U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEMP Federal Energy Management Program

Data Center Metering and Power Usage Effectiveness

July 28, 2016

Steve Greenberg

Lawrence Berkeley National Laboratory (LBNL)

Before We Begin

- Please do NOT put the call on hold
- All lines have been muted, to be unmuted or to ask a question, please go to your meeting controls panel and raise your hand
- To submit questions via chat, click the chat button in the top right of your screen and a text box will appear in the bottom right. Please select to send your message to Elena Meehan, enter text, and press enter.
- Slides will be posted at datacenterworkshop.lbl.gov
- Attendees can receive a certificate of completion by filling out an evaluation form, link provided at the end of the presentation.

Agenda

- Power Usage Effectiveness (PUE)
- Executive Order 13693
- Data center types, anticipated scenarios of metering systems, and how to calculate PUE
- Metering methods
- Challenges to installing meters and gathering data
- LBNL case studies
- Resources

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- **Power Usage Effectiveness (PUE)**
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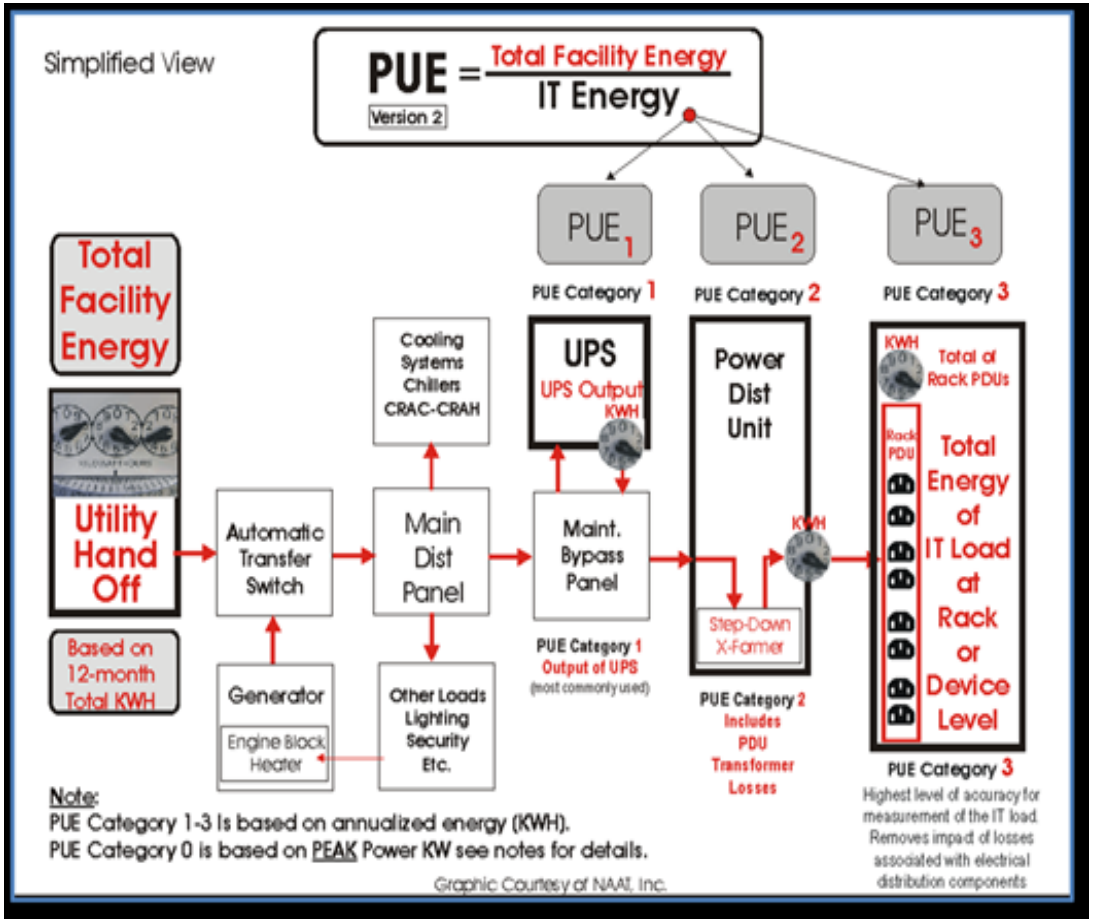
Power Usage Effectiveness

- The ratio of total energy use to that of the information technology (IT) equipment
- A measure of how efficiently the data center infrastructure uses energy
- What PUE is good for (infrastructure overhead)

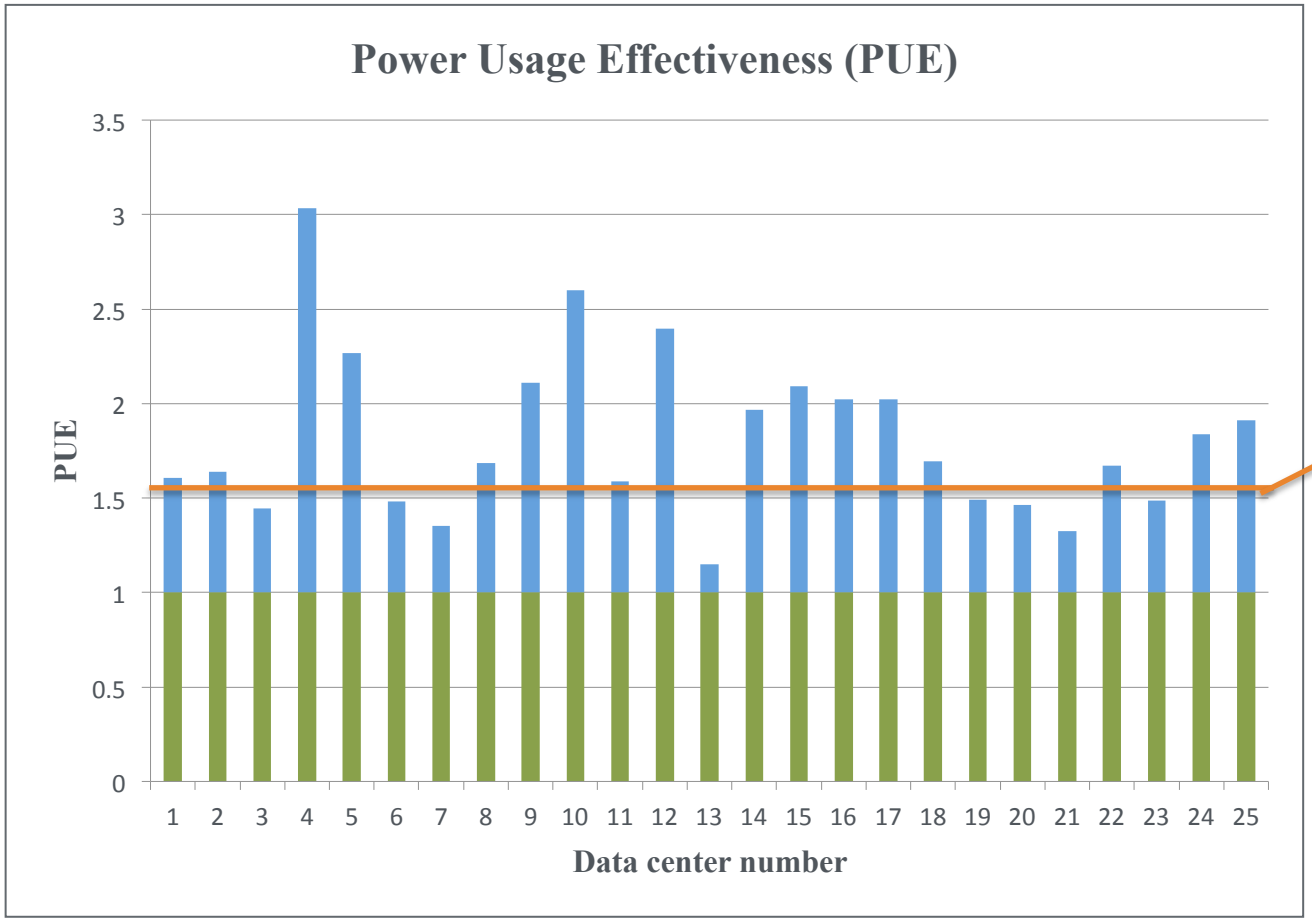
$$\text{PUE} = \frac{\text{Total Data Center Facility Annual Energy Use}}{\text{IT Equipment Annual Energy Use}}$$

Power Usage Effectiveness

- Three levels (1=Basic, 2=Intermediate, 3=Advanced)
  - Focus on Level 1, the default for Better Buildings



Power Usage Effectiveness, cont.



Federal goal - existing data centers

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Executive Order 13693 Mandates for Data Centers

- Ensuring the agency chief information officer promotes data center energy optimization, efficiency, and performance -- Section 3(a)(ii)(A)

- Install and monitor advanced energy meters in all data centers by FY ‘18 --Section 3(a)(ii)(B)

- Target 1.2 to 1.4 PUE for new data centers --Section 3(a)(ii)(C)

- Target less than 1.5 PUE for existing data centers (same)

Executive Order 13693 Implementing Instructions

- Calculating PUE
- Coordination with other Federal data center initiatives
- Training
  - All core data centers, to include existing, new and planned, shall have at least one certified Data Center Energy Practitioner (DCEP), either on-site or centralized, assigned to manage data center performance and continued optimization.
- Metering
  - The advanced energy meters installed by agencies as appropriate in all data centers shall be meters that enable the active tracking of PUE for the data center, as well as promote implementation of Data Center Infrastructure Management (DCIM).
- PUE Targets
- Best Practices for data center energy optimization, efficiency, and performance
- Contracted Data Centers and Cloud Services
- Reporting
- Definitions

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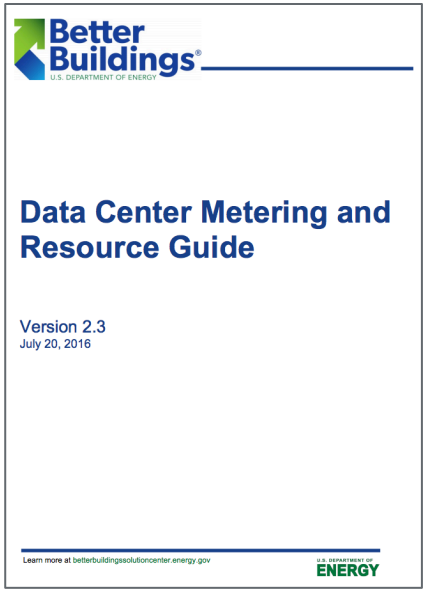
Data Center Types: Getting Started

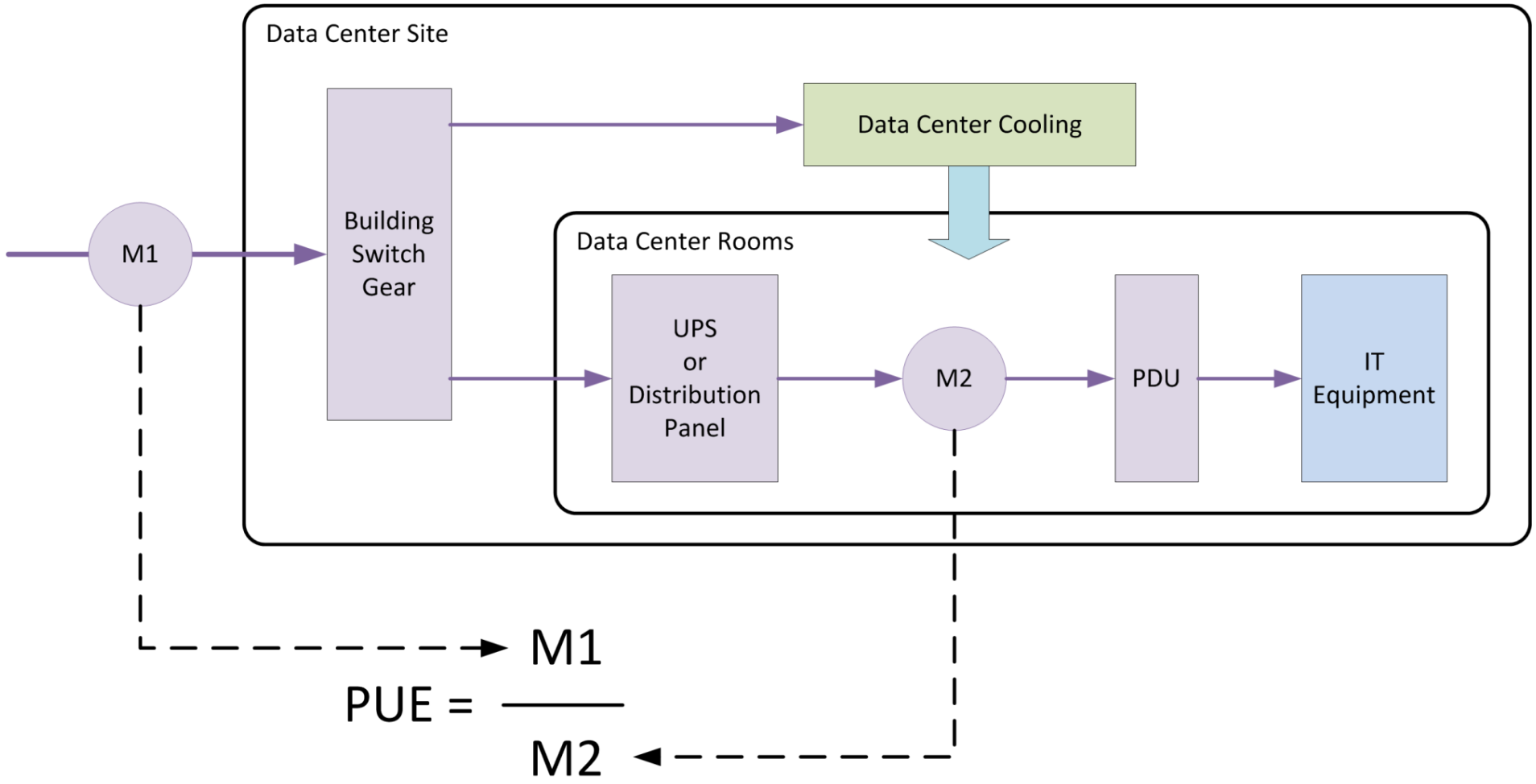
- Basic Data Center Types
  - Stand-alone
  - Embedded (focus)

- Data Center Metering and Resource Guide
  - Expands on the metering and PUE content covered in this webinar

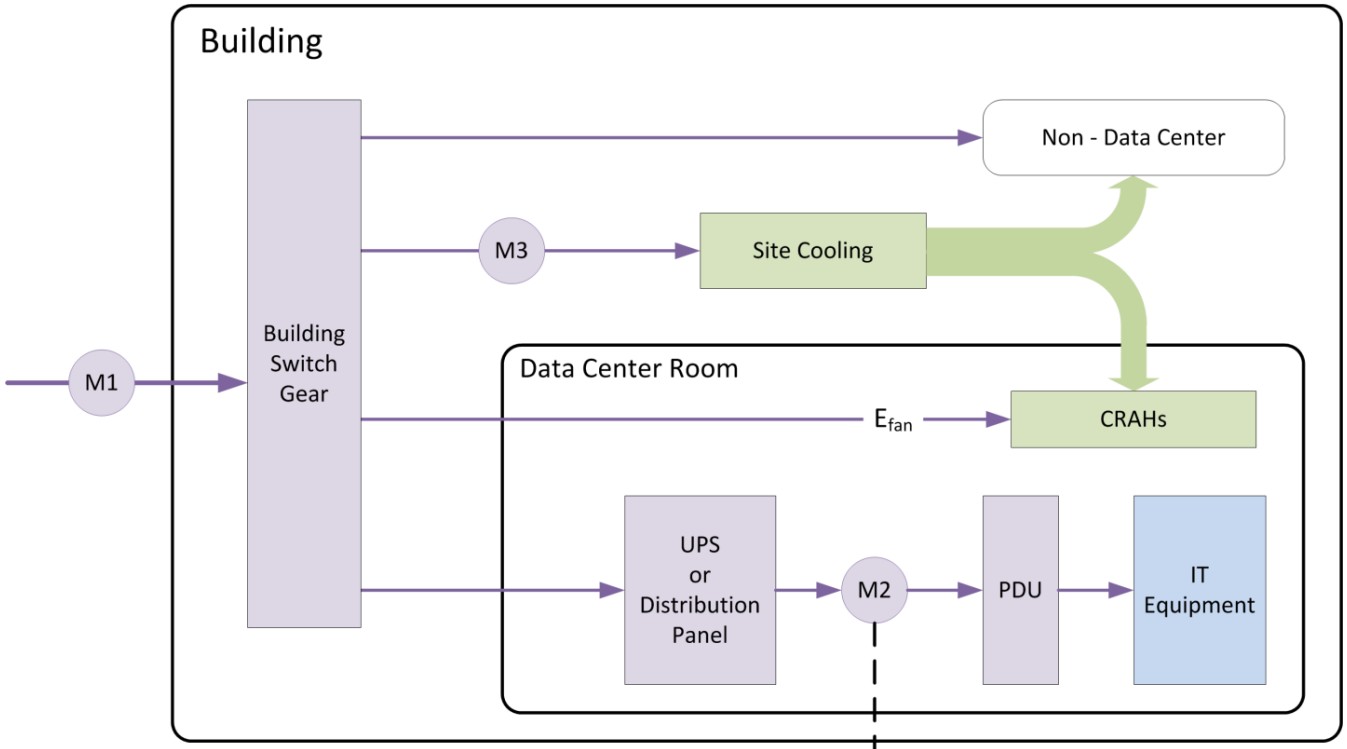


datacenters.lbl.gov/resources/data-center-metering-and-resource-guide

Data Center Types: 1. Stand-alone



Data Center Types: 2a. Embedded, w/additional metering beyond UPS output

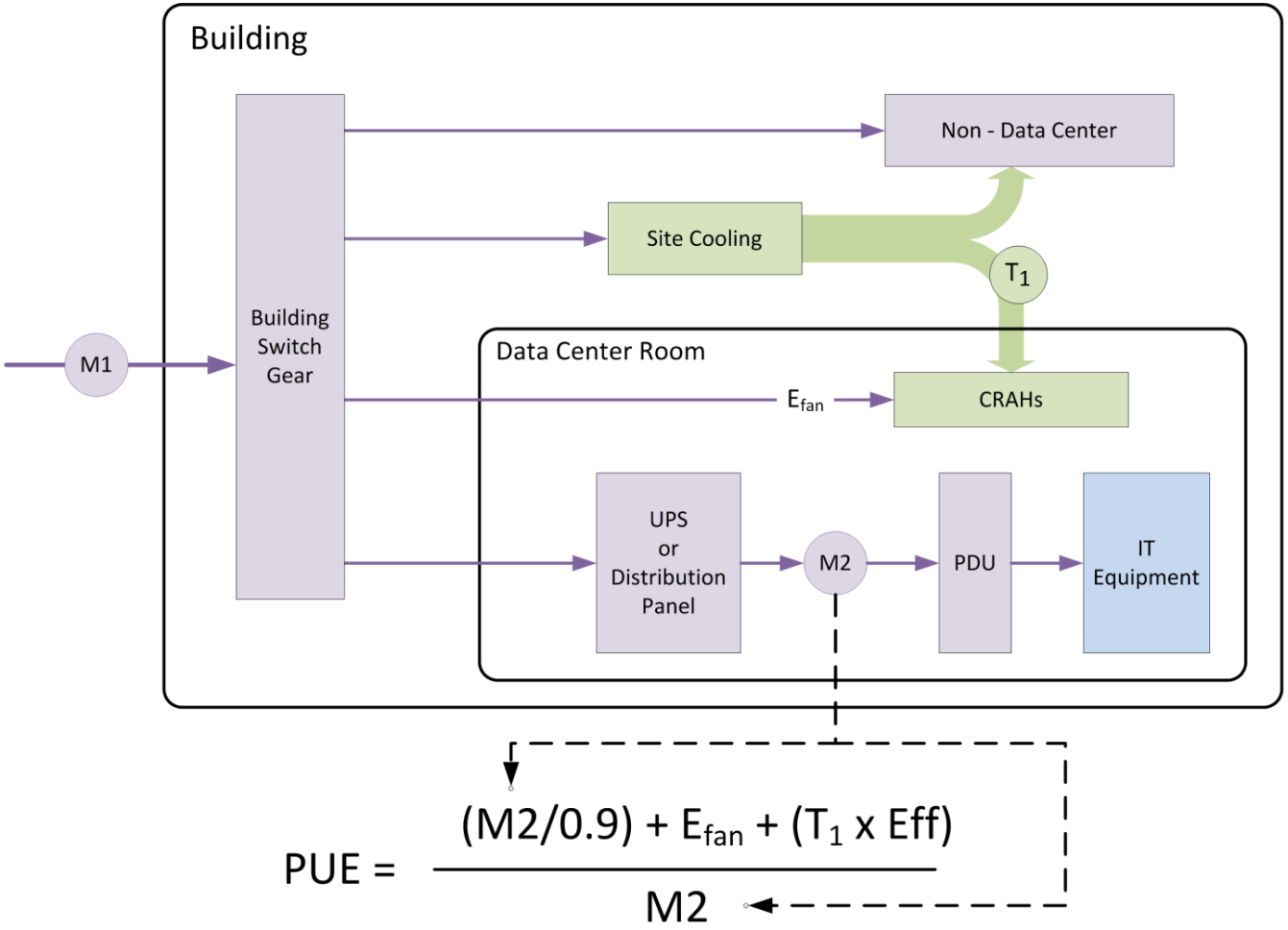


$$PUE = \frac{((M2/.9) + E_{fan}) \text{ X } (1+ (0.285 \text{ X } Eff))}{M2}$$

Where E_{fan}= CRAH fan energy use
Eff = average chiller plant efficiency in kW/ton (M3 is used to calculate; see "Data Center Metering and Resource Guide")

2a. Chiller Plant input (M3)

2b. Embedded, with metering beyond UPS output, cont.



2b. Data Center cooling (thermal) (T1)

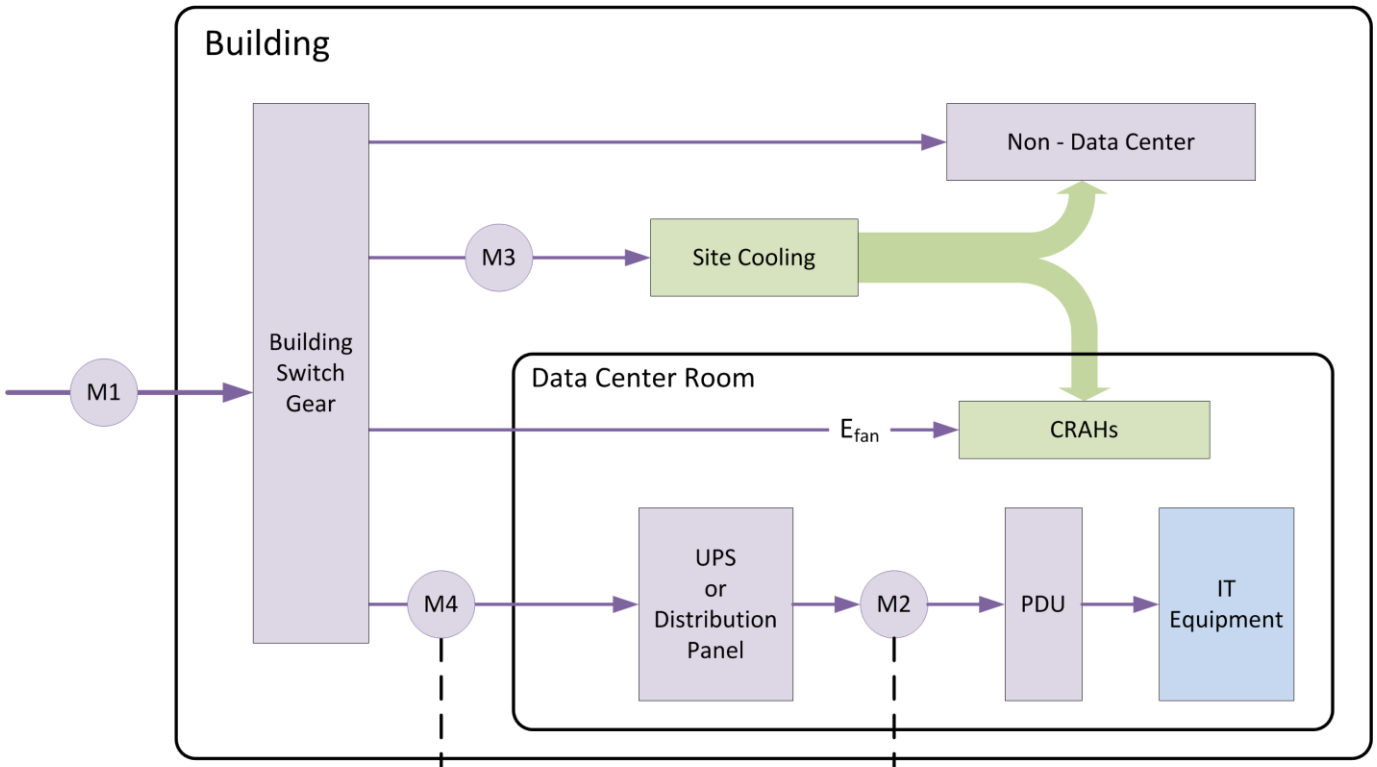
Eff = (Chiller efficiency + 0.2) kW/ton, where chiller efficiency can be obtained from Chiller Efficiency Table and 0.2 represents typical additional load of chilled water/condenser water pumps and cooling tower fans.

2. Embedded, with metering beyond UPS output, cont.

Chiller Efficiency Table (Edited from Table 6.8.1C - ASHRAE 90.1 – 2010)

Equipment Type	Size Category	Minimum Efficiency	Unit
Air- Cooled Chillers	<150 ton	≤ .960	kW/ton-IPLV
	>150 ton	≤ .941	kW/ton-IPLV
Water - Cooled Chillers Positive Displacement	<75 ton	≤ .630	kW/ton-IPLV
	≥75 ton and < 150 ton	≤ .615	kW/ton-IPLV
	≥150 ton and < 300 ton	≤ .580	kW/ton-IPLV
	≥300 ton	≤ .540	kW/ton-IPLV
Water - Cooled Chillers Centrifugal	< 300 ton	≤ .596	kW/ton-IPLV
	≥300 ton and < 600 ton	≤ .549	kW/ton-IPLV
	≥600 ton	≤ .539	kW/ton-IPLV

2c. Embedded, w/additional metering, cont.

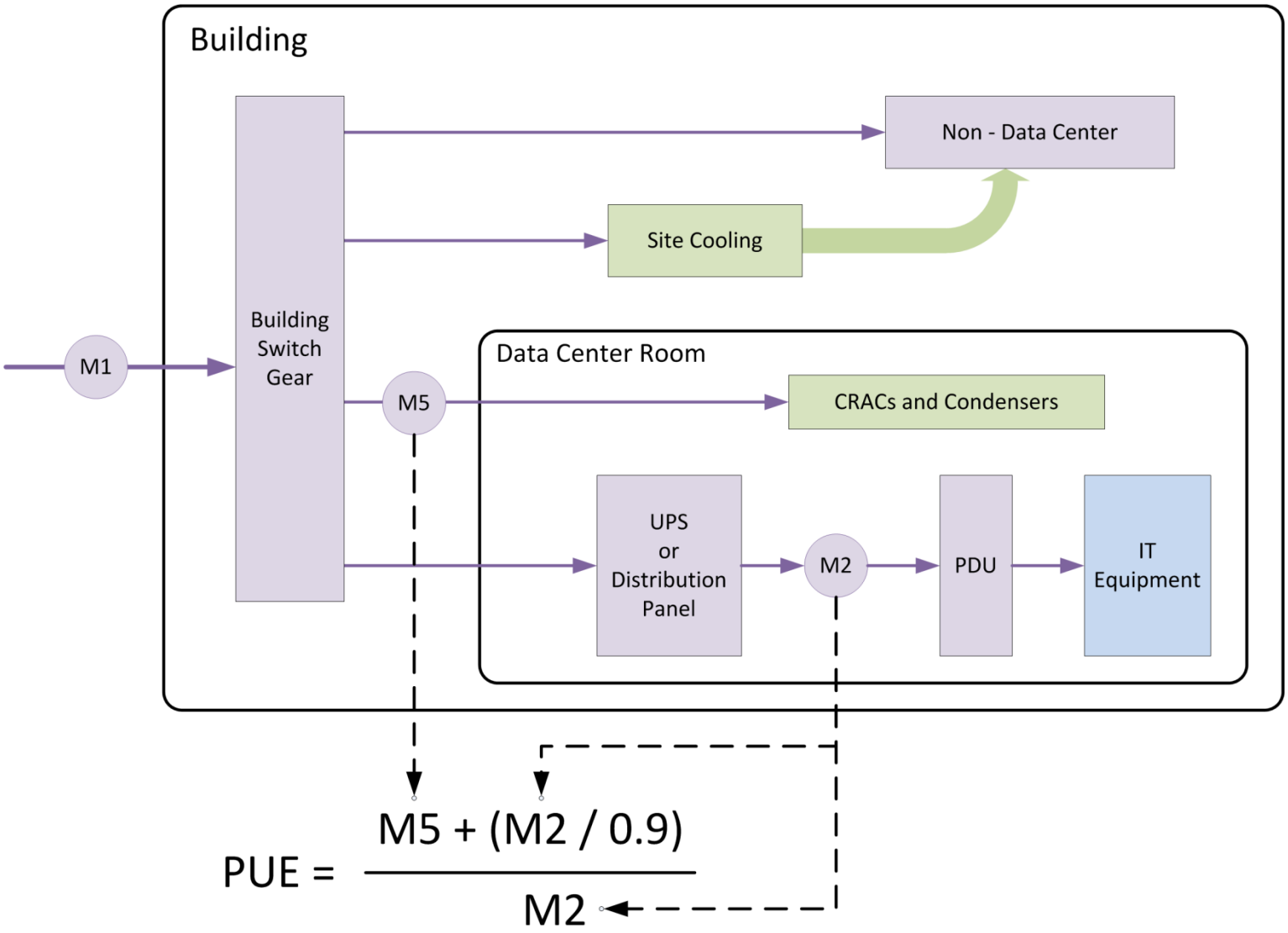


$$PUE = \frac{((M4 \times 1.03) + E_{fan}) \times (1 + (0.285 \times Eff))}{M2}$$

Where E_{fan} = CRAH fan energy use
Eff = average chiller plant efficiency in kW/ton (M3 is used to calculate; see "Data Center Metering and Resource Guide")

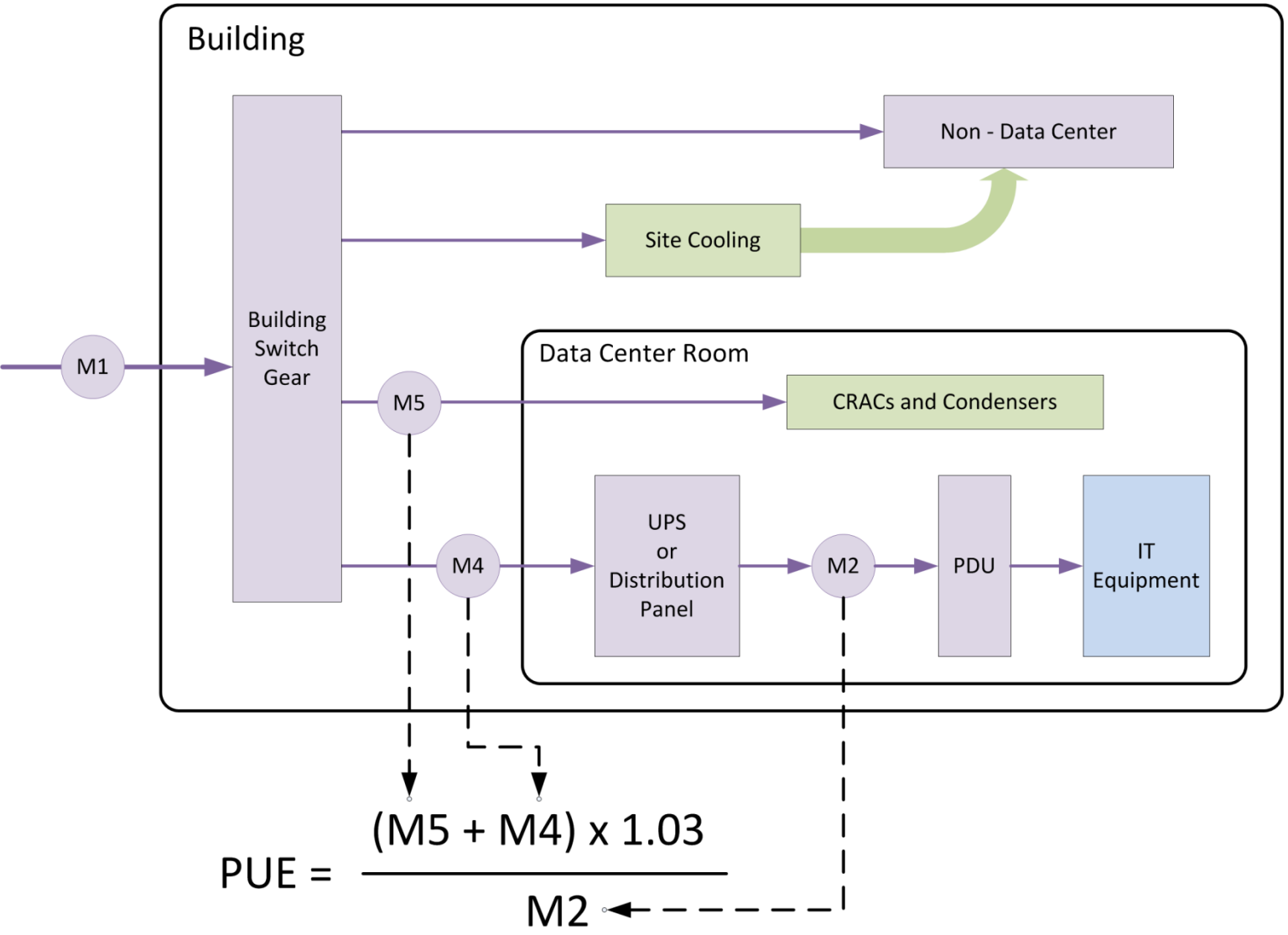
2c. Chiller Plant input (M3) and UPS input (M4)

2d. Embedded w/metering beyond UPS output, cont.



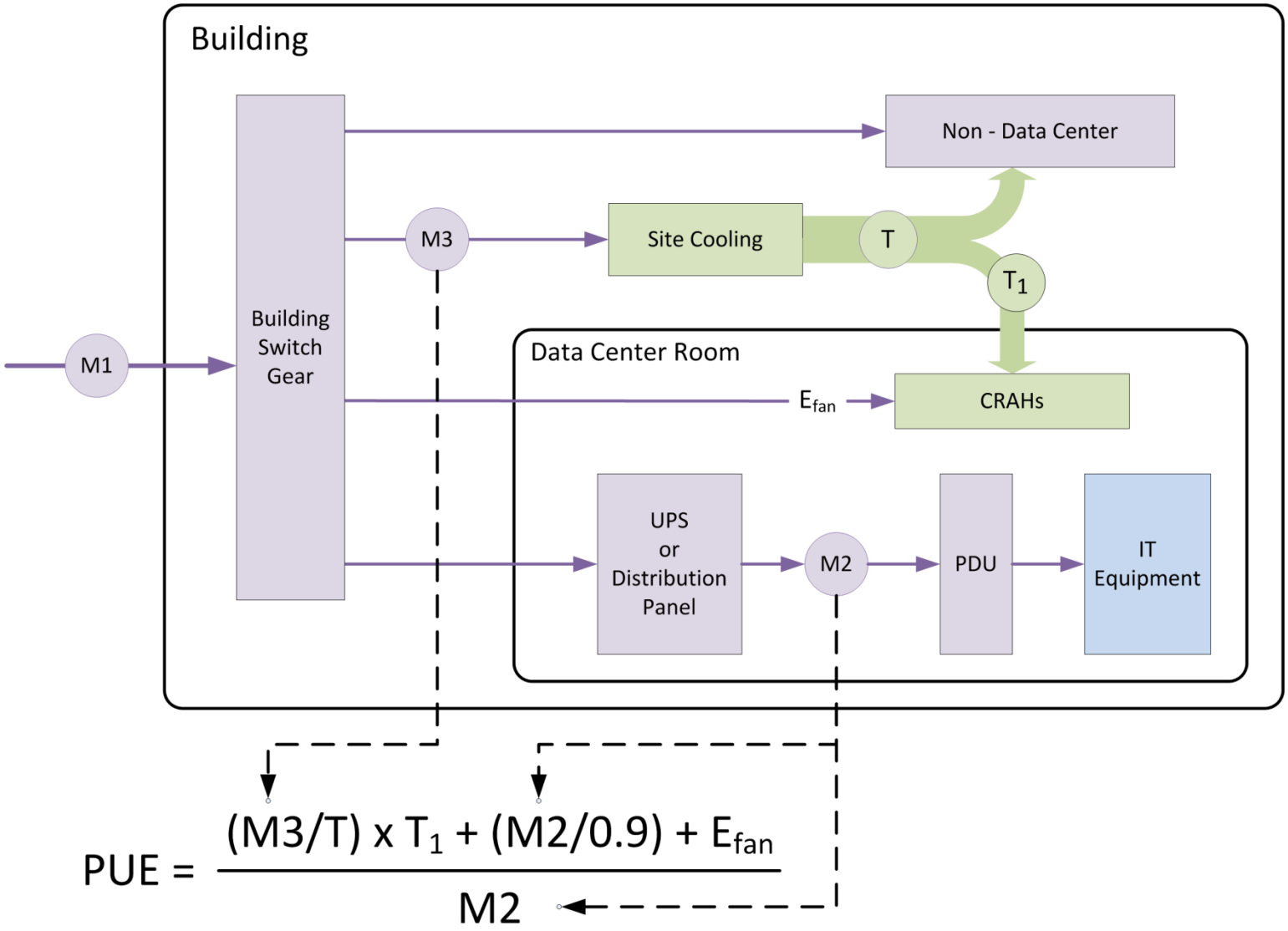
2d. CRACs and Condensers input (M5)

2e. Embedded w/metering beyond UPS output, cont.



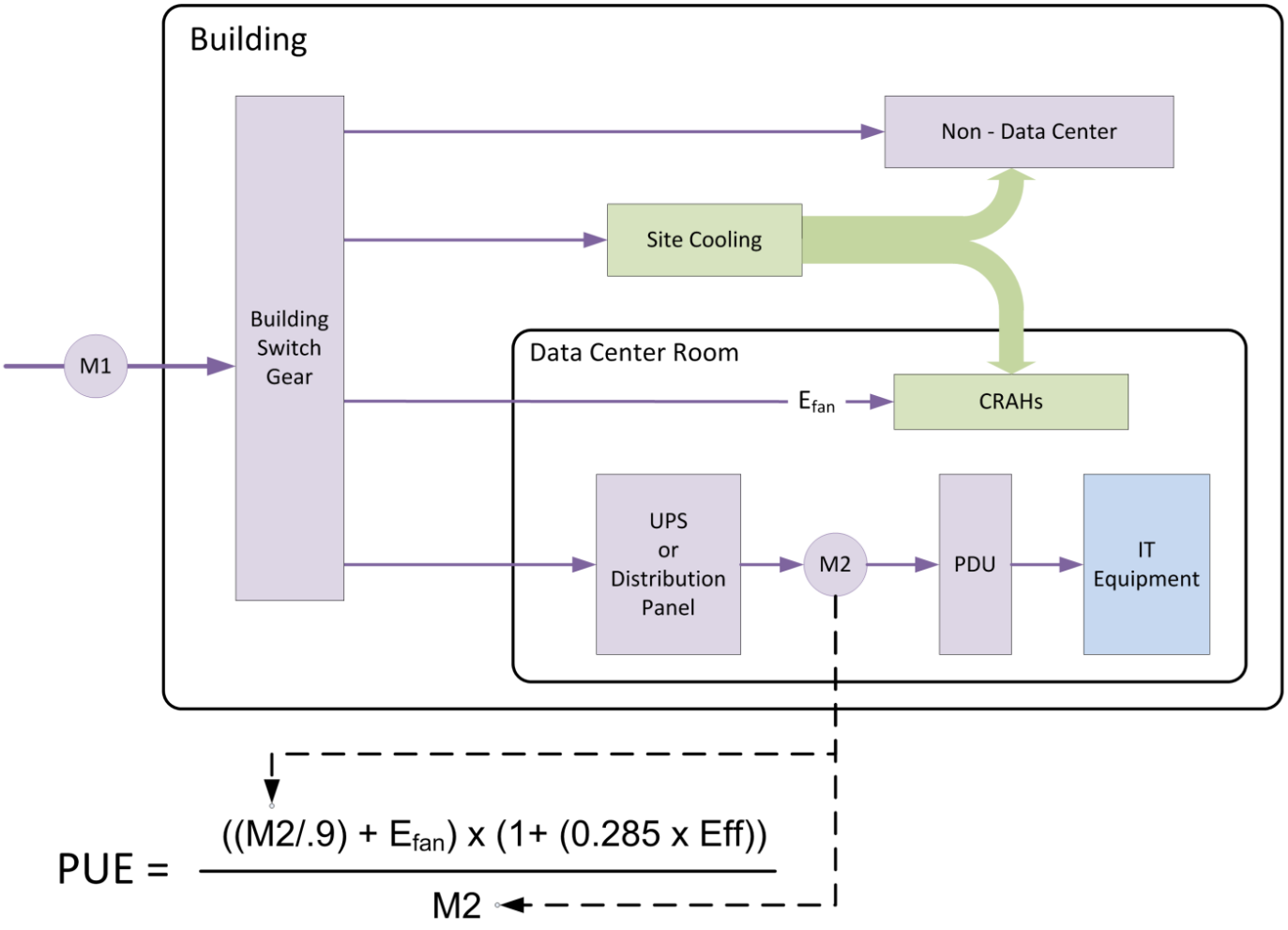
2e. UPS input (M4) and CRACs and Condensers Input (M5)

2f. Embedded w/metering beyond UPS output, cont.



2f. Chiller Plant input (M3) Chiller Plant output (T) and Data Center Cooling (T1)

Data Center Types: 3. Embedded, no additional metering beyond UPS output



3a. Water-cooled chiller plant with CRAHs

Eff = (Chiller efficiency + 0.2) kW/ton, where chiller efficiency can be obtained from Chiller Efficiency Table and 0.2 represents typical additional load of chilled water/condenser water pumps and cooling tower fans.

3. Embedded with no metering beyond UPS output, cont.

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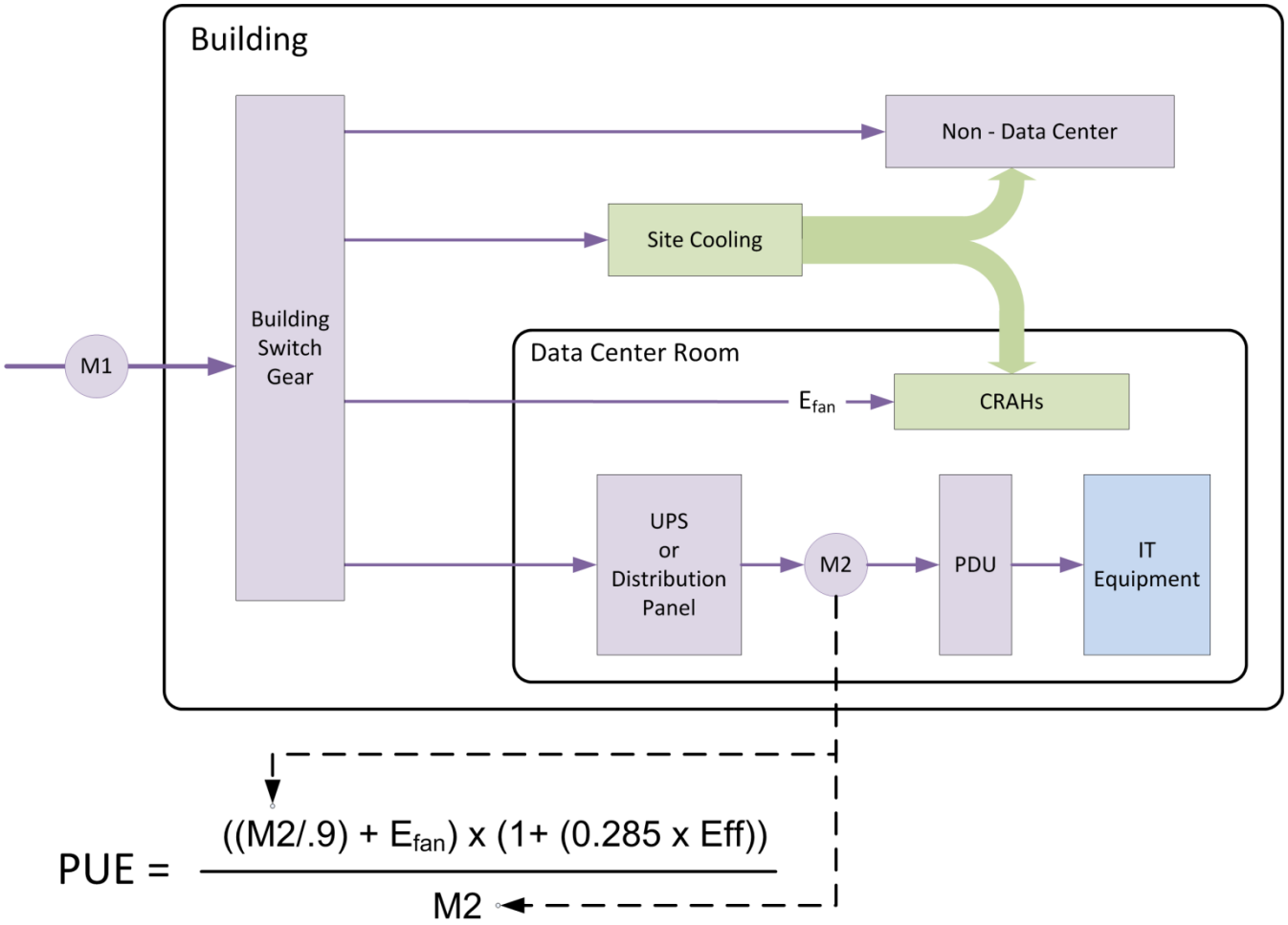
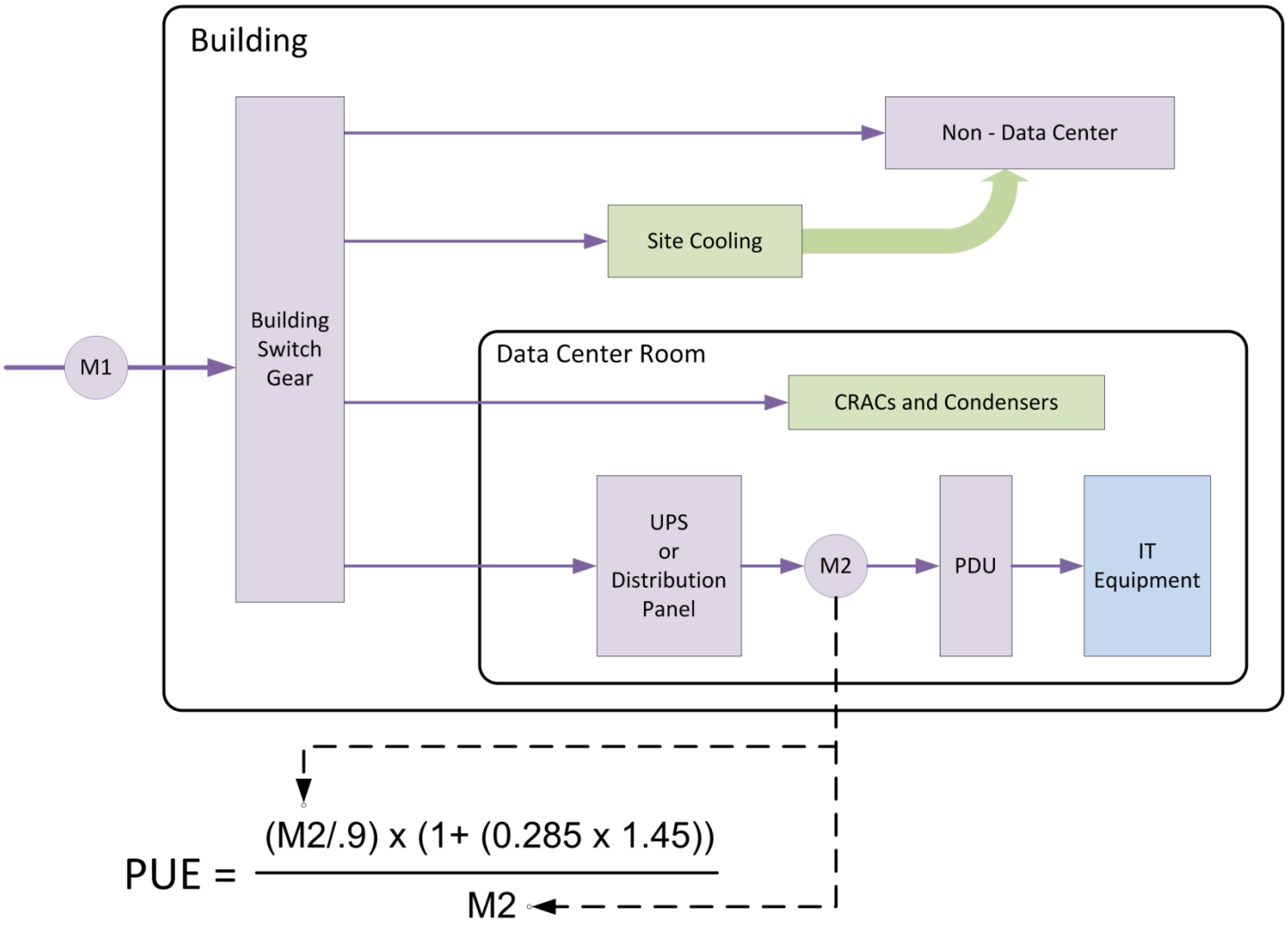
3b. Embedded, no additional metering, cont.



3b. Air-cooled chiller Plant with CRAHs

Eff = (Chiller efficiency + 0.1) kW/ton, where chiller efficiency can be obtained from Chiller Efficiency Table and 0.1 represents typical additional load of chilled water pumps.

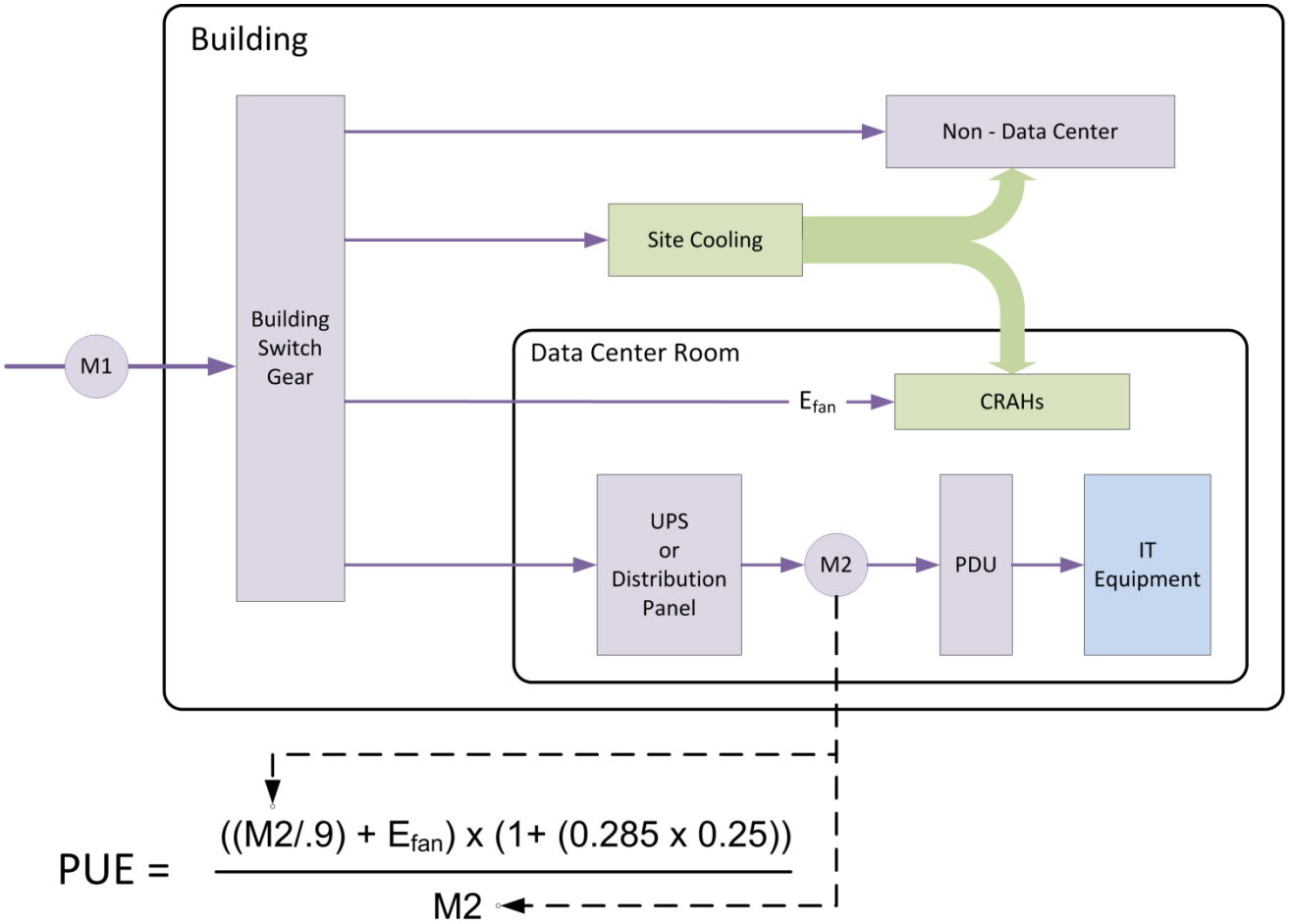
3c. Embedded, no additional metering, cont.



3c. CRACs with air-cooled condensers

1.45 kW/ton represents typical air-cooled CRAC efficiency including fans.

3d. Embedded, no additional metering, cont.



3d. Water- or air-cooled chiller plant with water-side economizer (WSE)

0.25 kW/ton represents typical cooling plant efficiency during economizer operation.

Use this equation for economizer operating hours and otherwise-applicable equation for non-economizer hours.

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- **Metering methods**
- Challenges to installing meters and gathering data
- LBNL case studies
- Resources (including Better Buildings)

Metering Methods

1. Plan
   - Determine data center type
   - Determine existing metering
   - Review drawings
   - Interview staff/visit site
   - Decide on PUE calculation approach

Metering Methods, cont.

2. Implement
   - Define needs and expectations
   - Obtain buy-in from all stakeholders
   - Design (including review cycles)
   - Install
   - Integrate and configure
   - Commission: end-to-end; sum-checking
   - Train

3. Use
   - Monitor and improve performance
   - Maintain metering

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Challenges and Potential Solutions to Meter Installation

- Electrical metering: Shut down one system at a time in N+x systems
- Electrical metering: Wait for system maintenance
- Thermal metering: Use hot-taps or ultrasonic meters

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Examples of getting to PUE at LBNL data centers

- Building 50A-1156: the hodgepodge
- Building 50B-1275: the case-study king
- Building 59: the many-megawatt supercomputer center

LBNL 50A-1156

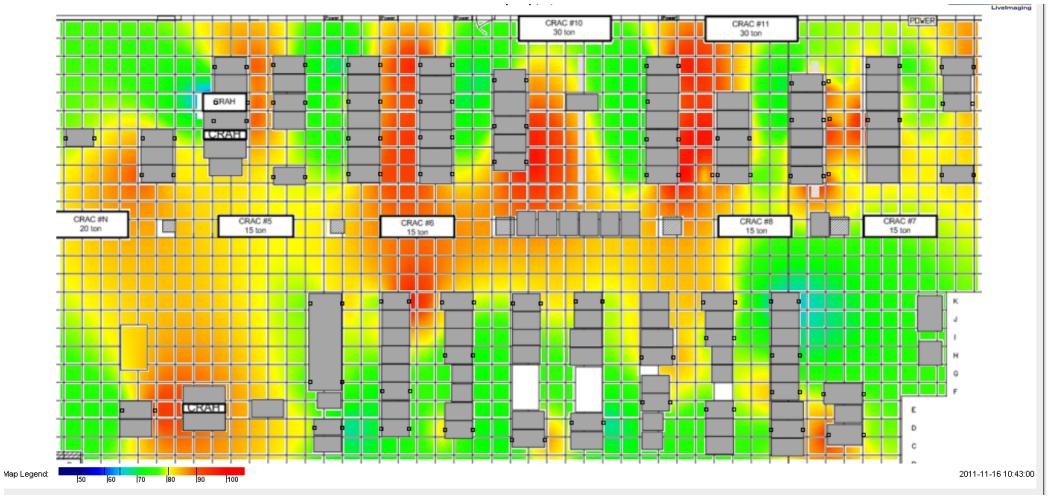
- The hodge-podge
- Decades old, embedded data center in office building
- 2450 square feet
- ~100 kW IT load
- Shared AHU for primary cooling on house chilled water
- Standby CRAC with remote air-cooled condenser
- 2’ raised floor
- Combination of telecom, house services, and high-performance computing
- Mix of UPS and direct power distribution

LBNL 50A-1156 Approach to PUE

- Level 1
- Measured IT
- Data center is embedded with multiple power and cooling feeds
- There are some existing meters on IT loads
- Identify meter additions needed
- Triage based on cost vs. effect on PUE
- Implement changes
- Calculation will use IT load and estimate HVAC based on system ratings and one-time readings

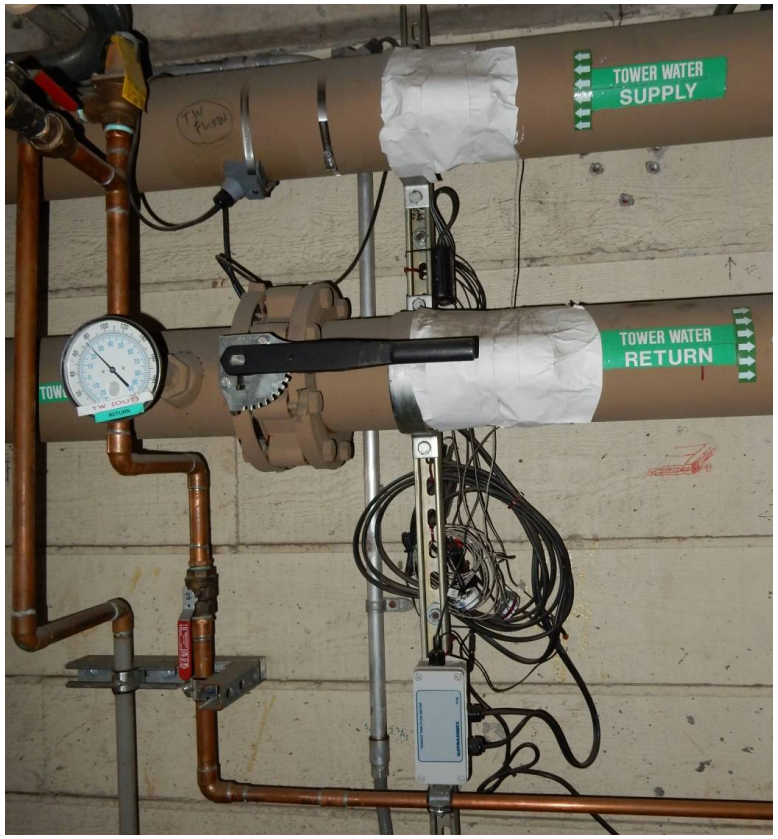
LBNL 50B-1275

- The case-study king
- 45-year-old data center
- 5600 square feet
- ~450 kW IT load
- 7 CRACs 15 to 30 tons of cooling each in 2-4 stages
- Down-flow units (raised floor)
- Water-cooled
- Other cooling including rear doors, enclosed racks, AHU



LBNL 50B-1275 Electric Metering

LBNL 50B-1275 Thermal Metering



LBNL 50B-1275 Approach to PUE

- Level 2 (transformer losses measured or estimated)
- Measured IT, HVAC, lighting
- Data center is embedded and has multiple power and cooling feeds
- PUE is already tracked in real time (~1.4) using numerous meters
- Metering needs update to reflect changes in power and cooling
- Identify meter additions, deletions, and moves needed
- Triage based on cost vs. effect on PUE
- Implement changes

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LBNL 59

- The multi-megawatt supercomputer center
- Brand-new Computational Research & Theory facility, embedded
- 142,000 square feet total
- 7 MW IT load to start, then up to 17, then ???
- IT load will dominate building
- 6 large AHUs for air-cooled loads
- 4 cooling towers with heat exchangers for water-cooled loads
- Water-cooled supercomputers
- Air and water side economizers
- Air-side heat recovery for heating offices
- IT loads cooled without compressors

LBNL 59 Approach to PUE

- Level 2 (PDU outputs for IT)
- Measured IT, HVAC, lighting
- Data center is embedded with multiple power and cooling feeds
- PUE will be tracked in real time (~1.06) using hundreds of meters
- Meter location, accuracy, and reporting capability in review and commissioning
- Identify meter additions needed
- Triage based on cost vs. effect on PUE
- Implement changes

Determining PUE at LBNL

- Is case-by-case—every center is different
- Takes advantage of existing meters
- Minimizes estimation
- Typically involves numerous meters to resolve energy flow in embedded spaces

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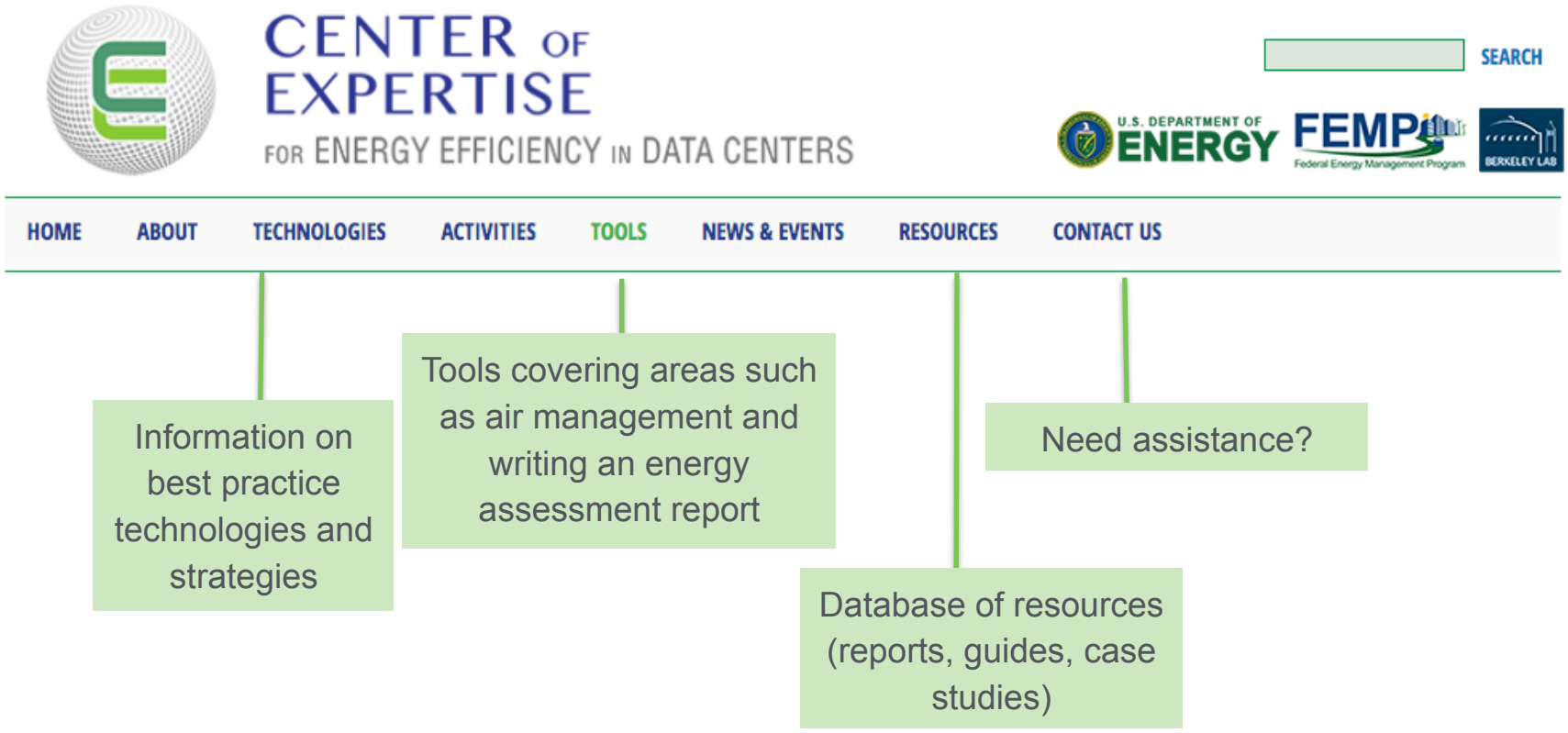
Center of Expertise for Energy Efficiency in Data Centers

Data Center Metering & Resource Guide

datacenters.lbl.gov

Center of Expertise for Energy Efficiency in Data Centers, cont.



Data Center Profiler (DC Pro) Tools

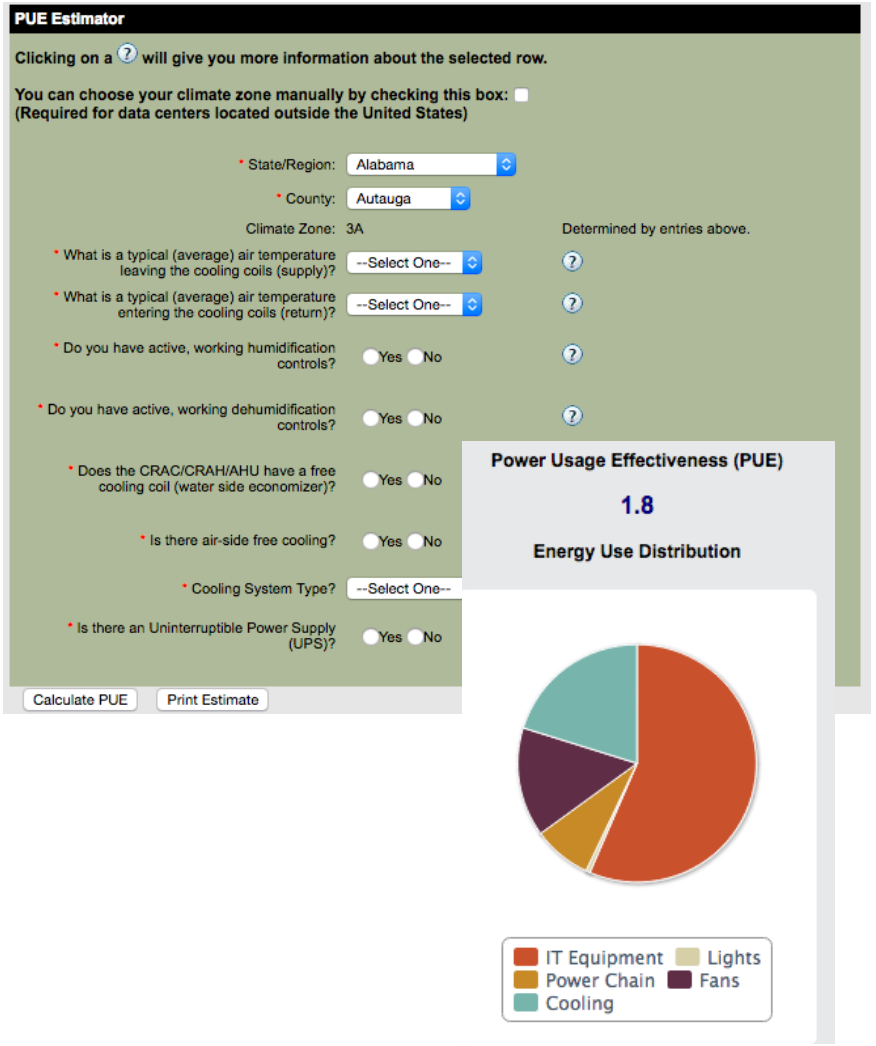
DC Pro Tools estimate PUE without sub-metering

DC Pro V4

DC Pro estimates current and potential PUE and energy use distribution. DC Pro also provides tailored recommended actions to start improvement process.

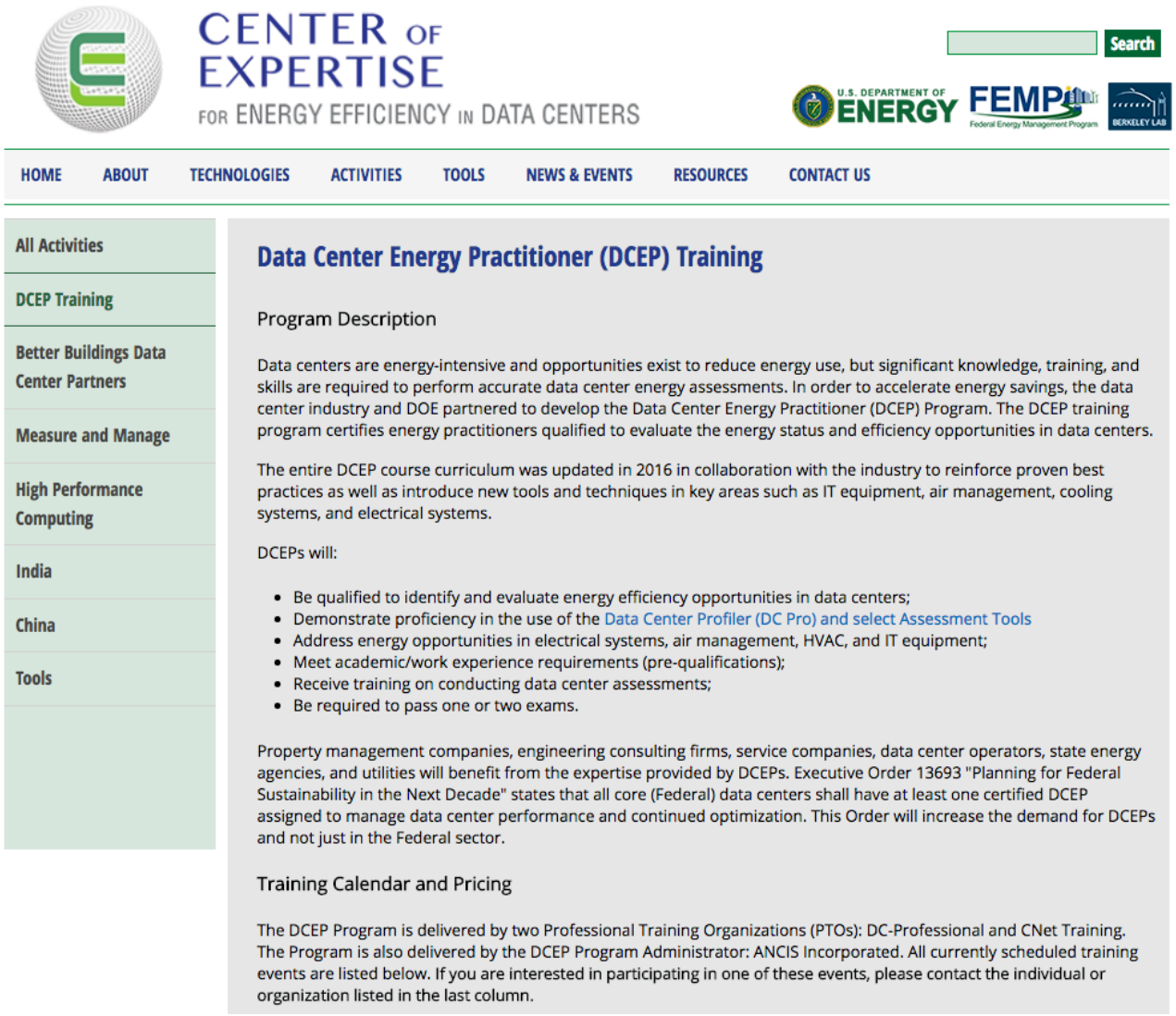
PUE Estimator, simplified DC Pro

PUE Estimator only asks questions that affect PUE and does NOT provide potential PUE or recommended actions.



datacenters.lbl.gov/dcpro

Data Center Energy Practitioner Program



datacenters.lbl.gov/dcep

Other Resources

- Data Center Metering and Resource Guide

  datacenters.lbl.gov/resources/data-center-metering-and-resource-guide
- PUE: a Comprehensive Examination of the Metric

  thegreengrid.org/en/Global/Content/white-papers/WP49-PUEAComprehensiveExaminationoftheMetric
- Executive Order 13696

  whitehouse.gov/the-press-office/2015/03/19/executive-order-planning-federal-sustainability-next-decade
- Executive Order 13696 Implementing Instructions

  whitehouse.gov/sites/default/files/docs/eo_13693_implementing_instructions_june_10_2015.pdf

Data Centers: Part of the Better Buildings Family

Better Buildings Challenge

Partners commit to increasing the energy efficiency of their entire data center and building portfolio by at least 20% within 10 years and share their implementation model, annual progress, at least one showcase project and results.

Better Buildings Data Center Accelerator

Partners commit to improve the energy efficiency of one or more data centers by at least 25% within 5 years, track and share progress, and showcase a project

Becoming a Data Center Partner

Why Sign Up?

- Leverage Dept. of Energy resources
- Network with your peers that have found solutions to similar challenges
- Gain Recognition for Leadership Activities
- Increase system reliability
- Reduce IT and infrastructure requirements
- Typical 20% to 40% reductions in energy cost with short paybacks

How to Sign Up:

- Email datacenterpartners@ee.doe.gov
- Commit to continuous improvement in energy efficiency of your data centers

Data Center Partner Roster – 34 partners

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In order to receive a certificate of completion, you **must** fill out the FEMP workshop evaluation form.

Access the FEMP workshop ***evaluation form*** and ***certificate of completion*** using this link:

https://fempcentral.energy.gov/Training/EventRegistration/EvaluationForm.aspx

Questions?

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- For content-related questions after the webinar, please use the Contact Us form on the Center of Expertise website: datacenters.lbl.gov/contact