

Advancing Data Center Professionals

Data Center Leadership In the DOE Better Buildings Challenge

Applying Best Practices to meet the Challenge

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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

Lighting

2%

Data Center CRAC Units 25%

Office Space

Conditioning-1%

Electrical Room

Cooling 4%

Cooling Tower

Plant

4%

Other

13%







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





9

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





10

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 \geq 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



12



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
 - \blacktriangleright 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





14

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, underfloor pressure, current

LBNL Wireless Monitoring System









Visualization getting much better







Real-time PUE Display







Environmental conditions: Safe Temperature Limits



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







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









Results: Tune Floor Tiles



Underfloor pressure changes during floor tile moves 0.08 5.78.08 0.07 0.06 € 0.05 Se 0.04 0.03 0.02 0.01 0.00 00:01 12:00 05-28 10:00 28 12:00 -28 18:00 5-28 00:00 8 -27 20:0 -27 22:0 -28 02:0 14:0 16:0 28 20:0 -28 22:0 28 08: 29 00: 28 04 28 06 05-U-PR-Pressure[3] — 08-G-PR-Pressure[3] — 14-F-PR-Pressure[3] — 14-U-PR-Pressure[3 19-U-PR-Pressure[3] 24-G-PR-Pressure[3] - 27-II-PR-Pressure(3) 28-G-PR-Pressurel - 51-T-PR-Pressure[3 35-G-PR-Pressure[3] 37-U-PR-Pressure[3] 43-G-PR-Pressure[3] 44-T-PR-Pressure[3]

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







Improve Air Management

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



Before











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 toweronly 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







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



% of Nameplate Power Output





Measured UPS Efficiency

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





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's Data Center Energy Efficiency Center of Expertise:



A new Department of Energy-Ied CENTER of EXPERTISE will demonstrate national leadership in decreasing the energy use of data centers. The Center will partner with key influential public and private stakeholders. It will supply know-how, tools, best practices, analyses, and the introduction of technologies to assist Federal agencies with implementing policies and developing data center energy efficiency projects.



The Data Center Energy Challenge will require participating Federal agencies and other data center owners to establish an efficiency goal for their data centers...

MORE DETAILS



Resources

The Center's activities will include establishing metrics, providing technical assistance to agencies piloting innovative measurement and management approaches...

MORE DETAILS







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** Better

Buildings

Quick Start Guide to Increase Data Center Energy Efficiency

A Problem That You Can Fix

Data Center energy efficiency is derived from addressing BOTH your hardware equipment AND your infrastructure.



Technology Case-Study Bulletin FEMP&

Data Center Airflow Management Retrofit

1 Introduction As data control energy densities in power-use per square (pp), joyoppy, energy savings for coding can be realized by optimizing airflow pathway within the data control. This is expectively important in existing network y pointing winew partway with the bia center. This is opeowily important in outper data center with bypical underface ar is distributed primarily due to centrain 1 from underfacer dimension, obstruction, and bakes. Fortunadly, afflow-cessive and be improved significantly in most data centers, as described below in the afflow mangement overview. Next, this care study builden presents air management improvements that were credited in an older "layer" data center as Lawrence Sorkeley National Laboratory (LSNL). Particular airflow improvements, performance results, and benefits are reviewed that enhanced cooling efficiency at LSNL. In addition, a more generalized lat of neasures to improve data conter airflow is provided. Finally, a series of lessons-learned gained during the chofit project at LBNL is presented

Airflow Management Overview

flow retrofits can increase data conter energy efficiency by freeing up stranded airflow and cooling



Data Center Rack Cooling with Rear-door Heat Exchanger Technology Case-Study Bulletin As data center energy densities in power-use per square foot increase Server meks can also be cooled with During operation, hot server-rack airflow empeting technologies such as modular, verhead coolers; in-row coolers; and is forced through the RDHx device by the server fans. Heat is exchanged from the energy savings for cooling can be realized by incorporating liquid-cooling close-coupled coolers with dedicated hot air to circulating water from a chiller devices instead of increasing airflow containment enclosures. or cooling tower. Thus, server-rack outle air temperature is reduced before it is discharged into the data center. volume. This is especially important in a data center with a typical under-floor 2 Technology Overview 2.2 Technology Benefits The rear door heat exchanger (RDHx) devices reviewed in this case study are cooling system. An airflow-capacity REHx cooling devices can save energy limit will eventually be reached that and increase operational reliability in data centers because of straightforward installareferred to as passive devices because is constrained, in part, by under-floor they have no moving parts; however, they do require cooling water flow. A passivedimensions and obstructions. tion, simple operation, and low maintestyle RDHx contributes to optimizing nance. These features, combined with energy efficiency in a data center facility compressorless, indirect evaporative cooling 1 Introduction in several ways. First, once the device is installed, it does not directly require make RDHx a viable technology in both Liquid-cooling devices were installed on new and retroft data center designs. It server racks in a data center at Lawrence Berkeley National Laboratory (LBNL) in Figure 1. The passive-technology device may also help eliminate the complexit and cost of under-floor air distribution infrastructure electrical energy to operate Second, RDHx devices can use less chiller energy since they perform well at Reduce Maintenance oves heat generated by the servers warmer (higher) chilled water set-points. from the airflow leaving the server rack. This heat is usually transferred to cooling water circulated from a central chiller Because passive RDHx devices have no moving parts, they require less main-Third, depending on climate and pip ing arrangements, RDHx devices can eliminate chiller energy because they can tenance compared to computer room air conditioning (CRAC) units. RDHs plant. However at LBNL, the devices are use treated water from a plate-and-frame heat exchanger connected to a cooling tower. These inherent features of a RDFix connected to a treated water system that devices will require occasional cleaning rejects the heat directly to a cooling tower of dust and lint from the air-side of the through a plate-and-frame heat exchanges help reduce energy use while minimizing coils. RDHx performa nce also depends thus nearly eliminating chiller energy use to cool the associated servers. In addition on proper waterside maintenance Reduce or Eliminate Chiller to cooling with passive heat exchang-era, similar results can be achieved with fan-assisted rear-door heat exchangers and 2.1 Basic operation The RDHx device, which resemble Operation RDHx devices present an opportunity an automobile radiator, is placed in the refrigerant-cooled rear-door exchangers. airflow outlet of a server raci to save energy by either rea



FEMP Data Center Training Opportunities

Online Presentations:

- No cost, no travel
- Available 24/7
- Online, openaccess courses

- Expert Instructors
- Self paced
- ➢ CEUs



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: <u>http://</u> <u>femp.energy.gov/training</u>

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







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