EPA Report to Congress on Server and Data Center Energy Efficiency

Executive Summary

The United States (U.S.) Environmental Protection Agency (EPA) developed this report in response to the request from Congress stated in Public Law 109-431. This report assesses current trends in energy use and energy costs of data centers and servers in the U.S. and outlines existing and emerging opportunities for improved energy efficiency. It provides particular information on the costs of data centers and servers to the federal government and opportunities for reducing those costs through improved efficiency. It also makes recommendations for pursuing these energy-efficiency opportunities broadly across the country through the use of information and incentive-based programs.

Background

As our economy shifts from paper-based to digital information management, data centers — facilities that primarily contain electronic equipment used for data processing, data storage, and communications networking — have become common and essential to the functioning of business, communications, academic, and governmental systems. Data centers are found in nearly every sector of the economy: financial services, media, high-tech, universities, government institutions, and many others use and operate data centers to aid business processes, information management, and communications functions.

The U.S. data center industry is in the midst of a major growth period stimulated by increasing demand for data processing and storage. This demand is driven by several factors, including but not limited to:

- the increased use of electronic transactions in financial services, such as on-line banking and electronic trading,
- the growing use of internet communication and entertainment,
- the shift to electronic medical records for healthcare,
- the growth in global commerce and services, and
- the adoption of satellite navigation and electronic shipment tracking in transportation.

Other important trends contributing to data center growth in the government sector include:

- use of the internet to publish government information,
- government regulations requiring digital records retention,
- enhanced disaster recovery requirements,
- emergency, health and safety services,
- information security and national security,
- digital provision of government services (e.g., e-filing of taxes and USPS on-line tracking), and
- high performance scientific computing.

Public Law 109-431

SECTION 1. STUDY.

Not later than 180 days after the date of enactment of this Act, the Administrator of the Environmental Protection Agency, through the Energy Star program, shall transmit to the Congress the results of a study analyzing the rapid growth and energy consumption of computer data centers by the Federal Government and private enterprise. The study shall include--

(1) an overview of the growth trends associated with data centers and the utilization of servers in the Federal Government and private sector;

(2) analysis of the industry migration to the use of energy efficient microchips and servers designed to provide energy efficient computing and reduce the costs associated with constructing, operating, and maintaining large and medium scale data centers;

(3) analysis of the potential cost savings to the Federal Government, large institutional data center operators, private enterprise, and consumers available through the adoption of energy efficient data centers and servers;

(4) analysis of the potential cost savings and benefits to the energy supply chain through the adoption of energy efficient data centers and servers, including reduced demand, enhanced capacity, and reduced strain on existing grid infrastructure, and consideration of secondary benefits, including potential impact of related advantages associated with substantial domestic energy savings;

(5) analysis of the potential impacts of energy efficiency on product performance, including computing functionality, reliability, speed, and features, and overall cost;

(6) analysis of the potential cost savings and benefits to the energy supply chain through the use of stationary fuel cells for backup power and distributed generation;

(7) an overview of current government incentives offered for energy efficient products and services and consideration of similar incentives to encourage the adoption of energy efficient data centers and servers;

(8) recommendations regarding potential incentives and voluntary programs that could be used to advance the adoption of energy efficient data centers and computing; and

(9) a meaningful opportunity for interested stakeholders, including affected industry stakeholders and energy efficiency advocates, to provide comments, data, and other information on the scope, contents, and conclusions of the study.

SEC. 2. SENSE OF CONGRESS.

It is the sense of Congress that it is in the best interest of the U.S. for purchasers of computer servers to give high priority to energy efficiency as a factor in determining best value and performance for purchases of computer servers.

During the past five years, increasing demand for computer resources has led to significant growth in the number of data center servers, along with an estimated doubling in the energy used by these servers and the power and cooling infrastructure that supports them. This increase in energy use has a number of important implications, including:

- increased energy costs for business and government,
- increased emissions, including greenhouse gases, from electricity generation
- increased strain on the existing power grid to meet the increased electricity demand, and
- increased capital costs for expansion of data center capacity and construction of new data centers.

For these reasons, there has been mounting interest in opportunities for energy efficiency in this sector. To its credit, the information technology (IT) industry is actively investigating and developing solutions, such as power-managed servers and adaptive cooling.

The direct energy use of IT and infrastructure equipment is not, however, the only way that data centers affect energy use. The data processing and communication services provided by data centers can also lead to indirect reductions in energy use in the broader economy, which can exceed the incremental data center energy expenditures in some cases.[1] For instance, e-commerce and telecommuting can reduce both freight and passenger transportation energy use. Nonetheless, even though IT equipment may improve energy efficiency in the economy as a whole, pursuit of energy efficiency opportunities in data centers remains important because of the potential for rapid growth in direct energy use in this sector and the resulting impact on both the power grid and U.S. industries.

Role of EPA

EPA has a more than 15-year history of advancing energy efficiency in IT equipment as well as commercial buildings, beginning with the first ENERGY STAR specifications for computers established in 1992 and the Green Lights program established in 1991. Through the ENERGY STAR program, EPA now qualifies a wide array of IT products, including personal computers, imaging equipment, printers, and monitors. EPA has made particular strides in addressing standby energy and power management for these products, demonstrating that it is possible to encourage rapid development and adoption of energy-efficient technologies and practices. The energy savings from efficiency improvements in these products are currently in the billions of dollars per year (US EPA 2006). EPA has also developed an innovative commercial building rating system that helps owners and managers assess the energy performance of their buildings and target efficiency improvements.

In January 2006, EPA convened the first national conference dedicated to examining energy savings opportunities for enterprise servers and data centers. Representatives from the utility, financial services, healthcare, internet, and manufacturing sectors attended the conference (http://www.energystar.gov/datacenters). EPA is now working on the first priority identified in that conference, the development of objective measurements of server energy performance, on which future efficiency criteria would be based.

To develop this report, EPA convened a study team led by researchers from the Lawrence Berkeley National Laboratory. The study team offered stakeholders multiple opportunities to give input to and review this report, including:

- conducting preliminary calls with key stakeholders to help plan the study;
- holding a public workshop on February 16, 2007 (attended by approximately 130 people) to solicit input on the topic of energy efficiency in servers and data centers;
- following up on workshop attendees' offers of assistance, to gather and refine information for the study;

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[1] The magnitude of indirect energy reductions attributable to IT equipment is uncertain; one of this report's recommendations is that research should be conducted to better understand this effect.

- posting on the ENERGY STAR web site an open call for interested parties to submit information, as well as a list of data needs;
- posting on the ENERGY STAR web site a public review draft of this report; and
- incorporating into the final version of this report comments on the public review draft from more than 50 organizations and individuals.

Energy Use in Data Centers Through 2011

The energy used by the nation's servers and data centers is significant. It is estimated that this sector consumed about 61 billion kilowatt-hours (kWh) in 2006 (1.5 percent of total U.S. electricity consumption) for a total electricity cost of about $4.5 billion. This estimated level of electricity consumption is more than the electricity consumed by the nation's color televisions and similar to the amount of electricity consumed by approximately 5.8 million average U.S. households (or about five percent of the total U.S. housing stock). Federal servers and data centers alone account for approximately 6 billion kWh (10 percent) of this electricity use, for a total electricity cost of about $450 million annually.

The energy use of the nation's servers and data centers in 2006 is estimated to be more than double the electricity that was consumed for this purpose in 2000. One type of server, the volume server, was responsible for the majority (68 percent) of the electricity consumed by IT equipment in data centers in 2006. The energy used by this type of server more than doubled from 2000 to 2006, which was the largest increase among different types of servers. The power and cooling infrastructure that supports IT equipment in data centers also uses significant energy, accounting for 50 percent of the total consumption of data centers. Among the different types of data centers, more than one-third (38 percent) of electricity use is attributable to the nation's largest (i.e., enterprise-class) and most rapidly growing data centers.

These energy consumption estimates were derived using a bottom-up estimation method based on the best publicly available data for servers and data centers. The estimation was performed as follows:

- estimated the U.S. installed base of servers, external disk drives, and network ports in data centers each year (based on industry estimates of shipments and stock turnover);
- multiplied by an estimated annual energy consumption per server, disk drive, or network port; and
- multiplied the sum of energy use for servers, storage, and networking equipment by an overhead factor to account for the energy use of power and cooling infrastructure in data centers.

This method was also used to develop five-year projections for future energy use. A five-year time horizon was chosen for the scenarios because this is the period for which equipment shipment forecasts were available, and a period for which change in the rapidly evolving IT sector can be reasonably forecasted. Two baseline scenarios were analyzed to estimate expected energy use in the absence of expanded energy-efficiency efforts. The "current efficiency trends" scenario projected the current energy use trajectory of U.S. servers and data centers based on recently observed efficiency trends for IT equipment and site infrastructure systems. The "historical trends" scenario did not reflect these current energy efficiency trends but simply extrapolated observed 2000 to

2006 energy-use trends into the future. The historical trends scenario projected the energy use of U.S. servers and data centers if no energy-efficiency improvements were made, and therefore indicates the energy savings associated with efficiency trends that are already under way.

Under current efficiency trends, national energy consumption by servers and data centers could nearly double again in another five years (i.e., by 2011) to more than 100 billion kWh (Figure ES-1), representing a $7.4 billion annual electricity cost. The peak load on the power grid from these servers and data centers is currently estimated to be approximately 7 gigawatts (GW), equivalent to the output of about 15 baseload power plants. If current trends continue, this demand would rise to 12 GW by 2011, which would require an additional 10 power plants.

These forecasts indicate that unless energy efficiency is improved beyond current trends, the federal government's electricity cost for servers and data centers could be nearly $740 million annually by 2011, with a peak load of approximately 1.2 GW.

These estimates of data center energy use should be considered approximate because limited data are available on current data center energy use, and there is significant uncertainty about the effects of future technology trends, such as server consolidation and developments in network and storage technologies. However, these estimates and projections illustrate the magnitude of energy use in data centers and the need for effective energy-efficiency strategies. Energy consumption monitoring and reporting may be needed to both improve these estimates and inform future policy initiatives.

Energy-Efficiency Opportunities in Servers and Data Centers

There is significant potential for energy-efficiency improvements in data centers. Although some improvements in energy efficiency are expected if current trends continue, many technologies are either commercially available or will soon be available that could further improve the energy efficiency of microprocessors, servers, storage devices, network equipment, and infrastructure systems. For instance, existing technologies and design strategies have been shown to reduce the energy use of a typical server by 25 percent or more. Even with existing IT equipment, implementing best energy-management practices in existing data centers and consolidating applications from many servers to one server could reduce current data center energy usage by around 20 percent. Energy-efficiency strategies could be implemented in ways that do not compromise data center availability, performance or network security, which are essential for these strategies to be accepted by the market. To develop a better understanding of energy-efficiency opportunities that would accelerate adoption of energy-efficient technologies beyond current trends, three energy-efficiency scenarios were explored:

- The "**improved operation**" scenario includes energy-efficiency improvements beyond current trends that are essentially operational in nature and require little or no capital investment. This scenario represents the "low-hanging fruit" that can be harvested simply by operating the existing capital stock more efficiently.

- The “**best practice**” scenario represents the efficiency gains that can be obtained through the more widespread adoption of the practices and technologies used in the most energy-efficient facilities in operation today.

- The “**state-of-the-art**” scenario identifies the maximum energy-efficiency savings that could be achieved using available technologies. This scenario assumes that U.S. servers and data centers will be operated at maximum possible energy efficiency using only the most efficient technologies and best management practices available today.

Details of the key energy-efficiency assumptions used in this analysis are shown in Table ES-1. These assumptions represent only a subset of the energy-efficiency strategies that could be employed in practice; it is not a comprehensive list of all energy-efficiency opportunities available in U.S. data centers.

Table ES-1. Summary of Assumptions for Analysis of Alternative Efficiency Scenarios

	Data Center Subsystem	
Scenario	**IT Equipment**	**Site Infrastructure (Power and Cooling)**
Improved operation	• Continue current trends for server consolidation • Eliminate unused servers (e.g., legacy applications) • Adopt “energy-efficient” servers to modest level • Enable power management on 100% of applicable servers • Assume modest decline in energy use of enterprise storage equipment	30% improvement in infrastructure energy efficiency from improved airflow management
Best practice	All measures in “Improved operation” scenario, plus: • Consolidate servers to moderate extent • Aggressively adopt “energy-efficient” servers • Assume moderate storage consolidation	Up to 70% improvement in infrastructure energy efficiency from all measures in “Improved operation” scenario, plus: • improved transformers and uninterruptible power supplies • improved efficiency chillers, fans, and pumps • free cooling
State-of-the-art	All measures in “Best practice” scenario, plus: • Aggressively consolidate servers • Aggressively consolidate storage • Enable power management at data center level of applications, servers, and equipment for networking and storage	Up to 80% improvement in infrastructure energy efficiency, due to all measures in “Best practice” scenario, plus: • direct liquid cooling • combined heat and power

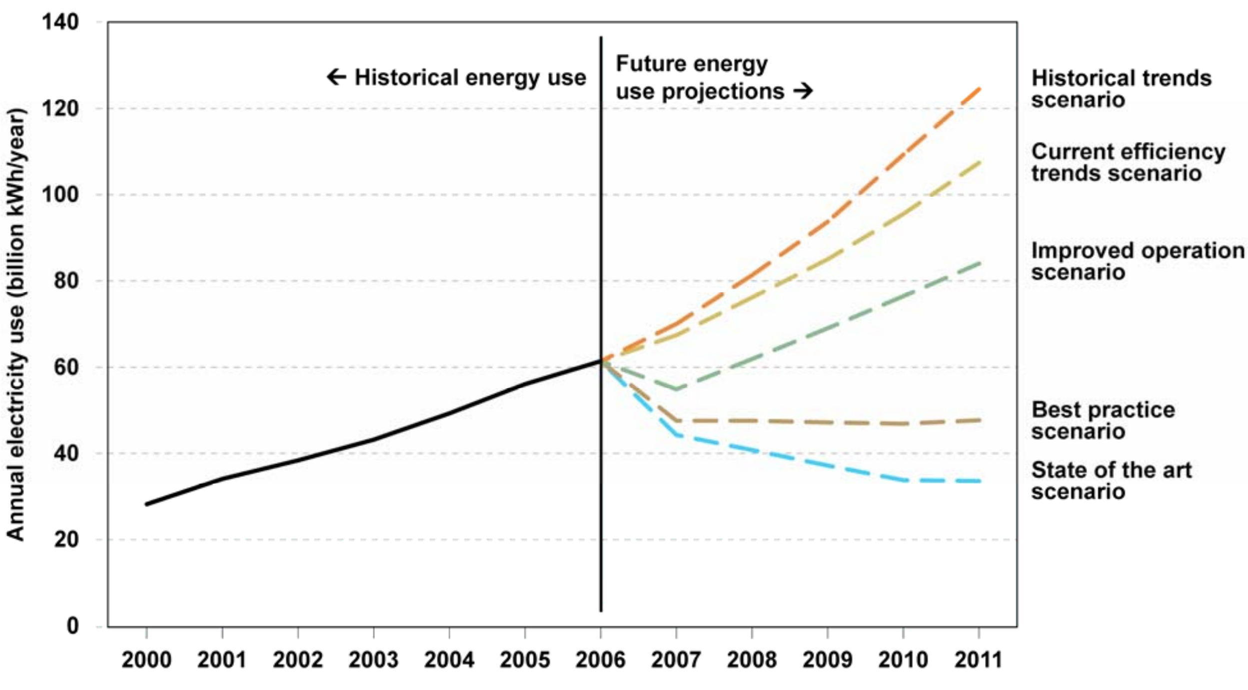
Note: These measures should be considered illustrative of efficiency opportunities in a typical data center. Some measures may only be applicable in new or expansion data centers or may be infeasible for a given data center because of local constraints. Selection of efficiency measures for a particular facility should be based on a site-specific review.

Because the best practice and state-of-the-art scenarios imply significant changes to data centers that may only be feasible to implement during major facility renovations, it was assumed in these scenarios that the site infrastructure measures requiring new capital investments would apply to only 50 percent of the current stock of data centers. For IT equipment, it was assumed that the entire existing stock turns over within the five-year forecast period.

These scenarios, based on the assumptions outlined above, illustrate significant potential for efficient technologies and practices to improve the energy efficiency of servers and data centers by 2011:

- The state-of-the-art scenario could reduce electricity use by up to 55 percent compared to current efficiency trends, representing the maximum technical potential.
- The best practice scenario could reduce electricity use by up to 45 percent compared to 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.

Figure ES-1. Comparison of Projected Electricity Use, All Scenarios, 2007 to 2011



These scenarios show annual savings in 2011 of approximately 23 to 74 billion kWh compared to current efficiency trends, which reduces the peak load from data centers by the equivalent of up to 15 new power plants and reduces annual electricity costs by $1.6 billion to $5.1 billion. The projected savings in electricity use correspond to reductions in nationwide carbon dioxide (CO_2) emissions of 15 to 47 million metric tons (MMT) in

2011. The best practice scenario shows that electricity use in servers and data centers can be reduced below its 2006 level during the next five years rather than almost doubling, which would be the result if current efficiency trends continue.

Based on the assumption that the federal sector accounts for about 10 percent of electricity use and electricity costs attributable to servers and data centers, the annual savings in electricity costs in 2011 to the federal government range from $160 million (for the improved operation scenario) to $510 million (for the state-of-the-art scenario).

Table ES-2. Annual Savings in 2011 by Scenario (Compared to Current Efficiency Trends)

Scenario	Electricity consumption savings (billion kWh)	Electricity cost savings ($billion 2005)	Carbon dioxide emissions avoided ($MMTCO_2$)
Improved operation	23	1.6	15
Best practice	60	4.1	38
State-of-the-art	74	5.1	47

These efficiency gains appear to be achievable without compromising product or data center performance. Because energy efficiency is a secondary attribute of the equipment used in data centers, changes that would compromise performance will generally not be implemented. In other words, data center designers and managers will first ensure that primary needs – performance and availability – are satisfied and will only then differentiate among products and practices based on energy efficiency. In some situations, improved energy efficiency increases performance and availability. For instance, better cooling distribution in data centers can eliminate hotspots and thereby prevent equipment faults. Finally, it is important to note that the energy-efficiency improvements addressed in this report reduce the costs of excess energy use and excessive power and cooling infrastructure.

The analysis in this report includes consideration of use of fuel cells and other distributed generation (DG) technologies in data centers. DG resources can reduce data center energy costs, particularly when used in combined heat and power (CHP) systems, which use waste heat to provide cooling. CHP systems can produce attractive paybacks and are well suited to the steady power and cooling loads of data centers. Clean DG also has the environmental benefits of reduced criteria pollutants and greenhouse gas emissions. Fuel cell DG systems offer many attractive qualities, such as DC power output, for use in data centers. But fuel cells, as a new-market entrant, have a premium price over more traditional DG systems. So while DG systems based on traditional gas turbine or engine technologies can be considered cost effective without incentives, fuel cells, in many cases, will need financial incentives to be cost effective. Finally, DG systems, particularly fuel cells, do not have a long track record in high power quality, high availability applications such as data centers Given the high cost of outages for these types of facilities, more demonstration and conclusive information about system availability are needed before most facility designers and operators would likely be willing to adopt DG and CHP technologies.

Incentives and Voluntary Programs to Promote Energy Efficiency

To realize the potential benefits from greater energy efficiency in the nation's data centers, a number of market barriers need to be addressed. The adoption of energy-efficient technologies and practices is often impeded by barriers such as higher first cost, lack of knowledge, institutional failures, and perverse incentives, and these issues apply equally to data centers. The barriers that prevent data centers from adopting changes that offer very reasonable paybacks are typically not technological but organizational. Three barriers of particular importance in data centers are:

- *Lack of efficiency definitions*: It is difficult to define energy efficiency for a complex system such as a data center or a server. "Energy efficient" is usually defined based on the delivery of the same or better service output with less energy input, but for servers and data centers service output is difficult to measure and varies among applications. Data center operators need standard definitions of productivity in order to purchase energy-efficient equipment, operate it in an optimal way, and design and operate the buildings to house it.

- *Split incentives*: In many data centers, those responsible for purchasing and operating the IT equipment are not the same people that are responsible for the power and cooling infrastructure, who in turn typically pay the utility bills. This leads to a split incentive, in which those who are most able to control the energy use of the IT equipment (and therefore the data center) have little incentive to do so.

- *Risk aversion*: With the increasing importance of digital information, data centers are critical to businesses and government operations. Thus, data center operators are particularly averse to making changes that might increase the risk of down time. Energy efficiency is perceived as a change that, although attractive in principle, is of uncertain value and therefore may not be worth the risk.

These barriers are not unique to data centers but may be more pronounced in this sector. There is a long history of incentive and informational programs to address barriers like these in other sectors – e.g., government agencies, public and private utilities. Although there are few current programs that specifically target data centers, existing energy policies and programs that promote high efficiency buildings and equipment – such as product labeling programs, commercial building technical assistance programs, financial incentives, and government procurement – may be applicable to data centers. These programs include:

- *Product labeling*: Labels identify products that meet certain specifications for performance, including high energy performance, based on standard methods for measuring energy efficiency. These labels can make customers aware of the energy costs associated with their purchasing decisions and encourage consumer acceptance and recognition of high-efficiency products. The performance specifications that underlie the labels form clear purchasing guidelines. This in turn encourages manufacturers to make increasing numbers of efficient products.

- *Commercial building technical assistance*: The growth of data centers is a relatively recent phenomenon, so best practices for design and operation are only recently being developed. Technical assistance programs provide information to facility designers and operators to help them effectively incorporate energy efficiency in the design and operation phases for their facilities. Newer practices in this area include establishment of whole-building energy performance benchmarking. Technical assistance can be provided by government agencies, electric utilities, professional organizations, and industry groups.

- *Financial incentives*: Electric utilities and governments often offer financial incentives to encourage investments in energy-efficiency measures. Financial incentives help buy down the additional cost of more efficient products when initial product costs are higher than for less-efficient products, help compensate for the increased effort needed to learn about and locate energy-efficient equipment, draw attention to technologies, and legitimize these technologies in the eyes of consumers. The most active utility in the data center sector is Pacific Gas and Electric Company, which offers incentives for server consolidation, among other strategies.

- *Government procurement*: Federal, state, and local governments spend tens of billions of dollars annually on energy-consuming products, which means that there are thousands of opportunities to reduce government energy use through the purchase of energy-efficient products. Government procurement programs help raise awareness of new-to-market energy-efficient products, increase comfort levels as efficient products are put into use, and reduce costs of manufacture through economies of scale. The federal government is required by law to purchase energy-efficient products unless these products are proven to be not cost-effective. The government has developed energy performance specifications for more than 70 types of products.

EPA has begun addressing the energy performance of equipment in data centers by supporting development of energy-performance metrics for servers. In addition, governments and utilities are exploring program mechanisms for promoting improved efficiency.

Recommendations

A mix of programs and incentives is necessary to achieve a significant portion of the potential savings identified in the energy-efficiency scenarios above. Improvements are both possible and necessary at the level of the whole facility (system level) and at the level of individual components. Although it is not possible to optimize data center components without considering the system as a whole, it is also true that efficient components are important for achieving an efficient facility (for instance, efficient servers generate less waste heat which reduces the burden on the cooling system). Nevertheless, the greatest efficiency improvements will likely result from a comprehensive approach, given that there are opportunities for improvement in many areas of the IT equipment and infrastructure systems.

Based on a review of a range of incentives and voluntary programs that have been used in other sectors, and considering the unique aspects of the server and data center market, a number of recommendations can be made to pursue improved energy efficiency in the near term. These recommendations include:

- **Standardized performance measurement for data centers —** Data center operators need standard metrics to assess and report the energy performance of their facilities. The federal government and industry should work together to develop an objective, credible energy performance rating system for data centers, initially addressing the infrastructure portion but extending, when possible, to include a companion metric for the productivity and work output of IT equipment. These metrics should account for differences in data centers in areas such as computing output and availability requirements.

- **Federal leadership —** The federal government can act as a model in encouraging improved data center efficiency. The government should commit to: publicly reporting the energy performance of its data centers once standardized metrics are available, conducting energy efficiency assessments in all its data centers within two to three years, and implementing all cost-effective operational improvements. Additionally, the Architect of the Capitol should implement the server-related recommendations from the Greening of the Capitol report (Beard 2007).

- **Private-sector challenge —** The federal government should issue a challenge to private-sector chief executive officers (CEOs) to conduct DOE Save Energy Now energy-efficiency assessments, implement improvements, and report energy performance of their data centers. These assessments require protocols and tools that should be jointly developed by government and industry.

- **Information on best practices —** 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. This information will help raise awareness of energy-efficiency issues in this sector and reduce the perceived risk of energy-efficiency improvements in data centers. The government should partner with industry to develop and publish information on field demonstrations and case studies of best practices. This information should be disseminated as part of a campaign to make data center managers aware of the benefits of energy efficiency in addressing power and cooling constraints in data centers.

- **Standardized performance measurement for data center equipment —** Purchasers of data center equipment, such as servers, storage, network equipment, and uninterruptible power supplies (UPSs), need objective, credible energy performance information if they are to purchase efficient products.
  - The federal government should work with industry to develop objective, credible energy performance metrics for this equipment.
  - Using these metrics, the government should also investigate whether development of ENERGY STAR specifications for these product categories would be an effective strategy to complement the whole-facility approaches outlined above.
  - If and when ENERGY STAR specifications are developed, federal procurement specifications that build on ENERGY STAR should be implemented.

- **Research and development—**The federal government, in collaboration with industry, universities, electric utilities, and other stakeholders, should initiate a comprehensive research and development (R&D) program to develop technologies and practices for data center energy efficiency. Specific research needs are identified in Chapter 8 (R&D recommendations) of this report, covering the following topics: computing software, IT hardware, power conversion, heat removal, controls and management, and cross-cutting activities.

- **Public/private partnership for energy efficiency in data centers—**The federal government should engage stakeholders to formulate a common initiative (including public policies and private-sector actions) to promote energy efficiency in data centers to continue the dialog that this report initiates. Logical next steps would include defining priorities for the various strategies outlined in this report, developing timelines, defining roles for the various stakeholders, and identifying gaps and issues that require further assessment.

In addition to these near-term actions, several other actions can also play an important role in saving energy used by servers and data centers:

Federal Government:

- Develop a procurement specification for the energy performance of outsourced data centers.
- Work with industry to develop better tools, such as life-cycle risk models and total cost of ownership models that incorporate energy costs, for management of energy in data centers.
- Separately meter all federally owned data centers with significant energy use.
- Charge data center tenants for energy consumption of IT equipment in government-owned data centers.
- Partner with electric utilities, universities, and the data center industry to develop one or more neutral, "real-world" testing and demonstration centers ("National Center for Data-Center Best Practices") to verify new technologies for reducing energy consumption in data centers.
- Help organize a technology procurement program to bring to market energy-efficient products for data centers.
- Partner with training organizations to develop education and training information and curricula about energy efficiency in data centers.
- Target data centers for efficiency upgrades using energy services performance contracts (ESPCs) and utility energy service contracts (UESCs).
- Provide technical assistance for demonstration projects of energy efficiency in data centers.
- Conduct demonstration and education projects for fuel cells and other clean, efficient DG technologies used for CHP in data centers.
- Develop a procurement specification to improve the efficiency of high-performance computing facilities.

State and Local Governments:

- Consider requiring separate utility meters on large data centers, either through utility regulation or building codes.

- Consider offering financial incentives for clean, efficient technologies used for CHP in high-availability installations (data centers, telecom facilities, etc.).

Electric Utilities:

- Consider offering incentives for energy-efficient data center facilities and equipment, based on the metrics described above.
- Consider partnering with the federal government to develop a neutral, "real-world" testing and demonstration center to verify new technologies for reducing energy consumption in data centers.
- Consider partnering with the federal government to develop a technology procurement program for efficient products.
- Consider offering education and training resources as a component of energy-efficiency programs for data centers.
- Consider offering financial incentives for clean, efficient DG and CHP in data centers.

Data Center Industry:

- Consider partnering with the federal government to develop an objective, credible energy-performance rating system for data centers.
- Consider partnering with the federal government to develop improved tools, such as "energy aware" total cost of ownership models and life-cycle risk models, for management of energy in data centers.
- Consider partnering with the federal government to develop a neutral, "real-world" testing and demonstration center to verify new technologies for reducing energy consumption in data centers.

Conclusions

This report helps define a vision for achieving energy efficiency in U.S. data centers. Although the growing energy use of servers and data centers makes this a challenging goal, there are large opportunities for savings. These savings will not be easy to achieve, given the barriers outlined in this report, but there are many policies available to overcome the barriers. Realizing these efficiency gains will take coordination and collaboration among many stakeholders: the government, the IT industry, data center operators, electric utilities, and others. The outlook for efficiency gains is encouraging, though, because industry is very engaged with these issues and is working with customers who are demanding solutions to the growing energy use in data centers. Federal initiatives should build on these efforts and partner in ways that develop objective, credible information, benchmarks, metrics, and industry standards. Finally, as a significant operator of data centers itself, the federal government can help facilitate change by changing the way it designs and operates its own facilities.