Five Best Practices for Increasing Efficiency, Availability and Capacity:
The Enterprise Data Center Design Guide

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Introduction

Data centers are one of the most dynamic and critical operations in any business. Complexity and criticality have only increased in recent years as data centers have experienced steady growth in density and capacity, straining resources and increasing the consequences of poor performance. The 2011 National Study on Data Center Downtime revealed that the mean cost for any type of data center outage is € 389,879, with the average cost of a partial data center shutdown being € 199,103. A full shutdown costs more than € 524,464. Since the cost of downtime is so high, availability of IT capacity is generally the most important metric on which data centers are evaluated. However, today, data centers must also operate efficiently - both in terms of energy and management resources - needing to stay flexible enough to quickly and cost-effectively adapt to changes in business strategy and computing demand. The challenges data center managers faces are reflected in the key issues identified each year by the Data Center Users' Group (Figure 1).

Spring 2008	Spring 2009	Spring 2010	Spring 2011
Heat Density	Heat Density	Adequate Monitoring	Availability
Power Density	Efficiency	Heat Density	Adequate Monitoring
Availability	Adequate Monitoring	Availability	Heat Density
Adequate Monitoring	Availability	Efficiency	Efficiency
Efficiency	Power Density	Power Density	Power Density

Figure 1. Top data center issues as reported by the Data Center Users' Group.

Efficiency first emerged as an issue for data center management in 2005, as server proliferation caused data center energy consumption to skyrocket while electricity costs and environmental awareness were rising. The industry responded to these increased costs and environmental impact of data center energy consumption with a new focus on efficiency; however, there was no consensus as to how to address the problem. A number of vendors offered solutions, but none took a holistic approach. Others achieved efficiency gains at the expense of data center and IT equipment availability - a compromise few businesses could afford to make.

In the traditional data center, approximately one-half of the energy consumed goes to support IT equipment while the other half is used by support systems (Figure 2). Emerson Network Power conducted a systematic analysis of the energy use in data centers and the various approaches to energy conservation to determine which were most effective.

The following five best practices serve as the foundation for data center design. These best practices provide planners and operators with a roadmap for optimizing efficiency, availability and capacity of new and existing facilities.

Five Best Practices for Enterprise Data Center Design

The following best practices represent proven approaches to employing cooling, power and management technologies in order to improve overall data center performance.

1. Best Practice One: Maximize the return temperature at the cooling units to improve capacity and efficiency

Maintaining appropriate conditions in the data center calls for efficient management of the air conditioning loop made up of supply and return air. The laws of thermodynamics allow computer room air conditioning systems to operate more efficiently by raising the temperature of the return air entering the cooling coils.
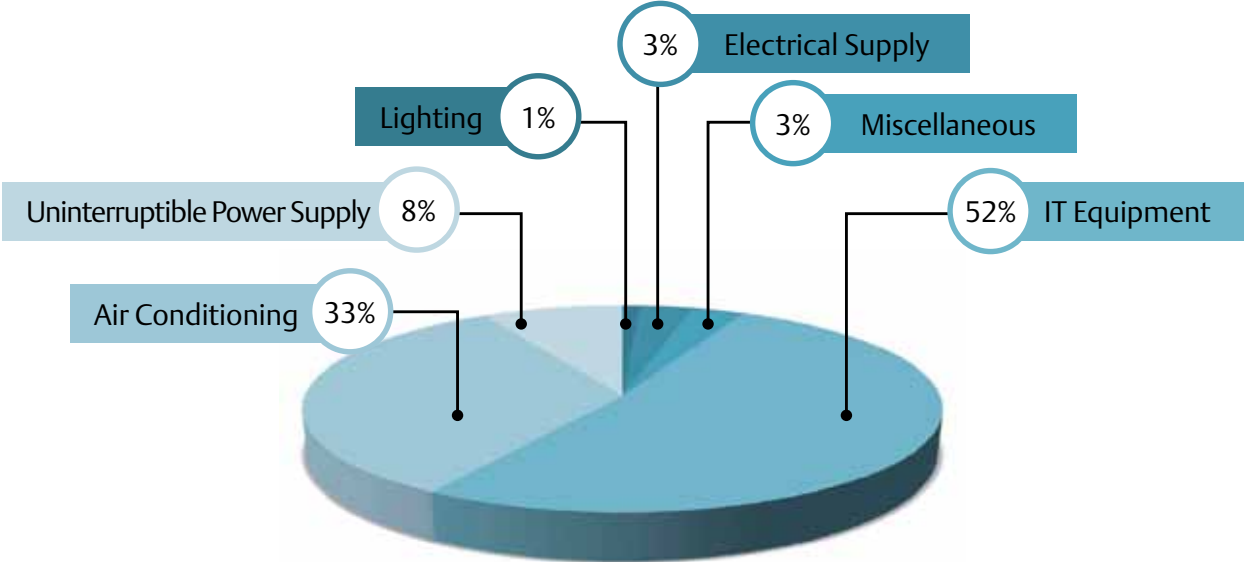

Figure 2. IT equipment accounts for over 50 percent of the energy used in a traditional data center while power and cooling account for an additional 48 percent.

This best practice is based on the hot-aisle/cold-aisle rack arrangement as shown in Figure 3, which improves cooling unit performance by reducing the mixing of hot and cold air, thus enabling higher return air temperatures. The relationship between return air temperature and sensible cooling capacity is illustrated below in Figure 4, depicting that a 5.6°C increase in return air temperature typically results in a 30 to 38 percent increase in cooling unit capacity.
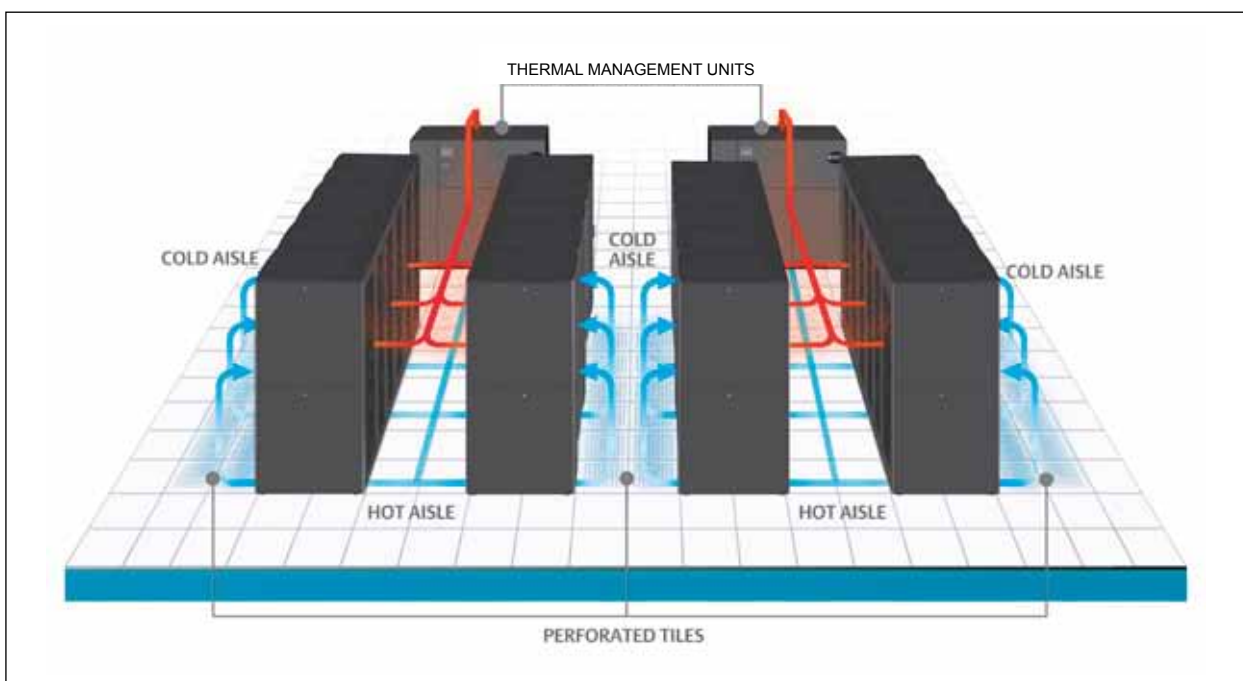

Figure 3. In the hot-aisle/cold-aisle arrangement, racks are placed in rows face-to-face, with a recommended 1,200 mm aisle between them. Cold air is distributed in the aisle and used by racks on both sides. Hot air is expelled at the rear of each rack into the "hot aisle."

However, the racks themselves create a barrier between the two aisles when blanking panels are systematically used to close openings. However, even with blanking panels, hot air may leak over the top and out the sides of the row, mixing with the air in the cold aisle. This becomes more of an issue as rack density increases.

To mitigate the possibility of air mixing as it returns to the cooling unit, perimeter cooling units can be placed at the end of the hot aisle as shown in Figure 3. If cooling units cannot be positioned at the end of the hot aisle, a drop ceiling may be used as a plenum to prevent hot and cold air from mixing. Another possible solution is to place cooling units in a gallery or mechanical room.

In addition to ducting and plenums, air mixing can also be prevented by applying containment and moving cooling closer to the heat source.
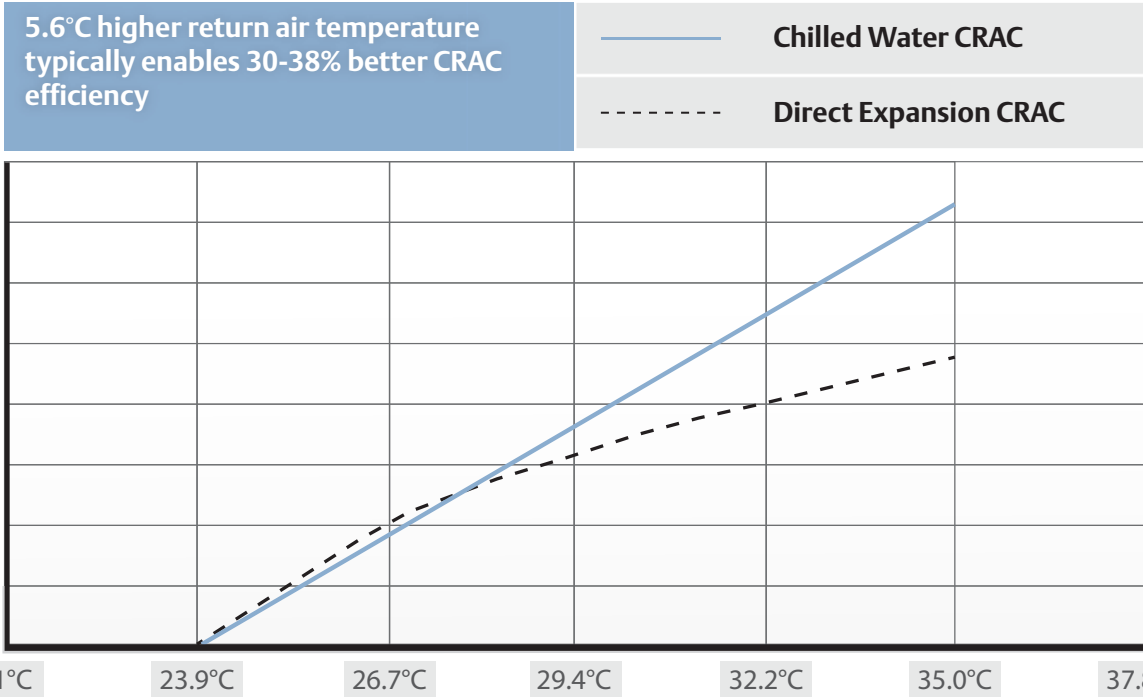
| 5.6°C higher return air temperature typically enables 30-38% better CRAC efficiency | ——————— Chilled Water CRAC |
| | - - - - - - - Direct Expansion CRAC |

Figure 4. Cooling units operate at higher capacity, and efficiency at higher return air temperatures.

1.1 Optimizing the Aisle with Containment and Row-Based Cooling

Containment involves capping the top or ends (or both) of the aisle to isolate the air within the aisle (Figure 5).

Generally, cold aisle containment is favored over hot aisle containment because it is easier to deploy and reduces the risk of hot air leaking into the cold aisle and servers in the event of a breach of the containment system. With hot aisle containment, opened doors or missing blanking panels allow hot air to enter the cold aisle, jeopardizing the performance of IT equipment as shown in Figure 6. In cold aisle containment, if cold air leaks into the hot aisle, the return air temperature is decreased and efficiency slightly compromised without threatening IT reliability.
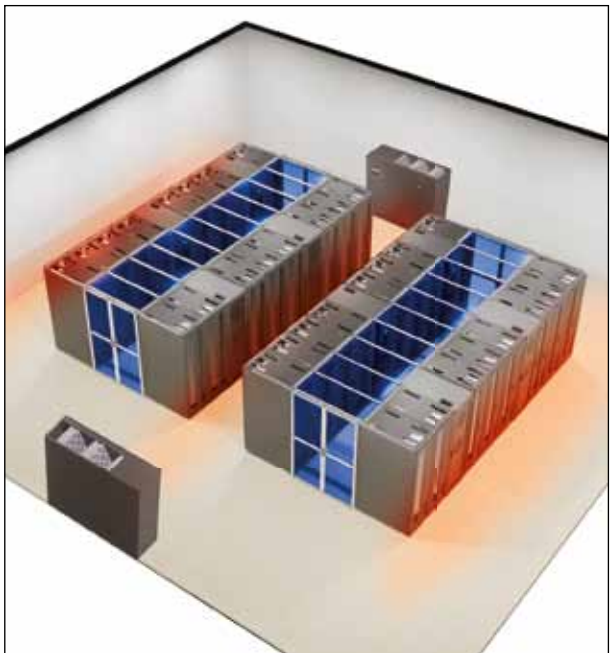

Figure 5. The hot-aisle/cold-aisle arrangement creates the opportunity to further increase cooling unit capacity by containing the cold aisle.

Row-based cooling units operate within the contained environment to complement or replaceperimeter cooling. This brings temperature and humidity control closer to the source of heat, allowing for a more precise control and reducing the energy required to move air across the room. By placing the Thermal Management units return air intakes of directly inside the hot aisle, air is captured at its highest temperature. Although this creates a larger footprint, cooling efficiency is maximized. Row-based cooling can be used in conjunction with traditional perimeter-based cooling in higher density "zones" throughout the data center.

	Hot Aisle Containment	Cold Aisle Containment
Efficiency	• Highest "potential" efficiency	• Great improvement in efficiency
Installation	• Requires ducting or additional row cooling units • Adding new servers puts installers in a very hot space	• Easy to add to existing data centers • Can work with existing fire suppression
Reliability	• Hot air may leak into the cold aisle and server jeopardizing the performance of IT equipment • Need to add redundant units	• Cold air may leak into the hot aisle just lowering efficiency • Redundancy from other floor mount units

Figure 6. Cold aisle containment is recommended based on simpler installation and improved reliability in the event of a breach of the containment system.

2. Best Practice Two: Match cooling capacity and airflow with IT loads

The most efficient cooling system is one that matches needs to requirements. This has proven to be a challenge in the data center since cooling units are sized for peak demand, which rarely occurs in most applications. This challenge is addressed through the use of intelligent cooling controls capable of understanding, predicting and adjusting cooling capacity and airflow based on conditions within the data center. In some cases, these controls work with technologies in 'Best Practice 3', which adapt cooling unit performance based on current conditions (Figure 7).

Intelligent controls enable a shift from cooling control based on return air temperature, to cooling control based on conditions at the servers, which is essential to optimizing efficiency. This often allows temperatures in the cold aisle to be raised closer to the 'safe' operating threshold now recommended by ASHRAE (max 27°C). According to an Emerson Network Power study, a 5.6°C increase in cold aisle temperature can generate a 20 percent reduction in cooling system energy usage.

The control system also contributes to increase efficiency by allowing multiple cooling units to work concurrently as a single system. The control system can shift the workload to units operating at peak efficiency levels while preventing units in different locations from working at cross-purposes. Without this type of system, a unit in one area of the data center may add humidity to the room while another unit is extracting humidity from the room. The control system possesses the ability to view conditions

across the room and the intelligence to determine whether humidification, dehumidification, or no action is required to maintain conditions in the room at target levels and match airflow to the load.

Figure 7. Intelligent controls like the iCOM™ system can manage air flow and cooling capacity independently.

3. Best Practice Three: Utilize cooling designs that reduce energy consumption

The third step in optimizing cooling infrastructure is to take advantage of newer technologies that use less energy than previous generation components.

3.1 Increasing Fan Efficiency
Fans that move air and pressurize the raised floor are a significant component of cooling system energy use. When considering chilled water cooling units, fans are the largest consumer of energy. Electronically commutated (EC) fans provide the best option for increasing cooling unit efficiency. EC plug fans are inherently more efficient than traditional centrifugal fans because they eliminate belt losses, which total approximately five percent of consumed energy. The EC fan typically requires a minimum of a 600 mm high raised floor to obtain maximum operating efficiency. When the energy consumption of EC fans were independently tested against variable drive fans, EC fans mounted inside the cooling unit created an 18 percent savings. However, when EC fans were placed below the raised floor, savings increased by 30 percent. Both options save energy and work with the intelligent controls described in Best Practice 2 to match cooling capacity to IT load.

3.2 Enhancing Heat Transfer
The heat transfer process within the cooling unit also consumes energy. New microchannel coils used in condensers have proven to be more efficient at transferring heat than previous generation coil designs. These coils reduce the amount of fan power required for heat transfer, creating efficiency gains of five to eight percent for the entire system.

3.3 Incorporating Economizers
Economizer systems use outside air to provide "freecooling" cycles for data centers. This can either reduce or eliminate chiller or compressor operation in Thermal Management units, enabling economizer systems to generate cooling unit energy savings from 30 to 50 percent-depending on the average temperature and humidity conditions of the site. A fluid-side economizer (often called 'water-side') works in conjunction with a heat rejection loop comprised of an evaporative cooling tower or drycooler to satisfy cooling requirements. It uses outside air to aid heat rejection, but does not allow outside air into the data center. On the other hand, an air-side economizer uses a system of sensors, ducts, and dampers to bring outside air into the controlled environment.

The effect of outside air on data center humidity should be carefully considered when evaluating economization options. The recommended relative humidity for a data center environment is 40 to 55 percent. Introducing outside air via an air-side economizer system (Figure 8) during cold winter months can lower humidity to unacceptable levels, causing equipment damaging electrostatic discharge. A humidifier can be used to maintain appropriate humidity levels; however, this offsets some of the energy savings provided by the economizer.

Fluid-side economizer systems eliminate this problem by using the cold outside air to cool the water/glycol loop, which in turn provides fluid that is cold enough for the cooling coils in the air conditioning system. This keeps the outside air out of the controlled environment and does not have to be conditioned. Depending on the climate, fluid-side economizers can be more efficient for data center environments (Figure 9).

Economizers obviously deliver greater savings in areas where temperatures are lower. Yet, when designed properly, they can deliver significant savings in warmer climates as well.
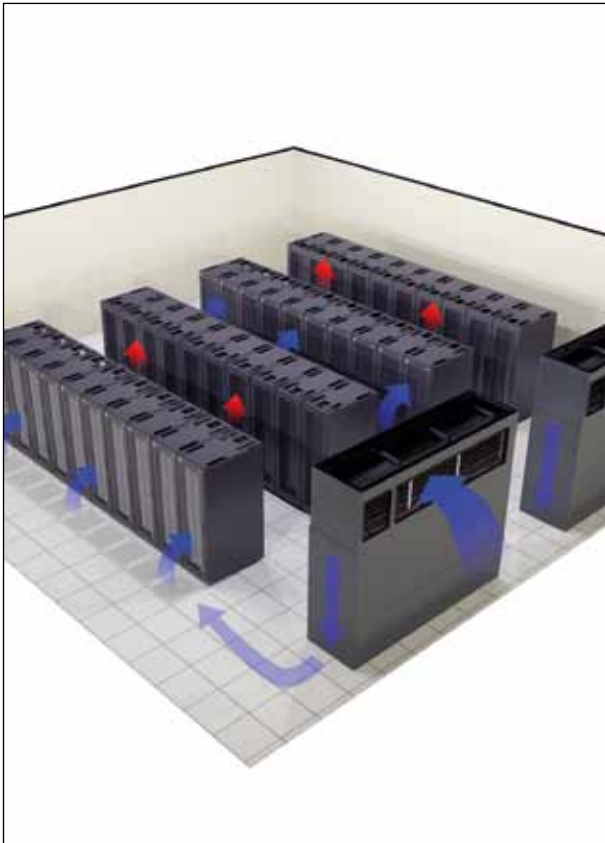

Figure 8. Liebert® PCW Thermal Management units utilize outside air to improve cooling efficiency when conditions are optimal.

	Air-Side Economization	Water-Side Economization
PROS	• Very efficient in particular climates	• Can be used in any climate • Can retrofit to current sites
CONS	• Limited to moderate climates • Complexity during installation • Humidity control can be a challenge; vapor barrier is compromised • Dust, pollen and gaseous contamination sensors are required • Difficult to implement in "high density" applications	• Maintenance complexity • Complexity during change-over • Piping and control more complex • Risk of pitting coils if untreated stagnant water sits in econo-coils

Figure 9. Air economizers are efficient but are limited in their application and may require additional equipment to control humidity and contamination.

4. Best Practice Four: Enable data center monitoring to improve capacity, efficiency and availability

At times, data center managers have been flying blind, lacking the proper outlook needed to understand system performance and the ways in which it optimizes efficiency, capacity and availability. Availability monitoring and control has historically been used by leading organizations; but managing the holistic operations of IT and facilities has lagged. This is changing as new data center management platforms emerge, bringing together operating data from IT, power, and cooling systems to provide unparalleled real-time visibility into operations.
Data center infrastructure requires the monitoring and control of physical assets. Cooling and power systems should have instrumentation integrated into them so that they can one day be complimented with additional sensors and controls to enable a centralized and comprehensive view of system infrastructures.

Installing a network of temperature sensors throughout the data center can be a valuable addition to the supply and return air temperature data provided by cooling units. By sensing temperatures at multiple locations, the airflow and cooling capacity is more precisely controlled, resulting in a more efficient operation.

Leak detection should also be considered as part of a comprehensive data center monitoring program. Using strategically located sensors, these systems provide early warning of potentially disastrous leaks across the data center from glycol pipes, humidification pipes, condensate pumps and drains, overhead piping and unit and ceiling drip pans.

Communication with a management system or other devices is provided through interfaces that deliver Ethernet connectivity and Simple Network Management Protocol (SNMP), as well as integration with building management systems through Modbus and BACnet. When infrastructure data is consolidated into a central management platform, real-time operating data for systems across the data center can drive improvements in data center performance:

- **Improve availability:** The ability to receive immediate notification of a failure, or an event that could ultimately lead to one, allows for faster, more effective response times to system problems. Taking a step further, data from the monitoring system can be used to analyze equipment operating trends and develop more effective preventive maintenance programs. Finally, the visibility and dynamic control of data center infrastructure providedby monitoring can help prevent failures originating from changing operating conditions. A steady rise in server inlet temperatures may dictate the need for an additional row cooling unit before overheating shuts down the servers.
- **Increase efficiency:** Monitoring power at the facility, row, rack and device level provides the ability to more efficiently and dynamically manage cooling. Greater visibility into infrastructure efficiency can drive informed decisions around the balance between efficiency and availability. In addition, the ability to automate data collection, consolidation, and analysis allows data center staff to focus on more strategic IT issues.
- **Manage capacity:** Effective demand forecasting and capacity planning has become critical to effective data center management. Data center infrastructure monitoring can help identify and quantify patterns impacting data center capacity. With continuous visibility into system capacity and performance, organizations are better equipped to recalibrate and optimize the utilization of infrastructure systems (without stretching them to the point where reliability suffers) as well as release stranded capacity.

5. Best Practice Five: Utilize local design and service expertise to extend equipment life, reduce costs and address your data center's unique challenges

While best practices in optimizing availability, efficiency and capacity have emerged, there are significant differences in how these practices should be applied based on specific site conditions, budgets and business requirements. A data center specialist can be instrumental in helping apply best practices and technologies in the way that makes the most sense for your business and should be consulted on all new builds and major expansions/upgrades.

For established facilities, preventive maintenance has proven to increase system reliability while data center assessments can help identify vulnerabilities and inefficiencies resulting from constant changes within the data center.

Preventive maintenance programs should be supplemented by periodic data center assessments. An assessment will help identify, evaluate, and resolve power and cooling vulnerabilities that could adversely affect operations.

Taking temperature readings at critical points is the first step toward thermal assessment that can identify hot spots and resolve problems that could result in equipment degradation. Readings will determine whether heat is successfully being removed from heat- generating equipment, including blade servers. These readings are supplemented by infrared inspections and airflow measurements. Cooling unit performance is also evaluated to ensure units are performing properly. Computational Fluid Dynamics (CFD) is also used to analyze air flow within the data center.

Conclusion

During the last few years, facilities have been expected to deliver more computing capacity while increasing efficiency, eliminating downtime, and adapting to constant changes. Infrastructure technologies evolved throughout this period as they adapted to higher density equipment and the need for greater efficiency and control.

The rapid pace of change has caused many data center managers to take a 'wait-and-see' attitude toward new technologies and practices. This was a wise strategy several years ago, but today the need for improved data center performance can no longer be ignored. Proper deployment of the practices discussed can have immediate TCO improvements – from capital benefits and astonishing energy efficiency gains to ease of computing adaptations.

In the cooling system, traditional technologies now work with newer technologies to support higher capacities and efficiencies. Raising the return air temperature improves capacity and efficiency while intelligent controls and high efficiency components allow airflow and cooling capacity to be matched to dynamic IT loads.

Ensuring The High Availability
Of Mission-Critical Data And Applications.

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Locations

Emerson Network Power
Global Headquarters
1050 Dearborn Drive
P.O. Box 29186
Columbus, OH 43229, USA
Tel: +1 614 8880246

Emerson Network Power
Thermal Management EMEA
Via Leonardo Da Vinci, 16/18
Zona Industriale Tognana
35028 Piove di Sacco (PD) Italy
Tel: +39 049 9719 111
Fax: +39 049 5841 257
ThermalManagement.NetworkPower.Eu@Emerson.com

Emerson Network Power
United Kingdom
George CurlWay
Southampton
SO18 2 RY, UK
Tel: +44 (0)23 8061 0311
Fax: +44 (0)23 8061 0852

Globe Park
Fourth Avenue
Marlow Bucks
SL7 1YG
Tel: +44 1628403200
Fax: +44 1628403203
Uk.Enquiries@Emerson.com

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