Principal Real Estate

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Data centers | Digest

A series of papers highlighting this exciting sector

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PRINCIPAL REAL ESTATE

Data centers: Empowering a data-driven world

JEFF MENZ
Managing Director,
Portfolio Management

CASEY MILLER
Managing Director,
Portfolio Management

Data centers have become critical components of our growing dependence on technology. Surging demand coupled with high barriers to entry for new supply and a global search for attractive investment returns have brought the sector to center stage.

At-a-glance—The data center opportunity:

- **Accelerating demand:** Structural shift in how consumers and corporates use data powered by Internet of Things (IoT), Infrastructure as a Service (Iaas), e-commerce, and gaming.
- **Limited supply:** Data center vacancy rate at lowest point ever in the U.S.; Rising land prices, longer lead-times for power and equipment, and increased labor costs all are driving up construction costs; Hyperscale users are competing for key locations
- **Compelling investment opportunity:** Low correlations to other assets, a favorable risk/return profile, and new liquidity from institutional capital make data centers a portfolio component worth considering
- **High barriers to entry:** Given the highly specialized and niche nature of the data center industry, experience is critical to successful execution—development, leasing, technical expertise, ESG, etc.

Big data keeps getting bigger. And faster. And more valuable. The amount of digital data expected to be created over the next five years will be more than double the amount of data created since digital storage was first invented in 1956.[1] By 2030, the number of internet-connected devices is expected to grow by 242% compared to 2019.[2] Data centers are not only real estate, they are the infrastructure lifeblood of the modern economy.

Processing, housing, streaming, and securing all this data has led to rapidly increasing demand for data centers. In fact, even though leased data center capacity has more than tripled since 2015[3], vacancy is at an all-time low. Given the growing awareness of the significance of data centers to the economy, investors are increasingly looking for ways to participate.

The elements that appeal most to investors today include:

- High demand for quality data center space—but limited supply of data centers able to keep pace with exponential data growth from developments in outsourcing, cloud adoption, and emerging technologies.
- Long-term leases and credit-worthy tenants have led to a stable cash flow and attractive returns in both up and down markets.
- Access to a specialized product type to diversify their portfolio.

Private data center investing requires a high degree of specialization to source, build, and lease the properties. With a favorable risk-adjusted return profile, high barriers to entry, and past resiliency in both up and down markets, we believe data centers represent an attractive long-term investment opportunity.

[1] BusinessWire, Data Creation and Replication Will Grow at a Faster Rate Than Installed Storage Capacity, March 24, 2021; IBM.
[2] Statista, July 2022.
[3] datacenterHawk, September 2022.

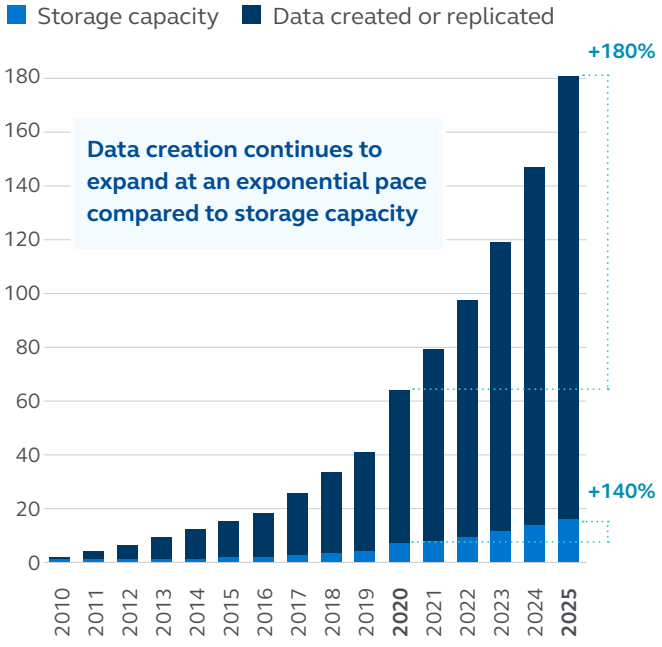
The demand for data centers

Data centers are the engines that propel the modern economy, as more and more systems become driven by some form of data. They've become the cornerstone of the information economy—the central nervous system of the interconnected internet network, further propelled by the COVID-19 pandemic which made everyday tasks from working to shopping completely dependent on data and fast connectivity. While data storage was once the primary purpose of data centers, computing power and network connectivity matter even more today. Digital technologies have transformed numerous aspects of society and the economy. Work, education, banking, healthcare, and shopping are a few examples of activities that individuals and businesses now perform online. Globally, ambitious digital mandates are underway to strengthen and expand digital data capabilities, including enhancing business usage of cloud technology, digitalizing public services, and extending 5G capabilities.

Exhibit 1 shows that the amount of digital data created in 2025 will be nearly ten times the amount of data created in 2015. The adoption of new technologies including personal devices and smart everything, in conjunction with the growing penetration of internet in developing markets are the main drivers behind this exponential growth. IDC, a global market intelligence provider, estimates that the volume of data in the world will pass 180 zettabytes by 2025. For reference, a single zettabyte is equivalent to one sextillion bytes, or a one followed by 21 zeros, enough data to fill 250 billion DVDs. Put simply, that's a lot of data that will drive significant investments in storage infrastructure.

Data centers are attractive in that they occupy physical infrastructure space but are also vital to the virtual infrastructure on which modern society depends. It is an asset class that sits at the intersection of infrastructure and real estate. Tenant demand for existing space continues to increase, with hyperscalers—the largest cloud computing providers—driving near-record demand. Hyperscalers continue to aggressively expand their operations to accommodate end users' needs, including social media, entertainment, gaming, and cloud services. Absorption of space has accelerated in most key markets, particularly in the largest data center clusters as shown in Exhibit 2.

EXHIBIT 1:
Volume of data generated vs. storage capacity



Source: IDC 2022.

EXHIBIT 2:
Demand for data centers continues to accelerate

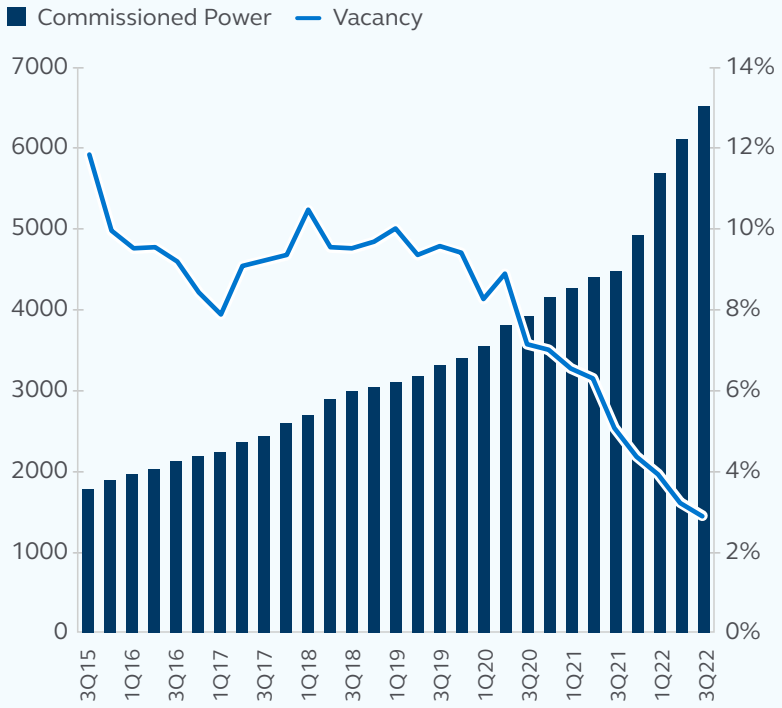
Net absorption by key market through 3Q 2022, megawatts (MW)

Source: datacenterHawk, Principal Real Estate, 3Q 2022

Demand is far outpacing supply

Growing demand has not been satisfied by the supply side, due in part to power grid limits imposed by local government. While rental growth slowed for a period of time, more recently the industry has seen a return to strong rental growth. Record low vacancy rates in key markets and accelerating demand have shifted the balance of pricing power toward landlords. We anticipate that this shift will result in higher rates and contract escalations going forward. This is important as data center tenants are not immune to many of the same concerns such as rising energy prices, supply chain issues, and labor shortages that are prevalent in other property sectors. Given the lack of supply, hyperscale users are having to compete for key locations and there are limited options for enterprise requirements.

EXHIBIT 3:
Market size and vacancy rate



Source: datacenterHawk, September 2022

Structural demand is driving investment opportunities

Data centers present a unique opportunity for real estate investors. With growth and defensive attributes, the data center industry has proven resilient in both economic downturns and periods of economic expansion. Low correlations to other assets, a favorable risk/return profile, and new liquidity from institutional capital make data centers a portfolio component worth considering. Longer leases, many times in excess of 10 years, also make data centers attractive giving investors exposure to cash flows from high-quality credit tenants at higher yields than most other property types.

For long-term investors—particularly those aiming to fund obligations by matching income and liabilities—stabilized data centers may offer some inflation mitigation—an attractive benefit given today's inflationary environment. Further, while sourcing opportunities in growth sectors during economic uncertainty is challenging, data centers are among the few areas where the structural growth story is intact.

The options to gain investment exposure to the data center sector are scarce due to limited offerings—core investments rarely trade and the pool of highly-technical developers who have capacity to build hyperscale datacenters is thin.

Investors who are able to partner with a strong developer may potentially achieve both an enhanced return and continued access to this sector, which is primed to further strengthen due to a number of factors, including the continued supply and demand imbalance, tenant preference to do repeat business with existing developers, increased headwinds to procure suitable sites with necessary power and fiber, and the long lead time on equipment necessary to commission a data center. All of these aspects point to the valuable opportunity in the develop and lease-to-core strategy, which we believe will prove advantageous for both tenants and investors going forward.

Attributes to focus on

While the technology supported by data centers has advanced rapidly, from a real estate perspective, most of the important requirements have remained unchanged. We believe key attributes of these assets include:

Location: As with all real estate investing, location is critical. The ideal data center location offers:

- Dependable access to low-cost power
- Proximity to a large population
- Fiber connectivity
- Low risk of natural disasters
- Sales tax incentives

Given the importance of these criteria, a handful of markets have emerged as more dominant than others, including: Northern Virginia, Dallas, Northern California, Phoenix, Chicago, Portland, Atlanta, and Austin/San Antonio.

Facility: Because these assets host critical applications, they're constructed with zero tolerance for downtime. They must offer multiple layers of protection, including:

- Structurally enhanced walls, floors, and roofs
- Multiple sources of power from multiple substations, as well as backup power through generators
- Temperature- and humidity- controlled environment with air handler components
- Controlled access with 24x7 security, mantraps, and biometric screening

Importance of experience in execution

Given the highly specialized and niche nature of the data center industry, we believe experience and access are critical to successful execution. As an active commercial real estate investor for more than 60 years[4]—including more than 14 years in the data center sector—we have witnessed the asset class evolve and adapt to the changing needs of occupiers. Our experience has resulted in a favorable track record and meaningful industry relationships:

- A top-10 global real estate manager with a fully integrated real estate platform.[5]
- Over 440 total development and value-add projects since 2001, valued at nearly $25.1 billion. Invested more than $2 billion in 20 data center transactions.[6]
- Our substantial equity and debt business gives us a distinct perspective of real estate and capital markets.
- In-house expertise in responsible property investing and ESG - data centers have many unique development, operational, maintenance, security, and energy requirements.
- Demonstrated ability to source and close significant volume of high-quality investments.[7]
- Able to source experienced partners that bring significant technical and location-specific expertise, as well as ability to attract strong tenants.

[4] Principal Real Estate Investors became registered with the SEC in November 1999. Activities noted prior to this date were conducted beginning with the real estate investment management area of Principal Life Insurance Company and, later, Principal Capital Real Estate Investors, LLC, the predecessor of Principal Global Investors Real Estate.

[5] Managers ranked by total worldwide real estate assets (net of leverage, including contributions committed or received, but not yet invested; REOCs are included with equity; REIT securities are excluded), as of 30 June 2022. "The Largest Real Estate Investment Managers," Pensions & Investments, 3 October 2022.

[6] Based on gross asset value as of 31 December 2022.

[7] Past performance is not indicative of future results and should not be relied upon to make an investment decision.

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PRINCIPAL REAL ESTATE

Data centers: Mitigating risks for continued growth

CASEY MILLER
Managing Director,
Portfolio Management

The essential role of data in our lives is a secular trend that continues to accelerate, fueled by surging digital data creation, cloud computing, the adoption of new technologies, and the growing penetration of the internet in developing markets. As businesses, consumers, and new technologies use ever-increasing amounts of data, data centers have become the cornerstone of our data-dependent world.

At-a-glance

- **Data centers are the cornerstone of our data-dependent world** as demand for data processing and storage accelerates.
- **As with other niche property types, data center investing includes some unique risks,** such as availability of power, supply chain delays, and natural disasters.
- **Certain risks may create an advantage for investors,** establishing high barriers to entry for new supply, which enhances the potential for rent growth and tenant renewals.
- **Investment managers with the experience, knowledge, and resources** to mitigate these risks are better positioned to navigate this critical property sector.

Many characteristics of data centers make them appealing investments, including attractive supply/demand fundamentals, high barriers to entry, and defensive and complementary valuation attributes relative to traditional real estate portfolios. However, given the relative newness of the space for many investors, concerns about the technology and significant technical and location-specific expertise required for successful data center development and operation, many investors remain on the sidelines as they seek to better understand the risks involved in this fast-growing property sector. We outline some of the key risks here and how we believe they can be mitigated.

RISK: Technological obsolescence

When considering the potential risks of data center investing, technological obsolescence may come to mind. Given the breakneck speed of technology change, that's a reasonable concern for the technology housed within data centers.

However, the servers and other equipment most susceptible to technological obsolescence are owned, maintained, and managed by the tenants—not the data center owner.

Also, the fastest-growing segment of data center tenants—hyperscale providers such as Google, Amazon, Apple, Microsoft, and others—are themselves leading technological advancements. These innovators are making long-term commitments to data centers through long-term leases and their significant investment in their data center space, often two to four times the landlord's investment in the building.

Data center infrastructure, for which owners are responsible, has mostly remained constant over the past 15+ years. Of course, alternative data storage methods are continuously under development. Among them are molecular and biological data storage—that could help minimize the amount of electricity needed to store data—and quantum computing. However, game-changing technologies such as these are likely decades away, let alone commercially feasible.

RISK: Diminished demand

Considering data centers are built for a particular purpose, what happens if demand for these facilities decreases? While that's theoretically possible, it's highly unlikely.

Almost all of the world's rapidly growing online traffic—including 8.5 billion Google searches *per day*[1]—goes through data centers, setting off a chain reaction of data storage and transmission. According to the International Energy Agency, "For every bit of data that travels the network from a data center to end users, another five bits of data are transmitted within and among data centers."[2]

That's why the "internet of things" (IoT) increases the need for data centers. When someone turns on a dishwasher from their phone, for example, a data center processes the exchange and also stores the information. That data may then serve dishwasher-related ads to that person.

It's no surprise that the data center market is estimated to grow by $616 billion from 2021 to 2026, with a compound annual growth rate (CAGR) of 22%. More than one-third (35%) of that growth will come from North America (primarily from the U.S.), as the North American data center market is projected to grow faster than the markets in Europe and the Middle East/Africa.[3]

Because of this growth and to allow for economies of scale, data centers are becoming larger, not smaller. As a result, a key distinguishing factor for data centers is the ability to expand—either by acquiring more land or accommodating more computing power in existing facilities. Our recent acquisitions, for example, all include additional land, and the designs of our data center buildings provide ample space for tenants to expand their capacity.

RISK: Interrupted access to power and water

Power is by far the biggest expense—and the most critical need—of a data center. Significant electricity is required to run the equipment, keep the facility at the appropriate temperature, enable security measures, and more.

Water is also a key resource for cooling equipment. However, as we'll discuss shortly, some approaches can significantly reduce the amount of water required on an ongoing basis.

Power availability

To ensure power is available without interruption, data center power should come from two separate, redundant sources. This helps mitigate the risk of power being cut accidentally, such as from construction- or utility-related digging (easements are then required to get the power from the source to the facility).

These requirements must be addressed in the predevelopment process and can significantly impact site planning and location selection. For instance, in two of the top three U.S. data center markets (Northern Virginia and

[1] Internet Live Stats, 2022
[2] "Data Centres and Data Transmission Networks," International Energy Agency, Nov. 2021
[3] Technavio, May 20, 2022

Northern California), local utility companies have the power but not the equipment to distribute power to new data centers—resulting in power availability potentially being delayed for years.

One way to significantly mitigate this risk is by building an on-site substation to power the data center directly. That gives the data center owners control over their primary power source, removing the risk of accidental power-line cuts and eliminating the need for easements.

Another way to ensure access to power is by securing power agreements with local utility companies. These agreements provide advance assurance of power availability and cost during the predevelopment stage.

Site selection also plays a role in managing this risk. Consider a site's proximity to a grid, the grid's age, and comparative costs per kilowatt-hour. Owners and tenants may also want to explore green power sources, such as wind or solar.

Water availability

Some data centers use significant amounts of water to control equipment temperature—as much as 3-5 million gallons per day.[4] This has led to considerable concern from an environmental perspective and significant pushback from drought-stricken communities.

A more forward-thinking approach can significantly reduce the amount of water needed for equipment cooling over time. This involves using a closed-loop water system where chillers reuse the same water day after day—eliminating the need for a constant supply of fresh water and only using a fraction of the water.

RISK: Security threats

Security of the entire data center space—both physical and digital—is a top priority. In the best-managed data centers, cybersecurity and physical security go hand-in-hand. Without protections on both fronts, bad actors can render card readers, video cameras, air handlers, power systems, or HVAC units unusable—ultimately resulting in damage or even access to a tenant's assets.

Multiple, diverse barriers between the uncontrolled area beyond the data center's property and the tenant's equipment can help to mitigate this risk. These barriers can include virtual local area networks (VLANs), segregated networks, doors, cameras, turnstiles, and more. Between those barriers are intervention zones where detection and response occur. If someone compromises the first barrier, for instance, the intervention zone is in place before the second barrier.

Holding compliance certifications is a mark of a responsibly managed data center. For example, the ISO/IEC27001 governance standard is regarded as the gold standard of information security. It defines how to implement, monitor, maintain, and continually improve the information security management system (ISMS). It also prescribes best practices that include documentation requirements, divisions of responsibility, availability, access control, security, auditing, and corrective and preventive measures.

[4] NBC News, June 19, 2021

RISK: Supply chain delays

Data centers aren't immune to global supply chain issues. Transportation bottlenecks, labor shortages, and lack of raw materials are causing major delays for the expansion of existing data centers and the construction of new facilities.[5] Critical equipment is often delayed by 18-24 months.

Vendor agreements are key to overcoming these delays. Principal Real Estate and our partners have developed and managed a vendor management program, allowing us to hold our spot in production lines. This helps us get the equipment we need faster and gives us more certain lead times. In turn, we can provide copies of purchase orders to current and potential tenants so they know we'll have the needed equipment to meet their timing needs.

RISK: Natural disasters

An 83% increase[6] in climate-related disasters over the last 20+ years means that the risk of natural disasters—fire, flood, wind, earthquakes, and more—is very real. Several steps must be taken to minimize the risk of natural disasters on data centers.

Careful site selection is the first step. This involves more than avoidance of areas prone to natural disasters and extreme weather. The site's ground elevation should be outside FEMA's 500-year flood plain. The site must also have access to robust fiber, utility power, and water. Ideally, land would be available for an optional on-site power station.

In addition to site selection, these strategies help to minimize natural disaster risk:

- Advanced sensors and controls allow for early detection of potential problems
- Structures built to help withstand hurricanes, tornadoes, major flooding, seismic activity, and more
- Uninterruptible power supply (UPS) systems
- Diesel-powered generators, along with the climate appropriate fuel or fuel additive
- Leading-edge fire prevention and extinguishing systems
- Physical presence of on-site, round-the-clock security staff

Opportunities abound

There's no doubt that data center investing brings risks. But the sector may hold significant opportunities for those working with managers and partners with the experience and resources to help overcome those risks.

In fact, the risks themselves may present opportunities by preventing less-experienced players from entering the market—making data center supply even more limited and allowing experienced providers to differentiate themselves. Combined with long-term leases and tenants with top-tier credit, data center investing offers the potential for extremely stable cash flows and a compelling return profile.

For a deeper dive into the data center opportunity, read our paper "Data centers: Empowering a data-driven world."

[5] Data Center Frontiers, March 23, 2022
[6] Yale School of the Environment, Oct. 13, 2020

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PRINCIPAL REAL ESTATE

Data centers: The tenants behind the demand

CASEY MILLER
Managing Director,
Portfolio Management,
Principal Real Estate

CHRIS BAIR
Chief Commercial Officer and Partner,
Stream Data Centers

We are living in the digital age. Society relies on digital applications—and the data creation, storage, and processing they require—for work, education, transportation, entertainment, healthcare, and just about every other aspect of our modern lives. In fact, three times as much new data was created and consumed in 2022 than 2018.[1] All that data is processed inside a data center, so it should come as no surprise that demand for data center capacity is at an all-time high and continues to rise, having grown 137% in the last year alone.[2]

At the same time, available data center space that meets the size and quality standards of the world's most demanding hyperscale and enterprise users is at an all-time low.[3] The cost and complexity of siting, powering, building, and maintaining data centers prevents many enterprise users from self-vending and creates high barriers to entry for new would-be providers. Even hyperscalers are challenged to meet all their internal needs with company-owned data centers, given the speed and scale at which demand for their services continues to rise.

Who is driving this demand? Which tenants offer the greatest opportunities for data center investors? We profile the key tenant segments in the data center industry—hyperscalers, enterprise users, and colocation providers—and examine their outlooks for growth.

At-a-glance—Data center tenants

- **Hyperscale users** are the largest and fastest growing tenant group for data centers. They are large technology companies that require vast data processing and storage requirements to provide cloud services to their enterprise and government customers. They represent top tier credit, require large amounts of capacity and expansion potential, and prefer long term leases.
- **Enterprise users** are organizations that operate their own data centers. While many organizations have turned to cloud service providers to manage a subset of their applications, such users prefer to maintain control over systems that are not well-supported in the cloud. Enterprise users credit is generally strong and they require small-to-medium amounts of capacity.
- **Colocation providers** are companies in the business of providing cloud services on a smaller scale than hyperscale users typically require. They serve as ideal partners for enterprise users pursuing a hybrid cloud approach, as well as for smaller companies seeking capacity that can be met with a single server or rack within the overall facility.

[1] IDC, 2022
[2] datacenterHawk, 4Q 2022 Data Center Market Recap
[3] datacenterHawk, 4Q 2022 Data Center Market Recap

Hyperscalers

By far, the largest and fastest-growing segment of data center users is hyperscalers—with a market size of $62 billion in 2021, forecast to grow to $593 billion by 2030. Hyperscalers are large, well-known technology companies such as Amazon, Google, Microsoft, IBM, Tencent, and Alibaba; the top three of these control two-thirds of the world's $227 billion cloud infrastructure services market.[4] They represent top tier credit, require large amounts of capacity and expansion potential, and prefer long-term leases.

Hyperscale providers use highly redundant, clustered infrastructure. This lets their customers take advantage of economies of scale to meet data/transaction loss requirements utilizing a platform that provides geographically dispersed customers fast, easy, and secure access to data storage and processing.

Hyperscale providers have a voracious appetite for internally constructed and leased data center space in key markets. In the past, they tried to meet most of their needs through the data centers they owned and maintained. But the massive uptick in demand means that hyperscale providers cannot build their own facilities fast enough. A variety of factors drive this need for aggressive growth, including the shift to working from home and significant increases in the use of:

- Cloud services (government and enterprise adoption)
- 5G technology
- Artificial intelligence (AI)
- Internet of things (IoT)

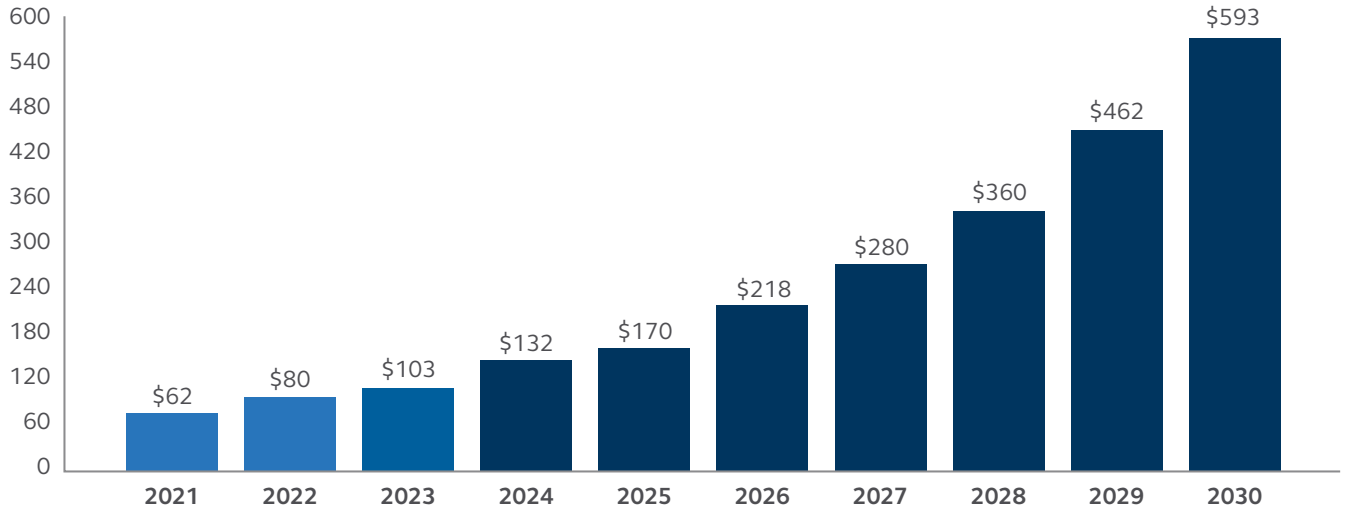
Department of Defense awards $9 billion cloud-computing contract

An example of the scope of demand faced by hyperscale users and the willingness of users to place highly critical information in the cloud is the $9 billion U.S. Department of Defense contract for cloud computing services awarded to Amazon, Google, Microsoft, and Oracle in 2022.

Source: APnews.com, December 2022

As a result, the market for hyperscale data centers worldwide is predicted to reach $593 billion by 2030. That's a compound annual growth rate (CAGR) of 28.52% from 2022 to 2030.

EXHIBIT 1: Hyperscale data center market size, 2021 – 2030 (USD billion)



Source: Precedence Research, September 2022

[4] Synergy Research Group https://www.srgresearch.com/articles/cloud-spending-growth-rate-slows-but-q4-still-up-by-10-billion-from-2021-microsoft-gains-market-share

In addition to the sheer scope of their demand, hyperscale users make attractive tenants for other reasons. As large, global corporations, they have strong credit ratings and long-term growth profiles. They have extremely stringent requirements and typically lease large amounts of capacity, further shrinking the pool of suitable data centers and competitors. But once they establish trust with a vetted, preferred data center partner, hyperscale users will typically take as much space as those partners can produce in key markets. Across the U.S., there is insufficient hyperscale-suitable turnkey capacity. As a result, hyperscale users are executing long-term, multi-facility leases—often in advance of breaking ground on those facilities, with delivery dates several years in the future. Data center providers with well-established development functions and a history of providing build-to-suit projects are outpacing the growth of smaller retail-oriented data center providers in meeting the needs of hyperscalers. By offering faster construction timelines and therefore providing hyperscalers a faster way to grow, according to CBRE[5], it is expected that the number of partnerships between data center providers and hyperscale users will continue grow in 2023.

Enterprise users

Most enterprise users are large, heavily regulated global corporations with substantial data storage and processing requirements. Historically, these users relied solely on their own on-site data centers, which housed the enterprise information technology systems and the resources needed to maintain them. Now, enterprise investment in incremental capacity within internal data centers is shrinking and investment in cloud and colocation is rising. In 2019, for the first time, enterprise users spent more annually on cloud infrastructure services than on data center hardware and software.[6] Today, 63% of businesses are "heavy cloud users," (defined as running more than 25% of their workloads in the cloud). That's up from 53% in 2020.[7] Public cloud markets are expected to grow by 10% to 30% every year between 2020 and 2027, highlighting the increasing trend that organizations are moving away from enterprise-owned IT systems and management, and evolving toward a cloud-based solution.[8]

Enterprise users' cloud adoption is driven by more than a Total Cost of Ownership (TCO) advantage. It is also driven by the unparalleled flexibility that comes from "renting" IT capacity instead of making massive, long-term commitments to internal IT service delivery (data centers, IT hardware, additional staffing, etc.). Most enterprises today take a hybrid approach, moving the workloads that can be effectively served in the cloud and maintaining owned or leased data center capacity for proprietary applications and sensitive data (especially enterprises operating in heavily regulated industries that have intense data-processing needs, such as healthcare and finance). This hybrid approach enables enterprises to maintain tight control over their most critical and/or proprietary applications and data. It also helps them to comply with security requirements and data privacy regulations, such as the European Union's General Data Protection Regulation (GDPR).

Enterprises that experience the unprecedented freedom of buying cloud services "by the drink'" also recognize the benefit of leasing data center capacity versus trying to build new facilities that will meet their projected 15 to 20-year growth requirements. When facing the decision to build more capacity internally or go to a reputable third-party data center provider, very few organizations choose new internally constructed data centers. Significantly higher TCO and decreased flexibility drive these users to buy data center capacity like they buy cloud services. No need to over-build to meet a 15 to 20-year projection when they can lease sufficient capacity to serve their sensitive and proprietary deployments in a highly predictable and scalable setting.

[5] CBRE U.S. Real Estate Market Outlook 2023, December 2022
[6] Synergy Research Group https://www.streamdatacenters.com/wp-content/uploads/2021/12/SDC_CloudBenchmarkWhitepaper_210507.pdf
[7] Flexera's State of the Cloud Report 2022
[8] JLL H1 2022

Colocation providers

Colocation service providers give their customers access to high-quality data center facilities without the need for significant capital commitments. Colocation customers include enterprises pursuing a hybrid approach and IT service providers that require fast, scalable capacity in a specific market.

Colocation providers operate under either a wholesale or retail model:

- Wholesale providers are generally in major data center markets and are typically more real estate centric than retail providers. Wholesale customers/tenants will typically be the only customer in a data hall and increasingly will lease an entire building or campus from a wholesale provider. Wholesale providers pass on the cost of power to their customers with no markup. They generally serve cloud service providers and larger companies with significant (1+ megawatt) capacity requirements.
- Retail providers are often located in secondary Tier 2 and Tier 3 markets with facilities that serve many (50+) smaller customer deployments in a single building. Retail providers are focused on providing additional services (such as network management or security services and typically sell electrical power to customers). Large organizations that require a small footprint in a specific market or small companies that require only a small amount of data center capacity are often served in retail facilities.

As companies of all sizes increasingly rely on data processing and connectivity, colocation providers globally are growing, presenting additional opportunities for data center investments. Their credit is improving as they take on new assets, diversifying their income streams and becoming less dependent on any particular site.

Significant growth opportunities across the tenant spectrum

Demand for data storage and processing by businesses of all sizes will continue to grow in the years to come. Having doubled between 2018 and 2020, data volume is predicted to triple, to 181 zettabytes, between 2020 and 2025.[9] The demand for services delivered from data centers is at an all-time high and tenant demand creates new investment opportunities. Combined, we believe these opportunities will continue to expand across the major tenant types and remain optimistic about the outlook for data center investments.

Learn more about data center investing:

- Data centers: Empowering a data-driven world
- Data centers: Mitigating risks for continued growth

[9] IDC, 2022

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PRINCIPAL REAL ESTATE

Data centers: The growing importance of sustainability

JENNIFER MCCONKEY
Managing Director,
ESG & Operations

STUART LAWRENCE
Vice President, Product Innovation & Sustainability, Stream Data Centers

As the emphasis on environmental, social, and governance (ESG) considerations continues to grow, so does the scrutiny on market segments that are significant contributors to emissions due to high energy use.

At-a-glance

- **Operating efficiency:** Between 2010 and 2018, data centers supported 550% more compute instances using just 6% more energy.[2]
- **Market growth:** Data center market size is projected to grow by 21.98% from 2021 to 2026.[3]
- **Geographic priority:** North America is estimated to contribute 35% to the growth of the global market.[3]
- **Mitigating risk:** Sustainable data centers address climate risk and may reduce both operational and reputational risk.

For data centers, sustainability considerations have proven to be particularly vital. These facilities account for more than two percent of global energy consumption–equivalent to the aviation industry–and is projected to rise to eight percent by 2030.[1] Consequently, energy efficiency is a priority in data center sustainability efforts that tend to include additional indicators of environmental performance such as carbon emissions, water, waste, and biodiversity.

Many of the largest data center tenants are Fortune 100 companies that are unequivocally committed to reducing the environmental impact of their infrastructure and operations. Sustainable data center practices do more than reduce the carbon footprint, they lower the tenant's total cost of ownership (TCO) and may reduce both operational and reputational risk.

Data demand is only expected to increase due to a structural shift in how consumers and corporates use data powered by Internet of Things (IoT), Infrastructure as a Service (IaaS), e-commerce, and gaming, as well as emerging technologies such as artificial intelligence (AI), driverless car technology, and 5G networks. There is rapidly growing digitalization, which places data centers at the confluence of supporting a wide variety of critical services around the clock, from email and file sharing to enterprise resource planning to support of core business processes.

[1] Data Center Frontier, "The State of Data Center Sustainability" July 2022
[2] Stream Data Centers, "Yes, the Cloud Is a Catalyst; It's Also a Competitive Benchmark" 2023
[3] Technavio, "Data Center Market Size to grow by USD 615.96 bn, Insights on the Key Drivers and Trends" November 2022

Data center market segment growth

The global data center market size is projected to grow by $616 billion, progressing at a compound annual growth rate (CAGR) of 22% from 2021 to 2026. More than one-third (35%) of that growth will come from North America (primarily from the U.S.), which is also expected to grow faster than the markets in Europe and the Middle East/Africa.[4]

One of the key drivers of global data center market growth is the rise in the adoption of multi-cloud and network upgrades to support 5G— in North America in particular, there has been a substantial increase in the adoption of cloud services by enterprises across industries. Another major factor is the rise in the adoption of edge computing, which is a network architecture wherein the data is stored and processed near its origin. There has also been a significant increase in the adoption of IT infrastructure due to the increase in demand for computing power and storage to support the growth in global data traffic.

Leading sustainability best practices

Principal Real Estate and Stream Data Centers are dedicated to providing common sense solutions that meet the needs of today's data center users while seeking to deliver positive financial and sustainability outcomes. Our sustainability objectives address environmental impact, climate resilience, data transparency, stakeholder engagement, and sustainable design.

Environmental impact is minimized through innovative cooling systems design, energy efficiency measures including raising data hall temperature setpoints, and sourcing renewable energy. Power is by far the biggest expense and most critical need for data centers, so efforts to reduce mechanical systems energy demand and offer uninterrupted power are a priority. Maintaining availability has traditionally been fulfilled with diverse utility feeds backed up by emergency diesel generators, but a more sustainable approach is to consider building an on-site substation to power the data center directly, securing power purchase agreements with local utility companies and competitive suppliers (ideally green power), or installing on-site renewable power generation along with Hydrogen Fuel Cell or LNG fueled Generators. Hyperscale providers such as Amazon, Facebook, Google, and Microsoft have led the charge toward 100% renewable energy commitments. According to the IEA World Energy Outlook 2017, the share of renewables in total power generation will increase from 24% in 2016 to 30% in 2022, and it predicts that renewable energy will account for two-thirds of global investment in power plants through 2040.[5] And, energy efficiency starts at design with efficient infrastructure and structural considerations like enhanced walls and roof that also align with withstanding natural disasters and extreme weather.

Climate resilience is fostered through climate risk analysis, site selection, and mitigation strategies to help ensure building safety and preparedness for both physical and transitional climate risks. Physical risks include natural disasters and extreme weather such as flooding, wildfire, extreme temperature, and tropical cyclones. This informs site selection or identifies high risks that require a mitigation strategy.

Data transparency involves tracking and reporting on asset performance in alignment with recognized ESG benchmarks and standards such as GRESB. Principal has clearly defined sustainability metrics and targets, benchmarks utility usage in ENERGY STAR Portfolio Manager, and discloses performance to GRESB, CDP, PRI, and others.

Stakeholder engagement focuses on tenants and industry organizations. Tenants can be effective partners in reaching sustainability goals by optimizing operations and reducing inefficiencies. Tenants may have their own ESG initiatives to support or align, which increases the likelihood for collaborative partnerships. Tenants are also integral in collecting ESG data to drive performance, such as energy usage that is used to calculate greenhouse gas emissions. Implementing green lease clauses, such as data sharing, can play an important role in effective tenant engagement and collaboration.

[4] Technavio, November 2022

[5] 451 Research "Smarter Datacenter Energy Procurement Can Improve Sustainability While Lowering Costs"

Sustainability measures are most effective when contemplated by stakeholders during the design and development phase and even earlier during site selection when cost of power and risk of natural disasters can be evaluated. Sustainability measures to reduce negative impacts on the environment and improve building performance include resource management, building certifications, and technology and equipment innovation. There are several industry organizations, such as the iMason Climate Accord, Data Center Coalition, and Data Centre Alliance that can provide valuable insight and resources for sustainable data center operations.

Innovative technology & renewables

While data centers are energy-intensive, much has been done to enable these facilities to operate more efficiently through the deployment of innovative technologies and a shift to renewable energy power sources. In the last decade, even as data use has skyrocketed, technological enhancements such as processor efficiency improvements and reductions in idle power, have reduced the electricity requirements of data center servers.[6]

Research has shown that IT Equipment has increased in density but become more efficient in doing so, which means the energy required to process a terabyte of data has fallen. Some research has estimated a 20% reduction in energy intensity over the last five years–representing a sharper decrease than other energy intensive industries.[7]

Beyond processor efficiency, landlords and tenants are seeking innovative building solutions such as hydrogen fuel cells, capturing waste heat, and water free cooling. Microsoft recently used hydrogen fuel cells to back up some of its data center services, which could help replace diesel-powered backup generators.

Utilizing the excess heat produced by data center cooling equipment is another emerging area of energy efficiency, particularly in Scandinavia, Netherlands, and Germany. For example, an initiative in Stockholm aims to use waste heat from data centers to heat 10% of the city by 2035.[8]

Water free cooling or air-cooled systems are a priority solution for water constrained climates. For example, Intel recently announced an effort to create a reference design for immersion cooling, which is a technique that involves immersing servers and other equipment in non-conductive liquids to enable hyper-efficient cooling.[9] Conversely, where water is abundant, using water can be a valuable tool for reducing emissions. However, there is increasing focus on water usage effectiveness (WUE) in data centers. As an example, Amazon committed to publishing Water Usage Effectiveness (WUE) reports on an annual basis. It also pledged to become water-positive, meaning it will make more water available than it consumes. One strategy has been to utilize recycled water for cooling in 20 of their data centers. Microsoft and Google Cloud have made similar pledges to be water-positive. Google's Senior Vice President of Technical Infrastructure Urs Hölzle also recently wrote in a post titled *Our commitment to climate-conscious data center cooling*, "There is no one-size-fits-all solution." [10]

Our energy efficiency and carbon reduction strategy is encapsulated in three stages in order of priority: reduce, renew, and restore. First, reduction in energy use and greenhouse gases is achieved by taking advantage of increased tenant thermal requirements and innovating on mechanical systems to benefit from these elevated service-level agreements (SLAs). Since up to 40% of a modern data centers energy can go to mechanical, electrical, and plumbing systems (MEP systems0 that support IT Loads, it's vital that these systems maximize the gains available from elevated thermal SLAs, better airflow design and utilize the most efficient components available.

[6] B. Wagner, "Intergenerational efficiency of DellEMC PowerEdge servers" (DellEMC white paper 2018)
[7] American Association for the Advancement of Science, "Recalibrating global data center energy-use estimates" February 2020
[8] Data Center Frontier, "Waste Heat Utilization is the Data Center Step Toward Net-Zero Energy" August 2020
[9] Data Center Knowledge, "Key Data Center Sustainability Trends in 2022" December 2022
[10] Urs Hölzle, "Our commitment to climate-conscious data center cooling" November 2022

Second, renewables are an increasingly viable investment decision for both reliable energy supply and improved environmental outcomes. Additionally, renewable energy is becoming more cost effective. Microsoft recently committed to acquiring 900 megawatts of additional solar and wind energy, which is enough to power several hyperscale data centers.[9] Along with Microsoft, large hyperscale data center tenants Amazon, Meta, and Google are represented in the top 10 of leading corporate purchasers of renewable energy globally, often by way of direct purchases from newly-built renewable generation under Power Purchase Agreements (PPAs).[11]

Third, carbon offsets can be purchased that reduce emissions and ideally are selected for their ability to restore forests, update power plants and factories or increase the energy efficiency of buildings and transportation.

Risk mitigation

Sustainable and resilient data centers address climate risk and may reduce both operational and reputational risk.

Recently 25 companies and 17 associations across Europe announced an agreement to take specific measures to make data centers climate neutral by 2030.[12] It is a best practice to implement resiliency measures into data center risk mitigation strategies. Resiliency planning can help ensure building safety and increase preparedness for physical and transitional climate risks through climate risk analysis, site selection, and implementation of risk mitigation measures.

Total cost of ownership can be directly affected by operating costs related to energy and water usage, waste production, and carbon emissions (assuming potential carbon taxes). TCO can also be affected by supply issues, whether related to energy security, water scarcity, or equipment supply chain issues. Therefore, a sustainable data center incorporates design and sourcing considerations such as reducing reliance on water for cooling, using equipment sources that provide less exposure to global supply chain risk (and lower environmental impact), and shifting to renewable energy for more energy security.

Conclusion

Forward-thinking ESG practices in data centers has the potential to benefit the environment and are good for business. By taking a proactive role in promoting and implementing sustainability initiatives, we believe the data center industry will be well positioned to service its essential role connecting the global economy.

[11] BloombergNEF " Corporate Clean Energy Buying Tops 30GW Mark in Record Year" https://about.bnef.com/blog/corporate-clean-energy-buying-tops-30gw-mark-in-record-year/

[12] European Data Centre Association, "Climate Neutral Data Centre Pact» https://mb.cision.com/Main/7526/3271434/1361839.pdf

Principal Asset Management℠

BEHIND THE GATE:

The anatomy of a data center

Society relies on digital applications for work, education, transportation, entertainment, healthcare, and just about every other aspect of our modern lives. Through these digital applications, we create and consume massive amounts of data (three times as much in 2022 than just four years earlier). All that data—even data 'in the cloud'—is processed and stored inside a data center.

Indeed, data centers are the cornerstones of our digital world. And yet few people have ever been inside one. Most data centers don't have signs advertising them. You might drive by one on your daily commute and not even know it. You can't walk up to the lobby and ask for a look around. But in this short paper, we'll give you a peek inside.

The site

It's a well-worn adage in real estate: location, location, location. True for homes and shops, and true for data centers. That's why leading data center developers have location strategy teams to find the right sites that meet tenant-specific needs.

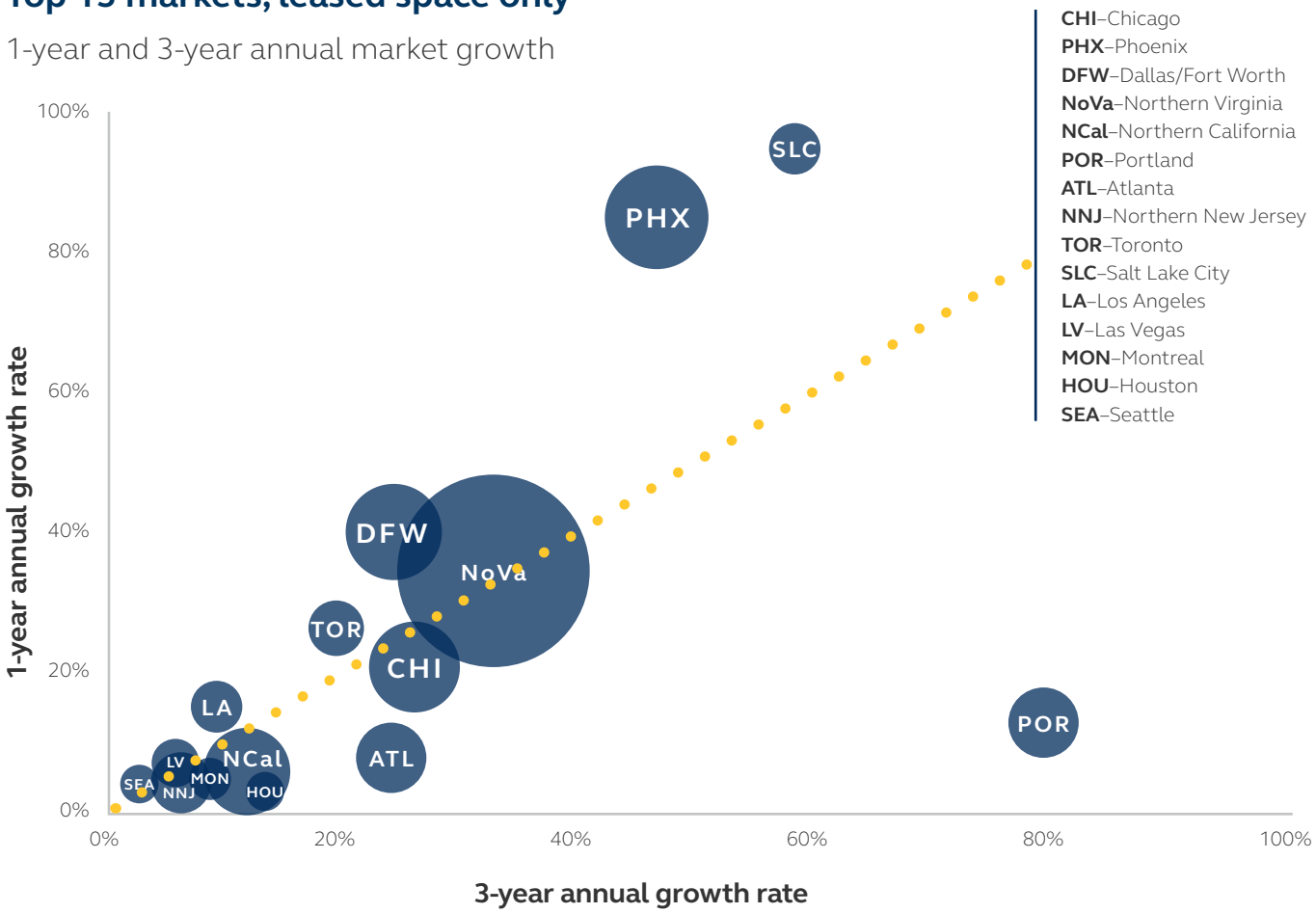
Both the market (city or region) and the specific site matter. Dallas, for example, is one of the world's top data center markets, with high marks on factors like power cost and network connectivity. But within the metro region, sites in the Eastern District of Texas are widely considered to be higher risk than sites in South Dallas.

SITE SELECTION FACTORS

- Low cost, high reliability power
- Low risk of natural disaster
- Strong network connectivity
- Favorable tax laws
- Renewable energy availability
- Access to technical talent
- Outside the FEMA 500-year floodplain

Top 15 markets, leased space only

1-year and 3-year annual market growth



As of 31 March, 2023. Source: datacenterHawk. The bubbles represent the size of the markets.

The building

Looking at a data center from the outside, you'll likely be struck by its resemblance to an enormous high-tech fortress. Indeed, hyperscale data centers are huge (one campus in Goodyear, Arizona, will be the size of 35 football fields). Many are designed to withstand or avoid natural forces like tornadoes and floods as well as human-caused risks such as a semitruck or an airplane crash.

BUILDING SPECIFICATIONS

- Concurrently maintainable or designed to "Tier III" standards means there are no single points of failure, the data center can remain online while equipment is being maintained or replaced, and can continue operating even in the event of a prolonged grid power failure.
- Secure yet accessible. Data centers must be secure enough to protect billions of dollars of tenants' IT equipment and the data on that equipment, while allowing 24x7 access to support, for example, large-scale deliveries by tractor-trailers.
- Resiliency to withstand natural forces. Data centers must meet International Building Code (IBC) 'importance factors' to help ensure continuous availability.
- Reduced risk via physical separation. Many data centers have setbacks from the property line to the data halls to help ensure protection of the data center even if the perimeter were breached.

Security

As you approach the data center, you'll encounter the first layer of security. Leading data center operators use a 'concentric rings' methodology with a number of barriers between the outside of the data center and tenants' IT equipment at its core. Between barriers, intervention zones allow for threat detection and response to stop the attack.

SECURITY LAYERS

- **Perimeter security** – Secure fencing (which can withstand vehicle impacts) and perimeter monitoring devices help ensure only authorized personnel are allowed within the 'security envelope' of the data center campus.
- **Exterior security** – A staffed perimeter security center helps ensure only authorized people can access the data center grounds and that authorized visitors (such as a tractor-trailer making a mission critical delivery) have clear direction on how to safely navigate the campus. Always-on video surveillance ensures a record of all activity outside the facility.
- **Interior security** – A main lobby security booth is staffed 24x7x365 with at least two guards who help ensure only individuals who have been thoroughly vetted and approved are allowed into the facility.
- **Restricted area security** – Dual authentication (biometric and color-coded key card) helps ensure only authorized personnel may enter into high-security areas. Security vestibules (sometimes called mantraps) help prevent 'piggybacking' by non-authorized individuals.
- **IT equipment** – A single tenant could have hundreds of millions of dollars in IT equipment in the data center (plus the company's most valuable asset of all: its data). Access to the data hall is restricted to individuals approved by the tenant. In shared data halls, suites or cages provide barriers between tenants' equipment and access into them is similarly restricted.

As important as the physical layers of protection is the data center's security personnel. Trained security professionals are critical as are rigorous continuous training programs that include security awareness, vendor management, and penetration testing to help ensure the team is ready to address developing threats.

Operations center

The ‘brain’ of the data center is often referred to as the Facility Operations Center or Network Operations Center (often referred to simply as the NOC). This is where technicians with various areas of expertise monitor the data center’s mission-critical systems—power, cooling, and network. They’re on the lookout for issues that could cause disruptions and are responsible for identifying and investigating any issues that arise.

Comparable to how you might imagine an air traffic control center or a crisis management room, NOCs are often outfitted with several rows of desks facing multiple screens displaying details about significant alarms, ongoing incidents, and general performance of the data center. The goal is to ensure that all team members have access to necessary information at the same time and can collaboratively solve problems when they arise.

THE PEOPLE OF THE DATA CENTER

Unlike with other forms of real estate (such as office buildings), in a data center the people who design, build, and operate the facility typically interface deeply with tenants’ technical and operations teams. These real estate professionals and technical experts with deep experience building and operating data centers are dedicated to providing the outstanding customer service that drives tenant satisfaction. And they have processes, honed over time, with a goal of ensuring optimal performance, cost containment and risk mitigation.

Mission-critical equipment

The mission of a data center is to ensure tenants can get data to and from their servers and storage devices and their end users. Delivering on that mission requires three components: network equipment, which manages the data flowing through the 'pipes' of the data center; power infrastructure to keep the network, cooling, and IT equipment on; and cooling infrastructure to remove the heat that IT equipment generates.

In a concurrently maintainable data center (designed to "Tier III" standards) mission-critical equipment is redundant. Essentially that means there are two of each of the critical components, with sufficient spares to keep the network, power, and cooling systems running even if one component is offline due to maintenance or failure.

Network redundancy means at least two different cable entry points, at least two different meet-me rooms, and at least two sets of cable distribution systems. It's critical to ensure physical network elements (such as a 'pair' of dark fibers) enter the data center diversely to avoid single points of failure upstream of the data center. Redundant power infrastructure means two diverse utility feeds, two sets of Uninterruptible power supply (UPS) equipment, and two sets of distribution systems. Cooling infrastructure like air handlers, chillers, and pumps likewise need to be redundant.

Network

Data comes in and out of the data center via fiber-optic cables operated by a network provider ('carrier') such as AT&T or Comcast or via 'dark fiber' dedicated to and operated by one tenant. Most data centers are 'carrier neutral' meaning they allow any carrier to deploy their network infrastructure and/or run fiber-optic cables into the data center.

Once inside the data center, network cables are diversely routed to a 'meet-me' room or directly to tenant-directed demarcation points in the facility. From here data center tenants run diverse, dedicated cables to their servers. The meet-me room also offers a secure location for tenants to economically 'cross connect' data from one carrier to another and to other tenants and service providers on a campus, or to networks providing access to major cloud providers.

Power

A hyperscale data center with 40 megawatts of IT capacity uses about the same amount of power in a year as 36,000 homes. That is a lot of power, but leading data center providers have implemented strategies to dramatically reduce power consumption; between 2010 and 2018 data centers globally did 550% more work with only a 6% increase in power.[1] In addition to efficiency measures, leading data centers now offer tenants the option to use renewable energy from sources such as wind and solar.

POWER INFRASTRUCTURE

- **Utility yard** – Like an engine room on a ship, the utility yard is a secure area outside of the data center building where diverse utility feeds deliver power from the utility. Here the utility power is transformed and prepared for distribution within the data center. Some data centers have on-site substations which enable faster time to deploy and give the operator more control, flexibility, and scalability.
- **On-site generators** – A concurrently maintainable data center (designed to "Tier III" standards) must be able to continue operating for at least 12 hours if utility power goes out. That requires on-site generating capabilities such as diesel generators and enough fuel stored on site to power them.
- **Uninterruptable Power Supply** – Instead of going directly to tenants' IT equipment, the power passes through a UPS system that protects the IT gear against disruptions like power surges and also provides temporary emergency power in the case of a utility outage, to keep the data center running.
- **Distribution** – After passing through the UPS, power is distributed directly to the data halls and the tenants' IT equipment.

[1] "Recalibrating global data center energy-use estimates" February 2020. https://www.science.org/doi/10.1126/science.aba3758

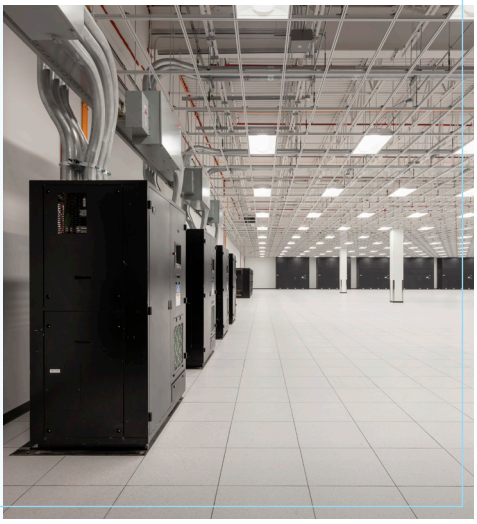
Cooling

Imagine bringing enough power for 36,000 homes into a single building. The IT equipment using all this electrical capacity generates a lot of heat—it's hard work processing quintillions of bytes of data every day! That heat has to get out of the data center somehow, and for that there is a range of cooling infrastructure technologies on the market. The 'best' depends on the type of work the IT equipment is doing (high density deployments like those used for AI applications, for example, create more heat per square foot and require more effort to cool), on the climate of the particular location, and on tradeoffs between energy efficiency and water efficiency—both of which are good for the business and the planet.

All else equal, closed-loop air-cooled chillers use less water but more energy than water-based evaporative cooling systems. In water-constrained markets and markets where renewable energy is readily available, leading data center developers are increasingly relying on air-cooled chillers. These systems use water pumped through a closed loop of pipes to extract the heat from the data hall and reject it into the outside air.

COOLING INFRASTRUCTURE

- **Computer room air handlers** – Fans distribute cold air into the data hall to remove the heat from the IT equipment. The hot exhaust air from the IT equipment goes back into the air handler where the heat is transferred from the air to the chilled water system via an air-to-liquid heat exchanger. A car radiator works essentially the same way, in reverse.
- **Chiller** – The chillers use a refrigeration cycle to transfer heat from the warm water leaving the air handlers to the atmosphere. The chillers are located outside of the data center building in the utility yard.
- **Pump room** – Located inside the data center building, pumps are used to move the chilled water in the chilled water loop from the chillers outside to the air handlers and the hot water from the data hall back outside to the chiller.



IT equipment

A large-scale data center houses hundreds of millions of dollars of IT equipment and—even more valuable—the IT systems and proprietary data that are the beating hearts of most companies. It all lives in the data hall. If you're standing just inside a data hall, you'll see a large room with rows and rows of servers stacked in racks. You may see network and power cables running overhead and connecting down into each rack of servers; or these cables may be hidden under access panels in the floor.

You may see the rows of server racks configured in sets of two facing each other with a door in between. This provides the opportunity for efficiency by installing hot or cold aisle containment, an airflow management strategy designed to optimize cooling efficiency by not allowing chilled supply air and hot exhaust air to mix. Chilled supply air can be delivered to the server racks in many ways, including through a raised floor plenum, through ductwork above the racks, or through rows of fans lining the data hall, aptly referred to as 'fan walls.' As densities within the data halls increase, tenants may look to other techniques to cool their equipment including using liquid cooling in addition to or instead of forced air. Oftentimes liquid cooling using equipment such as rear-door heat exchangers or even direct-to-chip cooling can be incorporated into traditional forced air data halls. Additional efficiencies can also be achieved by data center users through liquid immersion cooling, but that has yet to achieve widespread adoption due to requirements for specialized servers and cooling equipment, and proprietary (and costly) dielectric fluid.

How a particular data hall is configured depends on the particular needs of the tenant. Hyperscale companies that operate gigawatts of data center capacity around the world typically prefer standardized deployments across their portfolio—but the configuration of one company's data hall may be quite different from its competitors'. It requires a lot of experience and deep relationships for data center operators to ensure their data hall designs support the broadest set of tenants and allow for configuration without requiring one-off customization.

Conclusion

Now that you've taken a look behind the gates of a modern data center, the next time you stream a movie, bank online, post a video on social media, or have a video conference while working from home, you have some idea about the complex and vital digital infrastructure that makes that possible. In fact, the next time someone asks, 'But really, where is the cloud?' you can confidently answer that it's in a data center.

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PRINCIPAL REAL ESTATE

Data centers: Will big advancements in technology—like artificial intelligence—render existing data centers obsolete?

(Consensus is no.)

SEBASTIAN DOOLEY, CFA
Senior Fund Manager

CASEY MILLER
Managing Director,
Portfolio Manager

PAUL LEWIS
Director,
European Data Centres

BEN WOBSCHALL
Managing Director,
Portfolio Manager

There's a chip war going on. Semiconductor manufacturers continue to release increasingly powerful processors designed to manage new types of workloads, including artificial intelligence (AI) and machine learning (ML). Frequent headlines about this 'semiconductor arms race' have understandably made some investors concerned about whether the facilities supporting these servers—data centers—will become obsolete.

In an effort to address these concerns, we've gathered perspective from four of our data center experts around the world. As we've written before, innovation will indeed impact data centers, but we believe these risks are both limited and manageable. In fact, the global economy's increasing reliance on data has only made these facilities more attractive real estate investments.

"I have always taken great comfort from the vast quantum of capital investment being spent by the largest cloud companies (AWS, Google, Microsoft) on the basis of current data center technology. This is investment for the long term."

Paul Lewis, Director, European Data Centres

QUICK TAKE

- IT infrastructure has always evolved rapidly, and even data centers built 25+ years ago have not been rendered obsolete.
- Because the purpose of a data center is to power, cool, and connect IT equipment, its fundamental value is driven by power capacity and network connectivity—factors not likely to change unless new processing technologies such as quantum and biological computing are widely commercialized, and that is still decades away.
- There are innovations that affect data center design—including increasing density and evolving approaches to sustainability. But those won't make existing data centers obsolete.
- Leading data center developers build configurability into their facilities to support innovations like higher density and new approaches to sustainability.
- Even if the data center wasn't designed to be configurable, retrofitting an existing facility to support innovations is a much more likely course of action than decommissioning the data center entirely—in no small part because demand for data center capacity far outstrips supply. Old and new will continue to coexist.

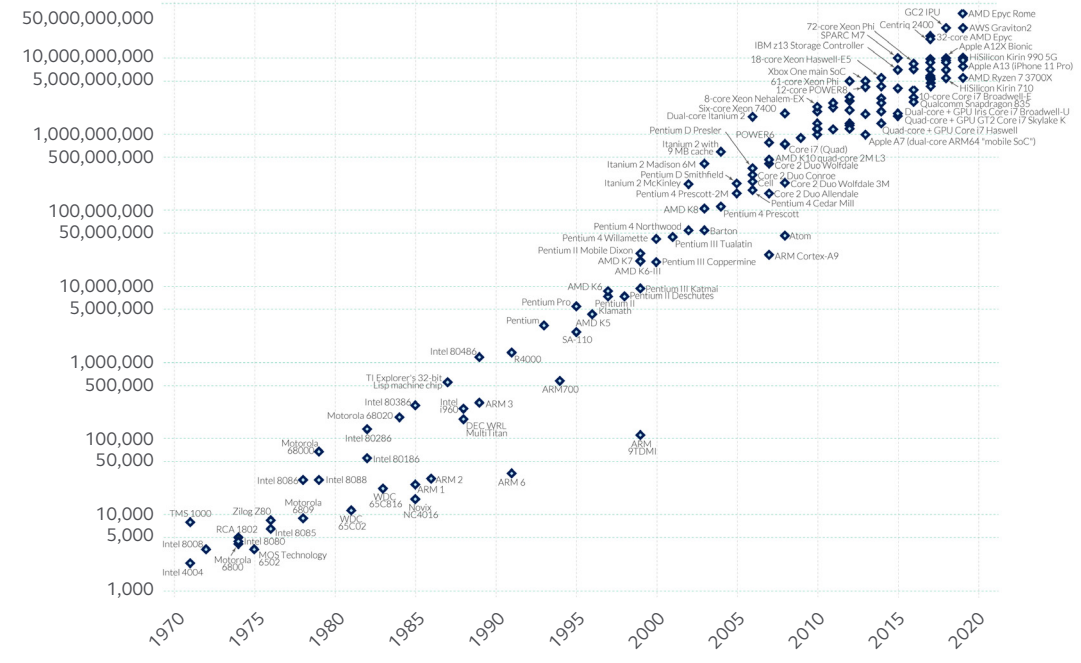
Rapid evolution in IT infrastructure has not rendered data centers obsolete

IT infrastructure has been evolving rapidly—exponentially, in fact—for over half a century. (Intel co-founder Gordon Moore observed this exponential evolution in 1965 and predicted it would continue, which it has.)

Moore's Law: The number of transistors on microchips has doubled every two years

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important for other aspects of technological progress in computing—such as processing speed or the price of computers.

Transistor count



Year in which the microchip was first introduced

Source: Our World in Data, *What is Moore's Law?*, March 2023

Moore's Law—the doubling of components in a dense integrated circuit every two years—is the reason IT leaders 'refresh' (i.e., replace) their servers every 3-5 years. The cost is substantial—about $20 million per MW of IT gear—but worth it, because that doubling every two years means server performance dramatically improves, and IT leaders have worked out that the cost of equipment replacement is worth the value of improved performance about every 3-5 years.

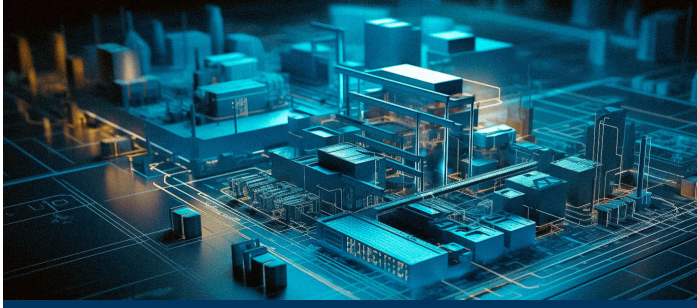
But even while IT leaders have been refreshing their servers every 3-5 years, they tend to stay in the data centers that house the servers for 15 years or more.

The value of a data center is driven by its fundamentals

> *"Rather than seeing innovation as a threat to data center demand, we view it as critical to driving demand. Our focus is on three universal factors that make good investment traits: Good connectivity to fiber cable networks; access to a power supply that can support the data center's capabilities; and proximity to the population it serves. For investors, owning properties with these difficult-to-find attributes will help ensure the data center will retain its relevance over time."*
>
> **Sebastian Dooley,** CFA, Senior Fund Manager

A data center's purpose is to facilitate the secure storage, processing, and transfer of data. That involves power (computers work by sending electrons around a circuit board), cooling (moving electrons around a circuit board creates heat), and connectivity (moving data from one place to another). The particular approaches for powering, cooling, and connecting a data center have and will continue to evolve. Some of these innovations do affect data center design. But we believe none of them will make existing data centers obsolete.

Unless new processing technologies such as quantum and biological computing are widely commercialized—still decades away—the data center fundamentals of power, cooling, and connectivity will persist, and in our opinion, the facilities that fulfil those obligations will remain in high demand.



RICH MILLER, Editor at Data Center Frontier, offers an illuminating anecdote:

"On Oct. 22, 2009, CNBC personality Jim Cramer warned his legions of viewers that the data center industry was ready for a fall. 'Get out of the data center stocks,' Cramer told viewers. 'I think the data center industry is in decline. I see an industry that's about to be brought low by new technology, so I think you should sell, sell, sell.'

Short version: Cramer's 'Sell, Sell, Sell' was Wrong, Wrong, Wrong. Investors who followed his advice missed out on a historic rally in data center stocks, with Equinix gaining 88% in value during that period, and looking like a laggard compared to industry rivals Terremark (up 172%), NaviSite (up 151%), Rackspace (up 139%) and Savvis (up 122%). Digital Realty, DuPont Fabros and Akamai were all between 50-65% higher.

Cramer seemingly didn't understand the historic relationship between faster chips and data center demand. He noted strong sales for Intel's new family of Nehalem DP processors, one of which can 'take the place of eight to nine older-generation servers.' Cramer did some math and concluded that data centers will soon be seven-eighths empty.

Nehalem was the latest in a series of regular technology updates from Intel, each of which introduced faster and more powerful processors, and none of which emptied out data centers. Here, history could have been an aid to Cramer. It would have been simple to compare the launch of faster Intel chips and data center growth to test his thesis."

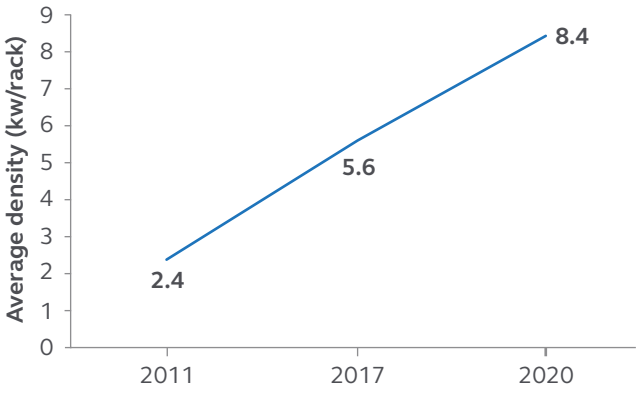
There are innovations that affect data center design, but they won't make existing data centers obsolete

Rapid evolution in IT infrastructure has not rendered data centers obsolete, in part because the value of a data center is in its fundamental ability to power, cool, and connect IT equipment. However, that's not to say data centers haven't evolved. They have. Rising density, for example, has led to innovations in both power and cooling infrastructure. Cooling infrastructure has also evolved as approaches to sustainability have changed. But none of these innovations have made existing data centers—even facilities built 25+ years ago—obsolete.

Rising density does affect data center design, but doesn't make existing data centers obsolete

When the components in a dense integrated circuit double every two years, the practical effect is increased performance—the ability for a given chip, or server, to do more compute work or store more data. All else equal, refreshing IT equipment with higher-performance gear increases the amount of work a set of servers in a rack can do, and since 'work' is moving electrons around a circuit board and therefore directly proportional to power input, it increases the power input to a given server rack (i.e., density).

Average density per rack is rising



Source: Uptime Institute Member Research, December 2020

Average server rack density has been rising steadily. And while the average server deployments remain under 10 kW per rack, some more recent deployments are reaching five times that level. Applications such as artificial intelligence run at those much higher densities, as they require more power-intensive computations from servers and storage systems than traditional workloads.

> *"Generally, as time has progressed, facilities have become larger and the power density increased. But the original facilities are far from redundant and utilization from the operator perspective is high."*
>
> **Paul Lewis,** Director, European Data Centres

Density affects data center infrastructure in two ways: power and cooling.

Density affects power infrastructure

Data center density is a measure of how much power is delivered to each server rack. From a pure power perspective (ignoring cooling for a moment), a data center's ability to support higher density deployments depends on two factors: the amount of utility power capacity it has, and the capacity of its existing power infrastructure.

If there is unused utility power and infrastructure, the data center can support tenants' higher density deployments with minimal modifications. In many cases, a data center may have additional utility power available but needs to deploy additional power infrastructure such as transformers and electrical backup systems to support increased density. If there is no extra utility power capacity, then supporting higher density deployments would require either bringing more utility power to the facility or reducing the number of servers to keep the total power consumption the same even as each server consumes more power.

> *"We are increasingly focused on sites that have or allow for the development of a dedicated power substation, as they generally provide for more flexibility in terms of power access and delivery. Sites with dedicated substations commonly enable more room for rapid expansion."*
>
> **Casey Miller,** Managing Director, Portfolio Manager

In any case, the facility is not rendered obsolete. Actually, the fact that utility power is an increasingly scarce resource, especially in primary data center markets, is one reason existing data centers have a distinct advantage over new construction.

Density also affects cooling infrastructure

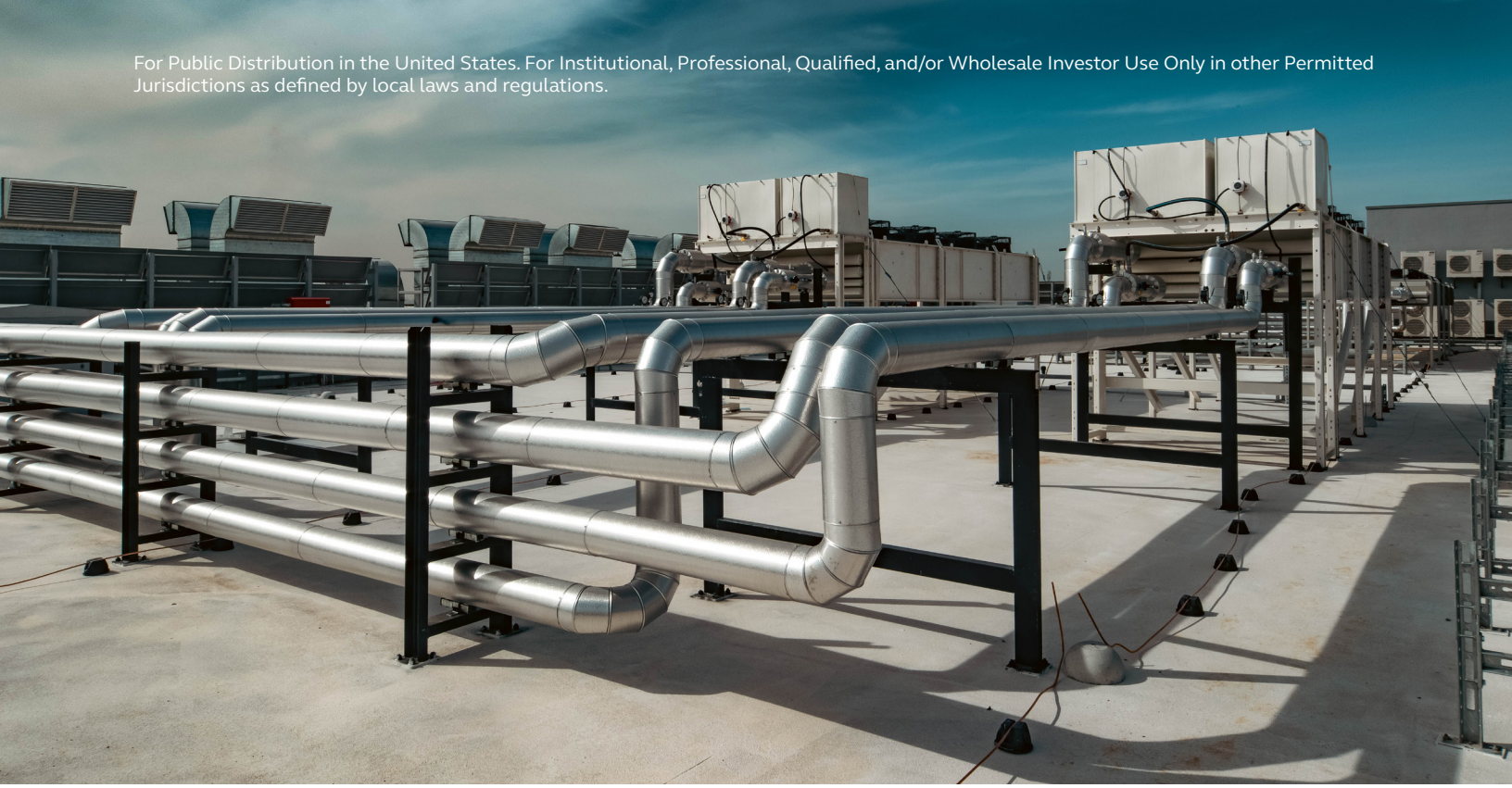
In reality, we can't ignore cooling, and because increasing density means more power in, it also means more heat out. So, for most data centers the bigger challenge associated with rising density is cooling (or more accurately, heat removal). Each cooling technology has limits on how much heat it can remove from the environment, and technologies have evolved over the years to remove more heat.

In the early 2000s, most data centers were designed with air-conditioning-like systems that cooled the entire data hall—not very efficient, but sufficient for rack densities under 2 kW. Then many data centers adopted new technologies where heat emitted from servers is drawn away by fans and then cooled with water or a refrigerant—much more efficient and effective for rack densities up to 20 kW or so.

> *"Immersion cooling is still a very new technology. I have only heard of a few instances of it being commercially used. But even immersion cooling systems can likely be retrofitted into existing data centers, and the other end of the cooling system (i.e., dispelling the heat from the data center as a whole) remains the same or similar. The floor loading would likely have to be higher as the units are heavier than existing racks, but this is something we believe can be worked around."*
>
> **Sebastian Dooley, CFA,** Senior Fund Manager

Supporting significantly higher densities, the likes of which we see with AI workloads, for example, will likely require either liquid cooling to the rack or immersion cooling. In liquid cooling to the rack, a cooling medium (typically chilled water) is piped to the server racks and then utilized by heat exchangers in the row or mounted on the server racks; or piped into cooling plates attached to servers or into plates and pipes integrated into the computing equipment itself. Immersion cooling is a very different technology; specially designed servers are fully immersed in a cooled, nonconductive refrigerant, although the building's heat-rejection equipment remains fairly similar for all cooling strategies.

> *"Many modern data centers are designed to accommodate water to the rack, a cooling technique that is likely to see more widespread adoption for today's high performance computing deployments. Liquid immersion is a very different process that requires entirely different server equipment as it needs to be designed specifically for immersion in the cooling medium. This will likely put a damper on the rapid growth of liquid immersion as it's not compatible with most existing tenant equipment, including the GPUs that are driving today's AI compute."*
>
> **Ben Wobschall,** Managing Director, Portfolio Manager



New approaches to sustainability do affect data center design, but don't make existing data centers obsolete

Besides density innovations that demand new approaches to cooling, sustainability concerns also impact the choice of cooling systems. For a long time, sustainability in the data center meant optimizing energy efficiency, as measured by Power Usage Effectiveness (PUE). More recently, data center operators and tenants have added measures of water efficiency to their ESG goals.

There are tradeoffs between energy efficiency and water efficiency. All else equal, water-based evaporative cooling systems are the most energy efficient, but more water intensive. Closed-loop air-cooled chillers are the most water efficient, but more energy intensive. Especially in water-contrained markets and markets where renewable energy is readily available, leading data center developers are increasingly relying on air-cooled chillers.

A data center designed for a water-based evaporative cooling system can be retrofitted to support closed-loop air-cooled chillers. Even where the operator doesn't retrofit the facility, most manage a mixed portfolio of both water-based evaporative cooling systems and closed-loop air-cooled chillers. In other words, evaporatively cooled data centers are not obsolete—especially considering the ESG implications of decommissioning an entire evaporatively cooled facility in favor of a new facility that uses a closed loop chiller.

> *"As ESG considerations become increasingly important, the desire to break ground for a new data center instead of using what has already been built will likely fade, again supporting the supply-demand imbalance benefiting investors in this space."*
>
> **Sebastian Dooley, CFA,** Senior Fund Manager

A revolution in how computers work will dramatically change data center design, but it's decades away

As long as computers in the data center rely on electrons, the data center fundamentals of power, cooling, and connectivity will remain. (Even quantum computing depends on those same fundamentals, though its widespread commercialization would require significant changes to data center design, in large part because quantum computers must be kept very cold.) There is one innovation that could render existing data centers obsolete: computers that rely on biological media rather than electrons. But biological computers only exist in the simplest form today, and commercial viability—much less widespread adoption—is likely decades away.

> *"Molecular and biological data storage and quantum computing could help minimize the amount of electricity needed to store data. However, game-changing technologies such as these are likely decades away, let alone commercially feasible, while demand for data transmission and storage continues to increase exponentially."*
>
> **Casey Miller,** Managing Director, Portfolio Manager

Leading data center developers design for configurability

Because there are innovations—like rising density and new approaches to sustainability—that affect optimal data center design, leading data center developers build configurability into their facilities to support innovation without rendering existing facilities obsolete. So even if higher density requires changes to how a data hall is laid out or cooled, those changes can be made within the existing data center—ensuring its usability for many years to come.

> *"Leading data center developers are very focused on future proofing their facilities and have a close relationship with their key customers to understand their current and future requirements. The major industry players all of course have a long term interest in the viability of their facilities."*
>
> **Paul Lewis,** Director, European Data Centres

Existing facilities can be (and are often) retrofitted to support innovations

Even if a data center wasn't designed to be configurable, retrofitting it to support innovations like higher density and a focus on water efficiency is a much more likely course of action than decommissioning the data center entirely—in no small part because the industry needs all the capacity it can get. (The average vacancy rate of the top 10 North American data center markets is 2.88% according to datacenterHawk, and "demand is still outpacing providers' ability to deliver new capacity.")

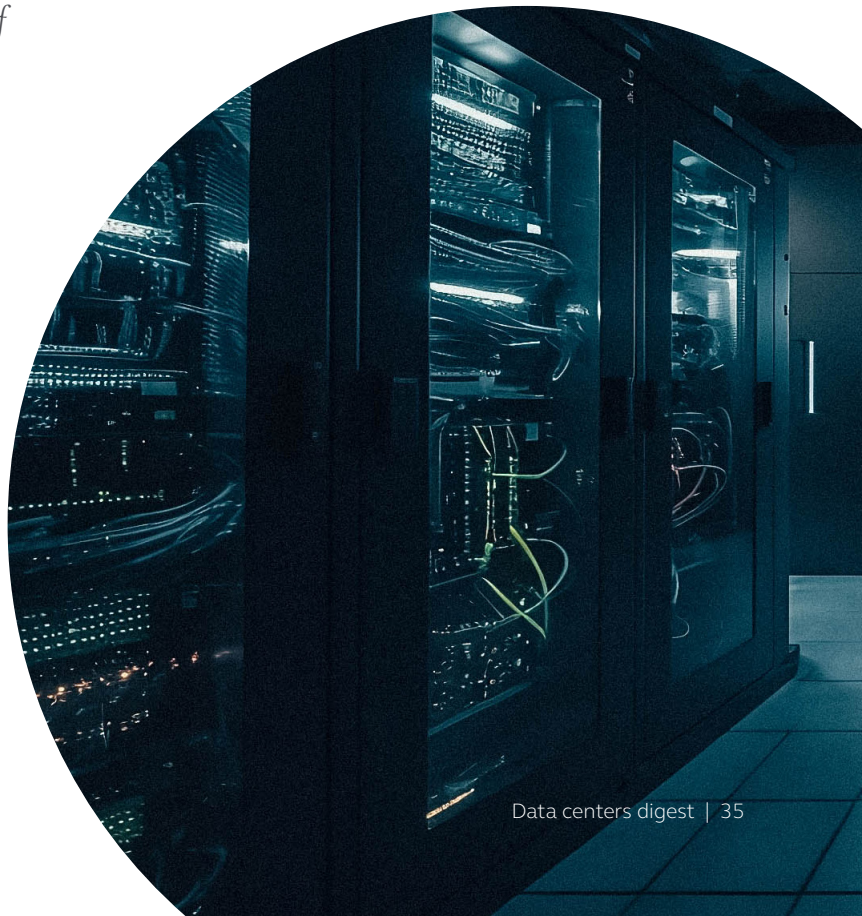
> *"A great example of the long term functionality of data centers is a facility we own which was originally commissioned nearly 15 years ago. It had been a bank-owned data center, originally designed to meet the highly redundant, low-density attributes characteristic of its time and for its use—nothing like today's hyperscale deployments. The key is that it had the functionality to deliver significant amounts of power and cooling. With some updating, this asset was retrofit and fully leased to a specialty cloud service provider to deploy an AI/ML strategy that at full deployment will be one of the largest supercomputers in the world."*
>
> **Ben Wobschall,** Managing Director, Portfolio Manager

Old and new will continue to coexist

Data center developers are already innovating the design of new facilities to support higher density and evolving approaches to sustainability. For example, Meta, which both leases and develops its own facilities, recently announced that its new generation of data centers will be liquid cooled, to support AI workloads at scale.

But even as more data centers run AI or other workloads that require higher density, old workloads will continue to run, and need existing data centers to support them.

> *"It's not an either/or discussion. The workloads of today aren't going away anytime soon, so users aren't giving up existing capacity in exchange for the next big thing. And while we think of technology changing very quickly, changes at the data center infrastructure level are gradual; mission-critical workloads aren't conducive to rapid transition to new, unproven technology. Being on the front line with tenants we're going to see these changes being implemented in plenty of time to position our portfolios appropriately."*
>
> **Ben Wobschall,** Managing Director, Portfolio Manager



Bottom line

IT infrastructure has always evolved rapidly, and even data centers built 25+ years ago have not been rendered obsolete. Because the purpose of a data center is to power, cool, and connect IT equipment, its fundamental value is driven by power capacity and network connectivity. These factors are not likely to change unless new processing technologies such as quantum and biological computing are widely commercialized, and that is still decades away.

Innovations that do affect data center design, including increasing density and evolving approaches to sustainability, won't make existing data centers obsolete. That's because leading data center developers build configurability into their facilities to support innovations. And even data centers not designed to be configurable can be retrofitted—much more likely than decommissioning, especially as industry demand for data center capacity far outstrips supply.

So, will big advancements in technology—like AI—render existing data centers obsolete? Quite the opposite; more likely, technological advancements will further increase the value of existing assets as they drive increased demand for data center capacity.

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