STRATEGIES FOR SOLVING THE **DATACENTER SPACE, POWER, AND COOLING CRUNCH**

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Table of Contents

Chapter 1
Introduction

Driven by the need to continually deploy new applications and support a larger number of internal and external customers, IT organizations everywhere are finding themselves in a space, power, and cooling crunch. A legacy of silo-architected applications with no resource sharing, and legacy, energy-inefficient servers, all sized to handle the maximum possible workload, have conspired to push datacenters to the limits in terms of real estate and energy consumption. Indeed, many datacenters built to last 10 to 15 years have reached a premature end of life because they were not built to support the growth that actually has taken place.

Limited space, power, and cooling capacity has led many organizations to recognize that capital and operating expenses for datacenters have become an increasing part of their budgets over time — and the lack of flexibility caused by outdated, inefficient datacenters has begun to affect organizations' business agility.

In the face of rapidly escalating energy costs and the fact that datacenters are contributing to global greenhouse gas emissions at a similar rate as the airlines, organizations are realizing that increased datacenter efficiency can simultaneously reduce costs and increase business agility.

Sun has a two-step approach to datacenter efficiency:

- *Optimize power* in the datacenter by replacing aging equipment with up-to-date, more powerful, and more energy-efficient servers and storage. Use virtualization to consolidate onto a smaller number of systems. And address power and cooling inefficiency in every aspect of operations, from servers to the equipment yard.
- *Restructure datacenter spaces* with a modular, flexible design that's more efficient, better supports growth, and can handle the constant equipment churn that characterizes most datacenters today. Whether retrofitting existing space or designing new datacenters, Sun has experience that can help.

Sun has undertaken a project to restructure its own datacenter space worldwide, resulting in reductions in datacenter real estate of up to 66%, decreases in operating expenses of up to 30% — and the ability to avoid the cost of building new space.

Sun has made these strides through an innovative approach to datacenter design — one that's available to customers through a comprehensive set of service offerings. This paper summarizes the advice that Sun has to offer.

Chapter 2

Optimize Power

IT organizations can continue to build more and more datacenters, and consume more and more power, but that's not a responsible choice from either a financial or an ecological perspective. A better option is to optimize existing datacenter space, resulting in lower capital and operating costs as well as a reduced carbon footprint.

IT organizations can optimize power in their datacenters in several ways:

- Decommission servers that are no longer associated with a running IT service
- Replace aging, inefficient servers with current, more energy-efficient technology that can perform more work and consume less space, while using less power.
- Consolidate multiple workloads onto a smaller number of servers by using appropriate virtualization technologies
- Consolidate physical datacenters into a smaller number of more efficient facilities
- Deploy modern storage systems and tape libraries that hold more data while using less power
- Use a number of techniques for improving cooling system efficiency
- Rightsize tier levels by implementing only the level of redundancy that an organization really needs

A coordinated effort

Because server replacement results in higher density, and thus higher spot-cooling requirements, the steps outlined above need to be taken in a coordinated fashion. The good news is that server power-consumption reductions are amplified by savings in datacenter power and cooling requirements. Estimates of this impact vary, but it's generally accepted that every watt delivered to IT equipment requires at least one watt in overhead, including power distribution and cooling. In its August 2007 report titled "Institute Opinion on EPA Report," the Uptime Institute states that 2.2 kW of power are delivered to the building for every 1 kW delivered to IT equipment — in other words, only approximately 45% of datacenter power actually drives the IT load. This estimate was derived by averaging a set of statistics from a range of Tier 1 through Tier 4 datacenters. Estimates by American Power Conversion (APC) for a full Tier 4 datacenter suggest that the number is even lower — approximately 30% (see Figure 1). Regardless of which numbers are most accurate, it's clear that reducing IT loads and increasing the efficiency of power and cooling systems can have a dramatic impact on overall datacenter power consumption.

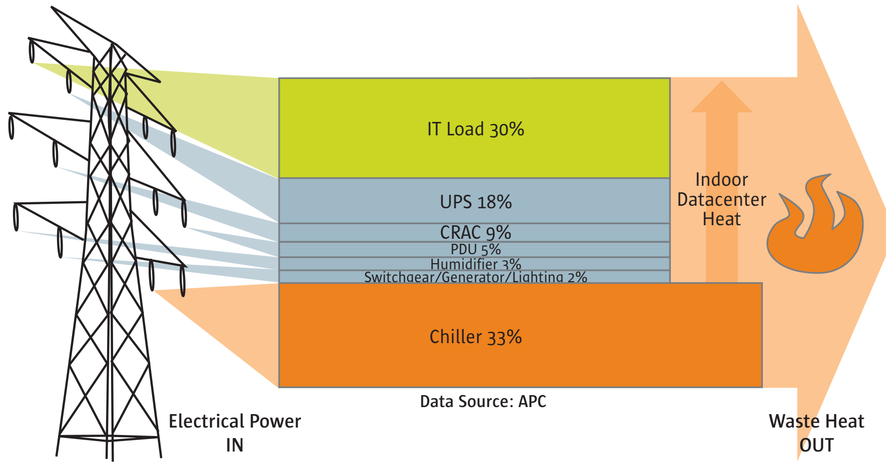

Figure 1. Only a fraction of incoming power is delivered to IT equipment in a datacenter, underscoring the need for both server and infrastructure efficiency improvements. Here are APC's estimates for Tier 4 datacenters.

Use energy-efficient servers

Replacing aging servers with energy-efficient systems helps to reduce overall datacenter space requirements while cutting the amount of energy required to deliver a given unit of compute power. The entire system design — including processors, memory, power supplies, and cooling systems — contributes to efficiency.

- *Processors*

  The CPU is one of the largest power consumers in today's servers, and the choice of processor has a significant impact on the server's power consumption. It's important to choose the processor that's best suited to the task it performs. Designed to excel at handling highly multithreaded workloads, Sun's UltraSPARC® T1, T2, and T2 Plus processors with CoolThreads™ technology consume less power per thread than any other processors in their class. Sun's x64 server product line is powered by AMD Opteron™ and Intel® Xeon® processors, each of which provides different trade-offs between power consumption and performance that depends on the workload.

- *Memory*

  As processor speeds have increased, manufacturers have begun using the fastest fully-buffered DIMMs, increasing power consumption per amount of memory. Installing the fewest, most dense DIMMs for the job will draw the least amount of power.

- *Power supplies*

  Power supplies must be designed to handle the worst-case scenario of a server with all memory and PCI slots occupied, running at 100% utilization. In practice, most servers operate at 50% or less of their nameplate power, a range where many power supplies can be relatively inefficient. In the United States, 80 PLUS — a program supported by electric utilities and the computer industry — is promoting the use of power supplies that are at least 80% efficient at 20%, 50%, and 100% of their rated load. Most of the power supplies on servers from Sun exceed this specification, with some of them 93% efficient at an 80% load.

- *Cooling*

- A server's internal cooling system can have a significant impact on power consumption. Servers that are engineered to optimize airflow can cool internal elements, including processors and memory, with less power consumed by fans. Good servers use strict front-to-back cooling with straight-through airflow, and their fan speeds are modulated by measured internal temperatures.

Consolidation, virtualization, and technology refresh

Technology refresh can dramatically reduce power consumption in its own right. Simply replacing aging, inefficient servers with new, more powerful, energy-efficient systems can help to reduce power consumption. Adding virtualization technology can help reduce the number of new servers required in a server-replacement effort because it simplifies the task of consolidating and running multiple workloads on the same server.

Choosing the right virtualization solution

Virtualization solutions vary in how they isolate applications, limit the propagation of faults, and support multiple operating systems. As a developer of its own virtualization solutions and a vendor of third-party solutions, Sun is in an ideal position to advise customers on making the most appropriate choice of virtualization technology, based on their business and technical requirements.

Following are four categories of server virtualization technologies that Sun supports, offering varying degrees of isolation between applications (also see Figure 2).

- *Resource management* simplifies the running of multiple applications on the same server and OS instance. Applications are isolated only to the degree that OS-level security and resource management features keep them (and their administrators) from interfering with each other. Solaris™ Resource Manager is an example of technology that helps isolate applications through precise control over their resource allocation and consumption.

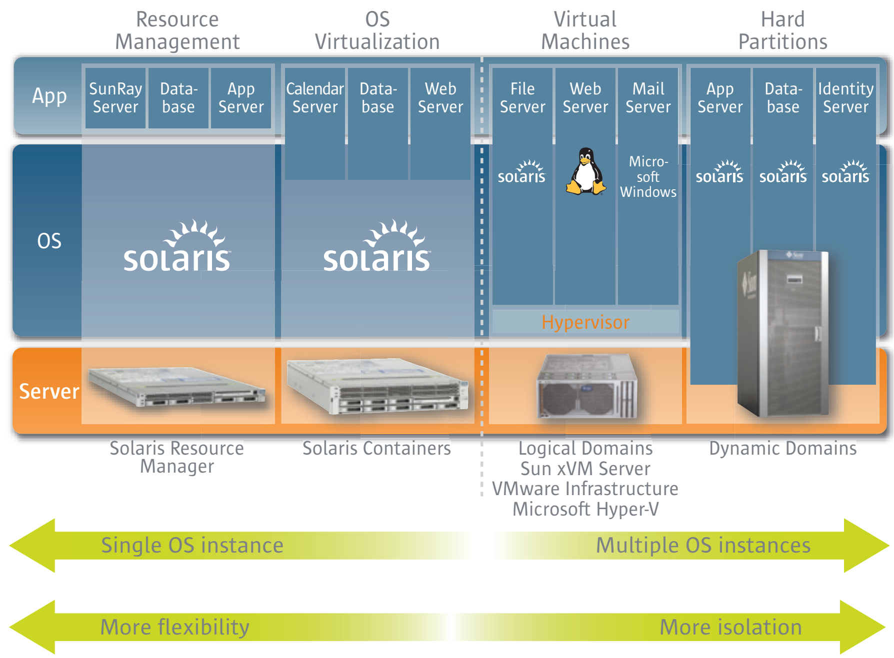

Figure 2: Sun supports a range of virtualization approaches based on its own and third-party technology.

- *OS-level virtualization* provides more isolation than simple resource management, allowing multiple applications to share the same OS instance with separate security domains for each application. With Solaris Containers, customers can migrate existing Solaris 8 and Solaris 9 operating system environments onto Sun's current hardware without having to redeploy existing applications.
- *Virtual machine monitors* provide still greater isolation by supporting multiple OS instances on the same machine. Each application can run in its own OS instance, and a hypervisor gives each one the illusion that it "owns" a complete, dedicated set of hardware. Available for Sun x64 servers, virtual machines can support multiple types of operating systems. Resource management and OS-level virtualization can also be used within each environment running the Solaris OS. Logical Domains technology is a virtual machine monitor that allows resources to be dedicated to virtual machines on a per-CPU-thread basis on servers powered by UltraSPARC T1, T2, and T2 Plus processors.
- *Hard partitions* support multiple operating system instances, without the overhead of a hypervisor. Available on Sun's high-end servers, including Sun SPARC Enterprise™ M Series servers, Dynamic Domains provide the ultimate in isolation, with a separate electrically isolated environment for each OS. With Dynamic Domains, one domain can be powered off and components replaced without affecting the state of other domains on the same server.

Increasing storage power efficiency

Organizations are often unaware of the ways they can improve the power efficiency of their storage. An assessment can highlight which of several approaches best meets an organization's goals. Here are some ways to drive storage power and cooling efficiency improvements:

- *Allocate data to different storage tiers based on information lifecycle management policies*. At the upper end, high-RPM drives and storage systems with multiple processors host the most critical data. At the low end, high-density, low-RPM SAS or SATA drives save cost and power. And archiving data onto tape is extremely energy efficient, with a tape cartridge at rest using no energy at all.
- *Use hybrid storage systems with solid-state drives (SSDs) mixed with SAS or SATA drives*. This setup provides performance similar to previous-generation high-end systems, but using only one-third to one-half the energy.
- *Centralize storage so it can be managed as a single pool of resources*. When virtual volumes can be carved out of a global pool and allocated to the servers and applications that need them, overall utilization levels can be raised and less energy spent on spinning disks that are only partially utilized. This can be especially useful if the file system (such as the Solaris ZFS™ file system) can manage the storage pool, allowing for the most appropriate utilization to be matched to the correct storage types in the centralized storage.
- *Replace older storage systems with ones offering higher density drives.* Efficiency also can be increased by choosing solid-state drives that have no moving parts, using less power.
- *Manage data replication and snapshot images with policies focused on removing copies as soon as possible*. In many datacenters, it's not at all surprising to find up to 10 copies of the same file. Data deduplication can help manage the archiving of data.
- *Leverage arrays and file systems that support thin provisioning*. With this technique, a much smaller amount of storage is allocated to a logical volume than its size, and storage consumption increases only as the volume fills. Thin provisioning allows for much higher disk space utilization because less storage is held in reserve.

Increasing datacenter power and cooling efficiency

Given that nearly two-thirds of a datacenter's power is dedicated to facility overhead, an IT organization's power optimization plans should include a strategy for increasing power and cooling efficiency.

Techniques for improving power efficiency

There are several ways in which customers can improve their datacenter power-distribution systems to improve overall efficiency:

For more information on this topic, refer to American Power Conversion's white paper titled "Increasing Data Center Efficiency by Using Improved High Density Power Distribution," located at www.apcc.com/wp/?wp=128.

- *Reduce power conversions.*

  A typical carrier datacenter converts power many times before it reaches its servers, each step introducing another degree of inefficiency. One way to economize is to make these power conversions more efficient. "World power" at 480/277 VAC allows the use of widely available, highly efficient transformers and eliminates a layer of power distribution units (PDUs). Instead of converting 480 VAC down to 120/208 VAC at a PDU, a more simple conversion can be performed at the output from the uninterrupted power supply (UPS) to provide 230 VAC to racks. Since nearly all computer equipment is manufactured to handle the 230 VAC standard, this approach to power can be used in most datacenters.

As defined by the Uptime Institute's white paper "Tier Classifications Define Site Infrastructure Performance," tier levels range from Tier 1 to Tier 4, with Tier 4 being the most fault tolerant.

- *Use appropriate tier levels.*

  Every organization would prefer to have a Tier 4 datacenter, with two complete power distribution systems that allow either system to be taken out of service (or fail) without affecting uptime. In practice, few organizations need this level of redundancy or the capital and operating costs to build and run it. Complete redundancy means that each distribution system normally provides 50% of datacenter power, but each must be sized to deliver 100% of the power in the event of a failure. This causes every power distribution element — from server power supplies to UPS's — to run at a lower, less-efficient utilization level. Instead, organizations can use a datacenter electrical design that supports multiple tier and use levels that are appropriate for the business task at hand.

- *Remove PDUs from the datacenter.*

  Most IT organizations configure their PDUs on the datacenter floor, adding to the cooling load. Sun's uses transformers outside the datacenter to feed a modular busway inside. These transformers do not require the same level of cooling as PDUs located inside the datacenter.

Techniques for improving cooling system efficiency

Improved cooling system efficiency is a requirement for high-density datacenters. Cooling-system improvements need to be part of an end-to-end strategy that efficiently moves heat from servers to the outdoor cooling tower. This transport mechanism can be improved at every step, from the choice of servers to the type of chilled-water systems employed. Here are some ways to improve cooling efficiency:

- *Choose servers with efficient cooling systems.*

  Cooling systems shouldn't be an afterthought. The most efficient servers have straight, unobstructed airflow that reduces turbulence, making the most of every watt provided to cooling fans. Server fan speeds should be modulated based on internal temperatures.

- *Block unused rack spaces.*

  Simply closing off unused rack spaces can increase efficiency by reducing the mixing of hot and cold air within the datacenter.

- *Contain hot/cold aisles.*

  Cooling efficiency can be increased significantly by fully containing either the hot or cold aisles to avoid mixing hot and cold air and feeding hotter exhaust air to the cooling units. This can be accomplished by various means, from simple draping systems to price-listed hard-containment systems. In a hot-aisle contained methodology, greater efficiencies can be achieved by aligning the cooling units directly with the hot aisle. This means that the heat exchangers work more efficiently by cooling the warmest air and handling only the air in the contained area. (Computer room air conditioners [CRACs] and air-handling units [AHUs] have to work on the entire volume of air in the datacenter).

  Efficiency also can be improved with variable-frequency drive fans within heat exchangers to match variable heat loads with variable airflow rates. This better matches actual cooling to cooling needs as systems go through different utilization cycles from fully idle up to fully utilized.

- *Install efficient spot cooling.*

  Nearly all datacenters end up with hot spots due to the inability to deliver the right amount of cooling to every rack — especially in datacenters where server density varies significantly. In datacenters without hot-aisle containment, there are a number of ways to perform directed spot cooling for racks with the highest heat loads. Some products sit directly above the rack, pulling warm exhaust air through a heat exchanger and pushing cool air down in front of the rack. Others fit over the hot aisle, pulling warm air through a heat exchanger and pushing cool air out into the cold aisle. And still other technologies sit among the racks and pull hot air the from the rear and push cool air out the front. Spot cooling can utilize either water or refrigerant in the heat-exchanger coils.

- *Choose innovative racks.*

  Some new rack designs can include a passive rear-door heat exchanger to provide localized cooling. They can be water or refrigerant based.

- *Increase ambient inlet temperature.*

  The legacy of cold air in datacenters is one that arises from the inefficiency of mixing hot and cold air in uncontrolled ways. As long as hot and cold air intermix randomly on the datacenter floor, supply air temperatures need to be kept low. As much as hot-aisle containment, spot cooling, or other techniques are able to control this mixing, then datacenter air temperatures can be higher, placing less of a load on the cooling system.

- *Install Variable-Frequency Drives (VFDs).*

  Datacenters use industrial motors throughout their cooling infrastructure. Using demand-driven VFDs allows the cooling system to adjust its output to closely match the load, increasing efficiency by providing only the cooling that's needed. VFDs are available in CRAC units, chilled-water pumps, chillers, and cooling-tower fans.

Chapter 3

Reconfigure Datacenter Spaces

For more information about Sun's own energy-efficient datacenters, visit sun.com/datacenterdesign. Many of the topics discussed in this chapter are discussed in detail in briefs and white papers available at this site.

To reap the most benefit from implementing power-optimization strategies, it's often necessary to reconfigure existing datacenter spaces, build new ones, or possibly augment space with a Sun™ Modular Datacenter (a datacenter housed in an enhanced shipping container). Sun has experience with reconfiguration and new construction projects for its own facilities and for its clients and has developed a design methodology and philosophy that has produced startling results.

Sun's design philosophy includes the following principles:

- *Availability* through a design that includes appropriate use of Tier levels and the ability to support multiple Tiers in the same datacenter
- *Agility* through a design that's flexible and adaptable, ready to align IT resources with changing business objectives
- *Efficiency* that's implemented through the techniques described in the previous chapter, with an emphasis on rightsizing IT equipment and the cabling, power, and cooling infrastructure that supports it
- *Future proofing* by designing not just for today, but also for the next few generations of equipment, which are likely to have even higher power, cooling, and cabling requirements; allowing organizations to avoid the cost and disruption of retrofitting additional infrastructure into a running datacenter
- *Environmental consciousness* that recognizes that "going green" makes good business sense, especially when it involves simple techniques — such as using outside air for cooling — that can save significant amounts of money over time
- *Intelligent monitoring* that allows power consumption to be monitored at every level in the power distribution hierarchy, giving visibility into current operational parameters and the impact of other energy-saving steps

Addressing inefficiency

Inefficiency can be difficult to address because facilities organizations don't always understand — or even believe in — the ever-increasing power requirements of IT organizations. Conversely, IT organizations typically don't understand the time and expense required to implement power and cooling infrastructure to support higher-density datacenters. Sun addresses inefficiency by helping clients achieve one or more of these goals:

- Create an independent organization with the funding and authority to make decisions for the IT and facilities organizations

- Define management processes that treat datacenter and IT management holistically
- Consolidate datacenter space to free up valuable real estate
- Improve the ability to accommodate current and future high-density servers
- Replace aging, inefficient equipment with current, more efficient systems
- Reduce the overall number of servers required to support existing activities
- Increase flexibility so that equipment can be changed to support new business and product development activities — including further increases in density — without significant changes to datacenter infrastructure
- Build an electrical and cooling plant that can scale as needed

Efficiency through density

It might seem counter intuitive to think that moving to higher-density equipment, which generates more heat in a smaller space, could actually increase efficiency. But server consolidation results in higher performance per watt, and space consolidation allows more efficient power, cooling, and cabling systems to be deployed. The energy savings of newer equipment is so substantial that it's worth dedicating a percentage of datacenter reconfiguration costs to acquiring new equipment.

Over the past few years, Sun has successfully consolidated 202,000 square feet of datacenter space to 72,000 square feet in Santa Clara, California, and an even more ambitious project in Broomfield, Colorado, consolidated 496,000 square feet of space into only 126,000 square feet. This averaged out to a 60% space compression, resulting in a 30% operating expense reduction. In one of Sun's datacenters in Santa Clara, more than 78% of the datacenter power budget is delivered to IT equipment (see Figure 3), whereas 30% to 50% is the norm, as discussed in Chapter 2.

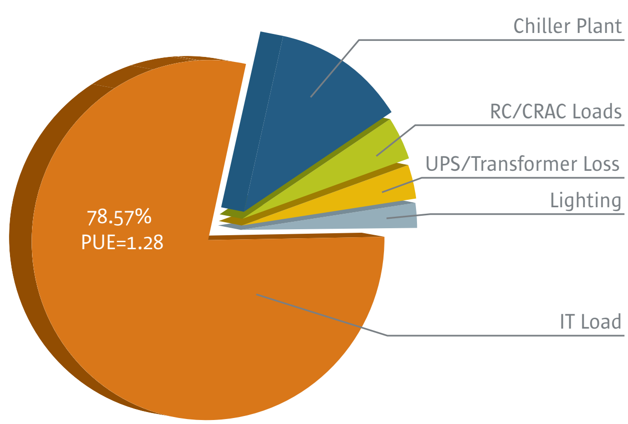

Figure 3. Sun's Santa Clara, California datacenter achieved a PUE of 1.28 — more than 78% of its power budget is delivered to IT equipment.

Efficient, pod-based design

Sun uses a set of generic design and construction standards to speed the process of building efficient, up-to-date environments. The standards can be adapted to different types of spaces including raised floors, and concrete slabs. Although generic, these standards support scalability and mobility, better supporting the normal churn of equipment and space reconfiguration.

Using these standards, Sun has created an innovative "pod" design — a self-contained group of racks that optimize power, cooling, and cabling efficiencies (see Figure 4). The design can be scaled up or down as needed and is easily replicated. Base power and cooling parameters can also be adjusted from 4 kW to 30 kW per rack. This allows complete flexibility in placing equipment in racks and pods, without having to be concerned about creating difficult-to-manage hot spots.

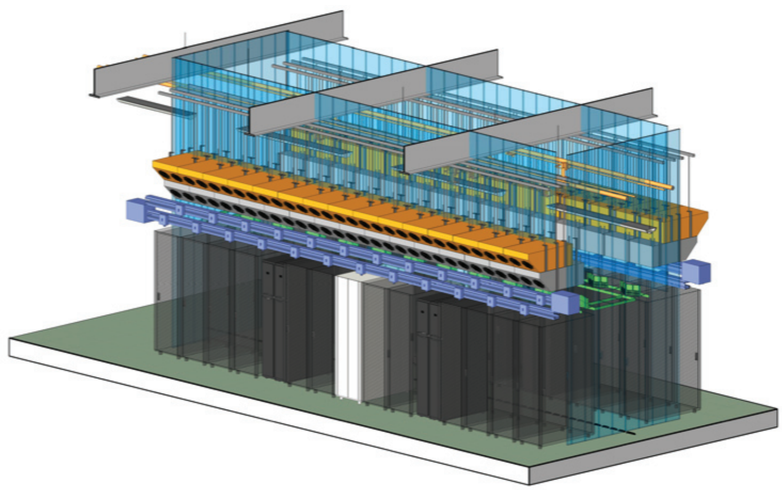

Figure 4. Sun's pod design defines flexible, modular spaces that can be replicated in datacenters around the world. This design is for a Tier 4 datacenter with high-density equipment and a total capacity of 860 kW, or 45 kW per rack.

Power

Where appropriate, Sun recommends building service yards containing power and cooling infrastructure that's adequate for today's needs, with conduit, plumbing, and transformer pads that allow the yard's capacity to scale over time. Ideal cooling systems — from evaporative cooling towers to chilled-water circulator pumps — use variable-frequency drives throughout. Depending on the datacenter's location, outside air can be used to chill the water directly, yielding a significant amount of free cooling.

Sun uses a rightsizing approach to UPS systems. If customers want to use traditional lead-acid-battery UPS's, the systems are sized to increase in capacity by adding modules over time. Today, Sun recommends a more environmentally friendly approach: a rotational UPS that stores energy in a flywheel that, after a power failure, provides sufficient power until generators automatically spin up.

Sun standardizes on a hot-pluggable overhead busway to distribute power to each rack. With the busway, it's a straightforward process to change breakers and receptacles or pull new cable when rack configurations change. The modular busway allows power drops to be installed and moved on demand, making the space much more flexible, while eliminating large amounts of copper and waste. The busway eliminates the need for on-floor PDUs, which consume costly floor space and generate heat. Instead, Sun uses energy-efficient transformers whose cooling requirements are much less stringent than the equipment on the datacenter floor.

The updated American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) TC9.9 standards not only broadened the recommended datacenter inlet temperature range, but also increased the dew point range. This allows organizations to set the overall environmental controls to allow the dew point to reach 59° F (15° C), so dehumidification systems, which are very energy intensive, can be used far less.

Cooling

As rack densities increase, standard CRAC units increasingly fail to provide sufficient cooling. The use of perforated floor tiles provides some degree of control over where chilled air is delivered, but the general mixing of hot and cold air that occurs in datacenters cooled this way requires lower ambient air temperatures, which causes greater inefficiency. Sun's approach is to deliver cooling capacity exactly where it's needed through in-row or overhead cooling units. Sun uses two different solutions, depending on the specific datacenter requirements.

In-row cooling and hot-aisle containment

One way to nearly eliminate the inefficient mixing of hot and cold air is to completely separate hot and cold areas through hot-aisle containment. For environments without high ceilings, or where floor space can be devoted to cooling devices, in-row cooling units with hot-aisle containment can be used. This mechanism completely contains the hot aisle, eliminating hot air recirculation. Hot air passes through the in-row units, which use chilled water to cool the air, while variable-speed fans provide the right amount of cooling based on real-time temperature measurements. Sun recommends installing double the capacity needed today, with every other unit stubbed out and baffled to block airflow. Figure 5 shows Sun's Santa Clara datacenter, where each pod's hot aisle is contained with a door at the end.

Figure 5. The use of hot-aisle containment with in-row cooling makes pods self-sufficient from a cooling perspective.

Overhead cooling for high-density equipment

In open datacenter designs, such as those where equipment is rolled in and out frequently, and in high-density situations, Sun uses overhead cooling systems to direct chilled air directly to the racks (see Figure 6). This design can be used with or without a draping system (illustrated in Figure 4) that contains the hot aisle.
For these situations, Sun recommends overhead heat exchanger systems that circulate refrigerant back to an in-room coolant chiller through preplumbed and tapped refrigerant pipes. This setup allows units to be installed right where they're needed. The coolant chiller moves heat from the refrigerant into the datacenter's chilled-water system, efficiently removing heat from the datacenter.

Water treatment

Sun recommends using technology, rather than chemicals, to treat cooling-system water. This helps to reduce pollution, promotes employee health, and saves a significant amount of water. Payback time from water and chemical savings can be less than one year, and used water is clean enough for grey water applications such as irrigation.

Figure 6. Overhead cooling units can effectively cool high-density racks in raised-floor or slab configurations.

Cabling

Sun's strategy is to move network racks, cabling, and equipment to the pod itself, increasing flexibility and reducing the amount of cabling required. Each pod is considered its own room, with high-speed uplinks from each pod to core switching equipment. Sun's approach can cut cable costs by more than 50%, saving copper, improving airflow, and simplifying reconfiguration for new, high-density equipment.

Chapter 4

Consult with Professionals

Sun has the technology, experience, and portfolio of services that can help customers through the process of developing a datacenter strategy, designing new datacenters or retrofitting existing ones, and building out the "datacenter of the future."

Here are just a few of the services Sun provides:

- *Eco Assessment and Optimization Services*

  Sun's Eco Services Suite leverages best practices and proven methodologies to help evaluate existing facility conditions, identify problem areas, and optimize energy usage by improving cooling efficiency, space utilization, and general environmental conditions. Sun's Intelligent Power Monitoring Service monitors, reports, and forecasts the energy consumption of server and storage systems, allowing organizations to better manage datacenter power bills, plan for capacity expansion, and meet emerging regulatory requirements for energy reporting.

- *Virtualization Suite*

  Sun can develop a strategic approach to virtualization with consulting offerings that help customers choose the best technologies to drive efficiency. Offerings are available for server, storage, and desktop virtualization.

- *Datacenter Strategy, Design and Build Services*

  For customers interested in retrofitting or adding new datacenters, Sun can help transform the current IT environment — using open systems and the latest in power, cooling, and networking technologies — to create an efficient and dynamic datacenter portfolio. With proven facilities infrastructure expertise and knowledge of next generation IT systems, Sun can help strategize, design and build more resilient and secure data centers that can respond to changing business needs.

With more than 25 years of hands-on experience in datacenter innovation, including creating some of the most efficient datacenters on its own campus, there is no better partner than Sun to deliver the services that help customers reach their goals.

Acknowledgments

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For more information

More information on Sun's energy-efficient datacenters is available at

- sun.com/datacenterdesign.

A Sun BluePrints™ Series article titled "The Role of Modularity in Datacenter Design" is available at

- sun.com/blueprints.

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