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?

- Data Center Server Load: 51%
- Data Center CRAC Units: 25%
- Cooling Tower Plant: 4%
- Electrical Room Cooling: 4%
- Office Space Conditioning: 1%
- Lighting: 2%
- Other: 13%

- Computer Loads: 67%
- HVAC - Air Movement: 7%
- Lighting: 2%
- HVAC - Chiller and Pumps: 24%
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)
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).

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

![Diagram of UPS, PDU, computer racks, and computer equipment with labels PUE1, PUE2, and PUE3]

Courtesy of TGG
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

Embedded w/metering

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

PUE = \frac{(M5 + M4) \times 1.03}{M2}
3a. Water-cooled chiller plant with CRAHs

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

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)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Size Category</th>
<th>Minimum Efficiency</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air- Cooled Chillers</strong></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><strong>Positive Displacement</strong></td>
<td>&lt;75 ton</td>
<td>≤ .630</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td><strong>Water - Cooled Chillers</strong></td>
<td>≥75 ton and &lt; 150 ton</td>
<td>≤ .615</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td></td>
<td>≥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><strong>Centrifugal</strong></td>
<td>&lt; 300 ton</td>
<td>≤ .596</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td></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>
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

- PUE: a Comprehensive Examination of the Metric
  [thegreengrid.org/en/Global/Content/white-papers WP49-PUEAComprehensiveExaminationoftheMetric](thegreengrid.org/en/Global/Content/white-papers WP49-PUEAComprehensiveExaminationoftheMetric)

- Center of Expertise for Energy Efficiency in Data Centers
  [datacenters.lbl.gov/](datacenters.lbl.gov/)
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