Defining Efficiency in a Rapidly Changing World: Specifications and Incentives for High Performance Data Centers and High Efficiency IT Equipment

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ABSTRACT

With the complexity and rapid innovation of IT equipment and data centers, how can energy efficiency programs effectively influence this market? Governments, utilities, and industry trade organizations have sought answers to this question since the U.S. EPA report to Congress on Server and Data Center Energy Efficiency brought this issue to the forefront in 2007. Despite this challenge, widespread consensus remains among energy efficiency program developers and other environmental advocates that the energy savings potential in this rapidly growing industry of highly concentrated energy use cannot be ignored.

Program administrators must overcome many challenges to create effective efficiency programs targeting the high technology industry. Such challenges include: understanding the complexity of IT equipment and its impact on supporting power and cooling systems; keeping efficiency specifications relevant and avoiding free ridership in a rapidly changing market; and addressing industry-specific barriers such as high reliability requirements and split incentives stemming from common business management structures.

This paper will assess the challenges to creating incentives for energy efficiency in the high technology sector by examining two key activities: the creation of high efficiency specifications for IT products, and the development of energy efficiency utility incentive programs for data centers. The paper will provide a high-level overview of current initiatives and explore the current barriers to the success of these initiatives.

Introduction

IT equipment (e.g., servers, storage or networking equipment) and data centers are increasingly central to economic growth and can help drive energy efficiency by raising productivity and decreasing the overall energy needed for communication and collaboration. These new efficiencies can be found through IT-enabled trends such as telecommuting, improved information management, and advanced automation and controls. However, the more demand for IT systems grows, the more the absolute energy load of these systems grows. The demand could potentially put this industry at odds with attempts to reduce the energy use and corresponding greenhouse gas emissions of the world economy. This potential conflict drives regulators, electrical utilities, vendors and businesses to constantly look for ways to increase the energy efficiency and slow the growth of energy use of IT equipment and data centers.

IT equipment and the facilities that support it (i.e. data centers) are particularly energy intensive. Data centers are estimated to be over 40 times as energy intensive as conventional office buildings[1] (Greenburg 2006). In addition, while some areas of the economy are leveling

[1] Energy intensity is a measure of energy used per square foot of the facility (kWh/sq ft).

off or shrinking, IT spending has remained steady or continues to grow in many sectors. For example, the US healthcare and finance sectors grew IT operational spending by nearly 5% in 2009 (Computer Economics 2009). This growth leads to an EPA estimated 14% yearly growth rate in electricity use in data centers (EPA 2007). One contributor to this trend is that IT equipment and the facilities that support it (i.e. the data center infrastructure) have not been traditionally designed or operated with energy efficiency in mind. Instead, the industry has tended to focus solely on reliability and guaranteeing uptime, often at the expense of energy efficiency.

For many data centers, the energy used for power conversion and the cooling of the equipment exceeds the consumption of the IT equipment itself. The EPA found that the average data center has a Power Usage Effectiveness (PUE)[2] of 1.91, with a range from 1.25 to 3.75 (EPA 2009). This means that data centers use an additional 25% to 275% more energy than is required by the IT equipment itself. Many efficiency efforts have been focused on reducing this overhead. However, focusing on improving the energy efficiency of IT equipment is even more effective, watt for watt. This is because energy savings from IT equipment has a compound effect as a result of reduced load in the infrastructure support equipment (e.g., efficient IT equipment produces less heat, thus requiring less energy for cooling).

Attention to improving the energy efficiency of IT has grown since the U.S. EPA began assembling its Report to Congress on Server and Data Center Energy Efficiency (EPA 2007). Following the release of the report, EPA extended the reach of the ENERGY STAR program to the data center with an energy efficiency specification for servers and a building rating system for data centers. In addition, utilities and public benefits organizations such as Pacific Gas and Electric (PG&E), BC Hydro, and Energy Trust of Oregon, have launched specific energy efficiency and demand reduction programs focused on IT equipment and data centers.

Although initial efforts by governments, utilities and other organizations have established a foundation for addressing energy efficiency in this sector, many barriers stand in the way of achieving the full potential for energy savings. The unfamiliar technologies, market actors, and design constraints that make up the IT industry presents a unique set of challenges for program developers. For these reasons, program efforts have struggled to define the efficiency of these devices and facilities. Key factors that complicate the design and delivery of these energy efficiency programs targeting this industry include:

- **Organizational barriers** – These include an aggravated split incentive, the primary focus on reliability, and the limited availability of experienced engineers.
- **The rapid rate of innovation –** IT encompasses many dynamic technologies that tend to change abruptly and dramatically.
- **Highly complex and adaptable hardware –** Unlike technologies traditionally targeted for energy efficiency (e.g., lighting, HVAC, white goods, etc.), IT equipment is designed to be highly configurable and intended to be capable of performing a wide array of functionalities and workloads.
- **Difficulty in classification –** The IT and data center industries do not fit cleanly into traditional classifications typically used by energy efficiency programs.

[2] Defined as the total energy used by the facility over the energy consumed by the IT equipment, as measured at the Uninterruptable Power Supply (UPS).

Despite these challenges, the opportunity for energy efficiency programs appears to be rich; industry estimates indicate opportunities to decrease the energy use of data centers by up to 60% (ADM Associates 2010). As a result, many energy efficiency advocates continue to push for energy savings in this industry. The need for leadership to drive more efficient equipment and better operational practices is apparent, but to make progress in this area, energy efficiency program developers must first understand the key barriers in order to develop effective techniques to increase the efficiency of this industry.

Current Initiatives

IT Equipment Energy Efficiency Specifications

An important tool in driving energy efficiency in any industry is the ability to measure and compare products in terms of their energy use relative to their performance or capacity. This measurement of "efficiency" of the equipment can be used to drive voluntary labeling programs, government or corporate procurement programs and utility incentive programs.

ENERGY STAR program. The U.S. Environmental Protection Agency began the ENERGY STAR program in 1992 with a specification for computer "sleep" modes. It was twelve years later, in 2004, that EPA addressed the energy use of computers while turned on and in an idle state[3]. Another two years later in 2006, EPA began developing its first specification for IT equipment intended for the data center – the enterprise server. To this date, both specifications address only efficiency in the idle state, and do not cover active modes when the device is performing useful work. More recently, the EPA has continued its expansion into the data center with a number of new specification development efforts for IT equipment.

ENERGY STAR also characterizes the efficiency of the building as a whole with a rating system and specification for data centers. This rating is based on the PUE of the facility. By relying on this metric, the relative efficiency of the data center infrastructure equipment (cooling, power distribution, etc.) is visible, but the efficiency of the IT equipment itself is not covered. Table 1 summarizes ENERGY STAR activities that cover the data center and IT equipment.

Table 1. Summary of ENERGY STAR Activities for IT Equipment and Data Centers

Existing Specifications (February 2010)	Specifications Under Development (February 2010)
Enterprise Servers V1.0 Computers V5.0 Data Center Rating V1.0	Enterprise Servers V2.0 Data Center Storage V1.0 Uninterruptable Power Supplies (UPS) V1.0

Source: ENERGY STAR Specification Development Website http://www.energystar.gov/productdevelopment

80 PLUS® program and the Climate Savers® Computing Initiative (CSCI). The 80 PLUS program is an upstream incentive program supported by a number of electrical utilities and public benefits programs, which at its peak included fourteen major sponsors across North America that represented approximately 20% of the population (Rasmussen 2008). Starting in 2004, the program took a significant first step by specifying minimum efficiency and power

[3] A computer is considered to be in an idle state when it is turned on but not performing useful work.

factor levels for computer power supplies across a wide range of loading conditions. Programs such as ENERGY STAR have since adopted program specifications and test procedures developed by the program.

In 2007 the program expanded into server power supplies and, in 2008 it harmonized its specifications for both desktops and servers with the Climate Savers Computing Initiative (CSCI), a campaign that markets technologies to reduce the energy use of computing equipment. Both organizations are now working to include standards for storage power supplies.

Energy benchmarking efforts for IT equipment. IT products have historically been compared using raw performance metrics such as number of computations, transactions, etc. IT equipment benchmarking organizations have recently begun to address energy consumption in their benchmarks. Benchmarking efforts have thus far focused on specific workloads performed by IT equipment, but efforts are now underway to develop universal metrics to assess the generalized efficiency of these devices. Generalized efficiency metrics would act as a "miles per gallon" equivalent for IT equipment, which would support the development of energy efficiency measures. Organizations working on performance and energy benchmarking for IT equipment include: the Standard Performance Evaluation Corporation (SPEC) for servers; the Transaction Processing Council (TPC) for data base systems; the Storage Performance Council (SPC) for data storage equipment, the Storage Networking Industry Alliance for data storage equipment, and the Business Applications Performance Corporation (Babco) for computers.

Utility Incentive Programs

Electric utilities have an essential role in promoting energy efficiency, and their resource acquisition programs must deliver measurable, verifiable and cost-effective energy savings. In many cases, these programs leverage the work of other programs by adopting existing energy efficiency specifications to identify more efficient product offerings.

In 2006, PG&E launched their High-Tech Program, which included measures specifically targeted at data centers and IT equipment. Other programs with similar offerings sprung up soon after. Examples of utilities and public benefits organizations offering specific data center efficiency programs include: Austin Energy, BC Hydro, Efficiency Vermont, Energy Trust of Oregon, Focus on Energy, NYSERDA, Oncor Electrical Delivery, PG&E, Silicon Valley Power and Xcel Energy (in Colo. and Minn. only).

Although efficiency programs that are focused on IT equipment and data centers are relatively new, there continues to be increasing development in this area. Many of these programs can be fit into a few defined categories:

- **Custom incentives–** Utilities offer incentives for custom measures with verifiable energy savings, calculated by engineers on a project-by-project basis. Incentives can be paid based on either energy (kWh) or demand (kW) savings.
- **Prescriptive rebates –** Rebates include fixed incentives paid for equipment or upgrades with deemed energy savings. Prescriptive rebates in data center programs can be for technologies specific to data centers (e.g., server virtualization, uninterruptable power supply [UPS] efficiency) or for more general measures (e.g., lighting, HVAC, Variable Frequency Drives [VFD]).

- **Design assistance –** Assistance comes in the form of subsidized engineering support, design services, or “checklist” energy audits. Programs often pay all or a portion of study costs. Such assistance programs often lead to measure installations.

Utility incentives can also be separated into measures that address the data center as a whole and by equipment type for measures within the data center. This break down is shown in Table 2 and shows the variety of individual measure types applicable to data centers.

Table 2. Data Center Utility Incentives by Equipment Type

Holistic Data Center Measures			
• Engineering Support (Technical Assistance and Energy Audits) • Custom Measures			
Cooling Measures	**Power Measures**	**IT Measures**	**Other Measures**
• Chillers / HVAC / Economizers • Air Flow Management • VFDs • Advanced Controls	• UPS • PDU • Transformers • Inverters	• Efficient Power Supplies • Efficient Servers • Server Virtualization	• Lighting • Computer Power Management • Desktop Virtualization • Plug Load Management

Most data centers receive energy efficiency incentives through custom programs or for measures that are not necessarily specific to data centers (e.g., HVAC, lighting and variable frequency drive [VFD] incentives), though some utilities have more targeted measures such as for server virtualization and UPS efficiency. Programs can also be targeted upstream (to manufacturers or to a specific distribution channel) or downstream (directly to customers). Programs are often held accountable to cost effectiveness metrics, which attempt to quantify the benefits of savings vs. program expenditures. These tests can examine the costs and benefits to the utility alone, or can include the larger community (e.g., the Societal Cost Test).

Barriers to Energy Efficiency Program Development

Barrier #1 - Organizational Barriers

The aggravated split incentive. The data center provides a prime example of the “split incentive” that creates a barrier to energy efficiency in many sectors. In the typical data center management structure, the data center is seen as an operational expense for a company as a whole, while the capital expense of the IT equipment inside is typically paid for by the individual business unit that will utilize the equipment. In this way, the true lifecycle cost of the IT equipment is not felt by the equipment purchaser, as they are not paying for the cost of powering and cooling that equipment over its lifetime. More efficient IT equipment can come at a cost premium (this is the incremental cost that programs attempt to overcome with incentives), but IT staff are not willing to invest this extra money, as they will not receive the return on investment from reduced operating costs. To combat this trend, organizational alignment must often be created where it does not exist. For example, some companies are working to close communication gaps between the IT and facilities staffs, while others, such as Microsoft, have addressed this issue by passing power and cooling charges directly to the individual business units installing the IT equipment.

The split incentive barrier is further exacerbated in colocation facilities – data centers that lease space to organizations that operate their own IT equipment within the leased space. In colocation facilities, the colocation company owns the infrastructure. Infrastructure costs, including power, are then typically charged to customers as part of “rack rates” or capacity rates. Because of this, the owners of the IT equipment (the colocation customers) are essentially isolated from any operational cost benefit brought on by efficiency. Few colocation facilities directly charge for power or provide visibility of electric consumption to their customers. In many cases, neither the colocation operator nor the colocation customer has significant motivation to reduce their energy use. Efforts by utilities to promote efficiency to either party can be frustrated by utility policies that restrict incentive payments to anyone other than the customer on record. As a result, companies leasing colocation space often cannot receive incentives for energy efficiency improvements within the facility—which can include the IT equipment.

Focus on reliability. Data center managers stake their careers on being risk-averse and providing continuous operation of their facilities. This industry relies on continuous uptime for many of the applications that are mission critical for business success. Reliability requirements are often expressed in terms of “nines,” in that a data center that achieves five “nines” of uptime will be operational 99.999% of the time - this translates to only five minutes of downtime a year. In addition, data centers can be designated in different “tiers” of reliability, as defined by the Uptime Institute. These levels of redundancy vary from I being the lowest to IV being a fully redundant data center with no single point of failure. In the data center industry, even a single short-term outage could cost a company serious revenue. Imagine if a credit card company data center, which performs millions of transactions a day, went offline for even a few hours.

This extreme expectation of and commitment to reliability creates a barrier to data center managers investing in new technologies even if they demonstrate markedly increased energy efficiency, as these technologies can be seen as being unproven. This barrier can be especially acute in existing, operational data centers. Once a facility is operational and performing reliably, IT managers are reluctant to alter the configuration. This fits in the old mantra, “if it it’s not broke don’t fix it,” and results in old technology entrenching itself as long as it continues to perform reliably.

Limited availability of experienced engineers. The limited availability of experienced technical staff can make it more difficult and expensive to implement energy efficiency upgrades. Few prescriptive rebates exist for data center focused measures, so these programs tend to be custom and require complex calculations to receive the incentives. Some operators of small colocation facilities, for example, cite the lack of internal expertise to complete engineering calculations as a barrier to participation in utility incentive programs for data centers (Cullen 2009). Experienced staff or consultants are in short supply and are therefore expensive, so procuring experienced personnel to complete applications can add significantly to the cost of the project and reduce the return on investment.

This lack of expertise also exists on the utility side. The former manager of a large high-tech program which includes data centers indicated, “We rely on engineering consultants who can accurately calculate the energy savings from implementing facility and IT improvements, and … we have a hard time finding firms that have this competency – especially on the IT equipment side" (Fry 2009).

Barrier #2 - Rapid Rate of Innovation

The rapid rate of innovation in the IT industry threatens to make some specifications and programs obsolete before they are even adopted. Much of this rapid innovation is driven by "Moore's Law" – the observation that the number of transistors on a chip will double roughly every one and a half to two years. The effect of Moore's law is that computer processors are driven faster and faster, and storage media becomes denser and denser to accommodate the additional data that must be stored. As IT equipment is asked to do more at increasingly greater speeds, the power demanded by these devices is climbing. At the same time, however, the equipment itself is becoming more efficient in terms of raw computations per kW (Koomey 2009). The pace of innovation results in a very high technology turnover (or "refresh") rate for companies who heavily rely on these technologies. While the effective useful life (EUL) of a water heater or furnace is about two decades; in comparison, the EUL of a computer server is as little as four years[4] (DEER 2008).

As program designers work to reach stakeholder consensus and perform due diligence on projected energy savings, program development can be slow compared to the rate at which technology is changing in this industry. For example, the ENERGY STAR specification for servers and the Version 4.0 specification for computers both took over two years to develop. This specification development time is acceptable for products with lengthy product lifecycles, but not necessarily for IT equipment. Servers can have a component refresh rate (including processors, memory and chipsets) of as little as 18 months, with full model redesigns roughly every three years (Taylor 2010).

Rapid innovation also creates competitive pressure that results in manufacturers being reluctant to share information on their most efficient and advanced designs or best practices. This presents a challenge for program developers who must have access to the most up-to-date data to set specification levels that will remain relevant over time.

One threat from the slow pace of efficiency program development is that energy savings are reduced if the baseline models have become significantly more efficient since the program was developed. Some technologies are so rapidly adopted in the marketplace that free-ridership (participants receiving incentives for measures they would have implemented anyway, even in the absence of an incentive) also becomes a concern. A good example of how rapid adoption of a disruptive technology by the IT market can lead to free-ridership concerns is provided by server virtualization. Server virtualization has gained much popularity as it affords an opportunity to greatly streamline the entire organizational makeup of an IT department. It has received such tremendous attention by the media that few IT professionals are ignorant of its potential benefits. Many organizations moved to implement the technology quickly; actions by early adopters were so swift and well publicized that some utility programs became concerned that server virtualization incentives were needless. While this rapid adoption has been true of some of the market, another portion of the market (especially small to medium IT organizations) have been slower to adopt the technology. Barriers to implementation remain - including IT staff training

[4] This is the EUL used by many utility incentive programs in their savings and cost effectiveness calculations. Examples include: BC Hydro, Energy Trust of Oregon and Xcel Energy.

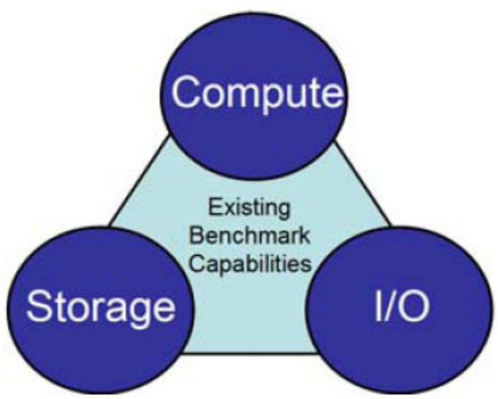
and application supportability issues. In addition, substantial hidden costs are becoming better understood and publicized which inhibits adoption in many firms. As a result, many IT organizations use virtualization primarily as a growth management strategy. The results are that even in organizations that say they have fully deployed virtualization, only about a third of their server infrastructure is actually virtualized (CDW 2010).

Barrier #3 - Highly Complex and Adaptable Hardware

IT equipment and data centers are designed to be highly adaptable to fit different tasks or "workloads". This stands in contrast to many products that perform a single duty or function, which are more easily amenable to efficiency specifications. For example, a compact fluorescent (CFL) light bulb puts out a certain amount of light measured in lumens, or a refrigerator cools a certain amount of space measured in square feet. This is why the ENERGY STAR lighting specification is based on lumens per watt for different bulb types and the refrigerator specification is based on energy use as a function of adjusted volume (a measure of volume which accounts for refrigerator/freezer combinations).

But what is the equivalent output or metric for IT equipment to gauge the amount of useful work performed? Most individual pieces of IT equipment and data centers on the whole do three main things: 1) perform computations, 2) store information, and 3) move information. Attempts to benchmark the performance of IT equipment typically measure the relative performance based on one or more of these three capabilities - compute, storage and input/output (I/O). The balance between these three capabilities is illustrated as a function of existing server benchmarks in Figure 1.

Figure 1. IT Equipment Capabilities



Source: Fanara 2009.

Different types and configurations of IT equipment use these three capabilities to varying degrees, and are customized to suit the performance requirements of the workload the equipment serves. Customizations may include upgrades such as additional processors, faster processors, increased memory, faster memory, on-board storage, high performance network cards, etc. Components are usually selected to achieve the required performance at the lowest first cost. For example, a High Performance Computing (HPC) system must accommodate a heavy compute load, while a server hosting a database or Website might be very heavy on storage and I/O (Fanara 2009). Customizing to match the end use is also true for the data center on a macro level.

One data center might be used primarily for webhosting, while another might be used solely for HPC modeling. The differences in configuration combined with different workloads makes developing generalized metrics to measure the efficiency of these devices and facilities very difficult.

Organizations like the Green Grid (thegreengrid.org) and SPEC (www.spec.org) are working to develop metrics for measuring the relative efficiency of IT equipment and data centers. These metrics should become increasingly useful for developers of specifications and incentive programs.

Barrier #4 - Difficulty in Classification

The data center industry is sufficiently unique and complex that it does not fit easily into any typical program categories. Most efficiency programs are structured around industry segments such as residential, commercial and industrial. But where do IT equipment and data centers fit in this paradigm? Smaller data centers, such as those contained in office buildings, might fit a commercial model, while large enterprise data centers could be seen to fit the industrial model. Based on the type of equipment they contain and the workloads supported, data centers can have varied load shapes that might not closely fit either model. This can lead to inconsistent program delivery, with different data centers being served by different rate schedules and fitting within multiple program jurisdictions in a given territory.

The unique nature of IT equipment and data centers requires that efficiency program developers must develop new relationships and technical competence in a market with unique needs, triggers, and procurement protocols. In many cases, data center operators and utility staff are not generally familiar to each other. In territories with established energy efficiency programs, some facilities managers may have experience with their local utility programs, but the IT staff may remain unfamiliar. Furthermore, there is an entirely different layer of vendors that program developers must get to know: software, hardware, system integrators, VARs, and specialist consultants.

Moving Forward

Many barriers to the effective delivery of energy efficiency programs for IT equipment and data centers have been encountered. The market and technologies are still new ground for efficiency program designers, and it has taken many years to become acquainted with this industry. Despite the challenges described in this paper, energy efficiency specifications and incentive programs can still have a significant role in moving IT equipment and data centers towards increased energy efficiency. They can do this by continuing to push effective energy efficiency program development through long-term engagement with the industry on an individual basis and through industry associations such as the Green Grid. At minimum, universal procedures for testing and specifying the energy efficiency of IT products are needed to empower customers to understand and compare the energy performance of products from different manufacturers. Vendor-neutral and internationally respected organizations such as the U.S. EPA ENERGY STAR program remain in a strong position to bring together stakeholders to develop specifications to achieve this. In addition, utilities can continue to be a driving force to encourage adoption of efficiency in local markets by providing vendor-neutral information on best practices through program outreach or design assistance, as well as financial incentives to help drive down the costs of implementing efficiency measures. They also benefit by establishing working relationships with data center operators to ensure effective efficiency strategies are implemented as IT growth continues. For these reasons, and because of the significant identified opportunity for energy savings in this industry, program designers should continue to work to overcome the existing barriers to promoting energy efficiency in this sector.

Summary and Conclusion

The IT and data center industries have been identified as an area of rapid growth of energy use as society becomes more and more dependent on digital media and online services. In the past, this industry has tended to focus solely on reliability, at the expense of efficiency, and significant opportunities exist for energy savings in this sector. While current efforts over the last half-decade have begun to make progress, significant barriers still exist for efficiency specifications and utility programs to effectively promoting energy efficiency in this sector. These include: specific organizational barriers (e.g., an aggravated split incentive, the primary focus on reliability, and the limited availability of experienced engineers), the rapid rate of innovation in this industry, the highly adaptable hardware and the difficulty in current program models classifying this industry. Despite the many barriers that exist, savings acquisition and market transformation programs can still make a difference by continuing long-term engagement with the IT equipment and data center industries, and by working to understand and overcome the barriers that inhibit efficiency in its current context.

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