*Five Strategies for Cutting Data Center
Energy Costs Through Enhanced Cooling Efficiency*

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Executive Summary

As electricity prices and IT power consumption continue to rise, IT-related energy costs are getting increased scrutiny. Cooling accounts for approximately 37 percent of electricity usage within a well-designed data center and, in many cases, represents a significant opportunity to reduce IT energy costs.

This paper presents five strategies for increasing data center cooling efficiency:

1. *Proper sealing of the data center environment*
   A vapor seal plays a critical role in controlling relative humidity, reducing unnecessary humidification and dehumidification.

2. *Optimizing air flow*
   Rack arrangement, computer room air conditioner placement and cable management all impact the amount of energy expended to move air within the critical facility.

3. *Using economizers where appropriate*
   Economizers allow outside air to be used to support data center cooling during colder months, creating opportunities for energy-free cooling.

4. *Increasing cooling system efficiency*
   New technologies, such as variable capacity systems and improved controls, are driving increased efficiency of room air conditioning systems.

5. *Bringing cooling closer to the source of heat*
   Supplemental cooling systems bring cooling closer to the source of heat, reducing the amount of energy required for air movement.

Together, these methods can reduce cooling system energy costs by 30 to 45 percent and generate significant, recurring savings. Coupled with emerging technologies such as higher-efficiency processors and new chip-based cooling technologies, these measures can keep energy costs in line as server densities and the price of energy continue to rise.

Introduction

Until recently, little attention has been given to the cost of energy used by IT systems. But as power consumption and electricity prices rise, energy costs are receiving more scrutiny from senior-level executives seeking to manage dollars. In fact, energy costs have now become one of the driving factors in decisions regarding data center location and design.

A recent survey by the Data Center Users Group[1] showed that data center energy efficiency is fast becoming a priority in the industry, with 42 percent of survey respondents saying they have either analyzed efficiency or are currently analyzing it. Respondents perceived significant opportunities for energy efficiency to be in the areas of cooling equipment (49 percent), servers (46 percent), power equipment (39 percent) and storage (21 percent).

EYP Mission Critical analyzed data center energy usage and estimated that 50 percent of data center energy is consumed by information technology systems[2]. It is understood that saving 10 percent of the energy consumed by the IT equipment will create an additional seven to 10 percent energy reductions as the cooling and power distribution loads are reduced. Thus energy reductions in this area have a downstream affect that can almost double savings.

There are a number of strategies that can be evaluated for reducing IT system energy consumption, most notably server consolidation and virtualization. For more information on these strategies, see the Liebert white paper, *Using Virtualization and Digital Control Technologies to Increase Data Center Operating Efficiency* available at **www.liebert.com**.

This paper will focus on the remaining 50 percent that is consumed by essential support systems, such as power, cooling and lighting (Figure 1). Next to technology systems themselves, the cooling system consumes the most energy in the data center, accounting for 37 percent of data center electricity use.

Demands on cooling systems have increased substantially in recent years as server densities have risen to unprecedented levels. This change has not only created the need for increased cooling system capacity, but also has exposed inefficiencies in existing approaches to data center cooling. As a result, cooling now represents the second highest opportunity for IT energy cost savings in many facilities (just after reducing the IT equipment load).

These savings can be significant. For example, a 3 MW IT facility would require 6 MW of power assuming support systems consume

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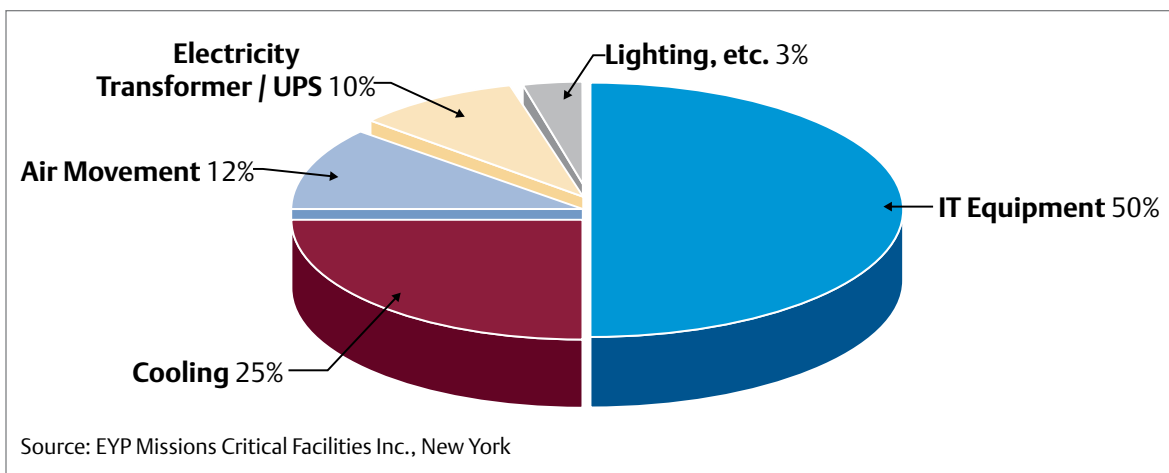

Source: EYP Missions Critical Facilities Inc., New York

Figure 1. Sources of data center energy consumption.

about the same amount of power as the IT systems. If electricity costs were $.10 per hour, the total annual energy costs for this facility would be $5.25 million ($600/hour x 8,765 hours). A 10 percent reduction in the IT load would create savings of $1.05 million, while a 30 percent improvement in cooling system efficiency would generate savings of approximately $580,000.

1. Proper Sealing of the Data Center Environment

Cooling losses through floors, walls and ceilings, or the introduction of humidity from outside the critical facility, reduce cooling system efficiency. Therefore, the data center should be isolated from the general building and outside environment as much as possible.

Keep doors closed at all times and use a vapor seal to isolate the data center atmosphere. The vapor seal is one of the least expensive and most important methods for controlling the data center environment and is particularly important in maintaining proper humidity levels.

If humidity is too high in the data center, conductive anodic failures (CAF), hygroscopic dust failures (HDF), tape media errors and excessive wear and corrosion can occur. These risks increase exponentially as relative humidity increases above 55 percent.

If humidity is too low, the magnitude and propensity for electrostatic discharge (ESD) increases, which can damage equipment or adversely affect operation. Also, tape products and media may have excessive errors when exposed to low relative humidity.

ASHRAE has defined the optimal relative humidity for a data center environment as 40 to 55 percent. Computer room precision air conditioners (CRACs) control humidity through humidification or dehumidification as required, both of which consume energy. An effective vapor seal can reduce the amount of energy expended on humidification or dehumidification.

The vapor seal is typically created using a combination of plastic film, vapor-retardant paint, vinyl wall coverings and vinyl floor systems. All openings in doors, windows and cable entrances should also be sealed.

This is the first step in any plan to increase efficiency. If the room is not properly sealed, all other measures for improving efficiency will be less effective. A data center assessment, available through various consulting engineering firms or your cooling system supplier, can help identify areas where outside air is entering the controlled environment and recommend strategies for proper sealing.
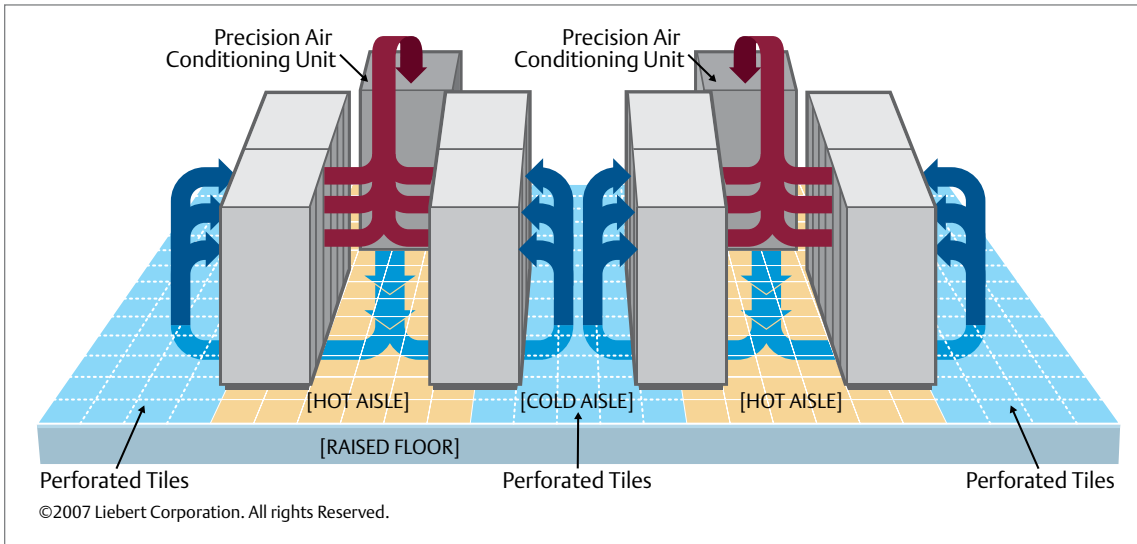
2. Optimizing Air Flow

Once the room is sealed, the next step is to ensure efficient air movement. The goal is to move the maximum amount of heat away from the equipment while utilizing a minimum amount of energy. Optimizing air flow requires evaluation and optimization of rack configuration, air conditioner placement and cable management.

Rack Arrangement
Most equipment manufactured today is designed to draw in air through the front and exhaust it out the rear. This allows equipment racks to be arranged to create hot aisles and cold aisles. This approach positions racks so that rows of racks face each other, with the front of each opposing row of racks drawing cold air from the same aisle (the "cold" aisle). Hot air from two rows is exhausted into a "hot" aisle, raising the temperature of the air returning to the CRAC and allowing the CRAC to operate more efficiently (Figure 2).

This approach is most effective when cold and hot air do not mix. Therefore, perforated floor tiles should be removed from hot aisles and used only in cold aisles. Blanking panels should be used to fill open spaces in racks to prevent hot air from being drawn back through the rack.

Figure 2: Hot aisle/cold aisle configuration.

When using the hot-aisle/cold-aisle approach, CRAC units should always be placed perpendicular to the hot aisle to reduce air travel and prevent hot air from being pulled down into the cold aisles as it returns to the air conditioner.

Some type of cabling grommet should also be used to prevent the cold air from entering the space through cable openings, which are typically at the rear of the rack.

Additional steps such as using a return ceiling plenum to draw the air back to the CRAC and physical curtains at the ends of the cold aisles have also proved to be very effective in minimizing mixing of the hot and cold air.

CRAC Placement
When using the hot-aisle/cold-aisle approach, CRAC units should always be placed perpendicular to the hot aisle to reduce air travel and prevent hot air from being pulled down into the cold aisles as it returns to the air conditioner (Figure 2). A return ceiling plenum can be effective in minimizing the mixing of hot and cold air.

Cable Management
The explosion in the number of servers that data centers must support has created cable management challenges in many facilities. If not properly managed, cables can obstruct air flow through perforated floor tiles and prevent air from being exhausted out the rear of the rack. Check the under-floor plenum to determine if cabling or piping is obstructing air flow. Overhead cabling is becoming increasingly popular, which eliminates the potential for obstruction. Deeper racks are now available to allow for increased airflow. Sometimes existing racks can be equipped with expansion channels to add depth for cables and airflow. Be cautious when using cable management "swing arms" as they are not compatible with all IT equipment air flow patterns.

Finally, but perhaps most significantly, investigate bringing high-voltage 3-phase power as close to the IT equipment as possible and increasing the voltage of the IT equipment. These steps will minimize the number and size of the power cable feeds under the floor. This can sometimes be accomplished by using high-voltage 3-phase managed power strips within the rack, but may also require the use of multiple-pole distribution panels or PDU's located within the row of IT equipment racks.

Fans can be added to the rear of racks to draw hot air out of the rack, but be aware that these fans consume energy and generate additional heat that must be removed from the room.

3. Use Economizers to Achieve Free Cooling

In many locations, outside cool air can be used to supplement data center cooling and provide "free cooling" during colder months. This is accomplished through the use of economizer systems. A study on building control systems by Battelle Laboratories[3] found that, on average, the normalized heating and cooling Energy Use Intensity (EUI) of buildings with economizers was 13 percent lower than those without economizers.

There are two basic types of economizer systems: air-side economizers and fluid-side economizers. Choosing the type for a specific project is a function of climate, codes, performance and preference.

Air-Side Economizers

The air-side economizer uses a system of sensors, ducts, and dampers to allow entry of the appropriate volume of outside air to satisfy facility cooling requirements. Air-side economizers are available in two types—a "dry air" system and an "evaporatively conditioned" air system. The former is the most common, but its use is restricted to a few geographic locations because of the high cost of energy required to add moisture to the room when the ambient dew-point is below 35° F. The evaporative conditioned solution is an economical method for conditioning the air prior to introduction to the data center, but reliability and high maintenance requirements have generally made this approach unattractive to most data center operators.

The key to either of these solutions is proper control. The control should be based on enthalpy comparisons, not just dry-bulb temperature. Also methods must be implemented to detect incidences of high pollen, dust or other external contaminants and effectively lock-out the economizer during these conditions.

Fluid-Side Economizer

A fluid-side economizer system is typically incorporated into a chilled water or glycol-based cooling system, and works in conjunction with a heat rejection loop consisting of either a cooling tower, evaporative cooler or drycooler. CRAC units incorporate a conventional glycol-cooled unit along with a second cooling coil, control valve and temperature monitor. During colder months, the glycol solution returning from the outdoor drycoolers or cooling tower is routed to the second coil, which becomes the primary source of cooling for the room. As long as the "free cooling" fluid is 8° F below the CRAC return temperature, there is some benefit for having the "free cooling" running, as it minimizes the load on the primary cooling method.

Fluid-side economizers are the system of choice for most data center environments because they are not affected by outdoor humidity levels and so are effective in a wider portion of the temperature/humidity band. They also do not add any additional air filtration requirements on the data center. For more detailed information on economizers see the white paper, *Utilizing Economizers Effectively in the Data Center* available at **www.liebert.com**.

4. Increase the Efficiency of Room Air Conditioners

Three factors are critical to optimizing the efficiency of CRAC units:

- How efficient the units operate at partial load.
- How efficient the units are at removing sensible heat as compared to latent heat.
- How well multiple units work together.

Increasing Efficiency at Part Load

Data centers are designed with some level of cooling system redundancy. Plus, the actual

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capacity of a direct expansion or air-cooled CRAC unit increases as the outdoor ambient temperature decreases below the peak design condition (typically 95˚F). This means equipment is operating at less than 100 percent load all of the time, creating the opportunity to design systems to operate more efficiently during normal operating conditions. Because operating conditions aren't stable, this requires some method of varying capacity based on operating conditions.

There are several approaches to providing variable capacity in a direct expansion CRAC unit. The two most common are four-step compressor unloading, and Digital Scroll™ compressor technology.

The concept of four-step compressor unloading works by shutting off the flow of refrigerant to some of the cylinders within the system; thereby, minimizing the need to cycle compressors on and off to control capacity. Because unloading essentially changes the compressor operating point, it enables the cooling system to operate more efficiently at lower capacities. For example, a system operating with two compressors "unloaded" will consume approximately 50 percent of the energy of a fully loaded system but will deliver 76 percent capacity because the condenser and evaporator are sized for full load. Figure 3 shows the efficiency improvements that can be achieved through compressor unloading.

For more information on four-step technology, see the white paper, *Using Four-Step Technology to Optimize Data Center Cooling Efficiency* available at **www.liebert.com**.

Digital Scroll compressor technology offers a newer way to precisely match capacity and power consumption to the desired load and can deliver significantly lower energy consumption compared to standard "fixed-capacity" compressors.
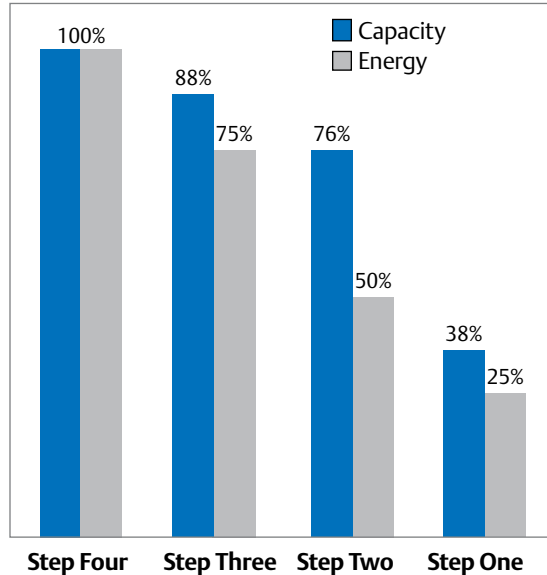

Figure 3. Operating capacity versus energy consumption for the four stages of operation enabled by compressor unloading.

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Traditional modulation technologies (cycling units on and off to match load conditions) often consumes close to full-load energy regardless of the required capacity. In a system designed for high reliability, the compressors do not just turn on and off. There is a turn-on delay period and a turn-off pump-down period where the compressor is actually running, ensuring proper oil lubricant to the compressor bearings, before power is removed.

Digital Scroll technology allows the compressor to never be cycled off. It reduces power consumption linearly as it modulates capacity, resulting in optimum system performance and control.

This technology is being applied to the data center through an exclusive agreement between Emerson Climate Technologies, which developed the Copeland Digital Scroll Compressor, and Emerson Network Power, which developed the Liebert DS precision cooling system. Integrating the Copeland Digital Scroll Compressor into the Liebert DS system enables the Liebert DS system to achieve capacity modulation from 10 percent
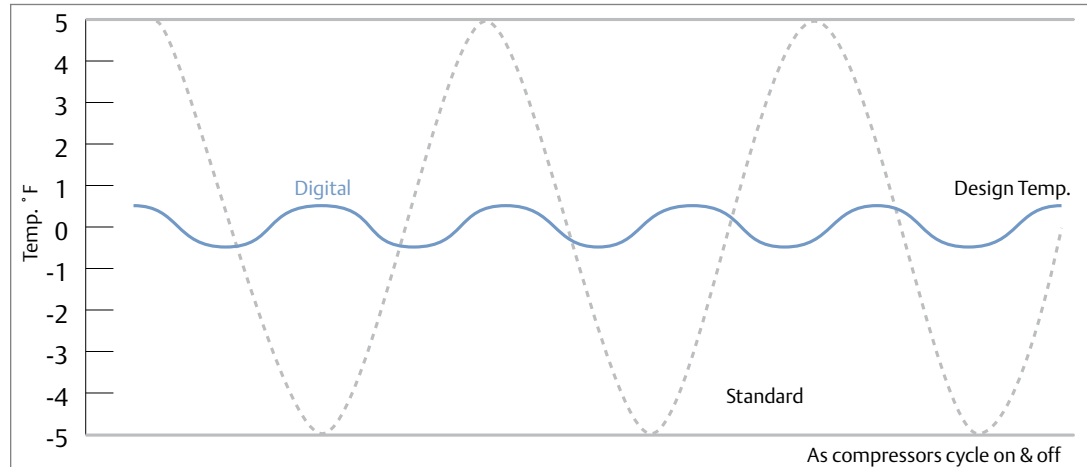
Figure 4. The Digital Scroll compressor eliminates compressor modulation as capacity changes, increasing efficiency.

to 100 percent. Precise temperature control is achieved in a simple, reliable manner as seen in Figure 4.

Improving Sensible Heat/Latent Heat Removal Capacity
IT equipment generates sensible (dry) heat. Latent heat comes from people and outdoor humidity infiltration (that can be minimized through the vapor seal discussed previously).

As server density or capacity increases, it creates a corresponding increase in the sensible heat load. The latent heat load is unaffected. Thus, using cooling solutions that can operate at a 100 percent sensible capacity, except when dehumidification is required, will result in reduced energy consumption. Operating a variable capacity compressor at a lower capacity raises the temperature of the evaporator coil. This means less latent cooling takes place. Under the vast majority of load conditions, the evaporator coil temperature will be high enough to achieve 100 percent sensible cooling. Thus, no energy will be required to add humidity that was inadvertently removed.

Improving Coordination Across Multiple Units
The data center environment has become more diverse as newer high-density servers are deployed alongside older systems. As a

result, without proper coordination between room cooling units, air conditioners may be operating in different modes of temperature and humidity control. For example, a unit on the north side of the room may be sensing low relative humidity conditions and adding humidity, while a unit on the south side of the room is sensing high relative humidity and removing moisture from the air. The actual moisture in the air is equal, but because the measurement is a relative measurement, the higher the temperature, the lower the relative humidity. Advanced control systems can be deployed across all the CRAC units in a room to enable the units to communicate and coordinate their operation, preventing the "fighting mode."

5. Deploy Supplemental Cooling

Supplemental cooling is a relatively new approach to data center cooling that was pioneered by Emerson Network Power with its Liebert XD System™ (Figure 5). Introduced in 2002, this approach gained rapid acceptance as data center managers seek solutions to help them:

- Overcome cooling capacity limitations of raised floor systems in high heat density applications.
- Increase cooling system efficiency and flexibility.

Raised-floor cooling proved an effective approach to data center environmental management; however, as rack densities exceed 5 kW, and load diversity across the room increases, supplemental cooling should be evaluated for its impact on cooling system performance and efficiency.

At higher densities, equipment in the bottom of the rack may consume so much cold air that remaining quantities of cold air are insufficient to cool equipment at the top of the rack. The height of the raised floor creates a physical limitation on the volume of air that can be distributed into the room, so adding additional room air conditioners may not solve the problem.

The Uptime Institute reports that equipment located in the top third of a data center rack fails twice as often as equipment in the bottom two-thirds of the same rack. The organization also estimates that, for every increase of 18˚ F above 70˚ F, long-term electronics reliability falls by 50 percent.

The solution to rising rack densities and high room diversity proved to be a pumped refrigerant cooling infrastructure that supports cooling modules placed directly above or alongside high-density racks to supplement the air coming up through the floor. This solution has a number of advantages, including increased cooling system scalability, greater flexibility and improved energy efficiency.

Two factors contribute to improved energy efficiency: the location of the cooling modules and the refrigerant used.

Higher density applications require fluid-based cooling to effectively remove the high concentrations of heat being generated. From an efficiency perspective, refrigerant performs better than water for high-density cooling. The R134 refrigerant used in the Liebert XD system is pumped as a liquid but converts to gas when it reaches the air. This phase change contributes to greater system efficiency. R134 is approximately 700 percent more effective in moving heat than water, which coincidentally, is 700 percent more effective than air. It also ensures that expensive IT equipment is not damaged in the event of a refrigerant leak.

Two factors contribute to improved energy efficiency: the location of the cooling modules and the refrigerant used.
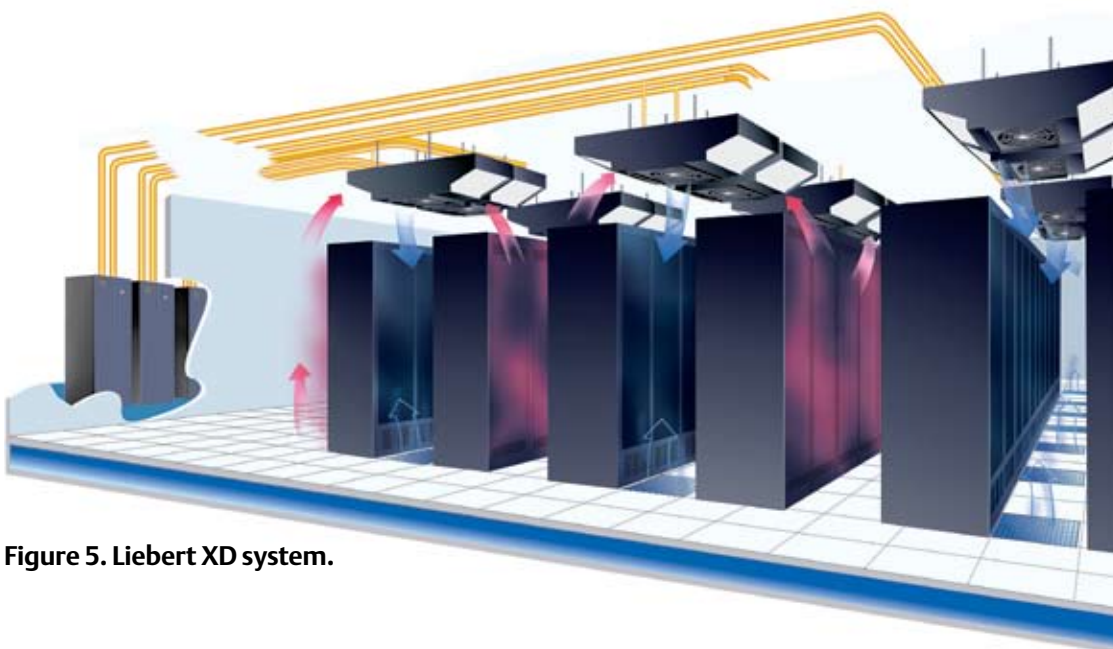

Figure 5. Liebert XD system.

Full Load

kW of Power to Cool 1kW of Sensible Heat

0.6
0.5
0.4
0.3
0.2
0.1
0.0

Traditional
Cooling

Liebert XD
Cooling

27%
Lower

Half Load

kW of Power to Cool 1kW of Sensible Heat

0.6
0.5
0.4
0.3
0.2
0.1
0.0

Traditional
Cooling

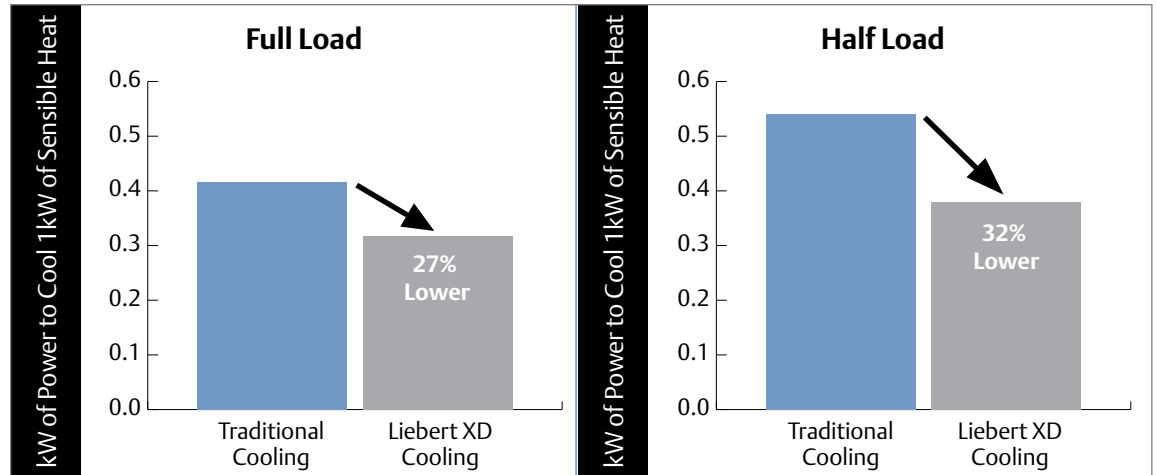Liebert XD
Cooling

32%
Lower

Figure 6. Supplemental cooling optimizes efficiency.

In the Liebert XD system, refrigerant is delivered to cooling modules mounted as close as possible to the source of heat. This reduces the energy required to move air, creating additional energy savings.

Together, the efficiency of the refrigerant and the location of the cooling modules can reduce cooling system energy costs by 27 percent (Figure 6) compared to relying only on raised floor cooling.

Additionally, refrigerant use reduces chiller capacity requirements by 20 percent. This increases energy savings and also enables additional cooling capacity without adding additional chillers.

Traditional floor-mounted cooling systems with under-floor air delivery will continue to play an essential role in data center environmental management. It is recommended that traditional systems be configured to deliver the required cooling for the first 100 Watts per square foot of heat load as well as solve the room's full humidification and filtration requirements. Supplemental cooling can be deployed for densities beyond 150 Watts per square foot.

For more information on supplemental cooling, see the white paper, *Blade Servers and Beyond: Adaptive Cooling for the Next Generation of IT Systems* available at **www.liebert.com**.

Emerging Technologies

Energy costs will likely continue to rise in the future as will the computing requirements of most organizations. Taking steps today to increase the efficiency of the cooling system can offset the impact of rising energy costs while newer, higher-efficiency technologies are deployed. Three technologies, in particular, have potential to significantly enhance data center energy efficiency:

• Multi-core processors
• Embedded cooling
• Chip-level cooling

Newer servers are now based on multi-core processors that enable a single processor to perform multiple separate tasks simultaneously, run multiple applications on a single processor, or complete more tasks in a shorter amount of time. Chip manufacturers claim multi-core processors can reduce power and heat by up to 40 percent.

Embedded cooling uses the Liebert XD cooling infrastructure to deliver high-efficiency cooling directly inside the rack. This approach brings cooling even closer to the source of heat and allows the cooling system to be optimized for a particular rack environment. An example of how effective this approach can be is the CoolFrame system from Egenera and Emerson Network Power. This system is able to prevent 20 kW of heat from an Egenera BladeFrame system from entering the room by removing the heat before it leaves the rack.

Chip-level cooling takes this approach to the next level by helping to move heat away from the chip. As embedded and chip-level cooling solutions are deployed, a highly efficient three-tiered approach to data center cooling will emerge. In this approach, heat is effectively moved away from the chip and then cooled in the rack, with stable temperatures and humidity maintained by room air conditioners.

These developments are not expected to reduce data center cooling requirements. Instead, they will result in an increase in the amount of computing power that can be supported by a particular facility. As a result, the efficiency improvements made today will continue to pay dividends well into the future as these new developments enable existing facilities to support densities that are not possible today.

Conclusion

The cooling system represents a significant opportunity for improving efficiency. In many cases, relatively simple and inexpensive changes, such as improving room sealing, moving cables or other objects that obstruct airflow or installing blanking panels, can pay immediate dividends. In addition, new technologies, such as variable capacity room air conditioners and sophisticated control systems, should be considered for their impact on efficiency. Finally, supplemental cooling systems provide a response to increased equipment densities that can increase the scalability and efficiency of existing cooling systems.

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