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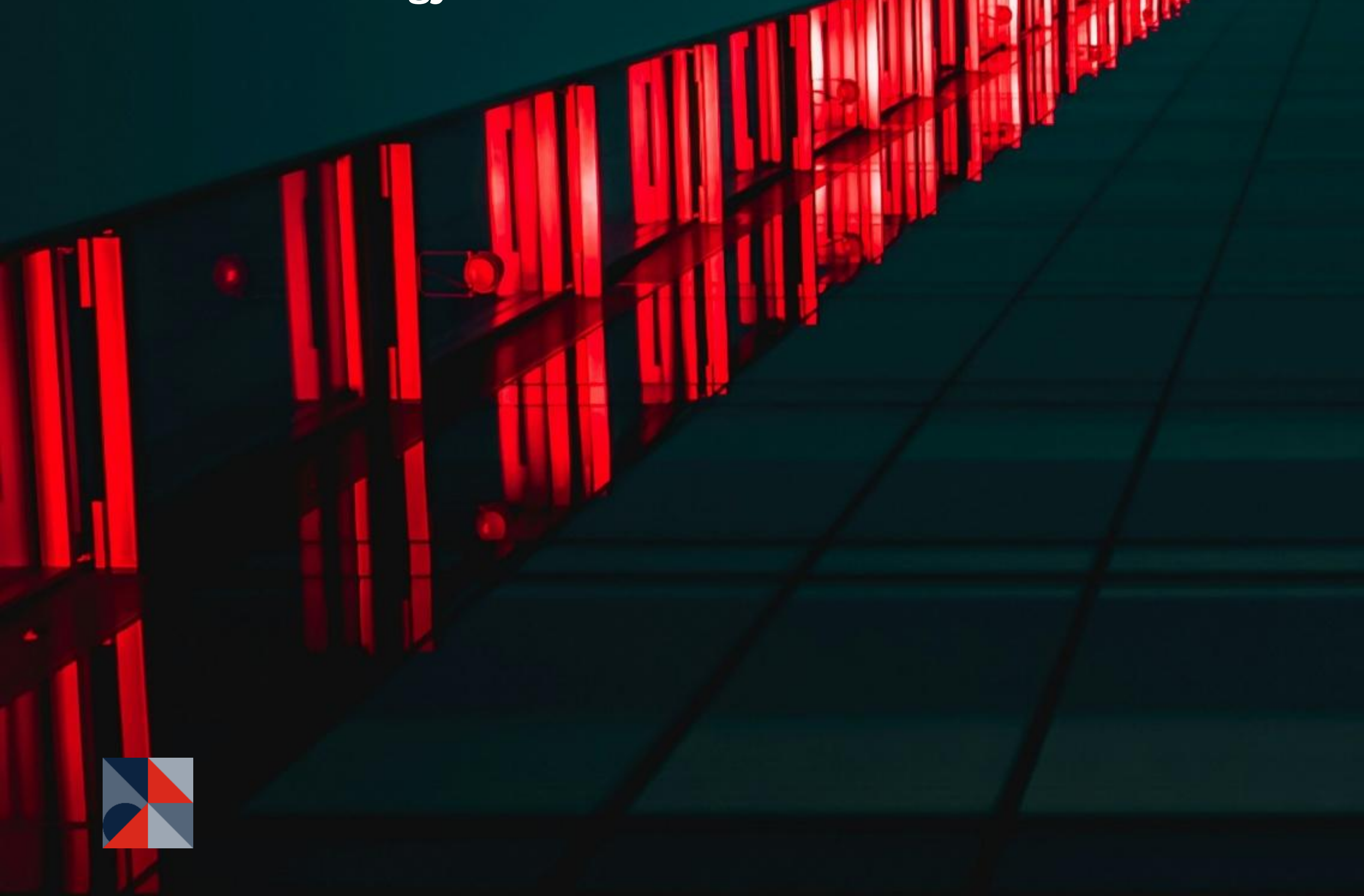
Data Centers assessment

The state of data centers and their role within the energy sector



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Executive Summary

Data centers have rapidly emerged as critical infrastructure underpinning the digital economy, mainly driven by exponential growth in the use of Internet and mobile devices, data generation, cloud computing, and artificial intelligence. As the global demand for computing power accelerates, data centers are consuming an increasing share of electricity, sparking both environmental concerns and strategic opportunities within the energy transition.

Since 2015, the data center industry has entered a phase of exponential expansion. The sector's installed power capacity has nearly tripled, led by the rise of hyperscale and colocation models. This growth has also altered the geographic and operational dynamics of data centers. Strategic site selection now depends on a complex mix of factors — e.g. energy costs, renewable availability, digital connectivity, and regulatory support — creating competition among regions to attract investment.

Data centers currently consume ~1.5% of global electricity, a figure expected to rise to over 3–4% by 2030 according to IEA. This growing energy demand presents both a threat and a unique opportunity for energy systems. Their stable, predictable, and high-intensity loads make data centers ideal allies for renewable integration, grid stability, and decarbonization efforts.

As large energy consumers, data centers can play a pivotal role in boosting electricity demand in alignment with renewable generation, particularly through Power Purchase Agreements (PPAs[1]) and geographic co-location with renewables.

Additionally, companies operating data centers are already setting climate-neutral targets (e.g. AWS, Google, and Microsoft have committed to 100% renewable energy and net-zero operations) and deploying innovative technologies. These include, for instance, advanced cooling systems, green hydrogen pilots, and direct renewable sourcing models.

Finally, some of these companies also start participating in flexibility markets by leveraging battery systems, backup generators, and load-shifting capabilities — helping balance supply and demand in real time.

Despite their potential, data centers face regulatory and economic hurdles in contributing to energy system flexibility. Also, high service-level requirements, limited energy awareness among data center operators and cybersecurity concerns remain key obstacles.

To unlock the full potential of data centers as enablers of the energy transition, this report recommends boosting Data Centers as enablers for the development of renewable projects, develop a favorable regulatory and legal framework, promote sector alliances and pilot plans to drive flagship initiatives that demonstrate technical and commercial viability, and support investments in electricity distribution networks and digitalization.

[1] PPA – Power Purchase Agreement

1. Introduction

Data centers are the backbone of the digital economy, enabling the adoption of mobile devices, cloud computing, data generation (e.g. IoT, e-commerce, industrial automation, social media...) and the development of artificial intelligence. As digitalization accelerates, the demand for data processing and storage grows exponentially, making data centers critical infrastructure. Simultaneously, their energy consumption and environmental impact are drawing increasing scrutiny, prompting a shift towards sustainable and energy-integrated models.

In this context, data centers are increasingly at the forefront of national digital strategies. Some countries —such as Chile, Singapore, Norway, or China—have already implemented dedicated plans to position themselves as sustainable and secure digital hubs. Meanwhile, others—such as Spain, Brazil, the United States, or Australia—are still shaping their regulatory and investment frameworks. However, despite this momentum, most countries worldwide still lack specific strategies, highlighting a significant gap in global policy development towards data centers development.

This report provides an assessment of the current state and outlook of data centers, emphasizing their growing role in the global energy landscape. It explores technological evolution, market dynamics, energy consumption trends, and the strategic opportunities and threats associated with integrating data centers into the energy sector, including final recommendations and next steps to be considered. The analysis is supported by data from international agencies, proprietary research by BIP and with the collaboration of multiple stakeholders interviewed for this purpose.

2. Data Centers: Current Situation and Future Outlook

2.1. Definition and Infrastructure

Data centers are specialized facilities designed to host servers and support infrastructures that process, store, and protect vast volumes of digital information. They are typically housed in purpose-built buildings and are divided into two main areas:

- White space: This area contains IT equipment such as servers, storage systems, switches, and racks
- Gray space: This area houses support systems including power supply, cooling, security, and cabling infrastructure. Traditionally, diesel generators have been used for backup power, but more sustainable alternatives such as hydrogen generators, fuel cells, and battery systems are being developed

Data Center Functioning Diagram

Figure 1 – Core infrastructure elements in a data center and their relationship with IT equipment (white space). Source: Bip analysis.

To evaluate the performance of data centers, the industry relies on a set of standardized indicators that measure how efficiently energy, water, and cooling resources are used. These Key Performance Indicators (KPIs) — namely *Power Usage Effectiveness (PUE)*, *Water Usage Effectiveness (WUE)*, *Carbon Usage Effectiveness (CUE)*, and *Cooling Capacity Factor (CCF)* — provide a quantitative view of both energy efficiency and sustainability performance. While PUE remains the most established metric, the other indicators complement it by capturing water consumption, carbon emissions, and cooling system effectiveness — all crucial aspects in assessing a data center's overall environmental footprint.

Example of quantitative KPIs frequently used to define and monitor data center infrastructure and operations include:

PUE

Power Usage Effectiveness indicates how efficiently a data center uses energy. The industry average is 1.56[2], while top performers have achieved 1.04[3]

PUE = Total Facility Energy Usage (kWh) / IT Equipment Energy Usage (kWh)

CUE

Carbon Usage Effectiveness indicates how carbon-efficient a data center. Ideally, a data center's CUE is zero, indicating a carbon-neutral footprint

CUE = Total CO_2 Emissions (kgCO_2eq) / IT Equipment Energy Usage (kWh)

WUE

Water Usage Effectiveness quantifies water use relative to IT energy consumption. The industry average is 1.8 L/kWh[4], but it is highly sensitive to local climate and cooling system type

WUE = Total Site Water Usage (L) / IT Equipment Energy Usage (kWh)

CCF

Cooling Capacity Factor indicates how much cooling capacity is provisioned relative to the IT heat load, including allowances for external heat sources. The industry average is 3.9, while the ideal CCF is 1.2[5]

CCF = Total Running Cooling Capacity (kW) / (IT Critical Load (kW) × 1.1)

These metrics are increasingly adopted as sustainability benchmarks across the industry. Best-in-class facilities achieve PUE values close to 1.1, WUE below 1.0 L/kWh, and CUE approaching zero when fully powered by renewable energy.
By tracking these indicators, operators can monitor progress toward carbon neutrality and resource efficiency and identify improvement areas to align with corporate Net Zero and ESG commitments.

2.2. Types of Data Centers

Data centers are classified based on their size and operational model:

- Enterprise: Owned and operated by a single company, typically on-premises
- Colocation: Facilities that lease space and services to multiple external clients
- Hyperscale: Massive data centers operated by major cloud providers like AWS, Google Cloud, and Microsoft Azure. These are the primary drivers of current market growth

Global Installed Data Center Power Capacity by Type, 2024 (GW)

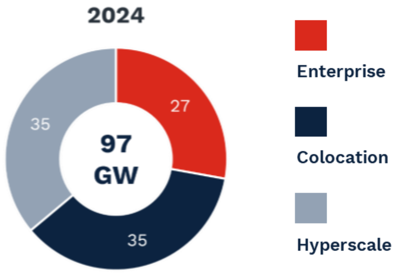


Figure 2 – Global installed data center power capacity split by enterprise, colocation, and hyperscale segments (2024). Source: Energy and AI (IEA Report; 2025), BIP Analysis.

[2] 2024 industry average, according to Uptime Institute, Global Data Center Survey 2024 (July 2024).
[3] According to AWS Sustainability, Amazon data centers have achieved PUEs as low as 1.04 (see: AWS Cloud Sustainability).
[4] 2016 industry average, according to Lawrence Berkeley National Laboratory, United States Data Center Energy Usage Report (June 2016)
[5] According to Uptime Institute, Global Data Center Survey 2024 (July 2024).

Edge data centers are small, decentralized facilities that provide computing and storage services closer to where data is generated and consumed. They are designed to reduce latency and optimize bandwidth, making them ideal for real-time data processing applications.

> "Hyperscalers continue to rely significantly on colocation data centers because these facilities offer pre-built infrastructure that allows for swift deployment. However, there is a noticeable trend of hyperscalers acquiring sites for self-build. This shift enables them to maintain full control over the development, ensuring that intellectual property remains in-house. While both approaches can coexist, the movement toward self-building is undeniably growing among hyperscalers.
>
> Edge data centers are poised to play a vital role in the data center ecosystem, driven by the increasing consumer demand for faster, low-latency experiences, similar to the dynamics seen in last-mile logistics. From an investment standpoint, the focus remains on larger sites with higher power capabilities, making the edge sector somewhat less enticing. Nevertheless, edge data centers are sensible from both societal and technological perspectives."
> **David Hunt-Cuadrado, Partner, Astra Partners**

2.3. Geographic distribution and key sitting criteria

Data centers are predominantly located near major urban areas in the United States, Europe, and China, with top 20 cities and regions accounting for over 65% of the global market share.

> "When deciding where to build a data center, the first thing I look at is the region's GDP. Without a strong economy, there's no client base or viable ecosystem. Energy comes next—it can represent up to 60% of a client's total cost. Other factors like connectivity, regulation, or talent are secondary. The sector follows economic demand. That's why real growth is concentrated in FLAP[6] markets."
> **Santiago Hernández Onís, Managing Director Spain, Iron Mountain Data Centers**

Global Installed Data Center Power Capacity by Region and Geographical Concentration, 2024 (GW)

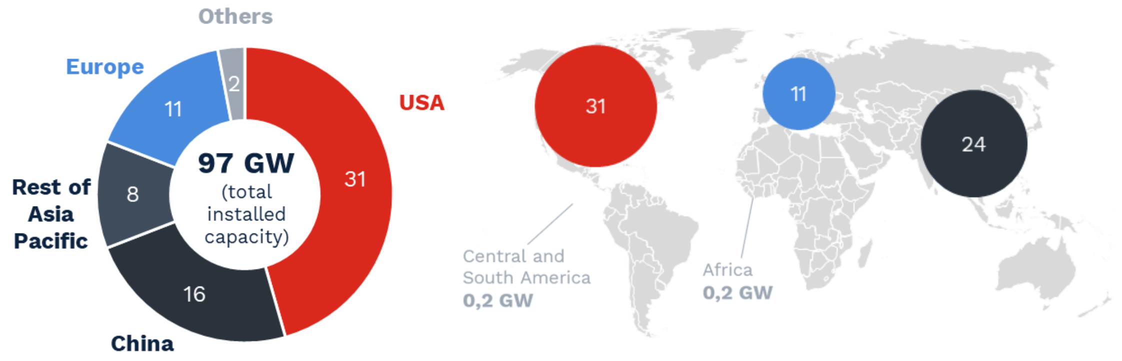


Figure 3 – Regional distribution and geographical concentration of global installed data center power capacity (GW), 2024. Sources: Energy and AI (IEA Report; 2025): Synergy Research Group (Top20 markets), BIP Analysis.

> "Aragón has worked on specific competitive advantages for data center investment: abundant renewable energy at competitive costs, permitting frameworks that shorten timelines, a stable institutional environment, and a strong technology ecosystem with specialized talent and clusters.".
> **Mar Paños, Managing Director Industrial Promotion & Innovation, Government of Aragon**

[6] Frankfurt, London, Amsterdam and Paris markets

Among the key criteria for locating data centers and beyond market economic attractiveness, good access to telecommunications and energy infrastructure stand out, however there are multiple criteria to consider (see details in figure below).

Key Site Selection Criteria for Data Centers

Energy availability and cost

- Grid Access Capacity
- Robust and Reliable Power Grid
- Low Energy Cost
- Availability of Renewable Energy (renewable energy mix, PPAs[7], etc.)
- Energy Scalability for Future Developments

Connectivity and network redundancy

- Proximity to telecom providers, fiber optics, internet exchange points, and submarine cables (aiming for low-latency connections)
- Multiple connection routes and diversity of telecommunications operators

Ease of implementation and favourable regulation

- Accessibility (transport, infrastructure)
- Land availability
- Ease of future expansion
- Ease of obtaining permits

Physical security and environmental risks

- Low risk of natural disasters
- Geographical stability
- Emergency services available

Favourable climate – Cooling efficiencies

- Favorable climate (cold, dry) to improve cooling efficiency (possibility of free cooling)
- Access to water for cooling

Access to talent and services

- Skilled workforce
- Proximity to clients/end users
- Quality of life in the area

Market economic attractiveness

Including: Regional GDP and growth, enterprise density, digital market maturity, corporate purchasing power, supportive service ecosystems, and future demand

Figure 4 – Main criteria for data center site selection, including energy, connectivity, regulation, physical risks, climate, and talent, 2024. Source: BIP analysis.

> “Institutional support is fundamental. The case of Aragon illustrates how proactive local governments can drive a boom in data centers’ investment. Several regions in Spain combine renewable energy with strategic locations, but strong public leadership can make a key difference. The second key factor is energy access — the backbone of data center development. Finally, data sovereignty. EU restrictions on data exports are driving local investment.”
> **Alejandro Fuster, CTO, SPAINDC**

[7] PPA – Power Purchase Agreement

2.4. Data Centers Value Chain

The development and operation of a data center span multiple years and involve a wide range of stakeholders. The following table summarizes the four main phases of the value chain, including their duration, core activities, challenges, and representative companies involved.

Main Phases, Activities, Challenges, and Key Players in DC development and operation, 2024

1 Planning, Design and Permitting	2 Construction	3 *Leasing*[8] of Spaces and Server Installation	4 *Operation and Maintenance*
Total: 1-6 years			Data Centre Lifespan (10-15 years)[10]
2-12 months	4 months – 3 years	6 months – 1.5 years[9]	
Main activities			
▪ Needs and feasibility analysis ▪ Site selection and land reservation ▪ Infrastructure design ▪ Construction and grid connection permitting ▪ Business plan definition and financing agreements	▪ Execution of civil works ▪ Installation of electrical systems ▪ Assembly of cooling systems ▪ Deployment of cabling and fiber optics ▪ Installation of security systems ▪ Final testing and certifications	▪ Space commercialization ▪ Resource adaptation for clients ▪ Installation of servers and equipment ▪ Provision of connectivity ▪ Security implementation ▪ Client access management	▪ Continuous monitoring ▪ Preventive and corrective maintenance ▪ Incident management ▪ Hardware and software upgrades ▪ Efficiency optimization
Associated challenges			
▪ Obtaining grid connection permits in saturated regions ▪ Securing viable and affordable land ▪ Ensuring project financing	▪ Cost overruns and construction delays ▪ Lead times for critical equipment	▪ Long lead times for computing systems ▪ Adapting to client requirements (technical and security)	▪ Energy and cooling efficiency losses ▪ Upgrading outdated infrastructure ▪ Security and reliability risks ▪ Availability of skilled workforce

Key players selection (not exhaustive)

- Real Estate: CBRE, JLL, Cromwell, Merlin, edged
- Suppliers of cooling systems: Vertiv, Schneider Electric, ABB, Delta, Alfa Laval, Munters
- Colocation Companies: Equinix, NTT Data, CoreSite, QTS, Digital Realty, CyrusOne, Iron Mountain, Vantage
- Architecture, Engineering and Construction: ARUP, DPR Construction, Holder, Turner, AECOM, Jacobs, Mercury
- Suppliers of connectivity systems: Cisco, Arista, Juniper
- Suppliers of energy systems: Schneider Electric, ABB, Siemens Energy, Hitachi, Eaton, CAT
- Computing Systems Providers: NVIDIA, intel, AMD
- Hyperscalers: aws, Google Cloud, Azure
- Energy suppliers: NextEra Energy, Duke Energy, Constellation, ENGIE, Iberdrola, enel, nationalgrid, Statkraft

Figure 5 – Summary of the main phases in the data center project life cycle, highlighting the activities, challenges, and principal players at each stage, 2024. Source: BIP analysis.

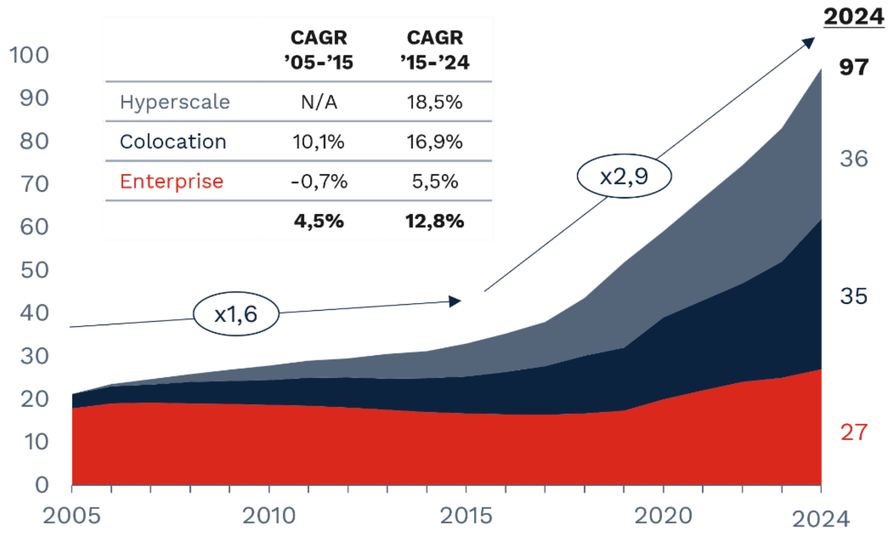
[8] 'Leasing' refers to colocation spaces; in other data center types, this phase covers commercializing and deploying infrastructure.
[9] Leasing duration can range from 6 months for small colocation spaces, up to 12 to 18 months when commercializing hyperscale facilities.
[10] Average operational lifespan of a data center before requiring major renovation: 10–15 years.

2.5. Exponential Growth of the Data Center Market

After a decade of relatively moderate expansion, the data center industry has entered a phase of exponential growth. This shift, particularly evident since 2015, reflects a structural transformation in how data is generated, processed, and stored globally.

The acceleration is not only quantitative but also qualitative: the market has evolved from a model dominated by enterprise-owned facilities to one increasingly led by colocation and hyperscale infrastructures. This change is visible in the rapid increase in installed capacity, which has nearly tripled between 2015 and 2024, driven by new digital demands.

Global Installed Data Center Power Capacity by Type, 2005–2024 (GW)



	CAGR '05-'15	CAGR '15-'24
Hyperscale	N/A	18,5%
Colocation	10,1%	16,9%
Enterprise	-0,7%	5,5%
	4,5%	**12,8%**

Figure 6 – Evolution of global installed data center power capacity by enterprise, colocation, and hyperscale segments (2005–2024). Sources: Energy and AI (IEA Report; 2025): IEA analysis based on data from IDC (2024a), OMDIA (2025), and SemiAnalysis (2025), BIP Analysis.

Several key trends have fueled this historical exponential growth so far:

- **Massive increase in connectivity:** The widespread adoption of mobile devices, the rollout of 5G networks, and the normalization of remote work have dramatically increased global data traffic
- **Cloud computing as the new standard**: Organizations across sectors are migrating to cloud-based solutions, shifting from traditional IT infrastructure to scalable, service-oriented models (e.g., SaaS, IaaS, PaaS), driven by the need for greater efficiency, cost savings, faster deployment and innovation, improved flexibility, and enhanced security
- **Explosion of data generation**: The proliferation of social media, connected devices (IoT), e-commerce platforms, and industrial automation has led to an unprecedented volume of data that must be stored, processed, and analyzed in real time
- **Rise of Artificial Intelligence (AI)**: AI and machine learning applications require enormous computational power and data throughput, accelerating investment in high-capacity data centers. For instance, a single ChatGPT query can

consume approximately 2.9 Wh, about ten times more than a Google search (0.3 Wh)[11], underlining the much greater energy intensity of modern AI workloads

Overall, Data center market has experienced exponential growth since 2015, with significant shifts not only in capacity but also in structure. This expansion reflects a qualitative transformation, marked by a move from traditional enterprise-owned data centers to collocation and hyperscale infrastructure models. The near threefold increase in installed capacity between 2015 and 2024 underscores the rising demand for scalable, efficient, and high-performance data solutions.

> "The sector's high EBITDA margins made it an attractive investment post-pandemic. But this isn't traditional real estate. The first question I ask is: do you have demand secured? Without clients or global agreements, there's no foundation. You can't just convert a warehouse into a data center—each megawatt can cost up to 14 million euros. This is a global, highly specialized business, and speculation without demand leads to failure."
> **Santiago Hernández Onís, Managing Director Spain, Iron Mountain Data Centers**

2.6. Future Outlook: Scaling Amid Energy Challenges

As Data Center infrastructure continues to scale at an unprecedented pace, the sector faces a critical challenge: balancing exponential growth with sustainable energy consumption. While past increases in demand were largely offset by gains in energy efficiency—mainly due to the shift towards hyperscale and colocation data centers — this dynamic is becoming harder to sustain.

Several structural limitations are emerging that hinder the sector's ability to continue offsetting demand growth through efficiency improvements:

- **Cloud Saturation**: The share of workloads running on cloud and hyperscale data centers—known for their significantly lower energy intensity—already exceeded 90% in 2020, up from 70–75% in 2015[12]. This leaves little room for further gains through migration
- **Technological Maturity:** Key efficiency improvements, such as those in cooling systems, appear to have plateaued. Between 2010 and 2024, average PUE[13] dropped from over 2.0 to below 1.5[14]. While emerging technologies like direct-to-chip cooling, immersion cooling, and hydrogen-based power solutions are under development, their potential for further large-scale efficiency gains is more limited

[11] Estimates based on SemiAnalysis (2023) and Google's public energy disclosures, as compiled by industry analyses. Figures represent typical energy consumption per query and may vary depending on model version, hardware, and context.
[12] According to the Cisco Global Cloud Index (2015–2020), the share of workloads processed in cloud data centers increased from around 75% in 2015 to 92% in 2020.
[13] PUE – Power Usage Effectiveness
[14] Based on global PUE averages from the Uptime Institute Global Data Center Survey 202.

As a result of these constraints, electricity consumption by data centers is projected to increase significantly over the coming years. According to the International Energy Agency (IEA), estimates for 2030 indicate that data centers could account for between 3% and over 4% of total global electricity demand, up from around 1.5% today. For comparison, electricity demand from electric vehicle charging is expected to reach approximately 2.5–2.7% by 2030 according to IEA.

Global Electricity Consumption and Energy Efficiency Gains in Data Centers, 2015–2030 (TWh, %)[15]

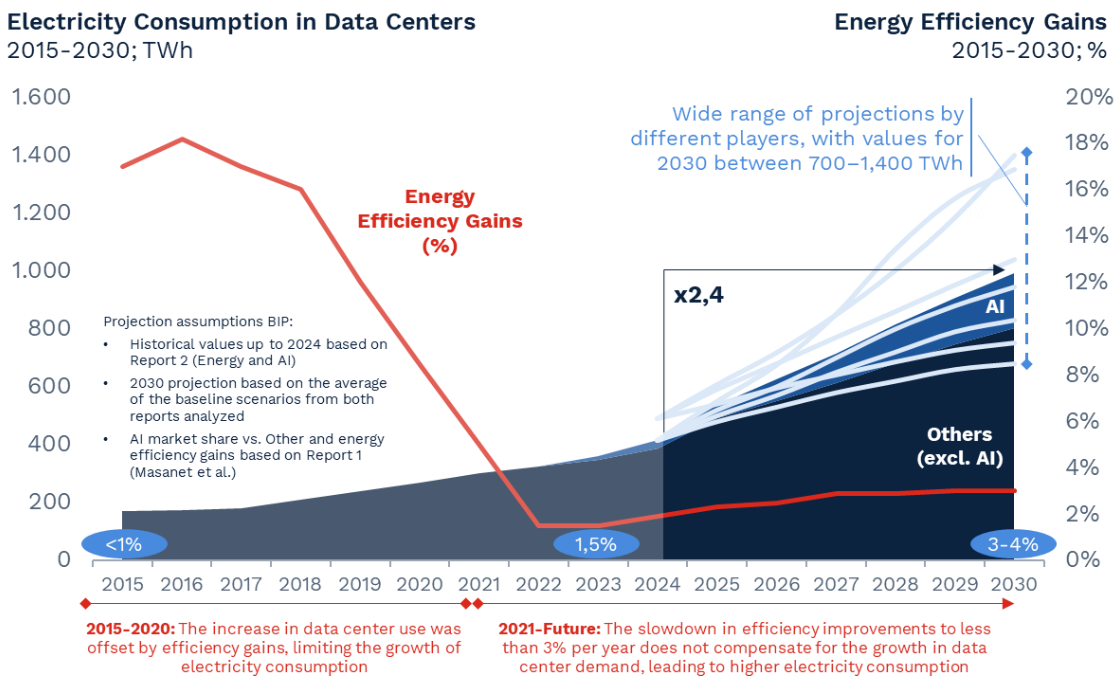


Figure 7 – Global data center electricity consumption (TWh) and energy efficiency gains (%)—historical and projected values, 2015–203). Sources: 1) Masanet et al. (2020), IEA, Cisco, Goldman Sachs Global Investment Research; 2) Energy and AI (IEA Report; 2025), BIP Analysis.

> “We often measure data centers in terms of energy, but that’s a limited view. What they really provide is computing capacity, digitalization, and value for citizens and businesses. Thanks to data centers, cities can optimize water usage, industries can reduce waste, and processes across sectors become more efficient.
>
> This is what I call transversal efficiency — benefits that go far beyond the data center itself.”
> **Alejandro Fuster, CTO, SPAINDC**

[15] Projection assumptions BIP: Historical values up to 2024 based on Report 2 (Energy and AI). The 2030 projection is based on the average of the baseline scenarios from both reports analyzed. AI market share vs. Other and energy efficiency gains are based on Report 1 (Masanet et al.).

3. The Role of Data Centers in the Energy Sector: Challenges and Opportunities

Data centers operate within the broader global effort to combat climate change. Key international milestones—such as the Kyoto Protocol (1997), the Paris Agreement (2015), and the COP26–29 conferences (2021–2024)—have shaped the direction of climate policy and accelerated the transition towards cleaner energy systems.

Electricity and heat generation account for over 25% of the global greenhouse gas emissions—category that includes the electricity consumed by data centers. According to the International Energy Agency (IEA), renewable energy is expected to become the leading source of electricity by 2025, reaching a global share of 35%.

In this context, data centers are not only adapting to the energy transition, but they are also becoming active enablers of it. We consider that their role spans three key dimensions:

1. Boosting electricity demand and align with renewable energy deployment
2. Deployment of decarbonization strategies aligned with existing technologies and mechanisms
3. Participation in flexibility markets

Key Enabling Dimensions of Data Centers in the Energy Transition

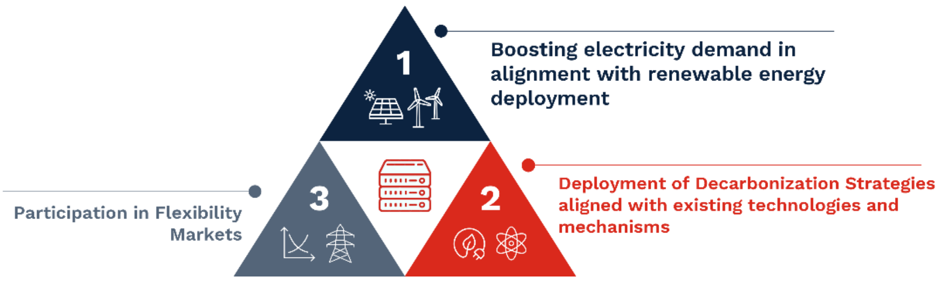


Figure 8 – Key Enabling Dimensions of Data Centers in the Energy Transition. Source: Bip analysis.

3.1. Boosting electricity demand and align with renewable energy deployment

The exponential growth of renewable electricity generation is creating new challenges for energy systems — not due to lack of supply, but due to insufficient demand and infrastructure to absorb it efficiently. Hence, the structural barriers currently limiting the full integration of renewables into the energy system can be summarized as follows:

Renewable generation is surging… Renewables now account for over 33% of global electricity production, and more than 50% in countries like Spain. Most national energy strategies aim to push this even further — for example, the EU targets 60% by 2030.

…but electricity demand isn't keeping up. Despite these ambitions, electricity consumption is growing more slowly than expected. The electrification of transport, industry, and heating is advancing at a modest pace, creating a mismatch between generation capacity and actual demand.

Electricity grid infrastructure is under pressure... New renewable plants are often located far from major consumption centers, creating a geographic mismatch that places increasing pressure on transmission and distribution networks. As a result, many systems are experiencing growing levels of congestion, which in turn leads to curtailments of renewable output, delays in connecting new projects, and underutilization of clean energy capacity.

As a result, renewable projects' profitability is being squeezed. During peak solar hours, electricity prices drop significantly, reducing the economic return of renewable projects. This weakens the investment case — especially in already saturated markets.

In this context, data centers can play a key role in addressing some of the structural barriers that hinder the full integration of renewable energy into the electricity system. Data centers can help address these challenges thanks to three key characteristics of their electricity demand:

1. **Stable, predictable, and manageable consumption.** Data centers operate with high and consistent energy loads, making their demand highly predictable. This allows for better integration into the energy system and enables demand-side flexibility strategies—such as reducing or shifting consumption during peak periods.

2. **Catalyst for renewable energy deployment.** The electricity demand associated with data centers can be directly linked to the development of new renewable energy projects. Through long-term procurement mechanisms like PPAs[15], data centers can provide the financial certainty needed to unlock investment and accelerate the deployment of clean energy infrastructure.

3. **Geographic alignment with renewable generation**. Data centers can be located near renewable energy sources, reducing the need for costly grid reinforcements. This proximity enables models such as on-site solar self-consumption or direct/off-site PPAs[16], improving system efficiency and minimizing transmission losses. This is illustrated, for instance, by the joint venture between Iberdrola and Echelon, planning large-scale data centers in Spain powered by renewables. Their first project, Madrid Sur, will host a 144 MW data center with a 1 TWh annual demand, to be met by a purpose-built on-site solar PV plant and additional clean energy from Iberdrola[17].

> "One of the key trends for data centers—and for all major energy consumers—is the shift toward renewable energy. Today, achieving 100% renewable supply is possible through Guarantees of Origin, but in the future, the goal will be 24/7 matching. That means aligning your energy consumption with the availability of renewable generation, ideally in real time. If this can also be done physically, such as through a direct cable connection, it can significantly reduce grid-related costs."
> **Mila Rey, Global Head of Energy, Cellnex Telecom**

[16] PPA – Power Purchase Agreement
[17] Source: Acuerdos de empresas: Iberdrola entra en el negocio de centros de datos, Soltec evita la quiebra – pv magazine España

> "In regions facing grid capacity limitations, our strategy involves generating and utilizing power directly on-site. With sustainability being imperative in this sector, we are committed to balancing local demand and supply, providing a demonstrable commitment to environmental responsibility."
> **David Hunt-Cuadrado, Partner, Astra Partners**

3.2. Deployment of Decarbonization Strategies in Data Centers

Most colocation and hyperscale operators have already embraced the energy transition by setting ambitious climate targets and deploying decarbonization strategies that combine renewable energy sourcing, energy efficiency, water stewardship, and circular resource management. Major companies in the sector are committing to carbon neutrality and responsible resource use, focusing on investments in renewable assets and long-term green energy procurement through Power Purchase Agreements (PPAs[18]). These efforts are further supported by technological innovation—such as energy-efficient chip design, advanced cooling systems, and AI-driven optimization as well as by green financing mechanisms like sustainability-linked loans and green bonds.

ESG Practices in European Data Centers

Regulatory Alignment:

Data center operators across the EU are reinforcing their Environmental, Social, and Governance (ESG) frameworks in line with key European regulations:

- EU Taxonomy for Sustainable Activities – defines criteria for environmentally sustainable investments
- Corporate Sustainability Reporting Directive (CSRD) – requires disclosure of detailed environmental and social performance data
- EU Data Center Sustainability Reporting Scheme (EED Recast) – mandates annual reporting (for IT loads >500 kW) on energy consumption and PUE[19], WUE[20], renewable energy share, waste heat reuse, and greenhouse gas emissions

These frameworks ensure measurable, verifiable, and comparable progress toward Net Zero goals, reinforcing accountability to investors, clients, and regulators.

Voluntary Standards & Initiatives:

- European Code of Conduct for Data Centres – operational best practices for energy efficiency and emissions reduction
- ISO/IEC 30134 series – standardized global performance metrics
- Climate Neutral Data Centre Pact (CNDCP) – industry commitment to carbon neutrality by 2030
- LEED for data centres – promotes sustainability design and construction

Together, these measures advance transparency, sustainability, and competitiveness in Europe's digital infrastructure landscape.

[18] PPA – Power Purchase Agreement
[19] PUE – Power Usage Effectiveness
[20] WUE – Water Usage Effectiveness

Decarbonization Commitments of Leading Data Center Industry Players

Amazon Web Services (AWS)

- Net Zero by 2040
- 100% renewable energy by 2025
- Development of energy-efficient chips (Graviton3, Inferentia)

Google Cloud

- Net Zero by 2030
- 50% reduction in absolute emissions
- 24/7 carbon-free energy operations

Microsoft

- Carbon negative by 2030
- 100% renewable energy by 2025
- Zero waste by 2030

Equinix

- Net Zero by 2040
- PUE[21] ≤ 1.39 (~6% reduction)
- $51M invested in energy efficiency
- WUE[22] ≤ 0.95

Digital Realty

- ~68% emissions reduction
- Financing through Green Bonds
- Focus on energy efficiency and sustainable supply chains

NTT Data

- Net Zero by 2040
- Achieve 100% renewable energy supply in data centers and offices

Figure 9 – Decarbonization Commitments of Leading Data Center Industry Players. Source: Bip analysis based on corporate websites data.

In line with these commitments, the data center sector is investing in next-generation technologies to accelerate decarbonization. These innovations aim to minimize environmental impacts across the full value chain, reduce emissions, and optimize energy and resource use during both operation and construction phases.

Zero-emission electricity generation is a key area of focus. Companies are exploring, for instance, the use of green hydrogen, particularly through hydrogen fuel cells for primary power and backup generation. Additionally, the development of Small Modular Reactors (SMRs) is gaining traction as a potential solution to supply clean, reliable electricity directly to data centers.

[21] PUE – Power Usage Effectiveness
[22] WUE – Water Usage Effectiveness

Microsoft's Data Center Decarbonization Strategy

Microsoft has deployed several initiatives at various stages of maturation to decarbonize its data center operations. Some examples include:

- **Advanced Liquid Immersion Cooling (2021):** Implemented at select data centers[23], this technology submerges servers in specialized fluids, reducing energy use significantly compared to traditional air cooling[24]
- **Battery Energy Storage Systems (2023):** A global roll-out of grid-interactive battery storage replaces diesel generators and balances renewable supply—illustrated by a 16 MWh, 24 MW-peak system in Sweden providing 80 minutes of backup[25]
- **Green Hydrogen Fuel Cells (2024):** In Dublin, Microsoft and ESB[26] piloted green hydrogen fuel cells, delivering 250 kW of zero-emission power during an eight-week demonstration—the first large-scale hydrogen backup in Europe[27]
- **AI-Driven Energy Optimization (2024):** An AI system that optimizes workload scheduling, raising server utilization from 50–60% to 80–90% and recovering up to 800 MW of unused energy[28]
- **Nuclear Power (2024–2028):** Microsoft signed a 20-year, $1.6 billion PPA[26] with Constellation to restart Pennsylvania's Three Mile Island nuclear reactor, which in 2028 will begin supplying 835 MW of carbon-free baseload power exclusively to Microsoft's data centers[27]

Cooling and thermal management are also evolving rapidly. Operators are testing and deploying advanced systems such as:

- **Free cooling**, which uses ambient air or water in suitable climates
- **Direct-to-chip cooling**, where coolant flows directly to server components
- **Immersion cooling**, which submerges hardware in dielectric liquids, drastically improving energy efficiency
- **Waste heat reuse**, which captures and redistributes heat for district heating or industrial applications, enabling **synergies with local communities and utilities** while reducing total water consumption

Taken together, these measures reflect a structural shift from an **efficiency-driven approach** to a **sustainability-driven model**, in which data centers evolve from high-consumption infrastructure into **active, low-carbon nodes** of the future energy ecosystem.

[23] Specific locations undisclosed
[24] According to Microsoft, "To cool datacenter servers, Microsoft turns to boiling liquid" (April 2021).
[25] According to Data Center Dynamics, "Microsoft replaces diesels with battery system at Swedish data center" (October 2023).
[26] ESB (Electricity Supply Board) is Ireland's state-owned electricity company, responsible for generation, transmission, and supply of electricity across the country.
[27] According to Microsoft News Centre Europe, "Microsoft announces pioneering green hydrogen pilot project with ESB" (September 2024).
[28] According to Microsoft News Centre Europe, "Sustainable by design: Innovating for energy efficiency in AI, part 1 (2024).
[26] PPA – Power Purchase Agreement
[27] According to ANS Nuclear Newswire, "Constellation announces TMI-1 restart, power purchase agreement with Microsoft" (September 2024).

3.3. Participation in Flexibility Markets

As electricity systems integrate increasing shares of variable renewable energy, the need for flexibility — the ability to balance supply and demand in real time — becomes more critical. While this transition is essential for decarbonization, it also introduces new operational challenges. Key challenges are emerging:

- **Intermittency and variability**, which make it harder to balance supply and demand due to fluctuations in solar and wind generation.
- **Reduced inertia and system stability**, as the shift away from synchronous generation complicates frequency control.
- **The urgent need for storage**, to manage energy surpluses and deficits across time.
- **The need for grid reinforcement and digitalization**, to prevent congestion and accommodate new generation capacity.

To address these challenges, it is essential to explore new sources of flexibility — and data centers are emerging as promising contributors. Their unique combination of attributes (e.g. energy assets, digital infrastructure, operational agility), enables them to support grid stability in innovative ways. The following sections outline six key attributes that enable data centers to support grid stability and participate effectively in flexibility markets.

A. Variety of Energy Resources

Data centers are equipped with a broad range of energy assets that can be leveraged to support grid stability and flexibility. These include:

- **Uninterruptible Power Supply (UPS)** systems, capable of delivering full power almost instantly - ideal for frequency balancing services (e.g., FFR[31], FCR[32])
- **Backup generators**, which can supply the entire facility for extended periods (2–8 hours), suitable for aFRR[33], mFRR[34], and reserve markets
- **Battery systems**, especially when hybridized with renewables, which can provide high power for 2–4 hours and support the creation of Virtual Energy Storage Systems (VESS)

This diversity allows data centers to offer versatile and adaptable solutions tailored to the evolving needs of the power system.

B. Operational Flexibility

Most of a data center’s electricity consumption is tied to computing tasks, many of which are not time sensitive. This enables:

- **Time-shifting**: Moving non-critical processing to off-peak hours
- **Location-shifting**: Redirecting workloads to other data centers in different regions

[31] FFR – Fast Frequency Response
[32] FCR – Fast Containment Reserve
[33] aFRR – Automatic Frequency Restoration Reserve
[34] mFRR – Manual Frequency Restoration Reserve

These capabilities allow operators to adjust demand dynamically, helping to balance the grid and optimize renewable energy use—without compromising service quality. Beyond these two core strengths, data centers benefit from several other features that enhance their value in flexibility markets:

C. **Adequate scale and geographic dispersion**: With loads typically exceeding 5 MW per site and facilities distributed across regions, data centers can provide both centralized and distributed flexibility

D. **Advanced control and communication systems:** Most centers already operate with sophisticated monitoring and automation tools, including AI-based load management, which facilitates real-time response without requiring additional infrastructure

E. **Overcapacity and redundancy:** Due to design standards and Tier classifications, data centers often operate below their maximum capacity, leaving room to activate unused resources when needed

F. **Established grid access:** Data centers already have high-capacity grid connections and permits in place, allowing them to participate in flexibility markets without the need for new infrastructure or regulatory approvals

These attributes position data centers as valuable assets in the evolving flexibility landscape. However, their ability to participate in such markets is not solely a matter of technical readiness — it also depends on the regulatory environment.

Flexibility market regulation is progressing unevenly across regions. Countries like France, Belgium, Switzerland, and Singapore already allow full data center participation, with relatively low barriers and active aggregator models. Other countries like Poland, Spain, and Brazil are advancing with some regulatory complexity or pending approvals. Meanwhile, the rest of Europe, much of Latin America, large parts of Asia, and Africa remain in early or pilot stages, with limited access and high entry thresholds.

This disparity highlights the need for harmonized frameworks to unlock the full potential of data centers in supporting grid flexibility.

> “Data centers could play a role in flexibility markets and support the energy transition, but today the conditions are not in place. Current compensation for providing flexibility services is not attractive, and regulation lags behind technology. Even with regional and private support, the national grid remains a bottleneck. For now, participation is limited — it will only become viable in the future if incentives improve and infrastructure is reinforced.”
> **Mar Paños, Managing Director Industrial Promotion & Innovation, Government of Aragon**

3.4. Case studies

The flexibility potential of data centers is already being tested in real-world scenarios. This section highlights how leading operators are applying energy and operational strategies to support the power system.

Google: From Load Shifting to Grid Integration

One of the most advanced examples of data centers supporting the energy transition is Google's deployment of demand response strategies between 2020 and 2023.

2020

Time-shifting: Hourly workload management within a single Data Center

Pilot project to shift non-real-time computing tasks to windows with higher local renewable generation (solar/wind). Using scheduling algorithms, tasks are shifted (time-shifting) to time slots with lower carbon intensity, while ensuring execution remains within a single data center

Impact of carbon intensity on data center electricity consumption patterns

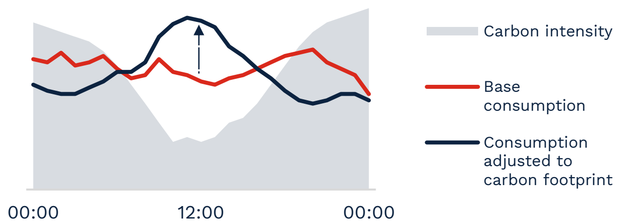


Figure 8 – Carbon intensity, base and optimized electricity consumption over 24 hours. Source: Projects' corporate web pages– Google, BIP Analysis.

2021

Location-shifting: Hourly workload management across different Data Centers

Pilot project to shift workloads across data centers (location-shifting), prioritizing sites with a higher renewable mix at any given time. It uses data on carbon intensity in the regional power mix to optimize locations in each hourly period

Figure 9 – Location-shifting of data center workloads to maximize renewable energy use. Source: BIP Analysis.

2022-2023

Coordinated management: Proactive workload support for grid operators

Demand response system in data centers that reduces power consumption in advance during periods when local grids are expected to become saturated. To do this, in coordination with grid operators, non-urgent tasks are shifted to times or locations with lower demand. Several real-world examples implemented:

- **Europe**: Reduced consumption during peak hours in several countries in winter 2022–2023 to support electricity grids during the energy crisis.
- **Taiwan**: Coordinated with the local utility in summers 2022 and 2023 to ease the load on the island grid.
- **US**: Lowered its consumption during heat waves and storms to help stabilize local grids

Beyond Google, in recent years, several data center operators across Europe have launched pilot projects and commercial initiatives to participate in electricity flexibility markets. From 2018 to 2022, notable examples include:

Selected Data Center Flexibility Initiatives Across Europe (2018–2022)

Figure 10 – Selected Data Center Flexibility Initiatives Across Europe (2018–2022). Sources: Web Pages or stakeholders' papers, BIP Analysis.

[35] UPS – Uninterrupted Power Supply
[36] FFR – Fast Frequency Response
[37] Statnett – Norway's transmission system operator (TSO), responsible for managing the national power grid.
[38] HIVE – Swedish data center operator (Bikupe Data Center project owner).
[39] Sympower – Flexibility services provider enabling demand response and load shifting.
[40] FCR – Frequency Containment Reserve, an ancillary service to maintain system frequency balance.
[41] Fortum – Finnish energy company active in generation, flexibility, and grid services.
[42] VPP – Virtual Power Plant, a system integrating distributed energy resources to act as one power plant.
[43] Eaton – Global power management company, provider of EnergyAware UPS systems.
[44] TSO – Transmission System Operator, entity managing high-voltage electricity transmission.
[45] EirGrid – Ireland's transmission system operator, responsible for electricity grid operation.
[46] Centrica – British energy services and solutions company (partner in Belgian data center project).

4. Challenges to flexibility participation

Despite their potential, several barriers hinder the full integration of data centers into energy flexibility markets:

- **Limited participation in electricity markets due to lack of regulation**
  In some regions, data centers are not recognized as valid agents to participate in capacity or flexibility markets, so there is a lack of legal and regulatory definition of their role in electricity markets (e.g., definition of participation conditions, independent aggregator figure, etc.)

- **Uncertainty about future profitability**
  The profitability of participating in flexibility markets may be insufficient in some cases and there is uncertainty about the potential long-term benefits. In some markets, clear economic signals are missing that sufficiently reflect scarcity or energy surplus to motivate load adjustments

- **Very restrictive service levels**
  Data centers have very high availability requirements within their SLAs[47], so modifying their consumption can put critical services at risk if the priority of loads is not well managed, creating reluctance to commit power to support the power system

- **Lack of awareness among data center operators**
  A lack of awareness among data center operators of the potential benefits they can gain from applying energy flexibility measures, as well as knowledge of the rules, actors, and procedures to participate in flexibility markets, slows project development and investments

- **Concerns about cybersecurity and external control**
  To participate in electricity markets, data centers must share data in real-time and allow some external control over loads and storage, generating exposure risks, attacks, or loss of autonomy that can create reluctance among operators to open their systems

[47] SLA – Service Level Agreement

> "Flexibility markets are an interesting opportunity, but not all data centers can or should participate. Introducing flexibility can mean adding operational risk, especially in colocation models with strict SLAs[48]. Even a microsecond disruption during a power switch can impact critical applications. Hence, flexibility can be part of the equation, but only for those who are operationally and contractually prepared to take that step."
> **Alejandro Fuster, CTO, SPAINDC**

> "One limitation of data centers is that they are behind the meter. Since they are not front of the meter, there are certain types of energy markets where they cannot participate if the necessary regulation is not in place. That's why it is important to advance regulation and allow behind-the-meter assets to participate in flexibility markets."
> **Mila Rey, Global Head of Energy, Cellnex Telecom**

[48] SLA – Service Level Agreement

5. Recommendations and Next Steps

To unlock the full potential of data centers in the energy transition, the following five actions are recommended:

Boost Data Centers as enablers for the development of renewable projects

Data Center development should drive stable electricity demand growth, supporting renewable energy generation projects. Key actions include defining roadmaps and deployment strategies (i.e., National Plans) that align facility locations with renewable energy sources, promoting programs and tax incentives for installations with sustainability requirements such as self-consumption or associated renewable projects, and supporting the integration of data centers as assets that stabilize the power system

Investments in electricity distribution networks and digitalization

Distribution networks with sufficient capacity and advanced digitalization are critical for data center deployment, associated renewable projects, and flexibility initiatives. Priority actions include reinforcing lines to ensure adequate capacity and avoid bottlenecks, digitalizing networks through monitoring sensors, data analytics and smart meters, enabling dynamic and bidirectional energy flow management, and increasing interconnection capacity between regions and countries

Sectoral alliances and pilot projects

Sector alliances and pilot plans are essential to drive flagship initiatives demonstrating technical and commercial viability. This involves exchanging best technical and regulatory practices, sharing success stories to encourage new operators, and developing and testing technological improvements. Large players have shown commitment through pilot projects in regions with favorable regulations (e.g., Nordic countries), yielding proven results that can be replicated

Favorable regulatory framework

Regulatory frameworks must adapt to facilitate data center deployment aligned with renewable projects and enable their participation in flexibility markets. This requires streamlining permitting processes for Data Centers and related renewable energy projects, creating and promoting balancing and flexibility markets (FFR[49], FCR[50], aFRR[51]/mFRR[52], capacity markets), and promoting the role of independent aggregators and local flexibility markets

Sustainability standards and ESG-driven innovation

Robust environmental standards and ESG frameworks are essential to ensure Data Centers contribute positively to climate goals while meeting regulatory requirements. Key actions include establishing minimum environmental standards through mandatory tracking of PUE[53], WUE[54], and CUE[55] metrics; aligning ESG reporting (e.g. with CSRD[56] and EU Taxonomy criteria); promoting circular economy technologies such as waste heat recovery and low-carbon materials; and fostering public-private research programs to accelerate innovation in sustainable cooling, renewable integration, and green infrastructure solutions

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[49] FFR – Fast Frequency Response
[50] FCR – Fast Containment Reserve
[51] aFRR – Automatic Frequency Restoration Reserve
[52] mFRR – Manual Frequency Restoration Reserve
[53] PUE – Power Usage Effectiveness
[54] WUE – Water Usage Effectiveness
[55] CUE – Carbon Usage Effectiveness
[56] CSRD – Corporate Sustainability Reporting Directive

"In countries like the Netherlands, projects related to renewable integration into the grid, demand management, etc., are given priority access to the grid. This is linked to whether the sector is considered strategically important for the country or provides a critical service. The idea is to prioritize anything that could be critical for the nation."
Mila Rey, Global Head of Energy, Cellnex Telecom

"Spain has all the ingredients to become one of Europe's leading hubs for data centers — abundant renewable energy, top engineering talent, strong infrastructure, and digital connectivity. In an industry where energy can represent up to 60% of total cost, that should be a decisive advantage. But to unlock this potential, we need two things: First, political vision: we're still explaining to policymakers that IT is the core of Industry 4.0, while other countries move ahead; Second, we need to address the limits of solar. It's our strongest asset, but we lose that edge for half the day. That's why hybrid energy strategies — combining batteries, grid supply, and on-site solar — are essential."
Santiago Hernández Onís, Managing Director Spain, Iron Mountain Data Centers

"To achieve meaningful progress in the data center industry, three foundational elements are essential: a transparent market with accessible grid data for all stakeholders; a strong public-private partnership to ensure coordinated infrastructure planning and investment; and a well-defined regulatory framework that caters to both national and regional nuances. Inconsistencies and lack of visibility transform each project into a complex, customized negotiation process, hindering the pace of deployment."
David Hunt-Cuadrado, Partner, Astra Partners

"Regional governments can do a lot to support data center investment — we can streamline procedures, align projects with our energy strategy, and work closely with companies to provide certainty. But there are clear limits: grid capacity and major infrastructure depend on the national level. Without stronger investment in the network, Spain has a whole risks losing international projects. That's why coordination between regions and the central government is essential."
Mar Paños, Managing Director Industrial Promotion & Innovation, Government of Aragon

6. BIP consulting: who we are

Bip is the consulting firm of the 21st century, born in the digital age, relies on a team of experts with cross-business skills and focuses on transforming clients' business through a "we make things happen" approach.

16 Countries
In which BIP has offices

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6.000+ Professionals

5.000+ Successful Projects

1.500+ Clients Worldwide

20+ Years
Founded in 2003

86% Loyalty Rate

BIP is one of the fastest-growing consulting firms globally, with over 6,000 employees and a strong presence in EMEA and the Americas. In Iberia, BIP operates offices in Madrid, Barcelona, and Lisbon, serving over 100 active clients and delivering more than 350 projects in 2024 alone.

Data Centre consulting – Bip areas of expertise	
Sustainability & Green Data Center	• ESG due diligence & EU reporting alignment • Decarbonization roadmaps & renewable sourcing (PPAs[57]) • Circular economy, resource optimization & recovery • Sustainability by design & environmental impact • Carbon footprint calculators & Digital Sustainability KPIs
Strategy & business	• Business & technical due diligence (M&A, investments) • Market & opportunity analysis, sizing & scenario comparison • Business planning & Go-to-Market strategy • Benchmarking of DC & IT quality and cost
Design & Tendering	• Feasibility analysis, high-level design & architecture blueprint • Migration & consolidation strategies • Vendor, colocation & cloud tendering support • Risk assessment, permitting & systems dimensioning
Delivery & Operations	• PMO, governance & change management for DC implementation • Operational excellence, KPI framework & service re-engineering • Operational performance monitoring (OLAs/SLAs, dashboards) • Business Continuity & Disaster Recovery frameworks

[57] PPA – Power Purchase Agreement

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Glossary

- **aFRR** – Automatic Frequency Restoration Reserve: Automatically activated reserve restoring grid frequency deviations.
- **CCF** – Cooling Capacity Factor: Ratio indicating the efficiency of cooling systems in DC.
- **CUE** – Carbon Usage Effectiveness: Measures carbon emissions relative to IT energy use.
- **FCR** – Frequency Containment Reserve: Reserve capacity stabilizing grid frequency continuously in real time.
- **mFRR** – Manual Frequency Restoration Reserve: Manually activated reserve to restore grid balance.
- **PPA** – Power Purchase Agreement: Contract between energy buyer and seller for electricity supply.
- **PUE** – Power Usage Effectiveness: Ratio of total facility energy to IT equipment energy.
- **RR** – Reserve Replacement: Metric showing replacement of extracted energy resources.
- **SLA** – Service Level Agreement: Contract defining service expectations and performance metrics.
- **WUE** – Water Usage Effectiveness: Metric for water consumption per unit of IT energy use.

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Data Centers assessment

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