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Practical Considerations for Metering and Power Usage Effectiveness

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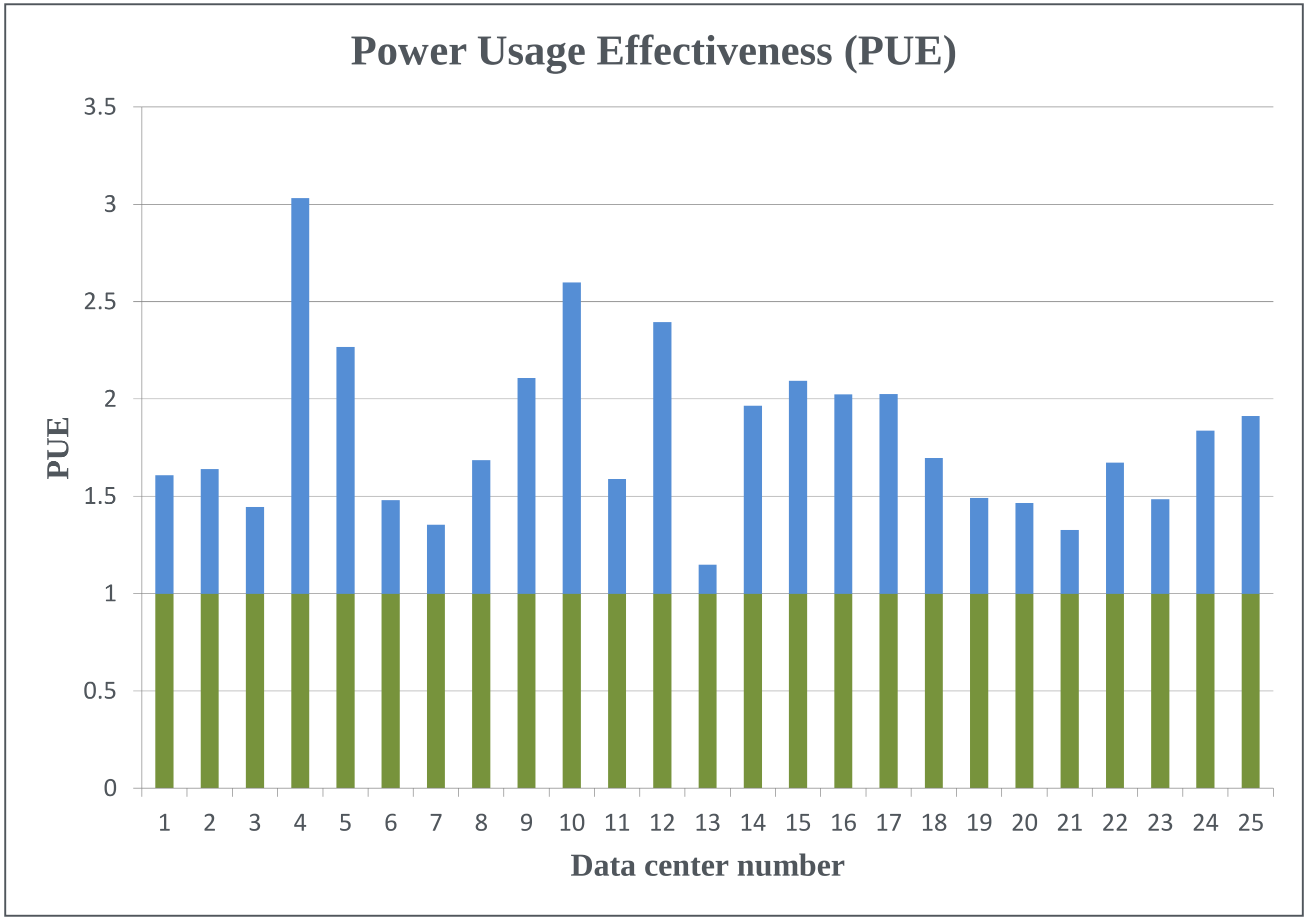
Power Usage Effectiveness

- 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

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

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

Green Grid's 3 Level Approach

Table 1. High-level breakdown of The Green Grid's three-level approach to PUE measurement

	Level 1 (L1) Basic	Level 2 (L2) Intermediate	Level 3 (L3) Advanced
IT Equipment Energy	UPS Outputs	PDU Outputs	IT Equipment Input
Total Facility Energy	Utility Inputs	Utility Inputs	Utility Inputs
Measurement Interval	Monthly/Weekly	Daily/Hourly	Continuous (15 minutes or less)

- Focus on Level 1, the default for Better Buildings
- Note table assumes standalone data centers where total is measured by the utility inputs

Standalone Data Center

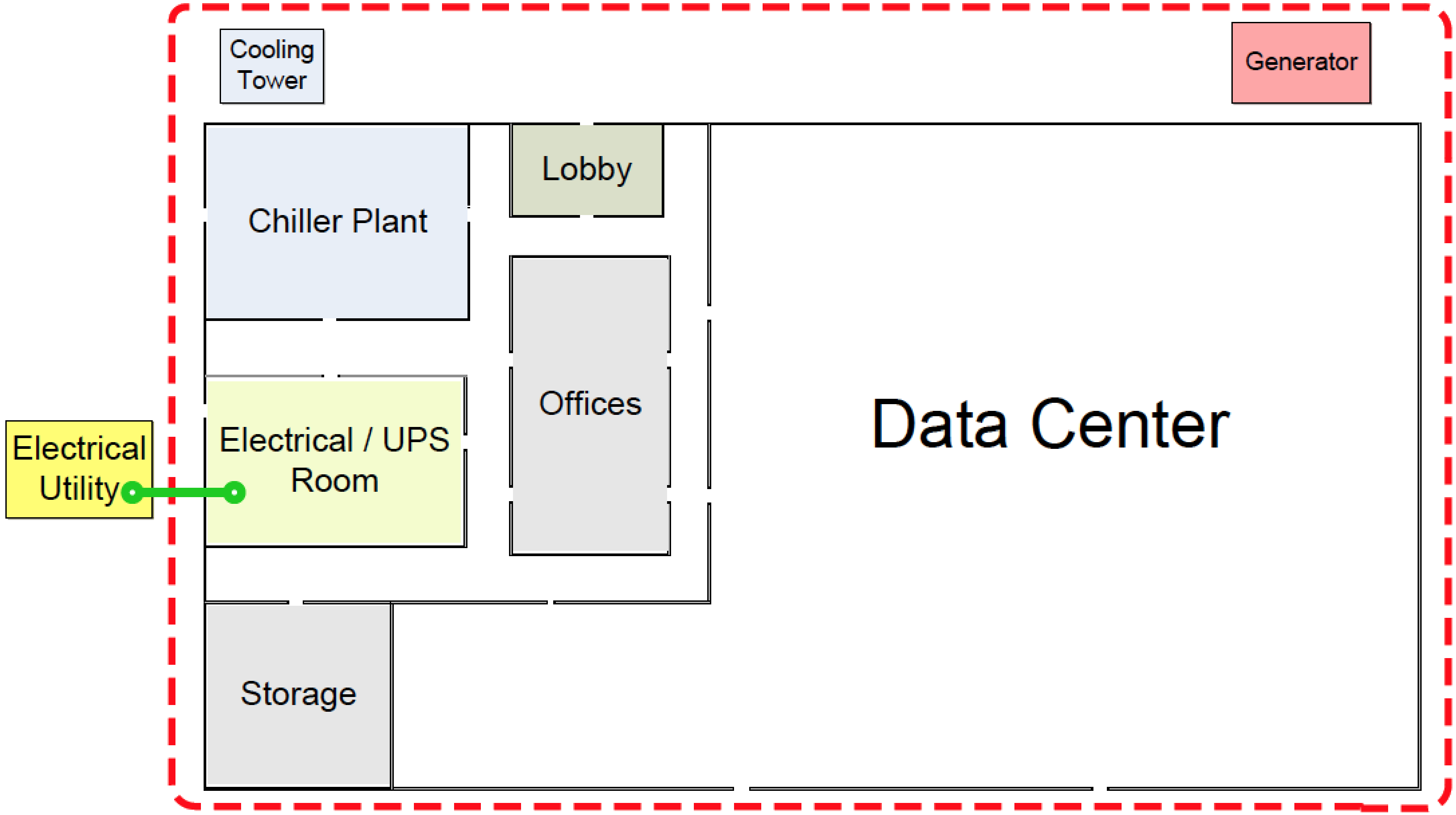


Figure 12. Control volume for a dedicated data center

Embedded Data Center

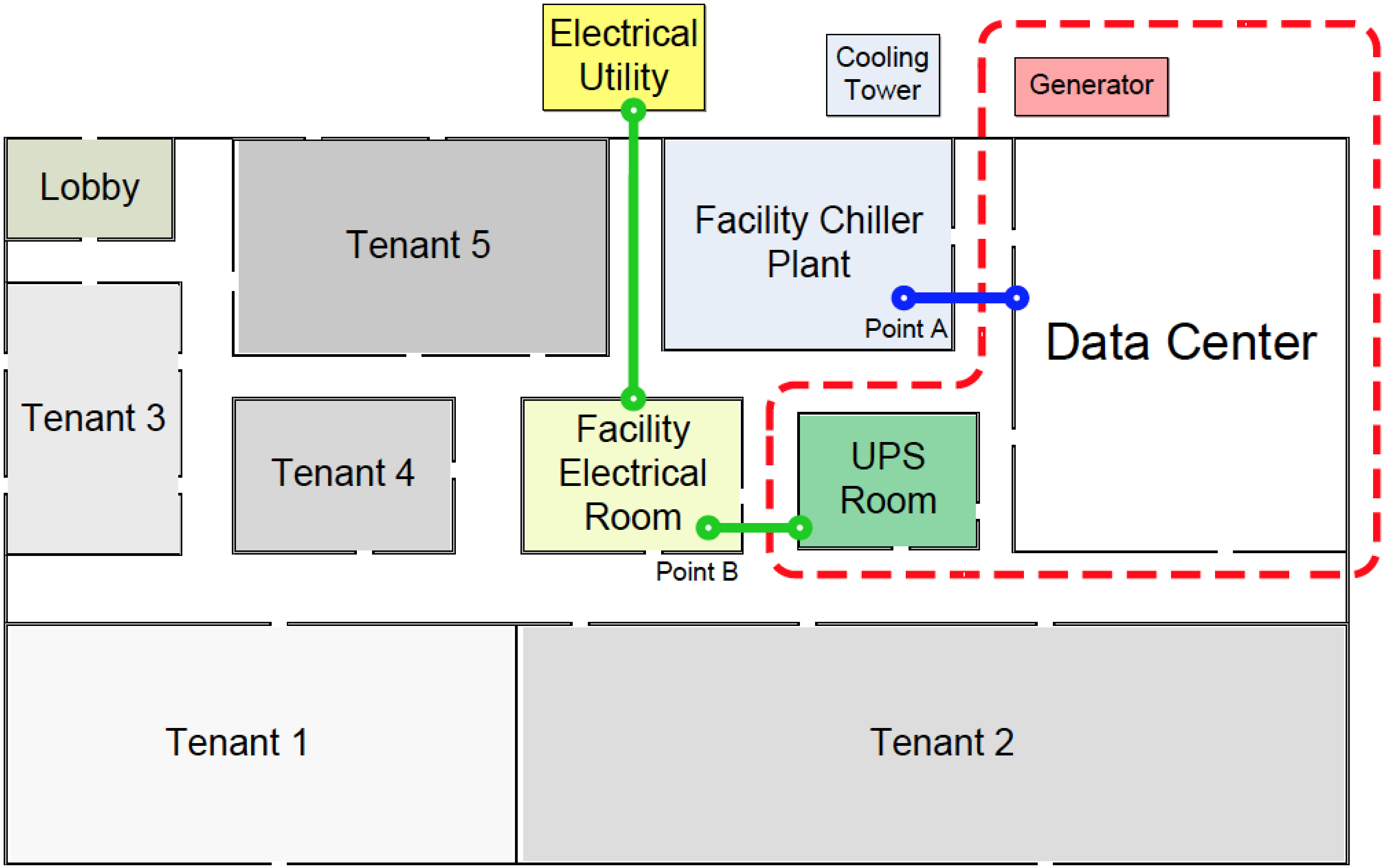


Figure 13. Control volume for a data center within a mixed-use building

Infrastructure Components

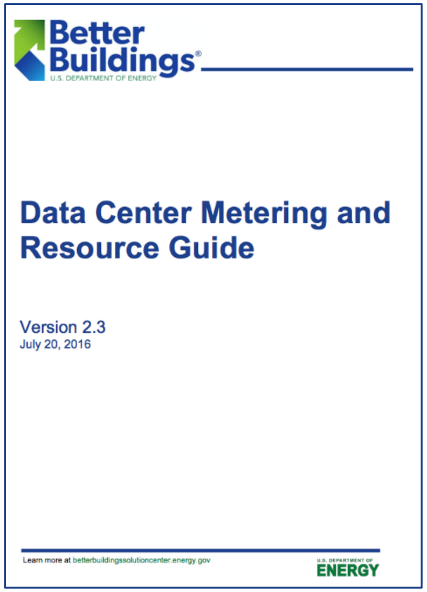
- Energy using Power and HVAC components contributing to the total data center energy use
- Each could require one or more meters in an embedded data center

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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Data Center Metering and Resource Guide

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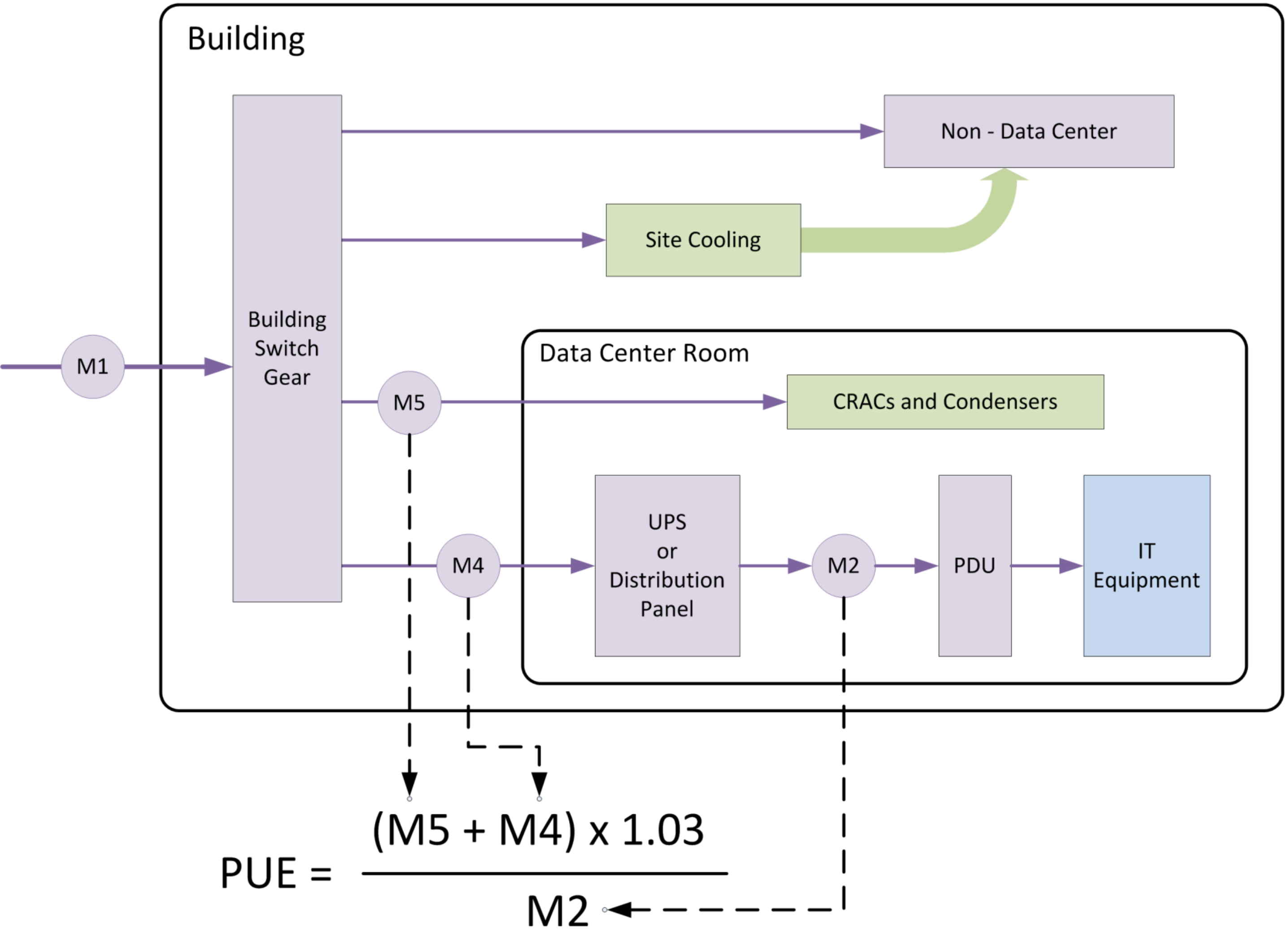
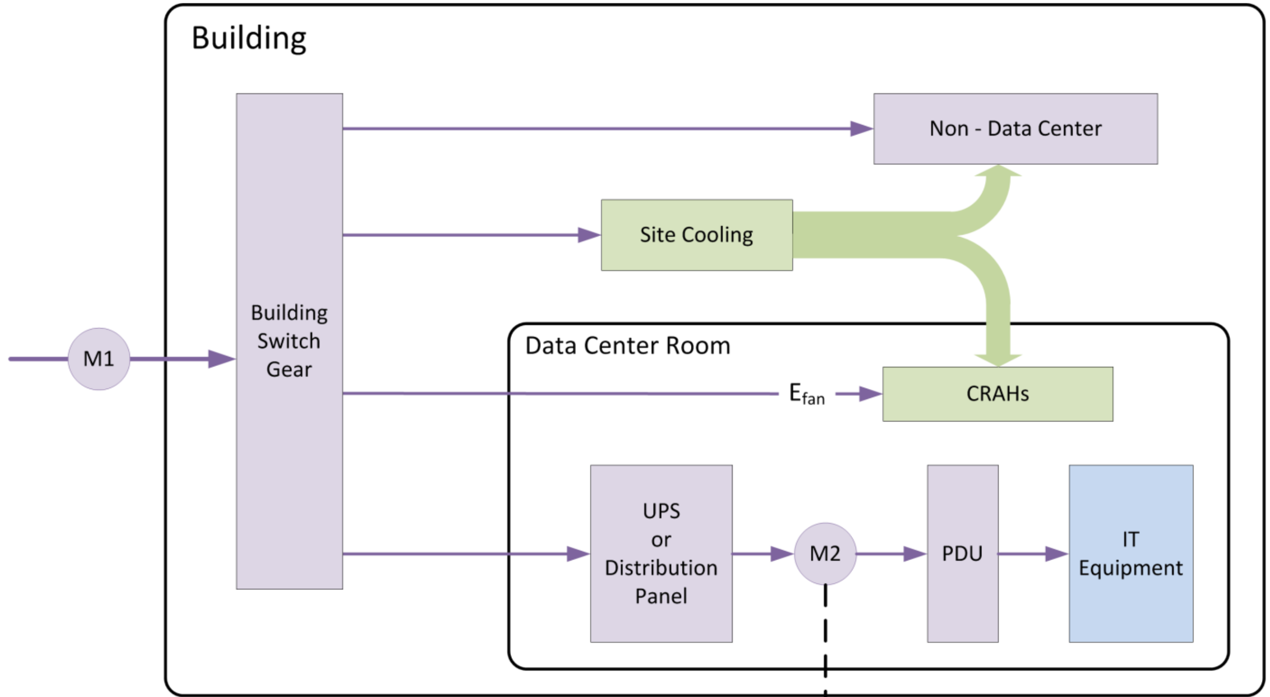
datacenters.lbl.gov/resources/data-center-metering-and-resource-guide

2e. Embedded w/metering



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

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



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

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

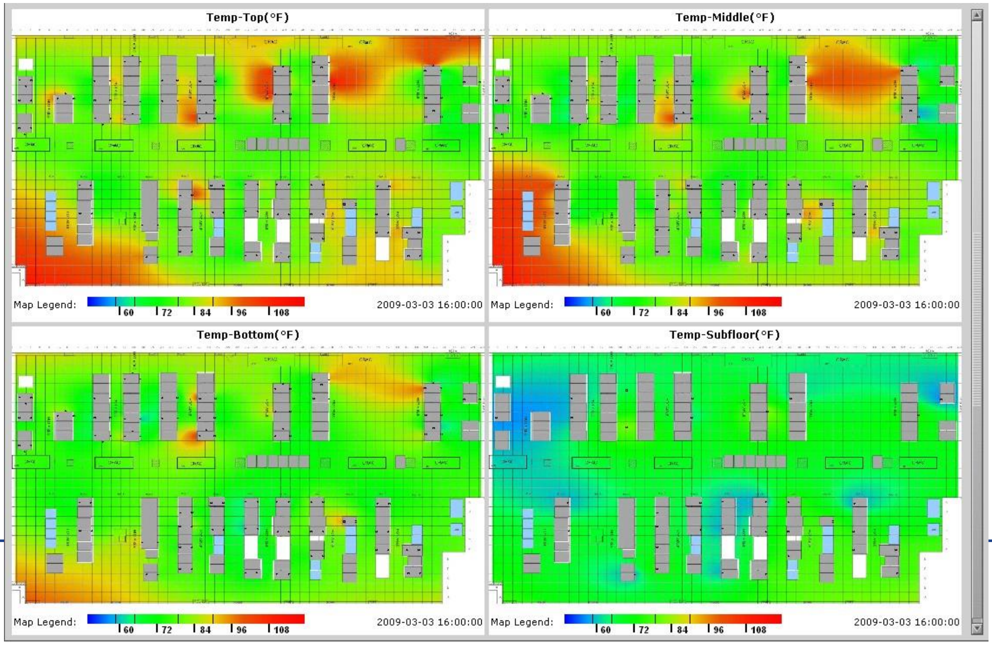
Lessons Learned Determining PUE at LBNL

- 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

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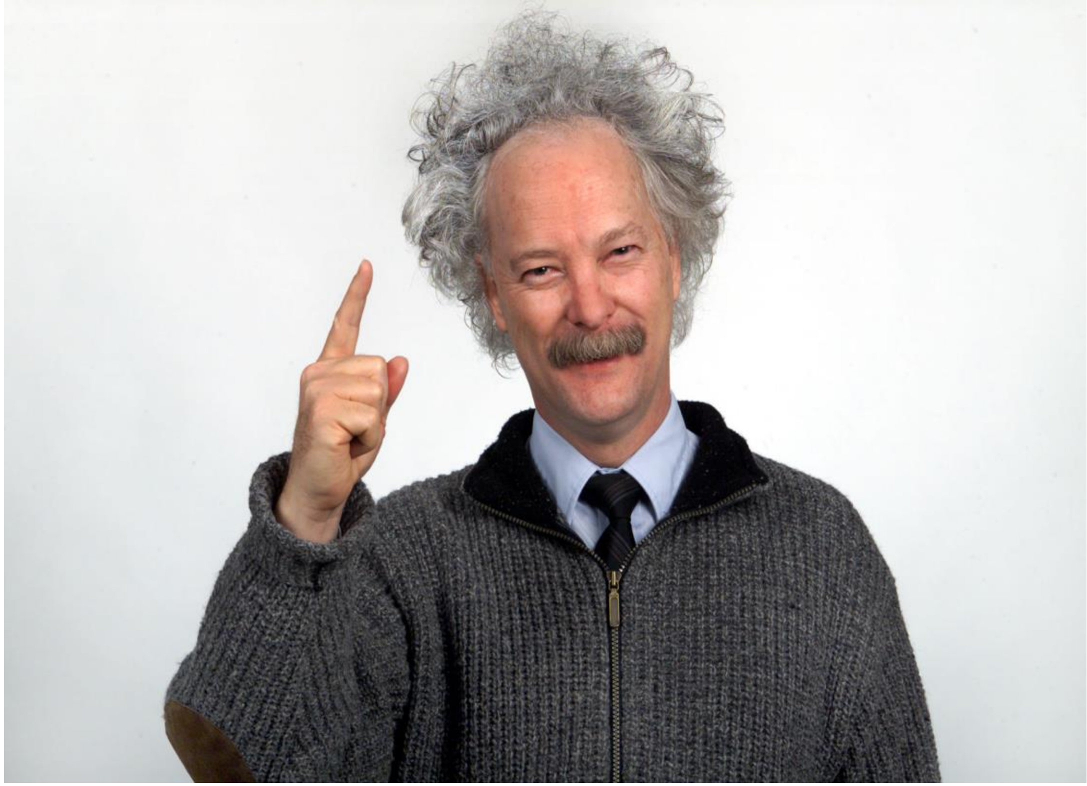


Backup slides

- LBNL case studies
- Metering methods/process
- Overcoming challenges

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

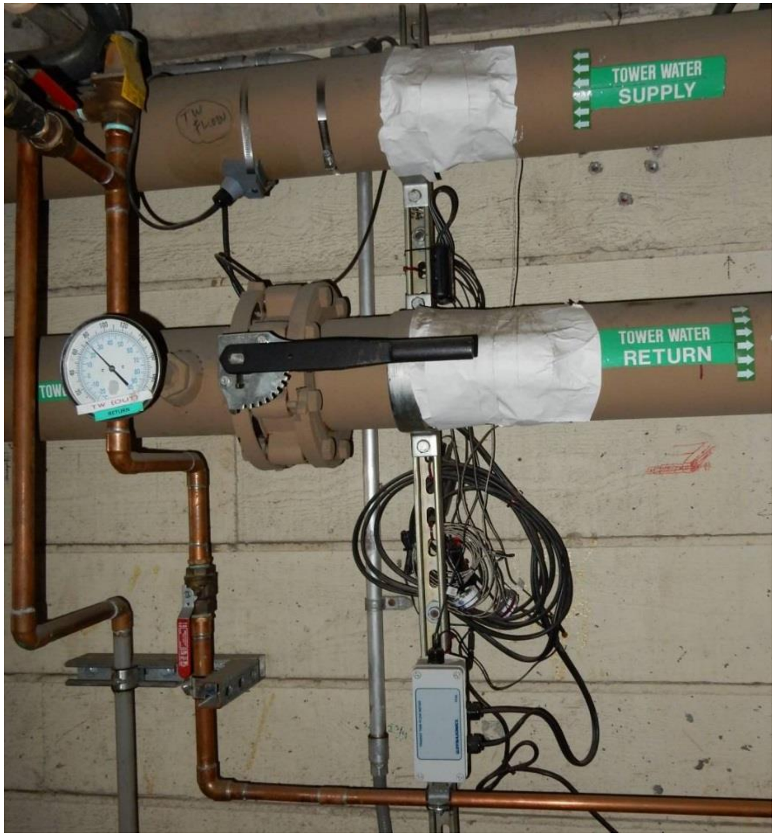
- Level 1
- Measured IT
- Data center is embedded with multiple power and cooling feeds
- There are some existing meters on IT loads
- Identify meter additions needed
- Triage based on cost vs. effect on PUE
- Implement changes
- Calculation will use IT load and estimate HVAC based on system ratings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

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

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

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