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U.S. Department of Energy Federal Energy Management Program

Practical Considerations for Metering and Power Usage Effectiveness

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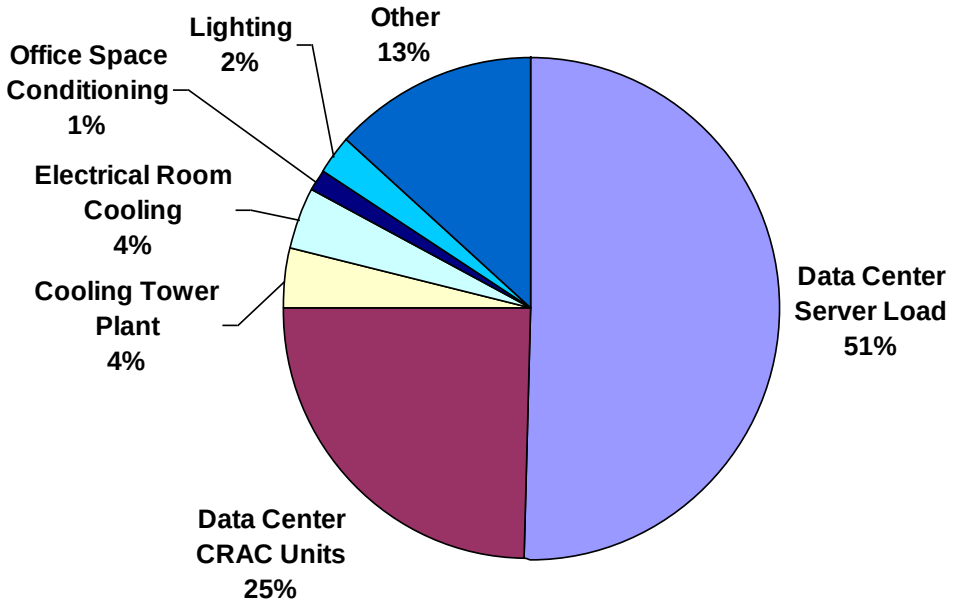
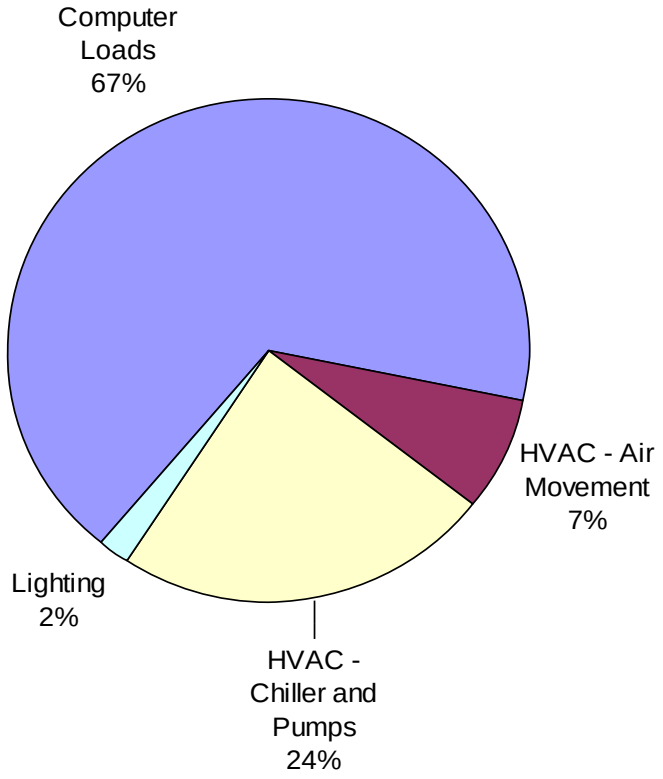
Implementing Instructions for New Directive

Installing and monitoring advanced energy meters in all data centers by fiscal year 2018

- Advanced energy meters installed by agencies *as appropriate* in all data centers shall be meters that enable the active tracking of power usage effectiveness (PUE) for the data center, as well as promote implementation of Data Center Infrastructure Management (DCIM).
- All new data centers shall include advanced *energy and water* meters.
- Agencies shall evaluate consolidation/closure for existing data centers unable to cost-effectively install meters by FY 2018

Benchmarking Energy Performance: So What is PUE?



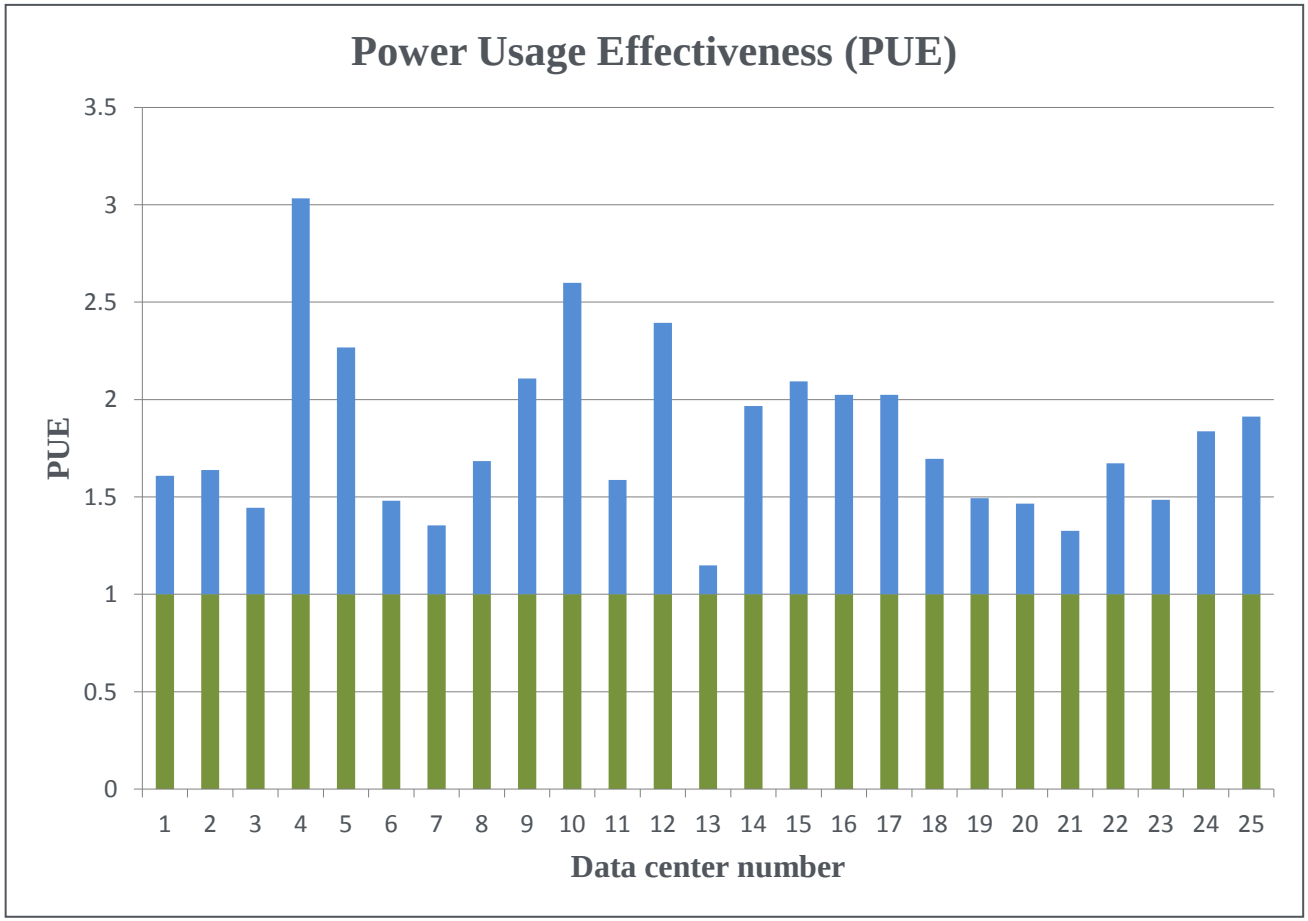


Power Usage Effectiveness

- 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

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

Power Usage Effectiveness, cont.



PUE Measurement Categories Recommended by the Green Grid

Table 1: PUE measurement categories recommended by this task force.

	PUE Category 0*	PUE Category 1	PUE Category 2	PUE Category 3
IT energy measurement location	UPS output	UPS output	PDU output	IT equipment input
Definition of IT energy	Peak IT electric demand	IT annual energy	IT annual energy	IT annual energy
Definition of Total energy	Peak Total electric demand	Total annual energy	Total annual energy	Total annual energy

*For PUE Category 0 the measurements are electric demand (kW).

Courtesy of TGG

Standalone Data Center

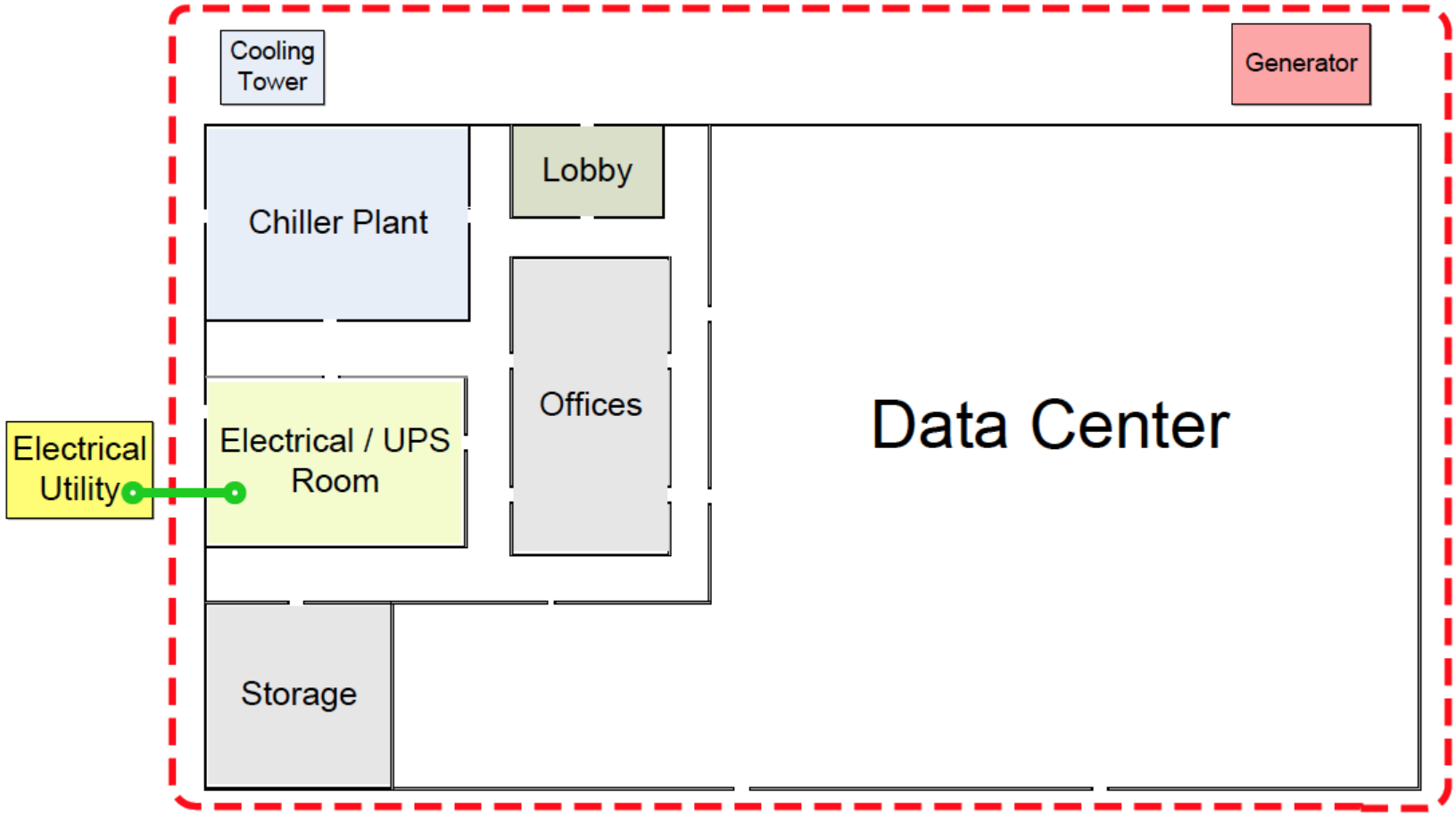


Figure 12. Control volume for a dedicated data center

Embedded Data Center

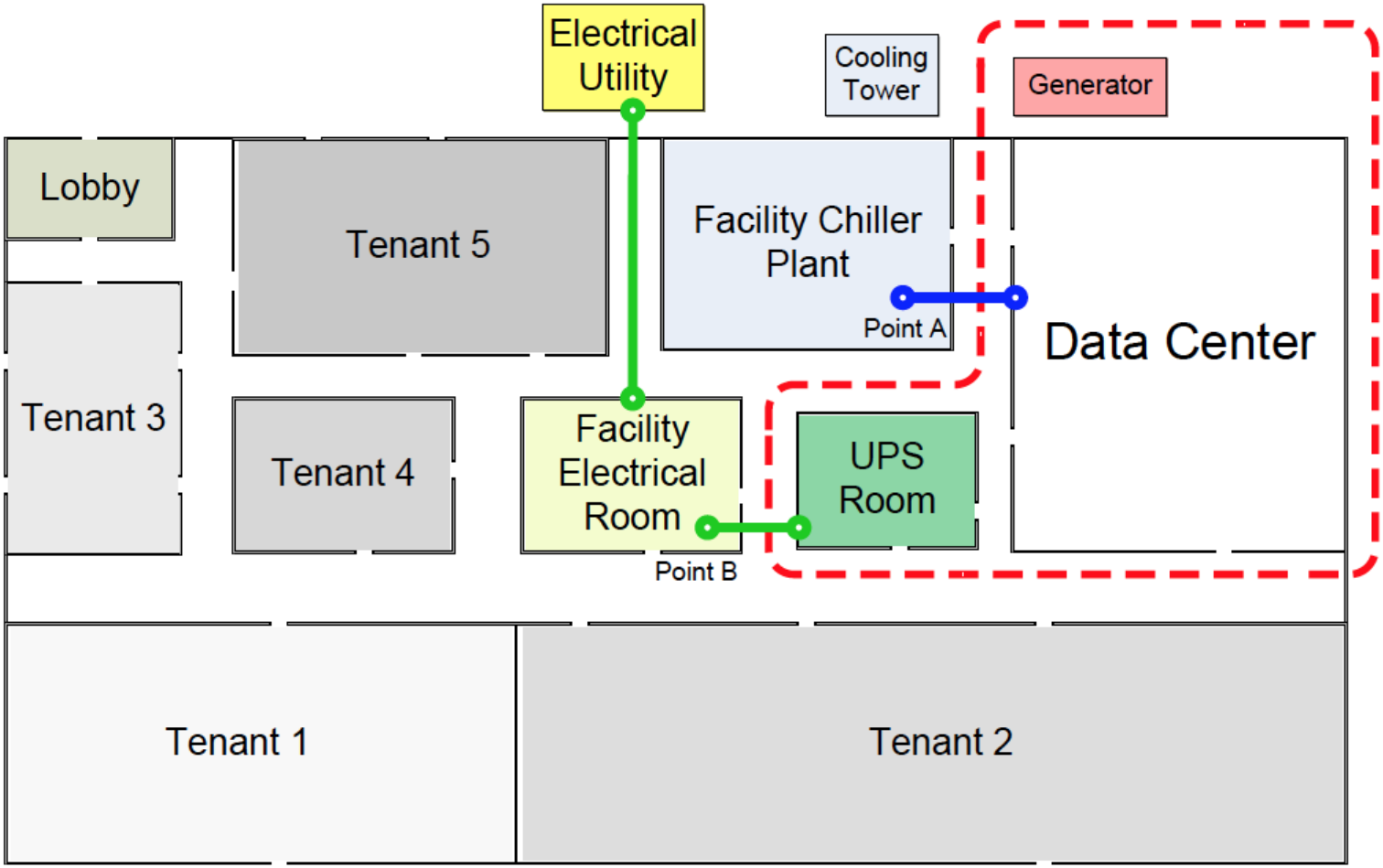


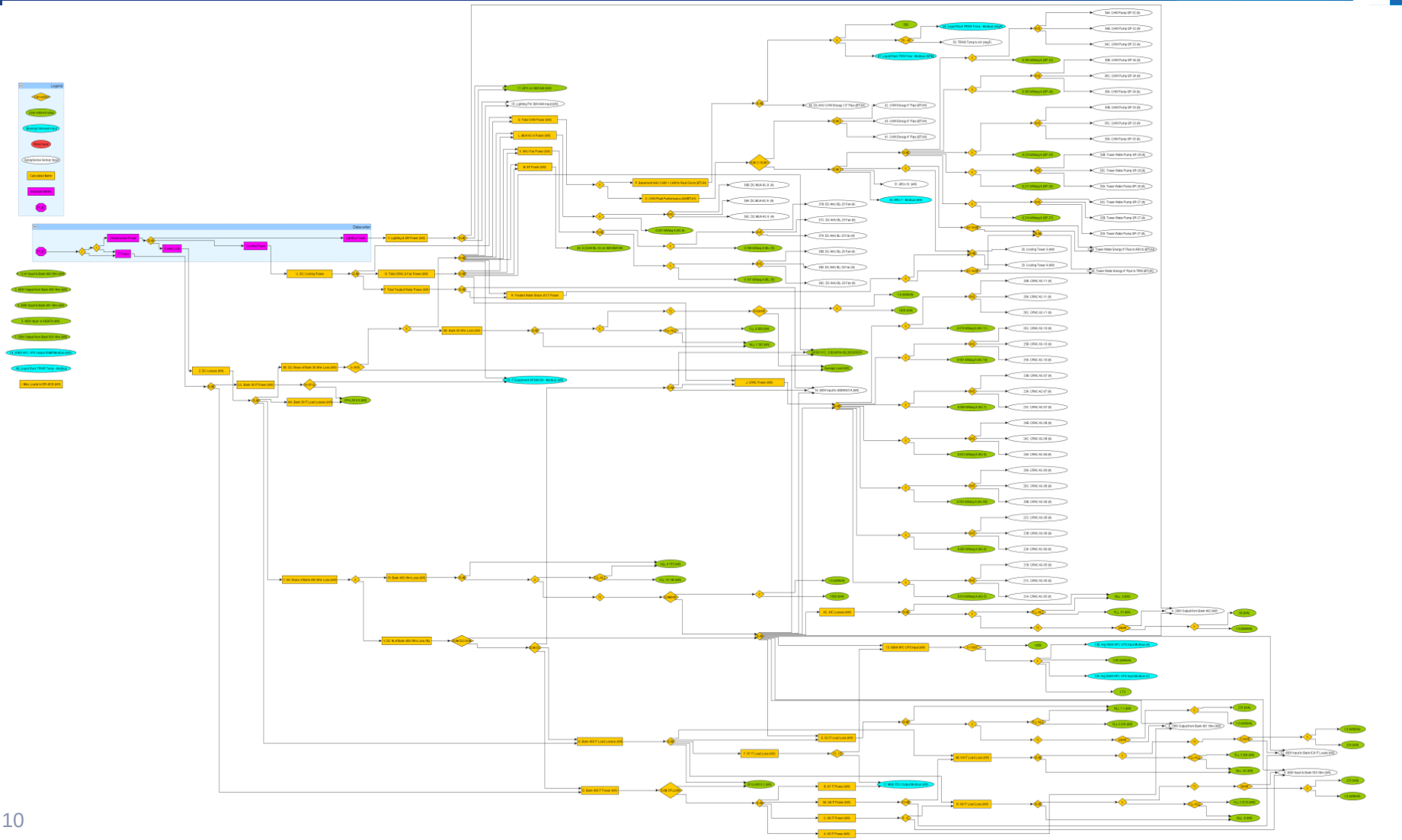
Figure 13. Control volume for a data center within a mixed-use building

Infrastructure Components

- Energy using Power and HVAC components contributing to the total data center energy use
- Each could require one or more meters in an embedded data center

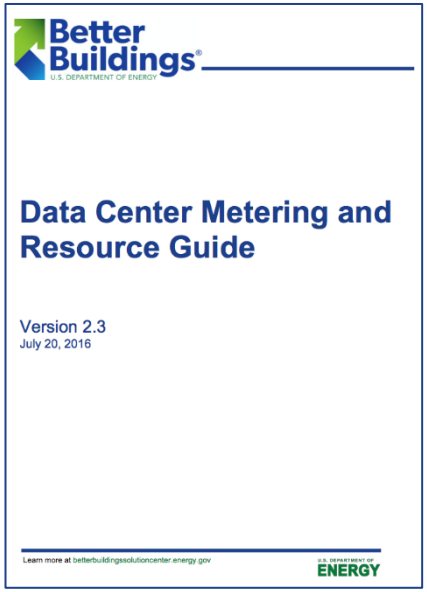
Power
Automatic transfer switches (ATS)
Switchgear
UPS
DC batteries/rectifiers (non UPS – telco nodes)
Generators
Transformers (step down)
Static transfer switches (STS)
Power distribution units (PDUs)
Rack distribution units (RDUs)
Breaker panels
Distribution wiring
Lighting
Heating Ventilation and Air Conditioning (HVAC)
Cooling towers
Condensers and condenser water pumps
Chillers
Heating Ventilation and Air Conditioning (HVAC)
Chilled water pumps
Water treatment systems
Well pumps
Computer room air conditioners (CRACs)
Computer room air handlers (CRAHs)
Dry coolers
Air compressors
Supply fans
Return fans
Air economizers
Water-side economizers
Dehumidifiers
Humidifiers
Heaters
In-row and in-rack cooling solutions
Condensate pumps

PUE Calculation Diagram



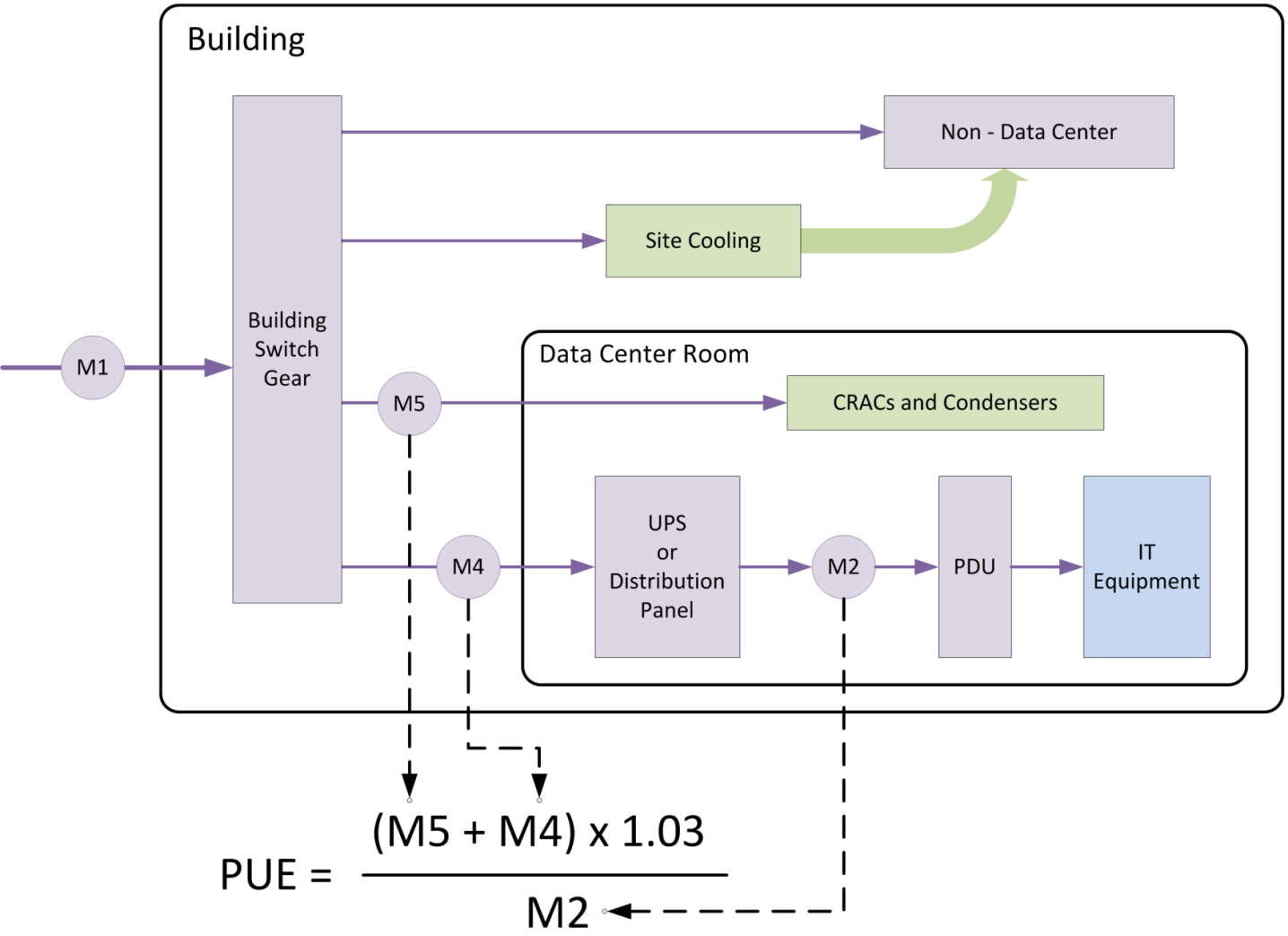
Getting Started

- Data Center Metering and Resource Guide
  - A practical guide to measuring PUE



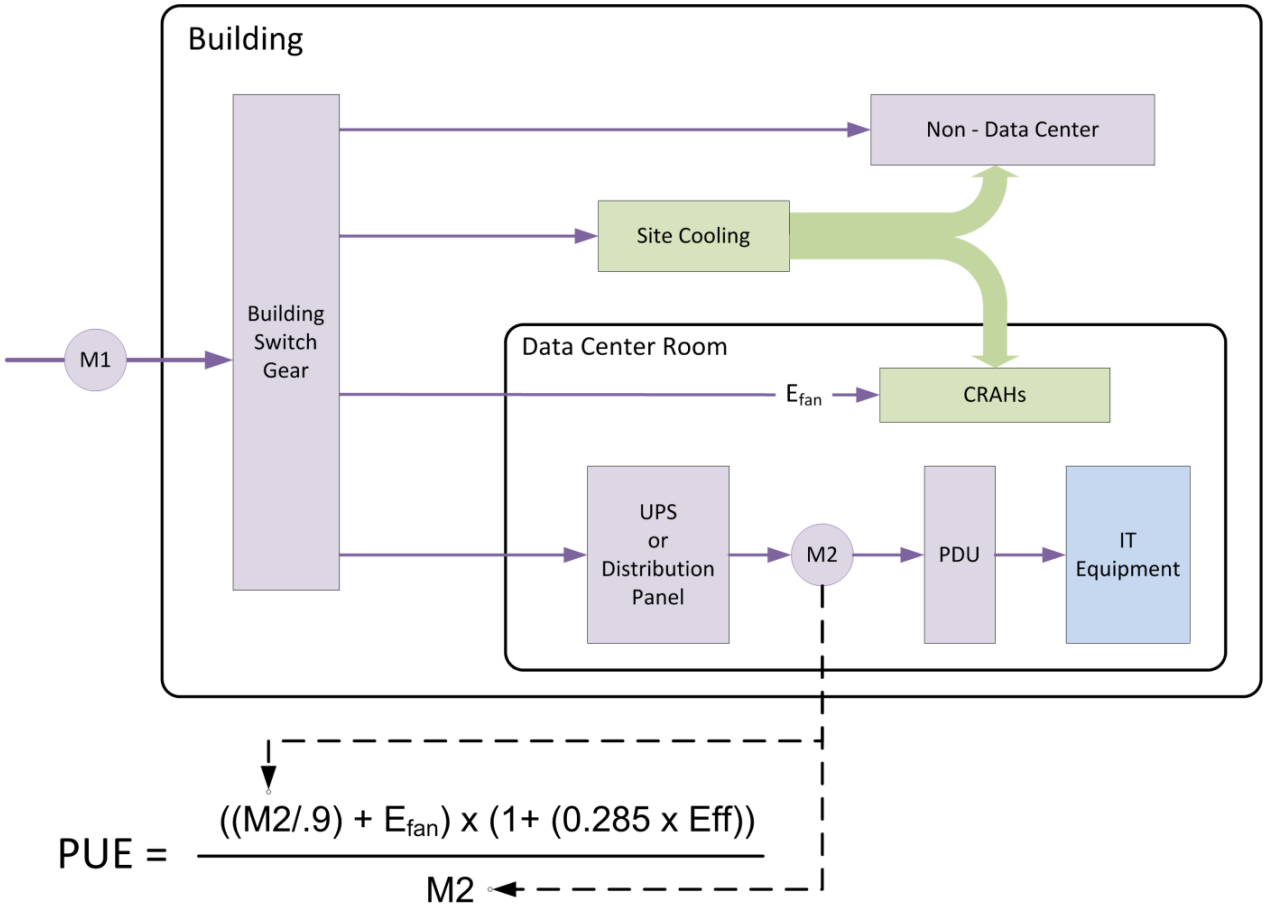
datacenters.lbl.gov/resources/data-center-metering-and-resource-guide

Embedded w/metering



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

Embedded, no additional metering beyond UPS



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.

Assumed Chiller Plant Efficiencies

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

Estimates Don’t Tell the Whole Story

- While such compromises allow one to estimate PUE, it does not allow one to track performance and improvement

Meter What is Important

- Need to meter enough to show changes (improvements with energy efficiency measures)
- Compromises reduce ability to compare to others but perhaps not to self
  - Estimate some loads such as:
    - Generator heaters
    - Lights
    - Transformer and cable losses
    - Estimates based on:
      - Engineering calculations
      - One time measurements of constant loads
  - Assume efficiencies
    - Chiller plant (see prior table)
    - UPS (use manufacturer's curves)

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

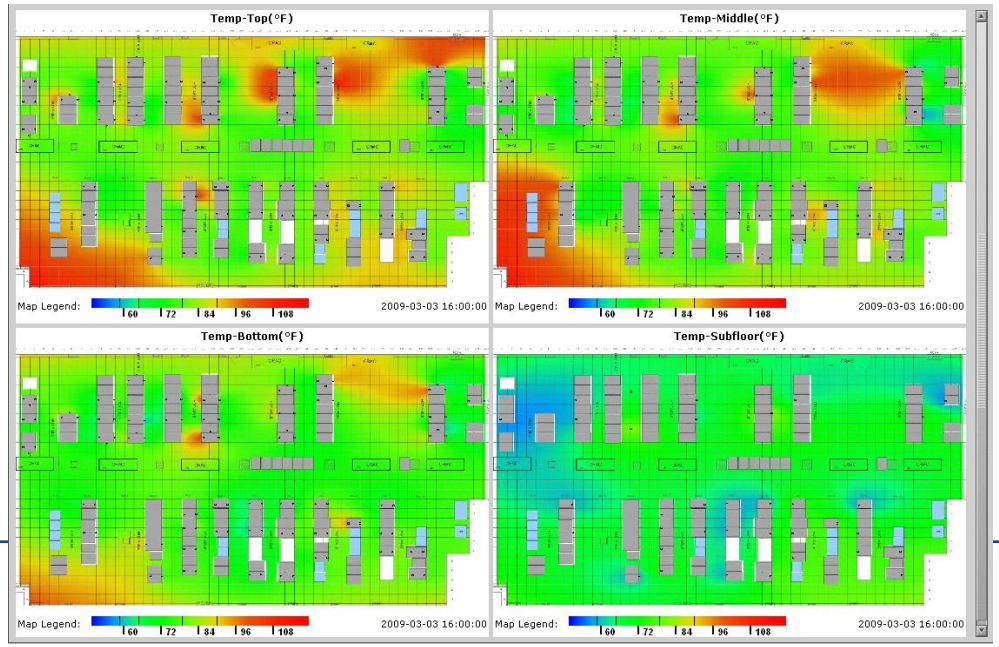
Lessons Learned Determining PUE at LBNL

- Is case-by-case—every center is different
- Take advantage of existing meters
- Minimize estimation
- Involves numerous meters

- How much is enough?
- How much is too much?

Other Needs

- Sub-metering often required to calculate PUE but also desirable for evaluation
  - TGG Level 2 and 3
  - Partial PUE (system level metrics and benchmarking)
- Metering environmental conditions
  - Measure temperature at inlet to IT equipment (top and bottom of rack)
  - Facilitates air management
  - Provides confidence to increase temperatures
  - Thermal maps can convert hundreds of measurement points into one picture:
- IT Metrics
  - Utilization



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
- Center of Expertise for Energy Efficiency in Data Centers

  datacenters.lbl.gov/

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