The webinar will start momentarily....
Tracking Data Center Efficiency: What PUE Can Tell Us and Where We Can Look To Better Understand Energy Performance

November 4, 2021
Webinar Logistics

• This webinar is being recorded. The Q&A section will not be made publically available.

• Your phone will be muted throughout the webinar.

• Enter any questions in the Question Box throughout the webinar.

• Instructions to take the quiz will be provided at the end of webinar.

• Slides will be sent out afterwards to those who attend the entire webinar.
Today’s Speakers

Ian M. Hoffman
Center of Expertise for Energy Efficiency in Data Centers
Lawrence Berkeley National Laboratory
ihoffman@lbl.gov

Steve Greenberg
Center of Expertise for Energy Efficiency in Data Centers
Lawrence Berkeley National Laboratory
segreenberg@lbl.gov

Jeff Murrell, P.E.
Jefferey.Murrell@ee.doe.gov
202-586-3874 Work
202-394-2240 Cell

Alexander Newkirk
Center of Expertise for Energy Efficiency in Data Centers
Lawrence Berkeley National Laboratory
acnewkirk@lbl.gov

datacenters.lbl.gov
Recent Training

- **Accessing Onboard Server Sensors for Energy Efficiency in Data Centers** – Oct. 25
- **Barriers to Data Center Energy Efficiency** – Sept. 2021
- **Thermal Guidelines and Temperature Measurements in Data Centers** – May 2021

**Webinar Series for the DOE/LBNL Data Center Energy Efficiency Toolkit**

- A Suite of Energy Assessment Tools
- Electric Power Chain Tool
- Air Management Tools
- IT Equipment Tool
## Today’s Training

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### Learning Questions

- What are the **pros and cons of Power Usage Efficiency (PUE)**?
- What does **our sample of data centers say** about efficiency?
- Why are additional **energy metrics needed**?
- What is the **Open Data Initiative (ODI)**?
- Why **collaborate on ODI**?
Power Usage Effectiveness: What PUE can tell us
Power Usage Effectiveness: What it is

\[ PUE = \frac{\text{Total annual data center energy}}{\text{Annual IT equipment energy}} \]

- Proposed by Green Grid in 2007 to track energy performance over time
- Now most widely recognized and applied metric for data center efficiency
- In essence: For every kWh or kW to power IT equipment, what is needed for all else – cooling, UPS/PDUs, lighting, misc.?

- With PUE, engineers can:
  - Set design and operational targets for infrastructure efficiency
  - Compare energy-saving actions by impact on overall facility load
  - Calculate energy cost of running IT equipment, carbon effectiveness

- System-level “Partial” PUEs can hone the comparison of efficiency opportunities, e.g., using cooling PPUE to isolate the efficiency gain with water vs. air cooling
Power Usage Effectiveness

PUE is not an ideal metric for energy efficiency.

It’s not comprehensive. It’s not comparable.

It’s just the best we’ve got.
The LBNL Data Center Database: Findings from 17 years of energy assessments
The LBNL Data Center Database: Description

• More than 100 data centers assessed 2003 to 2019

• 79 selected for documentation and confidence

• Mostly independent energy assessments by lab staff or trusted subcontractors but some self-attestations

• Confidential

• Diverse in comprehensiveness and resolution of the data
  • From loads, type and locations to chiller plant allocation and air flows
Caveats and Context

• Most data points were snapshots – not annualized

• Sample is not randomly chosen or representative

• Self-selection bias
  – 44 (56%) are federal
  – Overrepresents the South and California
  – Underrepresents closet servers, hyperscale and colo facilities. Overrepresents HPCs.

• 15 data points are re-assessments of data centers after retrofits
Energy uses vary widely

Avg. IT Load: 57%
Efficiency is so-so but improving – at least in the federal fleet

Power Usage Effectiveness (PUE)

<table>
<thead>
<tr>
<th>Data Collection Periods</th>
<th>Average PUE</th>
<th>IT Load-Weighted Average PUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003-2005</td>
<td>1.85</td>
<td>1.75</td>
</tr>
<tr>
<td>2006-2008</td>
<td>1.90</td>
<td>1.86</td>
</tr>
<tr>
<td>2009-2011</td>
<td>1.89</td>
<td>1.74</td>
</tr>
<tr>
<td>2012-2014</td>
<td>1.83</td>
<td>1.56</td>
</tr>
<tr>
<td>2015-2019</td>
<td>1.51</td>
<td>1.27</td>
</tr>
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</table>
Larger data centers tend to be more efficient
Size matters but so does time

![Graph showing Power Usage Effectiveness (PUE) from 2003-2019. The graph displays the average PUE and IT load-weighted average PUE for different periods. The average PUE is consistently higher than the IT load-weighted average PUE, indicating a trend towards improving efficiency over time.](image-url)
Some larger DCs take advantage of cooler climes

<table>
<thead>
<tr>
<th>ASHRAE Climate Zone</th>
<th>PUE</th>
<th>Load-Weighted Avg. PUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Hot, Moist Miami</td>
<td>1.65</td>
<td>1.66</td>
</tr>
<tr>
<td>Hot, Dry/Humid Tucson, New Orleans</td>
<td>1.82</td>
<td>1.82</td>
</tr>
<tr>
<td>Warm, Humid/Dry Atlanta</td>
<td>1.73</td>
<td>1.44</td>
</tr>
<tr>
<td>Mixed, Humid/Dry SF/LA, DC, Baltimore</td>
<td>1.83</td>
<td>1.33</td>
</tr>
<tr>
<td>Cool, Humid/Dry Chicago</td>
<td>1.62</td>
<td>1.51</td>
</tr>
</tbody>
</table>
Efficiency varies by data center type, business model

Power Usage Effectiveness (PUE)

<table>
<thead>
<tr>
<th>Data Center Type</th>
<th>Average PUE</th>
<th>Load-Weighted Average PUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterprise</td>
<td>1.84</td>
<td>1.72</td>
</tr>
<tr>
<td>Colo</td>
<td>1.80</td>
<td>1.77</td>
</tr>
<tr>
<td>HPC</td>
<td>1.47</td>
<td>1.30</td>
</tr>
</tbody>
</table>
Venturing Beyond PUE: Where else can we look for understanding energy performance
Power Usage Effectiveness: Where it falls short

PUE is a flawed barometer of energy efficiency

• Does not measure efficiency as useful work per unit of energy

• Problematic for comparability and fairness
  – PUE is not well suited for comparing different data centers
  – Fails to reflect the differences in type, scale, location and workload

• It ignores, even penalizes, reductions in IT load, the largest energy-savings target
  – Misdirects management attention to non-IT loads.
  – Decreasing IT load alone will increase PUE
  – Disincentivizes replacing older CPUs/servers; enabling server energy management; virtualization or consolidation; and removal of idled servers

• PUE can be manipulated
Sole focus of PUE on infrastructure energy ignores IT energy, the largest data center load and often a first, best efficiency target.

Reductions in IT energy use cascade through other facility systems, thus compounding the savings.

Unless each component upstream is downsized, PUE increases. Reducing energy use appears as a “loss” in efficiency.

Source: Intel Corp.
Power Usage Effectiveness: Only part of the story

What are we missing from the larger picture of resource performance?

• IT loads and savings opportunities
  • Enabling power management
  • Replacing inefficient servers more frequently
  • Virtualization or consolidation
  • Identifying and powering down unused or underused “ghost” servers

• “Cleanness” of the power supply - how renewable or carbon free
  • PUE alone offers no perspective on the potential for decarbonization or reductions in other emissions

• Water efficiency

• Use of data center waste heat
Key Complements to PUE

- **Data Center Compute Efficiency (DCCE)** – measures CPU usage, disk and network I/O, incoming connection requests and interactive logins to determine whether a server is providing primary services. ScE is measured as the percentage of samples that the server is providing useful services. Data center operators can use ScEs to identify servers for virtualization or consolidation and shutdown and aggregate them into the DCCE for the larger IT picture.

- **Data Center Energy Productivity (DCeP)** – network traffic/kWh or IT Equipment Energy Efficiency X IT Equipment Utilization.

- **Green Energy Coefficient (GEC) and Renewable Energy Factor (REF)** – percent of total energy supplied to the facility (GEC), or controlled by the facility (REF), from wind, solar, geothermal, etc.

- **Carbon Usage Effectiveness (CUE)** – measures carbon emitted per unit of IT energy consumed

  \[
  CUE = GHG \text{ Emissions Factor} \left( \frac{kg \ CO_2e}{kWh} \right) \times PUE
  \]

- **Water Usage Effectiveness (WUE)**

  \[
  WUE = \frac{\text{Annual Water Usage}}{\text{IT equipment energy use over a year}}
  \]

- **Energy Reuse Factor (ERF)** – percent of energy exported from DC for reuse, e.g., as building or district heating

  \[
  ERF = \frac{\text{Reuse energy}}{\text{Total data centre energy use}}
  \]
Summary

• LBNL database sample is not representative of the domestic or global fleet but suggests the fleet average efficiency is improving over time, consistent with other studies.
  – Size/compute density matters

• PUE is useful but not ideal as an efficiency metric.
  – Incomplete. For most data centers, PUE misses more than half the energy picture.
  – Not comparable. Unfair and unrealistic to compare the efficiency of a workhorse enterprise facility in a hot climate with a supercomputer in a cool, dry climate.

• There is no ideal efficiency metric for data centers. And that’s not a bad thing.
  – IT utilization metrics can help level the benchmarking field
  – Carbon and water effectiveness metrics are increasingly essential
The Open Data Initiative: An invitation to collaborate
The Open Data Initiative

Since 2007 (EISA), Congress repeatedly has asked for an energy-focused and voluntary “national information program” for data centers. Congress also has asked DOE to help develop a more comprehensive energy efficiency metric.

- The **Energy Act of 2020** (signed last December)
  - Says DOE and OMB “shall establish an open data initiative relating to energy usage at **federally owned and operated data centers**, with the purpose of making the data available and accessible in a manner that encourages further data center innovation, optimization, and consolidation.”
  - DOE also, “in collaboration with key stakeholders, shall actively participate in efforts to **harmonize** global specifications and metrics for data center energy and water efficiency...(including a) facilitating “**development of an efficiency metric that measures the energy efficiency of a data center** (including equipment and facilities).”
  - In these efforts, DOE “**shall not disclose any proprietary information or trade secrets** provided by any individual or company for the purposes of carrying out this section or...(its) initiatives.”
Key Issues In Developing the ODI

• What **insights** and **metrics** are **most valuable**

• Which **data**

• Resolution

• Security

• Motivations, incentives
Resources and Q&A
FEMP’s Data Center Program assists federal agencies and other organizations with optimizing the design and operation of data centers. The design and operation of energy and water systems in data centers to enhance agency’s mission.

### Assistance
- Project and technical assistance from the Center of Expertise including identifying and evaluating ECMs, M&V plan review, and project design review.
- Support agencies in meeting OMB’s Data Center Optimization Initiative requirements

### Tools
- Data Center Profiler (DC Pro) Tools (x2)
- Air Management Tools (x3)
- IT Equipment Tool
- Electrical Power Chain Tool
- Energy Assessment Worksheets
- The Energy Assessment Process Manual

### Key Resources
- Better Buildings Data Center Challenge and Accelerator
- Small Data Centers, Big Energy Savings: An Introduction for Owners and Operators
- Data Center Master List of Energy Efficiency Actions

### Training
- Better Buildings webinar series
- Nine on-demand FEMP data center trainings
- Center of Expertise Webinars
- Data Center Energy Practitioner Trainings
LBNL’s Center of Expertise (CoE)

Explore the diverse activities that CoE is engaged in.

Use CoE’s Energy Efficiency Toolkit

Filter CoE’s many resources by type and topic.

Choose from upcoming live webinars, pre-recorded trainings, and in-person Data Center Energy Practitioner (DCEP) trainings.

Search resources by topics of interest.

Follow us on Twitter @DataCenterCoE

Small Data Centers

Explore resources geared towards helping small data centers overcome the unique obstacles they face in reducing energy consumption and achieving monetary savings.

Visit us at datacenters.lbl.gov
CoE Data Center Energy Efficiency Toolkit

Start here!

Data Center Profiling Tools

- PUE Estimator
- DC Pro

Collect Data

Energy Assessment Workbook

Report Findings & Make Recommendations

- Master List of Efficiency Actions
- Energy Assessment Report Template

More detail

System-Level Assessment Tools

- AM Estimator
- AM Tool
- Power Chain Tool
- IT Equip. Tool

AM = Air Management

Keep it simple(r)

Data Center Energy Assessment Complete!
Energy Assessment Process Manual

- Multiple appendices include useful templates for the assessments.

Master List of DC Energy Efficiency Measures

• Living encyclopedia of all data center EEMs
  – Recognized as an essential desk reference for data center energy efficiency – top download for CoE
  – >250 energy-saving changes in components, operations or other actions

• Several tools recommend common EEMs:
  – DC Pro, Air Management Tool, Electric Power Chain Tool

• The Master List contains all common EEMs, plus many others that do not appear elsewhere in the toolkit.

• For each EEM, the list explains the principles involved and how energy cost savings are generated, plus tips on implementation and more in-depth references.
Federal Project Executives (FPEs)

Scott Wolf
Western Region
360-866-9163
wolfsc@ornl.gov

Doug Culbreth
Southeast Region
919-870-0051
culbrethcd@ornl.gov

Tom Hattery
Northeast Region
202-256-5986
thomas.hattery@ee.doe.gov
Questions?
Today’s Speakers

Ian M. Hoffman
Center of Expertise for Energy Efficiency in Data Centers
Lawrence Berkeley National Laboratory
ihoffman@lbl.gov

Steve Greenberg
Center of Expertise for Energy Efficiency in Data Centers
Lawrence Berkeley National Laboratory
segreenberg@lbl.gov

Jeff Murrell, P.E.
Jefferey.Murrell@ee.doe.gov
202-586-3874

Alexander Newkirk
Center of Expertise for Energy Efficiency in Data Centers
Lawrence Berkeley National Laboratory
acnewkirk@lbl.gov

datacenters.lbl.gov
The National Institute of Building Sciences’ (NIBS) Whole Building Design Guide (WBDG) hosts the FEMP training program’s learning management system (LMS).

The WBDG LMS:
• Allows for taking multiple trainings from multiple organizations through one platform.
• Houses the assessments and evaluations for all accredited courses.
• Allows you to:
  — Track all of your trainings in one place.
  — Download your training certificates of completion.
• Eases the CEU-achievement process.

Visit the WBDG at www.wbdg.org to view courses and create an account.
IACET Credit for Webinar

To receive IACET-Certified CEUs, attendees must:

• Attend the training in full (no exceptions).
  – If you are sharing a web connection during the training, you must send an e-mail to Elena Meehan (elena.meehan@ee.doe.gov) and indicate who was on the connection and who showed as connected (will reflect in the WebEx roster).

• Complete an assessment demonstrating knowledge of course learning objectives and an evaluation within six weeks of the training. A minimum of 80% correct answers are required for the assessment.

To access the webinar assessment and evaluation, visit:

https://www.wbdg.org/continuing-education/femp-courses/femplw05132021

If you have a WBDG account and enrolled previously, simply log in and click the Continuing Education tab on the user account page. Click Proceed to Course next to the course title.
Additional Slides
Average Energy Use Breakdown, 2003-2019

- IT: 57%
- HVAC: 32%
- Electrical (UPS & PDU losses, lighting): 8%
- Other: 2%