The Future of Data Centers
(... and the Stuff That Goes In Them)

Subodh Bapat
Vice President, Energy Efficiency
Sun Microsystems
The Coming Data Center Revolution

Size of Data Center
- 500,000ft²
- 50,000ft²
- 5,000ft²
- 500ft²

MIS Glass House
- Mainframes
- Card punches
- Line printers

Client-Server Back-End
- LAN Switches
- File Servers
- Print Servers
- Compute Servers

Internet Data Center
- Rack Mount Servers
- Blades
- Three Tier Architecture
- Load Balancers
- Switches
- Security
- Firewalls

Red-Shifted Eco-Grids
- Optimized Power
- Optimized Cooling
- Virtualization
- Energy Efficient
- Performance / Watt
- Fuel Cells
- Ambient Cooling
- Minimized Carbon Footprint

Power of Data Center
- 50,000kW
- 5,000kW
- 500kW
- 50kW

New Capital Cycle

500ft²
5,000ft²
50,000ft²
500,000ft²

1972
1984
1996
2008
2020

50kW
500kW
5,000kW
50,000kW
# Number of Data Centers Growing

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Large</td>
<td>100</td>
<td>106</td>
<td>120</td>
<td>160</td>
<td>175</td>
<td>185</td>
<td>210</td>
<td>230</td>
<td>250</td>
<td>270</td>
</tr>
<tr>
<td>Large</td>
<td>900</td>
<td>870</td>
<td>880</td>
<td>900</td>
<td>920</td>
<td>990</td>
<td>1,040</td>
<td>1,100</td>
<td>1,170</td>
<td>1,250</td>
</tr>
<tr>
<td>Medium</td>
<td>1,405</td>
<td>1,385</td>
<td>1,395</td>
<td>1,420</td>
<td>1,490</td>
<td>1,585</td>
<td>1,665</td>
<td>1,765</td>
<td>1,870</td>
<td>1,975</td>
</tr>
<tr>
<td>Small</td>
<td>2,180</td>
<td>2,100</td>
<td>2,110</td>
<td>2,190</td>
<td>2,230</td>
<td>2,290</td>
<td>2,360</td>
<td>2,430</td>
<td>2,500</td>
<td>2,570</td>
</tr>
<tr>
<td>Total</td>
<td>4,585</td>
<td>4,461</td>
<td>4,505</td>
<td>4,670</td>
<td>4,815</td>
<td>5,050</td>
<td>5,275</td>
<td>5,525</td>
<td>5,790</td>
<td>6,065</td>
</tr>
<tr>
<td>Growth Rate</td>
<td>-2.70%</td>
<td>1.00%</td>
<td>3.70%</td>
<td>3.10%</td>
<td>4.90%</td>
<td>4.35%</td>
<td>4.74%</td>
<td>4.80%</td>
<td>4.75%</td>
<td></td>
</tr>
</tbody>
</table>

**Small Data Center**
- Between 350 – 500 Servers Installed
- 15,000 Sq Feet Of Raised Floor
- Predominately Volume Server Architecture, with 1 -3 High End Server Systems

**Medium Data Center**
- Between 1,500 – 1,700 Servers Installed
- 20,000 Sq Feet Of Raised Floor
- Four or Five High End Systems Form The Basis Of Enterprise Systems

**Large Data Center**
- Between 2,000 – 2,500 Servers Installed
- 35,000 Sq Feet Of Raised Floor
- House Up To 7 High End Systems

**Very Large Data Center**
- Up to 25,000 Servers Installed
- 100,000+ Sq Feet Of Raised Floor
- Eight+ High End Systems

Source: Presentation by Vernon Turner from IDC at the Sun Summit on 21st Century Eco-Responsibility, November 14, 2005 for US Data Centers
Number of Servers in Data Centers Growing

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very Large</strong></td>
<td>449</td>
<td>503</td>
<td>565</td>
<td>630</td>
<td>695</td>
</tr>
<tr>
<td><strong>Greenfield</strong></td>
<td>40</td>
<td>54</td>
<td>62</td>
<td>65</td>
<td>67</td>
</tr>
<tr>
<td><strong>Brownfield</strong></td>
<td>409</td>
<td>449</td>
<td>503</td>
<td>565</td>
<td>630</td>
</tr>
<tr>
<td><strong>Servers in Very Large</strong></td>
<td><strong>11,227,357</strong></td>
<td><strong>12,572,577</strong></td>
<td><strong>14,115,316</strong></td>
<td><strong>15,754,862</strong></td>
<td><strong>17,509,290</strong></td>
</tr>
<tr>
<td><strong>Large</strong></td>
<td>2,340</td>
<td>2,491</td>
<td>2,700</td>
<td>2,949</td>
<td>3,208</td>
</tr>
<tr>
<td><strong>Greenfield</strong></td>
<td>140</td>
<td>151</td>
<td>209</td>
<td>249</td>
<td>255</td>
</tr>
<tr>
<td><strong>Brownfield</strong></td>
<td>2,200</td>
<td>2,340</td>
<td>2,491</td>
<td>2,700</td>
<td>2,949</td>
</tr>
<tr>
<td><strong>Servers in Large</strong></td>
<td><strong>5,265,040</strong></td>
<td><strong>5,603,777</strong></td>
<td><strong>6,075,723</strong></td>
<td><strong>6,635,948</strong></td>
<td><strong>7,295,537</strong></td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>3,746</td>
<td>3,987</td>
<td>4,333</td>
<td>4,714</td>
<td>5,095</td>
</tr>
<tr>
<td><strong>Greenfield</strong></td>
<td>220</td>
<td>241</td>
<td>346</td>
<td>381</td>
<td>385</td>
</tr>
<tr>
<td><strong>Brownfield</strong></td>
<td>3,526</td>
<td>3,746</td>
<td>3,987</td>
<td>4,333</td>
<td>4,714</td>
</tr>
<tr>
<td><strong>Servers in Medium</strong></td>
<td><strong>5,994,227</strong></td>
<td><strong>6,379,685</strong></td>
<td><strong>6,932,461</strong></td>
<td><strong>7,542,168</strong></td>
<td><strong>8,196,942</strong></td>
</tr>
<tr>
<td><strong>Small</strong></td>
<td>5,413</td>
<td>5,652</td>
<td>5,965</td>
<td>6,302</td>
<td>6,673</td>
</tr>
<tr>
<td><strong>Greenfield</strong></td>
<td>210</td>
<td>239</td>
<td>313</td>
<td>337</td>
<td>375</td>
</tr>
<tr>
<td><strong>Brownfield</strong></td>
<td>5,203</td>
<td>5,413</td>
<td>5,652</td>
<td>5,965</td>
<td>6,302</td>
</tr>
<tr>
<td><strong>Servers in Small</strong></td>
<td><strong>2,300,426</strong></td>
<td><strong>2,401,961</strong></td>
<td><strong>2,535,233</strong></td>
<td><strong>2,678,327</strong></td>
<td><strong>2,833,263</strong></td>
</tr>
<tr>
<td><strong>Total Number of Servers</strong></td>
<td><strong>24,787,050</strong></td>
<td><strong>26,958,000</strong></td>
<td><strong>29,658,733</strong></td>
<td><strong>32,611,304</strong></td>
<td><strong>35,835,032</strong></td>
</tr>
</tbody>
</table>

Number of Regulations Growing

July, 2006: U.S. House of Representatives passes bill mandating study of data center efficiency

September, 2006: California legislature passes bill mandating that carbon emissions be monitored and reported beginning in 2012

November, 2006: EPA publishes final server energy measurement protocol

December, 2006: U.S. Federal Government implements EPEAT purchasing requirements for multiple agencies

2007: EPA starts work on Energy Star for servers

2008: European Code of Conduct for data center operators goes into effect

2009: EU Eco-Design for Energy Using Products specifications for servers goes into effect

2010: 

Number of government/regulatory/legislative mandates to report and reduce data center power
National Average Retail Price of Electricity
Year-to-Date: February 2004 - 2008

Average Annual Increase:
- Residential: 5.77%
- Commercial: 5.36%
- Industrial: 7.48%

Source: Energy Information Administration Electric Power Monthly Archives; Average Retail Price of Electricity by Sector
http://www.eia.doe.gov/cneaf/electricity/epm/epm_ex_bkis.html, epxmxfile5_6_a.xls
The Cubing Effect

By 2012 data center power consumption costs could grow to $250B worldwide – demanding proactive energy management solutions

1. U.S. Energy Information Administration (www.eia.doe.gov)
2. Sun primary research
### What % of IT Costs is Power?

<table>
<thead>
<tr>
<th>Data Center Type</th>
<th>Percentage Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Enterprise Data Center</td>
<td>20% - 30%</td>
</tr>
<tr>
<td>Large Enterprise Data Center</td>
<td>25% - 45%</td>
</tr>
<tr>
<td>Managed Hosting and Colocation Provider</td>
<td>50% - 80%</td>
</tr>
</tbody>
</table>

Source: Gartner, IDC
What's Wrong With This Data Center?

Data Center Administrator Offices

Operations Center

Meeting Rooms

CRAC

CRAC

CRAC

CRAC

CRAC

CRAC

CRAC

Server Racks

Lobby
What the Infrared Camera Sees

- Data Center Administrator Offices: 55°F, 75°F
- Operations Center: 55°F, 75°F
- Lobby: 55°F, 75°F
- Meeting Rooms: 75°F
- Server Racks: 65°F, CRAC, 95°F, 75°F
Effective Use of Energy?

- **Operations Center**
  - CRAC: 65°F
  - Server Racks: 95°F, 75°F

- **Data Center Administrator Offices**
  - CRAC: 65°F

- **Meeting Rooms**
  - CRAC: 65°F

- **Lobby**
  - CRAC: 65°F

- **6MW Cooling Power**
- **6MW Server Power**
- **1MW Building Heat**
Modularity: Sun's Pod Architecture

- A group of racks with a common hot aisle used as a building block to simplify datacenter design for power, cooling, & cabling.

Can be used on concrete slab floor or raised floor.
Hot Aisle Containment

- Overhead Power Busway
- In-Row Refrigeration Unit
- Contained Hot Aisle
Air Side Economization

In milder climates, free air cooling with 100% outside air can be used for most of the year (San Francisco: 8,500 out of 8,760 hours annually)
Earth Pipes
Data Centers Underground
The Floating Data Center
The Law of Energy Conservation

- At steady-state operation, the total power coming into a data center must equal the total heat leaving the data center by radiation, conduction and convection.

Via radiation through the walls, air movement, and liquid movement.

50MJ/sec Heat

Data Center

50MW Power
MegaWatt Scale Energy Capacitors

“Today a data center just looks like a giant resistor in a multimegawatt circuit. It would be nice if it also was a capacitor.”

-- Mark Bramfitt, PG&E

Siphon off cheaper megawatts at night

20MW

Recover X%

“Freeze Water”
Freeze water at night, melt ice during the day to cool hot data center air, saving air conditioning costs

“Reuse Heat”
Find downstream applications that can use warm water

Time Shifting Utility Loads

Space Shifting Heat Applications
Putting 2 + 2 Together

- Chiller Plant
- Waste Hot Water (98° F)
- Cold Water
- Municipal Data Center
- Filtered Cold Water
- Warm Water (98° F)
- Water Heater
- Algae Based Sewage Treatment Holding Tanks
- Treated Sewage
- Effluent

Sun Microsystems – Proprietary and Confidential
Downstream Applications of Energy: 1

Treated, Filtered and Cooled Effluent

Municipal Data Center

Municipal Sewage Treatment Plant

Warm Data Center Exhaust Water

Treated Sewage

Raw Sewage
Downstream Applications of Energy: 2

Treated, Filtered and Cooled Effluent

Hospital Data Center

Hospital Laundry

Warm Data Center Exhaust Water
Downstream Applications of Energy: 3

Treated, Filtered and Cooled Effluent

Municipal Data Center

Municipal Swimming Pool

Warm Data Center Exhaust Water
The Three Principles of Data Center Energy Efficiency

- The Principle of Totality
- The Principle of Proportionality
- The Principle of Agility
Principle of Totality

An energy efficient data center has every component appropriately harnessed to deliver the most energy efficient operation possible.

Corollary: It is not just a chip problem, a server problem, a hypervisor problem, an OS problem, an application problem, a network problem, a storage problem, a PDU problem, a UPS problem, an air conditioner problem, or a chiller problem: All need to be involved.
Principle of Agility

An energy efficient datacenter must be responsive to fluctuating demand inputs (network workloads), fluctuating supply inputs (grid power availability) and changing corporate IT requirements (corporate policies).
Principle of Proportionality

An energy efficient data center calibrates its energy consumption in proportion to the computational work it is expected to deliver.

Corollary: It is not just servers that must deliver energy proportional computing, the entire data center must deliver proportionality.