The webinar will start momentarily....

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Tracking Data Center Efficiency: What PUE Can Tell Us and Where We Can Look To Better Understand Energy Performance

November 4, 2021

FEMP Federal Energy Management Program

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

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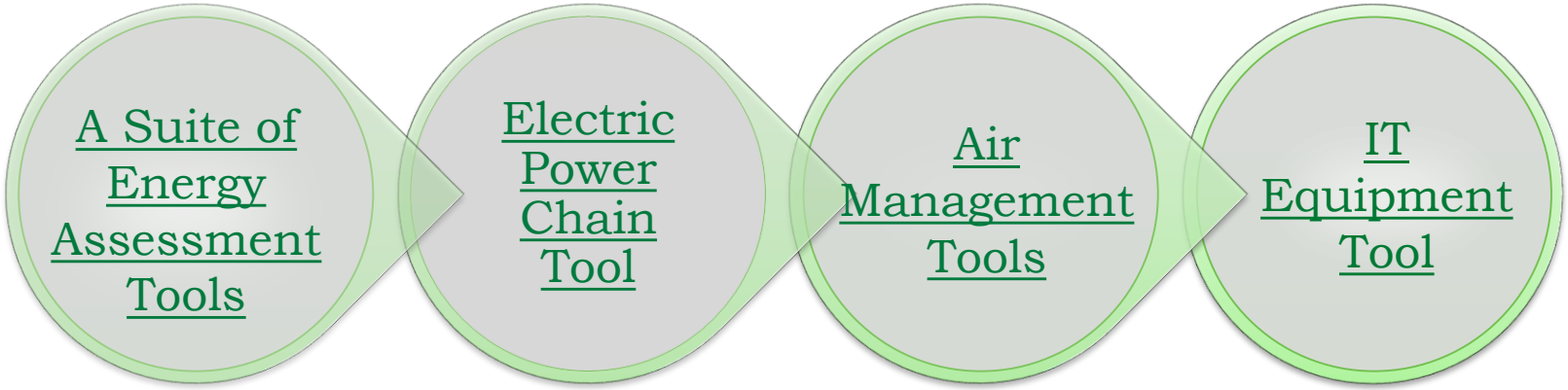
Recent Training

- 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



Today's Training

I.	Introduction
II.	What PUE is and what it can tell us
III.	Findings from the LBNL Data Center Database
IV.	Why PUE is fundamentally flawed
V.	Where else can we look to gauge efficiency?
V.	The Open Data Initiative (ODI)
VI.	Resources and Q&A

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

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

- 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

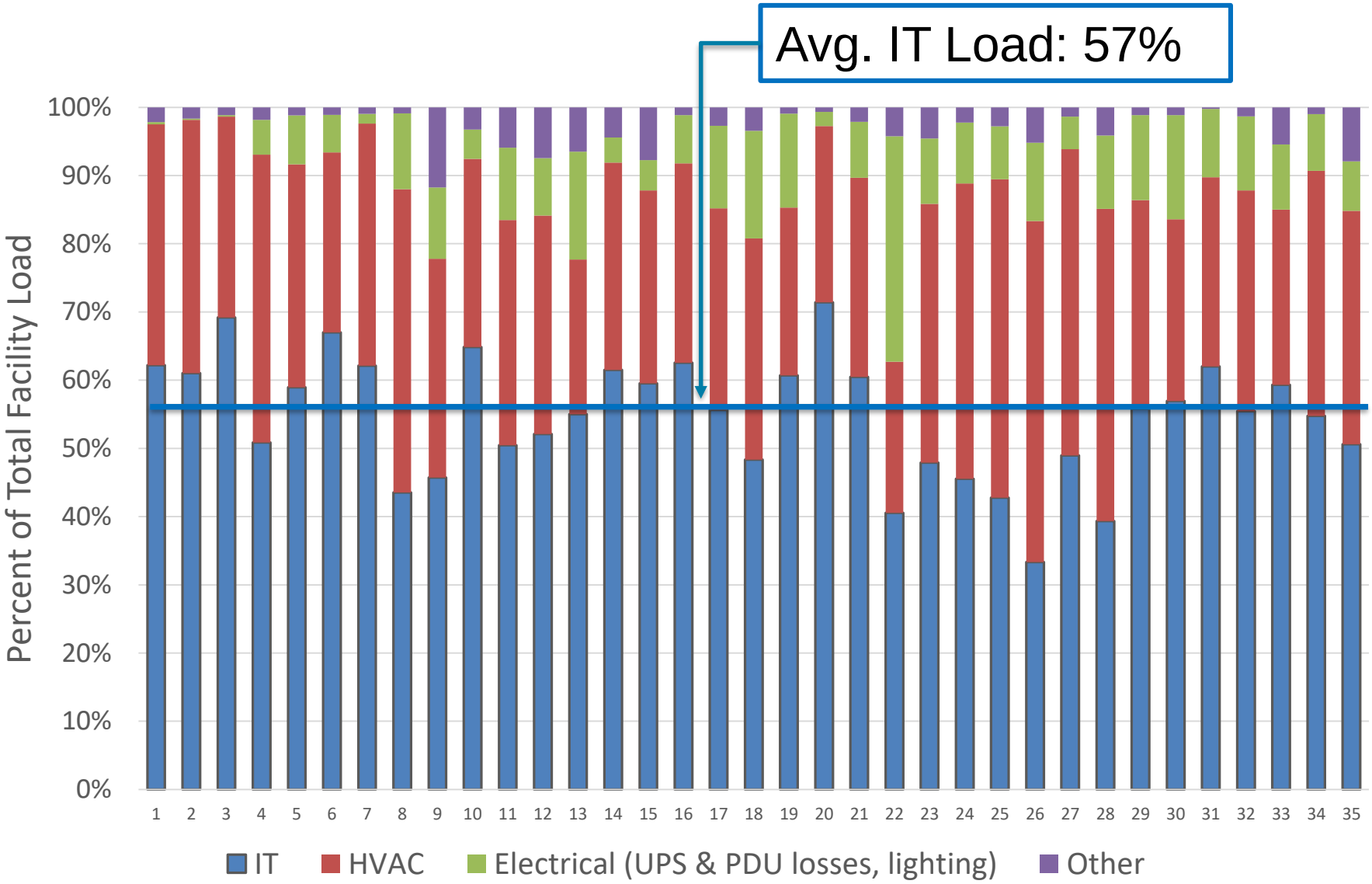
The LBNL Data Center Database: Description

- **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

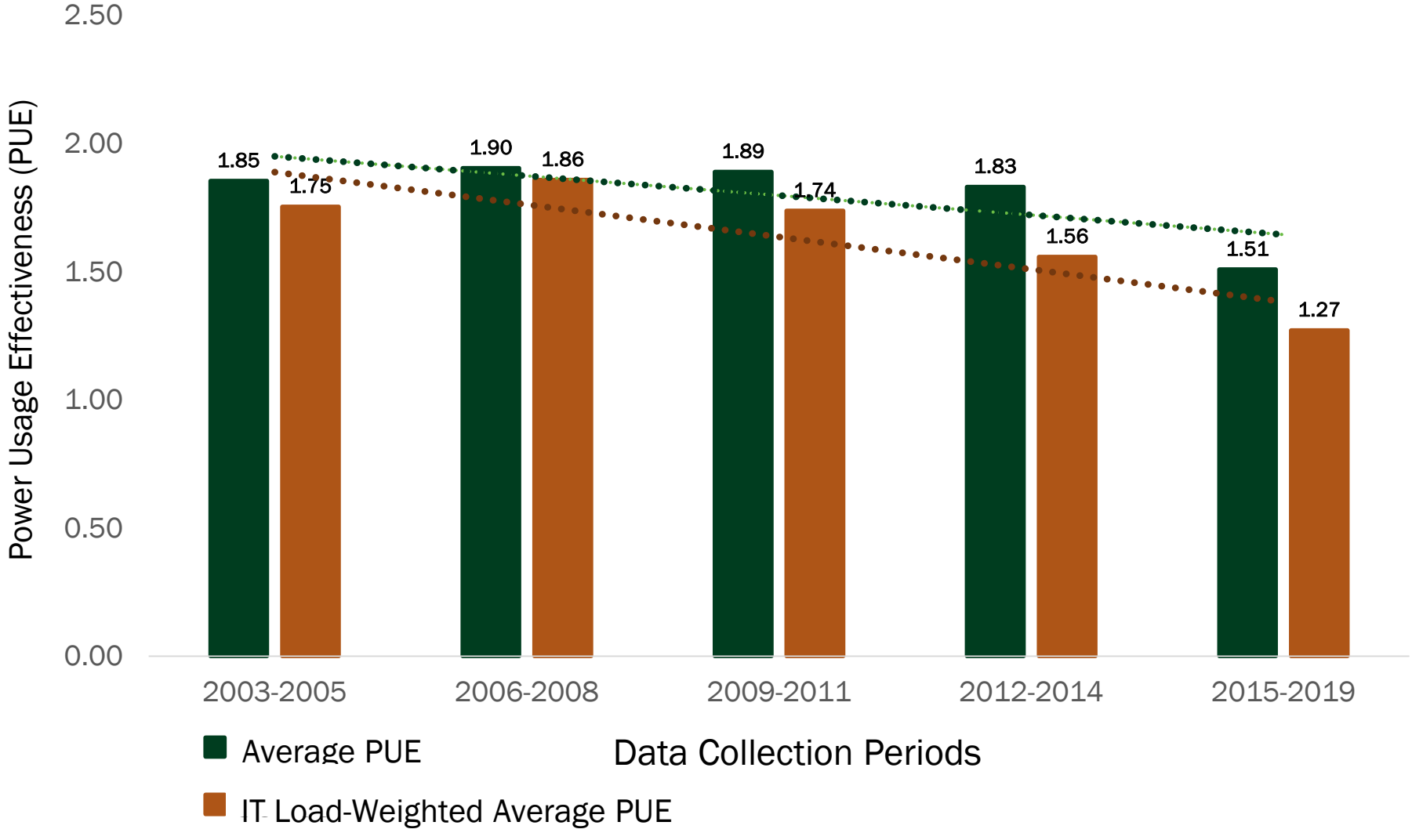
Caveats and Context

- **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**

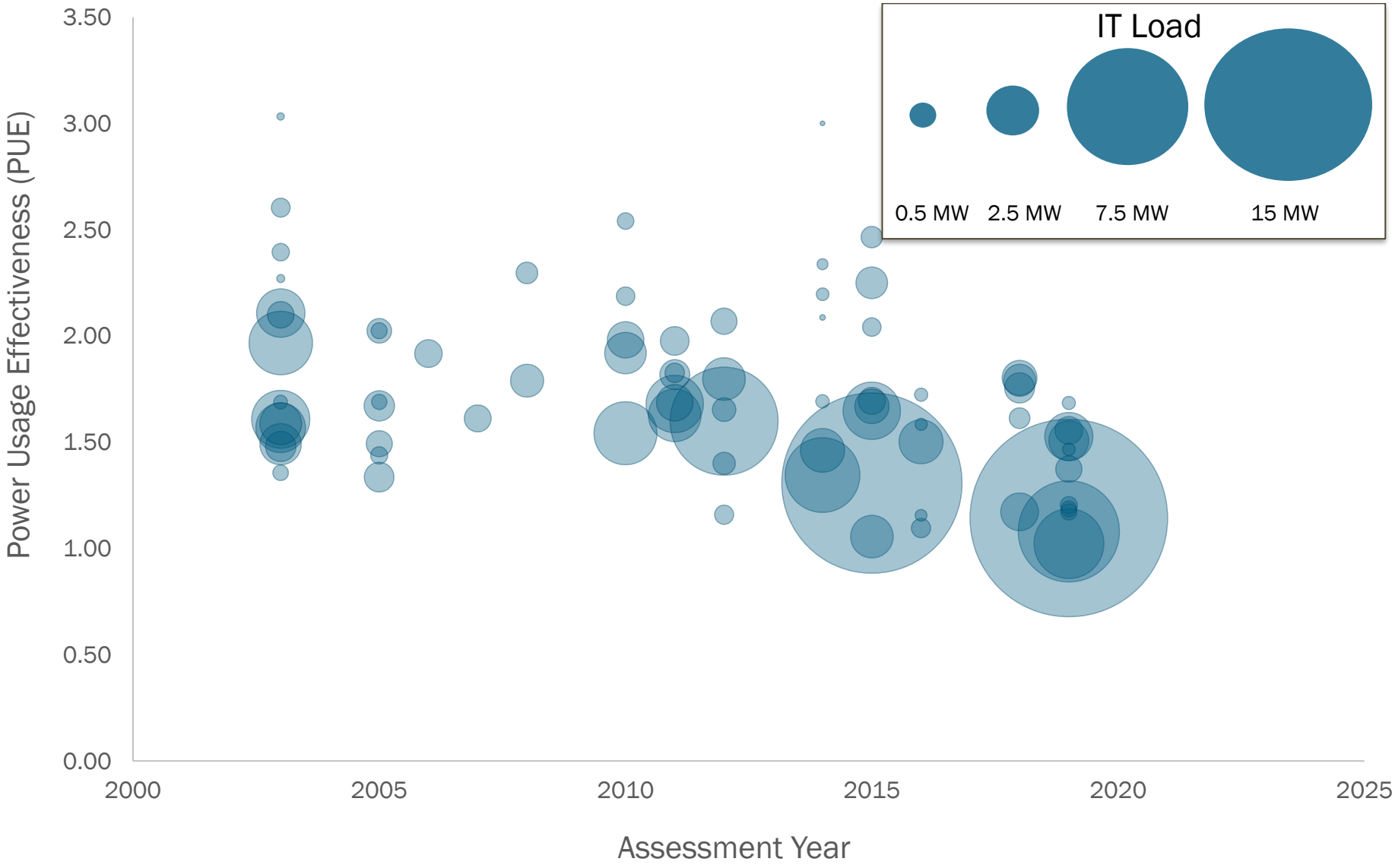
Energy uses vary widely



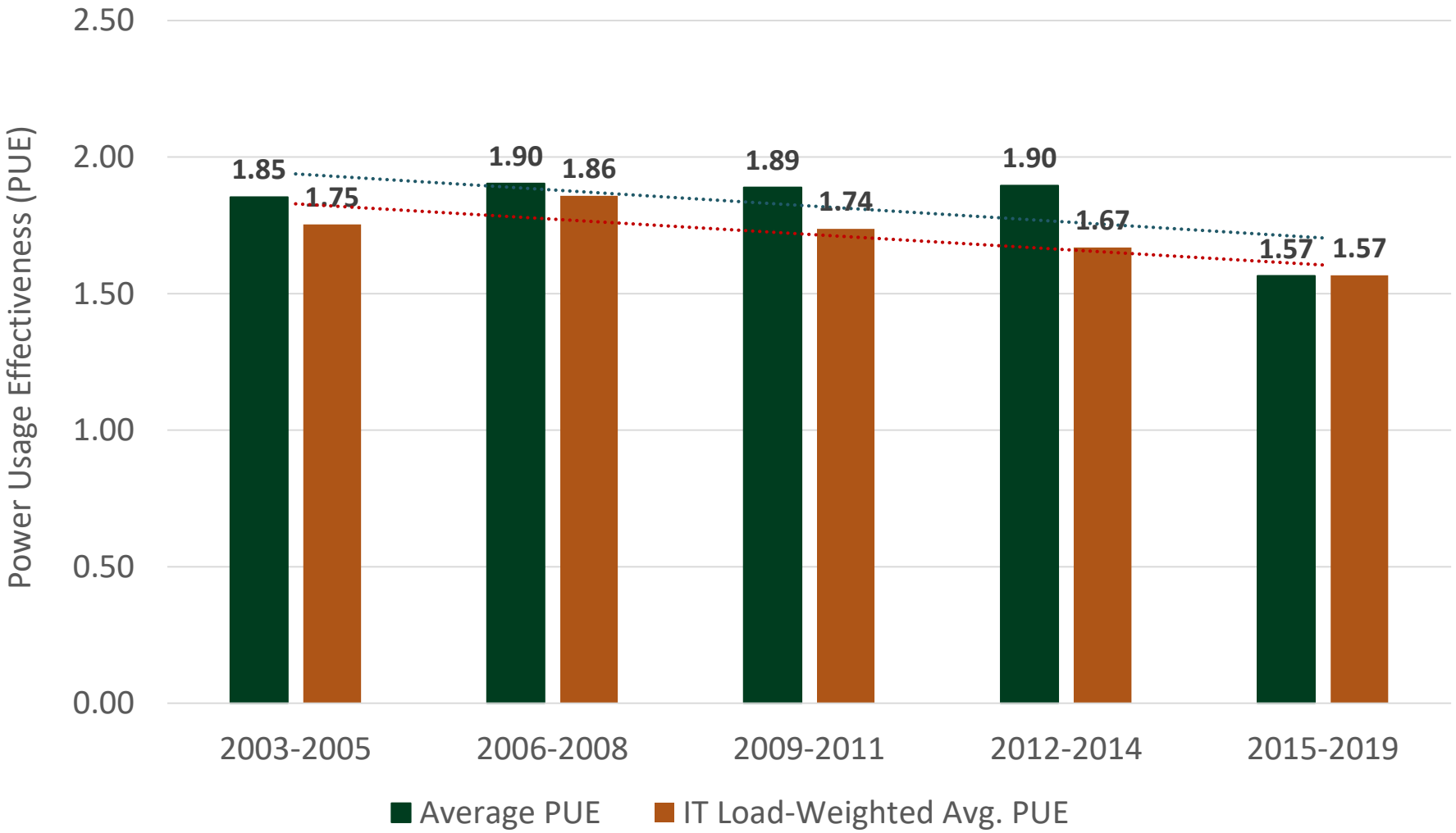
Efficiency is so-so but improving – at least in the federal fleet



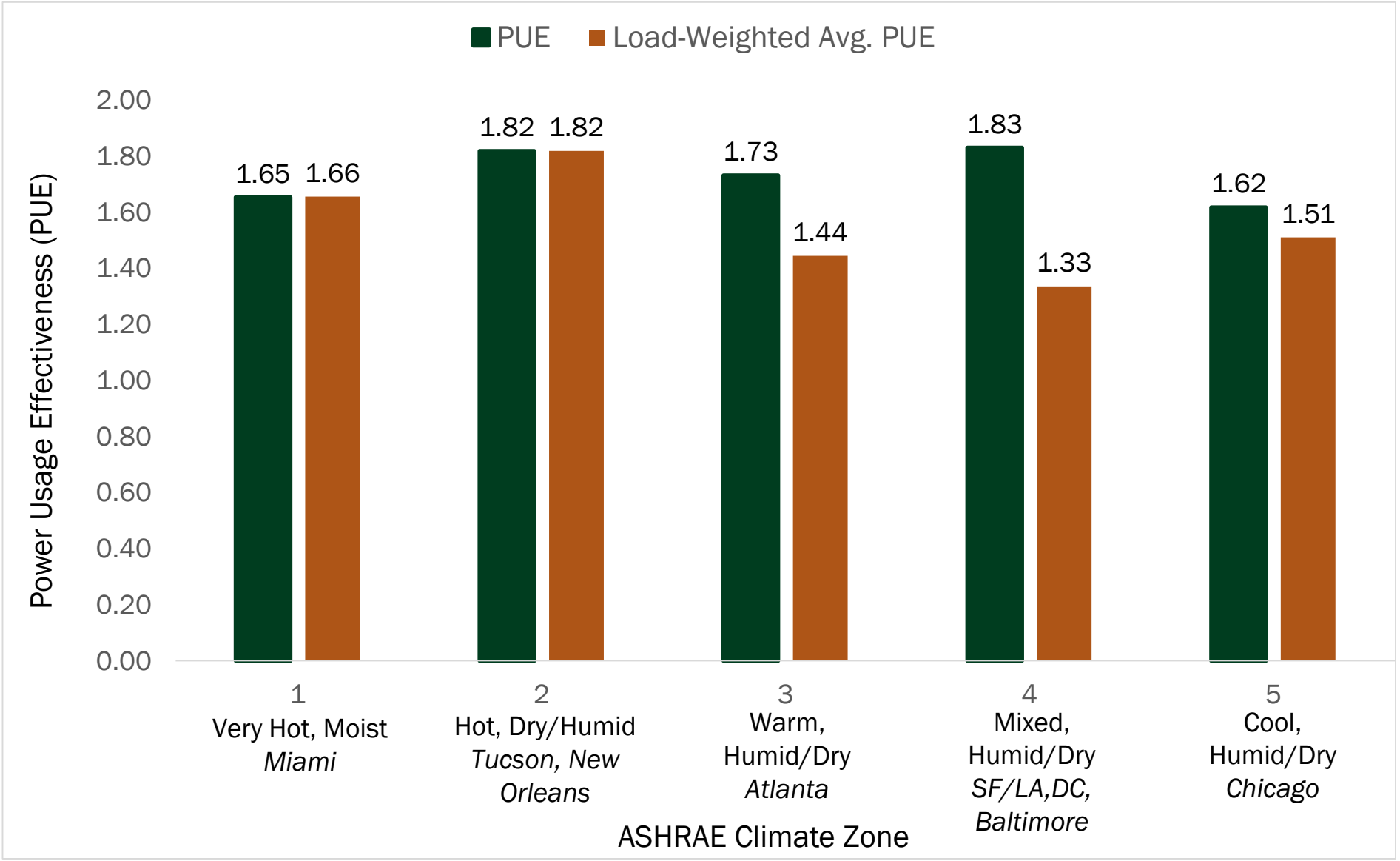
Larger data centers tend to be more efficient



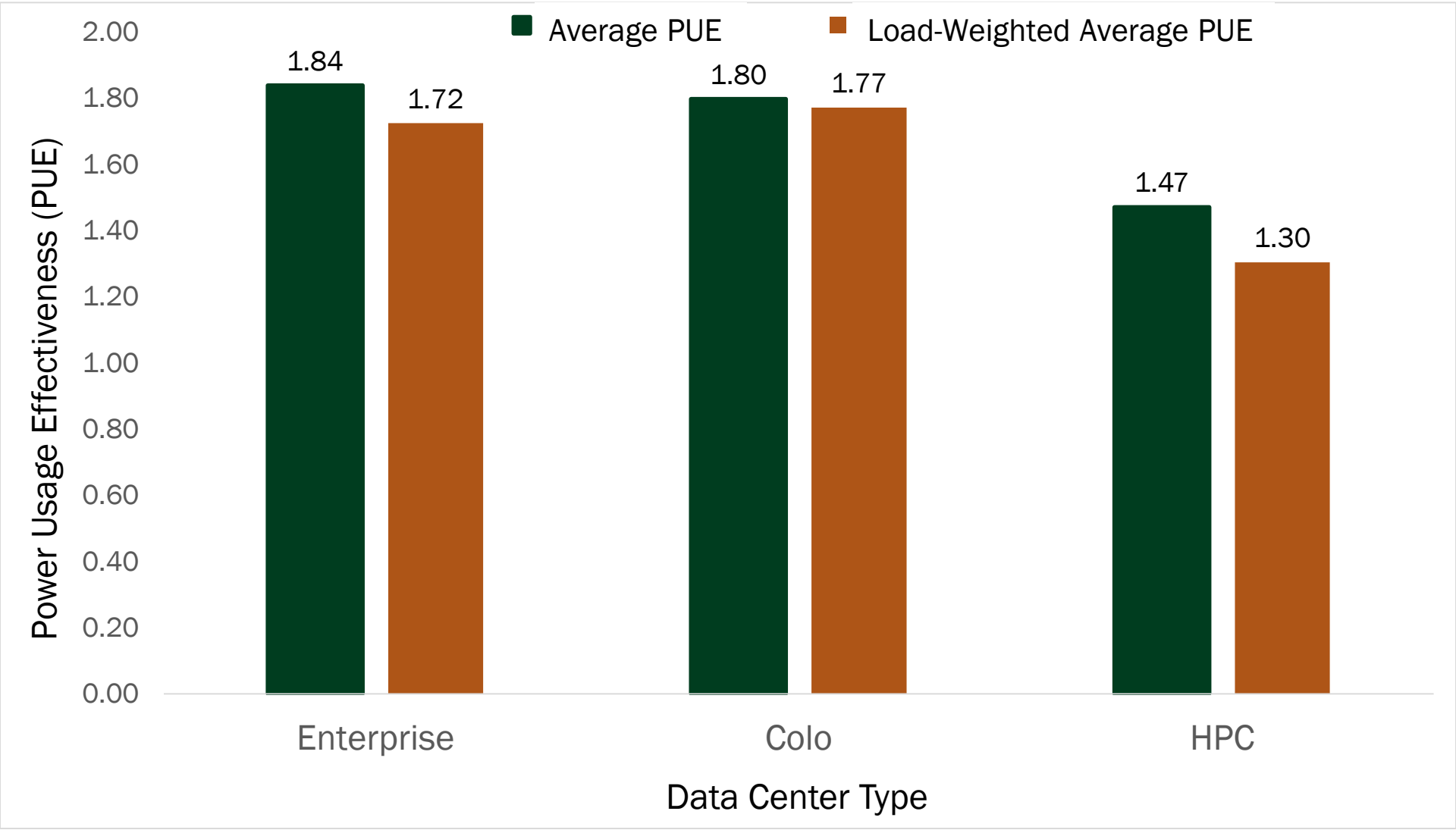
Size matters but so does time



Some larger DCs take advantage of cooler climes



Efficiency varies by data center type, business model



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

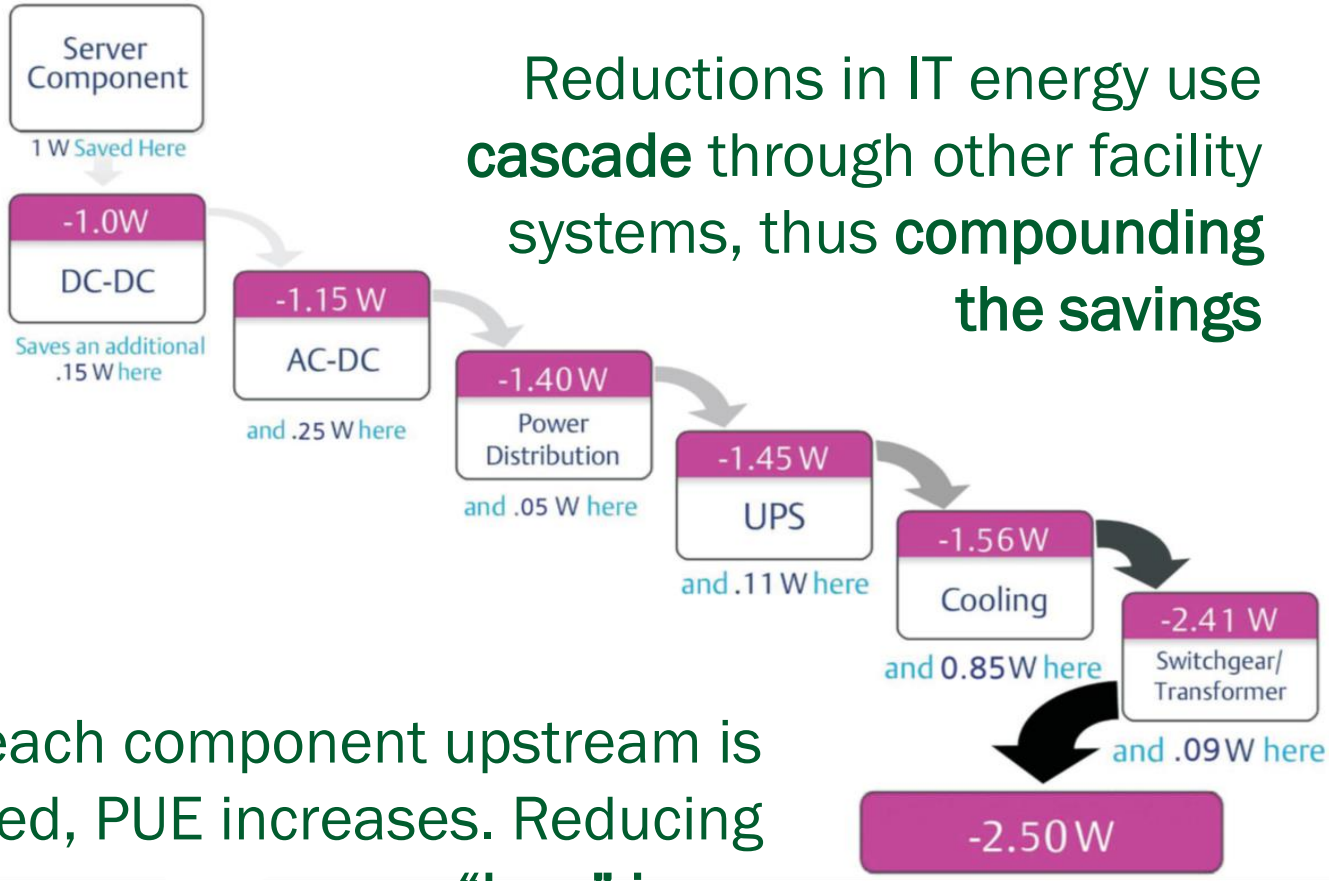
- **Problematic for comparability and fairness**
  - PUE is not well suited for comparing different data centers
  - Fails to reflect the differences in **type, scale, location and workload**

- **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**

Power Usage Effectiveness: Where it falls short

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

$$CUE = GHG\ Emissions\ Factor \left(\frac{kg\ CO_2e}{kWh}\right) X\ PUE$$

- **Water Usage Effectiveness (WUE)**

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

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

$$ERF = \frac{Reuse\ energy}{Total\ data\ centre\ energy\ use}$$

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

FEMP's Data Center program assists federal agencies and other organizations with optimizing the design and operation of data centers. 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)

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.

Explore the diverse activities that CoE is engaged in.

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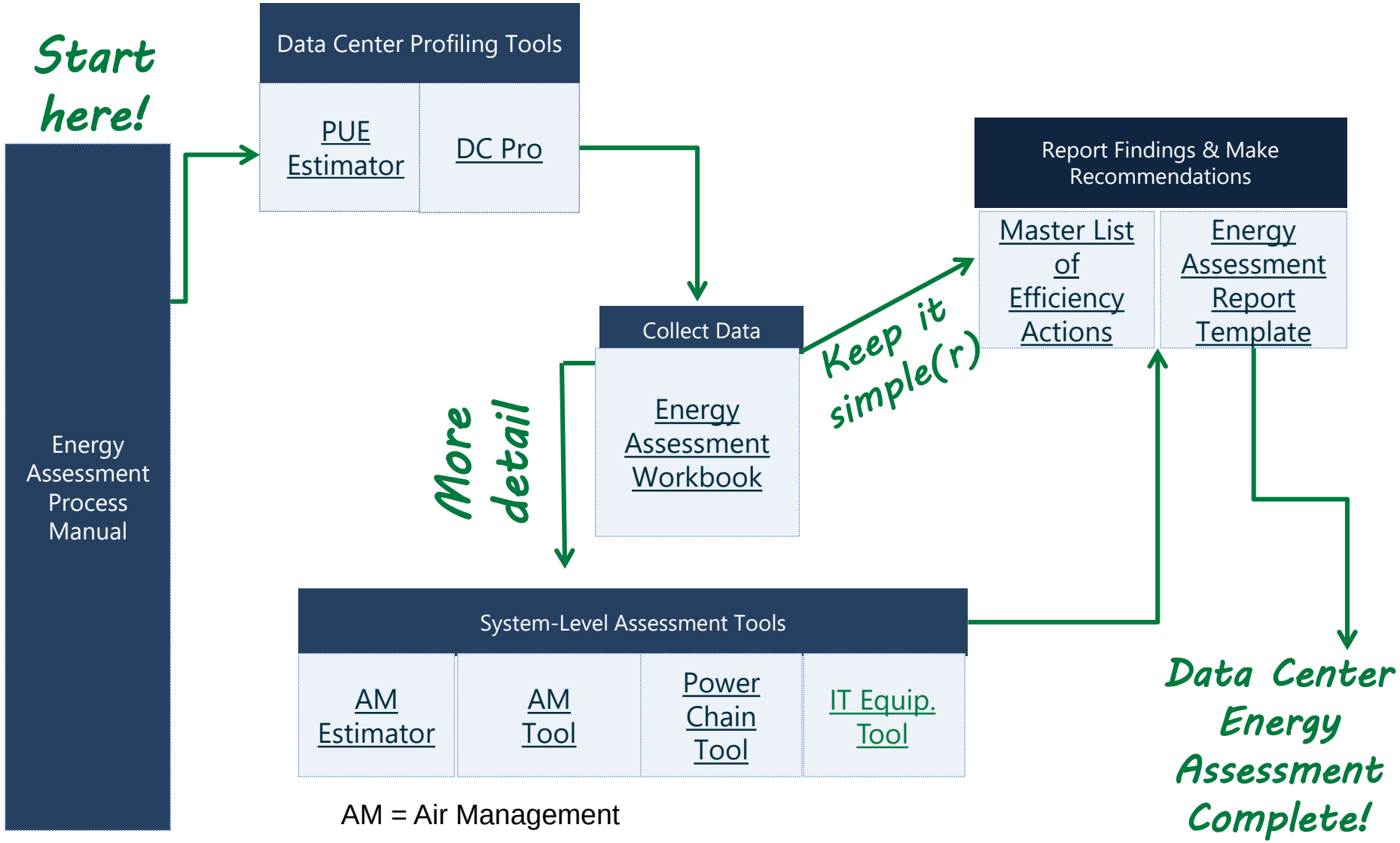
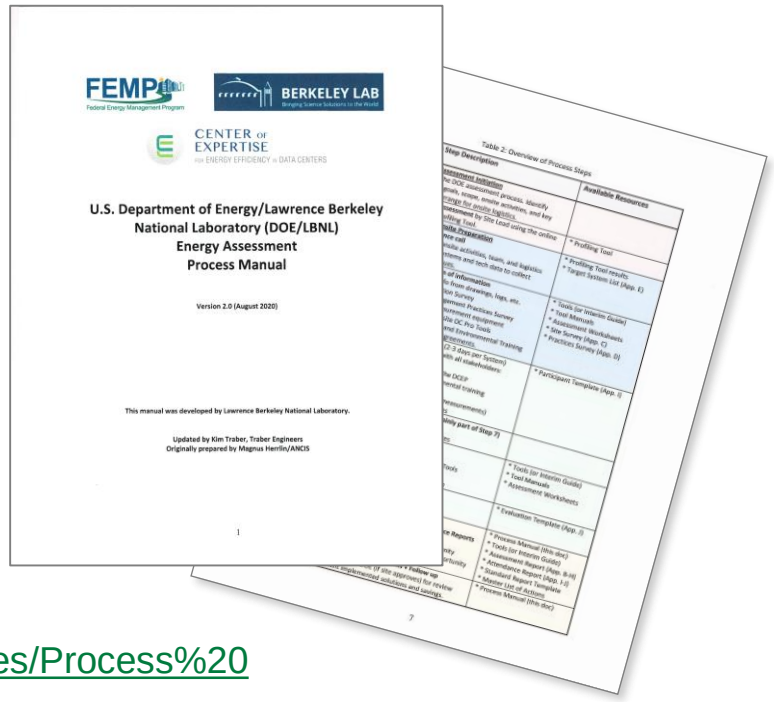
CoE Data Center Energy Efficiency Toolkit



AM = Air Management

Energy Assessment Process Manual

- The Process Manual provides administrative step-by-step instructions for conducting an energy assessment before, during, and after the onsite assessment
- Multiple appendices include useful templates for the assessments.



https://datacenters.lbl.gov/sites/default/files/Process%20Manual%20DOE%20v2_080320_0.pdf

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.**

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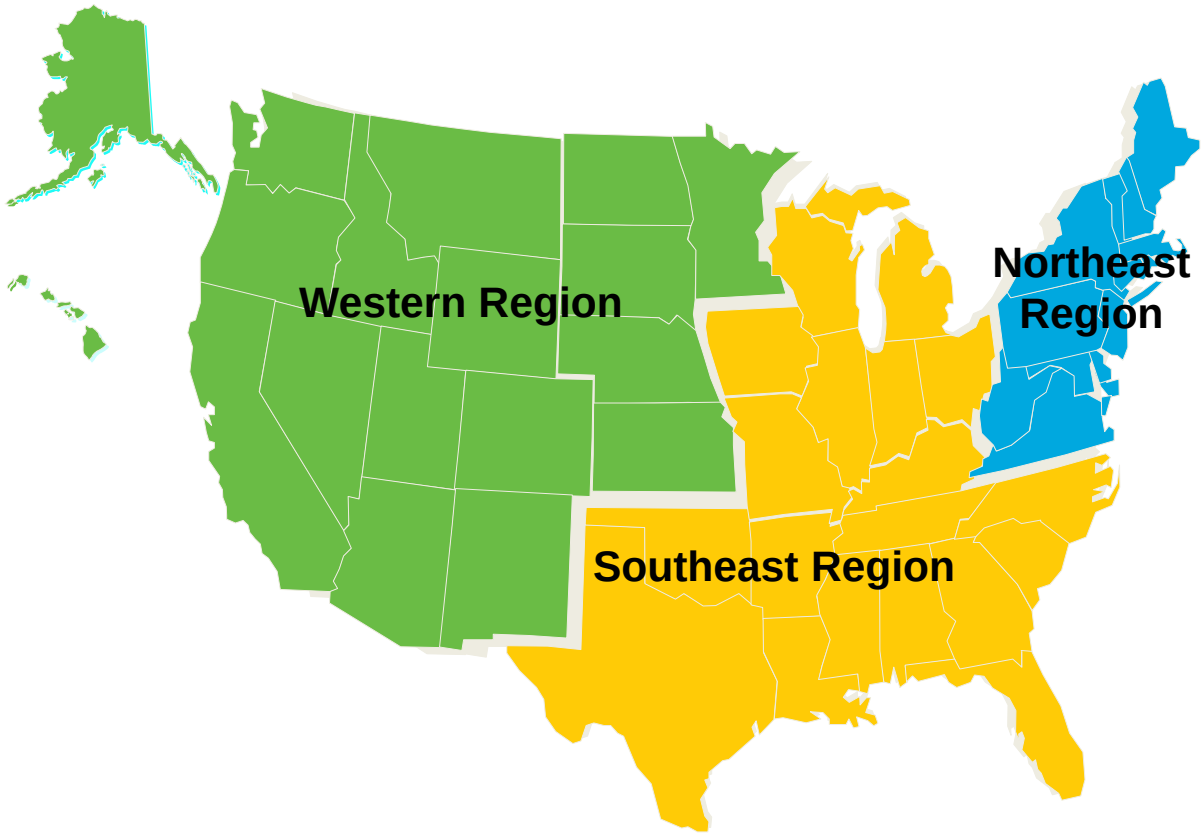

Questions?

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Additional Slides

Average Energy Use Breakdown, 2003-2019