Consortium for Energy Efficiency

Data Centers and Servers Initiative

June 2007

Consortium for Energy Efficiency
98 North Washington Street, Suite 101
Boston MA 02104
617-589-3949
www.cee1.org

TABLE OF CONTENTS

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

1 Background

Data centers are vital to the U.S. economy. More and more business is being done on-line, thereby, increasing reliance on information technology (IT) systems and driving the need for more data centers to meet this growing demand. This growth is being spurred by current activities such as Internet communications, the continued digital conversion of business applications, new regulations that require retention of digital records (e.g., Sarbanes-Oxley Act), and disaster recovery requirements.

The CEE Data Centers and Servers Initiative serves to identify activities that will help program administrators better understand the complexity related to the design and maintenance of these types of loads. Not only are the performance expectations and technological advances of this type of equipment fast-paced, the industry itself is somewhat complicated with a diverse range of stakeholders. In spite of these efforts, there is an opportunity for program administrators to come together nationally to better serve this highly energy intensive load type through activities that promote common understanding, clarification, consensus-building and validation. The following Initiative description provides details on the proposed activities to be undertaken by the Committee.

2 Introduction & Organizing Framework

The Data Centers and Servers Initiative is the result of an exploration activity authorized by the CEE Board in January of 2007. Currently, there are several national efforts underway, ranging from industry-formed coalitions to Federally-funded programs, addressing various aspects of energy efficiency in data centers and servers.

Data centers can be several buildings, one building, occupy one or several floors of a building, occupy one room or only a small closet space. Data centers are owned and operated by a multitude of businesses, including Fortune 500 and IT companies, financial and banking institutions, and by government and academic institutions.

To help programs build and deliver leveraged, informed and cost-effective data center and server programs, CEE expects to develop a comprehensive approach to address the complex set of technical issues and opportunities, market forces and barriers and business drivers at work. Initially, we have characterized this work area and associated energy efficiency opportunities according to physical data center space types. Section 3 provides an initial breakdown of these space types. The scope of facilities and systems to be covered by the initiative include: (1) existing and new data centers; (2) the broad range of data center types and sizes as well as server closets and server rooms; and (3) the key related systems, including the building infrastructure, power supplies and HVAC.

As this initiative evolves, we will develop a comprehensive understanding of the owners and industry stakeholders involved, business drivers, data center service providers and key market leverage points.

This Initiative Description is broken into two primary sections:

1. Data Centers and Servers Overview – includes definitions, market overview, industry and energy trends and current member program, Federal and other national activities
2. Initiative Activities – includes goals and strategy as well as activities to be undertaken by participants.

3 Data Centers and Servers Overview

There is some ambiguity for defining data centers and servers. We have not become aware of a dominant basis for defining and delineating data center and servers. In this section, we have proposed working definitions for data centers and servers based upon initial research and will continue to update and amend these definitions as more information is available.

3.1 Working Definitions

Data Centers: Data centers are designed to accommodate the unique needs of energy intensive computing equipment along with specially-designed infrastructure to accommodate high electrical power consumption, redundant supporting equipment and the heat given off in the process.

For the purposes of this initiative, CEE will incorporate these defining characteristics of a data center:

- A facility that contains concentrated equipment to perform one or more of the following functions: store, manage, process, and exchange digital data and information;
- Equipment includes computers, servers (e.g., web, application and database), mainframe computers, switches, routers, data storage devices, load balancers, wire cages or closets, vaults, and racks.

In addition, data centers often exhibit the following characteristics:

- Critical requirements for security and reliability;
- Raised floors (but not always);
- Specialized computer room AC systems;
- Redundant and uninterruptible power supplies (UPS). (LBNL High Performance Data Centers)

Servers: A server is a computer system that provides services to other computing systems, called clients, on a computer network. The term server can refer to either the hardware or software. Servers frequently host resources that they make available on a shared basis to other client computers, such as printers and file systems. (Wikipedia)

Server characteristics include:

- Run operating systems that are designed specifically for their use and applications designed to carry out server tasks;
- Operate continuously on a network and wait for requests for services from other computers on the network;
- Differ greatly in size, from 1U servers (pizza-box size) to huge storage silos that occupy many tiles on the floor;
- Differ from desktop computers in the software and not in the hardware. (Wikipedia)

For the remainder of this Initiative Description, we will refer to servers as the hardware "box" that is typically made up of the following components:

- Central processing unit (CPU), or processor;
- Disk drives (memory);
- Fans;
- Power supply.

3.2 Market Overview and Energy Use

The U.S. Environmental Protection Agency (EPA) and Lawrence Berkeley National Laboratory (LBNL) recently delineated data center types according to their space type, typical IT equipment and infrastructure characteristics. These space types include the following categories, from smallest to largest in terms of square footage:

- Server closet;
- Server room;
- Localized data center;
- Mid-tier data center; and
- Enterprise-class data center.

Table 1 details the typical IT equipment and infrastructure characteristics by space type. This table is incorporated from EPA's Draft Report to Congress on Server and Data Center Energy Efficiency, April 23, 2007 and as of the date of this report is not available for public consumption, citable, or quotable.

Data centers require large amounts of energy to operate. In 2005, data centers used about 45 billion kWh — roughly 1.2% of all U.S. electricity consumption (Koomey, 2007). Annually, the energy costs per square foot in data centers can be 15 to 40 times higher than standard office spaces (Greenberg, S. et. al., 2006).

Table 1: Data Center Characterization by Space Type (Do not cite or distribute)

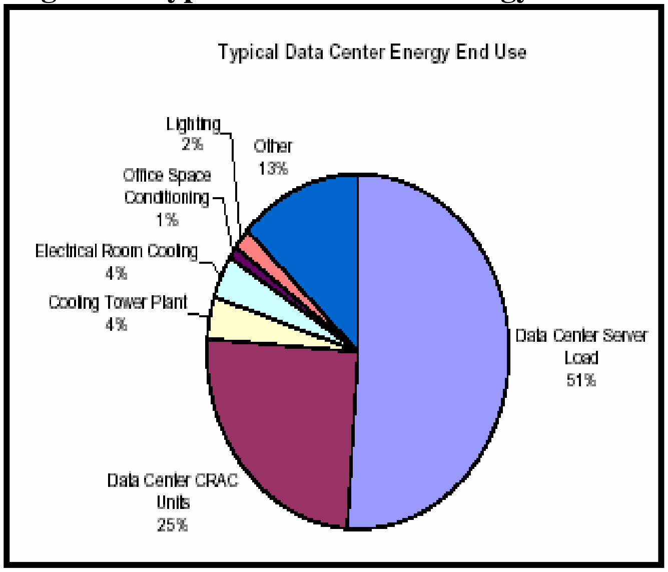
Space type	Typical size	Typical IT equipment characteristics	Typical infrastructure system characteristics
Server closet	<200 ft^2	1-2 servers No external storage	Typically conditioned through an overheard air distribution system that is part of an office HVAC system. No UPS or power redundancy is found in server closets and environmental conditions are not as tightly maintained as other data center types. HVAC energy efficiency associated with server closets is probably similar to the efficiency found in office HVAC systems.
Server room	<500 ft^2	A few to dozens of servers Moderate external storage	Typically conditioned through an overhead air distribution system, with additional cooling capacity, most probably in the form of a split system specifically designed to condition the room. The cooling system and UPS equipment will typically be of an average or low efficiency, since there are no economies of scale exist to make the efficient systems more first cost competitive.
Localized data center	<1000 ft^2	Dozens to hundreds of servers Moderate external storage	Typically use under-floor air distribution and a few in-room CRAC units. CRAC units in localized data centers are more likely to be air cooled and have constant speed fans and hence lower efficiency. Minimal operational staff is expected, increasing the probability that equipment orientation and airflow management are not optimized. Air temperature and humidity tightly monitored. More efficient UPS systems are typically used. However, power and cooling redundancy reduce overall system efficiency.
Mid-tier data center	<5000 ft^2	Hundreds of servers Extensive external storage	Typically use under-floor air distribution and in-room CRAC units. The larger size of the data center increases the probability that more efficient cooling is used, such as a central chilled water plant and central air handling units with variable speed fans. Staff at this size data center may be aware of equipment orientation and airflow management best practices. Efficient UPS systems can be expected in this size data center. However, power and cooling redundancy reduce overall system efficiency.
Enterprise-class data center	5000+ ft^2	Hundreds to thousands of servers Extensive external storage	The most efficient equipment is expected to be found in these large data centers. Along with efficient cooling and UPS systems, these data centers may be monitored with an energy management system. Equipment orientation and airflow management best practices are most likely implemented. Enterprise-class data centers are designed with maximum redundancy, which can reduce the benefits gained from the operational and technological efficiency measures.

Data center power use consists of information technology loads and infrastructure loads. The information technology loads include: servers, disk drives, and network equipment. The infrastructure loads consist primarily of: cooling, fans, pumps, lighting and uninterruptible power supplies. (Koomey, 2007)

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

On average about half the energy coming into the data center goes to the IT equipment, the bulk of the remaining energy goes to cooling the center and the rest is used for power conversions and backup with a very little (2%) going to lighting. Figure 1 shows this breakdown.

Figure 1: Typical Data Center Energy End Use



Source: Alliance to Save Energy 1/2007

According to IDC, a provider of market intelligence, advisory services, and events for the information technology, telecommunications, and consumer technology markets, servers are divided into three basic classes based on price point. Table 2 provides an overview of these server classes and market information.

The vast majority (90-95%) of the servers in data centers today and being manufactured are volume servers, which cost less than $25,000 each and on average use 200 Watts. The volume server category includes new and more compact blade servers, which are an important factor in the growth of servers (one blade is counted as one server). The mid-range servers, which cost from $25,000 to $500,000, represent 5-10% of the market. The high-end servers, which cost more than $500,000, represent just a small fraction of a percent of the market. These mid- and high-range servers are designed to undertake more sophisticated computing functions. (Koomey, 2007)

In the United States, the electricity used by servers doubled from 2000 to 2005 and represents about a 14 percent annual aggregate growth rate. Total power consumption by all servers in the United States in 2005 is about 2.6 million kW. Total server electricity consumption in the United States is 23 billion kWh in 2005, which represents about 0.6% of total U.S. electricity consumption in 2005. Most of the growth is attributed to growth in the number of servers — mainly the volume server category — with only a small part of that growth being attributed to the increase in the power per unit. (Koomey, 2007)

Table 2: Overview of Server Equipment Market					
Server Class	**Definitions (IDC defines classes based on cost of system)**	**Typical Power Use Range (2000 -2005 data)**	**Estimate Average Unit Energy Consumption (kWh/yr) 2005**	**% of installed Units U.S 2000 -2005**	**% of 2005 Units U.S Shipments**
Volume	Cost less than $25,000 per unit (includes 1-4 U and blade servers)	200 Watts 186 – 219	1,918	90-95%	97.7%
Mid-range	Cost between $25,000 and $500,000 per unit	540 Watts 424 – 625	5,475	5-10%	2.2%
High-end	Costs more than $500,000 per unit	6,650 Watts 5,534 – 7,651	67,023	.002 %	0.01%

Information source: Johnathan Koomey, LBNL, February 15, 2007

3.3 Industry and Market Trends

There are current technology trends that will put both upward and downward pressure on data center and server energy use in the future. Importantly, individual servers are becoming more powerful and data center power densities are increasing.

As data center operators run out of space, they are packing more servers into the racks and data centers. Large, energy consuming servers like blade servers are gaining popularity. From 2001 to 2006 the number of servers per rack has doubled from 7 to 14 and this number is expected to grow to 20 per rack by 2010 (VMWare presentation). It is now possible to pack a rack with equipment that requires 30,000 watts-per-rack or more compared to only 2,000 to 3,000 watts-per-rack a few years ago (Green Grid, The Green Grid Opportunity). Figure 1 displays a modern rack packed with servers.

Figure 1: A row of 19-inch racks in a modern server farm.

The dual trend of more powerful servers that are packed more densely has increased overall power density in data centers. A four-fold increase in server power from 2001 to 2006 (from 100 to 400 Watts) in combination with an increase in the density of servers at the rack-level has resulted in an eightfold rack-level power consumption increase. (VMWare presentation)

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

There are several key technology trends, however, that are helping to reduce the energy use of IT equipment. They include: advances in microprocessors (multi-core, new materials (IBM) dynamic frequency and voltage scaling), increase in the efficiency of storage devises and virtualization capabilities.

Processor advances are significant because half the energy that enters the server is used for processing. Multi-core processors are two or more processors on a computer chip. These processors run more slowly and can share some components, thereby, reduce the energy use. New advances in low voltage multi-core processors—targeted to the volume server market—are estimating savings ranging from 40% to 60%. Further, dynamic frequency and voltage scaling allows processors to ramp up or down (often automatically) to adjust to the computing demands. At times of low utilization the processor can ramp down reducing its energy use and the amount of heat that it generates.[1]

Virtualization, which is a software application that allows the consolidation of multiple work loads onto a single, physical system, is another important industry trend putting downward pressure on future energy use. On average, servers typically run at 5-15% utilization rates. Even at such low utilization rates servers still draw between 60% and 90% of their peak power. Virtualization increases a server's utilization and eliminates the need for a number of physical servers. While the replacement server is often more powerful (Intel, 2007) and it is running at a higher utilization rate, the net savings from reducing the total number of servers significantly reduces overall energy usage.[2] In addition to reducing the number servers required for a work load, it also reduces the floor space, cooling, and capital costs needed in the data center (Green Grid Guidelines).

3.4 Energy Growth Forecast

The most recent forecasts of energy use all predict a substantial increase in server and data center energy use over the next three to four years. Koomey (2007) estimates that if industry forecasts hold true that the installed base in volume servers will increase by 50% from 2005 to 2010. If average power use per unit continues to go up (as it did between 2000 and 2005) total electricity used by servers by 2010 would be 76% higher than it was in 2005. His forecast takes into account the effects of several trends such as the increase in blade servers (which increase energy use) and virtualization (which reduces the number of servers used). He also estimates that if power per server remains constant, server electricity use (worldwide) would increase about 40% from 2005 to 2010.

EPA offers two scenarios, called "business-as-usual" (BAU) and "current trend", in forecasting future electricity usage by the nation's servers and data centers. The BAU scenario extrapolates the 2000-2005 growth trends through to 2011. In the current trends scenario they make assumptions about the adoption of trends in the market

[1] The source of this information is the EPA Draft Report to Congress. Please do not cite or distribute at this time.

[2] The source of this information is the EPA Draft Report to Congress. Please do not cite or distribute at this time.

(virtualization, % of energy efficient servers, power management enabled and reduction of energy for storage).[3]

Table 3 provides an overview of these three scenarios.

Table 3: Data Center & Server Energy Growth Scenarios		
Scenario	**Assumptions**	**Energy Trend**
EPA – Business as Usual	No gain in efficiency from 2006 to 2011	Increase - Electricity use doubles (119 billion kWh for **data centers and servers** combined, or 2.8% of total U.S. electricity use) from 2006 to 2011
EPA (Current Trends)	Efficiency gains and electric use increases more slowly	Increase - Electricity use for **data centers and servers** increases by 75%, to 103 billion kWh or 2.4% of total U.S. electricity use, from 2006 to 2011
Johnathan Koomey	Average power use per server continues as it did between 2000 and 2005. Increased use of blade servers and virtualization.	Increase - 76% higher **server** electric use nationwide from 2005 to 2010

3.5 Program Environment

3.5.1 Efficiency Program Activity

CEE convened a data center and server exploration committee, which currently consists of 17 members. There are a few energy efficiency programs getting underway. In November of 2006, PG&E launched the first energy efficiency program targeted at increasing energy efficiency in data centers. Over the last eight months, PG&E has evolved its High Tech program to include a broad array of energy efficiency opportunities in data centers. Austin Energy is also expected to launch its data centers program in the fall of 2007. The program will evolve over time. Other CEE members have also expressed interest in launching programs.

3.5.2 Federal Activity

3.5.2.1 EPA

Congress passed Public Law 109-431 directing the EPA to study the energy use of data centers, the equipment inside them and opportunities for energy efficiency. The report is to be presented to congress in June of 2007. CEE has closely monitored their research effort and activities to inform the development of this initiative.

[3] The source of this information is the EPA Draft Report to Congress. Please do not cite or distribute at this time.

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

3.5.2.2 ENERGY STAR

Server Specification: EPA plans to move forward with a two-tiered data center server specification. The Tier 1 specification is expected to be some version of 80Plus[4], which will focus solely on the efficiency of the server "in-box" power supply and not the whole-server energy performance. This Tier 1 work is expected to be completed in 2007. EPA will ask manufacturers to submit additional information when they submit product information to qualify for Tier 1.

For Tier 2, EPA is awaiting the ongoing work of Standard Performance Evaluation Corporation (SPEC), a non-profit corporation formed by the IT industry to establish, maintain and endorse a standardized set of relevant benchmarks that can be applied to high-performance computers. SPEC has formed a Power and Performance committee to develop the test procedures and metrics for evaluating whole-server power performance (SPEC's work is further outlined in Section 3.7). Once these test procedures are established and SPEC collects power performance data from server manufacturers, EPA will utilize this information along with the data collected from manufacturers by Energy Star to develop its Tier 2, whole-server specification.

Developing Data Centers Performance Metric to Enable Benchmarking: Designers and operators have historically used a kilo-Watt per square foot (kW/sq.ft.) metric as a way to assess the energy use of a data center. Some designers and operators have moved to using the metric of Watts per server rack (W/rack). In order to understand actual data center energy performance and facilitate comparisons, it is important to have a consistent metric (LBNL HPDC).

Energy Star, Green Grid and the Uptime Institute have been working together to develop a consistent data center energy performance metric. They will then use this metric as the basis for establishing a data center benchmarking category in their Portfolio Manager benchmarking tool. The benchmarking metric is expected to be completed during 2007 (Conversation with Andrew Fanara, EPA).

3.5.2.3 DOE's "Save Energy Now" – Industrial Technologies Program

DOE's "Save Energy Now" program[5] will be expanded to address data centers. The data center campaign was launched earlier this year to foster work with data center owners and operators to benchmark energy use and identify opportunities for reducing energy demand through the adoption of energy-efficient practices.

This Program will:

---

[4] 80 PLUS is a program designed to integrate more energy-efficient power supplies into desktop computers and servers. The 80 PLUS performance specification requires power supplies in computers and servers to be 80% or greater energy efficient at 20%, 50% and 100% of rated load with a true power factor of 0.9 or greater.

[5] The "Save Energy Now" initiative is part of a national campaign, "Easy Ways to Save Energy," announced by DOE in 2005. The campaign is part of the Industrial Technologies Program and up until now has focused on industrial process systems.

- Conduct data center assessments. Twelve pilot assessments will be conducted this summer and the full assessment campaign will be launched in the fall;
- Develop data center operator training;
- Develop curriculum and a certification process;
- Disseminate information on energy saving opportunities & best practices;
- Train data center designers;
- Develop software tools (profiles & analyze energy use).

DOE will align with ENERGY STAR and will incorporate the ENERGY STAR benchmark and specification when complete.

3.5.2.4 U.S. Congress

Congress may take action in response to recommendations proposed by EPA in its "Report to Congress on Server and Data Center and Energy Efficiency" to be submitted in June of 2007.

3.5.3 Industry Activity

3.5.3.1 ASHRAE

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Technical committee 9.9 (Mission Critical Facilities, Technology Spaces, and Electronic Equipment) has published guidance on the following topics related to data centers:

- **Thermal Guidelines for Data Processing Environments** – Provides temperature and humidity guidance for data centers. The IT manufacturers were reportedly well represented on the ASHRAE Committee TC 9.9, resulting in the acceptance of related environmental classes and specifications. (Beaty, 2006)
- **Airflow Protocols for Servers –** Provides guidance on airflow exhaust so that a server's exhaust is not being taken in by another piece of equipment.
- **Power Trend Charts** – Addresses the mismatch of HVAC and IT equipment due to different lifetimes and helps data center operators/designers predict future IT requirements. (ASE)

3.5.3.2 Standard Performance Evaluation Corporation (SPEC)

SPEC is a world-wide non-profit consortium formed to establish, maintain and endorse a standardized set of relevant benchmarks that can be applied to high-performance computers. They also reviews and publishes submitted results from their member organizations. Early indications are that SPEC is endorsed by the IT industry and considered a neutral resource for application and hardware performance information.

SPEC has taken on two relevant efforts, including:

- "**SPECpower" Benchmark** – The SPEC Power and Performance committee has begun development of a first generation SPEC benchmark for evaluating the energy performance for server-class computers. The SPECpower benchmark goal is to provide a means to fairly and consistently report system energy use under various usage levels. Their initial developments are targeted at small to medium-sized servers, which roughly accounts for between 50-80% of the current server market.[6] The SPECpower benchmark will be BETA tested in June of this year and the final benchmark will be completed by year's end.

- **Virtualization Spec** — SPEC has formed a new working group to develop standard methods of comparing virtualization performance for data center servers. The group is investigating the use of heterogeneous workloads that are spread across multiple virtual machines on a single server, and the methods and metrics used by the benchmark will be defined as part of the working group's efforts.

3.5.3.3 Green Grid

Green Grid is a recently-organized, member-based consortium of information technology companies and professionals. They reportedly seek to lower the overall consumption of power and improve performance in data centers by developing neutral standards, measurement methods, processes and new technology. Members include Intel, AMD, Dell, Microsoft, HP, IBM and VMWare.

Green Grid has developed a set of "Guidelines for Energy-Efficient Datacenters" and has begun work with EPA to develop a metric to evaluate energy performance in data centers. They expect to complete this work in 2007.

4 Initiative Purpose

4.1 Objectives & Role

As described in the previous section, data centers are technically complex since they can be whole buildings or an integrated set of systems within a building. Energy solutions span across technologies, including computer equipment and data center infrastructure like HVAC and power distribution systems, as well as design and operational improvements. Understanding the inter-relationship between these systems and various energy solutions is important to help maximize energy savings over time.

Servers also vary significantly in their energy performance by type, application and work load (see Table 2). According to both industry and LBNL sources, it is difficult to measure and characterize whole-server energy performance.

Therefore, providing well-informed and leveraged energy efficiency solutions is a challenge. To better help members address energy savings opportunities in data centers and servers, the CEE Initiative objectives include:

- Facilitating our industry's collective understanding of the market players and industry motivations;

[6] Conversations with SPEC Power and Performance Committee Chairperson, 2007.

- Development and support of consensus-based definitions and performance specifications;
- Identifying recommended program strategies to help increase the energy efficiency of data centers and servers over and above that of the industry itself.

CEE's role to accomplish these objectives will be to:

- Facilitate collective member understanding of the energy efficiency opportunities in data centers and servers;
- Serve as a clearinghouse for relevant resources and information. Identify, clarify and help to validate energy efficiency opportunities through central collection of case studies;
- Exchange information on member program efforts as well as actions by industry and government;
- Collect and synthesize resources and information to help members along the learning curve;
- Obtain a better understanding of the industry and keep current on trends and rapid developments;
- Reach out to industry stakeholders to help inform members of partnership and educational opportunities, where relevant and desired;
- Mobilize the efficiency program community to respond to industry and government proposals.

4.2 Scope of Savings Opportunities

The exploratory committee created a broad initial scope for this work area, including: (1) existing and new data centers; (2) the broad range of data center types and sizes (see Table 1); and (3) the key IT systems and building support systems (e.g., HVAC, power supplies, etc.) Table 4 provides an overview of the exploratory committee's initial opportunity characterization in this work area (this information does not detail all identified opportunities or potential opportunity areas).

Table 4: Initial Data Center Opportunity Characterization

Work Area	General Description of Opportunity	Average Energy Use in Data Center	Benefit and/or Savings Potential
Data Center - Measure Data Center Energy Performance	Benchmarking and baselining data center energy performance. Use DC energy performance metric to measure the energy intensity of the DC and benchmark (a metric is currently under development)	N/A	Enables benchmarking and comparing data center energy use against similar space types. Results can be used to help screen candidates for energy savings opportunities, make business case to CEO and facilitate longer-term customer engagement and program buy-in
Data Center - Enhance O&M Practices	Encourage better O&M practices through training for facility/IT staff and organization of O&M Guidelines for Energy-Efficiency Data Centers	N/A	Estimates that most organizations can achieve at least a 10 percent power reduction without impacting IT performance, and without any significant new spending required to realize the savings (Brill)

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

Table 4: Initial Data Center Opportunity Characterization			
Work Area	**General Description of Opportunity**	**Average Energy Use in Data Center**	**Benefit and/or Savings Potential**
	(e.g., inform better HVAC for cooling, including wider range of temp controls)		
Data Center – Improve Power Distribution Efficiency (including transformers and uninterruptible power supplies (UPS))	Opportunities to help minimize AC/DC conversions and wiring, improve efficiency of uninterruptible power supply (UPS), and evaluate onsite power generation opportunities	ASE reports that distribution system, including transformers, AC/DC inverters, wiring and UPS system, represents 11% of DC consumption (ASE pg 6)	Potential to improve UPS efficiency and eliminate power conversions (AC to DC) to improve distribution efficiency
Improve Support System Efficiency (e.g., HVAC)	Increase cooling efficiency via liquid cooling. Potential utilization of air-side & water-side economizers, premium efficiency motors and VFDs	HVAC can represent about 25-35% of energy use in data center	While liquid cooling can be up to 30% more efficient than air cooling there is some controversy over its application
Server (Hardware)	The server "box". Computing operations including processors, memory, and in-box power supplies	Can make up about 51% of typical DC energy use (ASE, pg 6)	Within small to medium (volume) servers, efficiency can range significantly
Server (Software)	Virtualization software can enable server consolidation and energy savings by increasing server utilization and taking servers offline	N/A	Can enable 5 to 1 up to 30 to 1 server consolidation ratios

To identify how CEE could best focus its initial work and initiative efforts, the exploratory committee used the following, general criteria to evaluate these opportunity areas:

- The percent of energy consumed by data center equipment and system end uses;
- The significance of the potential energy savings and geographical distribution of those savings (i.e., national, regional);
- Activities underway that could be leveraged (e.g., ongoing industry and EPA ongoing activities to develop test procedures and specify energy efficient servers);
- The ability for the savings to be compounded (can savings in this area offset other system energy use).

Based on these criteria, the opportunity that stood out most to the exploratory committee was reducing the server load. Therefore, the exploratory committee chose to focus on servers as its top priority (1. computer hardware and 2. computer software). Servers and their infrastructure represent the largest energy consumers in the data center, on average accounting for 50% or more of the energy use.

Early, conservative estimates[7] are that volume server hardware performance efficiency can range significantly (about 25%). Virtualization software can also enable server consolidation and can result in significant energy savings. Improving server energy performance and maximizing their utilization will also compound energy savings by reducing heat gain in the data center (thereby reducing cooling load) and mitigating energy distribution line and power conversion (AC to DC) losses.

CEE has not identified any U.S. industry-accepted and agreed-upon test procedures to measure whole-server energy performance or the performance of virtualization software. The energy savings potential for server performance and virtualization performance depends on the type of server, the application(s) and the workload. VMWare, a virtualization software provider, has seen server consolidation increase server utilization rates from 5-15% to 60% to 80% (VMware Virtualization Overview White Paper). Brill (2007), of the Uptime Institute, reports that the average server change-out ratio is 10 to 1. Pacific Gas and Electric (PG&E) has seen consolidation rations of 5 to 1 for larger data centers and 20 to 1 for smaller centers (Conversation with M. Bramfitt, PG&E, 2007). Server companies like HP have begun to make virtualization-friendly features such as greater memory and specialized management software to help facilitate the virtualization process (Wall Street Journal, 2007).

As mentioned in Section 3.7.2, SPEC has begun initial work to develop test procedures for measuring whole-server energy performance for small- to medium-sized servers (these procedures would be relevant to approximately 50-80% of the server market). In addition, SPEC is also developing standard methods of comparing virtualization performance for data center servers. SPEC intends to complete its server power performance benchmarking work by the end of 2007. It is unclear at this time the timing of SPEC's virtualization benchmarking work.

4.3 Initial Activities

This section outlines the initial activities for the Data Center and Servers Committee. Table 5 provides a general timeline of relevant events and important milestones.

4.3.1 Build the Committee's Knowledge Base & Understanding

To stay relevant in this fast-paced and complex market and to fully leverage the numerous activities underway, initial activities will build the CEE Data Center and Servers Committee knowledge and sophistication about the IT industry and data center and server energy efficiency opportunities.

These activities will include:

- Continuing the exploratory committee's work to define and further characterize data centers and servers;

[7] Measuring server performance is difficult, as server energy consumption varies significantly depending on server type, application and workload. SPEC is currently developing energy performance test protocols and procedures for small- to medium-sized servers.

- Establishing an information clearinghouse for relevant research, publications, documented energy efficiency opportunities and case studies, and enhanced management practices. For example, LBNL, DOE, The Green Grid and the Uptime Institute have developed or are working on "best practices" for data center operations or other efficiency improvements. The Committee will continue identify these resources, develop and/or enhance guidelines and materials for use by energy efficiency programs to send credible and consistent messages to customers;
- Using the committee as a forum to bolster knowledge of identified technologies and business practices, such as virtualization, using both outside and internal expertise.

4.3.2 Support the Energy Efficiency Program Community in ENERGY STAR and Industry Processes

In this area, the exploratory committee has reached out to representatives at SPEC (the chair of their Power and Performance Committee) and ENERGY STAR regarding their respective data center and server benchmarking work. The Data Center and Servers Committee will continue to monitor their progress, inform members of this progress and important milestones.

Where applicable, CEE will work with ENERGY STAR representatives to monitor and comment on the development process of an energy performance metric for measuring data center performance (that forms the basis for data center benchmarking). The SPEC server benchmarking work will help the committee understand the range of efficiencies across servers; however, the data submission and evaluation process to identify what server energy performance level is efficient will still need to be done. EPA expects to take on this effort once the SPEC benchmark development is complete (scheduled for the end of 2007). Therefore, it is likely to take more than one year before ENERGY STAR completes their whole-server (Tier 2) specification.

In the interim, the committee will work with ENERGY STAR and SPEC to remain updated on their progress. Where relevant and appropriate, the committee will provide feedback and participate in the data center and server energy performance metric development processes.

4.3.3 Specification Development & Application Guidance

As the industry completes initial data center and server benchmarks and performance evaluation procedures, the CEE Data Centers and Servers committee can assess the timeliness and value of CEE energy efficiency specification levels for server hardware and/or software (virtualization) performance. In addition, the committee will develop program application guidance.

Table 6 provides an initial ranking by the exploratory committee of the top 6 data center and server work area opportunities. This table is a summary of the work areas, current initiatives and guidance available in each area, and potential CEE roles. Table 7 summarizes other significant work areas identified by the exploratory committee but that have not been prioritized for initial focus. The Committee will continue to evolve and evaluate this initial prioritization.

4.3.4 Outreach to Relevant Markets

The committee will communicate program activities, priorities, goals, and needs to the data centers and servers industry as appropriate. Opening the communication lines with industry is valuable in itself, and a positive and cooperative relationship with industry can help promote market transformation. Such a relationship is mutually beneficial, as well, as it allows industry to learn what CEE members' value and how they can profit from participating in the CEE forum and working with members.

Table 5: Timeline of Important Events & Milestones													
Work Area	**6/07**	**7/07**	**8/07**	**9/07**	**10/07**	**11/07**	**12/07**	**1/08**	**2/08**	**3/08**	**4/08**	**5/08**	**6/08**
Relevant to All Work Areas	EPA to release its Report to Congress			CEE industry partners meeting, 9/25 & 9/26 (data center track)									
Server (Hardware)	SPEC plans to beta-testing server performance benchmark						SPEC plans to complete server performance benchmark	Manufacturer Data submissions begin and ENERGY STAR begins whole-server specification development					
Server (Software)													
Data Center - Measure Data Center Energy Performance				ENERGY STAR data center benchmarking tool release planned									
Data Center - Enhance O&M Practices													
Data Center - Power Distribution													
Improve Support Systems Efficiencies													

Table 6: 2007 CEE Data Center & Server Initiative Focus				
Initial Priority	**Work Area**	**Description**	**Current Initiatives, Guidance & Activities**	**Potential CEE Role(s)**
1	**Server (Hardware)** Computing operations including processors, memory, and in-box power supplies. Servers make up about **51%** of typical DC energy load (ASE, pg 6)	**Promote high efficiency server equipment** - There is currently no established and agreed-upon metric to measure the efficiency of a server	***SPEC*** is in the process of developing "Specpower" that will be an industry benchmark for evaluating the energy efficiency for small to medium-sized server class computers under various usage levels. May be completed at the end of this year. ***Energy Star*** expects to piggy-back off of the Specpower work once complete. This year ES plans to develop a Tier 1 spec that covers the in-box power supply based on some variation of the 80+ criteria and collect other data from manufacturers. This data and the Specpower benchmark will be assessed to determine a full server Tier 2 spec.	1) Inform committee of industry and ENERGY STAR progress 2) Identify committee opportunities to provide feedback to ES and SPEC on their benchmarking work. 3) Work with the SPEC to understand the specification development process, advocate that the spec meet member needs and for quick completion. 4) Work towards development of CEE server specification.
2	**Server (Software)**	**Server consolidation--virtualization** for direct energy savings achieved by increasing the server utilization and taking servers offline (5 to 1 -- 30 to 1 consolidation ratios). Annual energy savings per server removed range from 1,875 kWh to 3,750 kWh (PG&E) not including energy savings associated with AC.	***PG&E*** provides incentives based on the annual kilowatt-hour savings that will accrue from removing equipment via a virtualization project. The incentive is 8 cents per kilowatt-hour solely based on the energy savings directly related to removing the computing equipment (i.e., not for the energy savings that will accrue from the reduced heat load in a data center environment). Incentives can range from $150 to $300 per server removed through a virtualization project and are capped at 50% of the total project cost ***SPEC*** is developing a standard method of comparing virtualization performance for data center servers. Unsure when it will be completed.	1) Develop a customer guide (set of questions/decision tree) on how to get the most energy efficiency from virtualization. 2) Develop guide to determine "Are you a good candidate for virtualization?" 3) Work with software companies to develop a general information piece on virtualization and the potential energy savings. 4) Help train members on virtualization software and its applications.
3	**Data Center - Measure Data Center Energy Performance**	**Benchmarking and baselining**. Use DC energy metric to measure the energy intensity of the DC (the metric is currently under development). Results can be used to help make business case to CEO.	***Energy Star***, ***Green Grid*** and ***Uptime Institute*** are working jointly to develop a benchmark category and energy metric (Andrew Fanara) ***LBNL*** has a "Self benchmark for energy performance"	1) Use committee forum to provide feedback to ENERGY STAR.

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

Table 6: 2007 CEE Data Center & Server Initiative Focus				
Initial Priority	**Work Area**	**Description**	**Current Initiatives, Guidance & Activities**	**Potential CEE Role(s)**
4	**Data Center - Enhance O&M Practices**	**Guidance development and training for facility/IT** staff on more energy-efficiency operations and maintenance practices in data centers **Determine if and what type of incentives** may encourage the implementation of key components	***DOE***--conducting DC assessments and developing "DC best practices" ***Green Grid*** --developing guidelines for energy efficiency DCs ***LBNL***-- produced the report "Measuring and Managing DC Energy Use Findings--resulting best practices from a study of energy use in 22 data centers" ***Uptime Institute--***is promoting a variety of practices to increase DC efficiency (e.g. enabling power saving features)	1) Develop understanding of current data center O&M practices across different types of data centers 2) Work with key groups to identify and/or develop an accepted set of O&M practices that programs can leverage and incorporate
5	**Data Center - Power Distribution** (including transformers, UPS, AC/DC conversions and wiring can represent **11%** of DC consumption) (ASE pg 6)	**AC/DC conversion** -- alternatives include DC power distribution equip or more efficient AC equip. **Increasing efficiency of power distribution systems within data centers, including uninterruptible power supplies (UPS) -** UPS systems provide back-up power (using batteries or flywheels) for servers in the event of a power outage. A typical UPS system is about 90% efficient with 95 and greater efficiencies available (ASE).	***AC/DC Conversion--LBNL*** conducted a study in Jan. 07 where they suggest that DC delivery systems are viable. Expect to work with customer/industry to BETA DC technology this year--URL process for equipment will take another year. 2009 is the earliest to have product in the market. ***LBNL*** did a review and analysis in this area in late 2005. LBNL proposed that EPA develop a UPS spec. ***PG&E*** estimates that if UPS systems had an efficiency improvement of 5% it would save 384,000 kWh a year and ($38,000 in electric bill savings at $0.10 a kWh) plus addition savings from reducing the cooling load (PG&E).	Assess the possibilities for improving power distribution systems, including, if appropriate UPS spec development. Work with industry and LBNL to develop test method and spec.
6	**Improve Support System Efficiencies**	**HVAC:** **(1) Improved HVAC sizing** **(2) Promoting better HVAC operating practices and training**: Train facility/IT and designers on HVAC "best practices" for cooling in DCs including wider range of humidity and temp controls. **(3) Liquid cooling**--while liquid cooling can be up to 30% more efficient than air cooling there is some controversy over its	***HVAC:*** **Best Practices**--LBNL, Green Grid and ASHRAE Humidity & Temp Control--ASHRAE has published guidelines for properly calculating temp and humid in DC (TC 9.9) **Air-side and Water-side Economizers**--PG&E is providing incentives to use this technology. **CH&P** --EPA conducted an analysis in its report to congress that identified potential cost savings and benefits to the energy	1) Identify and assess the range and magnitude of use of different HVAC system types across data centers 2) Identify, categorize and prioritize respective technological opportunities with respect to potential energy savings and current industry uptake 3) Weigh appropriateness of relevant technologies as a

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

Table 6: 2007 CEE Data Center & Server Initiative Focus				
Initial Priority	**Work Area**	**Description**	**Current Initiatives, Guidance & Activities**	**Potential CEE Role(s)**
		application. **(4) Combined heat & power (CHP) -** provide technical assistance and determine if incentives are necessary to facilitate uptake of this technology. **(5) Premium efficiency motors, VFDs, air & water side economizers, etc**. **Other:** **(1) Data storage system improvements -** Data storage consolidation through virtualization and Massive Array of Idle Disks (MAID), which allows long-term data storage to be taken off spinning disks and powered down.	supply chain through the use of distributed generation (CH&P) ***Other:*** **PG&E** has developed program elements and customer incentives for virtual storage consolidation, MAID and other virtualization applications and is providing incentives for customer adoption.	program component.

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

The following matrix lists out Initiative considerations for work beyond initial phase activities.

Table 7: CEE Data Center & Server Initiative Considerations for Future Work			
Work Area	**Description**	**Current Initiatives, Guidance & Activities**	**Potential CEE Role(s)**
New Construction	**DC Design Practices:** **- Training for design professionals** **- Technical assistance** for owner/design professional **- Incentives** for owner to incorporate key efficiency design practices/technology **Data Center Commissioning:** **- Technical and/or financial assistance** for DC commissioning services	***DC Design Practices:*** ***- LBNL***--The High Performance DC Design Guide Resource Handbook, 2006 - ***ASHRAE***-- has developed "Design Considerations for Data and Communications Equipment Centers" **Data Center Commissioning**: No consensus commissioning process specifically for data centers currently exists (info from PECI)	1) Monitor developing design/commissioning opportunities; disseminate information on DC design/comm practices to members; Coordinate feedback from CEE members to other CEE members and national organizations 2) Work with EPA to develop a data center commissioning process guide--should be consistent with O&M and HVAC guidelines below.
Data Center Retro-Commissioning	**Technical/financial educational opportunities and/or training**		Work with EPA to develop a data center retro-commissioning process guide-should be consistent with O&M and HVAC guides
Facilitating IT/Facilities Communication & Training	**Support/facilitate educational opportunities and/or training**	***Green Grid and Uptime Institute*** advocate the alignment of staff through the development of an IT Facilities Group that acts as liaison between IT & facilities group building group but is under the direction/control of IT. ***DOE's "Save Energy Now"*** will develop operator training, curriculum and certification process and software tools (profiles and analyze energy use).	Work with EPA to develop procurement guide for IT/facility managers

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

5 Participation Requirements

These requirements will be determined along with the Board's adoption of specific Initiative components.

CONSORTIUM FOR ENERGY EFFICIENCY
98 North Washington, Suite 101 Boston, MA 02114-1918 617-589-3949 www.cee1.org

References

Beaty, D. July 26, 2006. Searchdatacenter.com, Using ASHRAE specs for data center metrics.

Bramfitt, Mark. 2007. Personal Communication. PG&E.

Brill, Kenneth G. 2007. High-Density Computing: The Path Forward 2006. The Uptime Institute, March

Carlton, Jim. 2007. *Computer Rooms Feel the Heat; IT Managers Find Novel Ways to Cool Powerful Servers.* Wall Street Journal**.** (Eastern Edition). New York, N.Y. April 10.

Greenberg, S. et al. 2006. *Best Practices for Data Centers: Lessons Learned from Benchmarking 22 Data Centers.* ACEEE Summer Study on Energy Efficiency in Buildings."
http://eetd.lbl.gov/emills/PUBS/PDF/ACEEE-datacenters.pdf

IBM. 2007. IBM Brings Nature to Computer Chip Manufacturing. May 3.

IBM. 2007. *IBM Unveils Plan to Combat Data Center Energy Crisis; Allocates $1 Billion to Advance "Green" Technology and Services.* May 10.

Koomey, Jonathan G. 2007. *Estimating Total Power Consumption of Servers in the U.S. and the World.* February 15.

Lawton, Christopher, and Don Clark. 2007. *Virtualization' Is Pumping Up Servers.* The Wall Street Journal. March 6.

Loper, Joe, and Sara Parr.2007. *Energy Efficiency in Data Centers: A New Policy Frontier. Washington, DC: Alliance to Save Energy.* January.

PG&E. 2006. High Performance Data Center: A Design Guidelines Source Book. January.
http://hightech.lbl.gov/documents/DATA_CENTERS/06_DataCenters

Smoot, Rob. 2007. *Virtualization: Best Initiative for Alleviating the Power Crisis in the Data Center.* VMWare. (Presentation)

Sullivan, Bob. 2007. Personal communication. LBNL

The Green Grid. 2007. Guidelines for Energy-Efficient Datacenters. February 16.

The Green Grid. 2007. *The Green Grid Opportunity: Decreasing Datacenter and other IT Energy Usage Patterns.* February 16.

Tschudi, William, Evan Mills, Steve Greenberg and Peter Rumsy. Measuring and Managing Data Center Energy Use-Finding and Resulting Best Practices from a Study of Energy Use in 22 Data Centers. Lawrence Berkeley National Laboratory.
http://hightech.lbl.gov/Documents/DATA_CENTERS/HPAC_DC_BestPrac.pdf

Tschudi, William, Tengfang Xu, Dale Sartor, and Jay Stein. 2003. *High Performance Data Centers: A Research Roadmap.* Berkeley, CA: Lawrence Berkeley National Laboratory.

U. S Environmental Protection Agency, Energy Star Program. 2007. *Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431.* April 23. Review Draft –Do Not Cite or Quote.

VMware. *Virtualization Overview White Paper.*

Wigle, Lori. 2007, *Personal Communication.* Intel

Wikipedia. 2007. www.wikipedia.org/