U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Alternative Financing of Data Center Energy Projects

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FEMP
Federal Energy Management Program

Agenda

1. Data center energy:
   a. Trends
   b. Start with metrics and benchmarking
2. Drivers for Federal data center optimization.
3. Opportunities in data centers.
4. How can ESPCs/UESCs help?
5. Alternative financing examples.
6. Lessons learned/resources/discussion.

Data Center Energy

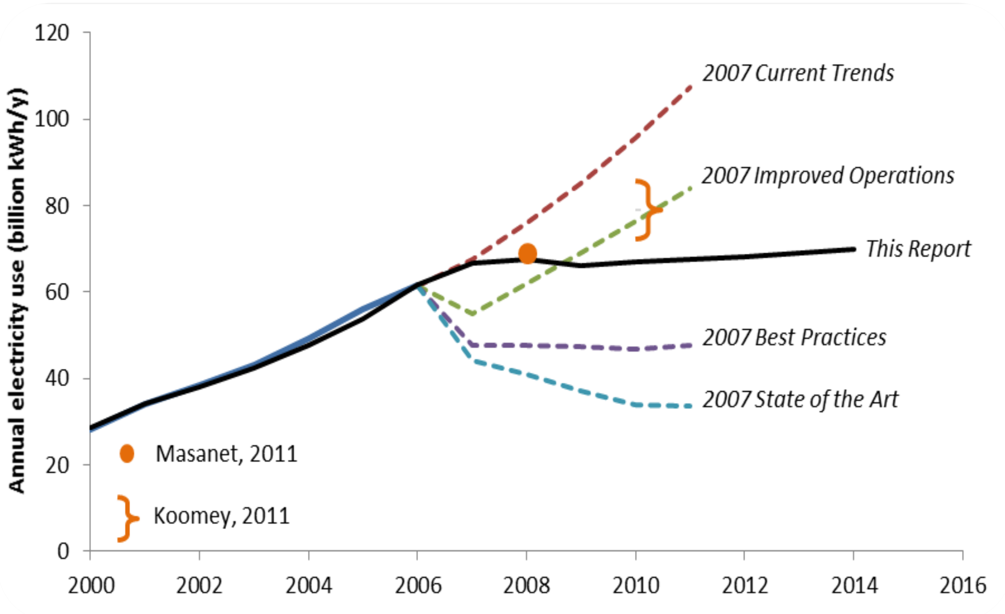
Data centers are energy intensive facilities

- 10 to 100+ times more energy intensive than an office
- Server racks now designed for more than 30 kW
- Surging demand for data storage
- 2% of US electricity consumption
- Power and cooling constraints in existing facilities
- Perverse incentives –
  - ✓ IT and facilities costs separate

Potential Benefits of Energy Efficiency

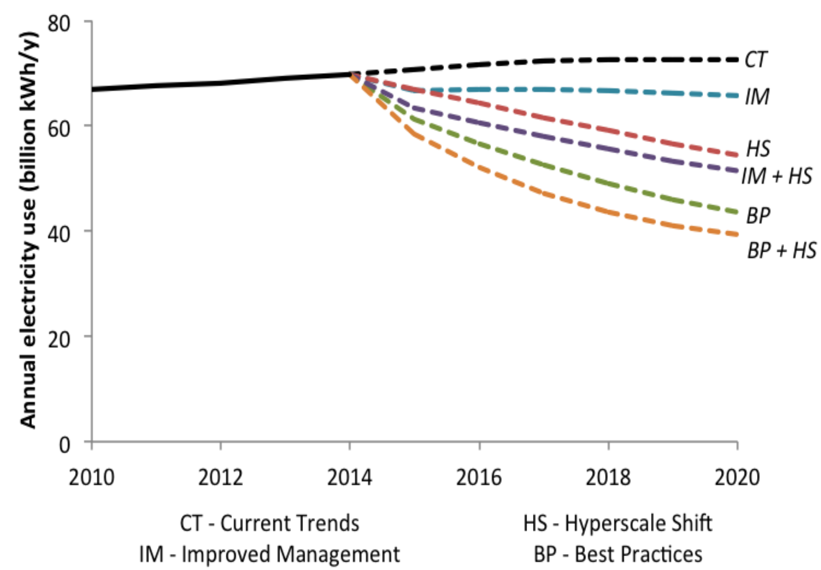
- 20-40% savings & high ROI typical
- Aggressive strategies can yield 50+% savings
- Extend life and capacity of infrastructures

US Data Center Energy Usage Reports (2007 & 2016)

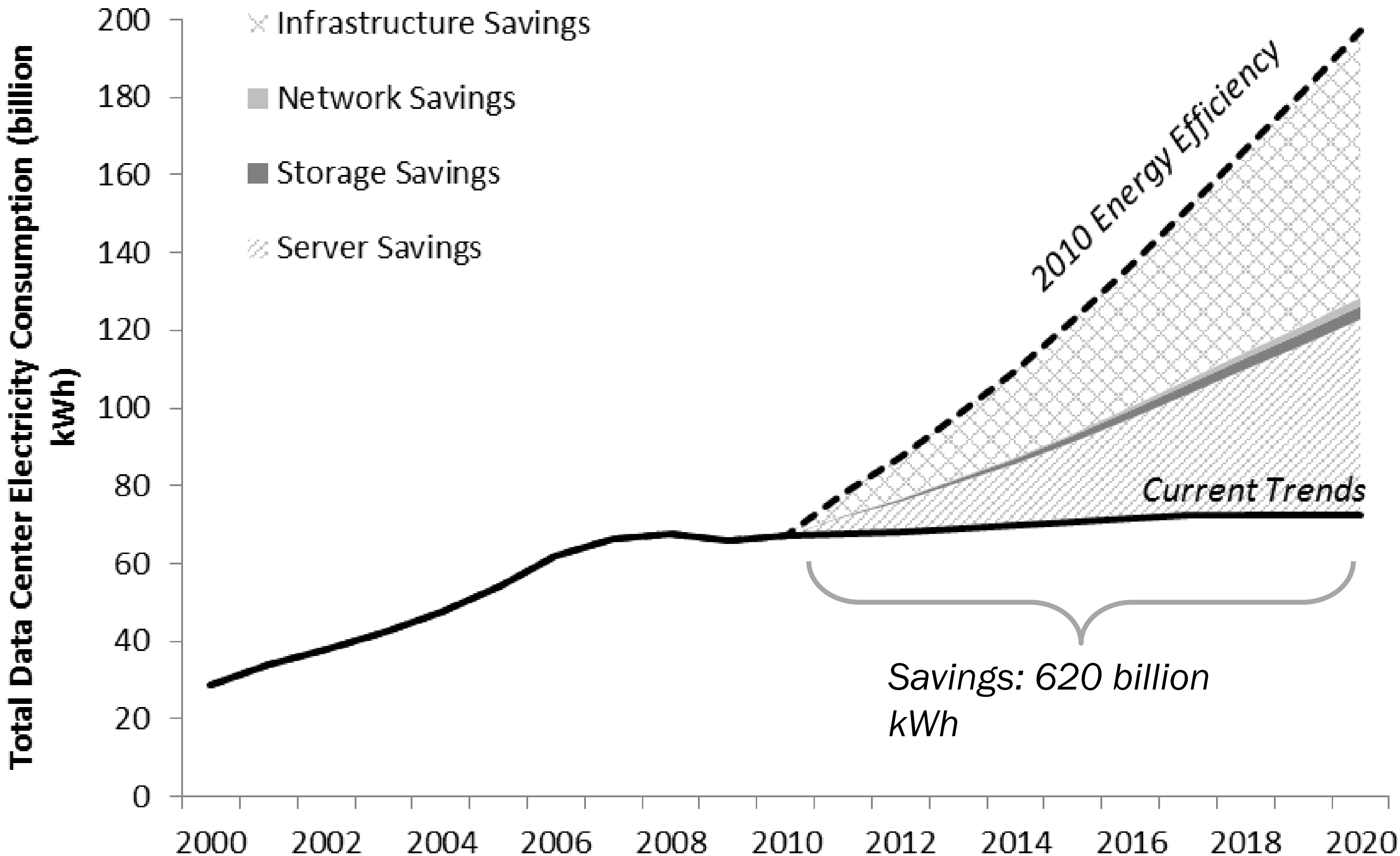


~1.8% U.S. Electricity

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

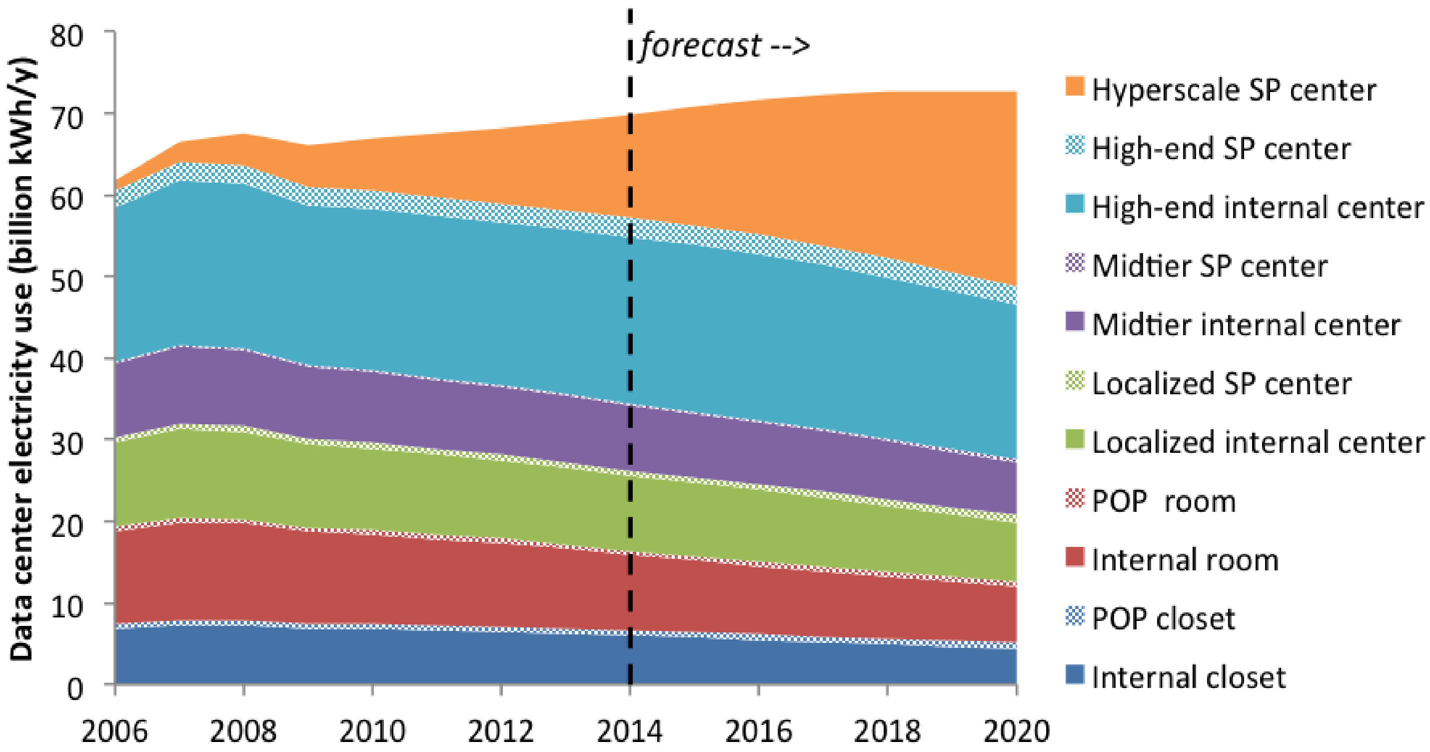


Energy Use Projections and Counterfactual

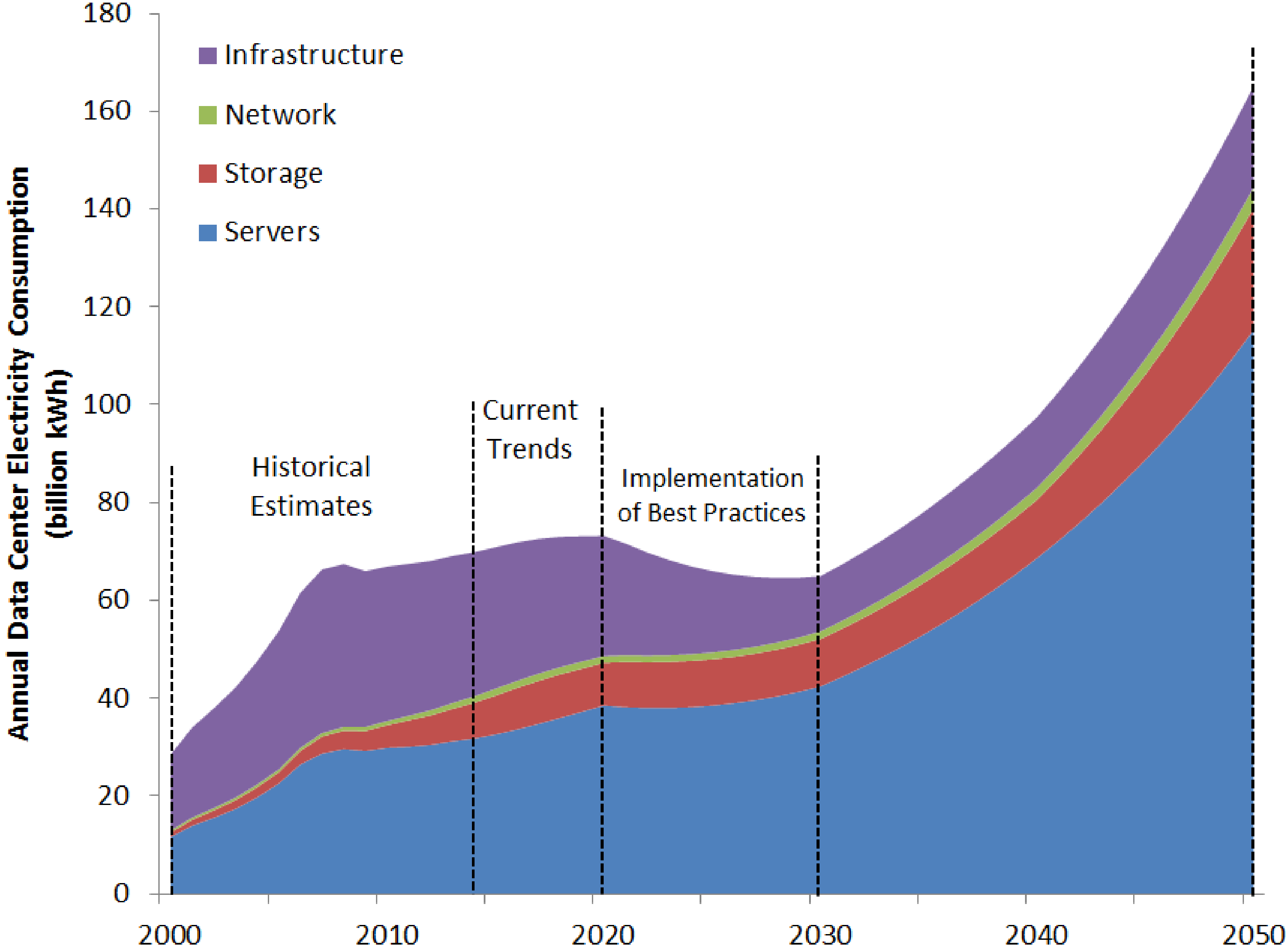


Energy Use Estimates by Data Center Type

- Hyperscale is a growing percentage of data center energy use



2050 Projections

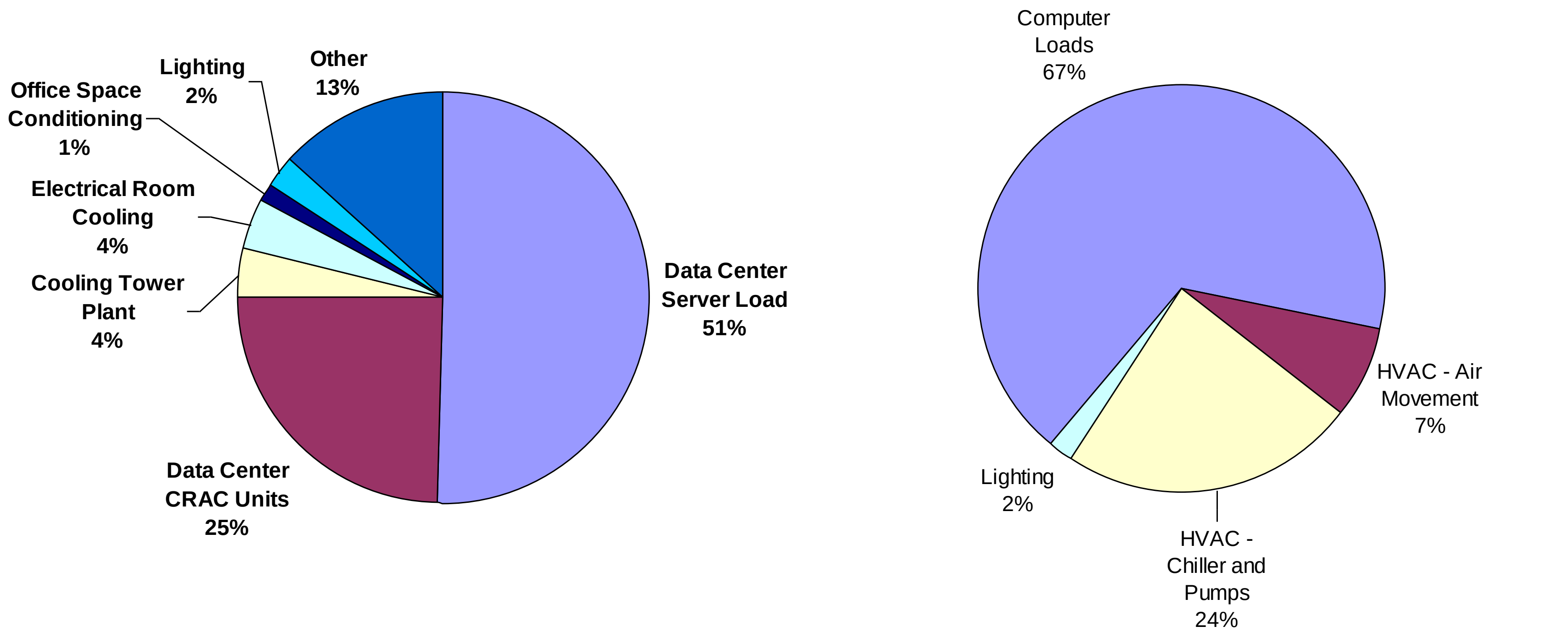


In Conclusion...

- **Data center energy use has approximately plateaued since 2008**
  - Expected to continue through 2020
- **Further efficiency improvements possible, but will eventually run out**
- **Next-generation computing technologies and innovative data center business models will be needed to keep energy consumption down over the next 20-30 years**

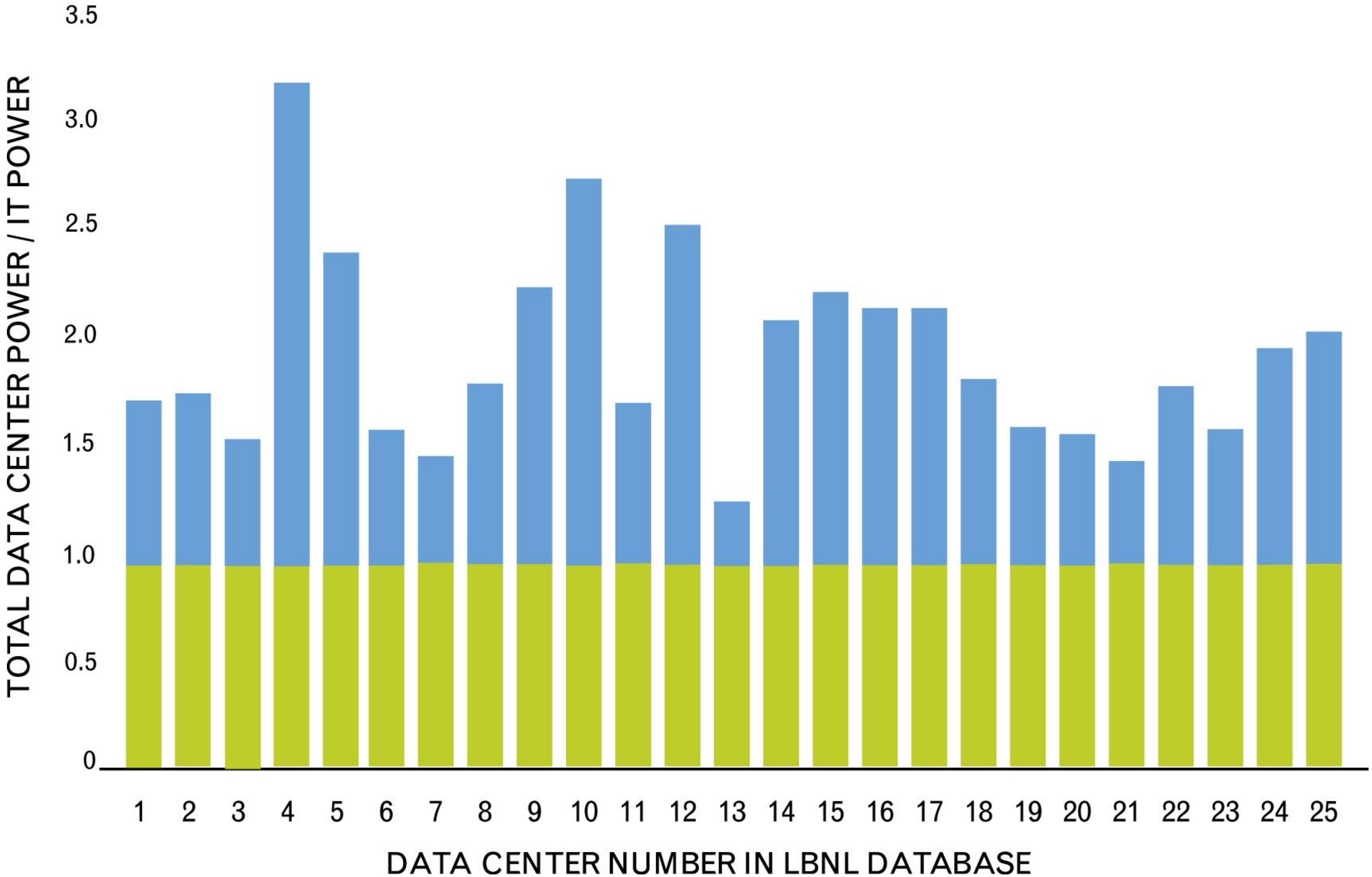
First Step: Benchmark Energy Performance

- **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



What drives Federal Data Center change?

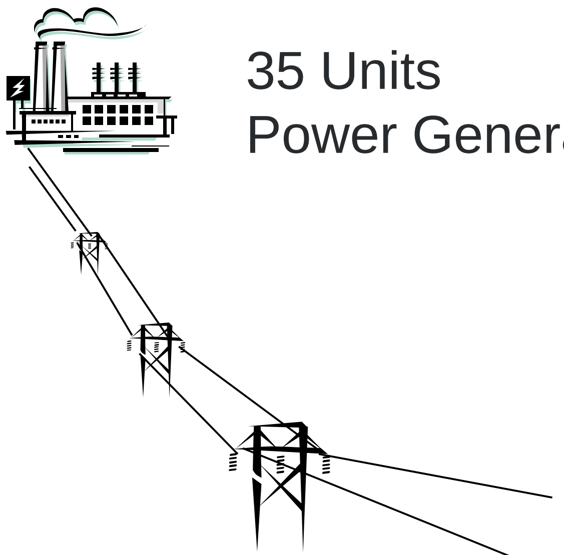
- Data centers (big energy usage sector and growing)
  - Account for >2% of US electricity consumption
- Federal Information Technology Acquisition Reform Act (FITARA) (2014)
  - Agencies must submit annual reports (inventories, strategies, timeline, savings)
  - OMB must set targets and publish agency cost savings and optimization improvements
- Data Center Optimization Initiative (DCOI) (2016)
  - Sets framework for agencies to meet FITARA consolidation and optimization requirements - Defines metrics and sets goals
  - Requires Installing and monitoring advanced energy meters in all data centers (by FY2018?)
  - Establishing a Power Usage Effectiveness (PUE) target of 1.2 to 1.4 for new data centers and less than 1.5 for existing data centers
  - Update expected soon
- Modernizing Government Technology (MGT) Act (Dec 2017)
  - Establishes $100M Technology Modernization Fund (TMF)

What is the opportunity in data centers?

- How is a typical Federal data center configured?
  - IT
    - Not virtualized (software/application tied to specific hardware).
    - Not consolidated (small data centers spread across campus/installation).
    - Under utilized (10-20% vs 45-60%).
    - Power management features disabled (e.g. 'sleep mode').
    - Many servers (10-20%) on but doing no work.
  - Air Management
    - No cold/hot air isolation, air pathways congested, server exhaust recirculation
    - CRAC controlled by return air temperature, constant speed fans
  - Cooling
    - CRAC-cooled (65°F, 60RH), (direct expansion coil, refrigerant compressor)
    - Over-spec'd: 2N (twice as many as needed, for backup)
    - Equipment "fighting" - e.g. simultaneous humidifying and dehumidifying
  - Electrical
    - Uninterruptible power supply (UPS) over-spec'd: 2N (instead of N+1) with all units running in parallel at very low loads (and efficiency)
    - Many AC->DC->AC->DC & voltage conversions.
  - Management
    - Little or no information systems (e.g. Data Center Infrastructure Management (DCIM) system) to monitor and track performance
    - Little or no systems integration (e.g. controls)

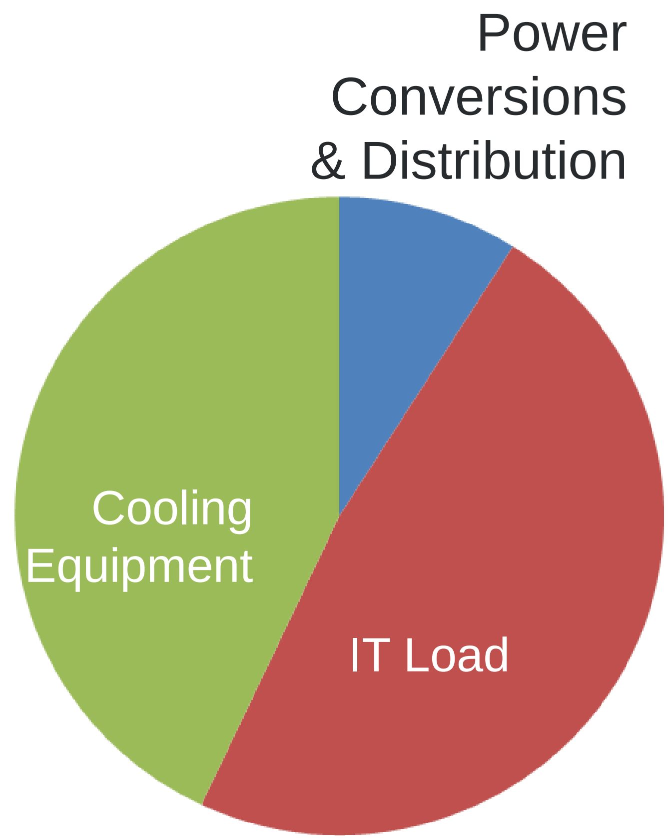
Typical Data Center Energy Efficiency ~ 15%

100 Units
Source
Energy

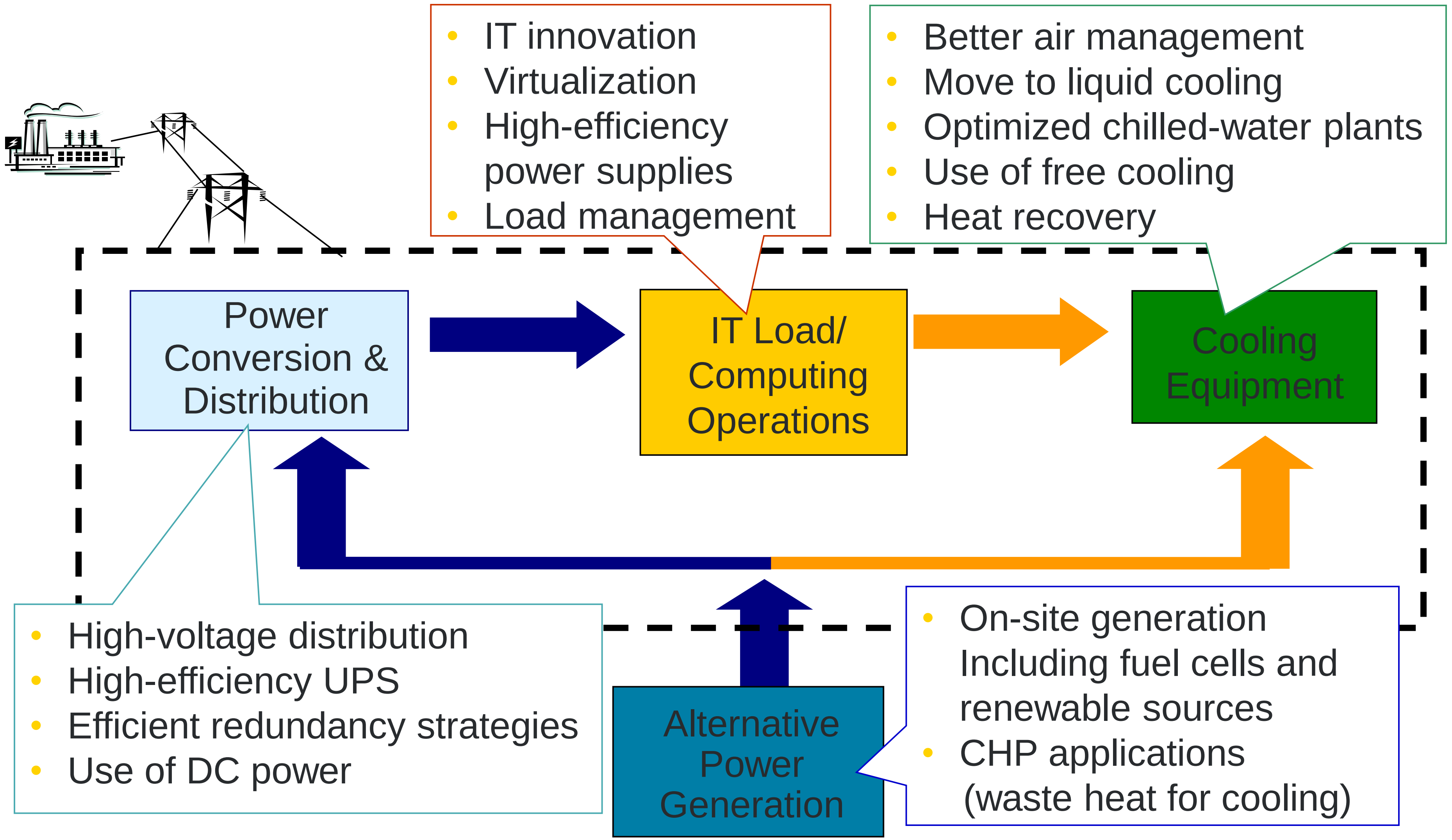


35 Units
Power Generation

33 Units
Delivered

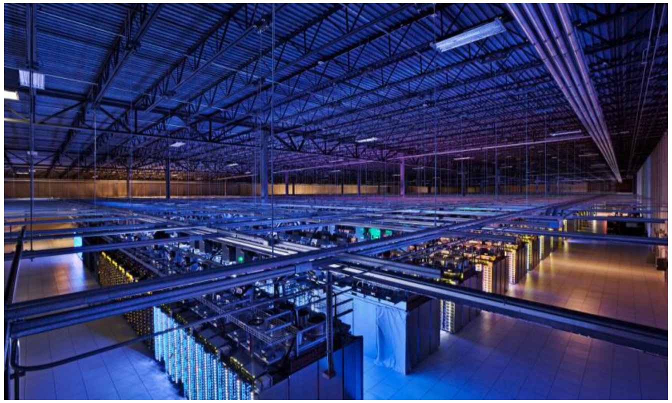


Energy Efficiency Opportunities



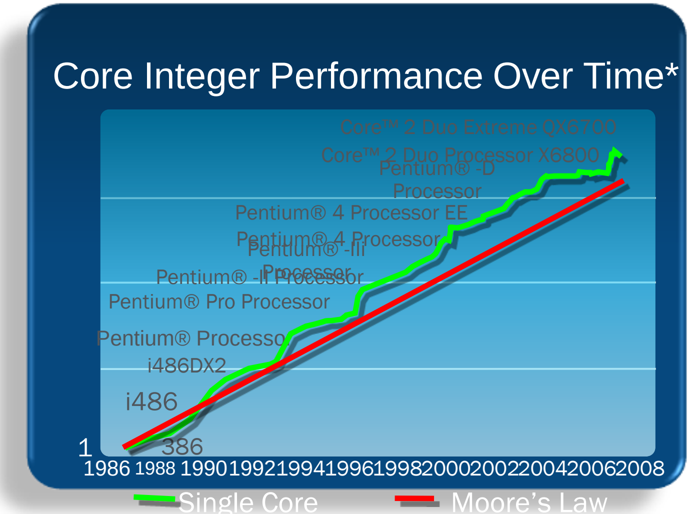
Best Practices

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



IT Load Can Be Controlled

Computations per Watt is improving

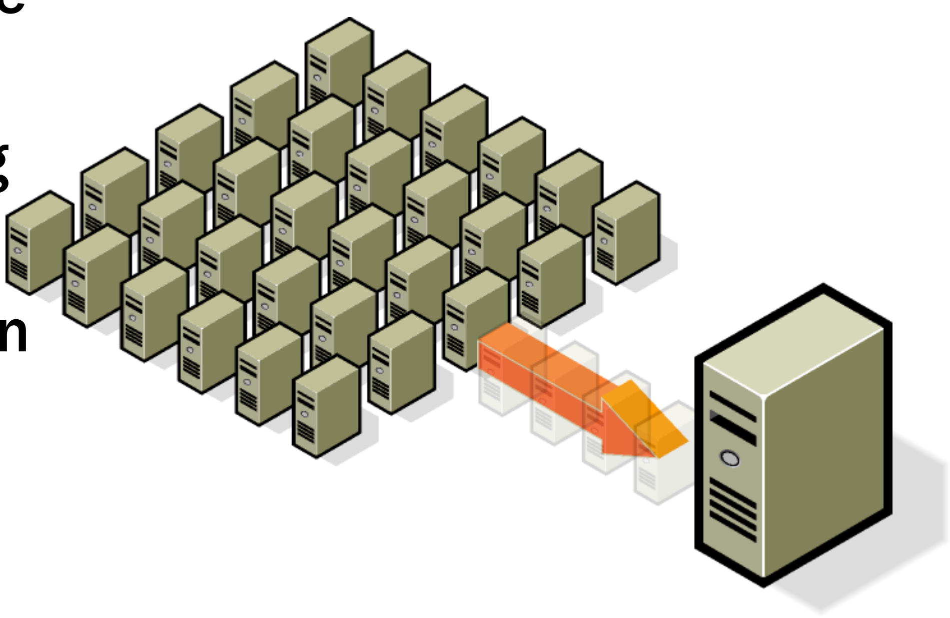


Opportunities:

- **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 <u>multiplier effect</u>**
  - Savings in infrastructure energy depends on PUE

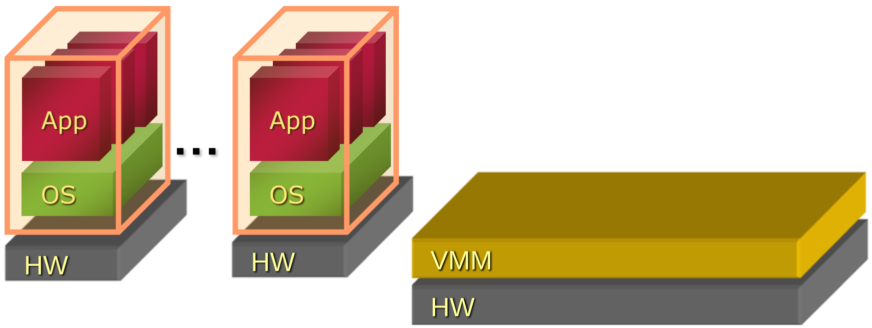
Virtualize and Consolidate Servers and Storage

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



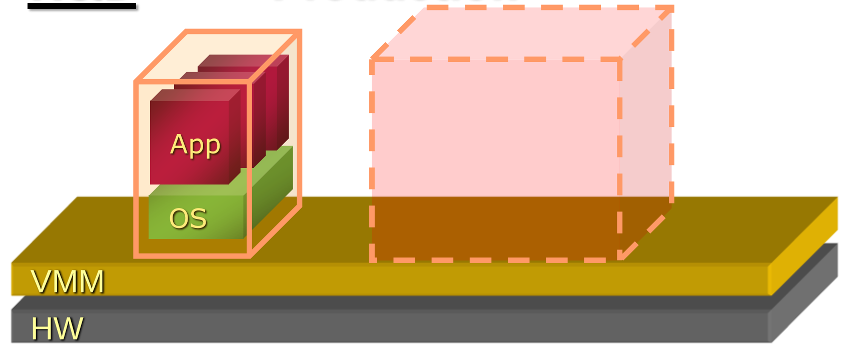
Virtualize and Consolidate Servers and Storage

Server Consolidation



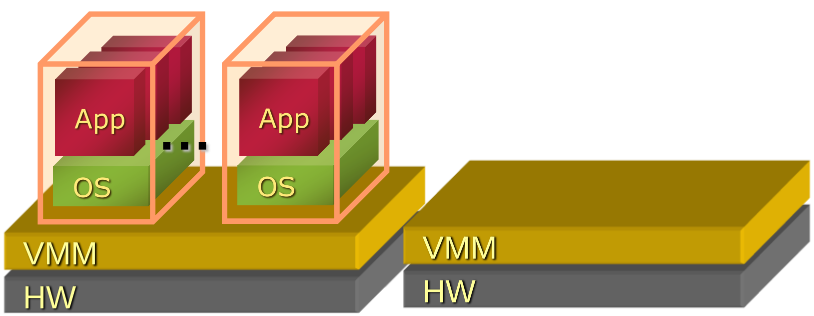
10:1 in many cases

R&D Production



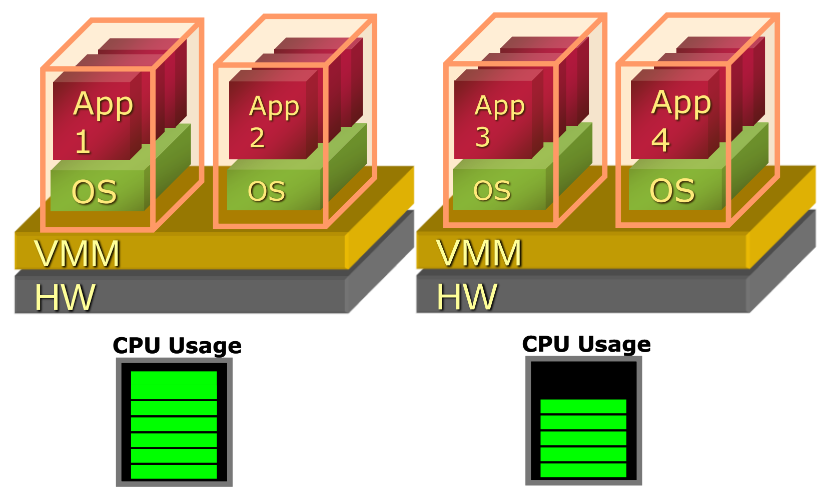
Enables rapid deployment,
reducing number of idle, staged servers

Disaster Recovery



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

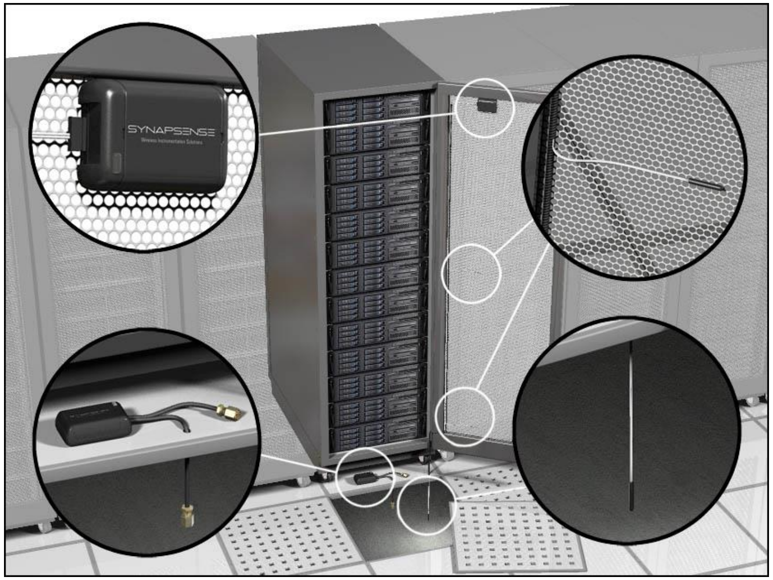
Dynamic Load Balancing



Balancing utilization with head room

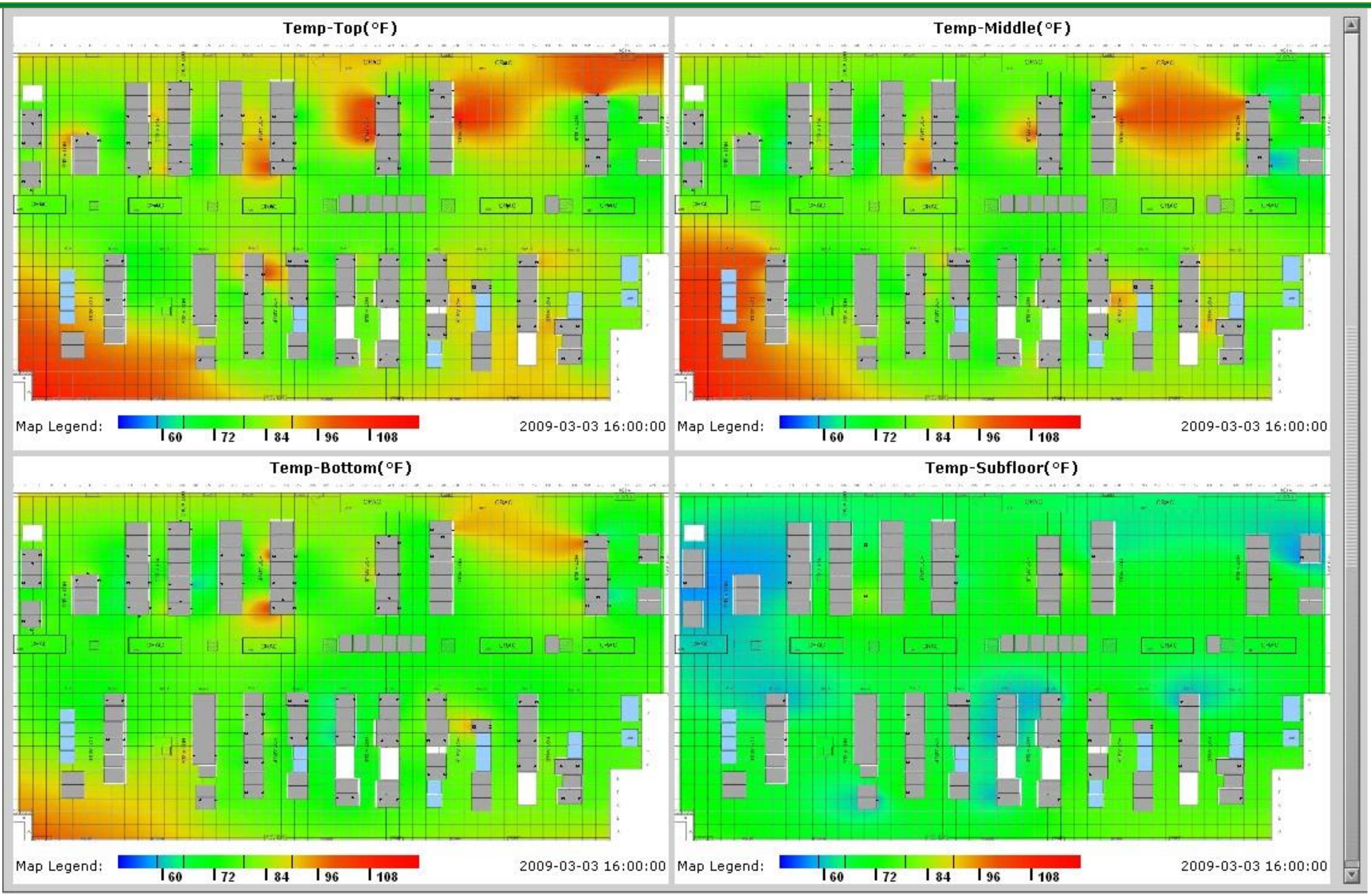
Using IT to Save Energy in IT

- 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



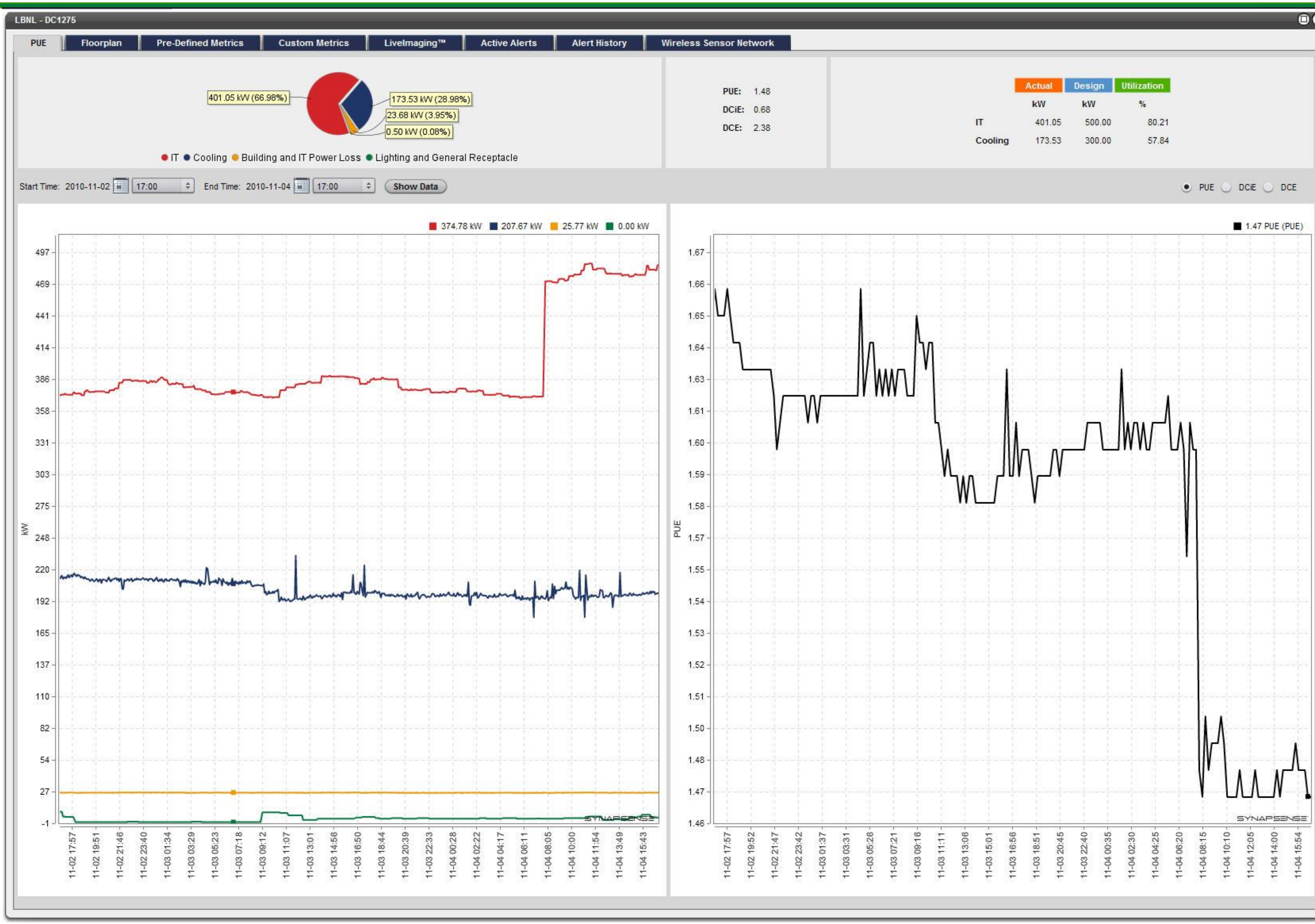
LBNL Wireless Monitoring System

Visualization getting much better



SynapSense™

Real-time PUE Display



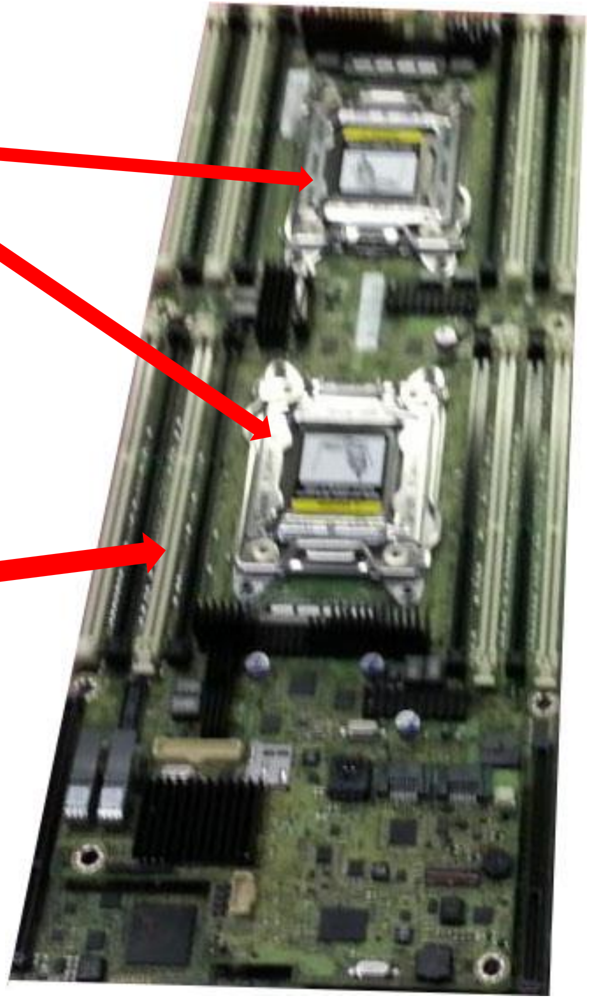
Environmental Conditions: Safe Temperature Limits

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 …

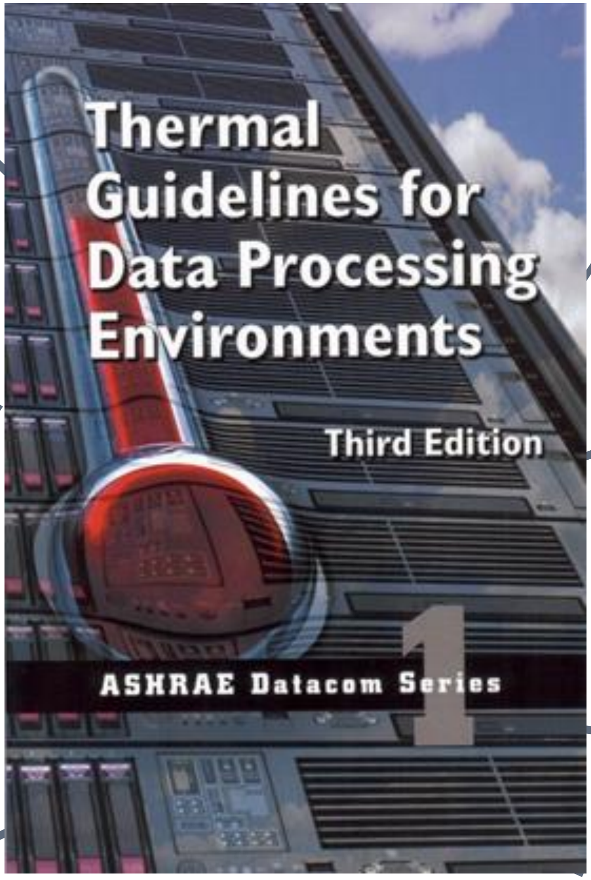
Slide courtesy of NREL

ASHRAE Thermal Guidelines
The defacto standard in the industry

Provides common understanding between IT and facility staff.

Developed with IT manufacturers

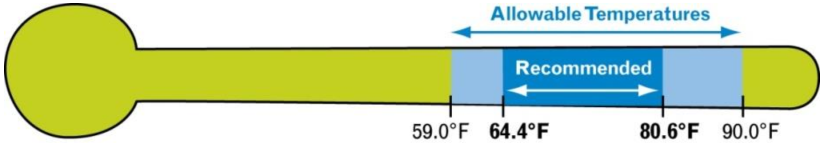
Provides wider humidity ranges



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 at LBNL

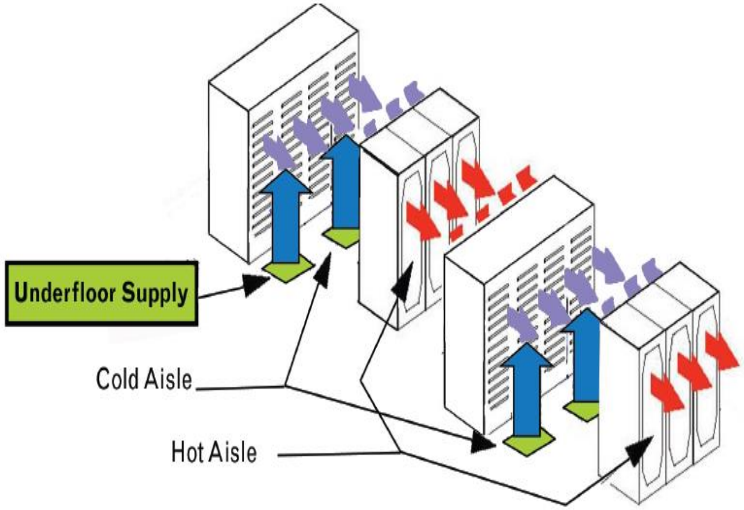
It was cold but hot spots were everywhere

Fans were used to redirect air

High flow tiles reduced air pressure

Air Management

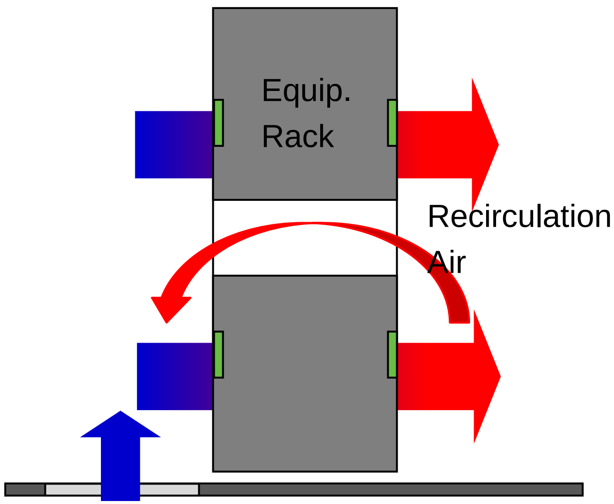
- Typically, more air circulated than required
- Air mixing and short circuiting leads to:
  - Low supply temperature
  - Low Delta T
- Use hot and cold aisles
- Improve isolation of hot and cold aisles
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity



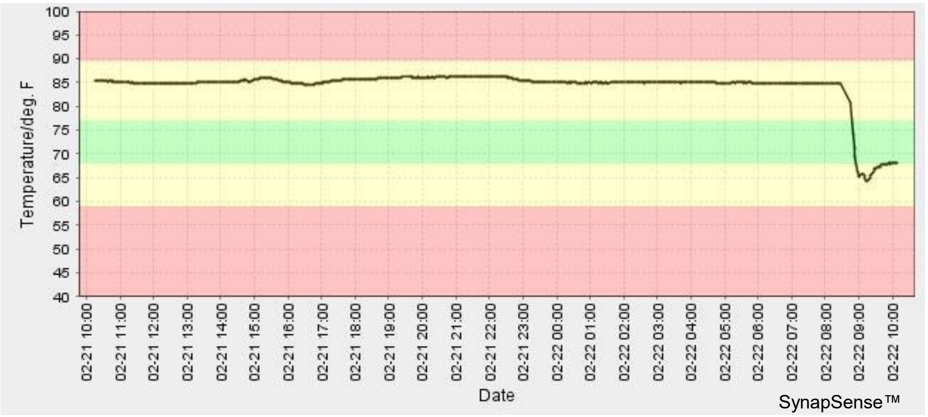
Hot aisle / cold aisle configuration decreases mixing of intake & exhaust air, promoting efficiency.

Results: Blanking Panels

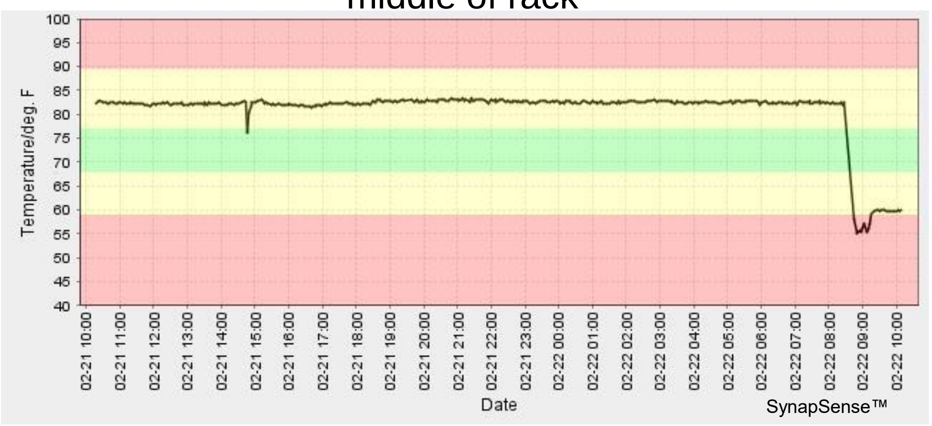
One 12 inch blanking panel reduced temperature ~20°F



top of rack

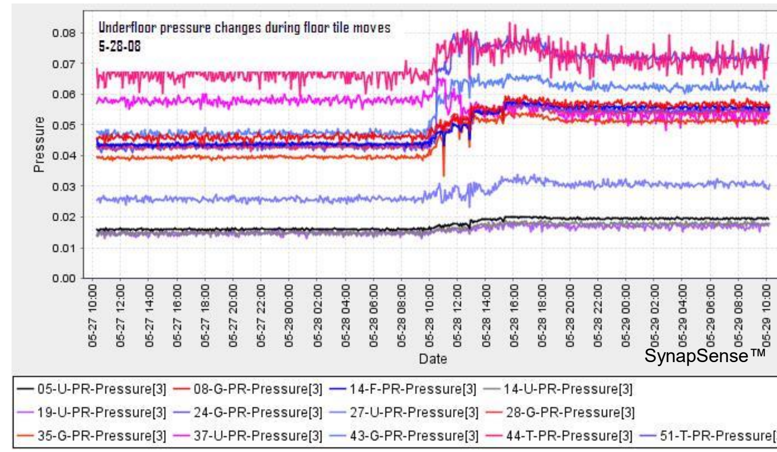


middle of rack



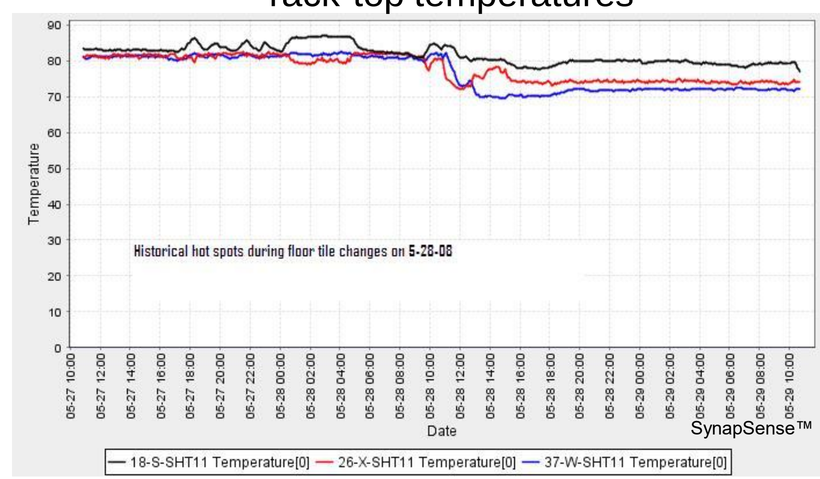
Results: Tune Floor Tiles

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**

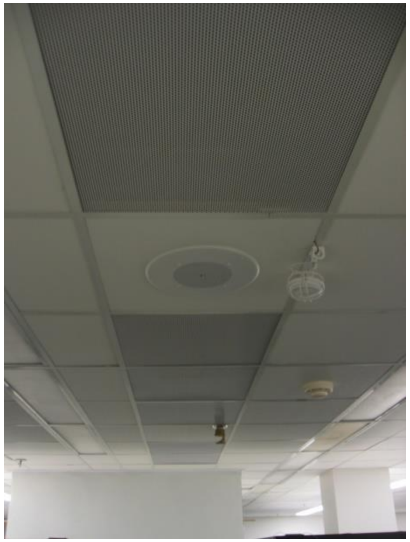
rack-top temperatures



Improve Air Management

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

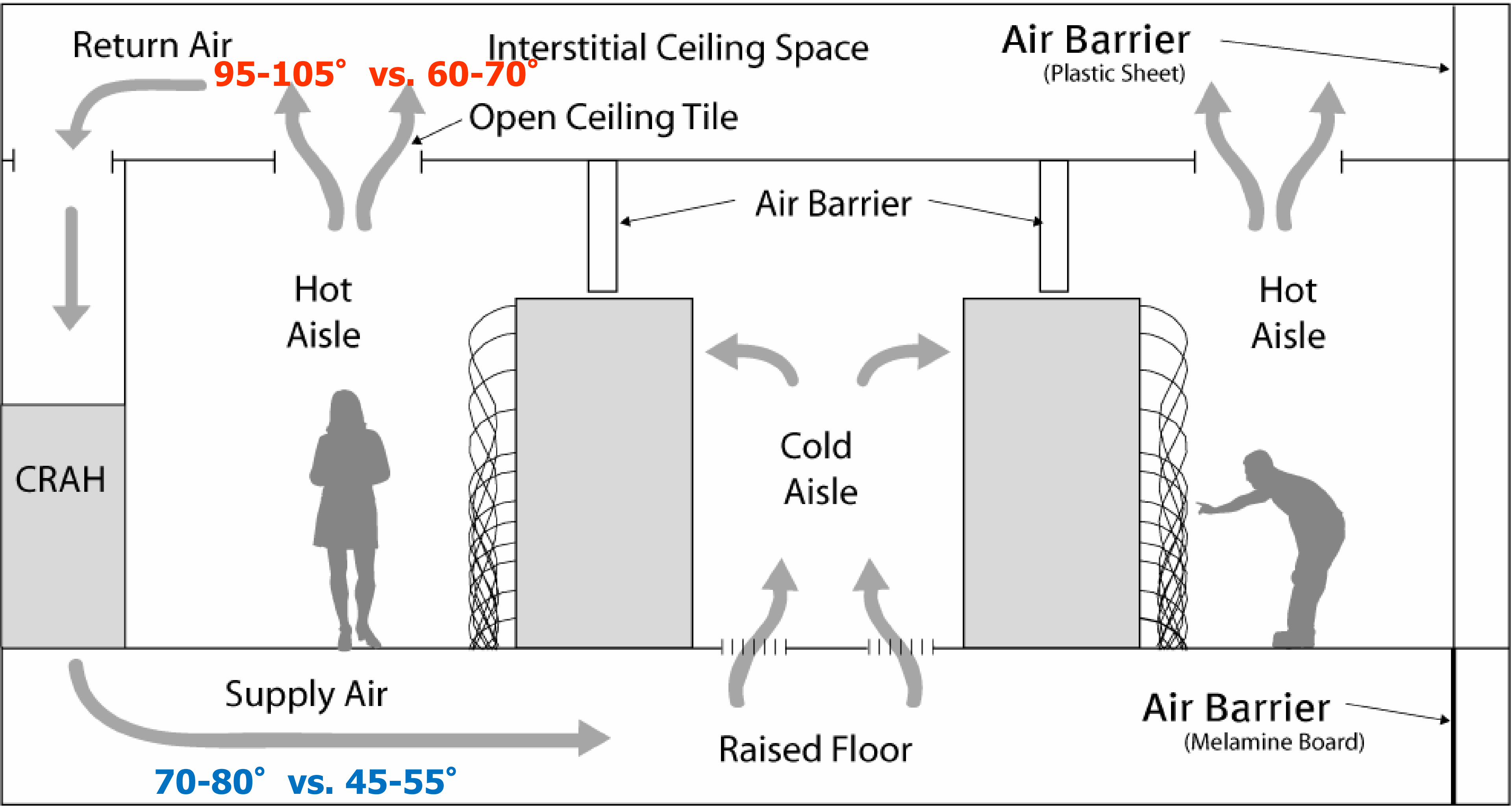
Before



After

Adding Air Curtains for Hot/Cold Isolation

Isolate Cold and Hot Aisles



Use Free Cooling

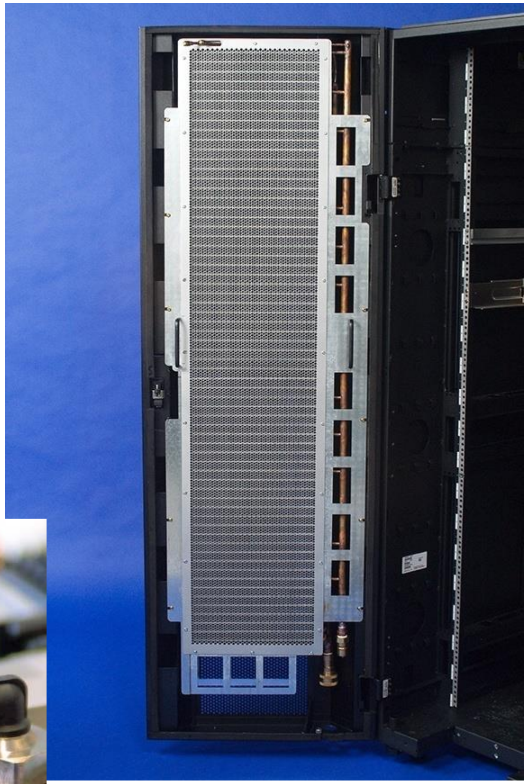
Cooling without Compressors

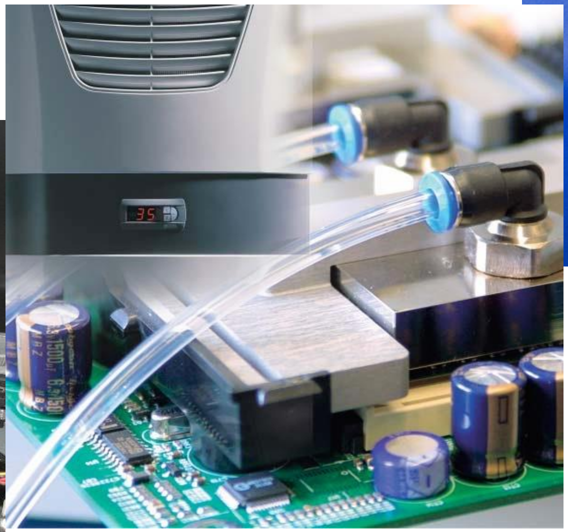
- Water-side Economizers
- Outside-Air Economizers

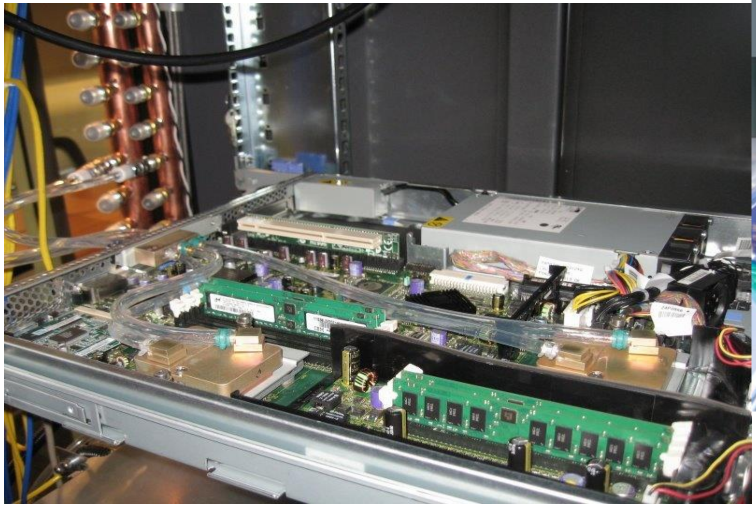
- Let's get rid of chillers in data centers

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!





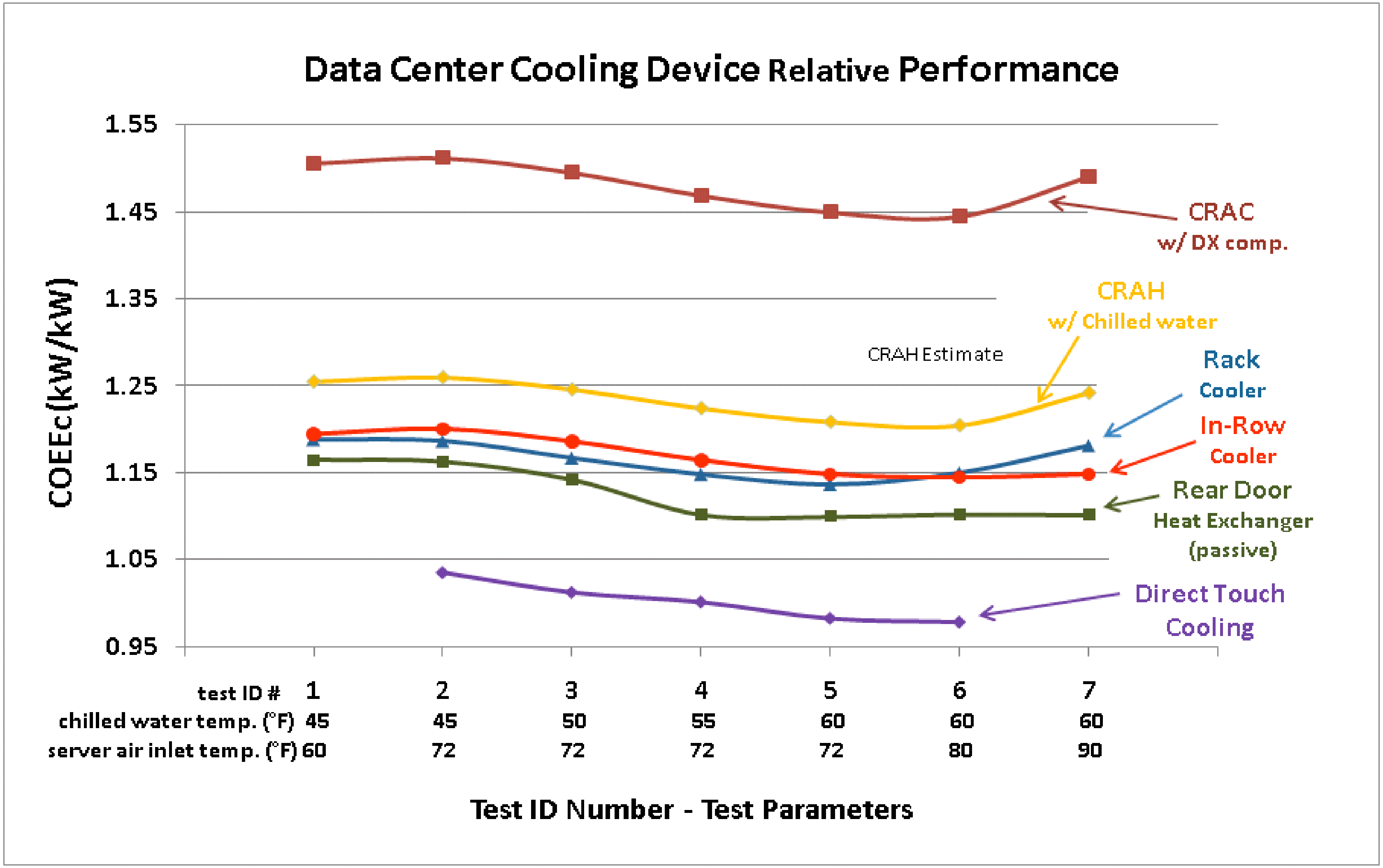


LBNL Example: Rear Door Cooling

- **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.

Data Center Opportunity: Getting Liquid Closer

“



Improve Humidity Control

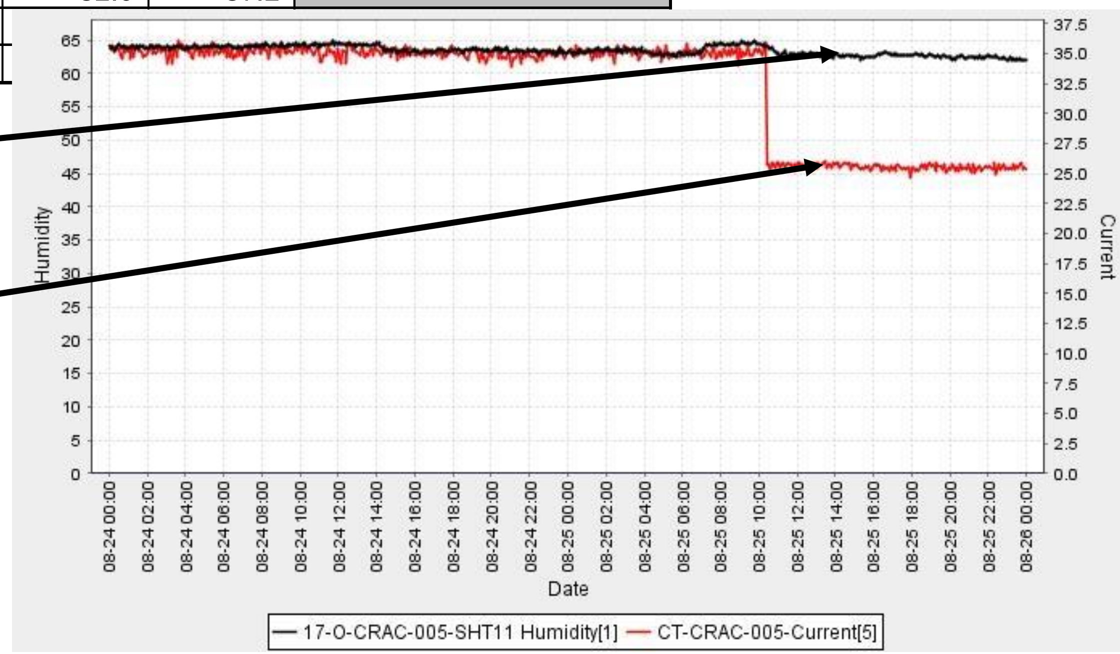
- **Eliminate inadvertent dehumidification**
  - Computer load is sensible only
- **Use ASHRAE allowable RH and temperature**
  - Many manufacturers allow even wider humidity range
- **Eliminate equipment fighting**
  - Coordinate controls
  - Turn off

The Cost of Unnecessary Humidification

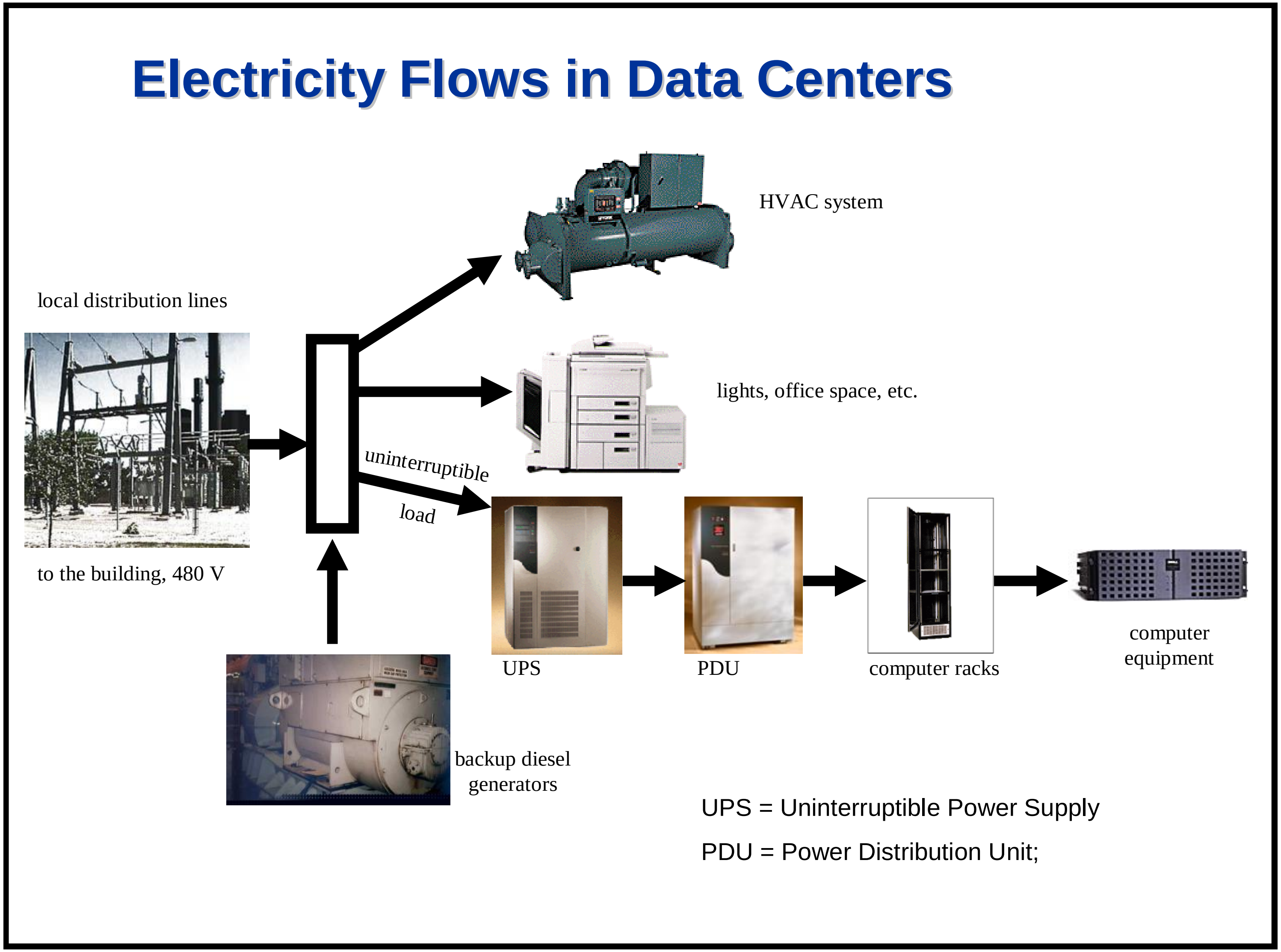
	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC 005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC 006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC 007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC 010	77.5	32.8	46.1	68	45.0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

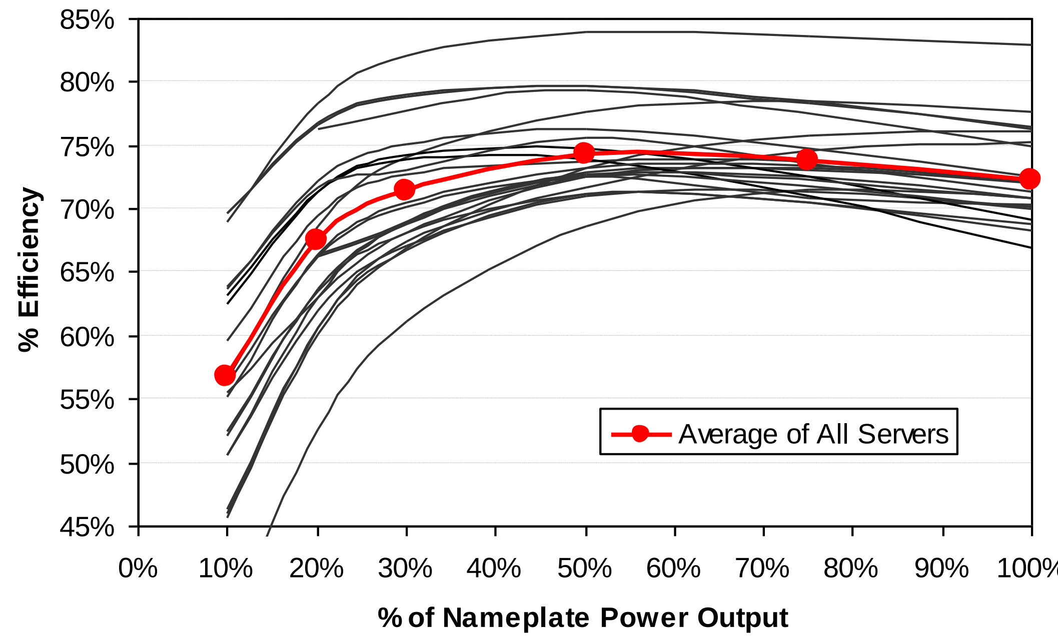


Power Chain Conversions Waste Energy

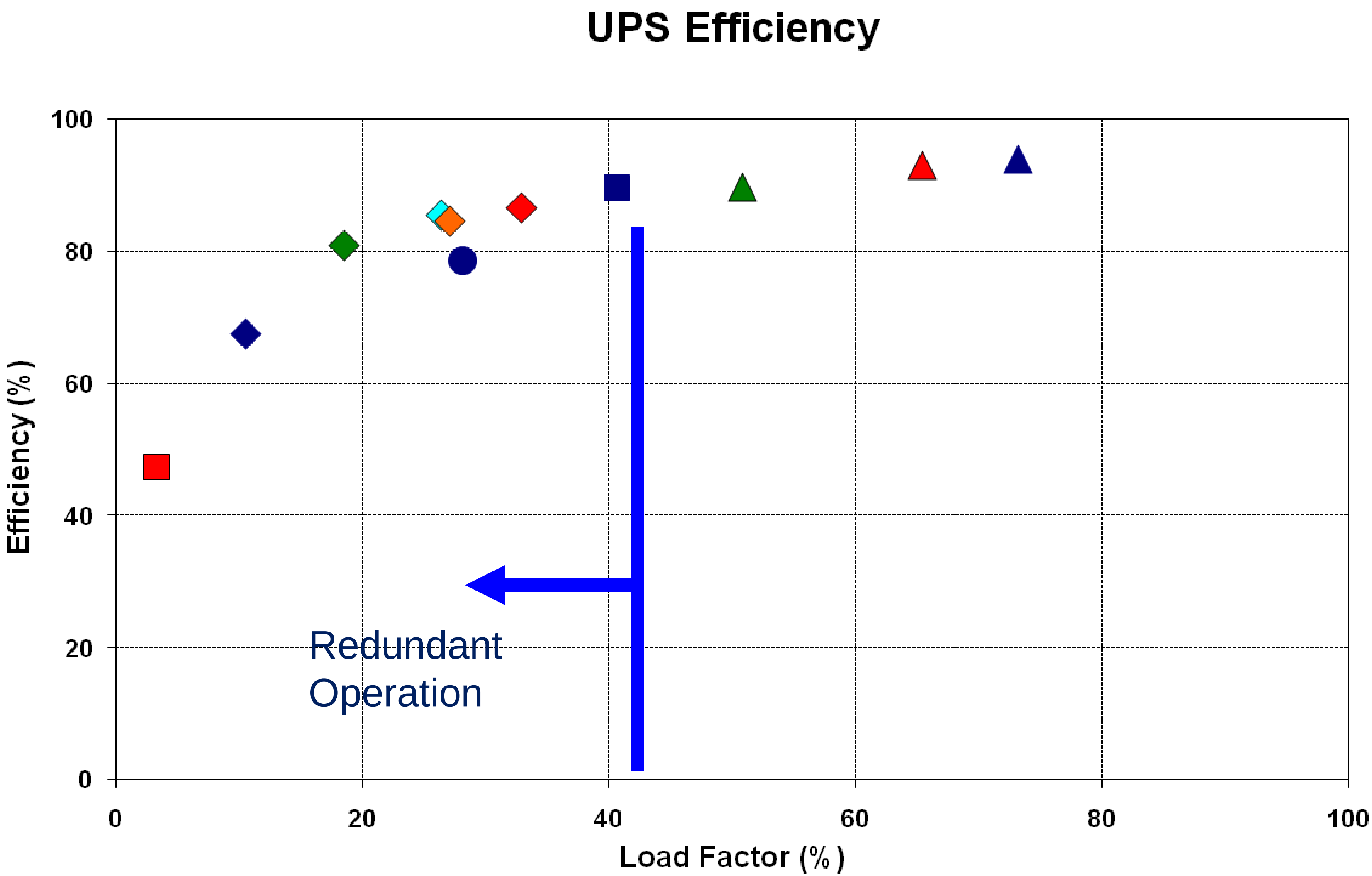


Improving the Power Chain

- **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
- Does everything need the same level?
- Redundancy in the network rather than in the data center

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)

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

How can ESPCs help?

- **What are the barriers to success?**
    1. Organizational Inertia and conflicting goals, risk aversion
    2. Lack of funding
    3. Lack of manpower / expertise
    - ➢ ESPCs can solve or help overcome barriers – at least 2 & 3!

2. Inflexible, flat funding stunts modernization of IT
    - ➢ Lowest up-front cost vs lifecycle cost of IT and infrastructure
    - ➢ TMF/WCF offer flexible means to invest/innovate (supplement ESPCs?)

3. Optimization and the Cloud require new skills, processes
    - ➢ Virtualization, consolidation, push to the cloud are big lifts ($ and time)
    - ➢ Pay-as-you-go can be cheaper than in-house data centers
    - ➢ Hybrid / Public cloud adoption fosters innovation / further modernization
    - ➢ Barrier 1 and 3 require very strong and credible team

Project Example – Army Ft Knox

- **Overview**
  - Replace existing constant speed fan motors on data center's computer room air handlers (CRAH) with variable speed fans.
  - Upgrade controls and increase temperature set point to 78°F.
- **Benefits to the Army**
  - Decrease cooling energy
  - Reduce fan energy
  - Improve data center efficiency and reduce PUE
- **Projected Year One Savings: $102K**

Project Example – NASA Jet Propulsion Laboratory (JPL)

- **Overview: $24M implementation**
  - Consolidate to two data centers.
  - Buildout and upgrades to existing data center.
  - Install a scalable Modular Data Center (MDC) to allow for geographic separation of IT assets.
- **Benefits to NASA**
  - Help facilitate NASA JPL's data center consolidation efforts.
  - Reduce NASA JPL's data center-related costs, including utility & IT costs (e.g. reduce IT refresh and O&M costs).
  - Provide lower PUE data centers with more efficient cooling infrastructure.
- **Projected Annual Savings: $2.7 Million**
  - Energy savings (annual): $0.6M
  - O&M / IT savings (annual): $2.0M

Project Example – Naval Base Coronado

- **Critical Goals: reliability, sustainability, resiliency, and efficiency**
  - 95% of the ESPC is in a mission critical data center with comprehensive ECMs
  - Task Order awarded February, 2016 with a value of $114 Million.
  - Performance guarantee is structured around ESCO guaranteeing temperatures on the server floor, uptime of critical equipment, and full O&M, in addition to energy savings.
- **Guaranteed savings are $4.4 million/year**

Project Example – Army Presidio of Monterey

- **Overview: UESC**
  - Replace interior and exterior lighting, new controls installed
  - Refurbish HVAC with new variable frequency drives on fans and pumps; building rebalanced and major HVAC systems recommissioned
  - Repair and balance economizer damper and VAV boxes for optimal cooling
- **Benefits to the Army**
  - Optimized the site's data center for efficiency and simplified future flexibility
  - Achieved over 50% savings in natural gas
  - Improved power usage effectiveness (PUE) by 33% from 1.9 to 1.6 – Actually achieved even better – 1.52 PUE
  - Exterior lighting improved by 70% with bi-level dimming LED parking lot lights
  - Addressed maintenance, airflow, and comfort issues through upgrades and retro-commissioning of systems.
- **Projected Annual Savings: $8 million over 10 years**

But there are few IT/Data Center ESPCs

- **Separate agency organization (Facilities & IT)**
  - ESPCs are traditionally employed by Building and Public Works departments, while IT managers are the key decision maker.
  - Split Incentive (Who pays utility bill? Who sets IT acquisition/ops policy?).
  - The data center also has customers / stakeholders that want control.
  - Performance should be enhanced, security increased (non-energy benefits will often "sell" the project)
- **Integrity of IT**
  - Criticality of performance raises concerns with risk adverse staff that any change could compromise IT integrity.
  - Technical solution must be developed by data center experts and remain in the control of the agency IT departments
- **Unique implementation challenges**
  - Keeping system current under program designed for long-term components (IT refresh 3-5 years with lots of unknowns)

Financing IT/Data Center ESPCs

- **High cost of consolidation and optimization strategies can be too high to be financed by energy savings alone:**
  - O&M savings and/or appropriations may be needed to make a project economic.
  - Technology Modernization Fund (TMF) and IT Working Capital Funds (WCF) are opportunities for leverage

ESPC and IT/Data Center

- IT/data center ESPC projects can stand alone or be part of a comprehensive project including other building systems.
- IT projects can save a high percentage of energy
- IT projects can save a very high percentage of energy
- For VDI (Virtual Desktop Infrastructure), the savings can be over 90%.
- If cloud solution is preferred, energy savings can be a very high percentage.
  - ESPC can help finance the move of equipment for colocation of equipment/cloud service.

DOE's Center of Expertise

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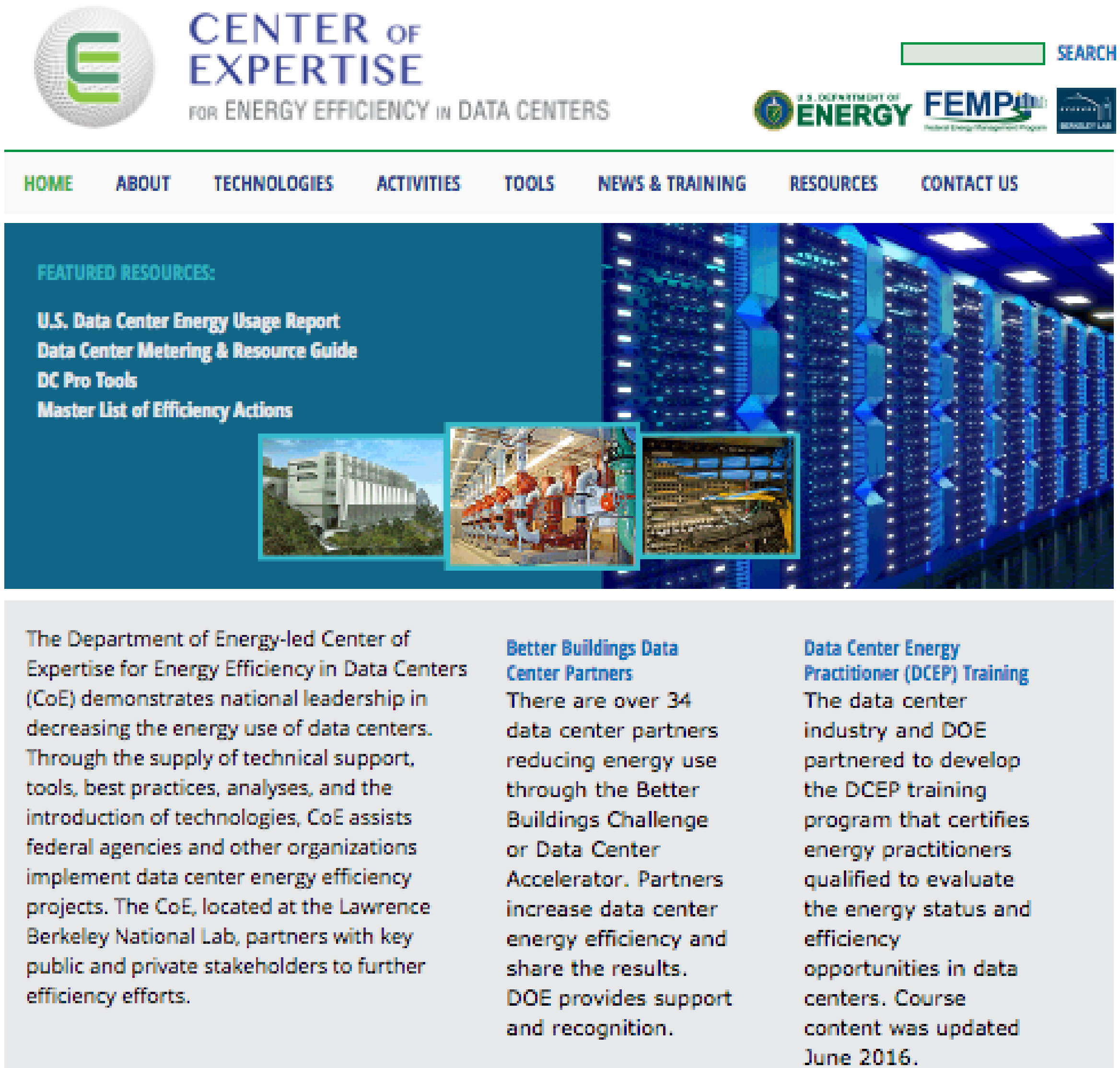

Featured Activities

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

Datacenters.lbl.gov

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FEMP's Data Center Team is ready to Help

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