WHITE PAPER

Virtualization – The Most Impactful Solution to the Data Center Power Crisis

vmware®

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1 Situation Overview: Data Center Power Crisis

The traditional "one workload, one box" approach to server provisioning inevitably leads to over-provisioning and under-utilization of server hardware assets. IT organizations typically provision at least one server for every application or service they deliver, yet most of these servers only operate at about 5-15% of their total load capacity. Meanwhile, the costs associated with power, cooling, network infrastructure, storage infrastructure, administrative overhead and real estate can skyrocket as the data center expands. The result is server sprawl: a situation in which servers take up more space and consume more resources than their workloads can justify. With escalating performance of server components, expanding IT footprint within the organization and the adoption of high-density form factors, many data centers have maxed out their power and cooling capacity.

1.1 The Escalating Server Performance, Density and Electrical Costs

Gartner forecasts that by 2008, 50 percent of current data centers will have insufficient power and cooling capacity to meet the demands of high-density equipment such as blade servers and storage arrays. [1] Servers use about 30% of their peak electricity consumption while sitting idle, [2] which is often more than 80% of the time. And the density of servers per square foot has doubled [3] at the same time — from 7 servers per rack to 14 servers per rack.[4] The overall power density of the data center is increasing by 15% per year. [5] And all the electricity consumed by servers is transformed into heat — so to prevent data centers from turning into hot houses, about 125% more electricity is consumed by the cooling equipment. [6] IDC estimates that the utility bill or the electricity bill for the data center these days actually may be approaching or in some cases exceeding the amount of money that customers are spending on new hardware in the data center.[7]

In summary, here are the three fundamental reasons that lead to this data center power and cooling crisis.

1. While a typical server 10 years ago consumed 100W of power, the average server today consumes four times as much.[8] So per unit, energy consumption per server has increased dramatically.
2. The size of servers have been decreasing, so per rack, companies now can squeeze more servers, and each one of these servers consumes more power, so the power density per square foot in the data center, or the power requirements, have been increasing significantly.
3. The cost of energy has been going up in recent years all over the world, and it's hard to see how energy costs will go down anytime soon. Hence customers find themselves under this triple whammy: individual servers consume more power; more servers per rack; and the cost of electricity is going up.

1.2 Utility Providers' Server Consolidation Rebate Program

VMware virtual machines cumulatively have saved more than five billion Kilowatt-hours of electrical power. The impact of virtualization on energy consumption is so significant that utility providers in California such as PG&E, SoCal Edison and SDG&E are paying customers for server virtualization projects that result in the removal of server computing equipment.

These programs compare the energy use of your existing equipment inventory to the energy use of the remaining equipment that will be in service after virtualization. Incentives are paid following the completion of a qualifying server consolidation project and are based on the net reduction in kilowatt-hours that will result from the project at the rate of 8 cents per kilowatt-hour. Incentives cover direct energy savings (cooling costs are excluded) and can be as high as $300 per server per year.

Incentives are paid following the completion of a qualifying server consolidation project and are based on the net reduction in kilowatt-hours that will result from the project at the rate of 8 cents per kilowatt-hour. Details on the energy efficiency incentive programs are available at: http://www.vmware.com/solutions/consolidation/green/pge.html

1.3 The Congress Is Paying Attention

The increase in power consumption is so dramatic that the federal government is getting involved to address this issue through policy changes, incentives, mandates to federal data centers, etc. United States Environmental Protection Agency submitted a Public Review Draft Report to Congress titled "Server and Data Center Energy Efficiency Public Law 109-431" on April 2007. The report analyzed the energy use associated with servers and data centers. It also discussed about the trend in growth and identified the opportunities for potential energy savings through improved energy efficiency. Recommendations for policy regulation, incentives and voluntary programs were made to the congress.

1.4 VMware and the Green Grid

VMware has been actively participating in promoting open standards in data center energy efficiency. VMware is a founding member and a board member of The Green Grid along with other industry-leading technology companies such as AMD, APC, Dell, HP, IBM, Intel, Microsoft, Rackable Systems, SprayCool and Sun Microsystems. VMware realizes that a standards-based industry solution is needed to coordinate efforts in developing specifications and metrics for power efficiencies. [9]

The Green Grid is a global consortium dedicated to advancing energy efficiency in data centers and business computing ecosystems. A non-profit trade organization of IT professionals, The Green Grid's charter is to address power and cooling throughout data centers and the information service delivery ecosystem. The Green Grid does not endorse any vendor-specific products or solutions, but will provide industry-wide recommendations on best practices, metrics and technologies that will improve overall data center energy efficiencies. [10]

Long term objectives for The Green Grid include defining new data center power efficiency architecture to implement energy-efficiency policies natively through the instrumentation of devices. This architecture will include automatic control of data center components via policy-based management geared toward IT objectives for power efficiency. To develop this architecture and set of specifications, The Green Grid has organized a governance body, communications committee, and technical committee.

For more information, visit The Green Grid at www.thegreengrid.org.

2 Virtualization Is the Most Impactful Solution

VMware virtualization technology can eliminate server sprawl and reduce power and cooling consumption in the data center by converting your physical machines into fully functional virtual machines. Each instance of VMware ESX Server can support more than 100 virtual machines, and the vast majority of our customers are able to run as many as 10 or more applications on a single piece of hardware. According to a recent research study, aggregate electricity use for servers doubled over the period 2000 to 2005 both in the U.S. and worldwide. Almost all of this growth was the result of growth in the number of the least expensive volume servers. [11] Reducing the number of volume servers in data centers through virtualization leads to dramatic savings on power and cooling costs. It can also make it possible to avoid costly data center upgrades and real estate expansions needed to meet the growing power and cooling requirements for today's data centers.

2.1 Server Consolidation Reduces Data Center Energy Consumption

VMware virtual machines run independently from the underlying hardware and are supported on broad array of physical servers. Each VMware virtual machine represents a complete system—with processors, memory, networking, storage and BIOS—enabling you to run Windows, Linux, Solaris and NetWare operating systems and software applications on the same piece of hardware at the same time. By running multiple workloads on highly configured x86 servers, your IT organization can increase the utilization of your server hardware from 10-15% to as much as 80%. Using VMware Infrastructure, your organization can significantly reduce the amount of IT hardware and the power consumption in the data center.

We estimate conservatively that for every workload moved from a physical to virtual environment, customers can save about $290 in electricity costs, and about $360 a year in cooling costs. The more important thing is that these savings accrue year after year. Beside the company bottom line effect, there are also significant environmental benefits from virtualization. The $650 per virtualized workload represents 8,000 kWh of electricity saved. With more than 1 million workloads running in VMware virtual machines, the aggregate power savings are about 8 billion kWh, which is more than the heating, ventilation and cooling electricity consumed in New England in a year.[12]

2.2 Using VMotion and DRS for Power Management

Besides server consolidation, VMware also helps improve power management across a farm of servers with innovative technologies such as VMware VMotion and VMware Distributed Resource Scheduler (DRS). VMware VMotion technology leverages the complete virtualization of servers, storage and networking to move an entire running virtual machine instantaneously from one server to another. The entire state of a virtual machine is encapsulated by a set of files stored on shared storage, and the VMware VMFS cluster file system allows both the source and the target ESX Server to access these virtual machine files concurrently. The active memory and precise execution state of a virtual machine can then be rapidly transmitted over a high-speed network. Since the network is also virtualized by ESX Server, the virtual machine retains its network identity and connections, ensuring a seamless migration process.

VMware DRS dynamically allocates and balances computing resources and continuously monitors utilization across resource pools. DRS intelligently allocate available resources among the virtual machines based on pre-defined rules that reflect business needs and changing priorities. When virtual machine resources are constrained, additional capacity is made available by migrating live virtual machines to a different physical server using VMware VMotion, and unutilized servers can be powered off or powered on when the demand for computing resources increases.

3 TCO Methodology Overview

Virtualization can help customers reduce the Total Cost of Ownership (TCO) of the data center. Thousands of VMware customers have achieved dramatic cost reduction associated with server hardware, storage, networking, power and cooling, real estate space, server administration and disaster recovery. The power and cooling cost savings are only a part of the overall TCO benefits of VMware Infrastructure.

3.1 Power Cost Savings Calculation

The power consumed by server hardware can be calculated by adding up the power ratings of each server in the data center. Because this number represents the maximum power used, it should be de-rated to achieve steady-state power consumption. The steady-state constant was determined empirically. According to the American Power Conversion Corporation "…the nameplate rating of most IT devices is well in excess of the actual running load by a factor of at least 33%." [13]

Inputs

TCO Calculation

$$Savings_{Power} = \lambda E_{\$}\left[(S_{TTLPWR})_{Before} - (S_{TTLPWR})_{After}\right]$$

3.2 Cooling Cost Savings Calculation

All data center electrical equipment produces heat. Heat producing items include IT equipment (servers, switches, SAN components), power delivery systems (UPS, Power Distribution), air conditioning units, lighting and even people. [17] For simplicity, this section focuses solely on the heat produced by server hardware.

Data center design plays an important role in determining the thermal efficiency and the cost of cooling. Many data centers still employ a front-to-back layout, which positions servers in the same direction. This means the heat emission from the back of one server feeds directly into the air intake of the front of another server. A better approach is the hot-aisle/cold-aisle layout, which mitigates the unacceptable temperature gradients associated with front-to-back layouts.

Input	Description	Default Value	Source
S_{TTLPWR}	Sum of the nameplate power ratings of all computing infrastructure in the data center in kW	Before/After 1 CPU: 475W / 550W 2 CPU: 550W / 675W 4 CPU: 950W / 1150W 8 CPU: 1600W / 1900W 16 CPU: 4400W / 5200W 32 CPU: 9200W / 11000W	Available from manufacturer's website (server specs). Also possible to use capacity tools such as Dell's Data Center Capacity Planner. [14]
$E_{\$}$	Price per hour of 1 kW of electricity	\$.0813 (average commercial value for United States in 2005)	Energy Information Administration [15]
λ	Steady-state constant	0.67	American Power Conversion: "On average, nameplate ratings are 33% higher than steady state load." [16]

Even with an optimized data center layout, as much as 25% airflow redundancy is still required. [18] In the event of a CRAC (Computer Room Air Conditioning) unit failure, airflow redundancy will continue to satisfy cooling requirements. Furthermore, many data centers have hot spots, where heat density is greater than other areas. Focused redundancy satisfies localized data center cooling requirements. [19]

Beyond requirements for airflow redundancy, data centers require additional airflow to account for inefficiencies related to humidification. Humidification is required to reduce the potential for damage resulting from a static discharge. [20] Most air conditioning systems, however, induce humidity loss that is caused by the air-cooling function of the air conditioning system initiating condensation of water vapor. To maintain an acceptable humidity level, supplemental humidification is required, which creates additional load on CRAC units. The additional over-sizing can be as much as 30% of the standard load. [21]

As a first-order approximation, the AC power consumed in the data center is completely converted to heat. Therefore, the power rating in Watts of server hardware is equal to thermal output. [22] Furthermore, according to experiments completed in the HP Laboratories, 0.8W of power is consumed by the cooling equipment for every 1W of heat dissipation in the data center (designated in this document as the Load Factor, L). Given the above information, the total cost of cooling can be calculated.

TCO Calculation

$$Savings_{Cooling} = \frac{l\, E_{\$}(1+r)}{d}\left[\left(S_{TTLPWR}\right)_{Before} - \left(S_{TTLPWR}\right)_{After}\right]$$

4 VMware Customer Case Studies

To illustrate how TCO methodology can be applied to real scenarios, VMware spoke with three customers who shared details about their VMware Infrastructure implementation and how it affected their power and cooling costs. This sample of VMware customers represents a range of industries, company sizes and implementation scenarios.

4.1 Case #1: 1800Radiator Reduces Power and Cooling Consumption by 25%

Two years ago, Radiator Express Warehouse (1800Radiator), a fast growing automotive-parts distributor, began franchising. While initial growth was slow and the company had time to add infrastructure and build servers, in the last year, its business skyrocketed. The company has grown to more than 130 franchise locations at a rate of three new openings per week.

Input	Description	Default Value	Source
STTLPWR	Sum of the nameplate power ratings of all computing infrastructure in the data center in kW	Before/After 1 CPU: 475W / 550W 2 CPU: 550W / 675W 4 CPU: 950W / 1150W 8 CPU: 1600W / 1900W	Available from manufacturer's web site (server specs). Also possible to use capacity tools such as Dell's Data Center Capacity Planner. [23]
$E_{\$}$	Price per hour of 1 kW of electricity	\$.0813 (average commercial value for United States in 2005)	Energy Information Administration [24]
λ	Steady-state constant	0.67	American Power Conversion: "On average, nameplate ratings are 33% higher than steady state load." [25]

Input	Description	Default Value	Source
L	Cooling Load Factor:-amount of power consumed by the cooling equipment for 1W of heat dissipated	0.8	Empirically determined in HP Laboratories[26]
ρ	Airflow Redundancy Constant: redundant airflow required to cool data center	25%	SearchData Center.com[27]
δ	Inefficiency (Humidification) Constant: redundant airflow to account for burden of humidification	25%	SearchData Center.com[28]

"Before we knew it," says CTO Mike Carvalho, "our computer room was almost at maximum power capacity, our computer racks were full, our switches were all used, and our air conditioning was on continuously. Rather than spend thousands on new power systems, racks and air conditioning, we chose to leverage VMware's product line to allow our company to keep pace with our growth."

To maintain its high service levels, 1800Radiator turned to VMware and partner AccessFlow. Using virtualization technology, the company was able to take 31 physical servers out of production—the benefits from which extended beyond the combined savings of a nearly $6,000 PG&E rebate check and 25-percent reduction in power and cooling costs. "

It was worth it to me just for the peace of mind in being able to support and grow my business. VMware High Availability (HA) and DRS, for example, provide automatic redundancy and resource management such that we can maintain maximum uptime—simply and affordably."

Results:

- Avoided purchase of $100,000 worth of new hardware
- Removed 31 physical servers, eliminated the "one app per server" rule, improving flexibility and availability
- Reduced power and cooling consumption by 25 percent in the data center, saving $5,000 per year
- Primary and disaster recovery site both managed from single VirtualCenter console
- Reduced downtime due to hardware failure and maintenance
- Primary and secondary data centers both run below 50-percent capacity, allowing instant failover support of entire computing load
- Received a PG&E rebate of close to $6,000 for consolidation project

4.2 Case #2: QUALCOMM Saves $1.87 Million in Space, Power and Cooling Infrastructure

QUALCOMM, a leader in the digital wireless communications field, is best known for pioneering and commercially developing Code Division Multiple Access (CDMA) and other digital wireless technologies. More than 470 million consumers worldwide rely on CDMA for reliable voice communications and data services. "

We are a VMware-first company. Our internal customers receive virtual machines as the rule. Our allocation model is based on resource needs, not server needs, and provisioning a physical server is the exception," says Paul Poppleton, senior staff engineer. As resource needs change, we add capacity through just-in-time hardware provisioning and retirement of unused virtual machines. in three years, our admin count in the Windows server group has remained flat, while the OS-instance count has more than doubled. The only explanation is virtualization."

Results

- Increased server utilization to nearly 80 percent
- Saved $19,000 per month in power and cooling costs
- Achieved a 12:1 server consolidation ratio
- Realized ROI upon deployment of its second virtual machine—currently have deployed approximately 1,600 virtual machines
- Reduced data center space by a 12:1 ratio
- Virtualized 60 percent of x86 environment
- OS instance doubled while staff remained flat over last three years
- Deploy new servers in hours rather than weeks
- Instituted a VMware-first policy

- Decommissioned more virtual machines than are currently active in efforts to manage virtual server sprawl
- Avoided building at least one data center
- Forewent the following capital expenses: $1.87 million in space, power and cooling infrastructure; $90,000 in wiring infrastructure; and $309,000 in networking infrastructure

4.3 Case #3: Solvay Pharmaceuticals Achieved $67,000 in Annual Energy Savings

Solvay Pharmaceuticals, Inc., is the U.S. subsidiary of the research-driven group of pharmaceutical companies that constitute the global pharmaceutical business of the Solvay Group. The company seeks to fulfill carefully selected, unmet medical needs in the therapeutic areas of neuroscience, cardio-metabolic, influenza vaccines, gastroenterology and men's and women's health. In 2002, Solvay Pharmaceuticals faced the all-too common problems of server sprawl. "

Every time we needed a new application, we would need to get three new servers: one for development, one for test and one for production," says Brue McMillan, manager of emerging technologies at Solvay." The production servers were usually only five percent utilized. Some test and development servers were less than one percent utilized, most of the time due to cyclical use. It took too long to provide development servers to those who requested them. Plus, we were running out of physical space in the data center. We are extending virtualization across our enterprise with VMware Infrastructure 3 because it has the increased scalability and performance for our larger applications, making our data center more responsive and self-optimizing."

Results:

- Saved more than $1.5 million in hardware costs
- Achieved server consolidation ratio of 10:1
- Achieved annual power and cooling cost savings of $67,000
- Increased CPU utilization from 0-5 percent to 15-25 percent
- Facilitated server management with VirtualCenter; four people manage more than 100 servers
- Decreased server deployment time from 6 hours to 30 minutes
- Achieved 585 days of continuous uptime

5 Conclusion

Data centers electricity usage has become a major IT concern that draws government attention and requires effective solutions. VMware Infrastructure reduces data center energy consumption by running applications on fewer physical servers, which in turn reduces the power and cooling requirements. VMware VMotion and VMware DRS technologies also enable effective power management in the data center. Thousands of VMware customers have achieved significant power and cooling consumption reduction in the data center through server consolidation and effective power management. VMware Infrastructure is one of the most impactful solutions to the data center power crisis.

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VMware, Inc. 3401 Hillview Ave Palo Alto CA 94304 USA Tel 877-486-9273 Fax 650-427-5001 www.vmware.com