FEDERAL UTILITY PARTNERSHIP WORKING GROUP SEMINAR

April 12-13, 2017
Savannah, Georgia

Partnering with DOE to Improve Data Center Efficiency

Dale Sartor, PE
Lawrence Berkeley National Laboratory

Hosted by:

FEMP
Federal Energy Management Program

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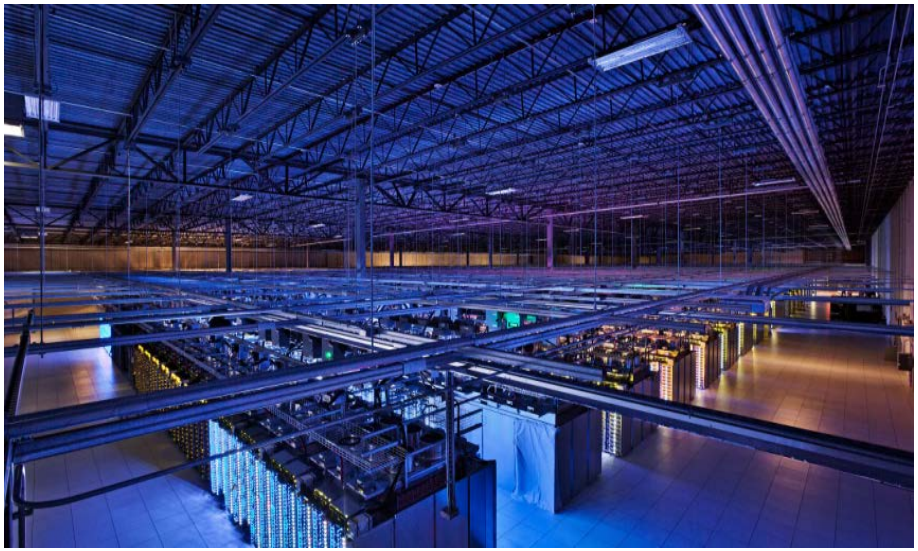
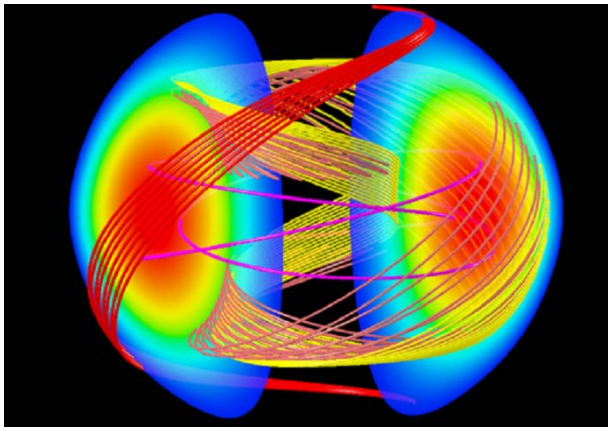
Agenda

- Data Center Energy Context
- Federal Drivers
- Performance metrics and Benchmarking
- DOE and Utility Collaboration
- Current Demo Project
- Resources to Help



Lawrence Berkeley National Laboratory (LBNL)

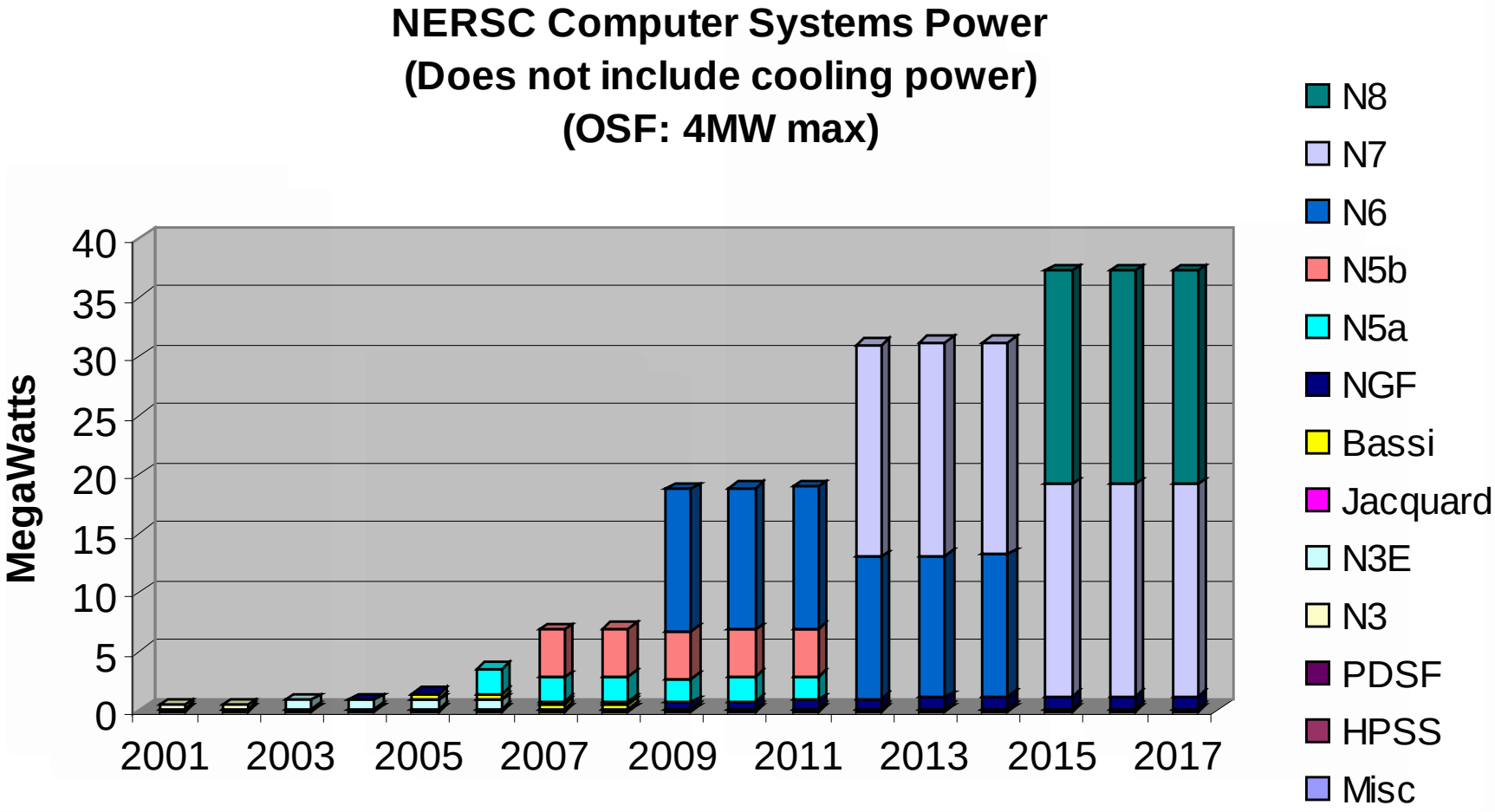
- Operates large systems along with legacy equipment



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

LBNL Feels the Pain!

LBNL Super Computer Systems Power



Data Center Energy

Data centers are energy intensive facilities

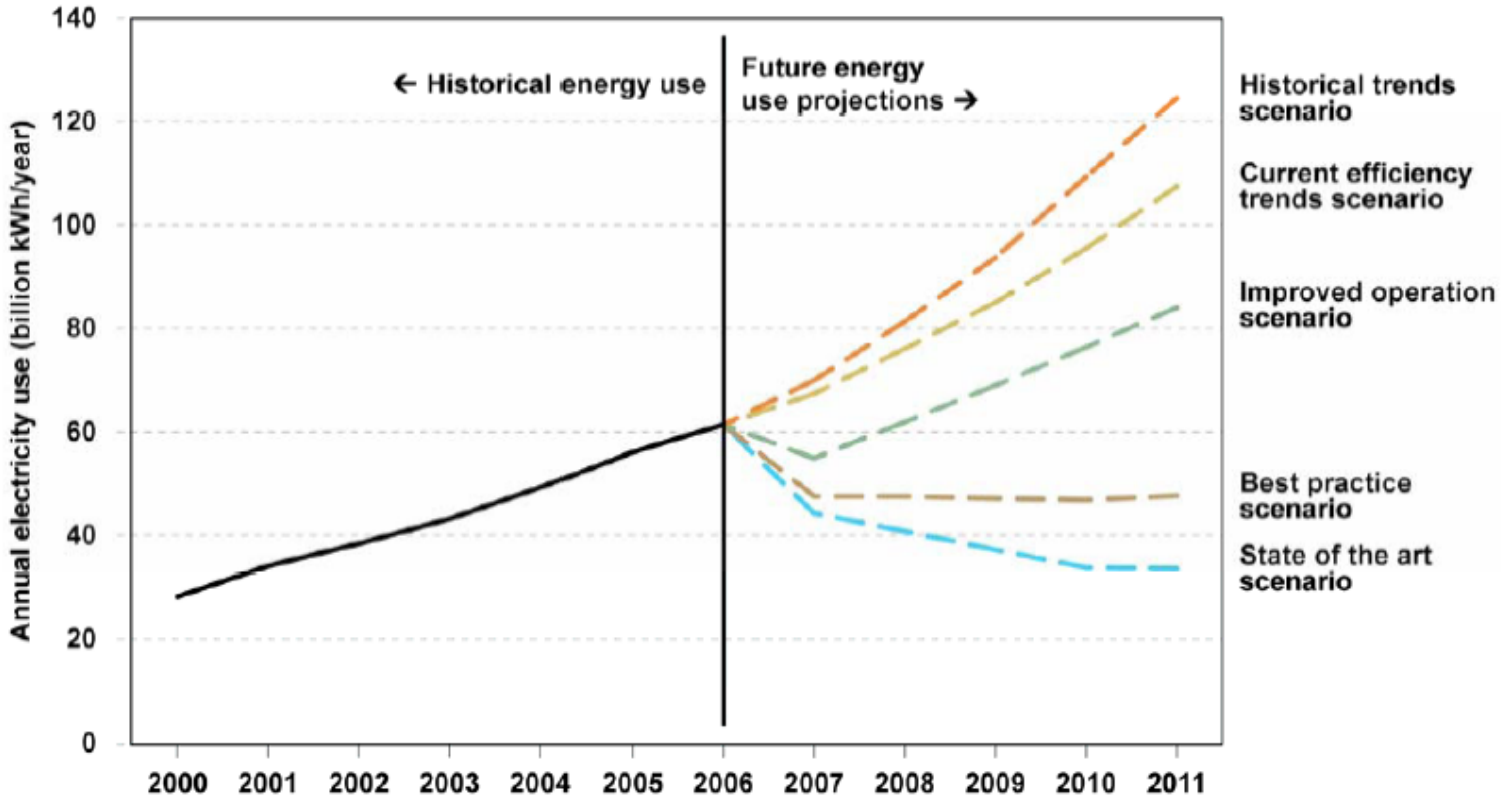
- 10 to 100+ times more energy intensive than an office
- Server racks now designed for more than 25+ kW
- Surging demand for data storage
- 2% of US electricity consumption
- Power and cooling constraints in existing facilities
- Cost of electricity often highest operating cost
- Perverse incentives -- 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

Data center energy projections in 2007

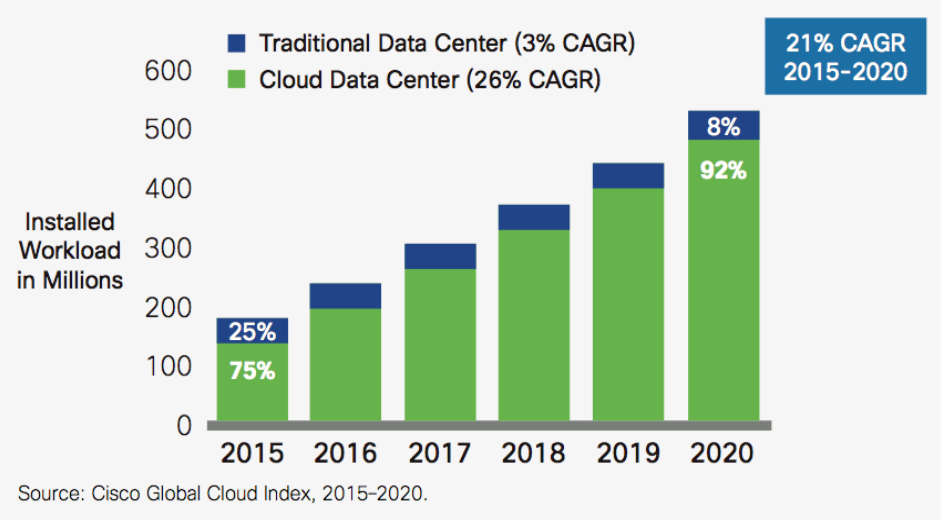
Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431

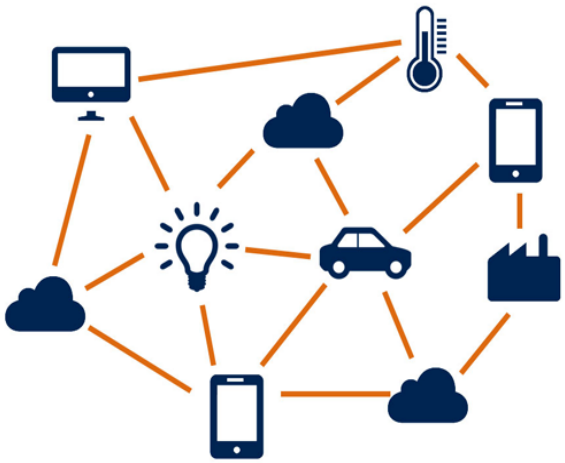


Brown et al., 2007, *Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431*

Data Center Landscape Different than 2007

- Emergence of cloud computing and social media
  - IP traffic increasing 20% annually
- Dominance of “hyperscale” data centers
- Growth in data storage
  - 20x increase since 2007
- “Internet of Things” capabilities
- New IT equipment
  - “Unbranded” ODM servers
  - Solid state hard drives
  - Faster network ports





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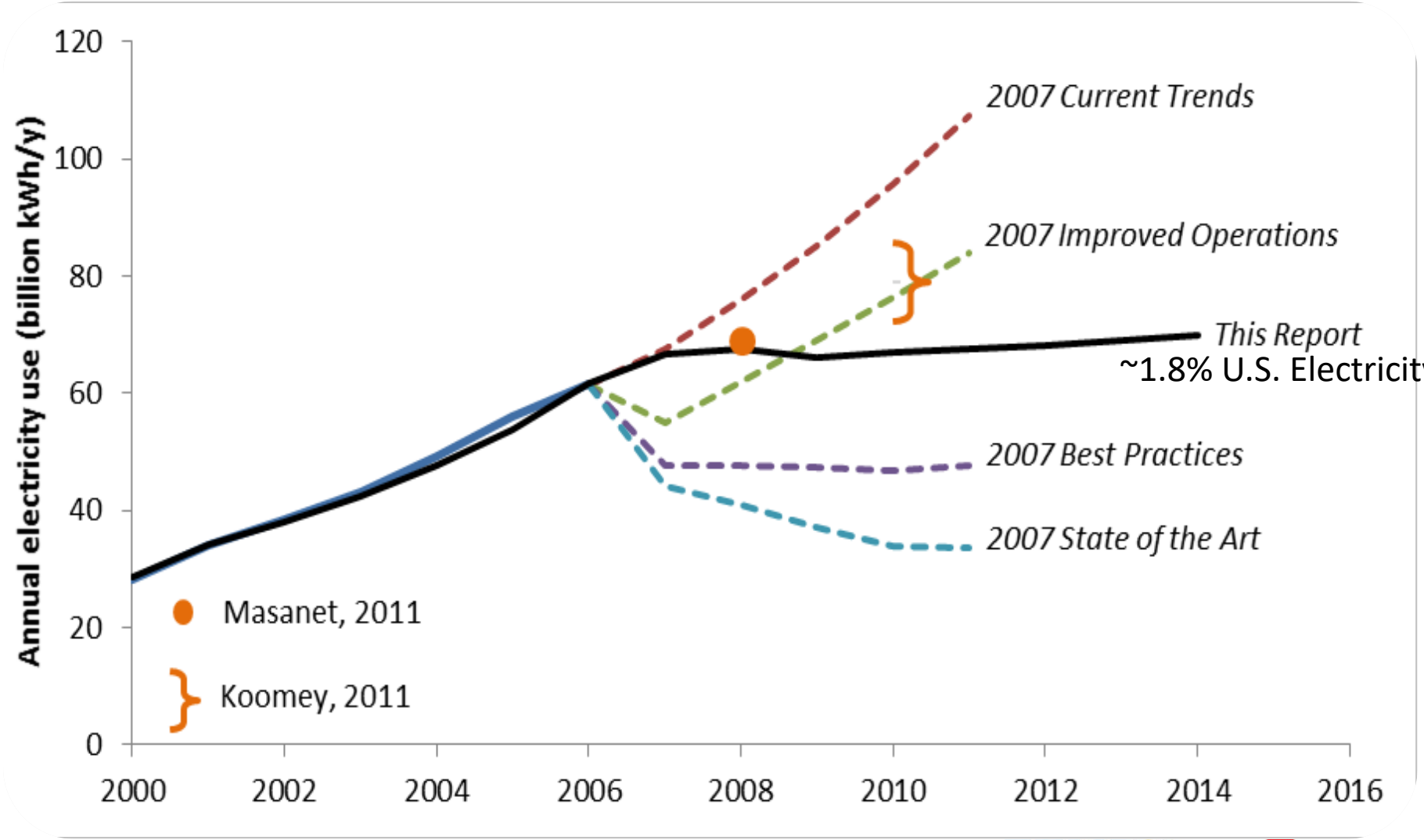
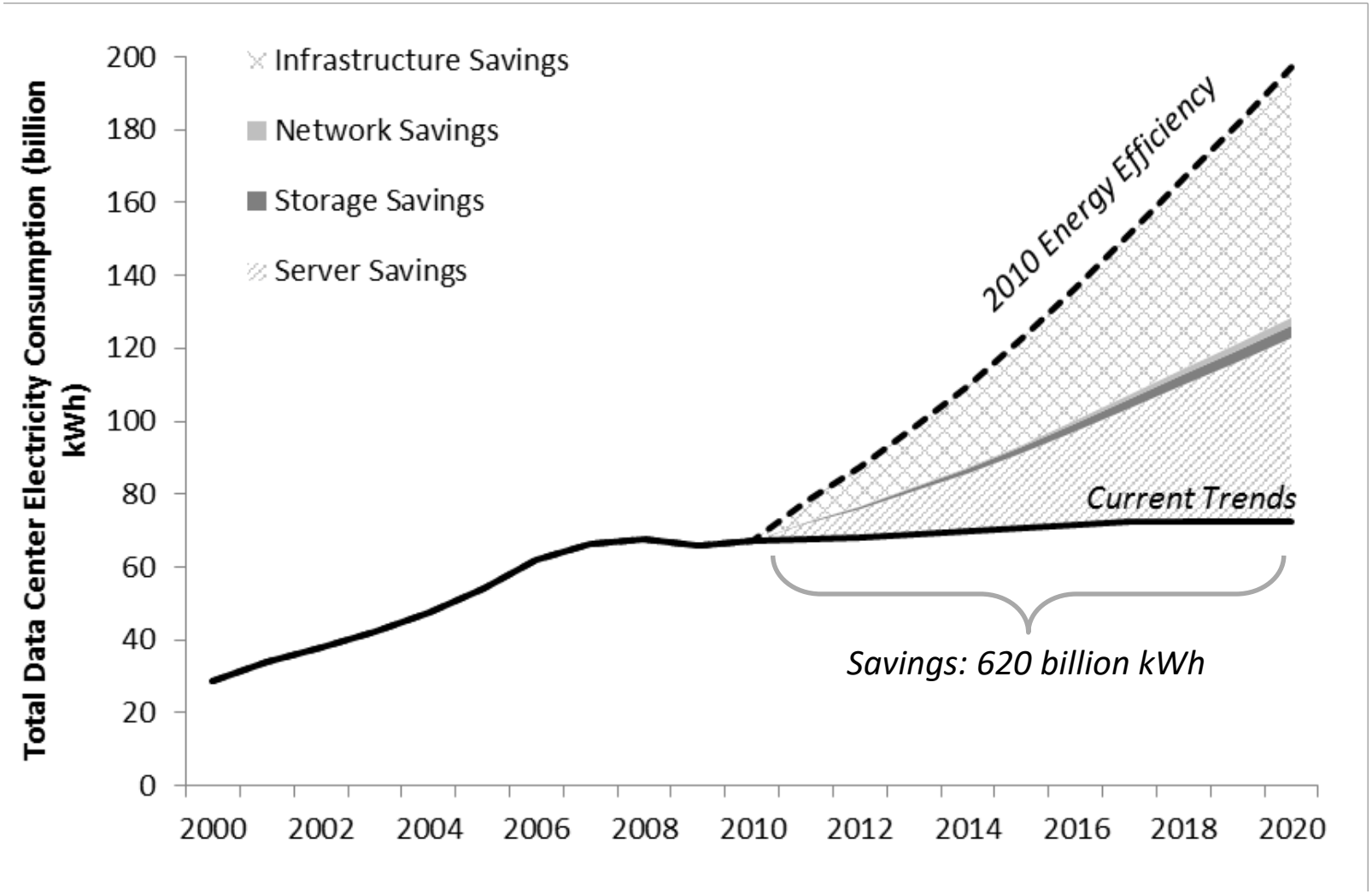
US Data Center Energy Usage Reports (2007 & 2016)



Results: Energy Use Projections and Counterfactual



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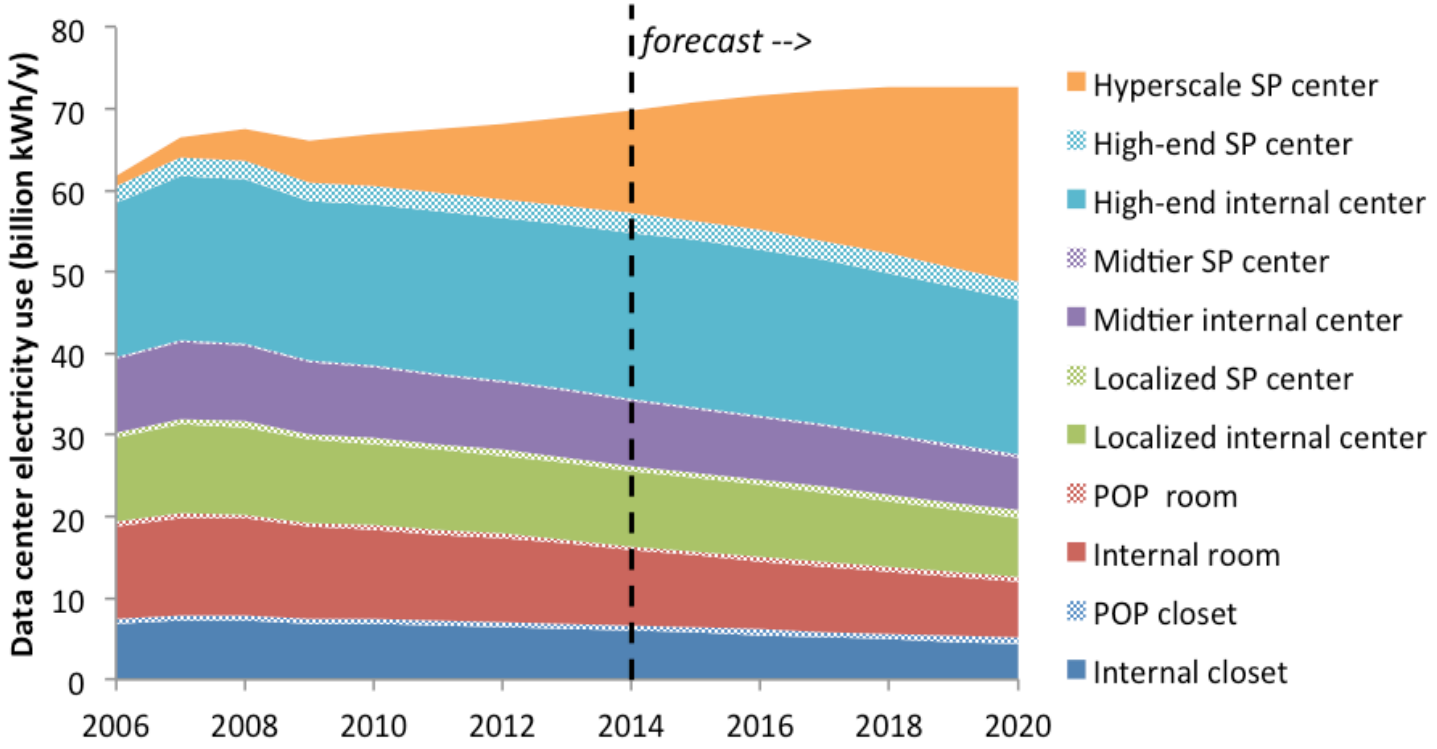
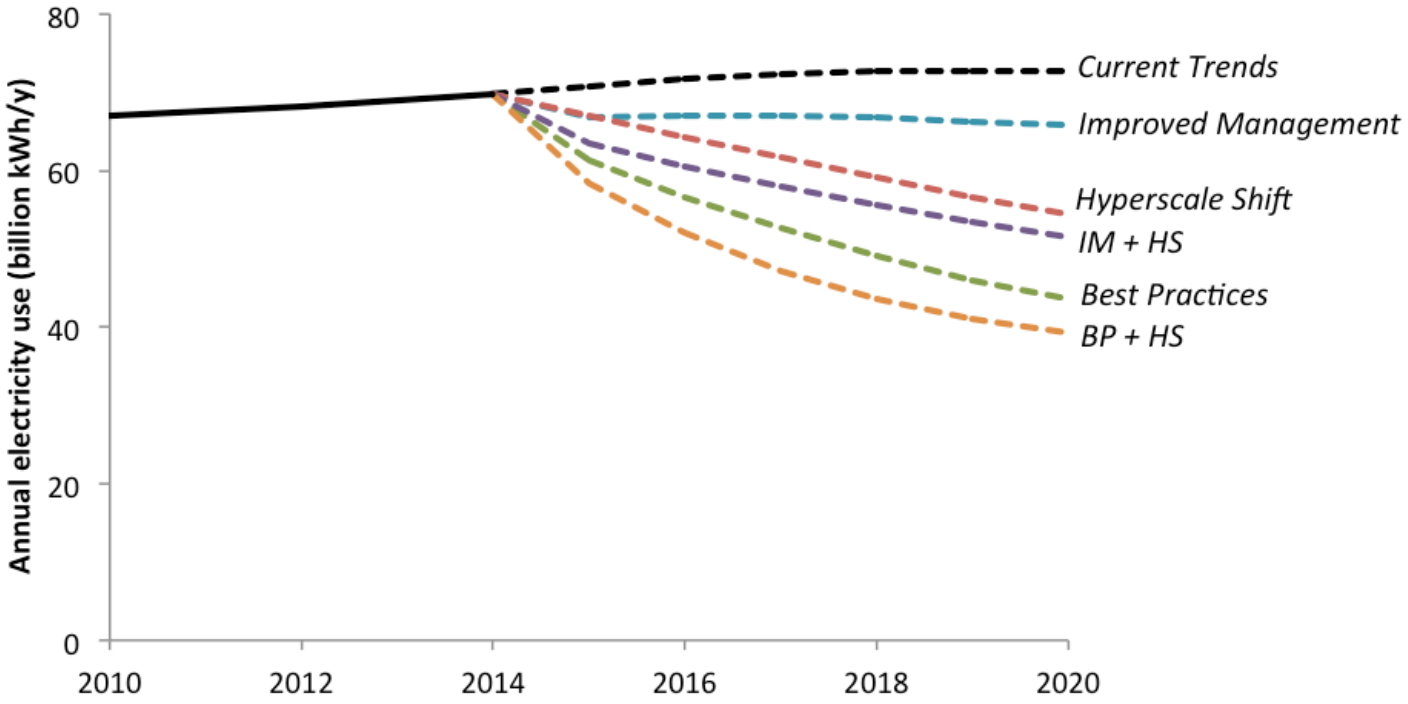
Energy Use Estimates by Data Center Type

- Hyperscale is a growing percentage of data center energy use



More Savings Available through Efficiency

- Annual saving in 2020 up to 33 billion kWh
- Represents a 45% reduction in electricity demand over current trends



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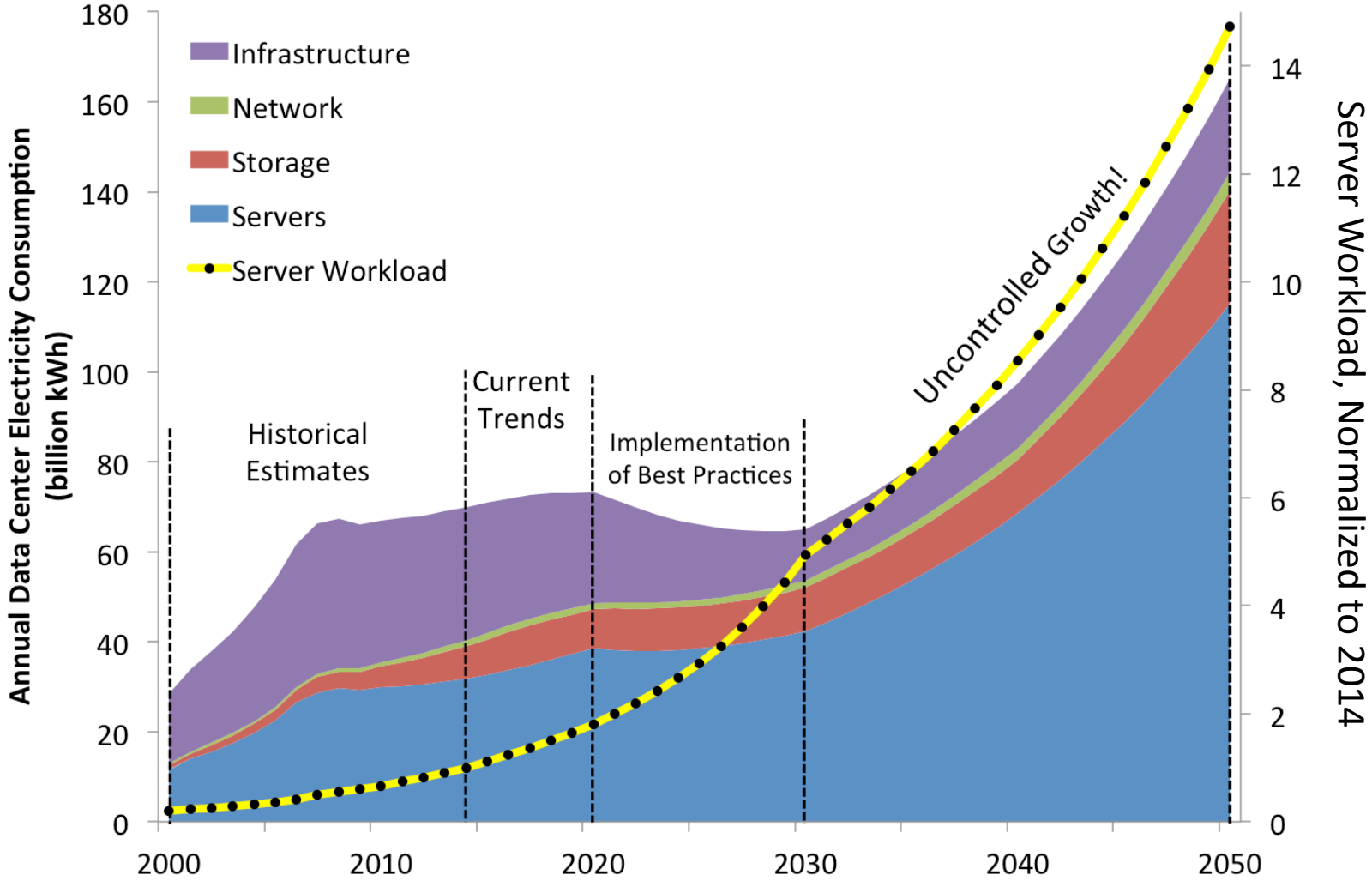
2050 Projections



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 innovating data center business models will be needed to keep energy consumption down over the next 20-30 years

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Fed Driver: Executive Order 13693

Specific goals for data centers

- Promote energy optimization, efficiency, and performance
- Install/monitor advanced energy meters in all data centers by FY2018
- Assign a Data Center Energy Practioner (DCEP)
- Establish a Power Usage Effectiveness (PUE) target
  - between 1.2 and 1.4 for new data centers
  - less than 1.5 for existing data centers

Other related goals

- Reduce building energy 2.5% per year per sq. ft. thru 2025
- Increase clean and renewable energy – to 25% & 30% by 2020 & 2025
- Reduce water consumption 2% per year per sq. ft. thru 2025
- Make ENERGY STAR or FEMP designated acquisitions

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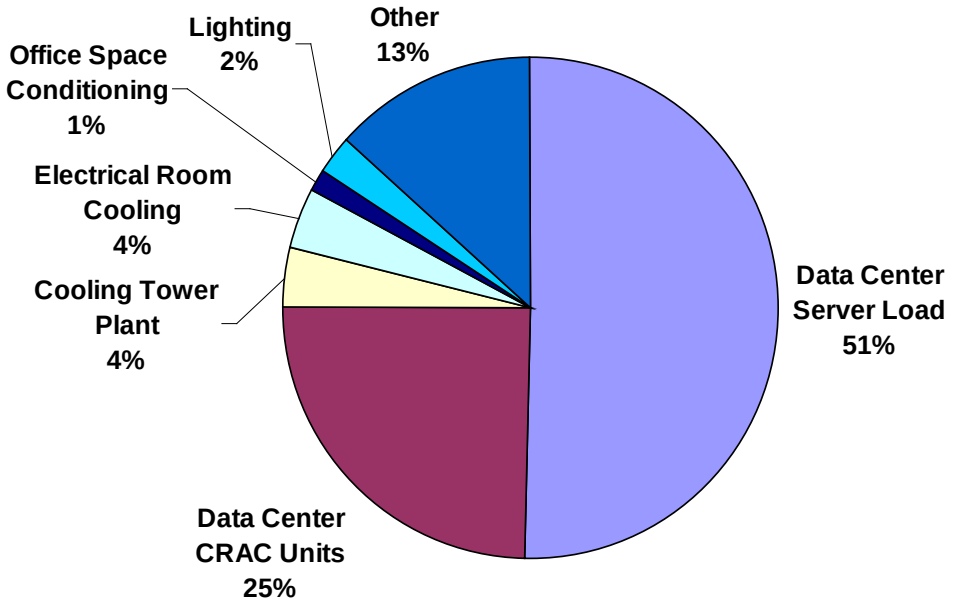
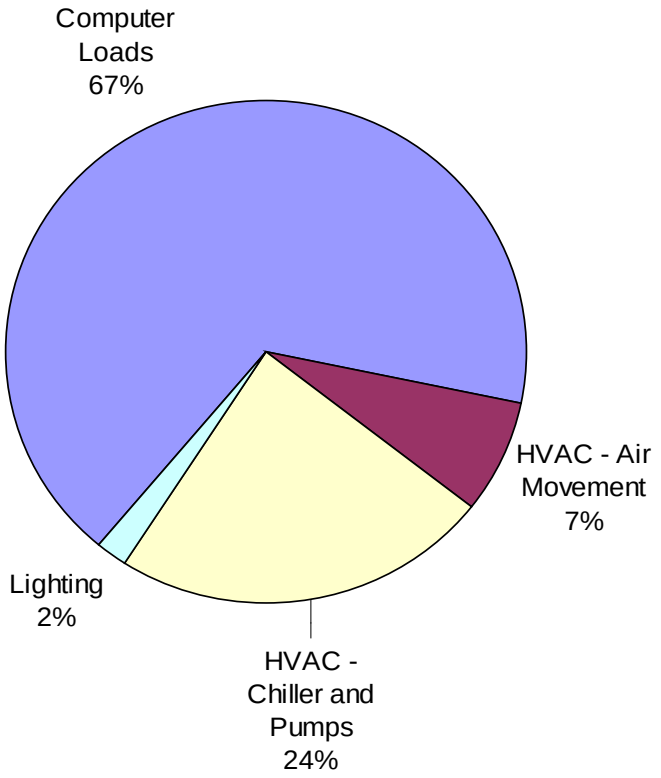
Benchmarking Energy Performance: So What is PUE?





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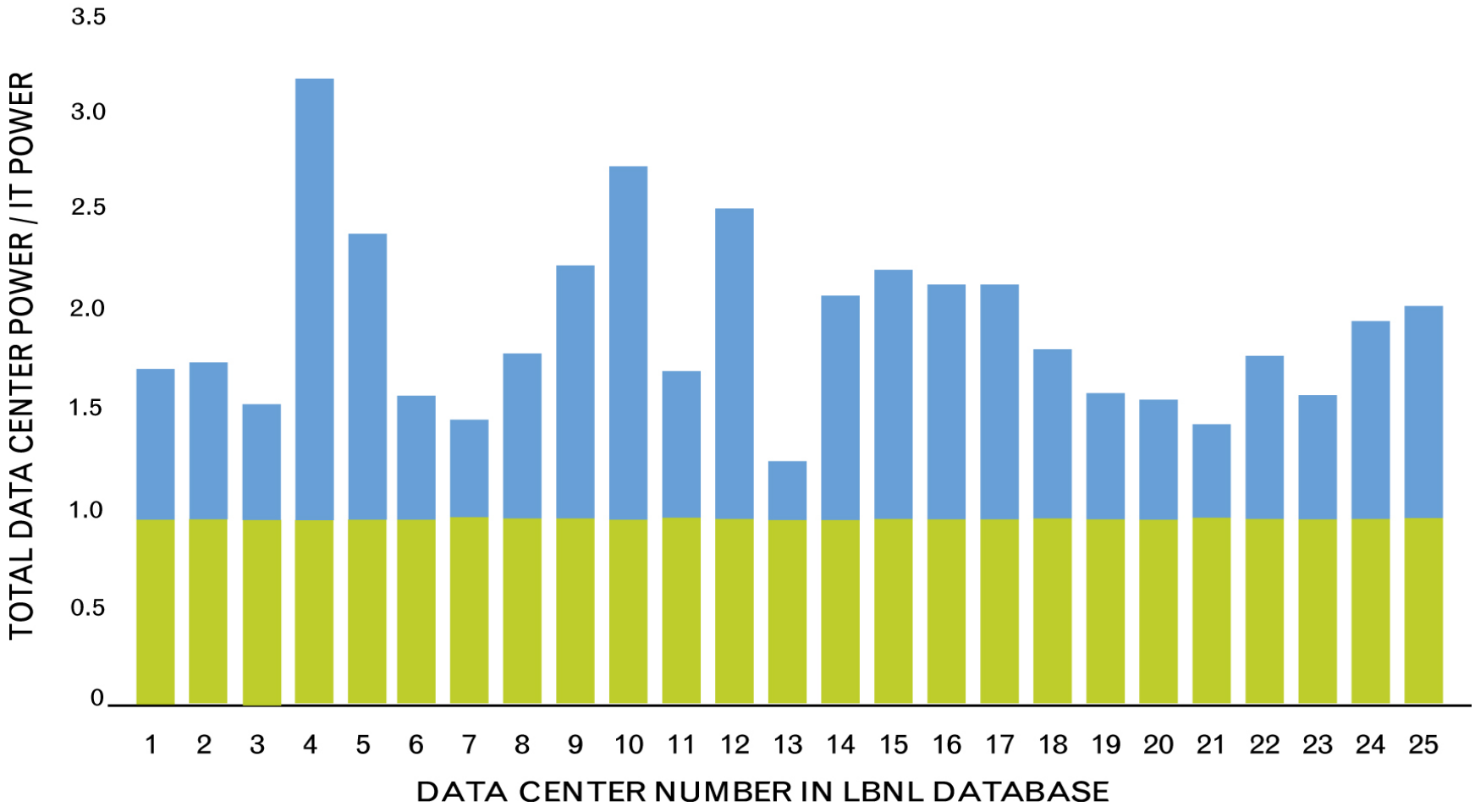
High Level Metric: PUE

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



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Sample PUEs

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

Source: Mike Patterson, Intel

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Data Center Best Practices

1. Measure and Benchmark Energy Use
2. Identify IT Opportunities, and modify procurement processes to align with the procurement policy
3. Optimize Environmental Conditions
4. Manage Airflow (Air Management)
5. Evaluate Cooling Options
6. Improve Electrical Efficiency
7. Use IT to Control IT

Bonus slides on each at end of presentation

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DOE and Utility Collaboration

- Federal efforts are resource constrained and cannot achieve significant market penetration on their own

  ➔ Key goal: leverage DOE and utility resources
- Initiated Strategic Plan in FY16
- FY17 activities:
  - Utility webinar on resources and partnering opportunities
  - Cost-sharing demonstration projects (targeting 2-3) for prescriptive air management “packages” for small data centers

Utilities

- Customer-facing efficiency programs
- A number of measures targeted through existing programs

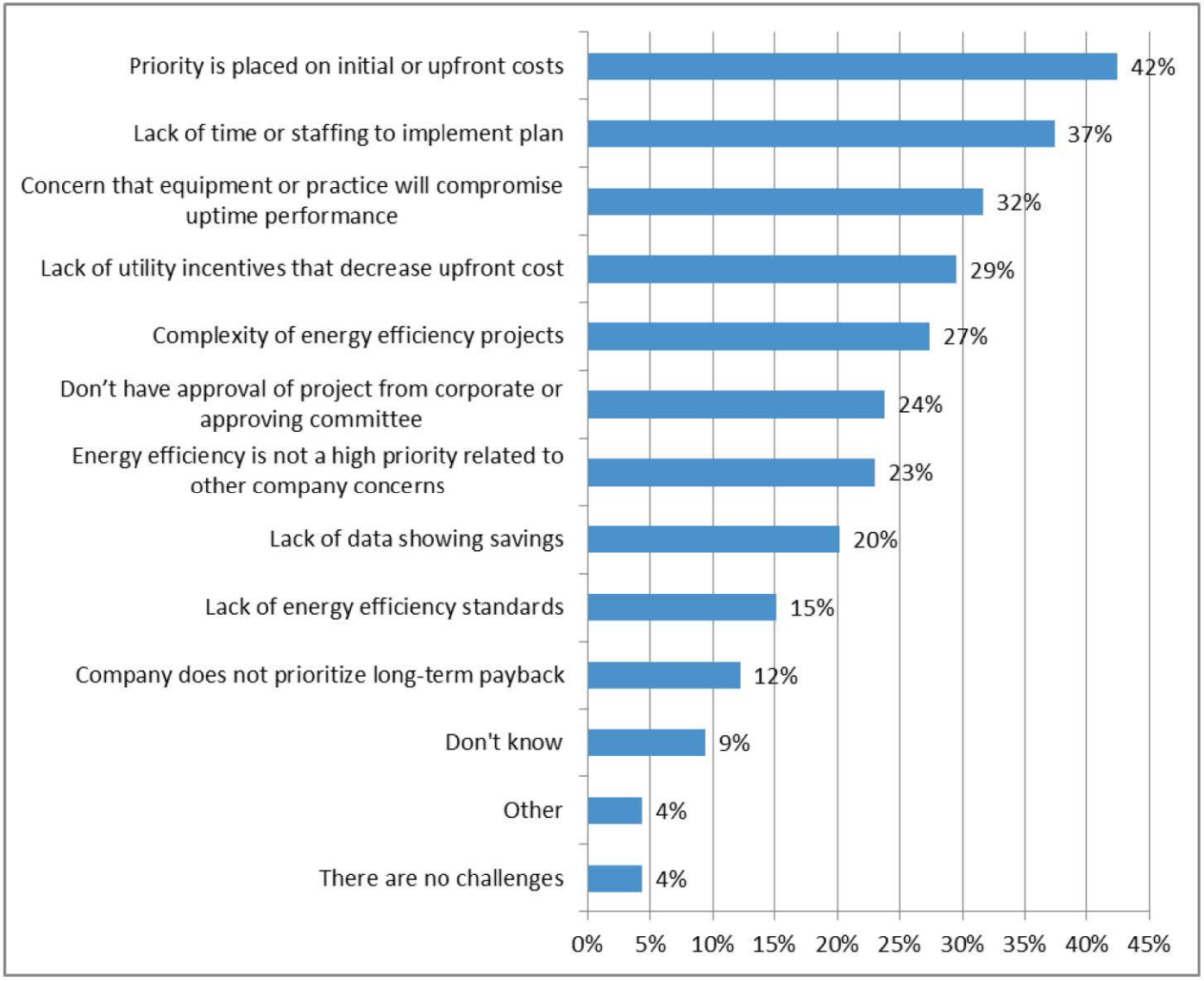
Virtualization	ENERGY STAR Server	Massive Array of Idle Disks	Uninterruptible Power Supply	Chillers/Cooling Towers	Thermal Energy Storage	Storage Consolidation	Airflow

Airflow	Variable Frequency Drive	Air-Side Economizer	Water-Side Economizer	Pumps/Motors	HVAC/CRAC	DC Power

Source: Environmental Protection Agency. 2012.

- Existing efforts often have low market penetration and savings
  - Federal data centers appear to be particularly under-served.
- Utility efforts are embedded in the marketplace but require technical resources and independent expert opinions.
- Utilities often find the existing technical information and literature complicated for their customers and “C-suite” audiences.

Barriers to data center energy



Source: Cadmus, et al. 2015 for NYSERDA.

By working more closely, Department of Energy (DOE) and utilities can be more responsive to the barriers perceived by data center managers.

Strategy Overview

DOE/LBNL can act as an "honest broker," providing credible third-party expertise. Efforts to-date have not focused on utility needs and audiences.

- 2016 report prepared by LBNL
  - Interviews with representatives from 16 utilities
  - Literature review and applied knowledge from LBNL's related work

- Seven strategies identified for DOE/LBNL and utilities to raise the energy efficiency of data centers. Goals:
  - More accessible information and tools better matched to utility needs
  - Reach broader audience, including less-sophisticated users
  - Scope expanded to include "softer" topics such as business-case analysis
  - Positive influence on regulatory process and decisionmaking (e.g. technologies allowable in programs, cost-benefit analysis, deemed savings, free-ridership risks).

- Can formalize strategy through a collaborative framework
  - Freestanding consortium or integrate efforts within an existing group

1. Expand audience of the Center of Expertise

Challenge: Strategic utility personnel often unaware of resources available on the Center of Expertise (CoE) website.

DOE/LBNL

- Tailor tools, best practices, and training for underserved groups such as small data center operators, utility customer representatives, senior managers, and others lacking deep background in data centers
- Reach broader audiences by publishing material in new places (e.g. business press)

Utilities

- Send staff to CoE trainings
- Incorporate pointers to CoE resources in customer-facing communications
- Provide view of market segmentation
- Customize CoE material to individual target audiences

2. Shift from emphasis on information "pull" to "push"

Challenge: Few people visit websites unprompted.

DOE/LBNL

- "Push" users to visit the CoE through email, social media, newsletters, and/or webinars
- Give more frequent and targeted presentations through:
  - Utilities
  - Consortium for Energy Efficiency (CEE)
  - Federal Utility Partnership Working Group (FUPWG)
  - The Green Grid
  - Trade associations

Utilities

- Engage customers in CoE's information streams

3. Support DOE partnership programs

Challenge: Limited utility awareness of and interest in DOE's programs including Better Buildings.

DOE/LBNL

- Further promote DOE deployment programs (e.g. the Better Buildings Challenge and the Data Center Accelerator)
- Further promote the Federal Utility Partnership Working Group (FUPWG), e.g. by extracting and publicizing success stories unique to datacenters

Utilities

- Engage the CoE to identify and approach promising data centers in service territory
- Provide support to partners/customers (measure identification, metering plans, reporting, etc.)

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4. Help utilities make the case for robust market interventions

Challenge: Low market penetration of existing programs and under- or misinformed regulators.

DOE/LBNL

- Leverage recent national market assessment and tailor to local conditions
- Ensure proper treatment of retrofit as well as new-construction applications
- Act as an "honest broker" to increase regulators' level of competence including tailored trainings, state-level market assessments, and technical "White Papers" used to vet program proposals
  - National regulatory entities such as National Association of Regulatory Utility Commissioners (NARUC)
  - FERC
  - NERC
  - ISOs
  - State/regional energy offices (individually and/or via NASEO)

Utilities

- Identify needs, helping DOE/LBNL establish priorities
- Share successes via CoE, FUPWG, and CEE
- Promote utility-branded versions of DOE tools and best-practice guides
- Focus on new-construction in relevant markets (e.g., Northwest)
- Increase competency of non-datacenter account managers to address datacenters embedded in a diversity of "ordinary" buildings

5. Provide more comprehensive and relevant characterization of benefits

Challenge: Current efforts do not emphasize benefits beyond engineering efficiencies.

DOE/LBNL

- Emphasize economics and non-energy benefits such as reliability (both within facilities and at the grid level) in CoE projects
- Address institutional barriers (e.g. IT staff vs. Facility staff needs)

Utilities

- Educate customers (end-users) with the goal of increasing perceived value of datacenter energy efficiency and program participation

6. Keep up with a changing technical landscape

Challenge: Emerging issues and opportunities such as demand response, smaller embedded data centers, liquid cooling, retro-commissioning, and waste-heat recovery need to be addressed.

DOE/LBNL

- Ensure core work on best practices, trainings, and tools keep pace including updating already produced material
- Expand definition of best practices beyond technologies to management practices, standardized savings-calculation methods, downsized/partially-loaded datacenters, project quality assurance, finanical analysis, etc.

Utilities

- Identify gaps in the existing CoE offerings
- Help set priorities for the targeting of existing federal resources for best practices assessment

7. Address practical aspects of implementation

Challenge: Utilities seek to go beyond defining idealized outcomes, i.e., to help customers in implementation in the context of practical constraints and challenges.

DOE/LBNL

- Help utilities address challenges, such as:
  - Harmonizing energy efficiency with fire codes
  - Coping with downsizing
  - The practical issues of metering and collecting data for computing PUEs,
  - Helping customers perform cost-benefit analyses
  - Educating regulators.

Utilities

- Promulgate new guidelines related to challenges

Next Steps: Utilities

- Encourage data center customers to participate in DOE & EPA programs
- Create a forum for customers to share best practices and lessons learned
- Utilize CoE tools and resources with customers to improve efficiency
  - Assist customers to benchmark energy performance of their data centers
- Sponsor training opportunities
  - Data Center Energy Practitioner (DCEP) training and certification
  - Awareness workshops
  - Webinars
- Support demonstration/showcase projects
  - Retrofit their own data centers – lead by example
- Target federal data center customers with Utility Energy Service Contacts (UESCs)
- Fund efforts through a collaborative framework

Next Steps: DOE/LBNL

- Initiate 2-3 demonstrations of retrofit packages for small data centers.
  - Cost sharing with 1-3 utilities (and their customers).
  - Federal customers will be targeted, but there may be a mix
  - Builds on work underway with PG&E

- Develop and host an annual webinar targeting utilities
  - Describe overall opportunities and trends in the rapidly changing data center industry
  - Describe current projects and resources
  - Similar to this presentation – feedback welcome

Current Demo Project

Prescriptive Air Management “Packages” for Small Data Centers

- Needed to overcome barriers

What is Air Management?

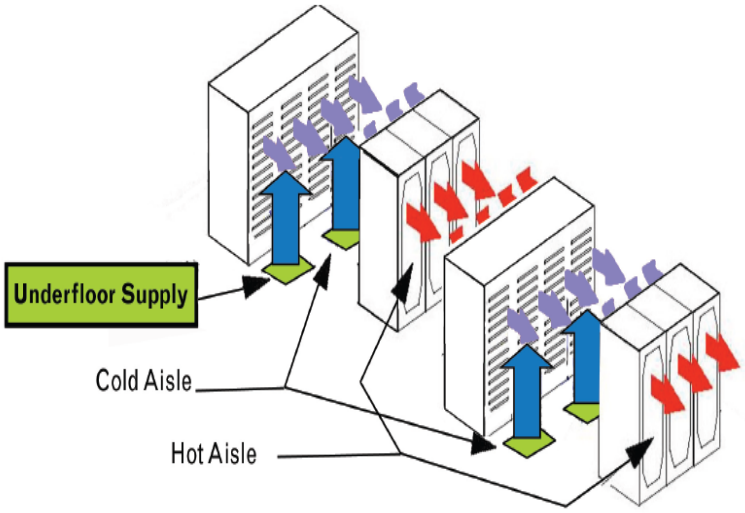
The Early Days at LBNL: It was cold but hot spots were everywhere

Fans were used to redirect air

High flow tiles reduced air pressure

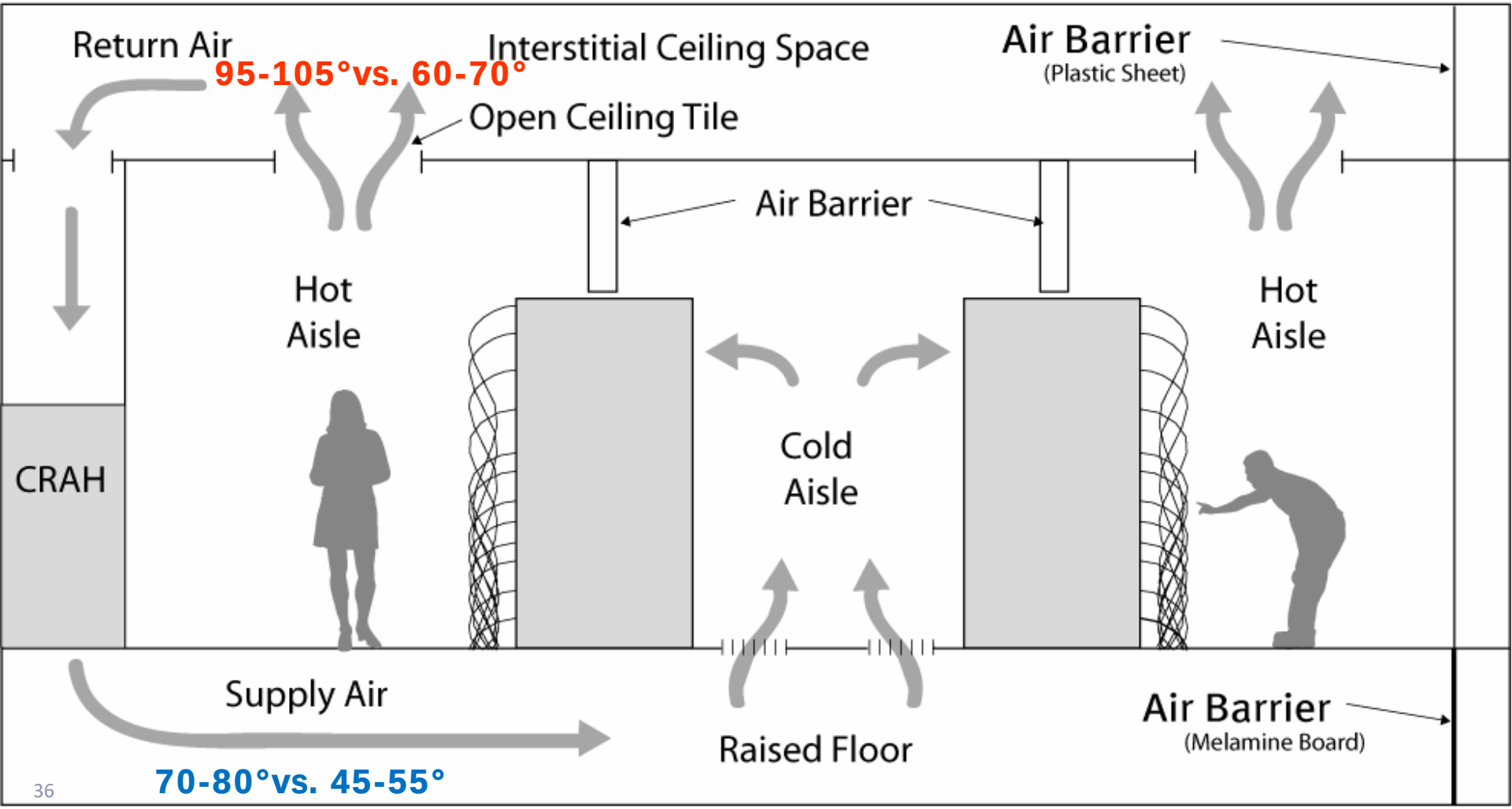
Air Management

- 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.

Isolate Cold and Hot Aisles



Background

- Air management is a first and effective step in improving data center energy performance
- "Small" data centers (<5,000 ft^2) use 50-60% of all energy used in data centers[1]
- … but a number of barriers:
  - Difficult to find (embedded)
  - Difficult to engage
  - Limited expertise and resources
  - Limited savings for each individual data center
  - High cost to implement custom solutions and custom incentive (rebate) programs

1) Shehabi, A. et al, 2016. U.S. Data Center Energy Usage Report.

Solution

- Prescriptive “packages” of air management measures for which savings can be stipulated
- Packages developed with PG&E in 2016
- Pilot demonstrations to be implemented in 2017-2018
  - PG&E
  - NYSERDA
  - Others (you?)

Resources to Help You and your Customers
CoE Website – Homepage

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?

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
- 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

Coming

Data Center Profiler (DC Pro) Tools

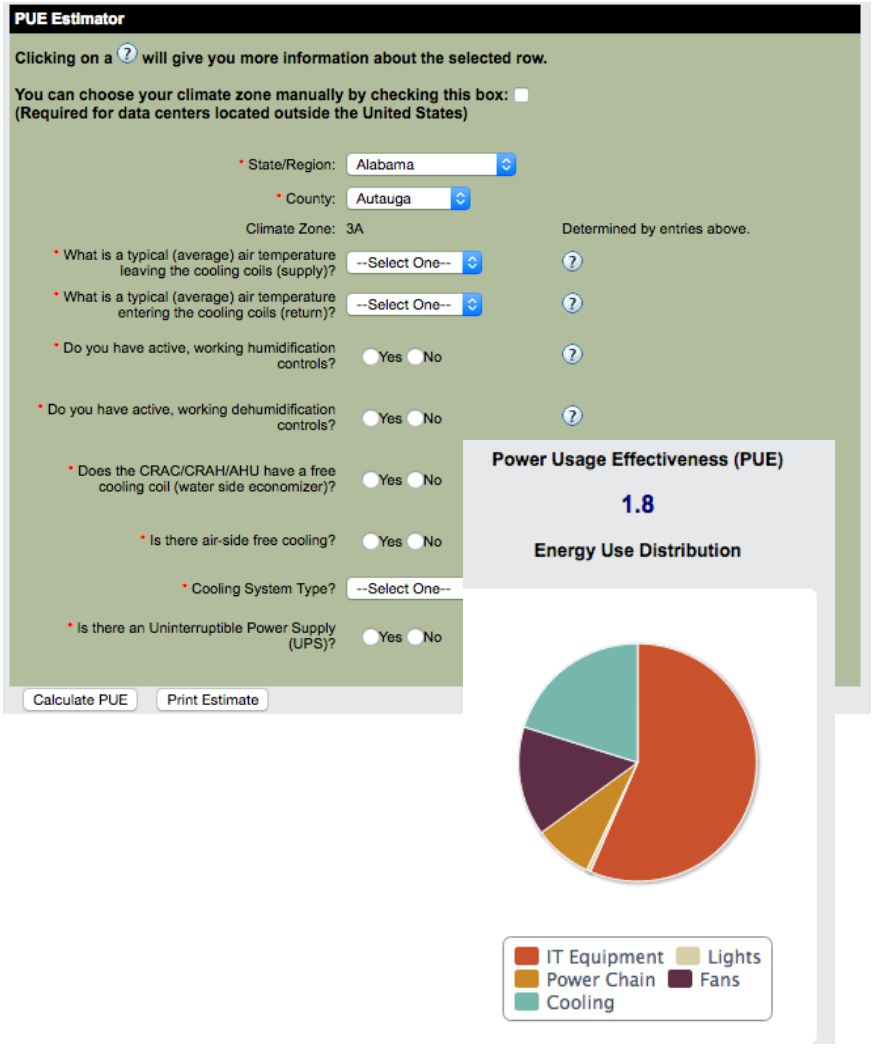
DC Pro Tools estimate PUE without sub-metering

DC Pro

- Estimates current and potential PUE
- Energy use distribution
- Tailored recommended actions to start improvement process.

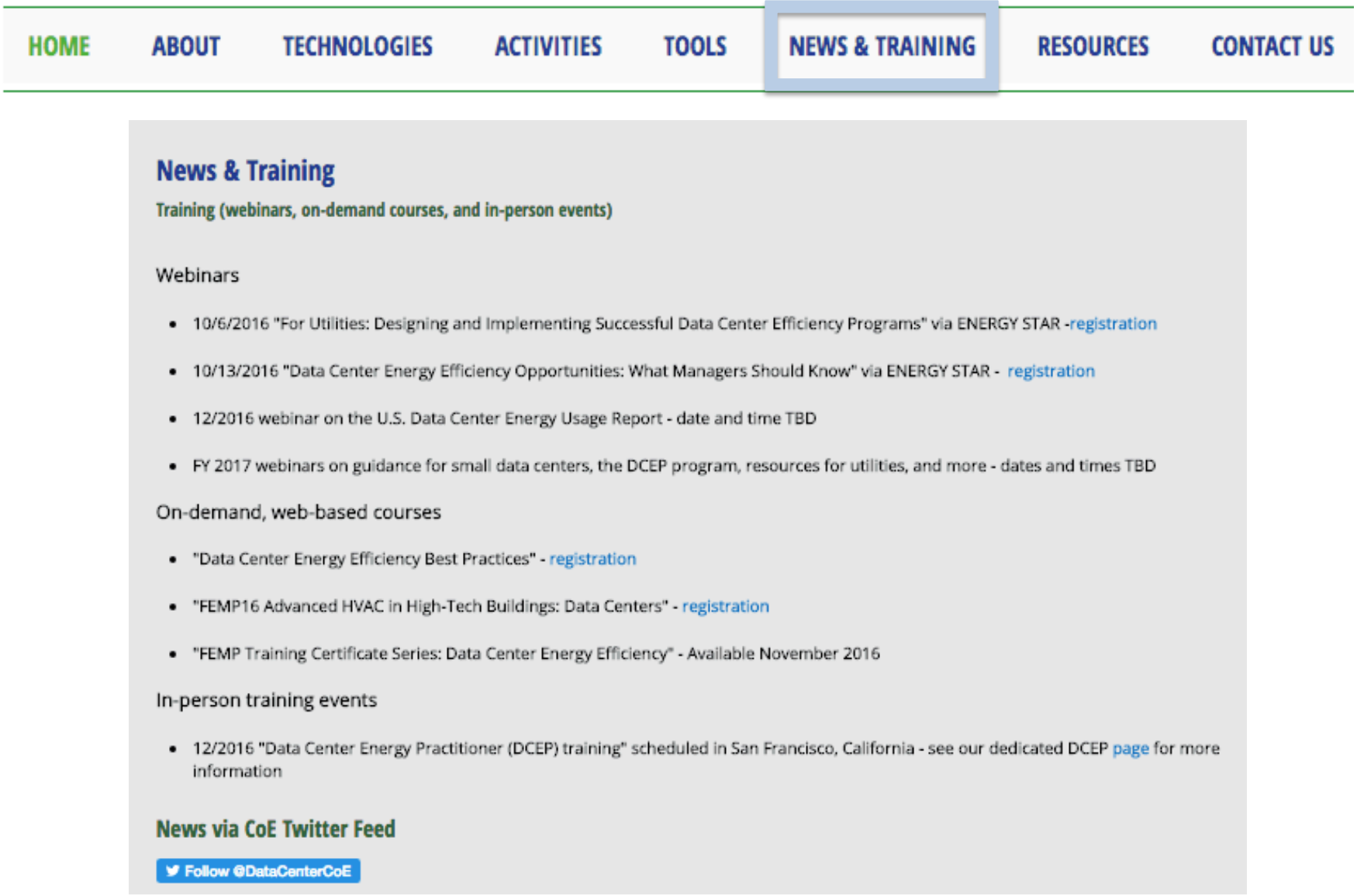
PUE Estimator, simplified DC Pro

- Only asks questions that affect PUE
- Does NOT provide potential PUE or recommended actions



datacenters.lbl.gov/dcpro

News and Training



News and Training, example

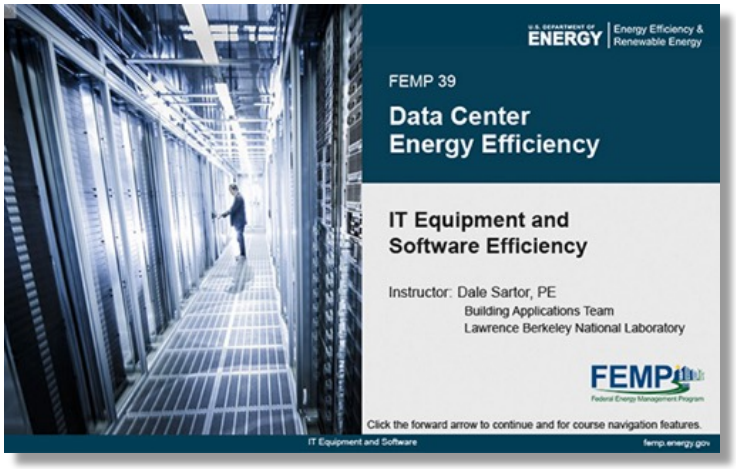
On-Demand Data Center Energy Efficiency Series

FEMP TRAINING

FEMP Certificate Series

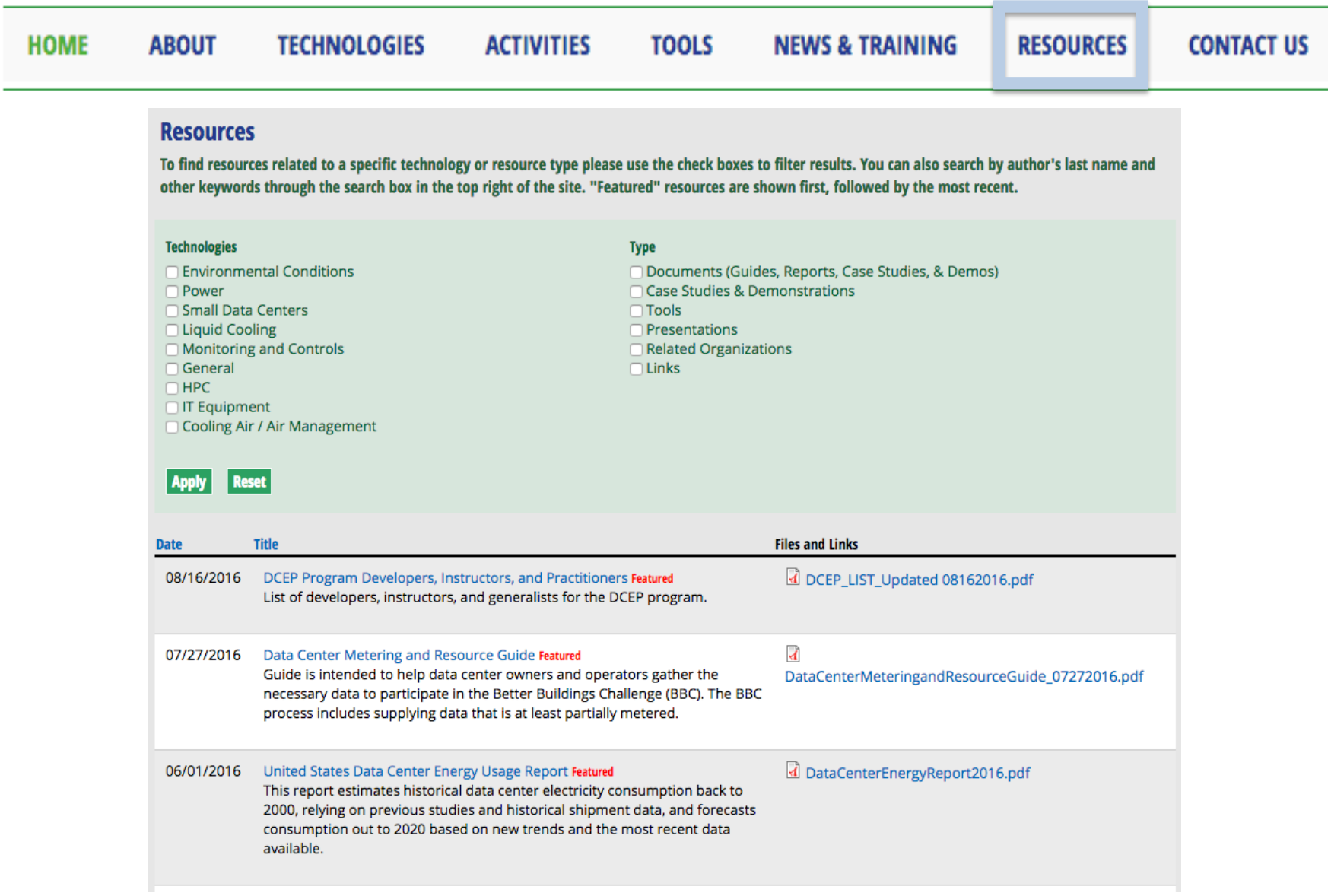
IACET

- **Data Center Energy Efficiency Best Practices**
  - 0.2 CEUs
- **IT Equipment and Software Efficiency**
  - 0.1 CEUs
- **Environmental Conditions**
  - 0.1 CEUs
- **Air Management**
  - 0.2 CEUs
- **Cooling Systems**
  - 0.2 CEUs
- **Electrical Systems**
  - 0.1 CEUs



eere.energy.gov/femp/training/

Resources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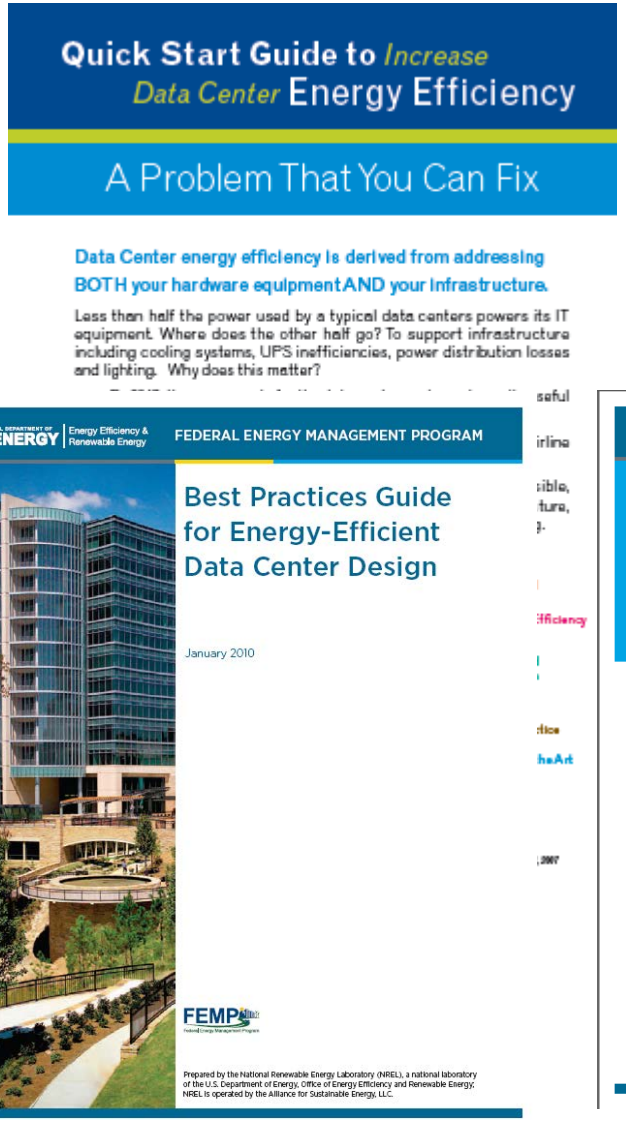
Tools
Presentations
Related Organizations
Links
Apply
Reset
Date
Title
Files and Links
08/16/2016
DCEP Program Developers, Instructors, and Practitioners Featured
List of developers, instructors, and generalists for the DCEP program.
DCEP_LIST_Updated 08162016.pdf
07/27/2016
Data Center Metering and Resource Guide Featured
Guide is intended to help data center owners and operators gather the necessary data to participate in the Better Buildings Challenge (BBC). The BBC process includes supplying data that is at least partially metered.
DataCenterMeteringandResourceGuide_07272016.pdf
06/01/2016
United States Data Center Energy Usage Report Featured
This report estimates historical data center electricity consumption back to 2000, relying on previous studies and historical shipment data, and forecasts consumption out to 2020 based on new trends and the most recent data available.
DataCenterEnergyReport2016.pdf

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)



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Questions

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

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

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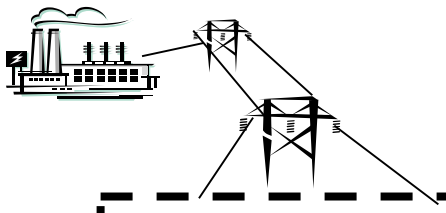
Opportunities (Back-up Slides)

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)

Data Center Best Practices

1. Measure and Benchmark Energy Use
2. Identify IT Opportunities, and modify procurement processes to align with the procurement policy
3. Optimize Environmental Conditions
4. Manage Airflow (Air Management)
5. Evaluate Cooling Options
6. Improve Electrical Efficiency
7. Use IT to Control IT

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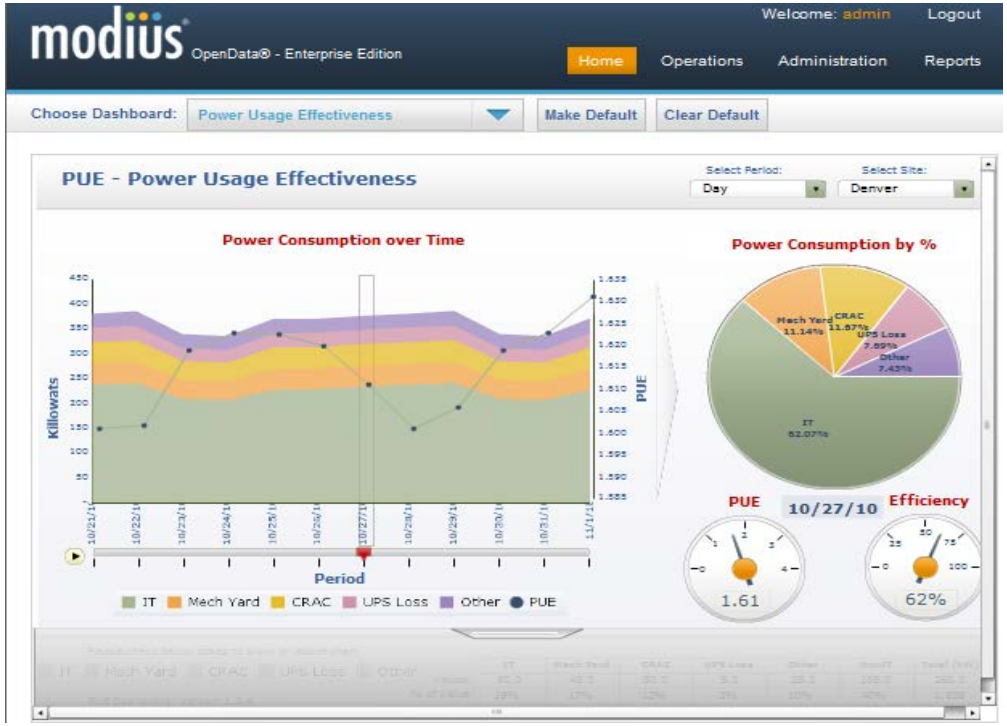
1. Measure and Benchmark Energy Use

- Use metrics to measure efficiency
- Benchmark performance
- Establish continual improvement goals



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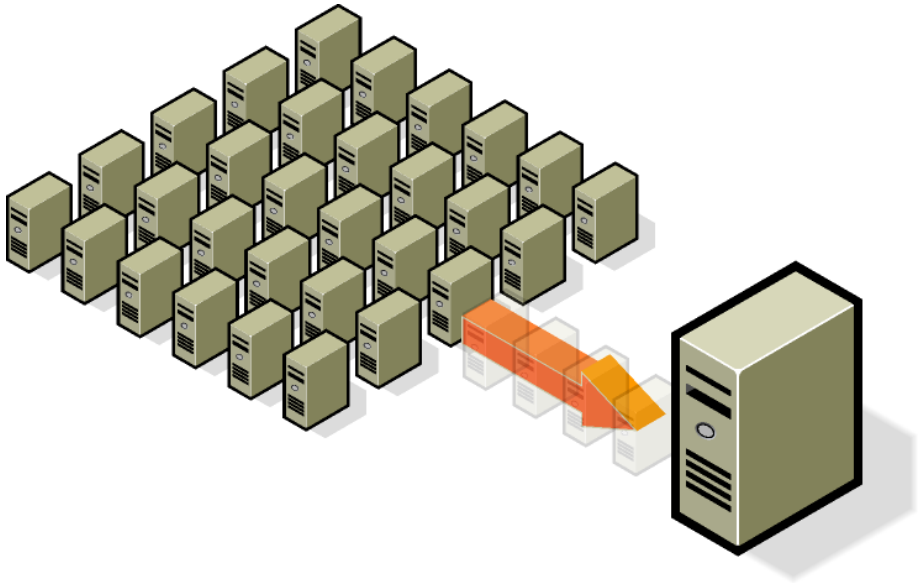
2. Identify IT Opportunities

- Specify efficient servers (incl. power supplies)
- Virtualize
- Refresh IT equipment
- Turn off unused equipment
- Implement acquisition systems to assure efficient products are purchased



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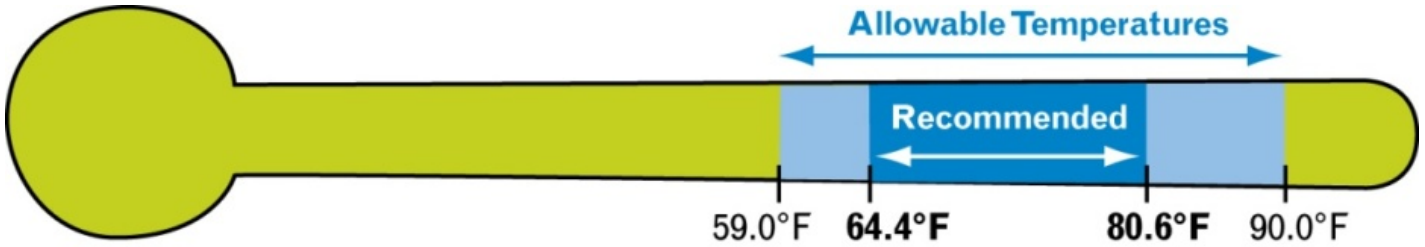
3. Optimize Environmental Conditions

- Follow ASHRAE guidelines or manufacturer specifications
- Operate near maximum of ASHRAE's recommended range
- Anticipate servers will occasionally operate in the allowable range
- Minimize or eliminate humidity control



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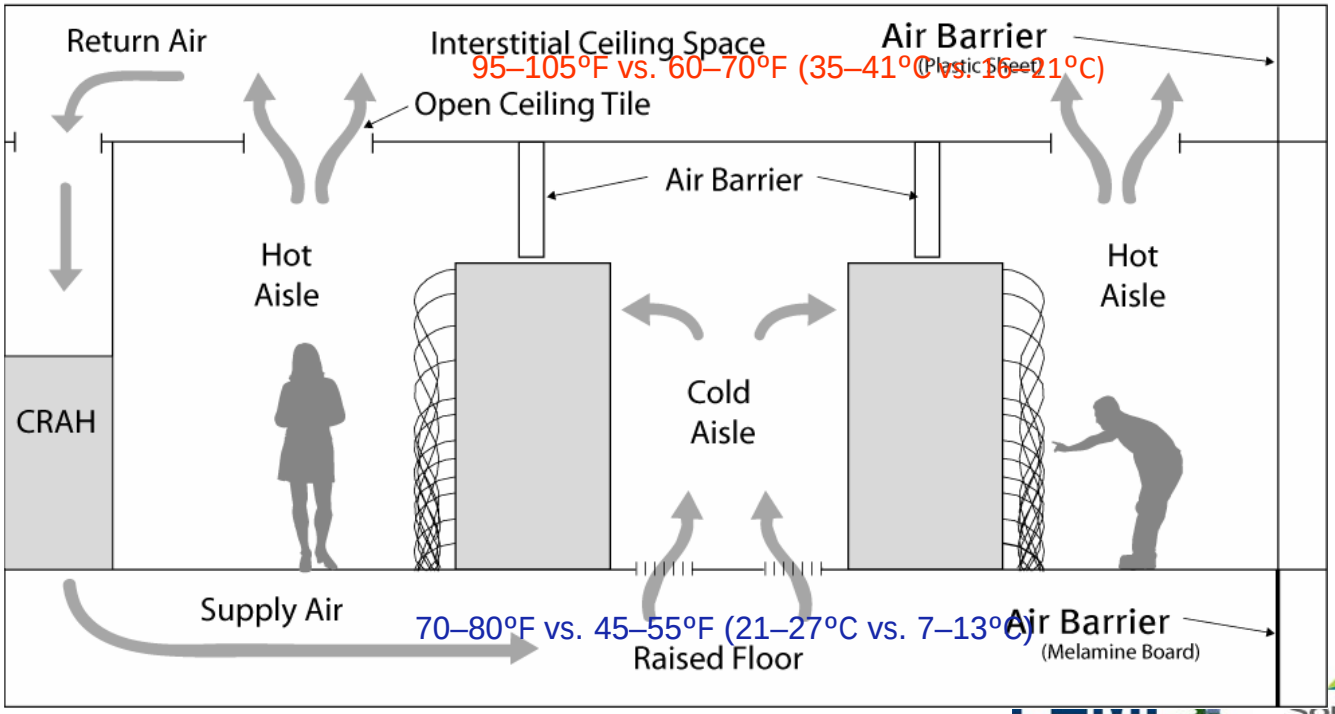
4. Manage Airflow

- Implement hot and cold aisles
- Seal leaks and manage floor tiles
- Isolate hot and cold air/contain hot or cold aisle
- Control air flow (save energy with VSD on fans)



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5. Evaluate Cooling Options

- Use centralized cooling system
- Maximize central cooling plant efficiency
- Provide liquid-based heat removal
- Compressorless cooling (“free” cooling)

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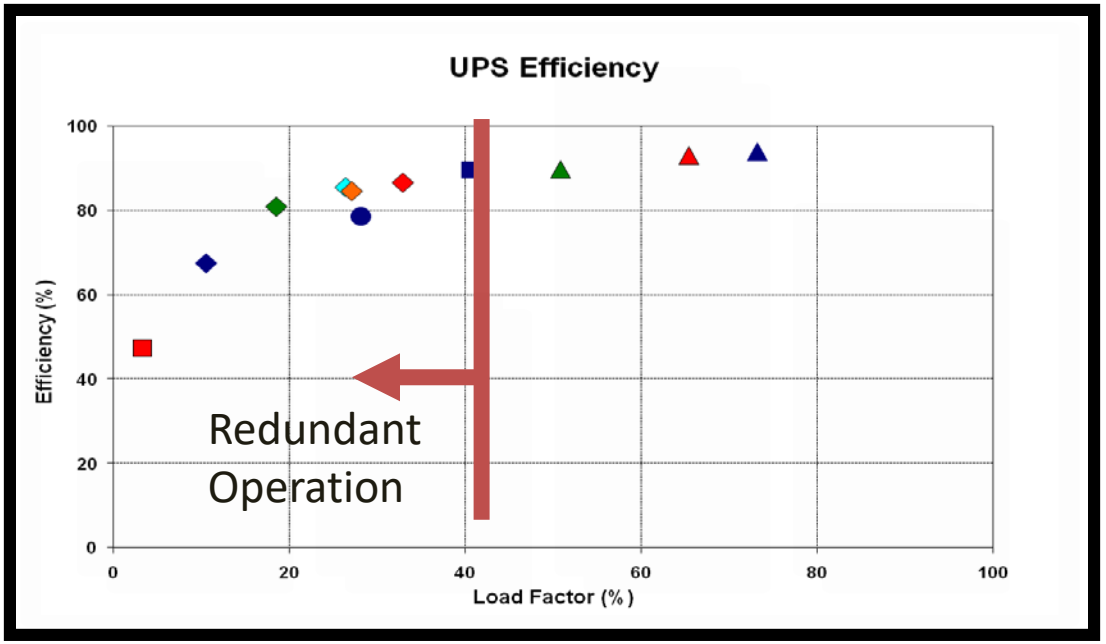
6. Improve Electrical Efficiency

- Select efficient UPS systems and topography
- Examine redundancy levels
- Consider redundancy in the network rather than in the data center (geographical redundancy)
- Increase voltage distribution and reduce conversions.



Source: LBNL Benchmarking study

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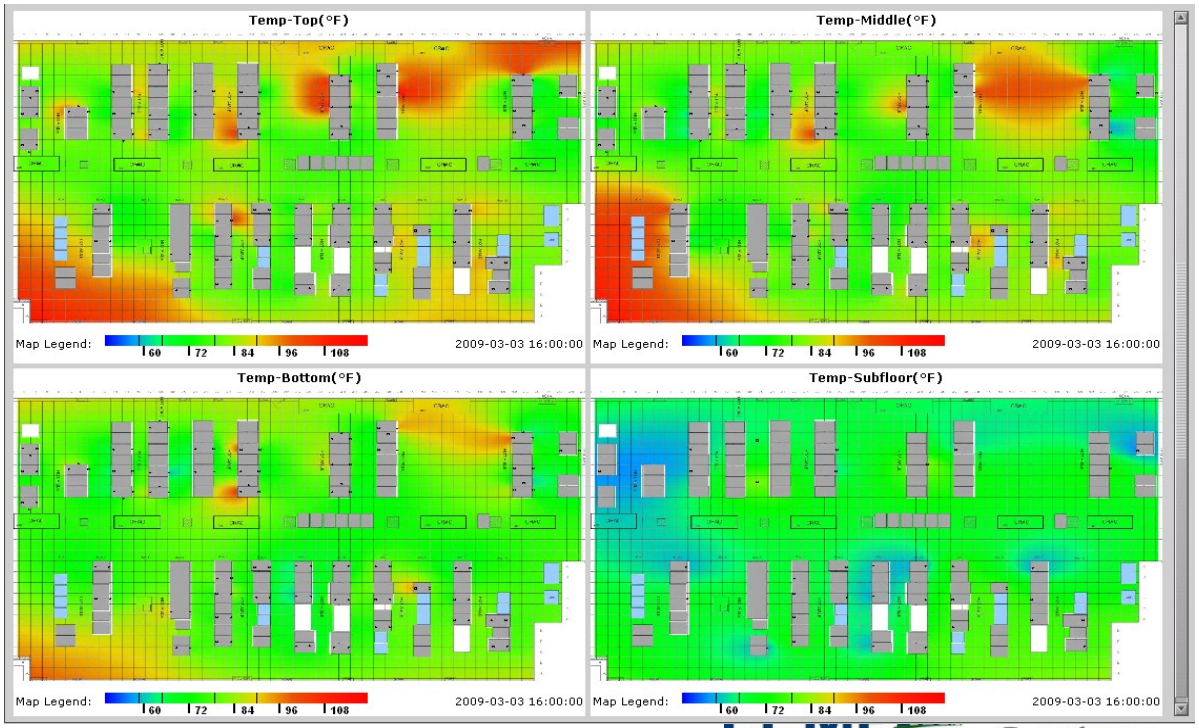
7. Use IT to Control IT Energy

- Evaluate monitoring systems to enhance real-time management and efficiency
- Use visualization tools (e.g., thermal maps)
- Install dashboards to manage and sustain energy efficiency



Most importantly

Get IT and Facilities people talking and working together as a team!

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