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External study on data centres
Final study report

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The study was undertaken by

PwC and Poznań Supercomputing and Networking Centre (PSNC)

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Definitions

The following table provides definitions of key terms used throughout this report to ensure clarity and facilitate understanding for all readers.

Table 1. Definitions of the terms used in the report.

Term	**Definition**
6R Principles (in DC context)	A set of sustainability principles applied to data centres: Rethink, Refuse, Reduce, Reuse, Recycle, Recover.
Adiabatic Cooling	A cooling process that uses the evaporation of water to lower air temperature, often used in data centre cooling systems to improve energy efficiency.
Backup Power Supply / Uninterruptible Power Supply (UPS)	A system that provides emergency power to a load when the main power source fails, ensuring continuous operation of critical data centre systems
Circular Economy (in DC context)	A sustainability approach in which data centres prioritize reuse, repair, recycling, and resource efficiency to minimize waste and environmental impact
Cloud Service Provider (CSP)	A company that offers network services, infrastructure, or business applications in the cloud, typically on a pay-as-you-go basis.
Colocation (Carrier-Neutral Colocation)	A data centre service model where a provider leases physical space, power, cooling, and connectivity to multiple external clients, allowing them to install and manage their own IT equipment. Colocation facilities are often “carrier-neutral,” enabling clients to connect to multiple network providers.
Data Centre (DC)	A facility that houses computer systems (i.e. data processing, data storage and networking, and IT monitoring systems) typically organised in floors, rooms, groupings of racks and racks as well as associated systems, including telecommunication devices, local and metro/wide-area networking elements (link terminations, switches, routers, firewalls) as well as auxiliary and environmental systems including power supply, cooling, air conditioning, environmental monitoring, building monitoring systems (BMS) and security systems such access control systems, as fire detection and extinguishing, leak detection systems etc. Data centres provide critical infrastructure for storing, processing, and managing digital data for businesses, governments, and cloud service providers.
Direct Liquid Cooling (DLC)	A cooling technology where liquid coolant is circulated directly to IT components (such as CPUs or GPUs) to remove heat more efficiently than traditional air cooling.

District Heating	A system for distributing heat generated in a centralized location (such as a data centre) for residential and commercial heating requirements, often using waste heat from IT operations
Carrier-Neutral	A facility or service that allows clients to connect to multiple telecommunications carriers or network providers, rather than being restricted to a single provider
Cloud On-Ramp	A dedicated, high-speed connection from a data centre or enterprise network directly into a public cloud provider’s infrastructure, bypassing the public internet for improved performance and security.
Edge Data Centre	A smaller, distributed data centre located closer to end-users or devices to reduce latency and support real-time applications (such as IoT, autonomous vehicles, or 5G). Edge DCs complement larger, centralised facilities
Electronic Communication Networks (ECNs)	Networks that provide electronic communications services, including fixed and mobile telecommunications infrastructure, fibre backbones, and internet connectivity.
Electronic Communication Services (ECSs)	Services provided over ECNs, such as internet access, voice, messaging, and data transmission. ECSs are regulated by national and EU authorities.
Energy Efficiency Directive (EED)	An EU directive aimed at improving energy efficiency across member states, including mandatory reporting and performance standards for data centres.
Energy Reuse Factor (ERF)	A metric indicating the proportion of total energy consumed by a data centre that is reused outside the facility, such as for district heating.
F-Gas Regulation	EU regulation that restricts the use of fluorinated greenhouse gases, impacting the choice of refrigerants in data centre cooling systems.
Free Cooling	A method of using outside air or water to cool a data centre, reducing reliance on mechanical refrigeration.
Guarantee of Origin (GoO)	A certificate that proves a certain amount of energy was produced from renewable sources
High-Performance Computing (HPC)	A specialised type of data centre or computing environment designed to perform complex calculations at high speed, often used for scientific research, AI training, and big data analytics.
Hyperscaler	A company or operator that builds and manages massive-scale data centres, typically to deliver global cloud services (e.g., Amazon Web Services, Microsoft Azure, Google Cloud). Hyperscalers operate facilities with very high IT capacity, advanced automation, and global reach.
Immersion Cooling	A cooling method where IT equipment is submerged in a thermally conductive, but electrically insulating liquid, allowing for efficient heat removal.

Internet Exchange Point (IXP)	A physical infrastructure that allows different internet service providers (ISPs), content delivery networks (CDNs), and other networks to exchange internet traffic directly, improving speed and reducing costs.
Latency	The delay between a user's action and the response from a system, critical for real-time applications and influenced by data centre location and network design.
Liquid Cooling	A cooling method that uses liquids (water or special coolants) to remove heat from IT equipment, often more efficient than air cooling for high-density racks.
Modular Data Centre	A data centre built using prefabricated, standardized modules that can be rapidly deployed, scaled, or relocated as needed.
Power Purchase Agreement (PPA)	A long-term contract between a data centre operator and a renewable energy provider to purchase electricity, often used to secure green energy for operations.
Power Usage Effectiveness (PUE)	A key metric for data centre energy efficiency, calculated as the ratio of total facility energy consumption to the energy consumed by IT equipment. Lower PUE values indicate higher efficiency.
Public-Private Partnership (PPP)	A collaborative arrangement between government entities and private sector companies to finance, build, and operate data centres or digital infrastructure, often to support national digital strategies or research initiatives
Renewable Energy Factor (REF)	A metric representing the share of a data centre's energy consumption that is sourced from renewable energy.
Sovereign Cloud	A cloud service or infrastructure that ensures data is stored, processed, and managed within a specific jurisdiction, complying with local data protection and sovereignty requirements
Submarine Cable	A fibre-optic cable laid on the seabed between land-based stations to carry telecommunications signals across oceans and seas, forming the backbone of global internet connectivity
TDP (Thermal Design Power)	TDP is the maximum amount of heat generated by a component (CPU, GPU) that the cooling system of the server must be able to dissipate during normal operation. It is an approximate measure of the component's maximum power consumption, expressed in watts (W).
Water Usage Effectiveness (WUE)	A metric that measures the amount of water used by a data centre per unit of IT energy consumption, typically expressed in litres per kilowatt-hour (L/kWh)

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1. Executive summary

This report, commissioned by the Body of European Regulators for Electronic Communications (BEREC) and the Agency for Support for BEREC (BEREC Office), delivers an evidence-based analysis of the deployment, use, and future trends of the data centres (hereafter: DCs) ecosystem in Europe. It is intended to inform regulatory discussions by mapping the current landscape, identifying key dependencies, and highlighting the interplay between technological, economic, and regulatory (electronic communications) factors. The study draws on desk research, a broad stakeholder – survey, and in-depth interviews with operators, academia, and regulators. The report's key findings are outlined below:

DCs as pillars of the digital ecosystem: DCs are fundamental to Europe's digital transformation, underpinning cloud services, AI-driven applications, and a wide array of IT services for citizens and businesses. Their role extends beyond data storage and processing; DCs are now central to Europe's ambitions for digital sovereignty, resilience, and sustainability. The interrelation and convergence between electronic communication networks (ECNs) and digital service providers' networks necessitate a holistic regulatory approach.

Geographic distribution and market structure: Europe's DC landscape is diverse including many different actors. While primary hubs – in Frankfurt, London, Amsterdam, Paris, and Dublin (FLAP-D) – dominate in terms of installed capacity and connectivity, rapid growth is occurring in other countries/cities, such as Madrid, Milan, Warsaw, and across the Nordic region. These shifts are primarily driven by grid congestion in existing hubs, lower costs and supportive regulatory environments. Ownership models are equally varied, encompassing independent colocation providers, hyperscalers, public sector and PPP initiatives, telecom operator-owned facilities, and hybrid/emerging models. Each category faces distinct challenges and opportunities, contributing to a dynamic and competitive market.

Key dependencies and operational challenges: The deployment and operation of DCs are shaped by a complex interplay of dependencies:

- Power and grid infrastructure availability are the most critical determinants of site selection and operational resilience. The rapid expansion of AI and cloud computing is causing electricity demand to soar, and projections suggest that DCs' power consumption could almost double by 2030 relative to what it is in 2024.
- Network proximity and connectivity remain essential for performance and competitiveness, with dense fibre backbones, IXPs, and submarine cables forming the backbone of Europe's digital economy.
- Cooling and water resources are increasingly significant, especially in the context of environmental sustainability and regulatory requirements. The adoption of advanced cooling technologies and water stewardship practices is becoming a differentiator.
- Hardware supply chains, regulatory frameworks, licensing processes, and skilled workforce availability further influence the viability and scalability of DC investments.

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Environmental sustainability and regulatory trends: Sustainability has become a central concern for both operators and policymakers. The EU's Energy Efficiency Directive, the Climate Neutral Data Centre Pact (CNDCP), and national laws such as Germany's EnEfG are driving the sector towards greater transparency, efficiency, and the integration of renewable energy. Operators are increasingly required to report on key performance indicators such as Power Usage Effectiveness (PUE), Water Usage Effectiveness (WUE), and Energy Reuse Factor (ERF). The sector is also embracing circular economy principles, with growing emphasis on equipment reuse, recycling, and waste heat recovery.

Competition, market dynamics, and regulatory oversight: The overall European DC market is characterised by vibrant growth, ongoing consolidation, and the entry of new players, including global hyperscalers and private equity investors. This dynamism fosters innovation and investment but also raises concerns about market concentration, vendor lock-in, and digital sovereignty. While not directly targeting DCs, EU regulatory initiatives related to cloud and platform services aim to address these challenges by promoting interoperability, reducing switching costs, and ensuring fair competition. At the same time, the discussion on the electronic communications regulatory landscape is driven by the recurring debate on the "sending party network pays" charging principle driven by large telecom operators, and the advantages and disadvantages of harmonised regulations/standards across EU Member States. Taken together, these trends highlight a complex and evolving digital ecosystem where infrastructure growth, platform regulation, and telecom policy increasingly intersect.

Future outlook and policy implications: Looking ahead, the European DC sector faces both significant opportunities and complex challenges. The demand for digital infrastructure will continue to grow, driven by AI, cloud computing, and the digitalisation of all sectors of the economy. However, this growth must be balanced with the imperatives of sustainability, resilience, digital sovereignty and strategic autonomy. Policymakers and industry stakeholders will need to work collaboratively to ensure that regulatory frameworks remain fit for purpose, supporting innovation while safeguarding competition, environmental goals, and European values.

This study provides a factual basis to inform future regulatory discussions and decisions. By mapping the current landscape, identifying key trends and dependencies, and highlighting the interplay between technological, economic, and regulatory factors, the report aims to support BEREC, national regulators, and all stakeholders in navigating the evolving DC ecosystem and the digital infrastructure environment. As Europe advances towards its Digital Decade 2030 objectives, coordinated action and evidence-based policymaking will be essential to ensure a resilient, sustainable, and competitive digital future for all.

2. Introduction

This study has been commissioned by the Body of European Regulators for Electronic Communications (BEREC) and the Agency for Support for BEREC (BEREC Office) to provide a comprehensive, evidence-based analysis of the deployment and use of data centres (DCs) in Europe. DCs are a fundamental pillar of the digital ecosystem, enabling the provision of cloud services and a wide array of IT services to citizens and businesses. The connectivity of DCs relies on high-speed, dedicated electronic communication networks (ECNs), which may be privately owned or part of public ECNs providers regulated by national regulatory authorities (NRAs) for the electronic communications sector.

As highlighted in the European Commission's "White Paper – How to master Europe's digital infrastructure needs?"[1], the boundaries between ECNs/ECSs (electronic communications services) providers (such as telecommunications operators) and platform/digital service providers are increasingly blurred. This convergence underscores the need for a holistic approach that considers the entire digital infrastructure ecosystem. DCs are not only critical for delivering digital services but also play a key role in supporting Europe's ambitions for digital sovereignty, resilience, and sustainability. The European Commission's Digital Decade 2030 initiative and European Data Strategy both emphasise the importance of a robust, energy-efficient, and competitive data infrastructure as a foundation for Europe's digital future.

The primary objective of this study is to deliver a thorough analysis of the current landscape and future trends of DC deployment and use in Europe. The study covers:

- The geographic distribution of DCs across Europe;
- Ownership models and business structures;
- Key dependencies, including connectivity, energy demand, and sustainability factors;
- Interdependencies with ECSs/ECNs and international submarine cables;
- Market dynamics, competition, and regulatory oversight;
- Environmental sustainability and energy consumption;
- Anticipated regulatory trends and future challenges.

A particular focus is placed on deepening BEREC's understanding of the relationships and dynamics between DCs and ECSs/ECNs, including the impact of technological, energy, and regulatory dependencies. The study also explores the implications of DC deployment for competition, environmental sustainability, and the evolving regulatory landscape for electronic communications in Europe. Importantly, this report is not a policy recommendation paper; rather, it provides a factual basis to inform future regulatory discussions and decisions regarding the DCs ecosystem in Europe.

[1] European Commission. (2024). *White Paper: How to Master Europe's Digital Infrastructure Needs. European Commission Digital Strategy*. Retrieved November 27, 2025, from https://digital-strategy.ec.europa.eu/en/library/white-paper-how-master-europes-digital-infrastructure-needs.

The findings presented in this report are grounded in a combination of desk research, an extensive survey, and in-depth interviews. The survey targeted a broad spectrum of stakeholders from the DC and electronic communications sectors, while interviews were conducted with representatives of DC operators, academia, and regulators. The annexes provide further detail on the methodology and summarise the key insights from these engagements.

This external study by BEREC is intended to contribute to the broader regulatory discourse by analysing the impact of DC deployment on ECSs and ECNs, environmental sustainability, competition, and the future regulatory landscape. The study also serves as an input to other BEREC work-streams, including the analysis of submarine cables, a critical component of global connectivity and digital resilience, reflecting the growing interdependencies between DCs and international connectivity infrastructure.

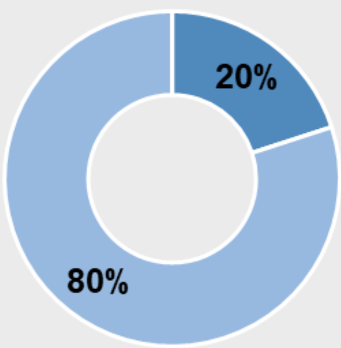
By providing a comprehensive, factual overview of the European DC landscape, this study aims to support policymakers, regulators, and industry stakeholders in navigating the challenges and opportunities of Europe's digital transformation.

3. Geographic distribution, ownership models, and key dependencies

DCs are a growing part of the global infrastructure market. According to BloombergNEF's *Data Center Market Overview* (as cited in Macquarie Asset Management[2]) DCs are a rapidly expanding part of the global infrastructure market. Globally, listings suggest well over 11,000 DCs across 170 countries[3]. The Figure 1 below provides an approximate overview of the spread of DCs across different regions in the world. In European Union, approximately 2,270 DCs are estimated to be distributed across the region[4], which represent near 20% of total DCs globally. The European DC market was valued at USD 47.23 billion in 2024 and is projected to reach USD 97.30 billion by 2030, representing a compound annual growth rate (CAGR) of 12.8%[5].

Global Data Centers – EU vs Rest of World

Share of Global Data Centers



EU-27 **2 270** data centers		**8 899 data centers**	
Top EU Countries		**Top Non-EU Countries**	
Germany	491	USA	4 225
France	321	China	381
Italy	210	India	276
Spain	200	Canada	295
Netherlands	194	Australia	282
Ireland	139	Japan	250

Top Non-EU Markets **80%**

Figure 1. Global data centre distribution by number (Research and Markets, 2025). Sources: https://www.researchandmarkets.com/reports/6012684/europe-existing-and-upcoming-data-center-portfolio; https://www.datacentermap.com/datacenters/; https://www.cargoson.com/en/blog/number-of-data-centers-by-country.

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[2] Macquarie Asset Management. (2025, August 20). *Data centres: Powering the growth of AI and cloud computing*. Macquarie Group. Retrieved November 25, 2025, from https://www.macquarie.com/fi/en/about/company/macquarie-asset-management/institutional-investor/insights/data-centres-powering-the-growth-of-ai-and-cloud-computing.html;
Dell'Oro Group. (2025, August 6). *Data center capex to grow at 21 percent CAGR through 2029* [Press release]. PR Newswire. Retrieved November 25, 2025, from https://www.prnewswire.com/news-releases/data-center-capex-to-grow-at-21-percent-cagr-through-2029-according-to-delloro-group-302522554.html.

[3] Data Center Map. (n.d.). *Data centers – database*. Retrieved October 18, 2025, from https://www.datacentermap.com/datacenters/.

[4] Newmark. (2025). *2025 data center site selection dynamics in Europe* [White paper]. Retrieved October 31, 2025, from https://nmrk.imgix.net/uploads/documents/2025-Data-Center-Site-Selection-Dynamic-Brief.pdf.

[5] Arizton Advisory & Intelligence. (2025). *Eu*rope data center market landscape 2025–2030 Arizton Advisory & Intelligence. Retrieved October 28, 2025, from https://www.arizton.com/market-reports/europe-data-center-market-analysis.

The European DC landscape features a diverse range of ownership structures and business models, reflecting both global trends and unique regional factors. Access to electric power, cooling water, fibre-connectivity and environmental or regulatory dependencies are among the most important factors influencing the geographic distribution of DCs[6], as we discuss below.

3.1. Key DC's dependencies

Nowadays, DCs anchor Europe's digital economy, but their growth is bounded by power availability, network proximity, cooling and water constraints, hardware supply chains, regulations and licensing, and several "soft" siting variables. Recent EU measures (notably the Energy Efficiency Directive (EED) and the DC sustainability rating scheme) have also made performance transparency a regulatory obligation, tying siting choices directly to energy and environmental policy[7]. As Ember[8] puts it, "ambitious grid planning can win Europe's AI race" but only where infrastructure, policy, and market incentives align. In the following sections, we examine in detail the principal factors shaping DC location and operation, including power availability and infrastructure, network proximity and connectivity, cooling and water resources, ICT hardware, environmental and regulatory dependencies, as well as other relevant considerations.

An analysis of prevalent challenges and failures, along with DC siting constraints reported across the broader market, was reflected in the survey conducted for this study. Specifically, 33% of respondents identified insufficient electrical capacity as a major issue, while 30% cited limitations related to cooling space or efficiency, and another 30% reported shortages in skilled personnel. Network reliability remains a significant concern, with 27.5% of participants experiencing at least one connectivity-related outage within the past three years – highlighting the importance of diverse carrier routes and robust edge or regional interconnections. Additionally, the most frequently encountered problems in DCs include limited development space and inadequate electricity supply; these concerns were noted by thirteen respondents (33%) out of d a total of 40 completed surveys – See Figure 2 below.

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[6] Datacenters.com Real Estate. (2025, September 26). Power, water, and permits: The new pillars of data center site selection. Retrieved October 20, 2025, from https://www.datacenters.com/news/power-water-and-permits-the-new-pillars-of-data-center-site-selection.

[7] European Commission. (2024, March 15). *Commission adopts EU-wide scheme for rating sustainability of data centres*. Retrieved October 22, 2025, from https://energy.ec.europa.eu/news/commission-adopts-eu-wide-scheme-rating-sustainability-data-centres-2024-03-15_en;

European Commission. (2024, May 17). *Commission Delegated Regulation (EU) 2024/1364 of 14 March 2024 on the first phase of the establishment of a common Union rating scheme for data centres*. *Official Journal of the European Union*, L 2024/1364. Retrieved October 30, 2025, from http://data.europa.eu/eli/reg_del/2024/1364/oj.

[8] Ember. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.

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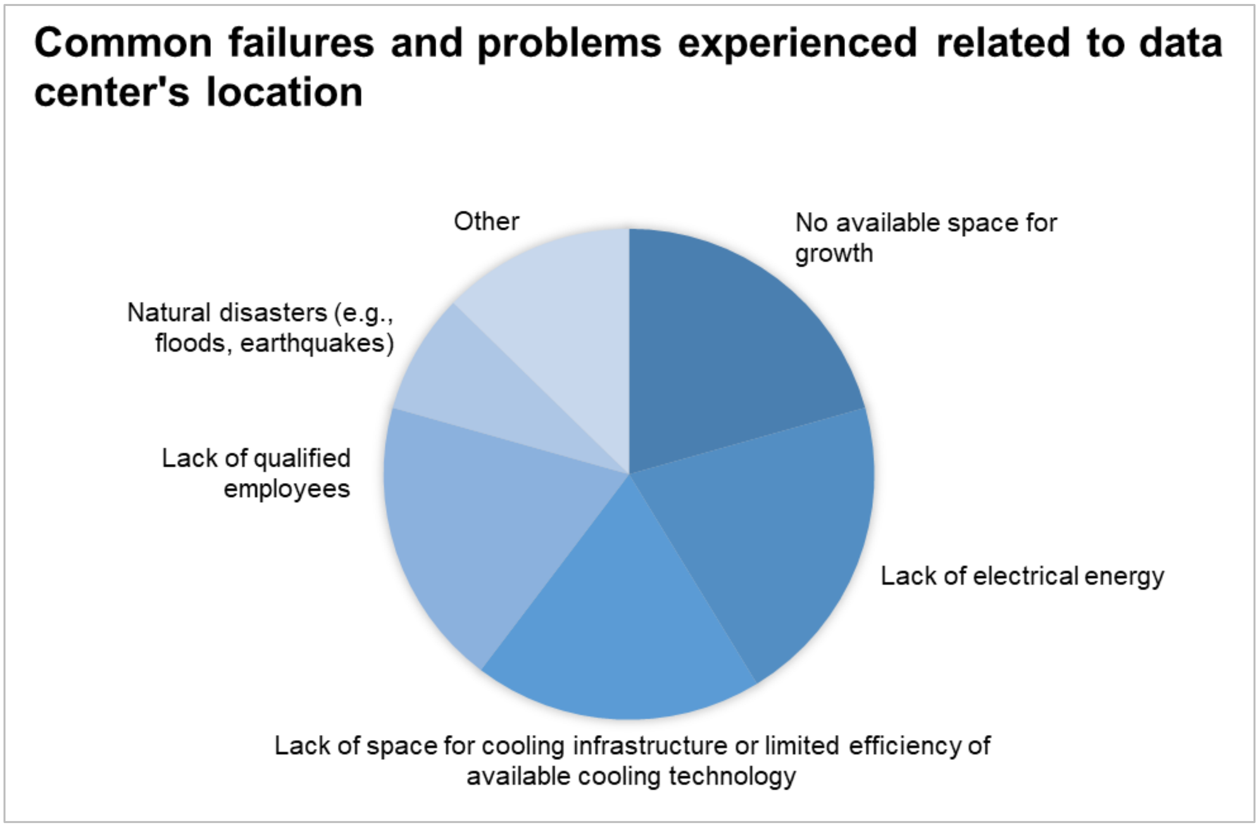

Figure 2. Common failures and problems experienced related to data centre's location.

3.1.1. Power availability and infrastructure

Power access is the most critical determinant of DC site selection in Europe. As workloads driven by AI, cloud services, and digitalisation in general expand, reliable and scalable electrical infrastructure has become a strategic constraint rather than a simple engineering variable.

Electricity Demand and Grid Congestion

Electricity consumption by European DCs is projected to rise from roughly 96 TWh in 2024 to 236 TWh by 2035, a near 150 % increase[9] , with total grid-connected DC capacity expected to grow from about 19 GW to around 33–34 GW over the same period[10]. S&P Global Commodity Insights[11] similarly forecasts that total power demand could double by 2030, warning that legacy transmission and distribution systems will face severe strain.

[9] Ember. (2025, June 19). *Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race* [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.
[10] Pexapark. (2025, October 21). *A data center tale: The hunger for PPAs.* Retrieved November 3, 2025, from https://pexapark.com/blog/a-data-center-tale-the-hunger-for-ppas/.
[11] S&P Global Commodity Insights (2025, April 10). Global data center power demand to double by 2030 on AI surge: IEA. Retrieved October 8, 2025, from https://www.spglobal.com/commodity-insights/en/news-research/latest-news/electric-power/041025-global-data-center-power-demand-to-double-by-2030-on-ai-surge-iea .

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Rising electricity demand is becoming a primary constraint for DC siting in Europe. Rapid growth in cloud, AI and high-density computing is driving a steep increase in DC power requirements, putting additional pressure on transmission and distribution networks that were not originally designed for such concentrated loads. In several established metro hubs, available grid capacity near suitable sites is already exhausted or heavily reserved, leading to long and uncertain connection timelines. As a result, grid congestion and the ability to secure firm, long-term capacity are now critical determinants of location decisions. Operators increasingly favour regions where transmission networks offer headroom for large new loads, where reinforcement plans are clearly defined, and where access to low-carbon generation can be contracted. This is shifting some new DC investments away from saturated core hubs toward emerging locations with stronger prospects for timely and scalable grid connections.

Renewable Sourcing and Procurement

Driven by the European Green Deal and the NDCP, operators have committed to match 75% of their electricity demand with renewable or carbon-free energy by 2025 and 100 % by 2030[12].

However, integrating this renewable share into congested electricity networks remains complex. The Beyond Fossil Fuels[13] analysis warns that "high data centre demand could limit the renewables available to decarbonise other critical sectors" if powered primarily by existing renewable capacity, as both industries increasingly compete for limited grid-connection points and substation capacity. Consequently, long-term Power Purchase Agreements (PPAs) have become the preferred mechanism to secure certified renewable energy while ensuring price stability and mitigating grid-access uncertainty.

Outcomes of the project's survey confirmed high renewable energy consumption. Thirty-one of the forty (78%) DCs' surveyed used some form of renewable energy. Twenty-seven of these have access to local renewable energy. Forty-one percent of the DCs' total electricity consumption in the last calendar year came from Guarantee of Origin-certified renewable energy sources. The most common sources were solar energy (36%) and hydropower (16%). The average Power Usage Effectiveness (PUE) reported by surveyed DCs ranged between 1.3 and 1.7, with an average value of 1.49.

[12] Climate Neutral Data Centre Pact (2021, January 15). Self-Regulatory Initiative – Climate Neutral Data Centre Pact. Retrieved October 21, 2025, from https://www.climateneutraldatacentre.net/wp-content/uploads/2021/01/20210115_Self_Regulatory_Initiative.pdf;
European Data Centre Association (EUDCA) (n.d.). Climate Neutral Data Centre Pact. Retrieved November 5, 2025, from https://www.eudca.org/climate-neutral-data-centre-pact.

[13] Beyond Fossil Fuels. (2025, February 10). *System overload: How new data centres could throw Europe's energy transition off course* [Report]. Beyond Fossil Fuels. Retrieved October 23, 2025, from https://beyondfossilfuels.org/2025/02/10/system-overload-how-new-data-centres-could-throw-europes-energy-transition-off-course/.

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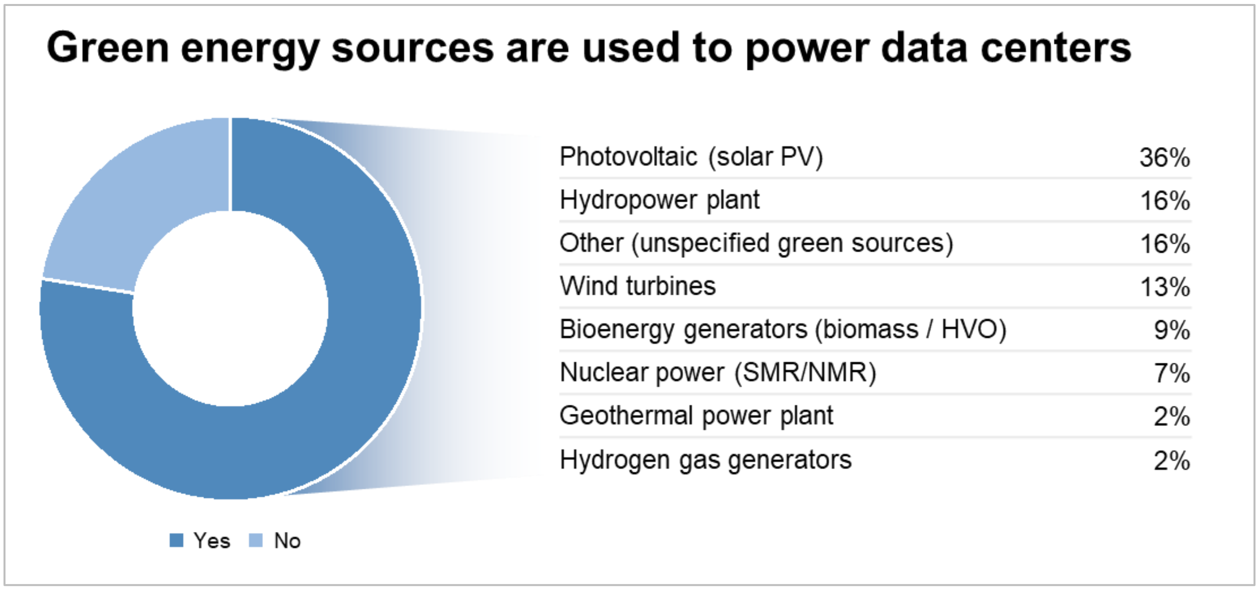

Figure 3. Green energy sources are used to power data centres.

Capacity Utilisation and Efficiency

Many European DCs currently utilise only 30 – 44% of their contracted grid capacity, tying up scarce energy network resources[14]. To address this, energy regulators and utilities are piloting phased-connection models, energising capacity in stages that correspond to actual IT load growth. This approach improves utilisation rates and reduces stranded-capacity risk, aligning private investment more closely with public-grid efficiency goals.

Resilience and Regional Policy Context

Operational resilience remains a baseline requirement. Facilities are designed with redundant utility feeds, uninterruptible-power supplies (UPS), on-site generation, and fuel storage, ensuring uptime even during grid disturbances. At the policy level, jurisdictions offering shorter permitting cycles, renewable headroom, and supportive grid-integration frameworks – such as the Nordic region, southern Europe, and emerging Central and Eastern European (CEE) markets – have become increasingly attractive for new deployments[15].

3.1.2. Network proximity and connectivity

Connectivity is another decisive determinant of the spatial distribution of European DCs. As workloads in AI, high-performance computing, and cloud applications expand, proximity to high-capacity network infrastructure has become as critical as access to electrical power. High

[14] Cremona, E., & Czyzak, P. (2025, June 19). *Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race* [Report]. Ember. Retrieved November 5, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.
[15] Ibid.;
Crellin, F. (2025, June 18). *Poor grid planning could shift Europe's data centre geography, report says.* Reuters. Retrieved 29 October 2025, from https://www.reuters.com/technology/poor-grid-planning-could-shift-europes-data-centre-geography-report-says-2025-06-18/.

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capacity/Low-latency links to cloud ecosystems, dense fibre networks, and Internet Exchange Points (IXPs) define both the operational reliability and economic competitiveness of DC facilities.

Proximity to Data and Cloud Ecosystems

Historically, DCs have been sited close to population centres to minimize delay (cache), particularly for latency-sensitive applications[16]. Nowadays, locating DCs near major data stores, cloud on-ramps [17], and hyperscale clusters [18] reduces latency, interconnection cost, and operational complexity. This tendency adheres to the principle of data gravity, which is defined as "the tendency for data to draw in digital infrastructure – the larger the datasets, the stronger the pull"[19] to reduce latency. In site planning, administrators often prefer locations adjacent to cloud and ecosystem hubs for performance and cost benefits[20]. Support for this pattern also appears in empirical market research: "proximity to customers is a key driver of the colocation market", meaning DCs cluster in economically dense metropolitan areas[21].

Fibre Backbone and Carrier Diversity

Access to high-capacity fibre backbones and diverse carrier connectivity remains fundamental for operational resilience and service continuity. Direct fibre connections to major IXPs such as AMS-IX (Amsterdam), DE-CIX (Frankfurt) and LINX (London) remain competitive differentiators. According to DE-CIX[22],"DE-CIX Frankfurt, Europe's largest Internet Exchange, alone had 45 exabytes of data flowing over its platform in 2024, a 13% increase compared to 2023", reflecting ongoing demand for low-latency, high-capacity connectivity between Europe's digital hubs. These exchanges reduce IP-transit costs and latency while enhancing routing stability. The IXP ecosystem increasingly influences digital-economy clustering, particularly in metropolitan areas with AI-edge and Internet of Things (IoT) platform build-out[23]. Facilities that host multiple carriers and physically independent routes – often complemented by 5G-based wireless fail-over – demonstrate superior network reliability[24].

Project survey responses underline the decisive role of network redundancy and bandwidth availability in siting choices. More than 70% of respondents reported having at least two independent broadband connections to their facilities, while 18% have four or more. The aggregated external bandwidth of surveyed DCs typically ranged between 10 and 200 Gbps, with

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[16] Mackin, A. (2024, August 22). *Navigating data centres: As demand for AI surges, what does this mean for data centres?* CBRE. Retrieved November 4, 2025, from https://www.cbre.com/insights/articles/navigating-data-centres-as-demand-for-ai-surges-what-does-this-mean-for-data-centres.
[17] Equinix. (2024, January 30). *What is a cloud on-ramp?* Interconnections – The Equinix Blog. Retrieved October 27, 2025, from https://blog.equinix.com/blog/2024/01/30/what-is-a-cloud-on-ramp/.
[18] See chapter "Geographical concentration patterns in EU countries " for description of DC hub types
[19] Bleess, J. (2024, January 11). *Data gravity vs. data velocity*. Interconnections – The Equinix Blog. Retrieved October 26, 2025, from https://blog.equinix.com/blog/2024/01/11/data-gravity-vs-data-velocity/.
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[21] Synergy Research Group. (2024, August 20). *Synergy identifies the world's top 20 metro markets for colocation*. Retrieved October 31, 2025, from https://www.srgresearch.com/articles/synergy-identifies-the-worlds-top-20-metro-markets-for-colocation.
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[23] RIPE Network Coordination Centre. (2025). The role of Internet Exchange Points (IXPs) in South East Europe [Report]. RIPE NCC. Retrieved October 29, 2025, from https://labs.ripe.net/media/documents/ripe_ncc_ixp_see_report.pdf.
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25% reporting above 200 Gbps. Nevertheless, 37% of participants indicated experiencing occasional network capacity shortages or reliability issues. Roughly 30% had suffered at least one outage in the past three years due to connectivity problems, most frequently related to overloaded links or lack of redundancy. A minority (15%) considered network-connection costs excessive, but over 40% emphasised that faster deployment of fibre routes remains a prerequisite for expansion.

Subsea Connectivity

Submarine cable systems remain the backbone of intercontinental digital communication, carrying nearly all long-haul data traffic. Approximately 99% of intercontinental data traffic is transmitted through submarine fibre-optic cables, underscoring their critical role as the backbone of global communications infrastructure[25]. Coastal landing hubs such as Marseille, Lisbon, Dublin, and Bilbao have become key European gateways for subsea and cloud connectivity. Proximity to major submarine cable landings improves network speed and reliability while stimulating DC and cloud-service investment, effectively concentrating interconnection ecosystems[26].

3.1.3. Cooling & water resources

Cooling and water availability have become decisive spatial determinants for the siting and operation of DCs across Europe. Water scarcity, rising tariffs, and new efficiency regulations are directly shaping site feasibility, cost structures, and sustainability strategies.

Water availability

DCs located in drought-prone or water-stressed regions face increasing permitting hurdles, community opposition, and operational risk. The Cloud Infrastructure Services Providers in Europe (CISPE) warned that water scarcity is “rapidly becoming a pressing challenge” for the sector[27]. S&P Global sees “water stress to be an emerging long-term business consideration, especially as attention to water use in water-stressed regions increases under evolving water management policies”[28]. Similarly, the European Environment Agency[29] identifies southern and densely populated regions as high-risk zones for water stress, urging diversification of industrial water sources. Such geographic differentiation is now integrated into DC location assessments.

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[27] Kobie, N. (2025, July 1). *Data center water consumption is out of control, but cloud providers want EU lawmakers to go easy on them*. ITPro. Retrieved November 2, 2025, from https://www.itpro.com/infrastructure/data-centres/data-center-water-consumption-eu-cispe.

[28] Laudisio, V., Cotran, H., Wu, N., & Pisaroni, F. (2025, September 15). *Beneath the surface: Water stress in data centers*. S&P Global Sustainable1. Retrieved October 18, 2025, from https://www.spglobal.com/sustainable1/en/insights/special-editorial/beneath-the-surface-water-stress-in-data-centers.

[29] European Environment Agency. (2024, June 4). Water savings for a water-resilient Europe. Retrieved October 21, 2025, from https://www.eea.europa.eu/en/analysis/publications/water-savings-for-a-water-resilient-europe.

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Cooling technology choices

Cooling design significantly influences both water consumption and sustainability performance. The metric Water Usage Effectiveness (WUE) expresses litres of water used per kilowatt-hour (kWh) of IT load; lower values indicate higher efficiency[30]. Air or liquid-loop systems can approach a WUE close to zero while evaporative cooling towers may reach up to 2.5 m³/MWh depending on local climate[31]. Across the EU, reported WUE values range between 0.07 and 1.28 m³/MWh, with an average around 0.58 m³/MWh[32]. These figures show that local water conditions and cooling technology interact directly to determine efficiency and sustainability outcomes.

In many prevalent design choices, direct abstraction of freshwater or surface water is required mainly when "normal" dry or air-based cooling is no longer sufficient – typically during heatwaves or prolonged periods of elevated ambient temperatures. These peak-load conditions often coincide with times when other users (households, agriculture, industry, and ecosystems) also place the highest demand on limited water resources. As a result, even relatively modest additional withdrawals by DCs can become contentious at precisely the moments when catchments are most stressed.

Moreover, for a wide range of water-based or adiabatic systems, cooling water must be chemically conditioned (e.g. anti-corrosion additives, biocides, anti-scaling agents) to protect piping, heat exchangers, and tower infrastructure. Blow-down and purge streams therefore contain residual treatment chemicals and cannot be regarded as "clean" water; they must be collected and treated before discharge or reuse. This shifts part of the environmental burden from water quantity to water quality, adding complexity to permitting processes and to the assessment of local ecological impacts.

During the research phase, cooling systems emerged as one of the most frequently replaced infrastructure components. According to the project survey, 63% of DC operators reported having replaced or upgraded cooling systems within the last 5–10 years. The dominant reasons cited were efficiency improvement (72%), end-of-life or manufacturer support expiry (56%) and equipment failures (48%). Nearly half of the surveyed DCs (47%) already use some form of free-cooling infrastructure and 35% reported access to external chilled-water or heat-reuse systems.

These results confirm that energy efficiency and water-use optimisation are leading operational drivers, closely aligned with EU regulatory emphasis on WUE reporting and heat-reuse integration[33].

Operational cost and disclosure

High water tariffs and abstraction levies have made water-intensive systems less attractive for long-term operation. Although water is often viewed as a way to boost efficiency and reduce

[30] Higgins, A. (2024, November 13). *What is water usage effectiveness (WUE) in data centers?* Interconnections – The Equinix Blog. Retrieved November 1, 2025, from https://blog.equinix.com/blog/2024/11/13/what-is-water-usage-effectiveness-wue-in-data-centers/.
[31] Ibid.
[32] Borderstep Institute. (2023). Data centres in the EU – facts and figures. Borderstep Institut für Innovation und Nachhaltigkeit gGmbH. Retrieved October 3, 2025, from https://www.borderstep.org/data-centres-in-the-eu-facts-figures/.
[33] This topic is described in more detail in the chapter _Water_usage.

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operating costs, its role in DC cooling is frequently assessed only partially. Relying on water-based cooling, especially in regions facing scarcity, increases annual operating costs due to the significant expenses associated with water treatment and system maintenance[34].

The revised EED obliges European DCs to publish key metrics, including water consumption and efficiency indicators[35]. Transparency measures have turned WUE into a reputational factor, with investors and clients assessing operators by their water-efficiency disclosures.

Regulatory and investor implications

Industry initiatives such as the CNDCP have introduced voluntary targets of 0.4 L/kWh in water-stressed regions by 2040[36]. Concurrently, the European Commission is developing stricter minimum water-efficiency standards for DCs, and industry groups warn that new water regulations and regulatory uncertainty could deter investment in European cloud and AI infrastructure[37].

Climate adaptation: Heat recovery and circular resource use

Modern DC campuses increasingly integrate reclaimed or harvested rainwater into their cooling systems and reuse waste heat through municipal district-heating networks. Microsoft reports that its European facilities in the Netherlands, Ireland and Sweden already employ rainwater harvesting and reclaimed-water systems to reduce freshwater demand and strengthen local climate resilience[38]. At the same time, Euroheat & Power and Codema[39] highlight that waste-heat recovery from DCs can supply substantial volumes of low-carbon energy to district heating and cooling grids, converting what was once a pure operating cost into a revenue-generating, circular-energy asset that enhances urban sustainability and system efficiency.

3.1.4. ICT hardware & supply chains

The spatial distribution and business model structure of DCs are profoundly influenced by hardware procurement and global supply-chain factors. Four inter-linked dependencies shape where DC investment is viable, how quickly it can be brought online and at what cost: hardware accessibility, trade policy, logistics, and standards and compliance.

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[34] Orr, R., & Klesner, K. (2016, June 17). *Ignore data center water consumption at your own peril*. Uptime Institute Blog. Retrieved October 15, 2025, from https://journal.uptimeinstitute.com/dont-ignore-water-consumption.
Vertiv. (2020, November 25). *Impact of water usage on data center costs and sustainability* (White paper SL-70704). Retrieved October 6, 2025, from https://www.vertiv.com/4ad73a/globalassets/documents/white-papers/vertiv-water-usage-and-sustainability-wp-en-na-web_317594_0.pdf.

[35] Jaymie Scotto & Associates. (2024, April 12). *EU's pursuit of sustainability: Impact of the Energy Efficiency Directive on data centres*. JSA Blog. Retrieved October 4, 2025, from https://www.jsa.net/eus-pursuit-of-sustainability-impact-of-the-energy-efficiency-directive-on-data-centres/.

[36] Judge, P. (2022, July 27). European operators plan to cut water use to 400 ml per kWh by 2040. Data Center Dynamics. Retrieved November 4, 2025, from https://www.datacenterdynamics.com/en/news/european-operators-plan-to-cut-water-use-to-400ml-per-kwh-by-2040/.

[37] Delille, T., & Giovannini, V. (2025, July). *The European Commission's 2025 Water Resilience Strategy – Emerging regulatory landscape and implications for businesses*. Squire Patton Boggs. Retrieved October 29, 2025, from https://www.squirepattonboggs.com/en/insights/publications/2025/07/the-european-commissions-2025-water-resilience-strategy-emerging-regulatory-landscape-and-implications-for-businesses.

[38] Microsoft. (2025, May 29). 2025 Environmental Sustainability Report. Retrieved October 31, 2025, from https://www.microsoft.com/en-us/corporate-responsibility/sustainability/report/.

[39] Euroheat & Power, & Codema. (2023, October). Harnessing waste heat from data centres for sustainable urban development [Position paper]. Euroheat & Power. Retrieved October 31, 2025, from https://horizoneuropencpportal.eu/sites/default/files/2024-06/ehp-position-paper-on-data-centres-2023.pdf.

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Hardware accessibility

The availability of critical hardware such as GPUs (and CPUs) and high-density switches has become a structural constraint on DC expansion. Bain & Company[40] projects that surging demand for AI-class GPUs could require production increases exceeding 30 percent, with long lead-times becoming the norm. Europe remains particularly dependent on imports, consuming roughly 20 percent of global chip output while manufacturing less than 10 percent[41]. This dependence makes DC installation timelines vulnerable to global semiconductor bottlenecks. As KPMG[42] notes, the sector remains "over-reliant on a few key suppliers", with diversification and forward procurement now viewed as essential risk-mitigation strategies.

The project survey revealed notable hardware-lifecycle patterns. Across all respondents, most computing and storage components (servers, SSD arrays, backup systems) have a typical usage time of 6–10 years. Network equipment such as routers, switches, and firewalls follows a similar replacement cycle, while roughly 20% of respondents operate certain systems beyond 15 years.

The main triggers for hardware replacement were "end-of-life or end-of-support" (58%), "efficiency improvement" (52%), and "availability of next-generation technology" (47%). These findings align with industry expectations that sustainability and energy-efficiency targets are accelerating replacement cycles, despite continuing global supply-chain constraints and high component prices.

Trade policy

Import tariffs and export restrictions on IT and power-distribution hardware directly affect construction costs. DataCentre Frontier[43] and Reuters[44] report that recently imposed U.S. and global trade tariffs on semiconductors, steel, and electronics are altering investment plans for hyperscale operators. Some equipment sourced from high-tariff countries now faces surcharges exceeding 100 percent[45]. Within Europe, the EU Chips Act and related industrial-policy initiatives aim to strengthen supply-chain autonomy and reduce exposure to geopolitical risk[46].

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[40] Bain & Company. (2024). Prepare for the coming AI chip shortage [Tech report]. Bain & Company. Retrieved October 31, 2025, from https://www.bain.com/insights/prepare-for-the-coming-ai-chip-shortage-tech-report-2024/.

[41] Deloitte. (2022, November 3). A new dawn for European chips: Semiconductor supply-chain risks under spotlight. Deloitte Insights. Retrieved October 31, 2025, from https://www.deloitte.com/us/en/insights/industry/technology/semiconductor-chip-shortage-supply-chain.html.

[42] KPMG Ireland. (2024, November 19). *Data centre supply chain* [Report]. KPMG Ireland. Retrieved October 11, 2025, from https://assets.kpmg.com/content/dam/kpmg/ie/pdf/2024/11/ie-data-centre-supply-chain.pdf.

[43] Vincent, M. (2025, April 3). How tariffs could impact data centres, AI, and energy amid supply-chain shifts. DataCentre Frontier. Retrieved October 31, 2025, from https://www.datacenterfrontier.com/hyperscale/article/55279670/how-tariffs-could-impact-data-centers-ai-and-energy-amid-supply-chain-shifts.

[44] Mary Sophia, D. (2025, April 3). Trump tariffs could stymie Big Tech's U.S. data-centre spending spree. Reuters. Retrieved October 31, 2025, from https://www.reuters.com/technology/trump-tariffs-could-stymie-big-techs-us-data-center-spending-spree-2025-04-03/.

[45] Sayegh, E. (2025, March 5). Trump's tariffs risk seismic implications for high-tech firms. Forbes. Retrieved October 31, 2025, from https://www.forbes.com/sites/emilsayegh/2025/03/05/trumps-tariffs-seismic-implications-for-high-tech-firms/.

[46] Gros, D. (2024). The (global) supply chain of chips: Chips in the European context (JRC Working Paper No. JRC139558). European Commission, Joint Research Centre. Retrieved October 31, 2025, from https://publications.jrc.ec.europa.eu/repository/bitstream/JRC139558/JRC139558_01.pdf;
Bonnet, P., Ciani, A., Di Girolamo, E. F., Molnar, J., Nardo, M., & Zaurino, E. (2025, January 17). *Monitoring framework to strengthen the EU semiconductor supply chain*. VoxEU.org. Retrieved November 7, 2025, from https://cepr.org/voxeu/columns/monitoring-framework-strengthen-eu-semiconductor-supply-chain.

Consequently, developers increasingly consider tariff exposure and regional trade alignment as primary location-selection variables.

Logistics: Ports, corridors, and lead-times

Large scale DC projects depend on the timely delivery of specialised modules, electrical systems, and IT hardware through complex logistics networks. Global evidence shows that the greatest sources of delay and cost variability occur at transport gateways – ports, airports, and border terminals – where customs and handling processes concentrate[47]. Proximity to major multimodal freight nodes – seaports, airports, and rail-freight corridors – has become a critical site-selection factor for hyperscale developments. Locations near efficient gateways enable faster movement of prefabricated modules and IT hardware, reducing customs cycles and overall delivery risk[48].

Standards & compliance

ICT hardware must meet electrical safety, electromagnetic compatibility (EMC), and environmental performance standards, which directly affect project cost and lead-time. Compliance in areas such as electrical integrity and energy management is essential to reducing operational risk. In Europe, stricter sustainability and reporting requirements under the EU Energy Efficiency Directive have made regulatory conformity a key consideration in DC planning[49].

3.1.5. Environmental & regulatory dependencies

Environmental policy and regulatory frameworks are increasingly decisive determinants of DC localisation, influencing site feasibility, operational cost structures and long-term business logic. DC operators must engage not only with power, cooling and connectivity infrastructures, but also with evolving rules on energy efficiency, refrigerants, water use, waste-heat recovery, land-use and permitting.

EU Green Deal & EED Recast

Under the recast Energy Efficiency Directive and associated Delegated Regulation (EU) 2024/1364, DCs above specified thresholds (for example IT power ≥ 500 kW) are obliged to report key sustainability metrics into an EU-wide database[50]. This reporting obligation affects permitting, operational transparency, investor perception, and ultimately cost of capital by placing DCs under a framework of accountability for energy, water, and heat-reuse performance[51].

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47 World Bank. (2023). Connecting to compete 2023: Trade logistics in an uncertain global economy (Logistics Performance Index). World Bank. Retrieved October 31, 2025, from https://documents1.worldbank.org/curated/en/099042123145531599/pdf/P17146804a6a570ac0a4f80895e320dda1e.pdf.

48 Gillin, P. (2020). *5 things to know about data center site selection*. *STACK Infrastructure*. Retrieved October 19, 2025, from https://www.stackinfra.com/wp-content/uploads/2020/11/Stack_SiteSelection111620.pdf.

49 Royal HaskoningDHV. (2024, August 28). Ensuring data centre compliance: A strategic approach. Royal HaskoningDHV. Retrieved October 31, 2025, from https://www.haskoning.com/en/newsroom/blogs/2024/ensuring-data-centre-compliance-a-strategic-approach.

50 European Commission. (2024, May 17). Commission Delegated Regulation (EU) 2024/1364 of 14 March 2024 on the first phase of the establishment of a common Union rating scheme for data centres. Official Journal of the European Union, L 2024/1364. Retrieved October 30, 2025, from http://data.europa.eu/eli/reg_del/2024/1364/oj.

51 CMS. (2024, June 11). *Specification of the European publication obligations for data centres*. Law-Now. Retrieved October 27, 2025, from https://cms-lawnow.com/en/ealerts/2024/06/specification-of-the-european-publication-obligations-for-data-centres.

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Local constraints and moratoria

Several metropolitan and regional jurisdictions are imposing moratoria or significantly tightening the conditions under which new DC loads may connect to the electricity grid, draw process water, or locate on environmentally stressed land. In the greater Dublin area, for example, a de facto grid-connection moratorium has been in place since 2022[52]. Meanwhile, water-scarcity conditions affect about 34% of EU territory for at least one quarter of the year[53]. Such constraints drive developers toward jurisdictions with less congested infrastructure and fewer environmental burdens.

Fragmented national regimes

Although the EU has introduced overarching directives, the transposition and enforcement of environmental, energy-efficiency and land-use rules vary significantly across Member States, resulting in a "complex matrix of laws and regulatory requirements"[54] and causing delays in investment due to regulatory uncertainty, as in Italy where "it lacks regulation and grid capacity … this situation delays investment decisions"[55].

Regulations on refrigerants

The updated Regulation (EU) 2024/573 on fluorinated greenhouse gases (commonly referred to as the F-Gas Regulation) tightens the phase-down quotas for high-GWP fluorinated gases, strengthens containment and leak-prevention obligations, and mandates a transition to low-GWP or natural refrigerants. The regulation, which entered into force on 11 March 2024, applies directly in all Member States and repeals the earlier Regulation (EU) No 517/2014[56]. Because cooling infrastructure typically represents a large share of both capital expenditure (CAPEX) and operational expenditure (OPEX) in DCs, compliance with the F-Gas Regulation directly impacts cooling-system design choices, refrigerant selection and cost structure. In practice this means DC operators must factor in longer term refrigerant availability risk, refrigerant-change-over cost, enhanced service and monitoring obligations, and potential equipment redesign[57]. These cost and design shifts act as a spatial and financial constraint on DC siting and upgrade decisions, particularly where legacy systems or high-density cooling are involved.

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[52] Gleeson, C. (2025, September 17). Ireland's data centre appeal 'fading' due to pressure on electricity grid, Barclays finds**.** *The Irish Times***.** Retrieved October 5, 2025, from https://www.irishtimes.com/business/2025/09/17/irelands-data-centre-appeal-fading-due-to-pressure-on-electricity-grid-barclays-report-says**.**

[53] European Environment Agency. (2022). Water exploitation index plus (WEI +). Retrieved October 31, 2025, from https://data.europa.eu/data/datasets/byobiw86oozdduikcwmlxg?locale=en .

[54] Norton Rose Fulbright. (2025, May 1). Navigating regulatory challenges in data centres. Retrieved October 31, 2025, from https://www.nortonrosefulbright.com/en/knowledge/publications/f7f64d0e/navigating-regulatory-challenges-in-data-centres.

[55] Lardizabal, E. (2025, May 27). European data centers aim to meet 75% of their energy demand with renewables this year, but face challenges. Strategic Energy Europe. Retrieved October 31, 2025, from https://strategicenergy.eu/european-data-centre/ .

[56] European Parliament and the Council. (2024, February 7). *Regulation (EU) 2024/573 of 7 February 2024 on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014*. *Official Journal of the European Union*. Retrieved October 28, 2025, from http://data.europa.eu/eli/reg/2024/573/oj;
Normec Verifavia. (2023). 9 critical updates you need to know in the new EU F-Gas Regulation 2024. Retrieved from https://normecverifavia.com/news/9-critical-updates-you-need-to-know-in-the-new-eu-f-gas-regulation-2024/.

[57] Vertiv. (2020, November 25). Impact of water usage on data center costs and sustainability (White paper SL-70704). Retrieved October 31, 2025, from https://www.vertiv.com/4ad73a/globalassets/documents/white-papers/vertiv-water-usage-and-sustainability-wp-en-na-web_317594_0.pdf.

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Standards and certification requirements

Standards and sustainability frameworks have become pivotal to how DC projects are permitted, financed, and positioned within competitive markets. Adherence to internationally recognised management standards – such as ISO 50001 Energy Management Systems or the ISO/IEC 30134 performance metrics series – provides a formalised structure for monitoring and improving energy performance across large-scale digital infrastructure.

At the same time, generic green building certifications including BREEAM, LEED, and DGNB are increasingly integrated into DC design strategies. These frameworks help DC operators demonstrate verifiable environmental performance and energy efficiency, often serving as prerequisites for access to green financing or ESG-linked investment instruments[58].

From a regulatory perspective, the European Commission's Energy Efficiency Directive[59] embeds mandatory reporting of energy and sustainability metrics for DCs above defined capacity thresholds, making performance transparency a condition of compliance. Concurrently, financial institutions and DC operators now assess certification status as part of due-diligence and procurement criteria, reinforcing the market value of certified, low-emission facilities[60].

Together, these developments signal a structural convergence between voluntary standards and binding regulatory obligations. Certification is no longer a secondary marketing tool but an operational and spatial determinant influencing location, investment eligibility, and long-term competitiveness across the European DC landscape.

Environmental and regulatory considerations are increasingly reflected in DC management. Over 60% of survey participants indicated they already collect and report environmental performance indicators, including PUE and WUE metrics, either to national authorities or internal ESG systems. Approximately 55% are pursuing certification under standards such as ISO 50001, ISO/IEC 30134 or BREEAM (standard dedicated for building's sustainability). One-third of respondents stated that clients or investors require such certification as a prerequisite for cooperation or financing.

In qualitative responses, collected through the interviews conducted as part of the study, operators highlighted the administrative burden of divergent national permitting rules and reporting templates as one of the main non-technical barriers to sustainability compliance across EU jurisdictions.

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[58] GBC Engineers. (2025b, May 14). *What are the key requirements for green data centers?* GBC Engineers. Retrieved October 8, 2025, from https://gbc-engineers.com/news/requirements-for-green-data-centers;
Novva. (2025, July 9). *Building standards for a green data center***.** Retrieved October 2, 2025, from https://www.novva.com/media-center/green-building-standards-data-centers.
[59] European Parliament and the Council. (2023, September 20). *Directive (EU) 2023/1791 of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast)*. *Official Journal of the European Union*, L 231, 1–128. Retrieved October 26, 2025, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOL_2023_231_R_0001.
[60] Datacenters.com. (2025, May 15). Are We Overlooking the Nordics? Europe's Silent Data Center Powerhouse. Retrieved October 31, 2025, from https://www.datacenters.com/news/are-we-overlooking-the-nordics-europe-s-silent-data-center-powerhouse.

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3.1.6. Other factors

Beyond power, connectivity, and regulation, the availability of suitable land, its cost, and access to skilled labour play a crucial role in DC site selection and long-term viability. These factors directly influence time-to-market, capital expenditure, and operational efficiency.

Land availability

Suitable plots with adequate size, zoning, and access to power and fibre are increasingly scarce in major European hubs. Demand from logistics, housing, and industrial users has intensified competition, driving up land values and pushing new DC projects toward secondary markets or rural areas[61]. Developers in mature hubs such as FLAP-D often face prolonged acquisition timelines, complex planning approvals, and heightened community scrutiny.

Tax incentives

National and regional governments across Europe employ fiscal incentives to attract DC investment. Tax reliefs such as property-tax exemptions, reduced business rates, or accelerated depreciation can significantly influence location decisions and total cost of ownership[62]. Ireland, Denmark, and Spain, for instance, have introduced targeted schemes combining streamlined permitting with local-tax reductions for hyperscale and colocation DC operators[63].

Permitting and regulatory complexity

Lengthy permitting processes remain a major barrier to timely deployment. Markets offering transparent, streamlined frameworks or pre-zoned "hyperscale-ready" enterprise parks are increasingly preferred[64]. Conversely, jurisdictions with fragmented approval processes face delays of up to two years for large-scale developments. Efficient permitting regimes are therefore a competitive differentiator for national data-economy growth.

Workforce availability

DC construction and operation require specialised expertise across electrical, mechanical, and IT disciplines. The sector faces an acute shortage of skilled technicians and engineers, especially outside metropolitan technology clusters. The World Economic Forum[65] highlights that Europe's digital infrastructure growth is constrained by a limited labour pipeline, prompting collaboration with vocational institutions and apprenticeships to address gaps. Proximity to universities, engineering talent, and training initiatives has thus become a formal site selection criterion.

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[61] Arizton Advisory & Intelligence. (2025, May). Europe data center market landscape 2025–2030. Arizton Advisory & Intelligence. Retrieved October 28, 2025, from https://www.arizton.com/market-reports/europe-data-center-market-analysis;
Linesight. (2025, July 7). Beyond real estate: Navigating the complexities of data-centre site selection and due diligence in the UK and Europe. Retrieved October 31, 2025, from https://www.linesight.com/insights/beyond-real-estate-navigating-the-complexities-of-data-centre-site-selection/.

[62] KPMG Ireland. (2024, September 23). *Data centres in Europe: A strategic approach*. KPMG Ireland. Retrieved November 1, 2025, from https://www.kpmg.com/ie/en/home/insights/2024/09/data-centres-in-europe-strategy.html.

[63] Ibid.

[64] Kalfa, F., & Abdelrazeq, K. (2025, July 7). *Beyond real estate: Navigating the complexities of data centre site selection and due diligence in the UK and Europe*. Linesight. Retrieved October 3, 2025, from https://www.linesight.com/insights/beyond-real-estate-navigating-the-complexities-of-data-centre-site-selection/.

[65] Timis, D. (2025, September 24). *The data centre boom needs a resilient workforce – here's how to build one*. World Economic Forum. Retrieved October 30, 2025, from https://www.weforum.org/stories/2025/09/data-centre-resilient-workforce/.

Community acceptance

Social acceptance increasingly influences permitting outcomes. Local resistance may arise due to competition for resources, visual impact, or perceived environmental cost. Developers are adopting proactive stakeholder-engagement strategies and sustainability commitments to build trust and mitigate opposition[66]. Transparent communication about heat reuse, renewable-energy sourcing, and water stewardship helps align projects with community interests.

3.2. Great variety of ownership structures and business models

The European DC market is highly diverse, reflecting different ownership structures, strategic priorities, and regulatory contexts. Unlike more centralised global markets, Europe is shaped by a mix of private, public, and hybrid actors, each pursuing distinct business models and facing specific challenges. For the purposes of this study, we distinguish five main categories of ownership: independent colocation providers, hyperscaler-owned facilities, public sector and PPP initiatives, telecom operator-owned DCs, and hybrid or emerging models. Each of these plays a different role in the ecosystem, with its own characteristics, business logic, challenges, and structural gaps and exhibits unique dynamics in terms of investment, regulation, and strategic positioning.

The project surveys also confirm the significant diversity observed among business model components. Among fully completed responses, 72.5% of DC operators report colocation capabilities, 67.5% offer hosting, and 60% provide cloud (IaaS/SaaS/PaaS) services; 32.5% indicate HPC/GPU/AI capacity and 35% operate or connect to IXP environments. This capability mix underpins a layered ownership landscape: independent, carrier-neutral providers coexist with telecom-integrated facilities, public/PPP and HPC centres and a fast-growing stratum of hybrid/edge deployments. Short-term expectations also skew expansionary: respondents anticipating growth include Collocation (52.5%), Cloud IaaS/SaaS (50%), AI workloads (47.5%), Storage (45%) and Backup/Archive (40%) (share of all respondents).

The following subsections analyse these categories in detail, highlighting how their evolution influences the broader European objectives of digital resilience, sustainability, and sovereignty.

3.2.1. Independent (private, enterprise) DC, collocation providers (carrier-neutral)

Characteristics

Independent colocation DCs are facilities operated by companies that specialise in leasing physical infrastructure – space, power, cooling, and network connectivity – to external clients. Unlike hyperscalers or telecom operators, they do not run global cloud platforms or national telecom backbones, nor active transmission equipment. Instead, they provide a carrier-neutral environment in which multiple network operators install and manage their own active systems

[66] Kalfa, F., & Abdelrazeq, K. (2025, July 7). *Beyond real estate: Navigating the complexities of data centre site selection and due diligence in the UK and Europe*. Linesight. Retrieved October 3, 2025, from https://www.linesight.com/insights/beyond-real-estate-navigating-the-complexities-of-data-centre-site-selection/.

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(e.g. WDM, IP transit or interconnection gear). This neutrality allows clients to select among different carriers to build redundancy, optimise latency or reduce connectivity costs.

These providers enable enterprises, hosting companies, content delivery networks, financial institutions, and managed service providers to deploy and manage their own IT equipment without investing in costly, large-scale facilities. The operator is responsible for maintaining the critical infrastructure (power, cooling, physical security, fibre cross-connects), while the customer manages its own servers, storage, and applications.

The service portfolio of independent colocation players is broad and typically includes rack space in quarter, half, or full racks, private cages or dedicated suites for larger tenants and on-site operational support such as *remote hands* services, physical security, and 24/7 monitoring. They may also provide optional compliance services aligned with international standards such as ISO 27001, PCI DSS, SSAE 18 SOC 1/2/3, HIPAA**,** depending on jurisdiction and sector.

Importantly, these providers differentiate themselves from telecom-operated facilities by their carrier-neutrality – meaning they do not operate their own telecom networks and allow clients to interconnect with multiple external carriers, Internet exchanges or cloud on-ramps without the restrictions typically associated with ECN/ECS operators-controlled facilities.

Examples of independent colocation players include Equinix, Digital Realty, Virtus Data Centres (STT GDC), Global Switch, and a number of strong regional providers in Europe, such as at North (Nordics), Data4 (France/Italy), Arubacloud (Italy), Beyond.pl (Poland), as well as many mid-sized national operators.

The project survey indicates that carrier-neutral colocation remains the backbone of many European deployments: 72.5% of respondents report colocation in their service portfolio and 70% provide remote-hands support. Product breadth is also visible in the types of co-location consumed: answers span full and partial cabinets, cages, suites, build-to-suite and footprints, signalling demand both from mid-market tenants and larger wholesale customers. This neutrality enables multi-carrier connectivity and straightforward access to cloud on-ramps and IXPs, consistent with the role of colocation as an interconnection hub in hybrid architectures.

Business model

The business model of independent colocation DCs is based on providing secure, reliable, and well-connected infrastructure, while customers retain full responsibility for procuring, installing, operating and managing their own IT hardware and applications Their revenues are highly predictable and recurring, as contracts are usually signed for multi-year terms and clients face high switching costs once deployed. Core income derives from monthly recurring charges for rack space or dedicated suites, billing for allocated power capacity, typically measured in kilowatts, cross-connect fees for interconnecting different customers or carriers and additional managed services such as on-site support, power usage monitoring, premium SLAs, and compliance certifications.

This model is capital intensive: operators must invest heavily in real estate, electrical and cooling infrastructure, and security systems. Once the facility is operational, profitability depends on achieving high utilisation rates, minimizing downtime, and retaining customers.

Colocation is particularly attractive for enterprises adopting hybrid cloud strategies: it allows them to combine hyperscale cloud workloads with secure, dedicated environments in colocation facilities. Many customers also rely on colocation for disaster recovery sites, business continuity, and regulatory compliance (e.g. requirements that certain data remain within national borders).

Typical customers include mid-market enterprises, managed service providers, content delivery networks, smaller cloud providers, and financial institutions, which demand reliability but cannot justify hyperscale investments.

Recurring revenue fundamentals are corroborated by near-term growth signals: 52.5% of all respondents of project survey expect collocation demand to increase in the short term, while 50% anticipate rising cloud computing (including IaaS/SaaS) consumption and 37.5% foresee more hosting. Cross-connect-centric positioning is reinforced by 35% reporting IXP capability/links. Certification is becoming a monetisation catalyst: among respondents who reported certifications (n=20), 75% hold ISO/IEC 27001, 25% ISO 50001, and 20% EN 50600, reflecting customer requirements for audited controls and energy-management practices.

Challenges

Independent colocation providers face a broad set of challenges that combine technological, infrastructural, competitive, and regulatory factors[67]. One of the most pressing challenges is ensuring sufficient and affordable access to electricity. Over the past decade, server rack density has risen from an average of 5–10 kW per rack to 80–100 kW per rack for high-density HPC, AI and GPU-optimised workloads, with some new racks expected to exceed 200- 400 kW per rack. Delivering this capacity often requires direct liquid cooling (DLC) systems, which demand additional infrastructure (dry coolers, pipes, pumps) that many older facilities cannot accommodate[68]. Also, the sharp increase in European energy prices since 2021 has significantly raised operating costs. For colocation operators, electricity is both a direct pass-through to customers and a key factor in competitiveness: clients demand low-cost, sustainable power, and operators must increasingly demonstrate sourcing from renewables[69].

Another key issue is infrastructure obsolescence. Rapid developments in server, chip, and networking technology mean that facilities can quickly become outdated. Modern GPU-accelerated systems and high-density compute servers used for AI and HPC workloads require new cooling and power topologies, forcing DC operators to continuously upgrade supporting infrastructure. Failure to do so risks losing competitiveness, especially against hyperscalers. Even

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[67] EY (2025) The new data center collaboration for utilities and developers Moving from demand growth to value creation. Retrieved November, 20, 2025 from https://www.ey.com/content/dam/ey-unified-site/ey-com/en-us/campaigns/data-centers/documents/ey-energy-data-center-report-vf.pdf.

[68] Sodhi R., Hyperview HQ. (2025, June 6). 8 Challenges Data Center Managers Must Overcome in 2025. Retrieved November 20, 2025 from https://hyperviewhq.com/blog/top-data-center-challenges-for-2025-revealed/.

[69] Ember Energy (2025), “Chapter 2: Greening Data Centres,” Ember Energy Report, 2024. Retrieved November 20, 2025 from https://ember-energy.org/chapter/greening-data-centres/.

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when demand is high, DC operators may struggle to guarantee space for client expansion. Urban DCs particularly susceptible to this issue because they frequently face space limitations. Expanding these facilities often necessitates acquiring new sites, which can be challenging due to permitting and land-use restrictions in many European countries.

In addition, operators face a complex regulatory environment, including EU and national rules on energy efficiency and emissions (such as the EU Green Deal and Fit-for-55), as well as local permitting requirements for water use, cooling systems and urban planning, can delay or constrain DC expansion, as demonstrated by temporary moratoria on new projects in cities such as Amsterdam[70]. On the service side, operators must also comply with data protection and sector specific regulatory requirements applicable to the workloads hosted in their facilities (e.g., GDPR for customer data processing, or financial and healthcare specific compliance frameworks), even though these do not apply to the buildings or support systems themselves.

Operational bottlenecks from the project survey mirror market headwinds. The most frequently cited site-level constraints were no available space for growth (33%) and lack of electrical energy (33%), followed by limited space/efficiency for cooling infrastructure (30%) and shortage of qualified employees (30%). Replacement/upgrade activity is concentrated in cooling systems, with efficiency and end-of-support as dominant triggers, underscoring the capex pressure to retrofit for higher rack densities and liquid-cooling readiness.

Interview results strongly support these findings. DC location significantly influences which limitations are most important. In rural areas, water and energy may be more accessible, but DC operators generally agree that location affects employee availability. However, this impact varies by whether the facility is in an urban or peripheral area, and if the organization is public or commercial. All organizations discussing this noted challenges or mitigating factors related to location.

Gaps

Despite their importance, independent colocation providers face several structural gaps compared to hyperscalers and telecom operators. They face a scale disadvantage, as smaller DC operators lack the vast capital reserves and global reach of hyperscalers. This creates vulnerabilities in modernization cycles and competitive positioning. Many older colocation sites lack the power density, advanced cooling, and green credentials demanded by AI and modern cloud workloads. Enterprises using colocation relinquish some infrastructure control, which creates auditability and compliance gaps, especially in regulated industries. Small and mid-sized providers often cannot deliver seamless management across multiple distributed sites, making hybrid cloud and edge integration more fragmented. Unlike telecom operators and hyperscalers, independent colocation providers do not operate their own long haul or metro backbone networks; instead, they rely on external carriers present in the facility for international and regional interconnection, which may result in less integrated hybrid or multi-cloud connectivity. These gaps mean that while colocation remains critical for many enterprises, operators must constantly

[70] Judge P., (2019, July). Amsterdam says no more new data centers. Retrieved November 20, 2025 from https://www.datacenterdynamics.com/en/news/amsterdam-pauses-data-center-building/.

innovate and invest to avoid marginalization in a market increasingly dominated by hyperscalers and ECN/ECS operators[71].

Project survey responses suggest scale asymmetries versus hyperscalers (e.g., constrained expansion space and power) and limited multi-site scalability among smaller operators. Talent scarcity (reported by 30%) and uneven access to renewable power contracts further widen the capabilities gap.

3.2.2. Hyperscaler-owned

Characteristics

Hyperscaler-owned DCs form a distinct segment of the global digital infrastructure landscape. These facilities are operated by large global technology American corporations such as Amazon Web Services (AWS), Microsoft Azure, Google Cloud, Meta, Oracle, or IBM, which build and operate DCs on a massive international scale. Their purpose is to deliver cloud computing, storage, and increasingly AI-driven services to businesses, governments, and consumers worldwide.

The distinguishing feature of hyperscaler DCs is their extraordinary scale and specialization. They are designed for ultra large workloads, with tens or even hundreds of megawatts of IT capacity, modular expansion, and advanced power and cooling systems. Unlike colocation providers, hyperscalers not only lease infrastructure but also operate the software and (hardware) platforms running on it, creating vertically integrated cloud ecosystems.

In Europe, the construction boom of hyperscale DCs is driven by global demand for cloud and AI services. Major hyperscalers (e.g. AWS, Google, Microsoft) are anchoring large campuses in key markets such as Frankfurt, London, Amsterdam and Dublin. According to CleanBridge[72], hyperscale DCs are expected to account for over 50% of global capacity by 2027, and over 440 new campuses are planned, including in Europe.

Beyond large campuses, hyperscalers also deploy smaller edge DCs, located close to urban areas and end users, to reduce latency for real-time applications such as video streaming, autonomous driving, or IoT deployments. The maximum power demand of the "edge" DCs does not exceed 2 MW. Such demand is relatively small in comparison to large HPC centres, AI factories, or AI gigafactories[73].

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[71] Tsoneva T., Affleck J. (2024, July 17), Data Center Investment: Decoding Opportunities. Retrieved November 20, 2025 from https://www.cbreim.com/insights/articles/decoding-data-centers;
Marketsandmarkets. (2025, June). Data Center Colocation Market. Retrieved on November 20, 2025 from https://www.marketsandmarkets.com/Market-Reports/colocation-market-1252.html.

[72] CleanBridge (2025), Global Data Center Report, Retrieved on November 20, 2025 from https://www.cleanbridge.co/insights/energy-transition/cleanbridge-global-data-center-market-report-2025/industry-size-growth-and-key-drivers-gdc2025/?utm_source=chatgpt.com.

[73] de Roucy-Rochegonde L., Buffard A. (2025, February). AI, Data Centers Reassessing and Exploring the Trends. Retrieved November 20, 2025 from https://www.ifri.org/sites/default/files/2025-02/ifri_buffard-rochegonde_ai_data_centers_energy_2025_2.pdf.

The survey data shows that hyperscaler-driven demand is influencing the broader market: although most respondents are not hyperscalers, 33% report offering GPU-based HPC services and 45–50% expect near-term growth in AI workloads, storage and cloud IaaS/SaaS. Respondents also indicate faster refresh cycles for performance-critical hardware: GPU and HPC servers are typically replaced within 3–5 years (or 6–10 years for some deployments), while general-purpose "cloud servers" follow similar cycles. Overall, the data suggests that hyperscaler demand is accelerating investment patterns across the ecosystem, particularly in GPU hardware and AI-related services.

Business model

Hyperscalers' business model relies on global scale, economies of scale, and continuous innovation. They deliver cloud services at prices that no European competitor can match, due to their massive scale, vertical integration, and ability to optimize across global infrastructure. Customers are attracted by predictable pricing models and the ability to scale up or down rapidly. Services are consistent across regions. Customers access multiple regions via a uniform dashboard and billing system, which ensures reliability and simplifies global IT operations. Hyperscalers operate in numerous countries, offering a global footprint and enabling clients to deploy workloads in multiple locations, thereby reducing latency and addressing regulatory requirements.

Analyses indicate that hyperscalers offer a wide range of services (IaaS, PaaS, sovereign cloud), which increases the risk of vendor lock-in, and their investments in AI-optimized infrastructure demonstrate deep ecosystem integration[74]. Continuous innovation remains a hallmark of hyperscalers, who reinvest significantly into infrastructure. For example, Oracle's Cloud Infrastructure (OCI) is undergoing aggressive expansion. Backed by the $300bn "Stargate" initiative with OpenAI, Oracle aims to transition from niche cloud player to hyperscale operator, focusing on AI-optimized clusters and sovereign clouds. In Q1 FY2026, Oracle reported Remaining Performance Obligations (RPO) of $455bn, up 356% YoY, much of it tied to AI-related contracts[75].

Challenges and gaps

Despite their dominance, hyperscalers face significant challenges and structural gaps in Europe and globally. One of the most pressing challenges relates to energy and grid capacity. Hyperscale facilities consume massive amounts of electricity – it is estimated that in 2025 alone, 10 GW of new capacity will be commissioned globally, with hyperscalers accounting for over one-third. European grids are struggling to keep pace: in the Netherlands and Ireland, local moratoria or restrictions on new DC construction have been introduced due to insufficient grid capacity and sustainability concerns.

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[74] Gartner Research (2023, April 12), Cloud Governance Best Practices: Managing Vendor Lock-In Risks in Public Cloud IaaS and PaaS. Retrieved November 20, 2025 from https://www.gartner.com/en/documents/4264599.
[75] Butler G., Data Center Dynamics, (2025, September), Oracle has $455bn in remaining performance obligations at end of Q1 2026. Retrieved November 20, 2025 from https://www.datacenterdynamics.com/en/news/oracle-has-455bn-in-remaining-performance-obligations-at-end-of-q1-2026.

The explosion in demand for AI training and inference workloads requires specialised GPU clusters and dense rack configurations, pushing beyond the capacity of many existing sites and necessitating enormous capital investment in new facilities optimized for AI[76]. Supply chain bottlenecks in acquiring transformers, GPUs, and advanced cooling systems have also emerged, with lead times for large electrical components extending from months to years, thereby slowing deployment[77].

Operating globally exposes hyperscalers to different regulations and sovereignty demands, which also reveals structural gaps in their operating models. European data protection rules (GDPR, EU Data Act, sovereign cloud frameworks) require that sensitive workloads remain within EU jurisdiction, compelling hyperscalers to build or partner locally, often reducing the flexibility and speed of independent expansion. Additionally, U.S. laws like the CLOUD Act create trust concerns for European regulators.

Public and governmental oversight of hyperscalers' water consumption, carbon footprint, and land use is intensifying. Hyperscale facilities are often viewed as consuming disproportionate local resources while contributing limited local employment, highlighting a gap between local societal expectations and hyperscalers' global-scale investment logic. As part of Europe's climate neutrality goals, hyperscalers are under pressure to use significant majority of renewable power, reduce emissions, and publish detailed sustainability reports.

3.2.3. Public sector and PPP initiatives

Characteristics

DCs developed through public sector investment and Public-Private Partnerships (PPPs) play a strategic role in supporting national digital infrastructure, government IT systems, and research institutions. Their design reflects a need for guarantying European sovereignty, public oversight, security, and compliance, combined with private sector expertise and innovation.

The PPP models are increasingly used across Europe to share the financial and operational risks of building and maintaining large-scale facilities. Governments provide strategic oversight and ensure compliance with national priorities (e.g., data sovereignty, public administration resilience), while private partners contribute capital, know-how, and efficiency in operations[78].

A particularly important category within this model is High-Performance Computing (HPC) DCs. These specialized facilities, often established in cooperation with universities, research institutes, or supranational organizations such as the EU, provide computational infrastructure for highly intensive workloads – including early detection and prevention of diseases, new therapies, understanding the functioning of the human brain, forecasting climate change, AI training, and big

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[76] Hyperview HQ. (2025, June 6). 8 Challenges Data Center Managers Must Overcome in 2025. Retrieved November 20, 2025 from https://hyperviewhq.com/blog/top-data-center-challenges-for-2025-revealed/

[77] Serafimov D., (2025, February 26). Breaking Bottlenecks: Overcoming Supply Chain Challenges in Data Centers. Retrieved November 20, 2025 from https://www.aimms.com/story/overcoming-supply-chain-challenges-data-centers/

[78] Costa E., Ivanov V., Azlaan M. (2024, September). Emerging PPP Models: Examining new and innovative PPP models that are being developed or implemented in Europe. Retrieved November 20, 2025 from https://www.researchgate.net/publication/384339002_Emerging_PPP_Models_Examining_new_and_innovative_PPP_models_that_are_being_developed_or_implemented_in_Europe.

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data analytics. HPC centres typically focus on GPU/TPU-heavy architectures and require very high-power density and advanced cooling systems, as well as high-bandwidth connectivity to research networks[79].

The PPP model is also heavily prevalent in national cloud platforms, research infrastructure, and public service digitization projects across Europe, e.g. the French “Cloud de Confiance” initiative, Germany’s “Sovereign Cloud” framework, and national government DCs in Poland, Spain, and Italy.

Business model

Public sector and PPP DCs operate under models that prioritise strategic goals and reliability over commercial profitability. The private sector typically provides most or all of the upfront investment (capital, engineering expertise, and technological solutions), while the public sector benefits from rapid modernization and access to advanced private sector technologies[80].

These business models often rely on several mechanisms that ensure both stability and performance. Governments may compensate private operators through availability payments, which are linked to the uptime of the facility and adherence to agreed performance standards. In other cases, service fees are tied to specific usage or performance metrics, creating a system of incentives for efficiency and reliability. Shared investment frameworks are also common, allowing governments to distribute costs across the lifecycle of a facility and avoid large upfront capital expenditures.

This approach allows governments to modernise critical infrastructure, meet sovereignty requirements, and access specialised technology (e.g. AI-ready GPUs, quantum accelerators), while avoiding budgetary shocks[81].

HPC centres are frequently co-funded by national ministries, EU programs, and industry partnerships, with costs justified by their role in enabling cutting-edge scientific and industrial innovation.

Challenges

Public sector and PPP DCs face structural challenges that differ from those of commercial hyperscalers. While HPC facilities are highly energy-dense, their overall energy footprint is smaller than that of hyperscale campuses. For public administrations, the more pressing issues relate to the cost of electricity, limited investment capacity and difficulties in securing long-term

[79] European Commission (2024, March). EuroHPC Joint Undertaking Multi-Annual Strategic Programme (2021 – 2027). Retrieved November 20, 2025 from https://www.eurohpc-ju.europa.eu/document/download/2a5db80d-6bd3-4ea9-9418-4b49cadcf040_en?filename=20240219_For_GB_Decision%20Amendment%20MASP%202021-2027%20v220324%20Final%201%20%281%29.pdf.
[80] Lee Y., Lee U. (2021). Reference Architecture and Operation Model for PPP (Public-Private-Partnership) Cloud. Retrieved November 20, 2025 from https://xml.jips-k.org/full-text/view?doi=10.3745%2FJIPS.04.0212.
[81] European Commission (2020, February). A European strategy for data. Retrieved November 20, 2025 from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A66%3AFIN.

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renewable energy contracts. These factors increase operational risks and place additional pressure on budgets, especially in periods of volatile energy prices[82].

Another significant challenge lies in procurement complexity and slow decision-making. Public procurement frameworks, coupled with multi-stakeholder governance, often slow project launches, upgrades, or expansions. In some instances, public DCs lag behind their global peers because investment cycles and bureaucratic procedures are misaligned with the rapid pace of technological innovations.

A further difficulty concerns the shortage of talent and expertise. Recruiting and retaining specialised professionals, particularly in fields such as quantum computing or advanced AI workloads, is challenging in a competitive global labour market. Public institutions frequently cannot offer salaries or benefits comparable to those of hyperscalers or private sector operators[83].

Finally, technological obsolescence represents a persistent risk. HPC and PPP facilities must evolve rapidly to accommodate breakthroughs in AI, big data, and quantum computing. Delays in adopting these technologies can quickly render national infrastructure less competitive, both scientifically and economically.

Gaps

Despite their critical role in promoting digital sovereignty and research excellence, public sector and PPP initiatives face several structural gaps[84]. The first limitation concerns investment capacity. Compared to hyperscalers, public budgets remain far smaller, limiting the ability to scale infrastructure rapidly and creating a reliance on partnerships and external funding mechanisms, such as EU programs or private equity participation.

Another persistent gap relates to adaptation speed. Slow procurement processes and rigid decision-making cycles make it difficult for public sector facilities to keep pace with the agility of private competitors. Furthermore, the energy dependency of HPC centres – which require vast amounts of electricity – makes them vulnerable to fluctuations in energy markets and grid capacity constraints. Among the challenges faced by these DCs are restrictions on acquiring land for construction, the size of the land, and its location, all of which affect building design possibilities and, consequently, the cooling systems used.

Sustainability pressure also weighs heavily on public operators. Publicly funded DCs are expected to lead by example in adopting green energy sources, implementing emissions-neutral operations, and reporting transparently on environmental performance. However, the costs of implementing such sustainability measures are significant and often exceed available budgets.

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[82] Cremona, E., & Czyzak, P. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 5, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.

[83] Data Center Frontier. (2021, June 4). How public-private partnerships will drive the next big wave of government data center optimization. Retrieved November 5, 2025, from https://www.datacenterfrontier.com/voices-of-the-industry/article/11428147/how-private-public-partnerships-will-drive-the-next-big-wave-of-government-data-center-optimization.

[84] Data Center Frontier. (2025, January 7). 8 trends that will shape the data center industry in 2025. Retrieved November 5, 2025, from https://www.datacenterfrontier.com/cloud/article/55253151/8-trends-that-will-shape-the-data-center-industry-in-2025.

Overall, while PPP and public sector DCs are indispensable for achieving European sovereignty, scientific advancement, and digital resilience, they continue to struggle with limited scalability, slower innovation cycles, and dependence on external partnerships.

3.2.4. ECN / ECS operator-owned

Characteristics

ECN/ECS operators in Europe – such as Deutsche Telekom, Orange, Telefónica, Vodafone, and TIM have long been significant players in the DC ecosystem. Unlike independent providers or hyperscalers, their facilities are often developed as an extension of core telecom infrastructure, supporting and offering ECNs (Electronic Communications Networks) and ECSs (Electronic Communications Services), enterprise connectivity, and emerging cloud and AI-driven applications.

Telecom-owned DCs serve multiple functions. They host core network operations that underpin ECN infrastructure, including switching, routing, and control systems. In addition, they deliver enterprise "IT" services, such as managed hosting, hybrid cloud, and IT outsourcing, providing corporate clients with secure and scalable computing environments. Increasingly, these DCs also operate as edge computing nodes that are tightly integrated with 5G networks and 6G networks in the future, offering ultra-low-latency environments for present and future potential use cases on Internet of Things (IoT) applications, industrial automation, autonomous mobility, and real-time analytics.

Ownership structures vary. Some facilities are fully owned by ECN/ECS operators, while others are developed as joint ventures or through EU-funded initiatives to advance digital sovereignty. Increasingly, ECN/ECS operators are participating in pan-European projects aimed at building sovereign cloud and edge infrastructure, often in response to regulatory concerns about reliance on non-European hyperscalers[85].

A notable example is the €1.2 billion Telefónica España-led project[86] to deploy federated edge nodes across Europe in partnership with other operators and vendors, designed to create alternatives to hyperscaler clouds.

Business model

Telecom-operated DCs derive their core revenues from colocation services: space, power, cooling and cross-connects, supplemented by DC interconnection such as private links and cloud on ramps. Telecom ECS products (e.g., dedicated Internet, VPN, MPLS) are often bundled with DC offerings but represent telecom rather than DC revenue streams.

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[85] Cremona, E., & Czyzak, P. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 5, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.

[86] TelcoTitans, 2023, Telefónica goes to the edge with telco rivals to build European cloud alternatives. Retrieved November 5, 2025, from https://www.telcotitans.com/telefonicawatch/telefonica-goes-to-the-edge-with-telco-rivals-to-build-european-cloud-alternatives/9105.article.

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The distinctive strength of telecom operated DCs comes from their direct integration with ECN/ECS infrastructures. Located within the operator's backbone and access network domains, these DCs can deliver predictable quality of service (QoS), reliable routing and strong local-compliance guarantees. This is particularly relevant for regulated and safety, critical sectors such as finance, healthcare, transport, automotive and aviation. Combined with edge nodes and 5G Standalone deployments, this network, DC integration enables new low latency and network-aware services.

In addition to customer-oriented functions, telecom operators also utilise their DCs for internal optimisation purposes, such as supporting network function virtualization (NFV), orchestration, and operational automation. This dual role positions them as trusted partners for enterprises seeking hybrid or trusted cloud solutions that combine infrastructure control with telecom-grade reliability.

Challenges

Telecom-owned DCs face a complex set of challenges arising from both technological evolution and regulatory diversity. Many of the facilities currently in operation were originally designed to support core network functions rather than high-density AI or cloud services, which means that modernisation requires extensive retrofitting and significant capital investment[87].

In parallel, the global energy transition places growing pressure on operators to adopt renewable power sources, minimise carbon emissions, and optimise water and resource efficiency[88]. Compliance with these environmental and sustainability goals demands costly upgrades and large-scale implementation of green technologies[89].

Although telecom activities are harmonised under the EU Electronic Communications Code, DC facilities are governed by national and local planning and environmental regulations. These differences across Member States make DC permitting and expansion slower and harder to standardise. Navigating land-use, environmental, and urban-planning rules can make the permitting process lengthy and unpredictable.

Moreover, many telecom groups prioritize investments in their core telecom infrastructure – such as fibre networks and 5G deployment – over modernizing DCs. This can reduce their agility and slow their ability to compete with hyperscalers and independent colocation providers[90].

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[87] McKinsey Report (2025, February 28). AI infrastructure: A new growth avenue for telco operators. Retrieved November 20, 2025 from https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-infrastructure-a-new-growth-avenue-for-telco-operators.

[88] McKinsey e-Power. (n.d.). The role of power in unlocking the European AI revolution. Retrieved November 20, 2025 from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-role-of-power-in-unlocking-the-european-ai-revolution.

[89] Grand View Research I. (n.d.). Data center construction market. Retrieved November 20, 2025 from https://www.grandviewresearch.com/industry-analysis/data-center-construction-market.

[90] McKinsey Report (2025, February 28). AI infrastructure: A new growth avenue for telco operators. Retrieved November 20, 2025 from https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-infrastructure-a-new-growth-avenue-for-telco-operators.

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Finally, competition from these hyperscalers and dedicated operators, who offer more scalable and cost-efficient solutions, forces ECN/ECS operators to either specialise in niche segments like edge computing or participate in larger joint ventures and consortia.

Gaps

Telecom operators continue to face structural gaps that limit their competitiveness within the broader digital infrastructure market. One of the key constraints is access to capital: operators must continuously balance investments between network expansion and DC modernisation, often resulting in underinvestment in the latter. Operational agility is another limitation, as ECN/ECS operators typically lack the innovation culture and specialised expertise that characterise hyperscalers and dedicated DC operators.

Regulatory complexity adds further burden, with diverse EU and local regulations (such as EU energy efficiency and sustainability regulation e.g. Energy Efficiency Directive (EED), fragmented national transposition of EU directives, local planning, permitting, and environmental regulations, overlap with broader EU digital and ESG frameworks, lack of dedicated DC regulations in some EU countries) compliance costs and extending project timelines. In addition, telecom operators suffer from a scale disadvantage: compared with hyperscalers, they are unable to deploy or scale infrastructure at comparable speed or efficiency. Telecom operators face a structural scale disadvantage because their investment budgets must cover multiple national priorities: 5G, fibre, spectrum, and legacy-network maintenance leaving limited capital for DC expansion. Hyperscalers, in contrast, focus their entire CAPEX on globally standardised mega-campuses, benefiting from massive economies of scale, integrated supply chains, and higher utilisation levels. As a result, telco-owned DCs remain smaller, more heterogeneous, and slower to scale. Finally, their reliance on partnerships and sovereign-cloud initiatives further introduces layers of governance that can slow execution[91].

In summary, while ECN/ECS operators-owned DCs are strategically positioned to integrate e.g. edge computing with 5G and to address local compliance needs, they face significant structural challenges that limit their ability to compete directly with hyperscalers. Their future relevance in the European DC ecosystem will depend on their ability to leverage edge synergies, sovereign initiatives, and partnerships while managing modernisation and sustainability pressures.

3.2.5. Hybrid and emerging models

Characteristics

Recent industry analyses[92] indicate a shift toward hybrid and distributed models, where enterprises combine on-premises infrastructure with public cloud to balance latency, compliance and cost efficiency.

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[91] Rastogi V., Luisada F., Elbert V., Wilms M., Bamberger S., Khanna P., Farag H. (2025, February). Returns May Be Declining, but Opportunity Is Calling. Retrieved November 20, 2025 from https://www.bcg.com/publications/2025/boosting-value-creation-in-telcos.

[92] McKinsey, (2025, August 1). Scaling bigger, faster, cheaper data centers with smarter designs. Retrieved November 20, 2025 from https://www.mckinsey.com/industries/private-capital/our-insights/scaling-bigger-faster-cheaper-data-centers-with-smarter-designs.

In parallel, many enterprises continue to operate their own dedicated on-premises server rooms as part of their hybrid IT strategy. These facilities enable full control over sensitive data, compliance, and customized infrastructure, particularly in highly regulated sectors such as finance, healthcare, and government.

Several leading industry analyses (e.g. IDC[93], Deloitte[94]) indicate that hybrid cloud adoption is increasingly common among regulated sectors, driven by compliance and data-residency needs. While not all workloads can move to the public cloud, regulated organisations are turning to distributed and hybrid deployment models to balance flexibility with control.

Another subset of emerging models involves specialised hosting and cloud service providers. These are medium-sized companies offering managed hosting, dedicated private clouds, or hybrid services that combine colocation and public-cloud interconnection[95]. Notable European providers in this category include Hetzner (Germany), OVHcloud (France), IONOS (Germany), Scaleway (France), and UpCloud (Finland), which emphasize data sovereignty, GDPR compliance, and regional customer support. They target clients seeking data sovereignty, regional support, and local-language service, competing with hyperscalers by emphasising compliance, customisation, and trust.

Finally, the emergence of sovereign and quantum-ready DCs reflects Europe's strategic response to geopolitical and technological dependencies. Sovereign facilities are designed to comply with EU data-protection and localisation rules and to operate under European jurisdiction, while quantum-ready DCs are built to host future quantum computing infrastructure and advanced AI workloads requiring high-density cooling and power distribution.

Business model

The business models of hybrid and emerging operators vary widely but share a common orientation toward flexibility, service differentiation, and cross-platform integration. Unlike the capital-intensive, single tenant hyperscale model, hybrid and edge operators favour modular design, shorter build cycles, and diversified revenue sources. Hybrid infrastructure operators often sell Data Centre-as-a-Service (DCaaS), where customers pay for capacity and services on a consumption basis rather than investing in their own facilities. This transforms fixed capital costs into operational expenses (OPEX) and allows clients to scale dynamically. Operators bundle rack

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Research and Markets (2024, July 13). Europe Data Center Market Landscape Report 2024. Retrieved November 20, 2025 from https://www.globenewswire.com/news-release/2024/07/23/2917017/0/en/Europe-Data-Center-Market-Landscape-Report-2024-A-64-5-Billion-Industry-by-2029-Driven-by-Growth-in-5G-Deployment-of-Edge-Data-Centers-and-Sustainability-Initiatives-Attracting-DC-.html.

[93] Venkatraman A., Vanara F., IDC, (2024, November). Future-Ready Hybrid Cloud Infrastructure Fit for the "AI Everywhere" Era. Retrieved November 20, 2025 from https://sp.ts.fujitsu.com/dmsp/Publications/public/IDC%20Infographic%202024.pdf.
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[94] Stanton B., Lee P., Buxo Ferrer A., Crossan G., Westcott K., Deloitte, (2023, November 23). Keeping it local: Cloud sovereignty a major focus of the future. Retrieved November 20, 2025 from https://www.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2024/tmt-predictions-focus-intensifying-on-sovereign-cloud-in-2024.html.

[95] SubOptic. (2025, June 6). Europe data center portfolio report 2025: Detailed analysis of 1,396 existing data centers, 252 upcoming data centers, and 569 operators / investors. Retrieved November 20, 2025 from https://www.suboptic.org/news/europe-data-center-portfolio-report-2025-detailed-analysis-of-1396-existing-data-centers-252-upcoming-data-centers-and-569-operators-investors---researchandmarkets-com.

space, power, and connectivity with managed services such as monitoring, cybersecurity, and compliance management[96] .

Edge-data-centre operators increasingly monetise proximity-based services – such as content delivery, industrial IoT, smart-city analytics and mobile edge computing (MEC) – by leveraging low-latency edge infrastructure. Many of them partner with telecom operators to integrate edge nodes into 5G networks and support real-time workloads. Moreover, micro and modular edge DCs are emerging as key sites for AI inference, enabling localized GPU-based processing and real-time data analytics[97].

The inflow of capital from institutional investors has shifted the market toward platform-based ownership, as infrastructure funds increasingly pursue long-term, stable returns and structure investments through regional platforms that integrate real estate, power, and network assets. Joint ventures between global funds and developers – including partnerships such as DigitalBridge and Vantage Data Centers, KKR and Global Technical Realty, or EQT and EdgeConnex – exemplify this transition toward scalable, multi-regional platforms focused on rapid capacity expansion and enhanced operational efficiency. These investors now embed renewable-energy sourcing and advanced energy-efficiency technologies into their strategies to meet growing ESG compliance requirements[98].

Smaller regional players combine colocation with managed hosting and private-cloud offerings. Their business model depends on localized customer support, flexible pricing, and compliance with national regulations. They often target SMEs and public institutions seeking sovereign, GDPR-compliant cloud alternatives.

Many hybrid or edge deployments are realized through partnerships between private (DC) operators, ECN/ECS operators, and governments, particularly in the context of sovereign-cloud or edge initiatives supported by EU funding. These partnerships reduce risk exposure and ensure alignment with Europe's digital-sovereignty agenda[99].

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[96] Foster A., Deep Market Insights (2025, November). Data Center as a Service Market. Retrieved November 20, 2025 from https://deepmarketinsights.com/report/data-center-as-a-service-market-research-report.
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Overall, the hybrid segment's success depends on the ability to integrate multiple service layers-physical infrastructure, connectivity, cloud interconnection, and managed services-within a unified operational framework.

Challenges and gaps

Despite strong growth potential, hybrid and emerging models face a number of complex challenges. Managing distributed infrastructures across multiple sites, vendors, and regulatory environments requires advanced orchestration tools. Smaller operators often lack integrated platforms for unified monitoring, automation, and workload management. There is still no common European standard for edge-data-centre interoperability or sovereign-cloud integration. Although edge and micro-DC markets are growing, monetization remains uncertain. Many deployments depend on future adoption of latency-sensitive applications (autonomous mobility, industrial IoT, immersive reality). Without critical mass, return on investment may remain below expectations[100].

Many hybrid/colocation operators rely on direct cloud interconnection, which may create dependency on hyperscalers for access to cloud services[101]. Operators must navigate evolving EU regulations such as the Data Act, AI Act, and Energy Efficiency Directive and others. Requirements for transparency, energy reporting, and data-sovereignty compliance increase administrative overhead and costs.

Operating distributed and software defined DCs requires new skill sets in automation, cybersecurity, and energy management. The talent shortage in Europe's digital infrastructure sector affects both scale-up speed and service quality.

The development of quantum-ready or AI-optimized DCs demands significant investment in high-density power and liquid cooling systems. Institutional investors remain cautious toward such specialized assets until clear demand and regulatory frameworks materialize[102].

Hybrid and emerging DC operators in Europe often develop new sites through joint ventures or with support from institutional and public funding, particularly for edge and sovereign-cloud initiatives. While this approach mitigates investment risk and aligns projects with Europe's digital-sovereignty goals, it also exposes structural gaps: smaller operators typically lack the global scale, integrated supply chains, and capital resources of hyperscalers, which can limit their ability to

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[100] Keshishyan, A. (2021). 9 Pioneers in Network Edge Orchestration. STL Partners. Retrieved November 20, 2025 from https://go.stlpartners.com/9-Pioneers-in-Network-Edge-Orchestration%E2%80%8B-PDF;
McKinsey & Company. (2025). Technology Trends Outlook 2025. Retrieved November 20, 2025 from https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/the%20top%20trends%20in%20tech%202025/mckinsey-technology-trends-outlook-2025.pdf;
Gaia-X AISBL. (2025). The Role of Data Spaces in the Digital Economy (White Paper). Retrieved November 20, 2025 from https://gaia-x.eu/wp-content/uploads/2025/03/White-Paper_The-Role-of-Data-Spaces-in-the-Digital-Economy-1.pdf;

[101] K Kerner, S. M. (2024, July 16). Data Center Trends: Industry Report Reveals Shift Towards Hybrid IT, Colocation. Data Center Knowledge. Retrieved November 20, 2025 from https://www.datacenterknowledge.com/cloud/data-center-trends-industry-report-reveals-shift-towards-hybrid-it-colocation.

[102] STL Partners. (2025). Data centre liquid cooling in 2025: Evidence, economics and the road to mainstream adoption. Retrieved November 20, 2025 from https://stlpartners.com/articles/data-centres/data-center-liquid-cooling/;
International Energy Agency – 4E (IEA-4E). (2025). Data Centre Energy Use: Critical Review of Models and Results. Retrieved November 20, 2025 from https://www.iea-4e.org/wp-content/uploads/2025/05/Data-Centre-Energy-Use-Critical-Review-of-Models-and-Results.pdf;
DC Market Insights. (2025). Data Center Cooling Market — trends & forecasts. Retrieved November 20, 2025 from https://www.dcmarketinsights.com/report/data-center-cooling-market.

expand rapidly or provide uniform service across multiple regions. Additionally, reliance on complex partnerships and regulatory compliance frameworks can slow execution and create operational fragmentation, highlighting the challenges these operators face in scaling their infrastructure and competing effectively[103]. While sustainability is central to Europe's strategy, smaller and mid-sized operators struggle to access affordable renewable power or grid-flexibility mechanisms.

In summary, hybrid and emerging models represent a critical innovation layer in Europe's digital-infrastructure landscape. They bridge the gap between global hyperscalers and localized, sovereign infrastructures, enabling new applications and improving resilience. Their long-term success will depend on the maturity of interoperability standards, availability of sustainable energy, and ability to attract institutional capital for continued expansion.

Summary/key observations

The European DC landscape is diverse and fragmented, reflecting the continent's mix of private, public, and hybrid ownership structures:

- **Independent colocation providers** remain critical for enterprises needing flexible, neutral interconnection hubs, but face challenges of scale, modernization, and compliance.
- **Hyperscalers** dominate growth, driven by economies of scale and AI demand, but face challenges in energy availability, regulatory compliance, and community acceptance.
- **Public sector and PPP initiatives** safeguard sovereignty and research capacity, especially through HPC centres, but struggle with investment limitations and slow procurement cycles.
- **ECN/ECS operators** leverage their networks and 5G deployments to integrate edge computing but often prioritize core telecom projects over DC innovation, limiting competitiveness.
- **Hybrid and emerging models** experiment with new architectures (edge, sovereign, quantum-ready), offering strategic sovereignty and flexibility but facing issues of scale, orchestration, and monetization.

Overall, Europe's DC ecosystem is defined by tension between global hyperscalers dominance and the need for European sovereignty, sustainability, and innovation. Policymakers, regulators, and industry stakeholders must navigate this balance to ensure digital resilience, green compliance and fair market conditions.

In summary, the project survey and interviews portrays a DC ecosystem where carrier-neutral colocation (72.5%) and hosting (67.5%) remain foundational, cloud interoperation (60%) and AI/HPC capabilities (32.5%) are rising, and short-term growth is expected across collocation

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[103] European Investment Fund. (2025). EIF and CDP Equity jointly invest EUR 200 million in the PIMCO European Data Centre Opportunity Fund to expand digital infrastructure across Europe. Retrieved November 20, 2025 from https://www.eif.org/InvestEU/news/2025/eif-and-cdp-equity-jointly-invest-eur200-million-in-the-pimco-european-data-centre-opportunity-fund-to-expand-digital-infrastructure-across-europe.htm;
PGIM Real Estate. (2025). PGIM Real Estate raises $2B final close for global data center fund. Retrieved November 20, 2025 from https://www.pgim.com/at/en/borrower/about-us/newsroom/press-releases/pgim-real-estate-raises-2b-final-close-global-data-center-fund.

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(52.5%), cloud IaaS/SaaS (50%) and AI (47.5%). Constraints are largely physical and grid related space (32.5%), power (32.5%), cooling (30%) and human capital linked (30%).

Certification patterns (among reporters: ISO/IEC 27001: 75%, ISO 50001: 25%, EN 50600: 20%) underscore the growing role of governance and energy management in procurement and financing. Certifications remain an important operational baseline across different ownership and business models; however, several organizations perceive them as costly and administratively demanding, which affects their overall attractiveness.

Table 2. Comparative overview of DC ownership and business models.

Model	Characteristics	Business model	Key challenges	Gaps
Independent colocation (carrier-neutral)	Neutral hubs offering space, power, cooling, connectivity	Lease-based (rack space, kW billing), recurring revenues, cross-connects, premium services	Rising power density (AI workloads), high energy costs, regulatory compliance	Lack scale vs hyperscalers, legacy infrastructure, limited reach
Hyperscaler-owned	Mega-sites by AWS, Google, Microsoft, Meta; global, standardized platforms	Scale-driven, cloud computing, storage, AI/ML, multi-cloud integration	Energy demand, grid limits, supply chain delays, geopolitical exposure	GDPR & sovereignty compliance, market concentration concerns
Public sector / PPP	State-led or PPP data centres, often HPC/AI-focused, serving public admin & research	Availability-based payments, mixed funding, risk-sharing	Energy-intensive workloads, slow procurement, limited flexibility	Investment constraints, slower adaptation to fast-changing needs
Telecom operator-owned	DCs integrated with networks (5G, fibre), supporting cloud & edge	Colocation + managed services + hybrid cloud, leveraging telco infrastructure	Balancing network CAPEX with DC upgrades; competition with hyperscalers; monetising MEC/edge.	Limited modernisation capex, slower vs hyperscalers, EU regs Limited DC innovation focus; incomplete edge/MEC monetisation; integration gaps across telco-cloud and DC stacks.
Hybrid / emerging	Mix of edge DCs, sovereign cloud, DCaaS, quantum-ready sites	Pay-per-use, opex-based, IoT/AI edge monetization, sovereign cloud offers	Lack of standards, monetization difficulties, fragmented regs	Limited scale, dependency on partnerships, weak orchestration

3.3. Overview of the spatial distribution of DCs across Europe[104]

DC infrastructure in Europe is not spread evenly but follows a clear spatial hierarchy. A large share of installed IT capacity is concentrated in a limited number of primary metropolitan hubs with dense fibre backbones, multiple IXPs, and strong grid interconnections, while secondary regional hubs, peripheral locations and edge sites host much smaller but fast-growing shares of the load. In parallel, power- and resource-intensive hyperscale campuses are increasingly located at the intersection of high-voltage transmission corridors and long-haul fibre routes, whereas smaller colocation and edge facilities tend to follow last-mile aggregation nodes and 5G transport rings. The resulting pattern is a layered landscape: core DC clusters in traditional FLAP-type markets and capital regions; regional aggregation nodes serving national or cross-border corridors; and edge DCs embedded closer to users, industrial sites and critical infrastructure. This chapter characterises these spatial distributions and shows how they reflect trade-offs between proximity to demand, access to resilient power and connectivity, land and cooling conditions, and emerging regulatory and environmental constraints.

3.3.1. Geographical concentration patterns in EU countries

Geographical concentration of DC capacity in Europe is pronounced: a handful of metro areas account for a dominant share of MW capacity, network on-ramps and cloud availability zones, while most other regions host only thin, fragmented footprints. This subchapter analyses these concentration patterns in terms of both absolute capacity and functional role. It follows market analyses commonly distinguish between primary (core) and secondary hubs, while also identifying emerging markets that are developing new capacity, and edge sites that bring computing closer to end users[105]. It describes global “gravity centres” where hyperscalers, large IXPs and carrier hotels co-locate; second-tier regional clusters along key fibre and power corridors; and nascent peripheral hubs where growth is driven by renewable availability, land, or specific industrial anchors. It also highlights how path dependency in ECN/ECS operators (legacy cable landing points, long-standing carrier nodes) and recent constraints (grid congestion, planning limits, water and emissions targets) jointly reinforce or redirect this concentration. Together, these patterns explain why certain locations emerge as strategic DC nodes in the European digital-infrastructure system, while others remain marginal or specialised.

Table 3. Short key characteristics of DC hub types.

Hub type	Examples	Key characteristics & role
Primary hubs	Frankfurt, London, Amsterdam, Paris, Dublin (FLAP-D)	Large, mature metros (often >1 GW) with dense connectivity and rich cloud/IXP ecosystems; act as Europe’s core cloud/AI

[104] When determining a country's affiliation to a specific European region, the UN Statistics Division's methodology was taken into account. UN Statistic Division (nd), “Standard country or area codes(M49)”. Retrieved November 20, 2025 from: https://unstats.un.org/unsd/methodology/m49/.

[105] Shepherd, L., & Fray, A. (2025, July 17). *H1 2025 EMEA data centre market update* [Report]. Cushman & Wakefield. Retrieved October 10, 2025, from https://www.cushmanwakefield.com/en/insights/emea-data-centre-update;
Newmark. (2025, January). 2025 Data Center Site Selection Dynamics in Europe [White paper]. Retrieved October 10, 2025, from https://nmrk.imgix.net/uploads/documents/2025-Data-Center-Site-Selection-Dynamic-Brief.pdf.

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		and interconnection nodes but face grid, land, and cost constraints.
Secondary hubs	Madrid, Milan, Warsaw, Berlin, Zurich, Lisbon	Fast-growing 100–800 MW metros with lower costs and less congestion than FLAP-D; serve as regional growth hubs that relieve primary hubs and support national/regional demand.
Peripheral / emerging hubs	Prague, Budapest, Athens, Bucharest, smaller CEE/SE capitals	Smaller (<100 MW) emerging markets with low costs but weaker grids, skills base and carrier/IXP density; provide sovereignty and resilience nodes for national/public workloads and future expansion.
Edge hubs / edge DCs	Small DCs near 5G aggregation points, metro rings, industrial sites	Highly distributed, small sites (often ≤2–20 MW) tightly integrated with networks; extend compute close to users/devices for low-latency AI/IoT/5G, complementing core and regional hubs.

Primary hubs ("FLAP-D")

The largest concentration of DCs in Europe remains within the so-called FLAP-D markets/cities, benefiting from established digital-infrastructure ecosystems, strong connectivity fabrics and a legacy of ICT demand[106]. Combined operating capacity for the FLAP-D metropolitan areas reached approximately 10.9 GW in H1 2025, underscoring their dominance even as growth rates begin to moderate[107]. Meanwhile, the presence of Europe's major IXPs – such as DE-CI X in Frankfurt, AMS-IX in Amsterdam and LINX in London – further anchors these hubs as global interconnection gateways for cloud and financial services.

At the same time, deployment constrains are pilling: new power-grid connections for DCs in FLAP-D may require 7 to 10 years on average, with some projects delayed up to 13 years, land in prime metropolitan settings is scarce and costly, and competitive pressures on labour and environmental conditions are intensifying[108]. As a result, although FLAP-D markets remain foundational, their relative attractiveness is nudging developers toward alternative locations.

Secondary hubs

These saturation effects are driving a surge in secondary hubs – metro areas such as Madrid, Milan, Warsaw, Berlin, Zurich and Lisbon are increasingly attracting DC investment[109]. Cost-differentials and infrastructure readiness are cited as key drivers: some Southern-European and Central/Eastern markets offer more favourable land availability and lower relative electricity and

[106] Shepherd, L., & Fray, A. (2025, July 17). *H1 2025 EMEA data centre market update* [Report]. Cushman & Wakefield. Retrieved October 10, 2025, from https://www.cushmanwakefield.com/en/insights/emea-data-centre-update;
Newmark. (2025). 2025 data center site selection dynamics in Europe [White paper]. Retrieved October 10, 2025, from https://nmrk.imgix.net/uploads/documents/2025-Data-Center-Site-Selection-Dynamic-Brief.pdf;
[107] Shepherd, L., & Fray, A. (2025, July 17). *H1 2025 EMEA data centre market update* [Report]. Cushman & Wakefield. Retrieved October 10, 2025, from https://www.cushmanwakefield.com/en/insights/emea-data-centre-update;
[108] Ember. (2025, June 19). *Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race* [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf;
Newmark. (2025). 2025 data center site selection dynamics in Europe [White paper]. Retrieved November 6, 2025, from https://nmrk.imgix.net/uploads/documents/2025-Data-Center-Site-Selection-Dynamic-Brief.pdf.
[109] fDi Intelligence. (2024, November 27). Record data-centre investment spreads to secondary markets. Retrieved November 6, 2025, from https://www.fdiintelligence.com/content/a45ee258-748d-5e70-8823-95a1489c49ed.

land costs compared with the most mature hubs[110]. Several governments have also introduced incentives – such as tax breaks, land-lease support and streamlined permitting – to enhance attractiveness in these newer markets[111]. Connectivity investment is also rising, with cable landings and cross-border fibre-projects progressively enhancing regional infrastructure[112]. Nevertheless, secondary hubs remain complementary rather than fully substitutive to the core FLAP-D markets; their long-term scalability depends on maturing local interconnection ecosystems, grid redundancy and workforce-skills development – a combination still uneven across Poland, Iberian Peninsula and parts of Italy[113].

Emerging hubs

Smaller, regionally emerging markets including Prague, Budapest, Athens, and Bucharest are increasingly entering the European DC landscape. Growth in these locations is driven by cost and availability advantages and by regulatory pressures on critical digital infrastructure (notably the NIS2 Directive), which raises governance and resilience requirements for DC operators across the EU[114]. Installed capacity remains modest by hub standards – for example, Hungary's total market is ~31 MW (2025e), Romania's Bucharest area accounts for ~46 MW (2024), and Greece is ~50 MW (2024) – underscoring the generally sub-100 MW scale per city in many of these markets[115]. Interconnection ecosystems are less dense than in core hubs, though they are strengthening: Prague's NIX.CZ reports ~3 Tb/s peaks, Budapest's BIX publishes live aggregate graphs, Athens' GR-IX has reported ~985 Gb/s peak, and Bucharest's InterLAN notes daily peaks over 800 Gb/s – still below the multi-terabit fabrics seen in FLAP-D but indicative of growing local peering[116]. Hyperscaler region presence remains limited in these specific cities (operators often rely on nearby regions such as planned/announced sites like Azure Greece Central and an AWS Local Zone Athens), which can influence latency-sensitive workloads and ecosystem maturity[117].

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[110] Arizton Advisory & Intelligence. (2025). *Europe data center market landscape 2025–2030* [Market report]. Arizton Advisory & Intelligence. Retrieved October 19, 2025, from https://www.arizton.com/market-reports/europe-data-center-market-analysis.
[111] Ibid.
[112] MarketResearch / Arizton. (2025). Europe Data Center Construction Market - Industry Outlook & Forecast 2025-2030 [Market brief]. Retrieved November 6, 2025, from https://www.marketresearch.com/Arizton-v4150/Europe-Data-Center-Construction-Outlook-40757886/.
[113] Uptime Institute. (2024, July). *Global data center survey results 2024* [Report]. Uptime Institute. Retrieved October 15, 2025, from https://datacenter.uptimeinstitute.com/rs/711-RIA-145/images/2024.GlobalDataCenterSurvey.Report.pdf.
[114] European Union. (2024). NIS2 Directive: Securing network and information systems (Directive (EU) 2022/2555). Publications Office of the European Union. Retrieved November 6, 2025, from https://digital-strategy.ec.europa.eu/en/policies/nis2-directive.
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Mordor Intelligence. (2025b). Romania data center market – growth, trends, and forecast (2024–2029). Retrieved November 6, 2025, from https://www.mordorintelligence.com/industry-reports/romania-data-center-market;
Arizton. (2024/2025). Greece Data Center Market - Investment Analysis & Growth Opportunities 2025-2030 [Reports]. Arizton Advisory and Intelligence. Retrieved November 6, 2025, from https://www.arizton.com/market-reports/greece-data-center-market.
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InterLAN (Internet Exchange Romania). (2025). Homepage – live traffic statistics. Retrieved November 6, 2025, from https://www.interlan.ro/en/homepage-en/.
[117] Google Cloud. (2025). Regions and zones – Europe (europe-central2 / Warsaw). Retrieved November 6, 2025, from https://cloud.google.com/compute/docs/regions-zones;
Microsoft. (2025, May 29). 2025 Environmental Sustainability Report. Retrieved November 6, 2025, from https://www.microsoft.com/en-us/corporate-responsibility/sustainability/report/;
AWS. (2025). Local Zones locations – Athens (eu-central-1-ath-1a). Amazon Web Services. Retrieved November 6, 2025, from https://aws.amazon.com/about-aws/global-infrastructure/localzones/locations/.

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As a result, these markets often focus on domestic and public-sector workloads and serve as redundancy nodes in multinational portfolios. Long-term scalability, however, will depend on addressing workforce-skills shortages and broader infrastructure readiness – including grid resilience and interconnection maturity – conditions that remain inconsistent in several Central, Eastern and Southern European locations[118].

Edge data centres

At the outer edge of Europe's digital-infrastructure landscape, a growing layer of edge DCs is emerging to support low-latency applications, and to offload 5G backhaul, for example in industrial IoT environments. These facilities are typically small to mid-scale (1–20 MW), located close to population clusters or industrial corridors to minimise latency and reduce network congestion[119].

Across Europe, the edge DC market was valued at USD 5.2 billion in 2024 and is projected to reach nearly USD 28.7 billion by 2034, growing at a compound annual rate of about 18 percent[120]. Demand is driven by rapid expansion of AI inference, autonomous system workloads, and 5G enabled IoT ecosystems, prompting operators to adopt modular and prefabricated infrastructure for faster deployment. Modular edge facilities are increasingly integrated into telecom networks and distributed-cloud fabrics, allowing compute resources to move closer to end users[121].

At the same time, structural barriers persist for edge DC deployment across Europe. Edge nodes frequently struggle with fibre-backhaul readiness and local grid interconnection limits, as modular deployments require not only rack space but assured low-latency links and resilient supply. National permitting frameworks remain uneven and often were designed for large-scale campuses rather than the distributed, microscale edge rollout model, leading to unpredictable timelines and increased compliance burden[122]. On the workforce side, edge sites place unique demands on skilled regional technicians and network engineers who can manage distributed infrastructure, but many European markets still report acute talent gaps and limited regional operator ecosystems[123]. Unless these issues are addressed – by harmonising regulatory processes, increasing fibre and grid readiness and upskilling regional hubs – edge deployment will remain slower and more costly than the headline growth forecasts suggest.

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[118] Uptime Institute. (2024). Global data center survey 2024 (Report). Retrieved November 6, 2025, from https://datacenter.uptimeinstitute.com/rs/711-RIA-145/images/2024.GlobalDataCenterSurvey.Report.pdf.
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[123] Lee, V., Seshadri, P., O'Niell, C., Choudhary, A., Holstege, B., & Deutscher, S. A. (2025, January 20). *Breaking barriers to data center growth* [Article]. Boston Consulting Group. Retrieved October 18, 2025 from https://www.bcg.com/publications/2025/breaking-barriers-data-center-growth.

Project survey evidence: among ECN/ECS operator respondents answering a dedicated question (n = 27), approximately 30% indicate plans to implement small, edge-type DCs, ~48% do not and the remainder are undecided/conditional. This split points to selective, use-case-driven edge buildouts rather than uniform adoption. Median on-site technical staffing of described facilities is 6 FTE (n = 29; 75th percentile 10), suggesting that regional talent availability will be pivotal for distributed/edge DC operations.

3.3.2. Geographic inequalities and related challenges

The spatial distribution of European DCs remains highly uneven. Western and Northern Europe have benefited from decades of early investment in ECNs infrastructure, strong enterprise demand, and mature ecosystems, concentrating the majority of installed capacity, connectivity, and hyperscalers' presence. According to recent analyses, most of the Europe's total DC power capacity is clustered within the FLAP-D markets, along with major Nordic hubs[124].

By contrast, parts of Southern and Eastern Europe remain under-represented, with far smaller installed DC capacities, and IXP ecosystems, and weaker grid resilience[125]. The combined DC capacity of Central and Eastern European countries is still below 1 GW, compared to more than 6 GW across the FLAP-D metropolitan areas[126]. This structural imbalance poses long-term risks for Europe's digital economy, reinforcing regional disparities in connectivity, latency, and sustainability.

Data reported by operators in the project survey confirms the geographical diversity across Europe, with the most frequently cited location factors being shortages of available electricity (19 responses), catastrophic risks (18), shortages of network infrastructure (14), and physical security measures (location-based physical risk factors) (14). Additional determining factors include compliance with data security regulations (11), local energy consumption constraints (9), and shortages of land for development (7). Labor issues, including shortages of skilled personnel (6), are also important, while climatic conditions (6) and tax incentives (4) appear to be secondary factors.

Capacity

The primary hubs (FLAP-D) continue to dominate Europe's DC footprint. They account for approximately 62% of Europe's total installed IT-power capacity[127]. Each of these cities now

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[124] Cremona, E., & Czyzak, P.. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf;
Savills. (2024, May 30). European Data Centres: Navigating The New Data-Centric Frontiers. Savills Research. Retrieved November 6, 2025, from https://pdf.euro.savills.co.uk/european/european-commercial-markets/spotlight-european-data-centres---may-2024.pdf.

[125] KPMG. (2024, September 23). *Data centres in Europe: A strategic aproach*. KPMG Ireland. Retrieved 12 November 2025, from https://kpmg.com/ie/en/insights/strategy/data-centres-in-europe-strategy.html;
Markeviciute, E. (2025, August 22). *Data centres: Too many blank spots in Central and Eastern Europe*. Euronews Next. Retrieved 25 November 2025, from https://www.euronews.com/next/2025/08/24/data-centres-too-many-blank-spots-in-central-and-eastern-europe.

[126] Arizton Advisory & Intelligence. (2022). Central and Eastern Europe data center market (2022–2027). Arizton. Retrieved November 6, 2025, from https://www.arizton.com/market-reports/central-eastern-europe-data-center-market.

[127] Ember. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.

surpasses 1 GW and is supported by dense fibre backbones, large hyperscale premises, and extensive Internet-exchange ecosystems[128]. By contrast, many locations in Southern and Eastern Europe account for a relatively small share of DC capacity. Although new projects are emerging, the legacy hubs still absorb most new supply and take-up, leaving secondary markets with modest base volumes and higher per-MW costs[129]. Consequently, enterprises and public institutions in under-represented regions often rely on long-haul backhaul to better established hubs, increasing latency and operational risk.

Network infrastructure

Network connectivity also reflects a clear west-east divide. Western and Northern hubs remain the natural landing zones for most trans-Atlantic and intra-European submarine cables and host the continent's largest IXPs, including DE-CIX (Frankfurt), AMS-IX (Amsterdam), and LINX (London), ensuring low-latency and resilient routes[130]. Southern and Eastern Europe's international submarine interconnection density is improving. New Mediterranean cables – 2Africa, Medusa, and BlueMed – have expanded connectivity to Lisbon, Barcelona, and Athens, while additional east–west routes are diversifying traffic across Central Europe[131]. Yet carrier-hotel maturity and peering ecosystems remain less developed, forcing many enterprises to depend on long-haul terrestrial links to major IXPs – raising latency and cost[132].

Power grids

Regional disparities in electricity infrastructure further influence DC siting. Western and Northern European grids are generally robust and renewable-rich but now face congestion and extended connection queues – especially in legacy hubs such as Frankfurt or Dublin[133]. Conversely, several Southern and Eastern European countries provide shorter connection lead times – typically 3 to 5 years – though this often conceals structural weaknesses such as limited redundancy and lower

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[128] Bauer, V. (2024, November 4). *Data centre market in the EMEA region continues to grow – German market in 2nd place behind UK.* Cushman & Wakefield. Retrieved October 22, 2025 from https://www.cushmanwakefield.com/en/germany/news/2024/11/wachstum-rechenzentrumsmarkt-emea-region;
Savills. (2024, May 30). European Data Centres: Navigating The New Data-Centric Frontiers. Savills Research. Retrieved November 6, 2025, from https://pdf.euro.savills.co.uk/european/european-commercial-markets/spotlight-european-data-centres---may-2024.pdf.

[129] CBRE Investment Management. (2024, July 17). Data Center Investment: Decoding Opportunities. Retrieved November 6, 2025, from https://www.cbreim.com/insights/articles/decoding-data-centers.
Arizton Advisory & Intelligence. (2022). Central and Eastern Europe data center market (2022–2027). Arizton. Retrieved November 6, 2025, from https://www.arizton.com/market-reports/central-eastern-europe-data-center-market.

[130] DE-CIX. (2024, November 21). New Record at DE-CIX Frankfurt: Europe's largest Internet Exchange hits 18 Tbps data throughput. Retrieved October 20, 2025 from https://www.de-cix.net/en/about-de-cix/media/press-releases/new-record-at-de-cix-frankfurt-europes-largest-internet-exchange-hits-18-terabits-per-second-data-throughput;
DE-CIX. (2025, January 23). DE-CIX sets new record with 68 exabytes of global data traffic in 2024. Retrieved October 20, 2025 from https://www.de-cix.net/en/about-de-cix/news/de-cix-sets-new-record-with-68-exabytes-of-global-data-traffic-in-2024.

[131] Wood, R., & Sherrington, S. (2025, January). State of digital communications: 2025 edition [Report]. Connect Europe; Analysys Mason. Retrieved October 20, 2025 from https://connecteurope.org/sites/default/files/2025-01/State%20of%20Digital%20Communications%20-%202025%20edit.

[132] Ibid.

[133] Cremona, E., & Czyżak, P. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf;
Reuters. (2025, February 5). European data centre space shortage expected in 2025 as AI booms. Retrieved October 20, 2025 from https://www.reuters.com/technology/european-data-centre-space-shortage-expected-2025-ai-booms-2025-02-05/.

substation density[134]. With total European DC power demand expected to double by 2030[135], coordinated grid expansion and renewable integration are critical to sustainable growth[136].

Legal frameworks

Differences in national and sub-national regulatory regimes (planning, environmental and energy-related approvals) continue to create permitting and compliance fragmentation across the EU. Western and Northern European countries generally operate under transparent permitting frameworks, predictable incentive programmes and mature environmental-governance arrangements aligned with EU energy-efficiency legislation[137]. By contrast, some Southern and Eastern European markets function under more decentralised regulatory systems, where varied procedures across planning, environment and taxation contribute to uncertainty and delays[138]. Some Member States – including Poland, Spain and Portugal – have introduced targeted incentives, but implementation is inconsistent. Legal analysts note that the lack of cross-border regulatory coherence complicates compliance with evolving EU policy frameworks for DC energy efficiency[139]. To mitigate these disparities, the European Commission is advancing harmonisation through its Digital Decade Policy Programme 2030 and Green Deal Industrial Plan[140].

Other discrepancies

Across Europe, a shortage of qualified personnel is constraining DC expansion. The Uptime Institute found that 58% of European operators face hiring difficulties and 34% lack formal training programmes[141]. Western and Northern markets benefit from mature engineering and contractor ecosystems, whereas Southern and Eastern Europe continue to develop the necessary technical capacity. The CEE Digital Coalition[142] observes that although ICT education has expanded, shortages in advanced digital skills and uneven training systems remain barriers to scaling complex infrastructure. PwC[143] similarly emphasises that with targeted investment in vocational education, mobility, and digital-skills frameworks, CEE countries could become competitive talent

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[134] Wood, R., & Sherrington, S. (2025, January). State of digital communications: 2025 edition [Report]. Connect Europe; Analysys Mason. Retrieved October 20, 2025 from https://connecteurope.org/sites/default/files/2025-01/State%20of%20Digital%20Communications%20-%202025%20edit.

[135] Naschert, C., & Dlin, S. (2025, July 30). European data centre power demand to double by 2030, straining grids. S&P Global Market Intelligence. Retrieved October 20, 2025 from https://www.spglobal.com/commodity-insights/en/news-research/latest-news/electric-power/073025-european-data-center-power-demand-to-double-by-2030-straining-grids.

[136] Ember. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.

[137] European Commission. (n.d.). *Energy efficiency – targets, directive and rules*. Retrieved 9 October 2025, from https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules_en.

[138] European Data Centre Association (EUDCA). (2025). *State of European data centres 2025* [Report]. Retrieved November 25, 2025, from https://www.eudca.org/documents/content/h_ZhGn_ZTu6O_sfWJxpztgo8b?download=0;
Besliu, R., Narawad, A., & Toniolo, A. (2025, July 24). *Infrastructure or intrusion? Europe's conflicted data center expansion*. AlgorithmWatch. Retrieved 22 October 2025, from https://algorithmwatch.org/en/infrastructure-intrusion-conflict-data-center/.

[139] Commins, J., & Irion, K. (2025). Towards planet-proof computing: Law and policy of data centre sustainability in the European Union. *Technology and Regulation*, 2025(001). Retrieved 19 October 2025, from https://doi.org/10.71265/c1nnwh92.

[140] European Commission. (2025, June 16). *State of the Digital Decade 2025 report*. Shaping Europe's digital future. Retrieved 28 October 2025, from https://digital-strategy.ec.europa.eu/en/library/state-digital-decade-2025-report.

[141] Weinschenk, R., & Donnellan, D. (2023, December). Operators struggle to overcome ongoing staff and skills shortage: Data Centre Staffing Survey 2023. Retrieved 19 October 2025, from https://datacenter.uptimeinstitute.com/rs/711-RIA-145/images/2023StaffingSurvey.Report.12152023.pdf.

[142] CEE Digital Coalition. (2024, March 26). The ICT sector in the CEE countries as a regional driver of mobilising digital talent (Report). Retrieved 19 October 2025, from https://ceedigital.org/assets/pdf/CEE_Digital_Coalition_Report_2024.pdf.

[143] PwC. (2024). How CEE can become a hub for tech talent. *PwC CEE Insights*. Retrieved 19 October 2025, from https://cee.pwc.com/cee-in-the-spotlight/how-cee-can-become-a-hub-for-tech-talent.html.

hubs. Sustained workforce investment will be vital to prevent project delays, control costs, and ensure a balanced, resilient European DC industry.

Overall challenges

The cumulative effect of these disparities is a bipolar European DC landscape. Western and Northern Europe face saturation, constrained by grid congestion, land scarcity, and environmental permitting delays. Meanwhile, Southern and Eastern Europe continue to struggle with energy infrastructural immaturity, slower regulatory adaptation, and talent shortages[144]. This imbalance threatens the objectives of the EU's Digital Decade Policy Programme 2030, which seeks a geographically balanced and sustainable digital ecosystem[145]. Without coordinated policy action, Europe risks reinforcing regional dependencies – where critical digital services, cloud capacity, and AI workloads remain concentrated in a few metropolitan areas, exposing the Union to resilience and sovereignty risks[146].

Addressing these challenges requires integrated grid planning, harmonised regulation, and targeted workforce development across Member States. Strategic investment corridors – linking renewable generation in Nordic countries, Southern and Eastern Europe with high-density demand in Western hubs – could help rebalance the map, improve latency, and reduce carbon intensity[147]. Such measures are essential to achieving a resilient, low-carbon, and spatially cohesive European DC network.

3.3.3. Promising locations

The previous chapter outlined the uneven geographic distribution of DCs across Europe. However, where some perceive risks, others identify opportunity. The landscape is gradually diversifying as DC operators seek alternatives to the saturated FLAP-D hubs. Notable growth is observed in several emerging regions.

There is observed growth in several emerging regions, particularly in Nordic, and Southern and Eastern Europe. According to the analysis conducted by Ember[148], with growth patterns slowing down in the traditional top five markets – which are projected to increase at a slower rate of approximately 1.5 to 2.5 times by 2035. In comparison, Nordic countries are expected to see increases of four to five times, potentially establishing them as key locations for future DC

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[144] Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.
PwC. (2024). How CEE can become a hub for tech talent. *PwC CEE Insights*. Retrieved 19 October 2025, from https://cee.pwc.com/cee-in-the-spotlight/how-cee-can-become-a-hub-for-tech-talent.html.
Brown, C., Mullooly, M., & Kwok, B. (2022, November). *The evolving data centre landscape* [Report]. KPMG Ireland. Retrieved 19 October 2025, from https://assets.kpmg.com/content/dam/kpmg/ie/pdf/2022/11/ie-the-evolving-data-centre-landscape.pdf.
[145] European Commission. (2025b). Digital Decade 2025: 5G Observatory Report. Retrieved 22 October 2025, from https://digital-strategy.ec.europa.eu/en/library/digital-decade-2025-5g-observatory-report.
[146] Besliu, R., Narawad, A., & Toniolo, A. (2025, July 24). *Infrastructure or intrusion? Europe's conflicted data center expansion*. AlgorithmWatch. Retrieved 22 October 2025, from https://algorithmwatch.org/en/infrastructure-intrusion-conflict-data-center/.
[147] Wood, R., & Sherrington, S. (2025, January). *State of digital communications: 2025 edition* [Report]. Connect Europe; Analysys Mason. Retrieved October 4, 2025 from https://connecteurope.org/sites/default/files/2025-01/State%20of%20Digital%20Communications%20-%202025%20edition.pdf;
Cremona, E., & Czyżak, P. (2025, June 19). Grids for data centres in Europe: Ambitious grid planning can win Europe's AI race [Report]. Ember. Retrieved November 6, 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf.
[148] Idem.

operations. Southern European countries such as Spain, Italy, Portugal, and Greece are also anticipated to experience growth of between three and 3.5 times, while Central and Eastern European countries including Austria, Hungary, and Slovakia may have similar developments. Overall, the data suggests that DC demand is moving towards Northern and Southern Europe, influenced by factors like renewable energy resources, cost considerations, and sustainability objectives.

Southern Europe

Spain, Italy (especially Milan), Portugal, and Greece are attracting areas of investment due to increased space availability, lower costs, and supportive government policies[149]. Milan stands out for its strategic location, abundant renewable energy (hydroelectric and solar), and improved permitting processes[150] and Madrid has already become a strong secondary hub, with capacity projected to exceed 1 GW by 2030[151]; Southern Europe is also seen as a gateway for intercontinental traffic. Spain and Portugal, in particular, are becoming hubs for the next submarine cables connecting Europe with America and Africa, including 2Africa, Medusa and EllaLink systems[152] and Nuvem and Sol (Google) in the near future. Greece is also gaining traction, with Athens emerging as a future regional interconnection point due to its strategic position for Eastern Mediterranean routes[153].

However, southern markets face challenges related to grid resilience and water scarcity, which complicate the deployment of large-scale cooling systems[154]. These constraints underline the need for coordinated energy-infrastructure and water-management strategies to ensure sustainable DC expansion in Mediterranean zones.

Central & Eastern Europe

Countries such as Poland, the Czech Republic, Hungary, and Romania are benefiting from the growing popularity of cloud computing, from EU funding for digitalisation, and rapid cross-border fibre-optic expansion. The Polish hub in Warsaw has become a regional leader, expanding

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[149] Business Wire. (2025, May 20). Europe data center market landscape 2025–2030: FLAP-D markets (Frankfurt, London, Amsterdam, Dublin) lead the sector, as Spain, Italy, and Greece gain traction due to space and cost considerations [Press release]. ResearchAndMarkets.com. Retrieved October 22, 2025 from https://www.businesswire.com/news/home/20250520159740/en/Europe-Data-Center-Market-Landscape-2025-2030-FLAP-D-Markets-Frankfurt-London-Amsterdam-Dublin-Lead-the-Sector-as-Spain-Italy-and-Greece-Gain-Traction-Due-to-Space-and-Cost-Considerations---ResearchAndMarkets.com;
DC Byte. (2023, October 24). The Iberian Peninsula: Spain and Portugal data centre markets. DC Byte. Retrieved October 22, 2025 from https://www.dcbyte.com/market-spotlights/the-iberian-peninsula/.
[150] Battey, R. (2025, April 28). Forget fashion, Milan is now Europe's hottest data centre hub. Global Construction Review. Retrieved October 22, 2025 from https://www.globalconstructionreview.com/forget-fashion-milan-is-now-europes-hottest-data-centre-hub/.
[151] Cushman & Wakefield. (2025, March 21). *Madrid among the top 10 cities for data-centre infrastructure in EMEA* [Press release]. Retrieved 3 November 2025, from https://www.cushmanwakefield.com/en/spain/news/2025/03/madrid-among-the-top-10-cities-for-data-center-infrastructure-in-emea.
[152] Ramos, D. (2024, July 19). Data-center boom turns Spain into a digital hub for Southern Europe. Retrieved October 22, 2025 from https://www.silicon.eu/data-center-boom-turns-spain-into-a-digital-hub-for-southern-europe-14440.html.
[153] Bauer, V. (2024, November 4). *Data centre market in the EMEA region continues to grow – German market in 2nd place behind UK.* Cushman & Wakefield. Retrieved October 22, 2025 from https://www.cushmanwakefield.com/en/germany/news/2024/11/wachstum-rechenzentrumsmarkt-emea-region.
[154] European Environment Agency. (2025, January 17). Water-scarcity conditions in Europe Retrieved October 22, 2025 from https://www.eea.europa.eu/en/analysis/indicators/use-of-freshwater-resources-in-europe-1;
GlobalData. (2025, August 20). Water scarcity emerges as the next big challenge for data centres in Europe. Retrieved October 22, 2025 from https://www.globaldata.com/media/technology/water-scarcity-emerges-next-big-challenge-data-centers-europe-reveals-globaldata/.

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capacity from 184 MW in 2020 to 481 MW in 2024[155], and is projected to surpass 1 GW by the early 2030s[156].

Other capitals – such as Prague, Budapest and Bucharest – are developing more slowly, with smaller footprints (< 100 MW) but providing critical redundancy and data-sovereignty capacity within the EU. Recent spatial-economic research confirms that DC investors increasingly value electricity costs, ECNs density and infrastructure stability when selecting locations across Central and Eastern Europe[157]. Sustained growth in these regions is supported by public investment incentives, affordable energy, and low-latency access to growing domestic markets.

Nordic countries

The Nordic region – offers nearly ideal conditions for hyperscalers, owing to cool climates, abundant renewable energy (hydro, wind, geothermal) and proactive sustainability policies. These countries have become leaders in integrating waste-heat reuse from DC facilities into district-heating systems, notably in the Stockholm district-heating network where excess heat is captured from DC operations and reused for local heating infrastructure[158]. Many facilities are designed for circular-energy integration and operate under stable governance with low electricity prices. Capacity expansion in the Nordics has accelerated, with demand expected to double by 2030[159]. However, challenges remain in long-haul connectivity to continental hubs – while high-capacity fibre corridors exist, latency-sensitive workloads may still favour central European locations[160], although new submarine cables may in part overcome that challenge.

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155 In one of the interviews conducted as part of the study, a representative from a colocation firm stated that Warsaw is the largest and fastest-growing DC market in Poland.
156 Arizton Advisory & Intelligence. (2022). Central and Eastern Europe data center market (2022–2027). Retrieved October 22, 2025 from https://www.arizton.com/market-reports/central-eastern-europe-data-center-market;
Mordor Intelligence. (2025). Poland data center market – Growth, trends and forecasts (2025–2030). Retrieved October 22, 2025 from https://www.mordorintelligence.com/industry-reports/poland-data-center-market.
157 Vas, Z. , Szakálné Kanó, I., & Vida, G. (2024). Spatial concentration of the ICT sector in Central and Eastern Europe. Retrieved October 22, 2025 from https://doi.org/10.1080/09654313.2024.2396485.
158 Stockholm Exergi. (2023, October 10). Stockholm, Sweden heat recovery from data centres. Retrieved October 22, 2025 from https://eu-mayors.ec.europa.eu/en/Stockholm-Heat-recovery-from-data-centres;
Terenius, P., Garraghan, P., & Harper, R. (2023). A material social view on data centre waste heat. Retrieved October 22, 2025 from https://www.diva-portal.org/smash/get/diva2%3A1891262/FULLTEXT01.pdf.
159 Business Sweden. (2018). Data centre opportunities in the Nordics. Retrieved 29 October 2025, from https://www.business-sweden.com/4b0b0a/globalassets/insights/reports/trend/data-centre-opportunities-in-the-nordics.pdf;
European Commission. (2024). *Commission Delegated Regulation (EU) 2024/1364 of 14 March 2024 on the first phase of the establishment of a common Union rating scheme for data centres*. Official Journal of the European Union, L 136. Retrieved 29 October 2025, from http://data.europa.eu/eli/reg_del/2024/1364/oj.
160 Vas, Z., Szakálné Kanó, I., & Vida, G. (2024). Spatial concentration of the ICT sector in Central and Eastern Europe. Retrieved 29 October 2025, from https://doi.org/10.1080/09654313.2024.2396485.

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4. DC interdependencies with ECNs and international submarine cables

Europe's digital economy relies on the interplay of DCs, ECNs, and international submarine cables that connect the continent to the world (and within the EU). DCs concentrate computing power and storage while also (inter)connected by telecommunications backbones to similar facilities. To maintain low latency and predictable throughput, these interconnections are carefully designed – combining public peering, virtual fabrics, and private interconnects. Submarine cables remain lifelines (vital for intercontinental connections but also for some within the Union), but the risk profile is expanding – from the accidental damage (fishing/anchoring, that accounts for most of the incidents), natural disasters, limited repair options but also (and more recently), intentional damage such as sabotage, coercion at landing sites, or hybrid attacks[161].

ECSs/ECNs providers business models on relation to DCs are also evolving. Traditionally focused on connectivity (transport and access), these companies are extending their focus towards DCs and cloud services – deploying edge locations nodes, investing in colocation platforms and offering network services. This model was challenged by hyperscalers that invest in their own infrastructure bypassing ECNs. This shift blurs the line between communications and IT infrastructures (DCs) and tightens operational coupling across the stack[162].

4.1. Role of DCs in the broader connectivity ecosystem

As Europe moves toward greater digital sovereignty, sustainability, and technological independence, the role of DCs becomes even more critical[163]. In fact, the EU sees DC infrastructure as vital for the internal market, digital sovereignty, keeping data governed under EU laws, ensuring security, and resilience against global service disruptions[164]. Thanks to DCs, it is possible to hold projects and services that are almost exclusively dedicated to initiatives in cloud computing, cybersecurity, and AI, while also representing a major focus of investment in energy-efficient and renewable-powered infrastructure[165]. Therefore, DCs function as the converging point where connectivity, computation, and innovation intersect, making them indispensable for the future of Europe’s digital transformation.

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[161] European Commision (23.10.2025) Report on Security and Resilience of EU Submarine Cable Infrastructures. Retrieved 29 October 2025, from https://digital-strategy.ec.europa.eu/en/library/report-security-and-resilience-eu-submarine-cable-infrastructures.

[162] BEREC. (2024, March 7). *BEREC report on cloud and edge computing services* (BoR (24) 52; Draft). Retrieved 29 October 2025, from https://www.berec.europa.eu/system/files/2024-03/BoR%20%2824%29%2052_Draft_Cloud_Report.pdf.

[163] Hulkó, G., Kálmán, J., & Lapsánszky, A. (2025). The politics of digital sovereignty and the European Union’s legislation: navigating crises. Frontiers in Political Science, 7. Retrieved 29 October 2025, from https://www.frontiersin.org/journals/political-science/articles/10.3389/fpos.2025.1548562/full?gad_source=1&gad_campaignid=23178707225&gbraid=0AAAAAC_sJ7k_QnQ2jE8EQJ5Qoo12QwKri&gclid=CjwKCAiAzrbIBhA3EiwAUBaUdXE9CWBW4uVtNHYRWtt7OxLiNO4zPn26NR_e6MLJKQuc2Ai1KrVpwhoCOgwQAvD_BwE.

[164] European Data Centre Association (EUDCA). (2025). State of European Data Centres 2025.

[165] Billones, R. K. C., Lauresta, D. A. S., Dellosa, J. T., Bong, Y., Stergioulas, L. K., & Yunus, S. (2025). AI Ecosystem and Value Chain: A Multi-Layered Framework for Analyzing Supply, Value Creation, and Delivery Mechanisms. Technologies, 13(9), 421. Retrieved 29 October 2025, from https://doi.org/10.3390/technologies13090421.

DC growth both drives and depends on extensive investment in power, fibre, and digital regulation (e.g. DORA[166] or EED[167]) as it was shown during COVID-19 pandemics[168]. Meeting escalating needs for bandwidth, security, and sustainability is central to Europe's overall competitiveness and its plans for AI leadership[169].

In summary, European DCs form the critical nexus that links the region's digital transformation with its connectivity, cloud, and AI ambitions. Their location, scale, and integration with fibre networks and IXPs are core determinants of Europe's digital future, economic growth, and technological sovereignty[170] .

4.1.1. Position in the digital value chain

A significant portion of the modern economy is now inseparably tied to digital assets, platforms, and services. Both private companies and public institutions are expected to maintain a strong online presence, not only through websites or social media profiles but also by offering a wide range of digital services, applications, and data-driven processes[171]. The success of global platforms depends on the constant availability of computing power, data storage, and colocation, all of which are provided by DCs.

Within the digital value chain, DCs occupy a central and enabling position. They serve as the physical and operational backbone through which data is collected, processed, stored, and made available. Every stage of the value chain, from the generation of data at the user or device level, through its transmission across communication networks, to its transformation into digital products and insights, depends on the reliability and capacity of DC infrastructure. In this sense, DCs transform raw data flows into usable digital value, acting as both a hub and a processing engine of the global information economy[172].

The evolution of DC models has fundamentally reshaped the structure of the digital value chain. In the past, many organisations, especially small and medium-sized enterprises, relied on their own local IT infrastructure to host applications and data. Today, these functions have largely migrated to external DCs and cloud platforms, where computing resources are provided as a service. This shift toward centralisation and virtualisation has allowed companies to scale flexibly,

[166] Regulation (EU) 2022/2554 of the European Parliament and of the Council of 14 December 2022 on digital operational resilience for the financial sector ("Digital Operational Resilience Act", DORA).
[167] European Parliament & Council. (2023, September 13). Directive (EU) 2023/1791 on energy efficiency and amending Regulation (EU) 2023/955 (recast Energy Efficiency Directive). Official Journal of the European Union.
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[170] European Data Centre Association (EUDCA). (2025). State of European Data Centres 2025.
[171] Gensler, S., & Rangaswamy, A. (2025). An emerging future for digital marketing: From products and services to sequenced solutions. Journal of Business Research, 190, 115230. Retrieved 29 October 2025, from https://doi.org/10.1016/j.jbusres.2025.115230.
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reduce costs, and focus on their core activities rather than maintaining physical infrastructure[173]. The emergence of multi-tenant facilities, where many organisations share the same physical space and resources, has further increased efficiency and lowered the entry barrier for innovation[174]. Many DC operators additionally offer private high-speed fibre links, enabling low-latency connections between facilities in the same metropolitan area or across regions. These interconnections not only enhance operational efficiency but also strengthen the resilience of digital supply chains[175].

AI is now acting as a powerful accelerator in reshaping how DCs fit into the digital value chain, both amplifying their importance and stretching their infrastructure requirements. AI workloads, training large models and conducting inference, demand very high compute density, substantial cooling capacity, very reliable power, and very fast interconnections. That means DCs are no longer just passive storage or hosting nodes; they are becoming specialized infrastructure hubs optimized for AI: with hardware accelerators (like GPUs or TPUs), dense racks and, high-bandwidth links (also, sustainable energy, and custom cooling solutions)[176]. As AI adoption across Europe grows, DCs are central in enabling value creation through advanced analytics, real-time insights, virtual assistants, autonomous systems, and more[177].

Recent reports this year show that investment in AI-related DC infrastructure is surging, what is clearly related to current advances in generative AI, especially LLM and image processing and generation. According to RLB's *Data Centre Trends Report 2025*, DC operators in Europe commissioned on average 33 megawatts (MW) of new capacity in 2024 (the average DC capacity commission in MW reported by organisations), more than double the capacity commissioned in 2023, largely driven by demand for AI-optimized infrastructure; expectations for 2025 push that figure further to 47 MW on average[178]. Meanwhile, the *Global Data Centres Report* by Knight Frank notes that AI workloads account for about 8-12% of investment activity in 2025 across the Eastern and Midland Regional Assembly (EMRA) region. The report forecasts live IT capacity as high as 55,646 GW in 2025. The prediction for total capacity supply in 2025 for Europe amounts

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[173] Koronen, C., Åhman, M., & Nilsson, L. J. (2019). Data centres in future European energy systems – energy efficiency, integration and policy. Energy Efficiency, 13(1), 129–144. Retrieved 29 October 2025, from https://doi.org/10.1007/s12053-019-09833-8;
Uddin, M., Hamdi, M., Alghamdi, A., Alrizq, M., Memon, M. S., Abdelhaq, M., & Alsaqour, R. (2021/). Server consolidation: A technique to enhance cloud data center power efficiency and overall cost of ownership. International Journal of Distributed Sensor Networks, 17(3), 155014772199721. Retrieved 29 October 2025, from https://doi.org/10.1177/1550147721997218.
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[175] Ibid.
[176] Karunakara Malige, L., & Ananth C., (2024). The Impact of Artificial Intelligence on the Modern Data Center Industry. , International Journal of Advanced Research in Innovative Discoveries in Engineering and Applications. Vol. 9, Issue 4, pp. 19-38. Retrieved 29 October 2025, from https://doi.org/10.2139/ssrn.4922638.
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Schwaeke, J., Peters, A., Kanbach, D. K., Kraus, S., & Jones, P. (2024). The new normal: The status quo of AI adoption in SMEs. Journal of Small Business Management, 63(3), 1297–1331. Retrieved 29 October 2025, from https://doi.org/10.1080/00472778.2024.2379999.
[178] Rider Levett Bucknall (RLB). (2025). Data Centre Trends Report 2025. Retrieved 29 October 2025, from https://www.rlbinsights.com/reports/data-centre-trends-report-2025/foreword.

for 19,4% of that value[179]. Also, the *Europe Data Center Market Landscape Report 2025-2030* reports that Brookfield Infrastructure Partners and its portfolio company Data4 have committed over USD 20.7 billion in France alone for AI infrastructure and DC development over the next five years[180].

In summary, DCs are no longer isolated repositories of servers, they are active participants in the digital value chain, shaping how data is produced, processed and transmitted, and monetized. By hosting diverse organisations, enabling direct (inter)connections, and providing access to global cloud ecosystems, they have become a vital strategic component of Europe's digital infrastructure and a key driver of its economic and technological competitiveness.

4.1.2. Interconnection strategies

Interconnection lies at the heart of modern DC operations, transforming isolated facilities into an integrated digital ecosystem capable of supporting the global flow of information. In the context of Europe's rapidly evolving digital landscape, the way DCs connect (to each other and, to networks) defines not only performance and reliability but also competitiveness, sovereignty, and sustainability.

The increasing demand for low-latency services, distributed computing, and data-intensive applications (e.g. AI-enabled) has shifted the focus from individual infrastructures to the connectivity fabric that binds them together[181]. Within this fabric, different types of DC interconnection serve distinct functions. Some provide high-speed local links within a single facility, while others form long-distance, high-capacity backbones between metropolitan hubs or across borders (or continents). Interconnections can be public or private, physical or virtual, centralized or distributed, each designed to balance speed, resilience, security, and cost. They enable cloud providers, enterprises, and network operators to exchange traffic efficiently, synchronise data, and deliver digital services seamlessly to users across regions[182]. Understanding these interconnection models is therefore essential to grasp how DCs collectively sustain Europe's digital value chain[183]. The figure below illustrates the main types of interconnections.

[179] Knight Frank. (2025). Global Data Centres Report 2025. Knight Frank. Retrieved 29 October 2025, from https://content.knightfrank.com/research/2982/documents/en/data-centres-global-report-2025-12054.pdf.
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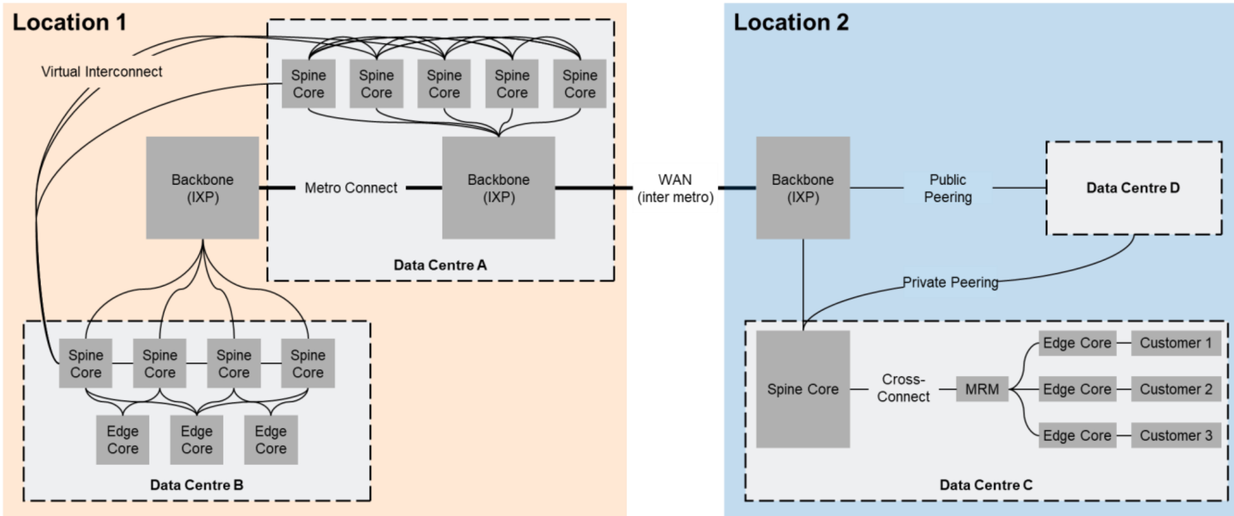

Figure 4. Main DC interconnection types.

Interconnection strategies among DC operators have undergone a fundamental transformation as the role of DCs themselves has evolved, from isolated compute silos to the distributed backbone of the digital economy. The strategy guiding how DCs interconnect has progressively shifted from ad hoc or bilateral (private) connections to sophisticated, multi-layered fabrics that integrate networking, storage, and compute resources across geographies and ownership boundaries[184]. In the early stages, interconnection strategies were primarily tactical and point-to-point, serving limited business purposes such as replication or basic connectivity between enterprise facilities. The dominant approach was physical and static dedicated leased lines (delivered by ECN providers) or exclusively owned network connections (delivered by ECN providers or by the enterprise itself) that were manually configured and optimised for reliability rather than flexibility. These strategies mirrored the monolithic nature of enterprise IT, where interoperability is a secondary concern[185].

As digital services became globalised and the Internet economy matured, the strategic focus moved toward enabling interoperability, interconnection and ecosystem growth. The introduction of DCs and IXPs marked a turning point. These hubs embodied a strategic shift from bilateral to multilateral interconnection: instead of individual organizations connecting directly, networks and enterprises began to converge at shared exchange points to transit costs, and dependency on single carriers. This evolution signified the emergence of interconnection as a core business and infrastructural strategy rather than a peripheral engineering problem[186].

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[184] Balodis, R., & Opmane, I. (2012). History of data centre development. In A. Tatnall (Ed.), *Reflections on the history of computing* (IFIP Advances in Information and Communication Technology, Vol. 387). Springer. Retrieved November 5, 2025, from https://doi.org/10.1007/978-3-642-33899-1_13.
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[186] Li, Y., Yu, W., Li, X., & Yang, Z. (2020). Research on the evolution of global internet network interconnection relationship in 21 years. *China Communications, 17*(8), 158–167. Retrieved November 4, 2025, from https://doi.org/10.23919/JCC.2020.08.013.

In the cloud/AI and hyperscale era, interconnection strategies have become deeply architectural. Rather than being built around discrete connections, they are now designed as integrated fabrics software-defined, policy-driven, and topology-aware (DC) systems that extend the logical continuity of the DC interconnection network across multiple sites and even across providers. This reflects the broader shift from static infrastructure to dynamic resource orchestration[187]. The distinction between "inside" and "between" DCs is increasingly blurred as modern strategies emphasise unified management, distributed security models, and intelligent traffic steering between locations based on workload demands and latency considerations.

Strategically, interconnection has become a key enabler of resilience, scalability, and compliance. Multi-cloud and hybrid-cloud topologies rely on diverse interconnection strategies (including private peering, cloud on-ramps, and virtual interconnects) to maintain performance and data sovereignty. At the same time, automation and software-defined networking (SDN) have transformed interconnection from a physical deployment challenge into a programmable service layer. This has allowed operators to scale interconnection capacity elastically and to orchestrate traffic flows across metro and global backbones[188].

Contemporary interconnection strategies also reveal a convergence between business and technical objectives. Where earlier strategies prioritised connectivity alone, today's approaches emphasise ecosystem participation and service differentiation[189]. Hyperscale and edge operators increasingly treat interconnection as a competitive asset, using it to minimise data gravity[190] effects optimise user experience, and facilitate distributed computing models such as AI inference at the edge. The rise of "interconnection-oriented architectures" (IOA) exemplifies this trend, where interconnection forms the structural foundation for workload placement, compliance management, and data exchange across heterogeneous environments[191].

Interconnection strategies among surveyed DCs show high dependence on telecom-operator connectivity and limited ecosystem interconnection across Europe. Most respondents rely primarily on leased fibre lines from carriers (reported by 29 of 40) supplemented by VPN/MPLS links for secure multi-site traffic (24 of 40). Direct peering remains far less common: only 9 of 40 respondents reported connectivity via an Internet Exchange Point (IXP) and just 6 of 40 indicated any use of dark fibre or self-owned backbone links. Available upstream capacity varies significantly – from below 10 Gbps (11 respondents) to above 100 Gbps (8 respondents) – confirming wide asymmetry in interconnection maturity across regions. Overall, the survey demonstrates that operators predominantly depend on carrier-provided infrastructure with selective deployment of higher-value interconnection (IXP dark fibre) limited to a minority.

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[190] Data gravity - the tendency of large datasets to attract applications, services, and infrastructure to where the data resides, because moving massive volumes of data is costly, slow, and energy-intensive.
[191] Lu, P.-J., Lai, M.-C., & Chang, J.-S. (2022). *A survey of high-performance interconnection* networks in high-performance computer systems. *Electronics, 11*(9), 1369. Retrieved November 6, 2025, from https://doi.org/10.3390/electronics11091369.

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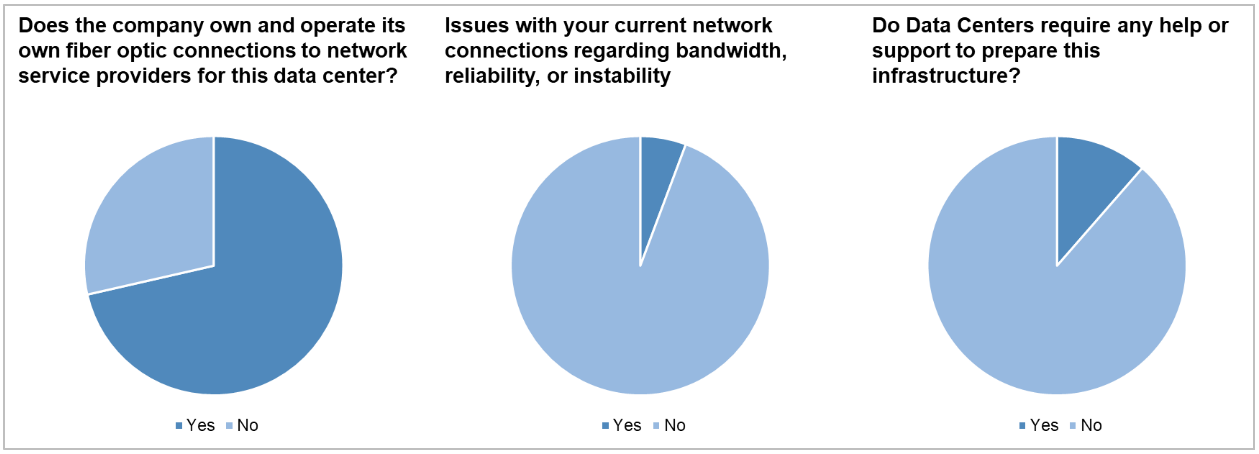

Figure 5. Interconnections.

Overall, interconnection strategies have evolved from static, link-centric models to dynamic, fabric-centric ones, integrating hardware (optical) and software layers into cohesive architectures that support distributed, resilient, and intelligent data and computing environments. This strategic evolution mirrors broader transformations in IT and networking, where adaptability, automation, and ecosystem integration now define success more than raw connectivity or capacity ever did.

4.1.3. Challenges and gaps

Looking ahead, the future of DC interconnection strategies will be defined by the convergence of automation, intelligence, and sustainability within increasingly heterogeneous infrastructures. As data creation shifts toward the network edge and as AI-driven workloads proliferate, the next generation of interconnection strategies will need to support massive, dynamic “cross-border” traffic patterns, ultra-low latency links, and context aware routing decisions that balance performance, cost, and energy efficiency. This will demand not only technological innovation in optical and packet fabrics but also the deeper integration of orchestration platforms that can dynamically reconfigure interconnect topologies in response to workload or threat changes. Emerging paradigms such as intent-based networking and autonomous network fabrics are likely to play a crucial role in enabling such adaptive, self-optimizing interconnection ecosystems.

However, this evolution also exposes critical gaps and challenges. The first concerns interoperability: as providers deploy private and/proprietary interconnection solutions, whether in the form of cloud on-ramps, private exchange fabrics, or virtual interconnects, cross-domain coordination remains limited. The absence of standardised interfaces for real-time orchestration across multiple operators and platforms hinders end-to-end automation and visibility. Similarly, ensuring consistent security and compliance policies across distributed interconnection environments is becoming increasingly complex. Each interconnection domain i.e., public, private, virtual, or cloud-based, introduces its own trust assumptions and potential vulnerabilities. Building a zero-trust architecture that spans these heterogeneous fabrics remains an unresolved challenge, particularly as data sovereignty regulations fragment the global network landscape.

Another emerging issue is (environmental) sustainability. As interconnection density and traffic volumes surge driven by AI training, content distribution, and immersive digital experiences the energy and cooling demands associated with data storage, transmission and, switching, and edge interconnects are escalating (for example, see current trends and challenges with multi-access edge computing[192]). Although total energy demand is rising, this increase is relative, as modern optical transmission (DWDM) systems remain vastly energy-efficient[193]. Future interconnection strategies will need to embed energy-aware routing, hardware efficiency metrics, and even carbon-intelligent workload placement. The push toward green DC ecosystems will likely redefine how and where interconnections are established, with metro-level exchanges and distributed micro DCs absorbing some of the load traditionally handled by large hyperscale hubs. Spreading operations between DCs maybe more efficient and provide more uniform energy demand, since optical data transmission at shorter distances can be performed at lower costs (less hops or amplifiers), particularly when combined with high-capacity spatial-division multiplexing technologies such as multicore fibres, which increase throughput without proportional increases in power consumption[194].

From a strategic standpoint, the most significant trend is the gradual abstraction of interconnection into a programmable service layer. Network functions, traditionally tied to physical interfaces, are now being virtualized, containerized, and exposed through APIs, allowing dynamic provisioning of interconnections at near-real-time scales. Yet, the economic and operational models for this transformation are still maturing. Questions of cost-sharing, service-level enforcement, and multi-provider coordination remain open. Moreover, the balance between automation and human oversight will continue to be delicate, particularly in mission-critical and regulated sectors. AI-driven automation is accelerating this shift by enabling predictive interconnection management, intent-based orchestration, and autonomous optimization across multi-provider environments.

In sum, the future of DC interconnection will hinge on achieving seamless integration (technologically, operationally, and environmentally ecologically) across a rapidly diversifying landscape of networks, clouds, and edge nodes. The vision is a globally distributed, intelligent interconnection fabric that operates as an extension of the computational continuum itself. Reaching that vision, however, will require overcoming fragmentation, establishing new standards for automation and trust, and embedding sustainability as a first-class design principle rather than an afterthought.

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[193] TrendForce (2025). AI data centers ignite a laser shortage wave; Nvidia's strategic lock-in reshapes the global laser supply chain. Consumer Electronics, TrendForce. Retrieved 17 December 2025 from https://www.trendforce.com/presscenter/news/20251208-12823.html

[194] Nooruzzaman, M., Jain, S., Jung, Y., Ul Alam, S., Richardson, D. J., Miyamoto, Y., & Morioka, T. (2017). Power Consumption in Multi-core Fibre Networks. In Proceedings of 43rd European Conference on Optical Communication IEEE. https://doi.org/10.1109/ECOC.2017.8346158

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4.2. Submarine cables

4.2.1. Strategic importance for global connectivity and data flows

Fiber-optic submarine cables soon became the primary medium for international data exchange (between Europe and other continents), quietly supporting everything from financial transactions and cloud computing to social media and video streaming[195]. Today, over 99% of all intercontinental digital traffic travels through an intricate network[196] of more than 400 active submarine cables stretching hundreds of thousands of kilometres across the ocean floor. While satellites provide supplementary connectivity, the modern Internet as well as the global economy that depends on submarine cables, and remains fundamentally tied to this largely unseen, yet indispensable, infrastructure[197].

Submarine cables remain the most viable and indispensable medium for global data transmission because they combine exceptional capacity, stability, and efficiency unmatched by any other form of long-distance communication. Fiber-optic cables can carry dozens of terabits of data per second with minimal latency, enabling the seamless functioning of global financial systems, cloud computing, and real-time communications. Their physical nature, directly connecting continents across the ocean floor, offers a level of reliability and speed that is critical for the modern digital economy[198]. Cables are still responsible for carrying the overwhelming majority of global digital traffic with speed that no alternative can yet rival[199].The map below represents the global network of submarine telecommunications cables, illustrating the locations and connections of undersea infrastructure that enable international data transmission.

[195] Ash, S. (2014). Chapter 1. The development of submarine cables. In *Submarine cables* (pp. 17–39). Brill | Nijhoff. Retrieved November 3, 2025, from https://doi.org/10.1163/9789004260337_003.
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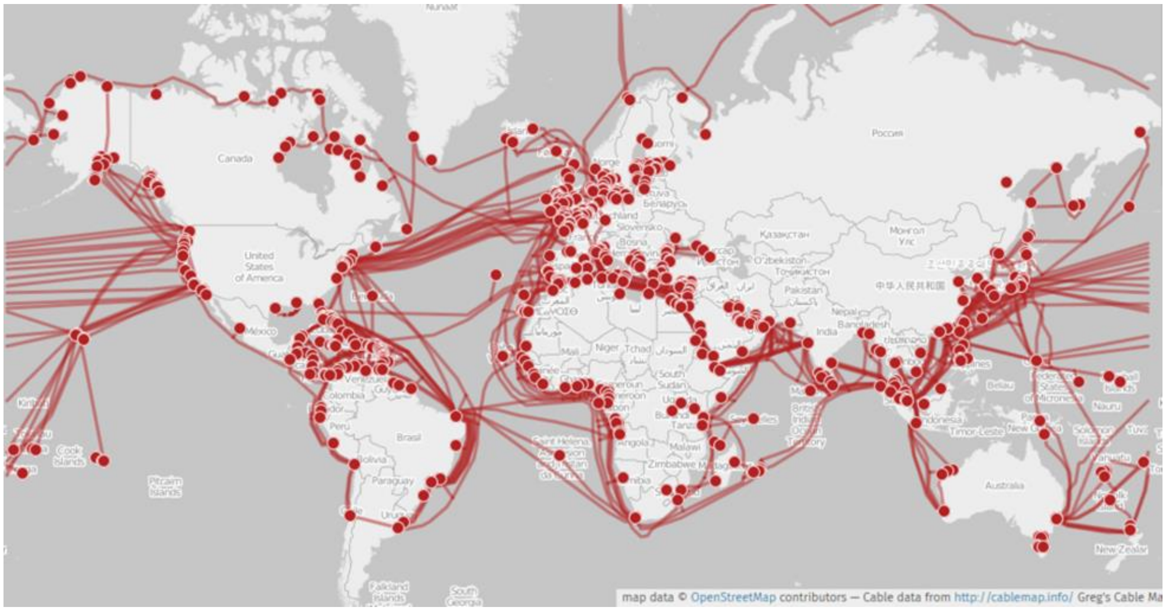

Figure 6. Global submarine cable network map. Data compiled from the OpenStreetMap project and CableMap (Greg Mahlknecht, GPLv3). Map visualizes the locations and connections of undersea telecommunications cables worldwide. Source: https://commons.wikimedia.org/wiki/File:Submarine_cable_map_umap.png.

Submarine cable connectivity follows several key patterns shaped by geography, economic demand, and geopolitical considerations. The most fundamental pattern is transoceanic connectivity, linking major continental hubs across the Atlantic, Pacific, and Indian Oceans. These routes form the backbone of global internet traffic, with the transatlantic corridor between North America and Europe remaining one of the most densely connected and heavily trafficked[200].

Another critical pattern is regional interconnection, where cables connect neighbouring coastal nations or island groups to strengthen intra-regional communication. Examples include extensive networks within Europe, in the Mediterranean, the Caribbean, and Southeast Asia, which enhance redundancy and facilitate local data exchange without routing through distant continents[201]. A third major configuration is hub-and-spoke architecture, where certain strategic landing points such as Singapore, Marseille, London, and New York act as major data hubs that aggregate and redistribute traffic. These hubs are often chosen for their political stability, advanced digital infrastructure, and proximity to large DC ecosystems[202]. Finally, redundant and ring-like architectures that were popular in the near past are increasingly being replaced by point-to-point "mesh" architectures, which enable traffic to be rerouted through any cable where the operator holds capacity or an indefeasible right of use. This approach eliminates the need to construct

[200] Ma, X., & Jiang, C. (2025). Global submarine cable network and digital divide. *Journal of Geographical Sciences, 35*(6), 1204–1232. Retrieved November 2, 2025, from https://doi.org/10.1007/s11442-025-2364-x.
[201] Idem.
[202] Xie, Y., & Wang, C. (2023). Spatial pattern of global submarine cable network and identification of strategic pivot and strategic channel. *Journal of Geographical Sciences, 33*(4), 719–740. Retrieved November 5, 2025, from https://doi.org/10.1007/s11442-023-2103-0.

parallel cables while offering enhanced redundancy, resilience, and operational flexibility[203]. Together, these interlinked patterns form a complex, multilayered web that underpins the stability and efficiency of the modern Internet.

Data centre-to-data centre (DC-to-DC) flows emerging as a primary driver of new infrastructure investment. Leading hyperscalers, such as Google and Meta, are spearheading the deployment of next-generation intercontinental systems. Whereas cables designed five years ago typically featured 4–6 fibre pairs at around 10 Tbps per pair, current projects are built with 8–16 pairs and design capacities of 20 Tbps per pair, with roadmaps extending to 24–36 pairs[204]. Today, the focus is on direct DC-to-DC connections, sometimes replacing traditional CLSs with modular units to house power and terminal equipment while delivering connectivity straight to DCs or interconnection-rich colocation facilities. These developments, however, introduce complexity: joint projects often combine the distinct requirements of OTTs, focused on DC-to-DC latency and capacity, with carriers seeking traditional landing and interconnection points, necessitating careful reconsideration of subsea system architecture and business models[205].

4.2.2. Ownership & control structures

Ownership and control structures of submarine cables have undergone significant transformation over the past two decades, reflecting broader shifts in global digital power. Historically, undersea cables were financed and operated by consortia of ECN/ECS operators and national carriers, ensuring distributed ownership and shared maintenance responsibilities. However, in recent years, the landscape has changed dramatically with the rise of hyperscalers, such as Google, Meta, Amazon, and Microsoft, emerging as dominant main investors and owners of private international submarine cable systems, that account for almost 70% of international capacity usage in 2021[206]. Between 2017 and 2024, major content and application providers have invested more than €2.4 billion in new subsea systems landing in Europe, amounting to 10 cable projects spanning 74,141 km and delivering at least 1,684 Tbps of design capacity across 125 fibre pairs[207].

The submarine cable sector is undergoing a major transformation as hyperscalers shift from being mere buyers of connectivity to becoming key owners and investors in new cable systems. Whereas telecom operators once dominated deployment through international consortia and controlled both infrastructure and specialised installation vessels, hyperscalers now build their own cables to support rapidly growing traffic, DC expansion, and global CDNs. This change reshapes industry relationships, strains limited construction and maintenance resources (including a global fleet of only about 50 cable ships) and reduces the traditional role of telecom operators on major routes. Nonetheless, operators remain essential for connecting regions that

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[203] Burnett, D. R. (2021). Submarine cable security and international law. *International Law Studies, 97*, 1659–1682. Retrieved November 6, 2025, from https://digital-commons.usnwc.edu/ils/vol97/iss1/55/.
[204] Nahpal V. (n.d.) Convergence of Data Centres, Subsea & Terrestrial Fibre, Portman Partners. Retrieved on November 20, 2025 from https://portmanpartners.com/convergence-of-data-centres-subsea-terrestrial-fibre/.
[205] Ibid.
[206] European Regulators for Electronic Communications (BEREC). (2024, October 3). BEREC report on the entry of large content and application providers into the markets for electronic *communications networks and services (BoR (24) 139)*. Retrieved on November 20, 2025 from https://www.berec.europa.eu/system/files/2024-10/BoR%20%2824%29%20139_BEREC%20Report%20on%20the%20entry%20of%20large%20CAPs%20in%20ECS-ECN_0.pdf.
[207] Ibid.

are not economically attractive to hyperscalers and for supporting research, education, and less commercially viable markets. Overall, the increasing ownership of submarine infrastructure by these companies is redefining connectivity, competition, and long-term investment patterns across the global submarine cable ecosystem[208].

Furthermore, the strategic nature of intercontinental submarine cables makes them sensitive to geopolitical tensions, leading to greater scrutiny and supervision by states seeking to secure their digital sovereignty. As a result, the global submarine cable network, shaped by evolution of markets and data flows will reflect in the future the interplay between private innovation, market efficiency, and the strategic imperatives of national and supranational governance[209].

Submarine cables can be owned either by a single entity or by a consortium of multiple investors, and the chosen ownership model has direct implications for maintenance and governance. Privately owned cables, controlled by a single company, such as Google's Dunant cable linking the United States and France[210], or Google's Grace Hopper cable connecting the U.S., the U.K., and Spain[211], offer operational efficiency and faster decision-making. A sole owner can coordinate construction, maintenance, and capacity upgrades without negotiating among partners, ensuring rapid technological adoption and streamlined management[212].

In contrast, consortium-owned cables, for example, the SEA-ME-WE 5 (South East Asia–Middle East–Western Europe 5) system, installed in 2016[213] or the Havfrue/AEC-2 cable between Ireland, Denmark, Norway and the United States (installed in 2020), are jointly financed and operated by ECN/ECS operators[214]. This shared model spreads financial risk and ensures broader access to bandwidth among stakeholders, but it also introduces coordination challenges[215].

Political influence further complicates both ownership models. Privately owned cables may face regulatory resistance from governments, e.g., NIS1 and NIS2 directives introduce necessity of incident reporting, adopting detailed risk management plans and cybersecurity governance. Governments wary of foreign control over critical infrastructure (e.g. the case of the South China

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[208] Ibid.
[209] Ganz, A., Camellini, M., Hine, E., Novelli, C., Roberts, H., & Floridi, L. (2024). Submarine Cables and the Risks to Digital Sovereignty. SSRN Electronic Journal. Retrieved November 20, 2025 from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4693206.
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[211] Koley, B. (2020). *Announcing the Grace Hopper subsea cable, linking the U.S., U.K. and Spain*. Google Cloud.
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TeleGeography & Infra-Analytics. (2025). *The future of submarine cable maintenance: Trends, challenges, and strategies* [Report]. TeleGeography. Retrieved November 4, 2025, from https://www2.telegeography.com/hubfs/LP-Assets/Ebooks/The%20Future%20of%20Submarine%20Cable%20Maintenance_%20Trends%2C%20Challenges%2C%20and%20Strategies.pdf.
[213] TeleGeography & Infra-Analytics. (2025). *The future of submarine cable maintenance: Trends, challenges, and strategies* [Report]. TeleGeography. Retrieved November 4, 2025, from https://www2.telegeography.com/hubfs/LP-Assets/Ebooks/The%20Future%20of%20Submarine%20Cable%20Maintenance_%20Trends%2C%20Challenges%2C%20and%20Strategies.pdf.
[214] Ibid.
[215] Ibid.

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Sea[216]), proposing new legislative initiatives[217]. Under the Connecting Europe Facility (CEF) Digital programme – Backbone Connectivity for Digital Global Gateways, EU has already allocated €809 million to subsidise 107 backbone connectivity projects. Additional €540 million will be invested between 2025 and 2027 to fund digital infrastructure projects, including sensorised submarine cables, prioritising strategic Cable Projects of European Interests (CPEI), bringing total funding to € 1 billion under the CEF[218]. Figure 7 below presents a map of fibre connectivity and submarine cables funded under the CEF Programme. This program supports data transmission both within Europe and internationally, helping to establish a pan-European infrastructure that facilitates cloud computing, artificial intelligence, and enterprise services.

According to TeleGeography and the recent report on security and resilience of EU submarine cable infrastructure, the total submarine cable capacity interconnecting EU Member States has expanded dramatically, from an estimated 318 Tbit/s in 2010 to 3,755 Tbit/s in 2024. This growth has been driven chiefly by the escalating international bandwidth needs of major hyperscalers (Google, Meta, Amazon, and Microsoft). Their share of all utilised international capacity has risen from just 10% in 2010 to approximately 71% in 2024[219].

[216] Desurmont J-M (2024) Territorial Claims and Subsea Cables: The Geopolitics of Invisible Lines in the South China Sea. Retrieved on November 22, 2025 from https://bisi.org.uk/reports/territorial-claims-and-subsea-cables-the-geopolitics-of-invisible-lines-in-the-south-china-sea.

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The SMART Cables Joint Task Force. (n.d.). About the JTF. Retrieved November 23, 2025, from https://www.smartcables.org/jtf.;
European Commission; High Representative of the Union for Foreign Affairs and Security Policy. (2025). Joint communication to the European Parliament and the Council: EU Action Plan on Cable Security (JOIN(2025) 9 final). Publications Office of the European Union. Retrieved on November 22, 2025 from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025JC0009;
European Health and Digital Executive Agency. (2025, November 20). ***56 projects selected for up to €389 million under 4th CEF-Digital calls***. Retrieved 17 December 2025 from https://hadea.ec.europa.eu/news/56-projects-selected-eu389-million-under-4th-cef-digital-calls-2025-11-20_en.

[219] Submarine Cable Infrastructures (2025) Security and Resilience of EU Submarine Cable Infrastructures - Mapping, risk assessments, stress tests Retrieved on November 22, 2025 from https://cdn.table.media/assets/europe/main_report__submarine_cables_expert_group_mapping_risks_stress_tests_sszvwacryqopjjtdpbfcrpgwfk_120904.pdf.

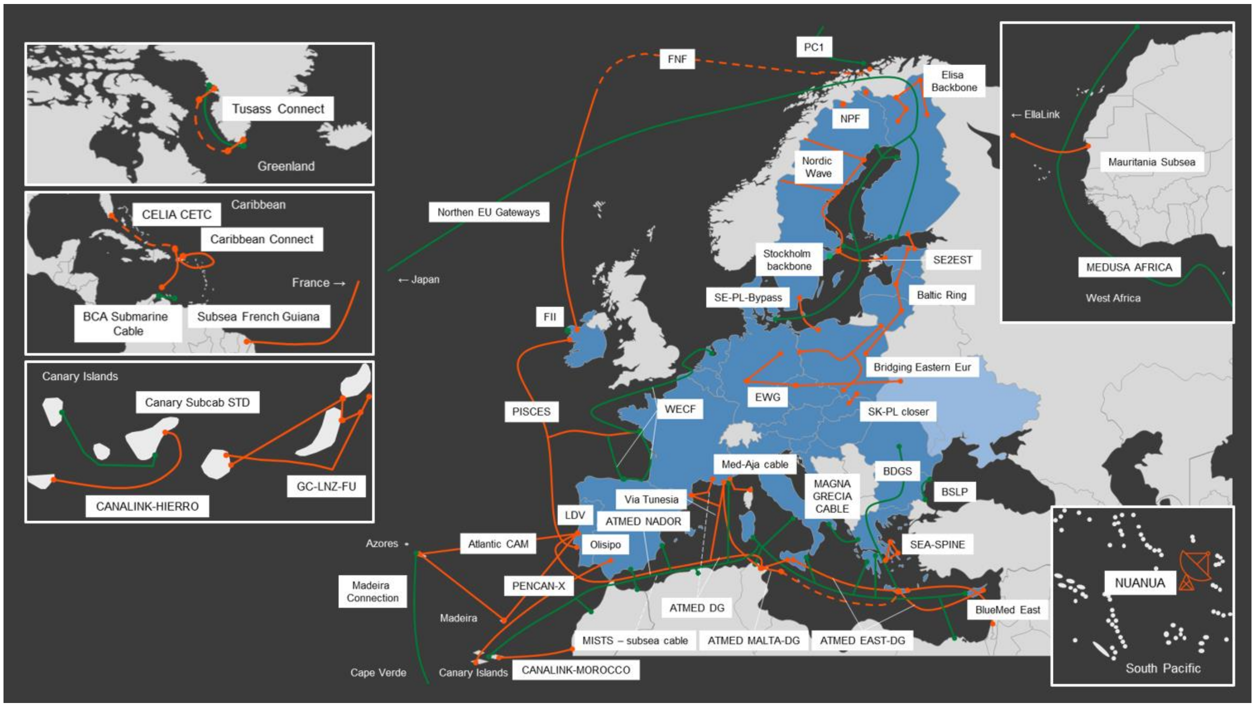

Figure 7. Map of Cable Project funded under the Connecting Europe Digital Facility Programme.

4.2.3. Vulnerabilities: physical security, sabotage, geopolitical leverage

Submarine cables, often are no thicker than a garden hose, lying unguarded on the seabed for thousands of kilometres. Their exposure and the difficulty of monitoring undersea environments make them susceptible to both accidental and deliberate disruptions that can have cascading effects on economies, communications, and national security.

Natural and environmental threats are an ever-present concern. Seismic activity, volcanic eruptions, and underwater landslides can sever or bury cables, especially in tectonically active regions such as the Mediterranean or North Atlantic margins[220]. Biological interference, though less frequent, can also pose risks, shark bites and corrosion due to microbial activity occasionally damage insulation or outer sheaths[221]. These natural hazards, while often unpredictable, tend to

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Clare, M. A., Yeo, I. A., Nash, J., Hunt, J. E., Panuve, S., Wilkie, A., Williams, R., Dowey, N., Rowley, P., Barclay, J., Phillips, J., Scarlett, J., Engwell, S., Henstock, T. J., Seabrook, S., Watson, S., Wysoczanski, R., Ribo, M., Cronin, S., Talling, P. J., … Cassidy, M., Watt, S., Robertson, R. (2025). Volcanic eruptions and the global subsea telecommunications network. *Bulletin of Volcanology, 87*, 51. Retrieved November 7, 2025, from https://doi.org/10.1007/s00445-025-01832-1.
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Matturro, B., Cruz Viggi, C., Aulenta, F., & Rossetti, S. (2017). Cable bacteria and the bioelectrochemical snorkel: The natural and engineered facets playing a role in hydrocarbons degradation in marine sediments. *Frontiers in Microbiology, 8*, 952. Retrieved November 7, 2025, from https://doi.org/10.3389/fmicb.2017.00952.

occur in specific geological zones, allowing operators to map risk profiles and design routes that minimize exposure[222].

Human-related incidents and threats are far more common. The majority of cable faults result from accidental damage caused by fishing trawlers and ship anchors, which can snag or crush cables near coastal areas[223]. Beyond these accidental causes, intentional interference has become a growing concern. Sabotage or espionage targeting subsea cables, whether through direct cutting or hybrid warfare tactics, presents a serious risk to both civilian and military communications[224]. Recent incidents in the Baltic and North Seas, including suspected acts of sabotage against data and energy infrastructure, have highlighted the geopolitical leverage that control or disruption of these cables can provide[225]. In times of conflict or tension, the ability to disable or monitor critical communication lines offers strategic advantage, making cable security an emerging domain of national defence planning.

Mechanical and technical failures also pose operational risks, often related to material fatigue, or errors during installation and repair. Modern cables are highly reliable, with an average lifespan of about 25 years, after that period their maintenance is usually no longer (economically) viable. Repair operations, however, are constrained by limited global capacity: only a small, aging fleet of specialised cable-laying and repair vessels exists, and their deployment is time-consuming and weather-dependent[226]. This scarcity becomes critical during multiple simultaneous faults, potentially leading to prolonged outages in affected regions (e.g., see the recent case of Congo Canyon[227]). The total length of global submarine cables is projected to increase by 48% between 2025 and 2040, accompanied by a 36% rise in annual repair activities. By 2040, approximately 850,000 kilometres of cable are expected to be decommissioned, with around half of that total likely to be retired by 2030. In addition to that an estimated investment of about $3 billion will be required to support vessel replacement and fleet expansion efforts[228].

Submarine cables in Europe represent both economic lifelines and strategic assets. Among the most significant are the Dunant (U.S.–France) and Grace Hopper (U.S.–U.K.–Spain) cables; the

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Huang, X., Jiang, D., Cen, Z., Li, H., Wang, Z., & Guo, Z. (2024). Global responses of exposed and suspended submarine cables due to anchor dragging. *Journal of Marine Science and Engineering, 12*(9), 1628. Retrieved November 7, 2025, from https://doi.org/10.3390/jmse12091628.

[224] Bueger, C., Liebetrau, T., & Franken, J. (2022, June). Security threats to undersea communications cables and infrastructure – consequences for the EU (In-depth analysis No. EXPO_IDA(2022)702557). *European Parliament*. Retrieved November 7, 2025, from https://www.europarl.europa.eu/RegData/etudes/IDAN/2022/702557/EXPO_IDA(2022)702557_EN.pdf.

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[226] TeleGeography & Infra-Analytics. (2025). *The future of submarine cable maintenance: Trends, challenges, and strategies* [Report]. TeleGeography. Retrieved November 4, 2025, from https://www2.telegeography.com/hubfs/LP-Assets/Ebooks/The%20Future%20of%20Submarine%20Cable%20Maintenance_%20Trends%2C%20Challenges%2C%20and%20Strategies.pdf.

[227] Madory, D. (2023, September 20). Dual subsea cable cuts disrupt African Internet. Kentik Blog. Retrieved November 7, 2025, from https://blog.apnic.net/2023/09/20/dual-subsea-cable-cuts-disrupt-african-internet/.

[228] Ibid.

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AEConnect-1 cable linking Ireland and the U.S., a key transatlantic data route; and the SEA-ME-WE 5 system, which connects Europe to the Middle East and Asia. Additionally, regional systems such as the Celtic Norse and Havfrue/AEC-2 cables link Northern Europe and the Nordics, playing a growing role in intra-European connectivity and data sovereignty[229]. These cables are critical to the continent's digital resilience, yet their ownership and routing often extend beyond European jurisdiction, creating strategic dependencies that are increasingly recognized as vulnerabilities[230].

Sovereign cable repair capacity is emerging as a priority[231]. While commercial repair agreements remain the norm, where private operators or consortia rely on third-party service providers, several European nations are now developing dedicated, state-coordinated capabilities to secure rapid intervention in case of sabotage or major disruption. Initiatives in France, the U.K., and the Nordic countries aim to integrate subsea cable security into national maritime defence frameworks, ensuring that repair and protection are not solely dependent on market mechanisms[232]. This shift reflects a broader understanding that submarine cables are not merely commercial assets but critical components of national infrastructure and international (inter)connections, requiring protection, surveillance, and response capacity equivalent to that afforded to energy pipelines or defence communication systems[233]. In addition to that on 21 February 2025, the European Commission issued Joint Communication to strengthen the security and resilience of submarine cables, entitled, EU Action Plan on Cable Security, with the objective of strengthening the security and resilience of submarine cables, through actions in a whole resilience cycle approach: prevention, detection, response and repair, and deterrence[234].

4.2.4. Gaps in mapping, governance, repair/maintenance capabilities

Despite the strategic importance of submarine cables, significant gaps remain in understanding and mapping the full spectrum of threats they face. Detectability and attribution of cable damages

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[229] European Commission; High Representative of the Union for Foreign Affairs and Security Policy. (2025). Joint communication to the European Parliament and the Council: EU Action Plan on Cable Security (JOIN(2025) 9 final). Publications Office of the European Union. Retrieved October 28, 2025, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025JC0009;
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Ganz, A., Camellini, M., Hine, E., Novelli, C., Roberts, H., & Floridi, L. (2024). Submarine cables and the risks to digital sovereignty. *SSRN Electronic Journal*. Retrieved November 4, 2025, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4693206;
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Heron, A. (2025, January 27). *A North Sea defence alliance: Challenges and opportunities for the UK*. Risk Analysis & Insights. Titan. Retrieved October 19, 2025, from https://atlasinstitute.org/a-north-sea-defence-alliance-challenges-and-opportunities-for-the-uk/.
Ministry for Europe and Foreign Affairs. (2025, July). *France's Indo-Pacific strategy* [PDF]. Retrieved October 25, 2025, from https://www.diplomatie.gouv.fr/IMG/pdf/france_s_indo-pacific_strategy_2025_cle04bb17.pdf.
[233] TeleGeography & Infra-Analytics. (2025). *The future of submarine cable maintenance: Trends, challenges, and strategies* [Report]. TeleGeography. Retrieved November 4, 2025, from https://www2.telegeography.com/hubfs/LP-Assets/Ebooks/The%20Future%20of%20Submarine%20Cable%20Maintenance_%20Trends%2C%20Challenges%2C%20and%20Strategies.pdf.
[234] European Commission; High Representative of the Union for Foreign Affairs and Security Policy. (2025). Joint communication to the European Parliament and the Council: EU Action Plan on Cable Security (JOIN(2025) 9 final). Publications Office of the European Union. Retrieved October 28, 2025, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52025JC0009.

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remain critical gaps. Even when a fault is detected, pinpointing its cause (e.g. natural, accidental, or malicious) is technically challenging. In fact, to deal with these and other issues the Commission Recommendation (EU) 2024/779 calls for improved situational awareness, enhanced monitoring and detection capabilities, coordinated risk assessments, and clearer attribution and response mechanisms involving both public authorities and private operators[235]. Underwater repair vessels rely on sonar and remotely operated vehicles, but deep-sea faults or damages in politically sensitive areas can remain undetected for extended periods. Attribution is further complicated when attacks are clandestine, involving sophisticated methods that leave minimal traces, or when multiple stakeholders own a cable and reporting is fragmented[236].

According to report published by TeleGeography and Infra-Analytics in next 5 years more than 400 000 km of subsea cables is expected to be retired[237]. Although this number may seem high, it must be considered in context. The total length of subsea cables is estimated at approximately 130,000 km[238]. Between 2014 and 2024, an additional 60–80 km has been deployed annually. Some estimates indicate that over the next five years, the total length of submarine cables will increase by around 110 km. It is important to note that cable infrastructure expected to be retired by 2031 is concentrated primarily in the North Atlantic as well as the North and Southwest Pacific. As a result, certain regions are projected to experience a temporary negative net change in cable length, notably the Northwest Atlantic, Southwest Atlantic, and Southwest Pacific[239].

Submarine cables are designed for a minimum operational lifespan of 25 years. However, due to a combination of economic factors and the highly heterogeneous subsea environment, it is estimated that approximately 42% of subsea cables require replacement after 10 years of service or less. In fact, cables that remain operational for more than 20 years account for only about 20% of the total[240]. To address current demand for repair and maintenance of subsea cables investment of $3 billion is forecasted as necessary to replace and expand specialized vessel fleet[241].

The governance of submarine cables suffers from significant gaps that reflect both the technical complexity of the infrastructure and the fragmented nature of international oversight. Unlike terrestrial telecommunications or energy networks, undersea cables traverse multiple jurisdictions and often cross vast areas of international waters, creating ambiguity over regulatory authority, enforcement, and accountability. International frameworks, such as the United Nations

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235 European Commission. (2024, February 26). Commission Recommendation (EU) 2024/779 on secure and resilient submarine cable infrastructures (C/2024/1181). Official Journal of the European Union. Retrieved 17 December 2025 from https://eur-lex.europa.eu/eli/reco/2024/779/oj/eng

236 Tagliapietra, A., & Soliman, M. (2024, October). *Subsea data cables security: A shared concern for global North and South (Policy Brief No. 55/24).* Policy Center for the New South. Retrieved November 2, 2025, from https://www.policycenter.ma/publications/subsea-data-cables-security-shared-concern-global-north-and-south.

237 TeleGeography & Infra-Analytics. (2025). *The future of submarine cable maintenance: Trends, challenges, and strategies* [Report]. TeleGeography. Retrieved November 4, 2025, from https://www2.telegeography.com/hubfs/LP-Assets/Ebooks/The%20Future%20of%20Submarine%20Cable%20Maintenance_%20Trends%2C%20Challenges%2C%20and%20Strategies.pdf.

238 The Joint Research Centre: EU Science Hub (2025), The JRC explains: Subsea cables: how vulnerable are they and can we protect them? Retrieved January 19, 2025, from https://joint-research-centre.ec.europa.eu/jrc-explains/subsea-cables-how-vulnerable-are-they-and-can-we-protect-them_en

239 TeleGeography & InfraAnalytics. (2025).

240 Idem.

241 Idem.

Convention on the Law of the Sea (UNCLOS), provide basic guidance on the laying and protection of cables, but they offer limited mechanisms for coordination, security enforcement, or dispute resolution in cases of damage, espionage, or sabotage[242]. At the national level, governance is uneven. Some states have established regulatory regimes and maritime surveillance to maintain safety and security[243]. This patchwork results in inconsistent standards for physical protection, maintenance obligations, and reporting of incidents, leaving vulnerable segments of the network exposed. In many regions, critical cables are owned or operated by multinational technology companies, whose private priorities may not align with national security or public interest objectives. In consequence, there is no centralised coordination mechanism for undersea cable infrastructure as a whole, what results with e.g., impaired resilience and redundancy planning[244].

In addition to that, there is a gap in strategic foresight and international cooperation. While global initiatives and industry groups exist to standardise technical practices and promote cable security, these efforts often lack enforceable mandates or integrated intelligence-sharing mechanisms[245]. In regions such as the Eastern Mediterranean, the North Sea, and transatlantic corridors, complex geopolitical dynamics intersect with commercial interests, creating vulnerabilities that cannot be fully addressed without coordinated multilateral governance. As a result, the global submarine cable network operates under a combination of private initiative, national oversight, and voluntary international norms, leaving significant gaps in regulation, security assurance, and resilience planning[246]. More detailed information can be found in BEREC report on report on the general authorisation and related frameworks for international submarine connectivity[247].

Within European waters, these issues are especially pronounced in regions where monitoring is limited by depth, traffic density, or jurisdictional complexity. The Bay of Biscay, the North Atlantic approaches to Ireland and France, and the deep waters of the Eastern Mediterranean present challenges for continuous observation. Likewise, areas such as the Norwegian Sea and the Baltic Sea, with complex coastlines and mixed international waters, are difficult to survey comprehensively[248]. In such zones, the combination of natural unpredictability, high maritime activity, and geopolitical sensitivity creates persistent blind spots in threat mapping[249].

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[242] Raha, U. K., & Raju, K. D. (2021). *Submarine cables protection and regulations*. Springer Singapore. Retrieved October 30, 2025, from https://link.springer.com/book/10.1007/978-981-16-3436-9.
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[244] Ibid.
[245] Ibid,
[246] Churchill, R., Lowe, V., & Sander, A. (2022). *The law of the sea*. Manchester University Press. Retrieved November 1, 2025, from https://chooser.crossref.org/?doi=10.7765%2F9781526159038.
[247] BEREC. (2023). BEREC report on the general authorisation and related frameworks for international submarine connectivity Retrived on November 22, 2025 from https://www.berec.europa.eu/en/document-categories/berec/reports/draft-berec-report-on-the-general-authorization-and-related-frameworks-for-international-submarine-connectivity.
[248] Bueger, C., Liebetrau, T., & Franken, J. (2022, June). Security threats to undersea communications cables and infrastructure – consequences for the EU (In-Depth Analysis No. EXPO_IDA(2022)702557). European Parliament. Retrieved October 31, 2025, from https://www.europarl.europa.eu/RegData/etudes/IDAN/2022/702557/EXPO_IDA(2022)702557_EN.pdf.
[249] Usewicz, T., & Keplin, J. (2023). *Hybrid actions and their effect on EU maritime security*. Journal on Baltic Security. Retrieved October 28, 2025, from https://doi.org/10.57767/jobs_2023_001.

4.3. Strategic investments by ECN/ECS operators

ECN/ECS operators – telecom carriers, mobile network operators (MNOs), and integrated service providers – play an increasingly important role as critical hybrid players, combining connectivity and (edge/local) computation. The noticeable ECN investment areas include capacity decentralisation, edge and sovereign-cloud enablement, and strengthening Europe's digital resilience. These actions stem from overlapping trends: the growth of AI-related workloads, the emphasis on low-latency services, and the EU's ambitions for digital sovereignty and sustainable infrastructure. This strategic transformation risks stalling at pilot scale without coherent regulatory alignment and predictable financial incentives.

4.3.1. Overview of ECN/ECS operators' role in DC investments

Historically, ECNs operated primarily as connectivity providers, offering fibre backbones, cellular networks, and leased lines/transit capacity. Over the past decade, their business models have evolved. Leading European ECN/ECS operators are moving beyond connectivity into the DC and cloud services domain, blurring the line between communications and computing infrastructure. These efforts enable them to host network functions closer to end users, support 5G edge workloads, and retain strategic control over key digital assets – especially important for Europe's digital sovereignty[250].

A visible expression of this shift is the pan operator push to expose common network capabilities and federate edge services through open APIs. Since 2023–2025, operators including Deutsche Telekom, Orange, Telefónica, and Vodafone have launched GSMA Open Gateway APIs in multiple EU markets – an on-ramp for cross-operator, low-latency services at the edge[251]. In parallel, the CAMARA open-source project (Linux Foundation + GSMA) standardises those (network) APIs for interoperability across networks and countries[252].

Leading European ECN/ECS operators are also investing in or structuring joint ventures with colocation and edge DC providers. A prominent example is Liberty Global, which together with DigitalBridge created AtlasEdge, a Europe-wide edge platform that aggregates and expands regional edge sites close to metro networks[253]. Operators are simultaneously re-balancing their

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[250] BEREC. (2022, October 6). *BEREC report on the 5G ecosystem* (BoR (22) 144). Body of European Regulators for Electronic Communications. Retrieved 25 November 2025, from https://www.berec.europa.eu/system/files/2024-03/BoR%20%2824%29%2052_Draft_Cloud_Report.pdf.
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[251] GSMA. (2024, February 26). *Open Gateway launch in Germany: Mobile operators open up new business models with network API launch* [Press release]. Retrieved 4 November 2025, from https://www.gsma.com/newsroom/press-release/gsma-open-gateway-launch-in-germany-mobile-operator-open-up-new-business-models-with-network-api-launch/.
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AtlasEdge. (n.d.). *AtlasEdge Data Centres – Built around you* [Corporate website]. Retrieved 2 November 2025, from https://atlasedge.com/.

own DC portfolios: for instance, Telefónica has combined divestments with strategic stakes and partnerships around DC assets to stay close to enterprise workloads and edge demand[254].

Sovereign cloud initiatives illustrate how ECNs blend connectivity with compliant compute. In France, Bleu – the Orange and Capgemini joint venture supported by Microsoft technology under "cloud de confiance" rules – aims to deliver trusted cloud regions for public-sector and critical-infrastructure workloads[255]. In parallel, several ECNs have expanded or modernised regional facilities to anchor these services: Orange commissioned new DCs in Amilly and Val-de-Reuil (France) in 2022 and opened the Warsaw Data Hub (Poland) in 2021, integrating ECN/ECS operators' networks with sovereign and hybrid-cloud offerings[256]. ECNs are also testing cloud-native RAN and moving selected 5G functions toward hyperscale infrastructure – steps that further tighten the compute-network interplay[257].

Overall, ECN/ECS operators are repositioning themselves as integrated digital-infrastructure providers – combining fibre, mobile, APIs, edge compute, and (where strategic) DC capacity – to deliver low-latency, compliant services at scale across Europe[258].

4.3.2. Drivers behind ECN/ECS operators' investments

Digital transformation across all sectors has triggered an investment wave by ECN/ECS operators into DC infrastructure, driven by:

- **Low-latency service demand and efficiency:** Emerging applications – autonomous systems, immersive technologies and services, and industrial IoT – require high-throughput, low-latency connectivity. While traditional core-network DCs cannot always support sub-20 ms round-trip times, such performance can be achieved by deploying edge and regional DCs integrated with 5G Standalone (SA), Multi-access Edge

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Computing (MEC), and Open RAN architectures[259]. Deploying edge and regional DCs allows functions such as caching, content delivery and user-plane routing to be offloaded locally, reducing backbone congestion and often lowering end-to-end latency and energy usage[260].

- **Revenue diversification:** Revenue from traditional electronic communications services faces persistent ARPU pressure and operates under a stricter regulatory regime, while cloud and data-processing markets are growing and creating new revenue streams around digital transformation of vertical industries. By integrating DCs and cloud services with their networks, operators can offer higher-value B2B solutions – such as private (5G) networks bundled with cloud-based analytics and AI services – and tap into new value pools based on network APIs and edge-enabled services[261].
- **Digital sovereignty:** EU frameworks (e.g., the Data Governance Act, Data Act, NIS2) and GAIA-X federation principles incentivise keeping sensitive data under EU jurisdiction and strengthening trusted data-infrastructure, encouraging domestic investment by ECNs[262].
- **Sustainability alignment:** Integrating renewable-power sourcing and waste-heat recovery on ECN/ECS operators' campuses supports ESG and EU Green Deal objectives. The recast Energy Efficiency Directive and Commission Delegated Regulation (EU) 2024/1364 establish reporting and a Union rating scheme for DCs (≥500 kW IT) that shape design and siting decisions; the EU Taxonomy guides green-finance alignment[263].

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- **Strategic control:** Owning or co-investing in compute/storage keeps telecom operators in the value chain as integrated digital-infrastructure providers, not just bandwidth suppliers, amid an AI-fuelled "data-centre gold rush" and intensifying competition[264].

4.3.3. Major investment areas

Across Europe, ECN/ECS operators are spreading investment across six buckets that align compute with connectivity: (1) edge nodes to meet stricter latency targets; (2) carrier-neutral colocation for hybrid cloud and interconnection; (3) new submarine and terrestrial backbones for capacity and route diversity; (4) "green" campuses that qualify under EU sustainability rules and enable heat-reuse; (5) public–private partnerships and sovereign-cloud platforms to meet regulatory and security requirements; and (6) AI-ready, high-density facilities. Choices are shaped by latency economics, interconnection gravity, grid and siting constraints, and evolving EU policy (EED rating scheme, EU Taxonomy).

Edge DCs (k*ey driver: reliable low-latency communications)*

The most visible investment stream involves deploying edge computing nodes and micro DCs at (local/regional) network aggregation points. Operators such as Telefónica, Orange, and Vodafone are developing micro DCs co-located with mobile base stations, internet exchanges, or metropolitan fibre rings. These facilities host latency-sensitive workloads, including AI inference, streaming, industrial IoT, and network functions (UPF, CDN caches)[265].

Colocation and hybrid-cloud facilities (k*ey drivers: revenue diversification, digital-sovereignty compliance***)**

ECN/ECS operators are increasingly co-investing in, partnering with, or leasing space from colocation providers to host hybrid-cloud and enterprise workloads. In Spain, Telefónica contributed DC assets and took a 20% stake in Nabiax, forming a long-term colocation platform with Asterion (clear co-investment)[266]. In Italy, Vodafone uses Equinix's GN1 facility in Genoa as

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a strategic interconnection hub for the 2Africa system (leased colo capacity)[267]. More broadly, Vodafone maintains network presence in 57 Equinix DCs across Europe and beyond supporting hybrid-cloud on ramps and enterprise interconnection[268]. In Poland, Deutsche-Telekom owned T-Mobile Polska has expanded its Warsaw colocation facility to serve enterprise workloads (operator DC capacity aligned to hybrid-cloud demand)[269]. Operators also partner with colocation platforms to deliver ECN/ECS operators-cloud capabilities – e.g., Orange with Equinix for "as-a-service" telecommunications infrastructure[270].

Submarine and terrestrial fibre backbones (k*ey drivers: strategic control, network efficiency)*

Many ECNs are shareholders in high-capacity fibre and submarine-cable consortia linking European hubs with global data routes. Such investments help ECNs to achieve control over long-haul routes, mitigate reliance on third-party carriers, and ensure secure traffic exchange. New routes shorten latency paths and reduce congestion in saturated corridors, improving network-connection efficiency. Examples include SEA-ME-WE 6 (Orange landing in Marseille; Telecom Egypt dual landings) and Medusa (first European landing hosted by Orange in Marseille), as well as PEACE-MED (Orange/PCCW Global landing in Marseille) and Nordic-Atlantic systems such as IRIS (Farice; Iceland–Ireland) and NO-UK (Altibox Carrier/Lyse; Norway–UK)[271]. In parallel, terrestrial expansion – for example Project Visegrád (EXA Infrastructure) and new cross-border long-haul routes like Deutsche Telekom Global Carrier's Budapest–Frankfurt path and Arelion's Scandinavian DC interconnect upgrades enhances east–west redundancy, increases route diversity, and supports secondary-hub growth[272].

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Renewable and energy efficient infrastructure (k*ey driver: sustainability alignment*)

Another "green" investment area focuses on embedding energy-management systems, PPAs, and waste-heat reuse into network DC campuses. These actions help operators, that operates at least one DC ≥ 500kW of IT load and other energy intensive enterprises to fulfil EU Green Deal/EED obligations and qualify under the EU Taxonomy for Sustainable Finance, attracting ESG-linked investment[273].

Public–private partnerships and sovereign-cloud initiatives (k*ey drivers: digital sovereignty, strategic control***)**

Governments increasingly establish PPPs with ECN/ECS operators to modernise public-sector IT and secure data-hosting capacity. ECNs provide infrastructure, while states contribute funding or guaranteed demand. The resulting sovereign-cloud platforms – e.g., Bleu (France) or GAIA-X-aligned federations – aim to ensure compliance with GDPR/NIS2 and national-security requirements[274].

AI-ready, high-density facilities (k*ey driver: revenue diversification)*

With rapid AI adoption, ECN/ECS operators and infrastructure subsidiaries, same as other actors, are upgrading power and cooling systems to support GPU-intensive workloads, including liquid-cooling retrofits, direct-to-chip heat exchangers, and modular energy-storage solutions[275].

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4.3.4. Constraints and gaps

Despite growing momentum, ECN/ECS operators face a complex set of financial, operational, and regulatory barriers that slow their transformation from network operators to integrated digital-infrastructure providers. These challenges vary across Europe's fragmented regulatory landscape, limited investment incentives, and the compliance challenges inherent in both telecommunications and DCs.

Financial and market constraints

DC development requires large upfront capex due to long lead times and rising land, power and cooling costs. For many ECN/ECS operators, DC construction competes with other priority investments such as 5G and fibre network and rollouts, and profit/dividend pressures can limit direct ownership[276]. Furthermore, grid congestion in legacy hubs (FLAP-D) causes years-long connection delays, which makes delivery schedules unpredictable[277]. Independent reviews of Europe's grid underscore large connection queues and reinforcement needs that affect all large loads (including DCs): the European Court of Auditors reviews grid bottlenecks, while Beyond Fossil Fuels estimates ~1,700 GW of renewable energy and hybrid projects awaiting connection across 16 countries[278]. In response, many operators favour joint ventures and long-term leasing over outright ownership; this can lower risk but slow capital deployment, leading to more gradual expansion[279].

Operational and organizational barriers

ECN/ECS operators entering the DC sector face a steep learning curve. Maintaining facilities with Tier IV–style availability targets (~99.995%) requires skills and tools beyond those of traditional network operations centres. Specialised labour shortages – particularly in mechanical, electrical, and critical-systems engineering – remain a persistent constraint[280]. Furthermore, integrating telecommunications and IT operations is challenging due to differences in objectives: network engineers optimise for resiliency and redundancy, while DC teams prioritise performance and utilisation.

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Regulatory and policy fragmentation

A fundamental barrier for ECN/ECS operators investing in DCs is the lack of coherence in permitting spatial-planning and environmental procedures across EU Member States. Under the recast Energy Efficiency Directive (EED) and the associated Delegated Regulation (EU) 2024/1364, DCs above defined IT-load thresholds (for example ≥500 kW IT) must report standardised sustainability indicators into an EU database; however, the way these obligations are embedded into national permitting and grid-connection processes remains highly heterogeneous[281]. As a result, ECN/ECS operators that own or lease DC capacity face not so much overlapping telecom-sector regulation as a patchwork of local rules, timelines and conditions that differ from one jurisdiction to another. In Ireland, for example, the regulator's Large Energy Users connection policy maintains tight constraints around Dublin connections, effectively creating a de facto cap on new capacity[282]. In the Netherlands, national measures have restricted hyperscale projects pending stricter criteria, reshaping siting options and pushing projects toward other regions[283]. These permitting and siting constraints apply to all large DC developers, but they are particularly relevant where ECN/ECS operators seek to collocate compute alongside network assets.

Permitting procedures, spatial planning, and environmental impact assessments also vary significantly. In Ireland, the regulator's Large Energy Users connection policy keeps tight constraints around Dublin connections[284]. In the Netherlands, national measures restricted hyperscale projects pending stricter criteria, reshaping siting options[285].

Standards and interoperability gaps

The absence of a single mandatory operational standard for DC design/operation increases uncertainty. Although the EU has adopted a common DC rating/reporting scheme (Delegated Regulation 2024/1364), much of the technical standardisation – e.g., EN 50600 series and ISO/IEC 30134 KPIs (PUE, WUE, CUE) – remains voluntary unless referenced in law or contracts, complicating comparable compliance and sustainability labels across borders[286].

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281 European Commission. (2024a). Commission Delegated Regulation (EU) 2024/1364 of 14 March 2024 on the first phase of the establishment of a common Union rating scheme for data centres (OJ L 17.5.2024). Retrieved November 3, 2025, from https://eur-lex.europa.eu/eli/reg_del/2024/1364/oj.

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283 Data Center Dynamics. (2022, February 17). *Dutch government halts hyperscale data centers, pending new rules*. Retrieved November 3, 2025, from https://www.datacenterdynamics.com/en/news/dutch-government-halts-hyperscale-data-centers-pending-new-rules/.

284 Commission for Regulation of Utilities. (2025, February 18). *New electricity connection policy for data centres* [Press release]. Retrieved 26 October 2025, from https://www.cru.ie/about-us/news/new-electricity-connection-policy-for-data-centre/.

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Similarly, interoperability frameworks such as GAIA-X and the future European Cybersecurity Certification Scheme for Cloud Services (EUCS) are still evolving, adding uncertainty for “sovereign/trusted” positioning in cross-border edge-cloud deployments[287].

4.4. Implications for long-term infrastructure development

Long-term investment decisions by ECN/ECS operators are increasingly determining where, how, and at what scale new DC capacity will emerge in Europe. Because network and DC assets share multi-decade lifecycles and high sunk costs, today’s choices on ECN/ECS operators-owned, co-invested or jointly financed facilities will lock in future corridors of power demand, fibre backbones, edge clusters and interconnection hubs. This chapter outlines ECN-led investment strategies influence the spatial pattern of DC development, the timing and sequencing of grid and backbone upgrades, and the balance between legacy hubs and newer regional markets. It also considers how these decisions shape Europe’s long-term competitiveness, the structure of the digital-infrastructure market, and the degree of strategic autonomy that can be achieved under evolving policy, regulatory and financing conditions.

4.4.1. Economic and competition impact

The integration of ECN and DC assets can unlock new value pools (low-latency services, interconnection, cloud adjacency), but it also intensifies competition for scarce inputs: power, grid connections, suitably zoned land, and specialised talent. Current market evidence shows demand outpacing supply in primary hubs and a shift of growth to secondary markets as power constraints bite[288]. At the ecosystem level, the European connectivity sector faces a decisive moment to sustain investment and competitiveness, with fragmentation and capital scarcity – strengthening the case for co-investment and platform plays that combine networks, edge and sovereign/hybrid cloud[289].

4.4.2. Infrastructure investment impacts

DC–ECN convergence is already shifting the impacts of where and how capacity is built and used, rather than just changing siting criteria. Long-term ECN investment decisions have several structural effects which are presented below.

Edge and regional capacity rebalancing

Sustained investment in edge nodes and regional clusters tightly integrated with 5G SA/MEC is redistributing compute away from a few national hubs toward more granular metro footprints. This

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[287] GAIA-X AISBL. (2024, September). *Compliance document 24.06*. Retrieved November 5, 2025, from https://gaia-x.eu/wp-content/uploads/2024/09/Compliance-Document_24.06.pdf;
ENISA. (n.d.). *EUCS – Cloud Services Scheme*. Retrieved November 6, 2025, from https://www.enisa.europa.eu/publications/eucs-cloud-service-scheme.

[288] CBRE. (2024, June 24). *Global data center trends 2024: Limited power availability drives rental rate growth worldwide* [Report]. Retrieved 22 October 2025, from https://www.cbre.com/insights/reports/global-data-center-trends-2024;
Sterling, T. (2025, February 5). *European data centre space shortage expected in 2025 as AI booms*. Reuters. Retrieved November 3, 2025, from https://www.reuters.com/technology/european-data-centre-space-shortage-expected-2025-ai-booms-2025-02-05/.

[289] Connect Europe, & Analysys Mason. (2025). *State of digital communications – 2025 edition*. Retrieved November 4, 2025, from https://connecteurope.org/sites/default/files/2025-01/State%20of%20Digital%20Communications%20-%202025%20edition.pdf.

enables sub-20 ms services for industry and enterprise workloads, but also locks operators into denser local site portfolios, higher backhaul requirements, and more complex lifecycle management across many smaller facilities[290].

Path-diversification shaping DC siting

Capital deployed into new high-capacity terrestrial and subsea routes is creating alternative low-latency corridors that make secondary metros and inland locations viable for latency-sensitive DCs. Projects such as Visegrád extend east–west redundancy, which in turn encourages DC developers and cloud providers to anchor capacity along these new fibre "spines", reducing over-concentration in a small set of coastal and FLAP-D gateways[291].

Clustering around energy-efficient campuses

Long-term commitments to energy-efficient campuses near renewable generation and district-heating infrastructure are driving a structural migration of large-scale DC builds toward energy-advantaged regions. Over time, this reorients both grid-upgrade plans and heat-network investments around a limited number of DC-anchored zones, reinforcing regional disparities in where hyperscale and AI campuses can be economically operated[292].

Operational efficiency altering expansion needs

Investment in AI-assisted operations – from cooling and IT-load optimisation to predictive maintenance – raises average utilisation, delays some greenfield builds and allows scarce power and specialist staff to support more capacity. This shifts part of long-term infrastructure growth from pure square-metre and MW additions toward deeper optimisation of existing estates, with implications for how quickly new markets reach critical mass[293].

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[290] ETSI. (n.d.). *Multi-access edge computing (MEC)*. Retrieved November 6, 2025, from https://www.etsi.org/technologies/multi-access-edge-computing;
Vodafone. (2021, June 16). *Vodafone uses AWS Wavelength to launch first Multi-access Edge Computing services in European region* [Press release]. Retrieved November 5, 2025, from https://www.vodafone.co.uk/newscentre/press-release/partnership-aws-wavelength-launch-first-multi-access-edge-computing-services-in-europe/;
Vodafone. (2023, July 28). *Vodafone expands access to AWS Wavelength for business customers in European countries*. Retrieved November 4, 2025, from https://www.vodafone.com/news/technology/vodafone-expands-access-aws-wavelength-business-customers-european-countries.

[291] EXA Infrastructure. (2025, September 4). *EXA Infrastructure launches Project Visegrád: Largest cross-border fibre backbone deployment in Central Europe in 25 years* [Press release]. Retrieved November 3, 2025, from https://exainfra.net/media-centre/press-releases/exa-infrastructure-launches-project-visegrad-largest-cross-border-fibre-backbone-deployment-in-central-europe-in-25-years/.

[292] European Commission. (2024, May 17). Commission Delegated Regulation (EU) 2024/1364 of 14 March 2024 on the first phase of the establishment of a common Union rating scheme for data centres. Official Journal of the European Union, L 2024/1364. Retrieved October 30, 2025, from http://data.europa.eu/eli/reg_del/2024/1364/oj;
Javadi, M. (2025, October 10). *Europe's AI energy test: From waste heat to civic dividend*. Trans European Policy Studies Association (TEPSA). Retrieved October 29, 2025, from https://tepsa.eu/analysis/europes-ai-energy-test-from-waste-heat-to-civic-dividend/;
Invest in Denmark. (2025, May 30). *Denmark removes price cap on surplus heat, unlocking investment and sustainability potential*. Retrieved November 2, 2025, from https://investindk.com/insights/denmark-removes-price-cap-on-surplus-heat-unlocking-investment-og-sustainability-potential;

[293] Uptime Institute. (2024, July). *Global data center survey results 2024* [Report]. Uptime Institute. Retrieved October 24, 2025, from https://datacenter.uptimeinstitute.com/rs/711-RIA-145/images/2024.GlobalDataCenterSurvey.Report.pdf.

Risk-sharing reshaping ownership and ramp-up patterns

The move toward joint ventures and long-term leasing models spreads risk across ECNs, investors and specialist operators. This enables projects that might not otherwise be financed under current power, permitting and supply-chain constraints, but it also leads to more phased and modular capacity ramp-ups. As a result, long-term DC infrastructure development becomes more contingent on staged investment decisions and renegotiated contracts, rather than single-owner, build-once life cycles[294].

4.4.3. Impact on resilience and sovereignty

Distributed edge and new long-haul routes can boost resilience against single-point failures, cable cuts, or metro-grid constraints, but also increase the attack surface and operational complexity, placing a premium on cybersecurity and incident response across multi-site footprints. The NIS2 framework expands obligations for "digital infrastructure" operators (including DCs and cloud service providers), and the forthcoming European Cybersecurity Certification Scheme for Cloud Services (EUCS) aims to clarify trust/certification for cloud services[295].

On sovereignty, EU policy underscores keeping critical capabilities and data stewardship within Europe. The State of the Digital Decade 2025 calls for renewed public/private investment and progress on secure digital infrastructure, including cloud/edge capacity aligned with EU standards[296].

Finally, with AI intensifying compute demand, strategic siting, grid upgrades and sustainability criteria will shape who captures future investment, Europe's choices now will determine competitiveness, cost-to-serve and carbon trajectories for the next decade[297].

[294] Farris, D. (2025, November 10). *Legal and strategic considerations in data center site selection and deal structuring*. Data Centre Dynamics. Retrieved November 3, 2025, from https://www.datacenterdynamics.com/en/opinions/legal-and-strategic-considerations-in-data-center-site-selection-and-deal-structuring/.
[295] International Comparative Legal Guides. (2025, November 21). *EU cybersecurity regulatory landscape: A deep dive into the NIS2 Directive*. In *Cybersecurity laws and regulations report 2026*. Retrieved 26 October 2025, from https://iclg.com/practice-areas/cybersecurity-laws-and-regulations/03-eu-cybersecurity-regulatory-landscape-a-deep-dive-into-the-nis2-directive;
ENISA. (n.d.). *EUCS – Cloud Services Scheme*. Retrieved November 6, 2025, from https://www.enisa.europa.eu/publications/eucs-cloud-service-scheme.
[296] European Commission. (2025, June 16). *State of the Digital Decade 2025 report*. Retrieved 4 November 2025, from https://digital-strategy.ec.europa.eu/en/library/state-digital-decade-2025-report.
[297] Cremona, E., & Czyzak, P. (2025, June 19**).** *Grids for data centres: Ambitious grid planning can win Europe's AI race.* London: Ember. Retrieved 4 November 2025, from https://ember-energy.org/app/uploads/2025/06/Grids-for-data-centres-in-Europe.pdf;
Sterling, T. (2025, February 5). *European data centre space shortage expected in 2025 as AI booms*. Retrieved November 3, 2025, from https://www.reuters.com/technology/european-data-centre-space-shortage-expected-2025-ai-booms-2025-02-05/.

5. Competition and market dynamics in Europe's DC market

Europe's DC market has rapidly grown into a critical pillar of the digital economy, underpinning cloud services, telecom networks, and enterprise IT services across the EU and broader Europe[298]. This sector is attracting billions in investment and enabling a range of technologies, from 5G to AI. However, this growth also brings competition considerations to the forefront. In particular, the interplay between traditional telecom operators, U.S.-based hyperscalers (like Amazon Web Services, Microsoft Azure, Google Cloud), and specialised colocation providers are redefining market dynamics. Meanwhile, a wave of new entrants and consolidation is reshaping the industry's structure, and regulators are scrambling to catch up – identifying potential blind spots in existing policies and competition law.

This chapter examines three key areas:

1. Market Dynamics – How telecom companies, hyperscalers, and other players (e.g. carrier-neutral DC operators) compete and collaborate in Europe.
2. New Entrants & Consolidation Trends – The impact of recent entrants and major mergers/acquisitions on market structure and competitive behaviour.
3. Regulatory Challenges & Blind Spots – Where European policy and competition oversight may adapt to address the industry's changes.

5.1. Market dynamics: ECN/ECS operators vs. hyperscalers vs. others

European telecom companies, hyperscalers, and specialised DC operators are vying for position in a fast-expanding market, each with different strengths and strategies. The following section provides an overview of the key aspects of their dynamic.

5.1.1. ECN/ECS operators repositioning

Telecommunications providers, such as national carriers, began to view DCs as a logical extension of their networks, enabling them to offer both hosting and connectivity services together. In recent years, however, many ECN/ECS operators have been retrenching from direct DC ownership to refocus on core network services and free up capital. For example, in 2025, Colt Technology Services sold eight of its European DCs to a specialised operator, citing a strategy to "focus on its core business (..) delivering sustainable digital infrastructure" while still using those sites for network connectivity[299]. Telefónica similarly divested 11 DCs to a private equity firm in 2019 as part of debt-reduction[300] and this transaction led to the creation of Nabiax to operate the

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[298] European Data Centre Association (EUDCA). (2025). State of European Data Centres 2025. Retrieved 18 October, 2025 from https://www.eudca.org/documents/content/h_ZhGn_ZTu6O_sfWJxpztgo8b?download=0.
[299] Colt Technology Services. (2025, April 16). Colt Technology Services announces sale of eight European data centres. Retrieved 18 October 2025, from https://www.colt.net/resources/colt-technology-services-announces-sale-of-eight-european-data-centres/.
[300] Telefónica. (2019, May 8). Telefónica agrees the sale of 11 data centers for €550 million to Asterion Industrial Partners. Retrieved 18 October, 2025 from https://www.telefonica.com/en/communication-room/press-room/telefonica-agrees-the-sale-of-11-data-centers-for-e550-million-to-asterion-industrial-partners/.

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DCs, offering colocation and hosting services. In a recent development, Altice Portugal also divested its principal DC – originally built by Portugal Telecom – to Asterion Industrial Partners[301]. However, ECN/ECS operators are not exiting the space: some are partnering or reinvesting in DCs via joint ventures. A recent example is France's Iliad Group, which carved out its DC unit and in 2024 sold 50% to InfraVia (an infrastructure fund) to create a major new hyperscale DC platform[302]. This partnership will inject €2.5 billion for expansion, aiming to build "hundreds of megawatts" of capacity across France, Poland, and Italy. In short, ECN/ECS operators are balancing acts of consolidation and collaboration – divesting non-strategic assets while teaming up where they see competitive advantage (especially to serve cloud demand or emerging edge computing needs in 5G networks).

5.1.2. Hyperscalers driving demand (and competition)

The U.S. tech giants – Amazon (AWS), Microsoft, Google, and to a lesser extent Meta and Oracle – have become the primary engines of growth in Europe's DC market. They account for an outsized share of new demand for DC space and cloud services. In Europe's top FLAP-D hubs, an estimated 83% of all new leasing in 2022 was for hyperscale deployments[303]. These firms either self-build massive facilities (often in less urban areas for cheaper land and power) or lease wholesale capacity in colocation centres for proximity to customers and networks. For example, even as they construct giant proprietary campuses, "major cloud providers such as Facebook, Microsoft, and Google have been leasing tons of capacity from colocation companies in densely populated areas across Europe"[304]. This dual approach gives hyperscalers immense leverage: they can choose between using their own infrastructure or bidding among third-party operators, putting competitive pressure on DC landlords to offer attractive terms.

Regarding market power, hyperscalers maintain dominant market positions in cloud services, which has raised concerns among regulatory authorities. It is currently estimated that hyperscalers, including AWS, Microsoft, and Google, represent approximately 70% of the European cloud market[305]. Moreover, the UK communications regulator Ofcom found that in 2021 the big three represented 65–80% of the UK's cloud infrastructure market, with AWS and Microsoft share together between 60 to 70%[306]. Similar trends are observed across Europe. Such concentration has raised concerns that customers face vendor lock-in, high switching costs, and limited choice. Hyperscalers argue the market remains competitive and that multi-cloud options exist, but authorities note features like data egress fees, technical interoperability limits, and long-

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301 Swinhoe, D. (2025, December 2). Asterion acquires Covilhã data center from Altice Portugal. Retrieved 17 December, 2025 from https://www.datacenterdynamics.com/en/news/asterion-acquires-covilh%C3%A3-data-center-from-altice-portugal/.

302 Swinhoe, D. (2024, December 4). InfraVia to acquire 50 percent of Iliad's OpCore data center unit. DatacenterDynamics. Retrieved 19 October, 2025 from https://www.datacenterdynamics.com/en/news/infravia-to-acquire-50-percent-of-iliads-opcore-data-center-unit/.

303 JLL. (2023, June 7). Core European data centre markets set for record growth in 2023. Retrieved 19 October 2025, from https://www.jll.com/en-uk/newsroom/core-european-data-centre-markets-set-for-record-growth-in-2023.

304 Yahoo Finance. (2024, February 21). Europe data center market overview. Retrieved 19 October, 2025 from https://finance.yahoo.com/news/europe-data-center-market-overview-090500255.html.

305 Goovaerts, D. (2025, July 28). Europe's cloud market poised for 24% growth. Fierce Network. Retrieved 23 November, 2025 from https://www.fierce-network.com/cloud/europes-cloud-market-poised-24-growth.

306 Sayer, P. (2023, August 1). Hyperscalers in crosshairs for anti-competitive pricing and lock-in. CIO. Retrieved 20 October, 2025 from https://www.cio.com/article/648048/hyperscalers-in-crosshairs-for-anti-competitive-pricing-and-lock-in.html.

term contracts as factors reducing effective competition[307] (We delve into regulatory responses in section 5.4 of this chapter). From a DC facilities perspective, hyperscalers' huge ongoing investments (e.g. building new "regions" in Spain, Italy, Nordics)[308] can be seen as both an opportunity and a threat for other actors: they bring demand (often signing as anchor tenants in new facilities) but also compete by self-supplying on a scale others cannot match. Another example is the international submarine cables market, where hyperscalers are also making significant investments, primarily for self-supply purposes, as noted in Chapter 4 of this report.

5.1.3. Independent colocation and wholesale DC companies

Independent colocation and wholesale DC companies represent the third crucial segment. These include global firms like Equinix, Digital Realty (which now owns Interxion), and NTT, as well as regional players (e.g. Global Switch, CyrusOne, Vantage, NorthC, and numerous local providers). They typically offer carrier-neutral facilities, housing equipment from many ECN/ECS operator and enterprises and together provide rich interconnection ecosystems.

An analysis of market structure reveals that the European colocation sector is notably more fragmented than the telecommunications or cloud markets, with the five leading colocation providers collectively holding approximately 25% of the total market share[309]. This indicates a relatively competitive supply side with dozens of operators serving different countries and niches. Many specialise in certain geographies or services (for instance, NorthC focuses on regional hubs in Benelux, Germany and Switzerland[310]; others target high-density interconnection in FLAP cities). These operators have been adapting to hyperscaler dominance in demand. Rather than mainly serving thousands of small retail colocation clients, the business has tilted toward a few very large customers. In fact, hyperscalers have become key clients for wholesale-focused providers – leasing entire halls or campuses – even as they remain competitors by self-building. This has led to a "shifting balance of power in favour of hyperscalers that could leave colocation providers displaced in the value chain", as industry analysts have noted[311]. In response, colocation firms are evolving:

- They pursue scale and geographic expansion (often via mergers/joint ventures) to meet cloud-scale requirements across multiple markets.
- They emphasise connectivity and ecosystem value – for example, Equinix pitches its global interconnection fabric as something cloud providers and customers benefit from by collocating in its facilities.
- They target secondary markets where hyperscalers need presence but might prefer to lease. As FLAP-D sites face space and power constraints, colocation providers are indeed

307 Ibid.
308 Riegel, L., Lasku, A., Humphreys, M., Hanson, A. (2023, July) Cloud expansion in Europe: Substantial opportunity, low risk for data centers. Arthur Little. Retrieved 21 October, 2025 from https://www.adlittle.com/en/insights/viewpoints/cloud-expansion-europe-substantial-opportunity-low-risk-data-centers#:~:text=HCPs%20are%20announcing%20new%20availability,high%2Dquality%20cloud%20computing%20services.
309 Yahoo Finance. (2024, February 21). Europe data center market overview.
310 Colt Technology Services. (2025, April 16). Colt Technology Services announces sale of eight European data centres. Retrieved 18 October, 2025 from https://www.colt.net/resources/colt-technology-services-announces-sale-of-eight-european-data-centres/.
311 KPMG. (2022, November). The evolving data centre landscape. Retrieved 22 October, 2025 from https://assets.kpmg.com/content/dam/kpmg/ie/pdf/2022/11/ie-the-evolving-data-centre-landscape.pdf.

moving into “tier-2” cities like Milan, Madrid, Berlin, Warsaw, and Oslo to establish capacity where hyperscalers and others are looking next[312].

- They also explore specialized offerings (edge DCs, sustainable designs, high-density racks for AI workloads, etc.) to differentiate in an increasingly scale-driven game.

5.1.4. Coopetition and alliances

Despite areas of rivalry, ECN/ECS operators, hyperscalers, and colocation operators often cooperate in complex ways. One prominent area is “sovereign cloud” partnerships. European governments and the EU have expressed concerns about data sovereignty – i.e. ensuring sensitive data can be kept under EU jurisdiction and not subject to foreign laws[313]. In response, hyperscalers have partnered with European ECN/ECS operators and IT firms to offer localised cloud services. Notable examples include Google’s alliance with France’s Thales (and a similar tie-up with German ECN/ECS operator Deutsche Telekom (T-Systems)), and Microsoft’s alliance with Orange and Capgemini in France[314]. These joint ventures create EU-based cloud offerings that meet stringent security requirements (sometimes called “Trusted Cloud” or “Cloud de Confiance”), blending hyperscalers’ tech with ECN/ECS operators’ local hosting. Such collaborations blur competitive lines.

Another area of coopetition is network infrastructure – hyperscalers are increasingly investing in subsea cables, fibre networks, and edge nodes, traditionally telecommunication realms, yet they often partner with ECN/ECS operators to deploy and manage these or exchange capacity. Likewise, ECN/ECS operators use public cloud for their IT and even for virtualising network functions (the emerging trend of network cloudification)[315], creating a supplier-customer relationship with hyperscalers. The net effect is an intricate web of relationships. ECN/ECS operators provide critical connectivity and local facilities to hyperscalers (and sometimes share in the cloud revenue via partnerships), while hyperscalers generate massive demand and technological impetus that boosts the DC industry at large. However, both sides take steps to avoid relying too heavily on each other – for instance, ECN/ECS operators advocate for regulations to limit hyperscalers' influence (as mentioned later), while hyperscalers diversify by building their own infrastructure or partnering with multiple providers to ensure no single telecom or colocation company becomes essential.

To summarise, the following table presents an overview of the principal dynamics and strategies implemented by various participants in the European DC ecosystem discussed above, along with their primary market impacts and illustrative examples.

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[312] Yahoo Finance. (2024, February 21). Europe data center market overview.
[313] Michels, J. D., Millard, C., & Walden, I. (2023, October 31). On cloud sovereignty: Should European policy favour European clouds? (Queen Mary Law Research Paper No. 412/2023). SSRN. Retrieved 22 October, 2025 from https://doi.org/10.2139/ssrn.4619918.
[314] Butler, G. (2024, April 4). EU relaxes cloud contract bidding rules for hyperscalers. DataCenterDynamics. Retrieved 21 October, 2025 from https://www.datacenterdynamics.com/en/news/eu-relaxes-cloud-contract-bidding-rules-for-hyperscalers/.
[315] BEREC. (2024, March 7). Report on cloud/edge services and competition dynamics. BoR (24) 52. Retrieved 25 October, 2025 from https://www.berec.europa.eu/system/files/2024-10/BoR%20%2824%29%20136_BEREC%20Report%20on%20Cloud%20and%20Edge%20Computing%20Services.pdf.

Table 4. Overview of the key aspects of the market dynamics.

Segment	Key Actions & Strategies	Market Impact	Examples
ECN/ECS operators Refocus & Partner	• Divesting DC assets to specialist operators/investor • Refocusing on core network services • Re-entering market via joint ventures and partnerships for strategic growth	• Freed capital for core business • Maintained access to DC capacity through partnerships • Enabled rapid expansion in targeted areas	• Colt (UK) sold DCs to NorthC (2025) • Iliad Group's €2.5 bn joint venture with InfraVia to grow DCs in Europe
Hyperscalers Driving Demand	• Driving majority of new DC leasing and builds (~83% of leasing in 2022) • Combining self-build mega facilities with large colocation leases	• Significant market leverage and bargaining power • Concerns over customer lock-in and reduced competition (cloud market share ~65–80% in UK)	• Amazon Web Services, Microsoft Azure, Google Cloud driving expansion
Independent Colocation and Wholesale DC Companies Adapt	• Carrier-neutral colocation operators serve both ECN/ECS operators and hyperscalers • Scaling up and expanding into emerging "tier-2" markets • Focusing on value-added services (interconnection, edge, sustainability)	• Fragmented but highly competitive sector (top 5 have only 25% market share) • Innovation and market expansion to avoid marginalization	• Growth in markets like Madrid and Warsaw • Firms like Equinix and Digital Realty enhancing service portfolios
Coopetition and Alliances	• Extensive partnerships and "coopetition" among ECN/ECS operators, hyperscalers, and neutral providers • ECN/ECS operators host cloud nodes; clouds use ECN/ECS operators' networks • Increasing number of sovereignty deals to meet EU regulations	• Hybrid ecosystem where collaboration is required for success • Regulatory compliance and local market adaptation	• Microsoft + Orange sovereignty deal in France • Cloud-ECN/ECS operators joint ventures for EU-local cloud solutions

5.2. Impact of new entrants and consolidation trends

The European DC landscape has been in flux as new players enter, and stablished colocation operators expand and consolidate. Recent trends show simultaneous fragmentation and concentration: new firms (often backed by significant capital) are launching or expanding in Europe, even as ownership of existing facilities gets concentrated into fewer hands via mergers and acquisitions. The net effect is an industry in rapid evolution, with competition taking on new forms.

5.2.1. Surging investment and new entrants

The strong fundamentals of Europe's DC market – high utilisation, rising demand for cloud/AI, and generally stable returns – have attracted numerous investors and new operators. In the last few years, infrastructure funds and private equity groups have poured capital into the sector, either by bankrolling startups or acquiring stakes in established operators. For instance, American and Asian DC companies have expanded into Europe: Vantage Data Centers (U.S.-based) has built campuses in multiple EU countries[316]; CyrusOne (U.S.) entered London and Frankfurt[317]; NTT (Japan) has grown its European footprint[318]. Some European ECN/ECS operators spun out their DC divisions as independent ventures (often financed by investors) – e.g. Denmark's TDC and Italy's TIM both created separate DC companies[319] and as noted, Iliad's OpCore aims to become a new pan-European platform[320]. Even firms not traditionally in this sector are entering; real estate developers, energy companies, and sovereign wealth funds see DCs as an attractive asset class and are backing new builds in regions like Spain, Italy, and Nordic countries. New specialist entrants also target emerging niches such as edge DCs (small facilities near end-users for low latency) – often in partnership with ECN/ECS operators deploying 5G.

This trend became apparent during the interviews conducted as part of this research. For instance, a representative of ECN/ECS operators shared that they intend to further develop edge DCs: "We intend to expand edge DCs both for our own needs and for our clients. Some of the data we collect enables us to provide customers with services directly linked to their operations. This forms an integral part of our offering. From an infrastructure architecture perspective, we are implementing solutions such as private office networks and online processing services, including real-time processing, which are available locally in selected cities."

These new entrants increase competition by adding supply in underserved markets and by pushing established colocation operators to expand. For example, Southern and Central European markets have seen a boom: investments in Italy, Spain, and Poland are rising fast as these areas become the "next frontier" beyond the FLAP-D core. For instance, According to JLL, Madrid added ~20 MW of new DC supply in in the first half of 2025; if second-half deliveries keep pace, full-year additions are on track to surpass the ~23 MW delivered in 2024[321].

[316] Vantage Data Centers. (n.d.). Data center locations in EMEA. Retrieved 18 October, 2025 from https://vantage-dc.com/data-center-locations/emea/.
[317] CyrusOne. (2023, June 20). CyrusOne announces sixth German facility in Frankfurt following Europark acquisition. Retrieved 18 October, 2025 from https://www.cyrusone.com/resources/press-releases/cyrusone-announces-sixth-german-facility-in-frankfurt-following-europark-acquisition.
[318] Sensi, J. (2024, April 10). NTT expands global data centre footprint. Retrieved 19 October, 2025 from https://capacityglobal.com/news/ntt-global-data-centre/.
[319] Macquarie Group. (2023, March 14). Digitalising Denmark. Retrieved 20 October, 2025 from https://www.macquarie.com/us/en/insights/digitalising-denmark.html.
Swinhoe, D. (2024, November 21). Italy's TIM to build data center outside Rome. DatacenterDynamics. Retrieved 18 October, 2025 from https://www.datacenterdynamics.com/en/news/italys-tim-to-build-data-center-outside-rome/.
[320] Swinhoe, D. (2024, December 4). InfraVia to acquire 50 percent of Iliad's OpCore data center unit. DatacenterDynamics. Retrieved 19 October, 2025 from https://www.datacenterdynamics.com/en/news/infravia-to-acquire-50-percent-of-iliads-opcore-data-center-unit/.
[321] Glover, T., Thorpe, D., & Januskeviciute, J. (2025). EMEA data centre report (Q2 2025). JLL. Retrieved 21 January, 2026 from https://www.jll.com/en-uk/insights/emea-data-centre-report.

5.2.2. Consolidation wave

At the same time, the industry has experienced a wave of consolidation as larger players acquire competitors to scale up. Over the past decade, several blockbuster deals reshaped the European market:

- In 2015, Equinix, the world's largest colocation provider, acquired UK-based TelecityGroup for £2.6 billion, expanding Equinix's European footprint dramatically[322]. Importantly, the European Commission intervened in this merger, requiring Equinix to divest eight DCs in London, Amsterdam and Frankfurt to address competition concerns[323]. Those sites were later sold to Digital Realty, demonstrating regulators' vigilance that consolidation should not create local monopolies.
- In 2020, U.S.-based Digital Realty Trust completed an $8.4 billion takeover of Netherlands-based Interxion[324]. This deal combined two major colocation portfolios, making Digital Realty "Europe's largest colocation company"[325] at the time – second globally only to Equinix. The merged company operates 50+ DCs across 11 European countries, serving roughly 70% of Europe's GDP areas. EU regulators cleared this acquisition, indicating that even post-merger, sufficient competition (e.g. from Equinix and others) remained in key markets.
- Private equity buyouts have also consolidated ownership. In 2021, investment giants KKR and GIP took CyrusOne (a significant EU/DC operator) private in a $15 billion deal[326], and Blackstone acquired QTS Realty Trust for $10 billion[327] – moves that, while involving U.S companies, affect Europe by bringing more assets under large financial sponsors. In Europe, Global Switch, a London-based DC firm with sites in EU and APAC, has long been eyed for sale: its Chinese owners attempted a ~$6 billion sale in 2023, even considering splitting European and APAC operations for separate buyers[328]. Meanwhile, Stack Infrastructure sold its entire European colocation DCs to funds managed by Apollo in 2025[329], marking yet another transfer of assets to "deep-pocketed" investors.
- ECN/ECS operators asset consolidation: as mentioned, many ECN/ECS operators have sold DCs to specialist operators, effectively consolidating those assets under fewer neutral

[322] Equinix. (2016, January 15). Equinix expands data center leadership position with close of Telecity acquisition. Retrieved 19 October, 2025 from https://newsroom.equinix.com/2016-01-15-Equinix-Expands-Data-Center-Leadership-Position-with-Close-of-Telecity-Acquisition.
[323] Equinix. (2016, May 16). Equinix Agrees to Divest Eight European Assets to Digital Realty Trust, Inc. Retrieved 19 October, 2025 from https://investor.equinix.com/news-events/press-releases/detail/367/equinix-agrees-to-divest-eight-european-assets-to-digital#:~:text=On%20January%2015%2C%202016%2C%20Equinix,Sofia%2C%20Stockholm%2C%20and%20Warsaw.
[324] Robuck, M. (2020, March 13). Digital Realty closes $8.4 billion deal to buy Interxion. Retrieved 20 October, 2025 from https://www.fierce-network.com/telecom/digital-realty-closes-8-4-billion-deal-to-buy-interxion.
[325] Ibid.
[326] KKR. (2021, November 15). CyrusOne to be acquired by KKR and Global Infrastructure Partners in $15 billion transaction. Retrieved 20 October, 2025 from https://media.kkr.com/news-details?news_id=6f0b8be1-2767-4e42-ad91-23b9d45f9126&type=1.
[327] Blackstone. (2021, June 7). QTS Realty Trust to be acquired by Blackstone funds in $10 billion transaction. Retrieved 21 October, 2025 from https://www.blackstone.com/news/press/qts-realty-trust-to-be-acquired-by-blackstone-funds-in-10-billion-transaction/.
[328] Butler, G. (2023, August 7). Global Switch looks to sell European and Asia Pacific data centers to different buyers. DatacenterDynamics. Retrieved 19 October, 2025 from https://www.datacenterdynamics.com/en/news/global-switch-looks-to-sell-europe-and-asia-pacific-data-centers-to-different-buyers/.
[329] Gooding, M. (2025, April 29). Stack Infrastructure sells European colo business to Apollo. DataCenterDynamics. Retrieved 21 October, 2025 from https://www.datacenterdynamics.com/en/news/stack-infrastructure-sells-european-colo-business-to-apollo/.

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providers. Colt's 2023 acquisition of 12 DCs from Lumen (Level 3) in Europe[330] followed by Colt's resale of 8 of them to NorthC in 2025[331] is a case in point of assets changing hands multiple times. Similarly, when Telefónica offloaded its DCs to Asterion/Nabiax in 2019[332], and then Asterion sold some of those to new investors in 2024[333], it effectively concentrated many Spanish and Latin American facilities under a new operator rather than Telefónica's distributed control.

- Global alliances: Some consolidations are more about partnerships than outright purchases. For example, Equinix and GIC (Singapore's sovereign fund) formed a $3.9 billion joint venture in 2021 to develop hyperscale DCs in Europe[334] – a way to expand capacity quickly for hyperscale clients while sharing risk.

These consolidation trends have pros and cons for competition. On one hand, at the European level, larger operators can offer more consistent pan-European services, reduce costs via scale and invest in new capacity, potentially benefiting customers with broader choices and efficiency. On the other hand, at the metro level, consolidation may reduce the number of independent providers, weakening competition and increasing the pricing power of the remaining landlords. This can result in higher prices, tighter contract terms or less tenant bargaining power – hence the importance of (competition) regulatory oversight in big deals. Thus far, the colocation segment still appears relatively unconcentrated at the continental level (with top five players barely a quarter of the market[335]), but at city-level or country-level there can be high concentration. For example, Equinix and Telecity were each very strong in London and Amsterdam, which is why combining them prompted divestitures to keep those local markets competitive[336]. In another merger case involving DCs, with a different outcome, Colony Capital (now DigitalBridge) and Canada's PSP Investments acquired joint control of UK-based Next Generation Data (NGD) in 2020. The European Commission reviewed the transaction as part of its merger-control process[337]. The Commission approved the joint-control arrangement without requiring any divestments, citing minimal competitive overlap in the UK colocation market.

All in all, it can be observed that the ongoing entry of new players (including those funded by investor consortia) has offset the consolidating effect to a degree – Europe has not yet seen an oligopoly of just 2-3 DC firms controlling everything. Instead, it is a mix of big global companies and regional ones, with substantial churn in ownership.

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330 Colt Technology Services. (2023, November 2). Colt completes $1.8bn acquisition of Lumen EMEA. Retrieved 19 October, 2025 from https://www.colt.net/resources/colt-lumen-emea/.
331 Colt Technology Services. (2025, April 16). Colt Technology Services announces sale of eight European data centres.
332 Telefónica. (2019, May 8). Telefónica agrees the sale of 11 data centers for €550 million to Asterion Industrial Partners.
333 Aermont Capital. (2024, November 11). Asterion Industrial Partners agrees sale of data center group Nabiax to Aermont. Retrieved 20 October, 2025 from https://www.aermont.com/wp-content/uploads/2024/11/Aermont-acquires-leading-Spanish-data-center-group-Nabiax-Nov-24.pdf.
334 ICEX. (2021). Data Center Construction Firms Face EU Raids Over Potential No-Poach Agreements. Retrieved 22 October, 2025 from https://www.investinspain.org/content/icex-invest/en/noticias-main/2021/equinix-singapore-sovereign-wealth-fund.html.
335 Yahoo Finance. (2024, February 21). Europe data center market overview.
336 European Commission. (2016, June 15). Case M.7678 – Equinix / Telecity Approval of Digital Realty as purchaser of the Divestment Businesses. Retrieved 21 October, 2025 from https://ec.europa.eu/competition/mergers/cases/decisions/m7678_1659_6.pdf.
337 European Commission. (2020, July 7). Case M.9843 – Colony Capital / PSP / NGD. Retrieved December 13, 2025 from https://ec.europa.eu/competition/mergers/cases1/20215/m9843_172_3.pdf

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5.2.3. European vs foreign influence & sovereignty

Another facet of "new entrants" is the balance between European-owned companies and foreign (notably U.S. or Chinese) ownership. Historically, Europe's DC industry includes homegrown firms (Interxion was Dutch, OVHcloud is French, etc.), but large portions are now under U.S. corporations (Equinix, Digital Realty, CyrusOne) or global funds. This has raised strategic discussions about digital sovereignty. EU policymakers have noted that reliance on non-EU hyperscalers and infrastructure could be a competitive and security disadvantage for Europe[338]. While not a traditional competition issue, this concern has spurred initiatives like Gaia-X (to foster federated European cloud services) and security-oriented conditions on ownership.

Although this is not a specific example from the EU, it illustrates a broader European trend. Citing national security concerns, the UK government mandated that its agencies move data out of a Chinese-owned DC company by 2025, effectively forcing a change in the ownership structure of Global Switch (which was Chinese-backed)[339]. Such pressures ensure that some mooted deals did not go through and instead alternative buyers are sought, which is a form of de facto regulatory intervention in consolidation.

5.2.4. Effects on customers and pricing

The consolidation trend among facility operators has not yet led to a lack of options for customers, partly thanks to new entrants filling gaps. DC capacity is still in high demand and often supply-constrained – recent reports show vacancy rates in major hubs are low and pricing for hyperscaler-suitable space is actually rising due to scarcity and higher costs[340]. As demand outstrips supply in various places in Europe, even multiple competitors cannot fully alleviate the tight market[341]. This dynamic means that for now the market power might lie more with suppliers who have available capacity (especially those holding scarce power grid connections) – an unusual trait for a consolidating industry. However, in the longer term if only a few large colocation providers and hyperscalers dominate, they could potentially exert more pricing power. The following table offers an overview of key events that highlight consolidation and new entrants in Europe's DC and cloud markets, as discussed in the previous sections.

Table 5. Timeline of notable events illustrating consolidation and entry in Europe's DC and cloud markets.

Date	Action	Overview
Nov 2015	Equinix–Telecity Merger	Equinix's acquisition of TelecityGroup (making Equinix the largest European colocation operator).
Mar 2020	Digital Realty acquires Interxion	U.S.-based Digital Realty acquires Interxion for $8.4 B, creating Europe's new #1 colocation provider by footprint. The combined

[338] BEREC. (2024). Report on cloud/edge services and competition dynamics. BoR (24) 52.
[339] Corfield, G., Mendick, R., & Mendelson, A. (2025, October 17). Revealed: The Chinese firm that stored classified government files. The Telegraph. Retrieved 22 October, 2025 from https://www.telegraph.co.uk/news/2025/10/16/chinese-firm-global-switch-stored-classified-government-files/.
[340] CBRE. (2025). European real estate market outlook 2025. Retrieved 23 October, 2025 from https://www.cbre.com/insights/books/european-real-estate-market-outlook-2025/data-centres.
[341] European Data Centre Association (EUDCA). (2025). State of European Data Centres 2025.

Date	Action	Overview
		company operates 270+ DCs globally and serves ~70% of Europe's GDP areas.
Sept 2022	UK Scrutinises Cloud Dominance	Ofcom (UK regulator) launches a study into cloud services, concerned that AWS, Microsoft and Google's 65–80% market share is harming competition. This heralds greater scrutiny of hyperscalers' market power in Europe.
Oct 2023	EU approves Data Act	The EU's Data Act is approved, including rules to phase out cloud switching fees and enforce interoperability. From 2027, cloud providers will be banned from charging data egress fees to retain customers, and they must ensure both data and service portability - allowing customers to migrate workloads and configurations easily. It is a regulatory step to counter lock-in.
Nov 2024	EU raids DC construction firms	The European Commission conducts unannounced antitrust inspections in the DC construction sector, investigating alleged no-poach agreements (employee non-solicitation pacts) among contractors. This unusual move shows regulators' expanding vigilance in the DC ecosystem (even labour practices).
Dec 2024	Iliad–InfraVia expand OpCore	French ECN/ECS operators Iliad and investor InfraVia partner to expand OpCore, Iliad's DC arm, with €2.5 B investment. Valued at €860 M for 50%, OpCore aims to become "a leading independent platform" serving hyperscalers across Europe.
Apr 2025	Colt sells 8 DCs to NorthC	Colt Technology Services sells 8 European city-centre DCs to NorthC (backed by DWS funds), continuing the trend of ECN/ECS operators divesting DC assets. Colt retains network presence at those sites and shifts to a partnership model.

5.3. Regulatory challenges

The rapid evolution of the DC and cloud markets has posed challenges for regulators and policymakers. European competition authorities and regulators are actively responding and engaging with these challenges – from merger reviews to sector inquiries and new legislation – yet certain areas remain work-in-progress, where regulation has not fully caught up with market realities, some of which remain heavily debated. This section highlights how EU institutions are handling competition in this sector and identifies gaps that have been or need to be addressed and issues that remain contested.

5.3.1. Merger control and competition law

The European Commission uses merger control powers to prevent excessive concentration in national markets. So far, this traditional tool has been reasonably effective; major consolidations have been either conditioned (divestitures) or allowed where enough competitors remain. However, competition law is typically reactive – it addresses specific deals or proven wrongdoing. One blind spot has been ongoing market power outside of mergers. For example, oligopoly power in cloud services did not fall neatly into any competition case for years. Only recently have regulators begun examining whether hyperscalers' behaviour constitutes abuse of dominance or anticompetitive agreements. For instance, in 2022, the European technology provider OVHcloud submitted complaints to EU regulators regarding Microsoft's restrictive licensing practices. This action prompted regulatory examination and negotiations beginning in 2022, which resulted in settlements reached later in 2024[342]. Moreover, in 2023, EU antitrust authorities initiated an investigation into Microsoft[343] following claims that the integration of Teams, a cloud-based communication and collaboration tool, into its business productivity suites Office 365 and Microsoft 365 may have affected competition among cloud service providers. The Commission highlighted the importance of cloud market competition and stated that Microsoft revised its licensing terms after the investigation, with a monitoring trustee overseeing compliance[344]. This serves merely as an illustrative example of a recent antitrust action taken by the EU Commission, highlighting a broader trend in this area. It shows a prior blind spot: for years, big software/cloud firms leveraged their ecosystems in ways that possibly stifled smaller European cloud providers, but only after formal complaints did the EU actively intervene. Similarly, Amazon's and Google's cloud practices (like data portability or bundling with their dominant platforms) have not yet faced major EU antitrust action, though the UK and France have put them under scrutiny[345].

5.3.2. Cloud service lock-in & interoperability – closing the gap

One issue that is recently being addressed is the lack of rules ensuring cloud portability and interoperability. Customers found it hard to switch cloud providers due to high egress fees (charges to move data out) and technical incompatibilities[346]. For years it was an unchallenged market conduct, effectively locking clients into one hyperscaler's DCs and services – an issue not addressed by telecom regulations (since cloud is not under telecom rules) and only by competition law. The EU's Data Act, which entered in force in January in 2024, is a direct policy response: it mandates that by 2027 cloud providers must eliminate egress fees and barriers to switching. In stages, providers will have to cap and then remove charges for data portability and improve interoperability standards. This provision of the legislation is supported by studies from bodies like BEREC and the French Competition Authority, which highlight switching costs as a competition concern[347]. An issue has been detected and action initiated – however, ongoing oversight is necessary to confirm hyperscalers genuinely adhere without exploiting potential loopholes. Another regulatory tool is the Digital Markets Act (DMA), which from 2023 designates

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[342] Pollet, M. (2023, February 20). Big Telco vs. Big Tech: The battle over 'fair share,' explained. POLITICO. Retrieved 22 October, 2025 from https://www.politico.eu/article/telecom-netflix-tiktok-youtube-fair-share-why-telcos-are-going-at-war-with-big-tech/.
[343] European Parliament. (2023, December 11). Answer given by Mr Reynders on behalf of the European Commission. Retrieved 21 October, 2025 from https://www.europarl.europa.eu/doceo/document/E-9-2023-002918-ASW_EN.html.
[344] European Commission. (2025, September 12). Commission accepts commitments offered by Microsoft to address competition concerns related to Teams. Retrieved 21 October, 2025 from https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_25_2048/IP_25_2048_EN.pdf.
[345] BEREC. (2024). Report on cloud/edge services and competition dynamics. BoR (24) 52.
Sayer, P. (2023, August 1). Hyperscalers in crosshairs for anti-competitive pricing and lock-in. CIO. Retrieved 22 October, 2025 from https://www.cio.com/article/648048/hyperscalers-in-crosshairs-for-anti-competitive-pricing-and-lock-in.html.
[346] Ibid.
[347] BEREC. (2024). Report on cloud/edge services and competition dynamics.
Autorité de la concurrence. (2023, June 30). Opinion No. 23-A-08 of 29 June 2023 on competition in the cloud sector. Paris: Autorité de la concurrence. Retrieved 19 October, 2025 from: https://www.autoritedelaconcurrence.fr/sites/default/files/attachments/2023-09/23a08_EN.pdf.

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large tech firms as "gatekeepers" within specific core platform services with ex-ante obligations[348]. If, say, a hyperscaler is designated for its cloud services, it will have to avoid unfair practices – for example, not unfairly preferencing its own software on its cloud or blocking interoperability (see section 7.2.1 for details and the latest updates in this area). Together, the DMA and the Data Act signal the EU's proactive turn toward ex-ante platform and data-economy governance – complementing case-by-case antitrust – with obligations that span gatekeeper conduct and horizontal rules for data access/sharing, including cloud-service switching and interoperability.

5.3.3. Large ECN/ECS operators vs Content and Application Providers ("Sending Party Network Pays" debate)

A contentious policy debate in Europe has been taking place whether Content and Application Providers (CAPs) should contribute to the access network deployment costs – the so-called "fair share" or network fee proposal. Major European ECN/ECS operators argue that companies like Google, Meta, Netflix, Amazon (all heavy DC and traffic users) are "free-riding" on ECN/ECS operators' investments in fibre and 5G, since they generate a huge portion of internet traffic (requested by end-users of internet service providers (ISPs)) but do not pay operators (beyond normal service contracts) for delivering content. According to the major ECN/ECS operators, increasing traffic has made it challenging to maintain high investment levels while still achieving satisfactory returns[349].

On the other hand, BEREC, stakeholders such as alternative operators, cloud providers, content providers, consumer associations, academia and internet advocacy groups counter that ECN/ECS operators are already compensated by end-users. Requiring content providers to pay additional fees would result in double-charging and could violate net neutrality principles. BEREC evaluated these fundamental assumptions, noting that net neutrality encourages innovation because any user can create and share content and applications without needing permission from ISPs or paying CAPs[350]. Exploiting termination monopolies by ISPs could shift network costs and reduce innovation, as ISPs would influence which content is available instead of end-users making those choices. Moreover, in its 2022 report, *Preliminary assessment of the underlying assumptions of payments from large CAPs to ISPs*, BEREC noted [351]:

i) Traffic originates from ISPs' customers.
ii) The costs of fixed access networks show minimal sensitivity to traffic volumes, whereas mobile networks display some traffic-related cost variation.
iii) There is no evidence of "free-riding".
iv) Costs for internet connectivity are typically covered and paid for by ISPs customers.

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[348] European Union. (2022). Regulation (EU) 2022/1925 of the European Parliament and of the Council of 14 September 2022 on contestable and fair markets in the digital sector (Digital Markets Act). Official Journal of the European Union, L 265, 1–66. Retrieved 23 October, 2025 from https://eur-lex.europa.eu/eli/reg/2022/1925/oj/eng.

[349] Pollet, M. (2023, February 20). Big Telco vs. Big Tech: The battle over 'fair share,' explained. POLITICO.

[350] BEREC. (2023, May 19). BEREC response to the European Commission's Exploratory Consultation on the future of the electronic communications sector and its infrastructure. Annex to complement section 4 of the BEREC response. BoR (23) 131d. Retrieved 24 November, 2025 from https://www.berec.europa.eu/system/files/2023-05/BoR%20%2823%29%20131d%20Annex%20to%20Section%204.pdf.

[351] BEREC. (2022, October 7). BEREC preliminary assessment of the underlying assumptions of payments from large CAPs to ISPs. BoR (22) 137. Retrieved 24 November, 2025 from https://www.berec.europa.eu/system/files/2022-10/BEREC%20BoR%20%2822%29%20137%20BEREC_preliminary-assessment-payments-CAPs-to-ISPs_0.pdf.

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Regulatory status: Market power in the telecommunications sector is regulated under the telecom regulatory framework, while digital service providers' market power is addressed by the DMA; both frameworks complement traditional competition law. While the DMA does not regulate IP interconnection, it targets certain large CAPs designated as gatekeepers, which may indirectly affect competitive dynamics but does not cover this specific market. There has been ongoing debate regarding market failures (mostly promoted by the large ECN operators) versus competitive dynamics within the IP interconnection ecosystem. According to BEREC's 2024 *Report on the IP Interconnection ecosystem*, disputes primarily occur when vertically integrated internet access services (IAS) providers leverage their termination monopoly to influence transit or peering markets, or when they impose higher IP interconnection (IP-IC) fees on CAPs[352]. Nevertheless, BEREC concluded that the IP-IC ecosystem generally demonstrates effective market forces, with notable cooperation among participants who predominantly resist additional regulatory measures.

The European Commission has been reviewing the possibility of implementing a sending-party network pays principle. In 2023, it conducted a public consultation on "Connectivity and Fair Contribution," soliciting stakeholder feedback[353]. A section of the consultation questionnaire focused on the topic of "Fair contribution by all digital players" which highlights the depth and seriousness of the discussions. Even though no final decision had been reached as of late 2025, in August 2025, a joint statement from the EU and USA as part of the trade agreement clarified that the EU "will not adopt or maintain network usage fees"[354]. As a result, it is highly improbable that any network usage costs will be incorporated into the forthcoming Digital Networks Act (DNA)[355].

Why it matters for DCs: The potential impact of the Sending Party Network Pays debate on DCs remains uncertain and largely depends on the specific design of any such intervention. Should hyperscalers be required to pay network fees, their cost structures and investment strategies could shift, possibly leading to an increase in on-network caching or the establishment of additional proprietary DCs to reduce transit costs. BEREC notes that major cloud and CDN providers could transfer these increased costs to their customers – including SMEs, enterprises, and public service providers – regardless of their size[356].

A direct contribution imposed on CAPs at the interconnection level might reduce direct peering and drive internet traffic away from local interconnection points, thereby diminishing both the

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[352] BEREC. (2024, December 5). BEREC Report on the IP Interconnection ecosystem. BoR (24) 177. Retrieved 24 November, 2025 from https://www.berec.europa.eu/system/files/2025-01/BoR%20%2824%29%20177_BEREC%20Report%20on%20the%20IP-IC%20ecosystem_0.pdf.

[353] European Commission. (2023, October 10). Results of the exploratory consultation on the future of the electronic communications sector and its infrastructure. Retrieved 25 October, 2025 from https://digital-strategy.ec.europa.eu/en/library/results-exploratory-consultation-future-electronic-communications-sector-and-its-infrastructure.

[354] European Commission. (2025, August 21). Joint Statement on a United States-European Union framework on an agreement on reciprocal, fair and balanced trade. Retrieved 24 November, 2025 from https://policy.trade.ec.europa.eu/news/joint-statement-united-states-european-union-framework-agreement-reciprocal-fair-and-balanced-trade-2025-08-21_en.

[355] Visser, C. (2025,August 28). Digital Networks Act: Proposal delayed and without 'fair share'. Table Briefings. Retrieved 25 November, 2025 from https://table.media/en/europe/news/digital-networks-act-the-proposal-comes-later-and-without-fair-share.

[356] BEREC. (2023, May 19). BEREC response to the European Commission's Exploratory Consultation on the future of the electronic communications sector and its infrastructure. Annex to complement section 4 of the BEREC response. BoR (23) 131d. p. 10.

performance and resilience of the interconnection ecosystem against cyber-attacks[357]. Given the complex business models of both operators and providers of internet access a mandatory payment may fail to incentivise the deployment of new infrastructure[358]. Furthermore, if such payments from CAPs to ISPs were mandated, ISPs could potentially discriminate or self-preference their own services, including cloud offerings [359].

BEREC concludes that currently, there is no evidence of competition issues or market failures negatively affecting end-users within IP-interconnection between networks and platforms[360]. However, the "sending-party-network-pays" debate represents a broader policy question that goes beyond IP interconnection, touching on cost allocation and investment incentives across the connectivity ecosystem. The debate also highlights fundamental tensions between ECN/ECS operators and hyperscalers, particularly regarding regulatory approaches to maintaining fair competition between two interdependent but distinct industry sectors. The outcome will have significant implications for the competitive landscape of both industries. Moreover, any regulatory action would likely affect demand, as hyperscalers are expected to pass increased costs on to their customers.

5.3.4. Data sovereignty & localisation rules

European policymakers have introduced rules around data localisation (for privacy/security), which indirectly affect competition by constraining how non-EU cloud providers operate. France, for example, required that cloud services for sensitive data be operated by a company immune from non-EU jurisdiction – leading to the joint ventures (Google-Thales, etc.) as described earlier[361]. The EU considered similar strict requirements EU-wide (in the EUCS scheme), effectively forcing hyperscalers to form EU-only subsidiaries for certain contracts[362]. This could have given an edge to European providers or forced structural changes. However, according to unofficial sources, as of 2024 the EU relaxed these draft rules, dropping the most restrictive clause under industry pressure[363]. The new approach relies on transparency of where data is stored and processed, rather than ownership requirements. Some see this as a pragmatic move to allow big players to compete, while others worry it leaves a sovereignty "blind spot" open. Nonetheless, big cloud firms have pre-emptively launched "sovereign cloud" offerings (Azure Sovereignty, Oracle's EU restricted zones, etc.) giving customers control over data residency[364].

5.3.5. Infrastructure constraints and local regulation

Not all challenges are competition-law issues; some are regulatory challenges that, if unaddressed, indirectly shape competition. A prominent example is power and environmental regulation for DCs. Several European cities (Amsterdam, Dublin, Frankfurt) have at times halted

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[357] Ibid. p. 16.
[358] Ibid. p. 9.
[359] Ibid. p. 8.
[360] Ibid. p. 7.
[361] Butler, G. (2023, August 7). Global Switch looks to sell European and Asia Pacific data centers to different buyers. DatacenterDynamics.
[362] Butler, G. (2024, April 4). EU relaxes cloud contract bidding rules for hyperscalers. DataCenterDynamics. Retrieved 19 October, 2025 from https://www.datacenterdynamics.com/en/news/eu-relaxes-cloud-contract-bidding-rules-for-hyperscalers/.
[363] Ibid.
[364] Ibid.

new DC permits or grid connections due to concerns about electricity consumption and land use[365]. These local moratoria, driven by sustainability goals, were arguably a regulatory blind spot in planning: officials didn't anticipate the surge in DC projects and then reacted abruptly, creating a risk of supply shortages. From a competition perspective, such moratoria favour incumbents – if no new DCs can be built in a hot market, the existing players face less competition and can enjoy high utilisation. Policymakers are now working on clearer frameworks (e.g. Amsterdam lifted its pause after new sustainability rules; London is adjusting its processes to ease a power crunch[366]. The EU's CNDCP (a self-regulatory initiative) and upcoming reporting mandates under the Energy Efficiency Directive will force all operators to meet certain green standards[367]. Ensuring power availability is integrated into urban planning is another area – some governments are investing in grid upgrades knowing DC growth is essential[368]. In sum, while not a classic antitrust issue, the regulatory coordination of energy, environmental, and digital policies has lagged behind the industry's growth, at times inadvertently affecting competition (through barriers to entry or expansion in key markets). This gap is starting to close via new guidelines and closer cooperation between DC industry groups and regulators[369].

5.3.6. Labour and supply chain collusion

A niche but noteworthy development was the European Commission's 2024 raids on DC construction companies over suspected no-poach agreements[370]. If true, construction firms may have been agreeing not to hire each other's specialised staff, which keeps wages lower and potentially slows projects. This kind of anti-competitive behaviour is a reminder that regulation must encompass the broader ecosystem – not just the DC operators themselves, but also the vendors and contractors that support them. It is a blind spot few expected the Commission to focus on, yet it shows how critical the sector has become (i.e. even its labour market practices are under the antitrust microscope). Breaking any collusion here should ensure a more competitive, and hopefully more efficient, market for constructing new facilities – aiding timely delivery of capacity for entrants and incumbents alike.

5.3.7. Role of telecommunications regulators

National telecom regulators (through BEREC, their European body) have begun weighing in on cloud and DCs, which traditionally laid outside their remit. In some Member States, NRAs began acting as the designated competent authorities for the application of the EU Data Act to cloud services. BEREC's 2024 report on cloud/edge services recognises that new competition dynamics are emerging between telecom networks and cloud providers and that the lines are

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[365] KPMG. (2022, November). The evolving data centre landscape.
[366] Yahoo Finance. (2024, February 21). Europe data center market overview.
[367] Knott, M. (2024, January 29). State of the European data centre market. Roland Berger. Retrieved October 24, 2025 from https://www.rolandberger.com/en/Insights/Publications/State-of-the-European-data-centre-market.html.
EUDCA. (2025). State of European Data Centres 2025.
[368] Cremona, E., Czyzak, P. (2025, June 19). Grids for data centres: ambitious grid planning can win Europe's AI race. Ember. Retrieved 20 October, 2025 from https://ember-energy.org/latest-insights/grids-for-data-centres-ambitious-grid-planning-can-win-europes-ai-race/.
[369] EUDCA. (2025). State of European Data Centres 2025.
[370] CPI. (2024, November 18). Data Center Construction Firms Face EU Raids Over Potential No-Poach Agreements. Retrieved October 24, 2025 from https://www.pymnts.com/cpi-posts/data-center-construction-firms-face-eu-raids-over-potential-no-poach-agreements/.

blurring[371]. They identify challenges such as “market concentration (…), switching barriers (…), digital sovereignty, and interoperability”, mirroring the issues discussed above[372]. BEREC suggests that regulatory frameworks may need updating to gain a broader view of these converged markets[373]. In other words, they see a risk of blind spots if regulators stick to siloed thinking – e.g. ECN/ECS operators might bundle cloud with network in ways not anticipated by pure telecom rules, or a hyperscaler might leverage cloud dominance to enter connectivity. No specific new regulations have been proposed yet, but this debate could influence future policy – potentially empowering telecom regulators to oversee certain cloud or DC-related competition aspects or at least coordinate with competition authorities.

In summary, Europe’s regulatory environment for DCs and cloud is actively evolving. Major competition-related issues – such as cloud lock-in and hyperscaler dominance – have been recognised and are starting to be addressed through instruments like the Data Act, DMA, and antitrust probes. Merger control remains crucial to prevent over-consolidation of infrastructure. Meanwhile, emerging concerns around sovereignty, and sustainability are prompting new policy responses which will further shape the competitive landscape. The challenge for regulators is to strike a balance that fosters a competitive, innovative market (with low entry barriers and technology-neutral rules) while safeguarding European interests (fair opportunities for EU players, consumer protection, and alignment with climate goals). Continuous dialogue between industry and regulators (as seen with the EUDCA’s input) will be key to illuminating any remaining blind spots.

5.4. Looking ahead

Europe’s DC market is characterised by vibrant growth and complex competition dynamics. ECN/ECS operators, hyperscalers, and independent DC firms are interdependent rivals, pushing each other to innovate and invest even as they collaborate in many areas. Recent consolidation, and hyperscalers’ growth, have produced a few very large players, but the market still sees new entrants and regional competition, ensuring diversity. From a policy standpoint, the last few years have seen Europe move from a relatively hands-off approach to a much more engaged stance: new rules and enforcement actions are now tackling issues that were previously ignored, such as cloud interoperability and anti-competitive contract terms.

Looking ahead (see Chapter 7 for further details, particularly within the regulatory domain):

- **Continued expansion** of DC capacity across Europe (notably in emerging markets of Eastern and Southern Europe) as digital demand soars – with hyperscalers leading the charge, often in partnership with local allies.
- **Further M&A activity** as scale remains important – but likely with regulators staying vigilant on competition impacts, possibly imposing conditions on big deals to protect local markets.

[371] BEREC. (2024). Report on cloud/edge services and competition dynamics.
[372] Ibid.
[373] Ibid.

- **Increasing regulatory clarity**: By 2025–2027, measures like the Data Act will apply, reducing lock-in and allowing European businesses to multi-cloud more easily. In parallel, under the DMA, if hyperscalers are designated as "gatekeepers" for their cloud computing services, ex-ante obligations would then apply to those services. This suggests a more level playing field might gradually emerge.
- **Innovation and differentiation** as key competitive angles: With commoditisation of basic colocation, providers will compete on energy efficiency, sustainability, and specialised **services**. The EU's push for climate-neutral DCs by 2030 will raise the bar for all players – those who lead in green energy usage and waste-heat recycling could gain an advantage (and avoid regulatory penalties)[374]. Likewise, ECN/ECS operators may find new life in edge computing sites (small DCs for 5G), carving a niche that hyperscalers alone cannot fill everywhere.
- **Sovereign and federated cloud efforts** (like GAIA-X) might yield new European alternatives or at least frameworks enabling smaller providers to interoperate, adding competitive pressure on the big players. Even if none rival AWS or Azure in size, their collective presence, supported by policy, can keep the giants in check and provide specialised choices.
- **User empowerment**: Ultimately, enterprise and government customers in Europe should benefit from these trends – more transparency, easier switching, and a variety of providers to choose from. Cloud pricing and contracts change in response to regulatory probes were already observed (e.g. Microsoft adjusting its licensing to appease EU objections). Going forward, large IT buyers can leverage an environment where regulators have their back regarding fair competition.

In conclusion, the European DC (and cloud) market is in a state of dynamic equilibrium – growing rapidly, with big players wielding significant influence, but also with mechanisms emerging to prevent that influence from stifling competition. The interplay between ECN/ECS operators and hyperscalers is evolving into a more symbiotic relationship, moderated by policy interventions. For Europe to stay globally competitive and digitally sovereign, it will need to nurture this sector carefully: encouraging the economies of scale and innovation that hyperscalers and large operators bring, while ensuring no player can abuse its dominance or exploit regulatory grey areas. Policymakers seem increasingly aware of the stakes, and the coming years will be crucial in refining regulations so that competitive, sustainable growth of the DC market can continue unabated, to the benefit of Europe's economy and consumers.

[374] EUDCA. (2025). State of European Data Centres 2025.

6. Environmental sustainability and energy consumption

DCs are not classified under any industry, whether heavy or light, yet they pose challenges for the environment due to their enormous demand for electrical energy, cooling needs related to power usage, consumption (and potentially pollution) of water, intake of raw material as well as creation of noise, and other factors. The most prominent factor of DC's influence on the environment is related to their ever-growing power consumption and related cooling needs, which have been accelerated by the rapid rise in demand for AI applications.

The number of processing units (servers) required for developing, training and using todays AI systems is constantly growing. Also, the content-rich IT services demand an enormous number of processing performed in a very short time in response to each query, generated image, or video production created by millions of users. This need for generating and processing content with the highest performance and quality leads to a massive increase of the processing units (servers, CPUs and GPUs and other auxiliary components) installed and housed in the DCs.

The power consumption of IT systems components grows dramatically. Power consumption of modern GPUs which are necessary for processing AI tasks exploded over the decade. Nvidia V100 GPU from in 2017 had a TDP (Thermal Design Power) of 300W while its recent version B200 has TDP of 1200W, which makes a 4-fold increase of the GPU wattage. Also, other elements of IT infrastructure (memory, network cards, system boards) tend to consume more power per unit, for the increased processing performance and network bandwidth served.

Due to this constant pressure on capacity and performance the overall energy density of the IT infrastructure has grown exponentially. Recent business practice of installing 5 kW per IT rack has become outdated with current systems reaching loads of 300 kW per rack, representing a 60-fold increase over less than a decade. This not only impacts the overall power supply demands of DCs but also creates challenges for the cooling infrastructure design and operation.

While DCs require ever higher power densities and power delivery capacities, ensuring the power supply quality is equally critical. This applies to the reliability of the power sources. Power line issues are the daily reality of the DCs, which is confirmed by surveys and interviews conducted, where respondents pointed frequent usage of backup power supply systems due to unexpected failures and instability in the external power grid. Six interviewed organizations and 17 out of 21 respondents indicated they had used their emergency systems in the past year, due to non-scheduled "blackouts" or large-scale grid synchronization issues.

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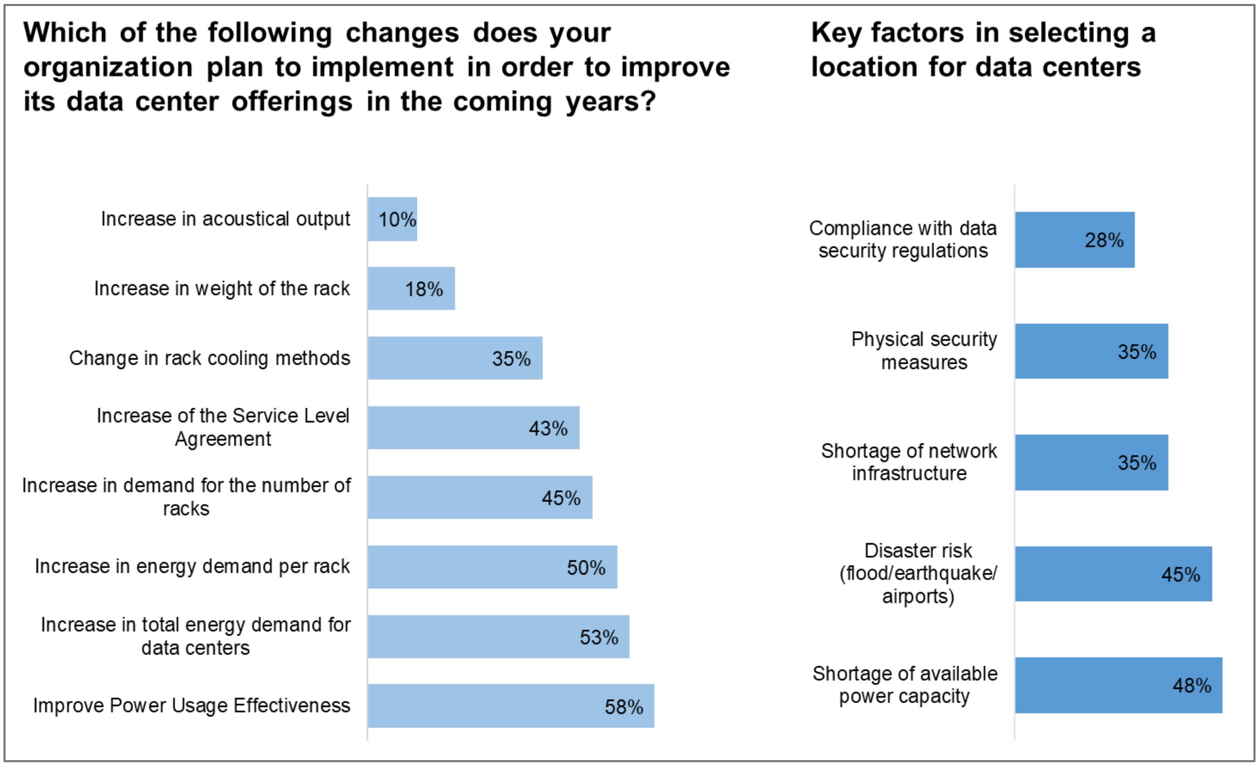

Figure 8. Challenges and location factors.

Overall, the most important aspect of environmental impact of DCs is their high energy demand, reaching tens of megawatts for larger DCs, with plans already in place for DCs consuming energy in the gigawatt range.

High energy usage has an overall impact on the environment, as it contributes to the overall power consumption (and carbon footprint) of today's economy. Other aspects of the DCs impact on their immediate surroundings include the water use, potential water and air pollution (due to usage of water in the cooling systems and diesel-based power generators activation) as well as the noise emission by the power generators and cooling systems including chillers or dry coolers, which are used in growing quantities and capacities due to power consumption grow.

Less obvious vectors of DC influence on environment, are their impact on availability of clean water through its vast use in cooling systems (where it may be lost or consumed) as well as DCs contribution to the consumption of raw materials due to the race to maintain the highest computational efficiency, which involves frequent replacement of IT systems components.

As it has been noted in the beginning of this section, DCs do not fall into any classified category among industries. Therefore, despite their significant contribution to the environmental impact of today’s economy, the regulations, directives and policies based on the recognition and identification of the DCs environmental impact and targeted at management and optimisation of the DCs influences on the environment are less extensively developed.

The domain-oriented, nuanced approach to ensuring environmental sustainability of DCS is the EU Energy Efficiency Directive (EED). EED is a crucial component of the "Fit for 55" package, aiming to enhance energy efficiency and sustainability across various sectors, including DCs, to achieve the EU's climate neutrality goal by 2050.

Key Aspects of the EED Directive for DCs:

- No Universal Power Usage Effectiveness (PUE) targets are defined in EED, but indirect influence is covered: The EED itself, updated in 2023, does not explicitly mandate specific targets for all EU member states. Instead, it focuses on mandatory reporting and sustainability metrics that indirectly influence PUE. However, national implementations, such as Germany's Energy Efficiency Act (EnEfG), do set concrete PUE targets.
- Mandatory Reporting and Monitoring:
    - DCs with a total rated power of at least 500 kW (IT power demand) are required to report their energy performance annually.
    - Key metrics to be reported include PUE, energy consumption, temperature set points, waste heat utilization, Water Usage Effectiveness (WUE), Renewable Energy Factor (REF), and Energy Reuse Factor (ERF).
    - This data is compiled and published in a European database, promoting transparency and enabling industry-wide benchmarking.
    - The first reporting deadline for data covering calendar year 2023 was September 15, 2024, and from 2025 onwards, reports are due by May 15 for the preceding calendar year. PUE calculations should adhere to EN 50600-4-2 guidelines.
- Waste Heat Utilisation (ERF): DCs with a total rated power exceeding 1 MW must utilize waste heat for heating or other energy recovery applications, unless technically or economically unfeasible. Germany's EnEfG introduces specific ERF targets for new DCs: ≥10% from July 2026, ≥15% from July 2027, and ≥20% from July 2028.
- Renewable Energy Integration (REF): The EED encourages the prioritization of renewable energy sources to reduce carbon footprint. Germany's EnEfG mandates that DCs source 50% of electricity from renewables by January 1, 2024, and 100% by January 1, 2027. Operators in Europe, including Connect Europe members, are actively working to reduce emissions through renewable energy and Power Purchase Agreements (PPAs).
- Future Measures (MPS): The European Commission may propose minimum performance standards (MPS) or a labelling scheme for DCs by 2025, potentially including PUE thresholds, based on the collected data. While the labelling system aims to identify high-performing facilities, MPS are designed to drive improvements or the decommissioning of underperforming ones.
- "Energy Efficiency First" principle: The EED emphasizes the application of this principle in energy policy and general investment decisions.
- Energy Management Systems: Large industrial energy consumers, including DCs, are mandated to implement energy management systems.
- Penalties: Non-compliance with these regulations can result in fines, with Germany's EnEfG setting potential fines up to €50,000 or €100,000.

Initiatives aimed at minimising the DCs environmental impact are also conducted at the national level in EU countries. The prominent example is the Germany's Energy Efficiency Act (EnEfG), that is in fact a national transposition of the EED, effective from November 18, 2023.

Key definitions of Germany's Energy Efficiency Act (EnEfG

- It applies to DCs with a nominal connection capacity of 300 kW or more (public) and 1,000 kW or more (private).
- For DCs commissioned before July 1, 2026:
    - PUE ≤1.5 from July 1, 2027.
    - PUE ≤1.3 from July 1, 2030.
- For DCs commissioned from July 1, 2026, onwards:

PUE ≤1.2, to be achieved no later than two years after going into operation and maintained permanently on an annual average.

EnEfG significantly tightens energy efficiency standards in German DCs – from the current average PUE values of around 1.7 to a maximum of 1.2–1.3 in the coming years. It is important to note, that the targets set by the Germany's Energy Act, while ambitious and aimed at achieving significant progress in the DC market environmental sustainability, might be challenging to achieve with today's DC cooling technology, which is mostly based on the indirect or direct air cooling. Reaching overall PUE lower than 1.2 might require migration to the liquid cooled systems solely, which requires extensive investments and can face technology limits.

These concerns are observed also at the EU level. EC links the EED with its digitalization and AI strategy, raising concerns that overly strict MPS with aggressive timelines could slow digital development, especially for edge DC capacity needed for AI inferencing. In the same time Uptime Institute estimates that at least 40% of European DC space will require modernization or relocation to meet proposed PUE and WUE standards (Uptime Institute, EED).

There is also a legal uncertainty due to differences between the EED (based on and referring to IT load) and EnEfG (based on nominal connected load), posing challenges for DC operators on interpreting the recommendations and ensuring the compliance to them.

Limitations of the PUE related approaches

While formulating and implementing recommendations or regulations related to power efficiency, focusing on PUE, might help in identifying and monitoring the DCs and IT systems that require improvement, redesign, decommissioning and replacement or configuration and operational improvements - it must be stated clearly that the work on improving power efficiency measures such PUE is only part of the story. The remaining aspect of the DC impact on the environment remains the exponential growth of the capacity and performance of IT systems installed in DCs, including highly optimised systems for AI and content-rich applications. Therefore, the efforts on improving the PUE of DCs should be accompanied with other efforts related to optimisation of the DCs and IT systems usage, including improvement of the software quality leading to lower resources use and better efficiency, technical and non-technical processes efficiency etc. The following section however focusses on the environmental impact aspects that are within the scope of this study subject.

6.1. Environmental footprint of DCs

The environmental impact of DCS necessitates urgent action through technological advancements, regulatory measures, and industry collaboration to achieve a sustainable digital future. By aligning technical innovation with regulatory frameworks, European DCs can continue to shrink their environmental footprint while supporting the continent's digital economy.

Key aspects of DCs impact on environment are discussed in the following subsections including energy consumption, carbon emissions, water usage, e-waste and resource use and heat reuse as well as sustainability efforts covering renewable energy, energy efficiency, circular economy and regulatory frameworks.

6.1.1. Energy consumption & carbon emissions

The International Energy Agency (IEA) mentions the DCs among three main contributors of the overall global electricity demand, next to cooling systems and electric vehicles[375]. While IEA points that the continuous growth of the global energy usage can be ultimately addressed by generation of electricity from renewables, for the time being large fraction of DCs still used the fossil fuels.

According to the report from "Beyond Fossil Fuels", the expected growth in the number of DCs could lead to an increase in the carbon footprint by a value of a 121 million tonnes over 6 years and up to 39 million tons of CO_2. This could undermine Europe's Green Deal and net-zero ambitions as DCs could consume 20% of new EU renewables, adding to demand pressure. The report reveals two calculations of sourcing options for DCs. In the first one, 61% is natural/fossil gas and the rest comes from renewables, and the other is for 100% renewables. The authors argue that traditional nuclear energy wouldn't be available at the necessary scale, speed and costs[376].

The EU targets carbon neutrality by 2050 and significant cuts (up to 55% vs. 1990) by 2030. Stricter regulations, sustainability ratings, and investor ESG requirements now push operators towards renewable energy sourcing, high efficiency (PUE ≤ 1.2) which can reduce 39 percent of the total energy consumed by the average DC that is nowadays spent on cooling, and heat reuse schemes. PUE is defined as the ratio of total energy consumption to total energy consumption of IT equipment. Efficient resource management, the use of energy-efficient technologies and the development of in-house sources of green energy, such as photovoltaic farms, are priority initiatives for DC's owners in their quest for sustainability and minimizing their carbon footprint[377].

Given the inevitable growing demand for computational power, that leads to continuously rising energy demand, realistic approaches for reducing the total energy consumption of DCs include

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[375] IEA (2024, October 16). Retrieved October 23, 2025, from https://www.iea.org/reports/electricity-2024.

[376] Beyond Fossil Fuels. (2025, February 10). System overload: How new data centres could throw Europe's energy transition off course [Report]. Beyond Fossil Fuels. Retrieved October 23, 2025, from https://beyondfossilfuels.org/2025/02/10/system-overload-how-new-data-centres-could-throw-europes-energy-transition-off-course/.

[377] Pawel Kruszec; (2025, August 27) Green data centres a step towards climate neutrality. Retrieved October 23, 2025, from https://polcom.com.pl/en/knowledge/colocation/green-data-centres-a-step-towards-climate-neutrality/.

limiting the energy use of auxiliary systems, by applying more efficient UPS power supplies, chillers, and, above all, by designing DCs for efficient energy consumption. Conventional DC cooling technology relies on gas evaporation, a process that consumes significant amounts of energy due to compressors operating 24h/day. This method has by low efficiency, with Power Usage Effectiveness (PUE) values in range of 1.7-2.0.

A major evolutionary change in cooling was reducing the time of compressors operation, leveraging cooler periods for dry cooling instead. By avoiding the use of compressors and relying solely on dry coolers (the air-cooled heat exchangers), PUE efficiency improved to range of 1.4. There are also dry coolers that use a small amount of water to lower outlet temperatures through evaporation near the cooling units. In addition, improving management of lighting and ventilation can also be considered, but the potential for improvement in these areas is quite limited.

According to the survey conducted in this study, energy-efficiency practices are broadly adopted: 77% of respondents declared active optimisation of power and cooling systems, 52.5% anticipate short-term increases in collocation services, 50% in cloud IaaS/SaaS, and 47.5% in AI workloads – all directly linked to rising IT energy demand. Among those reporting efficiency metrics, typical PUE values range from 1.3 to 1.6, with only a small group (< 10%) achieving ≤ 1.2, which confirms that achieving overall good efficiency of cooling is challenging.

These results also demonstrate that, while energy-efficiency measures are widely implemented, the continued growth of AI and cloud workloads may offset many of these gains, underlining the need for systemic improvements in cooling and power infrastructure.

6.1.2. Water usage

Liquid-cooled computers have been available on the market since the 1960s. Early mainframes, such as IBM's System/360 series, used water cooling in 1964. Cray-1 supercomputer released in 1976 was one of the most famous commercial liquid-cooled systems. The later Cray-2, launched in 1985, used full liquid immersion cooling. Liquid cooling gained widespread industrial use before becoming less common in favour of air cooling toward the late 1990s. Liquid-cooled servers reappeared on the market and became commercially available around the 2010. Early adopters, such as HPC facilities, began implementing liquid cooling solutions around 2014–2016 to address the thermal demands of high-density server racks, particularly for applications such as HPC, large datasets processing as well as machine learning and AI. Companies like Asetek, CoolIT Systems, and later Lenovo and Supermicro introduced liquid cooling solutions to the enterprise servers' sector, including direct-to-chip cooling and immersion cooling.

In DLC systems, pure water or glycol is circulated through pipes directly to processors, RAM modules, and other high-performance, heat-producing components, e.g. system board chipsets. Alternatively, entire servers are immersed in dielectric fluid. This technology can achieve PUE ~1.05 for computing systems themselves, average PUE values of ≤1.2 when considering entire server rooms (including storage, networking and other systems).

Storage systems and networking devices are not typically implemented in DLC technology due to lack of concentrated areas that generate the majority of the heat and could be effectively cooled by a coolant plate or similar mechanism. Implementing DLC would be complex and expensive as it might require redesigning the hardware entirely. In DLC cooling systems, the water circulates in a closed loop, ensuring efficient recirculation without excessive consumption. Only the evaporation process at the dry coolers requires additional water input. This means that, aside from dry cooler variants with evaporative assist, most of the system's cooling water is continuously reused, minimizing overall water demand.

Once-through cooling technology consumes the water from natural sources in order to remove heat generated by DC equipment. These systems pump cold water directly from a river or lake into the DC's heat exchangers. Important environmental aspect of such cooling systems is that the water that absorbs thermal energy from the IT infrastructure, becomes warmer. Once used, water is discharged back into the rivers or lakes, typically with a higher temperature due to the heat that it holds. So, unlike closed-loop systems, the once-through cooling systems constantly consume and release fresh water, resulting in potential water temperature increase. The temperature difference between intake and discharge is controlled by regulation to minimize ecological harm, but these systems can stress local environments, especially during periods of high demand or extreme weather.

River or lake-cooling can be highly efficient for power and energy use, as seen in examples like Interxion in France, which saves thousands of megawatt-hours annually using cold river water. PUE of the Marseille DCs is pushed down to ~1.2, thanks to using the nature-sourced cooling liquid, whereas the average in France is 1.6[378].

The Swiss National Supercomputing Centre (CSCS) in Lugano is another prominent example. It uses cold water from the alpine Lake Lugano for cooling its HPC systems. Water is drawn from a depth of 45m and pumped 2.8 km to the DC. Very low energy overhead of the cooling system itself helps Lugano DC to achieve PUE <1.25. To minimise the stress on ecological balance of the lake, the water returning to the lake never exceed 25ºC[379].

While water-based cooling is widely used and more energy-efficient, however it also drives considerable water consumption. Analysis suggests that cooling a DC for the workload required to generate 10 to 50 medium-length GPT-3 responses uses approximately a 500-milliliter bottle of water[380].

Advanced DCs require 0.4 litters per kWh in water-stressed regions by 2025 (per CNDCP), with the same target extended to all existing facilities by 2040. Alongside regulatory requirements, industry-led initiatives such as the CNDCP have set voluntary targets to enhance water efficiency. Signatories to this self-regulatory initiative commit to designing new DCs to achieve a water usage

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[378] TechTarget; (2021, December 6). Datacentres in France Use River For Cooling to Save 18,400 MWh Annually. Retrieved October 23, 2025, from https://www.despatch.com/blog/datacenters-in-france-use-river-for-cooling-to-save-18400-mwh-annually/?srsltid=AfmBOoqVU85JzyHN8VIY7VJL985mGaWn-qiunZQFtkBuWRdw6nwYdLOE

[379] CSCS (2025) Lake water to cool supercomputers. Retrieved October 23, 2025, from https://www.cscs.ch/fileadmin/user_upload/contents_publications/factsheets/lake_water/20150630_Lake_water_cool_supercomputers_EN.pdf.

[380] Bloomberg (2025, May 15) EU Will Work on Setting Water Use Caps for Thirsty Data Centres. Retrieved October 23, 2025, from https://www.energyconnects.com/news/renewables/2025/may/eu-will-work-on-setting-water-use-caps-for-thirsty-data-centres/.

effectiveness of 0.4 litres per kilowatt-hour (l/kWh) in water-stressed areas by 2025. Existing DCs are expected to meet this standard by 2040[381].

The industry is aligning on 1.2 LPM/kW as the new standard for liquid cooling. As liquid-cooled AI platforms become more prevalent, this flow rate strikes the optimal balance between thermal performance, energy efficiency, and Cooling Distribution Units (CDU) capacity planning. The liquid flow rate directly affects heat removal efficiency of the DLC. As Thermal Design Powers (TDPs) rise, the demand for higher flow rates increases, as an insufficient flow can reduce the ability to cool high-power components ultimately putting the performance and scalability needed for AI workloads at risk.

Overall, while the flow rate optimisation remains an important aspect of CDU design and overall liquid cooling system design, the growing pressure on the cooling capacity keeps the aggregated demand for the water-use growing. On the other hand. The European Commission is developing minimum performance standards and water-use caps for DCs, aiming to mitigate shortages and support water resilience. Policy and industry initiatives promote use of recycled or reclaimed water, incentives for conservation, and link water management to broader circular economy strategies. The EC's European Water Resilience Strategy, acknowledges the need for a coordinated and inclusive approach to address the complex challenges surrounding DC water management.

Project survey shows that location-specific cooling using local resources such as lakes, rivers or ambient cold air is in relatively low use, confirmed by 7 respondents (18%), while 29 (73%) reported no use of such cooling resources. This limited adoption indicates that closed-loop or air-based systems remain dominant, even in regions with favourable climatic conditions.

6.1.3. Materials and e-waste

By focusing on sustainable materials, extending equipment life, recycling e-waste responsibly, and adopting circular economy strategies, DCs can significantly reduce their environmental impact and improve overall sustainability.

DCs rely on resource-intensive materials like rare earth metals (e.g., for chips and batteries), plastics, and metals in servers, racks, and cabling. Mining and manufacturing these contribute to habitat destruction, water pollution, and high carbon footprints. Globally, DCs generate millions of tons of e-waste annually. Servers and networking gear is often replaced after 3–5 years of exploitation, leading to toxic leaks (e.g. lead) if not recycled properly. Only about 20% of global e-waste is formally recycled, per UN reports, turning landfills into pollution hotspots. This "unsustainability" drives up embodied carbon (emissions from production) and hinders circular economy goals, where resources are reused rather than discarded.

Implementing rigorous equipment tracking and life-cycle management helps to identify when hardware becomes obsolete and should be safely decommissioned or repurposed. Developing partnerships with certified e-waste recyclers ensures that retired IT equipment is disposed in

[381] DIGITALEUROPE (2025, July 3) Enhancing water resilience in the data, centre industry. Retrieved October 23, 2025, from https://cdn.digitaleurope.org/uploads/2025/07/DIGITALEUROPE_Enhancing-water-resilience-in-the-data-centre-industry_July-2025.pdf.

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compliance with environmental regulations and ensuring recovery of materials such as metals and rare earth elements. Reusing or donating functional equipment to universities, schools, non-profits, or community organizations extends the hardware lifetime and reduces overall electronic waste. Adopting circular IT asset disposition models – where hardware is refurbished, resold, or recycled in closed-loop systems – directly decreases the volume of e-waste generated and promotes material recovery.

DCs in EU are already obliged by regulations to collaborate with certified partners (companies with recycling authorizations) for the transfer of used equipment and other waste, prioritizing recovery over disposal in landfills, and to maintain waste records in accordance with legal requirements. Beside compliance, DCs that integrate materials management and e-waste strategies into their operations reduce their environmental impact, support the circular economy, and promote long-term sustainability. Monitoring and reporting material use, and e-waste metrics supports their transparency and continuous environmental impact improvement. DCs may also prioritize suppliers certified for sustainable practices, who hold ISO 14001 certificate for environmental management or use recycled or low-impact materials like bio-based plastics for cabling or aluminium from recycled sources for server chassis.

According to project surveys, hardware replacement cycles reported by respondents align with the typical 3–5year refresh interval for compute and network equipment. Around one-third of operators state that they apply formal IT-asset management or recycling procedures, and roughly 25% have implemented or plan to implement ISO 14001 environmental management or equivalent schemes. These results indicate that while awareness of material sustainability and e-waste management needs is increasing among DCs, they are still at the early stage of systematic implementation. Strengthening circular practices, extending hardware lifecycles and scaling certified recycling partnerships will be essential for reducing embodied carbon and meeting emerging EU environmental requirements.

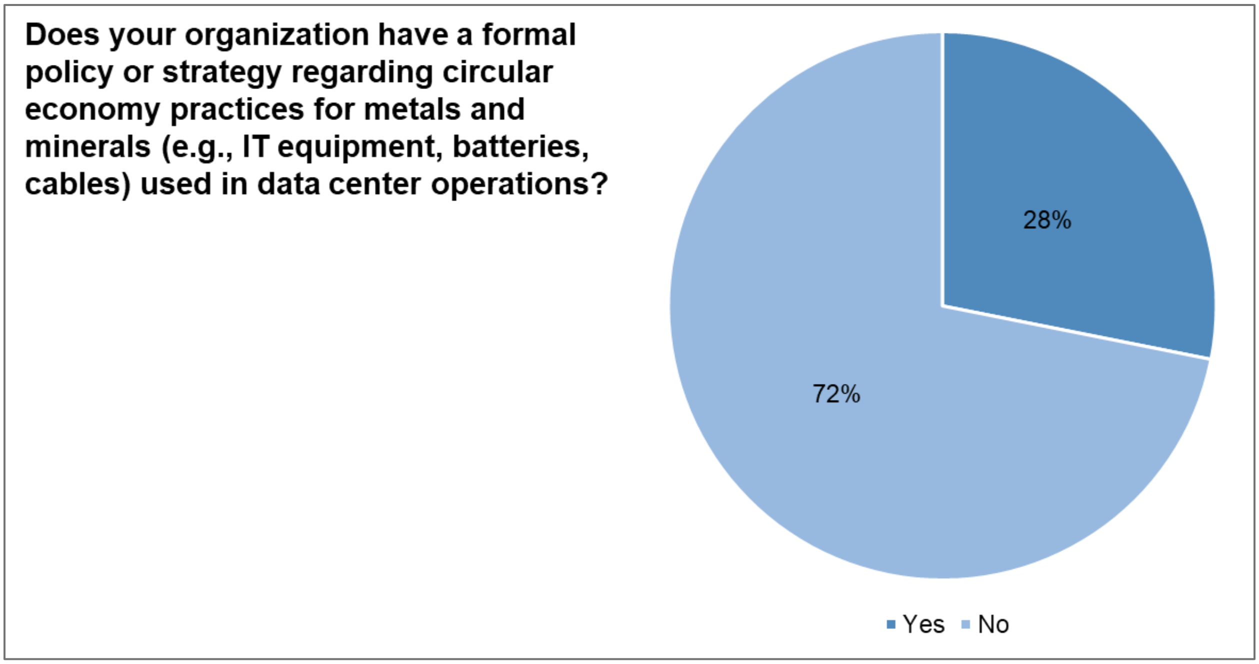

Figure 9. Formal policy or strategy regarding circular economy practices for metals and minerals.

6.1.4. Various DC architectures regarding sustainability performance

Europe is at the forefront of DC sustainability, driven by stringent EU regulations like the Energy Efficiency Directive (EED), that mandates annual reporting of key performance indicators (KPIs) such as Power Usage Effectiveness (PUE), Water Usage Effectiveness (WUE), Energy Reuse Factor (ERF), and Renewable Energy Factor (REF) for DCs with IT energy demand ≥500 kW.

The EU's Delegated Regulation (EU) 2024/1364 establishes a common rating scheme to promote transparency, renewable energy adoption, waste heat reuse, and grid efficiency.

Additionally, voluntary frameworks like *the EU Code of Conduct for Data Centres* encourage best practices, while certifications such as Building Research Establishment Environmental Assessment Method (BREEAM) and Leadership in Energy and Environmental Design (LEED) validate sustainable designs. These policies aim to curb DCs' projected energy demand, which could reach 945 TWh by 2030.

Key Sustainability Initiatives conducted in Europe include:

- **Renewable Sourcing**: Operators are investing heavily in on-site solar, wind, and direct grid procurement of green energy[382].
- **Heat Reuse & Efficiency**: Many new facilities deploy waste-heat recovery for district heating, advanced cooling, and resource pooling to further reduce their environmental impact[383] .

[382] Simon Hinterholzer (2025, August 19), The future of data centres at a glance: Measurable. Comparable. Improvable. Retrieved October 23, 2025, from from https://www.borderstep.org/data-centres-in-the-eu-facts-figures/.
[383] Pawel Kruszec; (2025, August 27). Green data centres a step towards climate neutrality. Retrieved October 23, 2025, from https://polcom.com.pl/en/knowledge/colocation/green-data-centres-a-step-towards-climate-neutrality/.

- **Reporting & Transparency**: ESG disclosures, voluntary codes (CNDCP), new EU directives make environmental metrics public, impacting investor relations and site selection[384].

To cope with regulations and market expectations DCs deploy various architectures varying in design, focusing on cooling, power distribution, and resource management. The table below compares various architectures of the DCs in the context of environmental sustainability, focusing on the cooling systems applied.

Table 6. DC Architectures comparison in the context of environmental sustainability.

Architecture	Description	Key Sustainability Features	Performance Metrics
Traditional DCs	Redundant infrastructure, relies on air cooling via CRAC units with direct expansion providing airflow, air filtration, and humidity regulation, using components like cooling coils, compressors and fans to maintain optimal temperature.	Can leverage natural ventilation in cooler climates; Can implement free cooling using additional dry coolers; low water use (no evaporation required).	PUE: 1.5-2.0; energy saving and CO_2 reduction potential: minimal; cooling modernization may improve the performance (e.g. by enabling free cooling, or deploy DLC systems)
Air-Cooled (Raised Floor/Free Air)	Redundant infrastructure power supply, air cooling systems via CRACS, airflow typically through raised floors; modular design with separate hot/cold aisle for IT rack, servers, storage and networking systems, suitable for low-density racks.	Could leverage chillers with improved efficiency to produce coolant for CRACK; could use water for evaporation to reduce power use by dry coolers; could leverage natural ventilation in cooler climates implementing free cooling using additional dry coolers.	PUE: 1.3-1.6; up to 10-20% annual energy reduction vs. traditional DCs; better in Nordic regions; heat reuse: high potential (e.g. district heating).
Hyperconverged Infrastructure (HCI)	Integrated compute, storage, and networking in software-defined nodes; scalable for cloud/AI workloads; hybrid air/liquid cooling.	Reduces hardware sprawl; enables dynamic load balancing; supports renewables and AI-optimized efficiency	PUE: 1.2-1.4; up to 30% annual energy reduction vs. traditional DC.
Modular/Prefabricated	Pre-built, containerized units; scalable deployment; hybrid cooling and edge computing focus.	Rapid setup reduces construction emissions; easy upgrades for efficiency; portable for low-impact sites.	PUE: 1.2-1.4; up to 30% annual energy reduction vs. traditional DC material waste: 20-30% less;
Hyperscale/Cloud-Native	Massive, centralized facilities with AI-driven orchestration; integrated renewables and waste heat recovery.	100% renewable sourcing; heat export to districts; circular economy (e.g., recycled materials).	PUE: 1.1-1.3;

[384] Jessica Commins and Kristina Irion (2025, March) Towards Planet-Proof Computing: Ten Key Elements EU Data Centre Sustainability Policy Should Take Onboard. Retrieved October 23, 2025, from https://www.europeanlawblog.eu/pub/1jb3tzus.

Liquid-Cooled (Direct-to-Chip/Immersion)	Coolant directly contacts chips (DLC) or submerges servers; closed-loop systems for high-density AI/HPC.	Up to 40% cooling energy savings; minimal air dependency; enables higher rack densities (300 kW/rack).	PUE: 1.05-1.2; Energy reduction: 30-50% vs. air; CO_2: Low with renewables; ERF.

6.2. Energy and water consumption patterns and dependencies

Previous section (6.1) introduced the overall features of energy and water consumption by DCs. This section details the energy and water consumption patterns in DCs and discussed the interplay among these aspects.

Overall, energy and water use in DCs are closely interlinked through what is known as the “energy–water nexus”. Water is required for energy-intensive cooling processes, while electricity is necessary to pump, treat, and circulate water.

This interdependence creates trade-offs: reducing water use through air-based cooling solutions often increases electricity demand, while using water-based cooling systems reduces energy consumption but increases water requirements. Optimising this balance is critical for the sustainable operation of DCs, particularly in regions facing water scarcity or high energy costs.

6.2.1. Electricity demand

Energy consumption in DCs is dominated by IT equipment consumption of electricity. Servers, storage devices, and networking hardware, account for approximately 50-80% of the total energy consumption, according to International Energy Agency (IEA) report. Cooling systems, which encompass chillers, Computer Room Air Conditioning (CRAC) units, and air circulation mechanisms, are the second-largest energy consumer, with 20-40% share of the total energy use by DCs. Power infrastructure systems: Uninterruptible Power Supplies (UPS), transformers, and Power Distribution Units (PDUs), contribute approximately 5-10% to the DC’s energy use due to conversion and distribution losses. Finally, ancillary systems such as lighting, security, and building management systems account for less than 5% of the total energy consumption.

Zooming out from within-the-DC power usage distribution, it is important to note that DCs are among the most energy-intensive components of the modern IT infrastructure. Electricity consumption of DCs patterns vary significantly depending on the operational model. Enterprise DCs have a relatively dispersed profile, with substantial fraction of energy directed towards cooling systems and other infrastructure, which indicates lower operational efficiency compared to other models. Colocation and service provider facilities follow a similar pattern, though with slightly greater emphasis on cooling requirements. In contrast, hyperscale DCs demonstrate a different pattern: the overwhelming majority of electricity is channelled to servers and IT equipment, while ancillary systems consume relatively less. Hyperscale DCs optimise power utilisation and reduce overheads, supporting cost-efficiency and sustainability objectives.

Energy consumption patterns in DCs are influenced by temporal and long-term factors. Energy use fluctuates based on workload demand, with peaks occurring during business hours and periods of higher ambient temperatures. Hyperscale DCs often employ dynamic load distribution across global networks of DCs in order to balance energy use and operational costs. In addition, DCs must maintain a constant baseline energy demand due to redundancy requirements, typically employing N+1 or 2N system designs to ensure continuous uptime.

Nordic countries have emerged as leaders in sustainable DC operations due to their favourable climate conditions and strong renewable energy integration. These regions provide a minimum of 4,000 hours of annual free cooling (45% of the year), enabling operators to make extensive use of airside and water-side economizers as well as indirect evaporative cooling systems. Such climatic advantages reduce both energy consumption for cooling and the overall carbon footprint of operations.

Beyond the Nordic region, other forward-thinking operators are adopting advanced liquid cooling technologies to further improve energy efficiency. IMany facilities have also replaced traditional diesel with Hydrotreated Vegetable Oil (VHO) fuel-based backup power generators, significantly lowering carbon emissions during power outages.

In Europe, the widespread presence of district heating systems has also become a key driver for energy sustainability in the DC sector. These systems allow excess heat generated by DCs to be redirected to local heating networks, supporting renewable energy integration and improving overall energy efficiency. DC operators are increasingly collaborating with district heating providers on incorporating renewable energy sources into these systems, enhancing sustainability and supporting local economics and reducing dependence on fossil fuels. This approach represents an innovative model that is expected to expand significantly across the European DC market.

Overall, the dependency on grid electricity is no longer limited to ensuring uninterrupted power. Modern DC operations require strategic consideration of grid capacity, renewables integration, cooling potential, and regional energy infrastructure density and quality, as these factors collectively influence operational efficiency, sustainability, and long-term resilience.

- While the multiple energy and cooling-related DC sustainability and economic efficiency factors create a complex set of dynamics influencing the design and operation particular DCs across Europe as well as the overall DCs market shape, key trends that are driving growth, boosting sustainability, and addressing power challenges have been summarised in the report prepared by ResearchAndMarkets.com. The main findings of this report are the following: Grid congestion in legacy hubs prompts a search for sites with reliable power and lower environmental barriers.
- Nordic countries excel at integrating renewables into electricity sourcing systems. These countries also offer a minimum of 4,000 hours of annual free cooling, increasing the investments in air/water-side economisers and indirect evaporative coolers.
- Germany, Ireland, the UK, and France are dominant markets adopting new cooling technologies. Germany and Ireland have seen substantial investments in DC cooling: –many co-location and hyperscale operators are deploying direct-to-chip and immersion liquid cooling to support high-density of computing power, AI-driven workloads and to meet

sustainability goals. Also, Central and Eastern Europe are increasingly adopting liquid cooling in their facilities with HPC and AI capabilities. Regulatory pressure for greener operations and energy efficiency is driving adoption, although upfront costs and standardization issues remain obstacles.

- The district heating system in Europe is significant in advancing sustainability in Europe and it is the innovative concept that is expected to grow significantly among DC facilities in the Europe DC market. DC operators are incorporating waste heat sources in district heating systems to enhance sustainability, further drive energy efficiency, and support local economic growth across the region.
- Southern European markets, including Spain, Italy, and Greece, are gaining traction due to local renewable energy agreements and new heat-reuse concepts. For instance, Amazon has signed significant renewable energy power purchase agreements in Greece to minimize emissions.

Abovementioned analysis applies to current situation and arising trends. Long-term projections of future energy consumption by DCs and related trends are conducted by many organisations.

Starting with the International Energy Agency's (IEA) analysis (2024 report), it is forecasted that the rapid growth in energy consumption by DCs will keep pace or accelerate, with predictions of global demand's doubling to 945 TWh by 2030, primarily due to the development of artificial intelligence (AI). In Europe, a 45 TWh growth is projected (a 70% increase) compared to the 2024 level[385]. It is worth mentioning, the IEA perceives AI not only as driver for increased energy demand but also as a powerful tool for optimization across the entire energy sector, capable of enhancing grid efficiency, improving renewable energy forecasting, and accelerating innovation in new technologies, such as materials for solar panels or battery chemistry[386].

Other forecasts indicate power demand doubling or tripling:

- From 62 TWh (2023) to 150-287 TWh by 2030[387]
- ICIS, the share of DCs in total electricity demand in Europe will increase from 3% to 4.5% by 2030[388]

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[385] IEA (2025); Energy and AI; Energy demand from AI. Retrieved November 20, 2025 from https://www.iea.org/reports/energy-and-ai;
George Kamiya, Vlad C. Coroamă, IEA 4E, (2025, March). "Data Centre Energy Use: Critical Review of Models and Results,". Retrieved November 20, 2025 from https://www.iea-4e.org/wp-content/uploads/2025/05/Data-Centre-Energy-Use-Critical-Review-of-Models-and-Results.pdf.
[386] IEA (2025); Energy and AI; Energy demand from AI. Retrieved November 20, 2025 from https://www.iea.org/reports/energy-and-ai.
[387] ICIS Power Analytics (2025); Data centres: Hungry for power. Forecasting European power demand from data centres to 2035. Retrieved November 20, 2025 from https://www.icis.com/explore/resources/data-centres-hungry-for-power/;
McKinsey & Company, (2024), "The Role of Power in Unlocking the European AI Revolution". Retrieved November 20, 2025 from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-role-of-power-in-unlocking-the-european-ai-revolution;
Beyond Fossil Fuels. (2025, February 10). System overload: How new data centres could throw Europe's energy transition off course [Report]. Beyond Fossil Fuels. Retrieved October 23, 2025, from https://beyondfossilfuels.org/2025/02/10/system-overload-how-new-data-centres-could-throw-europes-energy-transition-off-course/.
[388] ICIS Power Analytics (2025); Data centres: Hungry for power. Forecasting European power demand from data centres to 2035. Retrieved November 20, 2025 from https://www.icis.com/explore/resources/data-centres-hungry-for-power/.

- Up to 945 TWh in a high-AI scenario (IEA), or 4.5% of EU electricity[389]
- IT load from 10 GW (2023) to 35 GW (2030), with AI driving 70% of growth.

Table below summarizes the studies on current energy use dynamics in Europe.

Table 7. Overview of studies estimating the energy use of DCs in Europe.

Author / Publication	Summary	Results	Quality assessment
Bashroush (2018)[390]	Methodology not disclosed.	130 TWh in 2017	N/A – cannot be assessed due to lack of methodological details.
Beyond Fossil Fuels (2025)[391]	Initial estimates for EU27 based on IEA (2024a) plus Montelevecchi et al. (2020) with continuation of growth rates from IEA (2024a) to 2030 for "high demand" and from McKinsey (2024) for "low demand"; estimates and projections based on National Grid ESO.	104–110 TWh in 2022 (EU27 + UK); Projection 218–287 TWh in 2030 (EU27 + UK)	Low–medium: relies on limited data and assumptions; high uncertainty with 2030 projections.
BloombergNEF et al. (2021)[392]	Bottom-up estimates of location of hyperscale DCs based on data on installed DC capacity and assumptions on PUE and server shipments; includes estimates for hyperscale and colocation.	29 TWh in 2020 for Germany, Ireland, Netherlands, UK	Medium–high: high-quality data on hyperscale locations; assumptions on PUE and shipments.
Bie y Deloitte and Fraunhofer IZM (2015) Prepared for DG GROW[393]	Bottom-up estimates based on modelled markets (e.g., server shipments) and informed hardware assumptions. This study also explores size scenarios over the period to 2030.	78 TWh in 2015 for EU28	Medium: comprehensive study using available market data.
ICIS (2025)[394]	Initial (2024) estimates appear to be adapted from Kamiya & Bertoldi	126 TWh in 2023; 168 TWh in 2028 (EU27 + UK)	N/A – cannot be assessed due to lack of methodological details.

[389] IEA (2025); Energy and AI; Energy demand from AI. Retrieved November 20, 2025 from https://www.iea.org/reports/energy-and-ai.
[390] Bashroush, R. (2018). A comprehensive reasoning framework for hardware refresh in data centers. IEEE Transactions on Sustainable Computing, 3(4), 209–220. Retrieved November 20, 2025 from https://doi.org/10.1109/TSUSC.2018.2795465.
[391] Beyond Fossil Fuels. (2025, February 10). System overload: How new data centres could throw Europe's energy transition off course [Report]. Beyond Fossil Fuels. Retrieved October 23, 2025, from https://beyondfossilfuels.org/2025/02/10/system-overload-how-new-data-centres-could-throw-europes-energy-transition-off-course/.
[392] BloombergNEF. (2021). Energy transition investment: Tracking global investment in the low-carbon energy transitions. Retrieved November 20, 2025 from https://assets.bbhub.io/professional/sites/24/Energy-Transition-Investment-Trends_Free-Summary_Jan2021.pdf.
[393] Bio by Deloitte (2015). Study on data for a raw material system analysis: Roadmap and test of the fully operational MSA for raw materials – Final report. Retrieved November 20, 2025 from https://rmis.jrc.ec.europa.eu/uploads/Final_2015_MSA_Report.pdf.
[394] ICIS Power Analytics (2025); Data centres: Hungry for power. Forecasting European power demand from data centres to 2035. Retrieved November 20, 2025 from https://www.icis.com/explore/resources/data-centres-hungry-for-power/.

	(2024), not disclosed how future energy use is projected.		
IEA (2025)[395]	Hybrid estimate based on extrapolated values from Montelevecchi et al. (2020) and projections from IEA modelling.	145 TWh in 2026	Medium – uses reliable sources and projections.
Kamiya and Bertoldi (2024)[396]	Hybrid estimates combining country-level data and projections with available data on hyperscale and colocation, and assumptions on PUE and server shipments.	45–65 TWh in 2023	Medium – comprehensive and transparent methodology.
Masanet et al. (2020) [397]	Bottom-up estimates based on stock and shipment data for servers, storage and networking equipment, combined with assumptions on PUE and regional-specific electricity use.	38.4 TWh in 2018 for Western Europe	Medium – same as Masanet et al. (2020).
McKinsey (2024)[398]	Hybrid estimates based on initial 2023 estimates from Kamiya & Bertoldi (2024) extrapolated to 2030 using projections from IEA and proprietary McKinsey model.	72 TWh in 2023 for EU27+UK; 218–287 TWh in 2030 for EU27+UK	Low–medium: solid basis for 2023 but high uncertainty for 2030 projections.

DCs energy consumption growth analysed in abovementioned studies is one of the most observable and measurable symptoms of the DC market growth, that in turn is happening in response to the overall IT sector dynamic, accelerated by recent advancement and explosion of applications and systems based on and contributing to the AI technology development.

The rapid growth in demand for AI technology solutions is not only driving the overall development of the DC market but is also pushing its capacity limits. AI-oriented infrastructure is consuming a large share of DCs' space, energy, and cooling budgets. On one hand, this is causing Europe's broader IT sector to approach its limits for deploying new facilities or expanding existing ones. On the other hand, it is ironically putting future AI development into question, especially in the most densely populated regions of the Europe.

[395] IEA (2025); Energy and AI; Energy demand from AI. Retrieved November 20, 2025 from https://www.iea.org/reports/energy-and-ai.
[396] Kamiya, G., & Bertoldi, P. (2024). Energy consumption in data centres and broadband communication networks in the EU (JRC135926). Publications Office of the European Union. Retrieved November 20, 2025 from https://doi.org/10.2760/706491.
[397] Masanet, E., Shehabi, A., Lei, N., Smith, S., & Koomey, J. (2020). Recalibrating global data center energy-use estimates. Science, 367(6481), 984–986. Retrieved November 20, 2025 from https://doi.org/10.1126/science.aba3758.
[398] McKinsey & Company, (2024), "The Role of Power in Unlocking the European AI Revolution". Retrieved November 20, 2025 from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-role-of-power-in-unlocking-the-european-ai-revolution.

An example of such a situation is Ireland, where fears of rolling blackouts led Ireland's grid operator to halt new DCs near Dublin until 2028. These new buildings equipped with thousands of servers consumed 21% of the nation's electricity in 2023, according to official records. Moreover, the growing reliance on fossil fuels to generate energy to meet this demand casts doubt on Ireland's climate goals; as a result, this technological boom has become a hot political topic, with the country serving as a microcosm of both European and global energy challenges associated with AI and DCs growth in general[399].

When it comes to long-term projections, several sources predict further exponential grow of the energy demand. The dedicated report of IEA[400] report provides broader insight in relationship among the development of AI sector and the energy consumption trends on the regional and global level. Bloomberg New Energy Finance in their new report claim that World's DC power demand will double in the next 5 years and triple by 2035 – to 1,600 TWh over the next decade – driven by the development of AI, accounting for 4.4% of total electricity demand[401].

At the European level, Independent Commodity Intelligence Services' (ICIS) forecasts power demand from DCs to increase from 96TWh in 2024, to 168TWh by 2030 (>150% growth in 6 years), and to 236TWh by 2035 (>200% growth over the decade). This robust growth will result in DCs' share of total demand rising from about 3.1% at present to 5.7% by 2035, even as overall electricity demand experiences a significant increase over the next decade due to electrification in areas like mobility. ICIS has prepared several analyses regarding the growth in energy demand by DCs over the years. The figure below overviews the projected DCs energy demand distribution across particular European countries (blue vertical lines) along with indication of the percentage of the total per-country electricity demand accounted to DCs.

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[399] MATT O'BRIEN (December 19, 2024); Ireland embraced data centers that the AI boom needs. Now they're consuming too much of its Energy. Retrieved November 20, 2025 from https://apnews.com/article/ai-data-centers-ireland-6c0d63cbda3df740cd9bf2829ad62058.

[400] IEA (2025); Energy and AI; Energy demand from AI. Retrieved November 20, 2025 from https://www.iea.org/reports/energy-and-ai.

[401] BloombergNEF. (2025, April). *Power for AI: Easier said than built*. Retrieved November 20, 2025 from https://about.bnef.com/insights/commodities/power-for-ai-easier-said-than-built/.

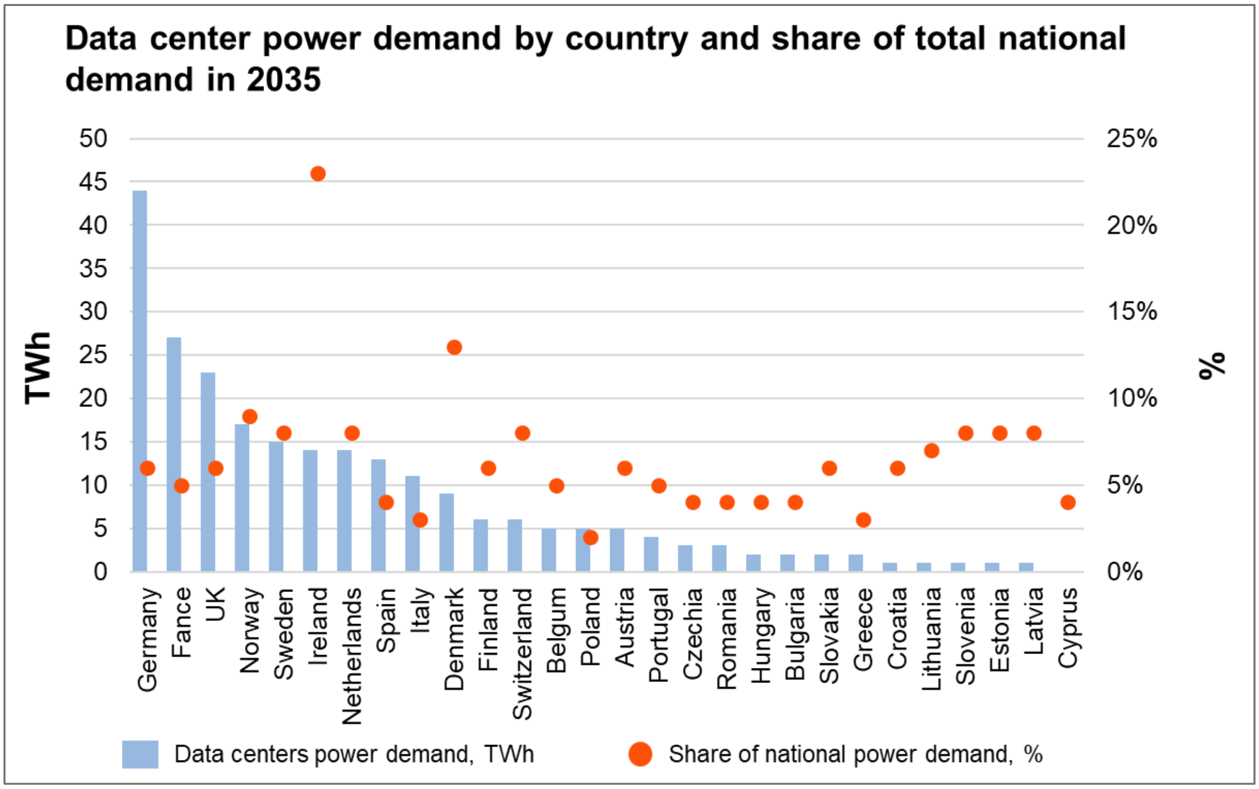

Figure 10. DC power demand by country and share of total national demand in 2035[402].

6.2.2. Water usage

Water consumption in DCs is primarily associated with cooling systems. Evaporative and adiabatic cooling mechanisms are the largest users of water, as they remove the excess heat from IT equipment. Water is also used in humidification systems to maintain optimal environmental conditions and prevent static discharge, which could damage sensitive hardware. Water consumption patterns are influenced by climate, operational load, and technological choices. DCs located in hot and dry regions require more water to maintain adequate cooling. Water use scales with the operational intensity of IT equipment and ambient environmental conditions. Water usage effectiveness (WUE) is a key metric used to evaluate water efficiency in DCs. It is calculated as the annual water consumption divided by the energy used by IT equipment. Among those operators who reported water usage effectiveness (WUE), the average was 0.31 litre per kW h for 2023, well below the CNDCP target of 0.4 l/kWh for water-stressed areas[403].

[402] ICIS Power Analytics (2025); Data centres: Hungry for power. Forecasting European power demand from data centres to 2035. Retrieved November 20, 2025 from https://www.icis.com/explore/resources/data-centres-hungry-for-power/.
[403] Michael Winterson (2025, June), "EUDCA launches its inaugural State of European Data Centres Report". . Retrieved November 20, 2025 from https://www.capacitymedia.com/article/eudca-report , https://www.linkedin.com/posts/konstruktresourcing_eudca-launches-its-inaugural-state-of-european-activity-7347882213335568385-HZac/.

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Cooling DCs using natural resources such as rivers or lakes can help reduce energy consumption, however, it requires extensive environmental impact analysis, as is the case at the Swiss National Supercomputing Centre (CSCS) mentioned in previous sections[404].

6.2.3. Material & Resource Dependencies

DCs heavily rely not only on energy and water, but also on a wide array of raw materials – especially metals and critical minerals. The construction of buildings, racks, power and cooling infrastructure involves large volumes of steel, aluminium, copper, concrete and other conventional materials[405].

Equally important, server hardware, networking gear and power equipment depend on critical minerals and raw materials used in semiconductors, circuit boards, batteries and electrical components –including silicon, copper, rare earths, lithium and others[406].

The rapid expansion of DC capacity and rise of AI/HPC workloads further amplify demand for these scarce resources. Projections suggest that DC growth could drive a measurable increase in global demand for copper, silicon, rare earth elements and other critical minerals by 2030[407].

This creates systemic dependencies and supply-chain risks: shortages, price volatility, mining constraints, or trade disruptions could affect the pace of DC expansion, especially in regions lacking diversified mineral supply or recycling infrastructure. Additionally, the generation of e-waste when equipment is decommissioned implies significant losses of embedded resources – unless effective circular-economy and recycling practices are established[408].

Therefore, sustainability assessments of DC ecosystems must include not only energy and water metrics, but also resource-use metrics and life-cycle impacts associated with materials and critical minerals.

6.2.4. Grid dependency

In 2024, DCs accounted for approximately 1.5% of global electricity consumption, according to the International Energy Agency. Electricity remains the sector's largest operational expense, the primary source of emissions, and, in many markets, it is increasingly challenging to secure at scale. Current limitations in grid access, ensuring supply stability, and enhancing operational resilience are notable concerns. Growing regulatory pressure to adopt green energy offers a practical approach to reducing costs and mitigating exposure to volatile wholesale energy prices.

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[404] CSCS (2025). Lake water to cool supercomputers. Retrieved November 20, 2025 from https://www.cscs.ch/fileadmin/user_upload/contents_publications/factsheets/lake_water/20150630_Lake_water_cool_supercomputers_EN.pdf.

[405] RICS (2023). *Data centres: the materials behind the machines.* Royal Institution of Chartered Surveyors. Retrieved November 20, 2025 from https://ww3.rics.org/uk/en/modus/natural-environment/renewables/data-centres-raw-materials.html.

[406] The Oregon Group (2024). *AI Data Centers to Drive 2% of Global Copper Demand by 2030.* Retrieved November 20, 2025 from https://theoregongroup.com/commodities/copper/ai-data-centers-to-drive-2-of-global-copper-demand-by-2030/.

[407] USGS (2023). *Key Minerals in Data Centers – Infographic.* U.S. Geological Survey. Retrieved November 20, 2025 from https://www.usgs.gov/media/images/key-minerals-data-centers-infographic.

[408] Ghinea, R. et al. (2024). *Critical raw materials in digital infrastructure and the circular economy.* OSF Preprints. Retrieved November 20, 2025 from https://osf.io/2zvkt_v1/download/.

Perger, J. et al. (2025). *Supply chain vulnerabilities for critical minerals in emerging high-density computing. Journal of Sustainable Computing.* Retrieved November 20, 2025 from https://www.sciencedirect.com/science/article/pii/S2667095X25000261.

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Grid infrastructure has become a critical factor influencing investment decisions, often outweighing other factors such as cost of land, economic incentives and attractive regulatory frameworks. Grid congestion is becoming a primary barrier in traditional DC hubs like the United Kingdom, the Netherlands, and Ireland. Only a handful of countries still offer relatively short timelines for large-scale connection[409].

It is being highlighted that grid congestion is emerging as a critical constraint for DC development across Europe. While certain regions still provide relatively short timelines for large-scale projects, traditional hubs such as the Netherlands and Germany are increasingly affected by capacity limitations[410]. Some of the challenges related to the grid faced by EU countries fare listed below

- **France** retains substantial hosting capacity in its western and northern regions (Paris, Bordeaux, Rennes, Lilles), and in southern and southern-west part (Lyon, Marseille, Toulouse) though localised congestion persists (north-west and east from Paris).
- **Belgium** experiences isolated congestion in Brussels and Antwerp, yet overall capacity remains sufficient in key industrial zones.
- **Germany** faces moderate congestion, with faster connection opportunities in southern industrial areas compared to the north.
- **Norway** offers available grid capacity, but regulatory and planning complexities hinder practical implementation.
- **The Netherlands** is actively addressing southern congestion, while northern and central regions provide greater flexibility.
- **Poland** encounters significant congestion in Warsaw and major industrial corridors, resulting in extended connection timelines.
- **Spain** suffers from severe connection queues in the south, whereas the north offers more flexibility.
- **Italy** is under rising pressure in regions such as Lombardy, although connection processes remain relatively transparent and efficient.
- **Ireland** is among the most constrained markets, with severe congestion and moratoriums on new projects, particularly in Dublin.

Renewable energy developers in Poland were lodging “fictitious reservations” for grid connection capacity without advancing or executing projects. These speculative applications clogged the grid-connection queues, blocking capacity and making it harder for serious projects to proceed. Such dummy reservations could delay or distort the allocation of network access and discourage

[409] BCG (Boston Consulting Group). (2025, January 20). Breaking barriers to data centre growth. Retrieved November 20, 2025 from https://www.bcg.com/publications/2025/breaking-barriers-data-center-growth.
Emilia Lardizabal (2025, May 27). European data centers aim to meet 75% of their energy demand with renewables this year, but face challenges. Retrieved November 20, 2025 from https://strategicenergy.eu/european-data-centre/.
Osborne Clarke (2025, September 29). Beyond the grid: how Europe's data centre sector is navigating its green energy options. Retrieved November 20, 2025 from https://www.osborneclarke.com/insights/beyond-grid-how-europes-data-centre-sector-navigating-its-green-energy-options.
[410] BCG (Boston Consulting Group). (2025, January 20). Breaking barriers to data centre growth. Retrieved November 15 from https://www.bcg.com/publications/2025/breaking-barriers-data-center-growth.

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investment in legitimate installations. To counter this, new rules are being proposed (or planned) to enforce stricter financial and procedural commitments by applicants:

- Increase in advance payment required for grid connection requests.
- Mandatory security deposit which will be tied to project milestones (i.e. to ensure commitment and progress, not just making the reservation).
- Implementation of clearer criteria and deadlines for connection offers so that non-serious or dormant applications no longer block capacity.

During the *Data Centre Nation 2025* conference, panellists mentioned that a similar fee will probably be implemented for applications for capacity for new DCs[411].

6.2.5. Renewable sourcing

There are limited methods for sourcing energy for DCs, primarily grid connection and self-consumption. Grid-based energy procurement can be achieved through several approaches: Power Purchase Agreements (PPAs), Virtual Power Purchase Agreements (vPPAs), Energy Attribute Certificates, and "Photovoltaics as a Service". A Power Purchase Agreement (PPA), often called a physical PPA, is the primary method for scaling renewable energy procurement. In a physical PPA, a renewable energy generator sells a fixed amount of electricity at an agreed price for a set term, typically 5 to 20 years, with power delivered through the grid, usually "sleeved" via a licensed supplier. Hyperscalers mainly decarbonize through green power procurement, which already accounts for 43% of clean power purchase agreements (PPAs) signed in 2024[412].

In carbon accounting practice, two complementary approaches must be distinguished in line with the GHG Protocol: the location-based method, which reflects the physical grid mix and does not account for renewable energy procurement and the market-based method, which reflects contractual instruments such as PPAs, vPPAs, GOs or green tariffs. For transparency and comparability, both methods are recommended when assessing the carbon footprint of DC electricity consumption.

The RE-Source Platform was founded in Brussels in June 2017 as an alliance of stakeholders representing clean energy buyers and suppliers. RE-Source seeks to remove barriers for corporates to renewable energy procurement in support of Europe's climate and energy goals. They are publishing annual markets updates in their web service[413].

From the online charts available on RE-Source website, it can be observed that ECN/ECS operators and ICT in Europe collectively signed more PPAs in 2024 than the heavy industry sector,

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[411] Data Center Nation 2025 conference - Warsaw EXPO XXI. Retrieved November 20, 2025 from https://datacenternation.com/dcn-warsaw-2025/agenda.
GLOBEnergia (2025, March 25), Koniec z fikcyjnymi rezerwacjami na przyłącza OZE. Rząd zapowiada nowe przepisy!'. Retrieved November 20, 2025 from https://globenergia.pl/koniec-z-fikcyjnymi-rezerwacjami-na-przylacza-oze-rzad-zapowiada-nowe-przepisy.
[412] Osborne Clarke (29th September 2025); Beyond the grid: how Europe's data centre sector is navigating its green energy options, 29th September 2025. Retrieved November 20, 2025 from https://www.osborneclarke.com/insights/beyond-grid-how-europes-data-centre-sector-navigating-its-green-energy-options.
BloombergNEF (August 26, 2025), Power Hungry Data Centers Are Driving Green Energy Demand. Retrieved November 20, 2025 from https://about.bnef.com/insights/clean-energy/power-hungry-data-centers-are-driving-green-energy-demand.
[413] RE-Source, PPA deal tracker. Retrieved November 20, 2025 from https://resource-platform.eu/buyers-toolkit2/ppa-deal-tracker/.

which ranked second. A Virtual Power Purchase Agreement (vPPA) is a contract, where the buyer agrees on a fixed strike price with a generator, and the parties settle the difference against a market index for the project's output. As vPPAs do not involve physical electricity delivery, the buyer continues to purchase electricity as usual.

In the "Photovoltaics as a Service" model or an onsite PPA, a specialist fund builds and operates the system, and the DC pays a service fee or an energy-linked tariff, sometimes with an option to purchase the asset at the end of the term. This model offers predictable costs, professional maintenance, and reduced construction risk on operational sites. Access rights, coordination of works, performance guarantees, and end-of-term options should align with DC leases and the facility's overall lifecycle.

Self-consumption involves using electricity generated by an on-site renewable installation for direct use by the DC. This approach can be appealing not only for its potential to reduce costs and carbon emissions but also for the opportunity to avoid regulatory requirements associated with exporting electricity [414].

A DC's sustainability is directly tied to the carbon intensity of the grid it draws energy from and the type of energy sources the grid includes. A facility in nuclear-heavy France or hydro/wind-rich Norway has a much lower carbon footprint than one in a country more reliant on coal or gas. During times of high demand or low renewable output, the grid relies on "peaker plants" (often natural gas) to maintain stability. DCs, with their constant load, contribute to this baseline demand, indirectly increasing reliance on fossil fuels. Nordic countries (Sweden, Norway, Finland, Denmark) offer abundant, low-cost, and low-carbon hydropower and wind energy, a cool climate reducing cooling costs, and government support.

DCs can use their large battery installations to provide services to the grid, such as frequency regulation (helping to stabilize the grid) and peak shaving (charging batteries during low demand/low-cost periods and discharging during peak hours). Google's planned Belgian DC includes on-site renewables to cover 20–30% of needs based on-site generation which could be achieved by use of solar panels, fuel cells (e.g. hydrogen), and microgrids.

DC operators are among the world's largest corporate buyers of renewable energy through Power Purchase Agreements. They sign long-term contracts with wind or solar farm developers to finance the construction of new renewable capacity, effectively adding green energy to the grid to match their consumption. Overall, Europe's DCs are pivotal in the energy transition, procuring half of corporate renewables and accelerating infrastructure like upgraded grids and storage.

The Boston Consulting Group (2025) highlights significant differences in the maturity of green Power Purchase Agreement (PPA) markets across Europe. Nordic countries, Spain, the UK, the Netherlands, and Ireland lead the way, offering flexibility and competitive pricing for industrial

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[414] Osborne Clarke (2025, September 29). Beyond the grid: how Europe's data centre sector is navigating its green energy options. Retrieved November 20, 2025 from https://www.osborneclarke.com/insights/beyond-grid-how-europes-data-centre-sector-navigating-its-green-energy-options.
BloombergNEF (August 26, 2025), Power Hungry Data Centers Are Driving Green Energy Demand. Retrieved November 20, 2025 from https://about.bnef.com/insights/clean-energy/power-hungry-data-centers-are-driving-green-energy-demand.

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users seeking low-carbon energy solutions. This leadership is reflected in contracted PPA capacity figures for 2024 – see the figure below.

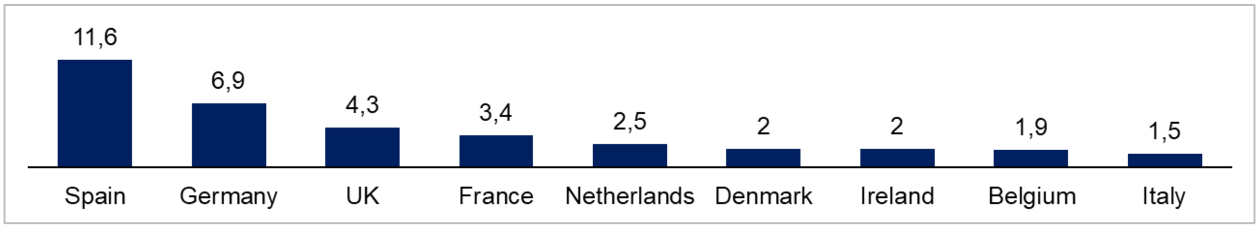

Figure 11. Contracted PPA Capacity[415].

This study identifies and sheds light on the following trends related to PPAs across Europe:

- **Spain, Norway, Denmark, Netherlands, UK, Ireland** feature mature and growing PPA markets with broad flexibility in contract structures, tenors, and pricing models. Large-scale renewables pipeline and gradual phase-out of subsidies (e.g., CfD schemes) may lead to slight PPA oversupply, driving competitive prices.
- **France** remains relatively immature, with illiquid PPA markets and regulatory complexity. Future attractiveness depends on policy continuity and access to low-carbon nuclear for industrial buyers.
- **Belgium** faces a small market and limited renewables, reducing project pool and flexibility. Buyers such as Google have secured bilateral deals, but overall market remains niche.
- **Germany** shows strong ambition with decarbonisation targets, yet high reliance on subsidies and fragmented processes lead to structural imbalances and higher PPA prices.
- **Italy** has an illiquid market with limited accessibility and complex processes for wind and solar, resulting in higher risk exposure for buyers.

Examples of implementations:

- Microsoft's agreements with Statkraft, Energia Group, and Power Capital Renewable Energy support the Government's Climate Action Plan by adding more than 900 MW of wind and solar energy to Ireland's electricity grid, enabling Microsoft's DCs to be powered by 100% renewable energy by 2025[416].
- Kao Data (UK): HVO used in all backups generators and its existing initiatives include using 100% renewable energy in line with its commitments as a signatory of the CNDCP, the use of Crown Oil HVO fuel marks another significant step in the company's plans to become a fully carbon neutral DC operator by 2030[417].

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[415] BCG (Boston Consulting Group). (2025, January 20). Breaking barriers to data centre growth. Retrieved November 20, 2025 from https://www.bcg.com/publications/2025/breaking-barriers-data-center-growth.
[416] Suzanne Sullivan (2022, November 24). Microsoft announces renewable energy contracts that contribute almost 30% of Ireland's corporate power purchase agreement target by 2030. Retrieved November 20, 2025 from https://www.powercapital.ie/solar/microsoft-announces-renewable-energy-contracts-that-contribute-almost-30-of-irelands-corporate-power-purchase-agreement-target-by-2030/.
[417] Kao Data (2021, July 19). The Road to Net Zero: : Kao Data Becomes First UK Data Centre To Transition From Diesel To Renewable HVO Fuel - Kao Data. Retrieved November 20, 2025 from https://kaodata.com/discover/news/the-road-to-net-zero-kao-data-becomes-first-uk-data-centre-to-transition-from-diesel-to-renewable-hvo-fuel.

- VIRTUS (UK) is implementing a strategy to reach net-zero emissions by 2030 through powering all ten of its sites with 100% renewable electricity sourced from wind power, secured through a PPA with Lynn and Inner Dowsing (LID) offshore windfarms[418.]
- Digital Realty: 100% renewables in Europe/U.S. operations, achieving 1 GW sustainable IT capacity, in 2023 has achieved a 100% renewable energy coverage. And, in France, its portfolio is carbon neutral[419.]
- Greenergy DCs (Estonia): DC powered by Baltic renewables and using certified renewable energy with PPA option (Power Purchase Agreement)[420.]

6.3. Existing environmental regulations

The construction of DCs is subject to all local regulations related to building codes, environmental requirements, and connections to electrical, water, and sewage networks; however, due to their significant energy consumption, new regulations are emerging that must be considered during their operation. Existing environmental regulations for DCs in Europe are shaped by several recent EU directives and frameworks focused on energy efficiency, climate neutrality, and broad sustainability targets. These rules mandate strict reporting, energy performance, and resource management requirements for both new and existing facilities. Since January 2025, all European DCs must measure and report their Power Usage Effectiveness (PUE), according to the updated Energy Efficiency Directive (EED). Operators with at least 500 kW installed IT power must submit annual reports on numerous Key Performance Indicators (KPIs), including energy and water usage, renewable energy sourcing, temperature set points, and waste heat utilization. The CNDCP commits DCs operators to PUE 1.3 (cool climates) / 1.4 (warm) for new builds by 2025 (existing by 2030) and 75% CFE/renewables by 2025, 100% by 2030[421]. France has introduced sector-specific obligations (reporting, energy & water info) and tighter rules for large installations, e.g. obligations to report energy performance for DCs above capacity thresholds and (for new/renovated sites above a threshold) obligations around waste-heat reuse where feasible[422.]

Major EU-level rules that affect DCs:

- **Recast Energy Efficiency Directive (EED):** Mandatory energy reporting & KPIs. The 2023/2024 recast of the EED introduces a specific obligation for monitoring and reporting the energy performance of DCs. Operators of DCs above defined thresholds must report key performance indicators into an EU database; a delegated regulation (setting KPIs and reporting detail) was adopted to implement the scheme. EED mandates annual reporting for DCs ≥500 kW to an EU database (first deadline 15 Sep 2024; then each 15 May). It is

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418 Inspired (2025, September 2). Inspired Drives VIRTUS's Net Zero Ambitions with Wind-Powered Tri-Party CPPA. Retrieved November 20, 2025 from https://inspiredplc.co.uk/insights/industry-news/inspired-news/inspired-drives-virtus-net-zero-ambitions-with-wind-powered-tri-party-cppa/.
419 Josephine Walbank (2022, July 04). Digital Realty reaches 1GW of certified sustainable capacity. Retrieved November 20, 2025 from https://datacentremagazine.com/articles/digital-realty-reaches-1gw-of-certified-sustainable-capacity.
420 Greenergy Data Centers, (2020). Retrieved November 20, 2025 from https://www.greenergydatacenters.com/about.
421 Climate Neutral Data Centre Pact (2025). Homepage and Certification Framework for Climate-Neutral Data Centres in Europe. Retrieved November 20, 2025 from https://www.climateneutraldatacentre.net/.
422 APL Data Centre (2023, September 22). "Overview of French Sustainable IT Regulations". Retrieved November 20, 2025 from https://www.apl-datacenter.com/en/overview-of-french-sustainable-it-regulations/.

expected that public KPIs on PUE, WUE, energy reuse (ERF), renewable factor (REF) will become the norm.

- **EU delegated regulation / sustainability-rating scheme for DCs:** The Commission adopted delegated rules establishing an EU-wide sustainability rating scheme (first phase rules and KPI reporting deadlines were published in 2024). These rules operationalise the EED reporting and create standardized metrics for energy/water footprint and sustainability performance.
- **F-gas Regulation (refrigerants): phase-outs and restrictions for cooling systems.** EU F-gas rules progressively restrict high-GWP refrigerants and impose controls on leakage, servicing and use of certain refrigerants – this directly affects DC cooling technology choices and replacement/retrofit planning. Industry guidance highlights the need to redesign cooling systems and move to lower-GWP/alternative cooling. Key aspects include a more stringent F-gas phase-down leading to a total ban by 2050.
- **Waste & hazardous-substances rules (WEEE, RoHS):** Servers, network equipment/hardware, UPSs and other electrical devices used in DCs fall under the EU WEEE (waste-electrical-and-electronic-equipment) rules (collection, take-back, recycling) and RoHS restrictions on hazardous substances. These set obligations for decommissioning equipment, packaging reduction/ reuse, producers/ importers and for treatment/ recycling.
- **EU Taxonomy, Sustainable Finance Disclosure Regulation (SFDR) and Corporate Sustainability Reporting (CSRD):** The EU Taxonomy defines environmental screening criteria that affect whether DC investments can be labelled "sustainable" and so eligible for certain finance flows. The CSRD will force companies to publish mandatory climate/sustainability reporting and scope-based emissions and sustainability info, increasing pressure on DC owners/operators to disclose environmental performance. CSRD and SFDR utilize the EU Taxonomy as a classification of sustainable activities and promote consistency within the European Green Deal. They enhance transparency for stakeholders (investors, consumers), enabling better ESG risk assessments. Companies reporting under CSRD facilitate financial institutions' compliance with SFDR, reducing duplication in data collection.

Other EU-level regulations that could impact DCs:

- **EU Emissions Trading System (ETS), ESR, LULUCF:** DCs are not directly a large industrial ETS sector today and the sector of the carbon pricing for power/industry/aviation is not directly impacting DC. It may, however, change in future.
- **Renewable Energy Directive (RED III)**: Adopted in October 2023 and entered into force in November 2023, is an EU directive that sets a legally binding target for the EU to consume at least 42.5% of its energy from renewable sources by 2030, with an additional aspirational goal of 2.5% more. It is a significant update to the previous directive, part of the "Fit for 55" package, aimed at accelerating the green transition and energy independence by boosting renewable energy deployment, promoting hydrogen, and setting sectoral targets for transport, industry, and buildings.

- **Energy Performance of Buildings Directive (recast 2024)**: Tighter building efficiency/renovation rules may affect old DC's buildings.
- **Electricity Market Design reform (2024)**: Measures include improving the integration of forward markets and enhancing solutions for system flexibility, such as demand response and storage. The reform supports the deployment of RES by enabling long-term investment incentives through mechanisms like power purchase agreements (PPAs) and contracts for difference (CfDs).
- **The Batteries Regulation (EU) 2023/1542** is an EU law that replaces the previous directive, setting new rules for the entire lifecycle of all batteries from 2023 to 2030. It mandates a low carbon footprint, durability, safety, recycled material content, and responsible sourcing for batteries. Key requirements include CE marking, improved collection and recycling, and the introduction of a "battery passport" for certain battery types[423.]
- **The Eco-design for Sustainable Products Regulation (ESPR)** is an EU framework that came into force on July 18, 2024, to make the EU market the norm for environmentally sustainable products and to promote circular economy principles across a wide range of goods. It expands upon the previous Eco-design Directive, establishing eco-design requirements for product durability, repairability, recycled content, and sustainability information through measures like the Digital Product Passport.
- **The Industrial Emissions Directive (IED)** is the main EU legislation for preventing and reducing industrial pollution to protect human health and the environment. It requires large industrial and intensive livestock installations to obtain permits based on Best Available Techniques (BAT), covering a wide range of environmental impacts including air and water emissions, waste generation, and energy use. The IED was recently revised and is now known as the Industrial and Livestock Rearing Emissions Directive.

6.4. Best practices for sustainable DC operations

DCs in Europe consume approximately 2-3% of the continent's electricity. This is projected to rise significantly by 2030-2035 due to AI and cloud growth, making sustainability critical. The EU's regulations enforce rigorous standards. Sustainable practices focus on certifications and align with EU regulations like , EU Green Deal, Digital Infrastructure Strategy, Energy Performance of Buildings Directive and others.

Among project survey's respondents declaring sustainability-oriented initiatives, 40% reported active participation in energy-management or certification programmes, while 30% stated plans to increase investment in renewable sourcing within the next 2–3 years. The majority cite cooling optimisation, energy audits and modernisation of UPS systems as primary means of improving efficiency.

[423] Flash Battery Blog (2025, May 14). "From production to recycling: a comprehensive guide to the new European Battery Regulation 2023/1542". Retrieved November 20, 2025 from https://www.flashbattery.tech/en/blog/eu-battery-regulation-obligations-updates/.

Sustainable development of DCs should be pursued in the following areas: renewable energy (CUE <1.25), waste heat reuse, top-tier PUE (achieving PUE <1.2 at least), and reduced consumption of water (WUE <0.2 L/kWh) and other resources. Comply with CSRD: Report under the EU Corporate Sustainability Reporting Directive (CSRD), covering: Energy use (kWh), carbon emissions (Scope 1, 2, 3), water consumption, waste, and circularity metrics.

Leading countries for DCs location include Sweden, Finland, Denmark (cold climates for free cooling), the Netherlands (heat reuse), and Ireland (renewables: wind and solar energy through PPAs).

Table 8. Key best practices by category.

Category	Best Practices[424]	Europe-Specific Tips	Metrics/Targets
Energy Efficiency	- Deploy AI/ML for real-time optimization of workload, cooling, and power (e.g. AI-driven cooling optimisation can lower energy comsumption while not affecting computing performance). - Use hyperscale designs with modular, scalable infrastructure. - Virtualization and containerization to maximize server utilisation (>70%) - High-voltage DC distribution to cut losses.	- Comply with EU EED Article 8 audits. - Leverage RE100 commitment for 100% renewables. - Tap into EU ETS for carbon credits.	- target PUE: <1.2 (best-in-class <1.1). - Renewable energy: 100% by 2030.
Renewable Energy Sourcing	- Long-term PPAs with wind/solar farms. - On-site solar PV and battery storage. - Green hydrogen HVO for backup power. - Hourly matching of consumption to renewables av (following EU's Climate Neutral DC pact assumptions).	- Use Guarantees of Origin (GOs) for proof. - Nordic hydro/wind abundance; German EEG subsidies. - Avoid fossil backups; transition to biofuels.	- track carbon intensity - 24/7 carbon-free energy.
Cooling Innovations	- Free air cooling (>80% annual uptime in cold climates <10ºC and -20°C ambient). - Direct-to-chip/immersion liquid cooling. - Adiabatic/evaporative cooling with recycled water. - Heat pumps for efficiency	- exploit Nordic/Atlantic climates - EU-funded projects like CoolDC for subsea cooling.	- track carbon intensity - Free cooling hours: >7,000/year.

[424] European Commission, Joint Research Centre, Acton, M., Bertoldi, P., & Booth, J. (2024). *2024 best practice guidelines for the EU Code of Conduct on data centre energy efficiency* (JRC136986) [Report]. European Commission. Retrieved October 21, 2025, from https://e3p.jrc.ec.europa.eu/publications/2024-best-practice-guidelines-eu-code-conduct-data-centre-energy-efficiency;

	- High efficiency pumps.		
Waste Heat Recovery	- Integrate with district heating networks - Aquifer thermal energy storage (ATES). - Greenhouse/agriculture heating.	- Follow examples of Stockholm Data Parks, Poznań City and Beyond DC cooperation as well as Tier-4 DCs in Berlin that supply heat to 50,000 residents. - EU Heat Roadmap 2050 targets 50% reuse from industry not only DCs.	- Avoided CO2: >1M tons/year per large DC.[425]
Water Stewardship	- Air-cooled systems or closed-loop circuits. - Rainwater harvesting and greywater reuse. - Dry cooling towers. - Monitor WUE rigorously.	- Scarce water regions (e.g., Spain, Italy) prioritize dry cooling. - Align with EU Water Framework Directive.	- target WUE: <0.2 L/kWh. - Zero discharge.
Hardware & Circular Economy	- Procure energy-efficient chips (e.g., ARM-based). - Modular designs for easy upgrades. - Reuse/refurbish servers (extend life 2-3x). - E-waste recycling partnerships.	- EU Ecodesign Directive for servers. - Right to Repair laws. - Circular hubs in Netherlands/Belgium.	- EER: >3 (Energy Efficiency Ratio). - 80% hardware reuse rate.
Monitoring & Governance	- DCIM tools with ESG dashboards. - Blockchain for supply chain transparency. - Annual sustainability reports. - Employee training on green ops.	- CSRD-mandated Scope 3 reporting from 2024. - EU Data Governance Act for data sharing. - Collaborate via EUDCA (European Data Centre Association).	- 100% auditable data. - Net-zero target by 2030.

To ensure the sustainable development of DCs, the incorporation of Direct Liquid Cooling (DLC) systems is essential.

Based on interviews conducted, important area of constraint of DCs' development is related to the technological limits of current cooling solutions when faced with increasing IT power density. Multiple organizations confirmed that traditional cooling capabilities fundamentally limit the power capacity that can be housed. DC operators expressly stated they cannot support AI customers requiring very high densities (e.g. 80 to 100 kilowatts per rack), defining these requirements as "*insane*" given existing capabilities. This constraint is particularly severe for flexible or mobile solutions; installations exceeding 15–20 kilowatts per cabinet are deemed "*impossible to cool in a container*". Looking toward the future, the power density required by emerging IT equipment (up

[425] How Data Centre Waste Heat can Boost Sustainability. Retrieved October 28, 2025, from https://www.digitalrealty.co.uk/resources/articles/how-data-centre-waste-heat-can-boost-sustainability.

to 120–150 kilowatts per single cabinet) means that such loads will "*only be possible through liquid cooling*".

Table 9. Recommendations for key stakeholders. Sources: Developed by authors drawing on George Kamiya, Vlad C. Coroamă[426].

Stakeholder	Best Practice (Do)	Poor Practice (Don't)
DC modellers	• Use bottom-up modelling approaches and granular data, combined with other modelling perspectives to triangulate results • Explain methodology and cite sources comprehensively and transparently • Report results precisely and transparently, ideally in a table format • Develop "what if?" scenarios and sensitivity analyses to explore uncertainties • Analyse the whole system • Advocate for policies that promote data collection and transparency regarding energy use of DCs to improve research quality • Consider economic, technological, societal, and other practical constraints	• Combine retrospective intensity parameters (e.g., energy intensity of DC IP traffic) with projected future service demand to project future energy demand • Average key parameters • Extrapolate results more than 5 years from baseline without using expert judgment or compound annual growth rates • Cite sources of key results or analysis as "Company X analysis or model"
DC companies	• Increase reporting frequency, timeliness, and detail (at minimum, total energy use of DCs; ideally at the DC level) • Disclose energy data transparently and consistently, e.g., in a table format with clear definitions • Support policies that promote data collection and transparency to support policy and strategic discussions	• Fail to disclose any energy or environmental data • Hide or obscure key energy data (e.g., company-wide energy use)
Policymakers and regulators	• Implement policies and regulations that require DC operators to disclose energy use • Collect, validate, and publish national and regional data regarding DC energy consumption • Base policy decisions on multiple credible sources	• Base policymaking on sources developed by those with limited domain expertise or conflicts of interest
Journalists	• Avoid cherry-picking the most extreme scenarios • Provide context for readers, including key uncertainties and differences between local and global impacts	• Cherry-pick the most extreme scenario results to overplay the energy and environmental impact of DCs

[426] Koomey, J., & Masanet, E. (2021). Does not compute: Avoiding pitfalls assessing the Internet's energy and carbon impacts. Joule, 5(7), 1625–1628. Retrieved October 28, 2025, from https://doi.org/10.1016/j.joule.2021.05.007;
George Kamiya, Vlad C. Coroamă, IEA 4E, (March 2025); "Data Centre Energy Use: Critical Review of Models and Results". Retrieved October 28, 2025, from https://www.iea-4e.org/wp-content/uploads/2025/05/Data-Centre-Energy-Use-Critical-Review-of-Models-and-Results.pdf;
Masanet, E., Lei, N., & Koomey, J. (2024). To better understand AI's growing energy use, analysts need a data revolution. Joule, 8(9), 2427–2436. Retrieved October 28, 2025, from https://doi.org/10.1016/j.joule.2024.07.018.

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	• Critically assess the quality of studies and speak to multiple experts to understand the quality of new research	
Civil society	• Advocate for policies that promote data collection and transparency regarding the energy use of DCs	• Develop or amplify poor quality analysis or extreme results to support positions

6.4.1. Circular economy – circularity

Circularity in DCs refers to a sustainable life cycle approach that prioritizes reuse, repair, and recycling of servers, electrical equipment, and related components to minimize waste, reduce environmental impact, and optimize resource use. DCs should shift from "take-make-waste" to "reduce-reuse-recycle-recover." By adopting modular design, energy efficiency, material recovery, and as-a-service models, DCs can cut costs, reduce environmental impact, and future-proof operations in a resource-constrained world. This aligns with the EU's push for a circular economy, aiming to decouple economic growth from resource consumption while meeting stringent climate goals, such as carbon neutrality by 2050 under the EU Green Deal. The CNDCP, a self-regulatory initiative, plays a key role by setting ambitious targets for operators to enhance sustainability. The CNDCP, signed by major operators and trade associations, commits DCs to climate neutrality by 2030. A core pillar is circularity, with a specific mandate that operators must assess 100% of their used server equipment for reuse, repair, or recycling. This involves:

- Reuse: Extending the life of functional servers or components by redeploying them within the same or other facilities.
- Repair: Refurbishing faulty equipment to restore functionality, reducing the need for new production.
- Recycling: Breaking down non-reusable components into raw materials for new products, ensuring minimal landfill waste.

This requirement applies to servers, storage devices, networking equipment, and related infrastructure like cooling systems or power supplies. Operators must track and report progress, with compliance integrated into broader EU regulations like the Energy Efficiency Directive (EED), which mandates sustainability reporting for DCs above 500 kW.

The "6R principles" are an extended concept of sustainable development and the circular economy, aiming to minimize environmental impact through responsible production, consumption, and waste management. While not legally binding acts, they serve as guidelines for EU projects and are increasingly becoming requirements, especially in programs supporting innovation and sustainable development. The European Commission plays a key role in promoting these principles through regulations and project evaluation criteria, stemming from initiatives like the Circular Economy Action Plan and the European Green Deal. In the context of environmental sustainability and energy consumption for DCs, the 6R principles are applied as follows:

1. **Rethink:**

- Definition: This principle encourages reflection on the necessity of purchasing or using a product, designing processes and products to minimize their environmental impact, and planning actions with consideration for the full product lifecycle.
- DC Context: For DCs, "Rethink" involves designing systems from the ground up to be sustainable, for instance, by considering modular design, sustainable architecture, and optimal geographical siting to leverage natural conditions. It also means proactively choosing low-GWP refrigerants in cooling systems and planning for energy-efficient IT infrastructure and operations from the outset. This underpins the broader shift towards sustainable cloud and edge architectures.

2. **Refuse:**
   - Definition: This means avoiding products, materials, or processes that generate waste or have a negative environmental impact. It involves rejecting items unsuitable for reuse, repair, or recycling, or those with known negative environmental or health impacts.
   - DC Context: DCs can apply this by refusing to use high-Global Warming Potential (GWP) refrigerants like R-410A in favour of alternatives such as propane (R-290). It also translates to prioritizing suppliers who adhere to ecological standards and use renewable energy sources, thereby refusing reliance on fossil fuels. The EU F-Gas Regulation explicitly drives this by phasing down HFCs and banning high-GWP refrigerants in new equipment.

3. **Reduce:**
   - Definition: This principle focuses on minimizing the consumption of resources such as energy, water, and materials to reduce waste and the ecological footprint.
   - DC Context: This is a critical area for DCs, directly impacting energy and water consumption:
     - Energy Efficiency: Key metrics include Power Usage Effectiveness (PUE), where a lower value (e.g., 1.2 instead of 1.8) indicates significant energy reduction. Advanced cooling technologies like Direct Liquid Cooling (DLC), free cooling systems (utilizing natural cool air or water like lakes or sea water), direct-to-chip cooling, immersion cooling, and rear-door heat exchangers are widely adopted to enhance thermal management and reduce energy waste. AI is increasingly used for energy optimization, adjusting cooling systems based on predictive workload demands and optimizing server workloads to minimize idle energy use.
     - Water Efficiency: Water Usage Effectiveness (WUE) measures water consumption per kWh of IT energy. DCs are moving towards waterless cooling technologies, closed-loop liquid cooling, and air-cooled systems optimized for dry climates to reduce high water usage.
     - Emissions: Reducing energy and water consumption directly leads to a reduction in CO_2 emissions and the overall carbon footprint.

- Regulation: The EU Energy Efficiency Directive (EED) mandates annual reporting of energy performance data, including PUE, WUE, and Energy Reuse Factor (ERF), for DCs with an IT power demand of 500 kW or more. National transpositions, like Germany's Energy Efficiency Act (EnEfG), set specific PUE targets (e.g., PUE ≤ 1.2 for new DCs commissioned from July 1, 2026) and require 100% renewable energy by 2027. PSNC, for example, has achieved a PUE of 1.09 for its liquid-cooled HPC systems and conducts research into energy-efficient ICT.

4. **Reuse:**
   - Definition: This principle promotes the repeated use of products or their components to extend their lifecycle and delay the moment they become waste.
   - DC Context: DCs can implement reuse strategies by repurposing older servers for less demanding computations instead of discarding them. This includes reusing servers, racks, and components like disks and RAM after upgrades or in other locations. Key Performance Indicators (KPIs) for this include the percentage of reused equipment and the average lifespan of components. Companies like Orange manage circular economy programs (e.g., OSCAR) that favour the reuse of network equipment across their subsidiaries.

5. **Recycle:**
   - Definition: This involves processing waste to reuse materials in new products, thereby reducing the demand for primary raw materials.
   - DC Context: DCs generate significant electronic waste. Recycling efforts involve processing decommissioned IT components (servers, cables, batteries) to recover valuable materials like rare metals. Compliance with regulations like the EU WEEE (Waste Electrical and Electronic Equipment) directive is crucial. Google, for instance, has reported recycling 90% of its retired equipment, and companies like BT are recovering copper from old cables. KPIs include the percentage of recycled equipment and the weight of recycled materials. The F-Gas Regulation also mandates the recovery of refrigerants at the end of equipment life, ensuring they are recycled or destroyed.

6. **Recover/Repair:**
   - Definition: Refers to repairing products instead of discarding and replacing them to extend their lifespan. In a broader sense for DCs, it can also refer to the recovery of energy.
   - DC Context: Beyond just repairing equipment, "Recover" in DCs strongly emphasizes waste heat recovery. DCs, especially those with a total rated power exceeding 1 MW, are encouraged – and in some national legislation, like Germany's EnEfG, required – to utilize waste heat for heating buildings or other energy recovery applications. PCSS, for example, reuses heat from its DC to warm laboratory and office buildings. The F-

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Gas Regulation also necessitates the recovery of refrigerants to prevent their release into the atmosphere.

These principles collectively aim to integrate environmental responsibility into the entire operational framework of DCs, aligning with the EU's broader climate goals and digital strategies.

Based on conducted interviews the application of the "6R" principles is widespread across DC operations, although a statistically significant majority of operators interviewed were unfamiliar with the formal 6R terminology. Despite this lack of formal recognition, every responding organization detailed operational practices that directly align with one or more of the "R" principles, often viewing them as intrinsic to efficient business practice, cost optimization, or regulatory compliance.

6.4.2. Energy efficiency

Energy efficiency can be enhanced through various optimizations in key areas of power supply, cooling, and DC operations. One has to remember that striving for better energy efficiency may result in actions that are in direct opposition to some of the 6R principles, especially the "reuse". Re-using some of the IT equipment, components that are evolving rapidly (compute servers with or without GPU accelerators) may result in huge benefits in terms of energy to work ratio (e.g. joules for FLOP or joules for token) however it may cause additional burden on the environmental metrics as the life span of computer hardware generation is significantly shorten.

Metrics and measurement

Effective energy management begins with consistent measurement using established metric Power Usage Effectiveness (PUE). The methodologies to determine (measure PUE) as well as CNDCP target for efficiency of DCs have been discussed in previous sections.

The EU Code of Conduct best practices consist of more than one hundred possible areas of improvement which not only need to be checked but it must also be supported by evidence. DCs largely comply with the EU Code of Conduct, as it is in their interest to achieve a low Power Usage Effectiveness (PUE), which reduces operational costs by lowering energy consumption[427].

As stated earlier, energy efficiency should be assessed holistically, taking into account the interdependencies among metrics such as PUE, WUE (Water Usage Effectiveness), ERF (Energy Reuse Factor), and REF (Renewable Energy Factor), as well as the geographical location of the DC. Optimizing PUE alone, for example, could inadvertently increase water consumption, thus worsening WUE.

The two ISO standards, ISO/IEC 30134 and ISO 50001, define KPI metrics that can be used by DCs. ISO/IEC 30134 provides a range of Key Performance Indicators (KPIs) for both the DC as well as the customer IT equipment. Objectives of the ISO/IEC 30134 include:

- Minimization of the energy and other resource consumption

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[427] Uptime Institute. (2024). Global data center survey 2024 – workforce & infrastructure trends [Report]. Uptime Institute Intelligence. Retrieved October 28, 2025, from https://datacenter.uptimeinstitute.com/rs/711-RIA-145/images/2024.GlobalDataCenterSurvey.Report.pdf.

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- Maximalization of the customer IT task effectiveness within the DC
- Energy re-use in the form of waste heat
- Use of renewable energy

The ISO/IEC 30134 KPIs apply to all DCs and are both technology- and geography-neutral. ISO/IEC 30314 currently covers the following standards:

Table 10. Standards currently covered by ISO/IEC 30314.

Metric	Standard
Overview and general requirements	ISO/IEC 30134-1:2016
PUE (Power Usage Effectiveness)	ISO/IEC 30134-2:2016
REF (Renewable Energy Factor)	ISO/IEC 30134-3:2016
ITEEsv (IT Equipment Energy Efficiency)	ISO/IEC 30134-4:2017
ITEUsv (IT Equipment Utilization)	ISO/IEC 30134-5:2017
ERF (Energy Reuse Factor)	ISO/IEC 30134-6:2021
CER (Cooling Efficiency Ratio)	ISO/IEC 30134-7:2023
CUE (Carbon Usage Effectiveness)	ISO/IEC 30134-8:2022
WUE (Water Usage Effectiveness)	ISO/IEC 30134-9:2022

ISO 50001 is an energy management system and implementation of ISO 50001 in DCs results in:

- Creating awareness for energy efficiency
- Unified structure of measurement and reporting on energy PUE
- Continuous improvement on PUE setting PUE targets
- Regular energy audits
- Identification of significant energy users/components
- Majority of the DC organizations report the PUE in their annual sustainability reports which has a competitive component
- Regulatory compliance

Advanced cooling technologies

Efficient DC cooling is essential for sustainability and performance in the digital age. Cooling systems are a major component of energy consumption, often accounting for 50% to 80% (sometimes more for small DCs) of total energy usage – PUE > 1,5. Cooling can account for 30–40% of a facility's total energy consumption so targeted AI-driven optimisations can lead to lower operational costs and help businesses meet energy targets – all without compromising essential computing performance.

Due to increasing power usage by DCs and power densities in rack, particularly from AI workloads, advanced cooling techniques are becoming essential components for efficiency. Direct-to-Chip

Cooling (Direct Liquid Cooling) is intended to lead adoption, increasing thermal efficiency and minimizing power loss by cooling components. The other method: immersion cooling effectively addresses the thermal demands of high-performance computing environments. Co-designed by Dell, Intel and the University of Cambridge, Dawn achieved an impressive Power Usage Effectiveness (PUE) of 1.14.

Individual server racks are where air as a coolant hits its limits; new types of temperature control will become necessary. For traditional air-cooling methods, effective airflow management is critical. Proper air management prevents 'hot spots' by implementing hot/cold aisle containment systems and sealing openings in the raised floor to minimize cold air leakage and enhance cooling efficiency. This technique enables DCs to operate at higher temperatures, aligning with modern ASHRAE thermal guidelines (e.g., A3 up to 40°C), thereby reducing cooling costs. For example, Equinix operates its facilities at around 27°C to optimize energy efficiency. Another technique involves using ambient outdoor conditions (air or water) to cool the DC, thus reducing the reliance on energy-intensive mechanical air conditioning or chillers.

The new regulations require improved efficiency for all cooling system components, such as pumps, dry coolers, and chillers. However, these directives can sometimes be ineffective due to increased costs, larger device sizes, or complex solutions, where improving one parameter often leads to the deterioration of another. Replacing one coolant by other to follow the F-Gas regulations requires to increase the size of heat exchanger or dry cooler because of the physical requirements to achieve the same cooling parameters. Coolants that "meet" F-Gas regulations are those with low GWP (typically under 150 for many new systems from 2025 onward) or non-F-gases (natural refrigerants are not subject to the phase-down). High-GWP F-gases can still be used in existing systems or with exemptions, but new installations favour compliant options to avoid bans and quotas.

The pumping system offers the greatest potential for savings within the entire cooling system. To assess the performance (output capacity) and efficiency (energy utilization) of pumps driven by electric motors, standardized indicators are used according to ISO 9906, IEC 60034-30, and ErP Directive 2015. The primary indicator is η (Overall Efficiency), supplemented by key performance metrics. IE4/IE5 refers to the highest efficiency class η > 90. The IE5 is known as "Ultra-Premium Efficiency". While IE5 is not yet a mandatory EU regulation for all motors, some manufacturers are already producing IE5-compliant motors that offer significant energy loss reductions compared to the current minimum standard of IE3. Regulations for IE4 and IE3 are already in effect in the EU, with ongoing discussions and developments to potentially incorporate IE5 standards in the future. Motors that meet IE5 standards offer benefits such as reduced energy consumption, lower CO2 emissions, and increased reliability.

Chillers with turbocor technology currently provide the highest performance and efficient low temperature cooling used by CRAC (computer room air handler), which can only be surpassed by high-temperature DLC systems based on open loop liquid cooling. Developing a DC cooling system design, while adhering to applicable standards for equipment and refrigerants, requires in-depth knowledge of regulations, standards, and guidelines for energy-efficient DC design.

Power infrastructure optimization

Efficiency measures related to power supply and distribution equipment are crucial to limit energy losses and overhead. There are several methods to improve efficiency.

DCs should select transformers, whose point of maximum efficiency lies close to the typical operating load, minimizing energy losses (heat) and reducing incremental cooling costs.

Rack Power Distribution Units (PDUs) and other power equipment should be designed to operate in high-temperature environments and be compatible with hot/cold aisle containment systems. It is recommended that new rack PDU products are designed with a maximum ambient air temperature rating of at least 60°C.

DCs using VRLA batteries with UPS systems should maintain them as close as possible to the ideal temperature of 25°C to ensure reliability, as temperatures above 27°C may reduce battery lifespan.

Operational management and digital tools

Harnessing software and advanced algorithms for facility management provide immediate operational efficiency gains. Integrating monitoring data (e.g., from intelligent rack PDUs) with DCIM (Data Centre Infrastructure Management) software helps controlling the DC temperature and manage power consumption more efficiently.

Utilizing machine learning algorithms to monitor, analyse, and optimize power and cooling operations in real-time proves to be very effective. Companies using AI have successfully reduced energy use for cooling by up to 40%. Increased facility efficiency is the top perceived benefit of using AI in DC operations (89%).

Several tech giants and innovative firms have leveraged AI and machine learning to optimize cooling systems in DCs, where cooling often accounts for 30-40% of total energy consumption. These efforts focus on predictive modelling, real-time adjustments to HVAC systems, and integration with hardware innovations[428].

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[428] NODA Intelligence, NODA Insight "Smart Summer: Using AI to Manage Peak Cooling Loads and Reduce Energy Costs". Retrieved November 20, 2025 from https://noda.ai/insights/smart-summer-using-ai-to-manage-peak-cooling-loads-and-reduce-energy-costs.
Siemens AG, "Cooling in data centers". Retrieved November 20, 2025 from https://www.siemens.com/global/en/industries/data-centers/services/thermal-optimization.html;
Ember Energy. (2025, May 27). Chapter 2: Greening data centres. In Ember Energy Report 2024. Retrieved November 20, 2025 from https://ember-energy.org/chapter/greening-data-centres;
Arun Poojari Univers, "Age-Old Systems, Smart New Solutions: How AI Is Transforming Buildings". Retrieved November 20, 2025 from https://univers.com/articles/age-old-systems-smart-new-solutions-how-ai-is-transforming-buildings/;
Schneider Electric, Ali Haj Fraj (2024, November 29) "Industrial artificial intelligence: Optimizing energy efficiency with Predictive AI". Retrieved November 20, 2025 from https://blog.se.com/industry/2024/11/29/what-is-predictive-ai.

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Water usage

Water usage management begins with consistent measurement using established metrics such as Water Efficiency and Conservation (WUE), aiming to minimise water consumption, especially in water-stressed areas.

Practices include using waterless cooling technologies, closed-loop liquid cooling, and utilising non-potable water sources where technically feasible and safe. The amount of water consumed can be reduced through investments in new dry cooler infrastructure, where increasing the heat exchange surface makes it possible to lower the temperature of the cooling medium used in the server room. However, such modernisation requires significant capital investment and the availability of space needed to install larger equipment.

Using water is a technique that, when employing smaller and thus cheaper devices, allows achieving a lower temperature. Another method involves redesigning the server room so that it operates with higher air temperature parameters in the room or in the DLC circuit. Cooling DCs with lakes or rivers can be used, but it requires studies of the impact of returned water on the environment.

Impact on water

DSs have impact on water pollution and broader water impacts, encompassing not only potential chemical contamination but also wider impacts of DC operations on water temperature, ecological conditions, and the availability and resilience of local water resources. In the context of DCs, water pollution therefore includes all mechanisms through which cooling processes, wastewater discharge, or high-volume water usage may affect aquatic ecosystems or local water infrastructure.

DCs that use water-based cooling systems can influence local water bodies through thermal pollution. A portion of cooling water is discharged as heated effluent, which even when temperature increases are slight reduce dissolved oxygen levels and place stress on aquatic organisms. Some facilities avoid direct discharge into rivers or lakes by using evaporative cooling or by sending wastewater to municipal treatment systems. However, thermal impacts remain an environmental concern, and EU regulations explicitly prohibit deterioration of water bodies' ecological status. Waste heat recovery solutions show how redirecting heat into district heating networks can eliminate thermal discharges entirely, preventing temperature-related impacts on surrounding water ecosystems.

Another dimension concerns chemical pollution risks. Water used in cooling loops typically contains treatment chemicals, including biocides, anti-scaling agents, and anticorrosion compounds. When cooling systems undergo periodic blowdown or maintenance, this water, if inadequately treated, may contaminate local soil or water sources. While most European DCs discharge into municipal wastewater treatment plants capable of removing or neutralising these substances, large discharge volumes during peak operating periods can strain existing treatment capacity.

Beyond direct pollutants, DCs may indirectly impact water quality by affecting water availability and the resilience of water infrastructure. High-volume water withdrawals and wastewater discharges can stress municipal networks, particularly in regions already operating near their sustainable limits. In Dublin, for example, the water supply system is described as being under chronic capacity stress, meaning that additional demand or discharge from DCs during dry periods may reduce water availability for communities and ecosystems, indirectly compromising water quality and environmental stability.

Together, these effects: thermal changes, chemical hazards, and pressure on water availability shape the broader impact of DSs on water systems. Regulatory frameworks such as the EU Water Framework Directive require operators to demonstrate that their water practices do not degrade water bodies. As a result, advanced mitigation strategies, including closed loop cooling, heat reuse, reliance on non-potable or reclaimed water sources, and minimising blowdown discharge, are increasingly adopted to reduce both pollution and wider water impacts.

ECN infrastructure planning for energy-efficient DC expansion

As highlighted throughout this report's analysis of DC siting dependencies, power availability and network proximity, ECN and DC infrastructure are increasingly co-dependent. Therefore, aligning ECN planning with energy-efficient DC expansion can reduce both total system energy use and the cost of meeting Digital Decade targets[429].

As stated in the document, the energy consumption profile of a DC is a sum of IT related consumption and overheads from accompanying infrastructure. Energy efficiency is heavily dependent on the efficacy of its cooling systems, a factor that is directly influenced by the local climate. In colder climates, the ambient air temperature is significantly lower, which makes it easier to cool down servers without the need for high-power, compressor-based air conditioning units. This enables the use of "free cooling" techniques – such as direct or indirect airside and water-side economisers – that dramatically reduce the PUE and the associated cooling power expenditure.

This advantage can be further amplified by strategically locating in cold climate areas close to places where their waste heat can be utilised. DCs convert nearly all of their input electrical energy into heat. In many regions, this heat is simply exhausted into the atmosphere, representing a significant loss. By integrating the DC into a district heating network, local greenhouses, or industrial processes (such as aquaculture), the thermal energy can be captured and repurposed. This concept transforms the DC from a net energy consumer into a beneficial component of the local energy ecosystem, thereby significantly increasing the total system energy efficiency and circularity.

The ability to build or expand energy-efficient DCs, particularly those leveraging cold climates for "free cooling" and integrated waste heat recovery, is fundamentally contingent upon the prior availability of robust ECN services and infrastructure.

[429] European Commission. (2025). State of Digital Decade 2025: Keep building the EU's sovereignty and digital future. Retrieved 23 November, 2025 from https://digital-strategy.ec.europa.eu/en/library/state-digital-decade-2025-report.

As established, a key dependency for viable DC siting is access to high-capacity fibre and diverse long-haul routes. This is especially critical for DCs located outside traditional urban hubs, such as those strategically placed in Nordic regions to maximise climate-based energy savings and waste heat utilisation. If ECN services are not planned and deployed in advance, the most climatically and thermally advantageous locations become inaccessible or prohibitively expensive to connect. This forces DC operators to choose less energy-efficient sites closer to existing infrastructure, sacrificing the potential PUE gains and the opportunity for circular economy benefits through heat reuse. Therefore, proactive ECN infrastructure investment in target regions is not just an enabler of connectivity but is a prerequisite for unlocking the system-wide energy efficiency benefits of optimal DC placement.

From a network-planning perspective, earlier chapters emphasise that access to high-capacity fibre and diverse long-haul routes is a precondition for viable DC deployment in both primary and emerging hubs.

Beyond conventional point-to-point fibre, research on passive optical networks (PONs) and arrayed waveguide grating router (AWGR)-based DC fabrics suggests that replacing multi-tier electronic switching with largely passive optical interconnects can deliver substantial reductions in intra-DC networking power while maintaining resilience and scalability[430]. These optical DCN designs align with the broader evolution of ECNs toward software-defined, optics-rich and energy-aware architectures. At the same time, advances in multi-core and hollow-core fibre enable up to threefold increases in bandwidth, while software-defined networking and optical orchestration enhance traffic management, flexibility and resilience across inter-DC links[431].

ECN/ECS operators' strategic repositioning towards cloud and edge services further reinforces the need for integrated planning. The European Commission's White Paper on digital infrastructure calls for coordinated investment in 5G SA, fibre and edge nodes to unlock new services while supporting the green transition. When operators co-design edge DC clusters with 5G macro and small-cell layers, caching, content delivery and user-plane routing can be offloaded locally, reducing backbone traffic and associated transport-network energy use. This complements the DC-focused efficiency and transparency requirements introduced by the recast EED[432] and the common Union rating scheme for DCs[433], which embed an "energy-efficiency-first" principle and harmonised KPIs into investment decisions.

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[430] Alharthi, M., El-Gorashi, T. E. H., Mohamed, S. H., Elmirghani, J. M. H., & Yosuf, B. (2021). Optimized passive optical networks with cascaded-AWGRs for data centers (arXiv:2111.01263). arXiv. Retrieved on 23 November, 2025 from https://doi.org/10.48550/arXiv.2111.01263.

[431] Petrovich, M., Numkam Fokoua, E., Chen, Y., Bradley, T. D., Mera, R. F., Poletti, F., & Richardson, D. J. (2025). Broadband optical fibre with an attenuation lower than 0.1 decibel per kilometre. Nature Photonics, 19, 1203–1208. https://doi.org/10.1038/s41566-025-01747-5 ; Melo, C., Reyes, M. F., Arroyo, D., Bravo, M., Deng, Y., Fuentes, F., Hayashi, T., Tsujikawa, K., & Rojas, J. (2025). All-fiber architecture for high-speed core-selective switch for multicore fibers. Communications Engineering, 4, 77. Retrieved on 23 November, 2025 from https://doi.org/10.1038/s44172-025-00412-7.

[432] European Union. (2023). Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast). Official Journal of the European Union. Retrieved December 3, 2025, from https://eur-lex.europa.eu/eli/dir/2023/1791/oj.

[433] European Commission. (2024). Commission Delegated Regulation (EU) 2024/1364 of 14 March 2024 on the first phase of the establishment of a common Union rating scheme for data centres. Official Journal of the European Union. Retrieved December 3, 2025, from https://eur-lex.europa.eu/eli/reg_del/2024/1364/oj.

Renewable-aligned planning is a further lever for joint optimisation of ECNs and DCs. Earlier parts of this report show that the most sustainable DC campuses cluster near abundant wind, hydro or solar resources and, where possible, district-heating networks. If long-haul fibre corridors, terrestrial backbones and submarine cable landings are planned together with such “green” sites, routing policies can steer latency-tolerant workloads and traffic via paths that terminate in low-carbon DCs, while more latency-sensitive traffic remains closer to users. This approach is consistent with industry pledges under the Climate Neutral Data Centre Pact[434], which commits operators to aggressive PUE and carbon-free energy targets by 2030.

6.4.3. Heat reuse

Heat Roadmap Europe 2050 (HRE 2050) was a comprehensive research initiative (part of a series of studies from 2012 to 2019) aimed at decarbonising the European heating and cooling sector by 2050. It provided evidence-based strategies for redesigning energy systems, focusing on energy efficiency, expanding district heating networks, and recovering waste heat, to meet the EU's target of reducing greenhouse gas emissions by at least 80–95% below 1990 levels by 2050. The project, led by institutions such as Aalborg University and partly funded by the EU's Horizon 2020 program, analysed scenarios in EU Member States, focusing on cost-effective pathways to net-zero emissions (Heat Roadmap Europe 4).

Approximately one-quarter (25%) of the project survey respondents indicated that waste-heat utilisation is considered in their planning or already implemented at some level. The remainder cited technical or economic limitations, consistent with varying feasibility across facility scales and regional heating network maturity.

Below, we outline several projects focused on heat reuse from DCs and district heating networks, along with completed implementations in cities such as Berlin, Poznań, and Stockholm. As highlighted, integrating waste heat from DCs offers significant potential, but its widespread adoption faces financial and technical challenges.

HEATWISE is a project founded by European Union (Funding: Horizon Europe) and dedicated to the topic of *Rethinking Thermal Energy Management for buildings and data centres*. The project is being implemented between 1st January 2024 and 31st December 2026. HEATWISE aims to tackle the growing thermal challenges in buildings with IT loads by developing and testing advanced liquid cooling technologies and holistic control systems. Later in the project, the objective will shift to the prototyping phase, which includes a trial-and-error process on integrating hardware and software solutions into the energy management system of the pre-defined use-cases. This ambition is divided into six core objectives to bridge the gap between cutting-edge technology and real-world applications:

- Introduce a thermal need evaluation framework to assess and improve the energy flows;
- Develop a future-proof cooling technology for high-density data processing;

[434] Climate Neutral Data Centre Pact. (2021). Climate Neutral Data Centre Pact. Climate Neutral Data Centre Pact Association. Retrieved December 3, 2025, from https://www.climateneutraldatacentre.net.

- Develop a digital twin-supported holistic energy management system to improve the energy efficiency and performance of DCs;
- Integrate the energy management needs of IT infrastructure and HVAC systems of the building by developing a new generation of integrated BEMS;
- Create a self-assessment tool for energy management needs in buildings with IT systems;
- Support vast adoption and upscaling of project results in the most common use-cases.

HEATWISE combines cutting-edge cooling and intelligent energy systems to optimise thermal performance in IT-heavy buildings. It focuses on recovery and reuse of the waste heat, enabling smarter, zero-waste energy strategies based on the study conducted a comprehensive analysis of thermal and cooling efficiencies in two distinct European DC environments located at university and supercomputing centre. Project KPIs include Power Usage Effectiveness (PUE) below 1.05, Energy Reuse Factor (ERF) improved by a minimum of 10% reaching 95% ERF, Primary Energy Saving (PES) of 20%.

PSNC, Poznan University of Technology and Veolia Energia Poznan S.A. took part in the RENergetic project (Community-empowered Sustainable Multi-Vector Energy Islands), implemented under the Horizon 2020 program. The aim was to develop and demonstrate innovative tools to manage energy islands. Veolia Energia Poznan S.A. operates in the business area of district heating and energy services, focusing on the production and distribution of heat and electricity, primarily through cogeneration systems.

The climate protection objectives had led to a rapid development of renewable and distributed energy in recent years. Local energy consumers had a special place in this process and in the European Union strategy. Among them, an important role was played by integrated local energy systems, so-called Energy Islands, characterized by energy independence and involvement of the local community in energy saving and management. Energy islands integrated renewable energy sources, energy consumers, and residents/users in local communities.

The RENergetic project developed and integrated solutions to improve energy efficiency, renewable energy production levels and energy independence of diverse energy islands in the urban environment, taking advantage of local community involvement. These objectives were achieved by integrating and optimizing the management of three energy vectors: electricity, heat and waste. To this end, IT technologies such as the Internet of Things were used, as well as data analysis, prediction and control of energy consumption and production using artificial intelligence techniques.

The energy islands were demonstrated in three different urban areas: the New Docs district in Ghent, the research and hospital complex in Segrate/Milan and the campus of PSNC and Poznan University of Technology in Poznan. In Poznan, the works included the use of waste heat from the DC to heat the campus buildings, the use of renewable energy from photovoltaic installations and efficiency management of the buildings. The project enabled the installation of appropriate measurement devices, creation of a prototype of a waste heat recovery system, analysis of measurement data from the campus facilities and application of tools for control and optimization

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of energy management. As a result, the project helped to reduce the cost of energy consumed on the campus and the related greenhouse gas emissions.

The integration of Tier IV DCs in Berlin with urban district heating networks represents a groundbreaking approach to sustainable energy utilization. Berlin emerging as a pioneering example of how mission-critical infrastructure can serve dual purposes. While the specific Tier classification of the featured Berlin DC requires clarification, the project demonstrates the potential for enterprise-grade facilities to transform waste heat into a vital community resource, serving over 10,000 residents through an innovative heat recovery system. NTT Data has launched a new waste heat recovery project in Berlin with Quartierswerk Gartenfeld GmbH. The agreement will see 8MW of waste heat capacity from NTT's 17MW Berlin 1 DC in the Spandau district of Berlin sent to "Das Neue Gartenfeld," a new residential and commercial development in Berlin-Spandau. They are demonstrating that CO2-free waste heat with a temperature level of 20 to 30 degrees Celsius from existing DCs can be used sustainably and efficiently for a large district. A power-to-heat boiler with an output of 3.6 MW will also be installed to cover temporary peak loads in winter. The energy centre also contains a hot water tank with a capacity of 300 cubic meters. Construction of the energy centre will start at the end of 2025. By the end of 2026, the district's local heat supply will be provided by the waste heat from the DCs.

Six hyperscalers committed 200+ MW thermal, powering 50,000 households (~125,000 residents) via Vattenfall's 2,000 km network [435]. With a robust district heating network that began in the 1950s and now spans 3,000 km, and a district cooling system covering 300 km, Stockholm's infrastructure capacity for heat recovery is significant. Stockholm Data Parks is a groundbreaking Swedish initiative launched in 2022 by Stockholm Exergi (district heating operator), Fortum, and partners like Interxion, EcoDataCenter, and Arelion. It transforms waste heat from DCs into renewable district heating, powering homes, offices, and hospitals across Stockholm. It serves as a leading global model for how cities can integrate the digital economy's physical demands into a sustainable urban energy system. The project has the potential to meet up to 10% of Stockholm's total heating demand in the future. Ambitious goal to use DC waste heat for 10% of Stockholm's heating needs by 2035[436].

The heating system in Poznań, operated by Veolia Energia Poznań, manages an integrated heating system with a thermal power demand of 1,182.8 MW. It comprises the Karolin Combined Heat and Power Plant (900 MW thermal capacity) and 76 additional heat sources contributing 234 MW, supplying heat to approximately 458,000 residents through a 703 km district heating network (Veolia Energia Poznań) (Veolia City System).

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[435] Alexa Schröder (2 April 2025); Waste heat from NTT DATA's existing data center enables climate-friendly heating concept in new Berlin district. Retrieved December 3, 2025, from https://www.engie-deutschland.de/en/press/waste-heat-ntt-datas-existing-data-center-enables-climate-friendly-heating-concept-new-berlin.

[436] EU Covenant of Mayors (10 October 2023); Stockholm, Sweden : Heat recovery from data centres. Retrieved December 3, 2025, from https://eu-mayors.ec.europa.eu/en/Stockholm-Heat-recovery-from-data-centres;
Arianna Tofani (2022-08-25), A case study on the integration of excess heat from Data Centres in the Stockholm district heating system. Retrieved December 3, 2025, from https://kth.diva-portal.org/smash/get/diva2:1723944/FULLTEXT01.pdf.

Veolia has implemented several waste heat recovery initiatives[437]:

- Volkswagen Poznań Partnership: This project recovers waste heat from aluminium melting processes at the Volkswagen foundry. The captured energy is sufficient to heat approximately 4,500 apartments;
- Beyond.pl DC Project: A recently announced partnership to recover waste heat from DCs, with a thermal capacity of approximately 30 MW, potentially reducing CO2 emissions by 52,500 tons annually;
- Geothermal Project: A pioneering geothermal initiative planned for 2029, expected to supply up to 20% of the municipal heating system's needs across three locations: Starołęka, Franowo, and Kopanina.

Veolia Energia Warszawa manages the distribution of heat, meeting 80% of the city's heating demand through the EU's largest district heating network, spanning 1,870 km. The system is supplied by external sources operated by PGNiG Termika SA, with a total thermal capacity of 4,614 MW, including the Siekierki CHP (2,065 MW), Żerań CHP (1,736 MW), and smaller peaking plants[438.]

The most significant waste heat recovery project, operated by ORLEN Termika, utilises large-scale sewage heat pumps:

- Phase 1 (by 2030): 182 MWt total thermal capacity.
- Phase 2 (by 2034): Expansion to 250 MWt capacity.
- Czajka Plant: The largest installation, with a 120 MWt capacity, serving approximately 108,000 households in Warsaw[439].

The Data Center Nation 2025 conference in Warsaw gathered leading figures from the European DC ecosystem, including operators, investors, technology providers, and policymakers. Discussions focused on Poland's growing role as a key European DC hub, as well as on regulatory frameworks, infrastructure readiness, and sustainability strategies in the age of AI and high-performance computing (HPC).Conference participants agreed that waste heat reuse is a "hot topic" and a cornerstone of sustainable DC growth. While technical and economic barriers

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[437] Veolia Press (2023, Septemeber 27). Veolia Poznań pionierem na drodze do odejścia od węgla. Retrieved November 20, 2025 from https://centrumprasowe.veolia.pl/262876-veolia-poznan-pionierem-na-drodze-do-odejscia-od-wegla;
Veolia (09 October 2024), Veolia Energia Poznań i Beyond.pl zamierzają odzyskać ciepło produkowane przez serwery. Retrieved December 3, 2025, from https://www.veolia.pl/media/aktualnosci/veolia-energia-poznan-i-beyondpl-zamierzaja-odzyskac-cieplo-produkowane-przez;
Biuletyn Miejski Poznan, (31.03.2025) Geotermia w Poznaniu. Retrieved December 3, 2025, from https://www.poznan.pl/mim/bm/news/geotermia-w-poznaniu,250799.html.
[438] Magazyn Ciepla Systemowego (2022, February 3). Veolia Energia Warszawa podsumowała 2021 rok. Retrieved November 20, 2025 from https://magazyncieplasystemowego.pl/wiadomosci-z-firm/warszawa/veolia-energia-warszawa-podsumowala-2021-rok/;
Aleksandra Komorowska, Tomasz Surma (2024); Comparative analysis of district heating markets: examining recent prices, regulatory frameworks, and pricing control mechanisms in Poland and selected neighbouring countries. Retrieved November 20, 2025 from https://epj.min-pan.krakow.pl/pdf-175328-113131?filename=Comparative+analysis+of.pdf.
[439] Cooling Post (2024, December 24). Warsaw to welcome €400m sewage heat pump project. Retrieved November 20, 2025 from https://www.coolingpost.com/world-news/warsaw-to-welcome-e400m-sewage-heat-pump-project/.

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remain, integrating DCs with district heating networks was seen as a key pathway to decarbonization and energy efficiency[440].

6.4.4. Renewables

Integrating renewable energy into DC operations is a key strategy for achieving sustainability goals in the European Union, especially considering the EU's Green Deal, Fit for 55, and Corporate Sustainability Reporting Directive (CSRD). Below the best practices for using renewables to support sustainable DC operations in the EU are summarised:

1. DCs should procure 100% Renewable Electricity

- Power Purchase Agreements (PPAs): Entering long-term PPAs (or multiple PPAs) with renewable energy developers (e.g., wind, solar) to source clean energy directly. This supports new renewable capacity and ensures traceability. *Example:* Offshore wind PPAs in Northern Europe (e.g., Netherlands, Denmark).
- Guarantees of Origin (GoOs): Use EU-compliant GoOs to certify renewable electricity consumption. Ensure GoOs are from additionality (i.e., support new projects) and avoid double counting.
- Prioritising locally generated renewable energy to reduce transmission losses and support regional energy transition.

2. DCs should utilize On-Site Renewable Generation

- Depending on the available land and the architecture of the DC, it is possible to install local photovoltaic panels on roofs, carports or adjacent land.
- If possible, obtaining local wind energy on a small scale where it is possible locally.
- For large DCs, generating energy on-site using small nuclear reactors can be cost-effective, reducing reliance on the grid and enhancing energy resilience. Advanced small modular reactor (SMR) technology creates an unprecedented opportunity to revolutionize DC power infrastructure.

3. DCs should use Energy Storage and Smart Grid Integration

- Pairing renewables with battery storage to manage intermittency.
- Using cold storage based on phase change fluids combined with cheap cooling generation, e.g. at night
- Using AI-driven energy management systems to optimize renewable use and grid interaction.
- Participating in demand response programs to support grid stability and reduce peak load emissions.

4. DCs should use Locational Optimisation

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440 Data Center Nation 2025 conference - Warsaw EXPO XXI. Retrieved November 20, 2025 from https://datacenternation.com/dcn-warsaw-2025/agenda.

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- Site new DCs in regions with high renewable penetration (e.g., Nordic countries, Iberia).
- Nordic countries offer abundant hydro and wind.
- Spain and Portugal have high solar potential.
- Leverage cooler climates to reduce cooling loads (free cooling), improving overall energy efficiency.

5. DCs should use Green Certifications and Standards

Aligning with EU sustainability frameworks:

- EU Taxonomy for Sustainable Activities – Ensure DC operations meet technical screening criteria.
- Energy Efficiency Directive (EED) – Comply with reporting and efficiency benchmarks.
- Code of Conduct for Data Centre Energy Efficiency (EU Code of Conduct) – Voluntary benchmarking and best practices.

Achieving certifications like:

- LEED, BREEAM, or DGNB for green buildings.
- ISO 50001 (Energy Management) and ISO/IEC 30314 (KPI definition).
- RE100 commitment global initiative led by the Climate Group and CDP (Carbon Disclosure Project) –100% renewable electricity

6. DCs should use Carbon Accounting and Transparency

- Measure and report Scope 1, 2, and 3 emissions per Greenhouse Gas (GHG) Protocol.
- Using hourly carbon accounting (e.g., 24/7 carbon-free energy matching) instead of annual averages to ensure real-time clean energy use.
- Disclose via CSRD and European Sustainability Reporting Standards (ESRS).

7. DCs should collaborate with Utilities

- Working with local DSOs (Distribution System Operators) to integrate renewables and support grid upgrades.
- Joining initiatives like CNDCP (voluntary initiative aligned with EU climate goals).

6.4.5. e-Waste

DCs, which rely on vast amounts of high-performance IT equipment, HPC servers, and AI systems with GPUs, require hardware replacements every 3–7 years. Only a small portion of IT equipment, such as storage servers or tape libraries, is designed for long-term durability, with disk storage systems typically lasting around 10 years and tape libraries often exceeding 20 years. Implementing effective e-waste management strategies not only promotes environmental stewardship but also unlocks significant economic opportunities through material recovery. EU regulations on the treatment of Waste Electrical and Electronic Equipment (WEEE) promote a circular economy. DC operators should plan WEEE-compliant decommissioning, reuse, and recycling contracts and ensure suppliers adhere to the Restriction of Hazardous Substances

(RoHS) directive. Contracts should clearly specify the fate of equipment, including whether ownership transfers to the recycler or if assets are sold for reuse.

Additionally, contracts must include compliance clauses explicitly stating that contractors must adhere to all relevant regulations, such as WEEE, RoHS, and GDPR for data protection. DC operators are required to provide detailed reports on the final disposition of each asset (e.g., X% reused, Y% recycled, Z% disposed of, with corresponding weights). Operators should also ensure adequate insurance coverage for potential data breaches or environmental incidents.

For intensive computations performed in HPC or AI, executed on hundreds of thousands of processors, it is necessary to replace servers every few years. This allows for significantly higher performance from the same physical space, resulting in faster computations and reduced energy consumption. In such cases, reusing these servers is not cost-effective for the DC. However, their use may be appealing to other companies that do not require the maximum processor performance or energy efficiency available on the market (European Commission, WEEE).

Modern IT Asset Management (ITAM) systems enable predictive disposal scheduling and lifecycle optimization, achieving asset utilisation rates exceeding 80% while minimising premature equipment retirement. Google's DC operations demonstrate leading practices through comprehensive maintain, refurbish, reuse, and recycle strategies, achieving 86% landfill diversion rates with six facilities reaching 100% diversion. Their approach includes 22% refurbished components for machine upgrades and 36% remanufactured servers in new deployments, substantially reducing new equipment needs. Google maximises the recycling of all DC materials. For hard drives that cannot be resold, Google has a multi-step destruction process designed to further ensure that none of the data can ever be accessed.

One step involves a “crusher” that drives a steel piston through the centre of the drive, deforming the platters and making them unreadable. The drives are then shredded before the remains are sent along with other electronic waste to a recycling partner for secure processing. Secondary market integration requires quality certification processes and performance guarantees to ensure refurbished equipment meets operational requirements for new users. Remarketing partnerships with specialized ITAD providers enable access to global secondary markets while maintaining compliance with local regulations and data protection requirements[441].

ITAD stands for IT Asset Disposition, which is the proper management and disposal of obsolete or retired IT equipment. It is important to protect sensitive data, comply with regulations, and minimize environmental impact. Depending on their condition, assets are either refurbished, recycled, or properly disposed in an environmentally friendly manner. Retired hardware is

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[441] Google sustainability (2018, March). Once is never enough. Retrieved November 20, 2025 from https://sustainability.google/stories/circular-economy/;
Laura Coope (2025, September 8). “ITAM vs ITAD: Key Differences & Benefits for UK Organisations”. Retrieved November 20, 2025 from https://astralistech.co.uk/itad-vs-itam-understanding-the-difference-and-why-it-matters-for-uk-businesses/.

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responsibly recycled, reducing electronic waste, and minimizing environmental impact by reusing scarce resources.

Table 11. IT Asset Management (ITAM) and IT Asset Disposition (ITAD) in UK[442].

Requirement	Regulation	Organisation Impact
E-waste Recycling	WEEE Regulations 2013 (as amended)	Mandatory recovery and reporting rates
Hazardous Substance Handling	Environmental Protection Act 1990	Safe treatment of batteries and electronics
Data Protection Standards	UK GDPR & Data Protection Act 2018	Certified destruction of personal data

6.4.6. Policy pressure

Best practices for sustainable DC operations under policy pressure in Europe have evolved due to mandatory reporting, regulatory incentives, and ESG compliance (E – Environmental, S – Social, G – Governance). These practices focus on energy efficiency, renewable sourcing, circular economy principles, water management, and transparency – driven by EU directives and national laws.

Designing and constructing a new DC based on green building principles enables the following benefits to be achieved from the outset of the process:

- Reduce environmental impact;
- Lower operational costs;
- Enhance investor and tenant appeal;
- Improve risk management;
- Increase access to green financing;
- Benchmark global performance;
- Enhance your corporate reputation;
- Optimise operational efficiency.

Maintaining business continuity and conducting operations in accordance with the following recommendations and requirements also ensures compliance with regulations:

- Base policy decisions on multiple credible sources;
- Implement policies and regulations that require DC operators to disclose key energy use information;
- Comprehensive sustainability reporting: ensure annual disclosure of energy consumption, renewable share, water usage, waste heat utilization, and carbon footprint to government

[442] Laura Coope (2025, September 8). "ITAM vs ITAD: Key Differences & Benefits for UK Organisations". Retrieved November 20, 2025 from https://astralistech.co.uk/itad-vs-itam-understanding-the-difference-and-why-it-matters-for-uk-businesses/.

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databases, as required by the Energy Efficiency Directive and national policies regional data regarding DC;

- Net-zero and renewable targets: transition all operations toward 100% renewable energy, prioritizing PPAs, on-site renewables, Guarantees of Origin, and full life-cycle emission accounting – addressing both operational and embodied carbon;
- Efficiency improvements: deploy advanced cooling (liquid, immersion, optimised airflow), upgrade IT hardware, monitor with AI controls, and minimize unnecessary loads to lower both energy and water use;
- Circular economy and water management: integrate principles of reuse, recycling, and responsible disposal; optimize water use and ensure eco-friendly discharge, especially in water-scarce regions;
- Heat reuse and community integration: recover and redistribute waste heat to district heating systems, maximizing both policy compliance and public benefit;
- Implement policies and regulations that require DC operators to disclose key energy use information;
- Do not base policymaking on sources developed by those with limited domain expertise or conflicts of interest.

By embracing these policy-driven practices, DCs reinforce regulatory compliance, futureproof their operations, and contribute measurably to decarbonisation and resource stewardship in the EU[443]. EU Emissions Trading System (ETS) – DCs are not directly a large industrial ETS sector today, but rising electricity consumption is an important risk/cost driver in future[444].

To keep up with European policy pressures, DCs must maintain close communication with local governments. Across Europe, organizations are emerging that connect DC operators to give them a stronger collective voice. An example is the Polish Data Centre Association (PLDCA), whose mission focuses on:

- Advocating for the sustainable growth of Poland's DC sector,
- Educating national and local authorities on the unique characteristics of DCs, distinguishing them from industrial or energy production facilities, and
- Promoting a dedicated legal and regulatory framework to streamline permitting and attract foreign investment[445].

[443] Catalyst Taylor Roughan; (2025, May 12). "Sustainable data centers: ESG, compliance, and futureproofing for success". Retrieved November 20, 2025 from https://www.gresb.com/nl-en/sustainable-data-centers-esg-compliance-and-futureproofing-for-success;
George Kamiya, Vlad C. Coroamă, IEA 4E, (2025, March). "Data Centre Energy Use: Critical Review of Models and Results". Retrieved November 20, 2025 from https://www.iea-4e.org/wp-content/uploads/2025/05/Data-Centre-Energy-Use-Critical-Review-of-Models-and-Results.pdf.
[444] Catalyst Taylor Roughan; (2025, May 12). "Sustainable data centers: ESG, compliance, and futureproofing for success". Retrieved November 20, 2025 from https://www.gresb.com/nl-en/sustainable-data-centers-esg-compliance-and-futureproofing-for-success;
European Environment Agency (2025, September 16). EU Emissions Trading System (ETS) data viewer. Retrieved November 20, 2025 from https://www.eea.europa.eu/en/analysis/maps-and-charts/emissions-trading-viewer-1-dashboards.
[445] Data Center Nation 2025 conference - Warsaw EXPO XXI. Retrieved November 20, 2025 from https://datacenternation.com/dcn-warsaw-2025/agenda.

6.5. Forecasts and scenarios for the coming years

Europe's DC scenario is one of both massive expansion and accelerating sustainability – requiring creativity in siting, technical innovation, and policy adaption to balance growth with climate targets.

Forecasts for environmental sustainability and energy consumption by DCs in Europe indicate rapid growth in both capacity and power demand, posing significant challenges and opportunities for green innovation and regulatory progress. DCs in Europe are projected to experience exceptional growth and transformation between 2025 and 2030, driven by surging digitalization, cloud adoption, and the rapid deployment of AI and edge computing.

Key trends for the DC market can be identified for the years 2025–2030:

- The DC footprint in Europe will rapidly expand, reshaping the energy landscape and supporting advanced digital services;
- AI, cloud, and 5G deployments will drive new capacity and technology upgrades;
- Regional market shifts will favour areas with uncongested grids, renewable energy, and supportive policies, while established hubs face grid and space constraints.
- Sustainability, transparency, and energy efficiency will be core requirements for both commercial viability and regulatory compliance.

Gandolfi's team evaluated new DC connection requests received by power grid operators in major European markets. Assuming similar developments in the rest of Europe, Goldman Sachs analysts calculated a pipeline of DCs in construction amounting to around 170 gigawatts (GW), equivalent to about a third of Europe's peak power demand in 2024. If all these DCs are eventually built, the potential increase in energy demand at peak times in the main EU regions could come to as much as 60%. In practice, though, the team has assumed that only 25-50% of the planned DCs will be built – that number comes from using the completion rate for renewable energy projects as a proxy for an assumed DC completion rate. In this scenario, the team forecasts that Europe's power consumption could increase by 10-15% in the next 10-15 years[446].

It was observed, based on a demand model developed from publicly available data, that the combined power requirements for DCs across the European Union, Norway, Switzerland, and the United Kingdom are projected to surge dramatically – from approximately 10 gigawatts (GW) today to an estimated 35 GW by 2030. This increase in the DC power results in an increase in consumption. Electricity demand will triple from 62 TWh to over 150 TWh by 2030, with DCs accounting for about 5% of total European power consumption (up from ~2% today). Based on the net-zero commitments announced by many major DC players, this demand is expected to be largely for green power. It was also predicted that to meet new IT load demand, more than $250 to $300 billion of investment will be needed in DC infrastructure, excluding power generation[447].

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[446] Goldman Sachs Research (2025, February 7). "Data centers could boost European power demand by 30%". Retrieved November 20, 2025 from https://www.goldmansachs.com/insights/articles/data-centers-could-boost-european-power-demand-by-30-percent.

[447] McKinsey & Company, (2024). "The Role of Power in Unlocking the European AI Revolution". Retrieved November 20, 2025 from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-role-of-power-in-unlocking-the-european-ai-revolution.

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It was also being predicted that new DC demand could drive a 121 million-tonne surge in CO2 emissions which is equal to 20% of new EU renewables by 2030 and this is the equivalent to the total emissions from all gas power plants in Italy, Germany, and the UK in 2024 combined[448].

The Climate Neutral DC Pact, which covers over 85% of European capacity, along with new EU regulations, sets a requirement for all European DCs to reduce the environmental impact by 2030. This includes matching electricity demand to 100% renewable or hourly carbon-free energy use. Both existing and new DCs are expected to meet the same targets: an annual PUE of 1.3 for total capacity in cool climates and 1.4 for full capacity in warm climates. DC electricity demand will be aligned with 100% renewable or hourly carbon-free energy[449]. ResearchAndMarkets.com provided a geographical analysis of the future development of the DC market in their report, "Europe Data Center Market Landscape 2025-2030: FLAP-D Markets (Frankfurt, London, Amsterdam, Dublin) lead the sector, with Spain, Italy, and Greece gaining traction due to space and cost advantages"[450]. FLAP-D DC markets are major players in the European DC sector, however due to limited land availability, their market share is projected to decline. As a result, DC companies are considering emerging locations such as Spain, Italy, Portugal, and Greece for new developments.

In the Nordic region, countries like Sweden, Norway, and Finland are seeing increased DC investment, encouraged by factors including a cool climate, access to renewable energy sources like hydropower, wind, and geothermal energy, and government support measures. Major companies like Google, Meta, and Microsoft are building sustainable, large-scale DCs in Nordic and Western Europe. Colocation firms are increasing investment in the region by adopting green practices such as renewable energy use, HVO generators, and advanced cooling. Russia is a major DC hub in Central & Eastern Europe, but war-related restrictions may limit its future role. Countries like Poland, Austria, Czechia, Hungary, Estonia, Slovakia, Bulgaria, and Croatia are attracting more DC investment, with some becoming new hubs for operators and tech giants.

Milan is Italy's primary DC hub, while Rome and Turin are emerging due to strong business environments. In Switzerland, Zurich and Geneva attract operators with political neutrality, strict data protection, and proximity to European markets. Marseille and Lyon in France are becoming alternatives to Paris thanks to available land and lower electricity costs.

6.5.1. Optimistic scenario

In the optimistic scenario for the DC market's evolution over the next few years, operators are expected to make significant strides toward sustainability and efficiency. A key priority will be achieving 100% renewable energy through Power Purchase Agreements (PPAs). Europe's

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[448] Beyond Fossil Fuels. (2025, May 13). How Europe's grid operators are preparing for the energy transition [Report]. Retrieved 7 November 2025, from https://beyondfossilfuels.org/wp-content/uploads/2025/05/REPORT_FINAL.pdf.
[449] Climate Neutral Data Centre Pact (2025). Homepage and Certification Framework for Climate-Neutral Data Centres in Europe. Retrieved November 20, 2025 from https://www.climateneutraldatacentre.net/.
[450] Report by ResearchAndMarkets.com (2025, May 20). Europe Data Center Market Landscape 2025-2030 | FLAP-D Markets (Frankfurt, London, Amsterdam, Dublin) Lead the Sector, as Spain, Italy, and Greece Gain Traction Due to Space and Cost Considerations - ResearchAndMarkets.com. Retrieved November 20, 2025 from https://www.businesswire.com/news/home/20250520159740/en/Europe-Data-Center-Market-Landscape-2025-2030-FLAP-D-Markets-Frankfurt-London-Amsterdam-Dublin-Lead-the-Sector-as-Spain-Italy-and-Greece-Gain-Traction-Due-to-Space-and-Cost-Considerations---Research.

strong wind and solar resources make it ideal for securing PPAs with local renewable projects, such as Nordic hydro and wind or Southern European solar. For instance, Google's €1.2 billion PPA in Spain supports a 200 MW solar and storage project.

Beyond annual renewable targets, DCs will increasingly adopt hourly carbon-free energy matching to ensure true sustainability and avoid "greenwashing." This approach, supported by the EU's Clean Energy Package, leverages tools like Google's Carbon Sense and Microsoft's Carbon Calculator to track and optimise clean energy use in real time.

A major focus will be on grid decarbonization, with operators choosing to locate DCs in regions where electricity grids already have low-carbon intensity – such as Sweden, Norway, and France, where renewables or carbon-free power plants make up over 90% of the mix. In contrast, coal-dependent regions like Poland will require offset mechanisms or decarbonization plans to remain viable.

Renewable-rich zones will become increasingly attractive for new developments. These include countries with high renewable penetration such as Iceland, Norway, and Sweden for hydro and wind, and Spain and Portugal for solar. Grid stability will also be a determining factor – areas like Germany's North Sea wind hubs will be favoured to minimise blackout risks.

The deployment of edge DCs will expand, with smaller, distributed facilities built closer to demand centres to reduce transmission losses and latency. Examples include Equinix's edge DCs in Paris, which enhance both efficiency and reliability.

Sustainability planning will also include risk avoidance strategies, with developers steering clear of flood zones, drought-prone regions, and biodiversity-sensitive areas in line with the EU Biodiversity Strategy.

In terms of innovation, green hydrogen fuel cells are expected to emerge as clean alternatives to diesel backup generators, following the example of EDF's pilot projects in France. Similarly, AI-driven grid optimisation will enable workload shifting to periods of high renewable generation, as demonstrated by AWS's carbon-aware computing initiatives.

The integration of small modular reactors (SMRs) could further enhance grid stability and supply consistent low-carbon energy. These reactors may also support district heating networks by complementing DC waste heat recovery systems. Projects such as Orlen Synthos Green Energy's SMR development in Poland – expected to be operational by 2032 – illustrate this potential. Finally, the broader policy and social environment will reinforce this transition. Regulatory pressure from the European Union's goal of a 40% emissions reduction by 2030 (compared to 1990 levels) and the inclusion of DCs in the EU Emissions Trading System (ETS) will drive carbon accountability. At the same time, economic incentives – including EU Recovery and Resilience Facility grants for renewable-powered DCs and tax breaks for waste heat reuse in countries such as Germany, Sweden, and the Netherlands – will make sustainable investment both environmentally and financially compelling.

6.5.2. Business-as-usual scenario: Limited transformation, incremental progress

DCs compete for energy recovery opportunities with other market players, as seen in Poznań, where, in addition to connecting the Beyond server room, the city already receives waste heat from the Volkswagen factory and plans to utilize geothermal sources. Warsaw is also preparing its infrastructure for future integration of such systems. All these energy sources compete, and it should be remembered that the demand for district heating capacity is limited, while energy transfer must remain economically viable. The integration of DC waste heat represents a growing opportunity, with Poznań leading the way through direct partnerships, while Warsaw focuses on infrastructure readiness for future implementation. The heat from server rooms is available year-round but has a relatively low temperature, requiring the use of heat pumps to raise it to a usable level, along with advanced automation and continuous post-commissioning fine-tuning to optimize efficiency and system performance[451].

The main barriers are low-quality waste heat, lack of heat demand nearby, high investment costs but there are some opportunities: new technologies such as a low-temperature district heating system could enable more opportunities of using low-quality excess heat[452].

In a business-as-usual scenario, the European DC market continues to expand rapidly due to increasing digitalisation, cloud adoption, and AI-driven workloads – but sustainability advances remain largely incremental rather than transformative.

Energy sourcing continues to rely on a mix of grid electricity and limited renewable PPAs. While some hyperscalers maintain their renewable commitments, smaller and colocation providers struggle to secure cost-competitive PPAs due to volatile energy markets and regulatory uncertainty. Many DCs still rely on annual renewable energy certificates (RECs) to claim “green” status, without achieving true hourly carbon-free matching.

Grid dependency remains high, with most DCs operating in regions where electricity grids are only partially decarbonised. Countries like Poland and parts of Central and Eastern Europe remain heavily reliant on fossil fuels, and DCs in these markets face rising carbon costs under the EU Emissions Trading System (ETS). However, relocation to cleaner grids is limited by latency requirements, real estate availability, and connectivity constraints.

Infrastructure design focuses mainly on incremental energy efficiency rather than deep decarbonisation. Cooling systems see gradual optimisation (e.g., improved free cooling and liquid

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[451] Veolia Press (2023, Septemeber 27). Veolia Poznań pionierem na drodze do odejścia od węgla. Retrieved November 20, 2025 from https://centrumprasowe.veolia.pl/262876-veolia-poznan-pionierem-na-drodze-do-odejscia-od-wegla;
Veolia (2024, October 9). Veolia Energia Poznań i Beyond.pl zamierzają odzyskać ciepło produkowane przez serwery. Retrieved November 20, 2025 from https://www.veolia.pl/media/aktualnosci/veolia-energia-poznan-i-beyondpl-zamierzaja-odzyskac-cieplo-produkowane-przez;
Biuletyn Miejski Poznan, (2025, March 31). Geotermia w Poznaniu. Retrieved November 20, 2025 from https://www.poznan.pl/mim/bm/news/geotermia-w-poznaniu,250799.html;
Cooling Post (2024, December 24). Warsaw to welcome €400m sewage heat pump project. Retrieved November 20, 2025 from https://www.coolingpost.com/world-news/warsaw-to-welcome-e400m-sewage-heat-pump-project/;
Data Center Nation 2025 conference - Warsaw EXPO XXI. Retrieved November 20, 2025 from https://datacenternation.com/dcn-warsaw-2025/agenda.
[452] Arianna Tofani (2022, August 25). A case study on the integration of excess heat from Data Centres in the Stockholm district heating system. Retrieved November 20, 2025 from https://kth.diva-portal.org/smash/get/diva2:1723944/FULLTEXT01.pdf.

cooling pilots), but large-scale integration of on-site solar or battery storage remains rare due to high upfront costs and limited space in urban locations.

Resilience and climate risk management receive limited attention beyond compliance. Some operators continue to operate in high-risk areas – including flood-prone or drought-affected regions – driven by short-term cost and connectivity advantages. Biodiversity and land-use concerns are acknowledged but rarely influence site selection in practice.

Innovation adoption also remains cautious. Green hydrogen backup systems, AI-driven carbon-aware scheduling, and SMRs are mostly in pilot or research phases, with commercial deployment delayed by regulatory barriers and uncertain economics. Similarly, quantum computing collaboration and workload optimisation for energy efficiency remain limited to a few high-profile partnerships without broad industry adoption.

Policy and market dynamics exert mixed pressures. EU climate regulations tighten, but enforcement is uneven across member states. Carbon taxes and compliance costs rise, yet many DCs pass these costs to customers rather than transforming operations. Public pressure for sustainability increases, but with limited impact beyond the largest tech firms. Economic incentives exist – such as grants for renewable integration and waste-heat reuse – but uptake remains modest due to complex application processes, uncertain ROI, and fragmented policy frameworks.

Overall, the DC industry under a business-as-usual scenario achieves gradual efficiency improvements but falls short of deep decarbonisation. By late 2020s, Europe's DCs are more energy-efficient than today, yet still responsible for a significant share of electricity demand and emissions. Sustainability leaders continue to set examples, but systemic transformation across the entire market remains elusive, leaving the region only partially aligned with the EU's 2030 and 2050 climate neutrality goals.

6.5.3. Restrictive scenario

In a restrictive scenario, the European DC industry faces a challenging operating environment shaped by tightened climate policies, energy scarcity, and public resistance. The sector remains essential for digital infrastructure, but its expansion is increasingly constrained by regulatory, environmental, and societal pressures.

Energy availability and pricing become major bottlenecks. Europe's ongoing electrification and the slow rollout of grid upgrades lead to chronic grid congestion and rising electricity prices. Priority access is often granted to critical industries and households, leaving DCs competing for limited clean power capacity. In several markets – including Ireland, the Netherlands, and parts of Germany – governments impose moratoriums or capacity caps on new DC connections to protect grid stability.

Strict regulatory oversight intensifies under the EU's Green Deal and "Fit for 55" framework. DCs are required to meet increasingly stringent energy efficiency and carbon intensity benchmarks, verified through real-time monitoring and reporting under the revised Energy Efficiency Directive.

Facilities that cannot demonstrate near-zero-emission operations face heavy carbon taxes or risk losing their operating licenses.

Site selection becomes highly restricted. Environmental permitting processes extend significantly, with new EU biodiversity and land-use regulations blocking developments in sensitive areas. Water-use limitations, especially in drought-prone regions like Spain and Southern France, force operators to abandon traditional cooling systems and shift to air- or liquid-based alternatives, raising costs.

Economic impact is uneven. Smaller colocation providers and new entrants struggle to absorb rising compliance and energy costs, leading to market consolidation around large hyperscalers with sufficient capital and policy influence. Investment shifts toward non-EU regions (e.g., Norway, Iceland, or even North Africa) where renewable energy is abundant and regulatory regimes are more flexible.

Operational costs surge as carbon pricing, energy tariffs, and reporting obligations mount. This drives higher service prices for cloud and AI customers, prompting enterprises to reconsider on-premise or hybrid solutions in some cases.

By the early 2030s, Europe's DC landscape under this restrictive scenario is characterized by slower growth, fewer new builds, and intensified scrutiny. The surviving operators are highly efficient and tightly integrated into local energy systems, but overall industry capacity grows far below demand. The EU achieves measurable emissions reductions – at the cost of innovation speed and digital infrastructure competitiveness.

Ember reports prepared in 2025 highlights the need to choose strategic siting of DCs to brings fast connections to the grid and reduces grid expansion needs. According to their opinion in the short term, grid operators can steer DC developers towards priority zones with available grid capacity – e.g. post-industrial regions or areas with abundant clean electricity. Several countries are already piloting this approach. In France, EDF is offering ready-to-use industrial sites with a grid connection capacity of approximately 2 GW for DC development through a call for expressions of interest, with the aim of reducing project completion timelines by several years. Similarly, the UK government issued an expression of interest in February 2025 to enable identification of AI Growth Zones (AIGZ), with more than two hundred responses received. Apart from identifying the most suitable sites, the call also sought to cluster the developments, looking for locations able to host or developers prepared to establish 500 MW+ of AI infrastructure. Italy's Terna is also looking to cluster requests from DCs for grid connection to minimise the risk of oversizing infrastructure[453].

In summary, forecasts show that Europe's DC sector will nearly double in capacity and drive unprecedented energy demand by 2030. Environmental sustainability will hinge on aggressive renewable energy sourcing, innovation in efficiency, and strict regulatory enforcement, with

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[453] Cremona, E., Czyzak, P. (2025, June 19). Grids for data centres: ambitious grid planning can win Europe's AI race. Ember. Retrieved November 20, 2025 from https://ember-energy.org/latest-insights/grids-for-data-centres-ambitious-grid-planning-can-win-europes-ai-race/.

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climate neutrality by 2030 as the benchmark scenario but substantial risks if fossil fuels remain central to the sector's growth.

At the end, it is worth to add, that project survey respondents' forward outlook indicates a dominant expectation of increasing energy and AI workload demand (≥ 50%) but only 30% foresee a corresponding rise in renewable-energy usage within their own organisations. This divergence suggests that while awareness of sustainability imperatives is high, implementation capacity remains limited, particularly among smaller operators.

7. Future regulatory trends in Europe's DC and cloud market

Europe's DC and cloud industries are entering a new phase of proactive regulation. Policymakers at both EU and national levels now regard these sectors as strategic for economic growth, digital sovereignty, and the green transition, and they are crafting rules to steer their development accordingly. Over the next 3–5 years, regulatory focus is expected to sharpen in two broad ways: first, by addressing anticipated regulatory needs to support Europe's competitiveness and digital infrastructure (e.g. closing investment gaps, curbing market power issues, and spurring innovation); and second, by advancing specific policy focus areas that will shape the industry's evolution – notably in competition policy, sustainability, and data sovereignty. This chapter outlines upcoming regulatory trends in these areas, drawing on current policy discussions, legislative proposals, and expert commentary from EU institutions and industry bodies.

7.1. Anticipated regulatory needs (next 3–5 years)

European policymakers recognise that the fast-evolving digital infrastructure landscape needs a proactive, coordinated approach. Several high-level needs have been identified for the coming years:

- **Balanced growth vs. market power:** Cloud computing in Europe is dominated by a few U.S.-based tech giants (Amazon AWS, Microsoft Azure, Google Cloud). It is estimated that these three leading global cloud providers account for roughly 70% of the European cloud market[454]. Such concentration raises concerns about market power and customer lock-in. Regulators acknowledge the importance of fostering competition and multi-vendor choice in cloud services, for example by supporting easier switching and addressing potential anti-competitive practices. Section 7.2 contains additional information pertaining to the competition policy area.
- **Acceleration of infrastructure deployment:** Despite operators and hyperscalers' investments in new DCs, the EU lags North America and Asia in aggregate cloud and computing capacity. There is a strategic imperative to triple the capacity of EU DCs in the next 5–7 years – a goal voiced in the European Commission's 2025 AI continent action plan[455]. Achieving this will require reducing obstacles to building new facilities (e.g. lengthy permitting processes or limited power grid access) and providing incentives for expansion. Additionally, analysis conducted by Cremona and Czyzak indicates that the IEA, IMF, and McKinsey project that the EU may not reach its target, with these sources, except

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[454] Synergy Research Group. (2024, July 24). European Cloud Providers' Local Market Share Now Holds Steady at 15%. Retrieved 25 November, 2025 from https://www.srgresearch.com/articles/european-cloud-providers-local-market-share-now-holds-steady-at-15.

[455] Penman, L., & Rasdale, M. (2025, May 21). Navigating the EU's new digital regulatory landscape: what data centre operators and investors need to know. DLA Piper – Technology's. Retrieved 25 October, 2025 from https://www.technologyslegaledge.com/2025/05/navigating-the-eus-new-digital-regulatory-landscape-what-data-centre-operators-and-investors-need-to-know/.

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McKinsey suggesting that doubling capacity by 2030 is a more likely outcome[456]. The figure below presents the predictions of each institution:

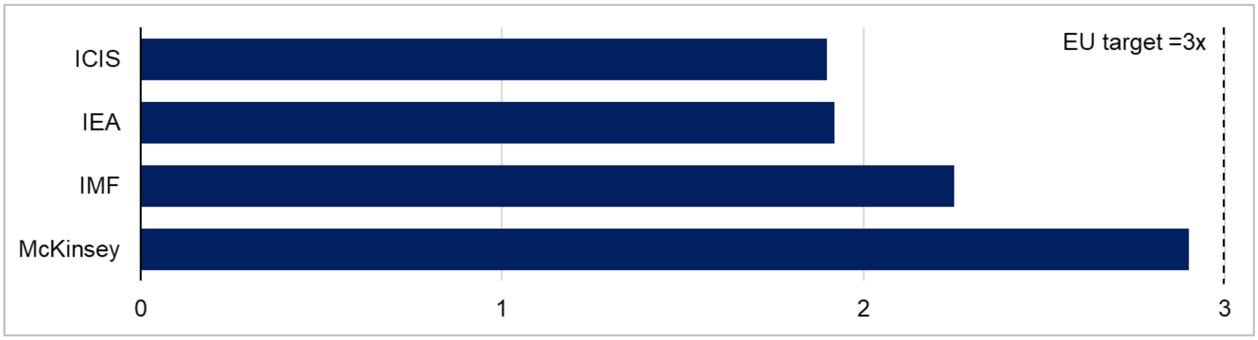

Figure 12. Projected EU DC Growth Rate Ratio 2024-2030

Regulators are thus crafting policies to facilitate DC development – but in a sustainable way, rather than a simple free-for-all construction boom. For example, EU officials have floated a forthcoming "Cloud and AI Development Act" (expected proposal by early 2026), aimed at streamlining permits for qualified projects and catalysing billions in private investment into European cloud infrastructure[457]. Ensuring speedy deployment of fibre networks is also critical; to that end, policymakers are examining ways to encourage faster roll-out of high-speed connectivity that DCs depend on. In essence, regulators acknowledge that Europe needs more digital infrastructure, and they are looking at levers (both reducing administrative obstacles and supporting new investments) to accelerate its deployment.

- **Sustainable & resilient operations**: DCs already account for a significant and growing share of electricity demand. EU climate initiatives like the European Green Deal and Climate Law set a binding target of net-zero emissions by 2050 (with a 55% cut by 2030). Thus, regulators have set a headline objective for carbon-neutral DCs by 2030. Meeting this will require new rules on energy efficiency, use of renewables, waste-heat reuse, and integration with the electric grid. The European Commission is preparing a Data Centre Energy Efficiency Package (expected in Q1 2026) to advance these goals[458]. Under the revised Energy Efficiency Directive (2023), large DCs (≥500 kW IT power) must already report detailed energy performance metrics annually to an EU database[459]. The upcoming package is anticipated to propose binding standards (for example, power usage effectiveness) thresholds or requirements to reuse a portion of waste heat) to ensure the 2030 climate-neutral goal is achievable.

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[456] Cremona, E., Czyzak, P. (2025, June 19). Grids for data centres: ambitious grid planning can win Europe's AI race. Ember.
[457] Penman, L., & Rasdale, M. (2025, May 21). Navigating the EU's new digital regulatory landscape: what data centre operators and investors need to know. DLA Piper – Technology's.
[458] Dodsworth, J., Burmeister, T., Trichkovska, I., Johnson, J., de Kersauson, Q., Hoffmann, E., … & Iffert, P. K. (2025, October 20). Data centres and energy consumption: evolving EU regulatory landscape and outlook for 2026. White & Case LLP. Retrieved 15 October, 2025 from https://www.whitecase.com/insight-alert/data-centres-and-energy-consumption-evolving-eu-regulatory-landscape-and-outlook-2026.
[459] Ibid.

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- In parallel, the EU is progressing with **cybersecurity and privacy legislation that reinforces digital sovereignty**. Ensuring infrastructure resilience against cyber threats and outages is on the agenda, as DCs are now classified as critical infrastructure. The EU's Digital Operational Resilience Act (DORA) and NIS2 Directive (both effective by early 2025) impose stringent security and continuity requirements on cloud and DC providers, supervised by financial and cybersecurity authorities[460]. The NIS2 Directive (Directive (EU) 2022/2555) mandates operators of essential services, including major DCs, to establish comprehensive cybersecurity risk management and incident reporting protocols by October 2024, with enforcement commencing in 2025. Non-compliance can result in fines of up to €10 million or 2% of global turnover, and management bodies face personal accountability[461]. NIS2 classifies large DCs as "essential entities", making cybersecurity a board-level responsibility rather than a back-office issue. In sum, regulators see an urgent need to align DC growth with Europe's security needs. Mandatory risk management practices to bolster operational resilience can be expected.
- **Digital sovereignty & control:** Europe's broader push for "technological sovereignty" underpins many of these initiatives. Policymakers want to avoid a scenario where Europe's digital economy is overly dependent on foreign cloud giants or subject to extraterritorial jurisdiction (such as the U.S. Cloud Act)[462]. Identified needs here include establishing standards and certifications to ensure local control over sensitive data, fostering European-owned cloud alternatives, and possibly setting requirements in public procurement or security laws that favour providers meeting EU sovereignty criteria. One concrete example is the debate around the EU's European Cybersecurity Certification Scheme for Cloud Services (EUCS). Earlier drafts of EUCS included strict "sovereignty" requirements (e.g. that top-tier certified clouds be operated by EU-headquartered companies immune from foreign law), but these were dropped after industry pushback, prompting concerns from some European stakeholders[463]. The compromise scheme now focuses on technical security controls, but EU policymakers and Member States (especially France) continue to discuss ways to reintroduce certain sovereignty safeguards via national cloud certifications or future updates[464]. The core need is balancing openness with autonomy: regulators want rules that keep Europe's data under

[460] Shoosmiths. (2024). NIS2 is here – What data centre providers & customers need to know about Europe's new cybersecurity regime. Retrieved 24 October, 2025 from https://www.shoosmiths.com/insights/articles/nis2-is-here-what-data-centre-providers-customers-europe-cybersecurity-regime;
Kalokyris, N., et al. (2025, April 9). Application of the Digital Operational Resilience Act (DORA): Key considerations. DLA Piper. Retrieved 25 October, 2025 from https://www.dlapiper.com/en-us/insights/publications/2025/02/application-of-the-digital-operational-resilience-act---dora.
[461] Shoosmiths. (2024). NIS2 is here – What data centre providers & customers need to know about Europe's new cybersecurity regime;
Greenberg Traurig LLP. (2025). EU NIS 2 Directive: Expanded Cybersecurity Obligations for Key Sectors. Retrieved 24 October, 2025 from https://www.gtlaw.com/en/insights/2025/8/eu-nis-2-directive-expanded-cybersecurity-obligations-for-key-sectors.
[462] Linthicum, D. (2025, June 13). Europe is caught in a cloud dilemma. InfoWorld. Retrieved 27 October, 2025 from https://www.infoworld.com/article/4006202/europe-is-caught-in-a-cloud-dilemma.html.
[463] European DIGITAL SME Alliance. (2024, September 5). Changes to the EU Cloud Services Cybersecurity Certification Scheme put EU citizens' data at risk: A call for digital sovereignty. Retrieved 27 October, 2025from https://www.digitalsme.eu/changes-to-the-eu-cloud-services-cybersecurity-certification-scheme-put-eu-citizens-data-at-risk-a-call-for-digital-sovereignty/.
[464] Kroet, C. (2025, February 27). EU cloud certification should mimic French scheme, says nationalist lawmaker. Euronews. Retrieved 27 October, 2025 from https://www.euronews.com/next/2025/02/27/eu-cloud-certification-should-mimic-french-scheme-says-nationalist-lawmaker.

EU-law control, whether through certification, contractual requirements, or by nurturing domestic providers via initiatives like Gaia-X[465]. Additionally, regulators emphasize strengthening Europe's own infrastructure capabilities. Projects like the EU's IRIS² satellite constellation (approved in 2022, operational by ~2027) aim to ensure independent European connectivity (for broadband and secure communications) to complement terrestrial networks[466]. In summary, the EU's policymaking needs in this area boil down to reducing strategic dependencies and asserting control over critical digital assets.

- **Holistic, cross-sector governance:** Finally, regulators see a need for better coordination across policy domains. The rapid growth of DCs affects energy grids and environmental goals; similarly, cloud services overlap with competition and trade policy. In the past, these issues were treated in silos. Now, initiatives are more cross-cutting. For instance, the European Council's *Budapest Declaration* of Nov 2024 called for realigning industrial, competition, and trade policies to boost Europe's tech competitiveness[467]. In the DC context, this means aligning energy regulations (to ensure sufficient electricity capacity for new server farms) with digital strategy (to encourage investments in underserved regions). Think tanks like CERRE note that Europe could "unlock 50–60 GW of demand-side flexibility by 2035" if DCs are fully integrated into grid planning and electricity markets[468]. More joint planning between energy and digital authorities could be expected – for example, designating "ready-to-connect" zones with ample clean power for new DCs, or incentivizing DCs to provide battery storage and demand response to help the grid[469]. On the legal side, the EU is pursuing an integrated approach in the Digital Decade program, which monitors progress on connectivity, skills, and digitalization targets together. The first *State of the Digital Decade* report highlighted gaps like insufficient fibre coverage and cloud uptake, prompting recommendations that blend regulatory and funding actions[470]. In essence, regulators are moving away from piecemeal solutions and toward an ecosystem approach, recognizing that DC policy is intertwined with energy, competition, and industrial policies. This trend will likely produce more cohesive strategies and multi-faceted regulatory packages (for example, a 2026 package might simultaneously address DCs' energy use, market competition, and security in a single proposal). Such holistic governance is needed to avoid one policy undermining another (like environmental rules inadvertently pushing investors away, or competition law unintentionally discouraging collaborative solutions). The challenge will be to achieve this coherence without diluting the efficacy of individual measures.

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[465] Gaia-X. (2025, March 21). Gaia-X strengthens European digital sovereignty at European Parliament reception [Press release]. Brussels: Gaia-X Association. Retrieved 28 October, 2025 from https://gaia-x.eu/gaia-x-strengthens-european-digital-sovereignty-at-european-parliament-reception/.
[466] European Commission. (2024, December 16). Commission takes next step to deploy the IRIS² secure satellite system. Retrieved 27 October, 2025 from https://defence-industry-space.ec.europa.eu/eu-space/iris2-secure-connectivity_en.
[467] European Council. (2024, Nov 8). Budapest Declaration on the New European Competitiveness Deal. Retrieved 24 October, 2025 from https://www.consilium.europa.eu/en/press/press-releases/2024/11/08/the-budapest-declaration/pdf/.
[468] Le Goff, T., Inderwildi, O., Már Baldursson, F., M. von der Fehr, N-H., (2025, September). From Gridlock to Grid Asset: Data Centres for Digital Sovereignty, Energy Resilience, and Competitiveness. Brussels: Centre on Regulation in Europe (CERRE). Retrieved 24 October, 2025 from https://cerre.eu/wp-content/uploads/2025/09/CERRE_Report_DCs_FinalPDF.pdf.
[469] Ibid.
[470] European Commission. (2025, June 16). State of the Digital Decade 2025 report. Brussels: European Commission. Retrieved 23 October, 2025 from https://digital-strategy.ec.europa.eu/en/library/state-digital-decade-2025-report.

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7.2. Focus area: Competition policy

European competition policy for digital infrastructure is shifting from a reactive stance to a more proactive, market-shaping approach. This section outlines the key trends and expected actions.

7.2.1. Assessing market concentration and switching challenges in cloud services

As noted, a handful of cloud providers hold a very large share of Europe's cloud market, raising concerns about customer lock-in and high switching costs. Regulators are addressing this head-on through the Data Act (adopted in 2023). This new regulation includes provisions to make switching cloud providers easier: for instance, by *2027, cloud contracts in the EU cannot impose data egress fees or other non-cost-related switching charges*, and providers must remove commercial, technical, and contractual barriers to interoperability[471]. This directly targets the lock-in tactics that have hindered competition – such as hyperscalers charging hefty fees to transfer data out or using proprietary formats that make migration difficult. Over the next year, cloud providers will need to adjust their practices to comply (caps on egress fees start earlier, phasing to zero by 2027, to comply with the Data Act). Regulators will closely oversee compliance and may impose penalties if providers do not meet required timelines. The Data Act's cloud provisions, combined with guidelines on fair contracts, are intended to lower entry barriers for alternative providers and empower customers to pursue multi-cloud strategies[472].

In parallel, the Commission and national competition authorities are scrutinizing hyperscalers' business conduct more visibly. For instance, one such case occurred in 2023, when European Commission commenced an investigation into Microsoft[473] after concerns were raised that the integration of Teams – a cloud-based communication and collaboration platform – within its Office 365 and Microsoft 365 productivity suites may have impacted competition among cloud service providers. Similarly, France's Autorité de la concurrence published a detailed cloud sector inquiry in 2023, identifying potentially anti-competitive practices and urging vigilance as new technologies like edge computing and AI emerge[474].

Continued antitrust scrutiny could be expected: if hyperscalers engage in exclusionary behaviour (e.g. tying their cloud with popular software or AI services in undermining ways, such as requiring customers to use proprietary AI accelerators or model-training platforms hosted only in their new DCs or disadvantaging European cloud rivals), the Commission or national authorities may pursue formal cases. Additionally, the DMA, which imposes ex ante obligations on large "gatekeepers", could also target cloud services. Cloud services are officially classified as a "core platform service" under the DMA; however, no provider has yet been designated as a gatekeeper and several European countries have invited the European Commission to designate them. In

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[471] European Union. (2023, December 13). Regulation (EU) 2023/2854 of 13 December 2023 on harmonised rules on fair access to and use of data (Data Act). Official Journal of the EU, L 333, 22.12.2023. Retrieved 20 October, 2025 from https://eur-lex.europa.eu/eli/reg/2023/2854/oj/eng.
[472] Ibid.
[473] European Parliament. (2023, December 11). Answer given by Mr Reynders on behalf of the European Commission. Retrieved 20 October, 2025 from https://www.europarl.europa.eu/doceo/document/E-9-2023-002918-ASW_EN.html.
[474] Autorité de la concurrence. (2023, June 29). Cloud computing: the Autorité de la concurrence issues its market study on competition in the cloud sector [Press release]. Retrieved 20 October, 2025 from: https://www.autoritedelaconcurrence.fr/en/press-release/cloud-computing-autorite-de-la-concurrence-issues-its-market-study-competition-cloud.

November 2025, the European Commission launched three market investigations on cloud computing services under the DMA[475]. Two market investigations will assess whether Amazon and Microsoft should be designated as gatekeepers for their cloud computing services Amazon Web Services and Microsoft Azure. Despite not meeting current quantitative thresholds, the Commission is analysing whether they act as important gateways between businesses and consumers. If that happens, hyperscalers could be required to ensure interoperability and refrain from self-preferencing its own apps on its cloud, among other obligations. The Commission third market investigation will assess if the DMA can effectively tackle practices that may limit competitiveness and fairness in the cloud computing sector in the EU, thus the Commission is gathering information from relevant market players – the investigation will cover obstacles to interoperability between cloud computing services, limited or conditioned access for business users to data, tying and bundling services, and potentially imbalanced contractual terms, among other aspects.

In summary, competent authorities are making sure that dominant cloud providers cannot abuse their position, via a combination of new legislation (Data Act, DMA) and traditional enforcement.

7.2.2. Supporting European initiatives

Alongside reining in the giants, the EU is trying to promote competition by nurturing alternatives. Through initiatives like Gaia-X (a project to create a federated European cloud infrastructure) and targeted funding (e.g. Important Project of Common European Interest on Next Generation Cloud Infrastructure and Services (IPCEI-CIS) to support research, development and initial industrial deployment of European innovations in cloud and edge technologies[476]), Europe is investing in home-grown solutions[477]. In parallel, the EU is rolling out a pan-European network of EuroHPC "AI Factories" – one-stop hubs attached to AI-optimised supercomputers – with 7 sites selected in December 2024 and further waves in March 2025 and October 2025, bringing the total to 19 across 16 Member States[478]. The Commission has also launched "InvestAI," including a proposed €20 billion fund for large-scale "AI Gigafactories" (frontier-model training hubs), alongside stakeholder consultations opened in 2025[479].

Although these initiatives may not immediately rival the dominance of hyperscalers, they are intended to create specialised niches and essential building blocks that, collectively, broaden market choice and help prevent complete market lock-in. For example, Gaia-X frameworks enable users to combine services from multiple providers in a "federated" manner, and the EU is backing

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[475] European Commission. (2025, November 18). Commission launches market investigations on cloud computing services under the Digital Markets Act. Retrieved December 1, 2025 from https://ec.europa.eu/commission/presscorner/detail/en/ip_25_2717.
[476] European Commission. (2023, December 5). IPCEI on Next-Generation Cloud Infrastructure and Services to boost Europe's Digital Decade. Retrieved 25 November, 2025 from https://digital-strategy.ec.europa.eu/en/news/ipcei-next-generation-cloud-infrastructure-and-services-boost-europes-digital-decade.
[477] Gaia-X. (2025, March 21). Gaia-X strengthens European digital sovereignty at European Parliament reception [Press release].
[478] European Commission. (2025, October 10). EU expands network of AI Factories, strengthening its 'AI Continent' ambition. Retrieved December 18, 2025 from https://digital-strategy.ec.europa.eu/en/news/eu-expands-network-ai-factories-strengthening-its-ai-continent-ambition
[479] European Commission. (2025, April 9). Commission sets course for Europe's AI leadership with an ambitious AI Continent Action Plan. Retrieved December 18, 2025 from https://ec.europa.eu/commission/presscorner/detail/en/ip_25_1013

this politically and financially – public procurement rules increasingly favour certified sovereign clouds for sensitive data, as seen in France and Germany[480].

Overall, the European Union is taking concrete steps to strengthen competition in the cloud and digital infrastructure sectors by supporting regional initiatives and adapting procurement practices to prioritise trusted, sovereign solutions. These strategies aim to balance the promotion of domestic alternatives with the realities of global competition within the DC (and cloud) ecosystem. The coming years will reveal whether these measures can translate into meaningful market presence and help Europe secure greater autonomy in its digital ecosystem.

7.2.3. Merger control

Another area of debate concerns merger control. Traditionally, EU competition policy has maintained a strict approach to horizontal mergers to safeguard market diversity. *The Future of European Competitiveness* report by Mario Draghi argued that facilitating consolidation in the telecom sector could be necessary to achieve greater investment capacity and scale for next-generation networks[481]. While this recommendation focuses on telecom rather than cloud or DCs, it reflects a broader discussion on whether certain consolidations might strengthen Europe's digital infrastructure.

Conversely, the DG COMP's June 2024 report, *Protecting competition in a changing world,* emphasises that diverse and competitive markets remain essential for Europe's overall competitiveness, signalling a different message than Draghi's. The report states that evidence from the telecommunications sector shows that higher market concentration often goes hand in hand with higher prices[482]. This supports the Commission's argument that mergers which reduce competition may end up raising prices for consumers, instead of delivering efficiency gains. BEREC echoed this standpoint, noting that there's no proof fewer competitors at the national level lead to more investment or innovation – in fact, past experience shows competition itself motivates ECN/ECS operator to invest and innovate[483]. According to BEREC, if competition policy is weakened, dominant operators could be encouraged to act anti-competitively, potentially leading to reduced competition, less investment and innovation, lower consumer welfare, higher prices, or poorer service quality.

An important recent development relates to the European Commission's public consultations as part of the EU Merger Guidelines review. One of the key points raised is the need to consider

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[480] European Commission. (2025, October 10). The Commission moves forward on cloud sovereignty with a EUR 180 million tender. Retrieved 27 October, 2025 from https://commission.europa.eu/news-and-media/news/commission-moves-forward-cloud-sovereignty-eur-180-million-tender-2025-10-10_en;
Deloitte. (2023). Cloud sovereignty in Europe: Three imperatives for the public sector. Retrieved 28 October, 2025 from https://www.deloitte.com/us/en/insights/topics/technology-management/cloud-sovereignty-three-imperatives-for-the-european-public-sector.html.

[481] Draghi, M. (2024, September 9). The Future of European Competitiveness: Part A | A competitiveness strategy for Europe. Brussels: European Commission. Retrieved 27 October, 2025 from https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en.

[482] European Commission, Directorate-General for Competition. (2024, June). Protecting competition in a changing world - Evidence on the evolution of competition in the EU during the past 25 years. Retrieved 24 November, 2025 from https://competition-policy.ec.europa.eu/system/files/2024-06/KD0924494enn_Protecting_competition_in_a_changing_world_staff_report_2024.pdf.

[483] BEREC. (2025, July 11). BEREC Input to the European Commission's Call for Evidence on the Digital Networks Act. BoR (25) 101. Retrieved 24 November, 2025 from https://www.berec.europa.eu/system/files/2025-07/BoR%20%2825%29%20101_BEREC%20Input%20to%20EC%20Call%20for%20Evidence%20on%20DNA.pdf.

dynamic factors such as innovation, R&D incentives, and long-term market evolution – not just short-term price effects – when assessing potential mergers[484]. This approach acknowledges that mergers can influence innovation both positively and negatively, requiring careful, evidence-based analysis. However, the ultimate form of the new EU Merger Guidelines is yet to be determined.

The discussion around consolidation in telecom and cloud markets signals a broader trend in how competition policy is evolving, particularly with the inclusion of dynamic elements in merger assessments. It remains to be seen how this approach will influence DC (and cloud) sector, where scale and efficiency matter but where competition and openness are equally critical for long-term innovation and customer choice.

7.2.4. Exploring regulatory parallels between cloud and telecom markets

Another angle is how traditional telecom regulatory concepts might be applied to cloud markets. As mentioned earlier, NRAs (through BEREC) have started examining cloud and edge services to understand their interaction with ECN/ECS and potential regulatory implications[485], and in some Member States, NRAs also act as the designated competent authorities for the application of the EU Data Act to cloud services. BEREC notes in its Report on cloud/edge services and competition dynamics that there are key issues regarding cloud services – including market concentration, high sunk costs, switching barriers, and limited transparency for users [486] that raise some concerns. These concerns bear some resemblance to challenges commonly encountered in traditional network industries. For instance, making it easy for cloud customers to transfer their data (as addressed by the Data Act) bears some similarities to number portability in telecommunications. However, it must be noted, that it is much more complex, involving not just moving data but also migrating applications, adapting data structures, updating security settings, and ensuring compatibility with new systems. As a result, enabling cloud switching is a far more intricate process, requiring multiple technical and contractual steps that are much more involved than simply keeping a phone number.

There seems to be interest in monitoring cloud service quality and contracts. The cloud sector may, over time, warrant additional oversight measures possibly through codes of conduct or co-regulation involving industry. The EU's Cloud Rulebook, a non-binding compilation of cloud-related rules and standards, as well as guidance on public procurement of data processing services, signals movement in this direction [487]. If voluntary measures prove insufficient, policymakers could potentially consider granting regulatory bodies certain powers to review cloud market conditions or enforce interoperability standards. The *BEREC Report on Cloud and Edge Computing Services*[488] notes that if voluntary or market-driven solutions to interoperability and fair competition in the cloud sector prove insufficient, regulatory intervention may be considered.

[484] European Commission. (2025). Review of the Merger Guidelines. Topic C: Innovation and other dynamic elements in merger control. Retrieved 25 November, 2025 from https://competition-policy.ec.europa.eu/document/download/7be3a583-0af0-4f75-af6b-f0335572c8dc_en?filename=Topic_C_Innovation_and_other_dynamic_elements_in_merger_control.pdf.
[485] BEREC. (2024). Report on cloud/edge services and competition dynamics.
[486] Ibid., p. 10.
[487] European Commission. (2024). Cloud computing – Shaping Europe's digital future. Retrieved 26 October, 2025 from https://digital-strategy.ec.europa.eu/en/policies/cloud-computing.
[488] Ibid.

BEREC recommends that NRAs and itself remain vigilant and assess whether existing legal instruments are adequate or if new rules are needed[489].

In summary, Europe's competition policy in the DC and cloud domain is becoming more proactive and interventionist in order to maintain an open and fair market. Through laws like the Data Act (which directly tackles switching costs and unfair contract terms) and potential DMA enforcement on cloud services, the EU is addressing structural issues that previously allowed dominance to translate into customer lock-in. At the same time, regulators are trying to empower competitors by supporting collaborative European projects to ensure there are viable alternatives in the market. The goal is a cloud and DC ecosystem where customers have more options available and where newcomers (or smaller players) can find competitive footholds, thereby driving innovation and possibly better alignment with Europe's values (security, privacy, etc.). Regulatory intervention requires careful consideration: insufficient action may allow major market participants to maintain their advantage, while excessive or overly broad measures could discourage overall investment and innovation. The EU's approach for the next few years appears to be a calibrated one, using both carrots and sticks under the umbrella of "competitive openness" – keeping markets contestable while setting guardrails against anti-competitive practises.

7.3. Focus area: Sustainability

Environmental sustainability has become a central focus for DC and cloud regulation in Europe, driven by the EU's ambitious climate goals and the surging energy footprint of digital infrastructure. The trends in this arena point to stricter requirements as well as supportive measures to ensure that DC growth is aligned with energy and climate objectives.

7.3.1. Energy efficiency and carbon targets

To push the industry towards climate neutrality, the European Commission will propose a Data Centre Energy Efficiency Package in early 2026[490]. This package is expected to include binding measures on issues like PUE, waste heat recovery, and perhaps minimum standards for the share of renewable energy used. Already, under the revised EED of 2023, large DCs must report a set of Key Performance Indicators annually (energy use, renewable share, water usage, etc.), with data published to a new EU database[491]. It is anticipated that minimum efficiency requirements could be further introduced. Some Member States are already moving in this direction: Germany's government, for instance, set aggressive PUE targets (1.2 for new DCs from 2026) and heat reuse mandates in its 2023 Energy Efficiency Act[492].

Beyond efficiency, carbon footprint is being addressed: many big cloud operators have voluntary 100% renewable energy commitments, but regulators may codify this (Germany will require DCs to use 100% renewables by 2027[493], for example). Moreover, the *CNDCP* (an industry pledge)

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[489] Ibid., pp. 28, 51-54.
[490] Dodsworth, J., Burmeister, T., Trichkovska, I., Johnson, J., de Kersauson, Q., Hoffmann, E., … & Iffert, P. K. (2025, October 20). Data centres and energy consumption: evolving EU regulatory landscape and outlook for 2026. White & Case LLP.
[491] Ibid.
[492] Dentons. (2023, September 25). How Germany's Energy Efficiency Act will impact data center operators. Retrieved 27 October, 2025 from https://www.dentons.com/en/insights/articles/2023/september/25/energy-efficiency-act-relevance-for-data-centers.
[493] Ibid.

will no longer rely on self-regulation[494]. With new governance agreed with the European Commission and mandatory reporting requirements, members now use official reports under the Energy Efficiency Directive instead of self-audits. As a result, energy efficiency and decarbonization standards for DCs are becoming stricter, shifting from simple reporting to enforced performance standards aimed at achieving net-zero.

7.3.2. Circular economy and 6R principles

The EU's circular economy action plan emphasizes reducing waste and resource use in all industries. For DCs, this involves considering the entire lifecycle of equipment and facilities through principles collectively called "6R": Rethink, Refuse, Reduce, Reuse, Recycle, Recover (details on each component are provided in chapter 6.4.1.).

The 6R framework will increasingly be referenced in DC standards. Some EU-funded initiatives (like CEDaCI – Circular Economy for Data Center Industry) are developing circularity metrics[495]. New metrics akin to PUE, such as materials reutilization rate, formalized into reporting could be introduced[496]. One outcome could be that potentially by 2027–2028, large DCs must publicly report not just energy KPIs but also how many servers they decommissioned and how those were handled (reused internally, sold, recycled, etc.). Through a combination of regulation and industry codes, the goal is to drastically reduce waste – as part of the Green Deal's aim to minimize e-waste and promote resource efficiency.

7.3.3. Integration with the energy grid

A notable emerging trend is treating DCs not just as energy consumers to be constrained, but as potential assets to support the power grid. Policy experts have pointed out that DCs, with their large power capacity and backup systems, could provide valuable services to the electricity system[497]. For instance, DCs can participate in demand response – temporarily reducing their load during peak demand or grid stress – and be compensated by grid operators. They could also use their battery systems, originally deployed for uninterruptible power supply (UPS), to provide energy back to the grid at critical moments. However, it is important to note that emergency battery backups should be thoroughly evaluated before being used for grid compensation. Battery systems are primarily intended to maintain DC uptime and are not suited for handling peak grid demand. Diesel generators are a better alternative, but it is essential to manage fuel reserves carefully to meet SLAs.

The Strategic roadmap for digitalisation and AI in energy, scheduled for publication by European Commission in early 2026, will address the growing energy consumption of DCs and examine

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[494] Climate Neutral Data Centre Pact. (2025, June 11). New Era For Climate Neutral Data Center Pact. Retrieved 28 October, 2025 from https://www.climateneutraldatacentre.net/2025/06/11/new-era-for-climate-neutral-data-center-pact/
[495] CEDaCI. (n.d.). Circular Economy for the Data Centre Industry. European Circular Economy Stakeholder Platform. Retrieved 27 October, 2025 from https://circulareconomy.europa.eu/platform/en/dialogue/existing-eu-platforms/circular-economy-data-centre-industry-cedaci.
[496] RMIS – European Commission. (2023). Circular economy: indicators, tools and methods. Retrieved 28 October, 2025 from https://rmis.jrc.ec.europa.eu/CE.
[497] Le Goff, T., Inderwildi, O., Már Baldursson, F., M. von der Fehr, N-H., (2025, September). From Gridlock to Grid Asset: Data Centres for Digital Sovereignty, Energy Resilience, and Competitiveness. Brussels: Centre on Regulation in Europe (CERRE).

how they can be integrated into the energy system in a more sustainable manner[498]. Moreover, in its *Guidance on anticipatory investments for developing forward-looking electricity networks*, the Commission recognises that new demand sources, such as DCs and electrolysers, require higher levels of grid investment than in the past[499].

Another aspect is requiring new DCs to coordinate with grid development. The rapid clustering of DCs in certain regions (e.g. Dublin, Amsterdam, Frankfurt) caused local grid bottlenecks, leading to moratoria on new connections in some cases[500]. In future, formal procedures could be introduced where DC proposals must consult grid operators earlier and perhaps even co-invest in needed upgrades. All these measures signal a more symbiotic relationship between DCs and energy systems, turning a potential grid strain into an opportunity for more efficiency and resilience[501].

7.3.4. Tightening environmental standards beyond energy

While energy use and carbon emissions are primary concerns, regulators are beginning to address the broader environmental impact of DCs as well. For example, water consumption for cooling is now a significant focus: Spain has proposed regulations requiring large DCs to publicly report their water use alongside other sustainability metrics[502]. Similarly, France has introduced sector-specific rules regarding energy efficiency, water consumption and environmental reporting[503].

Further guidelines on WUE, or even local restrictions could be introduced in future. Some U.S. states have already limited DC water use during droughts and EU regulators may follow suit in by establishing minimum performance standards[504]. Additionally, the EU's circular economy policies are coming into play. The Eco-design Regulation for servers (2019) and forthcoming rules on electronics recycling mean DC hardware will need to meet standards for energy efficiency and recyclability[505]. The new F-gas Regulation (2024) phases out certain high-global-warming

[498]European Commission. (2025). Digitalisation of the energy systems. Retrieved 28 October, 2025 from https://energy.ec.europa.eu/topics/eus-energy-system/digitalisation-energy-system_en.
[499]European Commission. (2025, June 2). Commission Notice on a guidance on anticipatory investments for developing forward-looking electricity networks. Retrieved 27 October, 2025 from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52025XC03179&qid=1756994959820.
[500] Swinhoe, D. (2024, December 10). Pre-emptive data center moratoria: The hot new trend of local government. Datacenter Dynamics. Retrieved 27 October, 2025 from https://www.datacenterdynamics.com/en/opinions/pre-emptive-data-center-moratoria-the-hot-new-trend-of-local-government/.
Gleeson, C. (2025, September 17). Ireland's data centre appeal 'fading' due to pressure on electricity grid, report says. The Irish Times. Retrieved 27 October, 2025 from https://www.irishtimes.com/business/2025/09/17/irelands-data-centre-appeal-fading-due-to-pressure-on-electricity-grid-barclays-report-says/.
[501] Le Goff, T., Inderwildi, O., Már Baldursson, F., M. von der Fehr, N-H., (2025, September). From Gridlock to Grid Asset: Data Centres for Digital Sovereignty, Energy Resilience, and Competitiveness. Brussels: Centre on Regulation in Europe (CERRE).
[502]Cognitud. (2025, August 12). Spain Mandated Transparency in Data Center Energy and Water Use. Retrieved 25 November, 2025 from https://www.cognitud.com/news/spain-mandated-transparency-in-data-center-energy-and-water-use.
[503] Cudennec, S., Hahn Duraffourg, S., & Bracewell LLP. (2025, September 25). Building data centers in France: Navigating regulatory hurdles and unlocking growth. The National Law Review. Retrieved 25 November, 2025 from https://natlawreview.com/article/building-data-centers-france-navigating-regulatory-hurdles-and-unlocking-growth.
[504] Ainger, J. (2025, May). EU will work on setting water use caps for thirsty data centers. Bloomberg. Retrieved 28 October, 2025 from https://www.energyconnects.com.
[505] Walsh, M. (2025). Exploring the future of circular economy eco-design requirements through servers and data storage products. Compliance & Risks Blog. Retrieved 27 October, 2025 from https://www.complianceandrisks.com/blog/exploring-the-future-of-circular-economy-eco-design-requirements-through-servers-and-data-storage-products/.

refrigerants used in chillers, pushing DCs toward low-GWP coolants or liquid cooling solutions[506]. In short, sustainability regulation is broadening from pure energy metrics to a more holistic environmental footprint approach – covering water use, waste heat utilization, hardware lifecycle, and even noise and land use.

7.3.5. Supportive measures and innovation incentives

Energy regulatory measures are being complemented by certain incentives. The EU and national governments are channelling funding into research and deployment of greener technologies for DCs. For example, the EU's Horizon Europe program has funded projects on advanced cooling (like immersive liquid cooling and heat reuse systems) and on AI-driven energy management for DCs. The upcoming efficiency package in 2026 may propose state aid allowances or financing tools for retrofitting older DCs with energy-efficient equipment[507]. Additionally, classification in the EU Taxonomy for Sustainable Finance can attract private capital – DC projects that meet certain efficiency and waste-heat criteria can be labelled as sustainable investment[508]. We are witnessing a push for innovation-friendly regulation: for instance, the EU is considering how to encourage the use of waste heat from DCs to warm nearby buildings. For example, Helsinki has successfully integrated DC heat into its municipal heating networks[509]. Some recommend that EU energy policy should incorporate incentives or even requirements for this where feasible[510].

However, as indicated by one of our interviewees, the colocation company they represent is generally open to giving away the heat generated for free: "For our part, for example, we are very happy to do this free of charge; we do not want any payment for such projects, as for us it is simply an opportunity to showcase our engagement in Green project".

Another supportive measure is streamlined permitting for sustainable projects: DCs that hit high efficiency benchmarks might get fast-track permit approvals under future rules[511]. The overarching strategy is one of "green competitiveness": regulators want Europe to lead in sustainable cloud infrastructure, which could become a selling point globally. If European DCs are demonstrably more efficient and cleaner, it bolsters the EU's climate credibility and could give European DC operators a competitive edge or at least parity in a world increasingly concerned with supply chain emissions.

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[506] European Parliament & Council. (2024). Regulation (EU) 2024/573 of the European Parliament and of the Council of 7 February 2024 on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014. Official Journal of the EU. Retrieved 28 October, 2025 from https://eur-lex.europa.eu/eli/reg/2024/573/oj/eng;
ÖKOTEC. (2024). Refrigerant phase-down: The F-Gas regulation. Retrieved 28 October, 2025 from https://www.oekotec.de/en/refrigerant-phase-down-the-new-f-gases-regulation/.

[507] Dodsworth, J., Burmeister, T., Trichkovska, I., Johnson, J., de Kersauson, Q., Hoffmann, E., … & Iffert, P. K. (2025, October 20). Data centres and energy consumption: evolving EU regulatory landscape and outlook for 2026. White & Case LLP.

[508]European Commission. (n.d.). EU taxonomy for sustainable activities (overview). Retrieved 28 October, 2025 https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en.

[509] Yuan, X., Liu, J., Sun, S., Lin, X., Fan, X., Zhao, W., & Kosonen, R. (2025). Data center waste heat for district heating networks: A review. Renewable and Sustainable Energy Reviews, 219, 115863. Retrieved 27 October, 2025 from https://doi.org/10.1016/j.rser.2025.115863.

[510] Le Goff, T., Inderwildi, O., Már Baldursson, F., M. von der Fehr, N-H., (2025, September). From Gridlock to Grid Asset: Data Centres for Digital Sovereignty, Energy Resilience, and Competitiveness. Brussels: Centre on Regulation in Europe (CERRE).

[511] Ibid.

7.3.6. Compliance and enforcement

With more rules coming, ensuring compliance will be critical. The EU is already tracking energy performance through annual reporting obligations for DC operators as part of the EED. Under Article 12 and the Delegated Regulation (EU) 2024/1364, operators of DCs with an installed IT power of at least 500 kW must report KPIs such as PUE, WUE, energy reuse factor (ERF), and renewable energy factor (REF) to a European database[512]. The first reporting deadline was September 2024, and annual submissions are due by May each year. This transparency could further expose lagging operators to increased scrutiny.

As a result, DCs face increasing operational challenges, as meeting sustainability reporting and energy management requirements under new regulations demands advanced technical capabilities[513]. Larger operators are generally better positioned to manage these expenses, whereas smaller firms may face competitive challenges. Regulators seek to address this imbalance through proportionality clauses and streamlined requirements for SMEs, including initiatives like the Voluntary SME Sustainability Reporting Standard (VSME) within the CSRD framework. These measures include transitional periods and scale requirements to avoid unintended market consolidation.

In essence, sustainability regulation for DCs is intensifying significantly. Europe is on a trajectory to make its digital infrastructure not only high-performing but also environmentally and socially responsible. By 2030, operating a DC or cloud service in the EU will entail strict obligations: the use of renewable or low-carbon power, best-practice efficiency, participation in grid balancing, and transparent environmental reporting. The industry has largely acknowledged the direction of travel, and many players are proactively adapting (e.g. major cloud firms regularly announce new green DC investments, and many are piloting battery and heat reuse projects). The success of these regulatory efforts will be measured in a few key outcomes: stabilizing or reducing total energy use even as demand grows (through efficiency gains), ensuring the sector's power is 100% renewable (or otherwise climate-neutral), and preventing local negative impacts (no more stories of DCs causing blackouts or water shortages). If Europe achieves that, it could genuinely claim global leadership in sustainable cloud infrastructure, potentially influencing other regions. If not, and if regulation is seen as too burdensome, there's a risk that investors simply build new facilities elsewhere (though data locality needs for performance and sovereignty somewhat limit that). Striking the right balance is crucial. The current approach, using a mix of mandates and incentives, reflects an understanding that innovation must be part of the solution – regulation is steering the market, but technology and industry initiative will ultimately deliver the results.

7.4. Focus area: Data sovereignty

"Data sovereignty" refers to Europe's ability to control and protect data according to its own laws and values. In the context of DCs and cloud, this has spurred a range of regulatory and policy

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[512] Covington. (2025, September). The EU's Energy Efficiency Directive and its impact on data centres. Retrieved 28 October, 2025 from https://www.cov.com/-/media/files/corporate/publications/2025/04/the-eus-energy-efficiency-directive-and-its-impact-on-datacenters.pdf.

[513] Simmons & Simmons. (2024, April 11). Top 10 issues for data centres. Retrieved 28 October, 2025 from https://www.simmons-simmons.com/en/publications/cluuzeox800hyuatcw3kkq0xs/top-10-issues-in-data-centres.

initiatives aimed at reducing dependency on foreign providers and ensuring that critical data infrastructure remains under EU governance. The following section highlights the main trends in this field.

7.4.1. Cloud Security and Certification (EUCS)

One concrete development is the upcoming EUCS, designed to certify cloud providers at different assurance levels across the EU. During its drafting, a major debate emerged over "sovereignty requirements." Some Member States – most notably France – advocated for provisions that, at the highest security level, would restrict certification to services operated by EU-based companies immune from non-EU governmental access[514]. Industry groups, including U.S. cloud firms and European business associations, argued this would fragment the market and exclude non-EU providers[515]. In April 2023, these sovereignty requirements were removed from the draft, a decision welcomed by industry but criticized by others as a missed opportunity to strengthen EU control[516]. The final EUCS scheme will likely emphasize technical security criteria without so-called sovereignty requirements[517].

However, the concept of sovereign cloud is not yet abandoned; it has shifted toward national and sectoral initiatives. France's SecNumCloud label, managed by ANSSI, imposes strict requirements such as EU-based data residency, operational control, and immunity from non-EU laws[518]. Similarly, Germany's Trusted Cloud label emphasises transparency, security, and compliance for sensitive workloads[519]. These frameworks have led to offerings like Microsoft's Azure France Operated by Orange and Capgemini, delivered through the Bleu joint venture, which aims to achieve SecNumCloud qualification by 2025[520]. Google partnered with Thales to launch S3NS, a sovereign cloud service in France designed to comply with SecNumCloud standards[521].

The prevailing regulatory approach involves a deliberate balance: maintaining rigorous security and compliance measures to safeguard European data, while permitting access to non-EU service providers in order to support innovation and ensure the continued availability of services.

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[514] Propp, K. (2023, June 27). Oceans apart: The EU and U.S. cybersecurity certification standards for cloud services. Open Legal Blog Archive. Retrieved 27 October, 2025 from https://www.crossborderdataforum.org/wp-content/uploads/2023/07/Oceans-Apart-The-EU-and-US-Cybersecurity-Certification-Standards-for-Cloud-Services.pdf.
Hogan Lovells. (2024, June 12). EUCS: Controversial sovereignty issues continue to drive debate for cloud services. Retrieved 27 October, 2025 from https://www.hoganlovells.com/en/publications/eucs-controversial-data-sovereignty-issues-continue-to-drive-debate-around-the-eu-certification-scheme-for-cloud-services.
[515] AmCham EU. (2024). Cybersecurity Certification Scheme for Cloud Services (EUCS): Industry position. Retrieved 28 October, 2025 from https://www.amchameu.eu/position-papers/cybersecurity-certification-scheme-cloud-services-eucs.
[516] European DIGITAL SME Alliance. (2024, September 5). Changes to the EU Cloud Services Cybersecurity Certification Scheme put EU citizens' data at risk: A call for digital sovereignty. Retrieved 27 October, 2025 from https://www.digitalsme.eu/changes-to-the-eu-cloud-services-cybersecurity-certification-scheme-put-eu-citizens-data-at-risk-a-call-for-digital-sovereignty/.
[517] Kroet, C. (2024, April 4). Cyber certification fix sought by mid-April over sovereignty issue. Euronews. Retrieved 27 October, 2025 from https://www.euronews.com/next/2024/04/04/cyber-certification-fix-sought-by-mid-april-over-sovereignty-issue.
[518] ITIF. (2025, May 26). France's cloud service restrictions. Retrieved 28 October, 2025 from https://itif.org/publications/2025/05/25/france-cloud-service-restrictions.
[519] Trusted Cloud. (n.d.). About Trusted Cloud. Retrieved 29 October, 2025 from https://www.trusted-cloud.de/en/about-trusted-cloud.html.
[520] Capgemini (2024, January 15). Launch of Bleu sovereign cloud platform based on Microsoft technology. Retrieved 27 October, 2025 from https://www.capgemini.com/news/press-releases/capgemini-and-orange-are-pleased-to-announce-the-launch-of-commercial-activities-of-bleu-their-future-cloud-de-confiance-platform.
[521] Butler, G. (2024, April 4). EU relaxes cloud contract bidding rules for hyperscalers. DataCenterDynamics. Retrieved 20 October, 2025 from https://www.datacenterdynamics.com/en/news/eu-relaxes-cloud-contract-bidding-rules-for-hyperscalers/.

The EUCS saga illustrates the cautious path the EU is taking on sovereignty – balancing between open markets and autonomy.

7.4.2. European cloud alternatives and GAIA-X

Beyond regulating foreign providers, the EU is actively investing in European cloud and data infrastructure capacity. The flagship initiative is Gaia-X, launched in 2020 to create a federated cloud ecosystem aligned with EU principles of data sovereignty and interoperability[522]. Gaia-X is not a single provider but a framework of standards, governance rules, and open-source components enabling interconnection among multiple providers. By 2024, Gaia-X had operational "data spaces" and demonstrated portability of data and workloads across federated environments[523]. EU and Member States are backing these efforts politically and financially. The Digital Europe Programme allocates billions to projects supporting cloud federation and sector-specific data spaces[524]. These initiatives aim to ensure diversity and reduce dependency on non-EU providers.

A related development is investment in sovereign connectivity, including the IRIS² satellite constellation and strategic submarine cable projects. IRIS², approved in 2024, will deploy a multi-orbit constellation of ~290 satellites to provide secure connectivity for EU governments and critical sectors, reinforcing Europe's autonomy in data transmission[525]. The project is specifically designed to tackle long-term challenges related to the security, safety, and resilience of the EU by providing improved connectivity services for government users.

7.4.3. Legal and regulatory measures for data control

Another aspect of data sovereignty involves developing the legal structure that governs data. The existing legal framework can be understood as having three layers:

1. Horizontal rules: The EU Data Act (Regulation (EU) 2023/2854)[526] serves as the overarching instrument for all types of international data transfers – personal and non-personal. It includes Article 32, which requires cloud providers to take "all adequate technical, organisational and legal measures"[527] to prevent unlawful access by non-EU governments, effectively mandating contractual and technical arrangements so foreign

[522] Gaia-X AISBL. (2022). Gaia-X - Architecture Document - 22.04 Release. Retrieved 28 October, 2025 from https://gaia-x.eu/wp-content/uploads/2022/06/Gaia-x-Architecture-Document-22.04-Release.pdf.
[523] Ibid;
Heinbach, C., Gessler, J., Rychlik, H., Stecenko, C., Wieker, H., & Schulz, W. H. (2024). Sharing Business Data Securely: Insights from the European Gaia-X Project on Technical and Economic Roles Enabling Federated Data Spaces. Journal of Telecommunications and the Digital Economy, 12(4), 66-84. Retrieved 28 October, 2025 from https://doi.org/10.18080/jtde.v12n4.1037.
[524] European Commission. (2025). Digital Europe Programme. Retrieved 22 October, 2025 from https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/digital-europe-programme_en.
[525] European Commission. (2024, December 16). Commission takes next step to deploy the IRIS² secure satellite system. Retrieved 26 October, 2025 from https://defence-industry-space.ec.europa.eu/eu-space/iris2-secure-connectivity_en.
[526] European Union. (2023). Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data. Official Journal of the European Union, L 2023/2854. Retrieved 23 October, 2025 from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302854.
[527] Ibid., p. 58.

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authorities cannot directly reach EU-held data without going through EU legal processes[528]. This is a subtle but important assertion of EU autonomy: it forces providers to push back legally on foreign subpoenas or structure services (e.g., through encryption and EU-only key management) so compliance with foreign demands becomes impossible without EU oversight.

2. Personal data protection: For personal data or mixed datasets where personal and non-personal data are inseparable, the General Data Protection Regulation (GDPR[529]) remains the cornerstone. GDPR ensures that Europeans' personal data is protected regardless of location. As part of the recent developments, in 2023, the EU and U.S. agreed on a new Data Privacy Framework (DPF) to facilitate transatlantic data flow. The framework was upheld by the EU General Court in September 2025, confirming its adequacy for now, though further appeals are possible[530]. If the DPF fails judicial scrutiny in the future, the EU may intensify requirements for local processing of personal data.

3. Sector-specific regulations: Additional safeguards apply to sensitive domains. For example, the European Health Data Space (EHDS) regulation includes strict provisions for health data security and conditions for transfers outside the EU[531]. This regulation aims to ensure that sensitive health information is processed in compliance with EU standards, mandating robust technical and organisational safeguards to protect patient privacy. This layered architecture is complemented by measures addressing government access to data.

Recent regulatory developments indicate a clear preference for maintaining oversight of critical data within the EU. While this does not amount to a mandate for total data localisation – since the free flow of data within the EU remains a central objective of the European Data Strategy[532] - it does set boundaries in areas where sovereignty is paramount, such as security and certain categories of personal data. Furthermore, it requires that general-purpose services operating within the EU adhere to applicable EU regulations when serving European citizens.

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[528] Barone, M. L. (2023, March 2). The EU Data Act and International Data Flows – Why Policymakers Should Clarify Art. 27 of the Data Act. ITI. Retrieved 26 October, 2025 from https://www.itic.org/news-events/techwonk-blog/the-eu-data-act-and-international-data-flows-why-policymakers-should-clarify-art-27-of-the-data-act.

[529] European Union. (2016). Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation). Official Journal of the European Union, L 119. Retrieved 24 November, 2025 from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R0679.

[530] JD Supra. (2025, November 4). Framework Intact, For Now: EU-US Data Flows Dodge Another Bullet. Retrieved 28 October, 2025 from https://www.jdsupra.com/legalnews/framework-intact-for-now-eu-us-data-1811919/;
A&O Shearman. (2025). EU-U.S. Data Privacy Framework: navigating the legal landscape after the General Court's verdict. Retrieved 28 October, 2025 from https://www.aoshearman.com/en/insights/eu-us-data-privacy-framework-navigating-the-legal-landscape-after-the-general-courts-verdict.

[531] European Union. (2025, February 11). Regulation (EU) 2025/327 of the European Parliament and of the Council of 11 February 2025 on the European Health Data Space and amending Directive 2011/24/EU and Regulation (EU) 2024/2847. Official Journal of the European Union. Retrieved 27 October, 2025 from https://eur-lex.europa.eu/eli/reg/2025/327/oj/eng;
Werry, S., Éles, K., Ridgway, W. E., Simon, D. A., & Kerr-Shaw, N. (2025, June 25). The European Health Data Space – What EU health care providers and data holders need to know. Skadden Publication / Cybersecurity and Data Privacy Update. Retrieved 27 October, 2025 from: https://www.skadden.com/insights/publications/2025/06/the-european-health-data-space.

[532] European Commission (2020, February 19). A European strategy for data. Brussels. Retrieved 27 October, 2025 from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0066.

Finally, as one of the most recent developments, the EU has proposed the Digital Omnibus Regulation in November 2025 to simplify and clarify its digital legislative framework[533]. This proposal introduces targeted amendments and consolidates provisions across several key regulation such as the Data Act, GDPR, Data Governance Act, and AI Act, aiming to reduce legal complexity and administrative burdens for businesses and public administrations. The Digital Omnibus streamlines requirements, repeals outdated rules, and introduces a single-entry point for incident reporting, while extending simplification measures to more companies. It aligns and harmonises definitions and procedures, supporting legal certainty and more efficient compliance, without lowering existing standards for data protection or fundamental rights.

In summary, the EU's approach to data sovereignty is a multi-faceted policy push: it includes technical measures (security certifications, encryption frameworks), legal measures (data laws asserting EU jurisdiction, contract requirements against foreign access), market measures (supporting EU providers, shaping procurement), and oversight measures (screening investments, scrutinizing subsidies). The goal is not to cut off Europe from global data flows but rather to ensure Europe has the capability to manage its own data and is not forced into dependency. Achieving this will likely result in a more hybrid cloud environment in Europe: one where foreign providers are present and important but operate under clear EU rules and increasingly in partnership with local entities; and one where European providers and infrastructure play a growing (if still supporting) role for specific needs. If effective, Europe will have a robust, sovereign-by-design digital infrastructure, where choices can be made on criteria beyond just price (like trust and compliance). The risk, of course, is that heavy-handed rules could reduce service availability or innovation if mis-calibrated. So far, the EU has mostly avoided draconian mandates and is instead using a subtler mix of requirements and incentives. A key example of this balanced approach is the Digital Omnibus Regulation, which aims to simplify and harmonise digital rules across the EU, reducing administrative burdens and clarifying compliance for businesses.

The next 3–5 years will test this approach: for instance, will companies embrace the opportunities of Gaia-X and EUCS, or will they find them cumbersome? Will foreign providers maintain full engagement with the European market or scale back certain offerings due to compliance burden? Early indications (such as Microsoft's and Google's continuous expansion of EU DCs and introduction of sovereignty options) suggest that the major players will adapt rather than retreat. That bodes well for Europe achieving sovereignty through strength, not isolation. Europe's data sovereignty journey is a long-term project, but the regulatory steps being taken now – like the Data Act's safeguards and the push for sovereign cloud certifications – mark a decisive move to shape the digital future on Europe's terms.

7.5. Outlook and implications

By 2030, Europe's DC and cloud sector will likely operate under a substantially different rulebook than it did in the 2010s. Competition policy will have introduced greater cloud interoperability and

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[533] European Commission. (2025, November 19). Digital Omnibus Regulation Proposal. Retrieved 25 November, 2025 from https://digital-strategy.ec.europa.eu/en/library/digital-omnibus-regulation-proposal.

curbed certain big-player advantages (with the Data Act's cloud switching provisions fully in force, and possibly some hyperscalers/cloud services' providers falling under the DMA's ambit if they are deemed gatekeepers). Sustainability mandates will have pushed DCs towards carbon neutrality, with energy efficiency and transparency not just encouraged but legally required, and integration with energy grids becoming standard practice. Data sovereignty measures will have given European customers more assurances about the jurisdictional control of their data and fostered a more diverse cloud ecosystem (through both stringent security rules and the nurturing of European alternatives).

For industry participants, these trends mean significant adaptation. Cloud providers (especially the largest ones) are already modifying offerings to meet Europe's evolving requirements – for example, offering EU-only data boundaries, signing up to codes of conduct, and investing in renewable energy and advanced cooling to meet sustainability goals. DC operators are accelerating efficiency upgrades and exploring ways to provide flexibility to the grid (some are signing contracts with utilities to supply emergency power or reduce load on demand). Many companies are beefing up their compliance teams to handle new reporting and security requirements spurred by NIS2, DORA, and other laws. There are ongoing discussions regarding potential additional regulatory measures in the cloud sector[534].Thus, it can be inferred that the landscape may become more regulated and complex, while also potentially becoming more stable and mature. Businesses and investors often prefer clear rules to uncertainty. The EU is in effect laying down rules of the road that, while initially burdensome, could create a predictable environment for long-term investments in European digital infrastructure.

Policymakers are expected to monitor outcomes and make adjustments as necessary. Recent legislation includes review clauses; for example, by 2028, the Commission is scheduled to evaluate the Data Act and assess factors such as its effect on reducing charges imposed by providers of data processing services during the switching process[535]. If certain measures are found to hinder innovation or impose disproportionate costs, the EU could amend them.

Globally, Europe's regulatory moves are being closely watched. On competition, other jurisdictions such as the UK and Japan are actively studying cloud market dynamics[536] and may emulate certain EU portability and interoperability rules. On sustainability, Europe's push for green DCs could set new benchmarks (if European facilities demonstrably run cleaner, multinationals might adopt those practices worldwide). And on sovereignty, Europe's stance is part of a broader trend. India, for example, has enacted the Digital Personal Data Protection Act, 2023, which

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[534] Manganelli, A., Schnurr, D. (2024, February). Competition and Regulation of Cloud Computing Services: Economic Analysis and Review of EU Policies. Centre on Regulation in Europe (CERRE). Retrieved 29 October, 2025 from https://cerre.eu/wp-content/uploads/2024/02/CERREreportCloudcomputingfeb24.pdf.

[535] European Union. (2023, December 13). Regulation (EU) 2023/2854 of 13 December 2023 on harmonised rules on fair access to and use of data (Data Act). Official Journal of the EU, L 333, 22.12.2023.

[536] OFCOM. (2023, November 6). Cloud services market study: Final report. Retrieved 20 October, 2025 from https://www.ofcom.org.uk/internet-based-services/cloud-services/cloud-services-market-study;
MIC Japan. (2024, October 4). Study Group on Addressing Issues related to Information Distribution in the Digital Space. Ministry of Internal Affairs and Communications. Retrieved 30 October, 2025 from https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/pressrelease/2024/10/4_3.html.

empowers the government to restrict cross-border transfers of personal data[537] – reflecting a move toward greater data sovereignty. However, the EU tends to pursue these objectives within a rule-of-law framework that could become a reference model for others. We may see international convergence toward some of the principles the EU is championing.

In conclusion, the regulatory trends in Europe's DC and cloud market reflect the EU's determination to shape the digital future in line with European interests and values. The next 3–5 years will be crucial in implementing this vision. If successful, Europe will have a thriving digital infrastructure that is open yet sovereign, innovative yet sustainable. Achieving this will require continuous dialogue between regulators and industry, fine-tuning of measures, and collaboration at all levels (from local grid operators to international standard-setters). The steps already taken – in competition, sustainability, and sovereignty – have set the direction. The journey now is about execution and adjustment. By the end of this decade, Europe aims to have not only caught up in the digital race, but to have done so on its own terms, ensuring that economic opportunities from the cloud do not come at the expense of European control, fairness, or environmental stewardship. It's an ambitious endeavour, but one that the EU has clearly prioritised as essential for its digital and strategic autonomy in the years ahead.

[537] Ministry of Law and Justice. (2023, August 11). Digital Personal Data Protection Act, 2023. Government of India. Retrieved 30 October, 2025 from https://www.meity.gov.in/static/uploads/2024/06/2bf1f0e9f04e6fb4f8fef35e82c42aa5.pdf.

8. Conclusion

Drawing on extensive desk research, a broad stakeholder survey, and in-depth interviews with representatives from DC operators, academia, and regulatory bodies, the study offers a factual foundation for future regulatory discussions concerning the digital infrastructure landscape. This comprehensive approach ensures that the perspectives and concerns of diverse sector participants are reflected, enabling policymakers to address emerging challenges and opportunities in a rapidly evolving environment. The following conclusion distils the most salient insights and findings, offering a forward-looking perspective on the challenges and opportunities facing the DC ecosystem in Europe.

Geographic and market evolution

Core hubs and emerging markets: Europe's DC capacity remains heavily concentrated in a handful of metropolitan hubs – Frankfurt, London, Amsterdam, Paris, and Dublin (FLAP-D). These cities benefit from mature digital infrastructure, dense fibre connectivity, and established ecosystems. However, grid congestion, high costs, and limited land are driving rapid expansion into secondary and emerging markets such as Madrid, Milan, Warsaw, and cities across the Nordic countries and Central/Eastern Europe. These regions offer more favourable conditions, including available grid capacity, lower costs, and supportive regulatory environments. The spatial hierarchy of DCs is becoming more pronounced, with distinctions between primary hubs, fast-growing secondary hubs, peripheral/emerging hubs, and distributed edge DCs designed for low-latency applications. This diversification is critical for resilience, performance, and the broader digital ambitions of the continent.

Ownership models and business structures: The European DC market is marked by diversity in ownership and business models. Independent colocation providers, hyperscaler-owned facilities, public sector and PPP initiatives, telecom operator-owned DCs, and hybrid models all coexist, each with unique challenges and opportunities. Colocation providers must balance flexibility and neutrality with the need for scale, while hyperscalers leverage global reach but face regulatory and sustainability pressures. Public sector involvement and hybrid models, including sovereign cloud and quantum-ready sites, are increasingly prominent, reflecting the strategic importance of DCs for national and regional digital infrastructure and sovereignty.

Critical dependencies and interdependencies

Power, connectivity, and sustainability: Access to reliable and scalable electricity is the single most critical factor for DC site selection. The surge in AI and cloud workloads is driving unprecedented demand for power, with forecasts indicating a near doubling of consumption by 2030. Grid congestion in established hubs is pushing new investments to less saturated regions. Proximity to high-capacity fibre backbones, IXPs, and international submarine cables is equally essential for performance and competitiveness. Environmental sustainability is no longer optional. Efficient cooling, water management, and advanced technologies are becoming differentiators, especially in water-stressed regions. Compliance with EU and national regulations on energy efficiency, emissions, and water use is shaping site feasibility and operational costs. Fragmented national regimes and local permitting complexities remain significant barriers.

Interconnection with ECNs and submarine cables: DCs are central nodes in Europe's digital ecosystem, enabling the storage, processing, and rapid exchange of data for cloud services, AI, and digital platforms. Their integration with electronic communication networks (ECNs) and submarine cables underpins Europe's global connectivity. Over 99% of intercontinental digital traffic is carried by submarine cables, making them indispensable for international data flows and cloud computing. Ownership of these cables is shifting from telecom consortia to major technology companies, raising questions about dependency, control, and digital sovereignty. Physical vulnerabilities and increasing geopolitical risks in submarine cable infrastructure highlight the need for enhanced security, resilience planning, and coordinated international oversight. Power grid, networks (ECN) density and proximity to submarine cables landings were among the key factors shaping DCs' distribution until recently. Soon, however, limits on grid capacity, cooling availability, and the rising pressure for environmental sustainability may shift new DC deployment toward regions with less-strained power infrastructure and better access to green energy. In this scenario, ECNs should follow this trend to ensure low-latency connectivity and support DC growth in these emerging locations.

Market dynamics and competition

Key players and competitive trends: The European DC market is shaped by telecom operators, hyperscalers (notably AWS, Microsoft, and Google), and specialist colocation providers. Hyperscalers are the primary engines of growth, accounting for the majority of new DC demand and leasing. Their dominance in cloud services has raised concerns about market concentration, vendor lock-in, and reduced customer choice. Despite competition, there is significant collaboration – hyperscalers often partner with telecoms and colocation providers for local hosting and connectivity, especially for "sovereign cloud" offerings. Expansion into secondary markets is accelerating, driven by constraints in core hubs. Providers are increasingly competing on energy efficiency, sustainability, and specialised services, as basic colocation becomes commoditised.

Investment, consolidation, and ownership: The sector has attracted significant capital from infrastructure funds, private equity, and new operators, leading to rapid expansion and a wave of mergers and acquisitions. While consolidation can bring efficiency and broader service offerings, it also raises concerns about local market concentration and foreign ownership. Policymakers are increasingly attentive to the strategic implications of non-European ownership, especially in the context of digital sovereignty.

Regulatory environment and future trends

Evolving regulatory landscape: The EU is taking a more proactive and integrated approach to regulating DCs and cloud services, with a focus on competition, sustainability, and digital sovereignty. Key regulatory developments include:

- The Data Act (until 2027), cloud egress fees must be banned and greater interoperability is required, reducing switching costs and promoting competition.
- The Digital Markets Act (DMA), imposing further obligations on "gatekeepers".

- Stricter requirements for energy efficiency, renewable energy use, and waste heat recovery, driven by the EU's Green Deal and climate targets.
- Harmonisation of data localisation and cloud certification rules, supporting the development of European initiatives such as Gaia-X and IRIS[2].

Policy focus areas: Policymakers are prioritising:

- Balanced growth and market power, with efforts to foster competition and support multi-vendor, multi-cloud strategies.
- Accelerated infrastructure deployment, streamlining permitting processes and incentivising investment while ensuring sustainability.
- Holistic, cross-sector governance, integrating digital, energy, competition, and industrial policies.
- Enhanced compliance and enforcement, with larger operators better placed to comply, while SMEs may benefit from proportionality clauses and transitional periods.

Strategic outlook and challenges

Balancing growth, sustainability, and sovereignty: The interplay between rapid market growth, sustainability imperatives, and digital sovereignty will define the future of Europe's DC sector. Operators must balance the need for expansion with the demands of energy efficiency, environmental stewardship, and regulatory compliance. The convergence of DC and ECN investments is reshaping Europe's digital infrastructure, influencing where capacity is built, how resilient and sustainable it is, and the balance between legacy hubs and emerging markets.

User empowerment and innovation: Cloud services' customers stand to benefit from greater transparency, easier switching, and more choice as regulatory oversight increases. Providers will compete on sustainability, energy efficiency, and specialised services, with EU climate targets raising the bar for all players. The regulatory environment is expected to become more stable and predictable, supporting long-term investment and innovation.

Final remarks

Europe's DC sector is at a pivotal juncture. The market is dynamic and competitive, with ECN/ECS operators, hyperscalers, and colocation providers both competing and collaborating. While consolidation and foreign ownership raise concerns about market power and sovereignty, new regulatory measures are being introduced to ensure fair competition, reduce lock-in, and promote sustainability. The coming years will be crucial for implementing and fine-tuning an ambitious regulatory agenda, ensuring that Europe's digital infrastructure remains competitive, secure, and climate-neutral, with strong safeguards for sovereignty and user empowerment.

The sector's ability to navigate these challenges – balancing growth, sustainability, and sovereignty – will determine its capacity to support Europe's digital ambitions and global competitiveness in the decades ahead.

9. Annex 1: Interview survey

This section presents a comprehensive overview of the key questions explored during the in-depth interviews (IDIs) conducted as part of the project. Each section provides a summary of the responses received for each question, offering valuable insights into current industry perspectives and practices. The aim is to highlight the main themes and trends that emerged from the interviews, setting the context for the detailed analysis.

Q1: What is the main driving force behind your company's adoption of mobile DC solutions? Is it primarily to address ad-hoc demand scaling, benefit from physical mobility, gain flexibility in energy sources, environmental/cooling capabilities, improve network connectivity, or are there other key factors?

The analysis of the interviews concerning the driving forces behind the adoption of Mobile Data Centre Solutions (MDC) revealed that a decisive majority of the surveyed companies do not implement or do not plan to adopt such solutions within their core operations.

The analysis showed that out of the sources containing a direct response to this question, overwhelming majority of respondents stated that they do not use MDC or see no such need for their business model.

Despite the dominant lack of adoption, key factors were identified that represent potential motivation for MDC implementation in highly specific, niche contexts, as well as major obstacles discouraging their widespread use.

Banking and a large global operator indicated that the scale of needs significantly exceeds the capabilities of completely MDC. MDC are considered minimal installations that cannot be strong centres due to capacity issues. In addition, serious security considerations were pointed out: mobile units are easy to abduct, posing a serious threat to confidentiality and critical data. Their location requires very strong security restrictions.

A large operator deemed MDC to be very risky and difficult to secure against sabotage or break-ins, disqualifying them as primary DCs for serious business.

Also, an important aspect that might impact the understanding of the question was raised: one operator clarified that their infrastructure is modular (based on containers that can be removed), not mobile (moved within days or weeks). The modular design emphasizes component replacement, not physical relocation.

Despite MDCs being generally considered niche solutions for general-purpose computing, one survey respondent highlighted a specific use case linked to 5G deployment. According to this respondent, MDCs can serve as temporary or rapidly deployable micro-facilities positioned near base stations to support local processing during network upgrades or pilot deployments. This view should not be interpreted as a general requirement for 5G, as most edge functionality is delivered through fixed micro-DCs or operator-owned edge nodes rather than mobile units. Instead, the response reflects an individual operational perspective rather than a broader industry pattern.

Q2: Are you encountering any technical, regulatory, security, or market availability-related barriers that prevent you from adopting a MDC approach when it is considered necessary or potentially profitable for your business?

Based on the comprehensive review of interview transcripts and survey responses, organizations encounter significant technical, security, regulatory, and cost-related barriers that prevent the adoption of MDC approaches, even when such deployment is considered potentially profitable or necessary for business operations.

Out of the sources detailing discussions or providing explicit feedback on MDC solutions, organizations provided specific concerns or barriers that would limit or prevent adoption when considering necessity or profitability.

The primary constraints are grouped below, ranked by the statistical prominence of the supporting arguments.

The high costs of placing a container with adequate cooling are considered prohibitive, creating a competitive disadvantage. One organization noted that these high costs limit the ability to redirect investment toward energy efficiency and generation improvements.

One operator stated that maintaining dedicated buildings has historically proven more effective over time in terms of costs, flexibility, independence, security, and maintenance compared to mobile alternatives. The requirement for, and high cost of, obtaining certifications for mobile units creates a competitive barrier. Also, a low market awareness is observed, where mobile DCs are often viewed as an "unnecessary excess" or merely treated as a "third DC".

High client power requirements, such as installations exceeding 15–20 kilowatts per cabinet, are incompatible with containerized cooling solutions, which struggle with limited space and redundancy, making adoption difficult even when technically necessary.

The technical challenge of developing a truly autonomous DC that is less dependent on the external grid and can generate and store its own energy for extended periods was highlighted as a major impediment.

MDCs containing critical information are considered significant security risks, described as "easy to abduct" and a "tasty morsel" comparable to cash transports (banking sector).

It is also challenging to secure these environments against breakage, fire, and sabotage. Deployment requires securing a dedicated, designated "safe, guarded, guarded territory".

The current licensing process is considered complex. A "common and simplified regulatory framework at national or European level" is required to facilitate adoption. Legal and regulatory aspects pose a barrier when a mobile DC needs to be moved abroad, sometimes requiring the law to be "changed overnight" to ensure service continuity (citing a case involving Ukraine)

Q3: Do you face any challenges or blockers in achieving or documenting your DC's compliance with industry best practices and standards, such as high certification costs,

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non-approachability of the certification processes, limited knowledge-sharing support, or lack of guidance on of various certification schemes at the European level?

Not all distinct Data Centre Operators (DCOs) provided feedback regarding certification processes and challenges, however all that did, acknowledged or detailed specific blockers related to cost, effort, or operational constraints, even if they ultimately achieved certification or chose to forgo it based on a strategic cost/benefit analysis.

The most statistically prominent barrier is the financial strain associated with certification relative to the perceived business benefit. Achieving compliance often requires a "high investment cost with a relatively low ROI" and certifications, such as Tier certification (Uptime Institute) or EN 50600, are considered "pretty expensive". For self-owned internal DCs (e.g., in the banking sector), the cost of external validation is often seen as money spent without gaining a necessary "marketing advantage". The costs are not limited to the audit itself but include the expense and risk associated with mandatory annual tests, which sometimes necessitate temporarily "stop the production" or introducing "some risk for the for the production".

One major global operator views the high cost of certification as "senseless spending", preferring instead to redirect that money into "innovations". This operator argues that their role is to "impose trends," not follow certification frameworks.

The costs are not always related to finances, the resources required for documentation, procedure implementation, and auditing impose a significant operational burden, particularly for technical staff. Achieving certification requires a "big effort," particularly for staff who must "write the procedures and then follow them". The certification process is widely criticized for being "challenging in the way that it quite it needs quite a lot of effort" and involves "a lot of bureaucracy".

For institutions already pursuing energy efficiency measures (e.g., achieving low PUE through warm water cooling), mandatory certification (such as ISO 50001) simply forces them to perform redundant "reporting" and documentation on goals they "pursue anyway".

In many sectors, particularly publicly funded or academic institutions, certification is not required by law or external clients, diminishing the motivation for adoption.

Organizations operating in the research sector noted that they simply "don't have the need" for certifications. They are publicly funded and only invest in changes "when there is funding".

The necessity for certification is often "not so much" unless explicitly "requested" by commercial customers.

Also, some concerns were raised regarding the standards themselves, their application, and the quality of external auditing, pointing to systemic weaknesses in the certification ecosystem.

What may be important for European companies is the fact that existing standards, like ANSI TIA, may be considered too strongly aimed at the "American telecommunications market," making them less suitable for European contexts.

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Meeting high-level security certificates (e.g., TEMPEST standards for defence) is "a little more difficult to meet" on non-standard platforms like MDCs than in traditional environments.

In summary, while organizations generally comply with mandated standards (such as ISO 27001 or regulations like NIS 2), voluntary compliance with more rigorous standards like Tier certification is actively blocked by the overwhelming cost and administrative effort, especially when the market does not enforce such requirements.

Q4: What other local or international certifications or compliance programs is your DC required to follow, and which of these do you believe may be relevant or of interest to other stakeholders in the European DC market?

Based on the analysis of the interview transcripts and survey responses, DC operators (DCOs) are primarily required to comply with ISO standards and European regulatory frameworks. Certifications considered most relevant to the broader European market generally relate to security, quality, resilience, and energy management.

Out of the eight distinct organizations that provided detailed answers to this question, all eight mentioned at least one type of mandatory or voluntarily implemented certification or compliance program, highlighting that compliance is a foundational necessity across the sector.

The most prominent compliance obligations fall into general regulatory adherence and established ISO security standards.

Compliance Program / Standard	Number of Supporting Organizations	Organizations (DCOs)
ISO 27001/27K (Security)	5	DCO_1, DCO_2, DCO_6, DCO_9, DCO_7 (implied via self-cert.)
EU Regulations (GDPR, NIS2, CRA, DORA)	4	DCO_2, DCO_3, DCO_8, DCO_9
ISO 50001 (Energy Management)	2	DCO_6, DCO_10
PCI DSS (Financial Sector)	2	DCO_7, DCO_8

ISO certifications are widely followed, often serving as a fundamental benchmark for operation.

Most of the organizations stated they follow or utilize ISO 27001 (Information Security Management), with one noting its implementation as early as 2011.Organizations also adhere to ISO 20K (IT Service Management), ISO 9000. ISO 50001 is followed in some cases, often mandated by national law (e.g., German law for facilities >300kW).

Q5: Could you indicate the main conditions that triggered the use of backup power supply systems? For example, were they related to scheduled maintenance, or to unexpected failures such as network overloads or blackouts?

Based on the comprehensive review of interview transcripts and survey responses, the activation of backup power supply systems (UPS and generators) is consistently and prominently triggered by two main factors: proactive, scheduled maintenance and testing and unforeseen external failures or grid instability.

A large majority of the distinct DC operators addressing this topic confirmed that both types of events are primary drivers for the use of emergency power. Specifically, six organizations detailed the importance of scheduled testing, and six organizations, supported by the broader survey data, detailed the necessity of activating backup power due to external grid issues.

The most structured and recurrent trigger for using backup power systems is scheduled maintenance and functional testing, which was cited by six unique organizations. Operators often confirmed that their generators accumulate significantly more running hours due to "testing and monthly controls" than they do from actual planned or unplanned power maintenance. These are mandatory procedures designed to ensure operational resilience and continuity of service. For instance, one major bank operator performs "full functional tests every quarter", which involve simulating a power cut-off from the city network, forcing the entire system to switch automatically to reserve power. Following recent geopolitical tensions, this organization doubled the test duration to two full hours to confirm resilience under extended operation. Other organizations perform regular infrastructure checks, with one operator confirming "regular starts of the entire infrastructure" at least every two weeks to verify correct reaction to potential outages. This testing culture is considered essential, as one respondent noted they would be "afraid not to do them" because it is the only way to be sure the backup system will function when needed.

In addition to scheduled use, backup systems are frequently triggered by unexpected failures and instability in the external power grid, a reality confirmed by six interviewed organizations and overwhelmingly supported by survey data, where 17 out of 21 respondents indicated they had used their emergency generators in the past year due to power loss or grid instability. These non-scheduled events include external "blackouts" or large-scale grid synchronization issues, such as the major failure that affected Spain, during which one operator reported their infrastructure continued working successfully due to backup power. Beyond catastrophic failures, activation can be caused by utility companies performing disconnects or experiencing delays in reconnection; one operator mentioned generators running for "even a month" outside Poland because the power grid supplier did not connect the DC back on time.

Finally, activation is dictated by the need to protect critical services and highly sensitive infrastructure. Backup power, consisting of UPS (Uninterruptible Power Supply) and diesel generators, is typically reserved for "the most urgent components", such as networking, storage systems, databases, web services, and systems requiring high availability. High-Performance Computing (HPC) compute nodes are frequently *not* backed up due to the excessive power requirements and immense cost associated with protecting systems that are "so powerful".

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However, specialty systems, such as quantum systems based on SQUIDs, require exceptionally high reliability and uninterrupted power due to the fact that their calibration can take a "very long time, like several a month at least" if power is lost, making backup power a vital necessity for these specific deployments.

Q6: Have you encountered situations where the cooling capabilities of your DC, due to factors such as environmental conditions, location, or limitations in cooling system technology or efficiency, have placed additional constraints on power usage, independent of the power supply system's capacity?

Out of ten distinct organizations that provided feedback on DC cooling capabilities, a statistically significant majority confirmed encountering situations where cooling limitations imposed constraints on power usage, capacity, or overall operational performance, independent of the available power supply. These constraints fall primarily into two categories: limitations stemming from environmental factors or aging technology, and fundamental constraints imposed by cooling technology on modern, high-density power requirements.

Constraints related to environmental conditions and aging infrastructure were frequently reported, predominantly affecting older facilities or systems with low redundancy. Operators recalled past situations where very high outdoor temperatures and unfavourable environmental conditions (such as high ambient heat or pollen) significantly reduced the efficiency of external cooling components (condensers or chillers). In these scenarios, the DC struggled to maintain required operational temperatures, sometimes necessitating extraordinary measures, like relying on the roof to lower ambient temperature, or leading to chiller failures and eventual replacement. Furthermore, aging, old cooling units lacking adequate spare power or redundancy necessitate extreme caution and vigilance in maintenance, as a lack of redundancy coupled with reduced efficiency risks a "cascade of misfortunes" that could halt the entire centre's operation. Issues in older sites were also linked to poor original architectural design, which made it difficult to upgrade cooling when internal heat loads increased.

The second major area of constraint is related to the **t**echnological limits of current cooling solutions when faced with increasing IT power density. Multiple organizations confirmed that traditional cooling capabilities fundamentally limit the power capacity that can be housed. Operators expressly stated they are not capable of supporting AI customers requiring very high densities (e.g., 80 to 100 kilowatts per rack), defining these requirements as "insane" given existing capabilities. This constraint is particularly severe for flexible or mobile solutions; installations exceeding 15–20 kilowatts per cabinet are deemed "impossible to cool in a container". Looking toward the future, the power density required by emerging IT equipment (up to 120–150 kilowatts per single cabinet) means that such loads will "only be possible through liquid cooling" confirming that conventional air-cooling technology acts as a rigid, independent constraint on maximum power utilization. This architectural limitation has led some organizations to avoid external commercial facilities, where they previously "had problems in terms of power capacity for cooling" because those centres were optimized for redundancy rather than the high-power needs of HPC/AI hardware.

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In contrast, four operators reported that cooling capability has not been a current problem, attributing their success to the design phase where cooling requirements are matched to IT load, implementing strict redundancy standards, or actively utilizing advanced methods such as direct warm water cooling, which eliminates the need for mechanical chillers entirely, even when scaling capacity up to 40 megawatts.

Q7: How do you cover 6R rules: Refuse, Reduce, Reuse, Recycle, Recover, Rethink? How do you measure 6R rules, what KPI are most important from your perspective to Refuse, Reduce, Reuse and Recycle How do you measure the KPI 'Percentage of Reused Equipment' using the weight or number of devices?

The application of the "6R" principles (Refuse, Reduce, Reuse, Recycle, Recover, and Rethink) is widespread across DC operations, although a statistically significant majority of operators interviewed were unfamiliar with the formal 6R terminology. Despite this lack of formal recognition, every responding organization detailed operational practices that directly align with one or more of the "R" principles, often viewing them as intrinsic to efficient business practice, cost optimization, or regulatory compliance.

DC operators generally cover the principles through continuous optimization, efficiency mandates, and resource management, which often happen consciously or unconsciously due to budget constraints or operational necessity.

The most universally practiced principle is Recover, usually manifesting as waste heat reuse. Six different organizations mentioned active or attempted heat recovery. Operators, particularly those in high-performance computing (HPC) or academic sectors, reported pioneering heat reuse or utilizing waste heat for heating internal buildings or academic campuses. However, external heat recovery efforts are often constrained by high transportation costs or safety concerns regarding potential receiving neighbours, leading one organization to estimate their external heat recovery rate at less than 10%.

Reduce and Rethink are covered through continuous efforts to maximize energy efficiency, often driven by the high cost of power and self-defined goals. This includes procuring new hardware that is more energy efficient than previous generations, implementing systems that rely on virtualization, and redesigning cooling architecture to eliminate the need for mechanical chillers, such as transitioning to warm water cooling.

Refuse is practiced in institutions with fixed budgets (such as publicly funded research infrastructure) which are compelled to evaluate necessity strictly. These organizations prioritize efficiency and refuse to blindly install new equipment, preferring instead to utilize existing systems.

Reuse and Recycle are primarily handled during equipment decommissioning. Several organizations noted that they are forced to reuse and repair equipment due to funding constraints. Equipment is either repurposed where there is an operational need or sold to companies that extract value by reusing components, such as memory chips, or specialized materials like gold or copper. Furthermore, some organizations impose requirements on vendors to dismantle and recycle or reuse systems when they are put out of operation. Recycling processes are often highly restrictive due to the presence of harmful components.

Q8: Measurement and Key Performance Indicators (KPIs)

Formal adherence to 6R principles through dedicated KPIs is less common; only six organizations indicated having any KPIs related to the 6R principles. Where measurements exist, they focus predominantly on quantifiable efficiency and compliance:

The most important metric consistently mentioned is efficiency. One research infrastructure explicitly stated they rely on efficiency measures (KPIs) for all equipment to identify and prioritize which components should be replaced and recycled. The high cost and administrative effort associated with certification discourage many operators from pursuing compliance that lacks clear ROI or market demand, suggesting that internal efficiency goals serve as the primary substitute for formal measurement.

Regarding the specific KPI 'Percentage of Reused Equipment,' the sources do not provide a detailed breakdown of whether this is measured by weight or number of devices. However, the operational data suggests that quantification is managed through a percentage relative to the total equipment utilized or decommissioned annually. Measured percentages varied widely among respondents, ranging from 0% to 100%, indicating diverse institutional priorities and resource availability.

Q9: Are there any aspects of your security infrastructure where you would benefit from systematic support or regulation at the national or European level by relevant bodies or institutions?

The majority of DC operators interviewed indicated that their current security infrastructure and compliance measures are generally sufficient and do not require new systematic support or regulation at the national or European level. A number of organizations explicitly stated they already fulfil existing regulations, follow established frameworks such as GDPR and ISO certifications (like ISO 27001), and collaborate internally within specialized communities, such as the High-Performance Computing (HPC) sector, where security is highly considered and managed. One survey respondent also noted that within their area of responsibility, they "do not identify specific aspects of security infrastructure that would require systematic support or regulation" at the EU or national level.

For entities facing mandated compliance, the existing regulatory pressure, such as the introduction of NIS 2 and DORA (Digital Operational Resilience Act) in the financial sector, is recognized as being beneficial because it "builds awareness of customers and allocate budgets" toward security improvements.

However, the key area where systematic improvement is desired is not the creation of new rules, but the stricter enforcement and rigorous application of existing regulations. One operator argued that the focus should be on following rules already in place rather than continually inventing new ones, suggesting that current rules are often "not followed". This perspective was amplified by another DCO, who observed that sometimes recommendations or requirements are "implemented on paper so that they can be ticked off, but in reality" the security solution is at a very low level. This operator suggested that regulatory bodies should enforce existing requirements more strictly, such as those related to critical registers and mandating specific geographical distances between primary and backup centres.

While some organizations noted the potential benefit of greater standardization in the world, particularly for features like two-factor authentication, they emphasized the concurrent need to maintain flexibility. Overall, the prevailing view is that existing security and compliance frameworks provide adequate guidance, and the primary challenge lies in consistent, rigorous implementation across the sector, often driven by the necessity of "demanding quality" from vendors and service providers.

Q10: Does the location of the DC affect employee availability?

The consensus among DC operators is that location does affect employee availability, but the nature and severity of this challenge vary significantly depending on whether the facility is situated in a high-cost urban hub or a less populated, peripheral area, and whether the organization is public or commercial. Out of the eight organizations that discussed this topic in detail, all acknowledged challenges or mitigating factors related to location.

In highly urbanized areas (close to large cities), the effect on employee availability is primarily economic and market-driven. One German operator reported that the high cost of living, including "crazy" rent rates for flats in the Munich region, makes it difficult to attract and retain staff, especially since public salaries are often not as high as those offered in the commercial world. Similarly, in Stockholm, competition from the expansion of commercial DCs makes it "not so easy to find people". However, a general survey response indicated that placement "within urban areas" ensures the required manpower is available in close proximity.

In rural or peripheral locations, the challenge shifts to accessibility and commuting. For instance, Portugal's research centres found that placement along the coast near universities eased recruitment, but hiring in the "interior of the country would be much more difficult". An Italian operator noted that transportation was historically an issue in their industrial area, though subsequent investment in public transportation resolved the difficulty in reaching the site. A German research centre, located in the small town, acknowledged its rural site is "not one of these big capitals" and may be unattractive to some.

Crucially, many organizations mitigate the negative effects of location through operational strategies or compensation:

- Quality of Work and Environment: Research centres attract talent despite less attractive locations by offering a "very good working environment," engaging work with "interesting machines," and access to a campus environment filled with scientists. The freedom of the academic work environment also helps in hiring.
- Financial Compensation: One global operator noted that the location problem can be "financially regulated", stating that high salaries "work wonders" and make people ready to move for a few years as a "business adventure".

- Staff Profile: The technical staff required for DCs are described as "specific" and "hard workers," who are often willing to work outside the city centre. One Serbian operator stated that employee availability is "not on my priority list" as a concern, contrasting sharply with the much larger logistical problem of securing a suitable physical location for the DC itself.

Overall, while the location of the DC does influence aspects like commuting and local housing costs, the sources suggest that the most pervasive hiring challenge across the industry is the fundamental scarcity of highly qualified IT specialists (such as system and network administrators), a problem described as a broader "social problem" unrelated to specific geographical placement.

Q11: Do you see opportunities and motivations for investing in DCs in Europe, and would any legal or regulatory changes influence the prospects for initiating new investments? Are there specific areas where legal changes or facilitations for European players, such as those related to data localization in server facilities, could enhance these opportunities?

Opportunities and motivations for investing in DCs in Europe are strong and are driven by fundamental technological and strategic needs, according to a significant majority of operators and regulatory bodies consulted. Seven distinct organizations provided detailed motivations, citing factors related to surging demand, economic necessity, and strategic autonomy.

The primary opportunities are linked to the escalating demand for cloud services, low-latency connectivity, digital transformation, and high-performance computing (HPC) and Artificial Intelligence (AI) workloads. Investing in scientific DCs, for example, is seen as mandatory to maintain European scientific leadership and economic health, a strategy actively supported by funding programs like EuroHPC. Furthermore, DC investment allows countries to ensure sovereignty, independence, and flexibility, granting greater control over data destiny and mitigating risks of data being transferred outside the EU or the country. From an economic perspective, investment is justified by the high demand for large technological hubs, especially those capable of supporting massive AI requirements (e.g., 300-megawatt campuses). This financial appeal is attracting non-traditional investors, with the Oil and Gas sector expected to invest heavily due to their crucial access to cheap energy, a key component for effective DC operation.

To enhance the prospects for initiating new investments, legal and regulatory changes are required, focusing both on creating a coherent framework and ensuring rigorous enforcement of existing rules. Seven organizations pointed to legal or regulatory factors influencing investment decisions. A major requirement, cited by four organizations, is the establishment of stability in the regulatory framework and the necessity for a common and simplified regulatory framework to facilitate implementation by reducing administrative complexity. This simplification is particularly needed in permitting and licensing processes, which are currently complex and lengthy, involving many public entities. Conversely, two organizations emphasized that stronger prospects could be achieved through the stricter and more rigorous application of existing laws, rather than simply inventing new ones. These existing mandates, particularly those concerning critical registers, require adequate budget allocation and forced investment by demanding secure infrastructure, such as geographically separated backup centres.

Specific legal changes that could further enhance opportunities for European players, mentioned by three organizations, centre on data localization and technological standardization. Operators require clear and harmonized rules on data localization to avoid fragmentation across member states, while others see data localization (or keeping equipment within the country) as a means to ensure sovereignty and independence. Additionally, facilitating investments in new technologies is key: regulatory bodies should foster the development of interoperable liquid cooling solutions (DLC) to manage the rapidly increasing power consumption per rack, and offer incentives for energy efficiency and renewable integration to support sustainable investment decisions.

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10. Annex 2: Questionnaire responses analysis

10.1. General information

Respondents represented a wide range of DC operators across Europe, with the majority originating from EU countries (35) and a smaller group from outside the EU (5). The most frequently represented countries were Italy (7), Poland (6), Spain (6) and Germany (4). Most organizations operate a single DC within one country, with a few managing multiple sites across up to eight countries.

The median year of entry into operation was 2012, with the earliest starting in 1994 and the newest expected in 2025. The median number of onsite technical staff was six, while global organization sizes ranged from 1 to over 10,000 employees. The distribution shows a balanced mix between legacy infrastructure and newly commissioned facilities, confirming continuous reinvestment cycles. Most respondents held managerial positions such as Data Centre Manager or Director.

Median survey completion time: 50 minutes.

10.2. Service offerings

DCs provide a broad range of services, with the most frequent being collocation, remote hands, storage, hosting and backup/archive. Cloud (IaaS/SaaS/PaaS) and emerging HPC/AI workloads are increasingly represented. Colocation models are dominated by full cabinets (27) and partial cabinets (25), followed by footprints and cages.

Respondents anticipate growth in cloud, collocation and AI services. Service portfolios reflect both traditional hosting and hybrid cloud convergence trends.

10.2.1. Capabilities of services.

Most frequently selected capabilities include colocation, hosting, cloud computing, storage and HPC workloads. Remote hands and managed backup are also prevalent.

The breadth of capabilities illustrates the hybridization of services across DCs, bridging traditional hosting and cloud-native environments.

This question provides functional insight for classifying DCs by operational scope and integration with ECS services.

10.2.2. If you selected 'Co-location' in the previous question, please choose the type of co-location service you use.

Most respondents indicate full or partial cabinet configurations, followed by cage and footprint solutions. A small number use shared racks.

Co-location architectures are optimized for flexibility and tenancy control, scaling from single cabinets to fully segregated environments.

The findings can be used to benchmark physical hosting typologies and energy provisioning per tenant footprint.

10.3. Physical infrastructure and certifications

Most DCs are powered through underground medium-voltage connections (90%) with redundant power supply in about 45% of cases. The median contracted power capacity was 10.5 MW and the average 48.2 MW. Certifications include ISO/IEC 27001 (15), ISO 50001 (5), EN 50600 (4) and compliance with legislative acts such as DSA, DMA and NIS2 (8).

Most facilities maintain certifications ensuring energy efficiency, cybersecurity and operational reliability.

10.3.1. What is the contracted power capacity [MW] of each power connection?

Declared capacities range between below 1 MW for edge or institutional facilities and up to over 50 MW for hyperscale operators.

The results confirm large disparity in size classes and underline the growing number of medium-sized regional DCs with 5–15 MW capacities.

The dataset supports load modelling and capacity planning exercises for different facility typologies.

10.3.2. What is the total annual electricity consumption of your DC in the last calendar year [MWh]?

Reported consumption values range widely, from several to over 1000 MWh per year. Outliers around 80,000 MWh correspond to hyperscale campuses.

The variability reflects differences in IT load, redundancy level and occupancy, enabling identification of operational scales.

Data serves as an empirical reference for estimating electricity intensity and total energy demand within the European DC sector.

10.3.3. What is the typical or maximum bandwidth of a single network connection to your DC [Gbps]?

Single-link bandwidth values cluster around 10–100 Gbps, with higher values up to 400 Gbps in hyperscale and research environments.

The responses indicate progressive scaling of connectivity infrastructure, aligning with current ECN backbone capacities.

Provides baseline information for modelling ECN-to-DC interconnection throughput and assessing scalability readiness.

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10.3.4. What is your DC's total annual water withdrawal (in cubic meters or litters)?

Water withdrawal values differ substantially, with a few large sites reporting tens of thousands of cubic meters annually and most smaller sites <5,000 m^3. Variation is linked to cooling method choice, with air-cooled and adiabatic systems displaying distinct consumption profiles.

Survey's data enables assessment of water resource demand in relation to technology selection and climate region.

10.3.5. What is your DC's annual Water Usage Effectiveness (WUE) in litters per kWh?

Most responses are below 0.5 L/kWh, with a small number exceeding 1 L/kWh, mainly in warmer climates with evaporative cooling. The results confirm adherence to efficient cooling practices, with performance varying by system type and ambient conditions.

WUE metrics can support comparative benchmarking across climatic zones and infrastructure classes.

10.4. Network connectivity and ECN integration

Networking solutions are diverse, with most centres using dedicated fibre links (29) or physical cable connections (29). Median total network bandwidth reached 200 Gbps, with typical single-link capacity of 10 Gbps. Most DCs (22 of 38) connect directly to IXPs, facing challenges such as infrastructure overloads, redundancy gaps and administrative delays.

Future network development plans focus on black fibre expansion, 5G/6G integration and satellite interconnections (LEO systems).

10.4.1. Which coolants or refrigerants are used in your cooling systems?

Common responses include R-410A, R-32, R-134a, glycol-based solutions and water. Some respondents mention transition plans toward low-GWP alternatives. Refrigerant selection indicates the ongoing shift toward environmentally responsible compounds and diversified system architectures.

The dataset supports mapping of refrigerant trends for environmental sustainability evaluations.

10.4.2. What percentage of your DC's systems are cooled using Direct Liquid Cooling (DLC) or immersion cooling?

Most facilities report 0–10% adoption, with several HPC-oriented sites indicating shares above 50%. Adoption of advanced liquid cooling remains niche but expected to grow with AI and HPC workloads.

These findings provide a baseline for technology penetration studies and efficiency projections.

10.5. Energy

Energy consumption varied significantly, with a median annual usage of 1,163 MWh. The median Power Usage Effectiveness (PUE) was 1.40. Renewable energy accounted for 41% of electricity, with on-site PPAs contributing 5% and off-site PPAs 40%. Solar and hydropower were the most common sources.

Challenges include bureaucratic expansion processes, grid limitations and high energy costs. Most respondents reported stable reliability but difficulties obtaining additional capacity.

10.5.1. Which of the following networking and connectivity options are present in your DC or at your ECN location?

Frequently cited options include dedicated fibre, leased lines, Ethernet interconnects and MPLS backbones. Wireless and satellite are minor. Connectivity options indicate mature physical integration with ECSs/ECNs and reliance on established telecom back haul.

Results provide technical detail for evaluating ECN-ECS convergence points and interconnect topology mapping.

10.5.2. If you have a direct connection to an external IXP, have you experienced any difficulties or challenges using the IXP?

Only a minority report challenges, mainly administrative delays, capacity limitations, or congestion during peak loads. IXP usage overall appears reliable, reinforcing the robustness of European interconnection ecosystems.

The information aids in assessing operational bottlenecks within DC-IXP integration frameworks.

10.6. Cooling systems

Compressor-based air conditioning is dominant (33 of 37). Free cooling is used in about half of the centres, particularly in cooler climates or near water sources. Common refrigerants include HFCs (R-410A, R-32, R-134a), water and glycol mixtures. Liquid and immersion cooling adoption remains low, with only a few facilities using it.

Waste heat recovery is implemented in 10 centres. Evaporative cooling is reported in 9 facilities. Water usage metrics show median withdrawal of 0 m^3 and consumption of 5.5 m^3 per year.

10.6.1. Which of the following energy efficiency metrics do you monitor at your DC?

PUE is universally tracked; WUE and ERF/ERE are less common. Few respondents mention integrated sustainability dashboards. Monitoring maturity varies but demonstrates increasing standardization around core metrics.

Collected data facilitates comparison of monitoring coverage and supports initiatives for harmonizing operational KPIs.

10.6.2. Which KPI management software does your DC use?

The most cited tools are DCIM platforms, spreadsheet-based tracking, SCADA systems and analytic tools like Power BI or Grafana. The diversity of solutions highlights a balance between commercial DCIM suites and in-house monitoring systems.

The question offers insight into digital maturity and integration of monitoring technologies.

10.7. DC infrastructure monitoring and management

PUE is the most commonly monitored metric, followed by WUE and ERE/ERF. KPI management tools include DCIM (12), spreadsheet software (10), SCADA (7) and Power BI (3). The average share of reused equipment was 29% and recycled 10%. Only one-quarter of organizations integrate sustainability KPIs (6R principles).

10.7.1. Which of the following common failures and problems have you experienced related to your DC's location?

Top issues include lack of space for expansion, limited power availability and cooling infrastructure inefficiencies. Environmental and structural limitations constrain scalability and directly affect capacity planning.

This information can be used to evaluate physical siting challenges and support regional risk assessment frameworks.

10.7.2. Which of the following failures and problems have you encountered with your cooling systems?

Leakages, shortage of replacement parts and impacts from rising ambient temperatures are the most cited problems. Cooling system reliability depends on component quality and preventive maintenance frequency.

Data supports maintenance modelling and identification of systemic vulnerabilities in HVAC operations.

10.7.3. Which of the following power-related failures and problems have you experienced?

Blackouts and brownouts are the most frequent incidents; a few notes supplier-imposed load limits during peak demand. The findings highlight dependence on external grid stability and backup system robustness.

The question provides empirical evidence for analysing power reliability risk factors.

10.8. Common failures and problems

Location-related challenges included lack of space (13), insufficient electrical capacity (13) and cooling inefficiency (12). Cooling failures included leakages (11) and climate-related impacts (9). Power issues primarily involved blackouts (18) and brownouts (10).

Replacement and maintenance drivers: for power infrastructure – end of life (27) and failures (23); for cooling – efficiency (27) and failures (24); for e-infrastructure – next-generation technology (26); for network – next-generation technology (28).

10.8.1. Do you plan to build a new network infrastructure?

Roughly one-third plan new deployments, focusing on fibre extension and higher-capacity links. Plans emphasize growing demand for redundancy and 5G/6G-ready architectures.

The responses provide a technical outlook for infrastructure expansion forecasting.

10.8.2. What are the key factors to consider when building a new DC?

Efficiency of cooling, space availability and certification requirements were identified as top priorities. Future developments aim to optimize energy usage and regulatory compliance.

These results offer parameters for modelling next-generation facility design requirements.

10.9. Future plans and development strategy

Around one-third of respondents plan to build new DCs within two years. Key construction factors: cooling efficiency (23), free space (22) and certification requirements (14). Location selection depends on power capacity, disaster risk and network infrastructure availability.

Strategic focus areas include improving energy efficiency (PUE reduction), hybrid service growth and modernization of power and network systems.

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