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, cont.

![Power Usage Effectiveness (PUE) Chart]

- **Power Usage Effectiveness (PUE)**
- **Data center number**
# PUE Measurement Categories Recommended by the Green Grid

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

<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></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></td>
</tr>
</tbody>
</table>

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

![Diagram showing UPS, PDU, computer racks, and computer equipment with PUE1, PUE2, and PUE3 labels.](image)

Courtesy of TGG
Green Grid’s 3 Level Approach

- 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. Embedded w/metering

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

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

\(Eff = (\text{Chiller efficiency} + 0.2) \text{ kW/ton, where chiller efficiency can be obtained from Chiller Efficiency Table and 0.2 represents typical additional load of chilled water/condenser water pumps and cooling tower fans.}\)
## 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>Water - Cooled Chillers</strong></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>≥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>Water - Cooled Chillers</strong></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
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
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
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
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