Data Centers

FALL EDITION

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An Expert View into the Future of Data Center Cooling

The landscape of data centers is currently undergoing a transformative shift. While there's little debate as to the dramatic growth rate of data centers, there's a need to understand the heating, ventilation, and air conditioning (HVAC) and building automation system (BAS) technologies needed to meet the various goals of each—not only today, but well into the future.

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As varied as data centers are, so too must their solutions be for cooling and building system management. Initially, a properly designed cooling system and building automation system must first consider the specific energy efficiency, sustainability, manageability, scalability, financial, Environmental, Social, and Governance (ESG) goals of each data center.

Designing a predictive data center thermal system requires a thorough understanding of its current operational nuances, as well as anticipating how these needs may evolve over the next two, five, or ten years. This foresight is crucial, as data centers are likely to add more servers and require additional physical space.

When this expansion takes place, a data center's cooling load, building automation requirements, and environmental impact may differ greatly from the original specifications. Retrofitting to address these changes poses a myriad of challenges. However, originally specifying a scalable thermal and building automation system can help mitigate these concerns and prevent the need for reactive measures later on.

Simply put, there is no better time to incorporate future needs of efficiency, sustainability, flexibility, and manageability than when initially designing a data center, aligning thermal capacity with demand for ultimate efficiency.

Data Center Types and their Unique Challenges

To understand how to specify correct cooling and BAS solutions for specific data centers, it's important to first understand the unique challenges of the following six data center types. Refer to the chart included at the end for a quick reference guide.

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Enterprise Data Centers are company owned to support their data storage and computing needs. Since this setup can be expensive, enterprise data centers appeal most to companies with unique data and network needs.

HVAC and BAS Challenges: Enterprise data centers need to manage variable loads, optimize energy efficiency, and maintain reliability in smaller, more constrained environments. These facilities face hurdles related to scaling cooling systems, integrating legacy infrastructure with modern automation tools, and managing airflow and containment in confined spaces. The BAS must be capable of real-time monitoring, predictive control, and fault detection while ensuring seamless integration with HVAC components.

Colocation (or multi-tenant) Data Centers serve businesses needing to host their servers off-site. Colocation data centers are typically owned by service providers and contracted by companies to provide power, security, cooling, and networking components for data processing and storage.

HVAC and BAS Challenges: Colocation data centers need to support diverse tenant requirements while maintaining operational efficiency and reliability. The HVAC system must be highly flexible to cool varying server loads. The BAS must provide precise control and monitoring, ensure energy and water efficiency, and provide real-time performance data to each tenant's environment across its different zones.

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Cloud Data Centers move computing strategies from traditional on-premises data centers off-site via the internet. Instead of managing their own infrastructure, an organization leases infrastructure managed by a third-party and relays its data over the Internet.

HVAC and BAS Challenges: Cloud data centers are massive in scale with high-density loads and require operational flexibility. Managing cooling requires advanced solutions like dynamic airflow control, hot/cold aisle containment, and liquid cooling (high density) systems. Maintaining low Power Usage Effectiveness (PUE) and optimizing energy efficiency are critical, often necessitating the integration of predictive analytics. Ensuring redundancy, scaling the HVAC infrastructure as demand grows, sustainability, adapting to climatic variables and the integration of emerging technologies highlight the need for continuous innovation.

Hyperscale Data Centers are the largest of data centers with extensive infrastructure to support large-scale IT projects like social media platforms and search engines.

HVAC and BAS Challenges: Driven by their sheer scale and complexity, cooling systems must manage immense heat loads, ensure scalability, maintain energy efficiency, and provide dependable and safe cooling under fluctuating server loads. BAS must integrate real-time monitoring, complex control algorithms, predictive modeling, and fault-tolerant mechanisms to optimize HVAC performance.

Edge Data Centers help businesses facilitate data transfer requiring minimum delay. They are smaller than other types and typically located near the end user.

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HVAC and BAS Challenges: Edge data centers present distinct challenges due to their smaller scale, decentralized nature, and need for rapid deployment in diverse locations. They prioritize energy-efficient and compact cooling solutions, often in constrained environments. These facilities require advanced airflow management, localized cooling, and passive or liquid cooling techniques to handle the high-density heat loads in smaller spaces. The BAS must provide real-time monitoring and control with minimal human intervention to ensure efficiency, scalability, cooling redundancy and remote operability across a network of dispersed sites.

Micro (also known as Modular) Data Centers, are small, self-contained data centers often containing hardware, power, cooling, and connectivity all packed into a containment unit about the size of a home refrigerator.

HVAC and BAS Challenges: Micro data centers face unique challenges due to their compact size, localized deployments, and need for efficient cooling in confined spaces. With their high-density equipment, cooling systems must be highly efficient, utilizing technologies like liquid cooling, in-row cooling, or passive cooling solutions. The BAS must be lightweight while providing real-time environmental monitoring, remote control, and automated adjustments to ensure optimal performance without requiring significant human oversight. Managing airflow and heat dissipation in such small environments can be complex, as these units are deployed in diverse and often non-ideal locations, such as remote offices, industrial sites, or urban areas.

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Cooling Technologies and Strategies for a Changing Environment

Data Centers must be viewed as dynamic environments—characterized by constant change—in the early stages of design. So too, their thermal systems must be equally dynamic. When specifying HVAC system components, efficiency stands out as one of the most important factors. Data center operators and owners are seeking thermal system components that deliver the highest energy efficiency possible, even as computing capabilities, operational demands, and size expand over time. This focus on efficiency is driven by the goal of controlling operating expenses—higher energy efficiency translates to reduced energy costs, helping to improve overall cost control and increase profit margins.

Designing thermal systems—whether air- or water-cooled—should minimize energy consumption, optimize performance, reduce environmental impact, and operate at peak efficiency. Selecting the appropriate chiller type and the HVAC configuration is driven by a variety of factors:

Water: A typical large-scale data center using water-cooled systems can consume millions of gallons of water per day. Water-cooled HVAC systems rely on these large amounts of water to dissipate heat and often utilize cooling towers or evaporative coolers. Conversely, air-cooled systems are less water-intensive but can often consume more energy.

Location: Geographic location is a significant factor to consider when designing HVAC systems for data centers, particularly in water-scarce regions. As data center operators and owners aim to balance cooling efficiency with environmental responsibility, the adoption of water-efficient HVAC technologies and BAS is critical to mitigate the impacts on local ecosystems.

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Building Load: Whether air- or water-cooled HVAC technologies are being considered, it's critical that they scale and modulate to meet the actual load. As demand for cooling fluctuates, chillers should immediately respond to the conditions.

Specific Applications: Air- and water-cooled chillers each come with their own set of advantages which should be matched to the specific operational demands of the data center. For example, if a smaller data center has a load requirement of 2,000 tons or below, air-cooled chillers would be the ideal choice due to lower initial costs, simpler maintenance, and the lack of need for cooling towers or water use.

The decision process for selecting a data center's HVAC solution differs significantly from nearly every other building type due to unique operating variables such as building scale, fluctuating cooling loads, local climate, water availability, maintenance costs, and long-term operational costs. The chiller solution must represent the latest technology, be able to respond quickly to fluctuating cooling demands, maximize efficiency, and align with sustainability goals.

Water-cooled chillers with a cooling tower or evaporator offer distinct advantages for mid- to larger-scale operations, including energy efficiency and their ability to maintain consistent cooling performance even in high-temperature environments. They generally have a longer lifespan and quieter operation compared to some air-cooled systems but come with higher initial costs, more complex maintenance requirements, and reliance on a reliable water source, which may not be ideal for locations with water scarcity.

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Today, Carrier is developing and implementing advanced HVAC equipment technologies and digital BAS lifecycle solutions to support the unprecedented growth and criticality of data centers.

"As the data center industry continues its rapid expansion and the needs of individual facilities evolve, our focus is on developing scalable technologies that help address the growth demands of the future," said Christian Senu, Executive Director of Data Centers & Mega-projects at Carrier. "Data centers today face common challenges—such as energy efficiency, cooling, and water consumption—but Carrier is providing tailored solutions that help empower owners and operators to optimize and scale their operations with confidence."

Carrier's range of smart and connected solutions deliver upstream data from the data center ecosystem to help cool, monitor, maintain, and analyze the facility. They also support efforts to meet green building standards, advance sustainability goals, and assist in maintaining compliance with local greenhouse gas emission regulations. The purpose-built solutions integrate efficient and high-performing HVAC equipment, data center infrastructure management (DCIM) tools, and building management systems to assist data center operators and owners in reducing power consumption while enhancing operating costs and profitability.

Carrier's innovative HVAC equipment technology is designed to address the specific and unique requirements of data centers. The following highlights some of Carrier's various equipment solutions for data centers:

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AquaEdge® water-cooled chillers combine innovative features, exceptional versatility and can restart swiftly following a power loss – just 150 seconds to reach full design capacity once power is restored—downtime being a critical issue for data centers.

AquaForce® 30XV variable speed air-cooled screw chiller delivers industry-leading efficiency, uptime, rapid capacity recovery and dependability. Its modular free cooling option maximizes savings and environmental benefits and is ideal for small to large-size data centers cooling.

Aero® Air Handling Units are custom and semi-custom units to meet specific data center requirements. Both the 39DC and 39M double-walled units offer a variety of filters, fans and factory-installed controls to help maintain efficient airflow and ventilation.

The Importance of Data Center Analytics

The importance of having HVAC and BAS analytics in any data center—regardless of type—cannot be understated. BAS health detection, diagnostics, HVAC system operating conditions, the ability to have real-time management data and analytics are essential. Data Center Infrastructure Management (DCIM) and Integrated Data Center Management (IDCM) tools are essential for optimization. These tools provide comprehensive visibility

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and control over physical assets, power consumption, and environmental conditions to help improve efficiency, reduce downtime, and manage resources more effectively. By integrating IT systems with infrastructure management, DCIM and IDCM tools streamline operations, enhance capacity planning, and support sustainability efforts, making them invaluable for data center management.

The Value of Holistic Management of Data Centers

The number of users and devices connecting to the internet continues to rise as organizations collect, store, and analyze increasing amounts of data each day. Furthermore, with the sharp rise of computing power required to support Artificial Intelligence (AI), the demand for data centers is in the midst of unprecedented growth. Carrier has the expertise to support this expansion and help manage costs and energy usage while supporting uptime, scalability, and security. While Carrier offers a comprehensive range of HVAC equipment solutions designed to cool, monitor, and protect data center environments, Nlyte (a Carrier company) delivers digital tools which are essential for optimizing operations. These tools help offer visibility and control over physical assets, power consumption, and environmental conditions, which can contribute to improved efficiency, reduced downtime, and managed resources.

Data Center Infrastructure Management (DCIM) manages all aspects of a data center to optimize its efficiency. It includes maintaining existing assets, monitoring network performance, and most importantly, planning for future contingencies.

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Carrier's Nlyte DCIM tools share detailed information between the HVAC equipment, power systems, and servers/workloads within data centers, providing transparency and control of the infrastructure for improved uptime. DCIM tools are gaining prominence in the context of environmental sustainability—essential for tracking and reporting carbon emissions, helping data centers meet their environmental goals and comply with new regulations.

Integrated Data Center Management (IDCM) Data centers must be increasingly efficient, resilient, and flexible. To achieve these objectives, it is beneficial to integrate critical infrastructure—such as power, cooling, security, and access control—with IT equipment and the applications themselves. Data centers are unlike other building types in that they are dynamically influenced by the behavior of the applications running within them. Nlyte's IDCM tools, which are controls agnostic, integrate numerous systems, from buildings to virtualization, to provide greater efficiency, streamline management, and improve insight across these previously disparate systems.

Enhancing Operational Transparency, Analytics and Security

To help maximize uptime, reduce energy consumption, and provide specified management data across all operating systems, Automated Logic's (a division of Carrier) WebCTRL® is an industry-leading data center management software that seamlessly integrates with Nlyte tools, providing a unified control platform. It

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maintains environmental control, enables integrated and interoperable systems, and supports sustainability goals. ALC's software is backed by the **Carrier Global Cybersecurity Program**. Here, ALC tools undergo rigorous testing to mitigate and protect them from vulnerabilities at every stage of the life cycle, so data center owners and operators can be confident that their BAS is secure.

The Changing Landscape of Environmental, Social and Governance (ESG)

As digital transformation accelerates, the rising demand for data centers is leading to increased energy consumption, carbon emissions, and water usage. As a result, data centers must focus on sustainable practices, stricter climate reporting, and the reduction of carbon emissions. ESG is a framework used to assess a data center's business practices and performance on various sustainability and ethical issues.

Awareness regarding sustainability is on the rise, prompting the emergence of key

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regulatory frameworks, such as the California Title 24 and United States SEC Climate Risk Disclosures. With unprecedented reporting requirements, building codes, and energy efficiency requirements, it can be challenging to know where to begin.

The Nlyte Data Center Sustainability Compliance Reporting Solution simplifies compliance reporting. It consists of:

The Data Center Sustainability Dashboard: A holistic dashboard with eight, industry defined metrics and one composite measure called the Data Center Sustainability Index™ to simplify sustainability compliance reporting.

Compliance Reporting Framework: Calculations, metrics and trends needed to support ESG, sustainability and carbon sourcing reporting mandated by emerging legislation.

Nlyte® Data Center Sustainability Index™ (DCSI): Provides an integrated score offering an immediate overview of a data center's overall sustainability.

Additionally, Nlyte's powerful reporting tools will facilitate data center's ESG compliance with precise data and powerful reporting tools that track energy consumption, Power Usage Effectiveness (PUE): Total CO_2, Carbon Usage Effectiveness (CUE), Water Usage Effectiveness (WUE), cooling efficiency, and Average Delta T (ΔT).

Nlyte's monitoring, managing, and reporting tools not only allow for accurate reporting to local, state, and federal entities, they also provide an inclusive accounting to existing stakeholders and future investors.

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Creating the Future...

The scale and complexity for data centers of the future will require an all-encompassing HVAC system and an integrated, intelligent, scalable, and predictive management system that can immediately tie demand and load to thermal capacity. Historically, data centers were designed assuming 100% utilization, which is not reality. Data centers do not have 100% utilization; they have high, medium, and low-density times. Therefore, a scalable and modular system which can quickly and efficiently modulate to meet the actual load at any given moment is essential.

Additionally, operating future data centers at the highest level of performance, with effective BAS health detection and diagnostics, will be challenging without the integration of precise HVAC equipment and analytical tools, such as those available from Carrier, Nlyte and ALC described earlier.

In the lexicon of technological evolution, the data center stands as a cornerstone, a digital fortress safeguarding the world's information. As the volume and complexity of data centers expand, the role of leading-edge and innovative HVAC and BAS technologies—coupled with informed consulting/specifying engineers—has never been more critical. Each specification-based recommendation must be looked upon as mission critical. HVAC and BAS decisions must be forward-thinking to ensure performance, reliability, efficiency, sustainability, and security of the digital infrastructure.

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Data Center Type	Definition	Purpose	Unique Challenges
Enterprise	Owned and operated by a single organization for their exclusive use.	To support the IT operations and services of a specific organization.	High energy consumption, stringent compliance requirements, significant cooling needs, and ongoing maintenance costs.
Colocation	Shared facility where multiple organizations rent space for their servers.	To provide a cost-effective solution for organizations to house their IT infrastructure.	Energy efficiency challenges, compliance with multiple clients' standards, shared cooling infrastructure, and maintenance coordination.
Cloud	Virtualized data centers provided by cloud service providers.	To offer scalable and flexible IT resources on-demand over the internet.	High energy usage, complex compliance across regions, advanced cooling technologies required, and extensive maintenance.
Hyperscale	Extremely large data centers operated by major cloud providers.	To support massive scale cloud services and applications.	Enormous energy consumption, global compliance issues, advanced and efficient cooling systems, and high maintenance demands.
Edge	Small data centers located close to the end-users to reduce latency.	To improve performance and reduce latency for end-users.	Energy constraints, localized compliance, compact cooling solutions, and frequent maintenance due to distributed locations.
Micro	Compact, modular data centers designed for specific applications or locations.	To provide localized processing and storage for specific needs.	Energy efficiency in small form factors, compliance with specific use cases, limited cooling capacity, and higher per-unit maintenance.

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The future of sustainable and scalable data centers is in all of our hands. While this brings great responsibility, it also holds profound opportunity. By designing data centers that are not only efficient and sustainable but also ethical and equitable, we can help create a world where the benefits of digital innovation are shared by all—a world where technology serves humanity, not the other way around. In doing so, we can ensure that the consequences of each decision and the solutions we implement for data centers will be triumphs of technological achievement.

For more information, visit **carrier.com/datacenters**

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About Carrier:

Founded by the inventor of modern air conditioning, Carrier is a world leader in high-technology heating, air-conditioning and refrigeration solutions. Carrier experts provide sustainable solutions, integrating energy-efficient products, building controls and energy services for residential, commercial, retail, transport and food service customers. Carrier is a part of Carrier Global Corporation (NYSE: CARR), global leader in intelligent climate and energy solutions that matter for people and our planet for generations to come.