Partnering with DOE to Improve Data Center Efficiency

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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

NERSC Computer Systems Power
(Does not include cooling power)
(OSF: 4MW max)
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

~1.8% U.S. Electricity
Results: Energy Use Projections and Counterfactual Savings: 620 billion kWh
Energy Use Estimates by Data Center Type

• Hyperscale is a growing percentage of data center energy use

![Energy Use Estimates Graph]

- Hyperscale SP center
- High-end SP center
- High-end internal center
- Midtier SP center
- Midtier internal center
- Localized SP center
- Localized internal center
- POP room
- Internal room
- POP closet
- Internal closet

*forecast -->*
More Savings Available through Efficiency

- Annual saving in 2020 up to 33 billion kWh
- Represents a 45% reduction in electricity demand over current trends
2050 Projections

- Infrastructure
- Network
- Storage
- Servers
- Server Workload

Annual Data Center Electricity Consumption (billion kWh) vs. 2014 Normalized Workload

Historical Estimates
Current Trends
Implementation of Best Practices
Uncontrolled Growth

FEMP Federal Energy Management Program
Southern Company
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
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
Benchmarking Energy Performance: So What is PUE?

- Data Center Server Load: 51%
- HVAC - Air Movement: 7%
- Lighting: 2%
- HVAC - Chiller and Pumps: 24%
- Computer Loads: 67%

- Data Center CRAC Units: 25%
- Office Space Conditioning: 1%
- Electrical Room Cooling: 4%
- Cooling Tower Plant: 4%
- Lighting: 2%
- Other: 13%
High Level Metric: PUE

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

DATA CENTER NUMBER IN LBNL DATABASE
## Sample PUEs

<table>
<thead>
<tr>
<th>PUEs: Reported &amp; Calculated</th>
<th>PUE</th>
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<tbody>
<tr>
<td>EPA ENERGY STAR Average</td>
<td>1.91</td>
</tr>
<tr>
<td>Intel Jones Farm, Hillsboro</td>
<td>1.41</td>
</tr>
<tr>
<td>T-Systems &amp; Intel DC2020 Test Lab, Munich</td>
<td>1.24</td>
</tr>
<tr>
<td>Google</td>
<td>1.16</td>
</tr>
<tr>
<td>Leibniz Supercomputing Centre (LRZ)</td>
<td>1.15</td>
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<tr>
<td>National Center for Atmospheric Research (NCAR)</td>
<td>1.10</td>
</tr>
<tr>
<td>Yahoo, Lockport</td>
<td>1.08</td>
</tr>
<tr>
<td>Facebook, Prineville</td>
<td>1.07</td>
</tr>
<tr>
<td>National Renewable Energy Laboratory (NREL)</td>
<td>1.06</td>
</tr>
</tbody>
</table>

Source: Mike Patterson, Intel
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
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
• Customer-facing efficiency programs
• A number of measures targeted through existing programs

<table>
<thead>
<tr>
<th>Virtualization</th>
<th>ENERGY STAR Server</th>
<th>Massive Array of Idle Disks</th>
<th>Uninterruptible Power Supply</th>
<th>Chillers/ Cooling Towers</th>
<th>Thermal Energy Storage</th>
<th>Storage Consolidation</th>
<th>Airflow</th>
</tr>
</thead>
</table>

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

Source: Cadmus, et al. 2015 for NYSERDA.
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-rider 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.)
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, financial 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
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

- 95-105° vs. 60-70°
- 70-80° vs. 45-55°
Background

• Air management is a first and effective step in improving data center energy performance

• “Small” data centers (<5,000 ft²) use 50-60% of all energy used in data centers¹

• ... 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

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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?)
The Department of Energy-led Center of Expertise for Energy Efficiency in Data Centers (CoE) demonstrates national leadership in decreasing the energy use of data centers. Through the supply of technical support, tools, best practices, analyses, and the introduction of technologies, CoE assists federal agencies and other organizations implement data center energy efficiency projects. The CoE, located at the Lawrence Berkeley National Lab, partners with key public and private stakeholders to further efficiency efforts.

**Data Center Energy Efficiency Certificate Series**

- Data Center Metering & Resource Guide
- DC Pro Tools
- Master List of Efficiency Actions

**Data Center Optimization Initiative (DCOI)**

DCOI was established in the Office of Management and Budget (OMB) memorandum M-16-19 dated August 1, 2016, and includes a number of energy efficiency requirements for federal data centers. The Center of Expertise is here to help.

**Data Center Energy Practitioner (DCEP) Training**

The data center industry and DOE partnered to develop the DCEP training program that certifies energy practitioners qualified to evaluate the energy status and efficiency opportunities in data centers. Course content was updated June 2016.

Datacenters.lbl.gov
Tools covering areas such as air management and writing an energy assessment report

Need assistance?

Database of resources (reports, guides, case studies)

Information on best practice technologies and strategies
**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

<table>
<thead>
<tr>
<th>Air Management</th>
<th>Electrical Systems</th>
<th>IT-Equipment</th>
<th>Cooling</th>
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<tbody>
<tr>
<td>Hot/cold separation</td>
<td>UPS</td>
<td>Servers</td>
<td>Air handlers/conditioners</td>
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<tr>
<td>Environmental conditions</td>
<td>PDU</td>
<td>Storage &amp; networking</td>
<td>Chillers, pumps, fans</td>
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<tr>
<td>RCI and RTI</td>
<td>Transformers</td>
<td>Software</td>
<td>Free cooling</td>
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<td>Lighting</td>
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<td>Standby gen.</td>
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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

Training (webinars, on-demand courses, and in-person events)

Webinars

- 10/6/2016 "For Utilities: Designing and Implementing Successful Data Center Efficiency Programs" via ENERGY STAR - registration
- 10/13/2016 "Data Center Energy Efficiency Opportunities: What Managers Should Know" via ENERGY STAR - registration
- 12/2016 webinar on the U.S. Data Center Energy Usage Report - date and time TBD
- FY 2017 webinars on guidance for small data centers, the DCEP program, resources for utilities, and more - dates and times TBD

On-demand, web-based courses

- "Data Center Energy Efficiency Best Practices" - registration
- "FEMP16 Advanced HVAC in High-Tech Buildings: Data Centers" - registration

In-person training events

- 12/2016 "Data Center Energy Practitioner (DCEP) training" scheduled in San Francisco, California - see our dedicated DCEP page for more information

News via CoE Twitter Feed

Follow @DataCenterCoE
News and Training, example

On-Demand Data Center Energy Efficiency Series

- 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

To find resources related to a specific technology or resource type please use the check boxes to filter results. You can also search by author’s last name and other keywords through the search box in the top right of the site. “Featured” resources are shown first, followed by the most recent.

### Technologies
- Environmental Conditions
- Power
- Small Data Centers
- Liquid Cooling
- Monitoring and Controls
- General
- HPC
- IT Equipment
- Cooling Air / Air Management

### Type
- Documents (Guides, Reports, Case Studies, & Demos)
- Case Studies & Demonstrations
- Tools
- Presentations
- Related Organizations
- Links

### Files and Links

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Files and Links</th>
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<tr>
<td>08/16/2016</td>
<td>DCEP Program Developers, Instructors, and Practitioners <strong>Featured</strong></td>
<td>![DCEP_LIST_Updated 08162016.pdf](DCEP_LIST_Updated 08162016.pdf)</td>
</tr>
<tr>
<td></td>
<td>List of developers, instructors, and generalists for the DCEP program.</td>
<td></td>
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<tr>
<td></td>
<td>Guide is intended to help data center owners and operators gather the</td>
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<tr>
<td></td>
<td>necessary data to participate in the Better Buildings Challenge (BBC).</td>
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<td>The BBC process includes supplying data that is at least partially</td>
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<td>metered.</td>
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<td></td>
<td>This report estimates historical data center electricity consumption</td>
<td></td>
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<tr>
<td></td>
<td>back to 2000, relying on previous studies and historical shipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>data, and forecasts consumption out to 2020 based on new trends and</td>
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<tr>
<td></td>
<td>the most recent data available.</td>
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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)
Questions

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http://datacenters.lbl.gov/
Opportunities (Back-up Slides)
Energy Efficiency Opportunities

### Power Conversion & Distribution
- High-voltage distribution
- High-efficiency UPS
- Efficient redundancy strategies
- Use of DC power

### IT Load/Computing Operations
- IT innovation
- Virtualization
- High-efficiency power supplies
- Load management

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

### 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
1. Measure and Benchmark Energy Use

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

70–80°F vs. 45–55°F (21–27°C vs. 7–13°C)
95–105°F vs. 60–70°F (35–41°C vs. 16–21°C)
5. Evaluate Cooling Options

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