IDCA

Global Energy 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:

Mehdi Paryavi
Chairman & CEO

Roger Strukhoff
Chief Research Officer

Mark Thiele
Entrepreneurship Counsel

Robert Cavey
Global Director of Strategic Relations

Dikran Kechichian
Chief Auditor and Consultant

01 Introduction

Introduction

The Infrastructure Paradigm Shift: From Reversible to Irreversible Decisions

If your infrastructure strategy was written before 2025, it is already out of date. In the old data center model, almost every decision was reversible—if you picked the wrong server generation, you refreshed it in three years. The entire discipline was built on the comfortable assumption that mistakes were depreciable and could be corrected in the next cycle.

The transition to gigawatt-scale AI infrastructure fundamentally destroys that model. When you commit to a generation strategy at gigawatt scale, you are placing a 20 to 40 year bet on a piece of infrastructure you cannot easily refresh, cannot easily move, and in many cases cannot easily exit. The operators who win the next decade will be the ones who understand that the most expensive mistake is the one you cannot take back.

The Financing Bottleneck and the Delay Tax

While grid interconnection queues frequently take the blame for stalled development, a deeper bottleneck lies in how projects are structured. The underlying constraint is that we are still trying to finance modern AI infrastructure using a model built for a very different generation of data center development. This mismatch creates massive unrealized costs. A 100MW deployment delayed by a year is not simply a project timeline problem. With the average lost revenue cost per MW per day at $10,000+, it represents a devastating financial penalty while demand migrates elsewhere. However, as recent federal FERC actions indicate, this bottleneck is no longer a static reality but a moving target as regulators attempt to force timeline updates.

A New Era of Constraints: Water and Workload Control

Furthermore, the constraints defining this infrastructure are multiplying. Five years ago the industry optimized primarily around power availability, but increasingly it has to optimize around power and water at the same time. A generation strategy that solves the power problem while creating a water problem is not actually solving the siting challenge.

At the same time, we are entering a period where the scarce asset is not compute or generation, but the control plane that decides when and where workloads run. As grids require flexibility and curtailment under stress, the true battle is over the interface—whether the grid operator, the hyperscaler, or the vendor gets to run the control loop for massive training clusters.

This report examines energy consumption by the world's data centers. It accompanies two other major IDCA reports focused on Digital Readiness and Data Center development.

This report identifies the energy stresses faced by nations, the use of sustainable energy in meeting demand, and how major data center operators and the nations in which they operate are addressing data center consumption. It does not make projections into the future, but does address scenarios that may face the industry. IDCA maintains research databases and related resources that can be brought to bear to create detailed country-by-country analyses and specific road maps for countries to use in developing optimal data center and AI hub plans, initiatives, and projects.

02 Executive Summary

Executive Summary

The world's data centers now consume 67.7 gigawatts (GW) of electricity, representing 1.9% of global generation and a 17% increase over the prior year. The United States alone accounts for 43% of this total, with its data center footprint reaching 6.0% of the national grid. Artificial intelligence is fundamentally reshaping the trajectory of this growth: AI-focused data centers grew their electricity consumption by 50% in 2025, and global data center consumption is projected to reach approximately 945 TWh by 2030 (IEA, 2026), more than double today's levels.

Key findings of this report include:

(1) Grid constraints are now critical in at least 12 major markets. While moratoriums are in place or under active consideration in Singapore, the Netherlands, Denmark, Germany, South Korea, Chile, and Mexico, Ireland recently ended its multi-year moratorium by mandating strict "bring your own power" and renewable energy obligations for all new facilities.

(2) The transition from evaporative cooling to closed-loop direct-to-chip liquid cooling eliminates on-site water stress but intensifies grid electricity demand, shifting the environmental burden from water systems to power infrastructure.

(3) An estimated 13% of U.S. data center power supports "zombie" applications, representing more than 3 GW of recoverable capacity equivalent to three nuclear reactors.

(4) Sustainable energy now supplies approximately 38% of global electricity generation, yet remains insufficient to meet accelerating data center demand; bridging strategies including Small Modular Reactors (SMRs), hydrogen fuel cells, liquefied natural gas (LNG), and Battery Energy Storage Systems (BESS) are being actively deployed.

(5) Twenty-seven developed nations possess sufficient grid headroom to absorb at least 1 GW of new data center capacity without new generation investment.

(6) IDCA has identified 41 "Goldilocks" nations that represent the most favorable environments for responsible digital infrastructure expansion.

The central recommendation of this report is that there is no single global solution. National governments, hyperscalers, colocation operators, and regulators must each develop region-specific roadmaps that balance energy security, environmental obligations, economic competitiveness, and community acceptance. IDCA's proprietary Digital Readiness Index and Efficiency Efficacy Rating (EER) framework provide the analytical tools to support those decisions.

Methodology and Data Sources

The data and analysis presented in this report draw on IDCA's proprietary research databases, which aggregate and normalize publicly available national energy statistics, colocation market intelligence, hyperscaler sustainability disclosures, and multilateral agency publications including the International Energy Agency (IEA), the U.S. Department of Energy's Lawrence Berkeley National Laboratory (LBNL), Eurostat, and national grid operators.

Consumption figures are expressed in gigawatts (GW) of installed or contracted capacity, and in terawatt-hours (TWh) of annual consumption, depending on context. Data center electricity consumption estimates are derived from installed IT load capacity, adjusted for average utilization rates and evaluated against the Efficiency Efficacy Rating (EER) controls within IDCA's AE360 Infinity Paradigm framework at the Site Facilities Infrastructure (SFI) layer.

Unless otherwise noted, all figures reflect calendar year 2025 data. Projections attributed to third parties are cited to their original sources and are presented for contextual benchmarking only; IDCA does not independently validate third-party forecasts.

03 Overview

Overview

The world's electricity grids produce 3.4TW (or 3,400GW) of energy. China is the world's largest consumer by far, with more than 1,000GW (1TW) of consumption, representing 31.8% of the world's total. The United States is in second place, consuming close to 500GW and 14.4% of the world's total.

Table 1.
World's Top Electricity Consumers by Nation (GW, % of World Total)

Country	GW	% of World Total
China	1,078.0	31.8%
USA	487.8	14.4%
India	223.4	6.6%
Russia	132.7	3.9%
Japan	115.7	3.4%
Brazil	82.8	2.4%
South Korea	70.5	2.1%
Canada	69.1	2.0%
Germany	57.7	1.7%
France	53.4	1.6%
Saudi Arabia	48.3	1.4%
Iran	43.4	1.3%
Mexico	40.8	1.2%
Indonesia	40.1	1.2%
Turkey	37	1.1%
Italy	35.7	1.1%
UK	35.3	1.0%
Taiwan	32.2	1.0%
Vietnam	31.8	0.9%
Australia	31.2	0.9%
Spain	30.3	0.9%
South Africa	26.5	0.8%
Thailand	25.6	0.8%
Egypt	24.9	0.7%
Malaysia	21.3	0.6%

Relevant to this report, the world's data centers consume 67.7 gigawatts (GW) of electricity. This amount represents 1.9% of the world's total generation, up from 1.7% a year ago. Consumption levels are highly varied, though, ranging from less than 0.1% in several developing countries to more than 10% in Singapore and a few EU nations.

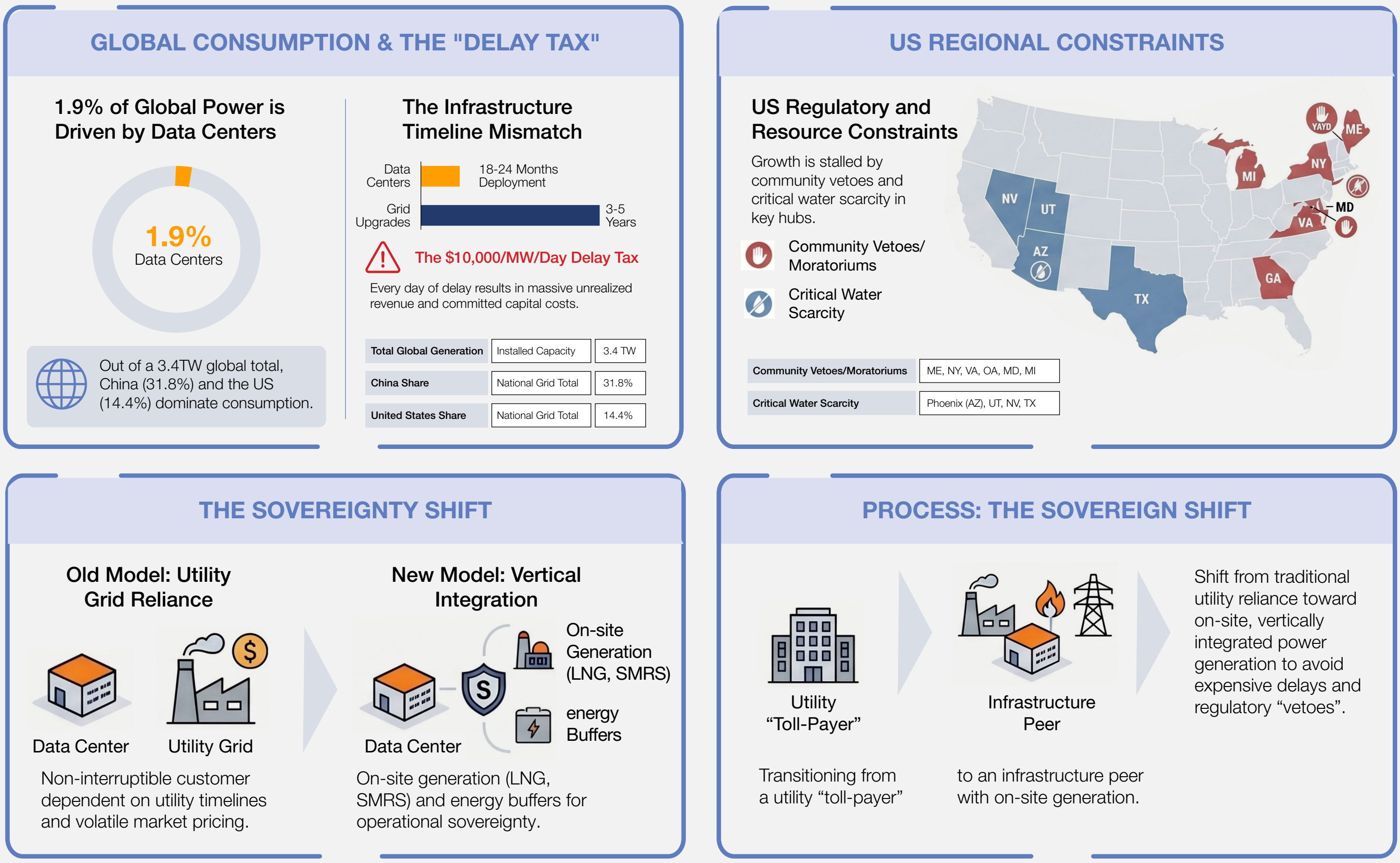
The Shift to Sovereign Power and Vertical Integration As consumption scales and grid constraints tighten, relying entirely on external public utility timelines introduces a level of exposure that is increasingly difficult to manage. Consequently, successful operators are shifting toward full-stack control and Sovereign Power, bringing power under direct control through on-site generation and integrated campus designs. Crucially, this is no longer just an aggressive, contrarian developer strategy—it is now federally backed grid policy. Recent June 18 FERC orders have explicitly directed RTOs to build tariffs that accommodate co-location and behind-the-meter generation. The M&A logic is actively shifting toward vertical integration, where the goal is to deliver compute alongside energy rather than just traditional space and power.

The "Delay Tax" This strategic pivot is necessary because the friction between the rapid 18-to-24 month deployment timeline of a modern data center and the 3-to-5 year timeline required to upgrade community power lines is creating devastating developmental bottlenecks. This mismatch creates a massive "Delay Tax." The average lost revenue cost of these delays is over $10,000 per megawatt, per day. However, this bottleneck is no longer a static reality but a moving federal target. Recent federal actions—specifically the June 18 FERC orders directed at major RTOs—are attempting to force tariff updates and streamline these interconnection delays, though the actual effects are currently projected rather than observed. When a 100MW deployment is delayed by just one year, the combination of lost revenue opportunity, cost of capital, and shifting demand can push the financial impact toward the billion-dollar mark.

The "Community Veto" and Legislative Pushback Inside the United States, this resistance has escalated into what is effectively a "Community Veto." Local opposition is no longer just episodic friction; it is highly organized, armed with technical consultants, pre-written ordinance language, and heavily funded ratepayer coalitions. Fundamentally, this pushback is driven by cost allocation—residential ratepayers are fighting to avoid subsidizing the massive transmission and generation upgrades required by data centers. For example, Virginia is introducing a new rate class starting in January 2027 where data centers will be required to cover 85% of transmission and distribution costs and 60% of generation demand. Maine appears to be the first state moving a statewide data center moratorium through its legislature, and at least 11 other states—including New York, Virginia, Georgia, Maryland, and Michigan—have introduced similar stop-build or stop-permit measures.

Water as a Hard Regulatory Constraint Furthermore, the industry can no longer view the electrical grid as its only boundary. Water has transitioned from a simple efficiency metric into a hard regulatory constraint. In major development hubs like Northern Virginia, Phoenix, Utah, Nevada, and Texas, the availability of cooling water is starting to shape site selection almost as much as electrical capacity does. A generation strategy that solves the power problem while creating a localized water problem will fail; operators must now prove absolute water neutrality to survive community and regulatory scrutiny.

FIGURE 1. **State of the Industry: The Data Center Power Constraint**



04 Data Center Electricity Consumption

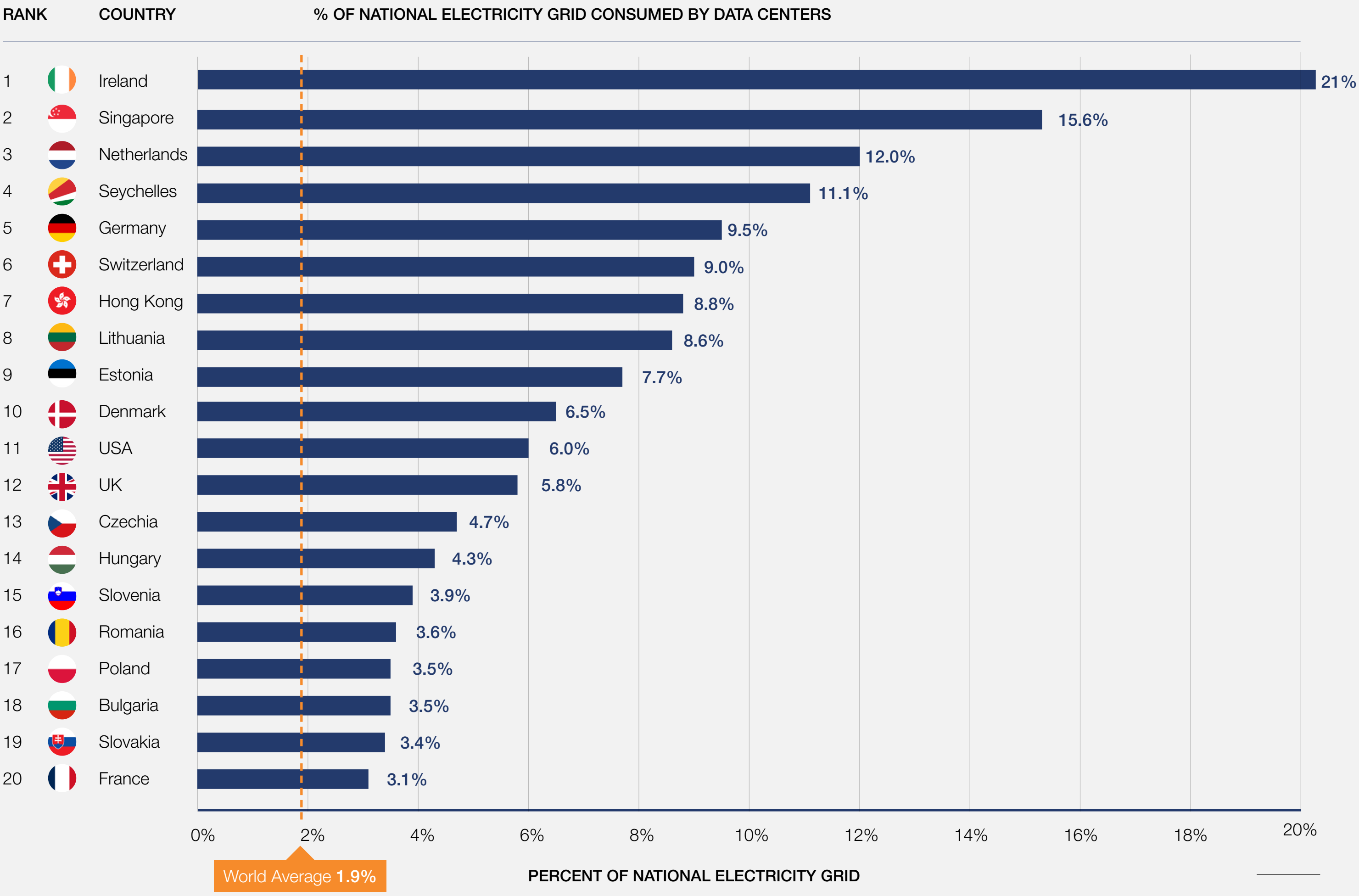
Data Center Electricity Consumption

Data centers in the United States consume 43% of the world total data center consumption, or 26.7GW. The collective footprint in the US has grown quickly over the past few years to reach 6.0% of the entire US electricity grids. This rapid growth has resulted in notable constraints in the Data Center Alley region of Northern Virginia, in California, and in a few other large hub areas, including Chicago and Dallas. A recent moratorium in Maine was vetoed by the state's governor, but calls for moratoriums are being introduced in several state legislatures.

The current grid constraints are only the beginning, as artificial intelligence fundamentally alters the trajectory of digital infrastructure power consumption. According to recent projections, data centers could jump from consuming approximately 6% of U.S. power in 2025 to 12% by 2030, in the absence of significant new grid construction.

FIGURE 2. **Top 20 Nations Global Data Center Electricity Consumption**

Share of National Electricity Grid Consumed by Data Centers (%)

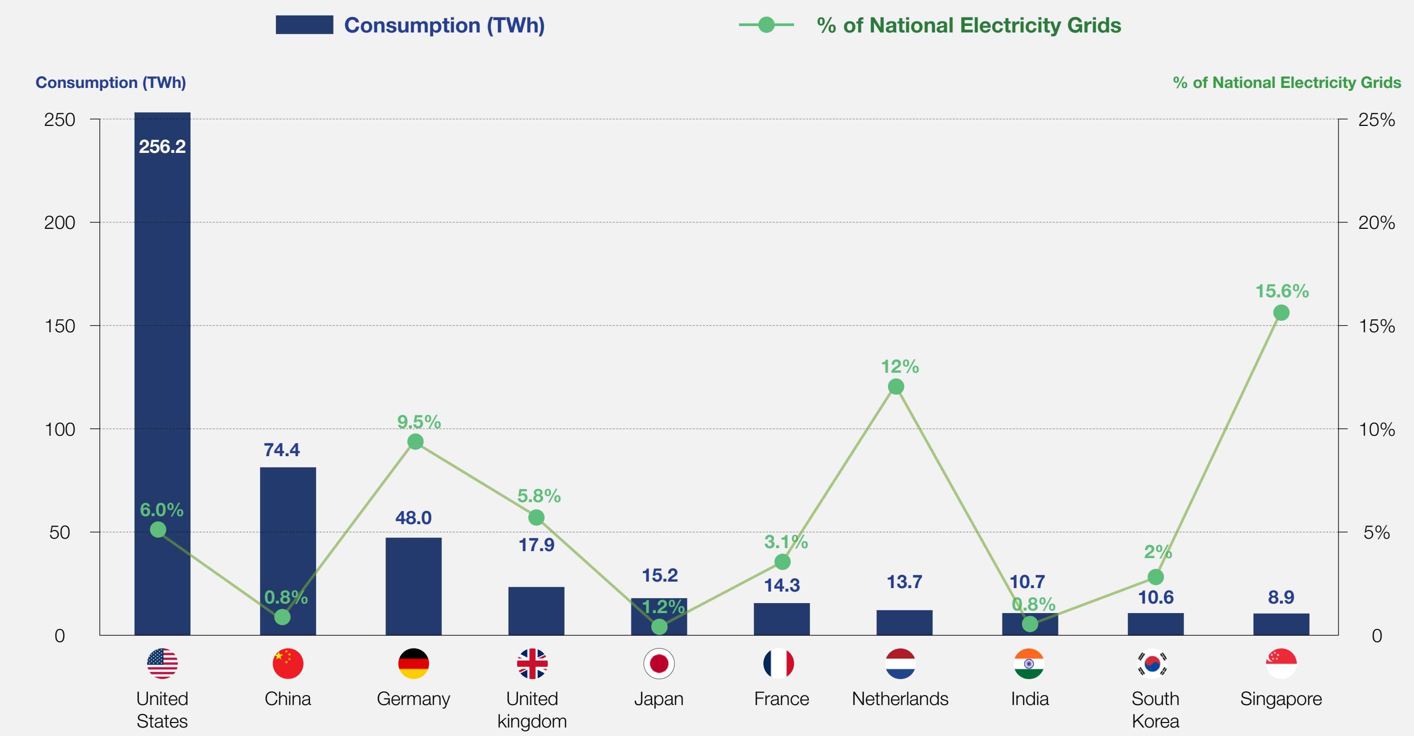


Source: IDCA Research

To fully understand the global landscape of data center energy use, it is critical to distinguish between absolute electricity consumption and the proportional burden placed on a nation's electrical grid. The table below details the top nations by annual data center electricity consumption, measured in terawatt-hours (TWh). While massive markets like the United States and China dominate in absolute power usage—with the U.S. alone consuming 213 TWh—the true measure of infrastructure stress is often revealed in the proportional data. For example, while Singapore and the Netherlands consume a fraction of the absolute power of the United States (10.8 TWh and 10.7 TWh, respectively), their data centers account for a staggering 19.5% and 9.7% of their entire national electricity grids. This disparity between total volumetric consumption and proportional grid density is a primary driver of the severe regional constraints and regulatory moratoriums emerging worldwide.

Table 2.
Top Data Center Consumption Levels (TWh)

Country	TWh	% of National Electricity Grids
United States	256.2	6.0%
China	74.4	0.8%
Germany	48.0	9.5%
United Kingdom	17.9	5.8%
Japan	15.2	1.2%
France	14.3	3.1%
Netherlands	13.7	12.0%
India	10.7	0.8%
South Korea	10.6	2.0%
Singapore	8.9	15.6%



Source: IDCA Research

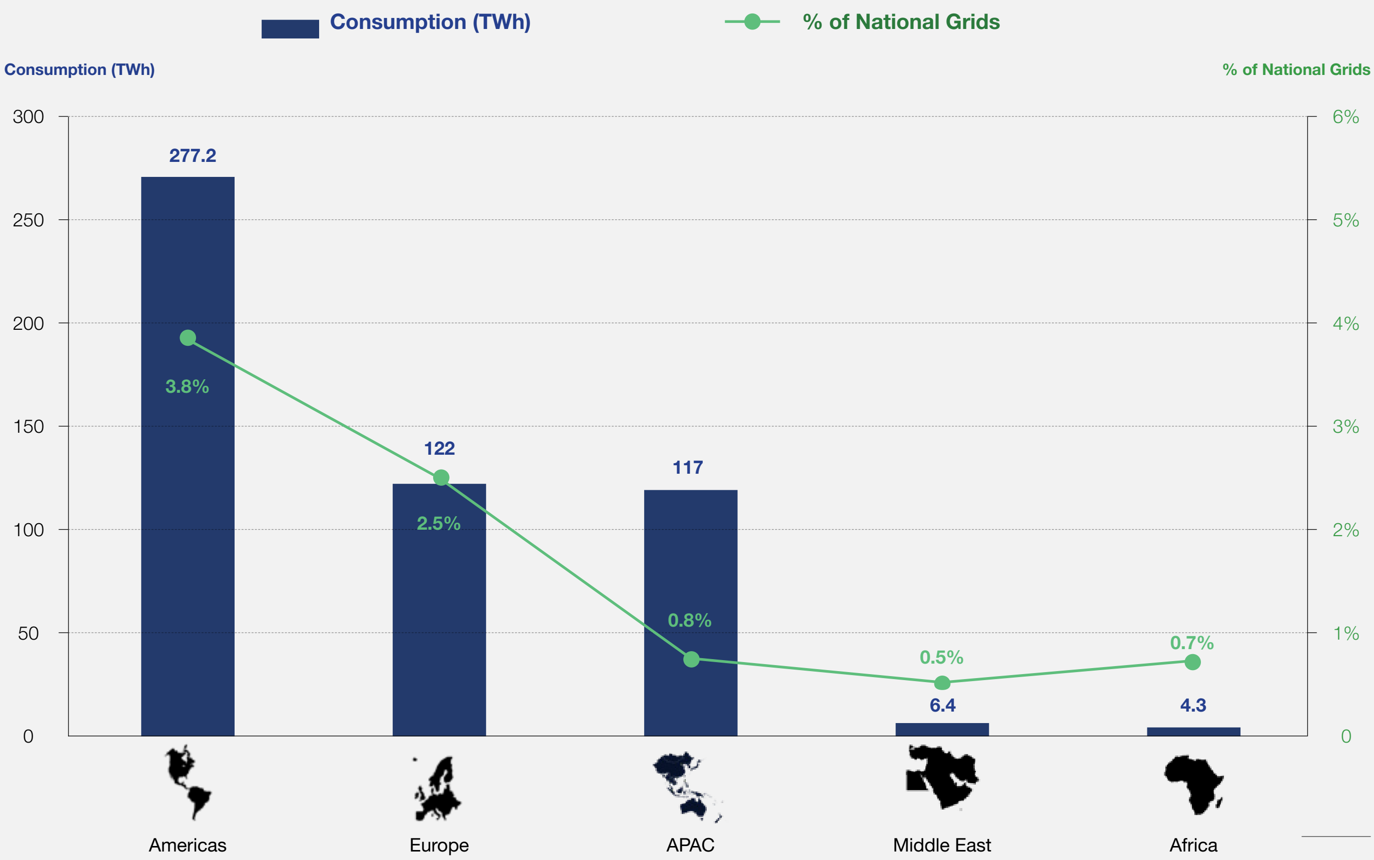
There are also well-known constraints in Europe and Asia, as well as incipient concerns over data center development in Latin America. Ireland's data centers, for example, now consume more than 20% of the nation's electricity, while Singapore has approached that level. While concerns about rising consumption initially prompted strict moratoriums in those nations, Ireland officially ended its multi-year moratorium in December 2025 by introducing the Large Energy Users Connection Policy.

Under the new Commission for Regulation of Utilities (CRU) rules, new facilities are permitted only if they operate under a "bring your own power" model. Data centers must install on-site or proximate generation (such as power plants or battery storage) capable of matching their maximum requested power demand.

Crucially, this generated power must be supplied to the wider Irish wholesale market to actively support national grid stability. Furthermore, facilities are required to meet at least 80% of their annual electricity demand through "additional" renewable energy projects generated within the Republic of Ireland within six years of connection, and grid operators (EirGrid and ESB Networks) must factor in local constraint severity before approving any application. Because these massive facilities consume roughly a fifth of Ireland's total generated electricity, these rules are explicitly designed to ensure tech titans actively contribute to the grid rather than strain it. Meanwhile, moratoriums or severe restrictions remain active in Singapore, the Netherlands, Denmark, certain regions of Germany, South Korea, Chile, and Mexico.

Table 3.
Data Center Consumption by Region

Region	TWh	% of National Grids
Americas	277.2	3.8%
Europe	122	2.5%
APAC	117	0.8%
Middle East	6.4	0.5%
Africa	4.3	0.7%



Source: IDCA Research

Edge Computing and Small Community Stress

While hyperscale developments in major hubs draw the most attention, the rapid expansion of Edge computing is creating an entirely new vector of energy stress. Driven by high-frequency trading, remote surgery, industrial automation, and edge AI, this sector is experiencing annual growth rates above 30% through 2030. This expansion pushes heavy power and water demands into smaller communities—such as those in Texas or Ohio—that never anticipated hosting such mission-critical infrastructure. Unlike major metropolitan areas with built-in substation redundancy, small towns are often relying on aging electrical equipment from the 1970s with limited power sources. The resulting friction between the rapid 18-to-24 month deployment timeline of a data center and the 3-to-5 year timeline required to upgrade community power lines is creating significant developmental bottlenecks.

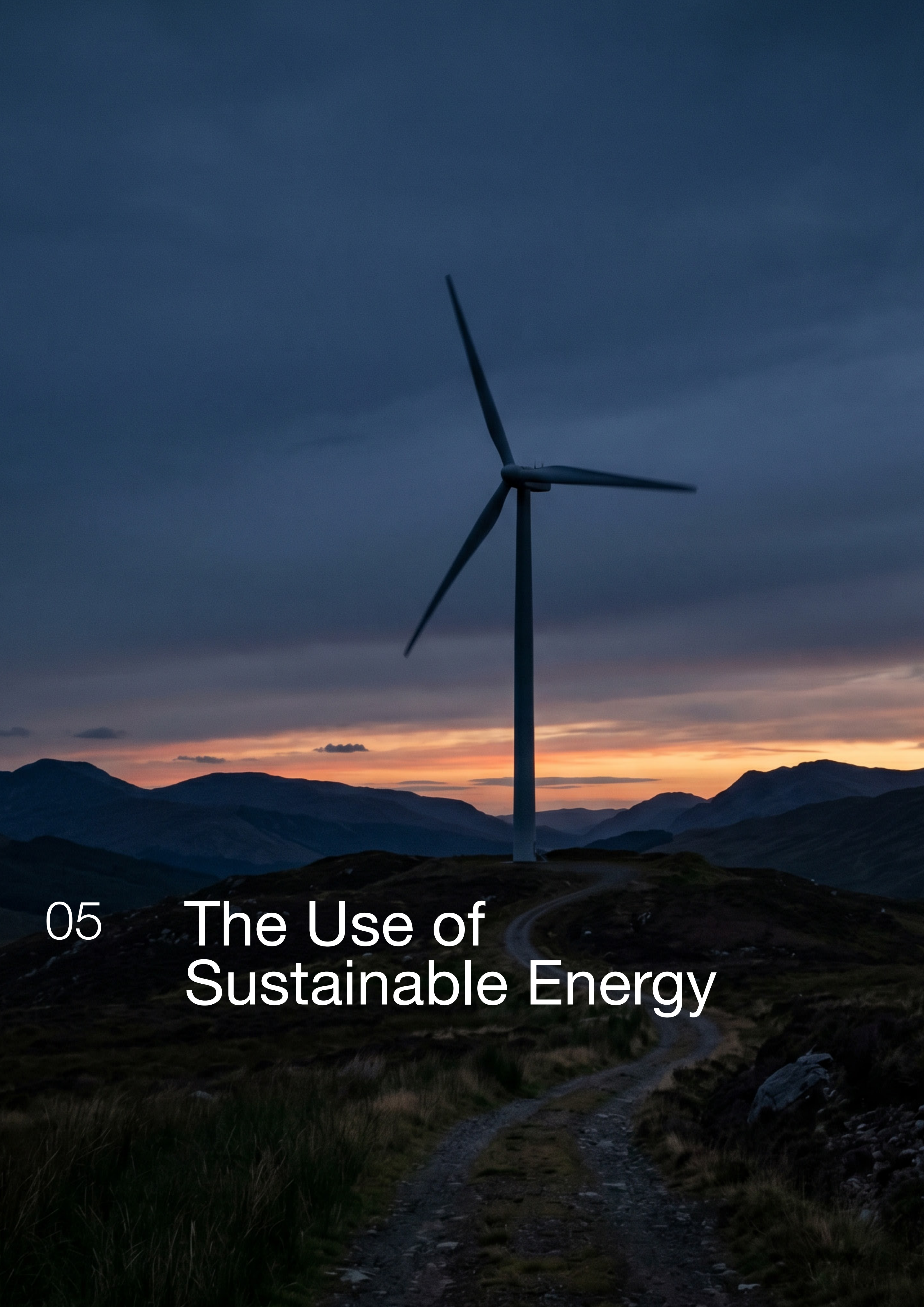
Reclaiming Stranded Power: The “Zombie” Workload Epidemic

The transition to sustainable energy must also be accompanied by a rigorous elimination of systemic energy waste. IDCA research finds that as much as 13 percent of data center power consumption in the United States is currently supporting “zombie” applications—unused cloud containers and services that were instituted, discarded, and never properly decommissioned. This wasted consumption totals in excess of 3 gigawatts, which is functionally equivalent to the energy produced by three entire nuclear reactors. Before developing new, capital-intensive power generation, operators and governments must audit their logical layers to eliminate these massive inefficiencies.

The PUE Loophole and the Hidden Fan Tax

Furthermore, operators must rethink how they measure internal consumption efficiency. The industry’s standard Power Usage Effectiveness (PUE) metric has a significant loophole: it treats server fans as productive IT load because they physically reside inside the chassis, even though they operationally function as a distributed cooling system. In many air-cooled environments, these fans can consume 10% to 15% of total server power, particularly once systems begin operating under sustained high-density workloads.

A fanless microfluidic architecture changes that accounting dynamic entirely. Removing fan loads from the IT denominator can actually make a facility’s PUE appear worse on paper, even while the overall system becomes materially more efficient from a compute yield perspective. The facility may consume a similar amount of total power, but a significantly larger percentage of that power is now being directed toward computational work instead of air movement. Operators who understand the distinction between infrastructure efficiency metrics and actual compute productivity may ultimately gain a meaningful capital efficiency advantage in constrained markets where the limiting factor is the amount of usable compute that can be deployed inside a fixed utility allocation.



05 The Use of Sustainable Energy

The Use of Sustainable Energy

Of the world's energy, renewable resources now deliver around one terawatt (1,000 GW) of electricity, representing 29.6% of the total. Nuclear energy delivers another 8.9%, thus increasing the world's sustainable energy footprint to 38.6% of the total.

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, also includes the use of geothermal energy where it's present, as well as the use of biomass. Green hydrogen remains essentially an experimental technology today, but represents another potential and significant renewable resource that may be developed more fully in future years. Finally, nuclear energy is not renewable, but is included as a sustainable source of energy because it emits no pollutants.

To bypass severe utility interconnection delays, major operators are aggressively securing their own on-site, zero-carbon power sources. Nuclear power shows signs of making a return via Small Modular Reactors (SMRs) and traditional plant revitalizations, although SMRs will take several years at minimum to be deployed in significant numbers.

Along these lines, Google recently signed a deal for 500 megawatts from Kairos Power's SMRs, expecting the first 50 megawatts to be operational by 2030. Microsoft has secured a 20-year agreement with Constellation Energy to restart the Three Mile Island reactor. Equinix has signed deals for more than a gigawatt of nuclear power, partnering with companies like Oklo and Radiant to explore microreactors, while Amazon has secured a massive power purchase agreement with Talen Energy for up to 1,920 MW from a Pennsylvania nuclear plant.

In addition to nuclear, hydrogen fuel cells are now being seriously considered and deployed by providers like Microsoft in partnership with companies like Bloom Energy. Fuel cells utilize a chemical reaction rather than combustion, meaning they produce zero carbon emissions and operate almost silently. Advanced fuel cells can burn hotter and cycle faster to chase dynamic electrical demand; by cracking hydrogen from water and releasing only oxygen as a byproduct, they provide a reliable, highly efficient microgrid solution without depleting local community water resources.

Table 4.
Global Sustainable Electricity

Energy Source	% of All Electricity
Hydroelectric	14.3%
Wind	7.2%
Solar	5.5%
Biomass	2.4%
Geothermal	0.3%
Sub-total Renewable	29.6%
Nuclear	8.9%
Total Sustainable	38.6%

Table 5.
Sustainable Electricity by Nation

Country	Sustainable %	Hydro %	Wind %	Solar %	Biomass %	Geothermal %	Nuclear %
Albania	115.0%	111.2%	0.0%	3.7%	0.0%	0.0%	
Algeria	1.0%	0.0%	0.0%	1.0%	0.0%	0.0%	
Angola	75.0%	72.5%	0.0%	2.2%	0.3%	0.0%	
Argentina	36.5%	19.0%	8.9%	1.9%	1.3%	0.0%	5.4%
Armenia	94.7%	26.5%	0.0%	10.6%	26.5%	0.0%	31.0%
Australia	34.8%	5.5%	11.7%	16.5%	1.1%	0.0%	
Austria	85.2%	58.2%	11.4%	8.5%	7.1%	0.0%	
Azerbaijan	8.6%	7.7%	0.3%	0.3%	0.4%	0.0%	
Bahamas	1.0%	0.0%	0.0%	1.0%	0.0%	0.0%	
Bahrain	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	
Bangladesh	1.5%	0.6%	0.0%	0.9%	0.0%	0.0%	
Belarus	14.9%	0.9%	0.5%	0.5%	1.2%	0.0%	11.9%
Belgium	79.7%	0.5%	18.2%	9.7%	4.9%	0.0%	46.4%
Belize	80.1%	27.4%	0.0%	1.4%	51.3%	0.0%	
Bhutan	91.7%	91.7%	0.0%	0.0%	0.0%	0.0%	
Bolivia	34.3%	25.1%	3.4%	2.5%	3.4%	0.0%	
Bosnia	48.2%	44.3%	2.2%	1.5%	0.2%	0.0%	
Botswana	0.2%	0.0%	0.0%	0.2%	0.0%	0.0%	
Brazil	89.7%	59.2%	13.2%	7.0%	7.7%	0.0%	2.5%
Bulgaria	68.0%	8.2%	5.4%	10.9%	10.9%	0.0%	32.6%
Burundi	61.2%	61.2%	0.0%	0.0%	0.0%	0.0%	
Cambodia	30.8%	26.5%	0.0%	4.2%	0.1%	0.0%	
Cameroon	60.1%	59.6%	0.0%	0.2%	0.2%	0.0%	
Canada	82.1%	60.1%	6.4%	1.3%	1.3%	0.0%	12.9%
CAR	71.4%	71.4%	0.0%	0.0%	0.0%	0.0%	
Chile	65.5%	29.6%	11.4%	19.4%	4.6%	0.5%	
China	35.6%	13.0%	9.4%	6.2%	2.1%	0.0%	5.0%
Colombia	36.5%	19.0%	8.9%	1.9%	1.3%	0.0%	5.4%
Congo	19.7%	19.3%	0.0%	0.2%	0.2%	0.0%	
Congo, Dem	92.6%	80.9%	0.0%	11.6%	0.2%	0.0%	
Costa Rica	110.5%	81.9%	9.1%	0.7%	0.5%	18.2%	
Cote D'Ivoire	30.0%	28.9%	0.0%	0.2%	0.9%	0.0%	
Croatia	65.4%	42.1%	15.8%	2.1%	5.3%	0.1%	
Cyprus	19.7%	0.0%	3.8%	15.0%	0.9%	0.0%	
Czechia	52.8%	3.0%	1.1%	4.5%	7.5%	0.0%	36.7%
Denmark	76.3%	0.1%	51.7%	8.2%	16.3%	0.0%	
Djibouti	9.9%	0.0%	9.9%	0.0%	0.0%	0.0%	
Dominican	13.0%	4.1%	4.1%	4.1%	0.8%	0.0%	
Ecuador	55.7%	50.0%	3.3%	1.3%	1.0%	0.0%	
Egypt	11.4%	6.4%	2.7%	2.3%	0.0%	0.0%	
El Salvador	77.0%	75.5%	0.2%	0.1%	1.2%	0.0%	

Table 5.
Sustainable Electricity by Nation

Country	Sustainable %	Hydro %	Wind %	Solar %	Biomass %	Geothermal %	Nuclear %
Eq Guinea	31.8%	31.8%	0.0%	0.0%	0.0%	0.0%	
Eritrea	11.4%	0.0%	0.0%	11.4%	0.0%	0.0%	
Estonia	27.7%	0.3%	8.8%	7.7%	11.0%	0.0%	
Ethiopia	113.2%	109.1%	3.6%	0.2%	0.1%	0.2%	
Finland	84.3%	18.2%	17.0%	0.8%	13.3%	0.0%	35.0%
France	92.2%	12.2%	10.5%	4.7%	2.1%	0.1%	62.6%
Gabon	53.3%	53.1%	0.0%	0.0%	0.3%	0.0%	
Gambia	171.8%	0.0%	0.0%	0.0%	0.0%	0.0%	
Georgia	80.8%	80.2%	0.7%	0.0%	0.0%	0.0%	
Germany	52.2%	4.0%	27.1%	12.1%	9.1%	0.0%	0.0%
Ghana	40.8%	40.3%	0.0%	0.4%	0.1%	0.0%	
Greece	46.0%	7.4%	20.5%	16.8%	1.3%	0.0%	
Guatemala	70.4%	43.1%	2.2%	1.4%	21.5%	2.2%	
Guyana	13.4%	6.7%	0.0%	1.5%	5.2%	0.0%	
Haiti	19.8%	19.8%	0.0%	0.0%	0.0%	0.0%	
Honduras	58.7%	33.6%	5.9%	8.4%	8.4%	2.5%	
Hong Kong	0.8%	0.0%	0.0%	0.4%	0.4%	0.0%	
Hungary	68.1%	0.4%	1.3%	15.0%	4.3%	0.0%	47.0%
Iceland	99.5%	69.6%	0.0%	0.0%	0.0%	29.8%	
India	22.6%	7.6%	4.2%	5.8%	1.9%	0.0%	3.1%
Indonesia	18.5%	7.1%	0.1%	0.2%	6.3%	4.8%	
Iran	8.2%	6.0%	0.3%	0.2%	0.0%	0.0%	1.7%
Iraq	0.9%	0.7%	0.0%	0.2%	0.0%	0.0%	
Ireland	41.7%	2.6%	34.8%	2.0%	2.3%	0.0%	
Israel	11.6%	0.0%	1.0%	10.4%	0.1%	0.0%	
Italy	37.7%	13.1%	7.7%	9.9%	5.1%	1.9%	
Jamaica	12.5%	2.2%	6.7%	2.2%	1.3%	0.0%	
Japan	28.1%	7.3%	1.0%	9.6%	4.1%	0.0%	6.1%
Jordan	22.0%	0.1%	8.8%	13.2%	0.0%	0.0%	
Kazakhstan	13.1%	7.9%	3.5%	1.7%	0.0%	0.0%	
Kenya	90.3%	23.0%	15.3%	4.6%	1.5%	45.9%	
Kuwait	2.6%	0.0%	2.3%	0.2%	0.0%	0.0%	
Kyrgyzstan	69.6%	69.6%	0.0%	0.0%	0.0%	0.0%	
Laos	262.9%	262.1%	0.0%	0.5%	0.3%	0.0%	
Latvia	72.5%	55.8%	4.2%	2.8%	9.8%	0.0%	
Lebanon	38.5%	15.5%	0.2%	22.1%	0.7%	0.0%	
Libya	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Lithuania	40.1%	3.3%	24.5%	5.7%	6.5%	0.0%	
Luxembourg	19.6%	1.4%	7.6%	4.6%	6.1%	0.0%	

Table 5.
Sustainable Electricity by Nation

Country	Sustainable %	Hydro %	Wind %	Solar %	Biomass %	Geothermal %	Nuclear %
Madagascar	34.5%	30.3%	0.0%	3.0%	1.1%	0.0%	
Malawi	113.8%	110.5%	0.0%	0.6%	2.8%	0.0%	
Malaysia	19.3%	17.1%	0.0%	1.6%	0.5%	0.0%	
Maldives	7.1%	0.0%	0.0%	7.1%	0.0%	0.0%	
Mali	47.4%	43.7%	0.0%	2.2%	1.5%	0.0%	
Malta	10.4%	0.0%	0.0%	10.1%	0.3%	0.0%	
Mauritius	40.1%	27.5%	0.3%	3.1%	9.2%	0.0%	
Mexico	25.7%	5.6%	6.1%	7.5%	2.0%	0.0%	4.5%
Moldova	9.6%	4.8%	3.2%	1.4%	0.2%	0.0%	
Mongolia	7.5%	0.6%	4.9%	2.0%	0.0%	0.0%	
Montenegro	71.4%	62.1%	9.3%	0.0%	0.0%	0.0%	
Morocco	21.5%	1.1%	15.8%	4.5%	0.1%	0.0%	
Mozambique	98.7%	97.8%	0.0%	0.4%	0.4%	0.0%	
Myanmar	36.9%	35.3%	0.0%	0.4%	1.2%	0.0%	
N. Macedonia	36.2%	27.7%	0.3%	6.9%	1.4%	0.0%	
Namibia	32.8%	21.6%	0.4%	10.8%	0.0%	0.0%	
Nepal	97.0%	96.1%	0.1%	0.9%	0.0%	0.0%	
Netherlands	53.4%	0.1%	25.5%	17.6%	7.0%	0.0%	3.3%
New Zealand	89.1%	59.3%	9.1%	0.9%	1.6%	18.2%	
Nicaragua	53.3%	12.7%	10.9%	0.5%	16.4%	12.7%	
Niger	1.0%	0.0%	0.0%	1.0%	0.0%	0.0%	
Nigeria	25.3%	24.9%	0.0%	0.2%	0.1%	0.0%	
Norway	111.5%	100.2%	11.1%	0.0%	0.1%	0.0%	
Oman	4.7%	0.0%	0.2%	4.4%	0.0%	0.0%	
Pakistan	41.3%	19.9%	3.5%	0.6%	1.2%	0.0%	16.2%
Panama	56.3%	28.1%	1.4%	14.1%	12.7%	0.0%	
Paraguay	220.6%	219.6%	0.0%	0.0%	1.0%	0.0%	
Peru	66.0%	62.5%	0.1%	1.1%	2.2%	0.0%	
Philippines	21.5%	9.0%	0.9%	1.8%	0.9%	9.0%	
Poland	26.2%	1.2%	13.7%	6.5%	4.8%	0.0%	
Portugal	60.6%	21.3%	23.0%	8.9%	7.1%	0.4%	
Puerto Rico	61.7%	47.2%	7.1%	7.1%	0.3%	0.0%	
Qatar	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	
Rest of World	10.7%	0.3%	3.3%	0.0%	0.3%	6.7%	
Romania	78.8%	33.4%	14.8%	3.7%	7.4%	0.0%	19.4%
Russia	37.6%	17.3%	0.4%	0.3%	0.1%	0.0%	19.6%
Rwanda	59.3%	55.6%	0.0%	3.7%	0.0%	0.0%	
Saudi Arabia	1.2%	0.0%	0.2%	0.9%	0.0%	0.0%	
Senegal	19.9%	3.5%	8.2%	7.0%	1.2%	0.0%	

Table 5.
Sustainable Electricity by Nation

Country	Sustainable %	Hydro %	Wind %	Solar %	Biomass %	Geothermal %	Nuclear %
Serbia	36.3%	33.2%	2.5%	0.1%	0.6%	0.0%	
Seychelles	14.3%	0.0%	1.6%	12.7%	0.0%	0.0%	
Sierra Leone	104.8%	95.2%	0.0%	9.5%	0.0%	0.0%	
Singapore	5.1%	0.0%	0.0%	1.6%	3.5%	0.0%	
Slovakia	84.5%	19.1%	0.0%	2.3%	3.8%	0.0%	59.2%
Slovenia	87.7%	35.6%	0.1%	7.1%	2.1%	0.0%	42.8%
South Africa	18.0%	0.9%	5.2%	6.9%	0.2%	0.0%	4.9%
South Korea	39.3%	0.6%	0.5%	4.7%	3.1%	0.0%	30.4%
South Sudan	6.8%	0.0%	0.0%	6.8%	0.0%	0.0%	
Spain	74.6%	9.4%	24.2%	18.5%	2.3%	0.0%	20.3%
Sri Lanka	52.1%	44.3%	3.9%	3.9%	0.0%	0.0%	
Sudan	69.2%	68.1%	0.0%	0.6%	0.6%	0.0%	
Sweden	113.0%	48.0%	24.7%	2.2%	8.7%	0.0%	29.4%
Switzerland	105.3%	62.2%	0.3%	6.4%	0.0%	0.0%	36.4%
Taiwan	8.9%	1.4%	2.1%	4.6%	0.7%	0.0%	
Tajikistan	104.1%	104.1%	0.0%	0.0%	0.0%	0.0%	
Tanzania	27.8%	26.9%	0.0%	0.3%	0.6%	0.0%	
Thailand	13.4%	3.1%	1.8%	2.2%	6.2%	0.0%	
Timor-Leste	171.8%	0.0%	0.0%	0.0%	0.0%	0.0%	
Togo	44.6%	39.6%	0.0%	5.0%	0.0%	0.0%	
Tonga	27.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Trinidad	0.2%	0.0%	0.0%	0.1%	0.1%	0.0%	
Tunisia	5.5%	0.0%	1.3%	2.1%	2.1%	0.0%	
Turkey	44.5%	19.8%	10.5%	5.6%	5.6%	3.1%	
Turkmenistan	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
UAE	15.4%	0.0%	0.0%	8.5%	0.0%	0.0%	6.8%
Uganda	104.3%	93.1%	0.0%	1.9%	9.3%	0.0%	
UK	57.9%	1.6%	26.5%	4.5%	11.0%	0.0%	14.2%
Ukraine	71.6%	9.7%	1.8%	4.4%	0.7%	0.0%	55.0%
Uruguay	73.0%	36.5%	4.6%	4.6%	27.4%	0.0%	
USA	36.5%	5.6%	5.6%	5.6%	1.1%	0.4%	18.2%
Uzbekistan	9.3%	8.8%	0.0%	0.5%	0.0%	0.0%	
Venezuela	79.0%	78.9%	0.0%	0.0%	0.0%	0.0%	
Vietnam	42.6%	29.1%	3.9%	9.3%	0.3%	0.0%	
Yemen	16.3%	0.0%	0.0%	16.3%	0.0%	0.0%	
Zambia	103.2%	102.2%	0.0%	0.6%	0.5%	0.0%	
Zimbabwe	50.2%	49.0%	0.0%	0.3%	1.0%	0.0%	
World	**38.6%**	**14.3%**	**7.2%**	**5.5%**	**2.4%**	**0.3%**	**8.9%**

The preceding table shows the broad spectrum of sustainable energy adoption across the world. IDCA has done further analysis to determine how much, if any, hypothetical "headroom" exists within each nation to add new data center capacity without adding new electricity resources.

IDCA research has shown that a developed nation's data centers can reach the level of 6.25% of all electricity consumption before significant political and community pushback occurs and moratoriums start being discussed and imposed. This percentage does not represent a hard cap, but correlates at the present moment with societal reality. As Table 3 shows, several nations have already reached and in some cases far exceeded the 6.25% level.

Others, including the United States and the UK, are approaching it, and data centers have become sources of local controversy. Another case is occurring in South Korea, where data centers are so heavily concentrated in the nation's capital city of Seoul that a local prohibition is in place. Chile and Mexico also have overall low consumption rates, but are experiencing significant local concerns.

Reclaiming Stranded Power: The "Zombie" Workload Epidemic

The transition to sustainable energy must also be accompanied by a rigorous elimination of systemic energy waste. IDCA research finds that as much as 13 percent of data center power consumption in the United States is currently supporting "zombie" applications—unused cloud containers and services that were instituted, discarded, and never properly decommissioned. This wasted consumption totals in excess of 3 gigawatts, which is functionally equivalent to the energy produced by three entire nuclear reactors. Before developing new, capital-intensive power generation, operators and governments must audit their logical layers to eliminate these inefficiencies, which are presumed to be apparent and increasing worldwide as cloud computing adoption rises.

06 Grid Stress & Headroom

Grid Stress & Headroom

While hyperscale developments in major hubs draw the most attention, the rapid expansion of Edge computing is creating an entirely new vector of energy stress. Driven by high-frequency trading, remote surgery, industrial automation, and edge AI, this sector is experiencing annual growth rates above 30% through 2030 . This expansion pushes heavy power and water demands into smaller communities that never anticipated hosting such mission-critical infrastructure . Unlike major metropolitan areas with built-in substation redundancy, small towns—such as those in Texas or Ohio—are often relying on aging electrical equipment from the 1970s with limited power sources . The resulting friction between the rapid 18-to-24 month deployment timeline of a data center and the 3-to-5 year timeline required to upgrade community power lines is creating significant developmental bottlenecks.

There are also dozens of developing nations with electricity grids insufficient to provide adequate, consistent power for general societal needs. Even though most of these nations devote between only 0.1% and 0.5% of their electricity to existing data centers, they clearly cannot grow in the absence of new power plants.

Table 6.
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**

So 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. 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 has 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 development thus presents a complicated picture to governments, investors, operators, and local populations. Most national governments, with the United States currently serving as a big exception, promote the use of sustainable energy resources in building out new electricity resources and developing data centers and AI hubs. But the renewable technologies (which do not include nuclear) each have limitations:

• **Solar.** Even though China has recently developed a GW-scale solar array just off its southeast coast, the reality is that there is no other nation with the combination of resources and governmental control possessed by China. Solar energy requires large amounts of land, requires large batteries to store and deliver electricity consistently, and faces questions as to the environmental benefits of manufacturing solar equipment.

• **Wind** energy faces concerns similar to that of solar. It requires land, batteries, and its equipment manufacture is not necessarily environment-friendly. China against provides the exception that proves the rule; it has created sprawling, multi-GW wind farms on a scale not attempted by any other country. The largest wind farm in the US, by contrast, delivers about 1.5GW through the Tehachapi Pass in Southern California.

• **Hydroelectric and Geothermal.** The first of these technologies, hydroelectric, can deliver multiple GW, but can only be created where nature has placed it. Today it is the largest source of renewable energy, delivering 14.3% of the world's electricity, more than solar and wind combined. It is an absolute boon to Canada and Norway, and to several small countries which have it and are able to export it, including Albania, Ethiopia, Laos, Malawi, Nepal, Paraguay, Tajikistan, and Zambia. But its ultimate ceiling remains limited. The second, geothermal, is even more limited by geographical location, and delivers only 0.3% of the world's electricity.

• **Biomass.** This technology has been a boon to what seems like a randomly selected array of smaller countries that have taken advantage of it: Armenia, Denmark, Estonia, Guatemala, Nicaragua, Panama, and Uruguay. It is classified as renewable in that it is created from dead plants and from wood, and maintains a complex relationship with advocates of other forms of renewable energy.

• **Nuclear.** Discussions about renewable energy today invariably lead to the more expansive category of sustainable energy, the category into which nuclear energy falls. Nuclear energy went into hibernation in the United States after the Three Mile Island incident in 1979, became unpopular worldwide with the Soviet's Chernobyl accident in 1986, and received further debilitating publicity with the Triple Disaster in Japan in 2011.

Nevertheless, nuclear energy received a new life when it was endorsed by more than 20 nations at the UN-sponsored COP28 conference in the UAE in 2023. The agreement signed there called for a tripling of the world's nuclear energy use by 2050. Presently, nuclear delivers 8.9% of the world's electricity, or around 300GW. It is used by 31 countries; expanded use throughout the world is aided by Article IV of the nuclear Non-Proliferation Treaty (NPT), which was put into effect by the US, UK, and then-Soviet Union in 1968. Nuclear energy nevertheless faces long, expensive development cycles, even in the form of 200-500MW Small Modular Reactors (SMRs) rather than traditional 1-2GW nuclear power plants. There is also an obvious potential for conflict related to any suspected intentions by new nuclear powers to try use it for military purposes.

07 Regenerative Infrastructure

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. 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.

- In Finland, for example, Microsoft has partnered with energy utility Fortum to supply around 40% of district heating demand for 250,000 people using waste heat from new data centers, while Verne Global's Helsinki campus elevates captured heat to 90°C to supply city-wide networks.

- In Denmark, Meta's data centers already contribute to municipal heating systems, and at the 2024 Paris Olympics, surplus heat from Equinix data centers helped warm swimming pools.

- In Ireland, the Tallaght District Heating Scheme saved 1,100 tonnes of CO_2 in its first year, redirecting waste heat from a nearby Amazon data center to local buildings.

- In the UK, the Mayor of London announced plans for a new district heat network expected to heat over 9,000 homes via local data centers. Stockholm has established itself as a world leader in large-scale waste heat recovery, with 30 facilities plugged into its district heating networks.

In some cases, data centers are also exploring ways to interact more dynamically with local energy systems, supporting grid stability and efficiency. New demand response technologies now allow operators to dynamically reduce energy use by powering down idle servers or limiting GPU power draw, enabling meaningful participation in grid flexibility programs without disrupting critical services.

The Use of LNG

Looking beyond the above hypothesis, the reality today is that the new sustainable resources are not expected to meet the quickly growing demand for data centers, particularly GPU-rich AI centers and hubs. 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. A key strategy evolving within this sphere of thought is the use of non-renewable liquid natural gas (LNG) is often being deployed as an on-site energy resource, delivered through gas turbines.

The federal government has recently validated this specific push toward operational energy sovereignty. The June 18 FERC orders explicitly told RTOs to build tariffs that accommodate co-location and behind-the-meter generation, officially transforming Sovereign Power from a defensive operator tactic into recognized grid policy.

Three firms, one each from the US, Germany, and Japan, dominate what's called the large-frame gas turbine business used for utility-scale generation and hyperscale data center campuses. The demand for these turbines is now so great that an order backlog now exists for some units until 2030.

Recent industry reports indicate that annual gas-turbine manufacturing capacity is limited to a small number of suppliers, while projected demand from large-scale data center developments is rising rapidly. This supply-demand imbalance has contributed to significant price inflation, with turnkey gas-fired generation projects reportedly increasing from roughly $1 billion per GW to as much as $2.5 billion per GW in some markets. The leading manufacturers and representative turbine models are shown below.

Table 7.
Gas Turbine Manufacturers and Representative Data Center Power Models

Manufacturer	Example turbine	Typical output
GE Vernova	7HA / 9HA series	~430–570 MW combined-cycle*
Siemens Energy	SGT6-9000HL	~400–570 MW
Mitsubishi Power	M501JAC	~430–680 MW

* Combined-cycle systems add steam recovery and raise overall system efficiency and output.

There are numerous ambitious projects driving this unprecedented demand for large-frame gas turbines, with the large share of demand coming from initiatives in the United States. In the US, there are initiatives afoot in the Data Center Alley of Northern Virginia, as well as the Midwest, Texas, Florida, Georgia, and Arizona.

All of the big hyperscalers are involved, along with Oracle, xAI, colocation developers, and utilities. A few prominent examples include NextEra Energy planning as much as 30GW of new capacity in Florida, NRG reserving more than 2GW of capacity for Texas-located projects, and a series of "power foundries" planned by GE in the US.

Looking beyond the immediate gas-turbine manufacturing bottleneck, data shows some unique potential for a few countries to benefit from using LNG to power large-scale data centers and AI hubs. The United States is the leader in this area, for example, producing 25% of the world's LNG and pacing it more than 60% ahead of second-place Russia.

China, Canada, Australia, and Iran are also large, resource-rich countries with abundant LNG reserves. On a smaller but significant scale lies Qatar, which plans to increase its output by 85% by 2030 and power a new era of AI hubs in this small nation of 3 million people (only 12% of which are native Qataris).

Indirect Water Consumption

When evaluating the environmental impact of data centers, operators and policymakers must look beyond direct facility water usage and account for indirect water consumption—the water required by utility plants to generate the electricity that feeds the grid. Over the last 25 years, the broader electricity industry has steadily reduced its water footprint by transitioning to wind and solar, which consume zero water during power generation. However, the unprecedented scale of new AI data centers means that even if a facility uses zero-water liquid cooling internally, the massive baseline electricity it draws from the grid could force utilities to rely on older, water-intensive power generation methods to meet the demand

08 Goldilocks Nations

Goldilocks Nations

Given the constraints on electricity in so many of the world's nations, it's instructive to seek nations that are currently more amenable to new data center and AI hub development. IDCA's research thus introduced the concept of Goldilocks nations in the 2026 Data Center Report. These nations continue to make strong, relative progress across the hundreds of parameters that are integrated into IDCA's Digital Readiness Index. The Index is itself the subject of a separate IDCA report.

The Geopolitics of Energy and Data Centers

The availability of robust energy resources is rapidly restructuring geopolitical influence, as nations recognize that whoever controls the power controls the future of AI. The disparity in global data center footprints is extreme, with server density varying by as much as 100,000 times between nations.

For instance, Canada possesses almost unlimited potential energy resources, yet its data center footprint remains a mere fraction of the United States' capacity. In stark contrast, China is viewed as a formidable competitor because its centralized control and aggressive energy agenda allow it to rapidly deploy massive 2 to 3-gigawatt data centers on highly condensed schedules. By prioritizing centralized nuclear and renewable energy integration, nations can bypass the regulatory delays plaguing Western grids, making energy policy a direct proxy for sovereign digital dominance

These nations also have a highly dynamic tech-development environment, but one in which growth is not untrammeled. Nations that run "too hot" with too-rapid technology growth over too-short a timeframe often find themselves disrupted, with rising societal instability. Goldilocks nations are not, according to IDCA's data, running too hot, but neither are they running "too cold." That is to say they are not lagging, either.

The list of 41 Goldilocks nations cuts across regions, income tiers, and population sizes. It thus includes Romania, Greece, Slovenia, Malaysia, Vietnam, Brazil, Chile, Ethiopia, Kenya, Tanzania, and more than 30 others.

(Their presence on the list is a function of their overall technology scores, which integrate data showing relative digital infrastructure development and use, calibrated by income levels and cost-of-living. They also tend to have existing room for expansion of their digital infrastructure footprints relative to their existing electricity grids, with the caveat that local conditions and community/political environments may inhibit their actual potential.)

(The Goldilocks nations reside within approximately 0.3 log10 points, or 0.5 standard deviation from the global average within IDCA's Digital Readiness Index. This puts them in approximately the most optimal one-third of nations for new digital infrastructure development, including data centers and AI hubs, of all the world's nations. The final Goldilocks results are expressed on a 0.0 to 10 scale for readability purposes.)

Table 8.
Goldilocks Nations

Country		Goldilocks	Country		Goldilocks
1	Colombia	5.2	23	Paraguay	4.4
2	N. Macedonia	5.2	24	Ecuador	4.4
3	China	5.2	25	Bolivia	4.4
4	South Africa	5.2	26	Chile	4.4
5	Montenegro	5.1	27	Senegal	4.4
6	Malaysia	5.1	28	Hungary	4.4
7	Kazakhstan	5.0	29	Romania	4.4
8	Morocco	5.0	30	Rwanda	4.3
9	Brazil	5.0	31	Nepal	4.3
10	Armenia	4.9	32	Gambia	4.3
11	Togo	4.9	33	Timor-Leste	4.2
12	Serbia	4.8	34	Laos	4.2
13	El Salvador	4.8	35	Namibia	4.1
14	Algeria	4.8	36	Albania	4.1
15	Cambodia	4.7	37	Turkey	4.0
16	Seychelles	4.7	38	Latvia	4.0
17	Argentina	4.7	39	Lithuania	4.0
19	Bulgaria	4.7	40	South Korea	4.0
20	Mauritius	4.6	41	Honduras	4.0
21	Pakistan	4.5	42	Peru	4.0
22	Ethiopia	4.5		**World**	**4.6**

Emissions by GDP

Concerns about CO2 and related greenhouse gas (GHG) emissions has been a primary driver of sustainable-energy adoption for a generation. Despite the world now closing in on the 40% in its use of sustainable energy, urgent concerns about the world's GHG emissions remain.Traditional views of GHG emissions by nation express either a total number or a per capita number. The world as a whole is running at an emissions rate of about 37 billion metric tons per year, for example. China is the world leader with more than 12 million tons, and the US is in the second position with emissions approaching 5 million tons per year. These numbers are available through any simple search.

Another view is the per capita (per-person) view, which shows the United States at three times the level of the world average and China at almost twice the world average. These numbers are also easily accessible.

Neither of these views takes into account economic efficiency. The challenge facing the world is to reduce GHG emissions without truncating existing developed economies and without impeding the growth of developing economies. IDCA thus views emissions in the context of economic efficiency. It measures the tons of emissions per $1 millions of GDP nominal, guiding for how best to maintain and improve socioeconomic conditions worldwide while at the same time addressing emissions reduction seriously.The two tables below show national emissions levels by this metric. The first table is an alphabetical list, and the second lists nations in order of their efficiency. The world average is currently 316.5 tons of CO2 per $1 million of nominal GDP. The US is more than twice as efficient as the world average, with a rate of 156.0 tons, while China is less than half as efficient, with a rate of 647.9 tons.

It behooves people to remember, however, that addressing emissions is a truly global problem, and that much of China's emissions, for example, come from the outsourced manufacturing this country does for the US and EU. In similar fashion, nations that are still highly dependent on oil production have high emissions levels as they supply the fuel required by the global economy.

Table 9.
CO2 Emissions by Country (Alphabetical)

Country		Emissions Index	Country		Emissions Index
1	Albania	145.7	45	Estonia	237.1
2	Algeria	612.5	46	Ethiopia	156.7
3	Angola	176.4	47	Finland	118.4
4	Argentina	279.5	48	France	96.6
5	Armenia	238.9	49	Gabon	228.7
6	Australia	221	50	Gambia	243.7
7	Austria	108.8	51	Georgia	311.6
8	Azerbaijan	484.8	52	Germany	133.7
9	Bahamas	90.3	53	Ghana	218.4
10	Bahrain	790.5	54	Greece	210.3
11	Bangladesh	227.1	55	Guatemala	165.9
12	Belarus	676.2	56	Guyana	145
13	Belgium	127.3	57	Haiti	117.3
14	Belize	80.6	58	Honduras	265.1
15	Bhutan	501.3	59	Hong Kong	77.2
16	Bolivia	380.7	60	Hungary	189.5
17	Bosnia	720.5	61	Iceland	91.1
18	Botswana	461.7	62	India	652.8
19	Brazil	207.3	63	Indonesia	477.5
20	Bulgaria	365.3	64	Iran	1,823.10
21	Burundi	132.1	65	Iraq	771
22	Cambodia	351.1	66	Ireland	55.1
23	Cameroon	178.4	67	Israel	108.2
24	Canada	264.1	68	Italy	126.5
25	CAR	1,704.30	69	Jamaica	255.1
26	Chile	272.1	70	Japan	253.4
27	China	647.9	71	Jordan	417
28	Colombia	279.5	72	Kazakhstan	801.2
29	Congo	473.8	73	Kenya	146.8
30	Congo, Dem	40.8	74	Kuwait	711.3
31	Costa Rica	87.4	75	Kyrgyzstan	3,433.50
32	Cote D'Ivoire	146.9	76	Laos	1,175.90
33	Croatia	166	77	Latvia	141.1
34	Cyprus	128.3	78	Lebanon	769
35	Czechia	272.2	79	Libya	1,220.20
36	Denmark	63.4	80	Lithuania	142.1
37	Djibouti	147.1	81	Luxembourg	76
38	Dominican	170.8	82	Madagascar	158.9
39	Ecuador	192.5	83	Malawi	407.3
40	Egypt	704.1	84	Malaysia	218.4
41	El Salvador	349.6	85	Maldives	220.2
42	El Salvador	97.9	86	Mali	263.2
43	Eq Guinea	316.9	87	Malta	63.9
44	Eritrea	339.8	88	Mauritius	257.8

Table 9.
CO2 Emissions by Country (Alphabetical)

Country		Emissions Index	Country		Emissions Index
89	Mexico	264.7	124	Singapore	96.3
90	Moldova	350.5	125	Slovakia	225.6
91	Mongolia	896.8	126	Slovenia	177.2
92	Montenegro	583.5	127	South Africa	938.2
93	Morocco	396.8	128	South Korea	342
94	Mozambique	407.8	129	South Sudan	1,103.80
95	Myanmar	621.5	130	Spain	139.6
96	N. Macedonia	442.9	131	Sri Lanka	184.5
97	Namibia	287.9	132	Sudan	666.7
98	Nepal	348.6	133	Sweden	57.3
99	Netherlands	100.3	134	Switzerland	36.3
100	New Zealand	124.8	135	Taiwan	315.2
101	Nicaragua	277.1	136	Tajikistan	525
102	Niger	119.5	137	Tanzania	184.9
103	Nigeria	274.8	138	Thailand	496.6
104	Norway	81.9	139	Timor-Leste	267.8
105	Oman	872.4	140	Togo	223.9
106	Pakistan	457.5	141	Tonga	350.5
107	Panama	218	142	Trinidad	1,067.10
108	Paraguay	208.3	143	Tunisia	612
109	Peru	200.7	144	Turkey	301.6
110	Philippines	307.9	145	Turkmenistan	849.2
111	Poland	296.3	146	UAE	375.6
112	Portugal	126.2	147	Uganda	108.5
113	Puerto Rico	125.8	148	UK	86.4
114	Qatar	461	149	Ukraine	532.8
115	Rest of World	89	150	Uruguay	103.5
116	Romania	182.2	151	USA	156
117	Russia	759.9	152	Uzbekistan	980
118	Rwanda	107	153	Venezuela	1,095.30
119	Saudi Arabia	499.2	154	Vietnam	680.2
120	Senegal	332	155	Yemen	678
121	Serbia	554.9	156	Zambia	312.7
122	Seychelles	375	157	Zimbabwe	227.1
123	Sierra Leone	127.3		**World**	**316.5**

Table 10.
CO2 Emissions by Country (Efficiency Index)

Country		Emissions Index	Country		Emissions Index
1	Switzerland	36.3	45	USA	156
2	Congo, Dem	40.8	46	Ethiopia	156.7
3	Ireland	55.1	47	Madagascar	158.9
4	Sweden	57.3	48	Guatemala	165.9
5	Denmark	63.4	49	Croatia	166
6	Malta	63.9	50	Dominican	170.8
7	Luxembourg	76	51	Angola	176.4
8	Hong Kong	77.2	52	Slovenia	177.2
9	Belize	80.6	53	Cameroon	178.4
10	Norway	81.9	54	Romania	182.2
11	UK	86.4	55	Sri Lanka	184.5
12	Costa Rica	87.4	56	Tanzania	184.9
13	Rest of World	89	57	Hungary	189.5
14	Bahamas	90.3	58	Ecuador	192.5
15	Iceland	91.1	59	Peru	200.7
16	Singapore	96.3	60	Brazil	207.3
17	France	96.6	61	Paraguay	208.3
18	El Salvador	97.9	62	Greece	210.3
19	Netherlands	100.3	63	Panama	218
20	Uruguay	103.5	64	Malaysia	218.4
21	Rwanda	107	65	Ghana	218.4
22	Israel	108.2	66	Maldives	220.2
23	Uganda	108.5	67	Australia	221
24	Austria	108.8	68	Togo	223.9
25	Haiti	117.3	69	Slovakia	225.6
26	Finland	118.4	70	Bangladesh	227.1
27	Niger	119.5	71	Zimbabwe	227.1
28	New Zealand	124.8	72	Gabon	228.7
29	Puerto Rico	125.8	73	Estonia	237.1
30	Portugal	126.2	74	Armenia	238.9
31	Italy	126.5	75	Gambia	243.7
32	Sierra Leone	127.3	76	Japan	253.4
33	Belgium	127.3	77	Jamaica	255.1
34	Cyprus	128.3	78	Mauritius	257.8
35	Burundi	132.1	79	Mali	263.2
36	Germany	133.7	80	Canada	264.1
37	Spain	139.6	81	Mexico	264.7
38	Latvia	141.1	82	Honduras	265.1
39	Lithuania	142.1	83	Timor-Leste	267.8
40	Guyana	145	84	Chile	272.1
41	Albania	145.7	85	Czechia	272.2
42	Kenya	146.8	86	Nigeria	274.8
43	Cote D'Ivoire	146.9	87	Nicaragua	277.1
44	Djibouti	147.1	88	Argentina	279.5

Table 10.
CO2 Emissions by Country (Efficiency Index)

Country		Emissions Index	Country		Emissions Index
89	Colombia	279.5	124	Tajikistan	525
90	Namibia	287.9	125	Ukraine	532.8
91	Poland	296.3	126	Serbia	554.9
92	Turkey	301.6	127	Montenegro	583.5
93	Philippines	307.9	128	Tunisia	612
94	Georgia	311.6	129	Algeria	612.5
95	Zambia	312.7	130	Myanmar	621.5
96	Taiwan	315.2	131	China	647.9
97	Eq Guinea	316.9	132	India	652.8
98	Senegal	332	133	Sudan	666.7
99	Eritrea	339.8	134	Belarus	676.2
100	South Korea	342	135	Yemen	678
101	Nepal	348.6	136	Vietnam	680.2
102	El Salvador	349.6	137	Egypt	704.1
103	Moldova	350.5	138	Kuwait	711.3
104	Tonga	350.5	139	Bosnia	720.5
105	Cambodia	351.1	140	Russia	759.9
106	Bulgaria	365.3	141	Lebanon	769
107	Seychelles	375	142	Iraq	771
108	UAE	375.6	143	Bahrain	790.5
109	Bolivia	380.7	144	Kazakhstan	801.2
110	Morocco	396.8	145	Turkmenistan	849.2
111	Malawi	407.3	146	Oman	872.4
112	Mozambique	407.8	147	Mongolia	896.8
113	Jordan	417	148	South Africa	938.2
114	N. Macedonia	442.9	149	Uzbekistan	980
115	Pakistan	457.5	150	Trinidad	1,067.10
116	Qatar	461	151	Venezuela	1,095.30
117	Botswana	461.7	152	South Sudan	1,103.80
118	Congo	473.8	153	Laos	1,175.90
119	Indonesia	477.5	154	Libya	1,220.20
120	Azerbaijan	484.8	155	CAR	1,704.30
121	Thailand	496.6	156	Iran	1,823.10
122	Saudi Arabia	499.2	157	Kyrgyzstan	3,433.50
123	Bhutan	501.3			

09 The Emissions Reduction Challenge

The Emissions Reduction Challenge

IDCA has developed another data set that measures the specific Emissions Reduction Challenge (ERC) facing the world. Integrating key factors such as total emissions, emissions per capita, current economic growth, and most important, the efficiency of an economy relative to its emissions level, this Index paints a less optimistic picture than the relative economic view expressed in the section above.

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).

Table 11.
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

Table 11.
Emissions Reduction Challenge (ERC) - Africa

Country	ERC (A)
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

Table 11.
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

Table 11.
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

Table 11.
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

Table 11.
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

10 Measuring Success: The Efficiency Efficacy Rating (EER)™

Measuring Success: The Efficiency Efficacy Rating

As power densities increase and infrastructure becomes more complex, operators require a standardized, holistic framework to evaluate the full spectrum of their performance. Point metrics that measure a single dimension of a single layer cannot capture the interdependencies of a modern Application Ecosystem, nor can they guide decisions that require balancing efficiency against availability, resilience, and capacity. Operators must therefore adopt holistic evaluation models such as the Efficiency Efficacy Rating (EER), defined in the IDCA Infinity Paradigm (AE360® 2.0) framework . The EER grades an ecosystem's effectiveness based on the actual resources consumed in production—integrating energy, water, and overall environmental sustainability into a single, comprehensive score . Crucially, the Infinity Paradigm dictates that maximizing efficiency cannot happen in a vacuum; power and cooling optimization (EER) must be carefully balanced against Availability (AER) and Resilience (RER) to ensure mission-critical applications survive

The AE360® Infinity Paradigm: A Full-Stack Performance Framework

Understanding how the AE360 Infinity Paradigm framework applies to energy evaluation is essential for any professional reading this report. AE360 defines seven Efficacy Ratings that together constitute a comprehensive, full-stack performance assessment of an Application Ecosystem (AE): the Availability Efficacy Rating (AER®), Capacity Efficacy Rating (CER®), Operations Efficacy Rating (OER®), Security Efficacy Rating (SER®), Resilience Efficacy Rating (RER®), Efficiency Efficacy Rating (EER®), and Innovation Efficacy Rating (IER®). These seven efficacies are evaluated across all seven layers of the Application Ecosystem — from Topology through Site, Site Facilities Infrastructure (SFI), IT Infrastructure (ITI), Compute, Platform, and Application — producing a grading matrix that culminates in an overall Efficacy Score Rating (ESR®). The EER is the efficacy most directly relevant to energy, water, land, workforce, and sustainability performance. Rather than measuring a single point metric in isolation, the EER grades a layer's total resource consumption effectiveness, incorporating energy intensity, water use, environmental sustainability, and operational efficiency as an integrated whole. This holistic approach ensures that efficiency improvements are evaluated in the context of their impact on availability, resilience, and operations — preventing the false economy of optimizing one dimension at the cost of another. Facility classification within AE360 uses Grade Levels (Gs®), ranging from G4 (minimum acceptable performance) through G3 (average), G2 (excellent), and G1 (exceptional, the highest grade achievable for a single Data Center Node). G0 is reserved for multi-node ecosystem-level resilience. Operators, investors, and regulators should require AE360 Grade Level assessments and ESR scores as the definitive basis for evaluating digital infrastructure capability — not as a replacement for regulatory filings, but as the authoritative technical evidence base that underlies them.

Battery Energy Storage Systems and Grid Flexibility

One near-term energy strategy deserving greater emphasis is large-scale Battery Energy Storage Systems (BESS). Gartner projects that within three to five years, rapid growth in BESS deployments will become the primary mechanism for balancing the intermittency of solar and wind generation at data center campuses. BESS enables operators to charge during periods of low grid demand and low carbon intensity, then discharge during peak demand, simultaneously reducing grid stress, lowering energy costs, and improving the effective carbon footprint of the facility. When co-located with on-site solar, a BESS installation can provide meaningful backup capacity and enables participation in demand response programs, generating revenue while improving broader grid stability. As interconnection queues stretch toward 2030 and beyond in many major markets, BESS represents one of the few scalable near-term tools available to operators seeking to expand capacity without waiting for new transmission infrastructure.

Regulatory Landscape: Key Frameworks

The regulatory environment for data center energy reporting is evolving rapidly and unevenly across jurisdictions. The European Union's Energy Efficiency Directive (EED, 2023 recast) requires all data centers above 500 kW installed IT capacity operating in EU member states to report energy performance indicators, renewable energy share, and waste heat reuse annually, with data submitted to the European Data Centre Register. IDCA's EER provides a framework that satisfies and exceeds these reporting requirements by embedding them within a broader, application-aligned efficiency assessment. Separately, the EU's Corporate Sustainability Reporting Directive (CSRD) mandates Scope 1, 2, and 3 greenhouse gas disclosures for large enterprises, directly affecting hyperscalers and major colocation operators. In the United States, the SEC's climate disclosure rules (finalized 2024) require publicly traded companies to disclose material climate risks and Scope 1 and 2 emissions, with phased implementation through 2026. The U.S. Department of Energy's Better Climate Challenge targets data center operators committing to reduce energy intensity by at least 20% over ten years. Operators expanding into Asia-Pacific must navigate Japan's Act on Rationalizing Energy Use, South Korea's Emissions Trading Scheme, and Singapore's Green Plan 2030, each imposing distinct efficiency and reporting obligations. IDCA recommends that all operators adopt AE360 as their primary performance framework and maintain a unified data architecture that maps AE360 EER controls to the specific reporting requirements of each applicable regulatory regime. This approach eliminates the need to manage multiple siloed metrics and provides regulators, investors, and boards with a single, authoritative, holistic assessment of infrastructure performance.

The U.S. Federal Regulatory Landscape

While international frameworks continue to evolve, the United States is experiencing a rapid regulatory shift at the federal grid level. On June 18, the Federal Energy Regulatory Commission (FERC) took direct action to address the infrastructure timeline mismatch by issuing tailored show-cause orders under Section 206 to major Regional Transmission Organizations (including PJM, MISO, SPP, CAISO, ISO-NE, and NYISO). These orders trigger immediate 30-day reliability reports and 60-day tariff deadlines.

Notably, FERC deliberately stayed in its federal transmission lane, leaving retail and facility siting decisions to individual states—a move that strongly reinforces the necessity for the industry to rely on region-specific roadmaps rather than waiting for a single national solution. Furthermore, as an emerging trend to watch, FERC singled out the Southwest Power Pool's (SPP) High Impact Large Load process as a potential model for other RTOs, essentially creating a federally blessed fast-track for operators and site selectors operating in SPP territory.

11 Conclusion

Conclusion

Digital infrastructure is no longer a niche sector; it has become an essential infrastructure in the modern era, with global investment now approaching $1 trillion annually, easily surpassing the the oil and gas industry. As data center power consumption rapidly scales to support artificial intelligence, the world is facing unprecedented electrical grid constraints.

There is no single, one-size-fits-all solution to this challenge. Success requires nations and operators to develop customized, region-specific roadmaps. By embracing advanced on-site generation like SMRs and hydrogen fuel cells, adopting zero-water liquid cooling, and measuring success through holistic frameworks like the Efficiency Efficacy Rating (EER), the industry can secure the power it needs while building a resilient and sustainable digital future.

The IEA projects global data center electricity consumption will reach approximately 945 TWh by 2030, nearly doubling from today's levels; on current trends this would represent close to 3% of all global electricity demand. This trajectory makes the energy decisions of the next five years among the most consequential infrastructure choices of the decade.

IDCA identifies five imperatives that should guide those decisions:

1. Audit and eliminate zombie workloads before any new generation investment, recovering the estimated 3GW of wasted U.S. capacity alone.

2. Accelerate the deployment of BESS alongside solar to smooth intermittency and reduce peak grid draws.

3. Require operators to conduct and disclose AE360 Efficacy Score Rating (ESR) assessments, with Grade Level evaluations at the SFI and Topology layers and EER scores as the primary efficiency benchmark, providing institutional investors and regulators with the holistic, auditable performance evidence they increasingly require.

4. Prioritize the 41 Goldilocks nations and 27 headroom nations identified in IDCA's research as the optimal near-term venues for new data center and AI hub investment, where grid capacity, political stability, and digital readiness align.

5. Treat the regulatory landscape not as a compliance burden but as a market signal, as jurisdictions that establish clear, predictable energy and sustainability rules for digital infrastructure will attract the most durable long-term investment. Digital sovereignty and energy sovereignty are now inseparable. Nations and operators that understand this connection and act on it with rigor and speed will define the architecture of the AI era.

I D C A

1801 Research Blv., Suite 550, Rockville, MD 20850
+1 (866) 422 1971
www.idc-a.org
research@idc-a.org
linkedin.com/company/international-data-center-authority-idca
IDCAorg