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White Paper

Top 10 Ways to Save Energy in Your Data Center

Even a small data center can save tens of thousands of dollars through smart choices in equipment and best practices

Get IT managers or CIOs together, and the topic will quickly turn to the biggest potential bottleneck in data center expansion: power. Although data centers can now pack more processing power into less real estate, high-density computing environments can be a huge drain on operating budgets, for several key reasons:

- **Expanding power demands**. High-density 1U/2U and blade servers that are required to satisfy business users' demands are consuming three to five times as much power as previous-generation equipment in the same footprint. Electricity consumption by U.S. data centers rose 39 percent between 1999 and 2005, according to an Uptime Institute survey of members (www.uptimeinstitute.org).
- **Increasing power costs**. Utility rates have risen three times in the last year alone, accounting for 20 to 30 percent of data center operating costs. For many IT organizations, energy costs represent the largest component of total cost of ownership – and the most stifling influence on IT expansion. According to IDC, for every dollar spent on new IT hardware, an additional 50 cents is spent on power and cooling, more than double the ratio of five years ago.
- **Excessive heat**. Blade servers generate a lot of heat. At 30 kW of power consumption per rack, you would need the equivalent of two five-ton household AC units for cooling. Cooling requirements add huge costs to the energy bill for data center expansion.

If you manage a data center—or engineer the architecture for clients who do—you know how critical these issues have become. It is a challenge to conserve energy while supporting these growing loads, without bringing unwanted governmental scrutiny or surcharges for being an energy hog.

The good news is that even a small data center can save tens of thousands of dollars simply through wise choices in management practices, IT hardware, power and cooling infrastructure. For example, the three-year utility savings from an energy-efficient server can nearly equal the cost of the server itself. Couple this strategy with energy-efficient power and cooling systems, and a mid-sized data center with 1500 servers could save millions of dollars—while reducing your organization's carbon footprint.

Sound good? It ought to. If the idea of dramatically reducing energy costs intrigues you, read on to discover how to gain this edge for your organization.

With available technologies and best practices, IT managers can reduce energy consumption by up to 50 percent, without compromising availability or reliability in the data center.

Top 10 Ways to Save Energy in the Data Center

1. Turn off idle IT equipment.
2. Virtualize servers.
3. Consolidate servers, storage and data centers.
4. Turn on the CPU power management feature.
5. Use IT equipment with high-efficiency power supplies.
6. Use high-efficiency uninterruptible power systems (UPSs).
7. Adopt power distribution at 208V / 230V.
8. Adopt best practices for data center cooling.
9. Conduct an energy audit of your data center.
10. Prioritize actions to reduce energy consumption.

1. Turn off idle IT equipment.

Issue: *IT equipment consumes high levels of power even when operating under light loads.*

IT equipment is usually very lightly used, relative to its capacity. Servers tend to be only 5 to 15 percent utilized, PCs 10 to 20 percent, direct-attached storage devices 20 to 40 percent, and network storage 60 to 80 percent.

When any of these devices becomes idle (because its workload is far below its capacity), the equipment still consumes a significant portion of the power it would draw at maximum utilization. A typical x86 server consumes 30 to 40 percent of maximum power even when it is producing no work at all. For every idle moment, that’s money in, nothing out—the kind of inefficiency that data center managers can no longer accept.

Solution: *Power down or retire underutilized equipment.*

The most obvious first step is to identify underutilized pieces of equipment and power them down. If a system hosts only one rarely used application, there may be resistance to retiring it, but there may be more cost-effective ways to serve that niche. Energy economics and sound IT portfolio management practices should prevail.

Another strategy is to identify and remove “bloatware”—ineffective software that uses excessive CPU cycles. More efficient software helps reduce CPU cycles, which enables a platform to generate more real processing output for the same power input.

2. Virtualize servers and storage.

Issue: *IT equipment consumes nearly maximum power even when it is underused.*

This is the same issue as above, but here it appears for a different reason. In this case, applications are inefficiently deployed across multiple systems—a dedicated server and storage for each application—just to maintain lines of demarcation among applications. Each platform consumes nearly all of the power it would require at peak load, yet each is doing very little work for the money.

Solution: *Use virtualization to increase utilization.*

With virtualization, data center managers can aggregate servers and storage onto a shared platform, while maintaining strict segregation among operating systems, applications, data and users. Most applications can run on separate “virtual machines” that, behind the scenes, are actually sharing the hardware with other applications. Virtualization dramatically improves hardware utilization and enables you to reduce the number of power-consuming servers and storage devices.

“It is reasonable to assume that virtualization will improve server use from an average of 10 to 20 percent for x86 machines to at least 50 to 60 percent in the next three to five years,” wrote Rakesh Kumar in “Important Power, Cooling and Green IT Concerns” (Gartner RAS Core Research Note G00145094, January 2007).

An Eaton customer looked at virtualization and found the opportunity to reduce its portfolio of 1000 servers to about 200 servers. Even if we assumed that utility power costs are only 10 cents a kilowatt-hour, this customer stands to save $700,000 in the first year alone.

Granted, virtualization will not be the salvation for everyone. Your data center might have to be designed for periodic peak loads, such as seasonal peak volumes for a retailer. In that case, having underutilized, idle hardware is just par for the course. But virtualization can bring great benefits for most typical data centers.

“Server virtualization could maximize operating levels and significantly reduce the number of physical servers required to have a direct effect on overall power consumption. Given rising energy costs, such a step could more than offset the additional software cost of virtualization.”

Stephen Prentice, in *Why Cool Is Now ’Hot’ for IT Planners*
Gartner RAS Core Research Note G00138041, May 2006

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3. Consolidate servers, storage and data centers.

Issue: *IT equipment consumes nearly maximum power even when it is underused.*

Is this issue starting to sound familiar? For whatever reason the equipment is underutilized, it is bad news for energy efficiency, because energy is being expended for relatively little productive output. In this third case, the equipment is underused because applications, storage or even whole data centers are duplicated across physical hardware or locations when they don't have to be.

Solution: *Consolidate many units of lightly used equipment into fewer, more productive systems*.

At the server level, blade servers can really help drive consolidation, because they provide higher density computing for the power consumed. That is, for a given amount of energy input, you get more processing output from a blade server, because each blade shares common power supply, fans, networking and storage with other blades in the same blade chassis.

Compared to traditional rack servers, blade servers can perform the same work for 20 to 40 percent less power. At 10 cents per kilowatt-hour for utility power, a data center with 1000 servers could save up to $175,000 a year simply by using more blade servers.

A second opportunity exists in consolidating storage, an issue that looms larger than ever, given users' growing appetite for graphics and video, along with regulatory requirements to archive more data than ever. While data center managers watch storage volumes mount, they are actually presented with an exciting opportunity to reduce energy usage in two key ways:

- *Tiered storage*. The larger the disk drive and slower its operating speed, the more efficient its energy usage. Consider using high-speed drives only where necessary, and using drives with lower rates for applications that don't require instant response.
- *Consolidated storage*. Since larger disk drives are more efficient, consider consolidating storage to improve utilization and warrant the use of those larger drives.

For example, if you replaced 44 mid-tier drives (885 terabytes in 146-Gb drives) with two high-end systems (934 terabytes in 146-Gb and 300-Gb drives), the data center could trim energy consumption for servers by 50 percent to save $130,000 a year.

If underutilized data centers could be consolidated in one location, the organization would reap great savings by sharing cooling systems and backup systems to support loads—not to mention the obvious real estate savings.

4. Turn on the CPU power management feature.

Issue: *The CPU itself could be consuming more power than necessary.*

More than 50 percent of the power required to run a server is used by the central processing unit (CPU), the single largest energy-grabber in a server. Major chip manufacturers such as

Intel and AMD are developing more energy-efficient chipsets, and dual- or quad-core technologies are processing higher loads for less power—but there are other options for reducing CPU power consumption.

Solution: *Vary the CPU's power consumption to match utilization.*

Several CPUs available today have a power management feature that optimizes power consumption by dynamically switching among multiple performance states (frequency and voltage combinations) based on CPU utilization, without having to reset the CPU.

When the CPU is operating at low utilization, the power management feature minimizes wasted energy by dynamically ratcheting down processor power states (lower voltage and frequency) when peak performance is not required. Adaptive power management reduces power consumption without compromising processing capability.

If the CPU operates near its maximum capacity most of the time, this feature would offer little advantage, but it can produce significant savings for typical scenarios, where CPU utilization is quite variable. If a data center with 1000 servers reduced CPU energy consumption by even 20 percent, this would translate into an annual savings of $175,000.

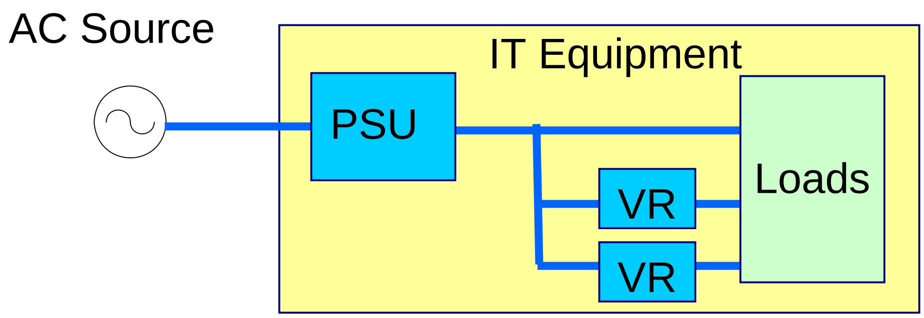
Many users have purchased servers with this CPU capability but have not enabled it.
If you have the feature, turn it up. If you don't have it, consider its potential when making future server purchases.

5. Use IT equipment with high-efficiency power supplies.

Issue: *Power conversion within the server could be consuming more power than necessary.*

After the CPU, the second biggest culprit in power consumption is the power supply unit (PSU), which converts incoming alternating current (AC) power to direct current (DC) and requires about 25 percent of the server's power budget for that task. Third are the point-of-load (POL) voltage regulators (VRs) that convert the 12V DC current into the various DC voltages required by loads such as processors and chipsets (Figure 1).

Figure 1: IT Equipment Power Conversion and Distribution Architecture



Overall server efficiency therefore depends on the efficiency of the internal power supply and voltage regulation. The typical PSU operates at around 80 percent efficiency – often as low as 60 or 70 percent. In a standard server, with the PSU operating at 80 percent efficiency and voltage regulators operating at 75 percent efficiency, the server's overall power conversion energy efficiency would be around 60 percent.

Solution: *Use certified energy-efficient power supplies and voltage regulators*.

Several industry initiatives are improving the efficiency of server components. For example, EPA Energy Star programs related to enterprise servers and data centers (www.energystar.gov/datacenters) and 80PLUS-certified power supplies (www.80plus.org) are both increasing the efficiency of IT equipment.

The industry really took notice when Google presented a white paper at the Intel Developer's Forum in September 2006, saying it had increased the energy efficiency of typical server power supplies to at least 90 percent, up from 60 to 70 percent previously (services.google.com/blog_resources/PSU_white_paper.pdf?prl).

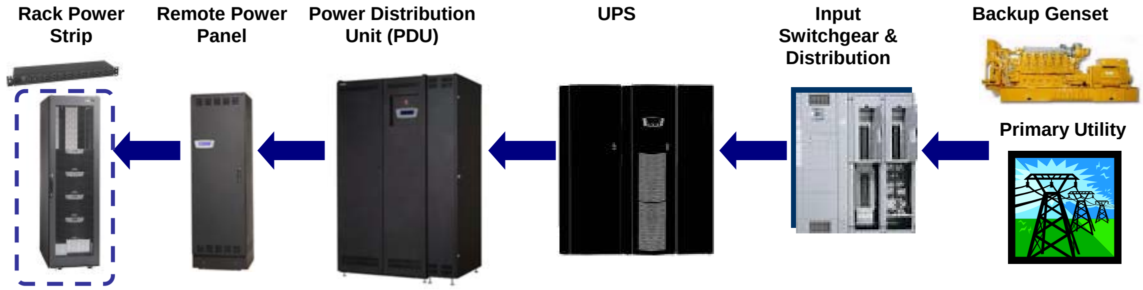
The initial cost of such an efficient power supply unit is higher, but the energy savings quickly repay it. If the power supply unit operates at 90 percent efficiency, and voltage regulators operate at 85 percent efficiency, the overall energy efficiency of the server would be greater than 75 percent. A data center with 1000 servers could save $130,000 on its annual energy bill by making this change alone.

6. Use high-efficiency UPSs.

Issue: *Power distribution and power quality systems can sap power.*

Most IT equipment is not directly powered from the facility power source. Power typically passes through an uninterruptible power system (UPS) for power assurance and power distribution units (PDUs) that distribute the power at the required voltage throughout racks and enclosures (Figure 2).

Figure 2: Data Center Power System



Between the incoming utility feed and IT equipment is a 'power chain' of several components, each one contributing to energy loss to some extent.

PDUs typically operate at a high efficiency of 94 to 98 percent, so the efficiency of the power infrastructure is primarily dictated by power conversion efficiency in the UPS. How much power does your UPS consume to do its job, keeping voltage within acceptable limits and supplying battery backup during utility outages?

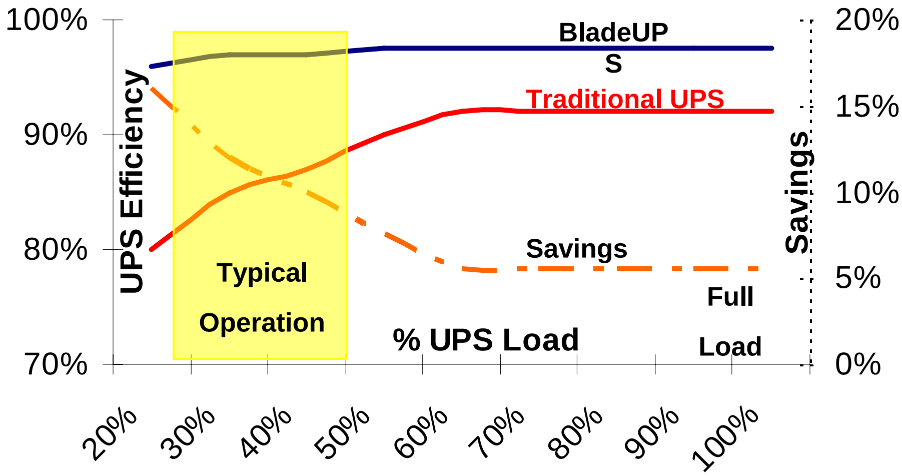
Solution: *Take advantage of new, high-efficiency power protection systems.*

Advances in UPS technologies have greatly improved the efficiency of these systems. In the 1980s, most UPSs used silicon-controlled rectifier (SCR) technology to convert battery DC power to sinusoidal AC power. Products using this technology operated at a low switching frequency and were 75 to 80 percent efficient at best.

With the advent of new isolated gate bipolar transistor (IGBT) switching devices in the 1990s, switching frequency increased, power conversion losses decreased accordingly, and UPSs could run at 85 to 90 percent efficiency. When even higher-speed switches became available, there was no need for UPS solutions to include transformers, which helped boost efficiency to 90 to 94 percent. The new Powerware® BladeUPS™ from Eaton®– optimized for today's IT equipment power supplies – operates at 97 percent efficiency.

Don't take vendors' efficiency ratings at face value. When evaluating a UPS, it's not enough to know the peak efficiency rating it can deliver at full load (the efficiency figure usually given). You are unlikely to be operating the UPS under full load. Since so many IT systems use dual power sources for redundancy, the typical data center loads its UPSs at less than 50 percent capacity, as little as 20 to 40 percent in some cases. You would expect efficiency to be lower when the UPS is operated at partial loads, but to what degree?

Previous-generation UPSs (those bought before 1990) are markedly less efficient at low loads. Even most of today's UPSs are noticeably less efficient under the low loads typically expected of them. For the very energy-conscious IT manager, the new Powerware BladeUPS system offers a very high efficiency profile of 95+ percent, all the way down to 20 percent loading.



Even small increases in UPS efficiency can quickly translate into thousands of dollars. If the new UPS consumed even 10 percent less power than a legacy UPS, a data center with 1000 servers could save more than $86,000 in energy costs. In addition to dramatic cost savings, high UPS efficiency extends battery runtimes and produces cooler operating conditions within the UPS. Lower temperatures extend the life of components and increase overall reliability and performance.

"Replacement of aging equipment with alternatives that consume less power may be more viable than you might think, when long-term energy pricing is factored into the total cost of ownership (TCO) evaluation."

Stephen Prentice, in *Why Cool Is Now 'Hot' for IT Planners*
Gartner RAS Core Research Note G00138041, May 2006

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7. Adopt power distribution at 208V / 230V.

Issue: *IT equipment could be operating at its least efficient voltage rating.*

To satisfy global markets, virtually all IT equipment is rated to work with input power voltages ranging from 100V to 240V AC. The higher the voltage, the more efficiently the unit operates. However, most equipment is run off lower-voltage power, sacrificing efficiency for tradition.

Solution: *Adopt the most efficient power distribution voltage the equipment can accept.*

Just by using the right power cord to the equipment, you could save money. An HP ProLiant DL380 Generation 5 server, for example, operates at 82 percent efficiency at 120V, 84 percent efficiency at 208V and 85 percent at 230V. A data center could gain that incremental advantage just by changing the input power (and the power distribution unit in the rack).

What about power distribution in the data center? Typically the UPS operates at 480V, and a power distribution unit (PDU) steps down that power from 480V to 208V or 120V. If you could eliminate that step-down transformer in the PDU by distributing power at 400/230V and operating IT equipment at higher voltages (using technology available today), the power chain would be more efficient. Distributing power at 400/230V can be three percent more efficient in voltage transformation and two percent more efficient in the power supply in the IT equipment. This slight increase in efficiency is still worthwhile; a data center with 1000 servers could save $40,000.

AC or DC power distribution in the data center?

There has been a lot of talk in the market about using high voltage DC power in the data center instead of AC power distribution. DC power can be about five percent more efficient, compared to AC power—but at a cost.

First, you would have to have IT equipment that can support high-voltage DC power, and the ability to deal with issues of fault protection and arc flash. There are no Underwriter's Laboratory (UL) safety standards for high-voltage DC in data centers yet, compared to the mature standards for AC systems.

In short, with high-voltage DC power, the safety risks are greater and the potential gain is minor. New, high-efficiency UPSs, such as the Powerware BladeUPS, can achieve similar efficiency on AC power distribution systems

8. Adopt cooling best practices.

Issue: *Too much of the power budget goes to cooling.*

As much as 30 to 60 percent of the data center utility bill goes to support cooling systems, including air handlers and chiller systems. If that figure seems too high, it is. Many computer room cooling systems are inefficiently deployed or not operated at recommended conditions.

Solution: *Simple, affordable practices can enhance cooling capabilities and reduce costs.*

Your organization might have some ready opportunities to reduce cooling costs through best practices:

- Use hot aisle/cold aisle enclosure configurations. By alternating equipment such that there is an aisle where there is a cold air intake and another with hot air exhaust, you can create a more uniform air temperature throughout the data center.
- Use blanking panels inside equipment enclosures so air from hot aisles doesn't mix with air from cold aisles.
- Seal cable outputs to minimize "bypass airflow," whereby cool air is short cycling back to cooling units instead of circulating evenly throughout the data center. This phenomenon affects as much as 60 percent of the cool air supply in computer rooms.

- Orient computer room air conditioning units close to the enclosures and perpendicular to hot aisles, to maximize cooling where it is needed most.

Further optimization of cooling systems can be achieved by using:

- Air handlers and chillers that use efficient technologies such as variable frequency drives (VFD)
- Air- or water-side economizers
- Humidity and temperature settings according to ASHRAE guidelines (http://tc99.ashraetcs.org/)

Take our hypothetical data center with 1000 servers; if this data center could trim 25 percent from its cooling costs using these practices, the annual energy savings would be $109,000.

The right UPS can minimize cooling costs.

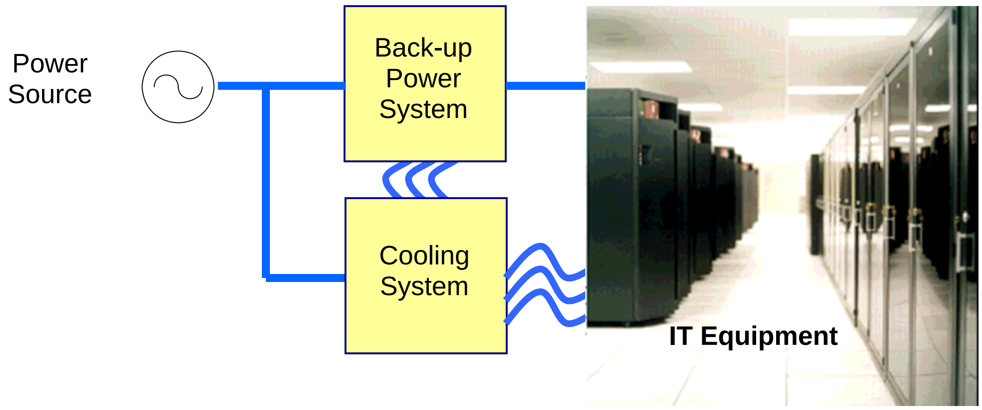
A more efficient UPS dissipates less power as heat and therefore reduces the cost of cooling. For example, a UPS operating at 97 percent efficiency can reduce air conditioning costs by $246 a month for a 60 kW system, compared to a model that rates only five points lower in efficiency.

The savings compound with data center size. For example, in a mid-sized data center with 200 racks at 15 kW per rack, the more efficient UPS would reduce cooling requirements by 47 tons. A large data center with 2000 racks at that same density could expect a 469- ton reduction in AC requirements just by selecting the more efficient model.

9. Conduct an energy audit of your data center.

Issue: *Easy opportunities for energy savings could be right at hand.*

Many data center managers don't know the efficiency of their IT equipment or the site infrastructure—or have a clear path in mind for maintaining and improving that efficiency. There's a lot of low-hanging fruit being overlooked, readily available opportunities to substantially reduce energy costs and become "greener" in the process.



Solution: *Assess data center efficiency, and compare it to industry benchmarks.*

How much of the data center power budget goes to IT systems, and how much to support systems? For every kilowatt-hour of power being fed to IT systems, how much real IT output do you get? The answers to these questions provide a picture of how much power is consumed for every unit of data center productivity, such as Web pages served, transactions processed or network traffic handled.

Data center efficiency can be calculated as the ratio of two components:

$$\text{Data center efficiency} = \text{IT efficiency} \times \text{Data center site infrastructure efficiency} = \frac{\text{IT output}}{\text{Data center power}}$$

In this equation:

- *IT efficiency* is the total IT output of the data center divided by the total input power to IT equipment
- *Site infrastructure efficiency* is the total input power to IT equipment, divided by the total power consumed by the data center
- *IT output* refers to the true output of the data center from an IT perspective, such as number of Web pages served or number of applications delivered

In real terms, IT efficiency shows how efficiently the IT equipment delivers useful output for a given electrical power input. Site infrastructure efficiency shows how much power fuels that IT equipment, and how much is diverted into support systems, such as backup power and cooling.

These figures enable data center managers to track efficiency over time and reveal opportunities to maximize IT output while lowering input power, and to reduce losses and inefficiency in support systems.

Although there are no true industry benchmarks for IT efficiency, there are some industry benchmarks for *site* infrastructure efficiency. The Uptime Institute recommends an approach called the Power Usage Effectiveness (PUE) ratio, where:

$$\text{PUE} = \frac{\text{Total data center power}}{\text{IT equipment power}} = \frac{1}{\text{Site infrastructure efficiency}}$$

In this equation, total facility power is the total power required to support all IT equipment, backup power systems and cooling systems. IT equipment power is the actual line cord power drawn by all IT equipment in the data center. A practical approximation for the IT equipment power would be the output power from UPSs.

After applying this calculation to several data centers, the Uptime Institute recommends an ideal PUE of 1.6 and a realistic goal PUE of 2 for a well-designed and operated data center. The Institute estimates that most U.S. data centers have a PUE of 3.0, with an average of 2.4.

10. Prioritize actions to reduce energy consumption.

Auditing the energy efficiency of your data center will help identify and prioritize opportunities to reduce energy consumption. You could have definite opportunities to improve energy efficiency by taking any of these actions:

- Identifying and powering down underutilized equipment
- Increasing equipment utilization through virtualization and consolidation
- Selecting high-efficiency IT equipment (CPUs, power supplies and voltage regulators)
- Upgrading UPSs to higher efficiency technology
- Implementing energy-efficient practices for cooling
- Adopting power distribution at 208V/230V

In a greenfield data center or major expansion/upgrade of an existing data center:

- Get executive-level sponsorship, and form a cross-functional team to develop an energy strategy for IT operations
- Include energy efficiency as a key requirement in design criteria, alongside expectations for reliability and uptime
- Consider energy efficiency in calculations of total cost of ownership when selecting new IT, backup power and cooling equipment

Conclusion

"The cost of electricity can no longer be ignored in IT," wrote Stephen Prentice in a Gartner Research report (*Why Cool Is Now 'Hot' for IT Planners,* May 2006). "Enterprises should take steps to understand the total power consumption in their IT environments as a preliminary move toward aggressive power reduction programs through all means available, since cost savings may be substantial."

When you combine energy-efficient IT equipment, power infrastructure and cooling strategies, the cumulative effect presents a powerful business case. Consider the example of a 1U server using 300 watts of power to do its work. In a typical data center, this 1U server would require about 1341 watts to operate. In three years, you would spend $3,500 to power this server, which is probably about what you paid for it in the first place.

Imagine you had best-in-class equipment and process – energy-efficient servers, power delivery and cooling systems. Now the 1U server requires only 696 watts to operate. In three years, your best-in-class equipment and best practices would save more than $1,700 in energy costs.

The savings quickly compound. A small data center with 350 such servers would save more than a half-million dollars in three years. Our hypothetical data center, the one with the 1000 servers… if it could capitalize on all of the energy-saving strategies described here, the savings would top $1.5 million a year.

With a more efficient allocation of power, you will not only reduce utility bills and total operating cost, but also achieve more with available backup power and cooling systems – delaying the point where those systems would have to be upgraded to match data center expansion.

With best practices and the right choice of equipment, data center managers can reduce energy consumption by nearly 50 percent.

That means that almost half of the power utility bill will fuel actual IT processing, compared to less than 25 percent of the power supplied to a nominal data center today.

About Eaton

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- **UPS products**—Rackmount and freestanding power protection systems for applications from the simplest desktop to the largest government, healthcare or industrial facilities
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