CAPTURING THE DATA CENTER OPPORTUNITY IN LATIN AMERICA AND THE CARIBBEAN

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IDB

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Contents

Abstract

This Inter-American Development Bank (IDB) report provides a strategic framework for governments in Latin America and the Caribbean (LAC) to harness the economic, technological, and environmental potential of the data center industry (DCI). As global demand for digital infrastructure accelerates—driven by cloud computing, artificial intelligence (AI), and the Internet of Things (IoT)—LAC countries are uniquely positioned to attract investment and become competitive players in the global digital economy. The report outlines how DCI development can generate high-value employment, attract foreign direct investment, increase tax revenues, and strengthen national digital sovereignty. It also highlights the critical role of government leadership in addressing infrastructure gaps, streamlining regulatory frameworks, and enabling green and resilient digital infrastructure. Through global case studies, regional benchmarks, and actionable policy recommendations, the report provides a two-phase roadmap for public sector leaders to (1) engage stakeholders to validate findings and build consensus, and (2) implement national and regional strategies focused on infrastructure, talent development, sustainability, and public-private partnerships. This report is a call to action for LAC governments to lead the digital transformation by creating the enabling conditions to attract and sustain DCI investment—unlocking long-term economic growth, competitiveness, and digital resilience.

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Keywords: artificial intelligence, cloud computing, connectivity, cybersecurity, data center industry, digital infrastructure, digital sovereignty, digital transformation, economic competitiveness, environmental sustainability, green data centers, infrastructure development, Internet of Things, investment incentives, Latin America and the Caribbean, public-private partnerships, regional cooperation, regulatory frameworks, renewable energy, workforce development

Executive Summary

Advanced digital infrastructure (DI) refers to the new bridges and roads that support the digital economy. In other words, DI encompasses the total physical and software-based infrastructure necessary to deliver digital goods, services, and products. A key pillar of advanced DI is the data center industry (DCI), which supports the full life cycle of data centers (DCs). This Inter-American Development Bank (IDB) report points out and analyzes the opportunities and challenges that the DCI represents for Latin America and the Caribbean (LAC) and proposes strategies to maximize its benefits.

Historically, DCs and the DCI have been constrained to the sectors' specialists and not been part of the social and political debate. This situation has evolved and as of the mid-2020s the DCI's challenges and opportunities are highly visible to both social and political observers. In this context, the DCI has become a new imperative for policymakers' understanding and involvement.

Therefore, the report's intended audience includes LAC high-level policymakers and other digital development stakeholders, including industry, academia, government, civil society, and international organizations' digital development practitioners. The main objectives of the report are the following:

1. To empower LAC policymakers to visualize the key elements of the DCI, its potential impact on countries' economic and competitive growth, and the challenges it presents.
2. To identify and illustrate the key conditions that a location (country, city, region) should fulfill to effectively compete in capturing DCI investments and development.
3. To recommend strategies and tools that policymakers could adopt to help countries capture DCI benefits while mitigating its risks and maximizing development impact in LAC economies and societies.

Since the early 2000s, the ever-increasing demand for cloud services, the unstoppable spread of connected devices, and the surge in interest for artificial intelligence (AI) deployments have accelerated the digital economy and the growth of the DCI. The expectation is for this growing trend to continue. Since the early 2020s, the explosive entry into generative AI markets has accelerated the DCI and increased the urgency for identifying new suitable locations.

A continued worldwide power shortage significantly inhibits the global DCI's growth. Sourcing power is a top priority for operators across all regions (North America, Europe, Latin America, and Asia-Pacific). Secondary markets with ample power could attract DC investment. Consequently, the DCI is under pressure to find new locations, bringing new opportunities to emerging markets like LAC.

The DCI is global and well organized, creating DCI hubs across the globe. Currently, the main hubs in North America are in Northern Virginia, Dallas–Fort Worth, Chicago, and Silicon Valley. The main hubs in Europe are Frankfurt, London, Amsterdam, and Paris, also known as the FLAP. In Asia-Pacific, DCI hubs are Tokyo, Sydney, Singapore, and Hong Kong; in Latin America, São Paulo (Brazil), Santiago (Chile), Querétaro (Mexico), and Bogotá (Colombia) are already recognized as the main hubs.

The economic benefits that DCI development can bring to countries and regions hosting this DI include tax revenues, employment, and infrastructure development investments. For example, in Northern Virginia, home to the largest DCI in the world, the industry paid US$860 million in state tax and US$777 million in local taxes in 2022. As of 2023, DCs employed 10,420 Virginians in operational jobs and 12,340 in construction jobs. This represents US$2.6 billion in associated employee pay and benefits. Considering all indirect jobs, estimations indicate 59,140 supported jobs, representing a total of US$5.4 billion in associated employee pay and benefits during 2023.

Two examples from LAC are a direct investment of US$7 billion currently planned in Mexico alone through 2027, and Google's 2024 announcement of their plans to build a new DC in Uruguay with an investment of US$850 million. Other key benefits are the overall acceleration of the digital economy and its positive impact on the country's economic growth and competitiveness.

On the other hand, there are concerns about the DCI's power consumption and environmental impact, as well as the need for regulatory frameworks in areas like data security. Countries that recognize the DCI opportunity and concerns confront readiness challenges in areas like DI, trained workforce, and power grid capabilities.

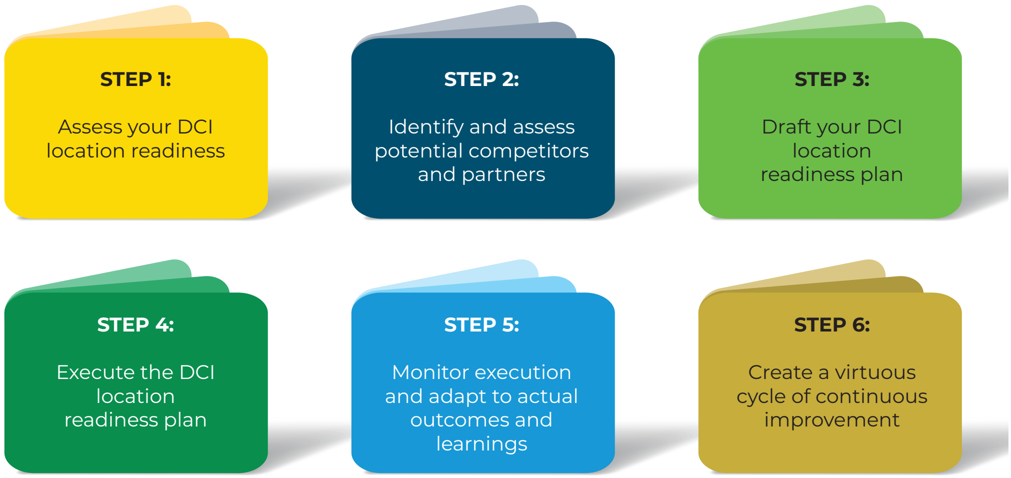
Location characteristics are fundamental for the DCI's needed expansion; the industry is already struggling in its most mature markets due to a lack of green energy supply, land availability constraints, or increasing costs, among other reasons. In this context, the LAC region is emerging as a new destination for the sector, and some countries like Brazil and Chile have already launched initiatives to build national strategies toward capturing the DCI opportunity.

Through the analysis of the DCI's benefits and challenges, the compilation of international best practices presented as reference cases in this report, and a set of annexes covering technical details, the authors of this report prepared a set of recommendations. The first recommendation is to provide initial guidance in supporting countries or regions looking forward to capturing the DCI opportunity (Figure 1).

DI development is imperative for all nations. However, depending on variables like geographic location, climate, population size, human capital, digital and innovation ecosystem maturity, geopolitical situation, economic development, and cultural characteristics, approaches to DI development are also diverse and there is no one-size-fits-all approach to digital development.

On one hand, there are plenty of lessons learned and best practices that could be leveraged to accelerate the roadmap for new entrants into the global competition to capture the DCI opportunity, but each case is unique, and smart crafting of a tailor-made strategy is paramount.

FIGURE 1
DCI Opportunity Capture Planning Process



Source: Authors' elaboration.

On the other hand, many dimensions and areas for further development have been identified. The conclusions presented here are seen as a first step into a further institutional and regional dialogue for validation, prioritization, and action (Table 1).

As this is the first IDB report on this topic, socialization and validation of conclusions and recommendations will be critical. Consequently, the recommendations are structured in two phases: (1) socialize and validate the report and construct a multistakeholder regional DCI dialogue platform (see Table 2) and (2) prepare a regional DCI development plan (see Table 3).

Given the dynamism of the DCI, the working methodology of the report adopted four key principles:

Acknowledge the need to conduct the research phase by selecting the latest publications and establishing direct exchange with active practitioners and field experts.

Establishing partnerships with leading sector players to infuse the report with the most innovative and up-to-date insights about technology, industry, and market trends.

Leverage most advanced countries' international lessons learned and best practices, aiming to discover and propose leapfrog opportunities for LAC countries' DCI development and impact.

Given the complexities of this topic, the report's main sections prioritize content aimed at high-level policymakers and practitioners, while technical details are included in annexes for those readers interested in further technical knowledge.

Three key global DCI players partnered with the IDB in the development of this report: CBRE, Data Center Dynamics (DCD), and Digital Bridge. Each one represents a specialized sector within the global DCI and their contributions have been invaluable in making the report relevant and up to date. Table 4 provides key report takeaways.

TABLE 1

Main Conclusions on Capturing the Data Center Opportunity in Latin America and the Caribbean

1. The DCI is struggling to grow in the most developed hubs, mainly due to power supply constraints, added regulatory complexities, and social and political concerns about environmental impact. This situation is pushing the DCI to explore new locations, generating a new opportunity for LAC countries and regions as well as other emerging economies.
2. Proximity to the largest digital economy markets used to be a key criterion for the DCI location selection due to latency considerations. However, the explosion of AI applications and advanced DC operation software tools have created new types of opportunities for non-latency-sensitive applications such as training for AI models or digital workload optimization across time zones. These new developments represent opportunities for LAC countries and regions.
3. The DCI is already present across LAC. São Paulo, Santiago, Querétaro, and Bogotá are becoming regional DCI hubs. The Brazilian and Chilean governments have already identified the DCI opportunity and are launching national DCI attraction strategies. This type of policymaking development creates conditions for broader regional dialogue and cooperation around the DCI opportunity for LAC.
4. Fundamental elements of the DCI development roadmap for countries or regions are already known but are constantly evolving. Nowadays, the environmental sustainability imperative has gained weight in this equation, shifting the vision toward the green DCI. To attract the DCI, incorporating green and resiliency aspects is imperative for LAC strategies.
5. Accelerating digital ecosystem maturity (talent, infrastructure, policy and regulation, industry, financial resources, higher education, and R&D) is a must for all developing economies and for the DCI. LAC countries have struggled for years to achieve higher ranks in the global digital ecosystems' maturity indexes. The DCI consolidation in LAC will drive synergies to boost the digital ecosystem maturity growth needed.
6. The overall cost of doing business is a key criterion for DCI location selection. Addressing the different aspects of the overall cost issues in LAC countries and designing a smart incentives program are short-term requirements to attract DCI opportunities.
7. A stable cybersecurity policy and regulatory framework should be implemented to attract the DCI. A multistakeholder approach is imperative.
8. DCI talent is global, and new mindsets and policy frameworks to leverage this global talent pool are needed. LAC countries should develop their own DCI talent but could also design strategies to leverage the global talent pool. Correspondingly, the LAC DCI talent pool will also become part of the global one.
9. The DCI is going through an unstoppable growth phase on an evolving path. Flexible, innovative, adaptive, and agile policy frameworks are needed.
10. Not all locations are ideal for becoming a DCI hub, but there is a potential role to play for everyone within the digital economy universe and the extended DCI ecosystem. Exploring regional and subregional DCI strategy codesign will help to better leverage each country's strengths and capabilities, enabling different models to benefit from the DCI opportunity.

Source: Authors' elaboration.

TABLE 2
Phase 1 Execution

Layer	Steps
1. Internal IDB dialogue	a. Organize and conduct an IDB internal dialogue program to socialize the report, collect feedback, and draft an internal action plan. b. Focus on the impact aspects of DCI development and regional digital economy maturity development.
2. Key DCI players dialogue	a. Organize and conduct a dialogue with key DCI players to socialize the report, collect business perspective feedback, and explore collaborations. b. Focus on key LAC barriers to DCI development and actionable recommendations to tackle those issues. c. Consider creating a permanent dialogue between the IDB and key DCI players. d. Explore further IDB involvement in LAC DCI development.
3. LAC governments dialogue	a. Organize and conduct a dialogues program with the governments of active LAC DCI hubs—Brazil, Chile, Colombia, Mexico, Peru, and Uruguay—to socialize the report, collect feedback, and explore collaborations. b. Schedule a regional dialogue with LAC governments to socialize the report, collect feedback, and explore collaborations. c. Explore ways for the IDB to further support governments aiming to capture the DCI opportunity.
4. LAC DCI-related communities dialogue	a. Map LAC DCI-related communities: academia, think tanks, associations, environmental sustainability organizations, digital development advocacy groups, etc. b. Organize and conduct a dialogue program to socialize the report, collect feedback, and explore collaborations.

Source: Authors' elaboration.

TABLE 3
Phase 2 Execution

Workstream	Steps
1. Regulatory frameworks and incentives	a. Assess countries' DCI-related regulatory frameworks and incentives. b. Draft recommendations for governments on updating or creating regulatory frameworks and incentives. Prioritize streamlining bureaucratic hurdles for DC construction and operation. c. Consider tax break incentives for investments in DC infrastructure, including import duty exemptions on equipment. d. Prioritize aligning cybersecurity regulatory frameworks with international data regulations.
2. Infrastructure development	a. Foster investments in robust and reliable connectivity infrastructure, including submarine cables and terrestrial fiber networks, to improve data transmission capacity and reduce latency. b. Foster countries' energy grid upgrades and improved integration of renewable energy sources.

(continued on next page)

TABLE 3
Phase 2 Execution *(continued)*

Workstream	Steps
3. Talent development	a. Foster development of specialized training programs and partnerships with educational institutions to build a skilled workforce in DC management and operations. b. Encourage R&D initiatives in DC technologies and energy-efficient solutions. c. Encourage enabling global talent pool's participation in LAC DCI development.
4. Green data centers	a. Promote the adoption of a full DC life cycle approach to green DCs, as explained in ITU and World Bank (2024). b. Promote innovation and the adoption of energy-efficient technologies and renewable energy to minimize the environmental impact of DCs. c. Promote adopting sustainability standards and green certification for DC construction and operations.
5. Public-private partnerships	a. Foster collaboration between governments, DCI players, and international investors to drive key initiatives and projects. b. Foster development innovation districts to attract talent, tech companies, and startups, thus creating a supportive ecosystem for DCs.
6. National strategies to capture the DCI opportunity	a. Support capacity building and multistakeholder collaborations to drive quality national strategies to capture the DCI opportunity. b. Promote sharing of best practices within LAC and internationally.

Source: Authors' elaboration.

TABLE 4
Key Report Takeaways

Key takeaway	Highlights
1. Increasing global demand for data centers	The demand for DCs is expanding worldwide due to the unstoppable growth of digitalization supported by key DI like cloud, Internet of Things (IoT), and AI. Generative AI, which requires extensive computing resources, further drives this growth. With challenges in mature DC markets like power shortages and regulatory hurdles, emerging markets such as LAC offer appealing new opportunities for DC expansion.
2. Key data center hubs in LAC	São Paulo, Santiago, Querétaro, and Bogotá are emerging as primary DCI hubs in LAC. Countries like Brazil and Chile are actively creating national DC strategies to improve their attractiveness and capture economic benefits.
3. Investment criteria for data centers in LAC	• Energy Reliability and Cost: Reliable, affordable, and green energy is essential because energy costs make up a large portion of DC operations. Sustainable energy availability is a major factor for investors. • Connectivity and Infrastructure: Strong internet infrastructure, including submarine cables and fiber networks, is crucial for meeting low latency and high data transmission needs. • Regulatory Environment: A stable and flexible regulatory framework with incentives, such as tax breaks and efficient bureaucratic processes, is essential to attract DC investments.

(continued on next page)

TABLE 4
Key Report Takeaways *(continued)*

Key takeaway	Highlights
4. Environmental sustainability requirements	There is a strong global focus on green DCs, prioritizing energy-efficient practices and renewable energy to reduce environmental impact. Achieving green certifications and meeting sustainability standards are key factors for responsible DC investments in LAC.
5. Workforce development	Building a workforce skilled in DC management is vital. Collaboration with educational institutions to provide specialized training is essential, along with strategies to attract and develop local and global talent for the DCI.

6. Strategic recommendations	• Multistakeholder Collaboration: This report recommends establishing platforms for dialogue between government, industry, and civil society. This includes supporting public-private partnerships, updating regulations, and reducing barriers for the DC sector.
	• Phased Action Plan: The report outlines a two-phase approach:
	  ◦ Phase 1: Socialize the report with stakeholders and gather feedback.
	  ◦ Phase 2: Implement a regional DC development plan, focusing on regulatory improvements, infrastructure, talent, sustainability, and strategic partnerships.

7. Key messages for regulators and government bodies	• Policy and Regulatory Support: Create clear, supportive, and stable regulatory frameworks with streamlined processes for permits and tax incentives. • Investment in Sustainable Energy: Prioritize renewable energy to attract green DCs and meet international standards for sustainability. • Collaboration for Development: Encourage partnerships across sectors to drive infrastructure, regulatory support, and workforce training. • Regional Cooperation: Foster collaboration between countries in the region to align best practices, share resources, and strengthen competitiveness in attracting DC investments.

Source: Authors' elaboration.

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Introduction

The acceleration of digital innovation brings increasingly sophisticated experiences to our daily lives and fuels the digital economy's relentless growth. Beneath these experiences resides a complex enabling ecosystem founded upon the convergence of advanced digital infrastructure (DI) and novel industry arrangements.

Advanced DI refers to the new bridges and roads that support the digital economy. In other words, DI encompasses the total physical and software-based infrastructure necessary to deliver digital goods, products and services. Nowadays, this global DI and its related industries support the digital life of more than 70 percent of the world's population (ITU, 2024).

A key pillar of advanced DI is the data center industry (DCI), which supports the full life cycle of data centers (DCs).[1] The present report points out and analyzes the opportunities and challenges that the DCI represents for Latin America and the Caribbean (LAC) and proposes strategies to maximize its benefits.

Historically, DCs and the DCI have been developed and operated by specialists, away from the social and political debate. However, things have changed due to the unstoppable growth of digitalization that provoked an explosive acceleration of the DCI. This growth made the industry's challenges and opportunities highly visible to both social and political observers. Today, DCs are the foundation of the DI on which our modern society and economy are built, and in this new context, the DCI became a new imperative for policymakers' understanding and involvement. Given the dynamism of the DCI, the working methodology of this report adopted four key principles:

1. Acknowledge the need to conduct the research phase by selecting the latest publications and establishing direct exchange with active practitioners and field experts.
2. Establishing partnerships with leading sector players to infuse the report with the most innovative and up-to-date insights about technology, industry, and market trends.
3. Leverage most advanced countries' international lessons learned and best practices, aiming to discover and propose leapfrog opportunities for LAC countries' DCI development and impact.
4. Given the complexities of this topic, the report's main sections prioritize content aimed at high-level policymakers and practitioners, while technical details are included in Annexes for those readers interested in further technical knowledge.

[1] See Annexes A and B for definitions and nomenclature of DCs and the DCI.

Location characteristics are fundamental for the needed DCI expansion because the industry is already struggling in its most mature markets due to a lack of green energy supply, land availability constraints, or increasing costs, among other reasons. In this context, the LAC region is rising as an emerging destination for the sector.

In fact, the DCI is already present in LAC and growing fast. São Paulo (Brazil), Santiago (Chile), Querétaro (Mexico), and Bogotá (Colombia) are currently LAC's top locations and markets for the DCI (CBRE, 2024). Some LAC countries like Brazil[2] and Chile[3] have already acknowledged their desire to capture the DCI opportunity: they have developed national DC strategies to improve their ability to capitalize on the potential economic and competitiveness benefits, while minimizing the environmental challenges the DCI entails. Table 5 presents a summary of the top DCI markets by region.

The largest and most mature DCI market in the world is in Northern Virginia in the United States, which houses more than 300 DCs that collectively cover more than 3.5 million square meters. Table 6 provides key highlights related to incentives, benefits, and challenges in the Northern Virginia region.

In the short term, DC construction brings highly visible economic impact to selected locations. Regarding DC construction activity, a DCD study focused on LAC (DCD, 2024b) provides useful reference points:

- In 2023, Brazil emerged as the leader in opening new DCs in LAC, followed by Chile, Mexico, and Colombia.
- A direct investment in the Mexican DCI of US$7.053 billion is planned through 2027.

The DCI is poised to stay on a fast-growing path but is confronting several constraints. As an initial reference, the Global Data Center Trends 2024 (CBRE, 2024) highlights the following:

- A continued worldwide power shortage significantly inhibits the global DCI's growth. Sourcing power is a top priority for operators across all regions (North America, Europe, Latin America, and Asia-Pacific). Secondary markets with ample power should attract more DC investment.
- Vacancy rates continue to decline across most global markets due to strong demand.
- Large corporations face increasing difficulty securing DC capacity. Low supply, construction delays, and power challenges are impacting all markets. For example, Querétaro, Mexico, has only 0.6 MW available for lease.
- The worldwide power shortage continues to fuel price increases for DC capacity.
- Artificial intelligence (AI) advancements are projected to drive significant demand for DC services in the future. High-performance computing will require rapid innovation in DC design and technology to manage rising power density needs.

2 https://datacenters.abdi.com.br/

3 https://www.minciencia.gob.cl/noticias/plan-nacional-de-data-centers-espera-acelerar-inversion-de-2500-millones-de-dolares-empujando-una-industria-sustentable

TABLE 5

Top DCI Markets by Region

Region	Four largest DCI markets by inventory
North America	Northern Virginia, Dallas–Fort Worth, Chicago, Silicon Valley
Europe	Frankfurt, London, Amsterdam, Paris (FLAP)
Latin America	São Paulo, Santiago, Querétaro, Bogotá
Asia-Pacific	Tokyo, Sydney, Singapore, Hong Kong

Source: CBRE (2024).

TABLE 6

Key Highlights of the Northern Virginia Data Center Market

Location and size	Incentives	Benefits	Challenges

Northern Virginia (U.S.)
Size (Operational IT load[a]): 2,500 M
	• Virginia exempts all manufacturing equipment from sales and use taxes, regardless of the amount of equipment purchased or how few workers the plant employs.
	• Sales and use tax exemption on DC equipment is available statewide until July 2035. To qualify, DCs must make an investment in Virginia of at least US$150 million and create at least 50 new jobs paying at least 150% of the local average wage. DCs investing in distressed localities can qualify with fewer jobs and less capital investment. For DCs investing even more and employing more people, the incentive is potentially extended until July 2050.
		• State tax revenue: US$860 million in 2022.
		• Local tax revenue: US$777 million in 2022.
		• Direct, indirect, and induced jobs (2023):
		  ◦ 40,390 operational jobs
		  ◦ 18,750 construction jobs
		• US$5.4 billion in associated employee pay and benefits in 2023.
		• For every job inside a Northern Virginia DC, 2.9 additional jobs are supported in the rest of the Northern Virginia economy, not including construction jobs.
			• Power supply restrictions. Power availability and permitting processes dictate DC construction timelines.
			• Land scarcity in core counties may increase development costs.
			• Social and Environmental: land usage, power consumption, carbon emissions, water usage, noise contamination.
			• Skills gap.

Source: Authors' elaboration based on NVTC (2024).
[a] The amount of power dedicated to running the IT equipment itself, which includes the servers, storage devices, and networking equipment. This capacity does not account for power used for cooling, lighting, or any other non-IT functions.

This report's intended audience includes LAC high-level policymakers and other digital development stakeholders, including industry, academia, government, civil society, and international organizations' digital development practitioners. The main objectives include the following:

- To empower LAC policymakers to visualize the key elements of the DCI, its potential impact on countries' economic and competitive growth, and the challenges it presents.
- To identify and illustrate the key conditions that should be fulfilled by a location (country, city, region) to effectively compete in capturing DCI investments and development.
- To recommend strategies and tools that policymakers could adopt to help countries in capturing DCI benefits while mitigating its risks to maximize development impact in LAC economies and societies.

Given the dynamism of the DCI, the working methodology of this report adopted four key principles:

1. Acknowledge the need to conduct the research phase by selecting the latest publications and establishing direct exchange with active practitioners and field experts.
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3. Leverage most advanced countries' international lessons learned and best practices, aiming to discover and propose leapfrog opportunities for LAC countries' DCI development and impact.
4. Given the complexities of this topic, the report's main sections prioritize content aimed at high-level policymakers and practitioners, while technical details are included in annexes for those readers interested in further technical knowledge.

Three key global DCI players partnered with the Inter-American Development Bank (IDB) to develop this report: CBRE, Data Center Dynamics (DCD), and Digital Bridge. Each one represents a key sector within the global DCI and their contributions have been invaluable in making the report relevant and up to date.

This report has five core sections. The initial part of the report is composed of two sections in which the DCI's current context and implications are explained, followed by its global and regional outlook, including market snapshots and reference cases. The second part is dedicated to ways in which LAC can capture the DCI opportunity as well as conclusions and actionable recommendations. Annexes with technical background on key topics are provided to clarify key concepts.

1

THE DATA CENTER INDUSTRY

Since the early 2000s, the ever-increasing demand for cloud services, the unstoppable spread of connected Internet of Things (IoT) devices, and the surge in interest for artificial intelligence (AI) deployments have accelerated the digital economy and the growth of the data center industry (DCI). The expectation is for this growth trend to continue. The explosive entry into generative AI markets has created further acceleration for the DCI and increased the urgency to identify new suitable locations. Consequently, the DCI is under pressure and new opportunities for emerging markets like Latin America and the Caribbean (LAC) are surging.

Table 7 provides key data points and projections from specialized research firms about these three drivers of DCI growth.

Digital Infrastructure: Enabling the Digital Economy

Digital infrastructure (DI) refers to the new bridges and roads that support the digital economy. In other words, DI encompasses the total physical and software-based infrastructure necessary to deliver digital goods, products, and services. Its main components are DCs and telecommunications systems. Like bridges and roads, DI also requires a multistakeholder ecosystem composed of industries, academia, government, and civil society, all articulated under a governance framework to enable and rule its development.

The IMD World Digital Competitiveness Ranking 2023 (IMD, 2024) highlights the role of DI in nations' competitiveness:

- The first ingredient in the recipe for a successful digital nation is DI.
- Infrastructure development requires both data governance and digital governance. Regulation is paramount for ensuring that the benefits of technology are captured by society and not misused or indeed exploited by corporations.
- A combination of DI and digital governance is needed to make technology available to citizens. Then, a final requirement for making a digital nation is the cultural acceptance of technology. Such acceptance can be endogenous to both infrastructure

TABLE 7

Key Drivers of Data Center Industry Growth

Market sector	Research source	Market forecast
Public cloud services	International Data Corporation (IDC, 2024b)	Worldwide public cloud services revenue will surpass US$800 billion in 2024, an increase of 20.5% over 2023, with a similar increase expected in 2025, and worldwide revenues reaching US$1.6 trillion in 2028.
Internet of Things (IoT)	Sinha (2024)	Global IoT connections grew by 18% in 2022 to 14.3 billion active IoT endpoints. In 2023, the firm expected the global number of connected IoT devices to grow another 16%, to 16.7 billion active endpoints. Global IoT connections are expected to surpass 29 billion by 2027.
Artificial intelligence (AI)	International Data Corporation (IDC, 2024a)	In 2024, organizations were projected to spend US$235 billion on AI, a figure that is expected to nearly triple to more than US$630 billion by 2028, fueled by an almost 30% compound annual growth rate (CAGR). Generative AI, a subset of this broader AI ecosystem, was estimated to account for 17.2% of global AI spending as of mid-2024. Its growth is particularly remarkable, with projections indicating it will make up 32% of AI investments by 2028, driven by a staggering 60% five-year CAGR.

Source: Authors' elaboration.

and regulation in the sense that people's trust in their national framework can be jeopardized by either weak data protection or unsafe DI, or a combination of both. This results in different degrees of technology utilization across countries.

- In conclusion, successful digital nations—that is, economies that utilize digital talent, have a resilient and agile culture, and rely on adequate DI—align their skills and competences, their capacity, and their planned future investments to adopt and explore new digital technologies that can transform government practices, business models, and society at large.

In this era of rapid digitalization, coupled with an increased emphasis on sustainability, the physical structures that facilitate the efficient transmission, storage, and processing of data play a critical role in accelerating global economic growth. The cellular towers that transmit and receive radio signals to wireless devices, the terrestrial and submarine fiber cables, and the DCs that host servers storing and processing data together form the backbone of the digital technologies that we use daily.

For the purposes of this report, two DI components of particular interest are described in the following subsections: the data center (DC) and the digital infrastructure hub (DIH).

The Data Center

A DC is a physical facility that houses computer systems and associated components, such as telecommunications and storage systems. It is designed to host the digital economy's computing power by providing a centralized location for information technologies infrastructure, including servers, storage, and networking equipment. DCs can vary in size and complexity, ranging from small rooms to large industrial buildings.

The DCI handles the planning, design, construction, marketing, operations, and maintenance of DCs. In addition to the DI components that are hosted in the physical facilities, the DCI also aligns the complementary elements needed for a 24/7 operation. These complementary elements include emergency power systems, cooling systems, access control security systems, fire detection systems, and special building components like raised floors. Nowadays, it is also becoming more common for large DCs to incorporate their own green energy infrastructure and shared facilities with the surrounding community, such as heating systems.

As a physical structure, the DC requires public services for land classification, construction permits, and local infrastructure (power, roads, water, etc.). DCs also require telecommunications infrastructure (primarily fiber optics) to be able to offer their services.

For governments and communities, DC development has demonstrated high returns and low public costs. This is because DCs pay substantial amounts in taxes but place few demands on local public services, resulting in a high fiscal benefit-to-cost ratio. For example, in Northern Virginia, DCs in Loudoun County pay US$26 for every dollar of local public services required (a 26:1 ratio). In neighboring Prince William County, the ratio is 13:1. For comparison, fiscal benefit-to-cost ratios for other types of development, such as manufacturing plants, rarely exceed 4:1 (NVTC, 2024).

On the other hand, concerns are also rising in communities with high concentrations of DCs that demand government, policymakers, and civil society involvement to address issues such as land availability and pricing, energy resources, noise, and water resources.

When dealing with the DC sector, government officials confront a plethora of technical terms and concepts. The fundamental terminology refers to the distinct types of DC facilities, which are described in Table 8.[4]

The Digital Infrastructure Hub

A DIH, also known as a DC cluster or a DCI hub, is a location where a high concentration of DCs and other key DIs are deployed. From the DCI perspective, these are key DCI markets. DCs themselves are part of the DIH, along with other DI components such as fiber optics infrastructure, other telecommunications devices, and internet infrastructure.

Components of the DIH are not necessarily located in the same building, but they are normally clustered within a specific geographic area. These components might be administered by different organizations, such as telecommunications or internet service providers. Because telecommunications is a highly regulated sector, fiber optic networks and towers to support telecommunications are also DIs, and government and policymakers are also involved. Similarly, because the existence of a DIH (according to this report's definition) implies a concentration of DCs, the involvement of government, regulators,

[4] Annex A offers additional technical details and key nomenclature on DC facilities.

TABLE 8
Data Center Categories

Category	Description
On-premises	A DC managed by an organization (e.g., government agency, company, financial institution, hospital, university, etc.) to host its own computing infrastructure.
Colocation	A DC with shared facilities (multitenant) that hosts the computing infrastructure of various organizations, with the day-to-day running of the site, like maintenance and security, outsourced to a third party. The hardware belongs to each organization, but the colocation provider usually ensures power, cooling, and connectivity to network service providers.
Wholesale	In this type of colocation, the provider leases large blocks or the entirety of a facility to a single customer/organization (single tenant).
Cloud	Unlike colocation sites, cloud DCs store customer data on systems belonging to the cloud provider. Instead of each server being allocated to a specific customer, the information is managed virtually.
Hyperscale	Hyperscale DCs are owned or leased by companies with massive data processing requirements. These are organizations like Google, Apple, and Microsoft/Azure that oversee massive chunks of the internet or manage technology systems for third parties. The entire building typically houses monolithic applications under one company's control, which provides significant economies of scale and allows hyperscale operators to push technology boundaries and experiment with new approaches.
Edge	Edge DCs seek to bring processing power closer to where it is needed—the "network edge," as it is known—to reduce latency (i.e., the time it takes for data to travel to a facility and back to where it is needed) for staples of modern living such as smartphones and the instant data transmission required to power driverless cars or operate citywide facial recognition systems.

Source: Authors' elaboration based on Dawn-Hiscox (2022).

and civil society is also relevant to the DCI development. For locations to attract DC investments, the fundamental enabling elements of the DIH should be in place.

To give an idea of the spread of DIHs around the globe, Figure 2 below provides the list of main DC markets by region as of the end of 2023. Each market (from the DCI perspective) corresponds to a DIH. Annex B offers additional details and key nomenclature on DIHs.

According to Cushman & Wakefield (2024a), due to the pipeline of DCs in construction, DCI growth in the coming years will also be explosive. Figure 3 provides an idea of the growth expectations by region for 2024–27.

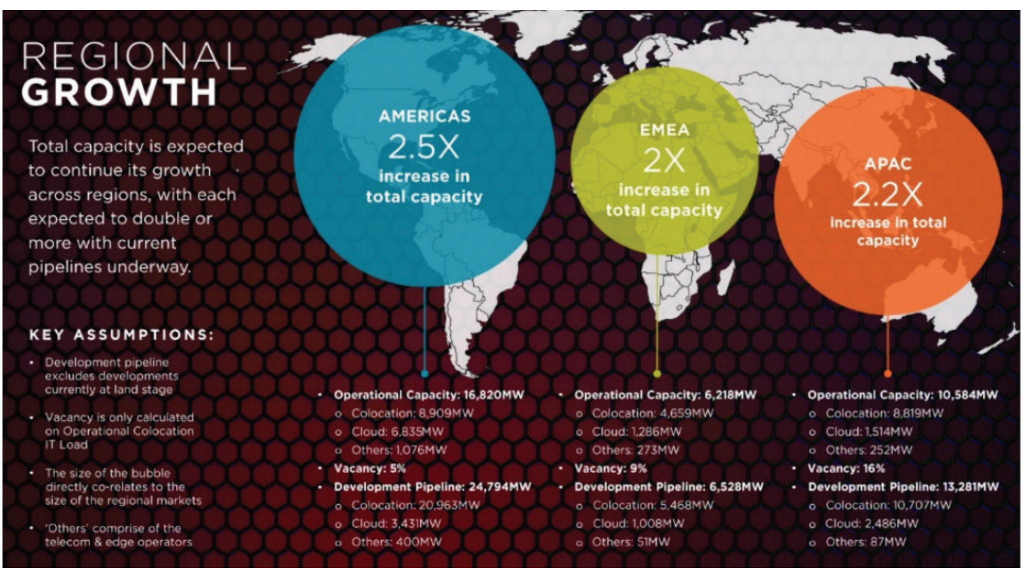
The Data Center Industry Evolution: From the Mainframe to the Hyperscale

During the early days of computing, DI was composed of two basic elements: a central computer and its peripheral devices. Those basic components of DI were in the same place or room, known then as a computer room or computing center. Later, the advancements in solid-state electronics, computing, and telecommunications enabled

FIGURE 2
Main Global Data Center Markets

Source: Cushman & Wakefield (2024a).

FIGURE 3
Regional Data Center Industry Growth Expectations



Source: Cushman & Wakefield (2024a).

distributed digital computing environments to ignite the subsequent growth in computing power, data storage, and data transmission speeds. Society and the economy entered the so-called digital age with the arrival of the personal computer and the internet, the consolidation of the global digital technology industry, and the realization of predictions related to Moore's Law (the observation that the number of transistors in an integrated circuit doubles about every two years).

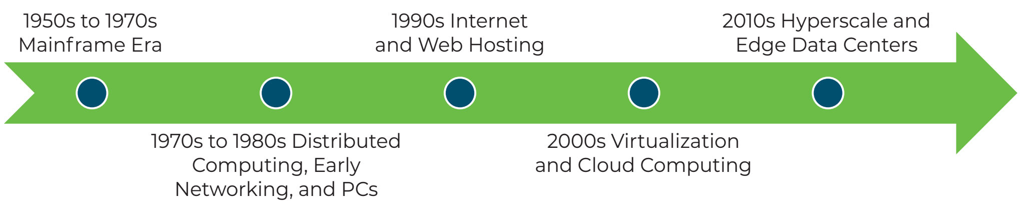
This digital age has been characterized by a continuous stream of emerging technologies that, through their maturity process, ended up integrated within the established DI platforms, leading to new capabilities and, in some cases, triggering paradigmatic shifts. The arrival of cloud computing technology marked one of those paradigmatic shifts in the tech industry and the digital economy. Cloud computing became one of the most impactful developments in the tech industry's history and a shakeup of the DI establishment. Currently, the cloud can deliver virtually unlimited computing power and data storage under the so-called hyperscale cloud category.

In addition to the growing computing power, new DC architectures started to prioritize users that require storage and processing power closer to their locations, opening the field for a category of small DCs called edge DCs. An edge DC is a small, decentralized facility that provides computing and storage resources closer to end users. This proximity helps reduce latency, improve bandwidth efficiency, and enhance the performance of applications and services. Figure 4 offers a chronological perspective of the DC evolution.

Things changed along the way and some terminology and concepts became obsolete or inapplicable in the digital age. As mentioned before, in the early days of computing, DI was basically a computer and its peripheral devices, all in the same room. The internet changed everything, allowing computers and their peripheral devices to be distributed across multiple buildings, cities, and countries. With the arrival of the cloud and high-speed connectivity, computing power has increased to larger scales. Along this transit, the old computing center became the new DC and, in general, its capabilities were no longer defined by data storage, processor memory, or processing speed. In fact, in this new age of DCs, computing capacity is usually expressed in terms of power consumption (megawatts [MW], gigawatts [GW], etc.). This refers to the amount of electricity the DC can consume and provide to its infrastructure. As a reference, hyperscale DCs contain 5,000+ servers, span a minimum of 10,000 square feet (930 square meters), and

FIGURE 4

Data Center Evolution



Source: Authors' elaboration.

offer at least 40 MW of IT capacity (50 MW DC total power), although the trend is for even bigger DCs.[5]

Key Opportunities in the Data Center Industry

Capturing the DCI opportunity is essential for countries or regions prioritizing the digital economy as a development strategy. The evidence and facts about locations around the globe that succeeded in transforming the DCI opportunity into real development impact are overwhelming. However, given the challenges that also emerged along their journey, the chances for new locations to capture this opportunity depend on their ability to attract the DCI while mitigating the implied risks and challenges. LAC countries are among those entering this race. Table 9 offers an overview of the key opportunities the DCI could bring to selected locations.

Case references and evidence on how countries and regions capture these opportunities are presented in Section 2 of this report. For readers interested in a detailed analysis of the most successful countries and some others achieving remarkable progress, Table 10 provides a selection of recommended readings.

Key Challenges in the Data Center Industry

DCs are places where innovation and change are part of the daily routine. At the same time, their unrelentless growth has generated the need for a deeper understanding of all their implications. The interest in the DCI increases as more locations realize their benefits, while at the same time the sense of urgency rises to understand challenges like their environmental impact and the pursuit of rightful regulatory frameworks. Table 11 provides an overview of the key challenges faced by the DCI.

In the past, addressing the sector's challenges was the responsibility of a small group of experts; nowadays, it is a multistakeholder task involving the DCI, the public sector, international standards organizations, industry associations, academia, and civil society organizations, among others. In Section 2 of this report, examples and reference cases are used to show how the sector's challenges have been addressed globally. In addition, various annexes have been prepared to facilitate a deeper understanding of the different strategies and instruments created to tackle the DCI's challenges.

Financial Instruments for the Data Center Industry

Historically, the traditional enterprise DC was financed through conventional financial instruments by the company or institution that owned it. The entrance into the market of DC colocation commercial offerings initiated a transformation of the DC financial landscape as the new business model was able to show stable revenue streams for the long term. This transformation accelerated with the advent of the cloud services industry.

[5] Annexes A, B, and C provide deeper technical definitions and current nomenclature about DCs, DIHs, and the DCI, respectively.

TABLE 9
Key DCI Opportunities Overview

Opportunity	Description
Economic growth	DCs attract substantial investments, creating jobs and boosting local economies.[a] Once a DIH is formed, it has a call effect on the whole DCI ecosystem, bringing all related industries such as specialized design and construction, IT services, telecommunications, power, cooling, etc.
Technological advancement synergies	The DCI drives technological innovation and DI development, enhancing a country's digital capabilities. It also enables the growth of tech startups and other digital businesses, while accelerating the digital economy's maturity.
Increased connectivity	DIHs improve internet connectivity and bandwidth, benefiting both businesses and consumers, leading to better access to digital services, and supporting the growth of e-commerce, online services, and the step-up of the digital transformation of the economy.
Energy efficiency and sustainability	DCs require energy-efficient technologies and renewable energy sources—that is, green DCs that promote sustainability and reduce their environmental impact. Incorporating those capabilities into the local DCI also diffuses across the whole economy, contributing to the acceleration of the green economy.
Enhanced security and data sovereignty	The presence of DCs in a location drives capabilities for data to stay within the country's borders, enhancing data security and enabling compliance with national and international data regulations. This can be particularly important as countries enter into international data regulations, cooperation, and agreements as they become global DIHs.
Global competitiveness	Countries with robust DCI ecosystems and growing digital economies can increase their relevance in the global economy to attract multinationals' presence and investments. This can enhance their global competitiveness and influence across sectors and geographies, creating more jobs and public sector revenues.
Resilience and redundancy	Local DCs can provide redundancy and disaster recovery options, ensuring business continuity in case of disruptions. This can be crucial for maintaining critical services and operations. These capabilities can support the local, regional, and global digital economy.
The rise of AI and non-latency-sensitive applications	With the growing adoption of AI, the demand for data services is skyrocketing. AI applications require substantial computing power and storage, especially those involving machine learning and large language models. Applications such as the training of AI models are non-latency-sensitive, allowing the DCI to locate facilities abroad where costs will allow resource allocation and operational cost optimization. This is indeed a new opportunity for emerging markets like LAC to host DCs that support AI.
Geographic, location, and geopolitics	As geopolitics evolves, new opportunities will surge depending on a country's positioning. For example, the nearshoring opportunity provided by the United States' post-COVID industrial policies impacts the DCI value chain and is also an opportunity for LAC countries due to geographic location. A second example is time zone leveraging to optimize digital workloads and talent attainment.

Source: Authors' elaboration.
[a] Global DC staff requirements are forecast to grow globally from about 2 million full-time employee equivalents in 2019 to nearly 2.3 million in 2025. A general accepted rule in terms of jobs expectations is that each direct job from the DCI supports six jobs in the extended ecosystem. See Annex G for further details.

TABLE 10

Recommended DCI Impact Reports

Report title	Comments	Download URL	Key highlights
The Impact of Data Centers on Virginia's State and Local Economies: 5th Biennial Report (2024)	This report is prepared every two years by the Northern Virginia Technology Council (NVTC). Along with its editions, the report has collected and analyzed evidence about the benefits the region and the state have achieved as the world's largest and most consolidated DIH and DCI hub. The impact is impressive, but it is important to keep in perspective that this is the most consolidated and largest DCI hub in the world. Economies of scale, local digital ecosystem maturity, and DCI industry maturity could not be compared with emerging geographies.	https://www.nvtc.org/topics/data-center-and-cloud/report/	In 2023, DCs in Virginia directly provided approximately: • 12,140 operational jobs plus 14,240 construction jobs, • US$2.8 billion in operational and construction pay and benefits, and • US$16.6 billion in operational and construction economic output. In 2023, the economic ripple effects generated by the growth of DCs had the following impact on Virginia's workforce and economy: • 78,140 jobs supported by operation and construction combined • US$6.2 billion in supported employee pay and benefits • US$31.4 billion in supported economic output For every job inside Virginia DCs, 3.5 additional jobs are supported in the rest of Virginia's economy, not counting construction jobs. Because DC facilities are taxed locally but serve customers globally, they import tax revenue from other states. In 2022, DCs paid US$640 million in taxes to the Commonwealth of Virginia and US$1 billion to local governments in Virginia.
Data Center Impact Report Germany 2024	This report is the first of its type, developed to survey the DCI impact on the German economy. The German Datacenter Association (GDA) commissioned the report and their intent is to produce a yearly update report.	https://www.germandatacenters.com/en/data-center-impact-report-germany-2024/	DCs provide around 65,000 direct, indirect, and induced jobs in Germany. There is a direct and indirect contribution to gross domestic product (GDP) currently totaling approx. 10.4 billion euros for 2024. This contribution is forecasted to more than double to 23 billion euros by 2029.

(continued on next page)

TABLE 10

Recommended DCI Impact Reports *(continued)*

Report title	Comments	Download URL	Key highlights
Green Data Centres: Singapore's Sustainable Data Centre Opportunity	This report commissioned by Amazon Web Services and published in 2022 provides broad visibility of the DCI impact on Singapore's economy and the country's priority to capture the green DC opportunity.	https://accesspartnership.com/green-data-centres-singapores-sustainable-data-centre-opportunity/	The DCI contributes more than S$2.0 billion (US$1.5 billion) in annual GDP in Singapore. DCs enable up to 1.6 million jobs across the country: • DCs employ around 7,000 people nationwide, including technicians and workers, each earning approximately 35% higher median wages with 2.6 times higher labor productivity than the national average. • 17,000 jobs are related to the DC supply chain. • Besides this direct employment, 1.6 million jobs, accounting for approximately 70% of the resident labor force, are enabled by the availability of low-latency cloud services. To date, 496,000 cloud implementation jobs and another 1.2 million cloud-enabled jobs have been generated because of DCs located in Singapore. DCs are crucial for Singapore businesses: they ensure reliable access to low-latency services for businesses and consumers, enhance disaster resiliency, reduce geopolitical risks, and ensure Singapore's continued status as a regional business and economic hub.
Study on the Impact of Data Centres in Spain 2022	Commissioned by the Spanish Association of Data Centers (SPAINDC), which has published a series of reports on other key areas of the DCI development in Spain.	https://spaindc.com/wp-content/uploads/2024/05/SpainDC_2024_Resultados_V5_ENTR.pdf	Between 2016 and 2022, DCs contributed 455 billion euros to the Spanish economy. Total of direct, indirect, and induced jobs was 482,000.
Snapshot Mexico Data Center Market 2023–2027	Published in 2024 by Data Center Dynamics, this report provides an overview of the DCI's ongoing development and impact in Mexico.	https://www.datacenterdynamics.com/es/whitepapers/snapshot-mexico-data-center-market-2023-2027/	US$7 billion of direct investment from 2023 to 2027.

Source: Authors' elaboration.

TABLE 11

Key DCI Challenges Overview

Challenge	Description
High energy consumption	DCs require significant amounts of electricity to operate, leading to high energy costs and potential strain on local power grids. This can also have environmental impacts if the energy comes from non-renewable resources. DCs, cryptocurrencies, and AI consumed about 460 terawatt hours (TWh) of electricity worldwide in 2022—almost 2% of total global electricity demand—and this figure could double by 2026. On a low and high estimation, this corresponds to an additional 160 TWh up to 590 TWh of electricity demand in 2026 compared to 2022, roughly equivalent to adding the energy use of at least one Sweden or at most one Germany. Most developed DCI hubs like Northern Virginia, Singapore, or the Netherlands are already confronting significant grid constraints to meet the demand. Due to infrastructure weaknesses, emerging DCI hubs also experience challenges in developing countries. See Annex D for further details.
Environmental impact	DCs and data transmission networks are responsible for 1% of energy-related emissions. In addition to their operational energy use and emissions, DCs and data transmission networks are also responsible for "embodied" life cycle emissions, requiring a holistic approach including design and construction of facilities, manufacturing, procurement, operations, reuse, recycling, and e-waste disposal. Beyond increasing energy efficiency and reducing carbon emissions, these steps can reduce e-waste and limit a DC's environmental footprint throughout the DC life cycle. Cooling requirements to achieve stable processing efficiency make up about 40% of electricity demand from DCs. In addition, DCs consume significant amounts of water for cooling, which puts pressure on local water sources and can contribute to water scarcity in regions already facing water stress. Careful management of water resources is critical at the national and facility levels. See Annex E for further details.
Cybersecurity threats	DCs are prime targets for cyberattacks due to the vast amounts of sensitive data they store. Ensuring robust cybersecurity measures is crucial to protect against data breaches, ransomware, and other cyberthreats.
Regulatory and compliance issues	DCs must comply with growing local and international regulations regarding data privacy, physical and digital security, environmental standards, construction code standards, taxation regulations, digital data security and sovereignty, and so on. Navigating these regulations can be complex and costly and adds uncertainty to the DCI investors' climate.
Physical security risks	DCs must be protected against physical threats such as natural disasters, fires, and vandalism. Ensuring the physical security of these facilities is essential to maintain uninterrupted operations. Avoiding locations with high exposure to natural disasters is a common criterion applied during the location selection process.
Geopolitics and economy fluctuations	Although DCI growth seems unstoppable, paradigmatic shifts in technology, geopolitics (e.g., global DCI value chain), climate change, or global economy fluctuations could impact the industry and, by contagion, their associated local economies.
Local infrastructure strain	The construction and operation of DCs can strain local infrastructure, including roads, land usage, water supply, and waste management systems. This can lead to increased costs and potential conflicts with local governments and communities.
Bureaucracy	As the DCI continues to grow, there is a constant search for new DC locations. During this quest, the industry faces several challenges related to local bureaucracies and the lack of standard policies, which can significantly impact its operations and expansion plans.

(continued on next page)

TABLE 11

Key DCI Challenges Overview *(continued)*

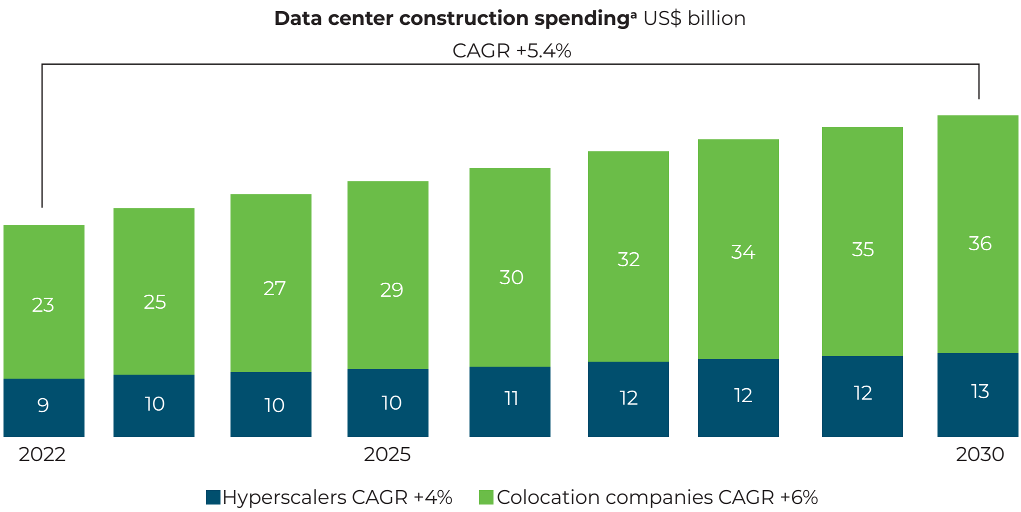
Challenge	Description
Digital ecosystem maturity	The DCI requires certain levels of digital ecosystem maturity to succeed. Some key aspects defining the maturity level are the availability of a skilled workforce, infrastructure readiness, community support, sustainability frameworks, and the regulatory environment.
Location selection	Considering new locations or local expansions is a key decision for industry players and the locations under consideration. This process is becoming increasingly challenging as the DCI prepares for the expected increase in demand and cities, regions, and countries compete to attract the industry. Nowadays, power availability has become paramount in the location selection process. See Annex C, Table A6 for further details.

Source: Authors' elaboration.

FIGURE 5

Global Spending on Data Center Construction and U.S. Data Center Demand Forecasts

Global spending on the construction of data centers is forecast to reach US$49 billion by 2030.



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As the market trends were clearly identified, the financial fundamentals for a new wave of financial instruments available to support the DCI came to fruition.

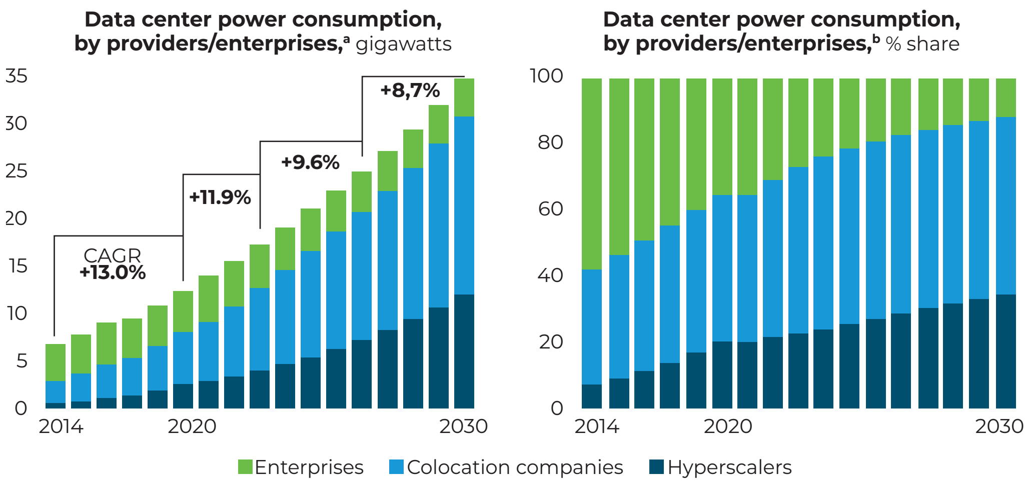
Figure 5 shows the evolving trend away from enterprise-owned DC investments and toward colocation and hyperscale cloud types of DC developments.

As a result of the clear trends and constant DCI growth globally, investment in DCs has been brisk. Funding sources include real estate financing, unsecured corporate

FIGURE 5

Global Spending on Data Center Construction and U.S. Data Center Demand Forecasts *(continued)*

US data center demand is forecast to grow by some 10 percent a year until 2030.



Source: McKinsey & Company (2023).
[a] Includes construction spending by providers. Excludes enterprise spending and any other capital expenditure outside of construction (such as equipment).
[b] Demand is measured by power consumption to reflect the number of servers a data center can house. Demand includes megawatts for storage, servers, and networks.

bonds, secured corporate loans, public and private equity, and private debt. Lately, securitization has provided the DCI with another funding source and access to often less costly capital from a broad range of investors through the capital markets. Securitization adoption was initiated in the United States in 2018 and has been growing since then in the U.S. market. However, other regions are not jumping as quickly into these types of instruments due to their regulatory environments and regional or national financial market maturity considerations.

Securitization has come in two forms:

- Commercial mortgage-backed securities (CMBS)
- Asset-backed securities (ABS)

Securitization can also be used to monetize future income generated through leases, services-related contracts, and fees associated with DC operations. This revenue stream becomes the expected cash flow that repays the outstanding bonds. The DC operator uses the proceeds from the sale of securities to finance new DC construction, upgrade existing facilities, or manage debt. In 2021, US$6.2 billion of ABS backed by DC revenue were issued. Following are some highlights on DCI investments from Linklaters (2024):

- 2023 was the second-largest investment year in the past decade for investment in DCs globally, with capital reaching US$36 billion.
- In the first five months of 2024, US$22 billion was invested globally, with 29 percent invested across Europe.
- ABS are becoming an attractive option for financing DCs and, since 2018, the United States has seen more than US$21 billion in ABS issuance.

Mergers and acquisitions (M&A) activity also offers perspectives on the dynamism of the DCI economy. In Synergy Research Group (2024a), the firm's chief analyst summarizes the global perspective as follows:

> "There has been an inexorable rise in the demand for data center capacity, driven by cloud services, social networking and a range of both consumer and enterprise digital services. The rise of generative AI is adding a further boost to demand. Specialist data center operators have either not been able to fund those investments themselves, or they were not prepared to put their balance sheets at risk. Meanwhile, data centers are very much being viewed as long-term safe havens for investments, even during turbulent times, which has caused a huge influx in private equity. We do not anticipate that picture changing any time soon."

Figure 6 presents M&A activity from 2015 to August 2024.[6]

Funding needs for the DCI will continue to grow thanks to initiatives such as the European Green Deal,[7] an ambitious green and digital revolution led by the European Commission that impacts several different sectors of the economy. The plan's goals include a target to decarbonize DCs by 2030,[8] which will require substantial investment from European DC providers and will undoubtedly prompt them to consider carefully the funding options available to drive this growth.

In conclusion, a singular, uniform approach has developed toward the financing of DCs. Investors in the DCI will need to take a number of factors into account, including the type of DC asset (e.g., hyperscale, colocation) and the DC's current stage in the life cycle (e.g., greenfield or brownfield).

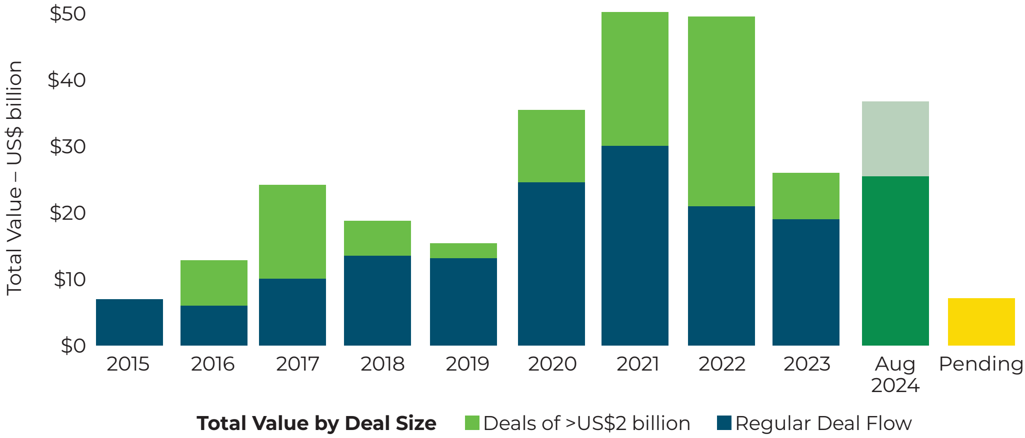
As expected, governments also play a crucial role in financing and developing the DCI by providing a supportive regulatory environment, financial incentives, and necessary infrastructure. Development institutions like the Inter-American Development Bank (IDB) could also play a key role as development advisers and provide financial support for government DI and private sector development.

[6] For an overview of the largest M&A deals from 2016 to September 2024, see https://www.datacenterdynamics.com/en/analysis/biggest-data-center-acquisitions-10-billion-dollar-data-center-deals/. The CBRE 2024 Global Data Center Investor Intentions Survey is also a recommended source of financial transactions and investor expectations; see https://www.cbre.com/insights/reports/2024-global-data-center-investor-intentions-survey

[7] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[8] https://energy.ec.europa.eu/news/commission-adopts-eu-wide-scheme-rating-sustainability-data-centres-2024-03-15_en

FIGURE 6
Data Center Mergers and Acquisitions



Source: Synergy Research Group (2024a).

Table 12 highlights key areas of government support.

TABLE 12
Government Support of Data Center Industry

Type of support	Description
Regulatory framework	Governments establish regulations that ensure DCs operate efficiently and securely. This includes data protection laws, cybersecurity standards, environmental regulations, operational standards, and financial sector regulation.
Incentives and subsidies	To attract investment, governments often provide financial incentives such as tax breaks, grants, and subsidies. These incentives can help offset the high costs of building and maintaining DCs and strengthen the overall DCI.
Infrastructure development	Governments invest in the necessary infrastructure, such as power grid and high-speed internet, that is essential for DC operations. This support can significantly reduce operational costs for the DCI and act as an enabler for its development.
Public-private partnerships	Collaborations between the government and the private sector can lead to the development of state-of-the-art DCs. These partnerships can leverage the strengths of both sectors to create more efficient and innovative solutions.
Sustainability initiatives	Governments increasingly focus on green digital finance, promoting using renewable energy sources and energy-efficient technologies in DCs. This not only helps reduce the carbon footprint but also aligns with global sustainability goals.

Source: Authors' elaboration.

2

DATA CENTER INDUSTRY OUTLOOK

Based on the existing pipeline for new facilities, the global data center industry (DCI) is poised to double its size across geographies from 2024 to 2027 (see Figure 3). At the same time, the industry is confronting a broad spectrum of challenges, including land availability for new construction, new regulatory frameworks coming from all levels, and varying issues across different political jurisdictions. Simultaneously, the DCI's high power consumption and environmental impact are causing social alert, particularly in the more developed markets.

Within these industry dynamics, the strong demand for digital services and the explosive growth expectations of artificial intelligence (AI) are leading to historically low vacancy rates; large corporations are facing increasing difficulty securing data center (DC) capacity. Indeed, low supply, construction delays, and power challenges are impacting all markets. For emerging markets, however, this situation might be seen as an opportunity that countries or regions with the proper commitment, capabilities, and planning could capitalize on.

This section has two subsections: one dedicated to an overview of the global DCI outlook and another that highlights key particularities of the DCI in Latin America and the Caribbean (LAC). Each subsection covers macroeconomics, selected reference cases, and key trends.

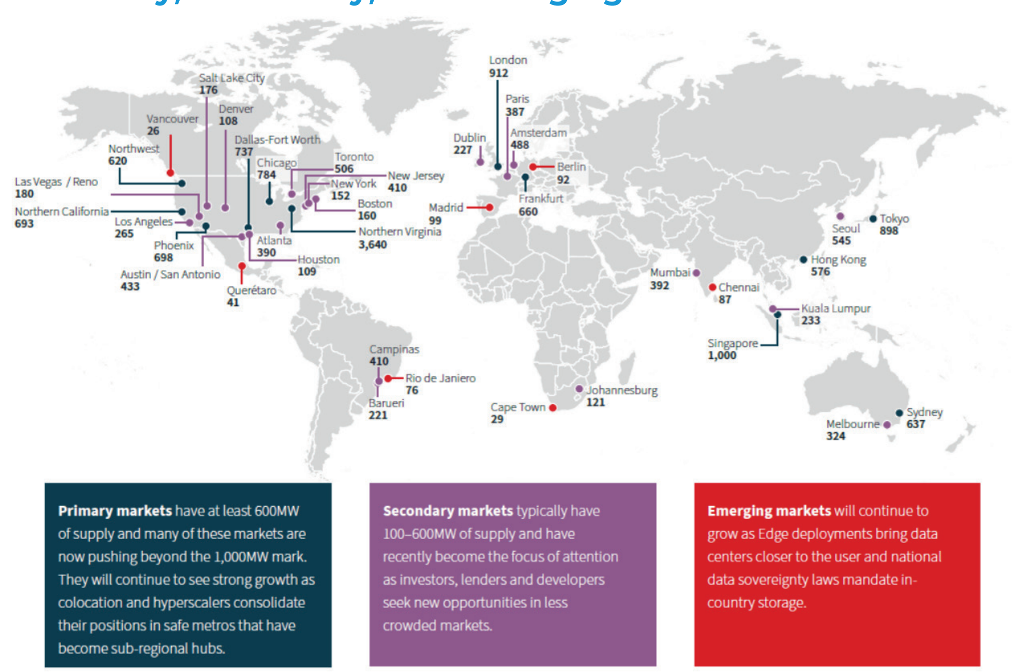
Global DCI Outlook

The DCI is shaping a new global digital infrastructure (DI) architecture. Figure 7 identifies the main DCI hubs across the globe; markets are classified as primary, secondary, and emerging, providing a glimpse of how the industry is spreading across geographies while giving a sense of its maturity level. It is important to highlight that the map in Figure 7 pictures only the colocation market and does not include other DC categories like enterprise or hyperscale. However, in general, the geographic distribution of the main hubs would be similar if those types were included.

Although the Chinese DCI is not included in Figure 7, it is also growing fast. Data Centers in Greater China (Cushman & Wakefield, 2024b) highlights four core categories of DCI hubs in China:

FIGURE 7

Global Data Center Colocation Market Size by Country in Primary, Secondary, and Emerging Markets



Source: JLL (2024).
Note: Numbers provided are megawatts (MW) of built-out critical IT load capacity based on June 2023 data.

FIGURE 8

Greater China Data Center Market Snapshot and Key Indicators, Q4 2023

Source: Cushman & Wakefield (2024b).

- Powerhouse markets: such as Beijing and Shanghai
- Established markets: such as Hong Kong
- Developing markets: such as Guangzhou
- Emerging markets: such as Taipei

Figure 8 offers additional insights about the Greater China DCI outlook and an interesting comparison with the Singaporean market.

Macroeconomics

This subsection presents an overview of the global DCI market through the following key industry metrics based on the colocation segment:

- Inventory or market size: existing capacity in terms of IT power (MW)
- Vacancy: DC availability within markets based on vacancy as a percentage of inventory
- Development pipeline: planned expansions and new developments
- Taxes: applicable tax references

Although DCI market size is mainly measured in terms of IT power in MW (and soon going into GW), the economic metrics vary. As a reference, Structure Research (2024) provides the following insights about the colocation market:

- The DC colocation market was estimated to be worth US$79.4 billion in 2023, representing a 13.2 percent year-over-year (YoY) growth.
- Looking ahead to 2024, the market is expected to continue this upward trend, growing 16.4 percent YoY to US$92.4 billion.
- The five-year CAGR for the 2024–29 period is expected to come in at 15.1 percent.

Regarding the enterprise and hyperscale segments, as seen in Figure 5 the latter is experiencing an unstoppable growth trend, despite potential shorter-term backlashes due to the cloud repatriation movement experienced during the post-COVID period.

Cloud repatriation refers to moving data, applications, or workloads from public cloud environments back to on-premises or private cloud infrastructure. This trend has been gaining traction for several reasons:

- Cost management: Many companies initially move to the cloud for its scalability and lower upfront costs. However, as data and usage grow, the ongoing costs can become significant. Repatriating data can help reduce these expenses.
- Performance and control: Some organizations consider it feasible to achieve better performance and greater control over their data and applications by managing them in-house.
- Security and compliance: Industries with strict regulatory requirements, such as healthcare and finance, may prefer to keep sensitive data on-premises to ensure compliance and enhance security.

Synergy Research Group (2024b) provides the following key insights about the hyperscale segment:

- Just 20 state or metro markets account for 62 percent of the world's current hyperscale DC capacity.
- Northern Virginia and the Greater Beijing Area alone comprise 22 percent of the total. They are followed by Dublin, the U.S. states of Oregon and Iowa, and Shanghai.
- Of the top 20 markets, 13 are in the United States, four in the Asia-Pacific region, and three in Europe. After the top 20, the next 20 largest state or metro markets account for another 18 percent of the market, with Europe and the Asia-Pacific region featuring more prominently in that batch.
- The prevalence of U.S. markets in the top 20 is mainly due to two factors: almost 60 percent of the world's hyperscale operators are headquartered in the United States, including the four most significant, and the United States accounts for almost half of all cloud market revenues.
- Looking ahead, the United States and China will continue to dominate the numbers, though countries like Malaysia, India, and Spain will start to feature much more prominently.
- While the general location decision criteria will remain the same over the coming years, the mix of top markets will change, driven mainly by high growth in emerging markets such as parts of Southeast Asia and Latin America.

Inventory

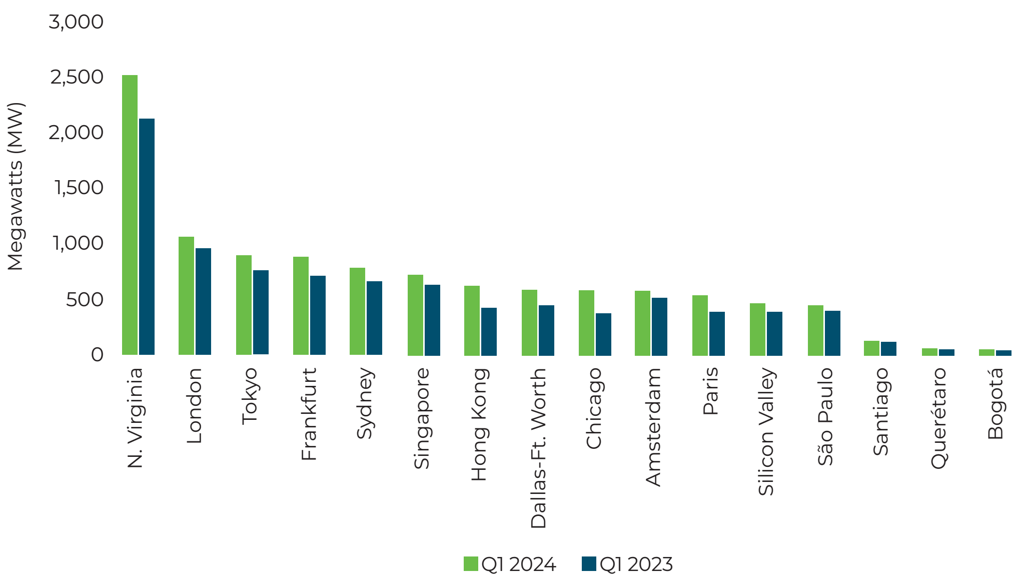
Figure 9 provides a perspective of the DCI market size across geographies, highlighting the main DCI hubs in each. The growing trend is evidenced in each market by the YoY comparison of their size in Q1 2023 versus Q1 2024. The selected markets represent the largest ones for each of the following geographies: North America, Europe, Latin America, and Asia-Pacific.

A more developed market like Northern Virginia, London, or Tokyo has many challenges, but it also appeals to clients and operators alike due to several competitive advantages. Usually, those markets have access to all major cloud services, vital ecosystems of operators, complementary services, talent for hire, knowledgeable sales representatives to assist with filling facilities, and the like. Local governments understand the planning approval process, and utilities are not surprised when operators inquire about large power requirements. The largest markets are thus able to grow through this momentum. However, this momentum will not be infinite; as markets expand, key challenges appear from various fronts such as land availability, power grid capacity, political perspectives, and social stress.

On the other hand, emerging markets represent different types of opportunities and challenges for clients and operators due to their lower maturity level in having the needed local ecosystems to support the industry. Examples of the key challenges faced in these markets are the lack of streamlined or established permit processes, a deficit of

FIGURE 9

Data Center Inventory by Market



Source: CBRE (2024).

trained workforce, and regulatory uncertainties. On the opportunity side, in some emerging markets governments are realizing the DCI opportunity and are willing to open new channels and mechanisms to capture it.

Remarks from CBRE (2024) about inventory in each region comparing Q1 2023 and Q1 2024 follow:

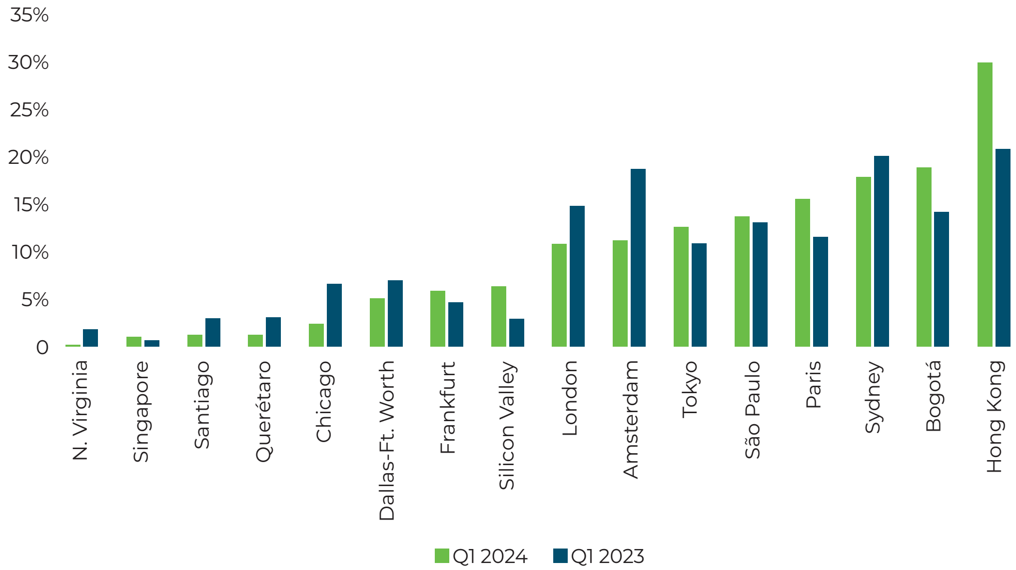
- North America: 24.4 percent growth YoY, while governments are addressing power constraints by simplifying permitting and integrating renewable energy into the grid.
- Europe: 20 percent growth YoY, while supply shortages persist across the continent, especially in core markets like Frankfurt. Preleasing new facilities is common, indicating a need for ongoing investment in DC development. Power sourcing remains a key challenge.
- Latin America: 15 percent growth YoY, while national governments such as those in Brazil and Chile are already working on national strategies to capture the DCI opportunity.
- Asia-Pacific: 22 percent growth YoY, while the capacity pipeline is strong, with numerous developments under construction across the region.

Vacancy

Figure 10 presents information about DC vacancy rates and provides valuable insights into the markets as demand evolves. This analysis offers key learnings to emerging

FIGURE 10

Data Center Vacancy Rate by Market



Source: CBRE (2024).

markets like LAC. A stretched market is a general indicator of heavy demand, while markets with higher structural vacancies often witness those vacancies vanish once hyperscale moves into the area. Mature markets like Dublin, Northern Virginia, Frankfurt, and Singapore are showing record-low vacancy rates, while the newest markets highlighted, like São Paulo and Bogotá in LAC, show higher vacancy rates.

Remarks from CBRE (2024) about vacancy by region comparing Q1 2023 and Q1 2024 follow:

- North America: Vacancy rates hit new lows across major markets. Northern Virginia's vacancy rate declined, dropping to 0.9 percent in 2024 from 1.8 percent the year prior despite an 18 percent increase in inventory over the same period. This means that demand continues, even after power availability delays and social movements against DCs environmental impact momentum.
- Europe: The FLAP (Frankfurt, London, Amsterdam, Paris) markets' combined vacancy rate fell by 2 percentage points YoY in Q1 to 10.6 percent. Amsterdam had the largest decrease, nearly 8 percentage points, to 11.5 percent. Despite the expected new supply, the low vacancy rate should persist due to strong demand. At the same time, emerging European DCI hubs across the Nordic countries, south of Europe, and eastern Europe, are also growing, offering new inventory and availability.
- Latin America: Vacancy rate held steady YoY at 11.1 percent. Querétaro had the biggest decline (1.9 percentage points) to a record-low 1.2 percent. There is persistently strong regional demand, mainly from hyperscale.
- Asia-Pacific: Vacancy rate slightly increased due to many new project completions, with primary market vacancies rising to 16 percent from 13.5 percent. Hong Kong's vacancy rate hit around 30 percent due to 195 MW of new 2023 supply amid softer leasing conditions. However, Singapore remained an extremely tight market with a vacancy rate of 1.0 percent.

Pricing and Rental Rates

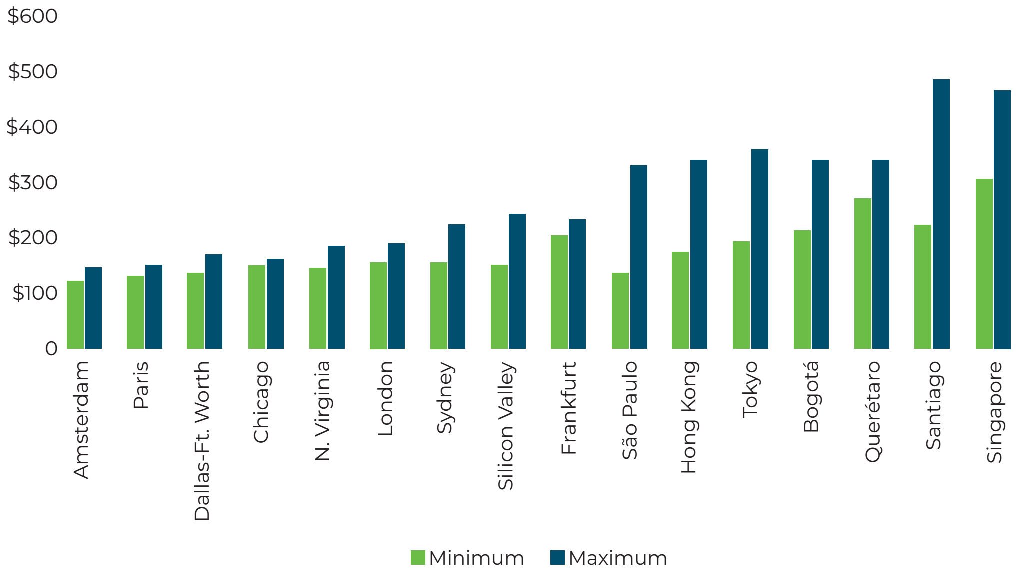
Figure 11 about DC pricing brings a key perspective to the sector. As demand rises and the DCI confronts growing pains, pricing will become more relevant when looking for new locations. This concerns LAC countries' pricing, which seems to be high compared to other geographies. This aspect should be carefully analyzed as the region explores strategies to capture the DCI opportunity. There are many factors to consider here, including demand, incentives, workforce, bureaucracy, needed infrastructure investments, and the local economy.

Remarks from CBRE (2024) about pricing by region comparing Q1 2023 and Q1 2024 follow:

- North America: Prices are accelerating significantly due to supply shortages and high demand. Average asking rates for a typical 250–500 kW requirement across all four featured North American markets surged by 20 percent YoY, the highest global increase.

FIGURE 11

Monthly DC Price Range for 250–500 kW (Min-Max, Q1 2023–Q1 2024) in USD without Electricity Cost



Source: CBRE (2024).

- Europe: Prices continue to increase due to high demand and rising construction costs. Rental rates in key markets like Frankfurt and London steadily climbed from Q1 2023 to mid-2024. Frankfurt saw a steeper 15 percent increase, reflecting its status as one of the most expensive markets in Europe.
- Latin America: Prices show a mixed picture in 2024. Overall rental rates rose slightly from the previous year, with market-specific variations. For example, Bogotá saw an unexpected 8 percent YoY colocation rate decrease, possibly due to increased competition or a temporary market correction. Conversely, Santiago's rental rates increased by 15 percent, reflecting strong demand and limited supply.
- Asia-Pacific: Prices have steadily increased due to strong demand and rising construction and operational costs, despite a relatively large amount of new inventory. In Singapore, one of the most expensive global markets, the monthly price range was more than US$300 per kW. Tokyo's prices generally increased, with rates around US$200 per kW on the low end. Sydney's prices remained steady at US$195 despite significant new supply.

Tax Incentives

Regarding tax incentives, there are plenty of models adopted by national, regional, and local governments. It is interesting to highlight the cases of Hong Kong and Portland

(Oregon, United States), where zero taxation has been adopted. Hong Kong is a global financial and business capital with a long history of pro-business policies and a robust DC sector. Portland is a rapidly growing DC market on the West Coast of the United States, with dense fiber and sites available in the local-market cluster in the suburb of Hillsboro.

It is also interesting to see some large markets offering lower taxation. Among those are Northern Virginia, Singapore, and the DC cluster in Northern New Jersey (United States). Some developing hubs, such as Johor and Kuala Lumpur in Malaysia, are also offering aggressive tax incentives.

For further analysis and details on other aspects like land price comparisons, power costs, colocation rental pricing, and a deep dive on various geographies, the following reports are recommended:

- CBRE: Global Data Center Trends 2024
- Cushman & Wakefield: 2024 Global Data Center Market Comparison
- JLL: Data Centers Global Outlook
- Cushman & Wakefield: Data Centers in Greater China (2024)

Reference Cases

When looking into the global DCI footprint, several experiences are worth analyzing to leverage lessons learned and best practices as LAC policymakers, DCI industry leaders, and other stakeholders shape the region's DCI. In this subsection, an overview of the largest and most developed DCI market—Northern Virginia—is presented and resources are recommended to review other key reference cases in Germany, Singapore, Ireland, Sweden, and learn about the impact of Google DCs.

Northern Virginia in the United States is the largest DCI hub in the world and its trajectory has been well documented. Table 13 provides a summary of NVTC (2024), a case

TABLE 13
Northern Virginia Reference Case

Subject	Highlights
Origin	• Location advantages have been seen as one of the reasons for the region's early success in the DCI due to its proximity to the Washington, DC, ecosystem of government and corporations and existing robust internet infrastructure established in the area since the early 1990s that includes strong fiber optics (submarine cables) connectivity infrastructure, and internet infrastructure. • Early internet infrastructure developments fostered the creation of a robust digital industry ecosystem (skilled professionals, industry, connectivity, stable regulatory frameworks) in the area, creating a call effect for new DI investments. • The first large DC was built in the area in 1998, followed by many others. • Relatively low electricity prices and power companies' ability to deliver new services on aggressive timelines. • Former farms offer land availability and relatively competitive prices. • Water availability.
Size	• The largest DCI globally, home to 300+ DCs, with a total power of approximately 2.5 GW. • Land used in Loudon County only is more than 26 million sq. ft. • Northern Virginia's DC market grew nearly 500% between 2015 and 2023.
Investments	• The accumulated capital investment in DCs across the state of Virginia amounted to US$203 billion in 2021. Virginia DCs spent US$5.4 billion in 2021 on operational expenses, the majority of which was for staffing and power. • A value change ecosystem is also establishing manufacturing and logistics support in the area.
Government incentives	• In 2008, Virginia established a sales tax exemption on computer equipment. • The state expanded the exemption in 2010 after losing a bid to attract Apple, which instead built a US$1 billion DC in Maiden, North Carolina. • Virginia became the sixth state to enact a sales tax incentive for DCs, which qualify for a sales tax exemption when investing at least US$150 million and creating 50 jobs with wages that are at least 150% of a county's average. • Local governments aggressively courted DC companies by streamlining the development approval process. • Sustained infrastructure development investments, like new transatlantic submarine cables, improve connectivity toward Europe and Latin America. • Local governments like Loudon County extended special tax incentives to different DCs that needed equipment like power generators or chillers. • In the United States more than 30 states have some type of incentive to attract DCs. In 2023–24, Arizona, Connecticut, Idaho, Maryland, North Dakota, Pennsylvania, and Utah all enacted or expanded sales and use tax incentives targeting DCs for economic development.
Employment	• As of 2023, DCs employed 10,420 Virginians in operational jobs and 12,340 in construction jobs. This represents US$2.6 billion in associated employee pay and benefits. • Considering all indirect jobs, the estimation indicates 59,140 supported jobs, representing US$5.4 billion in associated employee pay and benefits, during 2023. • For every job inside a Northern Virginia DC, 2.9 additional jobs are supported in the rest of the Northern Virginia economy, not including construction jobs.
Economic impact	• Total economic output in 2023: US$26.6 billion. • It is estimated that in 2022, DCs were directly and indirectly responsible for generating US$1 billion in state tax revenue in Virginia. • The DCI is associated with 62% of all the investments in the state of Virginia in 2021, totaling US$6.8 billion.

(continued on next page)

TABLE 13

Northern Virginia Reference Case *(continued)*

Subject	Highlights
Key challenges	• Land • Energy • Water • Community concerns: noise, power, water, landscape, land usage
Future perspective	• Constraints on key resources like power, cost increases, and social pressure caused secondary locations outside of the main hub in Loudon County to start attracting investments. The DCI has spread across the state of Virginia and is also expanding to nearby counties in the state of Maryland. • The development of advanced processors to support AI workloads and hyperscale's increased presence are adding pressure on top of the existing power and cooling technology challenges. • Competition is increasing within states.

Sources: NVTC (2024), Mullin (2023).

study of the hub's development journey, and highlights its key achievements, ongoing challenges, and future perspectives. Indeed, the full case study is recommended for the LAC audience.

Internationally, DCI success stories are built around similar indicators; attracted by the needed digital ecosystem and government incentives, strong locations for digital economies tend to be in or near major cities.

Recommended readings about other reference cases can be accessed via the following links:

- GDA: Data Center Impact Report Germany 2024
- SpainDC: Madrid Data Centers Report 2023–2026 (only in Spanish)
- Access Partnership: Green Data Centres: Singapore's Sustainable Data Centre Opportunity
- Government of Ireland: Government Statement on the Role of Data Centers in Ireland's Enterprise Strategy
- CBRE: Data Centres in Sweden
- Oxford Economics: Data Center Impacts (focused on Google's DCs)

Key Trends

The ever-growing digital economy—driven by increasingly sophisticated experiences with services like streaming, gaming, self-driving cars—and the ongoing democratization of AI is driving demand for more, larger, and increasingly powerful DCs. At the same time, power constraints, real estate–qualified assets demand, and pressure for optimized DC design and operations are starting to inhibit or delay availability. Below is an overview of key ongoing trends of the global DCI:

- A continued worldwide power shortage is significantly inhibiting global DCI growth. Sourcing power is a top priority for operators across all regions. Secondary markets with ample power should attract more DCI investment. Vacancy rates continue to decline across most global markets due to strong demand. Singapore, the world's most power-constrained market, has only 7.2 MW of available capacity and a near-record-low 1 percent vacancy rate. Querétaro has only 0.6 MW available for lease. The worldwide power shortage continues to fuel price increases. In U.S. dollar terms, over the period Q1 2023 to Q1 2024 Singapore had the highest rental rates at US$315–480 per month for a 250–500 kW requirement, while Chicago had the lowest at US$155–165. AI advancements are projected to drive future DC demand significantly. High-performance computing will require rapid innovation in DC design and technology to manage rising power density needs (CBRE, 2024).
- In an environment where adaptability and scalability are crucial, construction based in modular design has emerged as an innovative solution to meet changing business needs. Previously, DCs were built as monolithic physical structures, with designs and infrastructure projected for a lifespan of 10 years or more in some cases. This approach complicated the transition to new technologies over time, resulting in complex and costly processes that made it challenging to keep up with technological advancements. In contrast, modular DCs are designed and built using components that can scale according to the company's resource demand. This has led to greater efficiency in resource utilization, faster deployment, and unprecedented adaptability (DCD, 2024b).
- Advanced processors require highly specialized equipment, particularly for liquid cooling, and these needs are transforming traditional facility design. DC providers are rapidly changing designs to support these new requirements. In the quest to lower power usage effectiveness (PUE), DC operators are seeking new software solutions and algorithms to propel efficiency gains. Achieving better efficiency requires specialized expertise, which also requires further investments in staff training and specialization (JLL, 2024).
- Many countries are requiring stricter DC carbon emissions reporting. Operators have great expectations of direct liquid cooling in terms of improving efficiency and sustainability and reducing carbon emissions, but these benefits will be out of reach for many organizations.
- Another major shakeup in the industry is the build-out of new hyperscale colocation campuses connected by wide-bandwidth fiber, which will relieve pressure on traditional DC hotspots—and, in the long term, lower colocation prices. As a solution to rocketing demand for computing and storage, the hyperscale campus will emerge slowly—with the availability of fiber and power being critical factors (Donnellan et al., 2024).
- While the definition of "data privacy" varies across regions, everyone agrees that it is critically important—particularly in an age of rapid network globalization. Looking into the future is always challenging, but if the past decade is any indicator, local variations in the generation and application of data sovereignty law are likely to increase. Building a DC infrastructure able to support data sovereignty is essential and not impossible. Success hinges on being able to incorporate flexibility into the physical

infrastructure to ensure it can support future topologies and data rates for the next generation of servers and switches (DCD, 2023).

- The DCI remains particularly exposed to threats posed by geopolitical events. Geopolitical risks, however rare, have a starkly different profile from other major events. In contrast to a pandemic, natural disaster, or grid energy crisis, geopolitical events are more challenging to model in terms of occurrence and fallout—and, consequently, it is more difficult to develop effective contingency plans. The combination of global interdependency and regionally concentrated manufacturing has made DI—in particular semiconductor supply chains and submarine cable systems—vulnerable to potential economic and military confrontations (Lawrence et al., 2023).

LAC DCI Outlook

As an emerging economies region, LAC is full of challenges and opportunities for DCI development, under the umbrella of the global DCI opportunities, challenges, and trends presented in the previous section. Figure 12 shows the main DCI hubs across the region.

FIGURE 12

Data Center Industry Hubs in Latin America and the Caribbean

Source: CBRE (2023).

Looking into DCI performance in LAC during 2023, DCD (Rodrigues, 2023) highlighted how the year was marked by the inauguration of DCs, mergers, acquisitions, and the implementation of strategic initiatives, including the creation of the Mexican Association of Data Centers (MEXDC).[9] All these actions aim to empower a sector that continues its expansion driven by the growing demand for data and the incessant digital transformation. The article also listed and described the top 29 new DCs launched in 2023.

In Gheorghiu Taras (2023), DCD established the region's DCI 2024 expectations as follows:

- "The data center industry is growing at a dizzying pace. Every year, we witness the new steps that the sector is taking in its expansion across the map of the region with the announcement of new constructions, extensions of existing infrastructures, Data Centers that have already been launched or mergers and/or acquisitions, among other movements that only highlight the great dynamism of this market. Everything points to the fact that 2024 will continue to be synonymous with growth."
- The following subsections offer a high-level picture of macroeconomics data, reference cases, and key trends.

Macroeconomics

According to CBRE (2024), the region experienced significant growth from 2020 to 2024, with supply more than doubled since Q1 2020. Brazil has grown the fastest and is also the largest DCI in the region.

Analyzing key data references from the earlier section on global macroeconomics helps to understand the scale of the LAC market and how it compares to the global sphere. Table 14 shows the analysis snapshot.

Reference Cases

As the macroeconomic highlights clearly show, LAC governments are starting to embrace the DCI opportunity. Table 15 offers a high-level overview of the region's key markets.

In terms of the Mexican DCI, DCD (2024a) confirms all the previously mentioned points and provides much richer details about the country's level of investments, locations, energy issues, and strategic positioning as the connector between North, Central, and South America. The report's main conclusions are summarized below:

- Strong growth in DC infrastructure in Mexico is expected, with millionaire investments that will increase installed capacity from 81 MW to more than 500 MW (colocation) and add more than 1 GW to hyperscale. Expected investment for 2023–27 is more than US$7 billion.
- Querétaro is positioned as a key point in this growth, with hyperscale projects under construction that will consolidate it as a technological hub and main connection point with the United States.

[9] https://asmexdc.com/

TABLE 14

Macroeconomic Highlights of the Data Center Industry in Latin America and the Caribbean, Q1 2023 vs. Q1 2024

Aspects	Observations
Inventory	The region's DC inventory grew by 15% YoY in Q1 to 650.2 MW, with São Paulo accounting for 67% of the top four countries' total inventory. Bogotá's inventory grew the most at 25%.
Vacancy	The region's vacancy rate held steady YoY at 11.1%. Querétaro had the biggest decline (1.9 percentage points) to a record-low 1.2%. There is persistently strong regional demand, mainly from hyperscale.
Pricing and rental rates	Latin America's DC pricing showed a mixed picture. Overall rental rates rose slightly from 2023, with market-specific variations. For example, Bogotá saw an unexpected 8% YoY colocation rate decrease, possibly due to increased competition or a temporary market correction. Conversely, Santiago's rental rates increased by 15%, reflecting strong demand and limited supply.
Taxes	Querétaro and São Paulo are in the higher tax tiers globally, with 16% and 17% respectively, while tax rates in top global DCI hubs are below 6%. However, ongoing initiatives to drive national DC strategies adopted by countries like Brazil and Chile will certainly address taxes and incentives as competition instruments that can be applied to capture the DCI opportunity.

Source: Authors' elaboration based on CBRE (2024).

- The capacity for growth is linked to electricity infrastructure and energy sustainability. The demands for AI and energy-intensive applications are shaping future needs and require alignment with authorities to ensure sustainable growth.
- Established DCI companies such as KIO, Equinix, and others have an advantage in adapting to intense competition due to their experience, customer base, and knowledge in the local market.
- AI is a key disruptor, generating significant demand in the market. However, there are challenges related to the availability of immediate electrical power, skilled labor, and water for equipment cooling.

Key Trends

LAC is immersed in the global DCI dynamic of growth and challenges. Since 2022, a key trend in the region is government interest in countries such as Brazil and Chile in designing policies and strategies to attract the DCI and capture the opportunity.

Indeed, Brazil was the first country in LAC to draft a national DC strategy. The initiative was led by the Ministry of Development, Industry, and Services (MDIC) and the Brazilian Agency for Industrial Development (ABDI). The comprehensive and extensive Strategy for the Implementation of a Data Center Attraction Public Policy (ABDI, n.d.) is a compendium of seven consulting products available for download in English and Portuguese. A snapshot of the key objectives and proposed actions is presented in Table 16.

TABLE 15

Overview of Key Data Center Industry Hubs in Latin America and the Caribbean

Hub	Highlights
São Paulo, Brazil	This market's advantages include the country's best connectivity, strong energy supply and power infrastructure, and proximity to many corporate headquarters and a highly skilled IT labor force. Furthermore, it has the country's largest concentration of rapidly expanding DC retailers and wholesalers. Its clean energy sources, primarily hydroelectricity, are diversifying with increasing investments in solar and wind power, ensuring a stable energy supply. The market's potential for AI workload deployment has been studied, taking its clean energy matrix and energy availability into account. Space and energy constraints are forcing new development farther from the market's core. For example, certain areas in Barueri and Osasco have attracted development interest for smaller demands.
Santiago, Chile	The Santiago market is connected to several submarine cables through Valparaíso, including the US$400 million Humboldt submarine cable project, a public-private partnership with Google that is set to launch in 2026 and link the country to Sydney, Australia. This diverse DC market—encompassing retail, hyperscale, and public cloud providers—creates a robust ecosystem in a key Latin American country, despite its relatively small size and population. With market vacancy at a record-low 1.1%, hyperscale and public cloud providers are demanding more energy. Regulation has been widely discussed, with debates over DC permits and usage in different zones. The connection to Australia should bring more demand. New companies will likely enter the market with the lowest vacancy rate in Latin America, despite recent project completions. The government has embraced the DCI opportunity, launching its national DC strategy in December 2024.
Querétaro, Mexico	An internet backbone connecting Mexico City and the United States, Querétaro is a favored location for hyperscale development in Mexico. Its ample land, professional industrial park operators, and easy road access make it ideal for new developments. Additionally, it is home to several banks and telecom companies. The region already hosts cloud availability zones for Amazon Web Services and Microsoft. Odata, KIO, and Ascenty have consistently expanded their presence in the city since 2020. However, power challenges have slowed new DC launches and expansions in the city and in other Mexican markets. While there are many industrial parks, few have secure energy capacity. During the first part of 2025, positive steps were taken to increase power availability through deployment of new power grid substations and transmission lines (Aligned Data Centers, 2025). The state government's solid support for the tech sector enhances this market's appeal for DC investment. Furthermore, land costs remain attractive compared with other markets.
Bogotá, Colombia	Bogotá's DC market approached the size of Querétaro's in 2023–24 due to increasing demand for cloud services and data storage and the city's digital transformation initiatives. Hyperscale providers expanded their regional presence, and newcomers launched DCs through powered shell acquisitions in the main free trade zones. These zones offer tax benefits, and some are in strategic locations near main highways and industrial corridors, while others are far from the city's core and have only a few fiber paths. The market utilizes green energy, despite some transmission constraints. Establishing the energy infrastructure needed for hyperscale projects may delay delivery dates of DCs.

(continued on next page)

TABLE 15

Overview of Key Data Center Industry Hubs in Latin America and the Caribbean *(continued)*

Hub	Highlights
Rio de Janeiro, Brazil	Brazil's second-largest market has consistently grown, delivering key hyperscale developments. As some industrial regions become saturated, new areas are emerging, prioritizing energy supply expansion. Fortaleza and Porto Alegre are also becoming emerging hubs in Brazil.
Lima, Peru	Peru has garnered attention for its significant DC activity. The market is transitioning from telecom sites to a third-party focus, facilitated by the entry of international companies like Equinix and Odata.
Montevideo, Uruguay	This DC market, although small, benefits from its strategic position near Buenos Aires and Brazil. Uruguay boasts a stable economy, exceptional connectivity, and an electricity fuel mix heavily weighted to renewable energy (particularly hydropower and wind). It is expected that there will be continued interest from cloud service providers and DC operators. Google's US$850 million investment to build a local DC was announced in 2024 (MIEM, 2024), generating a call effect for the DCI ecosystem.

Source: CBRE (2024).

TABLE 16
Brazil's Key Objectives and Proposed Actions for Data Center Attraction Public Policy

Objective	Proposed actions
Attract new DC investments in the short term, with lower financial and political costs	**High priority:** • Sales and import tax reduction for DC equipment • Subsidies for renewable energy generation • Offer professional courses in partnership with the private sector • Create a mechanism for waiving permits for low-impact projects • Full regulation of the LGPD (data protection law) **Low priority:** • DC exemption from property tax • Grant incentives through energy efficiency programs • Grant subsidized credit to DC sector • Grant, rent, or sell public land at subsidized prices • Agreements with distributors to meet DCs' demands • Set deadlines and mechanisms for tacit permit approval • Create a special customs regime for DC equipment • Facilitate hiring of foreign skilled labor
Maximize DC investment attraction by reducing structural gaps and offering robust subsidies	**High priority:** • Sales and import tax reduction for DC equipment • Electricity tax reduction • Internet and connectivity tax reduction • Tax credit for investments in DCs • Build DC parks • Offer professional courses in partnership with the private sector • Full regulation of the LGPD (data protection law) **Low priority:** • Investment in support infrastructure • Adapt university curricula to market demands • Enable and encourage cloud use in the private sector • Promote greater cloud use in federal government and subnational entities • Harmonize administrative, security, and bureaucratic standards • Create a "single-window" channel for obtaining documents, registrations, and permits • Create a cybersecurity policy favoring the DCI.

Source: ABDI (n.d).

3

CAPTURING THE DATA CENTER OPPORTUNITY IN LATIN AMERICA AND THE CARIBBEAN

This section explores the following questions about the data center industry (DCI) in Latin America and the Caribbean (LAC):

- Why is enabling the DCI relevant for LAC countries, and what are the key aspects that should be addressed to foster its development?
- Is it imperative for every country in LAC to enable DCI development?
- How can countries or regions be supported in designing a customized DCI opportunity capture strategy and action plan?

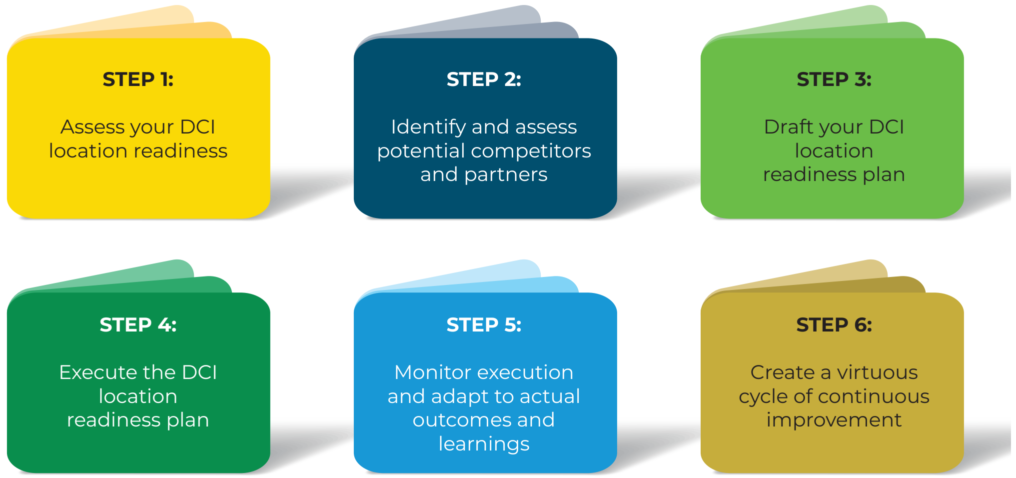
To capture the data center opportunity, several key premises must first be recognized, beginning with the critical importance of digitalization to the economic growth and prosperity of nations and regions. Second is that digital infrastructure (DI) modernization and its continuous improvement is imperative for nations to develop and sustain economic and competitive growth. The third premise to understand is that attracting the DCI to become part of a nation's DI represents opportunities and challenges that should be addressed.

Any nation looking ahead to capture the DCI opportunity must increase its attractiveness for data center (DC) deployments. To initiate this process, there are four fundamental steps to take:

1. Ensure reliable and sustainable (green) energy that is competitively priced.
2. Treat DI as a vital component of modern society.
3. Vocalize the value proposition and the ambition to become a relevant player in the sector.
4. Increase predictability in planning, permitting, and risk assessment.

Becoming a DCI hub offers several significant benefits for countries, as explained in Key Opportunities in the Data Center Industry in Section 1. In the short term, opportunities and challenges are associated with infrastructure development and capacity-building investments required to drive the country's readiness. In the medium to long term, the return on investment will be seen in sustained economic growth and country

FIGURE 13
DCI Opportunity Capture Planning Process



Source: Authors' elaboration.

competitiveness improvements. It is key to understand that the various potential roles for a country or region to play in the DCI will help them to capture the opportunity.

Since the early 2000s, the DCI has been consolidated as a global industry and, as in many industries, its development has been prompted by growing demand and was not planned or structured. Creating a new industry to meet that demand, with all its implications, challenged the initial industry and government players. Over time, the most advanced countries pioneered and developed the key learnings and best practices that now can be leveraged by emerging economies like those in LAC to evaluate, define, and plan their journey to become relevant DCI players.

Figure 13 depicts the DCI opportunity capture planning process that could be adopted by countries or regions that want to explore their potential.

Each step of the process implies specific considerations. Table 17 elaborates on key considerations for each step. There are two general thoughts to apply along the whole process:

1. The planning process should be a multistakeholder collaborative exercise with participation of leaders from, at the least, government, key DCI players, academia, and civil society organizations.
2. A permanent observatory and discovery activity should be established to identify international best practices and learnings.

Following these steps should deliver a national or regional strategy for the attraction or capture of DCI opportunities. Many countries have already gone through similar processes. Some examples can be accessed via the following links:

- Brazil's Strategy for the Implementation of a Data Center Attraction Public Policy
- Capturing the Data Center Opportunity: How Sweden Can Become a Global Front-Runner in Digital Infrastructure
- Driving a Greener Digital Future: Singapore's Green Data Centre Roadmap

TABLE 17

Key Considerations for the Planning Process

Step	Key considerations
Step 1: Assess your DCI location readiness	• Leverage the information in Table A5: Location Selection Challenges in Annex C to build a readiness assessment matrix. • Identify and assess your location risk levels: natural disasters, economic and rule of law situation, policy and regulatory environment, etc. • Select and leverage international benchmarks and indexes to rate your location maturity level on key aspects like DI, international and national connectivity, digital talent, power grid strength and energy cost, business facilities, and overall cost structures for doing business. • Assess and rate your government's relevant policies and regulations like data security, data sovereignty, cloud preference policy, artificial intelligence (AI) policy, taxation and fiscal incentives, land classification, industrial construction permits and regulations, environmental policies and regulations, investor climate and regulations, and employment regulations (particularly for international workforce).
Step 2: Identify and assess potential competitors and partners	• Potential competitors could be neighboring regions or countries, as well as more-distant jurisdictions with similar interests. In the DCI, markets are competing for global business. • Apply readiness assessment tools that are similar to ones used by competitors. • Discover potential partners: leading corporations, international organizations, financial partners, research partners, value chain partners, etc.
Step 3: Draft your DCI location readiness plan	• Identify key gaps in areas like DI, policy, regulation, and skills. • Define clear objectives, time horizon, and decision making and governance rules. • Apply participatory processes for consensus building. • Clearly identify needed resources and the corresponding sources.
Step 4: Execute the DCI location readiness plan	• Define short-, medium-, and longer-term priority tasks. • Apply parallel execution streams whenever possible. • Ensure sustained teamwork and engagement at execution and governance levels. • Apply dynamic adaptability routines.
Step 5: Monitor execution and adapt to actual outcomes and learnings	• Ensure feedback channels are open and active. • Build team capabilities to ensure empowerment and involvement.
Step 6: Create a virtuous cycle of continuous improvement	• Institutionalize the continuous improvement process into organization and team culture.

Source: Authors' elaboration.

4

CONCLUSIONS

While digital infrastructure (DI) development is imperative for all nations, the ways to approach such development are diverse and depend on different variables like geographic location, climate, population size, human capital, digital and innovation ecosystem maturity, geopolitical situation, economic development, and cultural characteristics. There is no one-size-fits-all approach to digital development.

On one hand, there are plenty of learnings and best practices that new entrants to the market can leverage to accelerate the roadmap to capture the data center industry (DCI) opportunity, but each case is unique, and a smart crafting of a tailor-made strategy is paramount.

On the other hand, in this first Inter-American Development Bank (IDB) report on the topic many considerations and areas for further development have been identified. The conclusions presented offer a first step into a further institutional and regional dialogue for validation, prioritization, and action.

With this goal in mind, the main conclusions of this research are summarized in Table 18.

TABLE 18

Main Conclusions on Capturing the Data Center Opportunity in Latin America and the Caribbean

1.	The DCI is struggling to grow in the most developed hubs, mainly due to power supply constraints, added regulatory complexities, and social and political concerns about environmental impact considerations. This situation is pushing the DCI to explore new locations, generating a new opportunity for Latin America and the Caribbean (LAC) countries and regions as well as other emerging economies.
2.	Proximity to the largest digital economy markets used to be a key criterion for DCI location selection due to latency considerations. However, the explosion of artificial intelligence (AI) applications and advanced data center (DC) operation software tools have created new types of opportunities for non-latency-sensitive applications such as training for AI models or digital workload optimization across time zones. These new developments represent opportunities for LAC countries and regions.

(continued on next page)

TABLE 18

Main Conclusions on Capturing the Data Center Opportunity in Latin America and the Caribbean *(continued)*

3.	The DCI is already present across LAC. São Paulo (Brazil), Santiago (Chile), Querétaro (Mexico), and Bogotá (Colombia) are becoming regional DCI hubs. The Brazilian and Chilean governments have already identified the DCI opportunity and are launching national DCI attraction strategies. This type of policymaking development creates conditions for broader regional dialogue and cooperation around the DCI opportunity for LAC.
4.	Fundamental elements of the DCI development roadmap for countries or regions are already known but are constantly evolving. Nowadays, the environmental sustainability imperative has gained weight in this equation, shifting the vision toward the green DCI. To attract the DCI, incorporating green and resiliency aspects is imperative for LAC strategies.
5.	Accelerating digital ecosystem maturity (talent, infrastructure, policy and regulation, industry, financial resources, higher education, and R&D) is a must for all developing economies and for the DCI. LAC countries have struggled for years to achieve higher ranks in the global digital ecosystems' maturity indexes. The DCI consolidation in LAC will drive synergies to boost the digital ecosystem maturity growth needed.
6.	The overall cost of doing business is a key criterion for DCI location selection. Addressing the different aspects of the overall cost issues in LAC countries and designing a smart incentives program are short-term requirements to attract DCI opportunities.
7.	A stable cybersecurity policy and regulatory framework should be implemented to attract the DCI. A multistakeholder approach is imperative.
8.	DCI talent is global, and new mindsets and policy frameworks to leverage this global talent pool are needed. LAC countries should develop their own DCI talent but could also design strategies to leverage the global talent pool. Correspondingly, the LAC DCI talent pool will also become part of the global one.
9.	The DCI is going through an unstoppable growth phase on an evolving path. Flexible, innovative, adaptive, and agile policy frameworks are needed.
10.	Not all locations are ideal for becoming a DCI hub, but there is a potential role to play for everyone within the digital economy universe and the extended DCI ecosystem. Exploring regional and subregional DCI strategy codesign will help to better leverage each country's strengths and capabilities, enabling different models to benefit from the DCI opportunity.

Source: Authors' elaboration.

5

RECOMMENDATIONS AND ACTION PLANS

As this is the first Inter-American Development Bank (IDB) report on the data center industry (DCI) in Latin America and the Caribbean (LAC), the recommendations are structured in two phases:

- Phase 1: Socialize and validate the report and construct a multistakeholder regional DCI dialogue platform.
- Phase 2: Prepare a regional DCI development plan.

Phase 1 requires a multilayered approach, as represented in Figure 14.

FIGURE 14

Layered Approach of Phase 1

Source: Authors' elaboration.

Recommendations for execution of Phase 1 are included in Table 19.

TABLE 19
Phase 1 Execution

Layer	Steps
1. Internal IDB dialogue	a. Organize and conduct an IDB internal dialogue program to socialize the report, collect feedback and draft an internal action plan. b. Focus on the impact aspects of DCI development and regional digital economy maturity development.
2. Key DCI players dialogue	a. Organize and conduct a dialogue with key DCI players to socialize the report, collect business perspective feedback, and explore collaborations. b. Focus on key LAC barriers to DCI development and actionable recommendations to tackle those issues. c. Consider creating a permanent dialogue between the IDB and key DCI players. d. Explore further IDB involvement in LAC DCI development.
3. LAC governments dialogue	a. Organize and conduct a dialogues program with the governments of active LAC DCI hubs—Brazil, Chile, Colombia, Mexico, Peru, and Uruguay—to socialize the report, collect feedback, and explore collaborations. b. Schedule a regional dialogue with LAC governments to socialize the report, collect feedback, and explore collaborations. c. Explore ways for the IDB to further support governments aiming to capture the DCI opportunity.
4. LAC DCI-related communities dialogue	a. Map LAC DCI-related communities: academia, think tanks, associations, environmental sustainability organizations, digital development advocacy groups, etc. b. Organize and conduct a dialogue program to socialize the report, collect feedback, and explore collaborations.

Source: Authors' elaboration.

Phase 1 execution will feed into the Phase 2 set of recommendations for final fine tuning. As an initial proposal, Phase 2 implies six streams of work that should be executed in parallel. Leveraging the multistakeholder platform constructed during Phase 1 execution is recommended. Table 20 presents the Phase 2 execution approach.

TABLE 20
Phase 2 Execution

Workstream	Steps
1. Regulatory frameworks and incentives	a. Assess countries' DCI-related regulatory frameworks and incentives. b. Draft recommendations for governments on updating or creating regulatory frameworks and incentives. Prioritize streamlining bureaucratic hurdles for data center (DC) construction and operation. c. Consider tax break incentives for investments in DC infrastructure, including import duty exemptions on equipment. d. Prioritize aligning cybersecurity regulatory frameworks with international data regulations.
2. Infrastructure development	a. Foster investments in robust and reliable connectivity infrastructure, including submarine cables and terrestrial fiber networks, to improve data transmission capacity and reduce latency. b. Foster countries' energy grid upgrades and improved integration of renewable energy sources.
3. Talent development	a. Foster development of specialized training programs and partnerships with educational institutions to build a skilled workforce in DC management and operations. b. Encourage R&D initiatives in DC technologies and energy-efficient solutions. c. Encourage enabling global talent pool's participation in LAC DCI development.
4. Green data centers	a. Promote the adoption of a full DC life cycle approach to green DCs, as explained in ITU and World Bank (2024). b. Promote innovation and the adoption of energy-efficient technologies and renewable energy to minimize the environmental impact of DCs. c. Promote adopting sustainability standards and green certification for DC construction and operations.
5. Public-private partnerships	a. Foster collaboration between governments, DCI players, and international investors to drive key initiatives and projects. b. Foster development innovation districts to attract talent, tech companies, and startups, thus creating a supportive ecosystem for DCs.
6. National strategies to capture the DCI opportunity	a. Support capacity building and multistakeholder collaborations to drive quality national strategies to capture the DCI opportunity. b. Promote sharing of best practices within LAC and internationally.

Source: Authors' elaboration.

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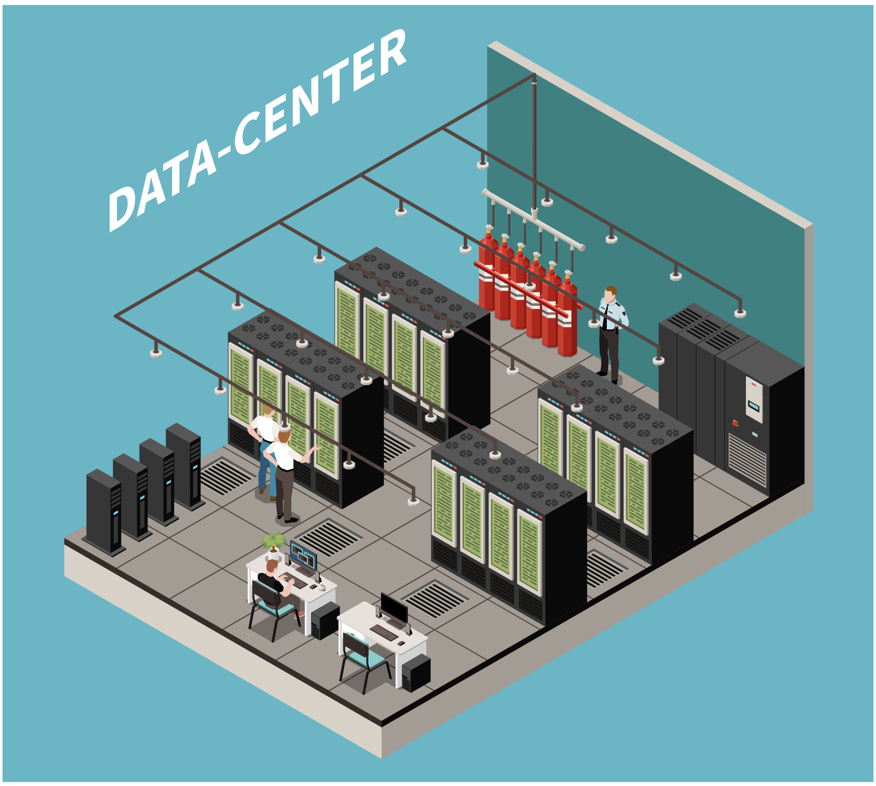
Annex A: The Data Center



Designed by Freepik.

There are several definitions of a data center (DC); they differ depending on the perspective applied. In this report, the following definition is used:

> A DC is a physical room, building, or facility that houses digital infrastructure (DI) for building, running, and delivering digital applications and services. It also stores and manages the data associated with those applications and services.

DCs started out as privately owned, tightly controlled on-premises facilities housing traditional DI for the exclusive use of one company. Over time, they have evolved into remote facilities or networks of facilities owned by cloud service providers (CSPs) and specialized companies known as DC operators.

DCs are classified in different categories depending on their size, ownership, and operational model. Table A1 provides a categorization reference.

DCs house large amounts of equipment, including routers, storage devices, servers, and complementary equipment such as environmental controls that mitigate the heat generated by the hardware, energy management systems, and security features to keep data operations uninterrupted and protected. Table A2 describes the main types of equipment hosted in the DC.

TABLE A1
Data Center Categories

Category	Description
On-premises	A DC managed by an organization (e.g., government agency, company, financial institution, hospital, university, etc.) to host its own computing infrastructure.
Colocation	A DC with shared facilities (multitenant) that hosts the computing infrastructure of various organizations with the day-to-day running of the site, like maintenance and security, outsourced to a third party. The hardware belongs to each organization, but the colocation provider usually ensures power, cooling, and connectivity to network service providers.
Wholesale	In this type of colocation, the provider leases large blocks or the entirety of a facility to a single customer/organization (single tenant).
Cloud	Unlike colocation sites, cloud DCs store customer data on systems belonging to the cloud provider. Instead of each server being allocated to a specific customer, the information is managed virtually.
Hyperscale	Hyperscale DCs are owned or leased by companies with massive data processing requirements. These are organizations like Google, Apple, and Microsoft/Azure (known as “hyperscalers”) that oversee massive chunks of the internet or manage technology systems for third parties. Hyperscale DCs provide extreme scalability capabilities and are engineered for large-scale workloads with an optimized network infrastructure, streamlined network connectivity, and minimized latency. The entire building is typically given over to monolithic applications under the control of the hyperscaler. This provides significant economies of scale and allows hyperscale operators to push technology boundaries and experiment with new approaches. A hyperscale DC requires a physical site large enough to house all associated equipment, including at least 5,000 servers. As such, hyperscale DCs can easily encompass 10,000+ square feet of space.
Edge	Edge DCs seek to bring processing power closer to where is needed—the “network edge,” as it is known—to reduce latency (i.e., the time it takes for data to travel to a facility and back to where it is needed) for staples of modern living such as smartphones and the instant data transmission required to power driverless cars or operate citywide facial recognition systems.

Source: Authors’ elaboration based on Dawn-Hiscox (2022).

TABLE A2

Main Types of Equipment Hosted in a Data Center

Type of equipment	Description
Computing infrastructure	"Computing infrastructure" refers to servers, which are systems or devices that can receive, store, and share data with other computers and devices. Servers accomplish these tasks through memory, storage, and processing capabilities.
Storage infrastructure	DCs must have some kind of storage system in place so servers can manage data.
Network infrastructure	The network infrastructure is a system of cables, switches, and routers that connect servers to each other and enable data flow throughout a DC. At the same time, DCs can monitor and regulate data traffic through firewalls, preventing cyberthreats from infiltrating DC networks.
Racks	Racks are an efficient setup designed to make room for different types of DI components to have their own cooling fans, cables, power supplies, and other features.
Support infrastructure	Companies and customers need DCs to be reliable storers and providers of data. To ensure seamless operations, DCs are equipped with additional features: • Uninterruptible power supplies (UPSs) sustain DCs during outages and surges. • Power generators run DCs during more extreme outages. • Ventilation and cooling systems keep servers at a reasonable temperature. • Fire suppression systems put out fires quickly to prevent damage to DCs. • Properly spaced power cables prevent crosstalk and overheating. • A redundant array of independent disks (RAID) makes copies of data as a precaution.

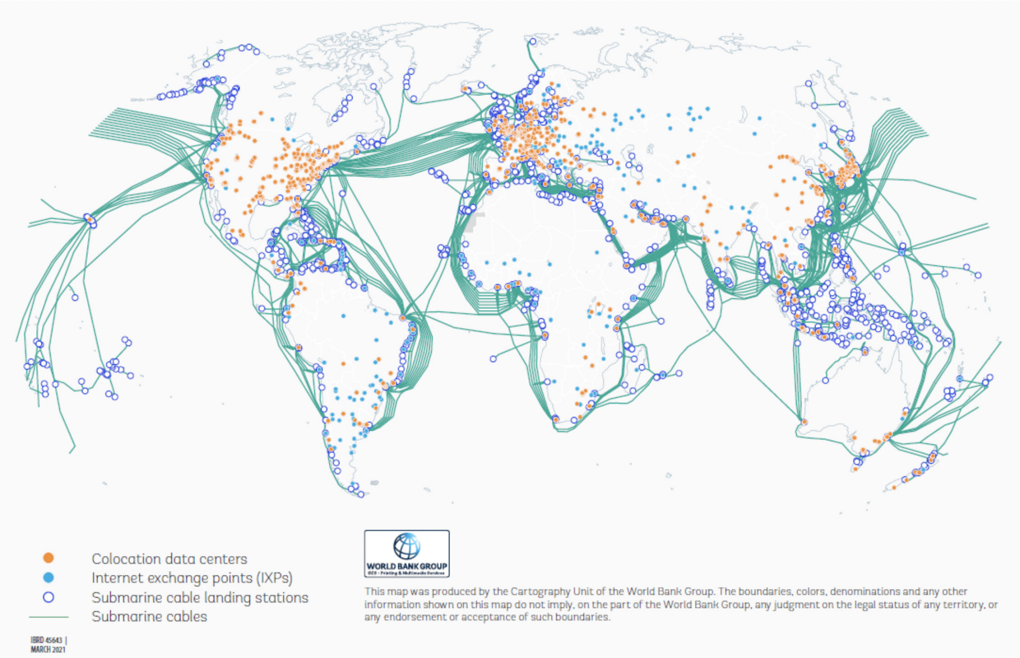
Source: Authors' elaboration.

Annex B: Digital Infrastructure Hubs

A digital infrastructure hub (DIH) is a place where the concentration of digital infrastructure (DI) components converges, enabling the delivery of global and advanced types of digital services. The core DIH components are telecommunications infrastructure and data centers (DCs). Although many different telecommunications technologies could be involved, the focus within DIHs is the fiber optics infrastructure and the DC itself. Table A3 defines the DIH's core components. Figure A1 reveals the complexities of this sector. The DI map shows the global DIHs interconnected through submarine fiber-optic cables and key data center (DC) hubs around the globe.

FIGURE A1

Distribution of Data Infrastructure and the Submarine Fiber-Optic Cable Network, March 2021



Source: ITU and World Bank (2024).

TABLE A3
Main Components of a Digital Infrastructure Hub

Component	Description
1. Submarine cable and landing stations	Submarine cables (normally fiber optic cables), interconnect the world with more than 200 independent systems and growing (see Figure A1). They are connected to terrestrial networks through facilities called landing stations and carry about 95% of global communications.
2. Ground stations, earth stations, or telecom ports	These stations connect terrestrial networks to satellite networks, which carry about 5% of global communications.
3. Cellular towers	Connect to cellular/mobile phones and data networks.
4. Telecom exchanges	Host the terrestrial interconnections and distribute them to locations.
5. Data centers	Storage, process, and protect data.
6. Edge nodes	Also known as micro DCs, edge nodes are located closer to end users to optimize processing, reducing the latency of services for targeted customers.

Source: Authors' elaboration based on DCD Academy (n.d.).

The submarine network continues its growth globally and in Latin America and the Caribbean (LAC). One of the most relevant projects for global interconnections and for LAC is the Humboldt transoceanic submarine cable, which will link Valparaíso (Chile) with Sydney (Australia).[10] Construction of Humbolt began in 2024, and the cable is expected to be operational in 2026. As of 2024, Brazil was the only LAC country with direct submarine interconnection to other continents (Europe and Africa).[11]

[10] https://www.subtel.gob.cl/cable-humboldt/, https://desarrollopais.cl/en/proyectos/humboldt/

[11] For updated maps and details of the global network infrastructure, see TeleGeography's Submarine Cable Map at https://www.submarinecablemap.com/.

Annex C: The Data Center Industry

The data center industry (DCI) supports the technology, business, and operations models of on-premises, colocation, and hyperscale data centers (DCs). The colocation sector, positioned at the heart of the DCI, has traditionally been seen as two distinct segments:

- Retail: Provides colocation services to multiple customers (also called multitenant)
- Wholesale: Provides colocation services to one customer (usually a large enterprise or hyperscale cloud provider)

Hyperscale computing is currently reshaping the market taxonomy due to its unique characteristics. Hyperscale can be part of a colocation service (multitenant), built-to-suit (single tenant), or self-build by a hyperscale cloud provider. Although the colocation market's early days were predominantly about retail, wholesale became more common when enterprises shifted from on-premises digital infrastructure (DI) to enterprise colocation service providers.

Tables A4 and A5 summarize technical specifications and useful data points related to capacity, power billing, contract length, and time to market for the different types of DCs.

Since the early days of computing, the DI value chain was created around the top computing corporations such as IBM, which became the de facto advisors for customers in the early days of designing and building on-premises computing centers. As industry grew and diversified, the colocation market started consolidating, leaving room for the rise of specialized companies offering the services needed by the new sector.

Consequently, expert niches have been developed around real estate, architecture, engineering, construction, cooling, power, operations, customer service, finance, and other services. Nowadays, the DCI is supported by four key specialized sectors: operators, investors, developers, and real estate. Figure A2 provides a high-level view of the DCI global value chain, referencing some key global industry players in each category.

Note that because the industry is continuously evolving, this picture represents only a given moment in time. The highlighted brands are the most visible ones globally, and most of them are also active in Latin America and the Caribbean (LAC). Table A6 provides a list of the main operators with a presence in LAC as of 2024, in alphabetical order.

Throughout the DC lifecycle, at each stage each player in the value chain participates at a different intensity. Figure A3 shows the players' levels of involvement from weakest to strongest across six key life cycle stages, depending on their ability to perform the required tasks of each stage.

TABLE A4
Specifications of Dedicated Hyperscale Data Centers

	Dedicated Hyperscale		
	Colocation	**Built to Suit**	**Self Build**
Typical Capacity Requirements	1–20 MW	20–50 MW	50+ MW
Land Ownership	Service Provider, Real Estate Developer	Service Provider, Real Estate Developer	Hyperscaler
Deployment Type	Multitenant	Single tenant	Single tenant
Infrastructure Environment	Dedicated Cage, Suite, and/or Data Hall	Dedicated Building	Dedicated Building and/or Campus
Customization Level	Low to Moderate	High	Very High
Time to Market	Weeks to Months	10–24 months	2+ years
Operations	Service Provider	Service Provider/Tenant	Hyperscaler

Source: Structure Research (2023).

TABLE A5
Specifications of Colocation Data Centers

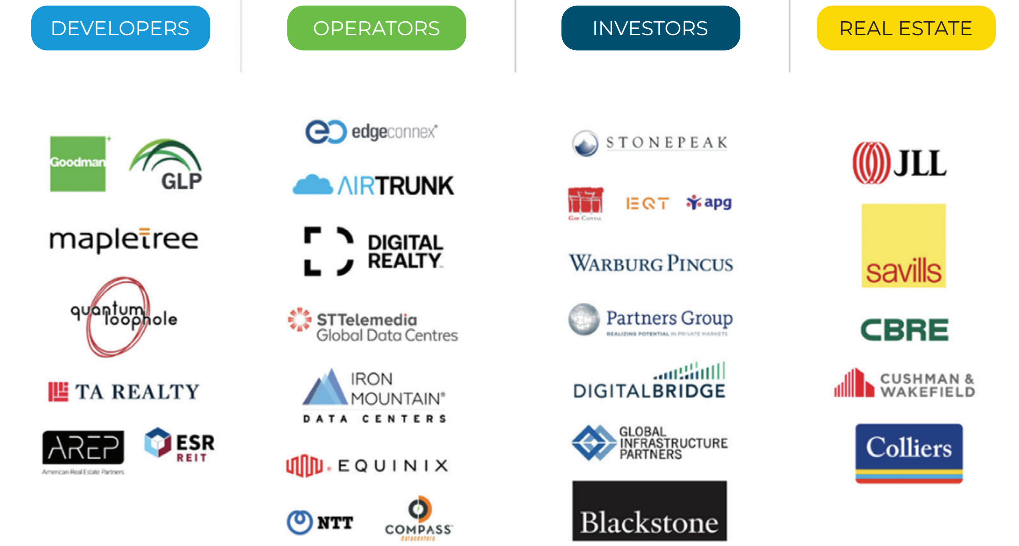
<table>
<tr><th></th><th colspan="2">Enterprise Colocation</th><th colspan="4">Hyperscale Colocation</th></tr>
<tr><th></th><th colspan="4">Interconnected Edge</th><th colspan="2">Core Hyperscale</th></tr>
<tr><th></th><th>Retail</th><th colspan="2">Retail +</th><th colspan="2">Edge Hyperscale</th><th>Dedicated Hyperscale</th></tr>
<tr><td>Typical Capacity Requirements</td><td colspan="2">< 240 kW</td><td colspan="2">240 kW–2 MW</td><td colspan="2">2–100+ MW</td></tr>
<tr><td>Infrastructure Environment</td><td colspan="2">Shared (multitenant)</td><td colspan="2">Shared or Dedicated (multitenant)</td><td colspan="2">Dedicated (multitenant) or Built-to-Suit</td></tr>
<tr><td>Customization Level</td><td colspan="2">Low</td><td colspan="2">Moderate</td><td colspan="2">High</td></tr>
<tr><td>Power Billing Model</td><td colspan="2">Flat Rate</td><td colspan="2">Flat Rate or Metered</td><td colspan="2">Metered</td></tr>
<tr><td>Carrier Density</td><td colspan="2">Moderate to High</td><td colspan="2">Moderate</td><td colspan="2">Low</td></tr>
<tr><td>Contract Length</td><td colspan="2">1–3 Years</td><td colspan="2">2–6 Years</td><td colspan="2">5–15 Years</td></tr>
</table>

Source: Structure Research (2023).

Within the four categories of players there is a much more complex ecosystem that includes research and development, architecture, engineering, construction, equipment manufacturing, distribution, installation, operations, maintenance, finance, policymakers, regulators, and consulting advisers, among others. They all operate within local markets to deliver the actual deployment and operation of these very sophisticated DIs.

FIGURE A2

Key Players in Global Data Center Industry Value Chain, 2023–24



Source: Structure Research (2024).

TABLE A6

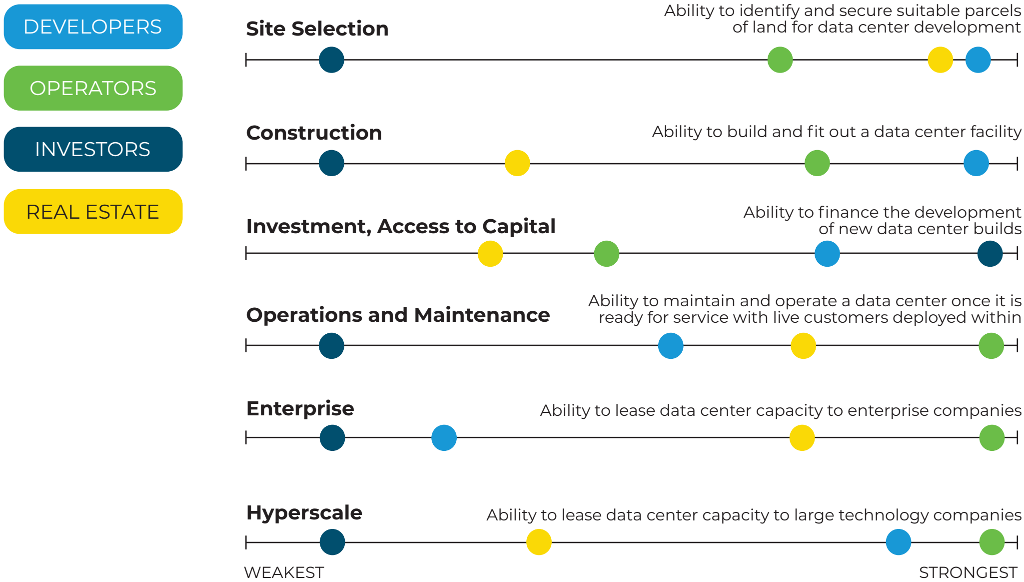
Main DCI Operators in Latin America and the Caribbean, 2024

Company	Website
ADA Infrastructures	https://adainfrastructure.com/en-US/locations/the-americas
Ascenty	https://ascenty.com/en/data-centers-en/
Cirion Technologies	https://www.ciriontechnologies.com/en/data-center/
Elea Data Centers	https://eleadatacenters.com/en/
Equinix	https://www.equinix.com/
Kio Data Centers	https://kiodatacenters.com/en/
ODATA	https://odatacolocation.com/en/
SCALA Data Centers	https://scaladatacenters.com/en/
SONDA	https://www.sonda.com/en/solutions/digital-services/cloud-datacenter
Tecto Data Centers by V.TAL	https://tecto.com/
Twenty Four Seven Data Centers	https://247datacenters.com/en/
Vantage Data Centers	https://vantage-dc.com/

Source: CBRE input.

FIGURE A3

Involvement of Key Players throughout Data Center Life Cycle



Source: Structure Research (2024).

As a reference, NVTC (2024) provides a list of the key business areas that supply the DCI value chain in Northern Virginia:

- Power distribution and management products and services
- Design, construction, optimization, and maintenance
- Facilities management cloud-based platform
- Energy management services
- Carrier-neutral fiber interconnecting Data Center Alley [as the local DCI hub is known]
- Electric transformer manufacturing
- DC and fiber consulting and marketing
- Cybersecurity
- Carrier-neutral fiber connecting Virginia Beach to Henrico DCs [more-distant locations]
- Cooling and air treatment
- Power transformation, distribution, and monitoring
- IT hardware immersion cooling
- Raised access floors, hot/cold aisle containment systems, structural ceilings, etc.
- Materials, cleaning, and disaster recovery
- Site certification and development
- Management consulting

TABLE A7
Location Selection Challenges

Key considerations	Description
Cost	Top locations for DC deployment generally ended up competing on cost. Because electricity makes up a large share of DC operation costs, the price per kW is one of the main factors overall. Other important cost items are land, taxes, construction, and labor.
Connectivity	Depending on the type of customers or applications, DCs may have different tolerances for latency. Latency is affected as much by a location's proximity to key markets (economic or industrial hubs, large cities) as its fiber infrastructure.
Time to market	Time-consuming bureaucracy for permits, equipment export/import barriers, or complex immigration rules to relocate expertise could create significant delays and financial losses.
Risk	DCs are built to be in service for decades. Minimal risk is imperative in areas such as downtime (caused by natural disasters, power failures), economic instability (to avoid cost increases), unstable regulatory environment, or political instability.
Digital talent and services ecosystem (DCI talent)	The availability of a skilled digital workforce and a DCI services support ecosystem is key. The latter comprises companies that can provide equipment and associated support services such as software and hardware, cooling systems, power management systems, and physical security.
Future growth enabled	As businesses expand, DC needs may grow. It is crucial to select a location that allows for future scalability. This includes considering factors like available space for expansion, access to skilled labor, and proximity to quality livable places.
Economic incentives	Economic incentives can offset some of the substantial costs of DC construction and operation. Whether these incentives provide financing, tax credits, or greater access to labor, they are conceived with one overriding goal: providing a return on investment for citizen taxpayers.

Source: Authors' elaboration.

Ultimately, the DCI gets consolidated in specific places, making location selection critical to the success or failure of the undertaking. The fewer the barriers, the higher the probability a location will be selected for DCI buildup and consolidation. Table A7 summarizes the key challenges confronted by the location wanting to attract the DCI and DCI decision-makers.

Annex D: The Energy Challenge

The high electricity consumption of the global data center industry (DCI) has increasingly raised concerns due to its potential contribution to global warming. However, evidence shows that the growth in electricity consumption was not directly proportional to the increasing computing power, transmission speeds, or digital workloads.

According to the International Energy Agency (IEA), between 2015 and 2022, the number of internet users increased by 78 percent, global internet traffic by 600 percent, and data center (DC) workloads by 340 percent. However, the energy consumed by those DCs rose by less than 70 percent (IEA, n.d.). This effect has been analyzed by several researchers and was explained in 2010 by Koomey's Law: "The idea is that at a fixed computing load, the amount of battery you need will fall by a factor of two every year and a half" (Greene, 2011).

Table A8 from the IEA provides a generally accepted framework to help explain the digital processing vs power usage equation, although estimations vary among sector researchers.

Consequently, as the evidence suggests, efficiency in electricity consumption associated with the global DCI is increasing, therefore mitigating concerns. On the other hand, the digital technology industry's strong embrace of renewable energy sources and policymakers' focus on the issue is shaping an optimistic scenario. It is also key to highlight that there are efficiency gains within the electric grid due to its ongoing digitalization process.

TABLE A8

Global Trends in Digital and Energy Indicators, 2015–22

	2015	2022	Change
Internet users	3 billion	5.3 billion	+78%
Internet traffic	0.6 ZB	4.4 ZB	+600%
Data center workloads	180 million	800 million	+340%
Data center energy use (excluding crypto)	200 TWh	240–340 TWh	+20–70%
Crypto mining energy use	4 TWh	100–150 TWh	+2300–3500%
Data transmission network energy use	220 TWh	260–360 TWh	+18–64%

Source: IEA (n.d.).

Amid the positive findings, the unstoppable growth of the DCI still represents a challenge. According to IEA (2024a), the demand for electricity from the DCI could double by 2026. Some data points from that report follow:

- "DCs, cryptocurrencies, and artificial intelligence (AI) consumed about 460 TWh of electricity worldwide in 2022, almost 2 percent of total global electricity demand."
- Electricity demand in DCs comes mainly from two processes: computing (40 percent) and cooling requirements to achieve stable processing efficiency (40 percent); the remaining 20 percent comes from other associated digital equipment.

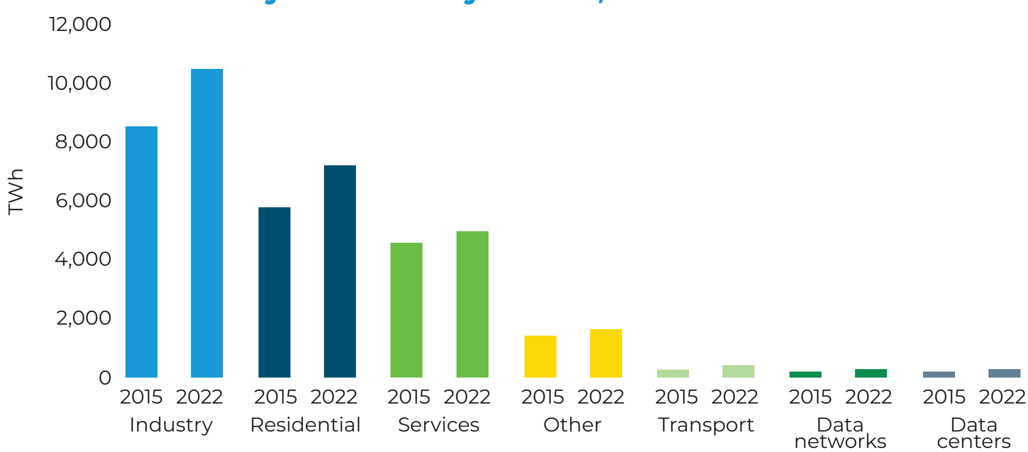
Scenarios explored by the IEA's electricity reports are summarized in Figures A4 and A5.

Response from the DCI and policymakers regarding expected energy demands has been strong. Some examples of ongoing initiatives are highlighted here:

- Net Zero,[12] also known as the Innovation Hub for Data Centers, is facilitating the DCI's path to net-zero emissions. It offers a joint setup for European DC operators and suppliers to address key challenges using a systematized methodology, scale the solutions to the whole industry, and present them to the public.
- New policies and legislation tighten regulations on DC developments, including zoning rules, mandatory environment and resource impact assessments, and guidelines on water usage (Data Center Knowledge, 2023).
- Nuclear-powered DC campuses are adopting the use of small modular reactors (SMRs) (Judge, 2023).

FIGURE A4

Global Electricity Demand by Sector, 2015–22

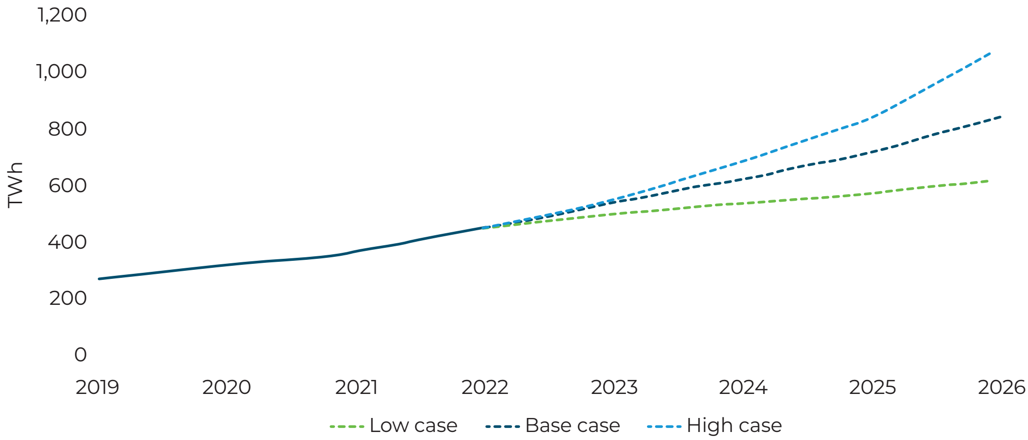


Source: IEA (2024b).
Note: "Services" excludes electricity demand from data networks and data centers.

12 https://www.netzerodatacenters.com/

FIGURE A5

Global Electricity Demand from Data Centers, AI, and Cryptocurrencies, 2019–26



Source: IEA (2024a).

- With the Climate Neutral Data Centre Pact, "over 100 data centre operators and trade associations are committed to the European Green Deal, achieving the ambitious greenhouse gas reductions of the climate law, and leveraging technology and digitalization to make Europe climate neutral by 2050. To ensure data centres are an integral part of the sustainable future of Europe, data centre operators and trade associations agreed to make data centres climate neutral by 2030" (Climate Neutral Data Centre, n.d.).

The increasing adoption of cloud services platforms and digital workload migration into those platforms, the unstoppable growth in the connected devices space, the growing data sovereignty and residency regulations, and the expanding amount of data that consumers and businesses generate are fueling the rapid development of the DCI globally. The democratization of artificial intelligence (AI) has been the most significant transformation in the DCI since the sector burst onto the scene. The growing demand for digital experiences means more and more DCs will be needed, and a large portion of them will be in the hyperscale DC category.

More sophisticated DCs also imply even more challenges around issues like land availability, energy consumption, and innovative cooling systems to respond to increasing heat generated by higher-density processors. Consequently, energy and cooling technology improvements are now vital to the industry's expansion. Several warnings from the IEA's Electricity 2024 report (IEA, 2024a) are highlighted below:

- "Data centers are a critical part of the infrastructure supporting digitalization and the electricity infrastructure that powers them. The ever-growing quantity of digital data requires an expansion and evolution of data centers to process and store it."

- "Electricity consumption from data centres, artificial intelligence (AI) and the cryptocurrency sector could double by 2026. Data centres are significant drivers of growth in electricity demand in many regions. After globally consuming an estimated 460 terawatt hours (TWh) in 2022, data centres' total electricity consumption could reach more than 1 000 TWh in 2026."

The abovementioned issues have already generated regulatory interventions across the globe. For example:

- In 2019, Singapore temporarily halted the construction of new DCs, concerned that building more might make it difficult to fulfill its commitment to achieving net-zero emissions by 2050. It began reissuing permits in 2023 (Economist, 2024).
- In Ireland in 2022, the national utility company stopped issuing connections to new DCs until 2028 out of concern for running out of grid-connected energy capacity (Hurley, 2022); DCs already account for 18 percent of electricity consumption there (Economist, 2024).
- In Northern Virginia, the utility company Dominion paused new power connections to DCs for several months in 2022 to, as the company put it, "make sure that the integrity of our system can support this growth" (Economist, 2024). As of January 2024, the company was not committed to new DC developments until 2025 or 2026 as the whole power distribution infrastructure is being upgraded.

In Latin America and the Caribbean (LAC), the region's clean energy potential is a competitive edge that can be leveraged for the development of the DCI. According to the IEA's Latin America Energy Outlook 2023 (IEA, 2023):

- Across many indicators, the Latin America and Caribbean region stands out for its extraordinary endowment of natural resources—both fossil fuel and renewable energy—and its history of policymaking that has notably delivered one of the cleanest electricity sectors in the world. The expansion of renewable energy technologies such as hydropower and bioenergy, initially driven by an emphasis on energy security, has more recently been propelled by a deepening commitment to sustainability. Sixteen of 33 countries in the region have pledged to reach net-zero emissions by midcentury or earlier, and most have presented updated and increasingly ambitious climate targets tied to the 2015 Paris climate agreement.

Notwithstanding the potential for renewables in LAC, global benchmarks provide more insight. One is the World Energy Trilemma Report (World Energy Council, 2024), prepared annually since 2010. It presents a comparative ranking of 126 countries' energy systems and assesses a country's energy system performance, reflecting balance and robustness in the three Trilemma dimensions: Energy Security, Energy Equity, and Environmental Sustainability.

Figure A6 summarizes the World Energy Trilemma Report's highlights of the LAC region. It is important to mention that the report includes Mexico as part of North America; therefore, it is not considered in these highlights.

FIGURE A6

World Energy Trilemma Highlights for Latin America and the Caribbean

LATIN AMERICA AND THE CARIBBEAN

HIGHLIGHTS

ENERGY SECURITY
The energy sector is adapting to climate impacts through regulatory reforms and market changes, while high prices fuel new oil and gas explorations. Political unrest adds investment uncertainties, highlighting the need for stronger regional integration to enhance security.

ENERGY EQUITY
Equity challenges persist, with subsidies being a primary mechanism for maintaining affordability amidst political and economic instability.

ENVIRONMENTAL SUSTAINABILITY
Environmental sustainability is highlighted by a heavy reliance on renewables, particularly hydro, but challenged by climate change. The rise of sustainability-linked and ESG bonds is unlocking finance, supported by frameworks to guide investments towards sustainable energy transitions.

MANAGING THE WORLD ENERGY TRILEMMA
Civil society's growing influence on energy projects affects security and equity. The rise in importance of critical minerals for future energy systems is an opportunity for the region. Managing the trilemma involves fostering public-private partnerships, adopting long-term visions resilient to political shifts, and enhancing institutional capacity.

Source: World Energy Council (2024).

The ranking of the main DCI countries in LAC in the 2024 World Energy Trilemma Index for the 99 participant countries is presented in Table A9.

A general interpretation of the index is that the higher a country is in the ranking, the more attractive it could be for the DCI. Thus, among LAC countries Chile offers the most attractive scenario from the Energy Trilemma perspective, while Mexico presents the worst. Notably, Chile's ranking is the same as that of Singapore, an established DCI hub.

The World Economic Forum provides a third perspective in Fostering Effective Energy Transition 2024 (World Economic Forum, 2024). This report provides key insight for DCI decision-makers and government policymakers regarding countries' progress on the transition to clean energy. Energy transition is paramount to the DCI and core to country strategies to attract the DCI. The heart of the report is the Energy Transition Index (ETI), which is an evolution of 14 years of country energy systems benchmarking.

The ETI scores 120 countries on two subindices: (i) current performance of energy systems on equity, sustainability, and security and (ii) readiness of the enabling environment in terms of policies and regulatory framework, infrastructure, innovation, education and

TABLE A9

Ranking in World Energy Trilemma Index for Selected Countries in Latin America, 2024

Country	Ranking
Chile	31
Brazil	36
Colombia	42
Mexico	49

Source: World Energy Council (2024).

human capital, and finance and investment. A country's final ETI score is a composite of its scores on the two subindices, weighted at 60 percent and 40 percent, respectively. System performance is equally weighted across equity, sustainability, and security. The ETI defines its sustainability dimension based on a mix of energy efficiency, decarbonization, and advancements toward clean energy systems. Costa Rica, Paraguay, and Sweden led the sustainability dimension charts for 2024. Countries from Sub-Saharan Africa and LAC rank in the top quartiles. Table A10 shows the final scores of DCI countries in LAC.

A general interpretation of the score is that the lower a country's score, the more attractive it could be for the DCI. Once again, as with the World Energy Trilemma Index, Chile and Brazil are better positioned than Colombia and Mexico to attract the DCI.

Brazil is highlighted in the report as one of the leading countries globally, together with Northern European countries and China. For LAC, World Economic Forum (2024) offers the following highlights:

- Latin America and the Caribbean saw the slowest growth in 2023, with ETI scores increasing by only 3 percent over the previous decade. Despite leading in the sustainability dimension, largely due to reliance on hydropower, the region surprisingly

TABLE A10

Energy Transition Index Scores for Selected Countries in Latin America, 2024

Country	Score
Brazil	12
Chile	20
Colombia	35
Mexico	57

Source: World Economic Forum (2024).

saw a 70 percent decline in investment in renewables scores in 2023. In addition, education and human capital and innovation environment both experienced declines of 5 percent and 9 percent, respectively, over the previous decade.

- Gas and electricity prices remained high in LAC in 2023 compared to previous years. The region's existing infrastructure is built to support oil and gas production and consumption, so it needs to expand its supportive infrastructure and build more interconnected grids to facilitate the development, storage, distribution, and transmission of renewables.

As policymakers in LAC consider their country's ability to capture the DCI opportunity, a detailed analysis supported by global benchmarking is recommended for various aspects, particularly the energy challenge.

Annex E: The Green Data Center

As the ubiquitousness of digital infrastructure (DI) increases, general awareness becomes more important, as well as an understanding of the multiple implications the digital transformation has on the United Nations' 2030 Agenda for Sustainable Development (UN, n.d., "2030 Agenda"). During the elaboration of the 2030 Agenda and its 17 Sustainable Development Goals (SDGs) (UN, n.d., "17 Goals"), it was clear that digital technologies are a needed tool to support the implementation of the SDGs and the immense task of designing this global endeavor. However, other implications of digital technologies—such as energy consumption, natural resources demand, e-waste and recycling, and climate change consequences—were not as much of a focus.

Just a decade after the adoption of the SDGs, a significant shift in the general mindset had taken place, leading to a better understanding of the role of digital technology as a necessary tool to fulfill the agenda as well as the urgent call to action for the overall digital technology value chain to support the world's sustainability and resiliency rather than hurt it. SDG 13: Climate Action is the one area that has received significant scrutiny (see the subsection The DCI and SDG 13: Climate Action below) from the technology industry and policymakers. However, the truth is that green and sustainable digital technology is just one aspect of a bigger picture where the impact of the data center industry (DCI) is unavoidable.

For the informed mind, it is relatively easy to read through the 17 SDGs and identify ways for digital technologies to help accelerate progress toward each one. For example, to help achieve SDG 1: No Poverty, digital financial inclusion tools have demonstrated a strong impact. Similarly, for SDG 2: Zero Hunger, digital technology in agriculture is also driving major breakthroughs.

Several initiatives are focusing on the enablement of digital technologies' catalytic effect to fulfill the SDGs. One of these initiatives is the SDG Digital Acceleration Agenda (ITU and UNDP, 2023), for which the Inter-American Development Bank (IDB) is one of the key partners. This initiative conducted research over a broad range of real-world examples, showing how game-changing digital solutions can accelerate progress in climate action, education, hunger, and poverty and the role of data and digital technologies in achieving at least 70 percent of the 169 SDG targets. By identifying solutions through a well-documented methodology, the aim is to help bring those proven digital solutions to scale to deliver a bigger impact. Another key contribution of the initiative is identifying non-technical digital enablers, like leadership and strategy, and technical enablers such as data centers (DCs) and digital connectivity.

It is recommended to review the annual SDGs reports, where the role of digital technologies is increasingly emphasized year after year. In particular, the 2023 and 2024 Sustainable Development Goals Reports (UN, 2023, 2024) are worth analyzing. The following recommended priority actions from UN (2023) are included here as examples.

- Invest in public sector capacity and infrastructure to identify trade-offs and drive large-scale change, enable complex decision making, leverage digital technologies, and boost implementation partnerships.
- Create active labor market policies to help workers upskill and re-skill to keep or change their job, adapt to the green and digital transitions, and find ways out of poverty.
- Invest in foundational inclusive and accessible DIs to ensure meaningful connectivity for all and build digital and data literacy in and outside the public sector.
- The shift toward knowledge-intensive services—such as professional services, government services, information technology services, and telecommunications—has highlighted the importance of DI and literacy. Data flows, growing at nearly 50 percent annually between 2010 and 2019, make DI fundamental.

A final aspect identified but not well developed in the SDG-related literature is the DCI's role as the ultimate enabler for the scale of data processing capabilities required to analyze data about the planet and its population. This scale of analytics can only be achieved through global digital connectivity, global data gathering, hyperscale computing power, and the application of emerging technologies like artificial intelligence (AI). The DCI can support the discovery of new opportunities and challenges as well as highly disruptive and innovative contributions to the success of the 2030 Agenda.

This point also intersects with the concept of digital public infrastructure (DPI), which essentially refers to how DI enables social and economic impact through digital services. Many international organizations, governments, academia, and business sectors are joining forces to promote DPI development.[13] A recommended resource is the Brookings Institution's working paper How Can Digital Public Technologies Accelerate Progress on the Sustainable Development Goals?,[14] which explores in depth the impact of digital public technologies on the fulfillment of the SDGs.

As discussed, the DCI is critical to the 2030 Agenda due to its leverage potential to help the global community achieve the SDGs. However, the industry is also under scrutiny regarding key aspects within specific SDGs, such as SDG 8: Decent Work and Economic Growth, SDG 9: Industry, Innovation, and Infrastructure, SDG 13: Climate Action, and SDG 17: Partnerships for the Goals. The following subsection discusses the Climate Action SDG from the DCI perspective.

13 See https://www.undp.org/publications/dpi-approach-playbook.

14 https://www.brookings.edu/articles/how-can-digital-public-technologies-accelerate-progress-on-the-sustainable-development-goals/

The DCI and SDG 13: Climate Action

The heaviest scrutiny toward the DCI regarding the SDGs has been under the umbrella of SDG 13: Climate Action, which is the global community response to climate change concerns. This is because while DCI solutions are essential for modern society, they are also highly energy intensive, consume refrigerants, and often use large amounts of water for cooling. As such, they leave a significant environmental footprint and contribute to greenhouse gas (GHG) emissions.

DIHs are also at risk due to the effects of climate change. For example, climate hazards such as floods and increasing temperatures put the world's DI at risk and require site-specific adaptation measures to protect investments and ensure resilient data storage. For sustainable and resilient digital transformation, efforts are needed to green DI. This includes managing climate risks and reducing the climate and environmental footprint of DIs, particularly within the DCI.

The report Green Digital Transformation: How to Sustainably Close the Digital Divide and Harness Digital Tools for Climate Action (World Bank, 2023) is recommended for readers interested in a deep dive into the connection between digital technologies and climate change. Figure A7 presents a framework for the needed analysis under an umbrella concept: the green–digital nexus.

FIGURE A7

The Green–Digital Nexus

	Greening the digital sector	Greening with digital technologies
Adaptation	Climate proofing digital infrastructure and services	Leveraging digital technologies to enhance resilience of economies, populations, and sectors
Mitigation	Energy efficiency measures and use of renewable energy	Leveraging digital technologies to decarbonize other sectors such as energy, transport, and cities

Source: World Bank (2023).

To illustrate how digitalization interacts with climate change, World Bank (2023) proposes a direct and indirect channel for the green–digital nexus framework. An extract is included here:

- Direct channel: The production, use, and disposal of digital technology contribute directly to GHG emissions. Digital infrastructure is also directly exposed to significant climate change–induced risks, including rising temperatures and sea levels; water scarcity; and extreme events such as drought, cyclones, and flooding.
- Indirect channel: As digital technologies become pervasive in social and economic activities, they also indirectly impact climate change at the macroeconomic level and across sectors. At the macro level, digital technologies increase productivity, thereby increasing total consumption and increasing emissions. Decoupling economic growth from emissions—ensuring that the growth rate of GHG emissions is less than that of its economic driving forces—becomes essential to achieving a sustainable growth trajectory. The fact that both production and consumption across sectors are being “dematerialized” thanks to the rapid development of digital technologies provides opportunities to achieve decoupling.

Figure A8, also extracted from World Bank (2023), is useful for better understanding the proposed framework.

Several research groups are analyzing the global impact of digitalization on climate change. Most common approaches focus on the relative impact on climate change of each of the three main components of the ICT sector:

- digital connectivity networks,
- data infrastructure, and
- end-user devices.

Figure A9, extracted from World Bank (2023), offers that report’s estimations. Although this general approach is commonly applied, there are distinct conclusions from different researchers and more efforts are still needed to determine a formal standard.

The ICT sector’s relative contributions to GHG over time have also been analyzed. Figure A10 presents data that shows DCs’ increasing contribution to GHGs, illustrating an opportunity for further research on the DCI’s growing impact on climate change.

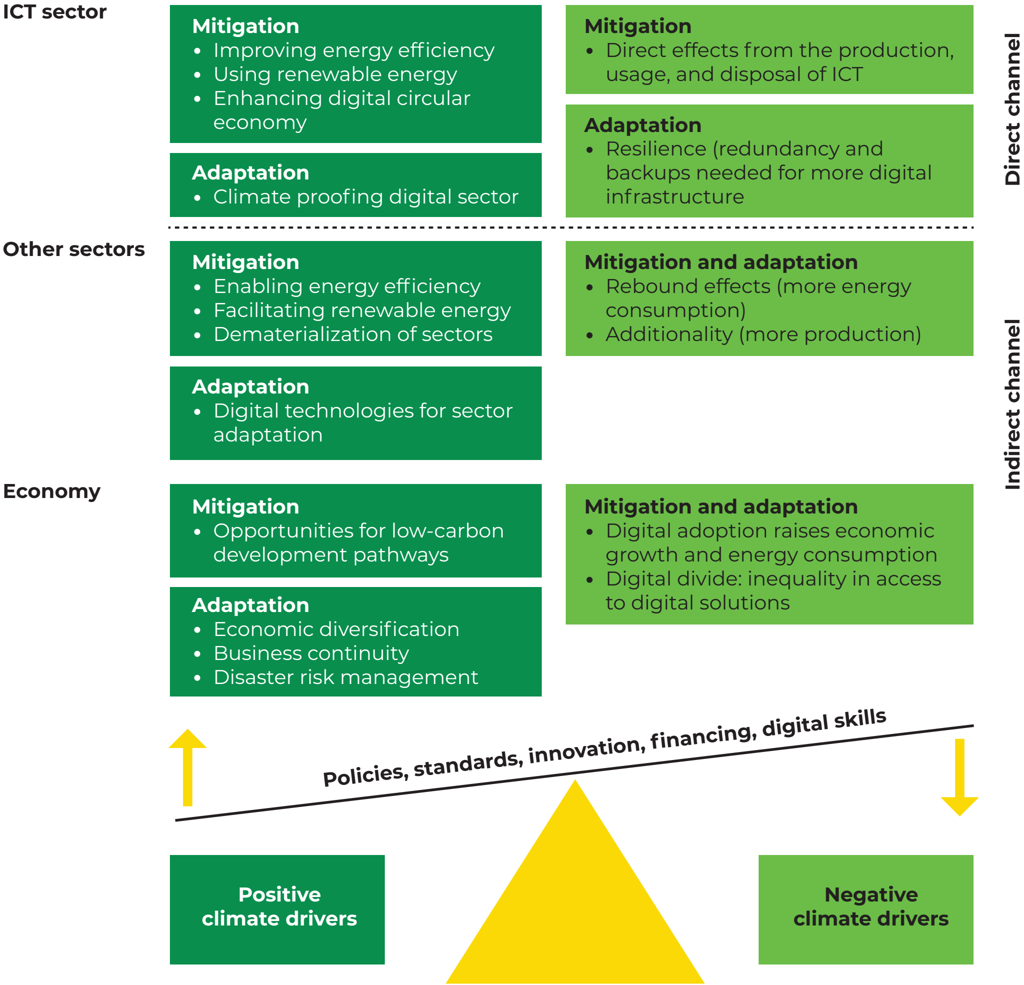
World Bank (2023) suggests a framework, summarized in Figure A11, to decarbonize the ICT sector.

On a positive note, the digital technology industry has embraced green transformation as part of its technology and market development agendas by setting its own climate change goals. Governments are also pushing the issues through green policies. Several references and case studies on each of these areas are included in World Bank (2023).

Specifically focused on the DCI and climate change is the World Bank and ITU’s joint report Green Data Centers: Towards a Sustainable Digital Transformation (ITU and World Bank, 2024). It is a recommended resource for readers looking for a deep dive into the connection between the DCI and climate change. The report suggests a DC life cycle approach and presents a set of recommended climate change mitigation strategies, which are summarized in Figures A12 and A13.

FIGURE A8

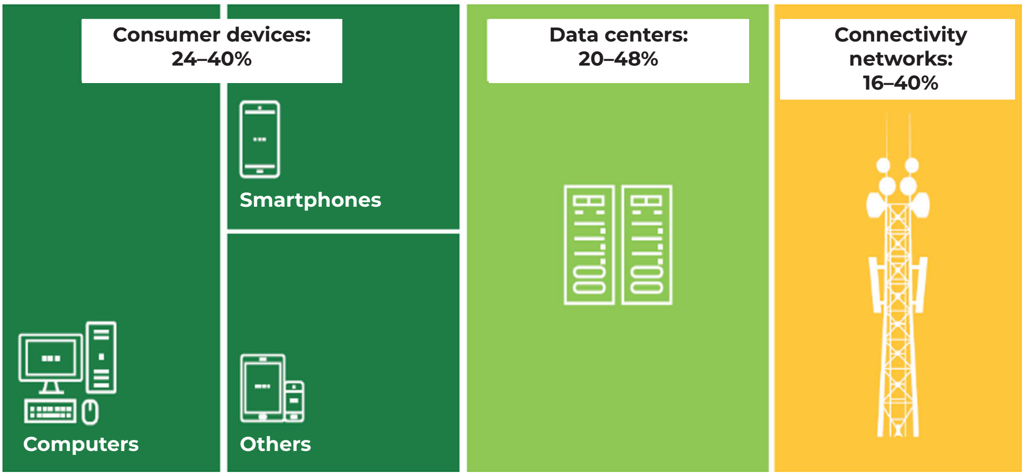
Conceptual Framework for Relationship between Digitalization and Climate Change



Source: World Bank (2023).

FIGURE A9

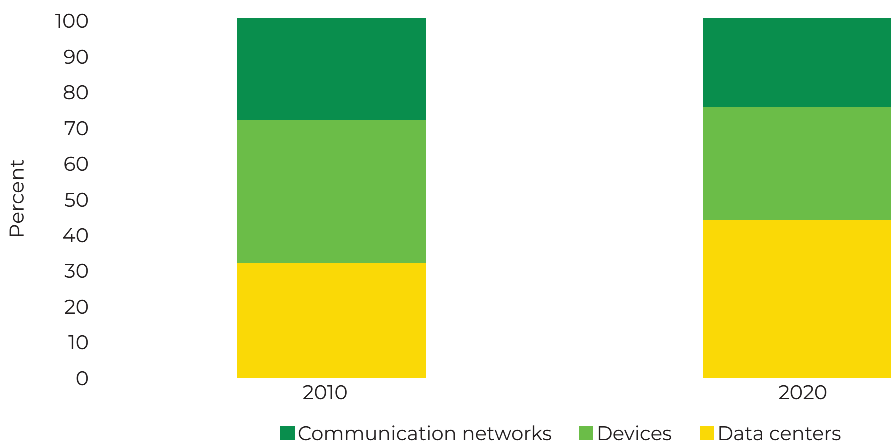
Relative Greenhouse Gas Emissions of the ICT Sector, by Main Component



Source: World Bank (2023).
Note: The midpoint of the range of the subsector's contribution to total emissions in the sector is reflected in the size of the boxes. "Other" includes routers and connected devices. Mobile network operations account for more than 50 percent of the emissions of connectivity network operations. Deployment and decommissioning account for 10 percent of the total emissions of connectivity network emissions.

FIGURE A10

Relative Contributions to Greenhouse Gases of Components of the ICT Sector, 2010 and 2020



Source: World Bank (2023).

FIGURE A11

Technical Strategies to Decarbonize the ICT Sector

Building

- Select site for low-cost or cost-free cooling solution
- Follow energy-efficient building standards
- Focus on energy conservation measures
- Encourage green construction

ICT equipment

- Conduct regular hardware audits
- Measure power usage efficiency routinely
- Upgrade hardware to improve server efficiency
- Consolidate server environment and network virtualization
- Implement dynamic power management to optimize loads of servers

Cooling

- Reduce cooling fluctuations
- Increase data center temperature
- Adopt innovative cooling solutions (free cooling, location optimization)
- Employ real-time building environment monitoring for data centers and servers

Energy input/output

- Operate with green or renewable energy (purchase from the system or self-production)
- Encourage waste heat utilization and sector coupling for data centers and servers
- Improve power efficiency (power-saving features)
- Consider a clean backup power system
- Monitor and control energy use

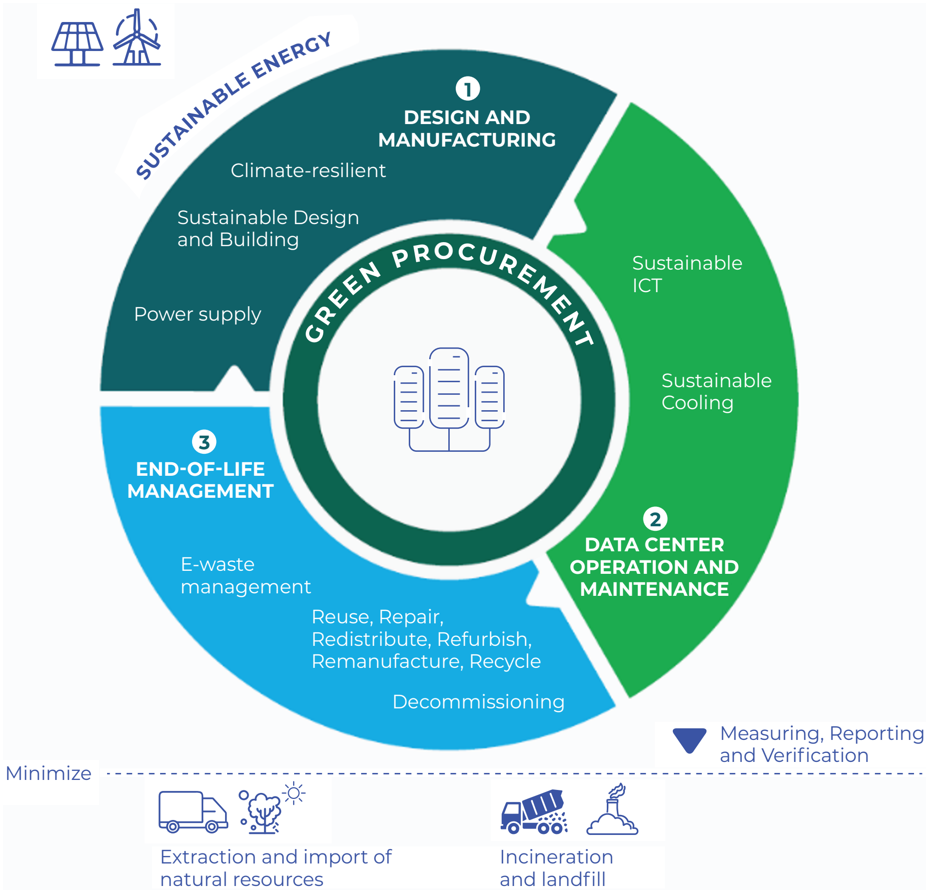
E-waste

- Commit to sustainable end-of-life management
- Minimize e-waste with recyclable equipment
- Optimize server and network equipment refresh cycle and life cycle of products
- Follow the waste hierarchy for equipment and devices: reduce > reuse > recycle
- Partner with waste disposal organizations for certified IT Asset Disposal program
- Use ecodesign of products
- Sell and use repairable products

Source: World Bank (2023).

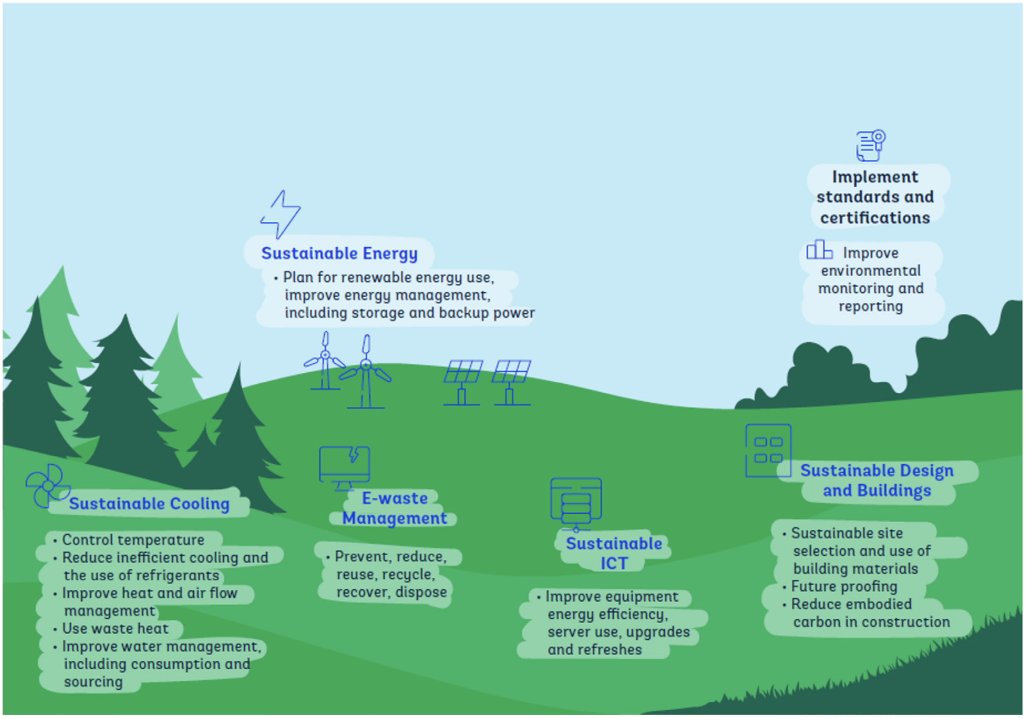
FIGURE A12

Data Center Life Cycle



Source: ITU and World Bank (2024).

FIGURE A13
Climate Change Mitigation Strategies for Data Centers



Source: ITU and World Bank (2024).

Annex F: Key Data Center Industry Standards and Metrics

Digital infrastructure (DI) involves various policy frameworks, regulations, international standards, industry standards, metrics, and benchmarks. The telecom industry has been regulated at large for decades, but the data center industry (DCI) is still young, particularly in developing regions like Latin America and the Caribbean (LAC), where policy interventions are in their early stage.

This report includes references to policy aspects regarding taxation, land, environment and natural resources usage, and workforce development. This annex discusses technical industry aspects, mostly standards and metrics that policymakers should recognize as part of the basic language commonly used in the DCI.

For a deeper view of technical standards applied to the DCI, review Appendixes A, B, and C of ITU and World Bank (2024), which cover key industry standards and certifications as well as resiliency and mitigation measures for data centers (DCs). Another recommendation is to familiarize oneself with the evolving DC metrics landscape, like the multidimensional data centers metrics concept[15] and the ongoing efforts to develop artificial intelligence (AI) preparedness–related metrics.[16]

In this annex, the focus will be on three of the most referenced technical aspects of DCs:

- Uptime Institute's Data Center Tier Classification System:[17] This standardized system ranks DCs in tiers that indicate the reliability of their infrastructure.
- Greenhouse Gas Protocol:[18] "GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions" (GHG Protocol, n.d.). Although it is of broad applicability, it has also been adopted in the digital sector, particularly in the DCI.
- The power usage effectiveness (PUE) ratio:[19] This metric is used to determine the energy efficiency of a DC. PUE is determined by dividing the total amount of power

15 Such as multidimensional DC metrics; see https://www.csemag.com/articles/understanding-changing-data-center-metrics/.
16 See https://www.imf.org/external/datamapper/datasets/AIPI.
17 https://uptimeinstitute.com/tiers
18 https://ghgprotocol.org/
19 https://www.iso.org/standard/63451.html

entering a DC by the power used to run the IT equipment within it. PUE is expressed as a ratio, with overall efficiency improving as the quotient decreases toward 1.0.

The Data Center Tier Classification System

Uptime Institute created the DC Tier Classification System in the mid-1990s. Today, it remains the leading industry standard for DC performance, defining the infrastructure required for DC operations. The four tiers correspond to the system availability needed. The system enables comparison of site infrastructures and alignment of infrastructure investments with business goals. The certification process is a service offered by Uptime Institute.

Each of the four tiers matches a particular business function and defines maintenance, power, cooling, and fault capabilities criteria. Each tier incorporates the requirements of the lower tiers, but this does not mean that a Tier IV DC is better than a Tier II; rather, the levels fit different types of business operations. Table A11 lists the basic characteristics of each tier.

Most Uptime Institute–certified DCs across LAC are currently Tier III, with some in Tier IV.[20]

Although the Uptime Institute DC tier certification is broadly accepted in the sector, international standards organizations are also addressing DC reliability. Currently, the main ongoing effort is the ANSI/TIA 942 Data Center Infrastructure Standard.[21] It specifies the minimum requirements for DCs and covers all physical infrastructure including, but not limited to, site location, architectural, electrical, mechanical, fire safety, telecommunication, security, and other requirements. Another effort is the International

TABLE A11
Uptime Institute's Data Center Tiers

Tier	Characteristics
Tier I	A Tier I DC is the basic capacity level with infrastructure to support information technology for an office setting and beyond. The requirements for a Tier I facility include: • Uninterruptible power supply (UPS) for power sags, outages, and spikes • Area for IT systems • Dedicated cooling equipment that runs outside office hours • Engine generator for power outages Tier I protects against disruptions from human error, but not from unexpected failure or outage. Redundant equipment includes chillers, pumps, UPS modules, and engine generators. The facility will have to shut down completely for preventive maintenance and repairs, and failure to do so increases the risk of unplanned disruptions and severe consequences from system failure. Downtime per year should be less than 28.8 hours.

(continued on next page)

[20] An updated list is available on the Uptime Institute website: https://uptimeinstitute.com/uptime-institute-awards/list.

[21] https://tiaonline.org/products-and-services/tia942certification/ansi-tia-942-standard/

TABLE A11

Uptime Institute's Data Center Tiers *(continued)*

Tier	Characteristics
Tier II	Tier II facilities cover redundant capacity components for power and cooling that provide better maintenance opportunities and safety against disruptions. These components include: • Engine generators • Energy storage • Chillers • Cooling units • UPS modules • Pumps • Heat rejection equipment • Fuel tanks • Fuel cells The distribution path of a Tier II DC serves a critical environment, and the components can be removed without shutting down the DC. As in a Tier I facility, the unexpected shutdown of a Tier II DC will affect the system. Downtime per year should be less than 22 hours.
Tier III	A Tier III DC is concurrently maintainable with redundant components as a key differentiator, with redundant distribution paths to serve the critical environment. Unlike Tier I and Tier II, these facilities require no shutdowns when equipment needs maintenance or replacement. The components of Tier III are added to Tier II components so that any part can be shut down without impacting IT operation. Downtime per year should be less than 1.6 hours.
Tier IV	A Tier IV DC has several independent and physically isolated systems that act as redundant capacity components and distribution paths. Separation is necessary to prevent an event from compromising both systems. A disruption from planned and unplanned events will not affect the environment. However, if the redundant components or distribution paths are shut down for maintenance, the environment may experience a higher risk of disruption if a failure occurs. Tier IV facilities add fault tolerance to the Tier III topology. IT operations will not be affected when a piece of equipment fails or there is an interruption in the distribution path. All the IT equipment must have a fault-tolerant power design to be compatible. Tier IV DCs also require continuous cooling to make the environment stable. Downtime per year should be less than 26.3 minutes.

Source: Authors' elaboration based on Uptime Institute (n.d.).

Computer Room Experts Association (ICREA) Standard 2023,[22] which defines DC service availability in six levels.

Greenhouse Gas Protocol

To take action to reduce GHG emissions, it is necessary to understand and measure their sources. The GHG Protocol, which is the world's most widely used GHG accounting method, is a framework based on three scopes of emissions that categorize the different kinds of emissions a company creates in its operations and broader value chain.

> "Developing a full [greenhouse gas] emissions inventory—incorporating scope 1, scope 2, and scope 3 emissions—enables companies to understand their full

[22] https://icrea-international.org/wp-content/uploads/2024/01/CriteriosGenerales-2023.pdf

emissions impact across the value chain and focus efforts where they can have the greatest impact" (GHG Protocol, 2022).

Following is the basic definition of each scope:

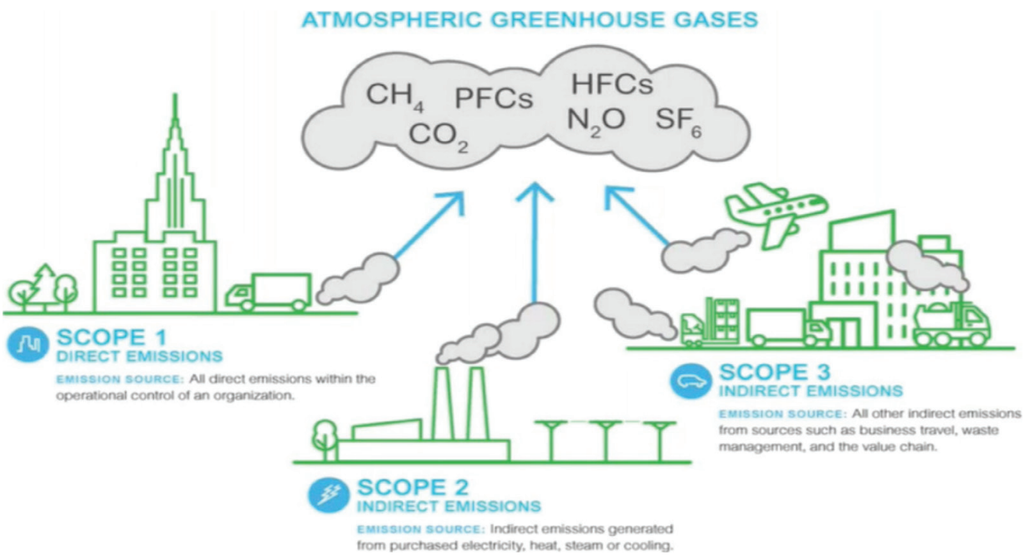
- Scope 1 covers emissions from sources that an organization owns or controls directly—for example, the fuel burned during the operation of a fleet of vehicles (if they are not electrically powered).
- Scope 2 are emissions that a company causes indirectly and come from the production source of the energy the company purchases and uses. For example, the emissions created while generating the electricity used in an office building fall into this category.
- Scope 3 encompasses emissions that are not produced by the company itself and are not the result of activities from assets owned or controlled by the company; rather, these are emissions it is indirectly responsible for up and down its value chain, such as those generated in the purchase, use, and disposal of products from suppliers. Scope 3 emissions include those from all sources not within the boundaries of Scopes 1 and 2.

Figure A14 explains the scopes graphically.

Of the three scopes, Scope 3 is the most difficult to assess because the data is more challenging to attain. Nevertheless, an increasing number of DC operators like Microsoft, Google, and Digital Realty are setting goals and declaring commitments for the

FIGURE A14

Three Categories of GHG Emissions



Source: Schneider Electric (2024).

reduction of Scope 3 emissions. As a result, as those players enter LAC, the region's DCI also aligns with the GHG Protocol goals.

Power Usage Effectiveness (PUE) Ratio

The Green Grid (TGG)[23] works to improve the resource efficiency of digital technology and DCs worldwide. In 2007, TGG published two "self-help" DC energy efficiency metrics for end users: power usage effectiveness (PUE™) and its inverse, DC infrastructure efficiency (DCiE™). Since the original publications, PUE has surpassed DCiE in industry adoption. In fact, PUE is currently viewed as the industry-preferred metric for measuring infrastructure energy efficiency in DCs.

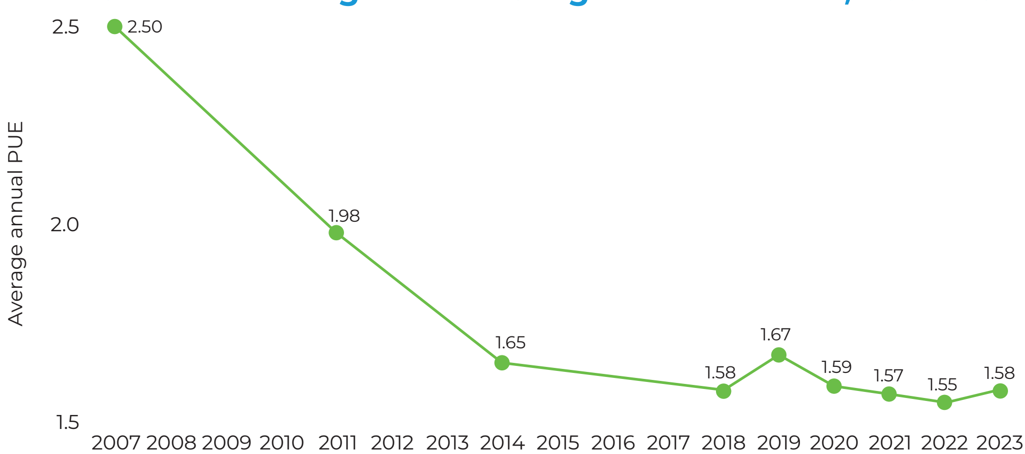
PUE provides a way to determine:

- Opportunities to improve a DC's operational efficiency
- How a DC compares with similar DCs
- If DC operators are improving the designs and processes over time
- Opportunities to repurpose energy for additional digital technology equipment
- A design target or goal for new DCs

Uptime Institute, among other organizations, tracks PUE average for data centers. According to Uptime Institute, PUE dropped from 2.5 in 2007 to 1.98 in 2011. It reached 1.65 by 2014, but from 2020 to 2023 it was stuck between 1.55 and 1.59 (Bizo, 2023). Figure A15 summarizes the metric's historical performance.

FIGURE A15

Data Centers' Average Power Usage Effectiveness, 2007–23



Source: Bizo (2023).

23 https://www.thegreengrid.org/

Reducing PUE is an ongoing challenge for the DCI. The Climate Neutral Data Centre Pact has committed to reaching by 2025 a PUE target of 1.3 for new DCs operating at full capacity in cool climates and 1.4 for new DCs running at full capacity in warm climates (Climate Neutral Data Centre, n.d.).

Other key metrics developed by TGG that are increasingly relevant are water usage effectiveness (WUE) and carbon usage effectiveness (CUE). The WUE metric—combined with the PUE and CUE metrics—enables DC operators to quickly assess the water, energy, and carbon sustainability aspects of their facility, compare the results, and determine if any energy efficiency and/or sustainability improvements need to be made. Since PUE has received broad adoption in the industry, the WUE metric is a natural extension of PUE and extends the family of xUE metrics.

The following article (in Spanish) is recommended for interested readers:

- Métricas de eficiencia en los Data Centers (PUE, CUE, WUE)

Technically detailed resources on the metrics are available on TGG's website:

- https://www.thegreengrid.org/

Annex G: Digital Talent and Data Center Industry Workforce Development

Digital workforce development has been a persistent challenge for the digital technology industry across the globe. On one side is the permanent wave of innovations and the unstoppable growth of the sector, while on the other side is the generally insufficient response from the formal education sector in updating curricula and offerings in response to market demands. Consequently, since the early days of the digital technology industry, leading players have developed their own in-house technical education programs.

Entrepreneurship in the technical education sector has also flourished over decades with the emergence of technical schools and sectorial associations' technical education programs. The data center industry (DCI) also reacted to the workforce gap by promoting and consolidating several programs such as the DCD Academy,[24] CNet Training,[25] EPI,[26] and ICREA.[27] In the largest DCI hubs, traditional education institutions like Northern Virginia Community College[28] have also jumped into offering training for the data center (DC) sector.

Emerging economies struggle with sector innovation momentum and changing demands, and they have paid the price with a wider gap in the digital workforce development race. One of the most effective approaches to help fill those gaps in developed and developing economies has been the creation of multistakeholder partnerships that usually involve government, academia, and industry. Consolidated programs that are not focused on the DCI, like the Cisco Networking Academy[29] and ISACA's[30] career-advancing credentials, among many others, are examples of these types of efforts.

Due to the relevance for Latin America and the Caribbean (LAC), it is worth highlighting the ongoing effort launched in Mexico by the Mexican Association of Data Centers.[31] The association's Talent Committee, created to address the industry's talent

24 https://learn.dcdacademy.com/catalog
25 https://www.cnet-training.com/
26 https://www.epi-ap.com/services/1/3/2/EPI_Data_Center_Training_Framework
27 https://icrea-international.org/certificacion-de-data-centers/
28 https://www.nvcc.edu/academics/programs/data-center-operations.html
29 https://skillsforall.com/#netacadStory
30 https://www.isaca.org/
31 https://asmexdc.com/en/

needs, launched its Data Centers Talent Scholarship[32] program in collaboration with the DCD Academy. It is expected that similar programs will grow across LAC's key DCI hubs through DC associations like the Brazilian Data Center Association[33] and the Chilean Data Center Association announced in late 2024.

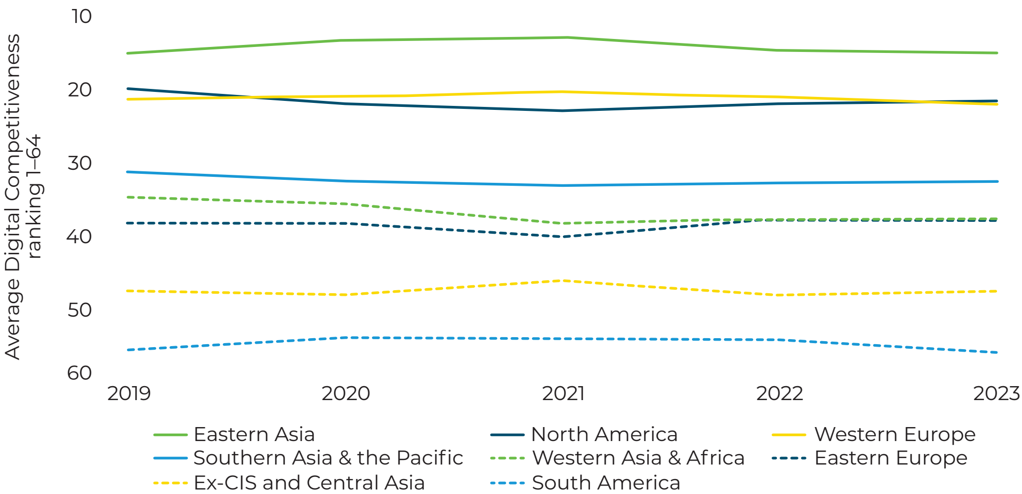
While efforts to fill gaps in the digital workforce continue globally, the landscape's permanent evolution also persists. For example, the World Digital Competitiveness Ranking 2023 (IMD, 2024) raised the following new issues created because of the ongoing digitalization:

> "In a world where talent is global, the importance of national education systems is decreasing. This is so because, today, companies can hire talent anywhere. Besides, because of the opportunities provided by technology, employees can now work remotely and, in the post-pandemic era, we have seen the emergence of digital nomads and international remote workers."

IMD (2024) also raised a significant concern regarding LAC's digital competitiveness performance during the 2019–23 period. Figures A16 and A17, extracted from the report, send a call to action for LAC countries to examine their digital competitiveness fundamentals, which certainly imply the need for DI maturity acceleration and increased digital skills in the region's workforce and societal development. The ranking included

FIGURE A16

Average Ranking by Region in Overall Digital Competitiveness, 2019–23

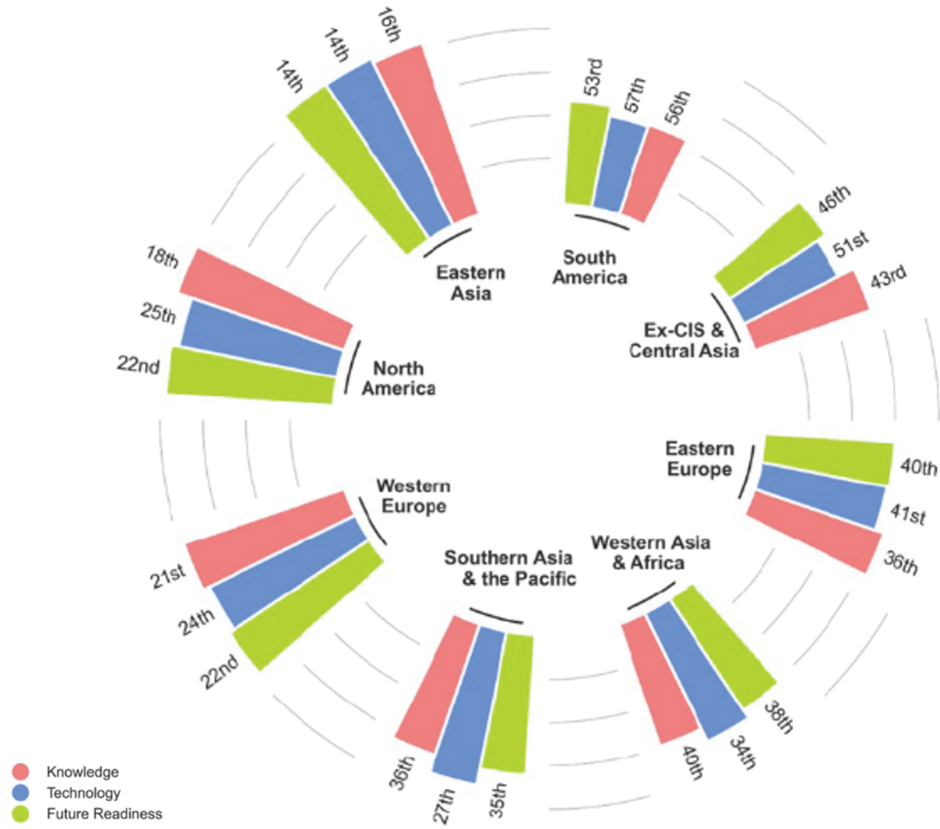


Source: IMD (2024).

32 https://asmexdc.com/en/data-center-talent-scholarship/
33 https://datacenter.org.br/

FIGURE A17

Average Ranking by Region in Digital Competitiveness Factors, 2023



Source: IMD (2024).

54 countries globally. From Latin America, the participant countries classified under South America were Argentina, Brazil, Chile, Colombia, Peru, and Venezuela. Mexico also participated in the ranking but was classified under North America in the charts.

For this report, the key DI components are the telecommunications industry and the DCI. For the telecommunications industry, the workforce development issue has been broadly documented over decades, but ongoing rapid transformation is putting the industry on a path for significant paradigm shifts. Some observations from McKinsey & Company (Lajous et al., 2023) follow:

> "Each technology will require telcos to grow and stretch in new ways, compelling telco leaders to determine early on where to place bets and to continually refine their priorities as the landscape shifts and technology evolves further. As telcos hire the talent needed to embrace the seven tech trends, they will have

less need for skills that can now be automated or are specific to outmoded legacy infrastructure. Having the right talent in place at every stage will distinguish the leaders from their less successful peers."

"The terrain here is not friendly. Long gone are the days when telcos were the employer of choice for technical talent. Over the next decade, demand for certain tech roles is expected to further increase 20 to 30 percent across U.S. industries—potentially outpacing the supply of recent STEM graduates, which grew just 5 to 10 percent annually from 2015 to 2019. For some roles, telcos' demand is expected to outstrip that of other industries: by 2031, for example, telcos' demand for electrical engineers is expected to grow 24.4 percent, compared with 5.9 percent in other sectors."

"Telcos' future success rests on their ability to make the most of the opportunities that emerging technologies present. Multiple elements will need to fall into place, and telco leaders are developing ambitious transformation plans. But talent strategy is also a critical part of the equation, and it is often not getting the attention it deserves. Business leaders would be well-advised to take the reins in shaping and steering tech talent strategy to ensure they have the people to get the job done."

According to Lajous et al. (2023), seven technology trends are reshaping the telecom industry. Those trends and their workforce implications are summarized below:

1. Ever-expanding connectivity: "This will require talent with skills in network and spectrum design to work on strategy and architecture; network engineering to design architecture and develop applications; network innovation to develop emerging RAN (radio access network), network functions virtualization, Kubernetes, etc.; network maintenance monitoring, to handle emergencies and to fix breaks; and Internet of Things (IoT), to develop applications, platforms, and interfaces. Engineering and operational capabilities specific to legacy technologies, such as digital subscriber line (DSL), 2G and 3G cellular networks, and traditional cable TV infrastructure, will likely no longer be needed. The talent base, therefore, will need to adapt."
2. Edge computing: "The move toward edge computing requires telco talent with skills in network and system design to work on data strategy and architecture; network engineering to enable the installation and integration of devices, software, and systems; network innovation to improve the performance of systems; network maintenance, to fix breaks and handle emergencies; database management, to manage data storage, distribution, and analysis; and security, to minimize fraud, monitor risk, and handle compliance. The rise of cloud-based solutions, automation, and managed services will reduce demand for on-site IT setup and maintenance roles."
3. Next-generation transportation: "Telcos will need talent with skills in network design to develop algorithms for vehicle connectivity; network engineering, innovation,

and maintenance, to enable vehicle-to-infrastructure connectivity; automation, to leverage machine learning and artificial intelligence (AI) for infotainment; IoT architecture, to enable voice recognition and gesture control; UX design, to enhance the user experience; and data science, for collecting and processing data."

4. Radio access networks (xRAN): "Telcos will need talent skilled in agile working to enhance engineering practices and innovation deployment; data engineering, to develop architecture; cloud, to develop and test solutions that xRAN enables; product management, to enable the evolution of xRAN; and DevOps, to build solutions and accelerate the transition to xRAN. There will be less need for proprietary hardware knowledge, closed system integration skills, and manual operational capabilities specific to legacy RAN systems."
5. Trust architecture and digital identity: "Telcos will need talent with skills in digital identity development to provide solutions and trusted technologies; cybersecurity solution architecture and engineering, to ensure assessment and secure access to networks and applications; automation, to create digital identity solutions and tools; privacy engineering, to handle risk and compliance; network engineering, to develop apps and architecture; network maintenance, to monitor and manage emergencies; and DevOps, to automate configuration, continuous delivery, and infrastructure. Manual production and review of compliance documentation will be phased out."
6. Artificial intelligence (AI): "To maximize the AI opportunity, telcos will need talent with skills in interface design to create excellent user experiences; natural language processing engineering, for AI speech recognition; data engineering, to work on data architecture, software, and big data; data science, to create mathematical machine learning models; and security, to prevent and manage cyberattacks. As infrastructure is increasingly managed through software, AI will supplant the need for routine manual troubleshooting."
7. Quantum technology: "To move beyond internal discussions and test-and-learn pilots, telcos will need talent with expertise in quantum technology (such as quantum algorithms, computer architectures, superconducting circuits, and machine learning); high-performance computing, to engage with the ecosystem on pilots in areas like quantum key distribution (QKD); software and hardware security and crypto-agility, to prevent cyberattacks and manage cryptography transformations as threat levels and standards evolve; network engineering, to design hybrid classical/quantum networks, codevelop and pilot critical equipment for optical communications, and explore the potential of satellite and fiber for quantum communications; and product management, to monetize quantum networks and security. Using classical computation, engineering and operational capabilities specific to traditional network optimization methods will become less relevant."

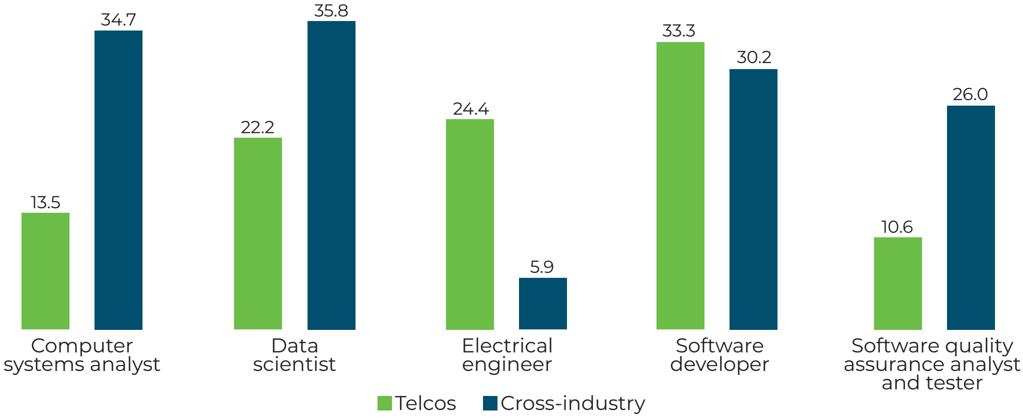
Figure A18 provides some insight into the tech talent demands of the telecom industry based on U.S. data.

On the DCI side, the workforce challenge is also colossal. Highly technical skills are needed to design, build, manage, and operate DCs, with additional skills required for green DC development. According to ITU and World Bank (2024):

FIGURE A18

Technology Talent Demand in Telcos and Cross-Industry

Estimated demand change for tech occupations, 2021-31, %



Source: Lajous et al. (2023).

- Currently, the demand for skilled green DC staff outweighs the supply worldwide, with many DC owners and operators unable to hire qualified personnel. Demand is projected to increase to about 300,000 engineers worldwide by 2025, with at least half of current DC engineers retiring.
- This challenge is even more significant in developing economies, where staffing requirements are expected to increase unevenly across regions. Most of the demand will be in Asia-Pacific, driven by expected cloud and internet giants and colocation capacity growth in China and Southeast Asia.
- Market demand in Europe, the Middle East, and Africa is foreseen to exhibit comparably aligned trends among these regions. In Latin America, growth is expected to be driven by several markets, including Brazil, Chile, Colombia, and Mexico. The available pool of qualified engineers in these regions is limited.
- By implementing sustainable standardized designs, DCs can streamline the construction and deployment process, reducing the need for highly specialized skills and labor. Modular designs allow for pre-engineered components that can be easily assembled, making it more feasible to build and operate sustainable DCs in regions where skilled workforce availability is limited.
- Governments and the private sector should work together to enhance educational efforts and provide training programs that include sustainability topics. This could be achieved by integrating these subjects into existing curricula, establishing short courses on best practices, and increasing awareness of green solutions and materials. Demand is projected to increase to about 300,000 engineers worldwide by 2025.

Uptime Institute's report The People Challenge: Global Data Center Staffing Forecast 2021–2025 (Uptime Institute, 2024) provides valuable insights. An extract from the report is included below; however, a deep dive into the report is recommended for the interested reader as it provides insight into global DC workforce needs by region, by DC type, and by education requirements.

- Global DC staff requirements are forecast to grow globally from about 2.0 million full-time employee equivalents in 2019 to nearly 2.3 million in 2025. This estimate covers more than 230 specialist roles for different types and sizes of DCs, with varying criticality requirements, from design through operation.
- New staff will be needed across all geographic regions. Most demand will be in the Asia-Pacific region, followed by North America, Europe, the Middle East, and Africa.
- In the large and mature DC markets of the United States and Western Europe, there is concern that many employees are due to retire around the same time, causing an additional surge in demand, particularly for senior roles.
- Globally, demand growth will come from cloud providers, internet giants, and colocation DCs. Cloud/internet giants' DCs—those either owned or leased by major public cloud/internet companies—will require the most staff, by a significant margin.
- Enterprise DCs will continue to employ a large number of staff, but the number will decline, eventually being surpassed by cloud/internet giants after 2025.
- Most of the workforce will require a university/college or technical trade school degree or—critically—equivalent experience. More on-the-job training and sector-specific education will be key for the sector to meet future talent demand.
- Technical staff are notoriously difficult to recruit in DCs. Mechanical and electrical engineers in strategy and operations roles and all types of control and monitoring employees are among the technical staff that will be increasingly needed through (at least) 2025.
- Innovations in artificial intelligence and automation are unlikely to flatten or reduce staff needs before 2025.

The Uptime Institute's employment forecast is presented in Figure A19.

Figure A20 presents projections by DC type, where cloud and hyperscale DCs are validated again as the predominant type.

Uptime Institute (2024) also identified key issues regarding the availability of qualified personnel. For example, a 2018 poll found that 38 percent of IT managers in DCs had difficulties finding qualified candidates to fill open positions, while in 2021 the number increased to 50 percent of respondents. The study identified more than 230 individual job roles related to the DCI. Table A12 offers a glimpse of the key job domains and their involvement across the DC life cycle stages.

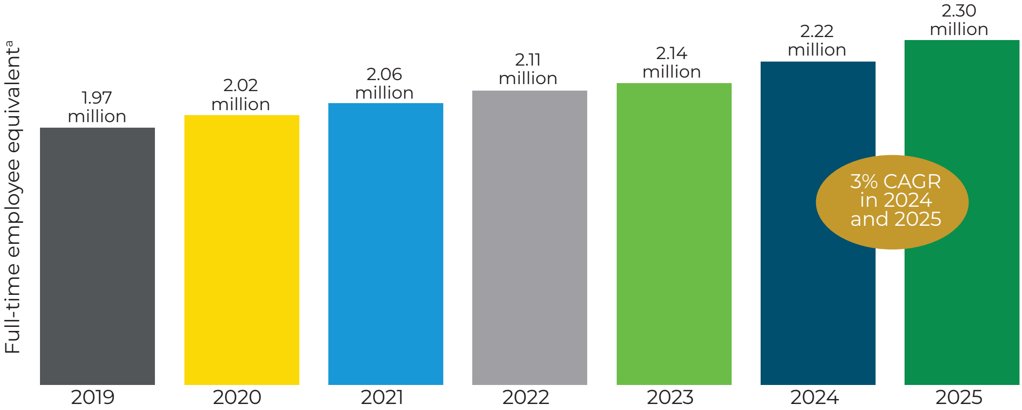
Uptime Institute (2024) also provided DC staff requirements by region, as summarized in Figure A21, which is extracted from the report.

Another useful reference is Data Center Coalition and PwC (2023), which provides key data from the U.S. market analysis that will be helpful as employment expectations are set for emerging geographies such as LAC. Key highlights follow:

- The DCI total annual impact (combining its direct, indirect, and induced impacts arising from DC construction and operations) on the U.S. national employment has

FIGURE A19

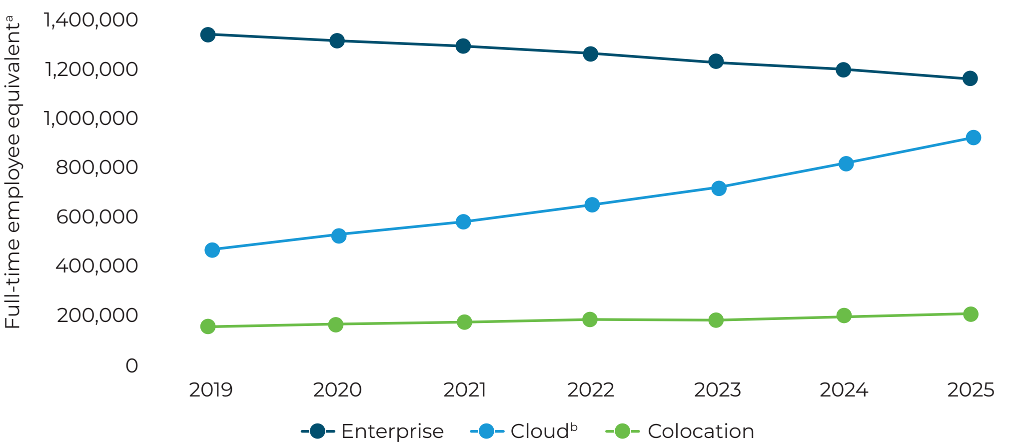
Global Data Center Staff Requirement Projections, 2019–25



Source: Uptime Institute (2024).
[a] Assumes a 40-hour work week.

FIGURE A20

Global Data Center Staff Requirement Projections by Data Center Type, 2019–25



Source: Uptime Institute (2024).
[a] Assumes a 40-hour work week.
[b] Includes wholesale leased.

grown from 2.9 million jobs in 2017 to 3.5 million jobs in 2021, a 20 percent increase over the period.

- Based on preliminary U.S. government data for 2022, the industry is estimated to have added more jobs in 2022 than it added over the entire 2017–21 period, resulting in 560,000 direct jobs and supporting 4.2 million total jobs across the country.

TABLE A12
Role of Key Data Center Job Domains across Data Center Life Cycle

Data centers employ amultidisciplinary teams of staff that share a common function (i.e., job domain) spanning the different stages of a data center's life cycle.

	Data center life cycle stage				
Job domain	**Strategic requirements**	**Design**	**Construction (build)**	**Commissioning**	**Ongoing operations**
Business Support	◆	◆		◆	◆
Strategy	◆	◆			
Design		◆	◆	◆	
Construction			◆	◆	
Operations Engineering	◆	◆		◆	◆
IT Hardware		◆			◆
Network and Connectivity	◆	◆		◆	◆
Controls and Monitoring	◆	◆		◆	◆
Operations					◆

Source: Uptime Institute (2024).

This report finds that at the national U.S. level, each direct job in the DCI supports more than six jobs elsewhere in the U.S. economy (including both operational and capital spending impacts).

The final aspect to investigate is the economic impact of the DCI as a way to understand its development impact potential beyond the enablement of digital transformation acceleration, employment, or direct investments. Data Center Coalition and PwC (2023) provides one of the most helpful analyses available, given the maturity level and documented journey of the DCI sector within the U.S. economy. Figure A22 extracted from the report provides a snapshot.

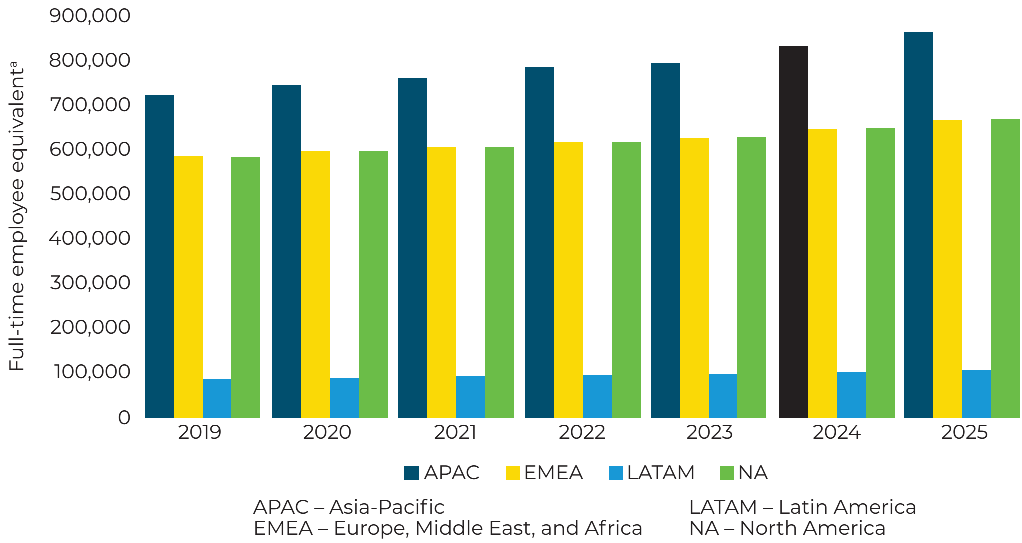
The report also details the different financial aspects analyzed, including federal, state, and local taxation, jobs, and environmental and social impact.

An additional recommended source to better understand the economic impact of the DCI is a set of reports created by Oxford Economics for Google.[34] The reports focus on Google's DC operations in different countries around the world. For example, some highlights from the U.S. 2022 findings are presented in Figure A23.

[34] https://www.oxfordeconomics.com/resource/data-center-impacts/

FIGURE A21

Data Center Staff Requirement Projections by Region, 2019–25



Source: Uptime Institute (2024).
[a] Assumes a 40-hour work week.

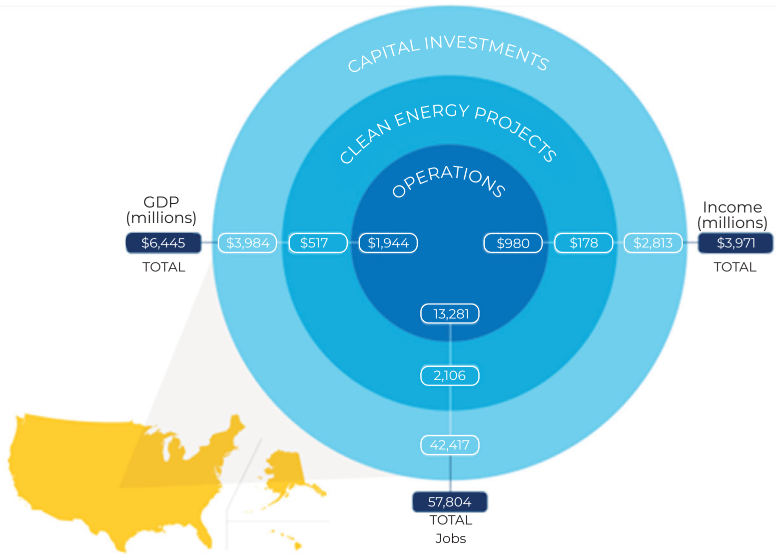
FIGURE A22

U.S. Data Center Industry Total[a] Annual Economic Impacts, 2017–21

Source: Data Center Coalition and PwC (2023).
[a] Total impact includes direct, indirect, and induced impacts. Direct impacts are those occurring directly within the DCI. Indirect impacts are those occurring within other businesses as part of the supply chain to the DCI. Induced impacts are those arising from household spending of income earned from the data center industry or its supply chain.

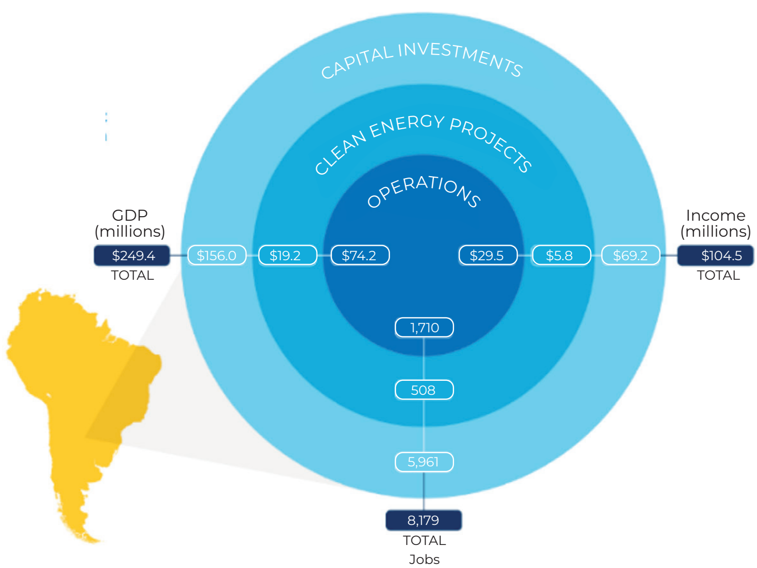
Figure A24 shows similar data from the Oxford Economics report on Chile and South America.

FIGURE A23
Google's Total Economic Impact in the United States, 2020



Source: Oxford Economics (2022a).

FIGURE A24
Google's Annual Economic Impact in South America, 2020



Source: Oxford Economics (2022b).

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