Saving Energy in Data Centers
Low Cost Energy Efficiency Measures
Case Studies

September 2013

Rod Mahdavi, PE. LEED AP
Building Technologies
Lawrence Berkeley National Laboratory (LBNL)
Objective

• Explore why saving energy in Data Centers?
• Get a general idea of the best practices
• Learn about low cost EEMs
  • Environmental conditions adjustments
  • Air management improvements
  • Chiller Plant
• Examine three Case studies
High Tech Buildings are Energy Hogs:

Comparative Energy Costs
High-Tech Facilities vs. Standard Buildings

Annual Energy Costs ($/ft²)

- School
- Office
- Hospital
- Laboratory
- Data Center
- Cleanroom (ISO Class 5)

Observed Range

Typical
US Data Center Electricity Use - 2000, 2005, and 2010

2% of US Electricity consumption

Potential to double in next 5 years

Source: Koomey 2011
Data Center Energy Efficiency = 15% (or less)

(Energy Efficiency = Useful computation / Total Source Energy)

Typical Data Center Energy End Use

- **Source Energy**: 100 Units
- **Power Generation**: 35 Units
- **Delivered**: 33 Units
- **Server Load/Computing Operations**: 33 Units
- **Cooling Equipment**: 35 Units
- **Power Conversions & Distribution**: 15 Units
Energy efficiency best practices

- Server innovation
- Virtualization
- High efficiency power supplies
- Load management

- Better air management
- Move to liquid cooling
- Optimized chilled-water plants
- Use of free cooling
- Heat recovery

Power Conversion & Distribution
- High voltage distribution
- High efficiency UPS systems
- Efficient redundancy strategies
- Use of DC power

Server Load/Computing Operations
- Virtualization
- High efficiency power supplies
- Load management

Cooling
- Move to liquid cooling
- Optimized chilled-water plants
- Use of free cooling
- Heat recovery

Alternative Power Generation
- On-site generation including fuel cells and renewable sources
- CHP applications (Waste heat for cooling)
LBNL develops publicly available resources

DC Pro tools
Data Center Energy Practitioner program
Computing metrics development

Federal consolidation guideline
ESPC contract content

Wireless assessment kit
Compressor- less cooling
Low Cost EEMs:

- Environmental conditions adjustments
- Air management improvements
- Chiller plant
Low Cost EEMs:

- Environmental conditions adjustments
- Air management improvements
- Chiller plant
### ITE Environment – 2011 Environment Specifications Table (Partial)

<table>
<thead>
<tr>
<th>Class</th>
<th>Dry Bulb (°F)</th>
<th>Humidity Range</th>
<th>Max Dew Point (°F)</th>
<th>Max Elevation (ft)</th>
<th>Max Rate of Change (°F / hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous</td>
<td>Current</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Recommended</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 &amp; 2</td>
<td>A1 to A4</td>
<td>64.4 to 80.6</td>
<td>41.9°F DP to 60% RH &amp; 59°F DP</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>Allowable</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>A1</td>
<td>59 to 89.6</td>
<td>20% to 80% RH</td>
<td>62.6</td>
<td>10,000</td>
</tr>
<tr>
<td>2</td>
<td>A2</td>
<td>50 to 95</td>
<td>20% to 80% RH</td>
<td>69.8</td>
<td>10,000</td>
</tr>
<tr>
<td>N/A</td>
<td>A3</td>
<td>41 to 104</td>
<td>10.4°F DP &amp; 8% RH to 85% RH</td>
<td>75.2</td>
<td>10,000</td>
</tr>
<tr>
<td>N/A</td>
<td>A4</td>
<td>41 to 113</td>
<td>10.4°F DP &amp; 8% RH to 90% RH</td>
<td>75.2</td>
<td>10,000</td>
</tr>
</tbody>
</table>

* More stringent rate of change for tape drives

© ASHRAE Table reformatted by DLB Associates

---

**Allowable Temperatures**

- **Recommended**: 59.0°F to 80.6°F
- **Allowable**: 64.4°F to 90.0°F

---

**ASHRAE 2011**
# The Cost of Unnecessary Humidification

## Visalia Probe vs CRAC Unit Panel

<table>
<thead>
<tr>
<th>Visalia Probe</th>
<th>CRAC Unit Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp</td>
<td>RH</td>
</tr>
<tr>
<td>AC 005</td>
<td>84.0</td>
</tr>
<tr>
<td>AC 006</td>
<td>81.8</td>
</tr>
<tr>
<td>AC 007</td>
<td>72.8</td>
</tr>
<tr>
<td>AC 008</td>
<td>80.0</td>
</tr>
<tr>
<td>AC 010</td>
<td>77.5</td>
</tr>
<tr>
<td>AC 011</td>
<td>78.9</td>
</tr>
<tr>
<td>Min</td>
<td>72.8</td>
</tr>
<tr>
<td>Max</td>
<td>84.0</td>
</tr>
<tr>
<td>Avg</td>
<td>79.2</td>
</tr>
</tbody>
</table>

## Diagrams

- **Humidity down 3%**
- **CRAC power down 28%**
Low Cost EEMs:

- Environmental conditions adjustments
- Air management improvements
- Chiller plant
Goal: Supply air directly to equipment intakes without mixing
By-pass air does no cooling

- Too much supply airflow
- Too high tile exit velocity
- Misplaced perforated tiles
- Leaky cable penetrations
Recirculated air causes localized cooling problems

- Short equipment rows
- Too little air supply
- Lack of blanking panels
- Gaps between racks
Adding Air Curtains for Hot/Cold Isolation
Return Air

Interstitial Ceiling Space

Open Ceiling Tile

Air Barrier
(Plastic Sheet)

CRAH

Hot Aisle

Air Barrier

Cold Aisle

Air Barrier
(Melamine Board)

Supply Air

70-80°F vs. 45-55°F (21-27°C vs. 7-13°C)

95-105°F vs. 60-70°F (35-41°C vs. 16-21°C)
Low Cost EEMs:

- Environmental conditions adjustments
- Air management improvements
- Chiller Plant
Better efficiency of chiller with higher load factor

Chiller 4 Performance
Sep 17 - 22, 2012

Maximum efficiency at the full capacity as provided by the manufacturer.
Condenser water supply temperature

Chiller 4 Condenser Water Temp and Outside Air Wetbulb Temp

- **CW Temp**
- **OA Wetbulb**

Temperature (F)

40
50
60
70
80
90

Federal Data centers Case studies

Data center 1

5,000 sf
500 kW IT
8GWh

Tropical climate
Air-cooled Chillers
CRAHs

53% IT Equipment
26% Chillers
8% UPS+PDU Losses
8% CRAH/Fans/Heater
8% Lighting
3% BH
1% UPS room cooling, Generator
1% Pumps

Federal Data centers Case studies
Case studies

Seal all floor leaks and those between and within the racks
Lesson learned: Seal the opening between the rack and floor

Supply Air temperature out of the perf tiles = 61.6\text{deg}F
Case studies

Air temperature between perf and rack pedestal = 89.1 degF
Case studies

Air temperature after space taped = 69.3\textdegree\text{degF}
Case studies

Replaced Perf tiles

Redirect cold air from the CRAHs
Case studies

Ceiling space as a plenum
Case studies

Before trials begin

RAT increased from 74degF to 84degF

After
Case studies

Individual racks intake top temperature change during trials (60-72)

Average rack exhaust temperature change during trials (75-87)
Case studies

CRAHs Return Avg. Temperatures 64 to 83

CRAHs Supply Avg. Temperatures 53 to 62
Case studies

Chillers Efficiency Improvement

<table>
<thead>
<tr>
<th>CHWST sp degF</th>
<th>45</th>
<th>49</th>
<th>54</th>
<th>56</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHWST degF</td>
<td>46</td>
<td>49</td>
<td>55.1</td>
<td>56.8</td>
</tr>
<tr>
<td>CH1 kW</td>
<td>75</td>
<td>75</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CH2 kW</td>
<td>75</td>
<td>75</td>
<td>100</td>
<td>75</td>
</tr>
<tr>
<td>CH3 kW</td>
<td>75</td>
<td>50</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>
Case studies

Saved annually:

800MWh
$240,000 utility cost
780 metric tons of GHG emission
Data center 2

30,000 sf
1,850 kW IT
30GWh
Case studies

Air management issues
Case studies

Top rack intake temp before shutting down 20% of the CRAHs

Top rack intake temp after
Case studies

Little rack intake temperature change after CRAHs shutdown
Case studies

Saved annually:

850MWh
$55,000 utility cost
820 metric tons of GHG emission
Case studies

Data center 3

8,000 sf
800 kW IT
12GWh

Current IT Load 59%

Cooling 28%
Fans 6%
Lighting 1%
Standby Gen 1%
PDU/Trans loss 2%
UPS Loss 3%

UPS Loss 3%
Case studies
Case studies

- Rack Door HX
- Dry Cooler
- CENTRAL AIR HANDLERs
- Ceiling return air plenum
- Rack Door HX
- hot aisle containment
- Under raised floor supply air plenum
- TES
- COIL
- CENTRAL AIR HANDLERs
Case studies

Chilled Water System – Thermal Energy Storage Tank

Level Temps

<table>
<thead>
<tr>
<th>Level</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 2</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 3</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 4</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 5</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 6</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 7</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 8</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 9</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 10</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 11</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 12</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 13</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 14</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 15</td>
<td>55.1 deg F</td>
</tr>
<tr>
<td>Level 16</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 17</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 18</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 19</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 20</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 21</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 22</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 23</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 24</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 25</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 26</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 27</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 28</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 29</td>
<td>55.0 deg F</td>
</tr>
<tr>
<td>Level 30</td>
<td>55.0 deg F</td>
</tr>
</tbody>
</table>

Level Above Temp Setpoint

<table>
<thead>
<tr>
<th>Level</th>
<th>Above Temp Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>No</td>
</tr>
<tr>
<td>Level 2</td>
<td>No</td>
</tr>
<tr>
<td>Level 3</td>
<td>No</td>
</tr>
<tr>
<td>Level 4</td>
<td>No</td>
</tr>
<tr>
<td>Level 5</td>
<td>No</td>
</tr>
<tr>
<td>Level 6</td>
<td>No</td>
</tr>
<tr>
<td>Level 7</td>
<td>No</td>
</tr>
<tr>
<td>Level 8</td>
<td>No</td>
</tr>
<tr>
<td>Level 9</td>
<td>No</td>
</tr>
<tr>
<td>Level 10</td>
<td>No</td>
</tr>
<tr>
<td>Level 11</td>
<td>No</td>
</tr>
<tr>
<td>Level 12</td>
<td>No</td>
</tr>
<tr>
<td>Level 13</td>
<td>No</td>
</tr>
<tr>
<td>Level 14</td>
<td>No</td>
</tr>
<tr>
<td>Level 15</td>
<td>No</td>
</tr>
<tr>
<td>Level 16</td>
<td>No</td>
</tr>
<tr>
<td>Level 17</td>
<td>No</td>
</tr>
<tr>
<td>Level 18</td>
<td>No</td>
</tr>
<tr>
<td>Level 19</td>
<td>No</td>
</tr>
<tr>
<td>Level 20</td>
<td>No</td>
</tr>
<tr>
<td>Level 21</td>
<td>No</td>
</tr>
<tr>
<td>Level 22</td>
<td>No</td>
</tr>
<tr>
<td>Level 23</td>
<td>No</td>
</tr>
<tr>
<td>Level 24</td>
<td>No</td>
</tr>
<tr>
<td>Level 25</td>
<td>No</td>
</tr>
<tr>
<td>Level 26</td>
<td>No</td>
</tr>
<tr>
<td>Level 27</td>
<td>No</td>
</tr>
<tr>
<td>Level 28</td>
<td>No</td>
</tr>
<tr>
<td>Level 29</td>
<td>No</td>
</tr>
<tr>
<td>Level 30</td>
<td>No</td>
</tr>
</tbody>
</table>

Legend

- 74.0 deg F
- 51.6 %RH
- 09:58:00 AM
- Tuesday, July 10, 2012
Case studies
Case studies

Reduction of water flow to TES from 1,000 to 300 gpm

Pump power reduced
Chiller more efficient (higher delta T and load factor)
PUE improved
Saved annually:

2,100MWh, $125,000 utility cost
2,000 metric tons of GHG emission
Questions?

Rod Mahdavi, PE. LEED AP
rmahdavi@lbl.gov
510.495.2259