IDCA

Global Data Center Report (2026)

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Contents

Acknowledgment

This comprehensive report is created through the efforts of seasoned subject matter experts of IDCA who have dedicated their time and expertise in hopes of bringing transparency and light for resourceful measures to the Digital Economies of the world:

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01

Executive Summary

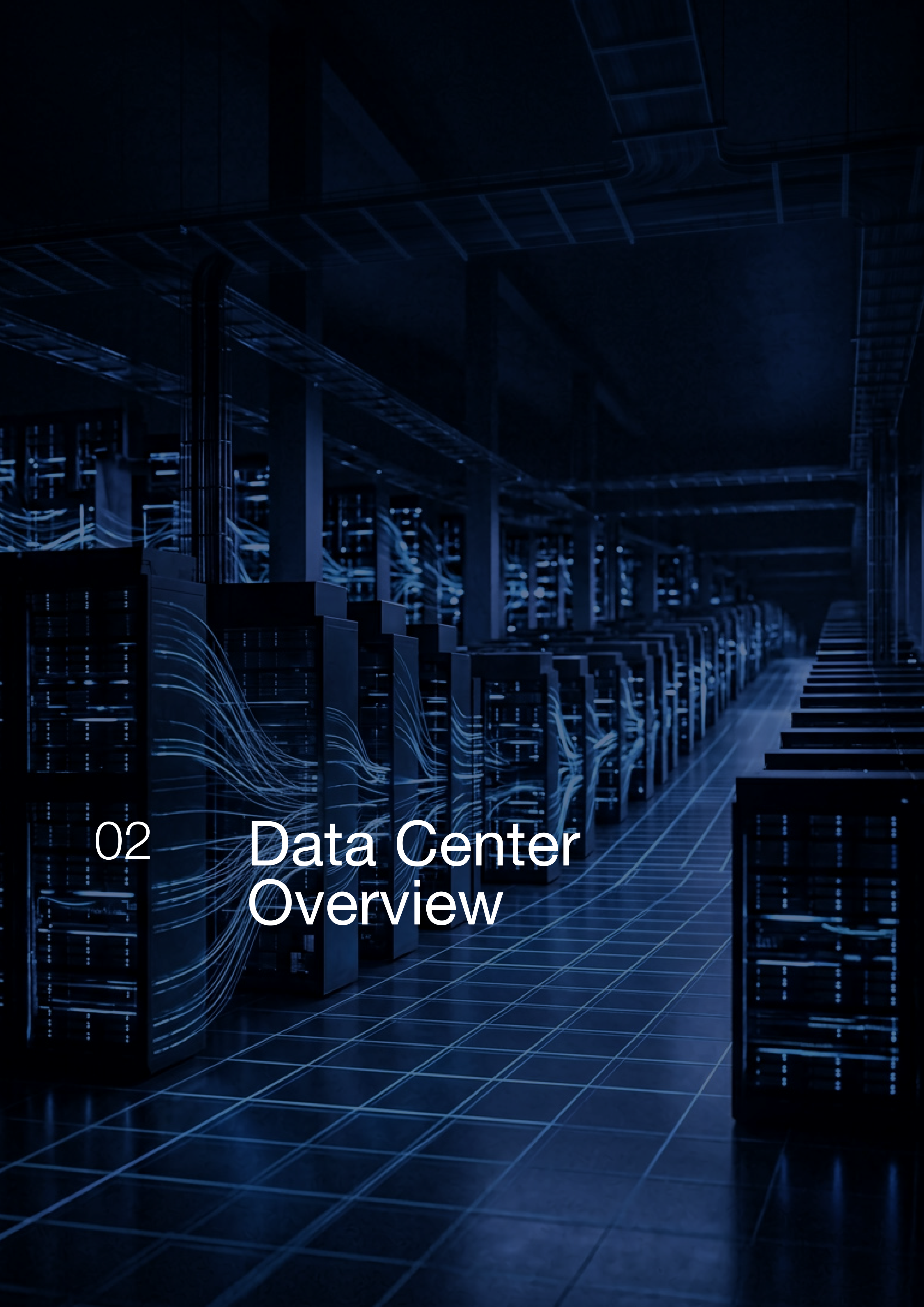
Executive Summary

This report accompanies the IDCA Digital Economy Report 2026, which was released in January 2026. The previous report focused on the global buildout of the Digital Economy, with an analysis of all aspects of digital infrastructure and its impact on societal prosperity.

This report, in contrast, focuses solely on data centers – their consumption, their location, their national footprints, their design, and the considerations that businesses, governments, other organizations, and investors should take into account when planning new data center facilities and hubs.

The Digital Economy Report, Data Center Report, and other IDCA reports are a product of IDCA's global research team, with a presence in each of the world's regions. IDCA's research process scans a number of publicly available reports from organizations such as the International Energy Agency, World Bank, United Nations, and International Telecommunications, as well as agencies within the United States, EU, and numeros additional governmental entities.

IDCA also receives private feedback from specific government sources globally, from major data center and cloud-computing operators, from developers, from investors, and from internal research.



02 Data Center Overview

Data Center Overview

Data centers have a global footprint of 67.7GW. This is a growth of 36 percent over the past two years. Data centers now consume 2 percent of the world's electricity, up from 1.7 percent in 2024 and 1.9 percent in mid-year 2025.

The US is by far the world's largest data center location, with 43 percent of global consumption. Data centers consume 29.2GW of electricity in the US, and now consume 6 percent of the nation's electricity.

The world's other Top Five data center consumers are:

- China, at 8.5GW, consuming 0.8 percent of nation's electricity.
- Germany, at 5.5GW, consuming 9.5 percent of the nation's electricity.
- UK at 2.0GW, consuming 5.8 percent of the nation's electricity.
- Japan at 1.7GW, consuming 1.5 percent of the nation's electricity.

IDCA's data for the US and several other countries are higher than some traditional estimates because of the presence of small, room-sized data centers in use by SMEs that must be counted. These facilities are numerous and inefficient compared to the large, building-sized facilities and campuses.

The continued use of smaller data centers by Mittelstand (family-owned mid-sized) companies in Germany increases that nation's estimate when compared to some other results as well. Similar considerations apply throughout a variety of nations in IDCA's analysis.

Additionally, IDCA research finds that as much as 13 percent of data center consumption in the United States comes from unused, "zombie" cloud containers and services. This wasted consumption totals in excess of 3GW, comparable to the energy produced by three nuclear reactors. This sort of inefficiency is presumed to be apparent throughout the world, with inefficiencies increasing as the percentage of cloud computing rises.

IDCA's China analysis, on the other hand, produces data that shows a smaller footprint than some traditional estimates. Neither China's government nor its major vendors or utilities are transparent in providing energy-use statistics. There is substantial unused capacity in China, and diverse global opinion of how much data center consumption exists. IDCA has revised its China estimate upwards by a couple of gigawatts when compared to analyses in 2025, and continues to seek optimal reporting of the nation's data center footprint.

China is an obvious sleeping giant within the world's data center sphere. IDCA's research shows the nation still devotes less than 1 percent of its energy grid to data centers. The nation now produces almost twice as much electricity overall as the United States, so has the potential to become a truly daunting consumer of data center services.

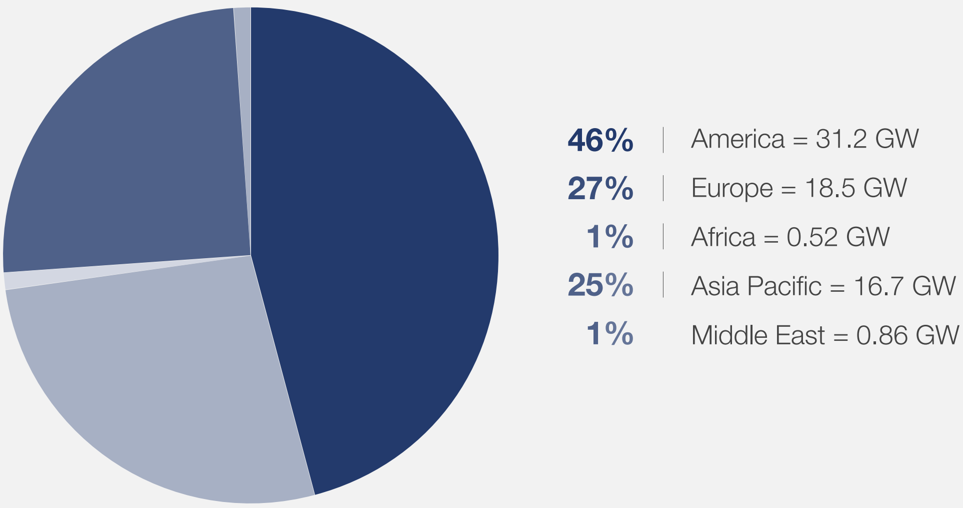
03 Regional Usage and Disparities

Regional Usage and Disparities

With the above advisories in mind, IDCA shows a regional breakdown of data center usage as shown below.

FIGURE 1.

Regional Breakdown of Data Center Footprint

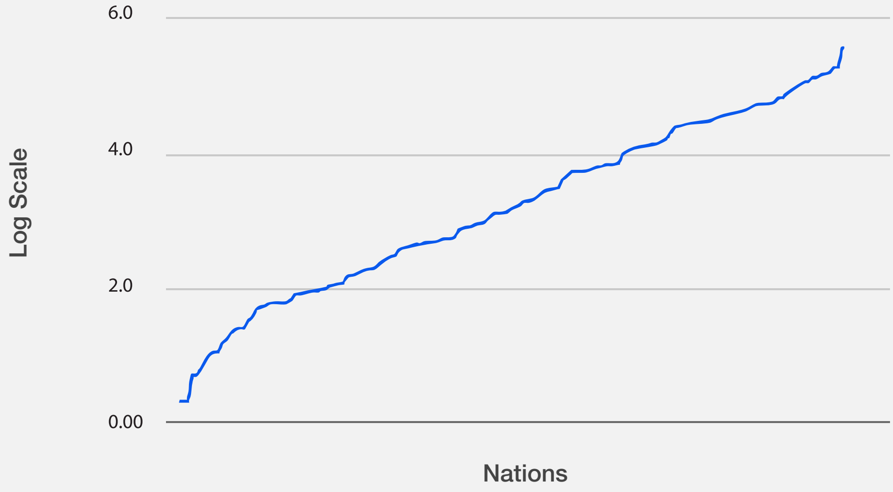


Source: IDCA

The figures above reflect a continuing, massive disparity in data center usage throughout the world. IDCA finds a difference of as much as 100,000X in the density of server usage – that is, the per capita presence of data servers and data centers varies by as much as 100,000 times.

FIGURE 2.

Data Server Density



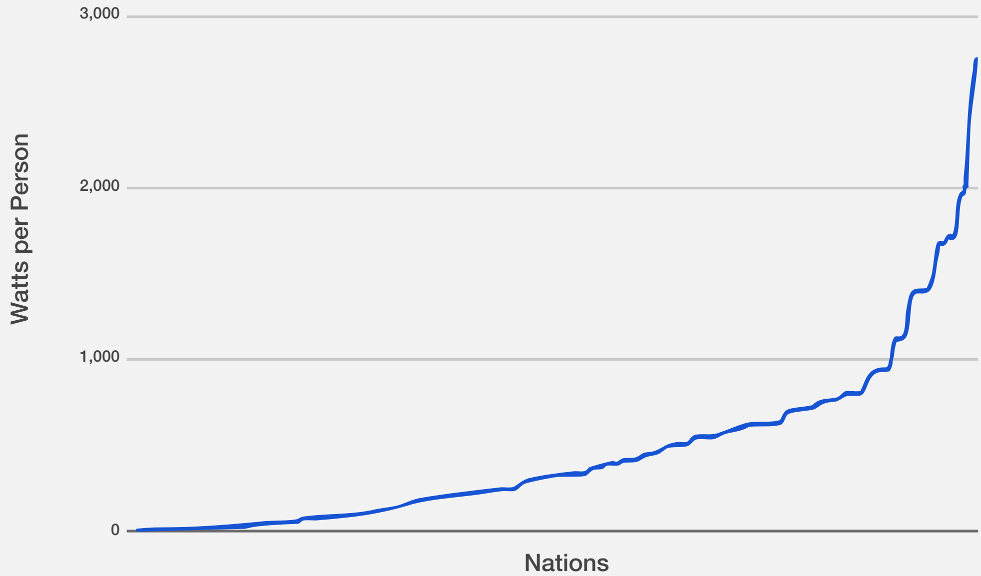
Source: IDCA

Note: This chart is plotted on a log10 scale. Each horizontal unit increase denotes a 10X increase in density. The five-unit disparity between the US (to the right of the chart) and least-developed infrastructures (on the left) thus represents a gap of 100,000 times in the number of servers per population.

The above disparity is largely a function of another disparity, that of the world's electricity grids, which vary 100X in their respective strength. This large disparity continues to exist at the same time that data centers and related digital infrastructure are consuming and increasing proportion of those grids.

FIGURE 3.

Disparity of National Electricity Grids



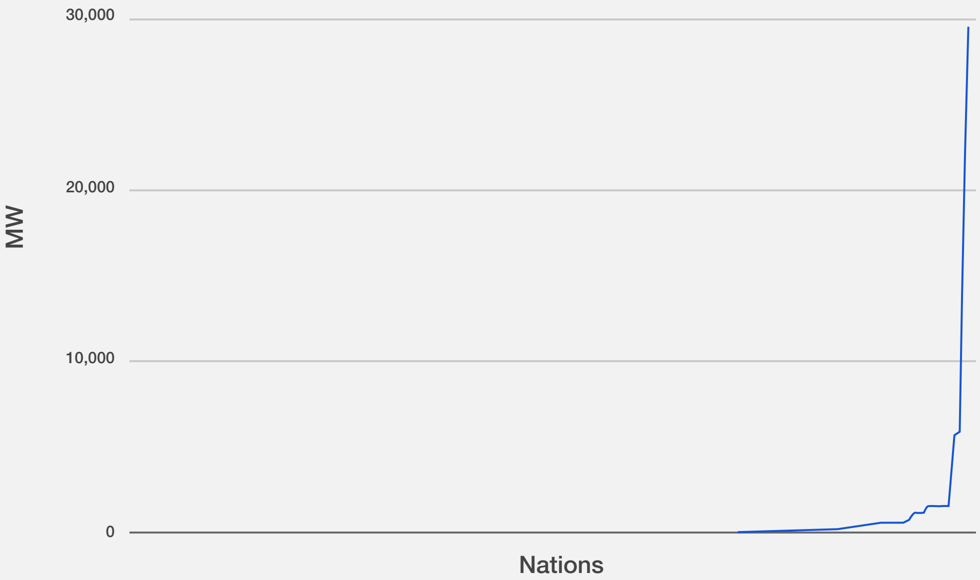
Source: IDCA Research

Data center consumption can also be viewed with respect to the amount of a nation's electricity it consumes. As noted above, the world as a whole has passed the 2-percent barrier in electricity consumption by its data centers.

This average is not troubling in and of itself; however, it masks a very wide disparity of electricity use from nation to nation, and obscures the very real constraints being experienced by a variety of nations across income tiers.

FIGURE 4.

Data Center Consumption



Source: IDCA Research

On the one hand, data centers in Singapore and the European nations of Netherlands, Germany, and Switzerland have exceeded the 9-percent consumption level. Data center consumption is provoking political and societal angst in those nations. It is also doing so in a few countries that are approaching this level in other European nations, including Ireland, Denmark, Lithuania, Estonia, and the UK.

The situation is mitigated somewhat in Singapore by strong data center development in the border regions of Johor, Malaysia and Batam, Indonesia. But there is no such immediate relief in Europe. Over the longer term, the large nation of France and smaller nations such as Slovakia and Slovenia, all of which have very strong electricity grids driven by nuclear energy, may serve to reduce some constraints. But this process would be a political process and presumably take time.

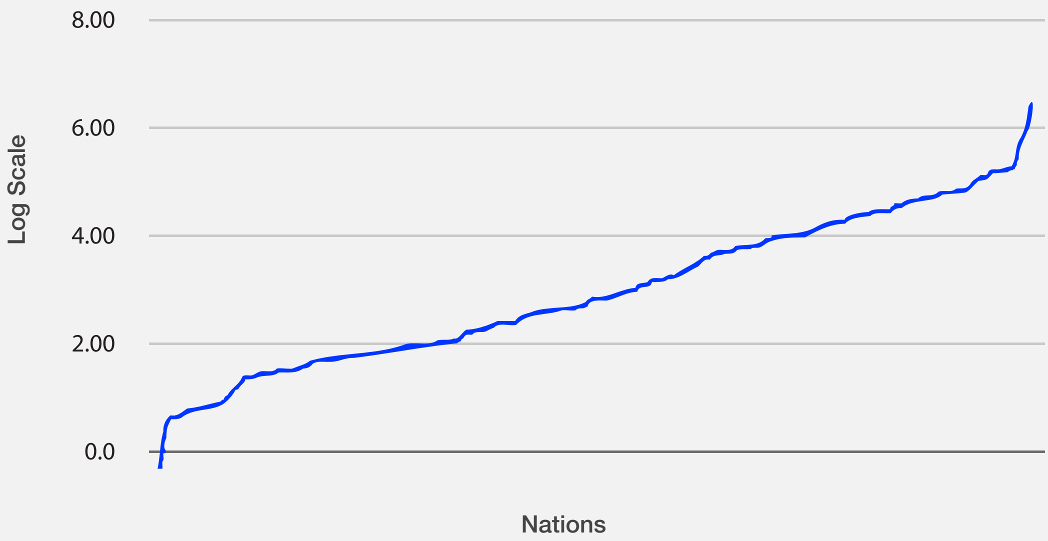
In the US, which has now reached the 6-percent level, community pushback over data center consumption has been seen in several regions. Data center developers in Northern Virginia, many parts of the Midwest, Texas, and California are finding multi-year delays in the ability to provision power for new data centers.

On the other hand, the lack of sufficient energy to meet basic needs throttles data center plans throughout the developing world. IDCA finds that more than 70 countries devote less than 0.1% of their power to data centers, with more than 30 countries devoting less than 0.01% to data centers.

Societal improvement in the 21st century cannot occur without a healthy digital infrastructure, and data centers are the obvious foundation of that infrastructure. Plans by some developers to ameliorate the situation in developing countries by providing their own power often involve the use of fossil fuels, and surely do not represent a long-term development view.

FIGURE 5.

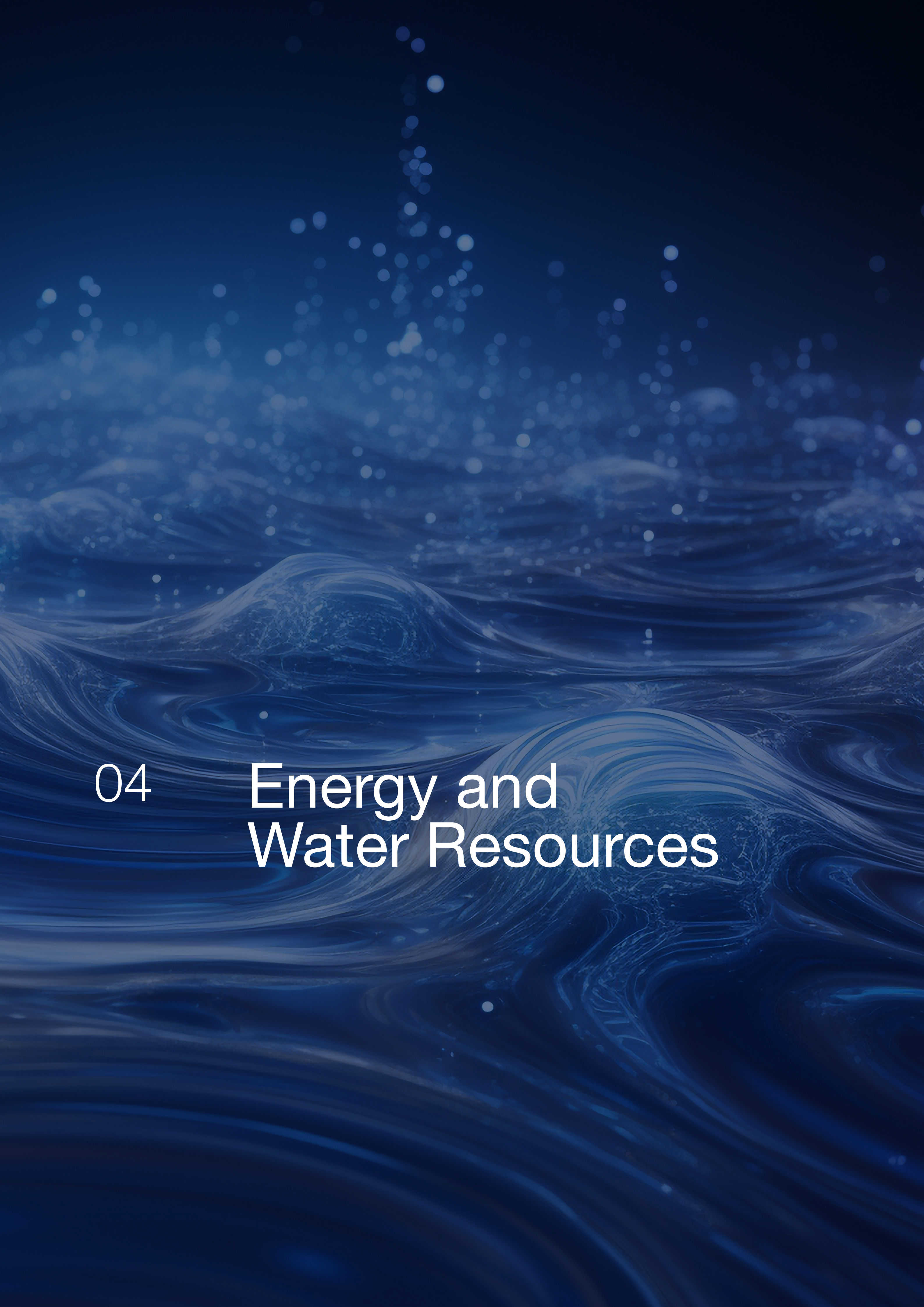
Data Center Consumption (log10)



Source: IDCA Research

Data Center Consumption and Expansion
IDCA has analyzed each of the world's nations with respect to its current data center consumption and its potential for expansion. The analysis involves the use of an optimized model, in which Socioeconomic conditions are ideal and data centers consume 6.25% of an electricity grid that is strong and powered 95% by renewable energy.

The optimized model takes into account the challenges facing developed nations – where energy use by data centers is straining grids – and developing nations, where current grids are insufficient to meet basic needs, let alone aggressive data center buildouts.



04 Energy and Water Resources

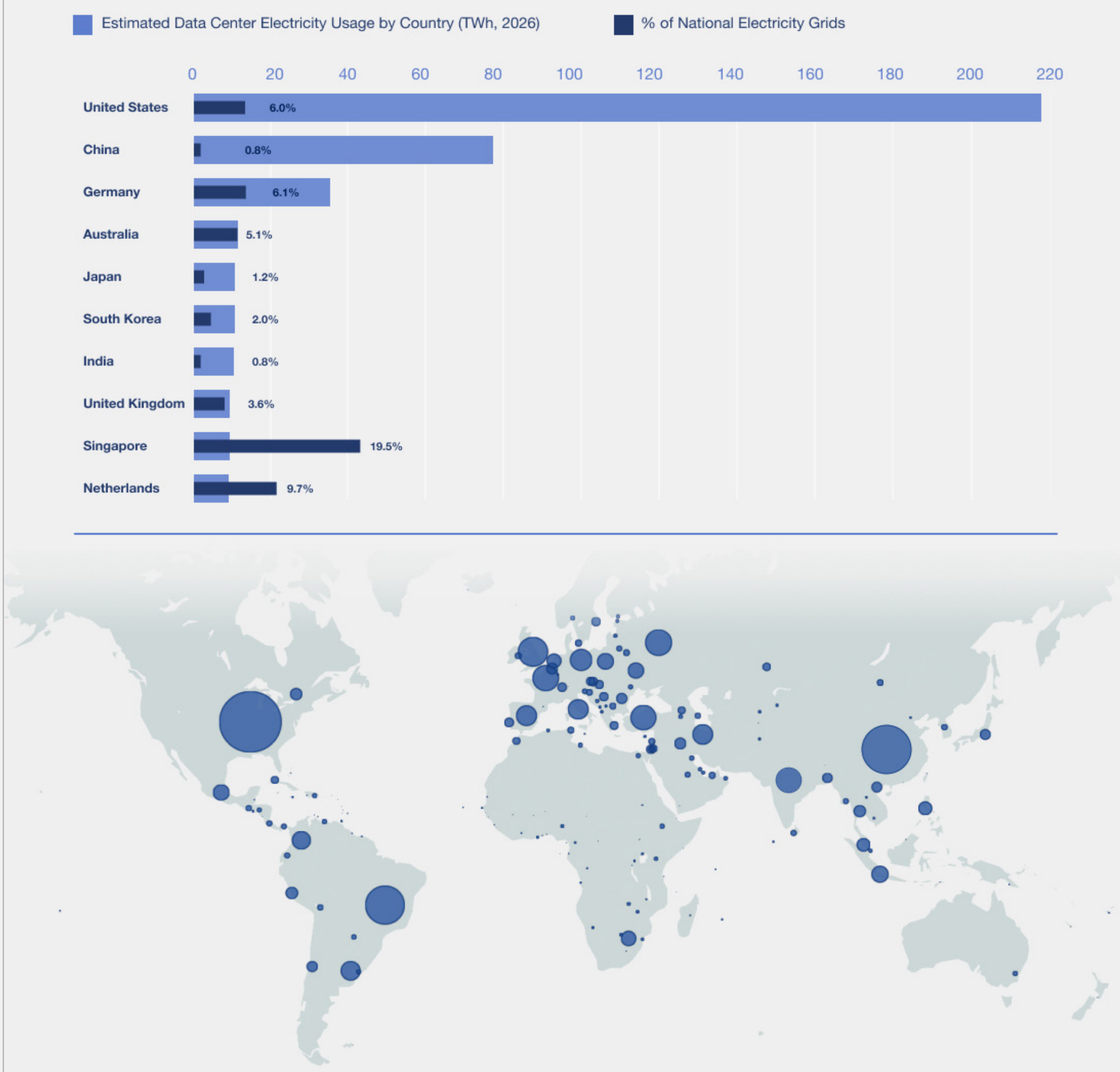
Energy

IDCA advocates the use of sustainable energy for development of new data center facilities and hubs. Sustainable energy includes the renewable sources of hydroelectric, wind, and solar power. It also includes the use of geothermal energy where it's present, as well as the use of biomass. Green hydrogen represents another renewable resource, one which may be developed more fully in future years. Finally, nuclear energy is included as a sustainable source of energy. A full review of the world's current use of sustainable energy is found in the upcoming IDCA Energy Usage Report.

The following figure provides an overview of global energy use and its consumption by data centers.

FIGURE 7.

World's Top 10 Data Center Grids (TWh)



Source: IDCA Research

FIGURE 8.

World's Top 10 Data Center Consumption Levels
(% of national grids)

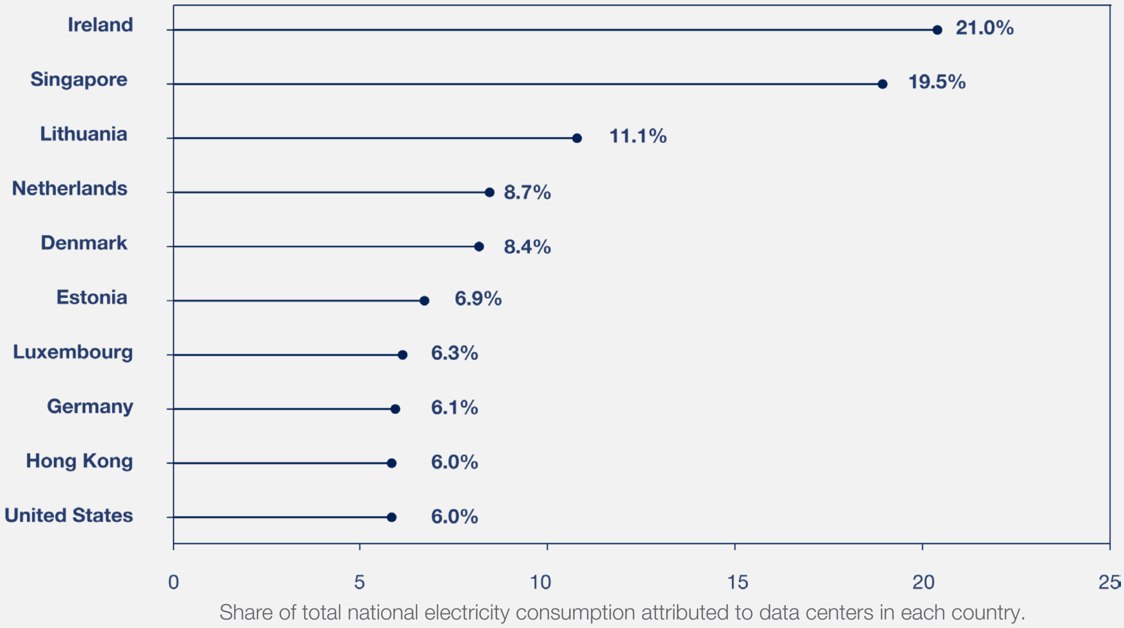
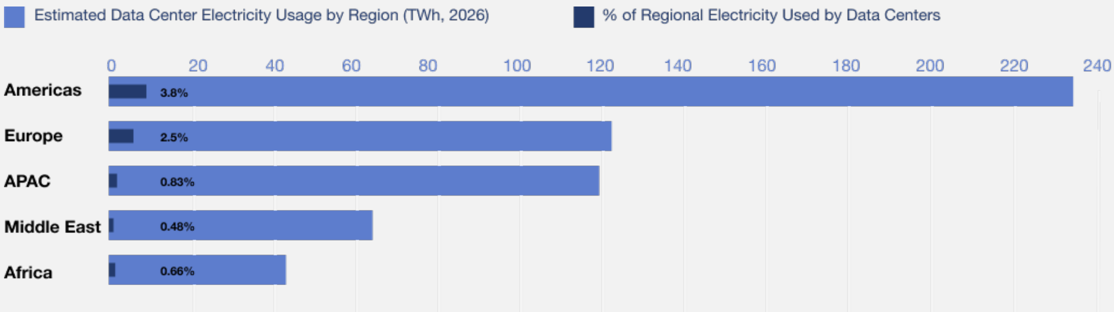


FIGURE 9.

Data Center Consumption by Region
(TWH, % of national grids)



Source: IDCA Research

Besides the big picture outlined above, there are also obvious local concerns about the total amount of data center electricity consumption. The world average is now 2.0 percent, which is not an alarming figure by itself. However, several developed nations have crossed the 5-percent level, sparking societal and political concerns.

IDCA works with an optimized national model to determine ideal consumption levels for each nation of the world. For many developing nations, construction of any new data centers is contingent on also developing stronger electricity grids and more robust fiber-optic networks to deliver data to and from data centers. For developed nations, which by definition have enough electricity to serve their populations very consistently (except in rate peak-emergency situations), IDCA finds that a cap of 6.25 percent of national electricity consumption is an effective cap on data center growth. This is not a prescribed or engineering number. Rather, it is the point at which the correlation is very strong between data center consumption and political actions such as usage caps, preferred operating hours, community pushback that results in project cancellation, and prohibition on new projects.

The United States has seen a recent flurry in new data centers coming into operation, resulting in an average usage of almost 6 percent. As noted earlier in this report, as much as 13 percent of this usage (or 0.78 percent of the total) supports “zombie” applications that were instituted, discarded, and never turned off. In any case, the US with its vastness has several areas in which data center usage is much higher than 6 percent, causing hard caps on new building and ongoing concerns about future growth.

Smaller nations that have exceeded the 6.25 percent level and which are experiencing a no-growth era, or close to it, include Germany, Netherlands, Ireland, Estonia, and Lithuania. Singapore in Asia is in a similar situation. South Korea provides a special case, with an overall usage of well below 6.25 percent but an extreme concentration in metropolitan Seoul. This has prompted the government to authorize new data centers only outside of the metro area. A full review of the world's current use of sustainable energy is found in the upcoming IDCA Energy Usage Report.

The table below provides a list of the 27 nations in the world that have a hypothetical capacity to add at least 1 gigawatt of new data center footprint without developing new electricity resources. These calculations were made by comparing current usage against the optimized 6.25 percent consumption level.

China is by far the largest presence in this table, but it is very difficult to get a precise number of what the opaque Chinese government will actually do in building out its footprint in coming years. For the other nations, this table should be viewed with the knowledge that any of these nations may not have the societal or political desire to build out to their capacity, and that every project must be built with respect to local power conditions and other local considerations.

Data Center Headroom

Country	Headroom (GW)
China	58.9
India	12.7
Russia	6.7
Japan	5.5
Brazil	4.5
Canada	3.6
South Korea	3.2
Saudi Arabia	2.6
Iran	2.4
Mexico	2.4
Indonesia	2.1
Taiwan	2.0
Turkey	1.9
Vietnam	1.7
France	1.7
Egypt	1.6
Thailand	1.5
Italy	1.5
Australia	1.4
Spain	1.3
USA	1.2
Pakistan	1.2
South Africa	1.2
UAE	1.2
Iraq	1.1
Argentina	1.0
Colombia	1.0
Group Total	**127.1**

Water

The convergence of cloud expansion, edge computing, and artificial intelligence has created a genuine shock to global electricity and water systems. Technology demand is doubling rapidly, and the underlying pipes, wires, and power plants were not designed for this scale of progress. Historically, large data centers were centralized in major metropolitan hubs with built-in utility redundancy. Today, edge computing is pushing infrastructure into smaller communities, resulting in power and water demand spreading into regions that never expected to host this kind of industrial infrastructure.

Small towns and municipalities are getting hit the hardest. In regions like the suburbs of Houston, or Columbus, Ohio, water systems are already stretched thin juggling the surging demands of residents, agriculture, and incoming data centers all at once. In extreme cases, such as a proposed facility in Marfa, Texas, a single site could potentially use more groundwater than the entire town currently consumes.

The Reality of Traditional Cooling Methods

To understand the water challenge, stakeholders must recognize that the data center market is now sharply bifurcated. The vast majority of existing traditional cloud and enterprise facilities rely on older, less efficient cooling architectures like water-cooled chillers or evaporative cooling towers. In these legacy designs, water is evaporated to remove the latent heat of vaporization from the air, and that evaporated water is never recovered.

These facilities can be massive water consumers. A single traditional hyperscale facility can burn through millions of gallons of water each day just for cooling. Because these sites frequently rely on municipal potable drinking water, a single large data center can consume as much water as 6,500 local households or the equivalent of maintaining 41 golf courses. While engineers historically accepted this design because using evaporative water significantly lowered electricity costs, communities in arid climates are now actively pushing back against the depletion of their limited resources.

Demystifying AI and Liquid Cooling

Because of the massive water footprint of older cloud facilities, a public narrative has emerged warning that the incoming wave of “AI Factories” will completely drain local water supplies. Factually speaking, this is a misconception. Next-generation gigascale AI facilities operate at such extreme chip densities that traditional air and evaporative cooling are physically incapable of removing the heat.

Instead, modern AI centers rely on Direct-to-Chip liquid cooling. These function as entirely closed-loop systems—much like an automobile radiator. Hot liquid is pumped directly from the chips to a massive dry radiator outside, where fans cool the liquid before it is recirculated back to the servers. Because the internal orifices of these cooling plates are as small as one micron, the systems are filled with highly purified water mixed with inhibited propylene glycol to prevent bacterial growth and corrosion.

Most importantly, once this closed-loop system is initially filled, these high-performance AI centers consume minimal water during daily operations. When the media reports that a new AI facility has a permit for “5 million gallons of water a day,” it is almost always referring to a one-time municipal permit required to initially fill the loop, maintain fire suppression tanks, or suppress dust during the construction phase. Once operational, the cooling loop is sealed, meaning the industry’s most advanced AI data centers do not contribute to ongoing local water scarcity.

IDCA

Putting Data Center Water Use in Context

While data centers can severely impact local municipalities, their global water footprint is remarkably small compared to other sectors. On a per-square-foot basis, modern data centers consume significantly less water than standard commercial buildings like hospitals, senior care facilities, or courthouses, and vastly less than the forest products industry requires just to manufacture toilet paper. Furthermore, the "indirect" water utilized by utility companies to generate data center electricity has steadily declined over the past 25 years—a reduction that continues to accelerate as national grids transition toward wind and solar generation, which consume minimal water.

The IDCA Water Stress Index

The rapid expansion of digital infrastructure has placed unprecedented strain on local water supplies, sparking fierce community pushback against new facilities. While legacy data centers rely on water-intensive evaporative cooling, the fear that incoming "AI Factories" will drain local aquifers is largely a misconception. Next-generation gigascale AI facilities utilize closed-loop, direct-to-chip liquid cooling. Once initially filled, these high-performance systems consume minimal water during daily operations.

Despite these innovations, resource scarcity remains a severe threat to long-term digital growth. To provide actionable guidance, the IDCA developed a proprietary Water Stress Index to evaluate a nation's hypothetical water availability alongside the socioeconomic and political factors that impede development. Because local water stress dictates project viability, this 0-to-100 metric is integrated directly into the overarching IDCA Sigma Index to measure a nation's true readiness for sustainable digital expansion.

Water Stress Index

Country	Water Stress (0-100)
Bahrain	100
Belize	86
Libya	80
Kuwait	80
South Sudan	73
Singapore	73
Saudi Arabia	72
Bahamas	71
Yemen	71
Qatar	70
Algeria	70
Seychelles	65
Turkmenistan	65
Maldives	65
Gambia	65
Oman	64
Lebanon	64
Eritrea	64
Bangladesh	63
Tunisia	62
Burundi	62
Trinidad	62
Haiti	61
UAE	60
Hong Kong	60
Djibouti	60

Water Stress Index

Country	Water Stress (0-100)
Iran	59
Malta	58
Jordan	58
Israel	56
Sudan	56
South Africa	55
Timor-Leste	55
Egypt	55
Cyprus	55
Nigeria	54
Azerbaijan	54
Uzbekistan	53
Niger	53
Dominican	53
Zimbabwe	53
Kenya	53
Moldova	52
Botswana	52
Morocco	51
Rest of World	51
Pakistan	51
Malawi	51
Togo	50
Philippines	50
Uganda	49
Myanmar	49
India	49
Iraq	48
Eq Guinea	47
N. Macedonia	47
Rwanda	47
Mexico	46
Kyrgyzstan	46
Romania	46
Poland	46
El Salvador	45
Ethiopia	45
Czechia	45
Tanzania	45
Cote D’Ivoire	45

Water Stress Index	
Country	Water Stress (0-100)
Ukraine	44
China	44
Lithuania	44
Tajikistan	43
Sri Lanka	43
Jamaica	43
Turkey	43
Guatemala	43
Venezuela	43
Kazakhstan	43
Ghana	42
Congo, Dem	42
Taiwan	42
Thailand	42
Senegal	41
Mozambique	41
Honduras	41
Mongolia	41
South Korea	40
Panama	40
Angola	40
Madagascar	39
Germany	39
Italy	39
Congo	39
Cameroon	38
Mali	38
Armenia	38
Indonesia	38
Cambodia	38
Netherlands	37
Nepal	37
Mauritius	37
Denmark	37
Belarus	37
Bosnia	37
Zambia	36
Vietnam	36
Nicaragua	36
Hungary	35

Water Stress Index	
Country	Water Stress (0-100)
Slovakia	35
Spain	35
Ireland	35
Luxembourg	34
UK	34
CAR	33
Greece	33
Bulgaria	33
Russia	33
Serbia	33
Estonia	32
Belgium	32
USA	32
Japan	31
Albania	31
France	31
Guyana	31
Argentina	30
Colombia	29
Bolivia	29
Portugal	28
Gabon	28
Laos	28
Paraguay	28
Sierra Leone	27
El Salvador	27
Croatia	26
Latvia	26
Montenegro	25
Australia	25
Brazil	24
Switzerland	23
Puerto Rico	23
Slovenia	23
Georgia	23
Ecuador	22
Malaysia	22
Peru	21
Namibia	20
Austria	19

Water Stress Index	
Country	**Water Stress (0-100)**
Costa Rica	14
Finland	10
Chile	9
Sweden	6
Uruguay	3
Bhutan	3
Canada	2
Iceland	1
New Zealand	0
Norway	0

05 Data Center Connectivity

Data Center Connectivity

Connectivity is critical to the success of a data center facility, hub, and national-scale network. Data center connectivity can be considered as a function of the amount of landing stations for submarine fiber-optic cable (or connectivity to them), as well as the amount of terrestrial fiber-optic cable a nation has installed.

Separately, a nation's overall connectivity can be seen as a function of its internet access, its internet speeds, and the density of mobile connections throughout the nation, whether served by land-based towers or satellite services.

As noted elsewhere in this report, the disparity among the world's data center footprints is gaping, with a difference in server density of 100,000x from top to bottom. In other words, a few nations at the top consume gigawatts of electricity through hundreds or thousands of data centers and many millions of servers, whereas dozens of nations at the lower end barely consume a few megawatts and have precious few servers serving their populations.

Consequently, data center electricity consumption ranges from well above 5 percent of several developed nations' grids to less than 1 percent for 30 percent of all nations, and less than 0.1 percent for dozens of nations.

Clearly, governments, companies, and investors wishing to rectify this enormous disparity must think in terms of developing electricity grids, data centers, and connectivity simultaneously, or at least as integrated into an overall vision and plan.

The high-level numbers for submarine and terrestrial fiber-optic connectivity follow:

Submarine fiber-optic network

There is an estimated 1.3-1.5 million kilometers (800-900K miles) of submarine cables installed along the bottoms of the world's oceans. The total encompasses about 550 cable systems, installed over the past decades with an investment on the order of $400 billion.

The cable systems reach about 1,200 landing stations to date, with about 70 in the United States, 50 in the UK, and more than a dozen in a diverse group of countries that includes the Philippines, Indonesia, Japan, Spain, Denmark, Sweden, and several countries in the Middle East regions.

The cables currently deliver a peak of 2.8 terabits per second (Tbps) to the United States, which is equal to 8 megabits per second (Mbps) to every resident of the country. Single cable projects now routinely can carry 100 to almost Tbps to their customers.

Terrestrial Fiber-Optic Networks

A much larger problem for the world, especially its developing nations, is to develop the terrestrial fiber-optic networks, data center hubs, and individual services required to improve socioeconomic conditions. Looking at the big picture reveals installed terrestrial fiber-optic networks that total about 10 times the size of the submarine installation. There are almost 14 million kilometers (850K miles) of terrestrial networks, with a heavy skew towards the United States and China. This figure applies only to main networks, which are supported by tens of millions of kilometers of local, campus, building and associated networks. Useful figures for individual nations and their regions are difficult to validate. But one good example can be found in a new, proposed project to quadruple the size of terrestrial fiber-optic cable in Nigeria from 30,000 to 120,000 kilometers. More than $1 billion is being earmarked for this project by the World Bank, African Development bank, sovereign funds, and private investors.

This project shows that Nigeria, with a population of 240 million people, has far less than 1 percent of installed fiber than the United States, which has 340 million people. A similar disparity exists throughout the world, with developing nations requiring a magnitude or two of development to bring themselves anywhere close to the developed-world standard.

Local Connectivity

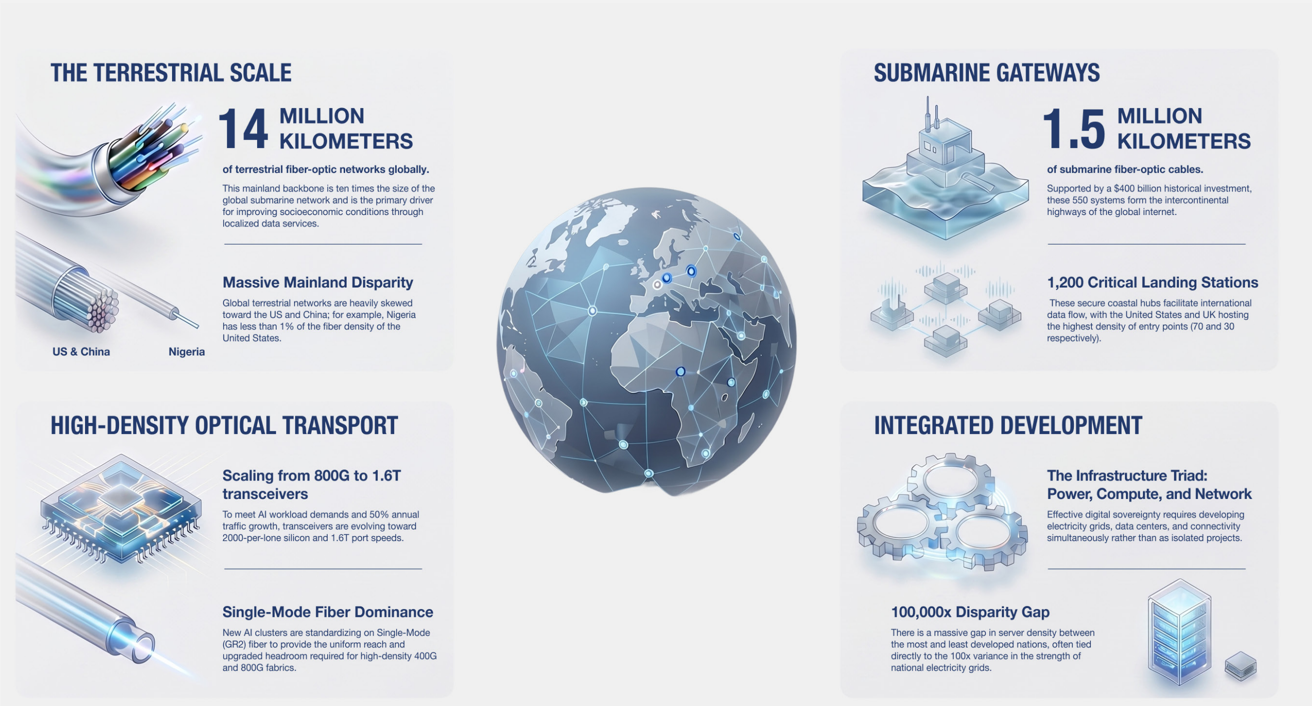
Fiber, whether brought by land or sea, is not the primary driver of overall national connectivity. As noted, copious seaborne bandwidth is available throughout the world, and local fiber trunk networks will be a function of new data center buildouts.

The fiber is thus manifested in the actual access and speed of internet service within each country. IDCA research finds a disparity of about 2X in local internet access, 3X in mobile access, and 10X in speed (whether uploading or downloading). These disparities are not as extreme as the disparities in the number of data centers and fiber networks, but can be expected to increase if the gaping chasm of 100,000X disparity among data center footprints Is not addressed.

There are disparities within the developing world as well. IDCA recognizes these differences through its Digital Readiness Index and related research, which takes a relative view of technology development. The Digital Readiness Index is found in the IDCA Digital Readiness Report 2026.

This table examines internet access (including mobile) and speed, adjusts it for the existing income levels within each country, and matches the data against an optimized model. The complex calculation can be expressed on a 0-100 scale, as shown in the table.

FIGURE 6. Global Data Center Connectivity



Source: IDCA Research

06 Data Center Security

Data Center Security

Historically, physical security was sometimes subjugated to cybersecurity rules, but today, industry leaders recognize both domains as co-equal pillars of a unified, comprehensive security strategy. The modern reality is that the cloud has a physical street address, and adversaries now utilize highly asymmetric tactics that completely blur the lines between digital and kinetic attacks. Whether a threat actor deploys a destructive malware payload to breach network defenses or utilizes an armed drone to physically disable a critical power substation, the ultimate goal is identical: to completely destroy or disrupt the data center's core mission execution.

Because a vulnerability in one domain can easily be leveraged to compromise the other, mitigating these threats requires security planning to begin at the highest organizational level rather than existing in isolated departmental silos. The financial and reputational stakes are unprecedented, with the average successful cyberattack costing enterprises around $20 million and operational downtime rapidly compounding those losses. True resilience demands that operators maintain absolute vigilance every second of the day, recognizing that threat actors constantly seek out the softest targets across both the network and the facility. The following sections detail the specific defensive architectures, normative standards, and operational protocols required to harden both the digital and physical perimeters of the modern data center.

Cybersecurity: Defending the Digital Ecosystem

The average successful cyberattack already costs G2000 companies around $20 million, according to IDCA research. But cybersecurity is now about much more than money – many attacks are catastrophic, designed to put companies and even entire nations out of business. Yesterday's potential for deepfake identities and related fraud have morphed into today's nightmare stew of AI slop and pernicious, AI-driven cybercrime and terrorism. Furthermore, the attacks on data centers – now viewed as critical infrastructure – in the Middle East have shocked data center operators and customers with the specter of breached physical security. As a result, cybersecurity is now twinned with physical security as part-and-parcel of a unified, comprehensive security strategy.

Normative Standards and Organizational Governance

To implement basic defensive measures, the 800-53 NIST standards have long been followed as the normative cybersecurity standards in the United States. They are continually updated and focus on protecting organizational operations and assets (and people) from hostile attacks, human errors, natural disasters, structural failures, hostile state actors, and general privacy risks. The NIST standards are "derived from mission and business needs, laws, executive orders, directives, regulations, policies, standards, and guidelines," according to the agency. Additionally, specialized frameworks like NIST 800-30 are highly utilized for risk assessment methodologies, particularly within the healthcare industry for HIPAA compliance, alongside other evaluative frameworks like OCTAVE.

Europe and much of the rest of the world follows the ISO/IEC 27000 standards. Identity management, access control, and threat identification remain at the heart of this approach. ISO has noted that “most organizations stick to the most basic form of threat intelligence,” and urge them to be more curious about the benefits of incorporating a more rigorous cybersecurity environment. Ultimately, security must begin at the organizational level. Developing security systems based on ISO-27001 requires continuous personnel training and education, the strict enforcement of policies, weekly reviews of security incidents, and both periodic internal and independent external audits to ensure compliance.

The Evolving Cloud and Malware Threat Landscape

Human-origin network risks, including hacker penetration, Denial of Service (DoS) network saturation, and malware, represent the most active daily threats to data center stability. Malware is actively targeting the cloud, shifting toward cloud control planes, SaaS apps, containers, Kubernetes, and even core hypervisors. If left unchecked, cloud-targeted malware compromises the vast computing power of the infrastructure, applications, and underlying data.

Modern threat reports highlight severe vulnerabilities, including ransomware that targets ESXi servers utilizing double-extortion tactics (data theft combined with leaks). Threat actors are increasingly deploying destructive wipers, supply-chain malware through poisoned CI/CD pipelines, and web shells used for persistent control and data exfiltration staging. Furthermore, cryptomining malware is frequently used to burn massive amounts of CPU and GPU resources, often masking deeper network intrusions. Once inside, attackers aggressively target Backup and NAS systems—sabotaging snapshots and encrypting files via SMB/NFS to systematically remove a facility’s recovery paths.

Defense-in-Depth and Infrastructure Hardening

Protecting the IT infrastructure requires a robust Defense-in-Depth strategy spanning external application security, network edge security, and inter-application/intra-application security. The foundational perimeter must be secured using firewalls, encryption, strict authentication protocols, and advanced Intrusion Detection and Prevention Systems (IDS/IPS). These IDS/IPS solutions, whether host-based (HIDS/HIPS) or cloud-native network appliances, are vital for recognizing and restricting malicious inbound traffic and analyzing system anomalies.

At the endpoint and workload level, operators must deploy modern Endpoint Detection and Response (EDR/XDR) platforms alongside Cloud Workload Protection Platforms (CWPP) to secure high-density VMs and Kubernetes clusters. To manage this massive influx of security data, data centers rely on Security Information and Event Management (SIEM) systems to provide centralized visibility and rapid threat response. Finally, these defensive architectures must never remain static; they require continuous validation through periodic internal and external vulnerability scanning, as well as aggressive Penetration Testing (Pen Tests) to discover and close exploits before hostile state actors or cybercriminals can leverage them.

Physical Security: Hardening the Modern Data Center

The attacks on data centers – now viewed as critical infrastructure – in the Middle East have shocked data center operators and customers with the specter of breached physical security. Cybersecurity is now twinned with physical security as part-and-parcel of a unified, comprehensive security strategy. As industry experts note, these are co-equal pillars; the cloud has a physical street address, and that address is increasingly vulnerable to kinetic attacks. Modern conflicts, such as the war in Ukraine, have demonstrated how drone warfare has fundamentally changed the battlefield, leaving traditional infrastructure highly exposed.

Core Principles and Perimeter Defense

All architectural, operational, and physical security measures must be designed to achieve one or more of the following: **Delay, Deter, Detect, Decide, and Act**. Physical security begins at the organizational level and heavily relies on establishing a secure perimeter. Best practices dictate installing a fence or wall at least 20 feet from the building, utilizing gate and guard kiosks, ensuring comprehensive lighting, and strictly avoiding any recognition signs that advertise the facility's purpose to the public.

Internal Access and Surveillance

Inside the facility, the security room should be located at or adjacent to the main personnel entrance, though the visitor sign-in area must be physically separated from the actual security operations. For highly critical facilities, this security room must be hardened with 16 mm (5/8 in) plywood, feature 180-degree peepholes, and maintain a fire separation of at least 2 hours from the rest of the data center. Strict access control is mandatory, requiring manual or automated Access Control List (ACL) management, detailed access logs, and RFID tracking for personnel, vendors, and equipment. Surveillance must include IP-based CCTV cameras running on UPS power, streaming directly to Network Video Recorders (NVR) with automatic cloud backups to maintain historical compliance.

Defending Against Modern Kinetic Threats

Facilities may already be resistant to accidental and other amateurish drone threats, but the recent war activity involves armed drones delivering missiles to breach the data centers. Attackers constantly seek "soft targets," which frequently include unprotected fiber vaults and rural electrical substations.

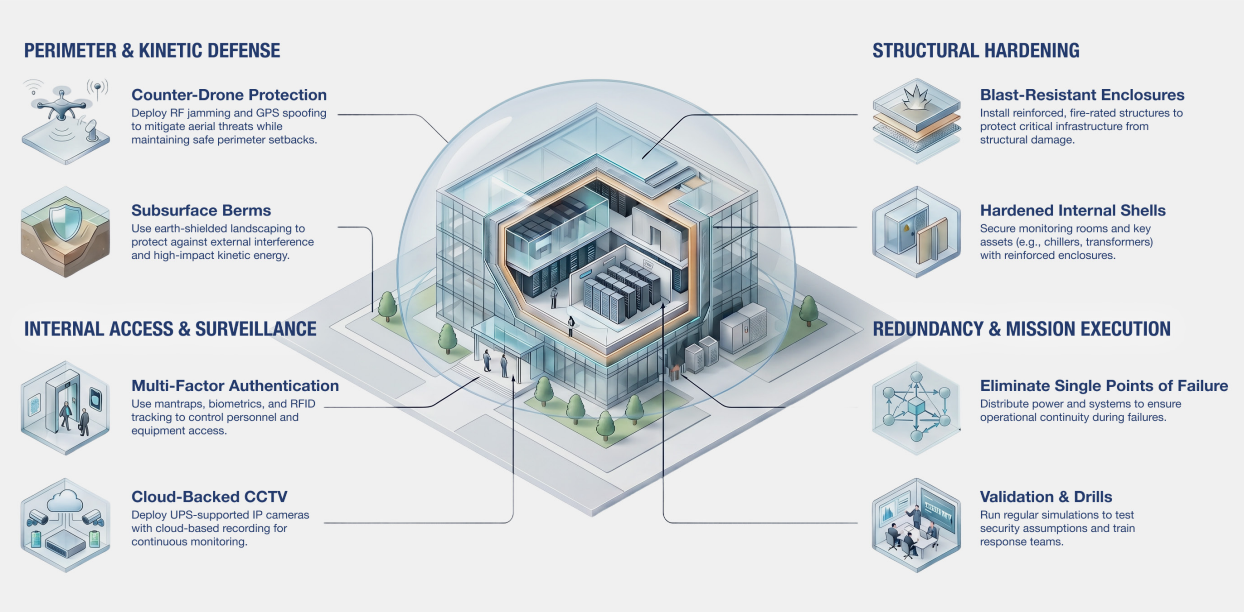
Immediate counter-drone measures include more sophisticated detection systems that can identify threats from further distances and trigger internal alarms. RF jamming and GPS spoofing can be brought to bear if facilities now operate in a consistently dangerous area, with budgetary concerns an obvious concern to be weighed against the effectiveness of these measures. Military installations can resort to interceptor drones and other weaponry, although this is not viable for most of the world's data centers. (For context, top-tier defense data centers are often built as underground bunkers capable of surviving a nuclear blast and feature extreme shielding against EMPs and biological weapons).

Cost/Benefit Analysis and Infrastructure Hardening
At a more modest budget and threat-aversion level, operators need to do a cost/benefits analysis regarding installing reinforced, blast-resistant roofs and facades, hardened enclosures for transformers, chillers, and fuel systems, and consider subsurface earth-shielded berms for certain infrastructure. To justify these investments, leadership must redefine the ROI of physical security by linking it directly to the safety of the workforce and the catastrophic brand impact of a business continuity failure.

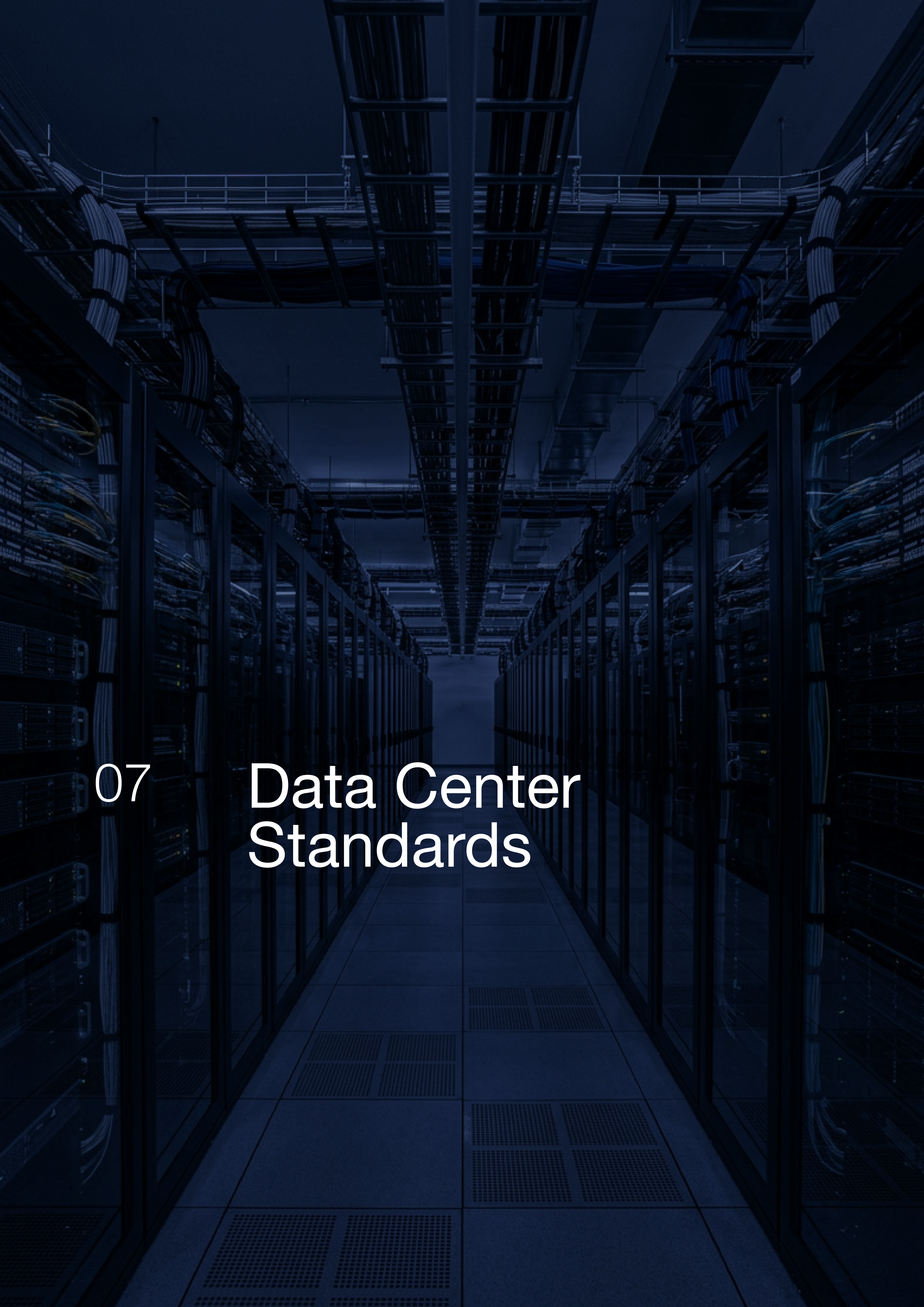
Redundancy, Topology, and Mission Execution
Redundancy takes on even more importance, with respect to electrical substations, cabling (especially exposed cabling), backup systems, and even walkways and service roads within a large facilities. But the best measure operators can take is to distribute resources as possible within the facility to lessen single points of failure. Large operators will have robust topology already in place, to distribute loads among data centers within a particular campus or wider region.

Ultimately, true physical security requires a focus on “mission execution”—identifying the absolutely essential elements required to keep an application running, and rigorously conducting tabletop exercises, drills, and continuous reviews of those continuity plans.

FIGURE 10. Hardened Data Center Security Architecture



Source: IDCA Research



07 Data Center Standards

Data Center Standards

There are a number of underlying, fundamental standards to be followed by data center builders and operators to reduce business risk and align performance with defined business requirements. Historically, many organizations have provided foundational guidelines for physical design, security, and operations. Today, modern frameworks like the IDCA's Infinity Paradigm leverage these foundational standards (such as those from ASHRAE, ISO, NFPA, and TIA) as a baseline, extending them into a comprehensive, application-centric model that governs the entire design, installation, and operation of a data center. The most important standards and frameworks come from the organizations shown below, and all should be familiar to experienced data center owners, operators, and managers.

ASHRAE

ASHRAE TC 9.9 Thermal Guidelines for Data Processing Environments is a core reference for allowable temperature/humidity ranges, recommended vs allowable operating environments, server inlet conditions, and reliability impact. The HVAC Handbook provides guidelines for cooling architectures, airflow management, and redundancy, and Standard 90.4 focuses on energy efficiency requirements for HVAC and power systems as well as PUE (Power Usage Effectiveness.)

BICSI

ANSI/BICSI 002 for data center design and implementation covers structured cabling, infrastructure lifecycle, security operations and commissioning.

IEEE

Relevant IEEE standards are the IEEE 3000 series for electrical series design, and IEEE 1100 for power quality and grounding of sensitive electronics.

ISO

International ISO standards include ISO/IEC 30134 for data center KPIs such as PUE, WUE, and CUE; and ISO/IEC 22237, which address data center infrastructure and facilities requirements.

NFPA

NFPA in the US covers fire protection. Relevant codes include NFPA 70 (National Electrical Code, NEC), NFPA 75 (Fire Protection of IT Equipment), and NFPA 76 (Telecommunications Facilities). They govern grounding and bonding, UPS/generator safety, and fire-rated cabling and power distribution.

TIA

TIA-942 is a common physical design standard for redundancy requirements, cable pathways, site space planning, resiliency, and topology.

IDCA: The Infinity Paradigm AE360® 2.0

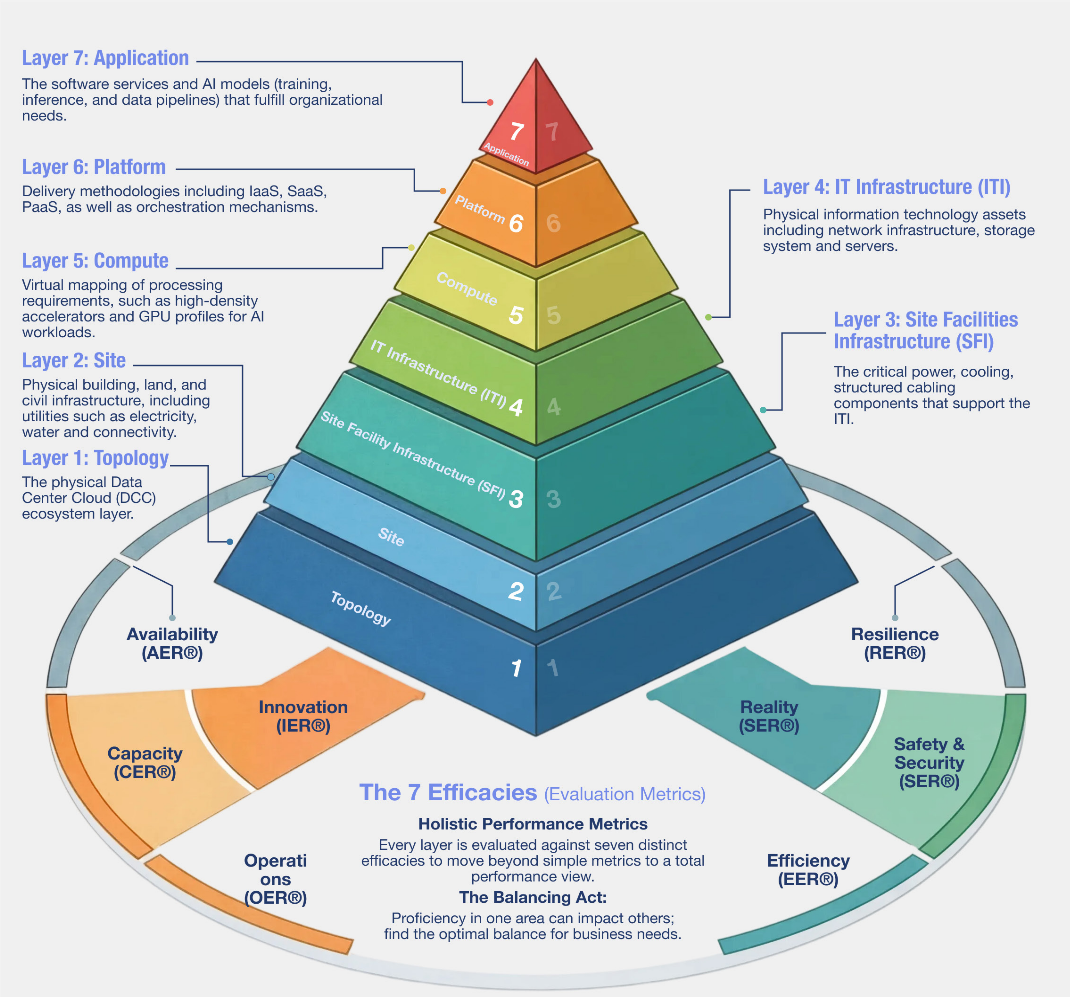
The Infinity Paradigm is a comprehensive, cloud-inclusive, and application-centric standards framework designed by the International Data Center Authority (IDCA). It serves as a framework for visualizing and analyzing an entire information technology system as a holistic and dynamic model. Rather than just evaluating the physical building, it qualitatively and quantitatively illustrates the myriad of interdependencies of a data center's various supporting components to ensure the facility successfully delivers applications.

The Application Ecosystem (AE)®

At the core of this standard is the concept that the data center is simply the infrastructure supporting the Application Ecosystem (AE). Because an application lives, breathes, and interacts only in an ecosystem that supports its purpose, the framework is modeled as a 7-layer pyramid that stacks physical infrastructure at the bottom and logical infrastructure at the top. The 7 layers are:

1. **Topology:** The foundation of the pyramid, specifying the connectedness, physical location, interconnectivity, and interrelation of various data center sites.
2. **Site:** The independently operated space (land, building, architecture, utilities) housing the data center infrastructure.
3. **Site Facilities Infrastructure (SFI):** Facility-level components utilized for application delivery, including power, cooling, structured cabling, and safety/security.
4. **Information Technology Infrastructure (ITI):** The hardware bridging the facility to the compute layers.
5. **Compute:** The processing resources driving the applications.
6. **Platform:** The software frameworks and operating systems.
7. **Application:** The peak of the pyramid and the ultimate purpose of the facility.

FIGURE 11. Application Ecosystem Layers



Source: IDCA Research

The 7 Core Efficacies

To understand the interdependencies of the 7 layers (Topology, Site, SFI, ITI, Compute, Platform, Application), AE360 evaluates them across seven specific metrics known as “Efficacies”. These are measured both quantitatively and qualitatively:

1. **Availability Efficacy Rating (AER):** Evaluates the probability that a layer or system will operate at or above required performance levels during its service mission.
2. **Capacity Efficacy Rating (CER):** Measures the ability to handle data and compute volume.
3. **Operations Efficacy Rating (OER):** Assesses the human and automated management practices.
4. **Resilience Efficacy Rating (RER):** Measures the ability to withstand and quickly recover from failures or disruptions.
5. **Safety & Security Efficacy Rating (SER):** Evaluates physical and logical protections against threats.
6. **Efficiency Efficacy Rating (EER):** Assesses the optimal use of power, cooling, space, and compute resources.
7. **Innovation Efficacy Rating (IER):** Measures the effective creativity in deploying new technologies and modernizing processes.

The Efficacy Score Rating (ESR)®

The ultimate goal of evaluating these layers and efficacies is to generate the Efficacy Score Rating (ESR) ®. The ESR is an aggregated scoring metric calculated through a complex algorithm that combines the Grade Levels and efficacy results. It applies weightings to favor functions most critical to the application’s survival.

The ESR provides a single, straightforward numerical output that represents the ecosystem’s true ability to reliably and sustainably meet business requirements, making it the most reliable rating for comparing data center delivery abilities. It can be applied to existing facilities and projects at the concept stage.

Grade Levels (G4 to G0)

While a single data center node might be evaluated, AE360 recognizes that application survival often requires multiple nodes. The Grade Levels (Gs) reflect this reality:

1. **G4 (Minimum Acceptable):** The lowest level of achievement awarded to a layer. It represents the highest allowable levels of risk, inefficiencies, and chances of failure.
2. **G3 (Average):** Represents an average exposure to risks, vulnerabilities, and inefficiencies.
3. **G2 (Excellent):** Represents a low exposure to risks and high operational performance.
4. **G1 (Exceptional):** The lowest possible level of risk and highest performance achievable within a single Data Center Node (DCN).
5. **G0 (Infinity):** The ultimate state of excellence. Because G1 is the maximum score for a single physical building, achieving G0 requires ecosystem-level resilience—meaning redundancies and failovers are embedded at the Logical Layers (Application, Platform, Compute) and spread across a multi-node Topology. Only the most demanding mission-critical environments require a G0 rating.

Controls and Regulatory Compliance

To determine these grades, AE360 utilizes a massive set of controls. It does not replace foundational standards like ASHRAE, ISO, NIST, NFPA, or TIA; rather, it uses them as a baseline and fills in the gaps.

Furthermore, AE360 integrates regulatory and governance criteria directly into the infrastructure grading. A facility’s grade can be impacted by its ability to physically and logically support compliance with Sarbanes-Oxley (SOX), PCI DSS, FISMA, HIPAA, and GDPR. For modern deployments, it even requires documented privacy constraints and ethical use policies for applications incorporating AI models and automated decision-making.

08 Data Center Investments

Data Center Investments

Global investment in data centers is approaching the $1 trillion mark annually, representing an amount close to 1 percent of the world's entire GDP. Data center investment has already reached $425 billion annually in the US, with an anticipated $600 to $700 billion planned for 2026 and beyond. Meta alone says it will commit $600 billion to data center development through 2028.

The major hyperscale cloud vendors are the largest and best-known investors in the US, and their reach extends into both developed and developing nations throughout the world. They account for 70 percent of data center investment spending in the US, and a substantial percentage in other nations.

United States

The big four players are AWS, Microsoft, Google, and Meta. Apple and Oracle also have multi-billion-dollar announcements. Nvidia, too, is indirectly driving a lot of investment as the demand for its AI chips has created a trillion-dollar backlog. And Elon Musk's Colossus project in Memphis, Tennessee is being operated by his xAI company, with 200,000 GPUs to date and stated plans to scale up to 1 million GPUs.

A survey of major plans from the big four vendors shows:

AWS

» More than $20 bllion for the Salem Township/Falls Township project in eastern Pennsylvania, encompassing 15 buildings and located close to an existing nuclear-power plant.
» A large commitment to the Midwest. This includes $15 billion for projects in Indiana, $12 billion for a project in Missouri, and $10 billion to expand its facilities throughout Ohio.
» $10 billion for a new facility located to the east of Charlotte, North Carolina.

Microsoft Azure

» Fairwater AI Center in Wisconsin. Now operational, this facility is receiving $3.3 billion initially to deliver 400MW of capacity, and planned to exceed a GW when fully built. It is located on a site originally envisioned for Foxconn to build mobile phones in the US.
» Another Fairwater project in Atlanta was built with a rack density of 140KW and row density of 1.36MW.
» Microsoft recently acquired 3,200 acres near Cheyenne, Wyoming to develop a hyperscale campus that would substantially augment its initial presence of almost a dozen data centers in the area.

Google

- $2 billion for a hyperscale facility in Ft. Wayne, Indiana.
- Project Peanut near Richmond, Virginia, part of an overall $9 billion buildout plan for multiple facilities in the state.
- Expansions ranging from $500 million up to expand facilities in the Midwest and West, including the states of Iowa, Nebraska, Oklahoma, and Nevada.

Meta Facebook

- $10 billion plan to bring gigawatt-scale facilities to Lebanon, Indiana, northwest of Indianapolis.
- Proposed Hyperion project in Richland Parish, Louisiana, in the northeastern region of the state, involving a surprising $27 billion investment. Meta would own 20 percent of the project, with private equity company Blue Owl commanding 80 percent. Blue Owl reports more than $300 billion under management. It has a worldwide reach with titular headquarters in New York, and Blackstone experience in its management team.
- Several other billion-dollar-scale projects in Texas, Wyoming, and the Midwest.

Private equity's role includes the Blue Owl investment noted above, as well as a $25 billion announced commitment from Blackstone, fluctuating announcements from Softbank, and an under-the-radar $15 billion investment fund from Japanese company Mitsubishi. Major data center operators, who still operate primarily as real-estate investments trusts (REITs) also remain active, including Digital Realty, Equinix, QTS Realty, CyrusOne, CoreSite, and Vantage.

Concerns about local power resources add another wrinkle to the discussion, with utilities such as NiSource, Black Hills Energy, and Constellation (which serves Data Center Alley in Virginia), increasingly becoming directly involved in data center development.

Other Regions

About half of the world's data center footprint operates outside of North America. There is thus several hundred billion dollars of annual investment in data centers planned in regions outside the US, even as specific information can be more difficult to validate. European nations are also increasingly focused on defining and protecting their data sovereignty, with concerns about loosening economic ties between the US and the world, and about major US cloud vendors operating in Europe being unable to stop their government from unwarranted intrusions into the privacy of European citizens. Similar legislative and policy initiatives are emerging in Asia, under the rubric of "localization" and data sovereignty.

Tables of key projects throughout the world's regions outside of North America is shown in the next few pages.

Europe					
Project / Platform	**Location**	**Capacity**	**Investors / Operators**	**Type**	**Status**
AWS Sovereign Cloud (Brandenburg)	Germany	Multi-campus (GW-scale planned)	Amazon Web Services	Hyperscale / sovereign	Announced
Microsoft Austria Region	Austria	Large region	Microsoft	Hyperscale	Under development
Google Sweden Region	Sweden	Hyperscale campus	Google	Hyperscale	Launched 2025
Pure DC Amsterdam Campus	Netherlands	~100+ MW	Oaktree Capital Management / Pure Data Centres	Hyperscale (leased)	Under construction
SEGRO / Pure DC London Campus	UK	Hyperscale	SEGRO	Hyperscale	Development
Digital Realty EU Portfolio	Pan-Europe	Multi-GW	Digital Realty	Colocation / hyperscale	Operational + expansion
Equinix EU IBX Expansion	Pan-Europe	Multi-site	Equinix	Colocation	Ongoing

Japan / Australia / Southeast Asia					
Project / Platform	**Location**	**Capacity**	**Investors / Operators**	**Type**	**Status**
AirTrunk Tokyo / Osaka expansion	Japan	~300+ MW combined	AirTrunk	Hyperscale	Expansion
AirTrunk Australia campuses	Sydney / Melbourne	Hyperscale	AirTrunk	Hyperscale	Operational + expansion
ST Telemedia Global DC	Singapore / Asia	Multi-GW pipeline	ST Telemedia Global Data Centres	Hyperscale	Expansion
Keppel DC Platform	Singapore	Large portfolio	Keppel Corporation	Colocation / hyperscale	Operational
Princeton Digital Group	Pan-Asia	Multi-country	Princeton Digital Group	Hyperscale	Expansion

India					
Project / Platform	**Location**	**Capacity**	**Investors / Operators**	**Type**	**Status**
AdaniConneX DC Platform	India (multiple cities)	Multi-GW target	Adani Group + EdgeConneX	Hyperscale	Under development
Yotta Infrastructure	Navi Mumbai	100+ MW campuses	Yotta Infrastructure	Hyperscale	Operational + expansion
CtrlS Datacenters	India	Large campuses	CtrlS Datacenters	Hyperscale	Expansion

Middle East					
Project / Platform	**Location**	**Capacity**	**Investors / Operators**	**Type**	**Status**
Khazna AI Data Center (Ajman)	UAE	~100 MW	Khazna Data Centres	AI / hyperscale	Under development
Gulf Data Hub expansion	UAE / Saudi	Multi-site	Gulf Data Hub + KKR	Hyperscale	Expansion
Saudi Vision 2030 DC program	Saudi Arabia	Multi-GW ambition	Public Investment Fund	Hyperscale / AI	Ongoing
AWS / Azure / Google regions	UAE / Saudi / Qatar / Israel	Regional	Big 3 hyperscalers	Hyperscale	Rapid rollout
Oman Digital Triangle	Oman	Multi-hub, 9GW	Sovereign	Private AI Hubs	Ongoing

Latin America					
Project / Platform	**Location**	**Capacity**	**Investors / Operators**	**Type**	**Status**
Ascenty Platform	Brazil / LatAm	300+ MW	Ascenty + Digital Realty	Hyperscale	Expansion
Scala Data Centers	Brazil	Hyperscale	Scala Data Centers	Hyperscale	Expansion
Querétaro DC cluster	Mexico	Growing hub	Multiple hyperscalers	Hyperscale	Rapid buildout
AWS Mexico Region	Mexico	Region-scale	Amazon	Hyperscale	Recently launched
Microsoft Chile Region	Chile	Region-scale	Microsoft	Hyperscale	Launch phase

Africa					
Project / Platform	**Location**	**Capacity**	**Investors / Operators**	**Type**	**Status**
Africa Data Centres Platform	Pan-Africa	Multi-country	Africa Data Centres	Colocation / hyperscale	Expansion
Equinix (MainOne acquisition)	West Africa	Regional	Equinix	Colocation	Expansion
Oracle Cloud (Kenya / Morocco)	Africa	Regional	Oracle	Hyperscale	Announced
AWS / Azure South Africa	South Africa	Regional	AWS / Microsoft	Hyperscale	Operational

09 Data Center Regulation

Data Center Regulation

United States

At the moment the United States does not have anything that could be described as a “data center law.” There are the usual environmental and emissions control concerns addressed by longstanding legislation, including the Clean Air Act, dating to 1963 and administrated by the Environmental Protection Agency (EPA). Its sibling, the Clean Water Act, passed in 1972, and administered at the federal and often state level by National Pollutant Discharge Elimination System (NPDES) regulations.

Consideration must also be made to the National Environmental Policy Act (NEPA), signed into law in 1970, which is coordinated by the Executive Office of the President of the United States through the Council on Environmental Quality. There is also the Federal Energy Regulatory Commission (FERC), an independent agency that was created during the very active era of 1970s legislation during the Nixon, Ford, and Carter administrations to address severe air and water quality problems throughout the US that were brought about by what was then a heavily industrialized economy. FERC overseas whole electricity markets and licenses hydropower projects, in addition to activities with transport of fossil fuels.

At the state level, there have been hundreds of recent bills regarding data centers introduced throughout several legislatures. Proposed areas of new regulation include prices for large-load electricity consumers, tax policies, renewable-energy mandates and energy efficiency standards, and controls over foreign ownership. One bill, in the state of Maine, has made it through the state legislature and is expected to become law. It will prohibit the construction of data centers larger than 20MW until 2027, and is positioned as a “pause” rather than a prohibition.

Outside of US

Outside of the US, the European Union has developed its Energy Efficiency Directive, which requires an honest reporting of data center energy performance. The more stringent ideas of mandatory sustainability reporting, efficiency benchmarks, waste heat reuse requirements, and AI regulation appear to be on the horizon.

There are, of course, nations that have already capped or banned the creation of new data centers, including Ireland, Singapore and South Korea. (There are also reportedly strict controls in China, but this nation is sui generis, that is, one of a kind in controlling and building out its data center and AI center footprint).

These caps and restrictions are driven by the single, simple issue of a lack of available electricity. Many regions in the US are also experiencing this phenomenon, with the result that county and local planners say they are simply unable to issue new data center permits. Developers are now waiting until 2032 for new land and power availability in Loudoun County, VA (the world's most densely packed data center hub), as well as several states in the Midwest (Illinois, Indiana, Wisconsin, Iowa, and Minnesota), according to recent IDCA research. Power scarcity is also present in California, effectively capping growth in several of its regions.

10 Community Pushback

Community Pushback

Community pushback against large new data centers has been reported over the past year in many parts of the United States. At the highest level, Senator Bernie Sanders from Vermont has urged a national "pause" on building new data centers, although his statements on the matter have received very little support. But the issue remains. It raises the question of whether legislation focused on data center construction, effects, limits, or even prohibitions will be considered in upcoming legislative sessions and future elections.

Over the past two years, however, most data center guidelines and potential pushback have occurred at the local level. A very recent proposed project in the St. Louis, MO metro led to the recall of city council members. A similar project in Joliet, IL received near-unanimous approval by local leaders after an extended public debate. A developer in the Los Angeles metro region recently withdraw plans for a project after vociferous community protests. And in the State of Maine, as noted above, a "pause" on data centers larger than 20MW until 2027 is apparently set to become law.

Dozens of similar efforts show the key areas of electricity and water use, noise, and economic impact emerging consistently.

Community opposition to data center expansion has intensified, particularly around energy, water, and land use.

Factually speaking, data centers throughout the US today consume one gallon of water for every 10,000 gallons consumed for overall human use. IDCA research has also found no direct connection between new data center electricity consumption and immediate consumer price increases. As far as noise, the majority of data center developers are now focusing on rural areas or locations on the edge of populated areas, and build in substantial setbacks for the actual facilities.

The seemingly key issue that arises repeatedly – and arose in the very early days of the original large data centers from Amazon, Google, and Microsoft – is a lack of transparency by the developers. A new data center is typically proposed by a local developer with a generic, opaque name that aims to mask the true developer. The true developer's name is often shared with some (but not all) local political and business leaders, however, leading to community frustration.

IDCA encourages developers to be transparent when they set their sights on a new data center site. This advisement is made now that there are often competitive reasons for the opacity (that is, one large cloud developer doesn't want one of its competitors to know early on where it is building), but recent experience has shown that concerns about electricity, water, and noise can be sufficiently addressed if companies are upfront about who they are and what they intend to do.

IDCA research has found that significant community and political pushback starts to occur in nations once their data center footprints have reached the 5-percent consumption level of national grids. Singapore has doubled that consumption level already, several European nations are well past it, and the United States has now reached the 6-percent level overall.

11 Workforce Development

Workforce Development

Data centers create the foundation for IT-related workforce development on a national scale. IDCA research shows that as of today IT-related jobs comprise a range of between 0.1 percent and 4.0 percent of the population of the world's nations. IDCA has created an optimized model that recommends that 2.5 percent of a nation's population is employed in tech in some capacity to ensure a thorough, successful Digital Economy creation and management. This number can vary based on local conditions and national expectations.

This recommendation calculates a lack of more than 100 million IT-related jobs worldwide, if nations are to benefit from the creation of healthy data center foundations and associated digital infrastructure.

Developing nations account for 80 percent of this deficit. Viewed regionally, Asia represents 45 percent of this need, Africa represents 27 percent, and Latin America 7 percent. It's important to remember, though, that even the most highly developed nations have a need for continuous improvement in their education, training, and workforce development.

To address this issue, IDCA recommends a workforce development program for data center and hub training and operations that encompasses a series of courses during a one-year period, ranging in length from one week to six weeks, scalable to certify a nation's total need. This program would serve as a complement and augmentation to the nation's overall IT education and training initiatives.

Specific country information is found in the following figure. More detailed information about program construction and execution is found in the IDCA Digital Economy Report 2026.

Global IT-Related Jobs Deficit

Country	Jobs Deficit
India	28,816,072
China	17,516,918
Rest of World	7,150,332
Pakistan	5,860,945
Nigeria	5,837,736
Indonesia	5,278,181
Bangladesh	3,782,670
Brazil	3,314,576
Ethiopia	3,182,710
Congo, Dem	2,807,133
Mexico	2,398,985
Philippines	2,359,553
Egypt	2,096,245
Vietnam	1,669,332
Tanzania	1,648,561
Iran	1,586,669
Russia	1,353,280
Kenya	1,313,598

Global IT-Related Jobs Deficit

Country	Jobs Deficit
Myanmar	1,286,549
Sudan	1,272,171
Uganda	1,239,108
South Africa	1,187,071
Yemen	1,032,083
Thailand	996,182
Turkey	964,529
Algeria	924,621
Angola	921,309
Iraq	899,138
Colombia	899,079
Mozambique	874,457
Madagascar	802,392
Ghana	796,562
Morocco	788,863
Uzbekistan	752,430
Cote D'Ivoire	744,130
Cameroon	722,858
Niger	687,125
Nepal	674,935
Venezuela	659,330
Peru	641,829
Ukraine	629,822
Argentina	628,058
Mali	614,405
Malawi	545,365
Zambia	521,628
Sri Lanka	457,854
Senegal	436,268
Guatemala	432,258
Zimbabwe	403,698
Cambodia	402,400
Burundi	357,539
Ecuador	353,786
Rwanda	338,788
South Sudan	304,628
Haiti	295,245
Malaysia	278,722
Bolivia	273,763
Honduras	253,771
Tajikistan	248,843
Jordan	247,018
Tunisia	234,693
Togo	232,485
Dominican	230,596
Turkmenistan	212,437
Sierra Leone	212,034
Kazakhstan	188,401

Global IT-Related Jobs Deficit	
Country	Jobs Deficit
Libya	185,388
Italy	184,661
Laos	173,139
Azerbaijan	171,526
Chile	162,011
Congo	159,768
Nicaragua	159,171
Kyrgyzstan	157,024
Paraguay	138,659
Lebanon	137,673
CAR	136,825
El Salvador	130,211
Romania	106,377
Eritrea	89,570
Serbia	86,955
Belarus	83,165
Greece	80,413
Spain	78,743
Costa Rica	68,620
Gambia	67,293
Kuwait	65,649
Israel	64,772
Poland	64,320
Namibia	63,655
Panama	63,241
Mongolia	62,226
Jamaica	58,612
Gabon	57,351
Eq Guinea	54,549
Bosnia	53,990
Oman	52,776
Hungary	50,317
Moldova	50,018
Albania	49,067
Slovakia	48,916
Bulgaria	48,009
Botswana	47,756
Armenia	45,848
Puerto Rico	44,810
Georgia	39,957
Portugal	37,640
Japan	33,242
Timor-Leste	33,165
Uruguay	30,665
Djibouti	27,582
N. Macedonia	26,452
Trinidad	22,676
Croatia	20,946

12 Data Center Planning & Design

Data Center Planning

IDCA finds development opportunities within the data, experiences, and insights from looking at each nation's unique conditions separately. An effective process typically begins by conducting an evaluation of the national digital infrastructure environment and projected workload demand. Based on this assessment, national digital infrastructure standards can be established, to define the baseline for a facility or strategy for multiple sites.

Considerations include optimal architecture, scalability pathways (how quickly and in which specific increments new facilities should be built), and also aligns projects with internationally recognized data center standards and certification frameworks.

As any government entity, NGO, or investor knows, standards serve as a key de-risking mechanism for financing partners and strategic investors. By ensuring that the design, governance structure, certification pathways, and supplier ecosystem are aligned with internationally recognized benchmarks, the project becomes more credible and bankable. It can also build upon work that has already been conducted.

In parallel, governance structure and potential joint-venture arrangements can be clarified, while ensuring that the facility operator, suppliers, and key contractors meet the relevant certification requirements. The objective is to structure projects in a way that allows them to be presented to investors as a robust, standards-based digital infrastructure asset.

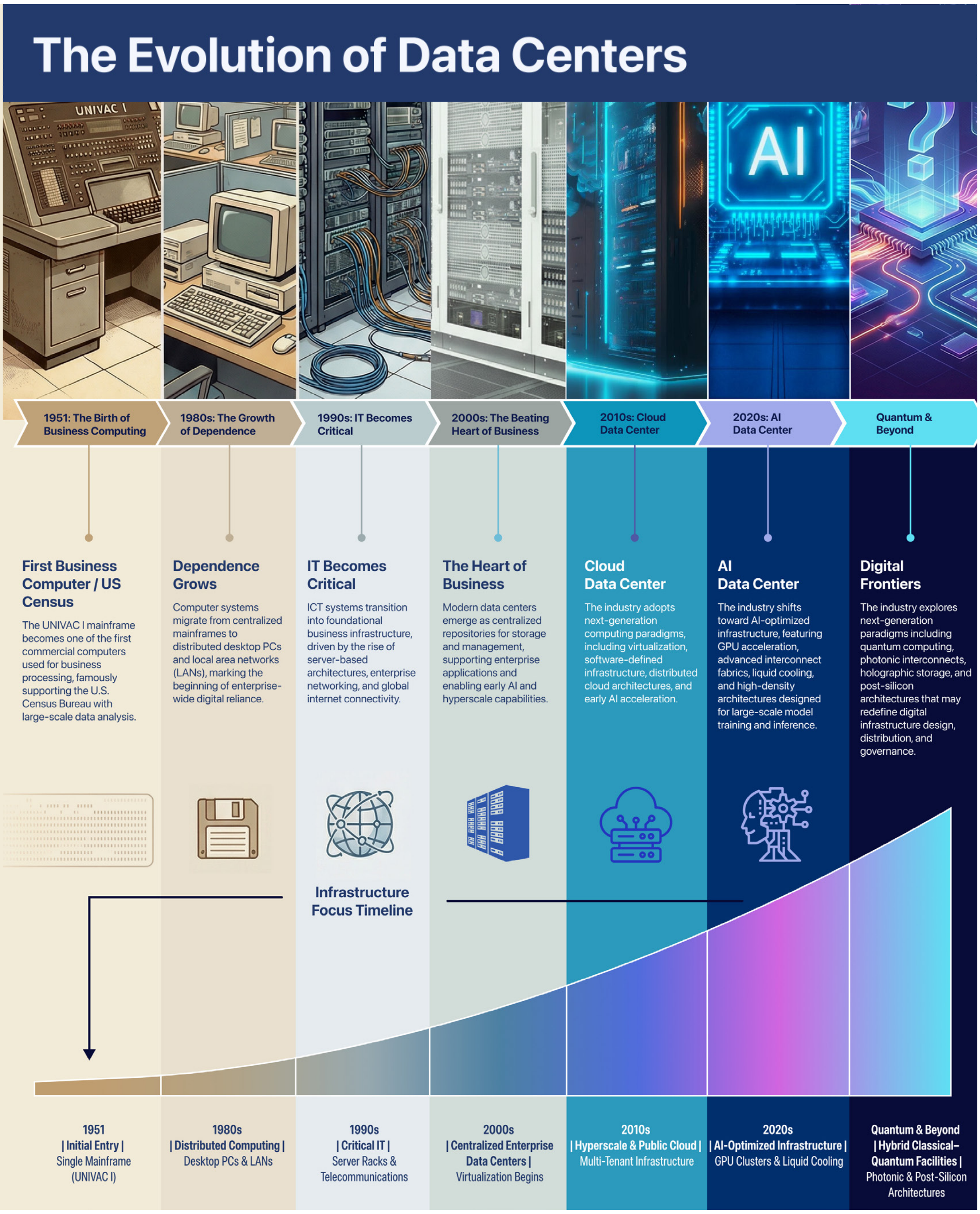
Many nations desperately need adequate digital infrastructure to enable government services, private-sector support, consumer experiences, and to build inherent digital sovereignty. The latter topic is now a top-level issue in a world that, paradoxically, can appear ever-more borderless by dint of today's sophisticated digital interoperability while at the same time is gravitating toward concerns about physical borders and sovereign security.
Long-term sustainability is also a priority as new facilities are conceived with digital sovereignty and scalability in mind.

Data Center Design

Data centers have evolved in the decades since they first made a significant appearance, and sit at the start of a new inflection point today. There are currently around 10,000 traditionally recognized data centers in the world, consuming almost 90 percent of the total data-server workload.

A rough calculation shows that 10,000 facilities consume slightly more than 60GW of power, or an average of 6MW per facility. One-third of this energy is consumed by cooling and administrative operations. Within these buildings, rack densities traditionally average 10-12KW per rack, which gives an average data center a few hundred racks.

FIGURE 12.



Source: IDCA Research

There is no need to be more precise about this particular calculation, as most data centers are several years old and reflect earlier times. There is also such a wide diversity in data center sizes that knowing the average data center size serves little useful purpose to most operators. The rack density number is more useful, however. IDCA has analyzed this issue, in particular throughout Northern Virginia's "Data Center Alley." This region, centered on Loudoun County, VA now has 50 million square feet of data center space under roof. Rack densities throughout this vast footprint average 10-12KW, exactly in line with global industry estimates.

But times are changing. Nvidia is the most prominent high-end chipmaker to make astonishing predictions, showing single-board densities of as much as 1.2MW for products that will appear as early as 2027. The question for data center developers and operators thus centers around future rack densities (and consequent cooling requirements), the amount of building and land space required for scalable facilities, and most important, the mix of applications, services, and required chips for new facilities. Even with talk of GW-level facilities and multi-GW strategies becoming an industry norm, it is essential to analyze future requirements with as much precision as possible

The range of scenarios for data center development across regions encompasses projects ranging from a single MW or two (as being deployed in many developing countries today), through 100-500MW facilities that will have a 60/40 to 70/30 mix of cloud computing and AI development, to "pure" AI centers devoted to AI training and to addressing the most difficult, complex problems across a variety of scientific disciplines. Within this continuum of scale, there are many paths to success for companies and nations. The situation does not lend itself to quick, facile calculations for particular projects, but a few key, general technological trends can be outlined and described.

Paas/IaaS/SaaS

Stepping back a bit, a traditional way to view data center development is to look at the well-established PaaS/IaaS/SaaS continuum, which has been a foundation of cloud computing for more than a decade. Along with this concept, designers can think of service models, site selection, and physical fundamentals such as cooling and topology, as shown in the following images.

FIGURE 13. Cloud Computing Service Models

Cloud computing is categorized into three primary service models - Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Each model offers different levels of control, flexibility, and operational responsibility.

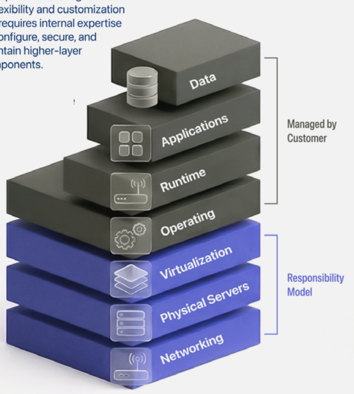
The key distinction lies in the solution stack, which defines which technology layers -from networking and hardware to applications and data - are managed by the cloud provider and which remain the responsibility of the customer.

As organizations move from IaaS to SaaS, operational complexity decreases and deployment speed increases. However, granular control over the environment is reduced as more responsibility shifts to the provider.

IaaS (Infrastructure as a Service)

Foundational Cloud Infrastructure
IaaS delivers virtual machines, storage, and networking resources on demand, effectively providing "compute as a service" to replace or extend physical data center hardware.

IaaS provides the highest level of flexibility and customization but requires internal expertise to configure, secure, and maintain higher-layer components.

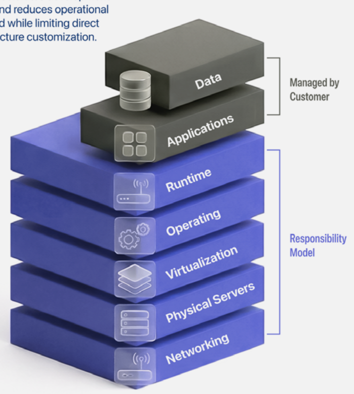


Common IaaS Examples:
Amazon EC2, Google Compute Engine, Microsoft Azure Virtual Machines.

PaaS (Platform as a Service)

Managed Application Environment
PaaS provides a managed runtime and application platform that simplifies software development and deployment without requiring infrastructure management.

PaaS accelerates development cycles and reduces operational overhead while limiting direct infrastructure customization.

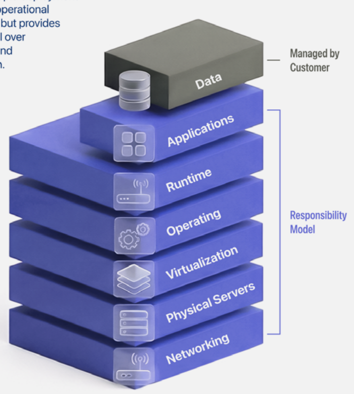


Common IaaS Examples:
AWS Elastic Beanstalk, Microsoft Azure App Services, Google App Engine.

SaaS (Software as a Service)

Fully Managed Applications
SaaS delivers complete, ready-to-use applications via the web on a subscription basis, eliminating the need for infrastructure or platform management.

SaaS offers rapid deployment and minimal operational responsibility but provides limited control over architecture and customization.



Common IaaS Examples:
Customer relationship management platforms, collaboration tools, business intelligence applications, and industry-specific cloud software.

Cloud adoption is not simply a technology decision, it is a shift in operational responsibility. Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) each redefine how control, risk, and accountability are distributed between provider and customer.

As organizations move from IaaS to SaaS:

- Deployment speed increases
- Operational complexity decreases
- Granular infrastructure control is reduced

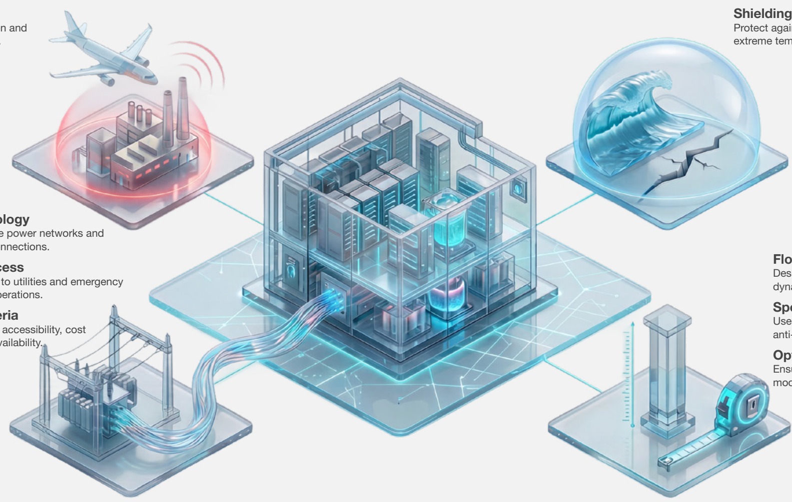
Understanding where responsibility sits — across networking, physical servers, virtualization, operating systems, runtime, applications, and data — is critical to governance, security posture, compliance, and long-term cost management.

Digital transformation requires clarity in architecture decisions. Responsibility models must be defined, measured, and aligned with enterprise risk frameworks.

In the realm of modern data center design and planning, digital twin concepts and advanced simulation tools are increasingly employed to validate infrastructure before physical deployment. By importing detailed 2D or 3D AutoCAD and Visio diagrams directly into Data Center Infrastructure Management (DCIM) platforms, developers can create a comprehensive virtual replica of the entire facility down to the device level. This virtual model seamlessly interfaces with Computational Fluid Dynamics (CFD) software to generate dynamic environmental and thermal flow simulations. These integrated simulation tools allow engineering teams to conduct rigorous "what-if" capacity planning, validate cooling architectures, and proactively identify potential operational vulnerabilities—such as thermal hot spots or airflow inefficiencies—based on predictive modeling and historical data patterns. Ultimately, leveraging these simulation technologies ensures that the facility's physical and logical infrastructure is fully optimized for maximum efficiency and resilience before any capital is committed to construction.

FIGURE 14.

Data Center Site Selection



Source: IDCA Research

Site-selection and ensuring that the right location is chosen are two of the most critical decisions in a data center lifecycle. Effective site selection directly influences avoidance of risk and exposure to hazards, operational resilience, scalability, energy availability, connectivity, and long-term sustainability.

As compute density increases and infrastructure becomes more strategic, the margin for error continues to narrow. Due site selection requires balancing access to scalable power, water, and workforce, as well as reliable connectivity with risk mitigation across environmental, industrial, and physical factors. This integrated approach forms the foundation for resilient, secure, and future-ready digital infrastructure.

AI Centers

AI appears set to fundamentally transform data centers, adding substantial new capacity and making them more efficient, secure, and sustainable. As the strategic importance of AI-driven data centers grows, they will continue to play a critical role in supporting the demands of AI and the broader Digital Economy.

Integrating AI into data center operations has led to significant improvements in power management, cooling, security, and resilience, ensuring that data centers can meet the growing demands of AI applications while minimizing their environmental impact. IDCA's research into AI is fully outlined and analyzed in the upcoming IDCA Special AI Report 2026.

Almost all data center developers at the moment need to think about creating what they would think of as AI centers. The question arises is whether a new AI center needs to have a gigawatt-plus vision, accompanied by tens or hundreds of billions of dollars of investment.

The answer is "yes" for some organizations and nations, but not for all. For example, when looking at creating an AI center, IDCA's research has found that different nations, with ambitions of different sizes, can use some general guidelines at the beginning of their planning. IDCA research envisions three levels of AI center, each with their own scale, cost, and goals:

Small AI Centers with power requirements of 1 to 5MW. Capital expenditure should be $15-20M per MW for facilities alone, with operational expenditure of $0.9-1.2M per MW annually. ROI timelines can be expected to be two to three years for commercial use cases, and three to five years for government applications. It should take from six to nine months from planning to operation.

AMD Epyc 7742 or similar chips would deliver between 10 and 20 petaflops per megawatt. This is not enough for AI modeling, but it can serve the models to users, conduct inference, process large data sets and regional analytics, and run AI research experiments.

A small AI center could also handle agriculture, education, and government services applications. Some percentage of its resources could, of course, also be used for traditional data center services.
Smaller data centers can also continue to be built in developed countries to spur and support local economic growth, improve internet speeds and reliability, and address repository issues involving digital sovereignty.

Mid-Size AI Centers would range from 5MW to 20MW in size. Capital expenditure should be $15-20M per MW for facilities alone, with operational expenditure of $0.8-1.2M per MW annually. ROI timelines can be expected to be three to four years for commercial use cases, and four to six years for research applications. It should take from nine to 15 months from planning to operation.

As with small centers, mid-size centers could deliver 10 to 20 petaflops per megawatt, or a maximum of 400 petaflops. For example, a Ruby installation of 10MW would also support 10 Ruby boards and the exaflops that come with them.

A facility of this size would appear to lie in the shadow of massive projects. But at this scale, they are approaching general AI modeling and training capability. Continued work on SLMs and the efficiency of even LLMs could make a mid-size facility tenable as an AI factory. They could support limited model training, training in fields such as autonomous vehicles, language processing in real time, specialized research, distributed inference networks, and edge computing distribution for larger-scale AI environments. As with small facilities, a percentage of a mid-size facility could also be used for traditional data center services.

Large AI centers extending from today's minimum of 20MW to several hundred megawatts and beyond will continue to be the province of government cryptography and defense research, the most demanding scientific modeling and visualization, and the continued growth and sophistication of training large models. Capital expenditure is an open question, giving the apparent need to replace the highest-end chips with new models every two years or less, given the aggressive projections that Nvidia has made with respect to its chip development. Operational expenditure of $0.7-0.9M per MW annually can be expected. ROI timelines might run five to eight or more years, as facilities of this scale are often justified through strategic national interests rather than direct financial returns It should take from 18 months to three years or more planning to operation.

AI-as-a-Service can be expected to become a popular application for the most demanding needs. Coreweave is the pioneer in this area, reportedly amassing more than 250,000 Nvidia GPUs to provide "GPU Cloud Computing." The company invested $1.6 billion in a facility in Texas that Nvidia has called "the fastest supercomputer in the world," supported by more than 6,000 miles of fiber-optic cable to meet its processing needs.

FIGURE 15.

The AI Data Center Matrix

Chip Model	Power Requirment (Watts)	Peak Performance	Cooling Necessity
NVIDIA H100	700 W	4 Petaflops	Advanced Thermal Management
NVIDIA H100	1,000 W	20 Petaflops	Direct-To-Chip (D2C) Liquid
NVIDIA H100	200 W	~ 0.5 Petaflops	High-Density Pod Deployment

Source: IDCA Research

On-Site Power Generation

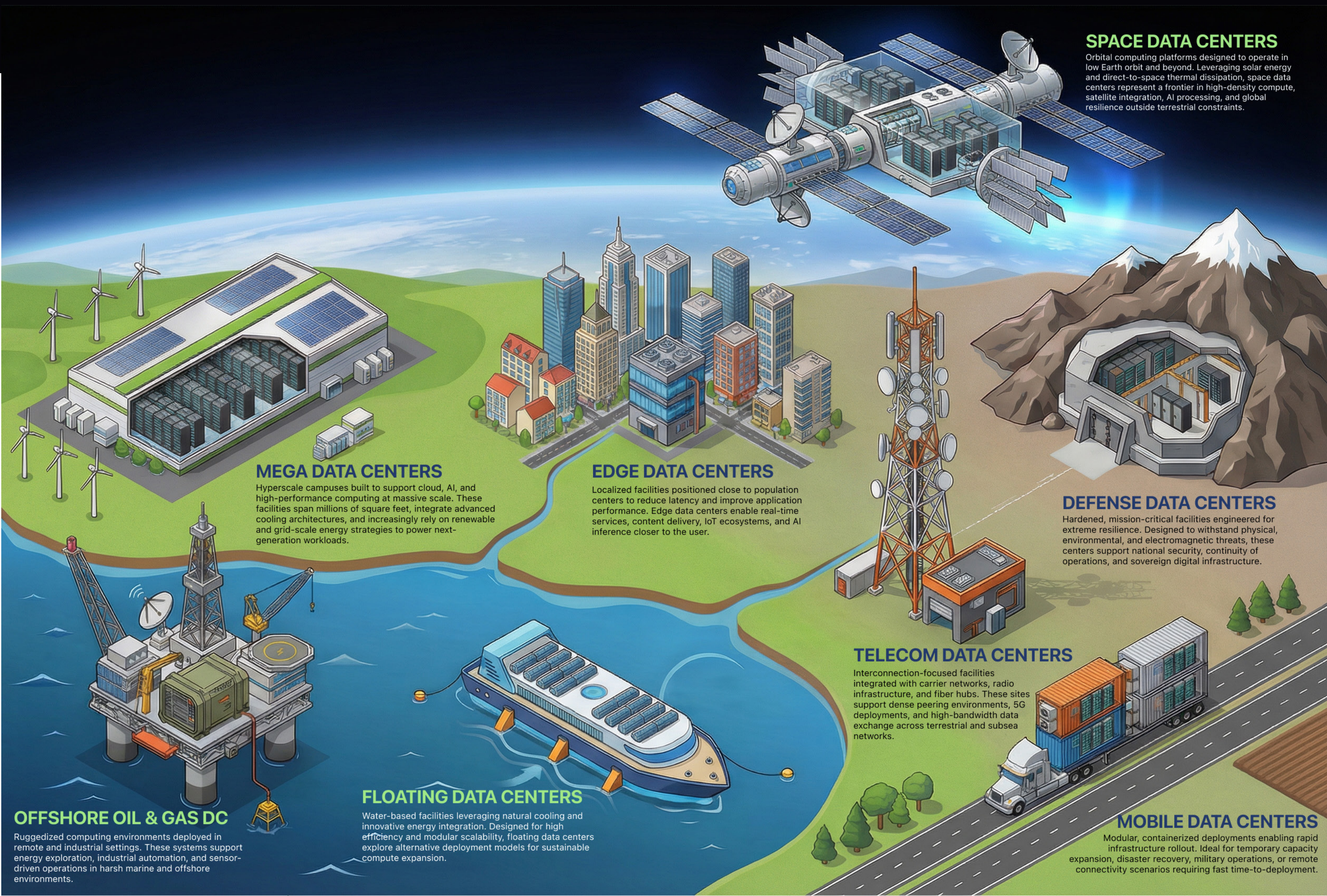
As data centers face severe utility transmission delays and unprecedented power requirements from AI workloads, relying solely on legacy municipal grids is no longer a viable strategy. To ensure deployment speed, digital sovereignty, and continuous operation, the industry is rapidly shifting toward resilient, sustainable on-site power generation.

Small Modular Reactors (SMRs)
Nuclear power is making a resurgence as a solution for on-site data center power. Small Modular Reactors (SMRs) are compact, prefabricated units that can provide reliable, zero-carbon, and scalable power typically ranging from 10 MW to 300 MW. Major hyperscalers are actively securing this technology: Google recently signed a 500 MW deal with Kairos Power, Microsoft secured a 20-year agreement to restart a reactor at Three Mile Island, and Amazon is utilizing up to 1,920 MW from the Susquehanna nuclear plant. While SMRs face strict regulatory licensing hurdles, high initial costs, and public perception challenges, their compact footprint and scalable output make them a critical enabler for the future of AI factories.

Hydrogen Fuel Cells
Through a chemical reaction combining hydrogen and oxygen, fuel cells generate direct current (DC) electricity with water as the only byproduct. Technologies such as Phosphoric Acid (PAFC), Proton Exchange Membrane (PEM), and Solid Oxide (SOFC) fuel cells can achieve high efficiencies ranging from 40% to over 80%. Because they operate almost silently and can be built to virtually any scale, they can be highly effective for situations where community noise regulations or rapid deployment are primary concerns. While challenges remain regarding the sourcing, infrastructure, and storage of hydrogen, as well as higher initial capital costs compared to diesel generators, major providers are actively deploying fuel cells to bypass constrained utility grids.

Renewable Energy and Advanced Storage Integrations
Renewable deployments are most viable when structured as grid-tied systems utilizing net metering, or when paired with highly advanced energy storage. For off-grid “island mode” facilities, excess renewable energy can be captured using pumped hydroelectric storage—where water is pumped to an upper reservoir during low demand, and released through turbines to generate electricity when wind or solar drops.

FIGURE 16. Spectrum of Data Center Architectures



From hyperscale campuses and urban edge facilities to offshore platforms, mobile deployments, hardened defense sites, and now orbital computing environments, data centers are expanding across multiple domains to support the growing demands of AI, cloud, telecommunications, and sovereign digital strategies.

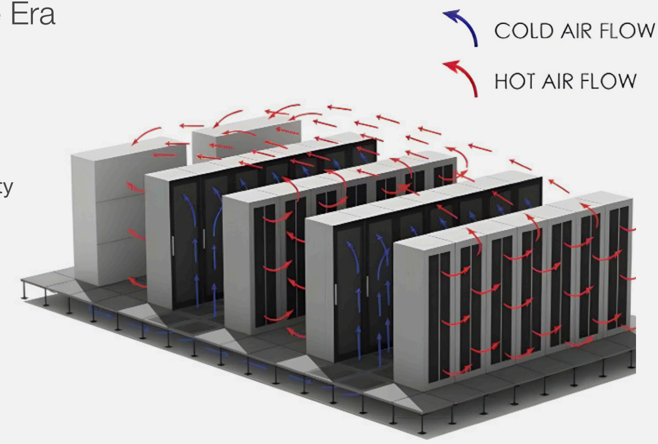
As compute intensity accelerates and resilience becomes a national priority, infrastructure must evolve beyond traditional boundaries. The future of the Digital Economy will be powered by a multi-domain ecosystem spanning land, sea, and space.

The spectrum of data center architectures reflects a fundamental shift: digital infrastructure is becoming specialized, and strategically aligned with energy, security, and performance requirements.

FIGURE 17.

Past Designs: The Warehouse Era

- Raised floors with CRAC/CRAH units
- Airflow via perforated tiles & plenum
- Scalability through floor space, not density
- Typical racks: <10 kW/rack



Source: IDCA Research

Data centers over the past 30 years use Computer-Room Air Conditioners (CRACs), a traditional, self-contained air-conditioning system that consumes substantial power. It originally matched the power required by a facility's computing and networking equipment, and today averages about a 50-percent premium to power requirements.

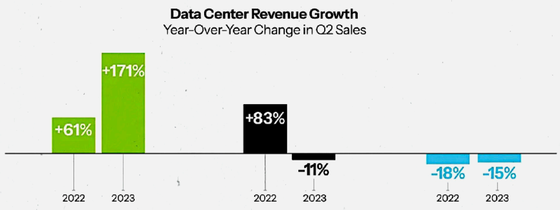
In contrast, a Computer-Room Air Handler (CRAH) needs chilled water that passes over a cooling coil to deliver the required chilled air. It does not have an internal compressor, as do CRACs. CRAHs are, in general, more efficient in large data centers than CRACs, but require substantial amounts of water and can lead to complaints from neighbors in residential areas about noise from their rooftop water chillers. Working to improve efficiency is the concept of hot aisle/cold aisle operations. As rack densities increase and the number of racks expands, heat management becomes a more difficult issue. Seeing that it was quite inefficient to achieve a uniform operating temperature, IBM engineer Dr. Bob Sullivan came up with the hot aisle/cold aisle approach, which improves air-flow and heat management by arranging the fronts of servers to face each other in a "cold" aisle and the backs of servers facing each other in a "hot" aisle.

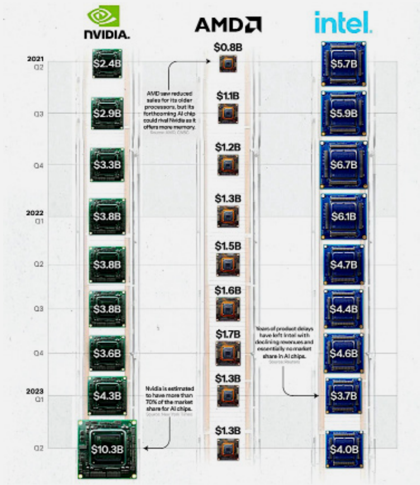
Cold air is delivered from raised floor tiles or overhead ducts into the cold aisle, then passes through the racks. The hot-air exhaust is then drawn back to the CRAC/CRAH units to be cooled. Initial cooling energy consumption dropped by 20 to 40 percent when this approach was first implemented, although now has become the industry standard.

FIGURE 18.

Catalyst: The Rise of AI Chips

- NVIDIA A100/H100: up to 700W TDP, 80GB HBM2e, MIG tech
- SambaNova SN40L: integrated 3-tier memory for fast training
- Recogni Edge Chips: ~25W power, 1000 TOPS for inference
- High-performance chips drive thermal and power redesign





Source: IDCA Research

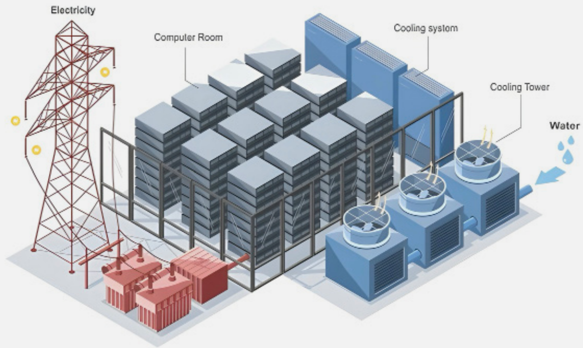
The figure above provides a brief look at a few of the newer, higher performance AI chips available for data center operators and builders. AI chips are almost uniformly also known as GPUs, or graphics processing units. They provide substantially more power – often magnitudes more – than their CPU predecessors. The AI chip development race shows no signs of slowing down. Nvidia, for example, has said its new "Vera Rubin" chips, set to be available sometime next year, will provide twice the performance as their current high-end "Blackwell" chips. Nvidia also claims to have a trillion-dollar backlog on orders for its Blackwell chips. IDCA can provide a complete analysis of all CPUs and GPUs being used in modern data centers and AI centers upon request, tailored to specific questions and data center designs.

FIGURE 19.

Source: IDCA Research

Catalyst: The Rise of AI Chips

- Direct-to-Chip (D2C) removes 70–80% of heat
- Rear-Door Heat Exchangers (RDHx): retrofit-friendly up to 25 kW/rack
- Immersion Cooling: gained efficiency, niche deployments, low scalability



AI chips reach a performance level that requires direct-to-chip cooling, as they produce too much heat to be managed solely by traditional CRAC/CRAH systems. This approach directly removes 70 to 80 percent of the heat they produce. AI chip manufacturers work steadily to reduce the amount of energy required by their chips even as performance continues to grow.

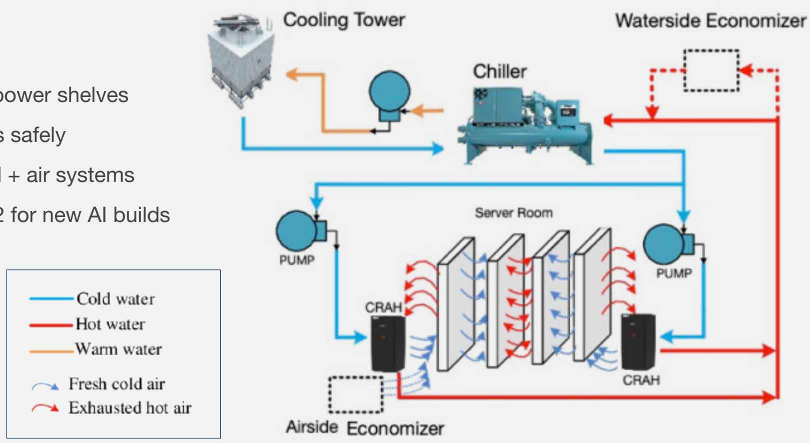
For example, the Nvidia H100 requires 700 watts and produces four peak petaflops. The more powerful B200/B100 (Blackwell) requires about 1,000 watts and produces 20 peak petaflops. In contrast, the Google custom ASIC TPU v5P requires about 200 watts to produce almost half a peak petaflop. This latter chip is designed to be deployed in swarms, or "pods" of tens of thousands of chips. As noted above in the description of Figure 12, IDCA can provide a complete analysis of all CPUs and GPUs being used in modern data centers and AI centers upon request, tailored to specific questions and data center designs.

FIGURE 20.

Source: IDCA Research

Modern Designs: Integration & Power

- Transition to 800V HVDC power shelves
- CDUs manage liquid loops safely
- Hybrid retrofits blend liquid + air systems
- Regulatory trend: PUE <1.2 for new AI builds

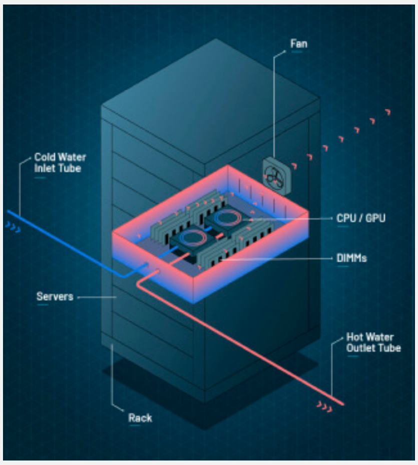


The higher densities and power requirements for modern data centers and AI centers require more robust power integration than in the past. The above graphic shows just one example of the basic overall power configuration, powered by 800-volt DC power shelves. In this approach the DC is delivered directly to the rack, then stepped down at that point. This approach adds a higher skill requirement to install and manage, but is a necessity in an age when rack densities are rapidly moving from the traditional 12-15KW to 100-200KW and higher.

FIGURE 21.

What is Direct-to-Chip Cooling?

- Closed-loop system: coolant circulates directly over CPU/ GPU cold plates.
- Primary loop: facility water -> CDU -> heat exchanger.
- Secondary loop: rack manifold -> cold plates -> return.
- Captures 70–80 % of chip heat before it enters room air.
- Enables >50 kW/rack densities with standard rack widths.



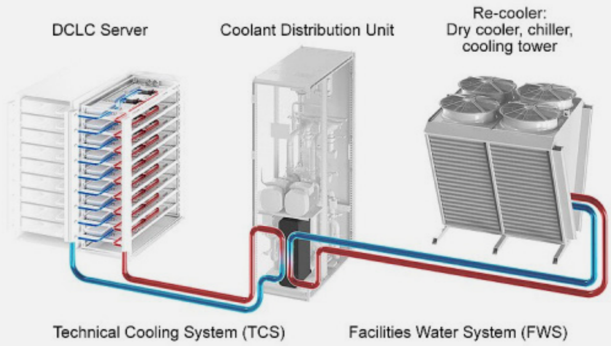
Source: IDCA Research

Direct-to-chip cooling is a more expensive way to cool than using CRAC/CRAH systems, but is a necessity in AI centers with their more moden, very high-performance GPUs. The illustration above provides a general picture of how it is accomplished.

FIGURE 22.

Components of a D2C System

- Direct-to-Chip (D2C) removes 70–80% of heat
- Rear-Door Heat Exchangers (RDHx): retrofit-friendly up to 25 kW/rack
- Immersion Cooling: gained efficiency, niche deployments, low scalability



Source: IDCA Research

The above illustration shows a big-picture view of the direct-to-chip cooling systems that will become predominant in AI centers.

FIGURE 23.

Design & Deployment Considerations

- Retrofit-friendly: use RDHx + CDU to integrate with existing plants.
- Material compatibility: avoid mixed metals to prevent corrosion.
- Maintenance: quick-disconnect couplings enable service without draining loops.
- Safety: leak sensors, dripless fittings, and dielectric coolants.
- Scalability: modular manifolds support incremental rack additions.

Source: IDCA Research

Every phase of the data center lifecycle is sequential and critical. IDCA provides holistic means and frameworks that unify feasibility and planning, site selection, engineering & design, construction, operations, optimization, and end-of-life decisions under a single strategic model aligned with business goals and objectives.

13

IDCA Data Center Indexes

Index Overview

IDCA conducts ongoing research across hundreds of social, economic, energy, and technological factors to derive a series of indexes that rank the nations of the world. The rankings are not meant to be a competition, but rather a relative look at how well each nation of the world is progressing as a society.

Data is examined with respect to how well each nation is progressing relative to its current income levels and societal conditions. The analysis employs an optimized model that describes a nation in which all factors are ideal. Furthermore, each factor is measured with respect to its effect on every other factor, creating a complex series of mathematical interactions within the optimized model as well as within each nation's results.

Overall scores can be derived from this analysis, and scores can also be derived across single factors and broader categories. A final step in the analysis is to express category scores and overall scores on a scale of 0-100, with 100 representing the ideal, optimized model. Scores on the 0-100 scale can be thought of more as percentiles rather than simple, linear numbers; that is, the higher the score the more difficult it becomes to improve it further. Conversely, nations that score in the lower sections of the rankings are those in which improvement, given a clean, fairminded application of investments, can be achieved most quickly.

Nations are complex entities, and the application of socioeconomic analysis, goals, and programs to any nation is not a precise science. However, IDCA in working with investors, companies, NGOs, and governments creates viable road maps for particular projects and nations as a whole. The data contained in the entire IDCA data set reveals unique insights that can be applied to immediate and long-term substantial improvement to a nation's digital infrastructure and societal conditions.

The complexity of the tasks involved with national improvement begets the notion that a single index will not provide all conceivable viewpoints or be able to focus on all conceivable priorities or drive all conceivable programs. IDCA thus produces a series of indexes, as noted at the beginning of this section.

For example, IDCA releases its Digital Economy Index and Digital Economy report each year, which expresses results across the broad categories of Economy (which includes digital infrastructure), Environment (which includes sustainable energy), and Social/Governance (which includes human development, income parity, and cost of living). Through this index, IDCA reports the percentage of each nation's Digital Economy with respect to its overall Economy. This approach is ideal to get a high-level view of where each nation stands, how much progress it has made relative to its resources, and where it should focus to achieve improvement.

In this Data Center report, the analysis drills into the particulars of data center consumption, stress on water resources and electricity grids, and societal progress. This report is therefore able to provide four ancillary indexes to the Digital Readiness Index. Each can be applied to specific viewpoints or issues under examination.

IDCA Gamma Index

This index examines the composite effect of all the technological and socioeconomic factors that go into the Digital Readiness index, without adjusting for sustainable energy. It is inspired by the mathematical gamma function, which provides compilation techniques for numbers of all types.

Doing this provides an unadorned view of how technology has affected each nation and how societal factors are either enhancing or impeding progress. By decoupling sustainability from the analysis, this index is useful in determining how investment in technology can achieve for society, independent of improving sustainable grids.

Data Center Usage and Growth Matrix

Country		Gamma Index	Country		Gamma Index
1	Finland	85	37	Bhutan	64
2	Scandinavia	83	38	Malta	63
3	Netherlands	83	39	Hungary	62
4	Estonia	80	40	Croatia	61
5	New Zealand	79	41	Oman	61
6	Switzerland	79	42	Greece	61
7	Germany	78	43	Ukraine	60
8	Belgium	78	44	Moldova	60
9	Slovenia	77	45	Israel	60
10	Austria	76	46	Italy	59
11	Japan	76	47	Armenia	59
12	Canada	74	48	Slovakia	58
13	UK	74	49	Kazakhstan	58
14	France	74	50	Romania	57
15	Singapore	73	51	Vietnam	57
16	Australia	73	52	Mauritius	57
17	South Korea	73	53	Tunisia	57
18	Malaysia	71	54	Bulgaria	57
19	Seychelles	71	55	China	56
20	Czechia	70	56	Costa Rica	56
21	Belarus	70	57	Montenegro	56
22	Luxembourg	70	58	Rwanda	55
23	UAE	70	59	Thailand	55
24	Hong Kong	70	60	Saudi Arabia	54
25	Lithuania	69	61	India	54
26	Poland	68	62	Kyrgyzstan	53
27	Ireland	68	63	Qatar	53
28	Chile	68	64	Jordan	53
29	Portugal	68	65	Serbia	53
30	Uruguay	68	66	Bahamas	53
31	Spain	67	67	Botswana	53
32	Taiwan	66	68	Argentina	53
33	Georgia	66	69	Azerbaijan	52
34	Cyprus	65	70	Algeria	52
35	Latvia	65	71	Mongolia	51
36	USA	65	72	Morocco	51

Data Center Usage and Growth Matrix

Country		Gamma Index	Country		Gamma Index
73	Bosnia	51	115	Guyana	40
74	N. Macedonia	51	116	Cambodia	39
75	Maldives	51	117	Togo	39
76	Timor-Leste	51	118	Sierra Leone	38
77	Albania	50	119	Paraguay	38
78	Indonesia	50	120	Zambia	36
79	South Africa	50	121	Malawi	35
80	Kuwait	50	122	Lebanon	34
81	Egypt	49	123	Nicaragua	34
82	Sri Lanka	49	124	Mali	34
83	Puerto Rico	49	125	Dominican	33
84	Brazil	49	126	Uganda	33
85	Turkey	49	127	Madagascar	33
86	Bahrain	48	128	Honduras	33
87	Peru	48	129	Gabon	32
88	Colombia	48	130	Zimbabwe	32
89	Nepal	48	131	Niger	32
90	Senegal	48	132	Mozambique	31
91	Jamaica	47	133	Djibouti	30
92	Ecuador	47	134	Venezuela	30
93	Philippines	47	135	Guatemala	27
94	Iraq	47	136	Angola	27
95	Belize	47	137	Cameroon	27
96	Russia	47	138	Sudan	26
97	Namibia	47	139	Yemen	26
98	Trinidad	46	140	Nigeria	25
99	Tanzania	46	141	Burundi	25
100	El Salvador	46	142	CAR	24
101	Ethiopia	45	143	Eritrea	24
102	Bangladesh	45	144	Libya	22
103	Uzbekistan	44	145	Congo	19
104	Myanmar	43	146	Congo, Dem	19
105	Gambia	43	147	Haiti	17
106	Ghana	43	148	Turkmenistan	17
107	Pakistan	42	149	Rest of World	16
108	Bolivia	41	150	South Sudan	12
109	Tajikistan	41	151	Eq Guinea	4
110	Laos	41		**World**	**52**
111	Panama	41			
112	Mexico	40			
113	Cote D'Ivoire	40			
114	Kenya	40			

IDCA Sigma Index

This index is inspired by the use of sigma in mathematics for summaries of all types. This index integrates the results of the Gamma index with adjustments for water stress and stress on electricity grids. The water and electricity stress factors are themselves complex formulas involving resources, current usage, and the effects of growing usage.

Among the components is the amount of current “headroom” in its electricity grid a nation has for immediate buildout of new data centers. The Sigma Index is useful in determining a nation’s overall suitability for rapid data center growth and the digital infrastructure that would accompany it. The highest ranking nations in this index approach the optimized model more closely than in other IDCA indexes, because the optimized model was created to face the same “headroom” constraints faced by real-world nations.

The list of Goldilocks nations cuts across regions, income tiers, and population sizes. It thus includes Romania, Greece, Slovenia, Malaysia, Vietnam, Brazil, Chile, Ethiopia, Kenya, Tanzania, and others. Each of these nations has its own unique conditions and challenges, so should not be viewed as highly similar. IDCA research has detailed information on each of these nations’ conditions and prospects, so queries about it are welcomed.

Data Center Usage and Growth Matrix

#	Country	Sigma Index	#	Country	Sigma Index
1	Finland	99	48	Vietnam	71
2	Sweden	97	49	Costa Rica	71
3	Norway	97	50	Slovakia	71
4	New Zealand	94	51	Tunisia	70
5	Iceland	94	52	Montenegro	70
6	Belgium	91	53	China	70
7	Austria	90	54	Romania	69
8	Japan	89	55	Bulgaria	69
9	Canada	89	56	Rwanda	68
10	Slovenia	89	57	Thailand	68
11	Australia	87	58	India	67
12	France	86	59	Kyrgyzstan	67
13	South Korea	86	61	Argentina	67
14	Malaysia	85	62	Serbia	66
15	UK	84	63	Saudi Arabia	66
16	Belarus	83	64	Jordan	66
17	Luxembourg	83	65	Azerbaijan	65
18	Uruguay	83	66	Bosnia	65
19	Chile	83	67	Mongolia	65
20	UAE	83	68	Timor-Leste	65
21	Denmark	82	69	N. Macedonia	65
22	Czechia	81	70	Morocco	65
23	Portugal	81	71	Albania	64
24	Spain	81	72	Ireland	64
25	Poland	80	73	Maldives	64
26	Taiwan	80	74	Bahamas	63
27	Georgia	80	75	Indonesia	63
28	Bhutan	80	76	Qatar	63
29	Latvia	78	77	Singapore	63
30	Cyprus	77	78	Brazil	63
31	Malta	76	79	Lithuania	63
32	Netherlands	75	80	Seychelles	63
33	Croatia	75	81	Algeria	63
34	Estonia	75	82	Sri Lanka	63
35	Greece	74	83	Puerto Rico	63
36	Oman	74	84	Peru	62
37	USA	74	85	Egypt	62
38	Hungary	74	86	South Africa	62
39	Ukraine	73	87	Colombia	62
40	Israel	73	88	Turkey	62
41	Armenia	73	89	Botswana	62
42	Switzerland	73	90	Kuwait	62
43	Moldova	72	91	Ecuador	61
44	Italy	72	92	Senegal	61
45	Kazakhstan	72	93	Nepal	61
46	Germany	71	94	Namibia	61
47	Mauritius	71			

Data Center Usage and Growth Matrix

Country		Sigma Index	Country		Sigma Index
95	Jamaica	61	129	Uganda	46
96	Russia	60	130	Dominican	46
97	Philippines	60	131	Gabon	46
98	Hong Kong	60	132	Honduras	46
99	Bahrain	60	133	Mozambique	45
100	El Salvador	60	134	Zimbabwe	45
101	Tanzania	60	135	Venezuela	43
102	Ethiopia	58	136	Niger	42
103	Bangladesh	57	137	Djibouti	42
104	Iraq	57	138	Guatemala	41
105	Uzbekistan	57	139	Cameroon	40
106	Myanmar	57	140	Angola	40
107	Ghana	56	141	Sudan	39
108	Gambia	56	142	Nigeria	38
109	Trinidad	56	143	Yemen	38
110	Laos	55	144	CAR	38
111	Bolivia	55	145	Burundi	37
112	Panama	55	146	Eritrea	36
113	Pakistan	55	147	Congo	33
114	Tajikistan	55	148	Libya	32
115	Guyana	54	149	Congo, Dem	32
116	Mexico	54	150	Haiti	30
117	Cote D'Ivoire	53	151	Rest of World	29
118	Kenya	53	152	Belize	28
119	Cambodia	53	153	Turkmenistan	26
120	Sierra Leone	52	154	South Sudan	25
121	Paraguay	52	155	Eq Guinea	17
122	Togo	52		World	63
123	Zambia	50			
124	Malawi	48			
125	Nicaragua	48			
126	Mali	47			
127	Lebanon	47			
128	Madagascar	47			

The Goldilocks Zone

This index is inspired by the fairytale notion of something being "not too hot, not to cold, but just right." It is derived from separating the purely technological factors found in several IDCA indexes, then comparing their performance relative to a nation's income and cost of living. Its inspiration comes from the notion that technology can be disruptive if applied too quickly, and that the ideal conditions exist in those nations in which technology is not lagging but is also not getting ahead of itself either. The Goldilocks Nations are "just right" in their current technology adoption, given their societal conditions.

Data Center Usage and Growth Matrix

	Country	Goldilocks		Country	Goldilocks
1	Colombia	5.2	24	Bolivia	4.4
2	N. Macedonia	5.2	25	Chile	4.4
3	China	5.2	26	Senegal	4.4
4	South Africa	5.2	27	Hungary	4.4
5	Montenegro	5.1	28	Romania	4.4
6	Malaysia	5.1	29	Rwanda	4.3
7	Kazakhstan	5.0	30	Nepal	4.3
8	Morocco	5.0	31	Gambia	4.3
9	Brazil	5.0	32	Timor-Leste	4.2
10	Armenia	4.9	33	Laos	4.2
11	Togo	4.9	34	Namibia	4.1
12	Serbia	4.8	35	Albania	4.1
13	El Salvador	4.8	36	Turkey	4.0
14	Algeria	4.8	37	Latvia	4.0
15	Cambodia	4.7	38	Lithuania	4.0
16	Seychelles	4.7	39	South Korea	4.0
17	Argentina	4.7	40	Honduras	4.0
18	Bulgaria	4.7	41	Peru	4.0
19	Mauritius	4.6		**World**	**4.6**
20	Pakistan	4.5			
21	Ethiopia	4.5			
22	Paraguay	4.4			
23	Ecuador	4.4			

Emissions Reduction Challenge (ERC) Index

Readers will note that sustainable energy is removed as a factor in the Gamma and Sigma Indexes above. This is done to enable a clear focus on technology development by itself and its related impact on societal conditions. However, sustainability is a key component in IDCA's Digital Readiness Index, representing around 25 percent of each nation's overall score. The global imperative for sustainable energy, and its use by data centers, remains.

Although data centers themselves use about 2 percent of the world's electricity, and thus contribute only about 0.5 percent of the world's greenhouse gas (GHG) emissions, it behooves the industry to be as active as possible in creating and using sustainable energy. Furthermore, data centers provide the foundation of the world's sustainable Digital Economy, so have amplifying effects on GHG production that reaches far beyond their local electricity use. With that in mind, IDCA has integrated each nation's current overall GHG emissions with its societal ability (according to hundreds of socioeconomic data factors) to address the challenge it faces in reducing these emissions.

The ERC Index groups 183 nations into four categories: green (representing a relatively small challenge), yellow (moderate challenge), red (serious challenge), and a zone that goes beyond red to purple (severe challenge). The bad news is that most of the world's top emissions producers fall into the purple zone: China, the United States, India, Russia, Brazil, Indonesia, and Mexico. These nations produce at least 60 percent of the world's GHG emissions, and tip the entire world into the purple zone.

Among developed economies, only Scandinavia and the Baltics exist within the green zone. Most nations within the green and yellow zones, by contrast, are in various stages of economic development; their relative lack of emissions is from economic under-development rather than great sustainability (with some notable exceptions such as Rwanda, the DRC, Uruguay and Costa Rica).

The Emissions Reduction Challenge (ERC) shows each nation's total challenge; it does not view the challenge on a per capita or relative economic basis. Thus, larger countries face larger challenges; whether they have the societal conditions in place to address the challenge effectively is borne out in the ERC data. IDCA expresses these results in color-coded layers, so as to list the challenges into least difficult (green), moderately difficult (yellow), very difficult (red), and extremely difficult (purple) categories.

The original process envisioned a three-layer, green-yellow-red chart of results. But the challenges facing the world's top emissions producers and their apparent lack of ability to address them significantly prompted the creation of a layer that goes "beyond red" in its difficulty. Thus, the purple layer was born. The sheer difficulty faced by the world's top producers, all of whom are in either the purple or red layer, skews the entire world into the red zone. This squares with the notion that everyone indeed lives on the same planet, and that the challenges each nation faces is shared by its planetary neighbors.

The ERC does not present an optimistic picture, to be sure. But it does provide a measurable guide to each nation's challenge; with its results presented in natural logarithms, it can also quickly be determined how relatively difficult each nation's challenge is as well, and investment levels correlated to that difficulty can be calculated, too.

The Emissions Reduction Challenge (ERC) - Africa	
Country	ERC (A)
Rwanda	0
Mauritius	0.6
Djibouti	2.3
Mali	2.7
Namibia	2.8
Gambia	2.9
Botswana	3
Tunisia	3.9
Tanzania	3.9
Gabon	4.1
Uganda	4.7
Senegal	5.2
Eq Guinea	5.7
Malawi	5.7
Burundi	5.8
Morocco	7.3
Zambia	7.5
Cote D'Ivoire	7.5
Ghana	7.6
Eritrea	8.1
Ethiopia	9.8
Madagascar	10.5
Algeria	10.5
Cameroon	11.4
Kenya	12.6
Mozambique	14.1
Egypt	14.3
South Sudan	14.7
Libya	14.9
Togo	16.1
South Africa	20.2
Congo	21.1
Angola	21.5
Sudan	23
Nigeria	34.6

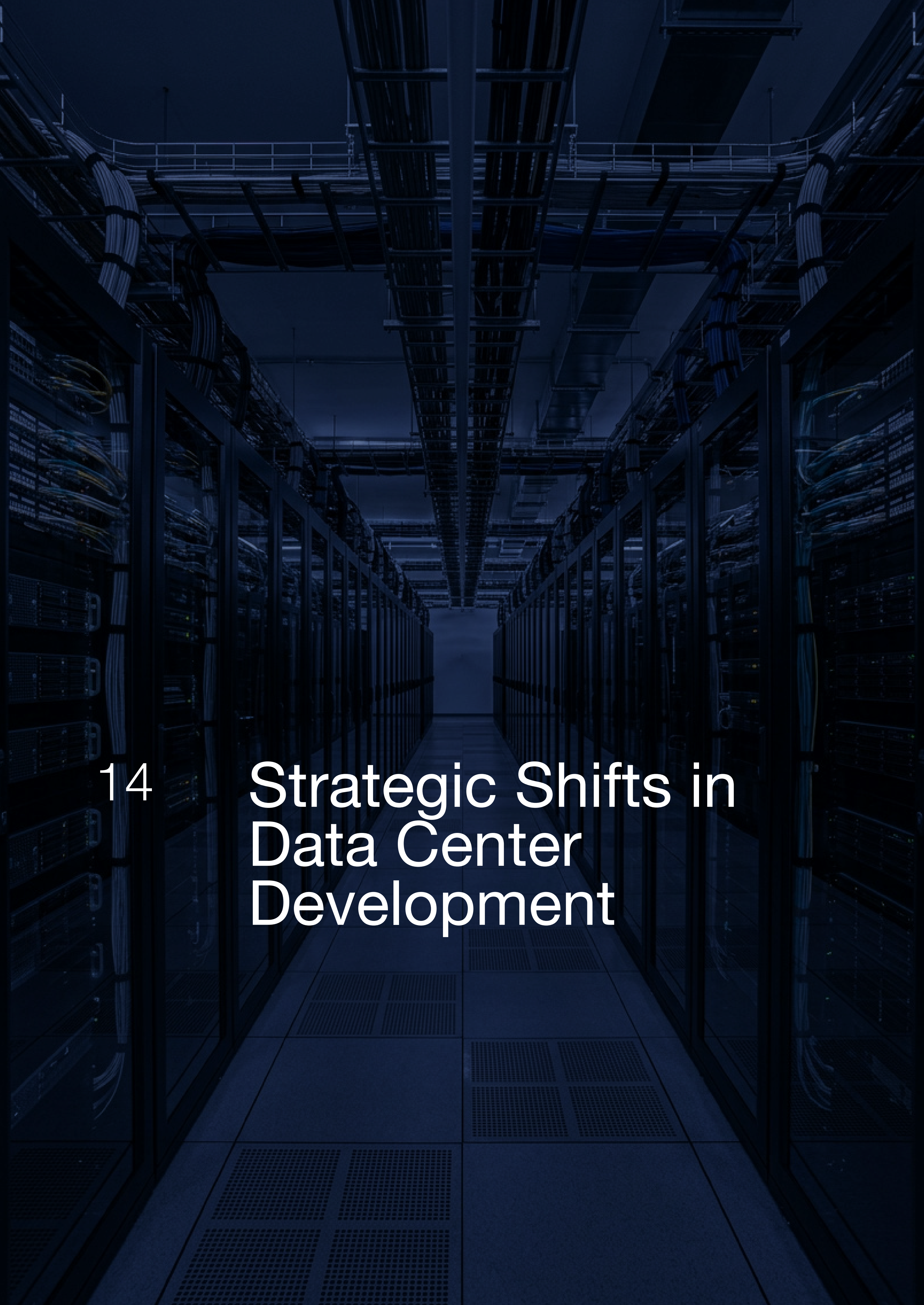
The Emissions Reduction Challenge (ERC) - Americas	
Country	ERC (A)
Belize	0.5
Uruguay	0.6
Costa Rica	0.9
Puerto Rico	-0.4
Bahamas	1.2
Guyana	2
Paraguay	3
Panama	3.1
Jamaica	3.2
El Salvador	3.5
Trinidad	3.7
Nicaragua	4.6
Chile	4.6
Dominican	5.7
Colombia	6.4
Honduras	6.9
Ecuador	7.5
Bolivia	7.7
Peru	8.2
Haiti	10
Argentina	10.3
Canada	10.8
Guatemala	11.1
Venezuela	16.5
Brazil	21.2
Mexico	25
USA	33

The Emissions Reduction Challenge (ERC) - Asia	
Country	ERC (A)
Maldives	0.9
Bhutan	1
Singapore	1.4
Hong Kong	1.4
New Zealand	2.4
Sri Lanka	2.9
Mongolia	4.1
Laos	4.2
Nepal	7
Taiwan	7
Cambodia	7.5
Myanmar	9.2
Malaysia	9.5
Australia	9.5
Kazakhstan	10.3
Vietnam	12
Thailand	12.9
Turkey	13.5
South Korea	13.7
Philippines	13.7
Bangladesh	15
Japan	15.9
Pakistan	20.1
Indonesia	20.8
India	61.4
China	87

The Emissions Reduction Challenge (ERC) - Europe

Country	ERC (A)
Malta	0.4
Iceland	0.9
Switzerland	0.9
Latvia	0.9
Denmark	0.9
Luxembourg	1.1
Lithuania	1.3
Albania	1.3
Montenegro	1.4
Sweden	1.4
Slovenia	1.4
Estonia	1.6
Croatia	1.8
N. Macedonia	2.1
Norway	2.2
Finland	2.3
Ireland	2.3
Moldova	2.3
Slovakia	2.5
Hungary	2.5
Portugal	2.9
Austria	3
Romania	3.2
Bulgaria	3.4
Bosnia	3.6
Netherlands	3.6
Belarus	4
Serbia	4.1
Belgium	4.1
Czechia	4.2
UK	5.1
Greece	5.3
France	5.5
Poland	7.4
Spain	7.8
Germany	8.9
Ukraine	9.5
Italy	10.5
Russia	27.1

The Emissions Reduction Challenge (ERC) - Middle East	
Country	ERC (A)
Georgia	1.2
Cyprus	1.4
Armenia	1.5
Palestine	2.6
Azerbaijan	3.5
Bahrain	3.9
Qatar	4.6
Israel	5
Oman	5.3
Kuwait	6.4
UAE	6.6
Jordan	9.6
Lebanon	10.6
Saudi Arabia	16.1
Yemen	18.3
Iran	20.8



14 Strategic Shifts in Data Center Development

Strategic Shifts in Data Center Development

Data centers have evolved beyond their traditional role as real estate or IT support assets to become foundational components of modern economic and geopolitical infrastructure. As artificial intelligence, high-density computing, and digital services continue to expand, the demands placed on energy, water, and connectivity systems are intensifying. Addressing these pressures requires a shift away from legacy facility models toward more integrated, adaptive, and strategically aligned approaches to infrastructure development.

Regenerative Infrastructure
The industry is gradually moving beyond conventional sustainability toward a more regenerative model, where data centers contribute positively to surrounding ecosystems. Rather than operating solely as large-scale resource consumers, facilities are increasingly being designed to integrate with local infrastructure systems. This includes the capture and reuse of waste heat for district energy applications, as well as the use of treated or recycled water for cooling processes. In some cases, data centers are also exploring ways to interact more dynamically with local energy systems, supporting grid stability and efficiency. This shift reflects a broader transition toward infrastructure that not only minimizes impact but begins to provide measurable value to the communities it serves.

Off-Grid and Sovereign Power Models
Ongoing transmission constraints and extended utility interconnection timelines are reshaping traditional approaches to site selection and development. In several major markets, power delivery delays extending toward the end of the decade are forcing operators to reassess reliance on centralized grids. As a result, there is increasing exploration of facility-level energy strategies that enhance resilience and reduce dependency on external infrastructure. These include co-located or dedicated energy generation approaches such as advanced nuclear technologies, geothermal systems, and fuel-based modular solutions. While still emerging and subject to regulatory and economic considerations, these models highlight a broader strategic shift toward greater energy autonomy and flexibility in infrastructure planning.

Recovering Hidden Capacity (Zombie Workloads)
Within existing data center environments, a significant opportunity exists in the recovery of underutilized or non-critical workloads. Many facilities continue to operate legacy systems or idle compute environments that consume power and cooling resources without delivering proportional value. Identifying and consolidating these "zombie" workloads allows operators to reclaim meaningful capacity within their current footprint. This recovered capacity can then be redirected toward higher-value applications, particularly AI and high-density compute workloads, without requiring immediate expansion. Reframing inefficiency as recoverable infrastructure capacity introduces a near-term pathway to support growth while managing cost and resource constraints.

Circular Resource Systems

Rising scrutiny around data center water usage is accelerating the transition toward more circular and self-contained resource systems. Traditional cooling methods, particularly those dependent on large volumes of municipal water, are increasingly exposed to regulatory pressure and community concern. In response, operators are adopting advanced cooling technologies such as liquid cooling and immersion systems that significantly reduce ongoing water requirements. These approaches enable facilities to minimize, and in some cases substantially reduce, reliance on external water sources following initial system deployment.

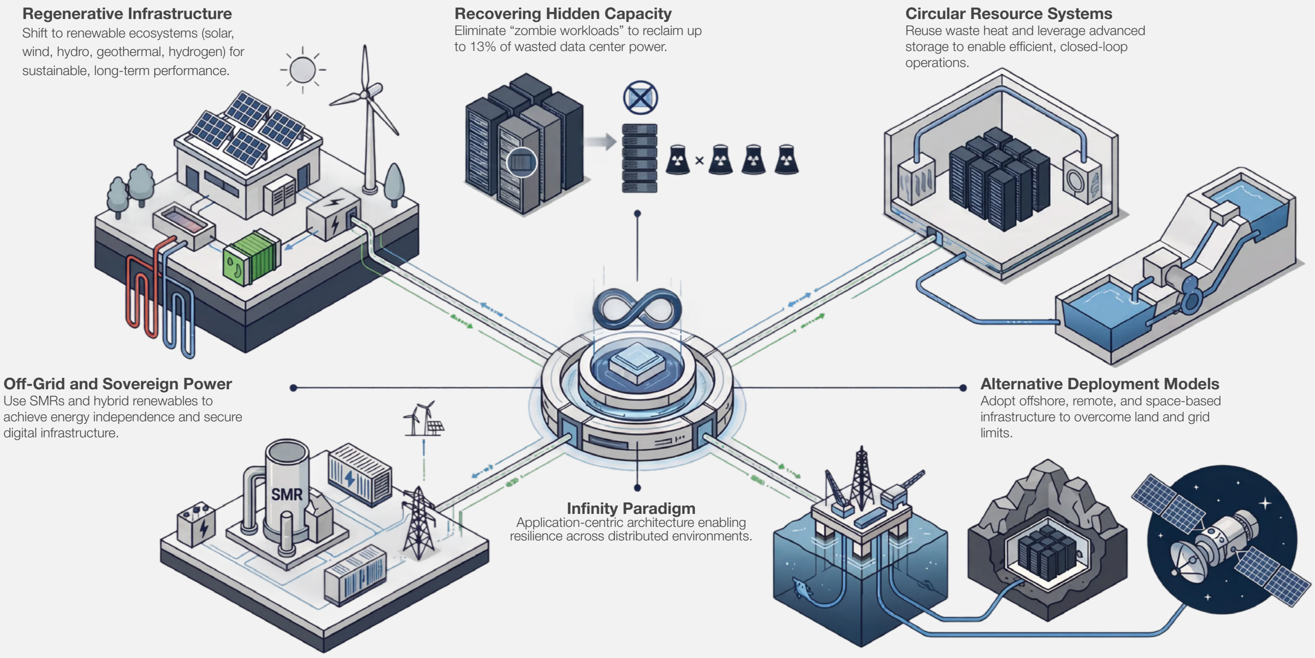
This shift toward circular resource management helps decouple data center expansion from local environmental constraints and enhances long-term operational sustainability.

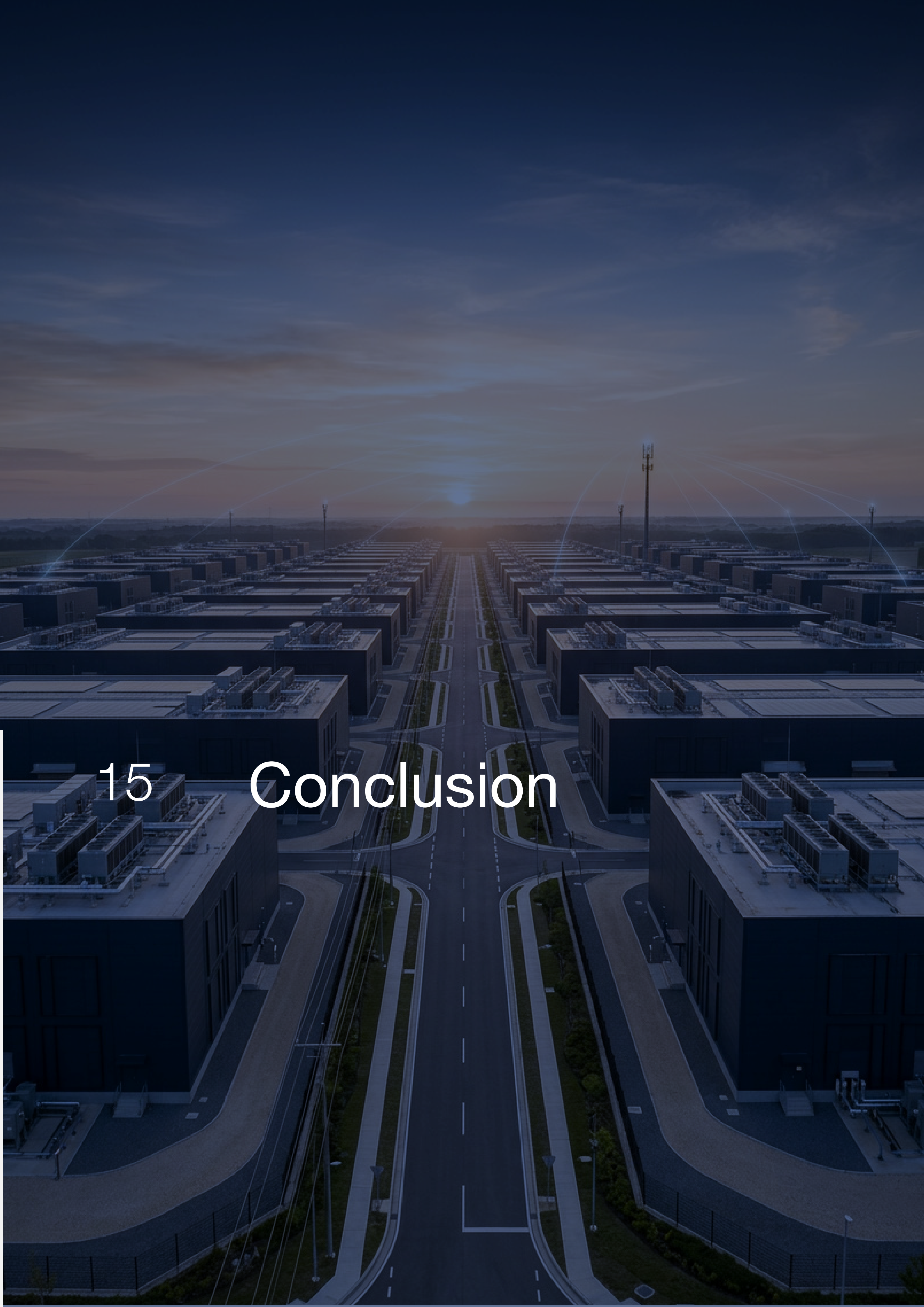
Alternative Deployment Models (Leapfrog Strategies)

As established data center markets approach physical and electrical limits, alternative deployment strategies are emerging to support continued expansion. In certain environments, particularly in developing regions or remote locations, infrastructure deployment is beginning to incorporate non-traditional connectivity and power solutions. These may include satellite-based communications, wireless backhaul, and localized energy systems such as microgrids. While not replacing conventional infrastructure development, these approaches can help mitigate some of the delays and constraints associated with traditional buildouts. This creates opportunities for more flexible and distributed deployment models, enabling faster access to digital infrastructure in previously underserved or constrained regions.

The convergence of regenerative approaches, evolving energy strategies, capacity optimization, circular resource systems, and more flexible deployment models reflects a broader maturation of the data center industry. Increasingly, infrastructure is being viewed not as a dynamic system that must continuously adapt to changing technological, environmental, and economic conditions. Frameworks such as the AE360® Infinity Paradigm provide a structured approach to aligning these shifts across the full Application Ecosystem, enabling organizations to move from fragmented design toward integrated, performance-driven infrastructure.

FIGURE 24. Design & Deployment Considerations





15 Conclusion

Conclusion

The world's data centers now consume 2 percent of the world's electricity, with 43 percent of the consumption in the United States. The world's approximately 10,000 data centers are thus very unevenly distributed throughout the world's nations.

Sustained, sustainable economic and societal growth depends on developing a more balanced data center ecosystem in all of the world's regions and nations. To address the current imbalance, governments, investors, and operators have a responsibility to work on developing data centers as the foundation of their digital infrastructure and Digital Economies.

As this report outlines, there are many key factors that must be considered in planning, locating, building and operating data centers, as well as interconnecting them with electricity and communications grids. Building data centers has implications for local environments, workforces, and the ultimate progress to which each nation can aspire.

This report delivers several indexes that integrate the key factors into unique, practical insights. As can be seen, the indexes in this report show only summary data for each nation. For individuals, organizations, and governments who wish to dive more deeply into the data, the indexes serve as useful tools for analysis and for developing individual road maps for each nation.

IDCA maintains highly robust data and the ability to deliver customized road maps, based on the insights of the global IDCA team, working in tandem to gain the knowledge and visions of the individuals, organizations, and governments who engage in improving their nations through building data centers as the foundation of their Digital Economies.

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