Data Center Metering and Resource Guide

Steve Greenberg
Lawrence Berkeley National Lab
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Learning Objectives

1. Know the definition of PUE.
2. Recognize stand-alone vs. embedded data centers.
3. Understand how to calculate PUE with imperfect metering.
4. Know how to recognize and overcome metering challenges.
Agenda

• Definitions, including Power Usage Effectiveness (PUE)
• EO 13693 mandates
• Discussion of data center types
• Anticipated scenarios of metering systems, how they integrate with data center types, and how to calculate PUE
• Metering methods, including leveraging existing meters and starting from scratch
• Challenges to installing meters and gathering data
• Resources
Definitions

PUE - Power Usage Effectiveness

• The ratio of total energy use to that of the information technology (IT) equipment.

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

• A measure of how efficiently the data center infrastructure uses energy.
• Three levels (1=Basic, 2=Intermediate, 3=Advanced)
  – Focus on Level 1

• What PUE is good for (infrastructure overhead)
Executive Order 13693 Mandates (for Feds)

- Install and monitor advanced energy meters in all data centers by FY ‘18 --Section 3(a)(ii)(B)

- Target 1.2 to 1.4 PUE for new data centers --Section 3(a)(ii)(C)

- Target less than 1.5 PUE for existing data centers (same)
Data Center Types

1. Stand-alone

Data Center Site

- Building Switch Gear
- Data Center Cooling
- Data Center Rooms
  - UPS or Distribution Panel
  - M2
  - PDU
  - IT Equipment

PUE = \frac{M1}{M2}
Data Center Types

2. Embedded, with additional metering

a. Chiller Plant
Input M3

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

Where $E_{fan}$ = CRAH fan energy use
Eff = average chiller plant efficiency in kW/ton (M3 is used to calculate; see "Data Center Metering and Resource Guide")
2b. Embedded, with additional metering, con’t.

$\text{PUE} = \frac{(M2/0.9) + E_{fan} + (T_1 \times \text{Eff})}{M2}$

$\text{Eff} = (\text{Chiller efficiency} + 0.2) \text{ kW/ton}$, 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.
2. Embedded, with additional metering, con’t

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></td>
<td></td>
<td></td>
</tr>
<tr>
<td></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></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Displacement</td>
<td>&lt;75 ton</td>
<td>≤ .630</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td></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>
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</tr>
<tr>
<td></td>
<td>≥300 ton</td>
<td>≤ .540</td>
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<td>≤ .596</td>
<td>kW/ton-IPLV</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>≥300 ton and &lt; 600 ton</td>
<td>≤ .549</td>
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</tr>
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2c. Embedded, with additional metering, con’t

Chiller Plant input (M3) and UPS input (M4)

PUE = \( \frac{((M4 \times 1.03) + E_{fan}) \times (1 + (0.285 \times Eff))}{M2} \)

Where \( E_{fan} = \) CRAH fan energy use
Eff = average chiller plant efficiency in kW/ton (M3 is used to calculate; see “Data Center Metering and Resource Guide”)
2d. Embedded, with additional metering, con’t

CRACs and Condensers input (M5)

PUE = \( \frac{M5 + \left(\frac{M2}{0.9}\right)}{M2} \)
2e. Embedded, with additional metering, con’t

UPS input (M4) and CRACs and Condensers Input (M5)

\[ \text{PUE} = \frac{(M5 + M4) \times 1.03}{M2} \]
2f. Embedded, with additional metering, con’t

Chiller Plant input (M3) Chiller Plant output (T) and Data Center Cooling (T₁)

PUE = \( \frac{(M3/T) \times T\_1 + (M2/0.9) + E\_fan}{M2} \)
3. Embedded, with no additional metering beyond UPS output (M2)

Data Center Types

a. Water-cooled chiller plant with CRAHs

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

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.
### Chiller Efficiency Table (Edited from Table 6.8.1C - ASHRAE 90.1 – 2010)

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3b. Embedded, with no additional metering, con’t

Air-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} + 0.1) \text{ kW/ton}, where chiller efficiency can be obtained from Chiller Efficiency Table and 0.1 represents typical additional load of chilled water pumps.
3c. Embedded, with no additional metering, con’t

CRACs with air-cooled condensers

PUE = \(\frac{(M2/0.9) \times (1 + (0.285 \times 1.45))}{M2}\)

1.45 kW/ton represents typical air-cooled CRAC efficiency including fans.
3d. Embedded, with no additional metering, con’t

Water- or air-cooled chiller plant with water-side economizer (WSE)

\[
PUE = \frac{(M2/0.9) + E_{\text{fan}}}{M2} \times (1 + (0.285 \times 0.25))
\]

0.25 kW/ton represents typical cooling plant efficiency during economizer operation. Use this equation for economizer operating hours and otherwise-applicable equation for non-economizer hours.
Steps in Metering

1. Plan
   - Determine data center type
   - Determine existing metering
   - Review drawings
   - Interview staff/visit site
   - Decide on PUE calculation approach
Steps in Metering, con’t

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 to Meter Installation & Possible Solutions

• 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
Simplified View

**PUE = \frac{\text{Total Facility Energy}}{\text{IT Energy}}**

**Version 2**

**Total Facility Energy**

- **Utility Hand Off**
  - Based on 12-month Total KWH

**PUE Category 1**

- Cooling Systems
- Chillers
- CRAC-CRAH

**PUE Category 2**

- UPS
  - UPS Output KWH

**PUE Category 3**

- Power Dist Unit
  - Step-Down Transformer

**PUE Category 1 Output of UPS**
- Most commonly used

**PUE Category 2**
- Includes PDU Transformer Losses

**PUE Category 3**
- Total Energy of IT Load at Rack or Device Level

**Note:**
- PUE Category 1-3 is based on annualized energy (KWH).
- PUE Category 0 is based on PEAK Power KW see notes for details.

Graphic Courtesy of NAAI, Inc.
Resources


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

• Data Center Energy Practitioner (DCEP) Program: [https://datacenters.lbl.gov/dcep](https://datacenters.lbl.gov/dcep)
Questions?

Steve Greenberg, P.E.
Lawrence Berkeley National Laboratory
(510) 486-6971
segreenberg@lbl.gov