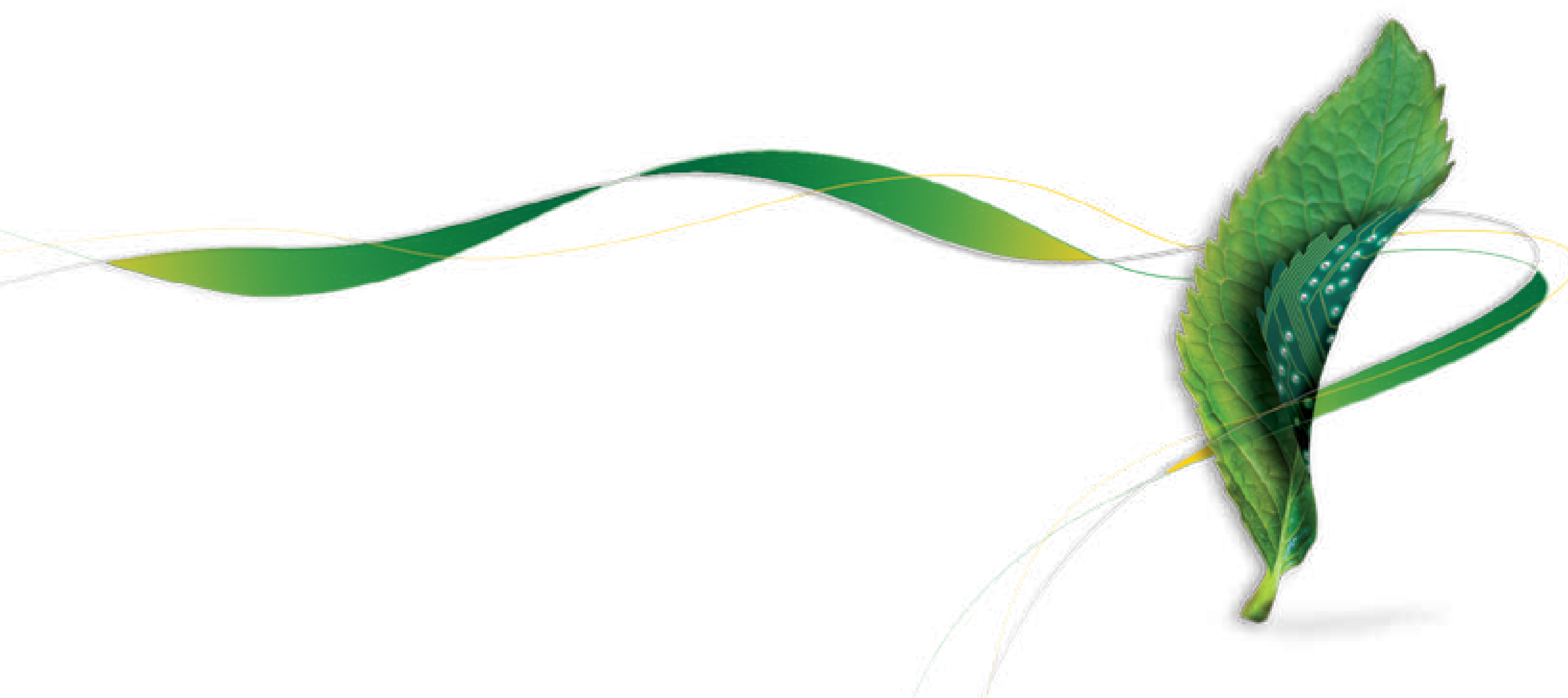
SOLUTIONS
WHITE PAPER



Reducing Data Center Power and Energy Consumption:

Saving Money and "Going Green"

gtsi®

Contents

Executive Summary

There are several compelling forces driving companies and government agencies to adopt a strategy for greening the data center. The recognition that there is a finite budget for operations and a finite amount of energy for power and cooling has made organizations aware that green IT is a practical way to optimize their data centers, reduce costs, consume less energy, and implement sustainable energy conservation measures to serve the public good.

Before embarking on a green strategy, it is vital that organizations view the data center holistically, from its design, layout, and cooling architecture to the technology infrastructure, applications, and lighting. This type of assessment should be undertaken for all data centers that are considering options to reduce power usage and costs.

The growing amount of energy consumed by a data center for powering equipment along with heating and cooling has led to higher operating costs and dwindling energy supplies. Recent data shows that data centers' power usage today has greatly exceeded past levels, and estimates indicate that this trend will continue. Companies and government agencies have reached a critical point where they recognize that they can no longer maintain the status quo for how their data centers use power.

While some strategies are best suited only for new data centers (new construction or retrofit), many ideas can be implemented in today's data centers. This paper will examine some of the most prevalent ways to save power in the data center today and the potential cost savings as well as other benefits gained by implementing power saving technology.

Achieving Power and Cost Savings Through Technology Applications and Energy Conservation Methods

For the purposes of this white paper, IT equipment refers to hardware such as servers, switches, and storage that use electricity in the data center. This paper begins by addressing IT equipment as it represents the largest area of potential savings, and it will later review similar savings opportunities in non-IT equipment.

IT Equipment

Recent estimates indicate that 60-70 percent of a data center's electricity is used by the IT equipment, with the rest dedicated to cooling, power conditioning, and lights. Table 1 gives a breakdown of the three major types of IT equipment and the total percentage of power they use in the data center.

Table 1

Component	IT Equipment % Usage	% of Total Power
Servers	56%	33.6%
Storage	27%	16.2%
Networking	17%	10.2%

In Table 2, the projection that a rack could consume an estimated 25kW of power is based on very dense systems, such as the HP C-class blade system, which provide significant computing and performance advantages. Racks configured for high density, however, can have unanticipated costs. For example, the C-class system is a 10U chassis with up to 16 half-height blades, each with up to dual-socket, quad-core CPUs, for a total of 256 cores per chassis. With four (4) chassis per 42U rack, there is a total of 1024 cores per rack. This means that if each chassis requires 5.5+kW, then more than 20kW will be needed at the rack.

High-density computing means increased power density, causing much faster thermal rise than in older, lower-density systems. A data center with an average heat load of 40W per square foot can cause a thermal rise of 25˚F in 10 minutes, while an average heat load of 300W per square foot can cause the same rise in less than a minute (Ziff Davis, 2006). In this scenario, there is not only an increase in the amount of money spent on electricity, but also the data center infrastructure is also at greater risk in case of a disaster, where a 25˚F increase in one minute can potentially cause sensitive electronic components to literally fry in three to four minutes.

Virtualized Server Infrastructure

Virtualization, in addition to its many other benefits, can help data centers save up to 40 percent of the power dedicated to the server infrastructure. Used since the 1960s in computing, virtualization is a broad term that refers to the abstraction of computing resources. But virtualization really refers to encapsulation—a technique for hiding the physical characteristics of computing resources from the way in which other systems, applications, or end users interact with those resources. Through encapsulation, the state of a virtual machine can be saved to disk and then the virtual machine can be restarted in the time that it takes to reload the data from the disk. Virtualization creates an external interface that hides an underlying implementation by combining resources at different physical locations or by simplifying a control system. The recent development of new virtualization platforms and technologies has refocused attention on this mature concept.

Software such as VMware (or XEN or Microsoft Virtual Server) can transform or virtualize the hardware resources of an x86-based computer—including the CPU, RAM, hard disk, and network controller—to create a fully functional virtual machine that runs its own operating system and applications just like a "real" computer. Note that virtual machines can cover most x86 operating systems (e.g., Windows, Linux, or Solaris x86). Multiple virtual machines share hardware resources without interference so that a single computer can run several operating systems and applications at the same time.

Table 2

	Power Required/ Rack	Heat Output/Sq. Ft.
Data centers of the recent past	2kW	40W
2007 data centers (average)	10kW	200W
Data centers of the near future	25kW	500W

Table 3

Virtualization Capabilities	Benefits
Server Consolidation/Infrastructure Optimization: Virtualization makes it possible to achieve significantly higher resource utilization by pooling common infrastructure resources and breaking the legacy "one application to one server" model.	Fewer servers are needed, and therefore less infrastructure (racks, power, cooling, switches, etc.). Less is spent on maintenance, training, administration costs, etc.
Physical Infrastructure Cost Reduction: Virtualization reduces the number of servers and related IT hardware in the data center. This leads to reductions in real estate, power, and cooling requirements, resulting in significantly lower IT costs.	Fewer servers are needed, and therefore less infrastructure (racks, power, cooling, switches, etc.). Less is spent on maintenance, training, administration costs, etc.
Improved Operational Flexibility & Responsiveness: Virtualization offers a new way of managing IT infrastructure and can help IT administrators spend less time on repetitive tasks such as provisioning, configuration, monitoring, and maintenance.	Less is spent on administration costs and there are measurable gains in efficiency. Procedures and processes are affected as the entire server provisioning process decreases by a factor of 10.
Increased Application Availability & Improved Business Continuity: Data centers can eliminate planned downtime and recover quickly from unplanned outages with the ability to securely back up and migrate entire virtual environments with no interruption in service.	Less downtime, resulting in better productivity and reliability.

In general, virtualization happens by placing a thin layer of software directly on the computer hardware or on a host operating system. This software layer contains a virtual machine monitor or "hypervisor" that allocates hardware resources dynamically and transparently so that multiple operating systems, each contained within its own virtual machine, run concurrently on a single physical computer. In the case of VMware, the hypervisor is referred to as the ESX server. (See Figure 1.)

The act of virtualizing a single physical computer is just the beginning. VMware offers a robust virtualization platform that can scale from one physical machine to across hundreds of interconnected physical computers and storage devices to form an entire virtual infrastructure. Figure 2 shows a representation of a fully virtualized data center.

Virtualization is utilized to support various data center related initiatives. Table 3 looks at several reasons to virtualize and the benefits to the adoptee.

VMotion

One of virtualization's greatest benefits is the ability to move one virtual machine from one physical machine to another in real time, without the users on the virtual machine experiencing any downtime or knowing that the move has occurred. This is most commonly referred to as VMotion and is utilized for scheduled hardware maintenance tasks to ensure zero downtime of critical services (See Figure 3).

Other Benefits of Virtualization

VMware also provides a technology called DRS (distributed resource scheduler), which enables virtual machines to be moved automatically from one physical machine to another to ensure that all virtual machines have the resources they require. These actions are based on policies implemented by administrators, but fulfilled by DRS. Furthermore,

Figure 1—A Look Inside a Virtual Machine

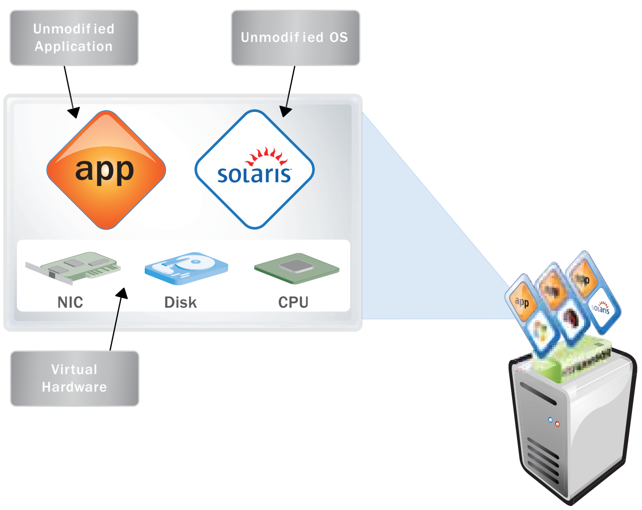


Figure 3—VMotion Technology

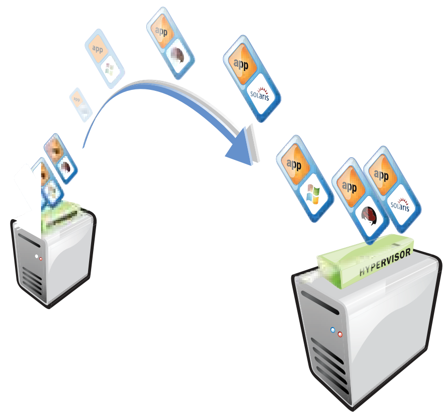


Figure 2—Virtualized Data Center

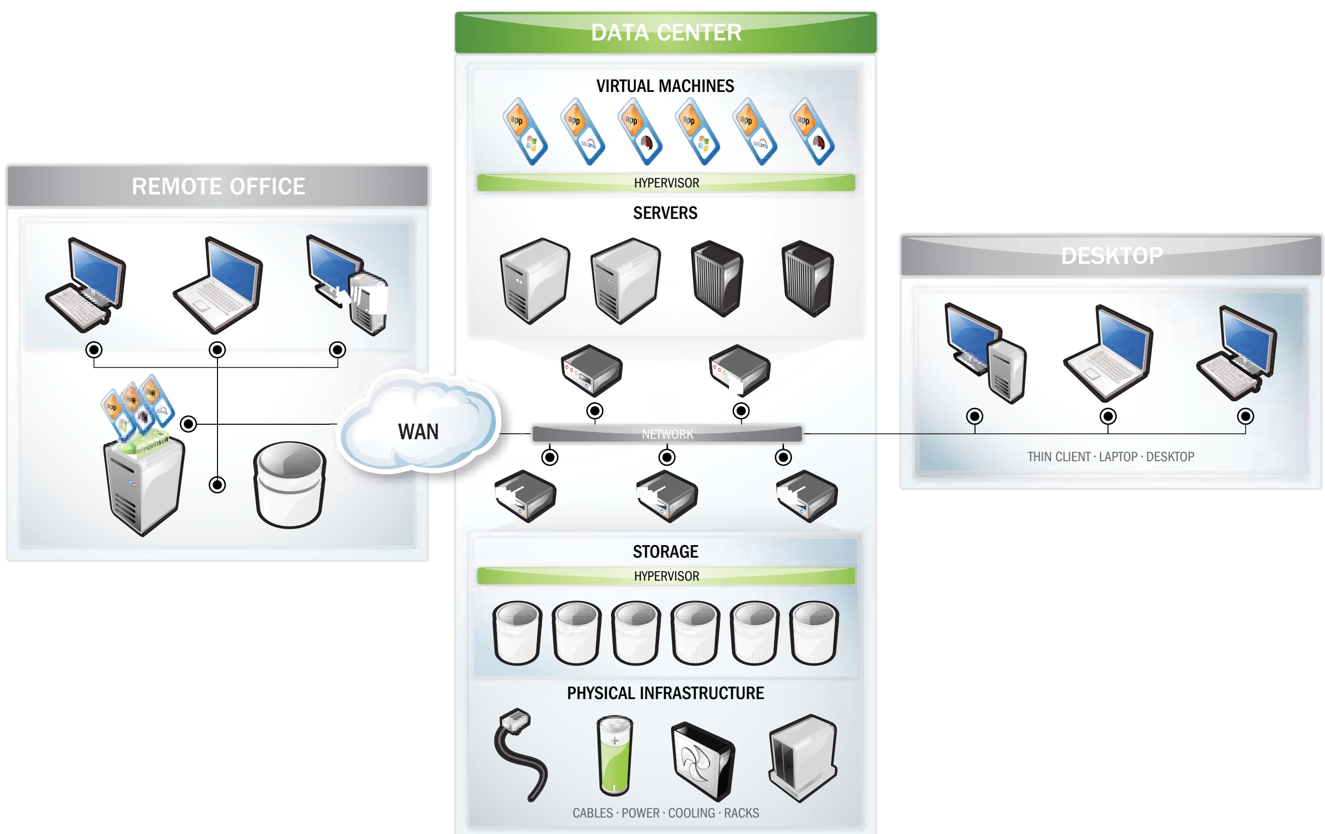
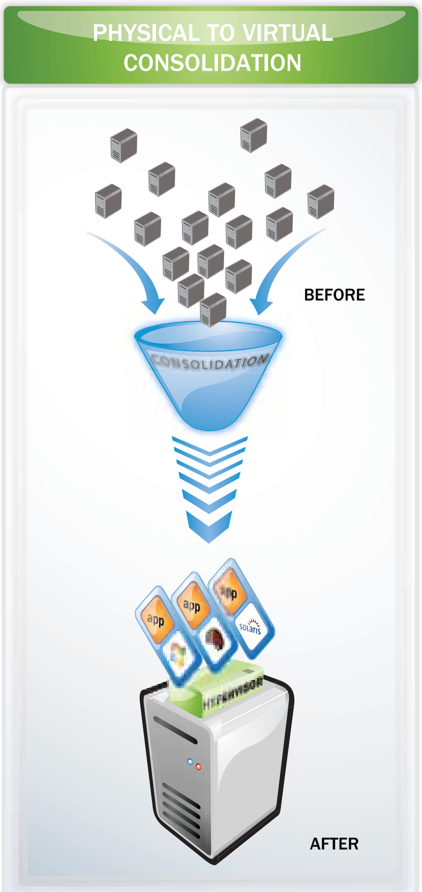


Figure 4—Consolidation: Customer Example



Before	
100 Physical Machines (2u)	
200u	
25,000 Watts	
After	
3 Blade Server Chasis	
30u	
8,127 Watts	

if architected correctly, virtual machines that are down due to a physical machine hardware issue can be automatically restarted with VMware's High Availability (HA) technology.

VMware has added a new technology that can shut down physical machines when load subsides and restart them when demand grows. For example, evenings are generally off-peak hours in which workloads are at a minimum because workers have gone home for the night. Because much of the server infrastructure is not needed, VMware can, if configured, gradually power off the servers during this time and then gradually power up additional servers in the morning as user demand grows. This new technology can have a dramatic effect on power consumption. Simply put, by powering off 33 percent of their servers for eight hours, data centers can decrease their total power bill by 12 percent and reduce air conditioning costs by nearly 25 percent.

These are only a few of the most prevalent benefits provided by implementing virtualization into the data center, and there are numerous degrees of savings, both tangible and intangible, that can be realized by moving to a well-designed and properly executed virtual infrastructure. Figure 4 depicts the impact that virtualization can have on data center consolidation initiatives.

By implementing a virtual infrastructure, the savings on electricity and cooling alone would show a positive return on investment (ROI) in an average of 3.5 years from acquisition.

Recommendations for Right-Sizing IT Equipment for Reduced Power Consumption

Data centers can realize a significant decrease in energy consumption by taking a few easy steps. The following recommendations for right-sizing IT equipment can have the greatest impact on the data center and by all accounts are very easy to implement.

Consolidate, Virtualize, Decommission
Consolidating services onto fewer and potentially more modern servers can result in significant power savings. In one instance, by removing stray "servers" from user workstations and bringing them into the data center, an organization was able to regain control over its equipment and make determinations as to whether or not this equipment needed to be running 24/7. Additionally, formalized backup procedures inherent in the data center could be utilized, protecting users from potential data loss.

Long-term monitoring of all of a data center's resources provides an accurate assessment of system utilization and equipment necessity. When systems, including servers, switches, and storage, are determined to be at end-of-life, a formal decommissioning process should be undertaken for the equipment's safe disposal. If a data center administrator determines that he/she wants to save any of the IT equipment to use as backup, powering down the equipment until it is needed will help eliminate needless use of power and cooling.

Up to 12 percent of the total electrical bill can be saved by employing modern-day best practices for data center layout.

Turn Off Unneeded Equipment
Are all servers, switches, SAN, or NAS systems powered up all the time? Is that necessary? These are the questions data center administrators and IT managers must ask. Turning off underutilized systems will help data centers conserve energy in two ways—reducing the amount of electricity needed to run the equipment and reducing the power to cool the equipment. Managers and administrators must move away from the "always on" mentality and look at powering down equipment that is not in use at that particular moment.

Data centers can benefit from VMware's enhanced virtualization functionality that enables administrators to set policies that recognize an underutilized, unnecessary system and power down the machine until loads demand its capabilities. As noted earlier, if services are at a peak during daytime hours, dynamically reallocating virtual machines in the evening may shrink the number of processors assigned to each application. The result will be fewer physical servers that need to be powered up through off-peak hours. As demands increase in the morning, VMware will gradually power on additional servers. The policies dictating these efforts can be set in a variety of ways, including CPU utilization and time, according to the preferences of the administrator.

Plan Appropriately for the Future
When planning for the future, it is necessary to think hard about right-sizing the equipment being purchased. This can be done most efficiently by taking a look at all of an organization's applications to determine what it is they do. Often, to account for growth, user requirements or demands well exceed the need for the services being requested. There are several tools available that will survey and monitor an organization's entire physical server inventory and provide a detailed analysis of what is being utilized. This information will greatly assist with consolidation efforts and is almost an absolute necessity when planning a virtualized infrastructure. Also, this information will help correlate the equipment or space that individuals or departments request with an organization's acquisition strategy.

This process can include assessing the impact that modern SAN systems with a virtualization layer built into them (called thin provisioning) can have on the data center to ensure all SAN space is used without waste.

Any time IT equipment is purchased, energy efficiency as well as the equipment price/performance must be considered. Vendors today try to accurately portray the true power usage of their processors. For example, AMD has moved from TDP (thermal design power—an indication of the theoretical power limit of the CPU) to a more accurate ACP (average CPU power—a measure of processor power draw while "running accurate and relevant commercially useful high utilization workloads"). AMD's quad core CPUs use the same amount of power as the older dual CPUs consume per socket. And the industry will have 6-way or 8-way cores available by the end of this year. Potentially, an upgrade to the latest core technology could be more than double the processing power without a corresponding increase in power usage. Intel, too, has developed more energy-efficient processors and has joined The Green Grid (http://www.thegreengrid.org) to promote the advancement of green computing technologies.

Today, many server vendors incorporate 90 percent energy efficient power supplies into their equipment. This is a marked improvement over traditional power supplies with a 60 percent or lower rating. A power supply's power rating is based on the maximum amount of power the device can deliver. Consequently, a 400W power supply in a server does not mean it is consuming 400W of power from the AC outlet. The actual power consumed from the power supply is solely a function of the load attached to it. A few percentage points, however, does make a difference.

For example:

R is the power supply's rated power.

E is its efficiency expressed as a fraction of 1 (i.e., 90 percent efficiency is expressed as 0.9).

A 400W (R=400) power supply with 90 percent (E=0.9) efficiency will waste 40 watts of power or 400 * (1.0 - 0.9).

The final number (40W) is only valid if the load is drawing the full 400W of power. With computer components that only draw 320W of power, this 400W power supply with 90 percent efficiency presents a different picture:

C, which replaces R in the above formula, represents the power draw of the computer:

C * (1 - E) = 320 * (1.0 - 0.9) = 32W

The number 32W indicates the power loss due to power supply inefficiency. With a 90 percent efficient power supply, this is not a substantial loss; however, the loss with a 60 percent efficient power supply has a different impact.

C * (1 - E) = 320 * (1.0 – 0.6) = 128W

When each server wastes 128W, and there are 20 servers per rack, the total amount of wasted power equals 2.56kW. This is 10 percent of the best-practices specifications for rack power usage. And because it is not unusual for a data center to have 20 or more racks, the numbers quickly mount, and at 50kW translate into an enormous waste of power. Further, the cost tied to 50kW in server electricity quickly becomes meaningful when reaching approximately $300,000 per year, depending on where the data center is located.

Data sheets of major systems manufacturers will list the power supply efficiency. Taking this data into account will help you determine which equipment will end up being the most cost efficient to operate.

Recommendations for Non-IT Equipment

According to the First Law of Thermodynamics, energy can be neither created nor destroyed. Therefore, when energy is added to a system it has to go somewhere. Servers take in electrical power and convert a significant portion of it to heat. Every time a data center adds new servers, more heat is produced, which doubles the amount of money spent on energy (once for powering the server and again to cool it).

The following is a list of common problems that reduce the efficiency of data centers (Rasmussen, 2006):

- Power distribution units and/or transformers operating well below their full load capacities.
- Air conditioners running with low output temperatures continuously dehumidify the air, which is then humidified with a humidifier.
- Air conditioners that expend heat while others in the same room are cooling.
- Air conditioners forced to consume excessive power to drive air against high pressures over long distances.
- Air conditioners operating with much lower return air temperature than the IT equipment exhaust temperature, reducing efficiency and capacity.
- Cooling pumps using throttling valves to adjust flow rate, dramatically reducing pump efficiency.

It is important to remember that 40 percent of a data center's power is used for lights, air conditioning, and other non-IT components. Creating a more efficient air conditioning architecture will have a significant impact through improved power usage and reduced costs.

Efficient Air Conditioner Architecture
Room-oriented, rack-oriented, and row-oriented cooling are the three methods used to cool data centers. Each has the following advantages and disadvantages:

- Room-oriented cooling, the historical method for cooling the data center, has one or more air conditioning systems working in parallel to push cool air into the data center while drawing out warmer ambient air. The basic principle behind this approach is that the air conditioners not only provide raw cooling capacity, they also constantly stir and mix the air in the room to bring it to a homogeneous average temperature, preventing hot spots.
- Rack-oriented cooling has computer room air conditioners (CRAC) mounted into a rack to decrease the airflow path length. This reduces the amount of CRAC fan power required to cool.
- Row-oriented cooling is where one row of rack-mounted CRACs is dedicated to high-density applications such as blade servers and another row meets the cooling requirement of lower-density applications such as communication enclosure. This method is the most efficient for high-density applications and also provides redundancy.

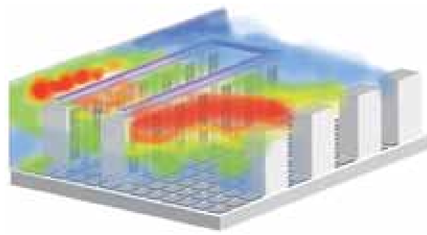
The traditional room-oriented architecture has technical as well as practical limitations because it cannot adapt to the needs of next-generation data centers and reliably support high and variable power density. For this reason, as well as to reduce electrical power consumption and other operating costs, both rack-oriented and row-oriented cooling architectures are gaining prominence. These two architectures are also more successful at cooling equipment with operating densities of 5kW per rack or greater.

Because there must be less distance between heat sources and heat removal systems to ensure proper airflow paths, the traditional method cancels out the ability for the hot and cold air streams to mix. By deploying an in-row air conditioning system with a horizontal airflow pattern, warm exhaust air is drawn from the hot aisle, cooled, and distributed into the cold aisle. This ensures that equipment inlet temperatures are constant and adequate for proper operation.

Closely coupling the air conditioner with the heat source provides warmer return air to the system. This design further increases the performance predictability by eliminating any chance of air mixing, which nearly eliminates the need for make-up humidification. With shorter air paths and less fan power, a data center can realize significant savings over its lifetime.

Some data centers are designed so that the hot aisle is fully contained. The hot aisle containment system ensures proper air distribution by completely separating supply and return air paths. The hot aisle is sealed off using doors and transparent ceiling tiles that extend the width of the hot aisle. Warm exhaust air is contained from the hot aisle, cooled, and distributed into the cold aisle, ensuring that equipment inlet temperatures are constant and adequate for proper operation. Anecdotal evidence indicates that this method works best with equipment running above 10–12kW per rack. And finally, some data centers are designed to use the cool night air as a cooling mechanism.

Figure 5—Cooling Architecture



A gap analysis can establish which cooling method will provide the best efficiency and cost effectiveness for a particular data center environment.

Efficient Floor Layout Design
Floor layout has a large effect on the efficiency of the air conditioning system. In fact, up to 12 percent of the total electrical bill can be saved by employing modern-day best practices for data center layout. For example, when designing a hot-aisle/cold-aisle configuration with aisle-based air conditioners, it is important to know how many kilowatts are allowed for each rack. If the answer is above 10kW, raised floors are useless. Even with 36-inch floors, not enough air can be pumped out of the floor vent holes to ensure that the servers in the top half of the rack are pulling in cool air.

Figure 5 shows an example of how cooling architecture affects air circulation.

Table 4

	Number of Circuits	Voltage	Amperes	Amount Delivered to Rack (de-rated)	Number of Circuits Required for Redundancy
120V option	3	120V	30 amp	8.6kW	8 circuits
208V option	2	280V	30 amp	9.98kW	4 circuits
208 3-phase option	1	280V 3-phase	30 amp	8.6kW	2 circuits

The blue at the bottom of the cool aisle represents colder air, and the yellow-green-orange colors at the top of the same row represent the hot air that the servers are taking in. The right-hand aisle's light-blue and greenish colors indicate that the air being expelled from the servers at the bottom is still relatively cool. At the top of the hot aisle, the reddest color indicates the air coming out of the servers is the hottest. In this scenario, it is vital to know that if equipment is drawing above 8kW per rack, raised floors may not be the most viable design. And in cases where the draw is above 12kW, hot aisle containment may be a better way to go.

Because both of these architectures require specific distances between rows, a professional assessment is probably the best way to ascertain which design will provide the highest ROI and energy efficiency.

Correctly Located Vented Floor Tiles

While the current best practice in data center cooling is to not use raised floors, many existing data centers already have them. These data centers may also have raised floors with vented tiles that are incorrectly located or improperly installed. All too often, the decision on where to place vented tiles is based on aesthetics or convenience. By relaying these tiles strategically, data centers have a very simple way to see immediate results and can save as much as 6 percent off their power bills. Once again, a professional assessment will help data centers gain the maximum benefits from the correct placement of tiles.

240V, 3-Phase Configuration

Today's IT equipment comes standard with universal power supplies that take a wide range of input power and most commonly can support 208V/230V power. In making a purchasing decision, understanding the difference between the two can lead to cost savings. While 208V power is more efficient than 120V power, the amount of power that a three-phase power whip can deliver, whether it is 20, 30, or 60 amps, is almost twice the power, or 1.73 times that of a single-phase whip. The lower number of power whips means that there are fewer cables at the bottom of the cabinet or under the floor to block airflow, fewer poles taken up at the power distribution panel, a lower number of cabinet power distribution units needed in the cabinet, greater power efficiencies, and less rework required as the data center expands or new equipment is brought in.

As an example, Table 4 shows how a rack of 10 HP DL380 servers that require 7.4kW to operate can provide power in a variety of ways.

With costs for each power whip estimated to be between $750 and $1,000, fewer whips equals less expenditure, which could potentially leave more funds for additional infrastructure improvements.

More Efficient Cooling Equipment

The Uptime Institute conducted a survey of 19 data centers with an average size of more than 200,000 square feet. Survey results indicated that, on average, only 40 percent of the cold air cooled the servers in the room. In fact, for every 100kW of power the computer equipment dissipated, there was 260kW of cooling capacity operating in the room. This means that instead of operating with the standard 1.25 times cooling capacity needed, these data centers had, on average, 2.6 times the cooling capacity required.

Many data centers may have multiple air conditioners that actually override the benefits of each; one may actually heat while another cools or one may dehumidify while another humidifies. Part of the problem stems from the phenomenal growth that some data centers have experienced and the ad-hoc cooling methods that were brought in to address hot spots. The latest best-in-class UPS systems have 70 percent less loss than legacy UPSs at typical loads.

Efficiency is a very difficult metric to validate when measuring many different pieces of equipment in the data center. A much better measurement is electrical power consumption. This is because total electrical consumption is the sum total of the power used by all devices in the data center. Consequently, if one device uses 1.5kW of electricity per month and another uses 2kW, it is a simple matter to add these values together.

Energy-Efficient Lighting
Lighting can have an impact on data centers' yearly electricity costs. Installing energy-efficient light bulbs along with turning out lights manually or remotely saves up to 2 percent in yearly electricity costs. The savings from reduced electricity use can be doubled because the heat produced by lighting itself will also reduce the amount of power used for cooling. Over the lifetime (15–25 years) of an average data center, the savings become significant.

Conclusion

In summary, there are many ways to save power in the data center. Some of them are easily accomplished (such as turning off unneeded equipment or installing blanking panels to assist in airflow), and some are more complex and require assessment work by competent professionals to ascertain how to best architect a solution with power savings in mind.

Going green in the data center is much like being on a diet. It takes effort and a lot of discipline to make the necessary changes to lead a healthier lifestyle. In the early phases of a diet, these changes are often uncomfortable and feel forced. But over time, the habits that were once uncomfortable become part of a daily routine.

Changing routines in the data center as part of a green strategy requires a concerted effort. Power and heat, and the costs associated with them, are quickly moving to the very forefront of data center problems. Savvy business and government agencies will need to refine and improve their approaches to power and heat management in the data center and capitalize on the power-saving opportunities discussed throughout this white paper.

Hopefully, this white paper successfully established the important role that power plays in the data center, gave guidance on how to calculate power usage, and provided a roadmap on how to implement power saving technologies that reduce costs and optimize performance. By answering "yes" to the following questions, data center administrators and IT managers can identify areas where power- and cost-saving measures should be implemented:

- Are there hot spots in my data center?
- Are there floor tiles stacked in the corner?
- Do I have systems "always on" and do they need to be?
- Is there supplemental air conditioning just to take care of hot spots?

Because a large percentage (84%) of data center managers cannot tell the number of watts per square foot that are in use, they can look for outside assistance and have an experienced power and cooling provider perform an assessment. A well-performed assessment can accurately ferret out the issues and provide the best recommendations for correcting problem areas. The ROI may not be immediate, say in the first year, but substantial cost savings can be created over the life of the infrastructure.

For more information on GTSI and our virtualization solutions, visit GTSI.com/virtualization, or call us at 800.999.GTSI.

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