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

\[
PUE = \frac{\text{Total Data Center Facility Annual Energy Use}}{\text{IT Equipment Annual Energy Use}}
\]
Power Usage Effectiveness (PUE)

Data center number
## PUE Measurement Categories Recommended by the Green Grid

<table>
<thead>
<tr>
<th>IT energy measurement location</th>
<th>PUE Category 0*</th>
<th>PUE Category 1</th>
<th>PUE Category 2</th>
<th>PUE Category 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPS output</td>
<td>UPS output</td>
<td>PDU output</td>
<td>IT equipment input</td>
<td></td>
</tr>
<tr>
<td>Definition of IT energy</td>
<td>Peak IT electric demand</td>
<td>IT annual energy</td>
<td>IT annual energy</td>
<td>IT annual energy</td>
</tr>
<tr>
<td>Definition of Total energy</td>
<td>Peak Total electric demand</td>
<td>Total annual energy</td>
<td>Total annual energy</td>
<td>Total annual energy</td>
</tr>
</tbody>
</table>

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

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![Image showing PUE measurement categories and categories 1 to 3](image-url)
Green Grid’s 3 Level Approach

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

<table>
<thead>
<tr>
<th></th>
<th>Level 1 (L1)</th>
<th>Level 2 (L2)</th>
<th>Level 3 (L3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Equipment Energy</td>
<td>UPS Outputs</td>
<td>PDU Outputs</td>
<td>IT Equipment Input</td>
</tr>
<tr>
<td>Total Facility Energy</td>
<td>Utility Inputs</td>
<td>Utility Inputs</td>
<td>Utility Inputs</td>
</tr>
<tr>
<td>Measurement Interval</td>
<td>Monthly/Weekly</td>
<td>Daily/Hourly</td>
<td>Continuous (15 minutes or less)</td>
</tr>
</tbody>
</table>

- Focus on Level 1, the default for Better Buildings
- Note table assumes standalone data centers where total is measured by the utility inputs
Figure 12. Control volume for a dedicated 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
Getting Started

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

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

PUE = \frac{(M5 + M4) \times 1.03}{M2}
Data Center Types: 3. Embedded, no additional metering beyond UPS

3a. Water-cooled chiller plant with CRAHs

\[ PUE = \frac{((M2/0.9) + E_{fan}) \times (1 + (0.285 \times \text{Eff}))}{M2} \]

\text{Eff} = (\text{Chiller efficiency} + 0.2) \text{ kW/ton, where chiller efficiency can be obtained from Chiller Efficiency Table} \]
\text{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)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Size Category</th>
<th>Minimum Efficiency</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air- Cooled Chillers</td>
<td>&lt;150 ton</td>
<td>≤ .960</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td></td>
<td>&gt;150 ton</td>
<td>≤ .941</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td>Water - Cooled Chillers</td>
<td>&lt;75 ton</td>
<td>≤ .630</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td>Positive Displacement</td>
<td>≥75 ton and &lt; 150 ton</td>
<td>≤ .615</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td></td>
<td>&gt;150 ton and &lt; 300 ton</td>
<td>≤ .580</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td></td>
<td>≥300 ton</td>
<td>≤ .540</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td>Water - Cooled Chillers</td>
<td>&lt; 300 ton</td>
<td>≤ .596</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>≥300 ton and &lt; 600 ton</td>
<td>≤ .549</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td></td>
<td>≥600 ton</td>
<td>≤ .539</td>
<td>kW/ton-IPLV</td>
</tr>
</tbody>
</table>
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
Speaker Contact Information

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Backup slides

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