Introduction

- Purpose
  - LLNL Data Center Master Plan
  - Key Competency – Benchmarking/Modeling

- Goals – Improve Overall Operations of B112 Enterprise Data Center
  - Evaluate optimization scenarios
  - Investigate efficiency improvements
    - Improve operational set point
    - Make building improvements
    - Identify consolidation
  - Present Results at SVLG
  - Develop whitepaper

- Team: LLNL, LBNL, Syska Hennessy, Romonet, California Energy Commission, DOE

- Timeline: August-October 2012

- Tool: Romonet Modeling Software

MASTER PLAN CHARTER:
Develop projects to improve optimization of LLNL’s data centers and reduce energy intensity
Data Center Site

Computer Room

UPS Room

Chiller Room
Data Center Modeling Demonstration

- Introduction
- Model Construction
- Evaluate Model Accuracy
- Use Model to Forecast Efficiency
- Observations
- Plans
LLNL Data Center Overview

- Building Information
  - Original Construction 1965, Retrofitted in 2007
  - 15,500 Sqft of Raised Floor
  - 14,000 Sqft of Infrastructure Space

- Electrical System
  - 2N UPS Systems (1,000 kVA Modules)
  - 2N & N Critical Power Distribution
  - 20 – PDUs on the Raised Floor

<table>
<thead>
<tr>
<th>IT Loads</th>
<th>2N (kW)</th>
<th>N (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>630</td>
<td>480</td>
</tr>
<tr>
<td>Current Load</td>
<td>325</td>
<td>7 (*Aug 2012)</td>
</tr>
</tbody>
</table>

- Mechanical Systems
  - Chilled Water System
  - N+1 Design
  - CRAH and AHU feeding under floor – Constant Speed Fans

* value during site visit, IT equipment load currently higher and expanding
Project Process - What We Did

- Survey site
- Create baseline model
- Compare baseline model results to meter readings (actual IT power was the model input)
- Calibrate model (adjust component performance toward actual)
- Model with actual IT loads to investigate accuracy
- Model “What If” scenarios
Example: Model Construction

Electrical Energy Flow

Thermal Energy Flow
Model Construction – Critical Electrical Dist.

- Utility Transformer
- Power Flow Connection
- 2N UPS System
- Dual Corded PDUs (14)
- Single Corded "A" PDUs (3)
- Single Corded "A" Side Load
- Dual Corded IT Load
- Single Corded "B" Side Load
- Single Corded "B" PDUs (3)
Model Construction - Mechanical

- UPS Rm
- CRAH s (2)
- Data Hall CRAH and AHUs
- Heat Flow Connector
- Chillers (2)
- Pumps (2)
- Office Space Heat Load
Comparison: Metering vs. Calibrated Romonet Results

Critical Power

- <= 5% Variance
- > 5% Variance *

UPS Input

UPS Output

Model Input

Site Metering

Romonet

Input

Site Metering

100 kW

200 kW

300 kW

0 kW

300 kW

200 kW

100 kW

0 kW

Critical Total

UPS Input

UPS Output

Model Input

UPS Room

Data Hall

IT Equip.

Romonet Calibrated Output

Metering Suspect – Service Scheduled

11% high

0.5% high

3.8% low

6.6% high

Romonet

Calibrated

Output

Site

Metering

381 380

170 188 191 192 180 173 166 177

325 325

Site

Metering

Romonet

Input

Lawrence Livermore National Laboratory
Comparison: Metering vs. Calibrated Romonet Results
Infrastructure Power

- <= 5% Variance
- > 5% Variance

Site Metering
Romonet Calibrated Output

709 Total
710 Total
Est. Other
Chiller
Est. Lighting
Investigate “What If” Using Romonet

- Increasing IT Load
  - Simulate IT load increase (332 kW to 1,110 kW)

- Adding CRAH / AHU Fan Speed Controls

- Adding Waterside Economizer
  - Dedicated Data Center Secondary Loop with elevated CHW Temperatures
  - Dedicated Data Center Cooling Tower
Waterside Economizer Flow Diagram

Office Building

Data Center Loop

Chilled Water Loop

Heat Exchanger

Heat Exchanger

Chiller

Cooling Tower

Economizer Loop

From Campus Condenser Water Loop
“What If” Analysis Comparison

Annual Average PUE

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Annual Average PUE</th>
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<tbody>
<tr>
<td>Baseline</td>
<td>2.16</td>
</tr>
<tr>
<td>Projected IT Load</td>
<td>1.62</td>
</tr>
<tr>
<td>CRAH &amp; AHU VFDs</td>
<td>1.56</td>
</tr>
<tr>
<td>Waterside Economizer</td>
<td>1.39</td>
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</table>

Not Included:
- Boiler Room (humidification) Gas Energy (missing data, unable to reconcile)
- Gen. Set Testing (gen. sets not installed at this site)
“What If” Analysis Comparison

Annual Energy Contribution (MWh)

Baseline
Projected IT Load
CRAH & AHU VFDs
Waterside Economizer and VFDs

Other
Chiller
CRAH & AHU
IT Load
## “What If” Analysis Comparison

<table>
<thead>
<tr>
<th>Project</th>
<th>Infrastructure Project Capital Expenditure</th>
<th>Annual Energy Cost</th>
<th>Simple Pay Back</th>
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<tbody>
<tr>
<td>Baseline</td>
<td>$ 0</td>
<td>$ 400,000</td>
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<tr>
<td>Projected IT Load</td>
<td>$ 0</td>
<td>$ 1,020,000</td>
<td><strong>BRAKER</strong></td>
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<tr>
<td>CRAH &amp; AHU VFDs</td>
<td>$ 161,000</td>
<td>$ 990,000</td>
<td>3 years</td>
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<tr>
<td>Waterside Economizer and VFDs</td>
<td>$ 1,700,000</td>
<td>$ 864,000</td>
<td>8 years</td>
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</tbody>
</table>

Energy cost $0.065/kWh
## Project Effort to Date
(person days)

<table>
<thead>
<tr>
<th>Activity</th>
<th>LLNL</th>
<th>Syska</th>
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<tbody>
<tr>
<td><strong>Model Development</strong></td>
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<td></td>
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<tr>
<td>Data Collection: Paper Survey</td>
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<td>1</td>
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<tr>
<td>Site Visit #1</td>
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<td>1</td>
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<tr>
<td>Develop Base Model</td>
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<td><strong>Model Calibration</strong></td>
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<tr>
<td>Site Visit #2</td>
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<tr>
<td>Analysis &amp; Model Adjustment</td>
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<td><strong>Sub-Total</strong></td>
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<td>8</td>
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<tr>
<td><strong>Model Change and Run “What If”</strong></td>
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<tr>
<td>CRAH &amp; AHU Fan Speed Control</td>
<td>.5</td>
<td>1</td>
</tr>
<tr>
<td>Waterside Economizer</td>
<td>.5</td>
<td>3</td>
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<tr>
<td><strong>Sub-Total</strong></td>
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<td>4</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td>4</td>
<td>12</td>
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<tr>
<td><strong>Total</strong></td>
<td>16</td>
<td></td>
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</table>

Modeler Experience: Subject Expert, Modeling Training Complete
What Did We Learn?

- Labor Required
  - Syska, LLNL, LBNL, Romonet

- Metering Issues
  - Slight variance in total metering
  - Variances encountered in UPS metering
    - Need to address with vendor during next maintenance cycle

- Office Tower Load (temporary Btu metering)

- Site Cooling Tower Water (not included in PUE)

- Chiller Performance Information
  - Not separately metered
  - Temporary load logging installed
  - Coordination required with rotation sequence of chillers
Conclusions / What Next?

- Accuracy- Testing was limited (one set of conditions): model accuracy deemed sufficient for “What If” investigation.
- The project uncovered a number of unknown metering issues.
- Adding IT load will provide the best ROI, in comparison other projects investigated will provide a much longer payback period.
- Work with customers to expand humidity level requirements. (Turn off or reduce boiler function)
Questions – LLNL Data Center Master Plan Team

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