Data Center Energy Forecast

Final Report

July 29, 2008

Silicon Valley Leadership Group

1 Introduction

In 2007 the Environmental Protection Agency (EPA) published its Report to Congress on Server Data Center Energy Efficiency (EPA Report)[1]. In response many companies implemented data center energy saving initiatives. This report recounts a number of these efforts and their results, particularly how much energy they were able to save and what it took to implement the initiatives. This report:

- Re-computes energy projections from the EPA Report (this report bases analysis on measured results when available instead of relying only on estimates)
- Presents a side-by-side comparison of energy savings achieved by the case studies
- Defines and analyzes a scenario consisting of the combined initiatives documented in this report.

These findings may help accelerate the adoption of energy saving technology in data centers; specifically they should help:

- Data center operators make better informed decisions on the effectiveness of energy saving initiatives
- Guide policymakers on potential regulation and certification by demonstrating achievable results
- Educate the public on the impact of data centers on energy use and on how data centers can save energy by implementing technology and applying leading practices.

1.1 About the EPA report

In response to Public Law 109-431, the United States EPA Energy Star program published a report assessing the energy used by government and commercial servers and data centers in the US. The EPA Report projects the near-term growth of energy use based on current trends and evaluates potential savings related to improving energy efficiency. The findings are based on historical data and expert estimates of the impact from energy efficient initiatives. These initiatives include both those promoting technology in terms of research, development, and implementation, and those promoting social responsibility via incentive programs, regulation, and certification.

The EPA Report suggests a series of recommendations that focus on the need for public and private sector collaboration in providing "objective, credible information about the effect of energy-efficient technologies and practices on data center availability and performance." Such information may help to define standards and benchmarks, promote the adoption of energy efficient technology, and encourage vendors to develop energy efficient products. This report documents the 2008 Data Center Demonstration Project; its findings are meant as a companion and a response to the EPA Report. As a companion, these findings are based on actual measurements that can be compared against those from the EPA Report, which are based on estimates. As a response, this project answers the EPA's call for the public and private sectors to take a role in implementing and benchmarking energy saving initiatives.

1.2 About the Data Center Demonstration Project

The Data Center Demonstration project responds to the EPA's call-to-action: "Objective, credible information is needed about the performance of new technologies and about best practices as well as the effect of both on data center availability" (EPA 113). This project is the first of its kind to present a collection of proof of concepts hosted in commercial data centers rather than vendor evaluations or research results. End user operators demonstrate the EPA's energy efficient initiatives via implementations within their production data centers. The initiatives encompass operations, equipment, and site facilities improvements covered in the EPA Report. Operators document in case studies the measured energy savings and the applicability of the solution within a commercial data center. This report compiles the findings from the individual case studies and uses them

[1] EPA, Environmental Protection Agency, Report to Congress on Server and Data Energy Efficiency, 2007.

to re-compute the energy saving scenarios defined by the EPA.

The inaugural Data Center Demonstration Project 2008 covers 11 technology initiatives with 17 case studies. Results are computed in terms of energy savings and its impact on the reduction of Greenhouse gas emissions and costs. Additionally the case studies elaborate on implementation realities that must be considered. This 2008 effort is the first of an ongoing series to show quantifiable results from adopting new technology. This project will continue with future iterations based on the commitment of many of the contributing organizations and through continued outreach to host data center operators and green IT and site infrastructure technology providers.

1.3 Participants

Data Center Demonstration participants comprise an informal group of technology, policy and implementation experts and partners who are engaged in creating a series of demonstration projects that show emerging and best available energy efficiency technologies and practices associated with operating, equipping and constructing data centers.

The project was launched by the Silicon Valley Leadership Group (the Leadership Group) and Lawrence Berkeley National Laboratory (LBNL). The Leadership Group's member companies cooperate with national and regional government to address major public policy issues affecting economic health and quality of life in Silicon Valley. The Leadership Group solicited participation from its member organizations to demonstrate energy efficiency techniques within their data centers. The members either implemented new initiatives or documented recently completed retrofit initiatives within their data centers, and then shared measured results and implementation details. LBNL collaborated with the EPA to help author and create the estimation model used in the EPA Report. For this project LBNL made available their model behind the EPA report and provided the technical expertise in identifying, implementing, measuring, and analyzing many of the initiatives studied.

Project contributors and their roles are set out below. Host data centers housed the projects and wrote case studies. Technology partners supported data center operators by providing equipment and expertise to implement the solutions. Sponsors helped offset the implementation costs. Sun Microsystems hosted the first Data Center Energy Summit event June 26, 2008 during which findings from the individual case studies and this consolidated report were presented.

1.4 Accenture's Role

As a non-biased independent participant Accenture provided certain project management assistance, helped aggregate the results, and assisted the Leadership Group with the consolidated analysis. For this role Accenture provided:

- A vendor agnostic position in industry
- Extensive Green IT industry experience and knowledge capital (Accenture is recognized as a leader in Green IT by Forrester[2])
- Deep technical background from its Data Center Technology and Operations practice.

Accenture is honored to be given the responsibility by the Leadership Group and LBNL to write this consolidated report.

Participants of Data Center Demonstration Project

Organizers
- Silicon Valley Leadership Group (SVLG)
- Accenture
- Lawrence Berkeley National Labs (LBNL)
- California Energy Commission (CEC)
- Department of Energy (DOE)
- Event hosted by Sun Microsystems

Host Data Center
- Digital Realty Trust
- LBNL
- NetApp
- Oracle
- Sun Microsystems
- Symantec
- Synopsys
- US Postal Service
- Yahoo!

Technology Partner
- APC
- Cassatt
- IBM
- Liebert
- Modius
- Power Assure
- Powersmiths
- Rittal
- SprayCool
- SynapSense

Case Study Sponsor
- CEC
- LBNL
- PG&E
- Silicon Valley Power

[2]Forrester, "The Dawn of Green IT Services," Feb 2007.

2 Summary of the EPA Report

2.1 Documented Growth in Energy Use by U.S. Data Centers

Data centers consume a significant amount of the nation's total supply of electricity. As of 2006, the electricity use attributable to the nation's servers and data centers was estimated at about 61 billion kilowatt-hours (kWh), or 1.5 percent of total U.S. electricity consumption. Since 2000 this electricity use has more than doubled, amounting to about $4.5 billion in electricity costs (EPA 25). It is more than the electricity consumed by color televisions in the U.S. It is equivalent to the electricity consumed by 5.8 million average U.S. households (which represent 5% of the U.S. housing stock). It is similar to the amount of electricity used by the entire U.S. transportation manufacturing industry (which includes the manufacture of automobiles, aircraft, trucks, and ships) (EPA 25).

The energy used by data centers is growing and impacts the nation's power supply with effects on enterprises, energy providers and the environment. When data centers use energy efficiently, enterprises can save on energy costs. Power providers face less energy demands, resulting in increased supply for its other consumers and possibly fewer blackouts. Less power generation also results in lower greenhouse gas emissions and fewer power plants. For these reasons, data center energy efficiency has become a public policy concern and it is imperative that data centers implement efficient methods to minimize their energy use.

2.1.1 A Growing Need for Computing Capacity

Business demands drive the growth of data center and server energy use. As businesses increase their offerings of digital services, the demand for compute and storage capability increases. Some examples of growing digital services are online banking, e-filing of taxes, music and video downloads, and online shipment tracking. The need for faster, more complex data processing is becoming widespread; for instance, consider how financial services moved to digital transactions, the research community to scientific computing, and retailers to real-time inventory and supply chain management. Additional demand for compute capability can only be met by increasing the processing capacity of compute servers within data centers.

Along with greater computing capability, businesses have increased demand for storing digital data, both in terms of amount and duration due to new and existing applications and to regulation. New applications, like healthcare's use of electronic medical records, require electronic storage, and existing applications like the growing needs of insurance databases, require more capacity. Disaster recovery also accelerates the need for increased storage (e.g., duplicate data sets) and redundant data center equipment and facilities. In addition, regulations mandate the retention of business records. The Sarbanes-Oxley Act, for example, requires long-term storage of financial information, including electronic records such as email (EPA 28). As a result, it is estimated that in some industries the number of records that must be retained is growing at a CAGR of 50 percent or greater (EPA 28). Data centers must meet the exploding demand for both compute and storage capacity.

2.1.2 Energy Needed for Hardware, Servers and Infrastructure to Meet Demand

Data centers have grown in terms of total energy draw. Until recently, businesses commonly bought IT to keep up with their demands. From 2000- 2006, the number of servers installed in the US grew from 5.5 million to 10.9 million (EPA 35). And those servers are typically smaller which means that more fit within the data center. Shipments of higher computing power server technologies, such as blade server shipments were increasing at a 20-30 percent CAGR, which is significantly higher than the shipment rate for the overall server market (EPA 30).

These practices led to data centers consuming more power, both individually and as a whole. Energy was not a concern. Typically data center operators were unaware of the energy use since someone else paid the electric bill. The consequence was increased energy use from the IT equipment exacerbated by facility overhead. The data center became a large draw for power.

Typically only about half the power entering the data center is used by the IT equipment. The rest is expended for power conversions, backup power, and cooling. Peak power usage for data centers can range from tens of kilowatts (kWs) for a small facility, to tens of megawatts (MWs) for the largest data centers (EPA 21).

Indeed, server hardware is no longer the primary cost component of a data center. The purchase price of a new (1U) server has been exceeded by the capital cost of power and cooling infrastructure to support that server and will soon be exceeded by the lifetime energy costs alone for that server (EPA 30).

2.2 How Data Centers Can Cut Consumption

Data centers use energy to power and support the IT equipment housed inside; how that energy is typically consumed is described here.

Data centers draw power either from the main supply electrical grid or a backup generator. Switch gear distributes the power for lighting, cooling, and powering. The electricity consumed by lighting may be improved by more efficient lights and lights-out operation (lights are on only when data center operators are present). However powering the lights accounts for only a small percentage of the electricity consumed; the large majority is used for powering and cooling the IT equipment.

Data centers require special power handling to smooth out and transform the inputted power into something that the IT equipment can safely consume. Power drawn from the switch gear passes through an Uninterruptible Power Supply (UPS) that acts as a large battery. The smoothed power travels through a Power Distribution Unit (PDU) that transforms the inputted power to the right phase and voltage, and then delivers it to the IT equipment. Within the IT equipment, internal power supplies transform the power down to those used at the electronic component level. As power is treated and transformed, some of it is wasted due to inefficiencies. The IT equipment includes servers, storage, and network drives, which compute, store, and communicate to fill business needs. If IT equipment itself is more efficient, it can produce better performance per Watt.

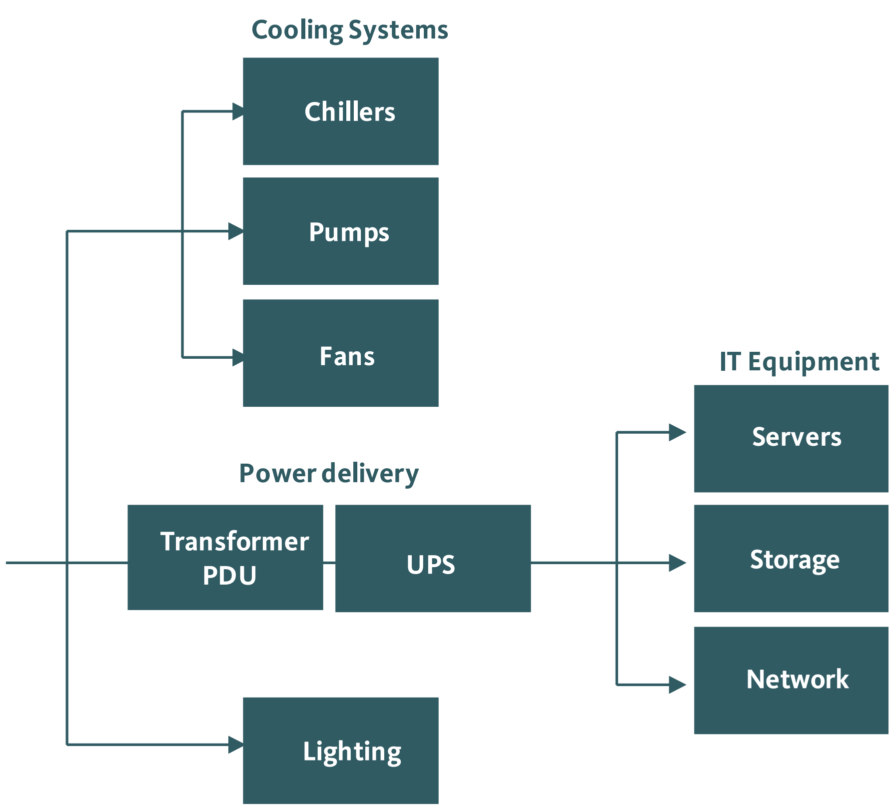
As power is delivered to and consumed by IT equipment, one byproduct is heat. To ensure proper operations and prevent system failures, this heat must be removed by the same amount of cooling, which consumes even more energy. Cooling equipment typically involves fans, pumps, and chillers. Most systems today produce and deliver the cool air to the IT and power delivery equipment by lowering the air temperature and then using fans to push the air to the equipment. Other technologies, such as direct water or refrigerant cooling, should deliver more efficient results.

2.2.1 Classifying Initiatives by IT and Site Infrastructure

The EPA initiatives include operations and technology that can improve the efficiency of energy consumers within the data center. These energy consumers are classified as IT infrastructure or site infrastructure.

IT infrastructure refers to servers, storage, and network. The EPA

Typical Electrical Components in the Data Center



Report identified server trends that improve the performance per Watt ratio for both the individual units and the installed server base. Multi-core and power management technology improved the efficiency of individual units, resulting in better performance per Watt ratio. The server base can improve its efficiency through consolidation, virtualization, efficient resource utilization, and improved capability of individual units. Thus, data centers can meet performance demands with fewer machines.

Storage and network were also analyzed, but they had lesser impact. The EPA Report identified storage trends that have manufacturers moving towards energy efficient storage devices. Enterprises are shifting from hard disk drive storage devices to smaller form factor disk drives and increasingly are using serial advanced technology attachment (SATA) drives. They are also improving their management strategies by focusing on storage virtualization, data de-duplication, storage tiering, and moving archival data to storage devices that can be powered down when not in use.

Site infrastructure refers to the lighting, power delivery, and cooling systems of data center facilities. The EPA Report recommends improving the efficiency of site infrastructure that may account for 50% or more of the total energy consumed by data centers. Lighting improvements, such as more efficient lights and lights-off operations, are noted. Power delivery improvements include upgrades to more efficient transformers and Uninterruptible Power Supplies (UPS). Cooling systems improvements call for improved airflow, optimization of temperature and humidity set points, and upgrades to water cooled chillers with variable speed fans and pumps.

2.3 EPA Energy Scenarios by Maturity of Technology

The EPA defined scenarios and measured electricity use and cost associated. Each scenario has a set of inputs that specify the maturity of IT and site infrastructure. For historical and current trends, the EPA determined the inputs based on the data available at the time. Trends were projected to 2011. For improved operations, best practice, and state-of-the-art scenarios, the EPA relied on industry experts to estimate the impact of the level of technology maturity defined for that scenario.

The EPA energy scenarios are defined below with examples of technology maturity for IT and site infrastructure in red. Each scenario represents a level of maturity characterized by efficiency rather than an exact set of technology.

2.4 EPA Energy Projections Can Be Achieved

IIn the state-of-the-art scenario electricity use is reduced by up to 55 percent compared to current efficiency trends. This represents the maximum technical potential. In the best practice scenario electricity use is reduced by up to 45 percent compared with current trends, with efficiency gains that could be realized using today's technologies. The improved operational management scenario offers potential electricity savings of more than 20 percent relative to current trends, representing low-cost energy efficiency opportunities (EPA 10).

Summary of EPA Energy Scenarios

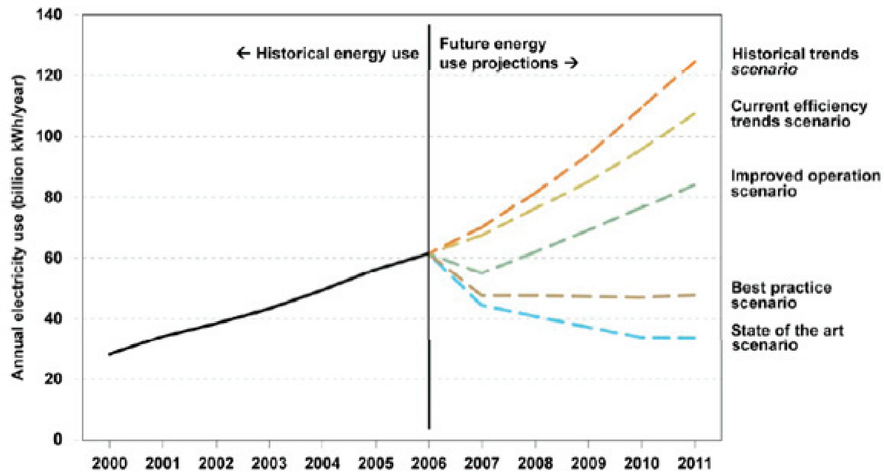
Scenario	Definition
Historical Trends	Extrapolates observed 2000 to 2006 energy-use trends without consideration of current trends In 2006, energy use of servers & data centers more than doubled from 2000 Site infrastructure accounts for 50% of data center energy consumption
Current Trends (2007)	Projects the energy use based on recently observed efficiency trends
Improved Operations	Represents "low-hanging fruit" from operating existing capital efficiently with little or no capital investment Eliminate unused servers, turn on power management Improved air flow management
Best Practice	Represents the increased adoption of the practices and technologies used in the most energy-efficient facilities in operation today Moderate consolidation of servers and storage Improved efficiency for power and cooling delivery and free cooling
State-of-the-Art	Identifies the maximum energy savings using only the most efficient technologies and management practices available today Aggressive consolidation of servers and storage Direct liquid cooling

The impact of the energy consumption may be quantified in terms of cost. Under the adoption of the improved scenarios, the EPA estimated annual savings in 2011 of approximately 23 to 74 billion kWh compared to current efficiency trends, which reduces annual electricity costs by $1.6 billion to $5.1 billion (EPA10).

These energy savings also have implications for the environment. Generating energy translates to carbon dioxide emissions specified in terms of million metric tons of carbon dioxide (MMTCO2). If the historical trend continues, CO2 emissions associated with the electricity use of U.S. servers and data centers will be up by 77 to 78.7 MMTCO2/year. The EPA Report shows annual savings in 2011 of approximately 23 to 74 billion kWh compared to current efficiency trends. This would reduce the peak load from data centers by the equivalent of up to 15 new power plants by adopting energy efficient scenarios (EPA 10). Current efficiency trends are expected to reduce nationwide CO2 emissions by nearly 11 MMTCO2 by 2011 compared to the historical trends scenario. However, efficiency improvements beyond current efficiency trends could further reduce nationwide CO2 emissions by an additional 15 to 47 MMTCO2 in 2011 (EPA 58).

These outcomes are based on EPA's analysis with its best representation of industry data consisting of limited case studies and experienced estimates. After 17 case studies and further analysis, this report answers that these results can be achieved using the technology available today and may even be exceeded by improvements to IT operations.

Comparison of Projected Electricity Use, All Scenarios, 2007 to 2011.



Source: EPA Report to Congress on Server and Data Center Energy Efficiency, 2007.

Projected Electricity Use (in billion kWh/year), All Scenarios, 2007 to 2011, from EPA Report (EPA 56)

Scenario	2007	2008	2009	2010	2011	2007-2011 Total	% of historical trends scenario	% of current efficiency trends scenario
Historical trends	70.0	81.3	93.7	109.3	124.5	478.8	100%	111%
Current efficiency trends	67.4	76.1	85.0	95.5	107.4	431.4	90%	100%
Improved operation	54.9	61.9	69.0	76.4	84.0	346.3	72%	80%
Best practice	47.6	47.6	47.2	46.9	47.7	236.9	49%	55%
State-of-the-art	44.3	40.8	37.2	33.8	33.6	189.7	40%	44%

3 Comparing Demonstration Results with EPA Estimates

The Data Center Demonstration Project expands on the EPA Report and strives to cover all technology areas and scenarios. Using the project's demonstrated results, this report presents its findings as compared to the EPA energy projections.

In this inaugural year the case studies provide good coverage of the initiatives, but they are limited in depth. The case studies cover a broad range of site technology, including many state-of-the-art solutions. Studies on IT infrastructure cover consolidation, technology refresh, resource optimization, and modest levels of virtualization. Initiatives are assessed by one to five case studies. As this project continues, the number of case studies and technologies assessed will continue to grow to provide additional certainty and coverage.

Participants in this project are self-selecting; they do not represent typical level of data center efficiency. Even before adopting new initiatives, most of the host data centers were likely more efficient than industry standards. Their commitment to energy efficiency prompted them to participate, to implement high-efficiency solutions and share those outcomes. Their demonstrated results show what can be achieved and the detailed case studies show how. In some cases similar results may not be attainable due to considerations like cost, climate, and operating conditions. The results instead indicate the current level of technology maturity and the amount of efficiency that may be attained with technology available for commercial data centers.

Although the data set is limited to 17 case studies, some conclusions can still be made. The 17 studies cover all equipment areas used by the EPA model. When not validated by measured results, this report uses the same assumptions used in the EPA Report. This report does not:

- Make predictions on technology uptake
- Predict the actual energy use by data centers, which would require knowledge of uptake.

This report, however, does:

- Demonstrate real-world findings of achievable energy savings in commercial data centers
- Compare the achieved savings of the initiatives side-by-side and with the EPA estimates from industry experts
- Calibrate the current level of technology maturity
- Project the impact on energy use, cost, and carbon dioxide emissions, using the reported measurements as inputs in the EPA model
- Compare the projections using demonstrated performance with EPA predictions.

For data center operators, this report helps compare the energy saving potential of the various initiatives. For policy makers, this report reveals the current technology maturity and the results that can be achieved if the initiatives are adopted. For the general public, this project shows that data centers are making strides to address their responsibility as a large energy consumer.

Note that these results show the savings in terms of energy use and the associated costs. In most cases the participants elected not to publish implementation costs. In many cases the implementation costs and ROI were shared with the Leadership group, and the reason these companies chose to implement these initiatives was because the business case justified ROI within 18 months, and typically within less than 1 year when available utility incentives were included.

Case Studies Covered in the 2008 Data Center Demonstration

Initiative	Improved Operations	Best Practice	State of the Art
Data Center Site Infrastructure Projects			
Data Center Cooling			
Data Center Airflow Management		X X	
Free Cooling in Large Scale Data Centers	X		X X
Data Center Cooling Optimization		X	
High Efficiency Chilled Water Systems		X	
Modular Cooling Systems		X X	X X X
Wireless Sensor Network Adaptive Cooling			X
Data Center Power Distribution			
High Efficiency Power Transformation		X X	
High Voltage AC Power			X
High Efficiency Stand-by Power Systems		X X	
IT Infrastructure Projects			
Consolidation and Optimization			
IT Computing Resource Optimization		X	X
IT Consolidation and Virtualization	X	X	
Server Power Characterization & Modeling	X		

Case Study Initiatives and Participants

Initiative	Host Data Center	Technology Partner	Sponsor
Data Center Site Infrastructure Projects			
Data Center Cooling			
Data Center Airflow Management	LBNL Oracle		
Free Cooling in Large Scale Data Centers	Digital Realty Trust NetApp Yahoo!		PG&E
High Efficiency Chilled Water Systems	Sun Microsystems	LBNL	
Modular Cooling Systems Efficiency Performance Testing	Sun Microsystems	APC, IBM, Liebert, Rittal, Power Assure, Modius	LBNL, CEC
Wireless Sensor Network Adaptive Cooling	Yahoo!	SynapSense	Silicon Valley Power
Data Center Power Distribution			
High Efficiency Power Transformation	USPS Yahoo!	Powersmiths Powersmiths	
High Voltage AC Power	Yahoo!		
High Efficiency Stand-by Power	NetApp Yahoo!		
IT Infrastructure Projects			
Consolidation and Optimization			
IT Computing Resource Optimization	NetApp Synopsys	Cassatt	
IT Consolidation	Sun Microsystems Symantec		
Server Power Characterization & Modeling	Sun Microsystems	Power Assure	

3.1 Measured Results Verify the Assumptions of the EPA Report

This report only suggests adjustments to EPA inputs in cases where the Data Center Demonstration Project provides measured results. The EPA model (see Appendix 4 of the EPA Report) takes into account two types of input: those that specify the amount of adoption and those that specify the efficiency of various technologies. The case studies cover all equipment areas. This report uses the same adoption assumptions as the EPA.

For historical trends and current trends, the EPA used inputs based on extrapolated data for their computations. The EPA Report defines scenarios based on infrastructure maturity: improved operations, best-practices, and state-of-the-art. For these scenarios the EPA used expert estimates based on the level of technology maturity as inputs. This report presents a side-by-side evaluation comparing the measured results and shows that EPA estimates can be achieved.

3.2 IT Infrastructure

This year's IT studies include server initiatives only and do not cover network or storage. Server efficiency is characterized by the energy draw per unit, the percentage of the server base with power management enabled, the percentage of the server base consisting of energy efficient servers, the fraction of virtualized servers and those permanently retired, and the Physical Server Reduction Ratio (PSRR) ratio.

PSRR is the ratio of installed server base from historical trends to the installed server base in the post-virtualization scenarios (current trends, improved operations, best practice, and state-of-the-art). A PSRR of 2:1 means that server growth trends are halved compared with the historical case. For historical trends the installed server base is derived from IDC data for 2006 to 2010 that the EPA extended to 2011. More details of the EPA analysis for IT infrastructure are outlined in the Appendix.

IT Maturity Assumptions per Scenario defined by the EPA Report

Scenario	Assumptions
Historical Trends	Energy use growth trends for IT equipment extrapolated from 2000 to 2006 to 2011. These trends indicate that U.S. installed base of volume servers will grow by nearly 50% by 2011, but high end and mid-range will decline by 30% and 12% respectively.
Current Efficiency Trends	• By 2011 volume server virtualization will lead to a physical server reduction ratio of 1.04 to 1 (for server closets) and 1.08 to 1 (for all other space types) • "Energy efficient" servers represent 5% of volume server shipments in 2007 and will represent 15% of shipments in 2011 • Power management is enabled on 10% of applicable servers • By 2011 average energy use per enterprise storage device will drop 7%
Improved Operations Scenario	• By 2011 volume server virtualization will lead to a physical server reduction ratio of 1.04 to 1 (for server closets) and 1.08 to 1 (for all other space types) • 5% of servers will be eliminated through virtualization (e.g., legacy applications) • "Energy efficient" servers represent 5% of volume server shipments in 2007 and will represent 15% of shipments in 2011 • Power management is enabled on 100% of applicable servers • By 2011 average energy use per enterprise storage device will drop 7%
Best Practice Scenario	• By 2011 moderate volume server virtualization will lead to a physical server reduction ratio of 1.33 to 1 (for server closets) and 2 to 1 (for all other space types) • 5% of servers will be eliminated through virtualization (e.g., legacy applications) • "Energy efficient" servers represent 100% of volume server shipments from 2007 to 2011 • Power management is enabled on 100% of applicable servers • By 2011 average energy use per enterprise storage device drops 7% • By 2011 data centers moderately reduceuse of applicable storage devices (1.5 to 1)
State-of-the-art Scenario	• By 2011 aggressive volume server virtualization will lead to a physical server reduction ratio of 1.66 to 1 (for server closets) and 5 to 1 (for all other space types) • 5% of servers will be eliminated through virtualization (e.g., legacy applications) • "Energy efficient" servers represent 100% of volume server shipments from 2007 to 2011 • Power management is enabled on 100% of applicable servers • By 2011 Average energy use per enterprise storage device drops 7% • By 2011 data centers will dramatically reduce use of applicable storage devices (~2.4 to 1)

3.2.1 Measured IT Results Achieve Best Practice Efficiency Levels

Four case studies cover the consolidation, server power modeling, and resource optimization. Their results, summarized below, achieve the EPA's best practice efficiency level where PSRR is near 2:1.

Symantec and Sun Microsystems reduce energy use by consolidation in a production and research and development (R&D) environment. They show how consolidation and technology refresh result in increased capability for less energy. By moving to high-performance, energy-efficient servers and storage systems, the IT organizations take advantage of the latest advancements while saving on power and cooling. The resulting data center environments support more applications requiring less power, in less space, and at less cost.

In Symantec's production environment, a total 1,635 servers across data centers (including switches, routers, firewalls, storage) were reduced to 386 servers (plus 152 servers in other sites). Symantec achieved this reduction of 3.04:1 by a combination of virtualizing 81 servers and decommissioning 1,062 servers, 206 of which were destroyed. Sun's R&D environment reclaimed 88% of its data center floor space, reduce power consumption by over 60%, and avoid more than $9 million in construction costs. Sun achieved replacement ratios near 2:1 and 3.28:1 for servers and storage respectively.

Synopsys and Cassatt reduce wasted power and hardware with resource optimization. Synopsys attains energy savings through performance modeling and job scheduling. Synopsys was able to meet its compute and storage demands by better operating and managing its data center rather than by buying hardware. Synopsys maintains approximately 10,000 nodes. Server utilization improved from 10%-20% to 70%-90%. Storage capacity of two petabytes increased from 10%-20% to 60%. Synopsys was able to put off purchase of 1000 more nodes over the next five years (a reduction of 1.10:1 over 5 years), resulting in additional cost and energy savings.

Cassatt piloted a new approach with a Silicon Valley company to manage data center devices. Data center operations traditionally keeps all devices on 100% of the time, the new approach leverages policy and intelligent control to power-off devices when they become idle – for periods as short as an hour. The outcome of the initial proof-of-concept validated the power management technology, thereby saving 26% of power on a per-machine basis during an 8 week simulated environment. A more comprehensive production pilot with further analysis of the larger data center environment indicated device power requirements could potentially be reduced overall by 21% -27%. Assuming a conservative savings of 20% reducing the power draw has the same effect of 1.25:1 PSRR.

3.2.2 Finding: Companies CanMore Aggressively Reduce IT Infrastructure

The potential of virtualization is not fully harnessed in the case studies. Virtualization enables a single server to be more efficient by replacing dedicated servers that operate at low average processor utilization with a single host server that provides the same services and operates at a higher average utilization level. Virtualization may offer significant energy savings for volume servers because these servers typically operate at an average processor utilization level of only five to 15 percent (EPA 42). The typical U.S. volume server will consume anywhere from 60% to 90% of its maximum system power even at low utilization levels (EPA 43). Thus it is more efficient overall to run fewer servers at higher utilization than more servers at low utilization.

The consolidation and resource optimization studies already achieve the best practice scenario efficiency for servers. Data centers should look towards more aggressive IT management, like virtualization and storage and network technologies, to help IT infrastructure meet or exceed state-of-the-art estimates.

IT Initiatives Measured Results Compares with EPA's Best Practice PSRR 2:1

Case Study	PSRR	Notes
Sun R&D Consolidation	1.76:1	3.28:1 storage ratio
Symantec Production Consolidation	3.04:1	12.6% servers not replaced
Synopsys Resource Optimization	1.10:1	70-90% server utilization
Cassatt Resource Optimization	1.25:1	Represents a 20% power reduction

3.3 Site Infrastructure

Site Infrastructure is evaluated using the Power Usage Effectiveness (PUE) defined as the ratio of data center power to IT power draw. For example a PUE of 2, means that the data center must draw 2 Watts for every 1 Watt of power consumed by the IT equipment. The ideal PUE is 1 where all power drawn by the data center goes to the IT infrastructure.

The EPA model breaks the PUE into its component-wise contribution from IT and site equipment. Site equipment is broken down into lighting, power delivery, and cooling systems. Power delivery is further broken down into transformer and UPS losses. The cooling system is separated into the chilled water system and the fans. The chilled water system includes both the chillers and the pumps. Thus the total PUE consists of adding the contribution from IT equipment, lighting, transformer losses, UPS losses, chilled water system, and fans. For instance the PUE contribution from lighting is the ratio of power used by the lighting to the power drawn by the IT load.

The case studies report measured results for all site equipment areas: lighting, transformers, UPS, chilled water systems, and fans.

Site Maturity Assumptions per Scenario as Defined in the EPA Report

Scenario Name	Assumptions
Historical Trends	Site infrastructure consumes 50% of all data center energy, which corresponds to a PUE of 2.0.
Current Efficiency Trends	A 1% drop in improvement per year resulting in a PUE of 1.90 at the end of 5 years (a 5% reduction).
Improved Operation Scenario	Essentially the same site infrastructure systems as in the current efficiency trends scenario. Equipment typically in cludes: • 95% efficient transformers • 80% efficient UPS • Air cooled direct exchange system chiller • Constant speed fans • Humidification control • Redundant air handling units.
Best Practice Scenario	Facility performs as well as the most energy efficient facilities identified in recent benchmarking studies of 22 data centers performed by Lawrence Berkeley National Laboratory (Tschudi et al. 2004; Greenberg et al. 2006). The best PUE ratios identified in these benchmarking studies were around 1.3. Infrastructure systems in such facilities use proven energy efficient technologies that commonly include: • 98% efficient transformers • 90% efficient UPS • Variable-speed drive chiller with economizer or water side free cooling • Variable-speed fans and pumps • Redundant air handling units.
State-of-the-art Scenario	Representative infrastructure equipment for a state-of-the-art facility includes emerging energy efficient technologies such as liquid cooling (instead of air), DC power distribution to reduce UPS losses, and distributed generation using combined heat and power (CHP). A cooling tower with variable speed pumps to rack coils would reduce cooling system power to roughly 0.15 kW/ton. Typical equipment in a state-of-the-art facility includes: • 98% efficient transformers • 95% efficient UPS • Liquid cooling to the racks • Cooling tower • Variable-speed drive pumps • CHP

Estimate of PUE Contribution by Equipment per Scenario Used in the EPA Report

		Site Infrastructure						
	IT Equipment	Transformer Losses	UPS Losses	Chilled Water	Fans	Lighting	Total	Rounded Value
Historical	1.00	0.05	0.17	0.54	0.16	0.08	2.00	2.00
Current Trends	1.00						1.90	1.90
Improved Operations	1.00	0.05	0.20	0.30	0.13	0.02	1.70	1.70
Best Practice	1.00	0.03	0.10	0.10	0.03	0.02	1.28	1.30
State of Art	1.00	0.03	0.05		0.04	0.02	1.14	1.20

3.3.1 Lighting consumes only a small fraction of energy used

NetApp's Building 11 data center reports a PUE contribution of 0.011 which is well under the 0.02 contribution estimated for the state-of-the-art scenario. Lighting is a small percentage of data center energy consumption.

3.3.2 Power delivery improves with better technology and management

The efficiency of power delivery items is defined as the fraction of output power over the input power. The difference from 100% of this efficiency is the loss; for a 98% efficient system, the loss is 2%. The EPA uses this difference as an estimate for the component-wise PUE. This estimate is inaccurate when used for both transformers and UPS since the power delivery equipment runs in series. Recall that the component-wise PUE is defined as the ratio of power lost by that component to the power drawn by the IT equipment. Typically IT power draw is estimated by the output of the transformers. So the loss estimate is inaccurate as the PUE contribution for the UPS. To be consistent, however, this report uses the same estimate given in the EPA Report and the difference is small.

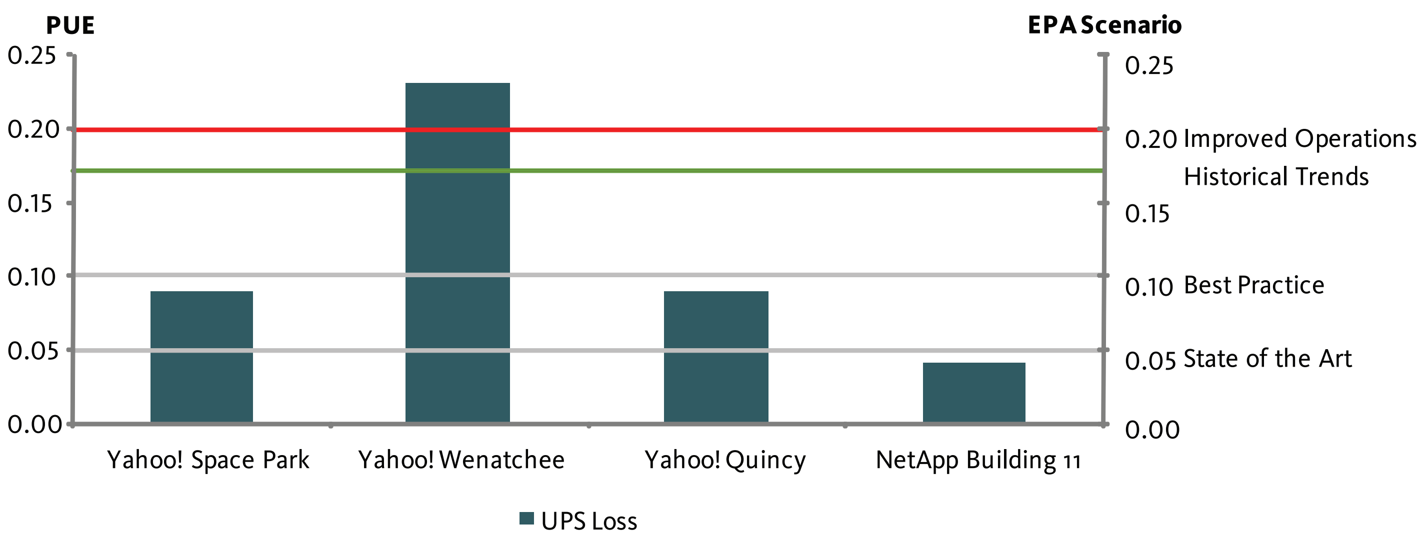
UPS

Typically manufacturers provide efficiency data for power equipment that is expressed as a percent of power output to full-power input. The result of using the manufacturer's published efficiency ratings at full load is that the electrical losses of real data centers are significantly higher than most users or designers anticipated. The efficiency curve of static UPS systems at light loads falls near zero. For this reason the efficiency of the UPS system at partial load must be considered for an accurate reading.

UPS systems vary significantly by both the technology and the active power load. This difference is because the actual efficiency of the UPS varies as a function of the IT load running on the UPS. In most data centers, which are designed with fully redundant (2N) UPS, each UPS system is typically carrying 40% of the IT load. In a (2N+1) scenario, each UPS is loaded to a maximum of 33% of full load.

The case studies compare the electrical losses of the most commonly used UPS technology, that is Double-Conversion, with Flywheel UPS, which the EPA rates best-in-class technology. To accomplish this task,

Effect on Total PUE—UPS



this study compares actual UPS electrical losses in four large-scale production data centers with comparable load factors (approximately 45% loaded except for Yahoo! Space Park running at approximately 60%). Yahoo! Space Park and Yahoo! Wenatchee data centers were designed with fully redundant static UPS systems with battery storage. Yahoo! Quincy and NetApp Building 11 data centers use diesel engine-generator based UPS systems with flywheel energy storage. The best case efficiency rating: flywheel technology and right-sizing UPS so they run at higher loads.

Transformers

Another opportunity to reduce power loss is within the transformers that convert the power into a form consumable by the IT equipment. Yahoo! Space Park, Yahoo! Wenatchee, and USPS Before provided baseline values of PDU loss. USPS After shows the impact of upgrading to high-efficiency PDUs. Yahoo! Qunicy shows the savings from eliminating the 480-208 medium voltage transformation. Even the baseline cases show good performance with almost all data centers exceeding the EPA estimates for state-of-the-art.

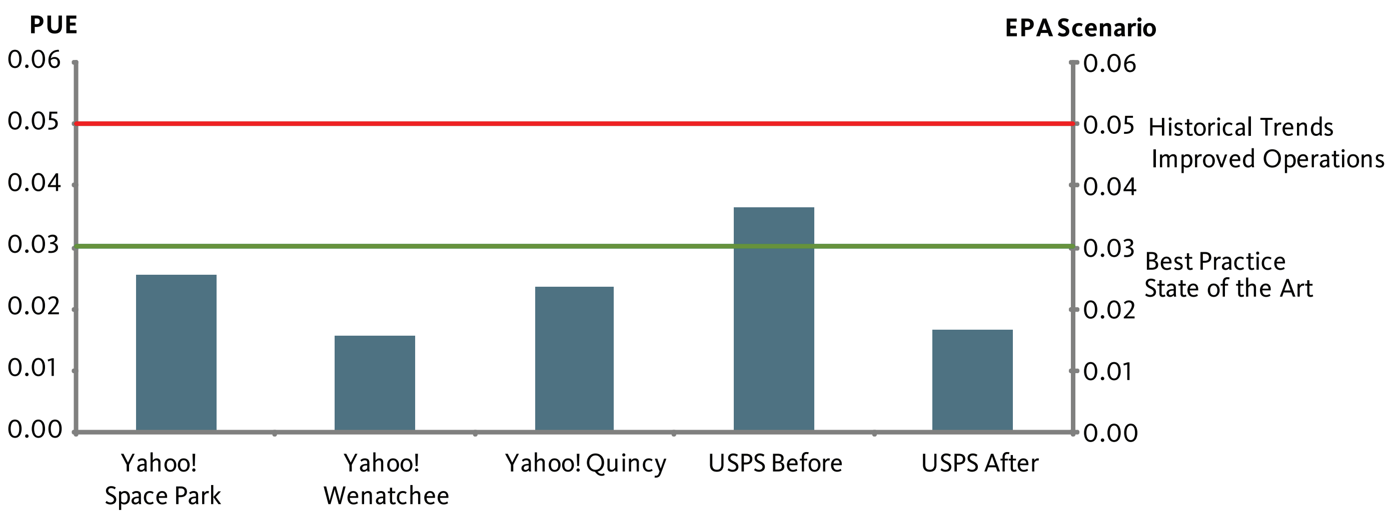
3.3.3 Data centers can make great strides in cooling delivery

The case studies cover a wide range of cooling improvements. Some, like optimized air flow management, are applicable for all data centers; others, like variable frequency drives or water-side economizers, may be appropriate for many existing data centers; and the rest, like air-side free-cooling or high-efficiency chilled water plants, may be suitable for installation at select or new data centers.

Cooling Delivery via Fans and Modular Cooling Units

Fans or modular cooling units deliver cooling to IT equipment. Oracle, LBNL, and NetApp implement optimized air flow management that maintains a greater temperature differential and reduces the power required by the fans to circulate air. NetApp Building 11 implements physical barriers between hot and cold aisles whenever possible; Oracle uses hot aisle containments, and LBNL uses cold aisle containments. Sun Santa Clara uses a modular cooling unit and also hosts a comparison of units from multiple vendors. In all cases, the results fall within the best-case scenarios from the EPA, and the best implementations of each solution achieve state-of-the-art efficiency levels.

Effect on Total PUE—Transformers

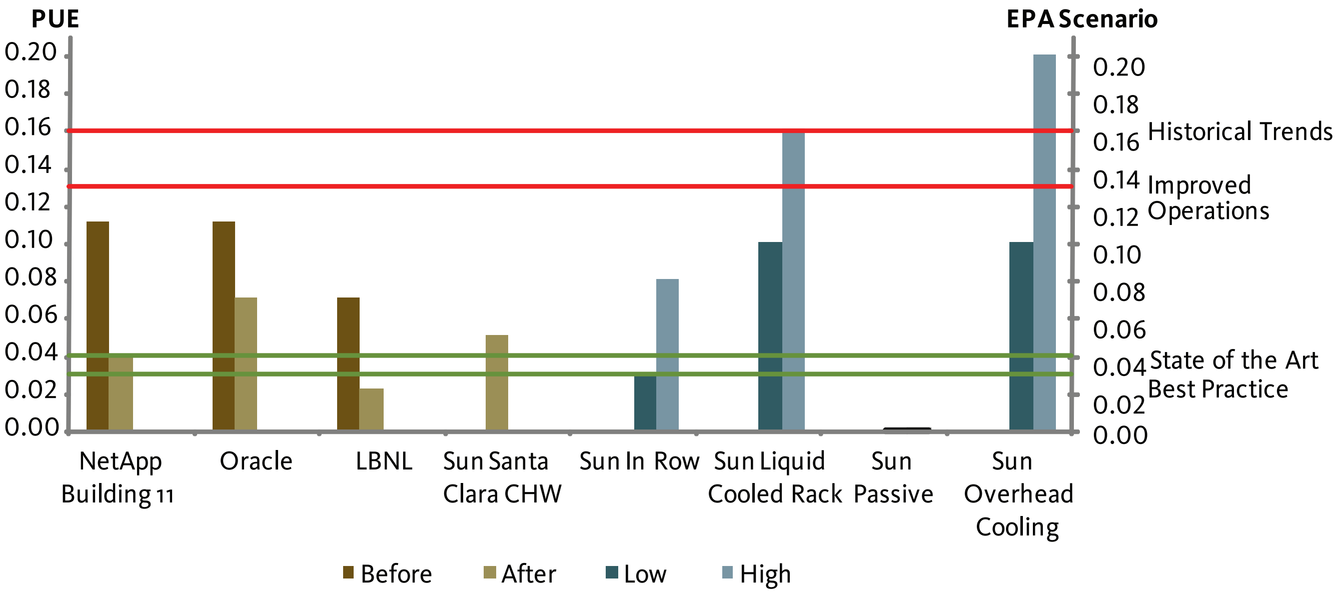


Chilled Water System

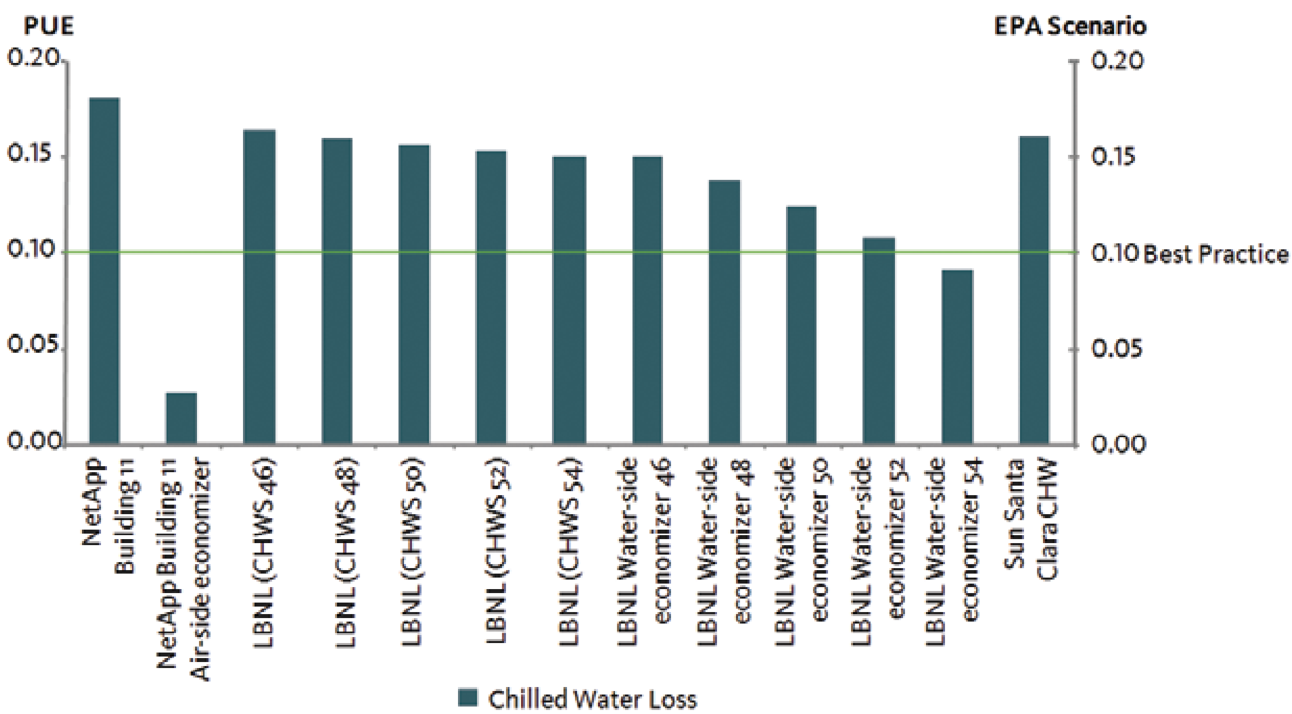
For data centers that use water as part of their cooling solution, several studies may apply. After optimizing air flow, LBNL raised the temperature of the chilled water supply (CHWS) and then implemented a water-side economizer. Sun Santa Clara data center installed a high efficiency chilled water plant. And NetApp Building 11 implements air-side free cooling. The air-side economizer achieved the greatest efficiency. Its effectiveness is due to data centers being located in cool, dry climates. Other solutions are more widely applicable to data centers regardless of location. Note that LBNL's combination of raising supply temperature and water-side economization is as efficient as Sun's implementation of a high-efficiency chilled water plant in its new data center.

For data centers that can take advantage of cool, dry climates, free cooling offers great savings. Yahoo Wenatchee used both air-side and water-side free-cooling. Digital Realty Trust is 65% economized for outside air, and NetApp Building 11 uses air-side economization. Note that NetApp's Building 11 achieves an annual PUE of 1.10, the best in this study.

Effect on Total PUE—Cooling Delivery (Fans and Modular Units)



Effect on Total PUE—Chilled Water System

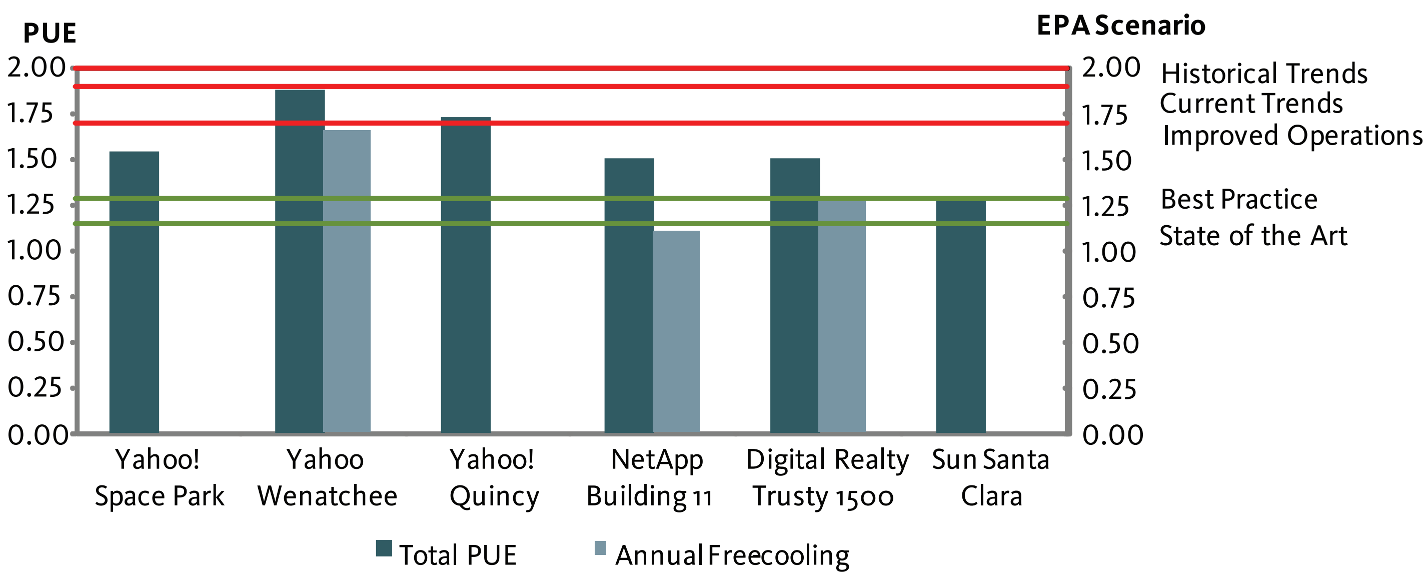


3.3.4 Finding: Site Initiatives offer High Efficiency Today

Measured results show that site initiatives achieve state-of-the-art efficiency levels across all equipment types. There is opportunity to achieve high efficiency in all categories. Even for categories, like lighting and transformers, which contribute the least to the overall PUE, a few points add up. As a result, the potential kWh electricity savings for a large scale production data center are on the order of 25,000,000 kWh or greater over a typical 10-year life of the facility.

The case studies demonstrate the effectiveness of technology available today. Technology maturity is on track to meeting the efficiency predictions of the EPA report. What remains is for companies and government to encourage adoption of these initiatives so that data centers can meet or exceed EPA assumptions. This report aims to encourage adoption of the initiatives by identifying and educating the public of their benefits.

Total PUE



4 Demonstration Results Verify EPA's Best-Case Scenarios

Like the EPA Report, this report presents consolidated analysis of the impact of IT and site improvements on energy use. For the analysis first the energy used by IT infrastructure was computed. Added to that was the amount energy needed by site infrastructure to support the IT load (by multiplying the IT energy use by the PUE).

To compare results, we classified case studies into four scenarios based on the differences in data center types that affect the applicability and effectiveness of the initiatives. Applicability of site initiatives varies across legacy data centers and new commissions, and effectiveness of IT initiatives across production and research and development (R&D) data centers. Production data centers require high performance and availability guarantees met via highly tuned, dedicated resources. As such, dynamic resource optimization is less applicable until technology matures enough for operators to become comfortable with a highly variable environment. Workload, however, is typically well characterized, which may make it easier to provide and consolidate IT resources for jobs.

In an R&D setting the compute resources serve the test and development functions, which must be flexible. These systems handle a wide variety of compute demands and typically require more capacity than production environments. The tradeoff is less stringent guarantees on performance and availability.

The R&D environment is a good candidate for starting virtualization and resource optimization to improve energy utilization.

Applying site infrastructure solutions depends on whether installation occurs as part of a new facility commission or as part of a retrofit of an existing legacy data center. In new data centers energy cost savings create the incentive to buy more expensive solutions that are highly energy efficient. While technically feasible in all data centers, retrofits of legacy centers may not always make sense. The typical lifespan for site infrastructure is at least 10 years. For some items, the cost savings from energy consumption may not justify purchasing upgraded, more efficient equipment. For other items, installation requires down time that cannot be accommodated. For the purpose of analysis, this report assumes that power delivery units, modular cooling, air side economizers, and chilled water plant are not candidates for retrofit situations.

This report depicts four scenarios: Legacy Production, Legacy R&D, New Production, and New R&D. The Legacy scenarios replace estimates of measured site and IT inputs within the EPA's Best Practice scenario. The New scenarios measured results are in the State-of-the-Art scenario.

Each input for these scenarios is measured data from a case study. There are other solutions that promise energy savings, but they are not included in this year's report since they cannot be represented by measured results. Each scenario includes the technology that demonstrates the best achievable results that can be applied to a large set of data centers. For instance, the newly commissioned scenario includes the high efficiency chilled water plant in combination with modular cooling in lieu of the free cooling air side economizer where results may vary by climate.

Thus some data centers will do better if they are located in a cool-dry climate and use free-cooling. Others may not be able to implement the cooling systems upgrades suggested (e.g., data centers that use refrigerant-based cooling instead of water-based, or data centers that cannot raise data center temperatures due to operating agreements). While these scenarios do not apply to all data centers, they do apply to many. On the basis of these scenarios, our findings are set out below.

4.1 Finding: Further Efficiency Can be Achieved with More Aggressive IT Initiatives

Production data center scenario applied Symantec's consolidation results of 3:1 PSRR. R&D data center scenario applied Sun's consolidation and Cassatt's resource optimization results and achieved a combined PSRR of 2.1:1. These values are modest and match the EPA's best practice efficiency levels 2:1 PSRR. These assumptions define the IT growth in the combined analysis. Next year's report will take into account more aggressive virtualization as well as storage and networking solutions.

Demonstration Scenarios Cover Combinations of IT and Site Data Center Types

Demonstration Scenarios Combine IT and Site Initiatives

Applied IT Initiatives for:		
Production Consolidation	**Legacy Production**	**New Production**
R&D Resource Optimization	Legacy R&D	New R&D

Applied Site Initiatives for:

Legacy Retrofit	**Newly Commissioned**
Variable Fan Drives Air Management Water-side economizer Right-sizing power, cooling	Air side economizer High efficiency chilled water plant + Modular cooling High efficiency standby power High efficiency PDU

4.2 Finding: Legacy Upgrades Can Be Nearly as Efficient as New Commissions

While legacy retrofits may not optimize power delivery for cost reasons, they can optimize cooling via a unique set of technologies. Legacy data centers can implement a combination of air management, variable frequency drives, and water-side economizers as appropriate.

All data centers should optimize air flow, but this step is especially effective in legacy data centers where air flow management was not considered at build-out or where current implementation is conventional hot-aisle cold-aisle set-up. In these arrangements there is poor separation between the cold supply and hot return airstreams. The optimized air management case studies involve creating a physical barrier separating hot and cold airstreams to provide the highest degree of separation.

Any of three approaches—cold aisle containment, hot aisle containment, and rack containment could provide the physical separation with each one offering its own advantages and limitations. NetApp added blanking panels where appropriate and hot aisle containment, LBNL tested cold aisle containment, and Oracle implemented hot-aisle rack level enclosures.

Once air management is in place, it prevents the mixing of hot and cold air, making it possible to raise the supply air temperature and reduce the volume of air provided to the data center. Variable frequency drives on fans and pumps scales the amount of cooling delivered to match the amount of heat required to be removed from the IT equipment. Raising the supply temperature enables the central cooling system to operate at higher efficiency and use less power. For many data centers that use chilled water in their cooling systems either direct or indirectly, water-side economizers are a form of free-cooling that can be implemented in retrofit situations to deliver savings in a wide range of climates. Combined with raising supply chilled water temperature, water-side economization is even more efficient as it widens the number of operating hours that outside air can be used for free-cooling.

The equipment efficiency assumptions and the case studies from which they are based are as set out below.

First describe the composition of measurements used to generate the PUE for the Legacy scenario. The Legacy scenario uses measurements for baseline power delivery units and only considers cooling upgrades. The LBNL study notes the general rule of thumb is 1% energy reduction for every degree F supply water temperature raised; this rule was verified with measurements. This analysis assumes that chilled water system starts with a PUE contribution of 0.2 (note that all measured data centers reported PUE contributions of less than 0.18) and that data centers have already raised water supply temperature. Then applying water-side economization results in further savings. Using the water-side economizer savings for 500 F chilled water supply in Oakland, CA, the PUE contribution is reduced by an additional 20%. The resulting PUE contribution by the chilled water system is 0.16.

Next is the composition of measurements used to generate the PUE for the New scenario. The New scenario consists of high efficiency equipment across the data center. The USPS and NetApp data provided the highest efficiency levels for transformers and UPS. This report identifies the combination of high efficiency chilled water plant and modular cooling as an efficient cooling technology applicable in new data centers regardless of climate. We assumed a 0.05 contribution based on the efficiency of the permanent installation at Sun that is tuned to its high-efficiency chiller plant (with 0.16 PUE contribution).

Combining measurements in a legacy retrofit results in a 0.23 contribution of cooling to PUE. The combination for new data centers results in a 0.21 contribution to PUE. So, by combining the technologies studied both legacy and new data centers can achieve comparable cooling efficiencies.

The PUEs 1.36 and 1.27 for Legacy and New data centers were used to estimate site efficiency in the analyses presented below.

Assumptions for the Legacy Data Centers

Equipment	PUE	Data Center Initiative
IT Equipment	1.00	
Transformer	0.04	Yahoo! Space Park
UPS	0.09	Yahoo! Space Park
Lighting	0.01	NetApp Building 11
Chilled Water System	0.16	LBNL's Air Flow Management and Water-side Economizer
Fans	0.07	Oracle's Air Flow Management and VFDs
Total	**1.36**	

Assumptions for the New Data Centers

Equipment	PUE	Data Center Initiative
IT Equipment	1.00	
Transformer	0.02	USPS High Efficiency Transformer
UPS	0.04	NetApp Flywheel UPS
Lighting	0.01	NetApp Building 11
Chilled Water System	0.16	Sun's High Efficiency Chilled Water
Fans	0.05	Sun's Modular Cooling Unit (Assume 0.05)
Total	**1.27**	

4.3 Finding: Data Centers are on Track to Meet the Best-case Scenarios

Demonstration Projects results show that given the maturity of technology, data centers can achieve EPA estimates. The demonstration scenarios perform at the EPA's best case scenarios, between the Best Practice and State-of-the-Art projections. Legacy retrofits improve upon existing data centers and are similar to the EPA's Improved Operations scenario. Our measured results exceed the efficiency projected by the EPA. New data center scenarios take advantage of the most efficient of all technologies studied; their projections track the EPA's State-of-the-Art.

By 2011, trajectories using the measured results offer significant savings over 2007 trends. With legacy retrofits data centers can:

- Save between 59.9 billion and 64.6 billion kWh/year annually
- Save up to $4.5 billion annually
- Cut 40.9 MMTCO2 (more than 7 million cars) annually.

With new commissions and legacy retrofits they can:

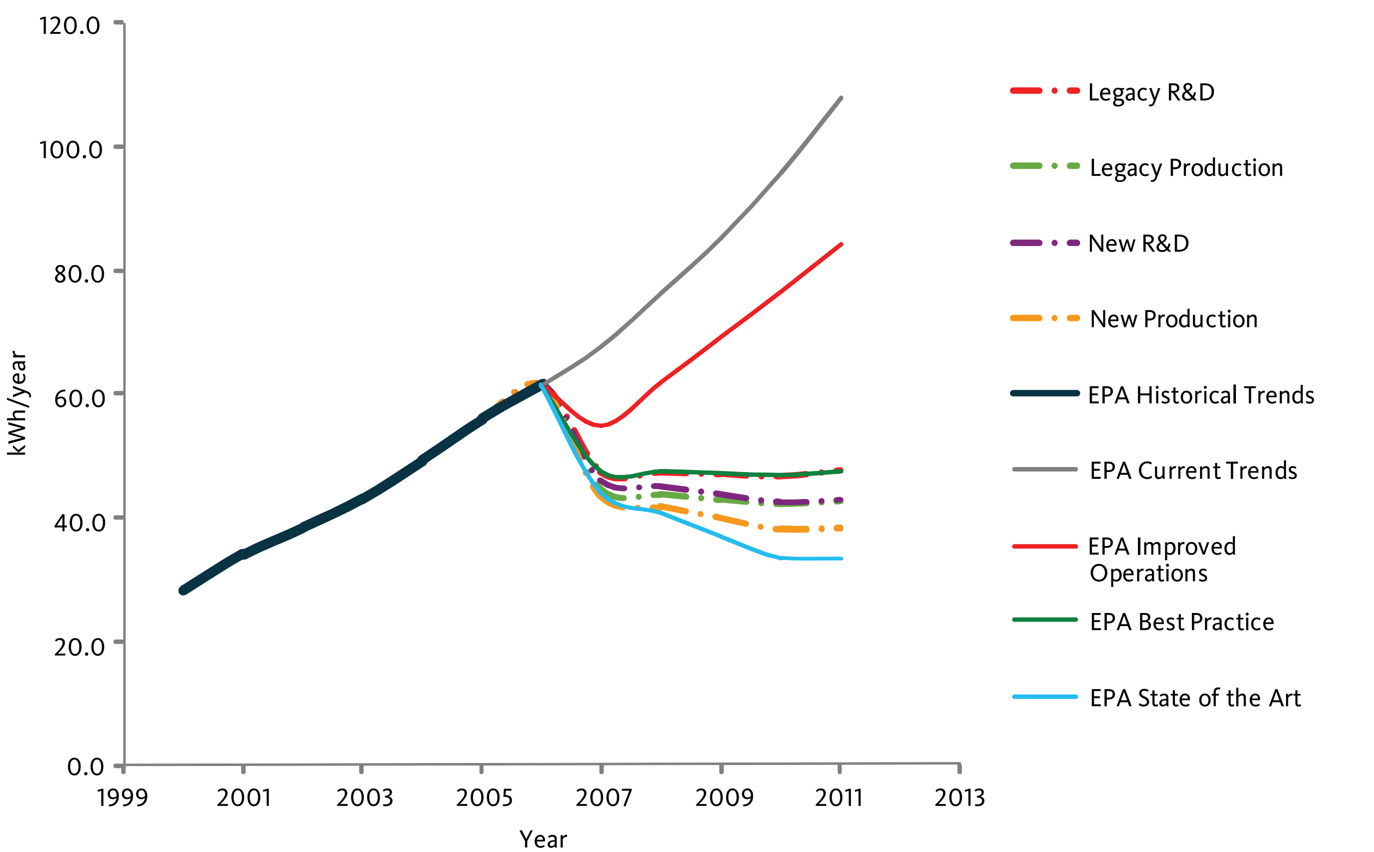
- Save between 64.2 billion and 68.9 billion kWh/year saved annually
- Save up to $4.8 billion annually
- Cut 43.6 MMTCO2 (almost 8 million cars) annually.

But even with this reduction, data centers will still be large consumers of energy since they must keep up with business demands. In 2011, under the measurement based scenarios, data centers will:

- Consume between 38 billion to 47 billion kWh annually
- Cost between $2.6 billion to $3.3 billion annually (computed for the 2007 average cost of electricity 8 cents/kWh used in the EPA Report—imagine if this doubles)
- Produce between 24.3 to 30.1 MMTCO2 annually (between 4.3 million to 5.3 million cars).

Using the EPA assumptions of adoption, these projections show the impact on data centers with increased energy use. These figures should motivate companies to adopt available technology so that their data centers can achieve or exceed these results.

Energy use by scenario



4.4 Finding: IT initiatives deliver greater impact than site improvements

The case studies verify that holistic IT transformation initiatives produce larger impacts than site improvements. For studies that reported energy savings, those savings are summarized below (some studies reported only efficiency metrics, energy difference of specific equipment, or total energy use when there was no "before condition" to baseline for comparison).

Although results are influenced by the different data center types (e.g., sizes, locations, purpose), this finding holds true because site power use depends on the amount of IT load supported. Data center energy consumption consists of IT power and site overhead. To estimate site overhead, site efficiency is multiplied by the energy draw of the IT load. So, reducing the energy of IT also reduces the energy needed by the site infrastructure to support the IT load.

These findings confirm the EPA's observation that "data centers may realize greater energy-efficiency gains by optimizing their operation and efficiency as a holistic system (e.g., through real-time, facility-level energy monitoring and management systems) (EPA 113)."

Summary of Reported Energy Savings (kWh)

Data Center Initiative	Annual
IT Initiatives	
Sun Consolidation	8,844,734
Symantec Consolidation	3,607,980
Site Initiatives	
LBNL Air Management + Water-side Economizer	1,140,000
NetApp Air-side economizer	1,159,065
USPS High-efficiency PDU	787,400
Yahoo! Free-cooling	2,250,000
Yahoo! High-efficiency UPS Santa Clara	1,253,124
Yahoo! High-efficiency UPS Wenatchee	829,196

3 Comparing Demonstration Results with EPA Estimates

The Demonstration Project, through 17 case studies of member companies in Silicon Valley leadership Group, aimed to demonstrate energy savings by using technology available today. The findings show that a variety of initiatives exist that can produce considerable energy savings and are viable for commercial data centers. Projections were even better than expected and validate the EPA estimates of the efficiency of technology maturity.

Data center technology is on track to meet the EPA's best case scenarios. Already the measured scenarios combining IT and site results achieve the Best Practice and State-of-the-Art efficiency levels, as defined by the EPA Report. With more aggressive IT optimization, data centers can exceed the EPA estimates. Findings from initiatives broken down by site and infrastructure should spur data centers and their organizations to action.

Site overhead—High efficiency site initiatives exist today. With them data centers can achieve the State-of-the-Art estimates of the EPA. Legacy retrofits can almost be as efficient as new commissions. Existing data centers can also contribute to reducing energy use. The onus is not only on newly commissioned data centers.

IT infrastructure—Holistic IT transformation initiatives deliver a greater impact than site improvements. Companies need to more aggressively reduce IT infrastructure.

Results show that individual data centers can save considerable amounts of energy by adopting available technology. Case studies include the measured energy savings and associated costs and carbon impacts. In most cases participants did not reveal implementation costs. However, for these businesses to implement these initiatives, it is likely that the business case had to justify return on investment within 18 months, and typically within less than one year.

Now with results that show cost and carbon savings, data center operators can make better informed decisions. Efficient data centers can increase capability, which will enable organizations to avoid or defer facility upgrades or expansions.

The studies covered a wide range of initiatives and this report helps operators identify solutions appropriate for their organizations and helps make the case for adoption. Policy makers may use the results to encourage the adoption of the technology outlined so that the energy projections can be achieved. The public should be aware that data centers are making strides to reduce their power consumptions. This report validates that technology is ready. Now data centers need to adopt energy saving initiatives. With widespread adoption, data centers can reduce energy use to levels below 2006 estimates.

Next year's Demonstration Projects will focus on green IT and cover more IT projects and advanced cooling and power distribution concepts. Future studies by the EPA will baseline 229 data centers across Tier 1-4 and across the U.S. The baseline study will help answer questions on technology adoption. Together the maturity and adoption data will allow us to build an even fuller picture of energy use in data centers.

Site Results Exceed Best Practice

EPA Scenario	PUE
Historical Trends	2.0
Current Trends	1.9
Improved Operations	1.7
Best Practice	1.3
State-of-the-Art	1.2

Measured Legacy PUE 1.355
Measured New PUE 1.265

IT Results Achieve Best Practice

EPA Scenario	PSRR
Historical Trends	N/A
Current Trends	1.08:1
Improved Operations	1.08:1
Best Practice	2:1
State-of-the-Art	5:1

Measured R&D PSRR 2.1:1
Measured Production PSRR 3:1

Appendix

Individual case study summaries may be accessed at **http://microsite.accenture.com/SVLGREPORT/Pages/CaseStudies.aspx**

A1 Classification of Data Center Size used in EPA Report

For IT technologies, the EPA bases trend assumptions on the data centers size classified into categories as defined by IDC. The following definitions are used in the EPA Report.

- **A Server Room (Entry Level Data Center)** typically contains one to a dozen servers, has no external storage, and may use the same HVAC system of building or be with a split system for more cooling capacity.
- **A Small Data Center (Localized Data Center)** houses dozens or hundreds of servers and moderate external storage, has a separate centralized HVAC system, and minimal operational staff.
- **A Medium Data Center (Departmental/Mid-tier)** holds hundreds of servers and extensive external storage, uses a centralized chilled water plants and central air handling units, and maintains a staff to manage airflow management.
- **A Large Data Center (Enterprise Class Data Center)** contains hundreds to thousands of servers and extensive external storage. These data centers maintain maximum redundancy and require expert management staff.

The Table below shows the distribution and is derived from EPA Report.

Under this classification of data centers, the EPA Report makes analysis and assumptions on the growth of IT equipment.

Estimated Distribution of Data centers by according to size, derived from the EPA report

Year	2000	2001	2002	2003	2004	2005	2006
Server room	33%	34%	35%	35%	36%	36%	36%
Small	17%	17%	17%	17%	17%	17%	17%
Medium	15%	15%	15%	15%	15%	15%	15%
Large	34%	34%	33%	33%	32%	32%	32%

A2 EPA Uptake Assumptions

A2.1 Servers Assumptions

EPA Historical Server Growth Assumption: The table and Chart below shows a brief overview of the electricity growth from servers from 2000 to 2006.

The EPA Report assumes that servers achieve 10% utilization pre-virtualization. As their numbers are reduced those servers replaced by virtual machines increase the server utilization on the remaining machines.

EPA Current Trends of Energy Efficient Server Assumption: The EPA uses an estimate of 25% energy savings for energy efficient server models to account for the current trends in server technology (EPA 44).

EPA Current Trends of Energy Efficient Server Penetration Assumption: The EPA estimated that "energy-efficient" volume servers, would represent approximately five percent of all U.S. volume server shipments in 2007 and that this percentage would increase linearly to 15 percent of all U.S. volume server shipments by 2011 (EPA 44-45).

At the time of the EPA Report, server manufacturers were already moving towards energy efficiency to reduce the performance per watt ratio. The definition of "energy efficient" design includes multi-core and power usage.

Multiple-core microprocessors contain two or more processing cores on a single die, which run at slower clock speeds and lower voltages than the cores in single-core chips but handle more work in parallel (with proper software support) than a single-core chip. Cores share architectural components like memory elements and management saves additional energy.

Improved power usage encompasses the adoption of high efficiency power supplies, internal variable speed fans, and power management described below.

EPA Current Trends of Power Management Adoption Assumption: The EPA assumes that power management (dynamic frequency and voltage scaling) is only enabled on around 10 percent of applicable volume and mid-range servers. This assumption is based on an industry expert's recent estimate of the current utilization rate of microprocessor power-management features (EPA 45).

Power management refers to dynamic frequency and voltage scaling that ramp up or down energy as needed to deliver performance. Frequency and voltage scaling constantly adjusts to changes in computational demand, continuously optimizing processor energy consumption by reducing the microprocessor's clock speed when the utilization is low.

EPA Current Trends of Virtualization Impact Assumption: Based on data from IDC, where worldwide x86 volume server shipments, which were once projected to increase 61 percent by 2010, are expected to grow just 39 percent during that same period because of increasing server virtualization (EPA 45).

Virtualization enables more efficient use of a single server. Virtualization replaces several dedicated servers that operate at low average processor utilization with a single 'host" server that provides the same services and operates at a higher average utilization level. Virtualization may offer significant energy savings for volume servers because these servers typically operate at an average processor utilization level of only five to 15 percent (EPA 42). The typical U.S. volume server will consume anywhere from 60 to 90 percent of its maximum system power even at low utilization levels (EPA 43), thus it is more efficient overall to run fewer servers at higher utilization than more servers at low utilization.

Estimated Total Electricity Use of U.S. Servers (in billion kWh/year) by Space Type, 2000 to 2006, from EPA Report (EPA 36)

Space type	2000	2001	2002	2003	2004	2005	2006
Server room	3.1	3.8	4.6	5.3	6.1	7.2	7.8
Small	1.9	2.3	2.6	2.9	3.3	3.8	4.2
Medium	1.7	2.1	2.3	2.6	3.0	3.4	3.7
Large	4.8	5.6	6.1	6.6	7.3	8.2	8.8
Total	11.6	13.9	15.6	17.4	19.8	22.6	24.5

A2.2 Storage Assumptions

The EPA Report also considers energy consumed by storage within the data center.

EPA Historical Storage Growth Assumption: The EPA estimates of the energy use of enterprise storage devices summarized in the Table below.

EPA Current Trends Storage Growth Assumption: As a result of storage trends, the EPA estimates that the average power use per drive will decrease by approximately 7% between 2007 and 2010 (EPA 45).

The EPA Report identifies storage trends that have manufacturers moving towards energy efficient storage devices. Enterprise hard disk drive (HDD) storage devices is shifted to smaller form factor disk drives and increasing use of serial advanced technology attachment (SATA) drives. Additionally improved management strategies focus on storage virtualization, data de-duplication, storage tiering, and movement of archival data to storage devices that can be powered down when not in use.

Estimated Energy Use (billion kWh/year) of Enterprise Storage Devices, by Space Type, 2000 to 2006 from the EPA Report

Space type	2000	2001	2002	2003	2004	2005	2006
Server closet	0	0	0	0	0	0	0
Server room	0	0	0	0	0	0	0
Localized data center	0.28	0.37	0.46	0.56	0.66	0.73	0.86
Mid-tier data center	0.25	0.33	0.42	0.50	0.59	0.66	0.78
Enterprise-class data center	0.57	0.74	0.90	1.07	1.23	1.35	1.58
Total	1.10	1.44	1.79	2.13	2.49	2.74	3.22

A3 Acknowledgements

Teresa Tung, Accenture Technology Labs authored the majority and oversaw the development of this report. Other Accenture staff that contributed includes Matthew Chow, Brian Leong, Mohanan Nair, Sandra Najem, and Karen Swanson with sponsorship by Rockwell Bonecutter, Lyle Ginsberg, and Jorg Heinemann.

Ray Pfeifer, Silicon Valley Leadership Group, founded and organized the Data Center Demonstration Project. In addition to Ray's herculean efforts with the project itself, Ray provided invaluable support with authoring, advising, and analyzing results contained herein.

Essential support was provided by Lawrence Berkeley National Laboratory in sharing the model used in the EPA Report, authoring case studies, and providing feedback. Support was provided by Rich Brown, Eric Masanet, Dale Sartor, Bill Tschudi, and Tim Xu.

We thank Victoria Barbero and Renée LaFlamme for their patience and efficiency with editing and formatting the report.

We would like to thank all participants of the Data Center Demonstration Project and especially identify the following authors of the individual case studies.

Pamela Courtot, Powersmiths
Donnie Foster, Power Assure
Mark Hydeman, Taylor Engineering
Mukesh Khattar, Oracle
KC Mares, Megawatt Consulting
Dean Nelson, Sun Microsystems
Kenneth Oestreich, Cassatt
Clemens Pfeiffer, Power Assure
Mike Ryan, Sun Microsystems
Earl Sacerdoti, Modius
David Shroyer, NetApp
Sriram Sitarman, Synopsys

About the Energy Efficient Data Center Demonstration Project

The project's goal is to identify key technology, policy and implementation experts and partners to engage in creating a series of demonstration projects that show emerging technologies and best available energy efficiency technologies and practices associated with operating, equipping and constructing data centers. The project aimed to identify demonstrations for each of the three main categories that impact data center energy utilization:

- operation & capital efficiency
- equipment (server, storage & networking equipment)
- data center design & construction (power distribution & transformation, cooling systems, configuration, and energy sources, etc.).

The project also identified member organizations that have retrofitted existing data centers and/or built new ones where some or all of these practices and technologies are being incorporated into their designs, construction and operations.

About The Silicon Valley Leadership Group (SVLG)

The SVLG comprises principal officers and senior managers of member companies who work with local, regional, state, and federal government officials to address major public policy issues affecting the economic health and quality of life in Silicon Valley. The Leadership Group's vision is to ensure the economic health and a high quality of life in Silicon Valley for its entire community by advocating for adequate affordable housing, comprehensive regional transportation, reliable energy, a quality K-12 and higher education system, a prepared workforce, a sustainable environment, affordable and available health care, and business and tax policies that keep California and Silicon Valley competitive.

About Accenture Technology Labs

Accenture Technology Labs, the dedicated technology research and development (R&D) organization within Accenture, has been turning technology innovation into business results for 20 years. The Labs create a vision of how technology will shape the future and invent the next wave of cutting-edge business solutions. Working closely with Accenture's global network of specialists, Accenture Technology Labs helps clients innovate to achieve high business performance. The Labs are located in San Jose, California; Chicago, Illinois; Sophia Antipolis, France; and Bangalore, India. For more information, please visit our website at www.accenture.com/accenturetechlabs.

Accenture Technology Labs compiled the final report supporting with analytics, background research, and project management.

About Accenture

Accenture is a global management consulting, technology services and outsourcing company. Combining unparalleled experience, comprehensive capabilities across all industries and business functions, and extensive research on the world's most successful companies, Accenture collaborates with clients to help them become high-performance businesses and governments. With more than 180,000 people in 49 countries, the company generated net revenues of US$19.70 billion for the fiscal year ended Aug. 31, 2007. Its home page is www.accenture.com

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