Energy Efficiency and Environmental Considerations for the Data Center

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Contents

- Introduction 03
- Data Center Energy Efficiency 03
- Site Infrastructure Defined 04
- UPS Systems 04
- Transformers and PDUs 04
- Cooling Infrastructures and Pathways 05
- Best Practices and Site Infrastructure Recommendations for an Energy Efficient Data Center 05
- Right-Sizing Infrastructure Systems 06
- Energy Efficient Infrastructure Components 06
- Cooling Strategies 06
- Environmental Impacts 06
- Conclusion 07
- About Anixter 07

Introduction

In 2007, the Environmental Protection Agency submitted a report to Congress with its findings on data center efficiency. As reported, data centers consume a significant amount of the nation's total energy supply. In 2008, that number is estimated to reach "61 billion kilowatt hours (kWh) or approximately $4.6 billion in electricity cost."[1] Based on current trends, this report projects an increase in near-term energy use and evaluates potential savings with efficiency gains.

The continued growth of data center power consumption impacts everything from the business enterprise to the power supply companies to the environment. With more efficient energy use in data centers, power supply companies will face less demand and the possibility of excess power, which could help limit blackouts, reduce carbon dioxide output and cut other greenhouse gases. For the business enterprise, an increase in data center efficiency can save significant energy costs. All of these factors are increasing the public's awareness and global concerns of these current power consumption trends. This white paper will review these power consumption factors as they relate to the data center environment and suggest some best practices to address the challenges and improve energy efficiencies.

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 impact of changes within the data center relative to efficiency and to set an industry benchmark to strive for.

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:

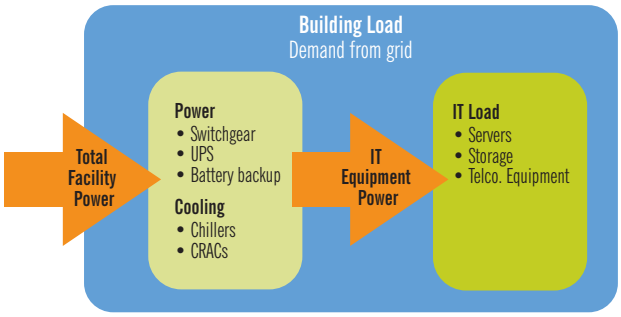
PUE = Total facility power/IT equipment power
DCiE = The reciprocal of PUE (1/PUE) or IT equipment power/total facility power.

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 such as:

- IT equipment: servers, monitors, storage, networking equipment, workstations, KVM, etc.



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

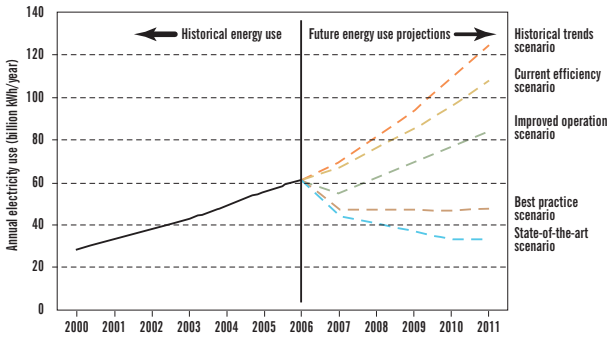
Obtaining DCiE or PUE is the initial step in understanding a data center's overall efficiency level. For example, a PUE of 2 indicates a data center must draw 2 watts of power for every 1 watt of power consumed by IT equipment. The ideal PUE is 1, meaning every watt of power drawn by the data center 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 process are impacting overall efficiencies.

While the EPA has not set an exact benchmark standard for the industry, competitive data centers and studies indicate PUEs less than 2.0, while striving to achieve obtainable numbers of 1.5 or less, should be the short-term goal. Later, this white paper will discuss the obtainable results as measured by the Silicon Valley Leadership Group.

For the purpose of the report to Congress, the EPA, along with independent laboratories, benchmarked 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, and the forecasted trends are shown below.

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



Source: U.S. Environmental Protection Agency ENERGY STAR Program, Report to Congress, Server and Data Center Efficiency, Public Law 109-431 August 2007

[1] U.S. Environmental Protection Agency ENERGY STAR Program, Report to Congress, Server and Data Center Efficiency, Public Law 109-431 August 2007

Site Infrastructure Defined

It is estimated that site infrastructure equipment on average may account for 50 percent or more of the total energy consumed within a data center. Power delivery improvements by upgrading to more efficient UPS systems and transformers can drastically impact 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.

The chart below provides more detailed definitions of the site infrastructure considerations included in the previously discussed EPA forecast.

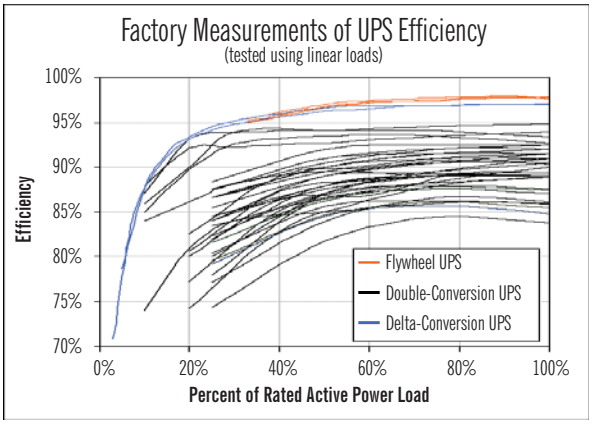
Scenario Name	EPA Assumptions
Historical Trends	Site infrastructure 50% consumption or PUE of 2
Current Efficiency	An increase of 1% in efficiency per year or a 1.90 PUE after five years
Improved Operations	A 95% efficiency rate for transformers An 80% efficiency rate for UPS systems Air-cooled direct 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 utilizing such equipment 1.2

Note: Benchmarked studies of 22 data centers performed 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)

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 impacts 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.

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.

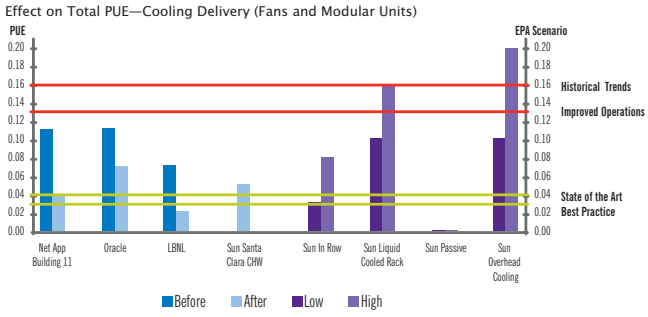
Cooling Infrastructures and Pathways

Given rapidly changing density trends, cooling 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, utilize 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 air flow 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 utilizing a state-of-the-art cooling delivery system.



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

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

NetApp, Oracle, LBNL – All locations "implemented optimized air flow 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]

Best Practices and Site Infrastructure Recommendations for an Energy Efficient Data Center

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 utilize 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. Their mission includes a focus 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 effect the efficiency of a data center include:

- Power distribution units and/or transformers that operate well below their full load capabilities

[2] APC Whitepaper #130, "The Advantage of Row/Rack Orientated Cooling Architecture for Data Centers," Dunlap K, Rasmussen N.

[3] Silicon Valley Leadership Group: Data Center Energy Forecast Final Report, July 11, 2008

[4] Silicon Valley Leadership Group: Sun Microsystems Energy Efficient Modular Cooling Systems

- 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 utilizing 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 air flow as well as ensures proper cooling capacity to the IT computing load. This is also important in traditional data center utilizing 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.

Environmental Impacts

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."

[5] The Green Grid "Guidelines for Energy Efficient Datacenters" February 16, 2007

[6] Silicon Valley Leadership Group: Data Center Energy Forecast Final Report, July 11, 2008

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).

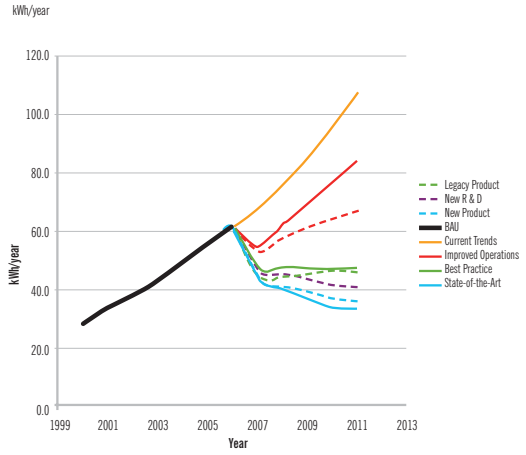
New commissions and legacy retrofits can:

- 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).

This graph represents the increase in data center energy usage.



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

These figures should motivate companies to adopt available technologies so their data centers can achieve or exceed these results.

Conclusion

As data center power consumption continues to grow, it impacts 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 such as those discussed in this paper.

Learn more about how to design an efficient data center in our white paper entitled, "Data Center Design and Infrastructure Considerations." Order your copy at **anixter.com/dcdesign**

About Anixter

As a global distributor of communications products, Anixter has the knowledge and products to make a data center more energy efficient. Anixter can manage the entire process by providing comprehensive and timely knowledge of data center issues. Anixter can also help you select the best products for your applications, including sourcing and supplying the most progressive products and services in the industry.

In addition the selecting the proper power and cooling products for your data center, Anixter can help with the deployment process of your project. The foundation to an efficient data center deployment project is having a distribution network leveraged for product inventory and coordinated deliveries with installation resources. Data centers require materials from multiple manufacturers to arrive at the right place, at the right time, to be installed on time and within budget.

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To learn more about Data Center College, go to **www.anixter.com/dcc**.

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