Green Capacity Planning: Theory and Practice

Amy Spellmann, Optimal Innovations
Richard Gimarc, HyPerformix
Charles Gimarc, LSI

Rocky Mountain CMG
June 02, 2009
Agenda

- Green Capacity Planning
  - Methodology
  - Energy Footprint Projection

- Case Study
  - Server Upgrade Scenario
  - Virtualized Scenario
  - Storage Upgrade Options
  - Comparison

- Conclusion
Green Capacity Planning: What is it?

- Extends established methods & best practices
- Introduces an **energy footprint projection**
- Views energy as a new resource for capacity planners to include in their analysis
- Focuses on cost-effective technologies & practices to manage today’s challenges
Green Capacity Planning Combines Tools & Best Practices

Predictive Capacity Planning

Energy Footprint Projection

Cost & Capacity Comparison

Commercial Capacity Planning Tools

Professional Services

Green Capacity Planning

Established Methods

New Resource to Evaluate
Green Capacity Planning: Why do we need it?

- By 2010, IDC expects that for every dollar of new server spending, an additional $0.70 will be needed for power and cooling.

- 2% of the world’s carbon dioxide emissions come from IT equipment—the same amount of pollution as the airline industry creates—Wall Street Journal.

- With the advent of high density computer equipment such as blade servers, many data centers have maxed out their power and cooling capacity—Gartner.

- New data center construction projects cost $250M and up.

- Google spent $600M each for four new data centers in 2007.
Green Capacity Planning: Value

- Determines the most efficient way to meet business needs while minimizing computing, power, cooling, space requirements
- Assures SLAs are met
  - Response times
  - Utilization
- Evaluates potential cost & energy savings of virtualization
Green Capacity Planning: Factors

- Must meet SLAs
  - Response times
  - Utilization
- Minimize power, space, cooling
- Evaluates potential cost & energy savings of virtualization

Cost Effective Solution
Methodology: Enhanced Traditional Approach

Business Requirements: Profile & SLA

IT Equipment Capacity & Workload Analysis

DataCenter Upgrade Plan

Cost Calculation: IT Equipment, Infrastructure & Energy

Energy Footprint Analysis

Loop until Optimized

Infrastructure & Energy

Traditional Capacity Planning

EFP
Green Capacity Planning Metrics

- **New Inputs**
  - Energy Footprint (calculated or measured)
  - PUE
  - Active Idle
  - Max Power
  - Cost of electricity

- **Comparison Metrics**
  - Energy Footprint Projection
  - Rack Space
  - Cumulative Costs
  - Productivity (Trans per kWh)

In addition to traditional capacity planning metrics, e.g., Utilization, Response Time, etc.
Energy Footprint Projection

- Determine energy required by each system component
  - Obtain active-idle, average, maximum power from measurements or vendor specifications
  - Compute energy usage over time (e.g., monthly)
- Add “site” infrastructure energy
  - Overhead energy for running components in the data center
  - Includes: cooling, fans, power distribution units, lighting, etc.
Energy Footprint Projection: Terminology

- **Terminology**
  - **Power**
    - Spot measurement, single point in time
    - Measured in watts (W)
  - **Energy**
    - Power consumption over a period of time
    - Measured in kilowatt hours (kWh)
    - You pay for energy, not power

- **Energy estimation**
  - Component-level power requirements (W)
  - Estimate consumption over a period of time (e.g., 1 day)

\[
\text{Power} \times \text{Time} = \text{Energy Usage}
\]
Energy Footprint Projection: Data Center Energy Usage

**General Flow**
- Energy enters in the form of electricity
- IT equipment used to store & manipulate information
- IT equipment generates heat
- Site infrastructure removes generated heat

**Questions**
- What if your data center’s power input is maximized?
- How can you increase your compute power without increasing your power draw?
- Can you improve site efficiency?
- Do you really need to build a new data center?
Energy Footprint Projection: Components

- Two components
  - IT Equipment
  - Site Infrastructure

- Approach
  - Compute IT energy
  - Estimate Site energy

- Power Usage Effectiveness

\[
PUE = \frac{\text{Site Power} + \text{IT Power}}{\text{IT Power}} \geq 1.0
\]

- Today’s average of 2.0
- Use to estimate Site energy
- Energy = Power x Time

\[
\text{EFP(Day)} = \text{IT}_k\text{Wh}_{\text{Computed}} + \text{Site}_k\text{Wh}_{\text{Estimated}}
\]
Energy Footprint Projection: Component Contribution

**Site Infrastructure** [ACC2008]
- Transformer - 5%
- Lighting - 8%
- Fans - 16%
- UPS - 17%
- Chillers - 54%

**IT Equipment** [EPA2007]
- Network - 10%
- Storage - 10%
- Servers - 80%
Energy Footprint Projection: Estimating EFP(Day)

\[ EFP(\text{Day}) = \text{IT}_\text{kWh}_{\text{Computed}} + \text{Site}_\text{kWh}_{\text{Estimated}} \]

Given Power\(_i\) for each IT device:

\[ \text{IT}_\text{kWh}_{\text{Computed}} = (\sum \text{Power}_i) \times (24 \text{ Hours/Day}) \]

Power Usage Effectiveness:

\[ \text{PUE} = \frac{\text{Site Power} + \text{IT Power}}{\text{IT Power}} \geq 1 \]

Estimate Site\(_k\text{Wh}\) using assumed PUE:

\[ \text{Site}_\text{kWh}_{\text{Estimated}} = \text{IT}_\text{kWh}_{\text{Computed}} \times (\text{PUE} - 1) \]

\[ EFP(\text{Day}) = \text{PUE} \times \text{IT}_\text{kWh}_{\text{Computed}} \]
Energy Footprint Projection: Server Power Usage

- How do you estimate the power usage of a server?
- Power specifications for a server (W):
  - Power supply
  - Max Power
  - Active Idle

- Approximation
  - Server power usage scales linearly with processor utilization
  - Validated across various servers ± 5% [TGG2008]

\[
\text{Power@Util\%} = (\text{MaxW} - \text{IdleW}) \times \left(\frac{\text{Util\%}}{100}\right) + \text{IdleW}
\]
**Energy Footprint Projection: Server Power Usage - Example**

### SPECpower_ssj2008

**Dell Inc. PowerEdge 2950 III (Intel Xeon E5440)**

<table>
<thead>
<tr>
<th>Test Sponsor</th>
<th>Dell Inc.</th>
<th>SPEC License #</th>
<th>55</th>
<th>Hardware Availability: Mar-2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tested By</td>
<td>Dell Inc.</td>
<td>SPEC Location: Round Rock, TX, USA</td>
<td>55</td>
<td>Software Availability: Oct-2007</td>
</tr>
<tr>
<td>System Source</td>
<td>Single Supplier</td>
<td>Test Date: Feb 12, 2008</td>
<td>55</td>
<td>Publication: Feb 27, 2008</td>
</tr>
</tbody>
</table>

### Benchmark Results Summary

<table>
<thead>
<tr>
<th>Performance</th>
<th>Power</th>
<th>Performance to Power Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Load</td>
<td>Actual Load</td>
<td>ssj_ops</td>
</tr>
<tr>
<td>100%</td>
<td>99.2%</td>
<td>298,188</td>
</tr>
<tr>
<td>90%</td>
<td>89.7%</td>
<td>269,554</td>
</tr>
<tr>
<td>80%</td>
<td>80.4%</td>
<td>241,701</td>
</tr>
<tr>
<td>70%</td>
<td>70.3%</td>
<td>211,354</td>
</tr>
<tr>
<td>60%</td>
<td>60.0%</td>
<td>180,508</td>
</tr>
<tr>
<td>50%</td>
<td>49.5%</td>
<td>148,959</td>
</tr>
<tr>
<td>40%</td>
<td>40.4%</td>
<td>121,477</td>
</tr>
<tr>
<td>30%</td>
<td>30.2%</td>
<td>90,702</td>
</tr>
<tr>
<td>20%</td>
<td>20.1%</td>
<td>60,493</td>
</tr>
<tr>
<td>10%</td>
<td>10.0%</td>
<td>29,990</td>
</tr>
<tr>
<td>Active Idle</td>
<td>0</td>
<td>147</td>
</tr>
</tbody>
</table>

\[ \text{Power@Util\%} = (\text{MaxW} - \text{IdleW}) \times \left( \frac{\text{Util\%}}{100} \right) + \text{IdleW} \]

\[ \text{Power@70\%} = (254 - 147) \times \left( \frac{70}{100} \right) + 147 \]

\[ \text{Power@70\%} = 221.9 \]

Assume server power usage scales linearly with CPU utilization
Demonstrate Green Capacity Planning

- Extend data center lifetime while supporting future business growth
  - Two year planning based on business projections
  - Limited data center power
- Develop a capacity plan for growth/change
  - Upgrade/add servers
  - Leverage virtualization
- Align with business requirements
  - Predict required infrastructure to meet SLAs
  - Reduce today’s energy footprint
  - Select cost-effective solution
Case Study: eCommerce System

- Growing eCommerce system
- Business Requirements
  - 5% monthly growth
  - 2-year upgrade plan to support growth & meet SLAs
  - Reduce IT & site energy costs
  - Optimize hardware utilization
  - Evaluate virtualization as an energy saving solution

Baseline System
- 24 servers
- 42U Rack space
Case Study: Baseline System

- **TPC-W Benchmark**
  - Published TPC-W Benchmark Result
    - May 2002
    - Full Disclosure Report - details
  - Simulates Web-based browsing & shopping
  - Provides the baseline specification
    - Application architecture
    - IT equipment
    - Workload
    - Utilization

**Benchmark Workload**
- 100,000 Items
- 76,000 Users
- 9,709 WIPSb@100,000
Case Study: Baseline Architecture & IT

<table>
<thead>
<tr>
<th>Function</th>
<th># of Systems</th>
<th>System</th>
<th>OS</th>
<th>Processors</th>
<th>Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web/Image/Cache Fill Server</td>
<td>18</td>
<td>PowerEdge 1650</td>
<td>Microsoft Windows Powered</td>
<td>2 - Pentium III 1.4GHz/512kB L2</td>
<td>2GB</td>
</tr>
<tr>
<td>Image/DNS Server</td>
<td>2</td>
<td>PowerEdge 1650</td>
<td>Windows 2000 Advanced</td>
<td>2 - Pentium III 1.4GHz/512kB L2</td>
<td>2GB</td>
</tr>
<tr>
<td>Web Cache</td>
<td>3</td>
<td>PowerEdge 1650</td>
<td>Volera Excelerator 2.2</td>
<td>1 - Pentium III 1.4GHz/512kB</td>
<td>2GB</td>
</tr>
<tr>
<td>Database Server</td>
<td>1</td>
<td>PowerEdge 6650</td>
<td>Windows 2000 Advanced</td>
<td>4 - Intel Xeon MP 1.6GHz/1MB L3</td>
<td>4GB</td>
</tr>
</tbody>
</table>
Case Study: Baseline Database Storage

- 12 HDD per enclosure
- Ultra320 SCSI
- 5 enclosures
- 3U rack space per enclosure
- 41 total disks

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Enclosure</th>
<th># of Disk</th>
<th>RAID Level</th>
<th>Capacity (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log</td>
<td>1</td>
<td>10</td>
<td>1 / 0</td>
<td>135</td>
</tr>
<tr>
<td>Backup</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>393</td>
</tr>
<tr>
<td>Database</td>
<td>3, 4, 5</td>
<td>24</td>
<td>0</td>
<td>812</td>
</tr>
</tbody>
</table>
Case Study: Database Technology Upgrade

- Move to current SAS technology that will allow scaling for 2 years
- Replace original Ultra 320 SCSI storage subsystem with newer SAS (Serial Attached SCSI) technology
- Reduce power by changing from 3½” to 2½” SFF disks
- Triple storage density by moving from 12 disks in a 3U space to 24 disks in a 2U space
- Achieve higher performance to meet the demands of the system after 2 years of workload growth
- Decrease power per enclosure by 50%
Case Study: Modeling Approach

- Utilizing HyPerformix’s Capacity Manager for Capacity Analysis
- Dell’s Datacenter Capacity Planner for Power Metrics
- Integrating results for Server/Resource Capacity, Power Requirements & Business Metrics
Case Study: Modeling Scenario Strategy

Server Upgrade
- 5% monthly growth for 2 years
- 70% capacity threshold
- Optimize the number of upgrades
- Dell PE 2950 for the database
- Dell PE 1850 for all other servers

Virtualization
- 5% monthly growth for 2 years
- 70% capacity threshold
- Optimize the number of upgrades
- Dell PE 2950 for the database
- Virtualize all other servers on a pool of Dell PE 1950s
- Optimize use of virtual hosts

For each scenario
1. Determine infrastructure required to support workload growth (Capacity Manager)
2. Estimate energy footprint
3. Calculate cost of IT equipment & energy
Scenario - Server Upgrade: Database Storage Provisioning

- **Growth Assumption:**
  - Database storage grows at same rate as workload (5% per month)

- **Baseline Assumptions:**
  - Use same capacity disks
    - 36GB for Log & Database
    - 73GB for Backup
  - Same disk fill factor
  - One RAID adapter per enclosure

- **Method:**
  - Estimate required disk space based on growth
  - Compute number of disks
  - Compute number of enclosures & adapters

- **Results:**
  - Start with 4 enclosures
  - Add new enclosure when disk count reaches 24
Scenario - Server Upgrade: Timeline

- Minimize number of server upgrade points
- Servers upgraded once per 3-month period
- Retire old servers (replace with faster more efficient servers)
Scenario - Server Upgrade: Infrastructure - Final Plan

- Final 2-year capacity plan
- Infrastructure supports 5% growth over 24 months
- Server upgrades grouped to reduce downtime (one upgrade per quarter)
Scenario - Server Upgrade: Infrastructure Components

At end of 2-years
- 27 Servers 21 kWh / mo
- $150K 42U rack
Scenario - Server Upgrade: Monthly Energy Footprint

Not achieving goal of reducing energy footprint
Case Study Modeling Scenario Strategy

Server Upgrade
- 5% monthly growth for 2 years
- 70% capacity threshold
- Optimize the number of upgrades
- Dell PE 2950 for the database
- *Dell PE 1850 for all other servers*

Virtualization
- 5% monthly growth for 2 years
- 70% capacity threshold
- Optimize the number of upgrades
- Dell PE 2950 for the database
- Virtualize all other servers on a pool of Dell PE 1950s
- Optimize use of virtual hosts

For each scenario
1. Determine infrastructure required to support workload growth (Capacity Manager)
2. Estimate energy footprint
3. Calculate cost of IT equipment & energy
Scenario - Virtualization: Server Utilization Results
Scenario - Virtualization: Infrastructure Components

- At end of 2-years
  - 6 Servers
  - 7.7 kWh / mo
  - $120K
  - 21U rack
Example - Storage Upgrade: Replace HDD with SSD

- Replace Database rotating disks with SSDs
  - Random workload
  - Other stores (Log, Backup) are mostly sequential
- Keep same data throughput and latency levels
  - Maintain SLA
- Reduce
  - DataCenter footprint
  - Power
  - Cost (CAPEX, Operating)
- Compare Storage at month 24 only
Example - Storage Upgrade: Replace HDD with SSD

- Replace 4 HDD with one SSD
  - Similar capacity, will be sufficient to maintain performance
  - Reduced space, power & cost (capex)

<table>
<thead>
<tr>
<th>Feature</th>
<th>HDD (3G SAS)</th>
<th>SSD (3G SATA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>36 GB</td>
<td>128 GB</td>
</tr>
<tr>
<td>Size</td>
<td>2.5” SFF</td>
<td>2.5” SFF</td>
</tr>
<tr>
<td>Active Power, W</td>
<td>7.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Idle Power, W</td>
<td>5.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Cost, $/disk (est)</td>
<td>300</td>
<td>800</td>
</tr>
<tr>
<td>Sequential IOPs</td>
<td>30K – 100K</td>
<td>50K – 100K</td>
</tr>
<tr>
<td>Random RD IOPs</td>
<td>300</td>
<td>10K – 30K</td>
</tr>
<tr>
<td>Sequential RD MB/s</td>
<td>120</td>
<td>240</td>
</tr>
</tbody>
</table>
Example - Storage Upgrade: Replace HDD with SSD

HDD Solution

- 17 HDD Log
- 17 HDD Log
- 21 HDD Backup
- 20 HDD DB1
- 20 HDD DB2
- 19 HDD DB1
- 19 HDD DB2

7 x 2U

133 HDD
3395 W Active
$68,040 capex
14U rack

SSD Solution

- 17 HDD Log
- 17 HDD Log
- 21 HDD Backup
- 11 SSD DB1
- 11 SSD DB2

4 x 2U

55 HDD
22 SSD
1579 W Active
$66,961 capex
8U rack

42%
53%
2%
43%
## Scenario Comparison: Server Upgrade vs. Virtualization

<table>
<thead>
<tr>
<th></th>
<th>Server Upgrade</th>
<th>Virtualization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Server Count</strong></td>
<td>27</td>
<td>6</td>
</tr>
<tr>
<td><strong>Energy Footprint</strong></td>
<td>21,000 kWh</td>
<td>7,700 kWh</td>
</tr>
<tr>
<td><strong>Cumulative Cost</strong></td>
<td>$150,000</td>
<td>$120,000</td>
</tr>
<tr>
<td><strong>Rack Space (U)</strong></td>
<td>42</td>
<td>21</td>
</tr>
</tbody>
</table>
Scenario Comparison: Infrastructure Sprawl

**Baseline**

- 24 svr, 42U
- 15.6 kWh/mo
- 9,700 WIPSb

**Server Upgrade**

- 27 svr, 42U
- 21 kWh/mo
- 31,300 WIPSb

**Virtualization**

- 6 svr, 21U
- 7.7 kWh/mo
- 31,300 WIPSb
Scenario - Virtualization: Monthly Energy Footprint

Significant reduction:
Energy Footprint (50%)
Scenario Comparison: Rack Space

Total Rack Space per Month

- **Server Upgrade requires same rack space at end of 2-year plan**
- **Virtualization rack space @ 50%**
Scenario Comparison: Detailed Cumulative Cost

- Identical storage costs
- Virtualization server cost 30% lower
- Energy cost 60% less
Looking Ahead

Emerging technologies are already impacting Green Capacity Planning in the DataCenter

- **SSD**
  - Reduce # of disks & power

- **Multicore Processors**
  - Higher CPU capacity in same physical & power footprint

- **Dynamic Power Management**
  - Manage power of subsystems & components relative to current load

- **Virtualization**
  - Combine multiple servers into one server

Facilities improvements

- **Creative Cooling**
  - Fluid cooling, higher temp operation

- **Decreasing PUE**
  - Driving PUE very close to 1.0 (lights, fans, chiller)

- **Climate-driven locations**
Reducing PUE doesn’t necessarily mean reduction in energy utilization.

First 3 bars all have the same PUE, but different monthly KWH.

Applying PUE reductions reduce energy utilization.

C.S. Base = Case Study Baseline system.

C.S. Virt = Case Study system, virtualized, after 24 months of upgrades.
Green Capacity Planning
- Energy is a resource
- Introduce Energy Footprint Projection
- Expands traditional capacity planning

Case Study
- Demonstrates the methodology
- Analyzes alternative infrastructures
- Reduces energy footprint with Virtualization

Value
- Actionable metrics
- Quantifies IT and Site energy usage & costs
- Supports responsible decision making
- Bridges the gap between IT & Facilities
This presentation is based upon a 2008 study by:

Amy Spellmann, Optimal Innovations
amy@optimalinnovations.com

Richard Gimarc, Hyperformix
rgimarc@hyperformix.com

Charles Gimarc, LSI Corporation
Charles.Gimarc@lsi.com

And a paper presented at the 2008 Computer Measurement Group conference, December 2008. The paper may be downloaded from:


