Achieving Energy Efficiency in Data Centers
Meet Your Panelists:

Mike Carter

Justin Kale
NEEA Northwest Industrial Training

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  Northwest Regional Industrial Training Center:
  
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  - Bonneville Power Administration
  
  - Northwest Food Processors Association

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Upcoming In-Class Trainings

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  - **Energy Efficiency of Chilled Water Systems and Cooling Towers**
    - April 25-26: Medford, OR
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    - September 10-11: Seattle, WA
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  - **Energy Efficiency and Data Centers**
    - June 4: Bend, OR
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  - Motors Systems Management Best Practices
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- **Refrigeration:**
  
  **Industrial Refrigeration Systems Energy Management**
  
  March 21: Pocatello, ID
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  - Developing and Energy Plan
    - May 21: 9-10am PST
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  - Adjustable Speed Drives
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- **Power Factor:**
  - Improve Power Factor and Your Facility
    - December 17: 9-10am PST

- **Space Conditioning:**
  - Boiler and Chiller Maintenance for Maximum Efficiency
    - July 16: 9-10am PST
  - PGE Webinar: Intro to Ammonia Refrigeration
    - March 26: 8-9 am PST

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Table of Contents

- Introduction
- Measure
- Power Conversion
- Server Load
- Cooling Equipment
- Case Studies
- Resources

Source: LBL
Introduction

- Over 6,700 data centers in 2006
- More than 1,220 colocation data centers (for rent) in the US

Source: Data Center Map
Introduction

- Ideal site selection criteria*
  - Protection from hazards
  - Easy accessibility
  - Features that accommodate future growth and change
- Zoning and ordinances
- Known hazards
  - Natural disasters
  - EMI
- Multiple access routes

*Douglas Alger, Cisco
Introduction

- Pre-Existing Infrastructure
- Power Analysis
- Cooling Capabilities
  - Geographic enthalpy maps
  - Economizers
- Structured Cabling
- Amenities and Obstacles
  - Clearances
  - Freight Issues
  - Loading Dock
  - Freight Elevators

Source: LBL
Introduction

- 2009 Avetec Study
  - 41 data center managers responsible for 223 data centers
  - Industry (63%), academia (22%), government (10%)
    - 59% of the sites track and report direct power and cooling costs.
    - Only 34% use specific metrics and/or statistics (e.g., PUE) to measure and report energy efficiency.
      - More than two-thirds of the data centers do no in-house testing to validate the energy efficiency of computer hardware.
      - Rely on vendors' performance specifications.
    - Only 29% of the surveyed organizations said they have a formal roadmap for moving their data center(s) to greater power and cooling efficiency.
Measure, Measure, Measure

- Benchmarking

Source: LBL
Energy intensity

- 35X higher than office building
- 100 to 400w/sqft
- 15,000 sqft
- 25 kW+ racks
  - Typically 8 kW

Electric Intensity (kWh/sqft) -- Data Centers

575.46 kWh/sqft

Electric Intensity (kWh/sqft) -- Large Office Buildings

16.4 kWh/sqft
Measure, Measure, Measure

- Benchmarking
  - Power Utilization Effectiveness (PUE)

  \[
  \text{PUE (0)} = \frac{\text{Total Data Center Power}}{\text{IT Power}}
  \]

  - <1.3 PUE Excellent
  - 1.3 to 1.7 PUE Good
  - >1.7 PUE Fair
    - Can be 3.0+

Source: LBL

Avg. = 1.83
Measure, Measure, Measure

- Benchmarking
  - PUE (0) at part loading
  - Affects peak demand

Source: William Kosik, HP Technology Services
Measure, Measure, Measure

- Benchmarking
  - Improving PUE from 2.0 to 1.6 for a data center with a 2.5 MW IT load
    - A 20% energy savings or over $800,000 annual savings at $0.08/kilowatt hour.

Real-time PUE Display

Source: FEMP
## Measure, Measure, Measure

- **PUE Categories**

<table>
<thead>
<tr>
<th></th>
<th>Cat. 0</th>
<th>Cat. 1</th>
<th>Cat. 2</th>
<th>Cat. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IT energy</strong></td>
<td>UPS Output</td>
<td>UPS Output</td>
<td>PDU Output</td>
<td>Server Input</td>
</tr>
<tr>
<td><strong>measurement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Definition of IT</strong></td>
<td>Peak IT electric demand</td>
<td>IT annual electric energy</td>
<td>IT annual electric energy</td>
<td>IT annual electric energy</td>
</tr>
<tr>
<td><strong>energy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Definition of</strong></td>
<td>Peak Total electric meter demand*</td>
<td>Total annual energy (electric, gas)</td>
<td>Total annual energy (electric, gas)</td>
<td>Total annual energy (electric, gas)</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>energy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*All-electric
Measure, Measure, Measure

- Other Benchmarking Metrics
  - kWh over time for IT loads
  - Watts per CFM for cooling loads (<1.2 w/CFM)
  - Watts per square foot by rack, work cell and usable floor space
  - Total energy cost per square foot
  - IT energy cost, by rack, by zone, by floor
  - Transactions per kWh

Source: The Green Grid Association
Measure, Measure, Measure

- Benchmarking
  - Lighting power density
    - Goal is <1 watt/sqft
    - Occupancy sensors
    - Bi-level lighting
    - Task lighting

Source: LBL
Measure, Measure, Measure

- Benchmarking
  - Cooling plant efficiency
    - Goal is <1 kW/ton

Source: LBL
Solutions

- Three major opportunities for energy savings.
Power Conversion

- **Electrical infrastructure**
  - Four components represent the majority of losses

  Efficiencies: 99.0% - 99.4%  84.0% - 93.7%  98.5%  90% - 95%

<table>
<thead>
<tr>
<th>N losses</th>
<th>0.5%</th>
<th>6%</th>
<th>1.5%</th>
<th>5%</th>
<th>13%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2N losses</td>
<td>0.5%</td>
<td>12%</td>
<td>1.5%</td>
<td>6%</td>
<td>20%</td>
</tr>
</tbody>
</table>

- Redundancy decreases efficiency

Source: Ken Kutsmeda, KlingStubbins
Redundancy affect on UPS efficiency

- Efficiency falls as loading decreases
- Average loading of 20% to 30% is not uncommon.
- Goals
  - >50% UPS Load Factor
  - >85% system efficiency

Source: FEMP
Redundancy affect on UPS efficiency

- Shutdown UPS modules when Redundancy Level exceeds N+1 or 2N
- Install a scalable/modular UPS
- Install a smaller UPS size to fit present load capacity
- Transfer loads between UPS modules to maximize load factor % per active UPS

Source: LBNL
Power Conversion

- Eliminate inefficient equipment

Source: Ken Kutsmeda, KlingStubbins

Facebook
Prineville, OR
Power Conversion

- Facility-Level DC Distribution

- Demonstration project at Sun Microsystems
- 10% to 20% efficiency improvement
- Lower cooling load
- Fewer points of failure
Power Conversion

- Rack-Level DC Distribution

  - Smaller savings
  - Thermal benefits
  - Smaller power supply in server

Source: FEMP
Server Load

- Multiplier affect
  - Reduce IT load → reduce infrastructure load

- Retire unused IT servers

- ENERGY STAR servers
  - 30% more efficient
  - Minimum efficiencies @ 10% load
    - 80% for power supplies
    - 0.80 power factor
  - 55 to 150 watt idle power
Server Load

- Enable power management features
- Consolidation and virtualization
  - High utilization is goal (60% to 80%)
  - 10% to 40% savings
- Data management
  - Put less accessed data on lowest efficiency servers
  - Massive array of idle disks (MAID)
  - Deduplicate data

Source: ENERGY STAR
Server Load

- Power/space monitoring

Source: FEMP
Cooling Equipment

- Traditional data center cooling infrastructure

Source: Dr. Madhu Iyengar, IBM
Cooling Equipment

- Better air management
  - Higher temperature limits
    - ASHRAE Thermal Guidelines for Data Processing Environments
      - Server fan speeds/energy will increase with higher temperatures
      - Requires containment and possible conductor derating
      - Enables “chillerless” facilities

<table>
<thead>
<tr>
<th></th>
<th>Class 1, 2 Recommended</th>
<th>Class 1 Allowable</th>
<th>Class 2 Allowable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temperature</td>
<td>64.4F DB</td>
<td>59F DB</td>
<td>50F DB</td>
</tr>
<tr>
<td>High Temperature</td>
<td>80.6F DB</td>
<td>89.6F DB</td>
<td>95F DB</td>
</tr>
<tr>
<td>High Moisture</td>
<td>60% RH, 59F DP (50% RH, 80.6F DB)</td>
<td>80% RH, 62.6F DP (40% RH, 89.6F DB)</td>
<td>80% RH, 69.8F DP (45% RH, 95F DB)</td>
</tr>
</tbody>
</table>
Cooling Equipment

- Air mixing is inefficient

Source: EPA
Cooling Equipment

- Containment
  - Reduces fan energy (8% to 10%)
  - Improves AC efficiency
  - Increases cooling capacity (20%)

COLD-Aisle Containment (existing)

HOT air in room

Cold Aisle

HOT-Aisle Containment (new)

COLD air in room

Hot Aisle

Source: Schneider Electric, Joe Capes
Cooling Equipment

- Containment
  - Enclose return air
    - Barriers
    - Air curtains

Source: FEMP
Cooling Equipment

- Containment
  - Use blanking panels (Δ20F)
  - Do not overuse permeable floor tiles
    - Reduces under-floor pressure

Source: FEMP
Cooling Equipment

- Free cooling
  - Outside-air economizers
    - 40°F to 80°F DB OA
    - Dust and humidity are a concern
    - Savings example
      - 4,000 hours of economizer run time
      - 300 tons for 1 MW load
      - 0.5 kW/ton chiller efficiency
      - $0.08/kWh electric rate
      - $48,000 savings

Source: LBNL

Source: www.42u.com
Cooling Equipment

- Free cooling
  - Water-side economizers
    - 40F to 64F WB OA
    - Half the hours of air-side
    - Compatible with “warm” inlet temperatures
    - No air contamination concern

Source: LBNL

Source www.42u.com
Cooling Equipment

- InRow Cooling
  - Close-coupled

Source: Schneider Electric
Cooling Equipment

- **InRow Cooling**
  - Capable of cooling high densities > 30 kW per rack
  - Dynamic fan control matches heat removal to heat generation
  - Elimination of mixing enables a predictable cooling pattern
  - Reduced deployment cycle through use of modular components
  - 10% to 20% more efficient than central or computer room air handlers (sensible cooling operation)

Source: Joe Capes, Schneider Electric
Cooling Equipment

- **Liquid cooling**
  - Liquid has greater heat removal capacity (3500X air)
  - Pumps are more efficient than fans (10% of fan HP)
  - Water damage is a concern
  - 15% to 25% savings

Source: Dr. Madhu Iyengar, IBM
Source: LBNL
## Cooling Equipment

### Air Energy Recovery

- **Baseline:** 10,000 sqft, 2 MW, 78F supply, 96F return, Denver (CO)

<table>
<thead>
<tr>
<th>OA Economizer Technique</th>
<th>Annual Savings</th>
<th>Investment Delta</th>
<th>Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct mixing</td>
<td>$400</td>
<td>$1,250</td>
<td>3.2 yrs</td>
</tr>
<tr>
<td>Indirect tempering</td>
<td>$1,300</td>
<td>$5,150</td>
<td>4.0 yrs</td>
</tr>
<tr>
<td>Enthalpy wheel</td>
<td>$4,350</td>
<td>$20,750</td>
<td>4.8 yrs</td>
</tr>
<tr>
<td>Dual duct</td>
<td>$6,530</td>
<td>$43,450</td>
<td>6.7 yrs</td>
</tr>
</tbody>
</table>

Source: John Peterson, HP 2012 ASHRAE Winter Conf.
Case Studies

- Lucasfilm Ltd. (CA)
  - 13,500 sqft
  - 4,300 AMD processors

<table>
<thead>
<tr>
<th>Measure</th>
<th>kWh/year</th>
<th>Cost Savings/ year</th>
<th>Capital Cost ($)</th>
<th>Simple Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove redundant rack mounted UPS</td>
<td>109,500</td>
<td>$12,000</td>
<td>$0</td>
<td>immediate</td>
</tr>
<tr>
<td>Turn servers off during downtime/power management</td>
<td>273,800</td>
<td>$30,000</td>
<td>$10,000</td>
<td>0.3</td>
</tr>
<tr>
<td>Stage chillers to maintain high load factor</td>
<td>92,800</td>
<td>$10,000</td>
<td>$4,000</td>
<td>0.4</td>
</tr>
<tr>
<td>Operate UPS in switched by-pass mode</td>
<td>887,300</td>
<td>$98,000</td>
<td>$100,000</td>
<td>1.0</td>
</tr>
<tr>
<td>Improve airflow</td>
<td>806,700</td>
<td>$89,000</td>
<td>$113,000</td>
<td>1.3</td>
</tr>
<tr>
<td>Implement water-side economizer</td>
<td>928,600</td>
<td>$103,000</td>
<td>$200,000</td>
<td>1.9</td>
</tr>
<tr>
<td>Install lighting controls</td>
<td>10,500</td>
<td>$1,000</td>
<td>$2,500</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>Total for all measures</strong></td>
<td>3,109,200</td>
<td><strong>$343,000</strong></td>
<td><strong>$429,500</strong></td>
<td><strong>1.2</strong></td>
</tr>
</tbody>
</table>
Case Studies

- Sybase, Inc. (CA)
  - 16,000 sqft
  - 440 racks
  - 100 cabinets
  - 2,500kVA transformer @ 13kV/480V
  - Two redundant 500kVA UPS

<table>
<thead>
<tr>
<th>Measure</th>
<th>Energy Savings (kWh/year)</th>
<th>Cost Savings ($/year)</th>
<th>Capital Cost ($)</th>
<th>Simple Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cooling Plant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Install high-efficiency base-load chiller</td>
<td>476,000</td>
<td>$54,000</td>
<td>$510,000 (rebate $54,000)</td>
<td>8.4</td>
</tr>
<tr>
<td>Implement custom control program</td>
<td>75,000</td>
<td>$9,000</td>
<td>$6,000</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Air Management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relocate perforated tiles</td>
<td>112,000</td>
<td>$13,000</td>
<td>$0</td>
<td>0</td>
</tr>
<tr>
<td>Seal raised floor</td>
<td>150,000</td>
<td>$17,000</td>
<td>$0</td>
<td>0</td>
</tr>
<tr>
<td>Install variable frequency drives (VFD) on 20 CRAHs</td>
<td>866,000</td>
<td>$99,000</td>
<td>$123,000 (rebate $22,000)</td>
<td>0.8</td>
</tr>
<tr>
<td>Install partial air-side economizer</td>
<td>313,000</td>
<td>$36,000</td>
<td>$53,000 (rebate $24,000)</td>
<td>0.8</td>
</tr>
<tr>
<td>Add heat recovery to air-side economizer</td>
<td>65,000</td>
<td>$7,000</td>
<td>$1,000</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control lights with 30-minute enabled zones</td>
<td>238,000</td>
<td>$27,000</td>
<td>$17,000</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Total for all measures: 2,295,000 kWh/year, $262,000/year, $710,000 (rebate $130,000) with 2.2 years payback.
Case Studies

The Hanover Insurance Group (MA)

- 13,000 ft² data center overcooled

- Solutions
  - Implemented Demand Based Cooling™ (DBC) airflow and thermal management system
  - Installed cut-out covers into floor openings
  - Blanking panels into key rack openings
  - Adjusted some CRAC set points

- Results
  - Five out of 13 CRAC units were placed into hot-standby
  - Energy usage for cooling reduced by 27%
  - Increased cooling redundancy
  - Increased IT load capacity by 70kW

<table>
<thead>
<tr>
<th>Cost of project:</th>
<th>$144,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual energy savings</td>
<td>600,000 kWh</td>
</tr>
<tr>
<td>Energy cost savings</td>
<td>$96,000/yr</td>
</tr>
<tr>
<td>Utility incentive</td>
<td>$21,500</td>
</tr>
<tr>
<td>Company payback</td>
<td>16 months</td>
</tr>
</tbody>
</table>
Resources

- DOE Data Center Profiler (DC Pro) Software Tool Suite
  - A web-based application accessible from any computer
  - DC Pro Profiling Tool
  - Air-Management Tool
    - Raised floor w/hot/cold aisles
  - Electrical Systems Tool

DC Pro Tool

Inputs
- Description
- Utility bill data
- System Information
  - IT
  - Cooling
  - Power
  - Onsite generation

Outputs
- Overall picture of energy use and efficiency
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy-use reduction potential
Resources

- EPA/DOE Labs for the 21st Century
- ASHRAE Green Tips for Data Centers
- Data Center Energy Practitioner Program
  - Level I & Level II certification
  - Specialists tracks
- 80 PLUS® Certified Power Supplies and Manufacturers
- ENERGY STAR Portfolio Manager data center model
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  December 17: 9-10am PST

- **Space Conditioning:**
  *Boiler and Chiller Maintenance for Maximum Efficiency*
  July 16: 9-10am PST
  *PGE Webinar: Intro to Ammonia Refrigeration*
  March 26: 8-9 am PST

[http://neea.org/get-involved/calendar](http://neea.org/get-involved/calendar)
Thank You

- Please take our [online survey](#)