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Data Center Metering and Resource Guide

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Learning Objectives

1. Know the definition of PUE.
2. Recognize stand-alone vs. embedded data centers.
3. Understand how to calculate PUE with imperfect metering.
4. Know how to recognize and overcome metering challenges.

Agenda

- Definitions, including Power Usage Effectiveness (PUE)
- EO 13693 mandates
- Discussion of data center types
- Anticipated scenarios of metering systems, how they integrate with data center types, and how to calculate PUE
- Metering methods, including leveraging existing meters and starting from scratch
- Challenges to installing meters and gathering data
- Resources

Definitions

PUE - Power Usage Effectiveness

- The ratio of total energy use to that of the information technology (IT) equipment.

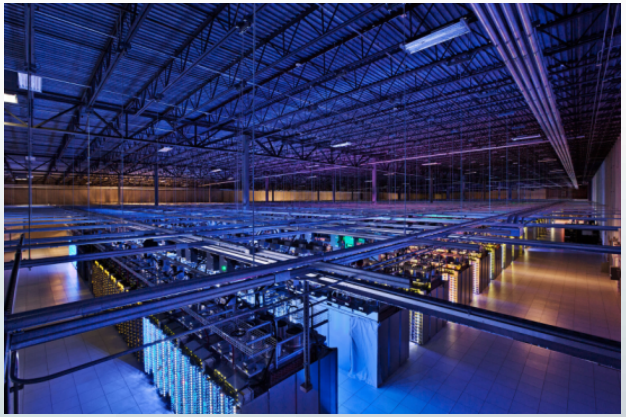
$$\text{PUE} = \frac{\text{Total Data Center Facility Annual Energy Use}}{\text{IT Equipment Annual Energy Use}}$$

- A measure of how efficiently the data center infrastructure uses energy.
- Three levels (1=Basic, 2=Intermediate, 3=Advanced)
  - Focus on Level 1

- **What PUE is good for (infrastructure overhead)**

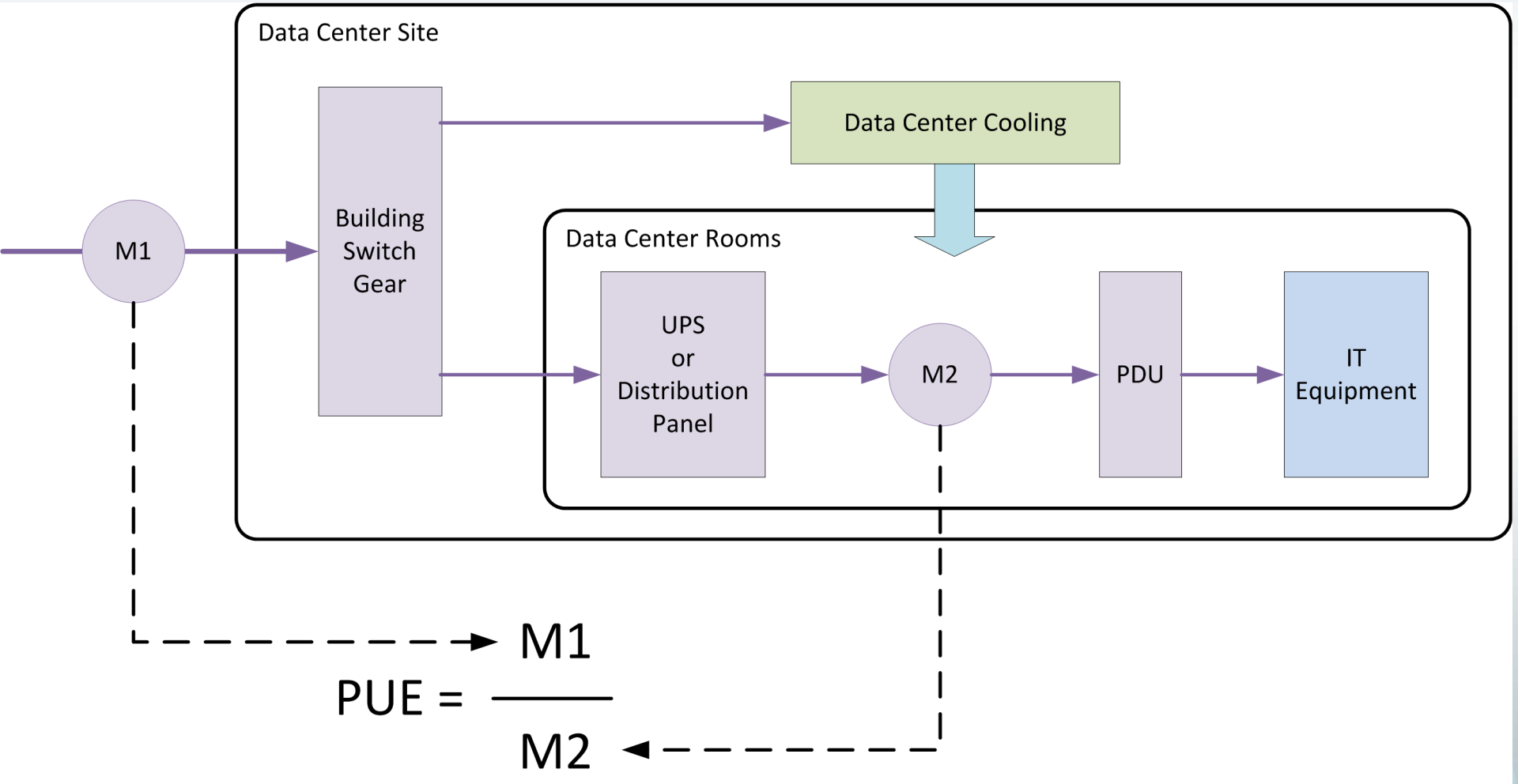
Executive Order 13693 Mandates (for Feds)

- 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)



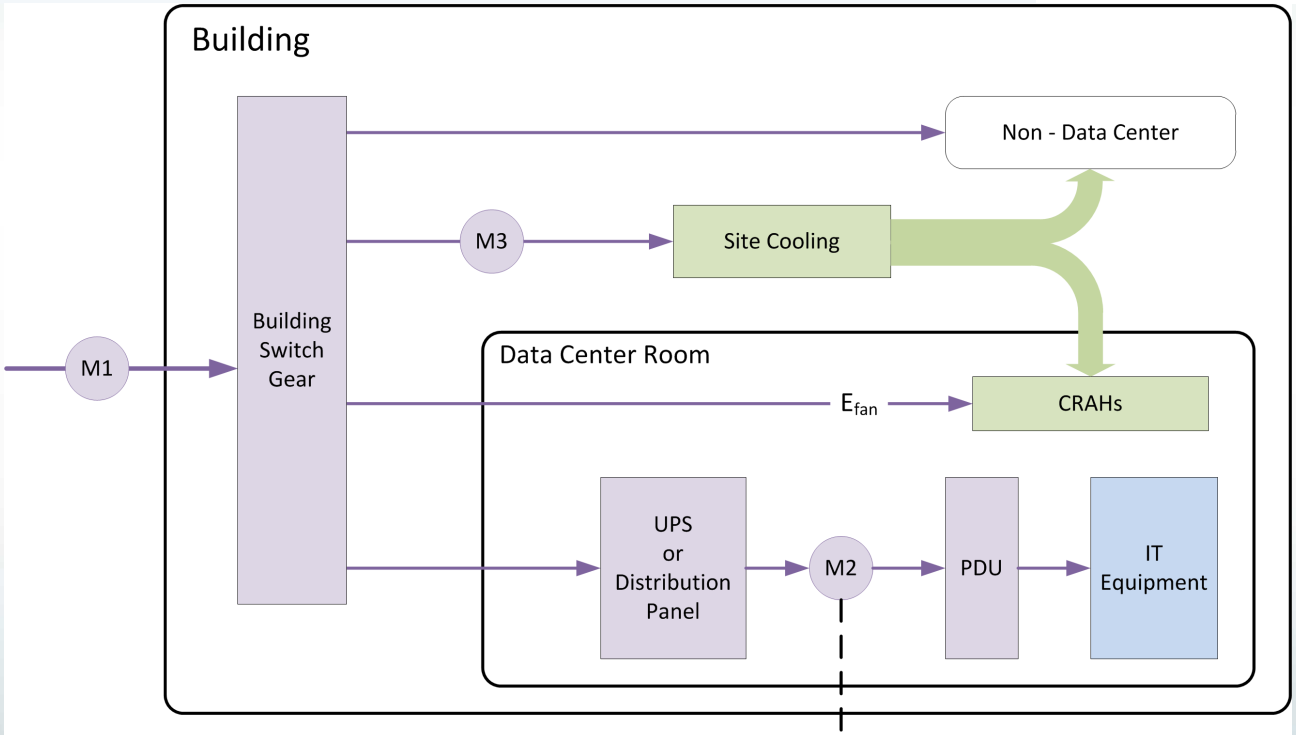
Data Center Types

1. Stand-alone



Data Center Types

2. Embedded, with additional metering

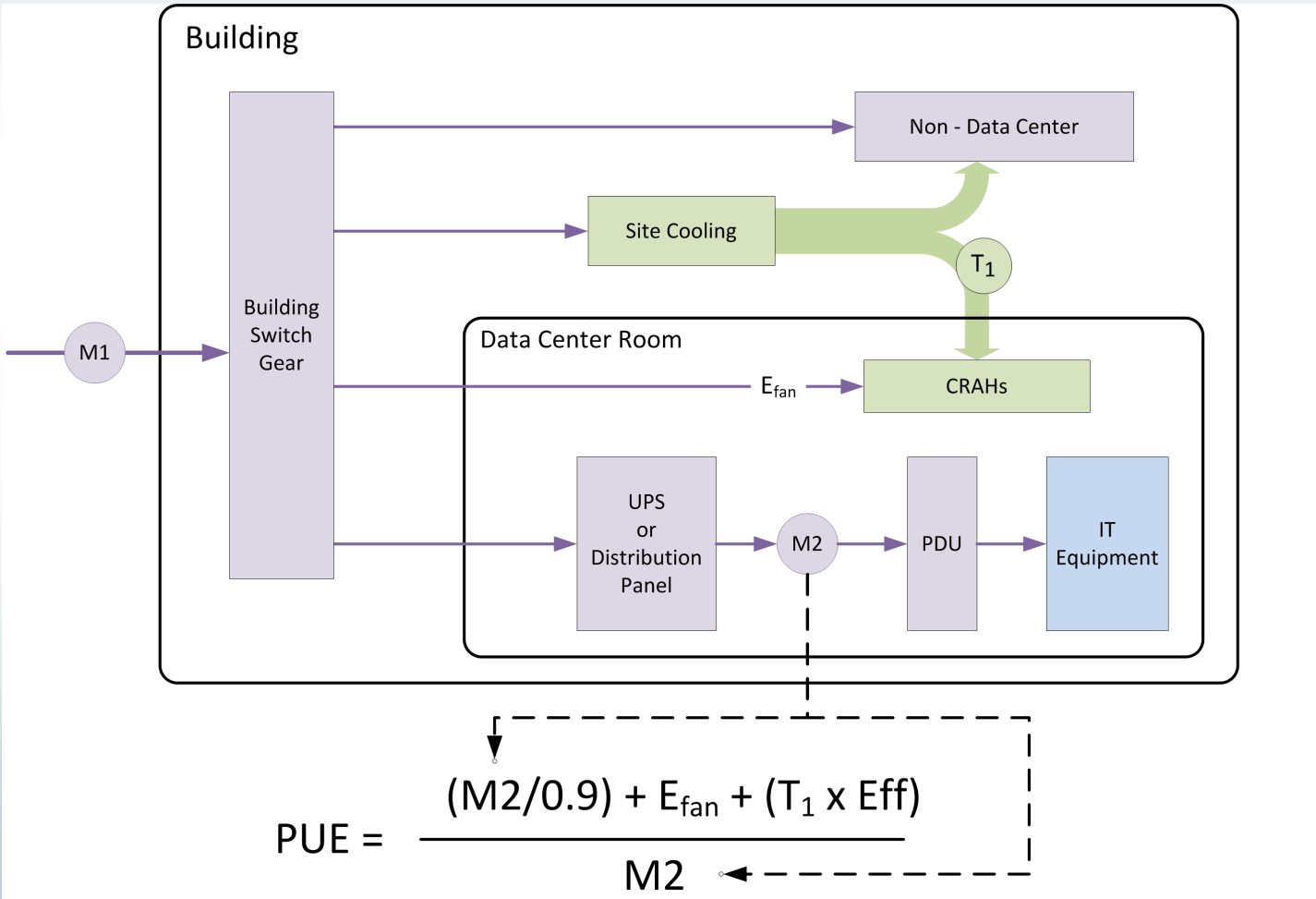


a. Chiller Plant Input M3

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

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”)

2b. Embedded, with additional metering, con't.



Data Center Cooling (thermal) T1

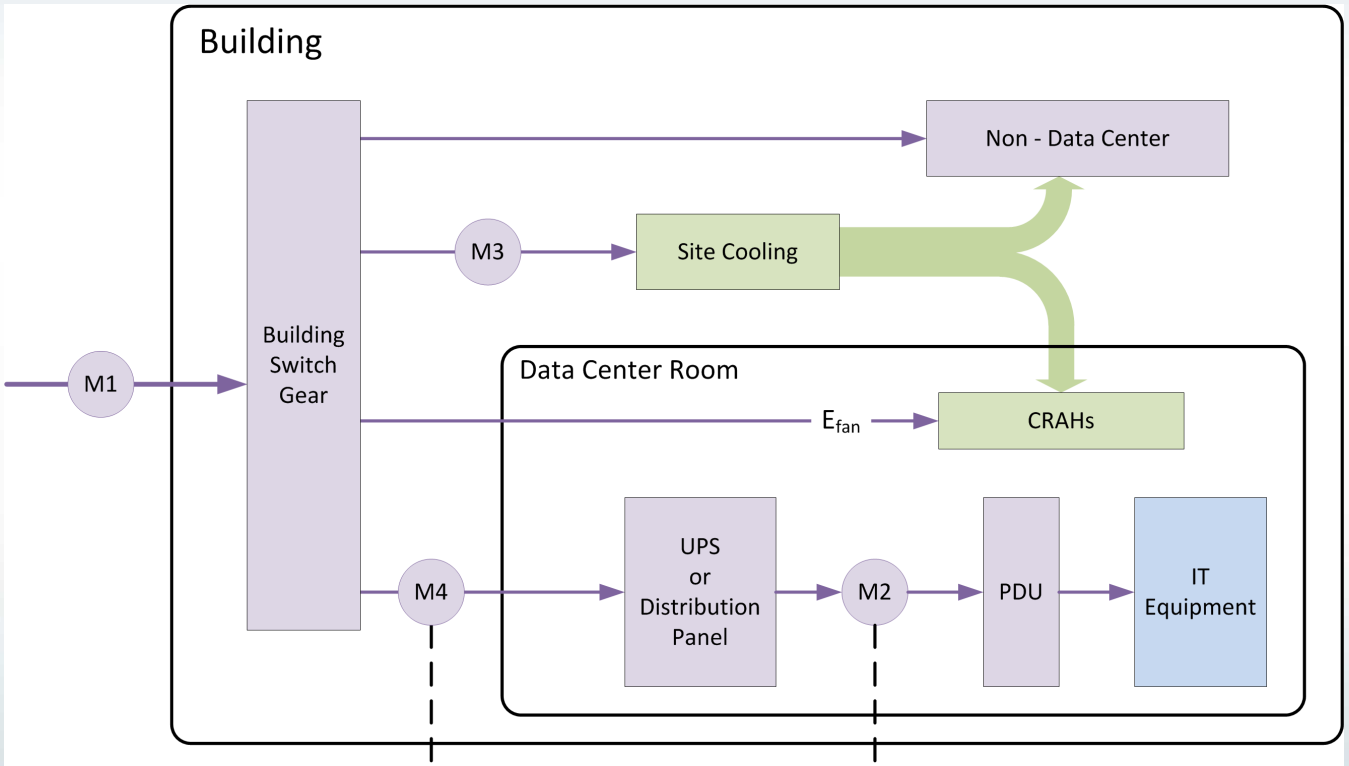
Eff = (Chiller efficiency + 0.2) kW/ton, where chiller efficiency can be obtained from Chiller Efficiency Table and 0.2 represents typical additional load of chilled water/condenser water pumps and cooling tower fans.

2. Embedded, with additional metering, con't

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, with additional metering, con't

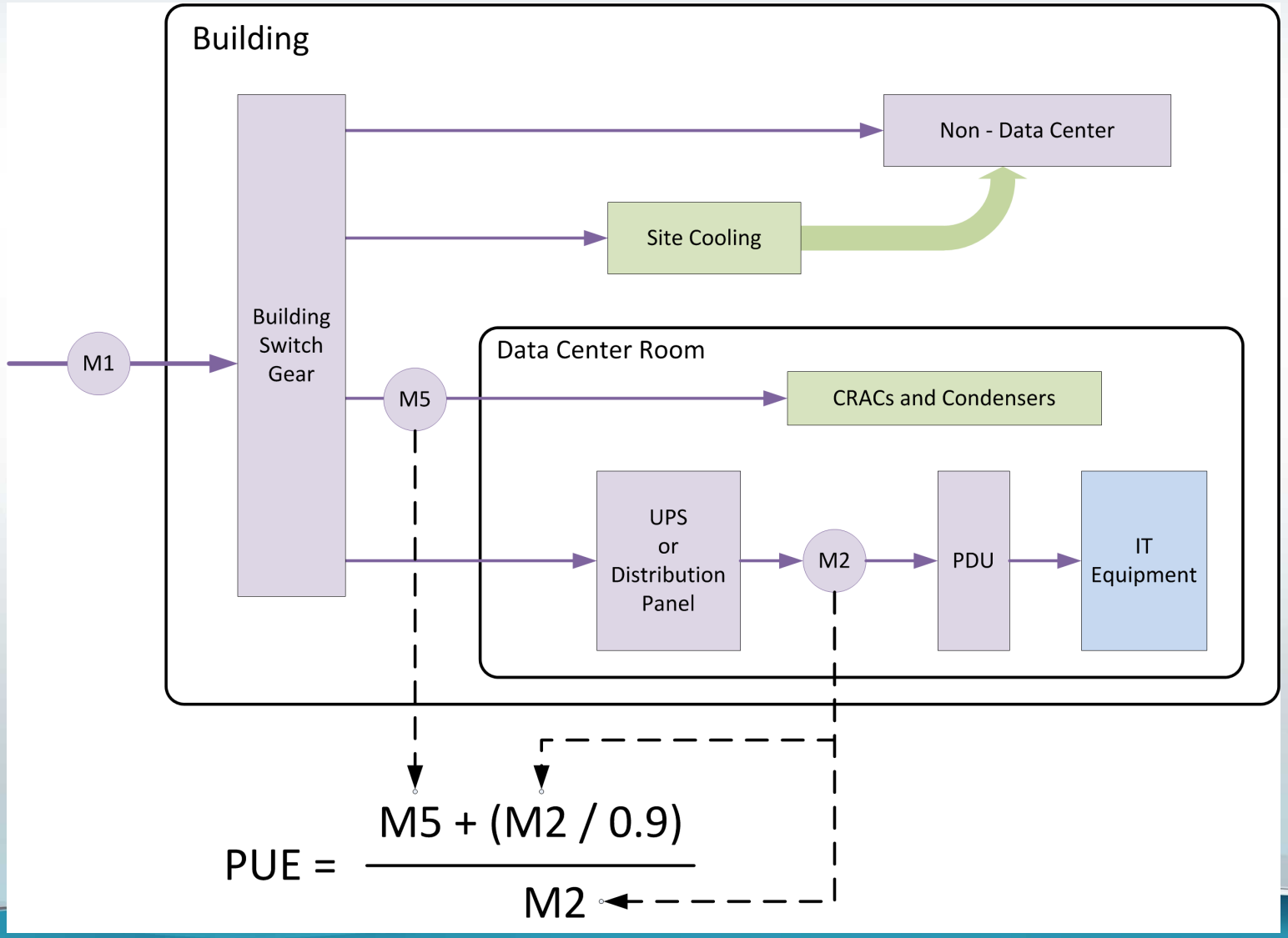


$$PUE = \frac{((M4 \times 1.03) + E_{fan}) \times (1 + (0.285 \times Eff))}{M2}$$

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")

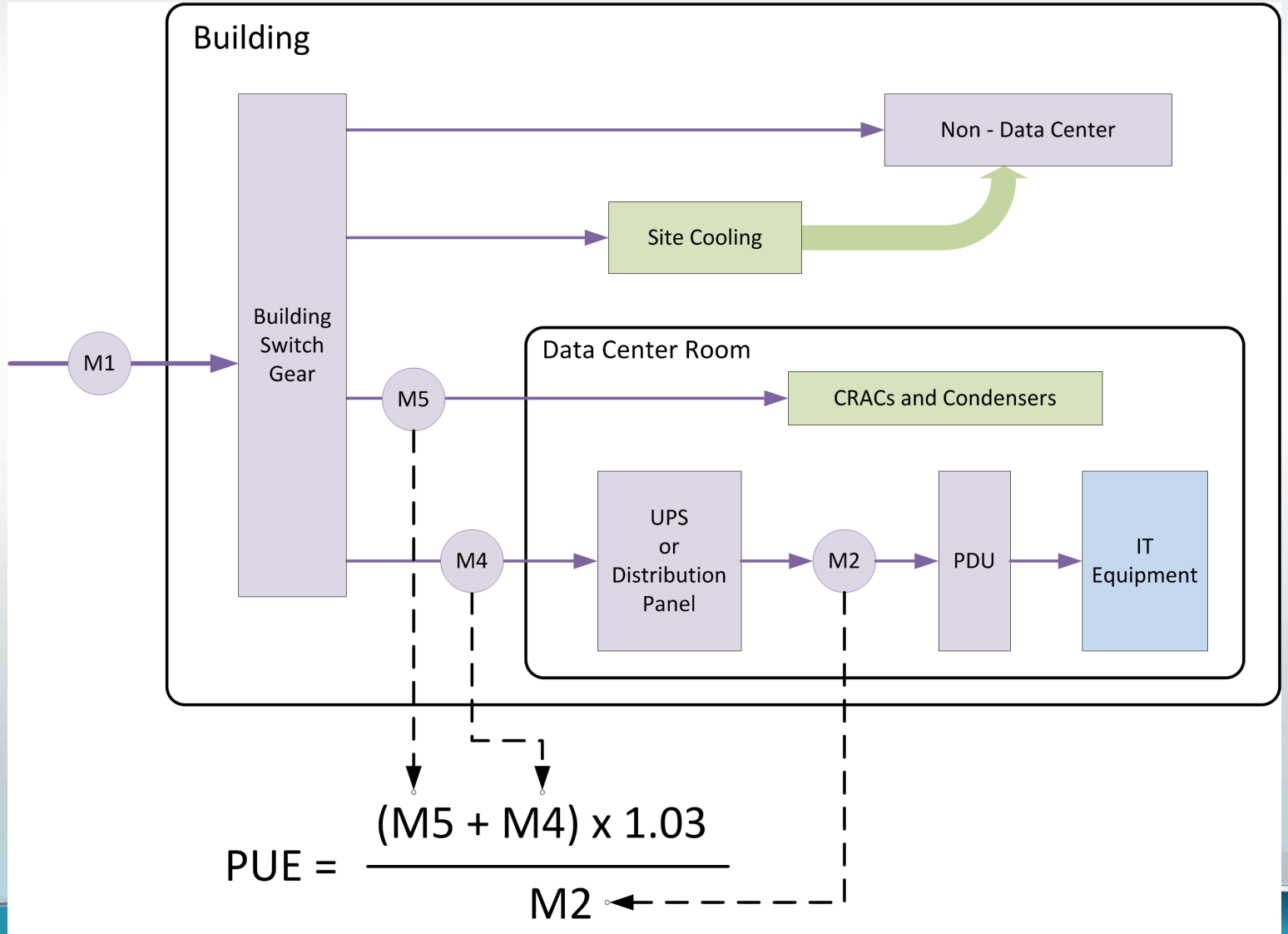
Chiller Plant input (M3) and UPS input (M4)

2d. Embedded, with additional metering, con't



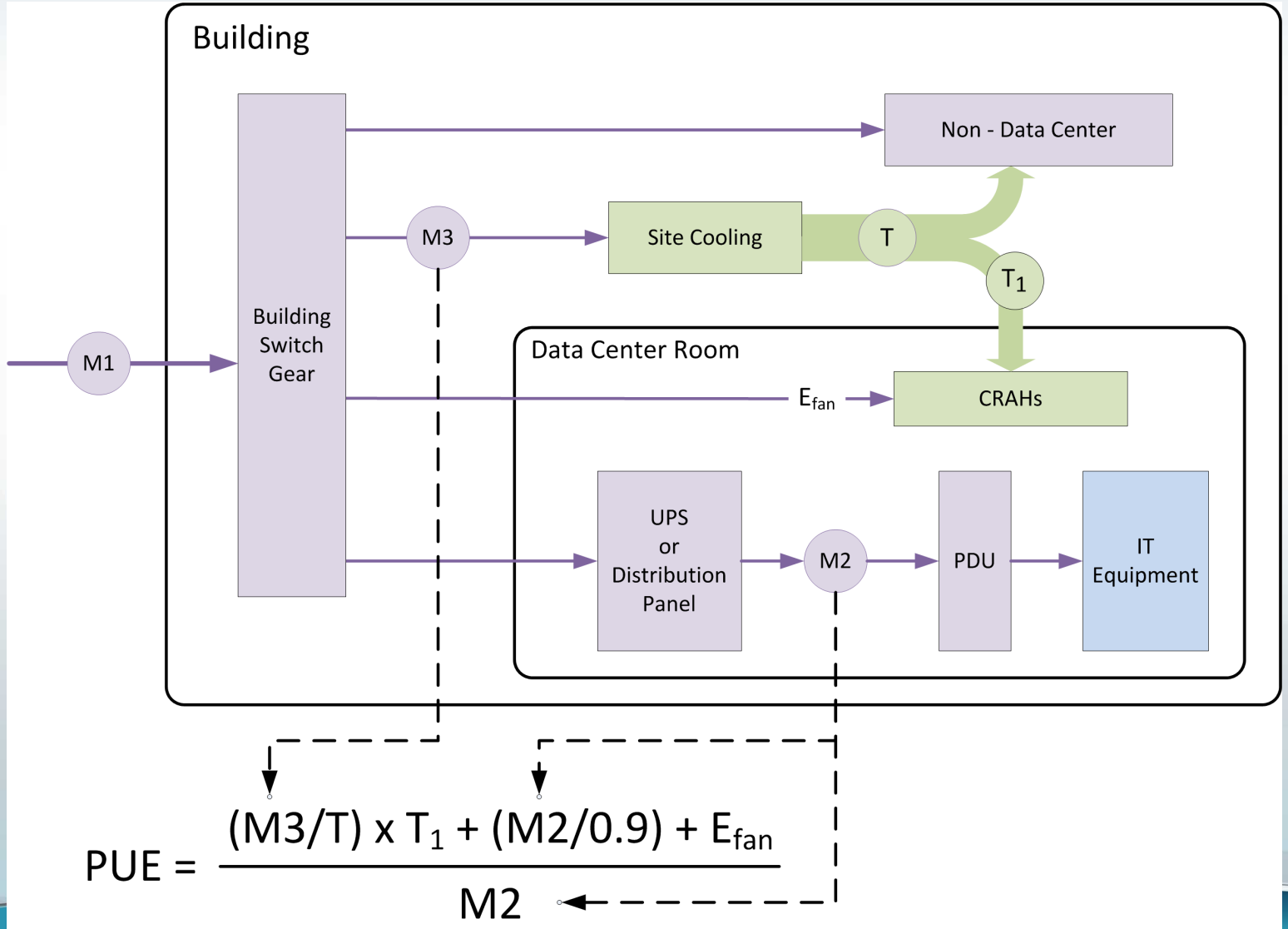
CRACs and Condensers input (M5)

2e. Embedded, with additional metering, con't



UPS input (M4) and CRACs and Condensers Input (M5)

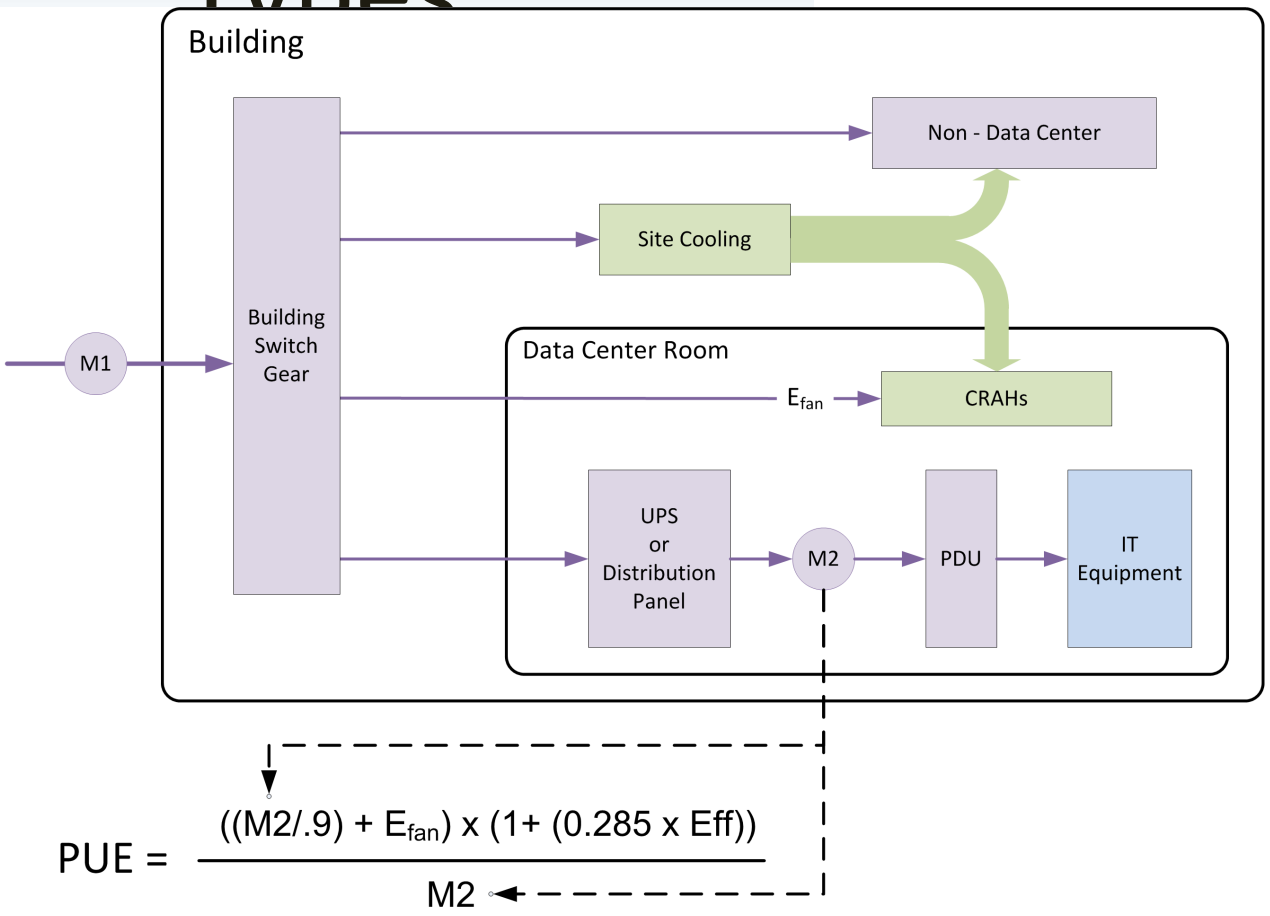
2f. Embedded, with additional metering, con't



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

Data Center Types

3. Embedded, with no additional metering beyond UPS output (M2)



a. 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 additional metering, con't

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

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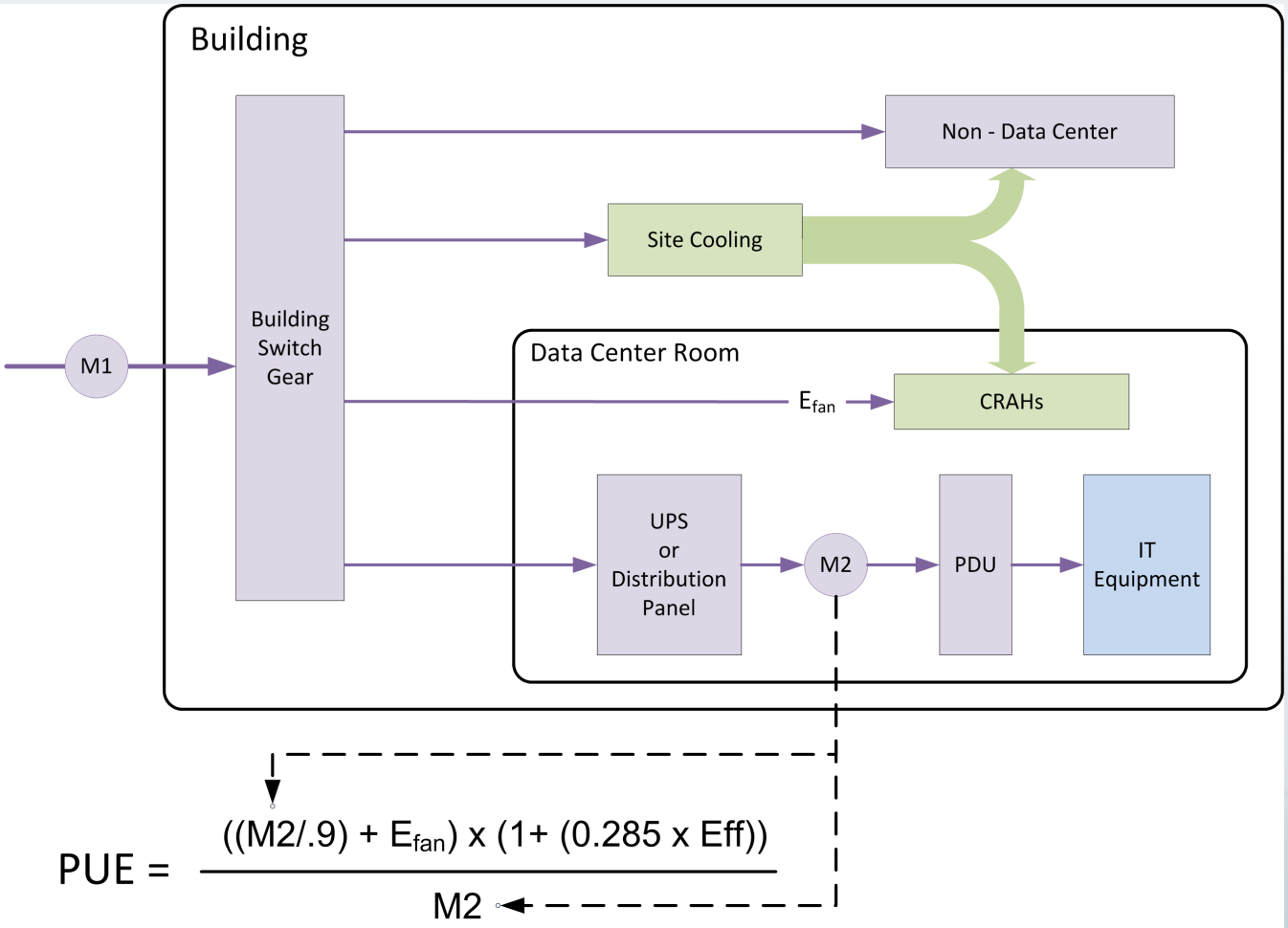
	≥600 ton	≤ .539	kW/ton-IPLV

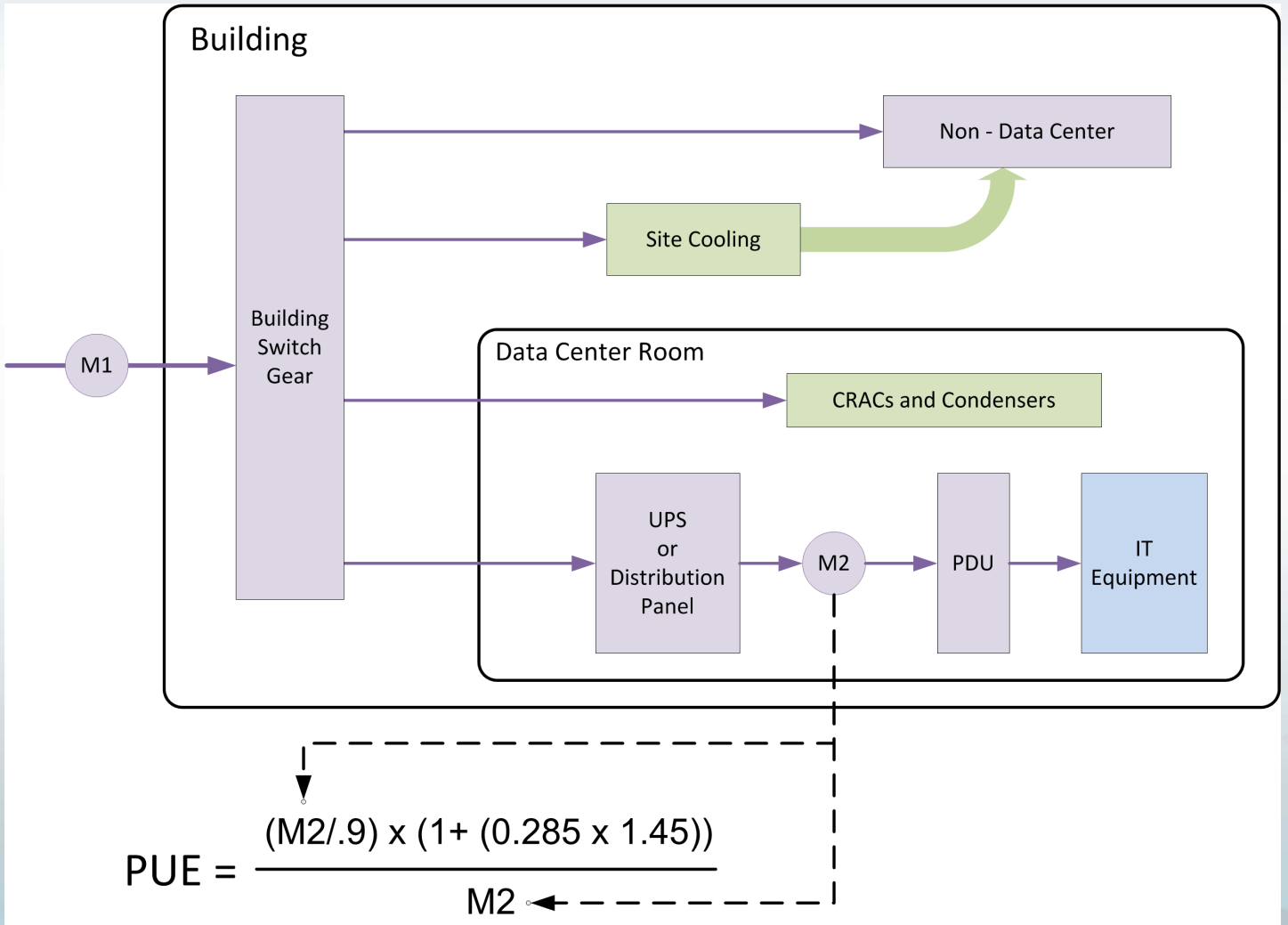
3b. Embedded, with no additional metering, con't



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.

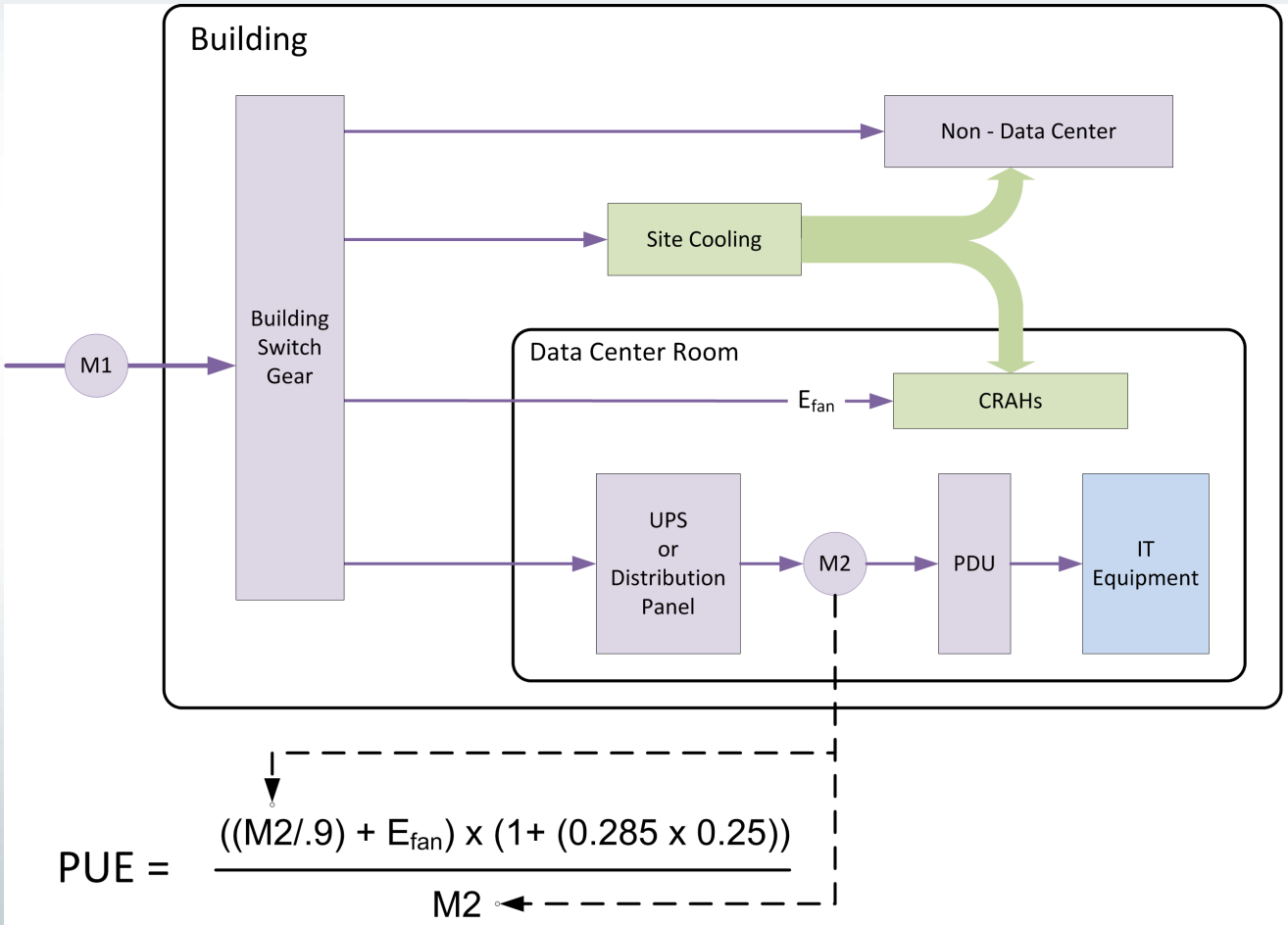
3c. Embedded, with no additional metering, con't



CRACs with air-cooled condensers

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

3d. Embedded, with no additional metering, con't



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.

Steps in Metering

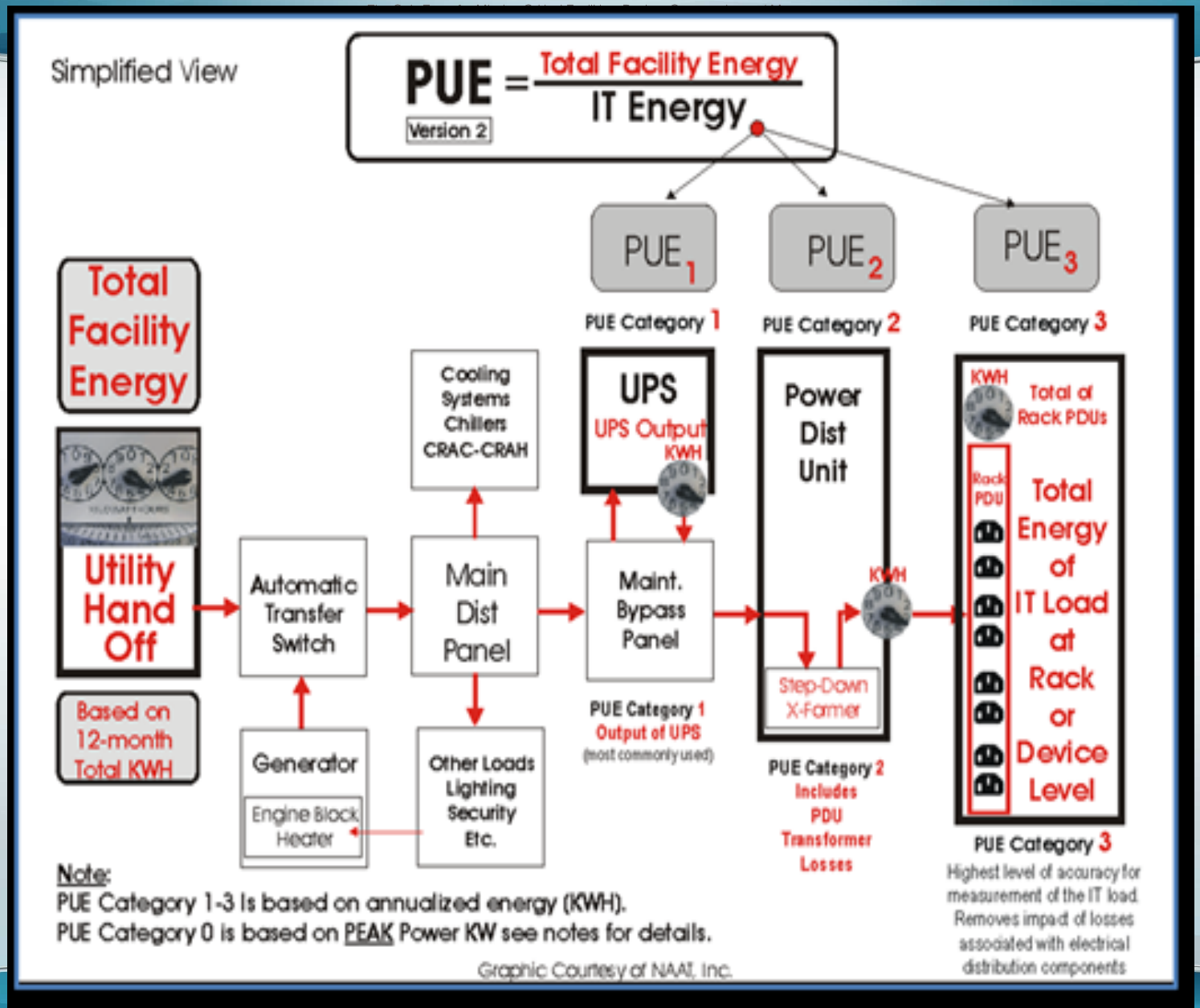
1. Plan
   - Determine data center type
   - Determine existing metering
   - Review drawings
   - Interview staff/visit site
   - Decide on PUE calculation approach

Steps in Metering, con't

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

Challenges to Meter Installation & Possible Solutions

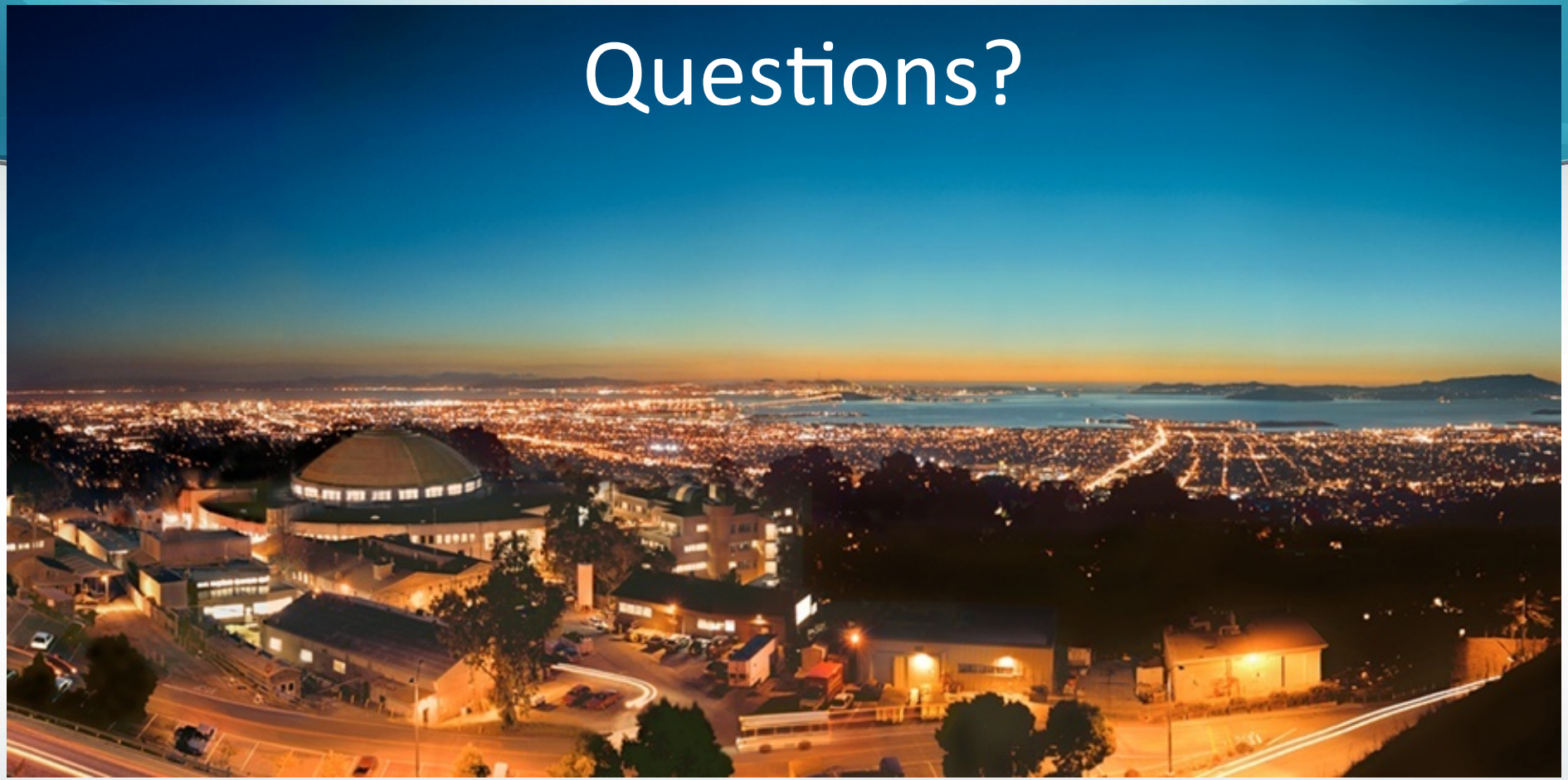
- Electrical metering: Shut down one system at a time in N+x systems
- Electrical metering: Wait for system maintenance
- Thermal metering: Use hot-taps or ultrasonic meters


Simplified View
PUE = Total Facility Energy / IT Energy
Version 2
PUE1
PUE2
PUE3
PUE Category 1
PUE Category 2
PUE Category 3
Total Facility Energy
Utility Hand Off
Based on 12-month Total KWH
Automatic Transfer Switch
Generator
Engine Block Heater
Cooling Systems Chillers CRAC-CRAH
Main Dist Panel
Other Loads Lighting Security Etc.
UPS
UPS Output KWH
Maint. Bypass Panel
PUE Category 1 Output of UPS (most commonly used)
Power Dist Unit
KWH
Step-Down X-Former
PUE Category 2 Includes PDU Transformer Losses
KWH
Total of Rack PDUs
Rack PDU
Total Energy of IT Load at Rack or Device Level
PUE Category 3
Highest level of accuracy for measurement of the IT load. Removes impact of losses associated with electrical distribution components
Note:
PUE Category 1-3 Is based on annualized energy (KWH).
PUE Category 0 is based on PEAK Power KW see notes for details.
Graphic Courtesy of NAAT, Inc.

Resources

- Data Center Metering and Resource Guide:
  https://datacenters.lbl.gov/resources/data-center-metering-and-resource-guide
- PUE: a Comprehensive Examination of the Metric:
  https://www.thegreengrid.org/en/Global/Content/white-papers/WP49-PUEAComprehensiveExaminationoftheMetric
- Center of Expertise for Energy Efficiency in Data Centers:
  https://datacenters.lbl.gov/
- Data Center Energy Practitioner (DCEP) Program:
  https://datacenters.lbl.gov/dcep

Questions?



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