ENERGY EFFICIENCY AND ENVIRONMENTAL CONSIDERATIONS FOR THE DATA CENTER

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INTRODUCTION

Since the release of the Environmental Protection Agency (EPA) report on data center power consumption to congress in 2007, numerous organizations have joined the cause to operate more efficiently, with The Green Grid (TGG) gaining worldwide acceptance as the industry leader for data center efficiency. Although financial rewards are the prime driver of efficiency, many companies and data center organizations care about their carbon impact.[1] Reducing carbon emissions is a global target; while current U.S. economic and political climates would indicate no formal government-based reporting policy, the industry is supporting sustainability efforts led by TGG, LEED from the USGBC (U.S. Green Building Council), and EPA's data center ENERGY STAR program.

For a more current look at data centers' key power contribution to the EPA's report, Jonathon Koomey, Ph.D., indicates that in 2010 the data center energy usage worldwide was roughly 1.5 percent. Specifically, U.S. data centers consumed roughly 76 billion kilowatt-hours or about 2 percent of the total electricity used. This represents a 36 percent growth from 2005–2010 as compared to the 100 percent growth forecasted in the original EPA report. Koomey contributes this to a few factors including the current economic slowdown and virtualization, but he also indicates significant progress within the industry to improve operational efficiency. He further defines data centers into four groups: public cloud computing providers (e.g., Amazon, Google, Facebook and Mircosoft), scientific computing centers (e.g., national laboratories and universities), co-location facilities, and in-house data centers (i.e., facilities owned and operated by companies whose primary business is not computing). The fourth category is by far the dominant one in terms of floor area and total electricity used.[2]

Increased efficiency is not just about financial savings through energy costs or environmental improvements; it is also about optimizing infrastructure capacity. As companies consider whether to build a new facility or outsource within the co-location market, there is often stranded or unused capacity within their current environment. This white paper illustrates what infrastructure changes within a current environment can yield greater capacities and technologies that drive energy efficiency gains and reduce environmental burdens.

DATA CENTER ENERGY EFFICIENCY

The EPA's report to Congress clearly defined the basis of a useful efficiency metric of "a meaningful measure of site infrastructure needs to meet the following criteria: 1) clearly convey its meaning; 2) correctly define an efficiency metric in which the output metric is in the numerator and the energy input is in the denominator; and 3) apply only to the site infrastructure side of the data center."[1] These metrics were developed in order to understand the effect of changes within the data center relative to efficiency and to set an industry benchmark.

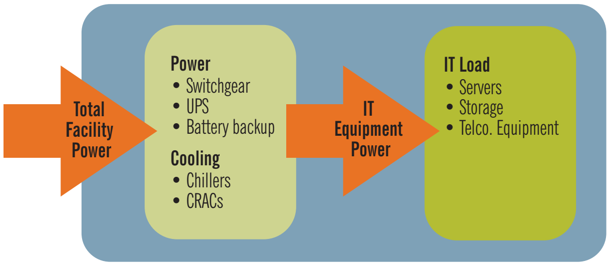
Currently, the two most adapted and widely used measurements are known as power usage effectiveness (PUE) and data center infrastructure efficiency (DCiE), which are represented as:

PUE = Total facility power/IT equipment power
DCiE = The reciprocal of PUE (1/PUE) or IT equipment power/total facility power.

For these equations, total facility power is defined as power measured at the utility meter and is solely used to support data center infrastructure, such as:

- Power pathways: generators, switchgear, automatic transfer switches, UPS systems and PDUs
- Cooling system components: cooling towers, pumps, chillers and computer room air conditioners (CRAC)
- Miscellaneous: lighting, etc.

IT equipment power is defined as the total load used for all IT equipment, such as servers, monitors, storage, networking equipment, workstations and KVM.



Source: The Green Grid, "Data Center Power Efficiency Metrics PUE & DCiE," 2007

Figure 1: Building Load–Demand from Grid

Obtaining DCiE or PUE is the initial step in understanding a data center's overall efficiency level. For example, a PUE of 2 indicates a data center must draw 2 watts of power for every 1 watt of power consumed by IT equipment. The ideal PUE is 1, which means that every watt of power drawn by the data center is delivered to IT equipment. The PUE or DCiE will allow the comparison of results against other competitive data centers and will illustrate:

- Opportunities for improving efficiency
- How and whether design and processes are affecting overall efficiencies.

Even though the EPA has not set an exact benchmark standard for the industry, competitive data centers and studies indicate PUEs less than 2, while striving to achieve obtainable numbers of 1.5 or less, should be the short-term goal.

For the purpose of the report to Congress, the EPA, along with independent laboratories, evaluated historical and current efficiency trends against improvements in three different scenarios: improved operations, best practices and state-of-the art technology deployments. These three scenarios were applied to the IT equipment and operation and site infrastructure equipment.

SITE INFRASTRUCTURE DEFINED

According to the EPA, site infrastructure equipment on average may account for 50 percent or more of the total energy consumed within a data center.[5] Upgrading to more efficient UPS systems and transformers can drastically affect the amount of energy consumed within the data center. Other improvement areas are within the cooling systems, such as improving airflow, optimizing temperature and humidity set points, and using variable speed fans, pumps and chillers.

Table 1 provides more detailed definitions of the site infrastructure considerations included in the previously discussed EPA forecast.

Scenario Name	EPA Assumptions
Historical Trends of 2	Site infrastructure 50% consumption or PUE
Current Efficiency	An increase of 1% in efficiency per year or a 1.90 PUE after five years
Improved Operations	A 95% efficiency rate for transformers An 80% efficiency rate for UPS systems Air-cooled direct exchange system chillers Constant speed fans Humidification controls Redundant air handling units
Best Practices	A 98% efficiency rate for transformers A 90% efficiency rate for UPS systems Variable speed drive chillers with economizers or waterside free cooling Variable speed fans and pumps Redundant air handling units
State-of-the-Art	A 98% efficiency rate for transformers A 95% efficiency rate for UPS systems Liquid cooling to racks Variable speed drive pumps - Reported PUE using such equipment 1.2

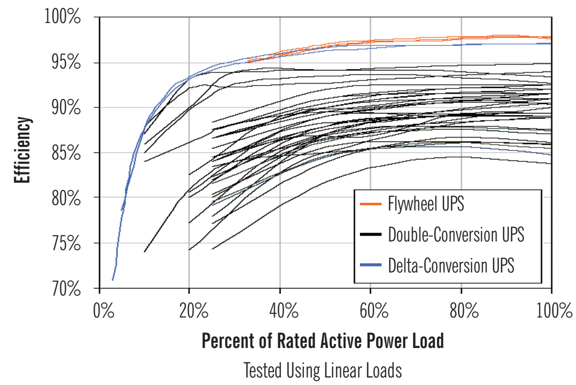
Note: A study of 22 data centers by Lawrence Berkeley National Labs indicated PUE ratios on average of 1.3 that included these efficient technologies. (Silicon Valley Leadership Group: Data Center Energy Forecast Final Report, July 11, 2008)

Table 1: EPA Site Infrastructure Definitions

UPS SYSTEMS

UPS systems not only vary in technology, but also in efficiency levels. As the industry strives for increased levels of operational efficiency, more manufacturers are publishing efficiency levels based on IT loads. Actual UPS efficiencies vary as the function of the IT load varies throughout the day of operation. The level of redundancy design within the data center also affects the level of load. In a 2N system, the UPS will carry a load around 40 percent, whereas a 2N+1 system will carry a maximum load of only 33 percent.

Upgrading a legacy UPS system offers an immediate return on increased efficiency levels within the site infrastructure. According to recent studies, the operational efficiency levels of legacy UPS equipment are between 60 and 80 percent. Currently, the most commonly used UPS technologies within data centers are double-conversion UPS systems. The EPA rates flywheel UPS systems as state-of-the-art technology.



Source: APC Whitepaper #63, "AC vs. DC Power Distribution" Rev. 5 2007, Rassmussen N.

Figure 2: Factory Measurements of UPS Efficiency

TRANSFORMERS AND PDUS

An isolation transformer and PDU are often integrated into a single component within the data center. Because they're typically rated at a fraction of the UPS capacity, most data centers will contain several PDUs. Each one represents a potential energy and efficiency loss within the typical AC data center distribution scheme. The function of the isolation transformer within the PDU is to step down the voltage into a consumable level. The PDU also houses circuit breakers to create multiple branch circuits that feed IT racks from a single feeder.

Until new power distribution models are developed and accepted, PDUs and isolation transformers will remain a key component within power distribution schemes. The EPA reports that legacy transformers are operating around 80 percent efficiency while state-of-the-art transformers have operating efficiency levels at 98 percent. A significant increase in the overall system efficiency will translate into less energy loss (represented as heat) and wasted cooling resources, which are dedicated to cooling these inefficiencies.

Given rapidly changing density trends, manufacturers have made great strides in technologies used to cool data centers and improve overall efficiencies. Whether the implemented technologies increase airflow, optimize hot-and cold-aisle air containment, use free cooling or increase efficiencies in chilled water systems, energy savings here can quickly add up.

Close-coupled cooling, liquid-cooled racks and hot- and cold-aisle containments are perceived as state-of-the-art technologies as reported by the EPA to congress. These technologies optimize airflow management by reducing distances of air paths, by requiring less fan energy and by removing heat at the source rather than attempting to cool the entire room. "The close-coupled approach greatly increases the efficiency of cool air distribution and hot-air removal. In these environments, all capacity can be delivered to the load or densities up to 25 kW or four times greater practical densities for room designed architecture."[2]

Other state-of-the-art technologies that can be integrated within the cooling pathway are variable frequency speed drives for fans or pumps and air- or water-side economizers. These economizers can offer free cooling in appropriate environments, which can further lower the cooling pathway PUE. With optimized airflow management through hot and cold aisles or rack containment systems, data center room set points and chilled water temperatures can be increased, reducing total cooling energy consumed and overall cost.

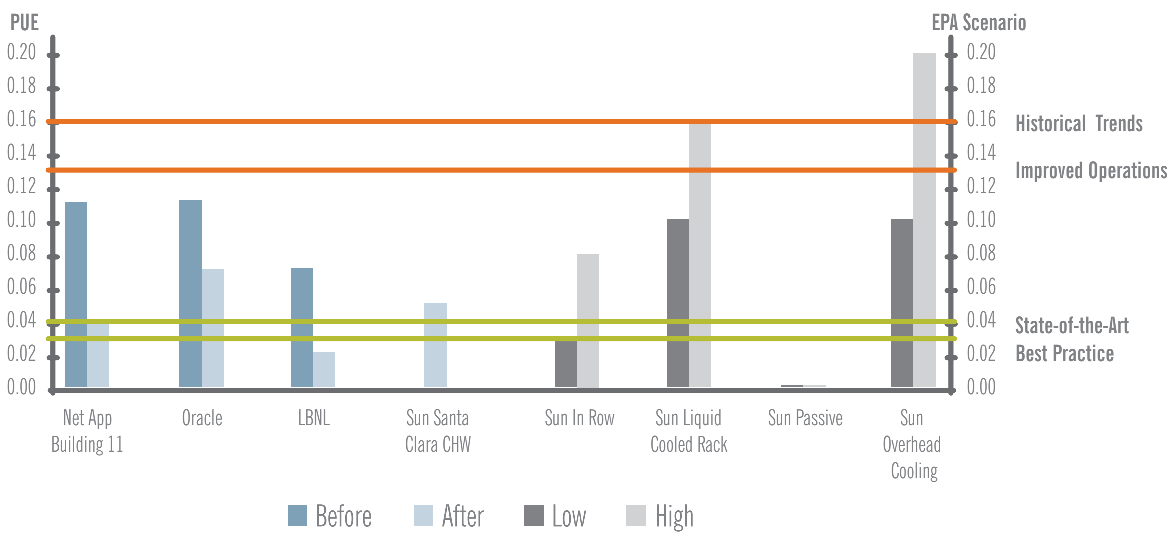
The Silicon Valley Leadership Group recently released a study that published the following results of the total PUE using a state-of-the-art cooling delivery system.

The before and after graphical representation in **Figure 3** shows the effects on a data center's total PUE percentage in relation to EPA trends as compared with different technology deployments. Different technologies were implemented in the following locations:

NetApp, Oracle, LBNL – All locations "implemented optimized airflow management that maintains a greater temperature differential and reduces the power of the fans needed to circulate air."[3]
NetAPP – Installed physical barriers between hot and cold aisles when possible
Oracle – Hot-aisle containment
LBNL – Cold-aisle containment

Sun Santa Clara – This was a test facility, so there was not a before-and-after comparison, just a measurement of PUE results based on the IT load. This was also the host site for comparisons of multiple manufacturer products.

Manufacturer comparisons represent low and high levels of PUE, which is representative of corresponding PUEs by varying the inlet air and water temperature. For the in-row and overhead cooling units, the inlet water temperature was 45° F with varying inlet air temperatures. For the passive and liquid-cooled rack units, inlet water temperatures were raised between 50 to 70° F. The variations were the result of exploring the feasibility of using higher chilled water temperatures. The passive system provided a "higher energy efficiency rating than other systems, as one would expect using only hydraulic power inherited from the chilled water system."[4]



Source: Silicon Valley Leadership Group: Data Center Energy Forecast Final Report, July 11, 2008

Figure 3: Effect on Total PUE–Cooling Delivery (Fans and Modular Units)

BEST PRACTICES

High-efficiency site initiatives exist in today's data center. When implemented, data centers can meet or exceed reported PUE findings established by the EPA. Deploying the state-of-the-art technology available today into legacy or newly commissioned data centers can contribute to reduced energy consumption. When designing the site infrastructure for today's data center, it is important to use the latest practices to implement an energy-efficient data center. To maintain efficiencies, data center managers must develop operating and deployment procedures. They must also maintain these disciplines throughout the life cycle of the data center.

The Green Grid organization is a global consortium of companies that are dedicated to developing and promoting energy efficiency for data centers. The organization focuses on topics such as the advancement of standards and improved processes and measurement methods to ultimately increase the performance and energy efficiency of data centers. According to The Green Grid, "system design issues that commonly affect the efficiency of a data center include:

- Power distribution units and/or transformers that operate well below their full load capabilities
- Air conditioners forced to consume extra power to drive air at high pressure over long distances
- Cooling pumps that have their flow rate automatically adjusted by valves, which drastically reduces the pump efficiency
- N+1, 2N designs that under utilize components
- Tradition of oversizing UPS to avoid operating near its capacity limit, while decreased UPS efficiency operating at lower loads." [5]

RIGHT-SIZING INFRASTRUCTURE SYSTEMS

Traditionally, data centers overcompensated for their site infrastructure equipment, whether for redundancy, to eliminate operating at near capacity or for future expansion considerations. In today's rapidly changing IT data center environment, these operating inefficiencies are adding to the overall energy consumed. Loading conditions within a data center are very dynamic due to the varying computing and storage needs in the short term and the incremental build-outs in the long term. "Of all the techniques available to users, rightsizing the physical infrastructure system to the load has the greatest impact on physical infrastructure electrical consumption." [5] Within the power and cooling pathway, there are fixed losses, whether an IT load is present or not. When oversized, these fixed losses become a larger percentage of the overall power consumed and increase costs.

"Rightsizing has the potential to eliminate up to 50 percent of the electric bill in real-world installations. The compelling economic advantage of rightsizing is a key reason why the industry is moving toward modular, scalable, physical infrastructure solutions. The very nature of the modular, scalable infrastructure implies that new physical infrastructure equipment is added only when additional IT loads are added." [5]

ENERGY-EFFICIENT INFRASTRUCTURE COMPONENTS

A typical data center's infrastructure equipment life span is at least 10 years. Whether in a legacy retrofit or a newly commissioned data center, efficient best-in-class technologies are available today. While upgrading or installing new equipment, manufacturers are providing actual efficiency levels based on loads.

Within the electrical distribution pathway, replacing legacy UPS systems with state-of-the-art or best-in-class technologies will produce immediate efficiency returns. The UPS efficiency level increases with applied IT load, so it is important to ensure that the UPS is also right-sized.

COOLING STRATEGIES

Previous approaches to cooling data centers were to flood the room with as much cool air as possible. As kW densities increase, hot spots sprung up throughout the data center. To handle these hot spots, data center managers would lower the temperature set points on the CRAC unit's output. In a room environment, this cool air mixes with the heat generated, which makes it difficult to manage and address individual hot spots.

With the highest percentage of energy consumption dedicated to cooling infrastructure, this also represents the area for greatest efficiency improvements. Today, data center managers have options on what proven cooling technologies should be implemented. Whether it's hot- and cold-aisle containment, optimized passive air ducting systems or close-coupled cooling, technologies may be chosen based on their installation environment.

State-of-the-art deployments can achieve greater efficiencies by drastically reducing the site infrastructure PUE percentage. This can be obtained by deploying liquid cooling to the racks, along with variable speed drive pumps, chillers and free cooling by either water or air-side economizers.

In an environment that uses liquid cooling, companies can evaluate efficiency trends and obtain the best results by supplying higher water temperatures from a cooling tower or chilled water plant. They must also keep in mind that these modular systems require additional power and access to the chilled water supply.

Higher density computing platforms, such as blade servers, require more power and cooling capacity to be delivered into a much smaller footprint than what may have been originally allocated within the data center for traditional IT systems. Careful consideration should be given to a thermal management and cooling strategy that optimizes airflow as well as adds proper cooling capacity to the IT computing load. This is also important in traditional data centers that use hot- and cold-aisle arrangements. In these environments, there is generally poor separation of the chilled air supply and the hot air return streams that are generated as a result of higher density systems.

COST REDUCTION

Individual data centers can save considerable amounts of energy by adopting the latest technologies and techniques. There are opportunities to achieve even greater efficiency results in every category reported by the EPA. Every little improvement adds up, even by implementing more efficient data center lighting, transformers and UPS systems. Each system contributes to electrical savings. "As a result, the potential kWh electrical savings for a large scale production data center are on the order of 25,000,000 kWh or greater over a typical 10-year life of the facility."[6]

The latest report from the Silicon Valley Leadership Group demonstrates that even with the maturity of the technology available today, data centers can achieve EPA forecasted results. "By 2011, trajectories using measured results offer significant savings over 2007 trends."[3]

Legacy data center retrofits can:

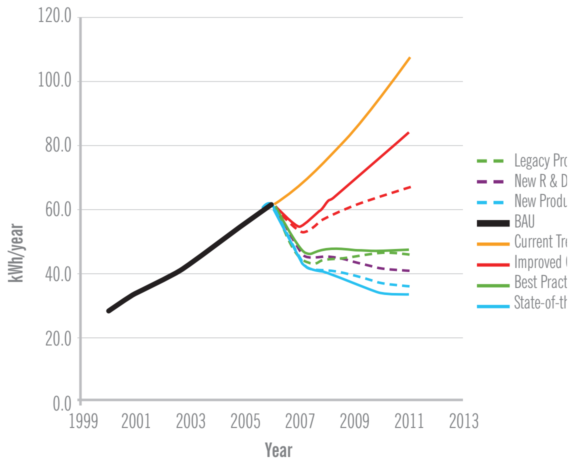
- Save between 59.9 and 64.6 billion kWh a year annually
- Save up to $4.5 billion annually
- Cut 40.9 MMTCO2 (more than 7 million cars annually).

New commissions and legacy retrofits can:

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

Even with these reductions, data centers will still be large consumers of energy because of business demands. In 2011, under the measurement-based scenarios, data centers will:

- Consume between 38 and 47 billion kWh annually
- Cost between $2.6 and $3.3 billion annually (based on kWh cost of 0.08)
- Produce between 24.3 and 30.1 MMTCO2 annually (between 4.3 and 5.3 million cars).



Source: Silicon Valley Leadership Group—Data Center Energy Forecast Final Report, July 11, 2008

Figure 4: Increase in Data Center Energy Usage

CONCLUSION

As data center power consumption continues to grow, it affects the business enterprise, power supply companies and the environment. With more efficient energy use in the data center, power supply companies will face less demand or excess power, which could help limit blackouts. It can also help reduce carbon dioxide outputs and other greenhouse gases. For the business enterprise, it can also significantly save on energy costs. All of these factors are increasing the public's awareness and global concerns of these current trends and should be addressed and managed with best practices and industry recommendations.

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