federal Energy Management Program

Outline

- Data Center Energy Context
- Applying Best Practices – LBNL case study
- DOE Resources to Help

Challenging Conventional Wisdom: Game Changers

Conventional Approach

- All data centers are “mission critical”
- 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

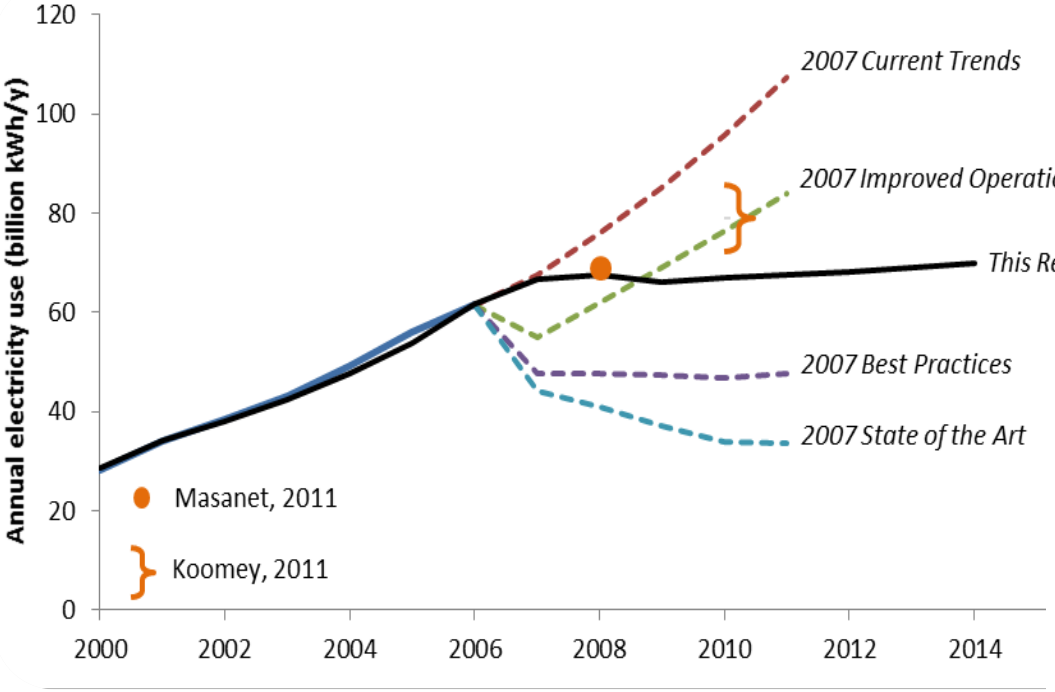
Data centers are energy intensive facilities

- 10 to 100+ times more energy intensive than an office
- Server racks now designed for more than 30 kW
- Surging demand for data storage
- 1.8% of US electricity consumption
- Power and cooling constraints in existing facilities
- Perverse incentives –
  - ✓IT and facilities costs separate

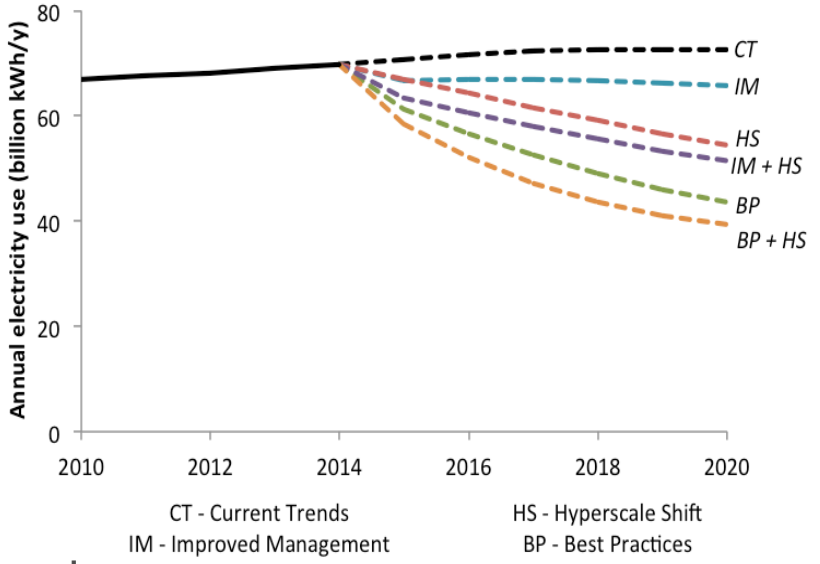
Potential Benefits of Energy Efficiency

- 20-40% savings & high ROI typical
- Aggressive strategies can yield 50+% savings
- Extend life and capacity of infrastructures

US Data Center Energy Usage Reports (2007 & 2016)



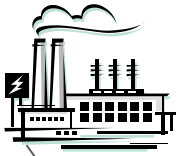
~1.8% U.S. Electricity



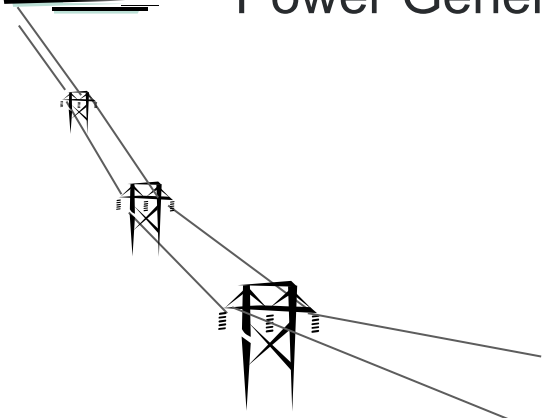
45% Reduction Possible with Best Practices and greater shift to hyper-scale

Typical Data Center Energy Efficiency ~ 15%

100 Units
Source
Energy

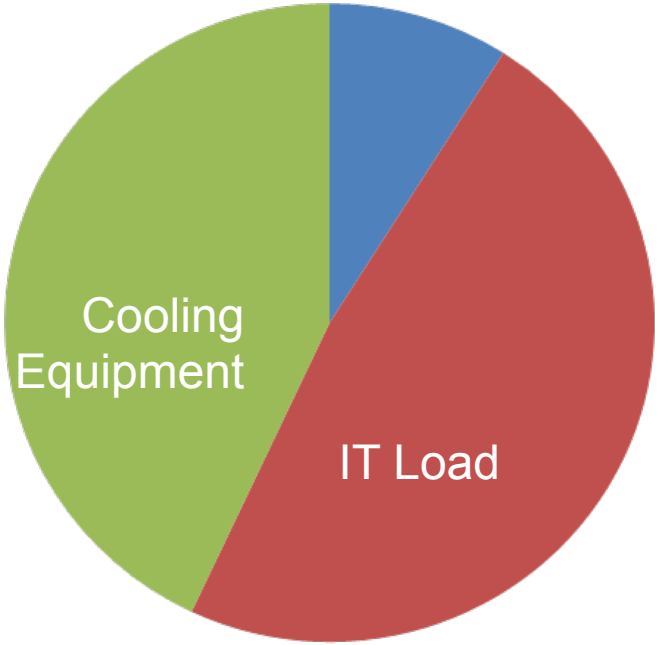


35 Units
Power Generation

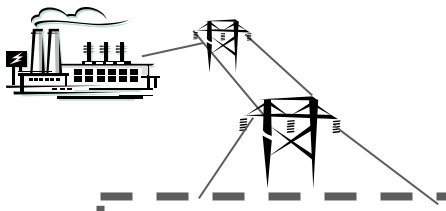


33 Units
Delivered

Power
Conversions
& Distribution



Energy Efficiency Opportunities



- IT innovation
- Virtualization
- High-efficiency power supplies
- Load management

- Better air management
- Move to liquid cooling
- Optimized chilled-water plants
- Use of free cooling
- Heat recovery

Power Conversion & Distribution

IT Load/ Computing Operations

Cooling Equipment

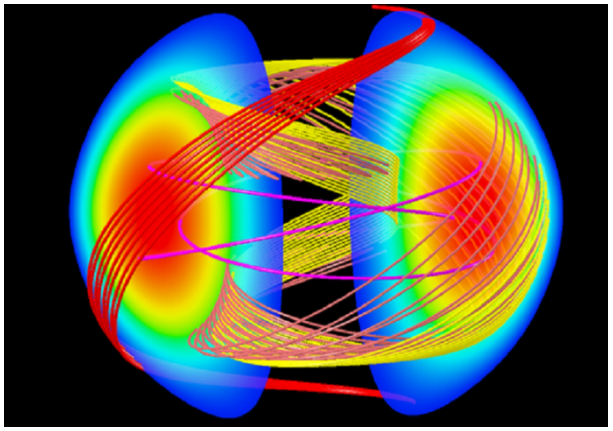
- High-voltage distribution
- High-efficiency UPS
- Efficient redundancy strategies
- Use of DC power

Alternative Power Generation

- On-site generation Including fuel cells and renewable sources
- CHP applications (waste heat for cooling)

Lawrence Berkeley National Laboratory (LBNL)

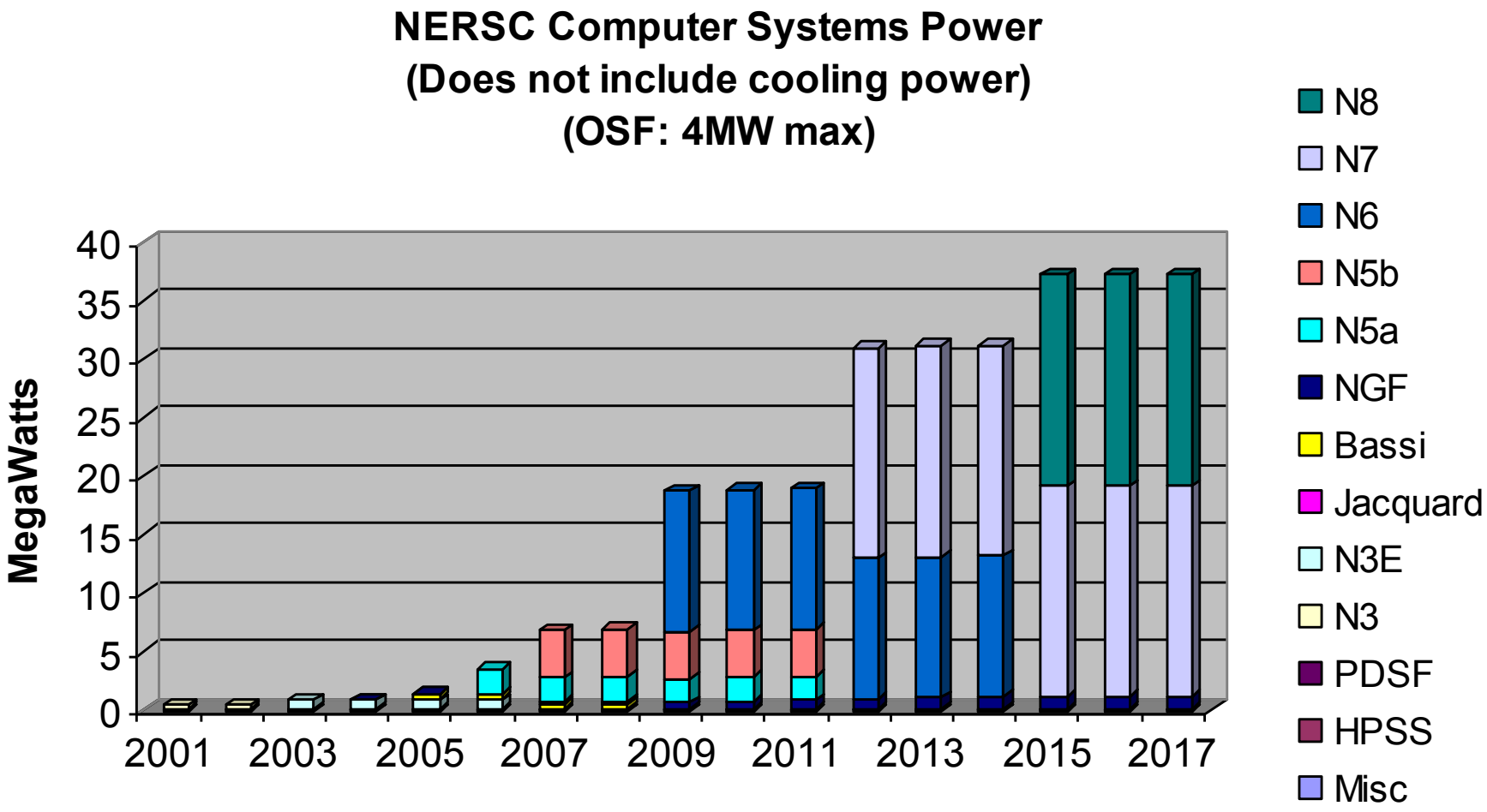
- Operates large systems along with legacy equipment



- We also research energy-efficiency opportunities and work on various deployment programs

LBNL Feels the Pain!

LBNL Super Computer Systems Power



Applying Best Practices at LBNL

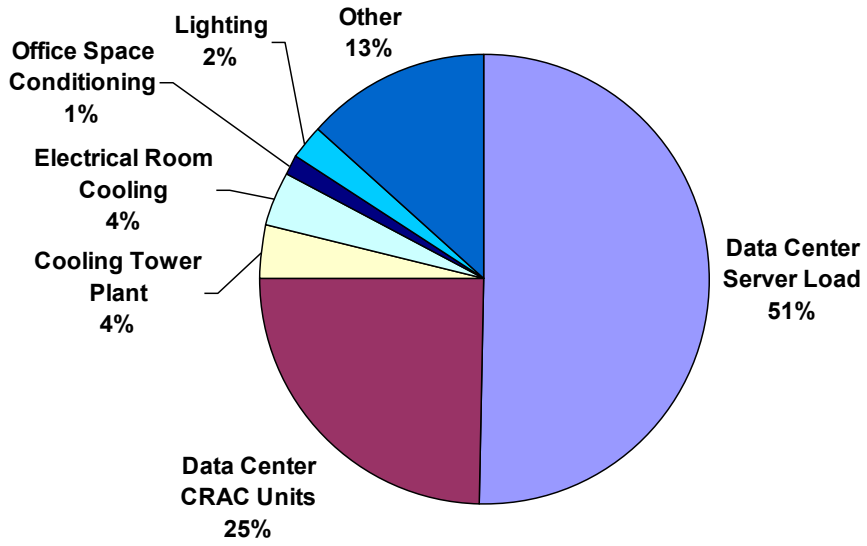
- Partnership between CIO, CS, and energy efficiency researchers, facilities
- Existing data centers relatively efficient
  - NERSC: PUE = 1.3 (1.4), takes advantage of central plant
  - 50B-1275: PUE = 1.45 (1.65), tower cooled CRACs
- Increased efficiency frees up needed “capacity”
- New data centers 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

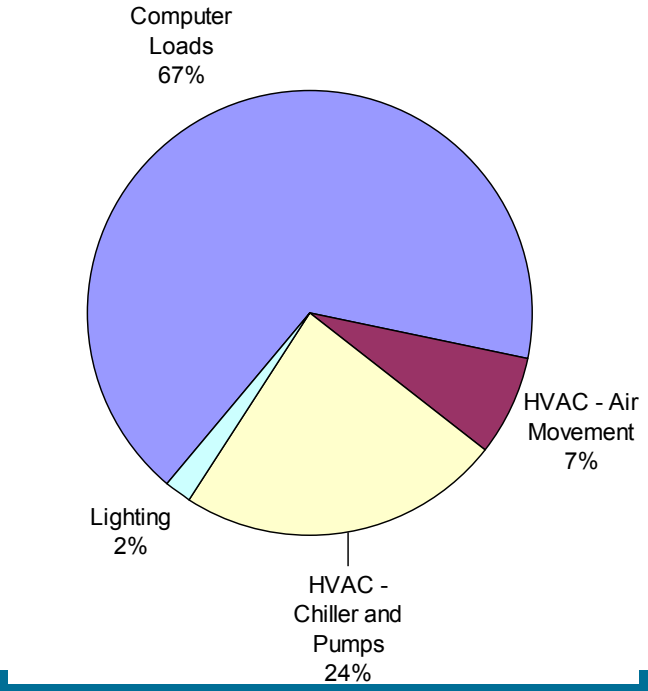
Best Practices Summary

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

Benchmark Energy Performance

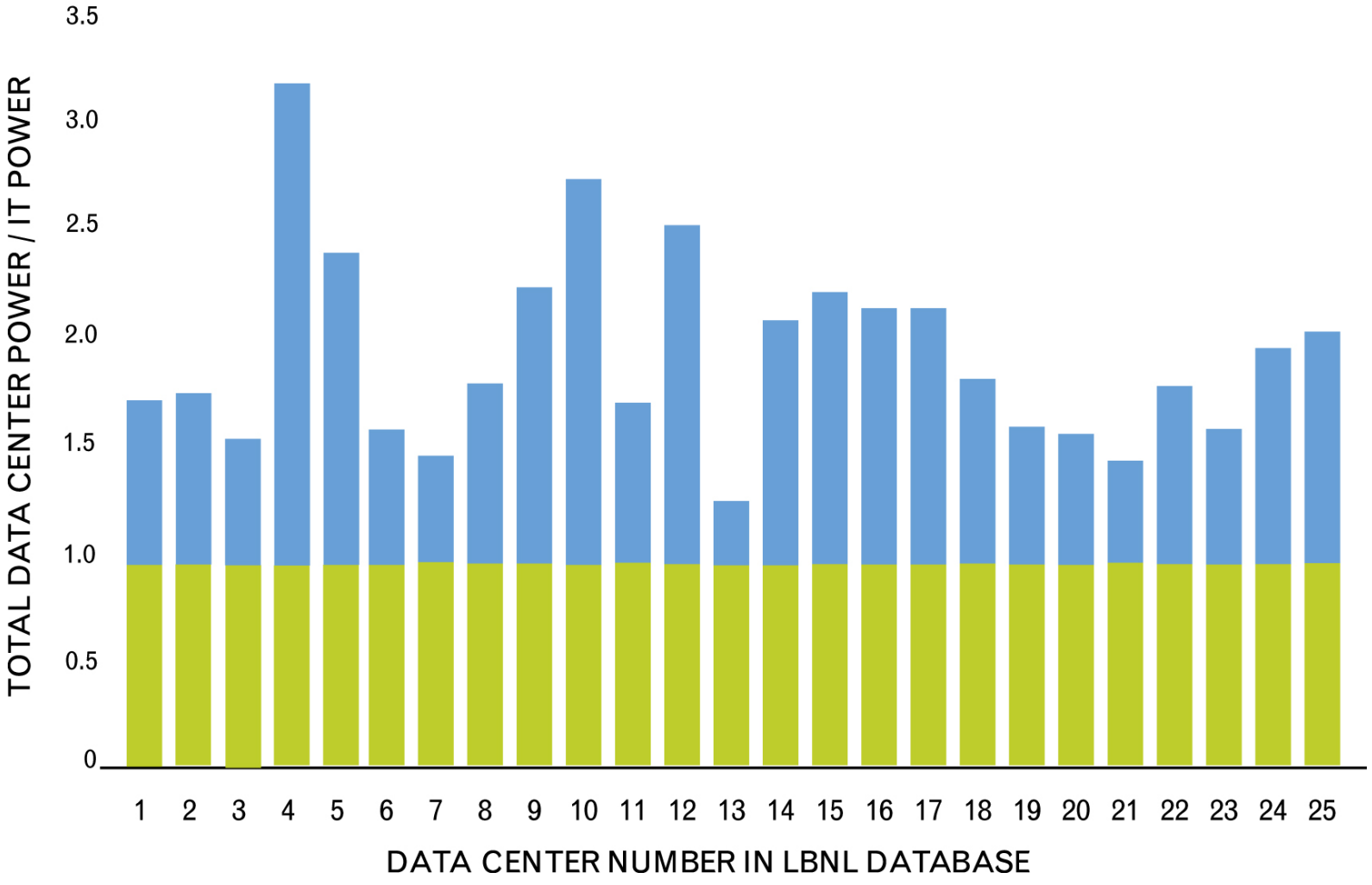
- Compare to peers
  - Wide variation
- Identify best practices
- ID opportunities
- Track performance
  - Can't manage what isn't measured
- The relative percentage of energy actually doing computing varies





High Level Metric: PUE

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



Example PUE Values

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

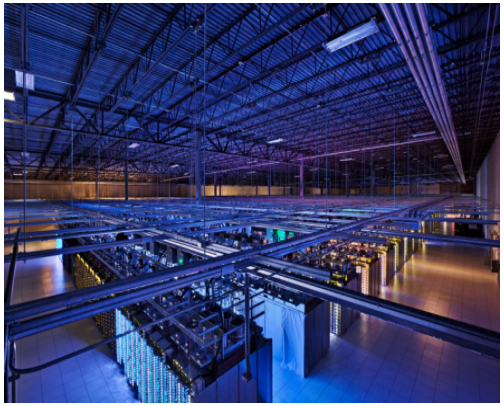
Slide Courtesy Mike Patterson, Intel

Drivers: Executive Order 13693 and the Data Center Optimization Initiative (DCOI)

Specific federal goals for data centers:

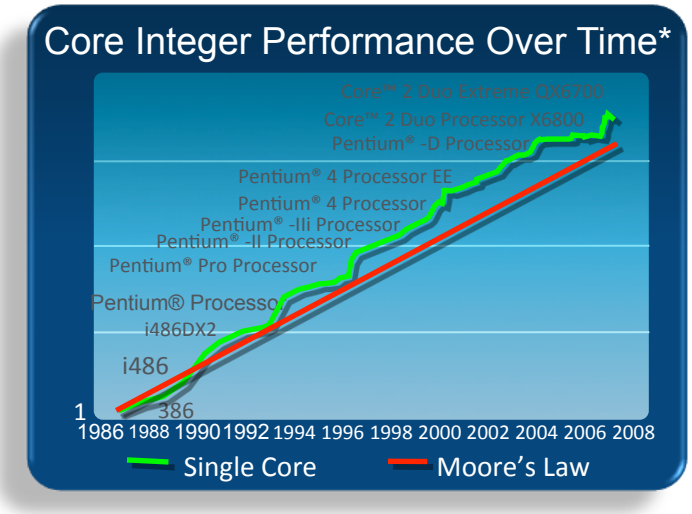
- Promote energy optimization, efficiency, and performance
- Install/monitor advanced energy meters in all data centers by FY2018
  - Active tracking of Power Usage Effectiveness (PUE)
- Establish PUE targets: *PUE=Total Data Center Facility Power or Energy/IT Equipment Power or Energy*
  - between 1.2 and 1.4 for new data centers
  - less than 1.5 for existing data centers
- Option: close the data center (consolidate, move to the cloud)

Power Usage Effectiveness (PUE) is a measure of how efficiently a data center'snfrastructur e uses energy.



IT Load Can Be Controlled

Computations per Watt is improving

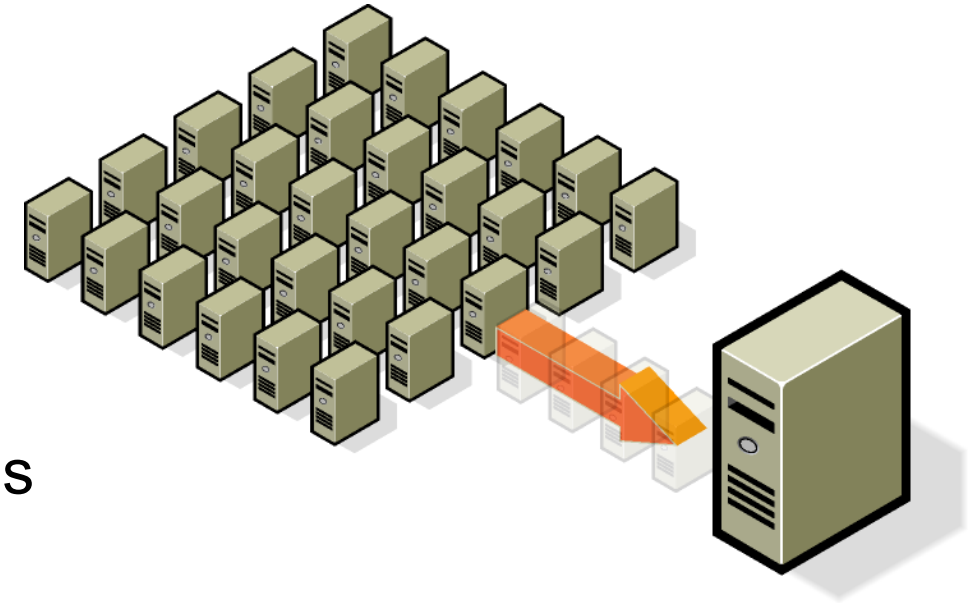


Opportunities:

- Consolidation
- Server efficiency (Use ENERGY STAR)
  - Flops per Watt
  - Efficient power supplies and less redundancy.
- Software efficiency
  - Virtualize for higher utilization
  - Data storage management.
- Enable power management (e.g., sleep mode)
- Reducing IT load has a multiplier effect
  - Savings in infrastructure energy depends on PUE

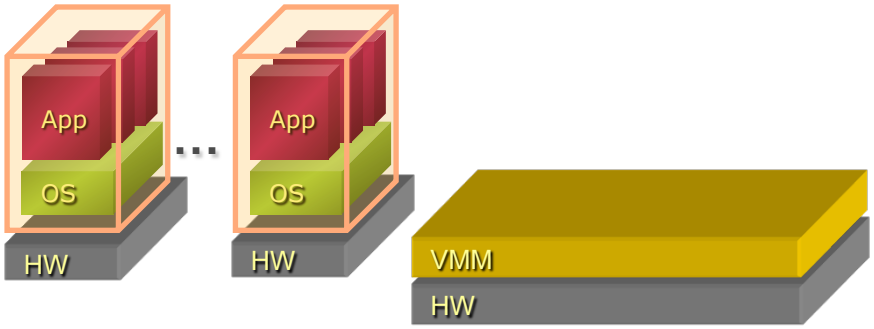
Virtualize and Consolidate Servers and Storage

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



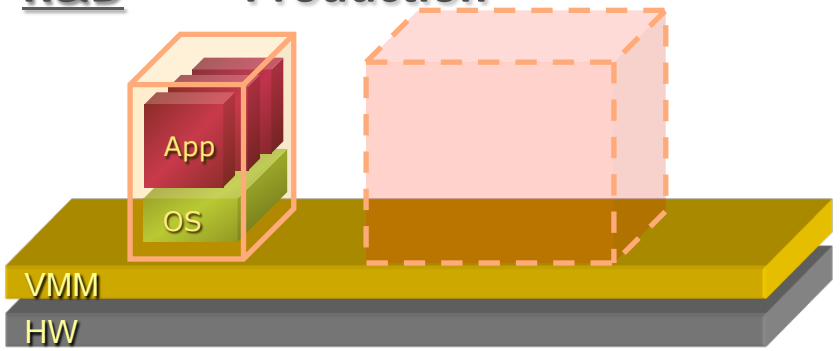
Virtualize and Consolidate Servers and Storage

Server Consolidation



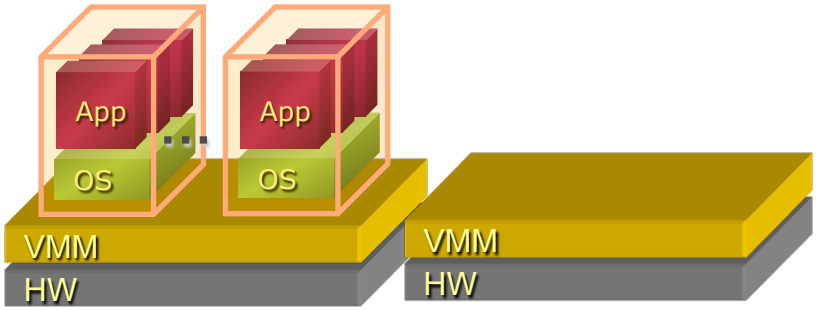
10:1 in many cases

R&D Production



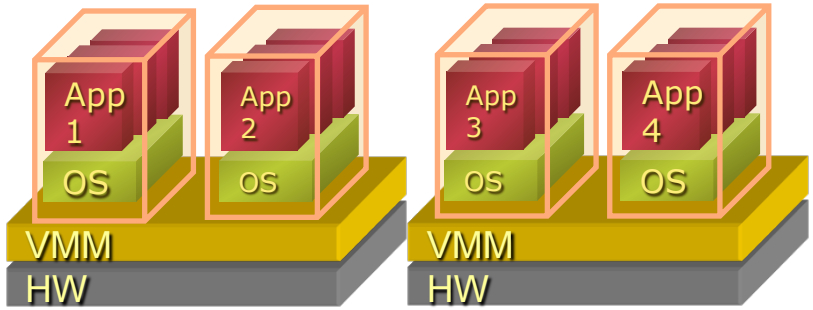
Enables rapid deployment,
reducing number of idle, staged servers

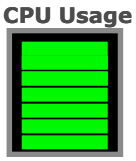
Disaster Recovery

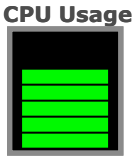


- Upholding high-levels of business continuity
- One Standby for many production servers

Dynamic Load Balancing





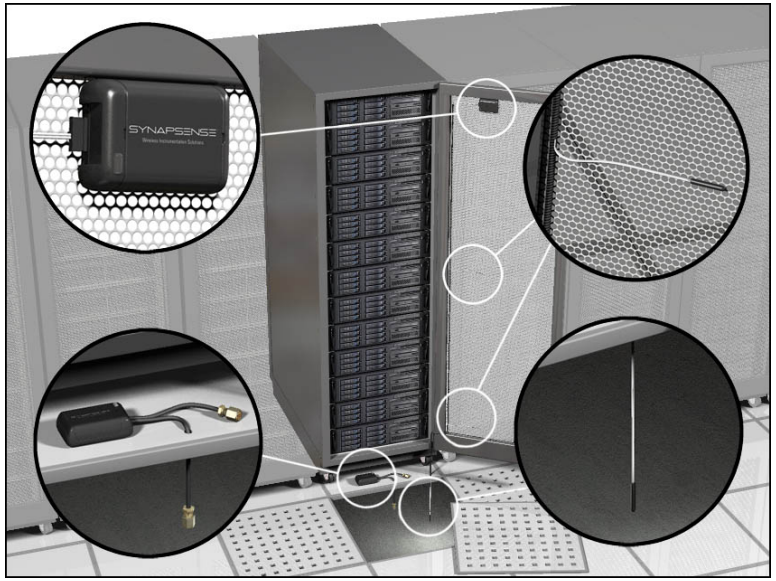


Balancing utilization with head room

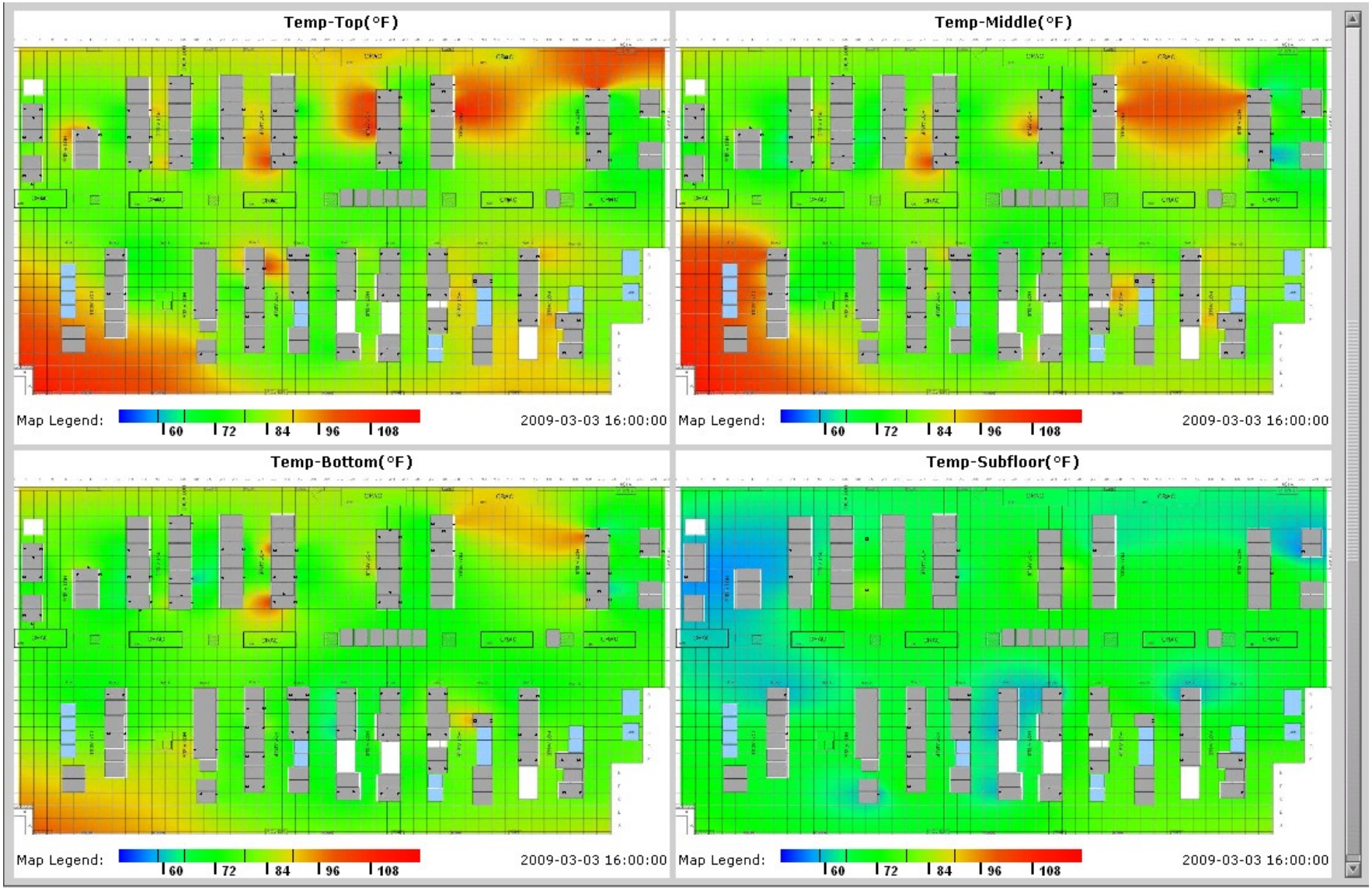
Using IT to Save Energy in IT

- 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
- Example: 800 point SynapSense system
  - Temperature, humidity, under-floor pressure, current

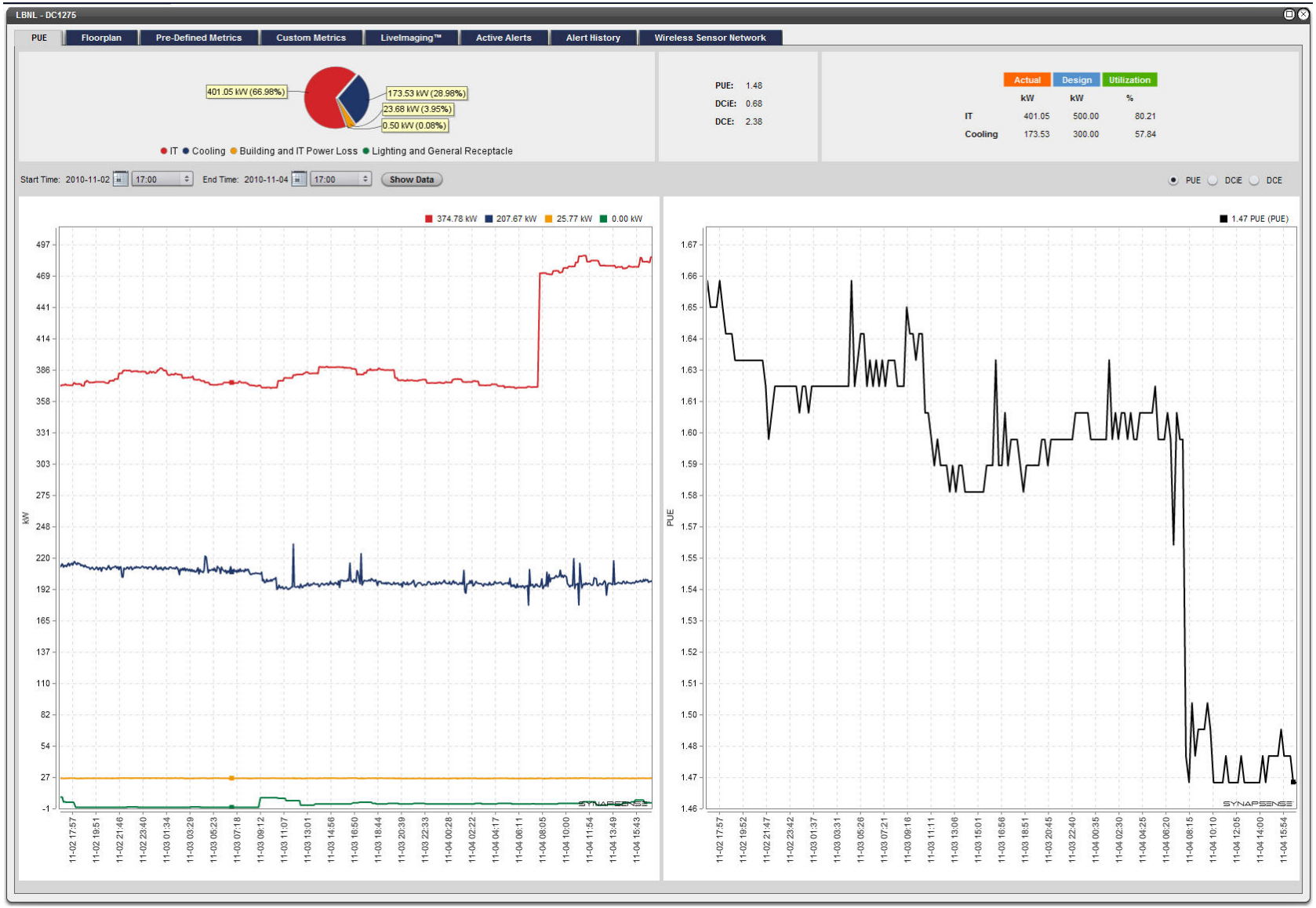
LBNL Wireless Monitoring System



Visualization getting much better



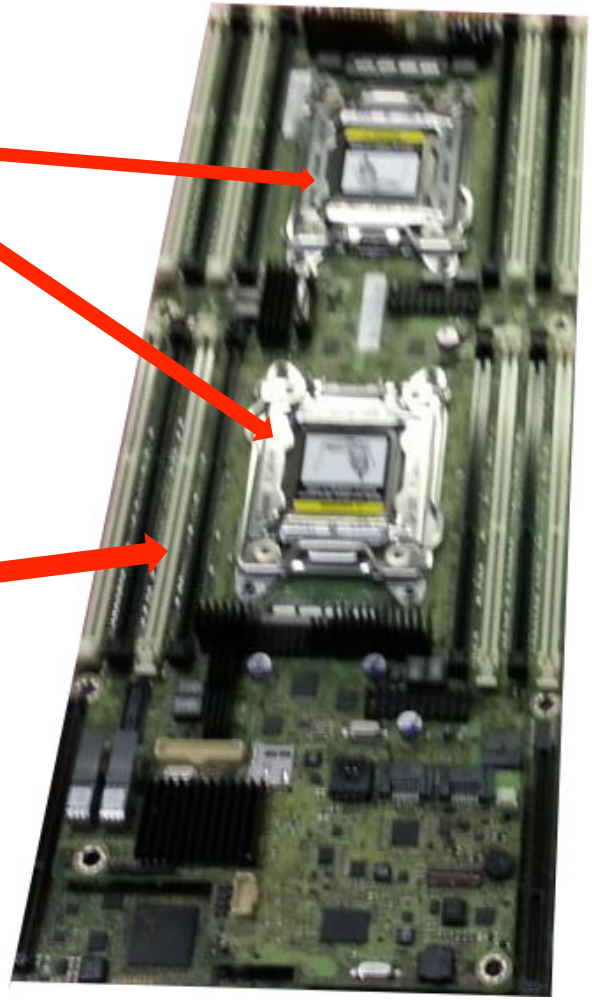
Real-time PUE Display



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 …

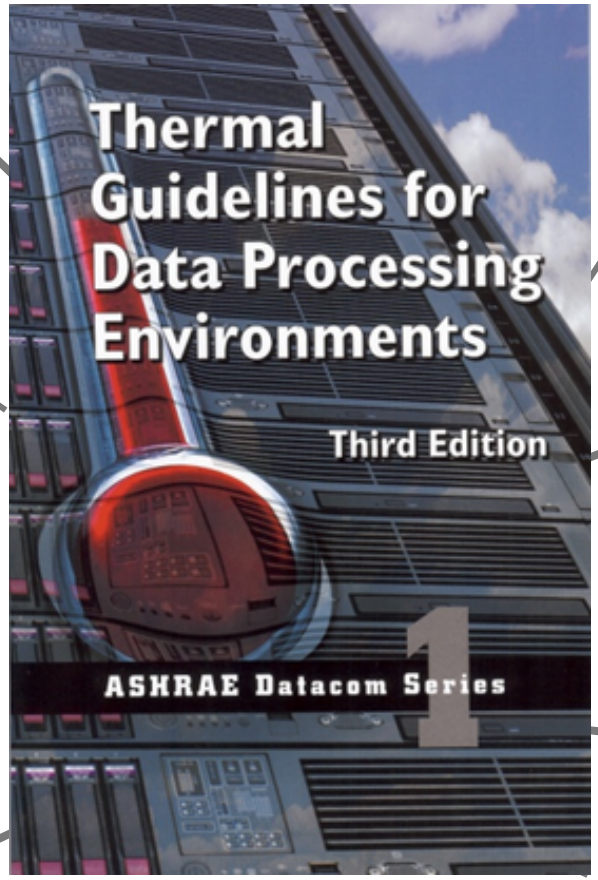
Slide courtesy of NREL

ASHRAE Thermal Guidelines
The defacto standard in the industry

Provides common understanding between IT and facility staff.

Developed with IT manufacturers

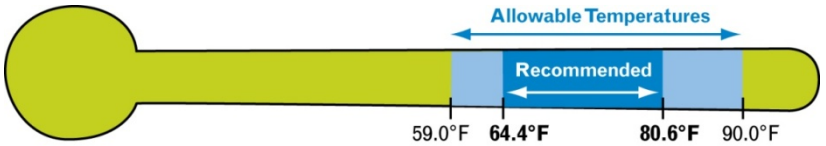
Provides wider humidity ranges



Recommends temperature range up to 80.6°F with "allowable" much higher.

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

Provides more justification for operating above the recommended limits



Air Management: The Early Days

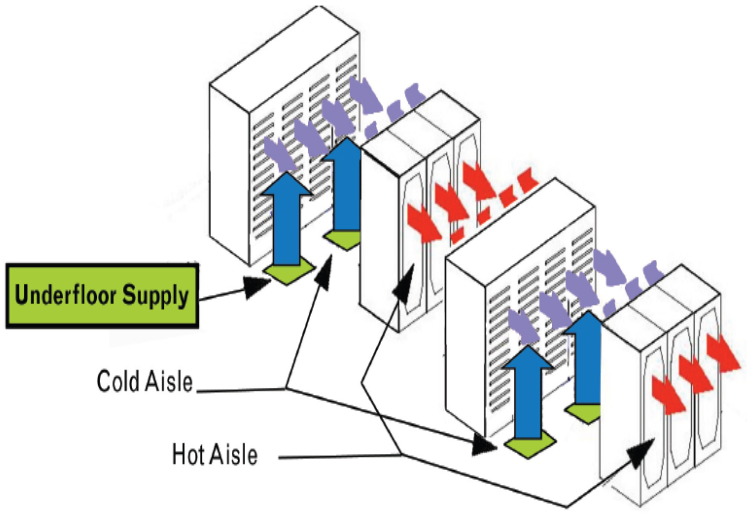
It was cold but hot spots were everywhere

Fans were used to redirect air

High flow tiles reduced air pressure

Air Management

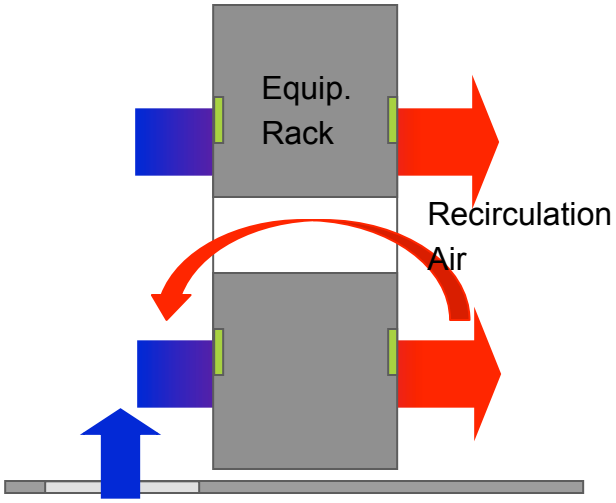
- Typically, more air circulated than required
- Air mixing and short circuiting leads to:
  - Low supply temperature
  - Low Delta T
- Use hot and cold aisles
- Improve isolation of hot and cold aisles
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity



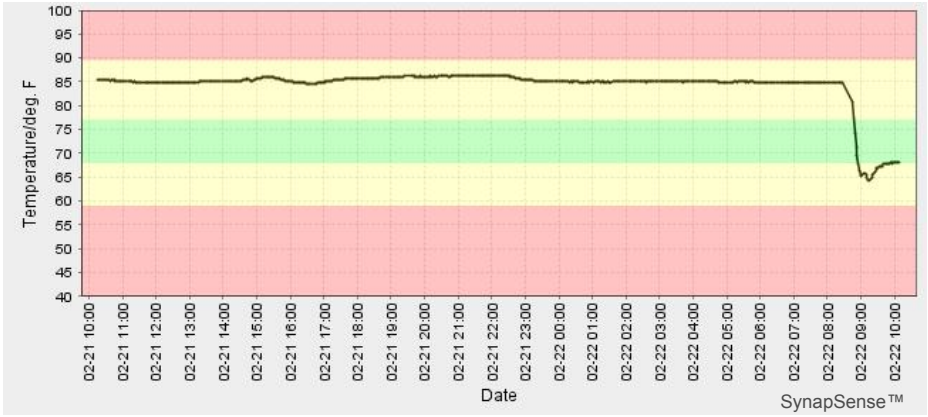
Hot aisle / cold aisle configuration decreases mixing of intake & exhaust air, promoting efficiency.

Results: Blanking Panels

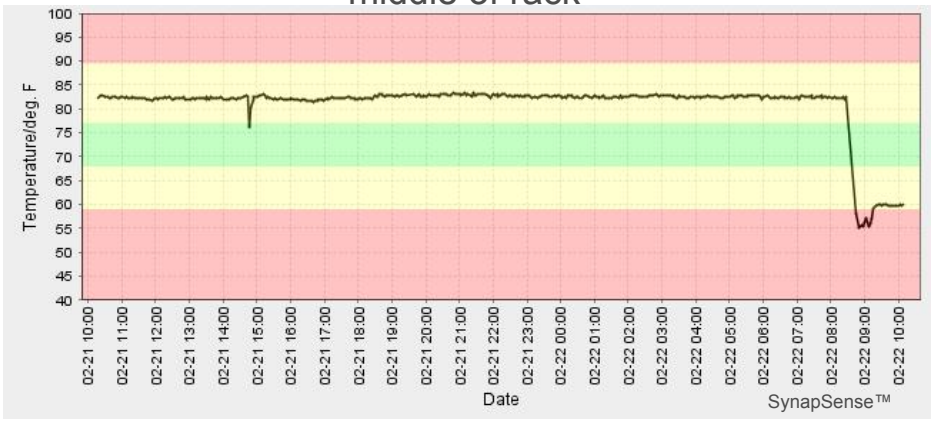
One 12 inch blanking panel reduced temperature ~20°F



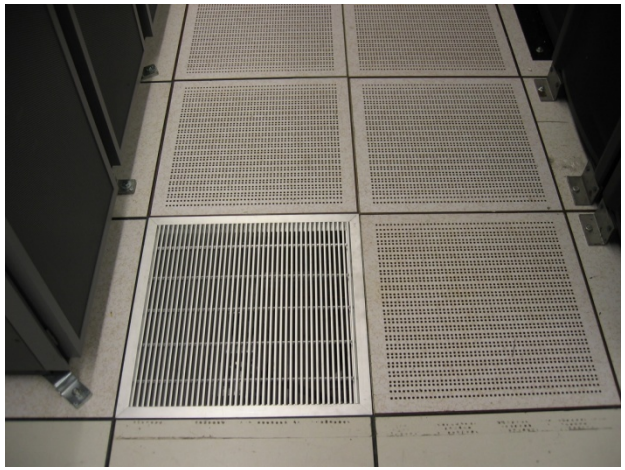
top of rack



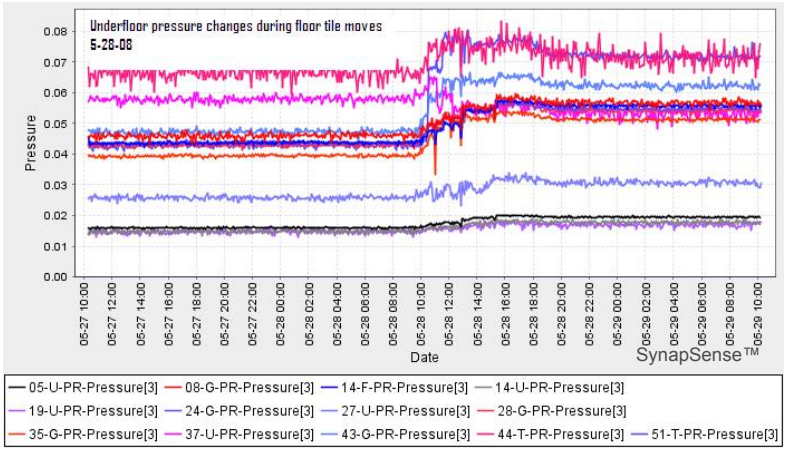
middle of rack



Results: Tune Floor Tiles

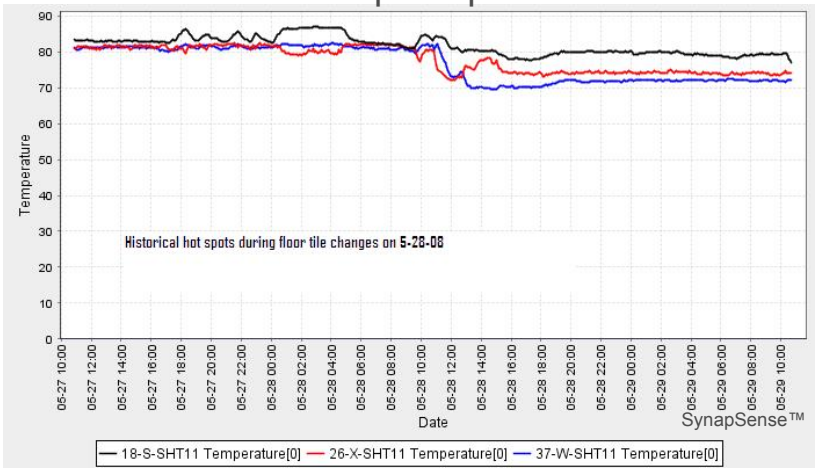


under-floor pressures



- 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

rack-top temperatures



Improve Air Management

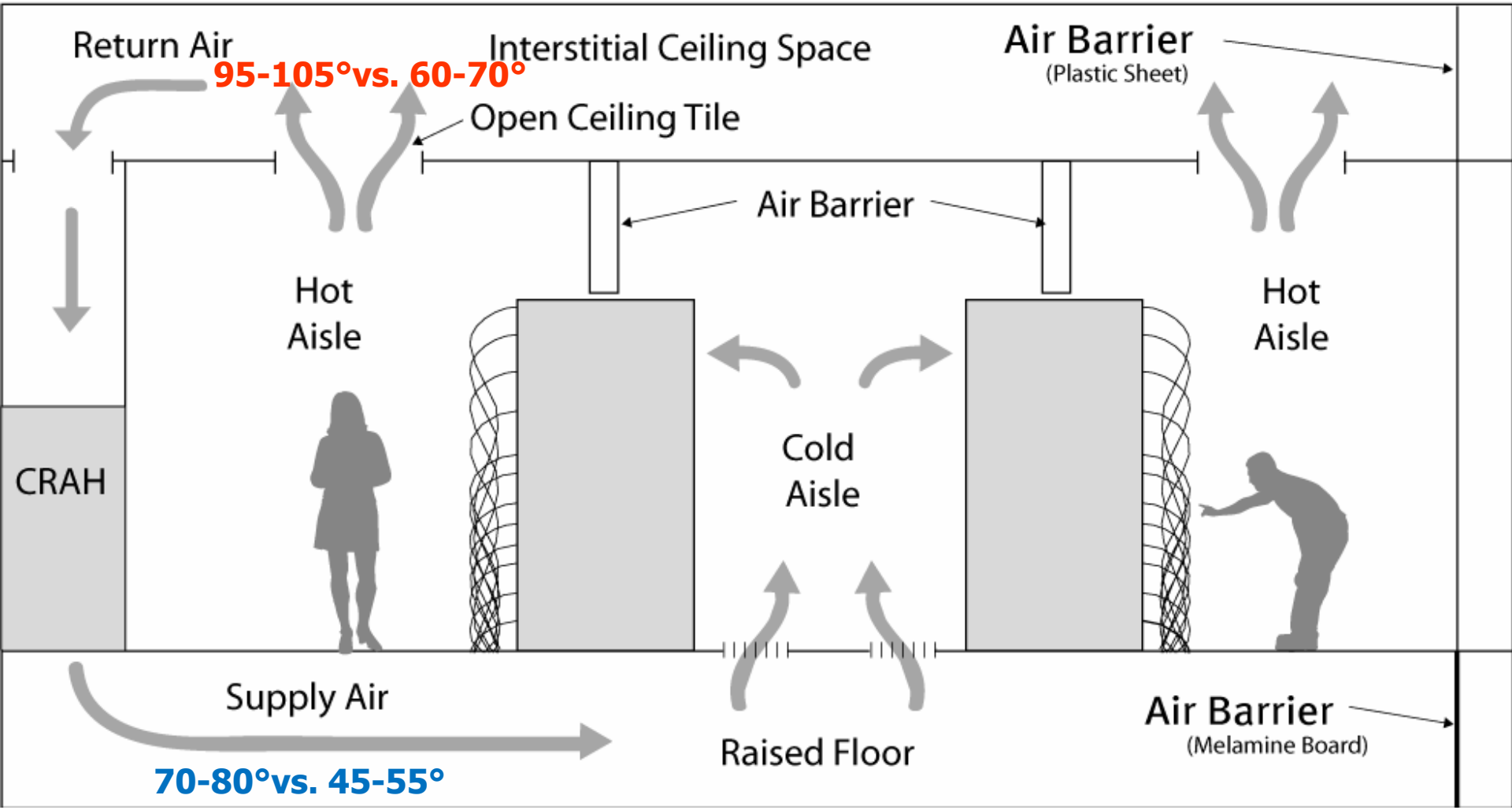
- Overhead plenum converted to hot-air return
- Return registers placed over hot aisle
- CRAC intakes extended to overhead

Before

After

Adding Air Curtains for Hot/Cold Isolation

Isolate Cold and Hot Aisles



Use Free Cooling

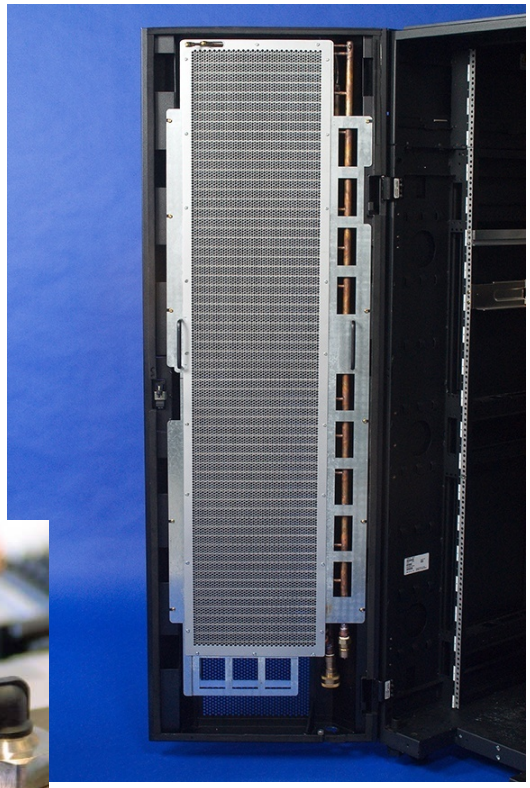
Cooling without Compressors

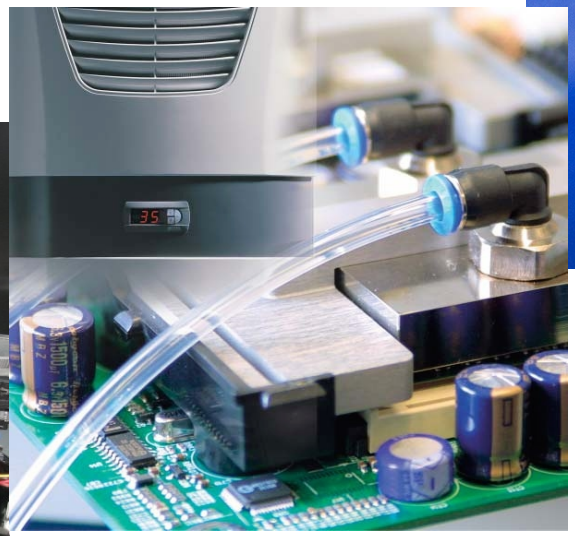
- Water-side Economizers
- Outside-Air Economizers

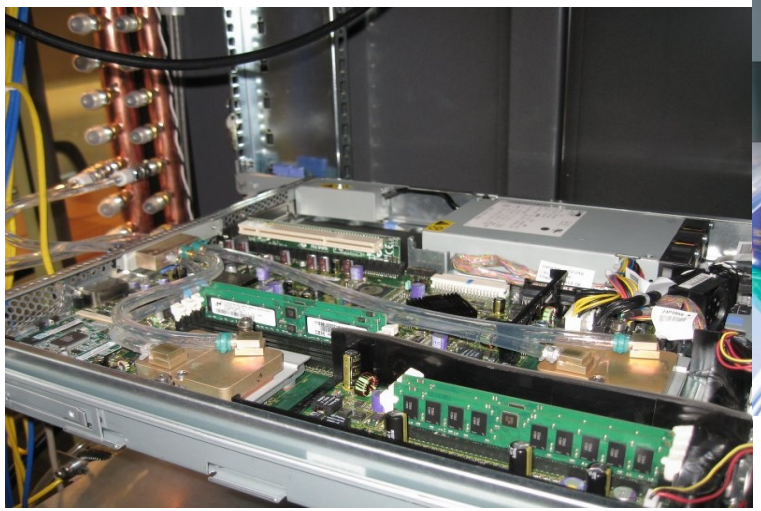
- Let's get rid of chillers in data centers

Liquid Based Cooling

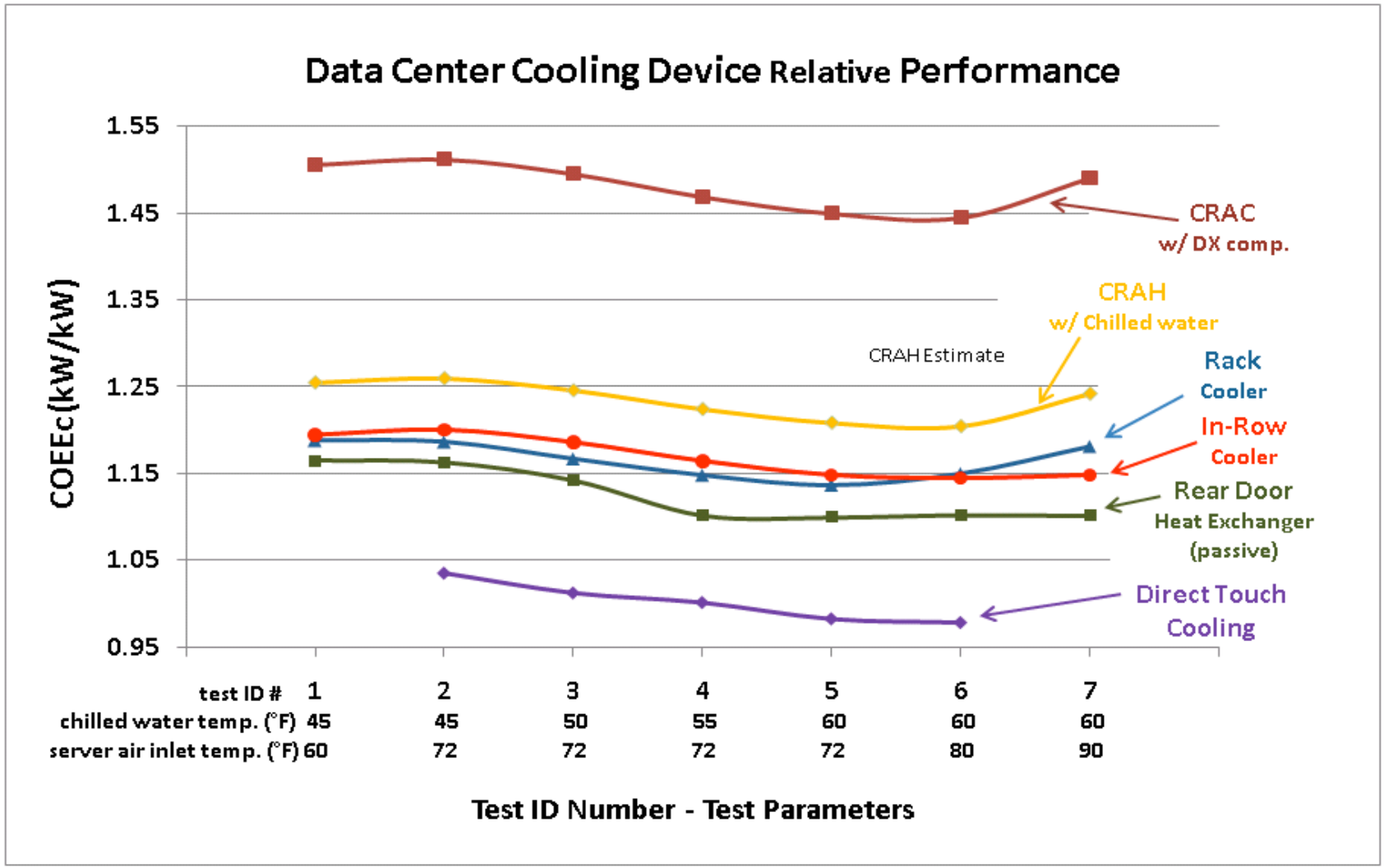
- Liquid is much more efficient than air for heat transfer
- Efficiency improves the closer the liquid comes to the heat source (e.g. CPU)
- Most efficient data centers often don't have raised floors!







"Chill-Off 2" Evaluation of Liquid Cooling Solutions



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.

Improve Humidity Control

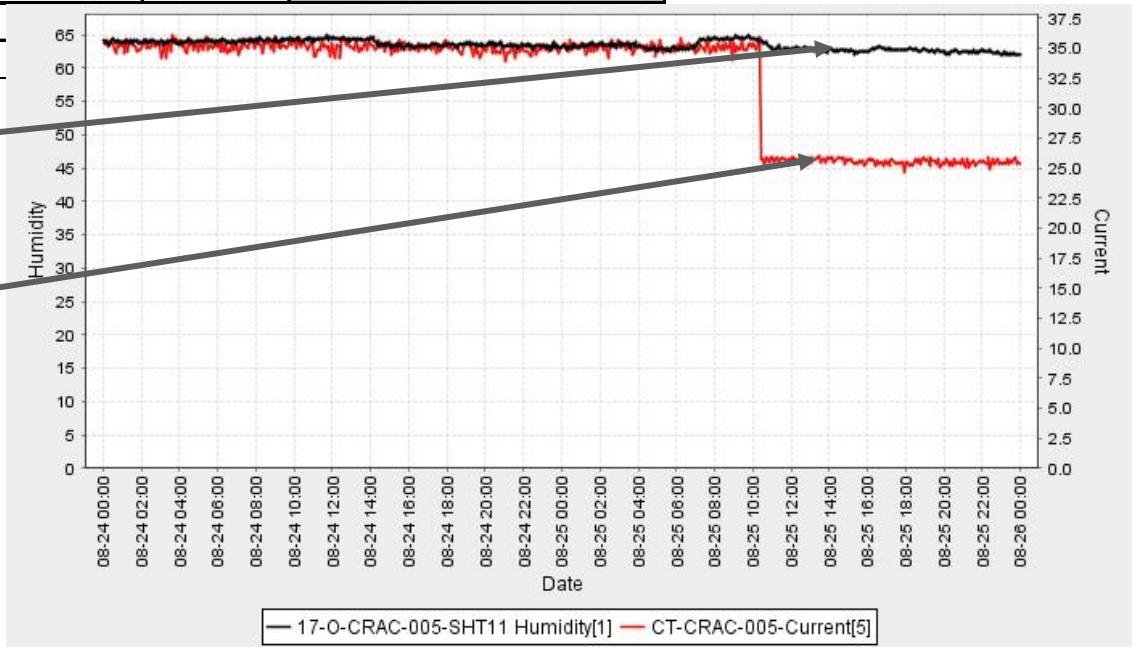
- Eliminate inadvertent dehumidification
  - Computer load is sensible only
- Use ASHRAE allowable RH and temperature
  - Many manufacturers allow even wider humidity range
- Eliminate equipment fighting
  - Coordinate controls
  - Turn off

The Cost of Unnecessary Humidification

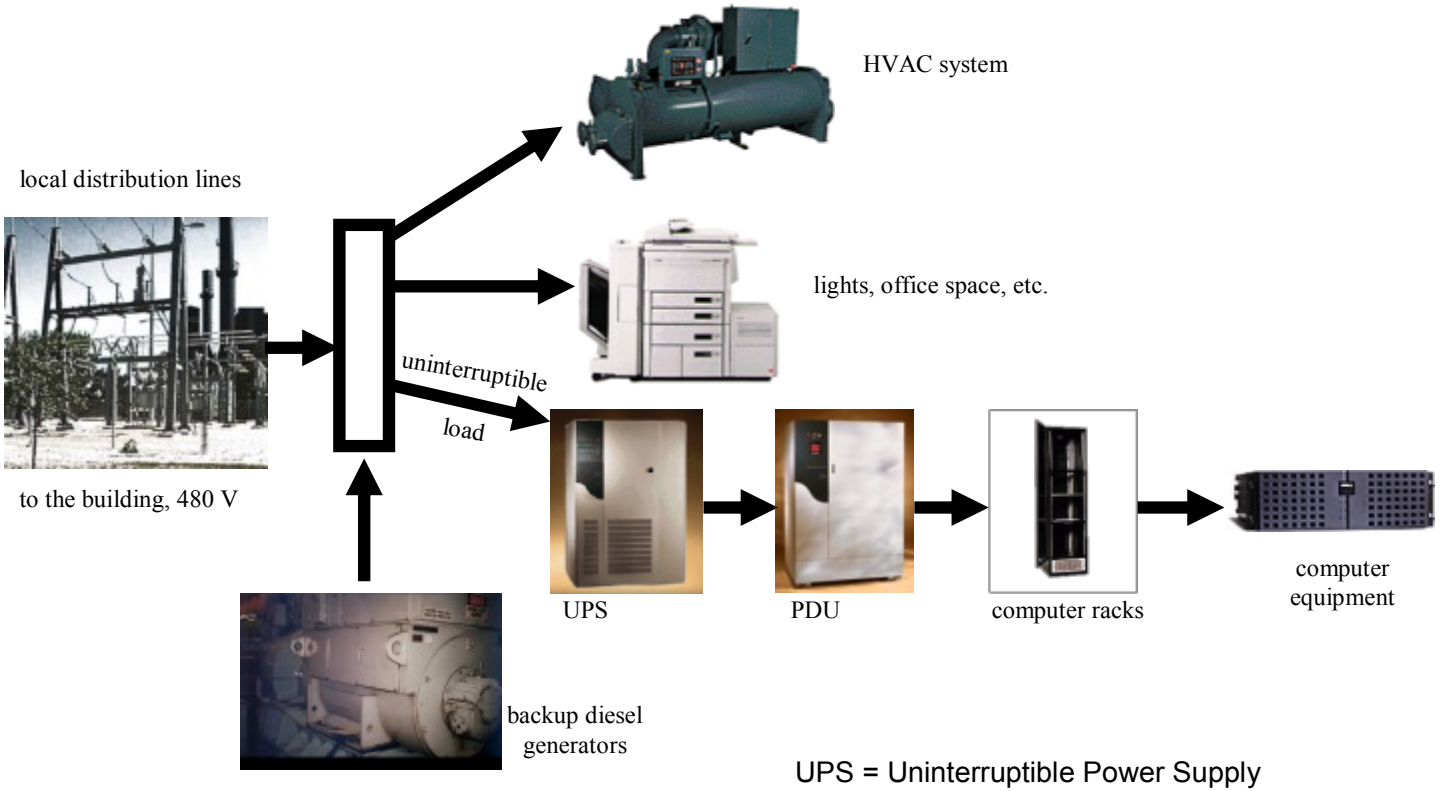
	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC 005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC 006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC 007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC 010	77.5	32.8	46.1	68	45.0	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 2%

CRAC power down 28%



Electricity Flows in Data Centers

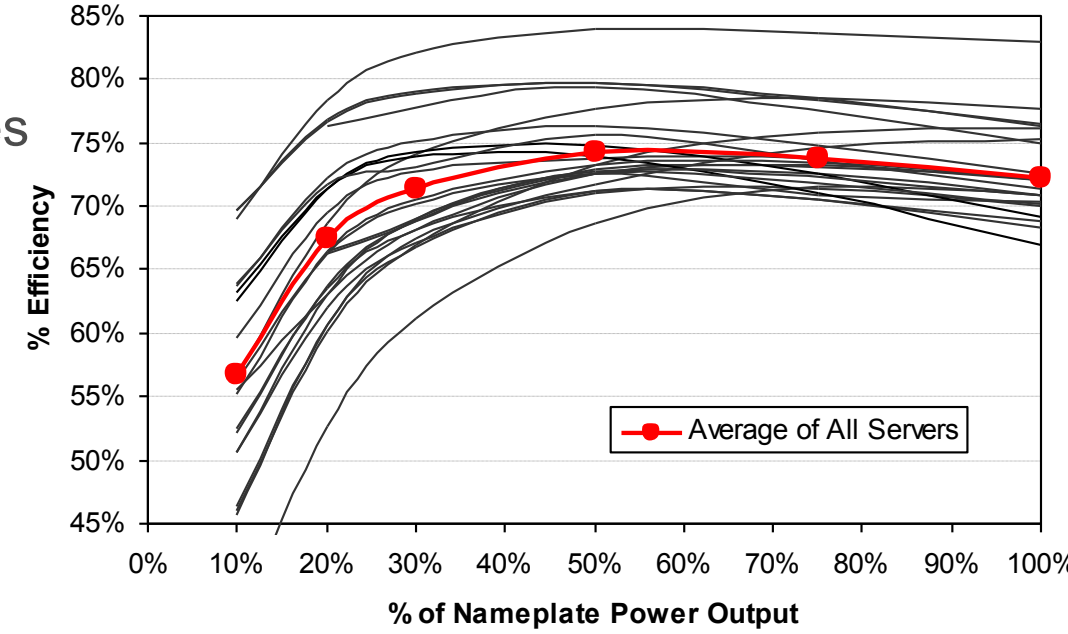


UPS = Uninterruptible Power Supply

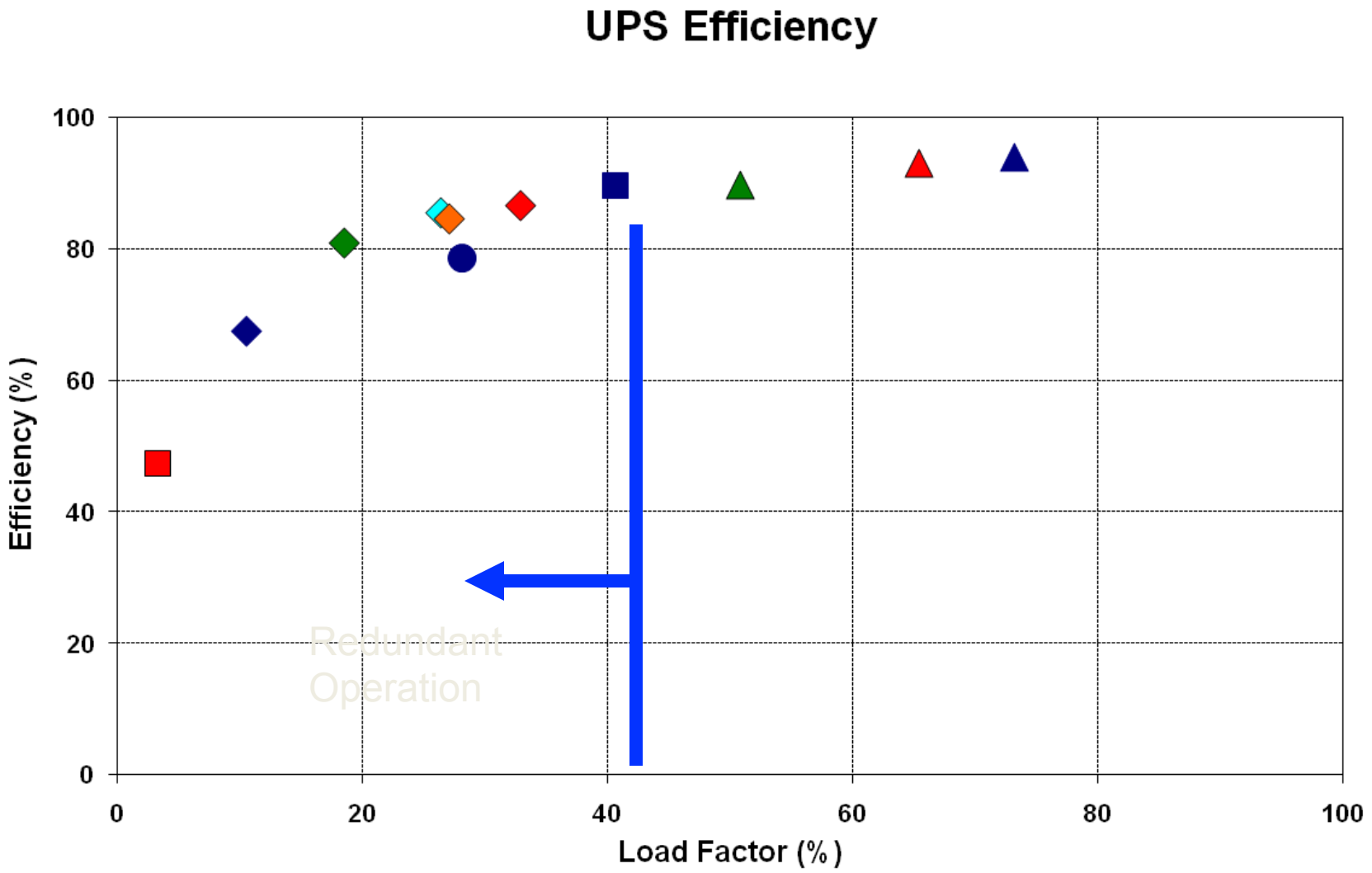
PDU = Power Distribution Unit;

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
- 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 (e.g. 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

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

DOE Better Buildings

- Tool suite & metrics for baselining
- Training
- Showcase Case studies
- Recognition of high energy savers

Better Buildings
U.S. DEPARTMENT OF ENERGY

Federal Energy Management Program

- Workshops
- Federal case studies
- Federal policy guidance
- Information exchange & outreach
- Qualified specialists
- Technical assistance

FEMP

EPA

- Metrics
- Server, UPS, network equipment performance rating & ENERGY STAR label
- Data center benchmarking

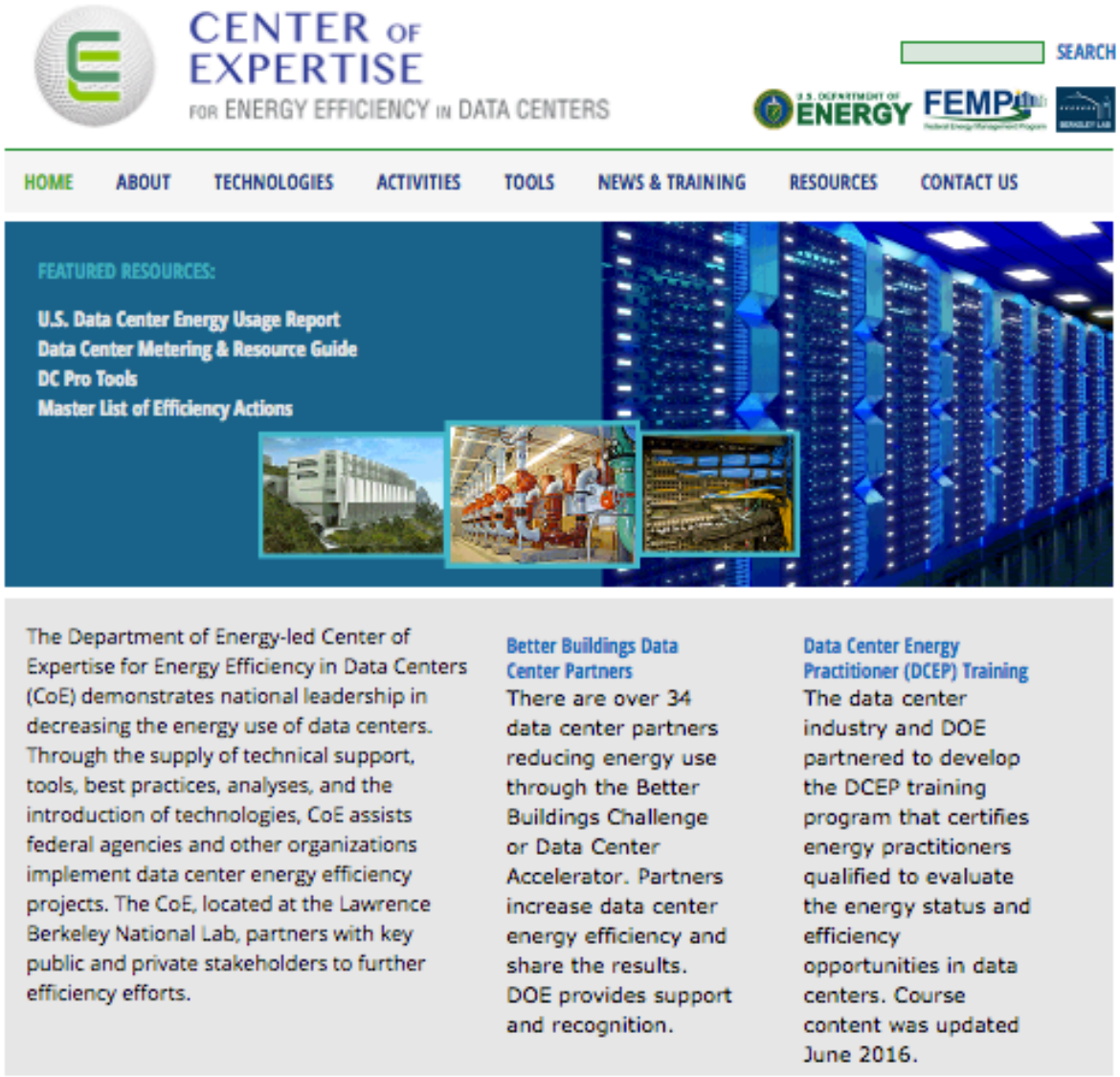
ENERGY STAR

Industry

- Tools
- Metrics
- Training
- Best practice information
- Best-in-Class guidelines
- IT work productivity standard

INFORMATION TECHNOLOGY INDUSTRY COUNCIL
the green grid
Uptime Institute
AFCOM
7X24 Exchange
Silicon Valley Leadership Group
Critical Facilities ROUNDTABLE

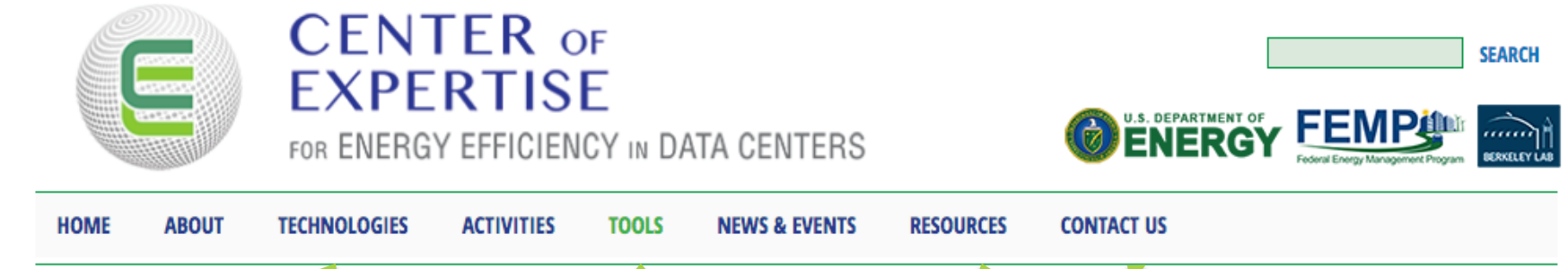
DOE's Center of Expertise



- FEMP provides technical resources and assistance through the Center of Expertise:

Datacenters.lbl.gov

Center of Expertise Navigation



Information on best practice technologies and strategies

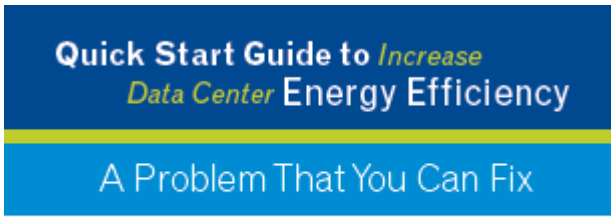
Tools covering areas such as air management and writing an energy assessment report

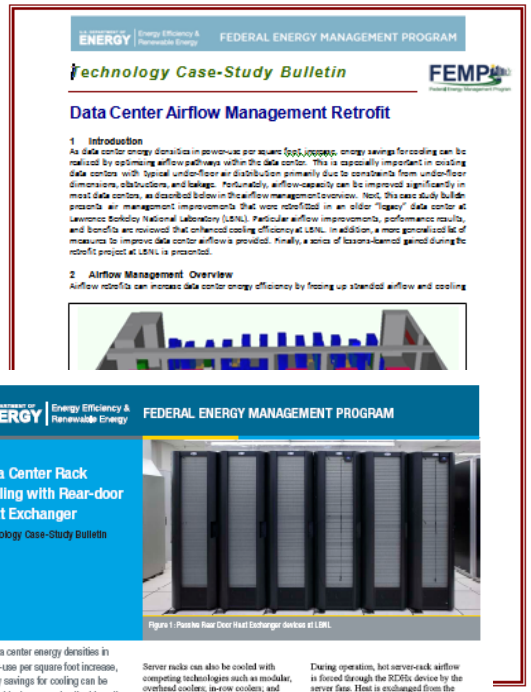
Database of resources (reports, guides, case studies)

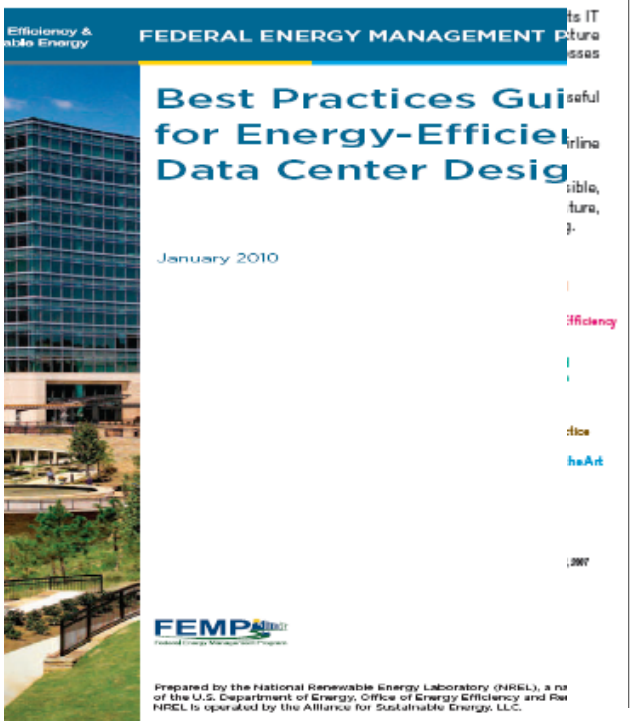
Need assistance?

Available Resources

- Profiling Tool
- Assessment Tools
- Best Practices Guide
- Benchmarking Guide
- Data Center Programming Guide
- Technology Case Study Bulletins
- Report Templates
- Process Manuals
- Quick-Start Guide
- Professional Certification (DCEP)







DOE Data Center Tool Suite

High-Level On-Line Profiling

- 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	Electrical Systems	IT-Equipment	Cooling
• Hot/cold separation • Environmental conditions • RCI and RTI	• UPS • PDU • Transformers • Lighting • Standby gen.	• Servers • Storage & networking • Software	• Air handlers/ conditioners • Chillers, pumps, fans • Free cooling

Coming

Data Center Profiler (DC Pro) Tools

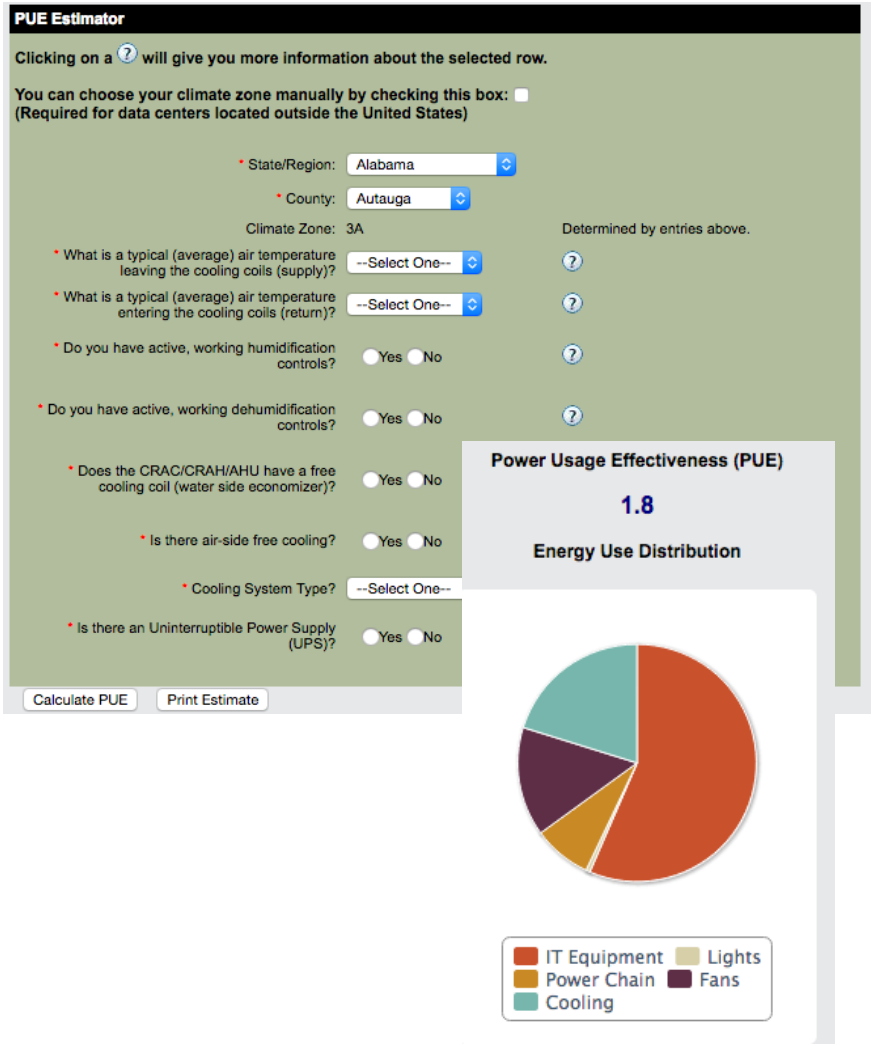
DC Pro Tools estimate PUE without sub-metering

DC Pro V4

DC Pro estimates current and potential PUE and energy use distribution. DC Pro also provides tailored recommended actions to start improvement process.

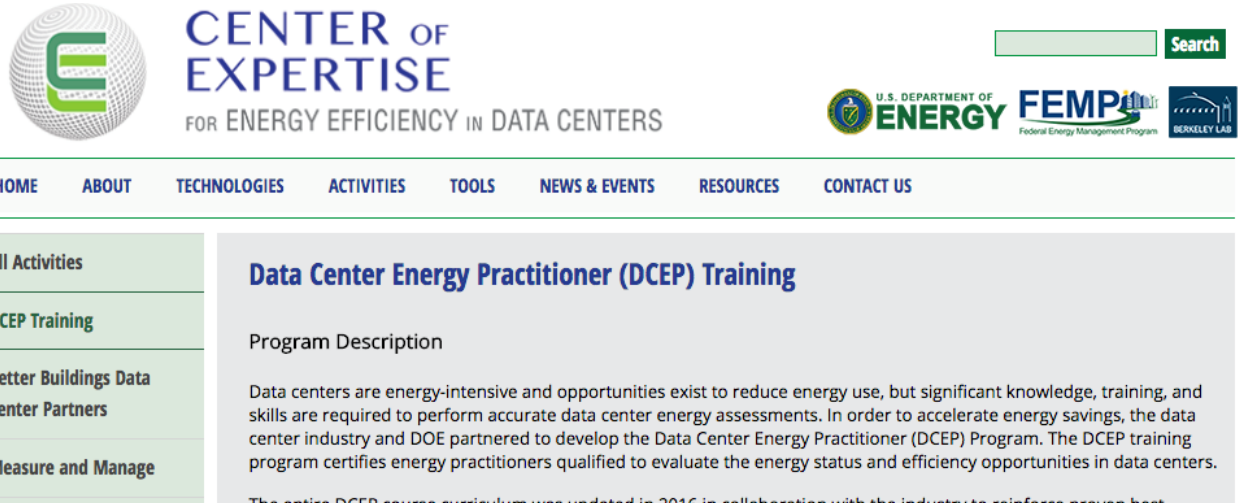
PUE Estimator, simplified DC Pro

PUE Estimator only asks questions that affect PUE and does NOT provide potential PUE or recommended actions.



datacenters.lbl.gov/dcpro

Data Center Energy Practitioner Program



datacenters.lbl.gov/dcep

Data Center Energy Practitioner (DCEP) Program

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

Data Centers:
Part of the Better Buildings Family

Better Buildings Challenge

Partners commit to increasing the energy efficiency of their entire data center and building portfolio by at least 20% within 10 years and share their implementation model, annual progress, at least one showcase project and results.

Better Buildings Data Center Accelerator

Partners commit to improve the energy efficiency of one or more data centers by at least 25% within 5 years, track and share progress, and showcase a project

Becoming a Data Center Partner

Why Sign Up?

- Leverage Dept. of Energy resources
- Network with your peers that have found solutions to similar challenges
- Gain Recognition for Leadership Activities
- Increase system reliability
- Reduce IT and infrastructure requirements
- Typical 20% to 40% reductions in energy cost with short paybacks

How to Sign Up:

- Email datacenterpartners@ee.doe.gov
- Commit to continuous improvement in energy efficiency of your data centers

Data Center Partner Roster – 34 partners

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