cerre Centre on Regulation in Europe

FROM GRIDLOCK TO GRID ASSET: DATA CENTRES FOR DIGITAL SOVEREIGNTY, ENERGY RESILIENCE, AND COMPETITIVENESS

REPORT

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Executive Summary

Data centres (DCs) are critical to Europe's competitiveness and digital sovereignty. They are essential to productivity-enhancing technologies like cloud computing and artificial intelligence (AI). Yet their impact on Europe's energy systems is complex. They are among the most electricity-intensive elements of the digital economy but, at the same time, can enable the optimisation of energy and infrastructure use.

But, with the right policies in place, DCs can become active contributors to grid flexibility, economic competitiveness, and the EU's climate and environmental objectives.

The EU's current policy approach to DCs requires significant reform to help achieve these objectives. Without changing its approach, the European Union risks:

- **seeing connection queues and permitting delays** become a brake on the construction of sovereign computing power, and on innovation and European competitiveness;
- **missing out on an economic opportunity** to attract foreign investment in the DC industry;
- **contributing to the widening of the technological gap** with other countries such as the United States, which today hosts the most DCs;
- **undermining the stability of European energy infrastructure** rather than coordinating development to enable DCs to become assets for the energy system; and
- **uncontrolled development**, which could have a negative impact on the environment (e.g., carbon dioxide emissions, monopolisation of water resources) and jeopardise the EU's climate objectives.

The idea that the growth of DCs would not impact environmental targets, as the rising demand would be offset by improvements in energy efficiency, chip design, workload management and cooling technologies, no longer holds. As DCs grow in number, density, and diversity, with demand skyrocketing due to AI, so too does their impact on energy systems, competitiveness, and climate policy.

Key recent developments that demand this change in approach include:

- *Efficiency Limits and AI Growth*: Gains in semiconductor and facility efficiency are levelling off, while AI applications such as large language models are driving energy demand far beyond that of traditional workloads.
- *Regional Disparities*: Electricity price differentials, grid capacity constraints, and planning frameworks vary sharply across Member States, sometimes leading to shifting deployment toward the Nordics and peripheral zones.
- *Edge and Modularity*: New IT architectures and types of DCs, including modular and edge DCs, are creating fragmented and location-sensitive load profiles that complicate grid management and investment planning.
- *Lifecycle and Carbon Metrics*: The scope of sustainability has expanded to include embodied

carbon, lifecycle impacts, and water use, in line with the EU Taxonomy and Ecodesign for Sustainable Products (ESPR) regulations.

- *Capacity Inefficiencies:* Analysis reveals DCs routinely reserve 30–40% more grid capacity than they actually use, creating artificial bottlenecks and inefficient resource allocation.
- *Evolving Policy Toolkit*: Data centre-oriented regulation alone is not sufficient. Effective intervention requires a mix of mandatory and voluntary instruments, ranging from planning and incentives to market-based and informational tools.
- DC demand estimations should be treated with caution as they are surrounded by fundamental uncertainties. DC demand growth depends on many parameters, like data demand growth, technology trends and hardware efficiency. All bets would be off if any major technological breakthrough (at the software or hardware levels) happens, which one cannot predict.

To align DC growth with energy resilience and climate targets, policymakers must adopt a more flexible, layered approach:

1. **Streamline data centre regulation**: National authorities should adopt simpler permitting processes and harmonised efficiency standards across EU Member States to help ensure that regulation does not pose unnecessary bureaucratic barriers to building DCs. At the same time, the EU needs to consider the best way to require DCs to report on their emissions and institute mandatory but regionally specific environmental performance standards, in order to maintain sustainability and environmental standards. Rather than singling out DCs, we recommend that fast-track permitting procedures should benefit all projects with high positive social impacts, including but not limited to qualifying DCs. **Smart and adaptive regulatory frameworks, aligned with the Better Regulation guidelines,** should build on existing feedback loops and embed performance-based criteria, allowing policies to evolve with technological developments rather than creating rigid compliance requirements that quickly become obsolete.

2. **Update metrics to create a holistic view**: The efficiency metrics currently used for sustainability reporting, such as Power Usage Effectiveness (PUE), are outdated and do not give an appropriate picture of the real efficiency of computer hardware and infrastructure. In addition, the systemic impact – through e.g., flexibility – has to be taken into account. Consequently, we propose a 3 Tier approach to assess the efficiency of the digital infrastructure, representing (1) hardware and (2) DC real estate efficiencies as well as (3) systemic efficiency, including contributions to flexibility.

3. **Create incentive mechanisms to help make DCs an asset to energy systems**: Currently, DCs pose significant stress on energy grids. They could become more of an asset if they could play a stronger role in helping grids balance supply and demand. To do this, policymakers should provide incentives for DC investors to deploy battery storage at DC sites, to provide demand response mechanisms (reducing their use of power through the grid at peak times), and integrate with renewable energy sources. These incentives could include tailored network tariffs (the amount which DCs must pay to energy network operators), electricity prices, promoting co-investment models, and enabling long-term pricing agreements (PPAs) between

DC operators and energy generators. The EU could unlock 50–60 GW of demand-side flexibility by 2035 through strategic DC integration using smart & adaptive policies.

4. **Strengthen strategic planning for the integration of DCs in energy systems**: Energy regulators and system operators must better include digital infrastructure projections in spatial planning and when planning the future development of electricity systems. Stakeholders should cooperate to designate 'ready-to-connect' zones in areas with low-carbon generation and uncongested or oversupplied grids, to avoid reliance on overheated hubs while improving regional equity. This will require policymakers to have more participatory and inclusive planning mechanisms.

5. **Use market and informational signals**: Informational and market-based instruments empower investors to make better decisions. More transparency from businesses on their use of energy, carbon emissions and contributions to grid flexibility, as well as standardised tools (like data-sharing platforms) to incentivise demand side response, e.g., through flexible connection agreements, would be helpful. A higher voluntary participation in markets for ancillary services (including, but not limited to, balancing, voltage control, and inertia) and congestion management services are also essential instruments for operational optimisation, load shifting, and the voluntary take-up of climate-aligned practices.

6. **Strengthen cross-sector and cross-border coordination**: Encourage a structured dialogue between TSOs, DSOs, and industrial actors (including across national borders) to help resolve technical and regulatory issues. The European Commission **is taking the right steps with the revision of the roles of those stakeholders in charge of planning and coordinating** cross-border capacity, in order to promote a more coherent EU-wide strategy.

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About CERRE

Providing high quality studies and dissemination activities, the Centre on Regulation in Europe (CERRE) is a not-for-profit think tank. It promotes robust and consistent regulation in Europe's network and digital industry and service sectors as well as in those impacted by the digital and energy transitions. CERRE's members are regulatory authorities and companies operating in these sectors, as well as universities.

CERRE's added value is based on:

- its original, multidisciplinary and cross-sector approach covering a variety of markets, e.g., energy, mobility, sustainability, tech, media, telecom, etc.;
- the widely acknowledged academic credentials and policy experience of its research team and associated staff members;
- its scientific independence and impartiality; and,
- the direct relevance and timeliness of its contributions to the policy and regulatory development process impacting network industry players and the markets for their goods and services.

CERRE's activities include contributions to the development of norms, standards, and policy recommendations related to the regulation of service providers, to the specification of market rules and to improvements in the management of infrastructure in a changing political, economic, technological, and social environment. CERRE's work also aims to clarify the respective roles of market operators, governments, and regulatory authorities, as well as contribute to the enhancement of those organisations' expertise in addressing regulatory issues of relevance to their activities.

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1. Introduction

Data centres (DCs) are critical to Europe's competitiveness and digital sovereignty. They are essential to productivity-enhancing technologies like cloud computing and artificial intelligence (AI). Yet their impact on Europe's energy systems is complex. They are among the most electricity-intensive elements of the digital economy but, at the same time, can enable the optimisation of energy and infrastructure use (Inderwildi & Kraft, 2022). This requires a carefully aligned set of policies to balance risk and opportunity – but the EU's current policy framework does not reflect today's realities.

One problem is that DC growth is rapid but unpredictable. CERRE produced a report on DCs in 2021 (CERRE, 2021), but since then the development of large language models (LLMs) has drastically reshaped electricity consumption profiles across Europe. The growth of AI, with its many industry newcomers, has made even sophisticated forecasts of energy usage quickly obsolete. It is not just the growth of AI which is unpredictable: while most trends increase DC demand, some current trends – such as edge computing and localisation of sensitive tasks – decrease it. Figure 1.1 illustrates the degree of unpredictability for three markets - AI, cloud and edge computing – all of which are relevant to DC demand. Policy changes matter too: digitalisation has become an important subject of concern for European competitiveness, innovation, and strategic autonomy, especially following Draghi and Letta's reports (Draghi, 2024 ; Letta, 2024), which means DC demand is inextricably tied to a range of policy imperatives.

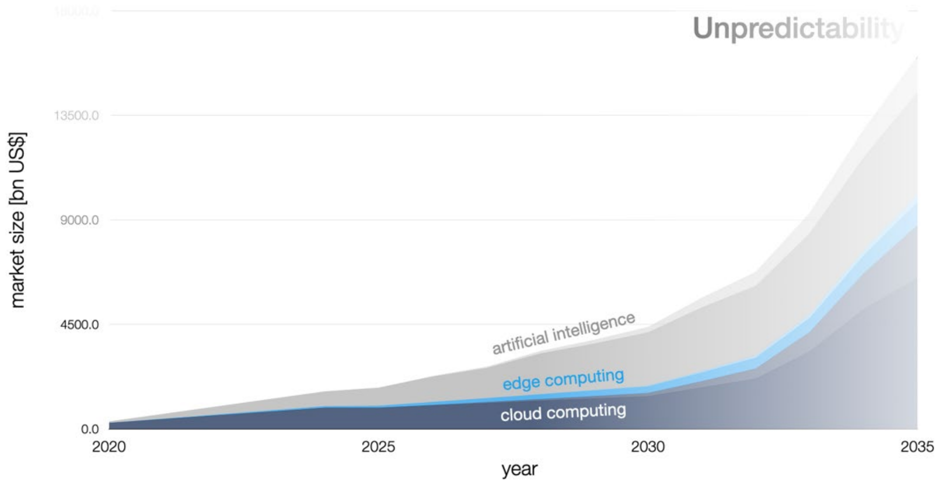

Figure 1.1: Unpredictability of digital services: AI, cloud and edge computing

Note: Technological trends have become more unpredictable, market entry, growth and potential exit occur faster than the forecasting cycles.

Yet the impact of DCs on Europe's energy systems is complex. They are among the most electricity-intensive elements of the digital economy but, at the same time, can enable the optimisation of energy and infrastructure use (IEA, 2025). DCs are a fast-growing and relatively unregulated market, yet their growth relies on – and impacts – an inherently slow and highly regulated market: electricity provision. The growth of digital infrastructure is outpacing energy planning, grid and generation expansion, and consequently, the energy footprint of digital infrastructure – particularly that of DCs – has emerged as a central concern for energy security, grid congestion, and climate policy. Energy policy has never had to cope with such rapid changes.

The purpose of this report is to evaluate the EU's policy framework covering the interaction of DCs and the energy grid and to recommend urgent updates required to ensure DCs can become active contributors to grid flexibility, economic competitiveness, and the EU's climate and environmental objectives.

To clarify terminology, we refer to the 'energy system' as the full chain of energy provision (production), conversion, transmission, distribution, and consumption – including all energy carriers such as electricity, gas, and heat. The 'electricity system' is a subset of the former, focused specifically on the generation, transmission, and use of electric power. The 'grid' refers more narrowly to the physical network of infrastructure (overhead power lines, cables, substations, transformers) that enables the transmission and distribution of electricity. While often used interchangeably in public discourse, each term implies distinct planning, investment, and regulatory frameworks, all of which are increasingly impacted by the expanding footprint of data centres. A comprehensive set of definitions for these and other key terms used throughout the report is provided in the Glossary in Section 8.

To anchor the discussion, it is useful to clarify what is meant by 'DCs' in this report. We adopt the definition featured in the revised Energy Efficiency Directive (EU/2023/1791). There are different types of DCs that may be identified: on-premise DC (serving one customer and located within the premises of the company), co-location DC (a DC facility where several customers locate their computing networks and hardware), enterprise DC (operated by one enterprise to deliver services to its employees and customers), and hyperscale DC (a large scale facility and improved efficiency, operated by specialised companies, to offer services to a variety of customers) (CERRE, 2021). While their technical configurations differ, their growing electricity demand and strategic role in digitalisation place them at the core of the energy-digital nexus.

A change in policy approach is essential because of an earlier assumption that the growth of DCs would not impact environmental targets, because rising demand would be offset by improvements in energy efficiency, chip design, workload management and cooling technologies. These assumptions no longer hold. As DCs grow in number, density, and diversity, with demand skyrocketing due to AI, so too does their impact on energy systems, competitiveness, and climate policy. This new report builds on CERRE's 2021 findings by incorporating key shifts in technology trends, market behaviour and regulatory approach (CERRE, 2021). Most notably:

- *DCs as Critical Part of the Energy Infrastructure:* DCs are no longer seen as passive consumers of energy but as programmable, dispatchable loads – potential contributors to grid flexibility both for grid and system balancing.
- *DCs as Flexibility Providers*: It is estimated that DCs could provide 60 GW of demand-side flexibility in the EU by 2035, particularly from on-site storage and generation, cooling and AI workload shifting.
- *Technology Trends:* The rate of innovation is not only constantly accelerating but also marked by leaps, such as the introduction of LLMs, making forecasts difficult to impossible.
- *Counter Effects:* Edge computing and corporate AI policies, for instance, shift some demand away from hyperscalers back to devices, in-house servers or small, local DCs. This generates uncertainty for DC demand and the associated electricity needs.

- *Evolving Regulatory Landscape:* Voluntary initiatives have matured into regulatory obligations, with several EU Member States now mandating grid flexibility, transparency, and carbon-aware scheduling.
- *New Complexities & Opportunities:* AI and accelerated computing workloads are introducing new complexities; while more energy-intensive, their ability to shift computing temporally makes them highly compatible with variable renewable energy (VRE) systems.
- *Evolving Metrics:* The DC sector's carbon metrics are evolving, with growing pressure to report beyond PUE – toward indicators like the Load Flexibility Index or Training Efficiency.
- *Energy Security and Competitiveness:* Recent disruptions have re-elevated energy costs and security as decisive factors for national competitiveness and security. Strategically integrating DCs into energy planning is now essential – not only to meet climate goals but also to maintain economic resilience.
- *No need to single out DCs under EU Law:* given their need to have an uninterrupted power supply (UPS) and their opportunities for flexible power use via backup generation and on-site batteries. All new loads should be subject to the same enabling environment.

This evolving policy and technological context requires a fundamental update of European policy with regard to DCs and their role in the European energy system. The role of DCs must be reconsidered – not just as critical enablers of digitalisation, but as integral components of a sustainable and resilient energy system. With the right policies in place, DCs can become active contributors to grid flexibility, economic competitiveness, and the EU's climate and environmental objectives.

Without changing its approach, the European Union risks:

- seeing connection queues and permitting delays become a brake on the construction of sovereign computing power, and on innovation and European competitiveness;
- missing out on an economic opportunity to attract foreign investment in the DC industry;
- contributing to the widening of the technological gap with other countries such as the United States (US), which today hosts the most DCs;
- undermining the stability of European energy infrastructure rather than coordinating development to enable DCs to become assets for the energy system; and
- uncontrolled development, which could have a negative impact on the environment (e.g., carbon dioxide emissions, monopolisation of water resources) and jeopardise the EU's climate objectives.

This study goes further than the targeted regulatory and policy recommendations of CERRE's 2021 report that reflect the dual pressures of decarbonisation and digitalisation. In doing so, it reframes DCs as both challenges to grid stability and opportunities for flexible, carbon-aware demand response – with growing potential to function as virtual power plants (VPPs) in support of Europe's energy and climate goals.

This report sets out how this can be achieved by intelligent and proactive policy interventions. While DCs have significant positive potential for sustainability (See Case Study 2), it is also essential that the development of DCs in Europe is not to the detriment of environmental protection and does not jeopardise carbon neutrality objectives.

2. The Economic and Strategic Role of DCs

2.1. DCs, Economic Competitiveness and the Energy Cost Factor

As Europe's digital infrastructure deepens, DCs have become far more than technical backbones – they are emerging as strategic economic assets with measurable impact across gross domestic product (GDP), employment, investment, and innovation ecosystems. New evidence confirms that the sector's role in enabling digital and green transitions is not only structural but increasingly macroeconomic in scale. In 2023, colocation DCs alone contributed approximately €30 billion to EU GDP (EUDCA, 2025). This figure is projected to nearly triple by 2030, reaching €83.8 billion (Copenhagen Economics, 2019). This growth trajectory is fuelled by hyperscale expansion, AI workloads, and the increasing digitalisation of industry and services. An example would be Google's European infrastructure investments between 2007 and 2018, amounting to €6.9 billion, which have alone supported €15.2 billion in economic activity and over 13,000 full-time jobs annually across construction, operations, connectivity, and related services. Figure 2.1 displays investment projections (Grand View Research, 2024) and economy-wide job creation (JLL, 2024; EUDCA, 2025), to illustrate the overall economic impact.

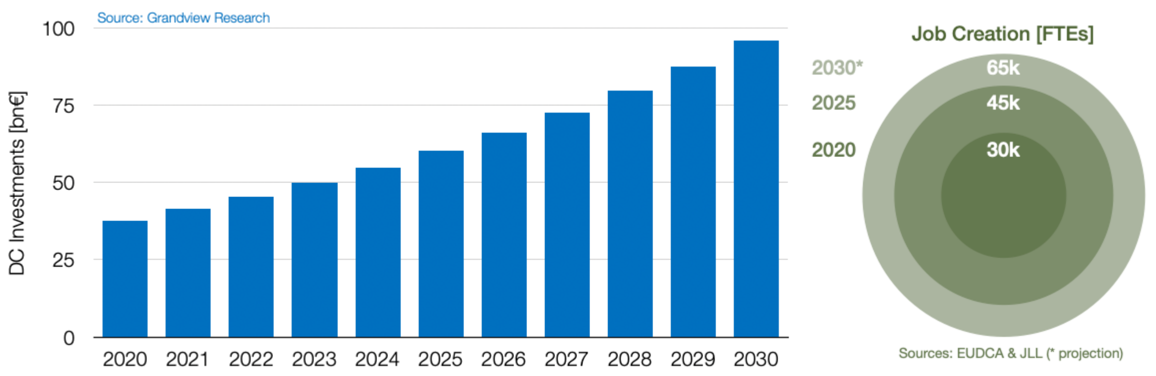

Figure 2.1: Investments in DCs and economy-wide job creation through DC deployment

Sources: Grand View Research (2024); JJLL (2024); EUDCA (2025).

While the GDP impact is significant, job creation merits particular attention. The data centre sector supports employment well beyond its physical footprint. In Ireland, where detailed figures are available, DC investments have sustained an average of 5,700 full-time equivalent jobs annually, combining construction, operations, and induced economic effects across local supply chains (IDA Ireland, 2018). These roles tend to be high-skilled, well-remunerated, and distributed across a wide value chain. Beyond direct economic metrics, DCs play an increasingly catalytic role. They are integral to digital sovereignty, attracting cloud-region anchor investments, improving data governance capacity, and enabling downstream digitisation of small and medium enterprises (SMEs) and public services (European Investment Bank, 2025).

In addition, two further critical factors for economic competitiveness have resurfaced: energy security and the cost of energy. Electricity-intensive sectors such as digital infrastructure are particularly vulnerable to price volatility and supply disruptions, which affect both the operating costs of existing facilities and the investment calculus for future deployments. The conflict in Eastern Europe has brought significant increases in electricity prices for both households and industrial consumers, putting significant stress on – already-strained – energy-intensive industries and households. Figure 2.2 shows the evolution of average electricity prices in the EU since 2020; this illustrates the significant pressure both industries and consumers are under as price increases surpassed 200%, escalating to almost a three-fold increase!

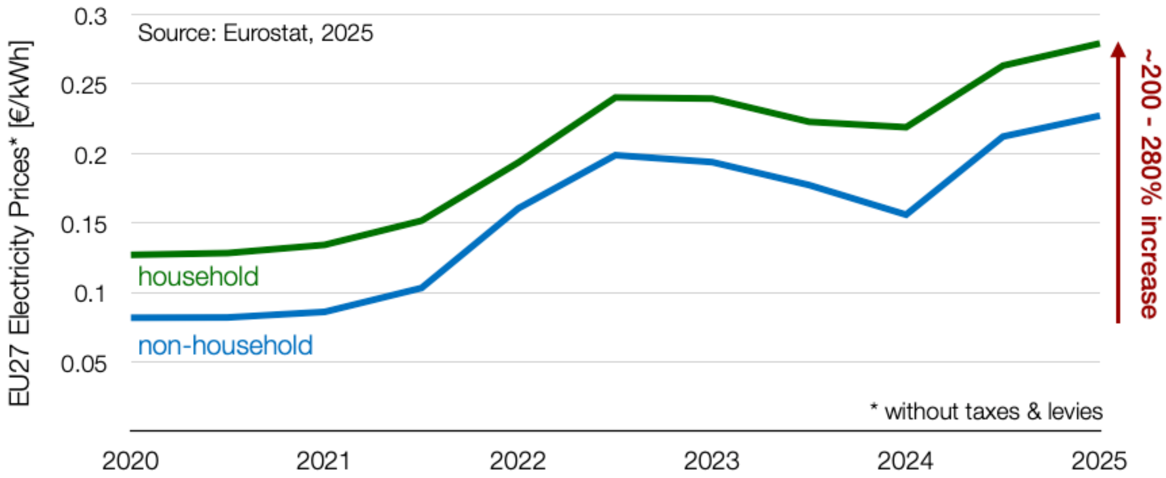

Figure 2.2: Evolution of electricity prices for household and non-household consumers.

Source: Eurostat (2025).

Note: The conflict in Eastern Europe has taken a significant toll, most notably reflected in persistent inflation.

A comparison of average industrial electricity prices in the EU with those in the US and China reveals a persistent cost disadvantage for European operators (Figure 2.3). This energy price gap is particularly concerning as it coincides with stringent carbon pricing mechanisms and ambitious emission reduction targets in the EU, both of which further exacerbate the cost pressures on European industry. The regional differentials are mainly due to the significantly higher cost of carbon emissions in the EU. Meanwhile, low energy prices in the US and parts of China offer a distinct competitive advantage to operators in those regions. Adding to this imbalance is the so-called 'Asian premium' – a surcharge often faced by Asian economies when importing fuels – which places additional strain on their industrial competitiveness. The combined effect of higher energy costs and stricter climate policies illustrates the growing burden on economic competitiveness in Europe. If the political union is to remain globally competitive while meeting its climate ambitions, structural solutions must be found. Nevertheless, the EU stringent decarbonisation targets are likely to be an economic advantage on the long run (Draghi, 2024; Letta, 2024).

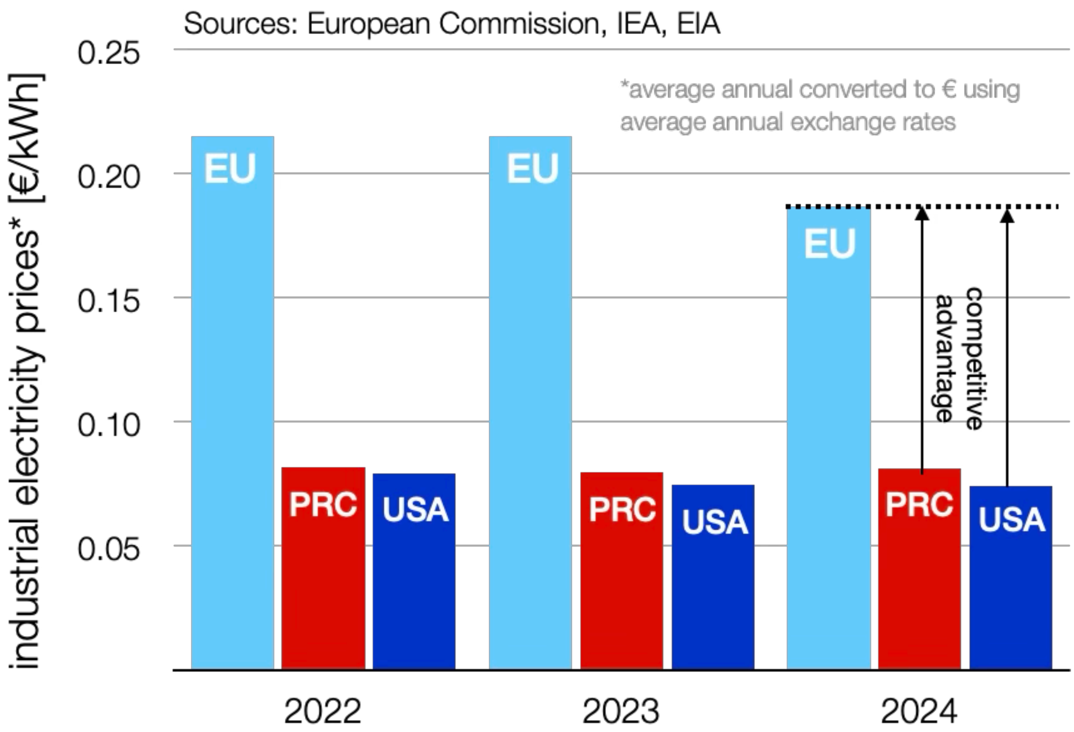

Figure 2.3: Comparative industrial electricity prices – EU vs. US and China, 2020–2025

Sources: [European Commission (2025)](), IEA (2025), [EIA (2025)]().

Uncertain electricity price signals are undermining the ability of DC operators to plan and invest reliably. Volatility in wholesale energy markets, combined with the limited availability of long-term contracting mechanisms like tailored power purchase agreements (PPAs), exposes operators to heightened financial risk throughout the lifetime of their assets. Fragmented grid tariffs across Member States further complicate site selection, creating a patchwork of cost structures that discourages cross-border optimisation and strategic deployment.

At the same time, rising energy security concerns are reshaping risk assessments for new data centre projects. In regions facing grid constraints, large-scale digital infrastructure may encounter delays due to regulatory hurdles, connection delays, or even local moratoria on grid expansion.

Without targeted policy reforms to enhance price signal efficiency, harmonised tariff structures, and clearer provisions for strategic infrastructures, Europe risks losing digital capabilities to jurisdictions offering more predictable and supportive investment environments, ultimately weakening its digital sovereignty and competitiveness. This report sets out clear options to rectify this and readjust the European trajectory towards competitiveness.

2.2. Future Demand Trajectories: Growth and Uncertainty

The European Union has set ambitious targets through, e.g., its Digital Decade Strategy and the European Green Deal (EC, 2024; Draghi, 2024), making both digitalisation and electrification central pillars of future competitiveness and climate neutrality. Digitalisation is now a core competitiveness factor, while electrification is essential to achieving the EU's climate goals.

However, the energy price escalation discussed earlier poses significant challenges to both processes. High electricity prices risk undermining Europe's ability to deliver on its digitalisation agenda and slow progress towards decarbonisation.

At the same time, the proliferation of AI, particularly LLMs and the expansion of cloud computing, is driving a new wave of electricity demand. Emerging evidence suggests that a typical LLM query can consume up to ten times the energy of a conventional web search (Figure 2.4), illustrating the scale of the shift[i][1].

These rapidly evolving technological trends – highlighted in the introduction – make long-term demand planning increasingly difficult. For instance, projections from Goldman Sachs estimate that global data centre electricity consumption could double by 2030, with approximately 20% of that growth attributable to the rise of AI-based services (Goldman Sachs, 2024).

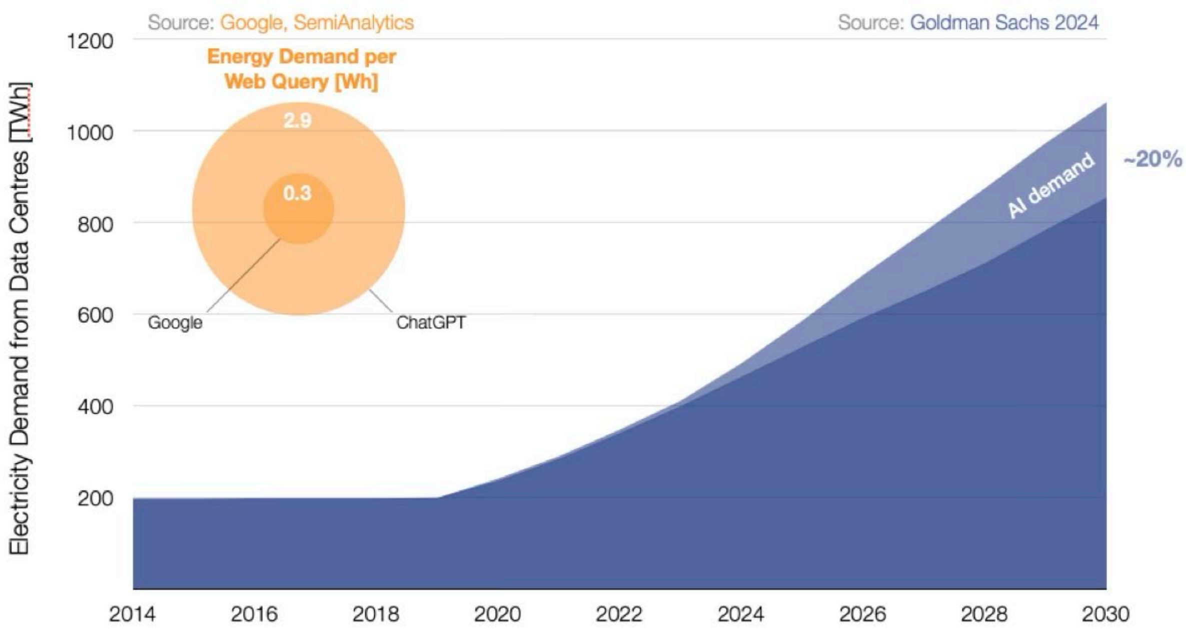

Figure 2.4: Projected Global Electricity Demand from Data Centres to 2030 and the Impact of LLM Query Growth

Sources: Goldman Sachs, 2024; Google DeepMind, 2023; SemiAnalytics, 2023.

Note: The figure *presents the projected global electricity demand from data centres (blue) and illustrates how the shift from traditional web searches to LLM queries is expected to increase electricity needs almost ten-fold (orange).*

[1] The efficiencies of LLMs have likely improved over the past month, however, at the time of writing, no research that quantifies this improvement was available. It is anticipated that LLM efficiency will be studied in detail in the foreseeable future.

The future pathways remain highly uncertain, as scenarios developed by McKinsey and Company – shown in Figure 2.5 – illustrate: in more 'optimistic' scenarios, efficiency improvements, flexible workload management, and supportive regulation moderate global demand grows to – still a considerable – compound average growth rate (CAGR) of 19%. In a more 'pessimistic' scenario, unmoderated AI expansion and rising digitalisation drive DC demand with a CAGR of 27% (McKinsey, 2025).

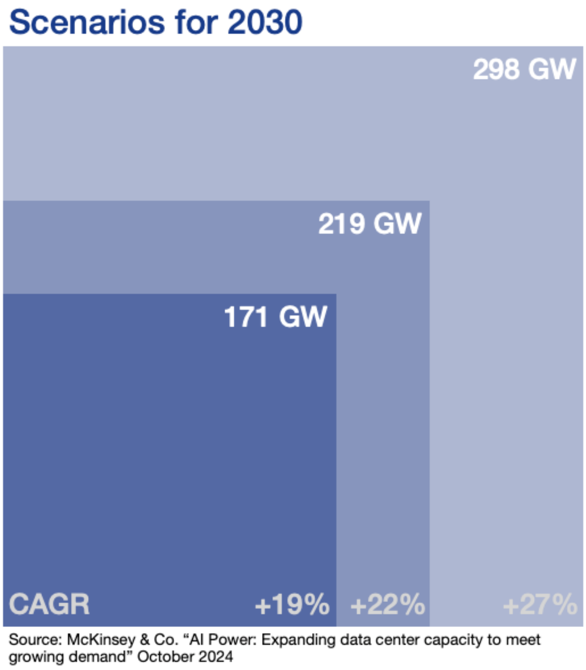

Figure 2.5: Scenario Range for Global Demand for Data Centre Capacity by 2030

Source: McKinsey & Co. (2025).

Note: Compound Annual Growth Rates (CAGR) Vary Significantly due to the Inherent Unpredictability of the Sector (2022–2030).

While these global projections are instructive, they mask significant geographic variation. Electricity demand from DCs is not distributed evenly across Europe, and national planning bodies and grid operators face very different challenges depending on whether they operate in saturated urban hubs, emerging hyperscale regions, or underutilised zones with ample renewable energy. Adding regional granularity – highlighting, for example, the demand concentrations in Central and Western Europe versus the emerging dynamics in the Nordics and Iberia – would enable more actionable policy design. Visualising spatial mismatches between digital growth and grid capacity would also reinforce the case for more intelligent, location-aware infrastructure planning. One example of location-aware planning is the colocation of DCs in areas where the phasing out of coal-fired power stations frees up grid capacity that can be utilised by co-locating renewable energy projects.

2.3. The Changing Energy Profile of Digital Infrastructure

The rise of AI-specific accelerators utilising Graphics Processing Units (GPUs) and Tensor Processing Units (TPUs)[*], the proliferation of the internet of things (IoT), and the emergence of early-stage quantum computing are fundamentally reshaping the energy characteristics of digital infrastructure. These technologies are creating highly heterogeneous load profiles that diverge significantly from the more predictable patterns of traditional data processing. In parallel, cooling and water requirements are becoming critical siting constraints, limiting viability in regions facing thermal or hydrological stress (see, for example, the case of Greece in Table 9.5).

AI clusters, for example, generate dense and sustained electricity demand, driven by continuous training and inference workloads. Quantum computing installations, though still nascent, concentrate high power requirements in ultra-compact physical footprints. Meanwhile, the expansion of IoT and edge computing multiplies the number of geographically distributed low-load sites, placing additional strain on the electricity system.

In parallel, the rise of modular and prefabricated DC designs is transforming how digital infrastructure is deployed, particularly in Tier 2 cities and latency-sensitive locations. These scalable, containerised systems could allow for faster permitting, reduced construction times, and more resilient energy configurations. Often deployed near demand centres, modular builds support decentralisation while enabling flexible siting in regions with spare grid capacity. As such, they are increasingly relevant to policy and planning frameworks – especially where localised resilience, rapid deployment, or regulatory constraints are key considerations.

Again, circumstances have changed drastically since the publication of CERRE's report in 2021: at the time, the main issue was the growing energy intensity of digitalisation, and while that remains an issue, the increasing fragmentation and complexity of energy demand is now a focus as well. Since then, AI workloads have surged due to the widespread adoption of large-scale models, and quantum computing has moved from theory to early deployment. A notable example is the establishment of IBM's first European quantum DC in Ehningen, Germany, which is expected to significantly boost the region's quantum capabilities and contribute to the emerging layer of high-density, non-linear energy consumption in the DC sector[2].

This shift challenges conventional approaches to thermal design, grid capacity allocation, and long-term infrastructure investment. Policymakers and system operators can no longer rely on aggregated averages to plan for energy provisioning. Instead, new strategies are required to manage both

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* GPUs (Graphics Processing Units) and TPUs (Tensor Processing Units) are specialised hardware accelerators designed to efficiently handle the parallel processing demands of machine learning and AI workloads; unlike general-purpose CPUs, they perform massive computations simultaneously, leading to significantly higher energy consumption per chip, particularly under sustained, high-throughput tasks such as deep learning model training.

[2] Fraunhofer Gesellschaft "Ehningen: the center of the quantum era in Baden-Württemberg" 2023.

centralised energy-intensive clusters and the growing web of distributed, low-load nodes. Table 2.1 provides a comparative snapshot of energy impacts across these emerging technology classes, highlighting the scale and diversity of future demands.

Table 2.1: Emerging technologies impacting DCs and electricity demand

Technology	Energy Impact	2025 Status
AI-specific accelerators (using e.g., TPUs and GPUs)	High	Mainstream; denser, hotter racks driving new cooling demands
Quantum Computing	High	Early-stage but growing; strategically critical; extremely energy-intensive per qubit
AR/VR & Metaverse Computing	Moderate	Persistent localised demand despite slowed growth
IoT/5G Edge Devices	High	Rapid expansion of edge nodes and local compute
Cryptography, Post-Quantum Encryption, Blockchain	Low-Moderate	Energetically significant in niche applications

Countertrends: Alongside the continued expansion of hyperscale DCs, a structural shift is underway in the architecture of digital computing. Driven by latency-sensitive applications, corporate data protection concerns, and energy price differentials, workloads are increasingly migrating toward decentralised architectures. This includes the installation of edge devices, local DCs as corporate on-premise installations, local clouds for the internet of things (IoT) operating at the network edge – so-called ‘edgification’. Figure 2.6 illustrates the main trend – ‘cloudification’ – and its countertrend – edgification. While cloudification clearly continues, sensitive data is withdrawn from the cloud.

Such fragmentation of demand has implications far beyond the IT sector. It reconfigures the geography of electricity demand, imposes new load management requirements on distribution grids, and increases uncertainty for national energy planning. However, it also opens new possibilities for load balancing, local energy integration, and geographic dispersion of digital infrastructure. Figure 2.6 visualises this architectural evolution that mitigates data traffic increase and shifts DC demand from hyperscalers to smaller servers in proximity or even on-site servers and devices (IEA, 2025).

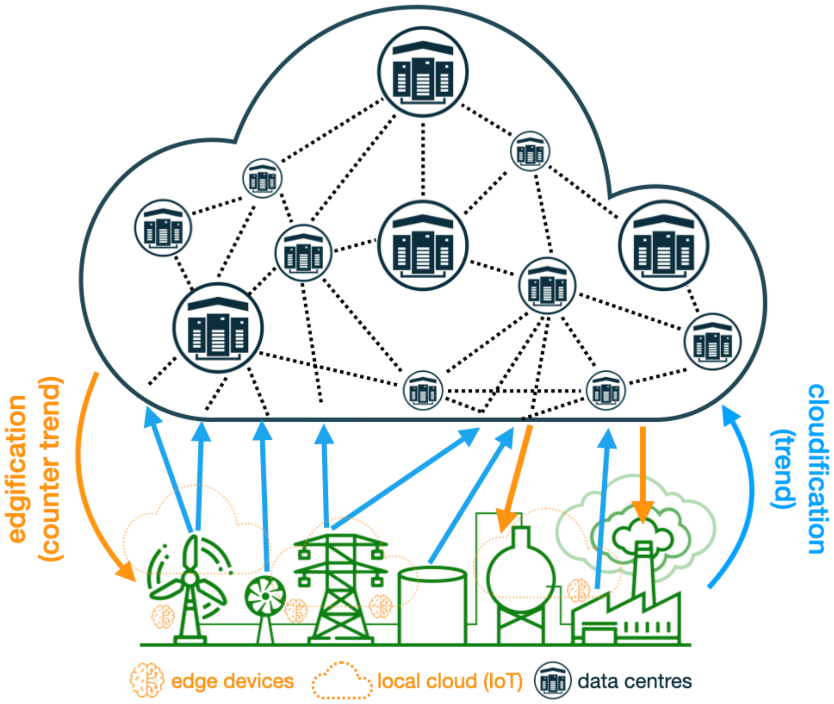

Figure 2.6: Shift from Centralised to Distributed Computing Architectures

2.4. Efficiency Gains Slowing: Toward New Sustainability Metrics

Historically, the rising energy footprint of digital infrastructure was largely mitigated by exponential improvements in semiconductor efficiency, cooling technologies, and workload management. For decades, advances in chip design allowed performance per watt to improve rapidly, effectively keeping overall energy demand in check even as digital services expanded. However, these gains are now levelling off: for example, while energy efficiency for GPUs improved by nearly 300% between 2012 and 2018, gains over the past five years have slowed dramatically to less than 20%.

CERRE's 2021 report correctly assumed at the time that ongoing efficiency improvements would broadly offset rising demand. While this assumption held true at the time, recent trends indicate that it needs to be reconsidered (Nature, 2024). A leading chip manufacturer has confirmed that efficiency gains have consolidated to single-digit percentages and will likely remain at that level.

The levelling-off of technological efficiency gains, combined with a surge of new AI-driven applications – not just LLMs, but also generative AI across image, video, and audio – is driving a structural increase in electricity consumption (IEA, 2025).

Nevertheless, as modern data centres with PUEs of 1.2 or lower enter the market, the overall average will continue to improve. However, a substantial share of legacy data centres remains in operation – often with much higher energy intensities. Reducing their electricity consumption through retrofitting and modernisation is both possible and desirable but lies largely in the hands of operators and hinges on access to capital. Targeted financial instruments or blended finance mechanisms could help unlock these efficiency gains. Case Study 2 will dive into the benefits of advanced digital technologies for overall efficiency.

Simultaneous to these improvements, a pronounced rebound effect – commonly referred to as the Jevons paradox – is amplifying energy use[3]. As services become more efficient and accessible, usage scales even faster, offsetting earlier savings. LLMs, for instance, are not only expanding but are increasingly replacing traditional web searches at an order of magnitude higher energy cost per interaction. Similarly, video streaming has overtaken traditional broadcast television, shifting content delivery to more energy-intensive on-demand networks, often delivered through high-bandwidth cloud infrastructure.

Figure 2.7 visualises these dynamics, contrasting the trajectory of rising DC electricity demand with the now-flattening trend in chip efficiency improvements. The widening gap illustrates the growing tension between Europe's digitalisation goals and the mounting energy requirements of next-generation computing.

[3] The rebound effect or Jevons Paradox is a phenomenon observed when efficiency gains lead to an increase in a technology usage, which eventually increase overall emissions.

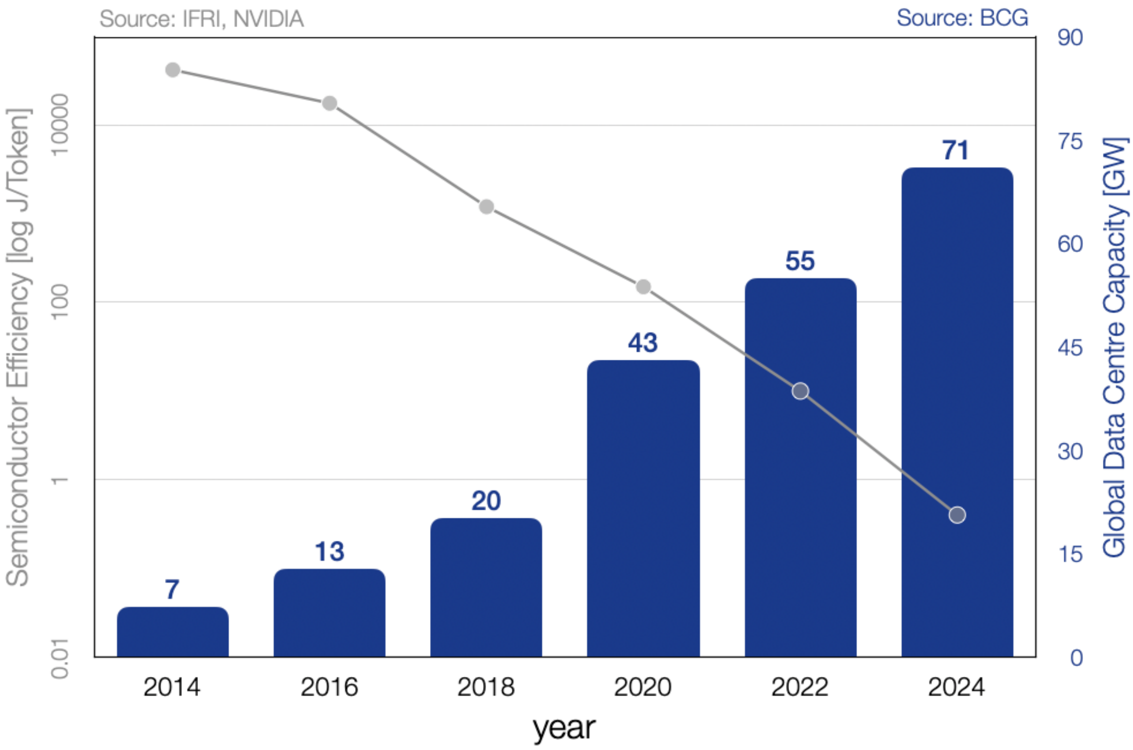

Figure 2.7: Data Centre Demand Growth vs Chip Efficiency Improvements

Sources: IFRI (2024), NVIDIA (2024), and BCG (2024).

As processor-level improvements yield diminishing returns, the focus is increasingly shifting to higher-level optimisations across the technology stack. To systematically address this evolution, this report proposes a three-tiered approach to efficiency: (1) hardware-level efficiency, (2) facility-level infrastructure efficiency, and (3) system-level or grid-integrated efficiency. Each layer targets different aspects of sustainability, requires distinct metrics, and highlights existing policy gaps. Table 2.2 summarises this framework, outlining the efficiency focus, suggested metrics, and policy levers or gaps for each tier.

Recognising the limitations of processor-level gains and the urgent need for sustainability, the industry has acknowledged the challenge and responded with ambitious decarbonisation targets. In parallel, it has begun developing metrics that capture efficiency improvements across the three identified levels. These metrics are designed to describe specific phenomena at each tier: hardware-level indicators such as training efficiency (e.g., FLOPS/kWh or Joules/Token), facility-level measures like Power Usage Effectiveness (PUE), Water Usage Effectiveness (WUE), and Energy Reuse Factor (ERF), as well as system-level metrics including carbon-aware scheduling and the Load Flexibility Index (LFI). These efforts are being driven by a mix of hyperscalers (e.g., Google, Microsoft), industry consortia (e.g., Open Compute Project), and standards bodies (e.g., ISO/IEC JTC 1, CEN-CENELEC), reflecting a growing consensus around sustainability benchmarks. Yet another complication is that tenants (e.g., cloud providers) only control the IT load, while operators manage infrastructure. Because of this division of competencies, regulatory interventions targeting energy efficiency and aimed at unlocking demand-side flexibility (see Section 2.5) must distinguish between tenant-controlled and operator-controlled demand.

Table 2.2: Three-Tier Approach to Address DC Efficiency on Different Levels

Tier	Layer	Efficiency Focus	Suggested Metrics	Policy Levers/ Gaps
1	**Hardware Efficiency**	Processing performance per watt	FLOPS/Watt, Inferences/kWh, Joules/Token	AI-specific benchmarks and procurement standards still missing
2	**Facility-Level Infrastructure**	Total energy vs. IT energy	PUE, WUE, ERF, COP	JRC Code of Conduct exists, but no binding EU retrofitting rules
3	**System-Level Efficiency**	Integration with energy system and grid	Load Flexibility Index (LFI), Carbon-Aware Scheduling	Flexibility markets in early stage; reporting obligations limited

Table 2.3 provides a comparative overview of these metrics; those not available in 2021 are marked in italics; it organises the metrics according to the three-tier approach proposed. This evolution in measurement demonstrates the industry's growing commitment not only to environmental sustainability but also to long-term energy security (IEA 2025, Uptime Institute, 2024).

Table 2.3: Evolving Digital Sustainability Metrics Organised in the Three-Tier Approach

Metric	Focus Area	Dimension	Status	Pros	Cons
Tier 1: Computing Hardware					
PPE (Power to Performance Effectiveness)	Server efficiency	Performance / kW	Useful but not widely reported	Accounts for server utilisation	Difficult to standardise across workloads
CUE (Carbon Usage Effectiveness)	Carbon emissions intensity	$kgCO_2$ / kWh IT Equipment	Gaining relevance with environmental, social and governance (ESG)	Links energy to emissions; policy-relevant	Relies on accurate emissions factors per region

Metric	Focus Area	Dimension	Status	Pros	Cons
CUE (Carbon Usage Effectiveness)	Carbon emissions intensity	$kgCO_2$ / kWh IT Equipment	Gaining relevance with ESG	Links energy to emissions; policy-relevant	Relies on accurate emissions factors per region
Training Efficiency	AI training energy use	FLOPS / kWh	Early adoption by hyperscalers	Captures compute intensity of AI	Opaque for public comparison, workload-specific
Inference Efficiency	AI inference energy use	Inferences / kWh	Early adoption by hyperscalers	Relevant for scaled inference operations	Highly variable by task type
Tier 2: Facility-Level Infrastructure					
PUE (Power Usage Effectiveness)	IT vs Total Energy Use	Total Facility Energy / IT Equipment Energy	Industry Standard	Simple to calculate, widely adopted, trackable over time	Ignores energy source or computing productivity
DCiE (Data Centre Infrastructure Efficiency)	IT vs Infrastructure Energy Use	IT Equipment Energy / Total Facility Energy	Inverse of PUE; Less common	Intuitive as a percentage (0–100%)	Redundant if PUE is known; rarely used in reports
WUE (Water Usage Effectiveness)	Water use for cooling	Litres / kWh IT Equipment	Growing importance	Captures water sustainability	Difficult to compare due to varied cooling systems
EER (Energy Efficiency Ratio)	Cooling system efficiency	Cooling Output / Power Input	HVAC-specific; used in design	Established HVAC metric	Does not measure IT productivity
COP (Coefficient of Performance)	Heat pump/cooling efficiency	Cooling Output / Work Input	Standard in thermal systems	Standardised, widely used in HVAC	Limited to thermal systems, not full DC

Metric	Focus Area	Dimension	Status	Pros	Cons
DCeP (Data Centre Energy Productivity)	Useful work per energy used	Tasks / kWh	Conceptually strong; rarely implemented	Directly links output to input	Hard to define 'useful work' consistently
Tier 3: System-Level Integration					
ERF (Energy Reuse Factor)	Heat reuse	Reused Energy / Total Energy (0–1)	Gaining traction in Europe	Supports circularity and local heat reuse	Depends on external heat demand
Carbon-Aware Compute Score	Workload timing vs grid carbon	% Workload during low-carbon hours	Piloted by Google, Microsoft	Aligns computing with renewables availability	Requires real-time grid carbon data
Load Flexibility Index (LFI)	Demand response capability	Flexible Load Hours / Total Load	Pilot-tested (EU/US)	Quantifies grid-service potential	Requires operational telemetry and incentives
Energy Proportionality Index (EPI)	Idle vs Load power scaling	Deviation Ratio (0–1)	Conceptual; R&D phase	Addresses underutilisation in high-power servers	Still undefined industry standard
Embodied Energy Efficiency	Lifecycle sustainability	Compute Units / Lifecycle kWh	In discussion (EU, Scope 3)	Incentivises circular design and reuse	Hard to assess consistently

Note: metrics that were developed after CERRE's 2021 report are in italics.

2.5. From Liability to Asset: The Flexibility Potential of DCs

Just as digital technologies have evolved rapidly, so has the perception of DCs. Only a few years ago, DCs were largely viewed as inflexible electricity consumers – passive liabilities in the energy system with ever-growing demand profiles. Today, that view has shifted fundamentally. Advances in infrastructure, software, and systems integration have revealed their potential as active participants in system and grid management. Through mechanisms such as load shifting, geographic workload distribution, on-site energy storage, and heat reuse, DCs are emerging as valuable assets for enhancing system and grid flexibility and supporting the integration of variable renewable energy. This transformation – driven by both technical innovation and smarter operational strategies – shows how quickly a sector once seen as a challenge can become part of the solution. For more details on grid flexibility and its importance for the energy transition, we refer to CERRE's 2025 report "Flexibility in the Energy Sector" (CERRE, 2025).

With regards to DCs, the IEA study quantified this potential: Europe could unlock 50–60 GW of such flexibility by 2035 – comparable to the peak load of a mid-sized EU Member State or the flexibility large-scale electric vehicle (EV) deployment could provide. This would make DCs a critical tool for integrating variable renewables and reducing reliance on dispatchable fossil capacity (IEA 2025). Figure 2.8 details these flexibility mechanisms by type and scale.

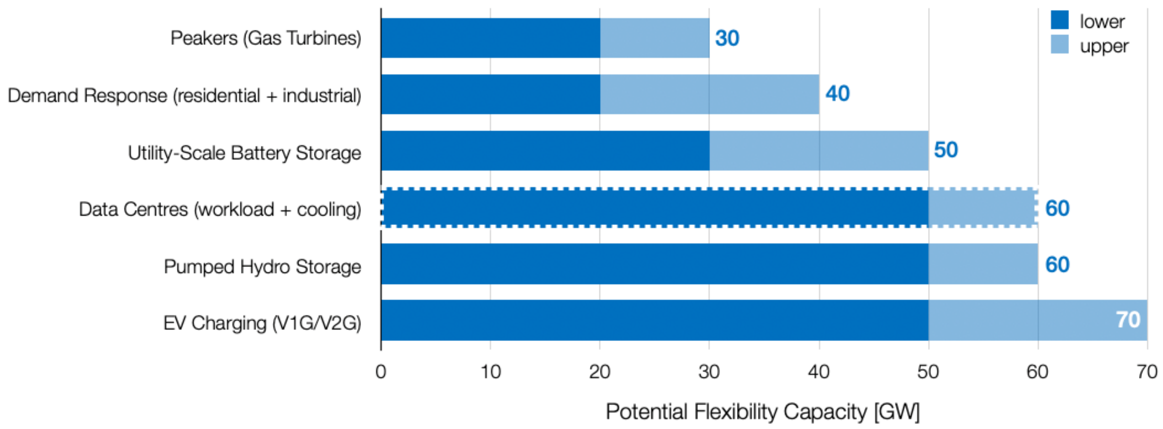

Figure 2.8: Temporal Flexibility Potential – Dynamic Alignment with Grid Conditions

Source: IEA (2025).

Crucially, the inherent flexibility of DCs themselves – particularly through temporal load shifting – can significantly ease integration into the power system without requiring major new generation or storage infrastructure.

Even modest levels of data centre flexibility can unlock substantial system-wide capacity. As illustrated in Figure 2.9, if just 0.1% of total EU electricity demand were made temporally flexible within the DC sector, the resulting system optimisation would free up an estimated 15 GW of usable capacity across the grid. Scaling this to 1% could unlock nearly 40 GW – comparable to the peak load of several EU Member States. These estimates are not direct fractions of total capacity, but modelled (theoretical) outcomes from simulations of grid efficiency gains under different DC flexibility scenarios. This elasticity illustrates a powerful dynamic: small improvements in DC flexibility can yield disproportionately large benefits for the wider energy system, making DCs a key enabler of a more resilient and renewable-powered grid.

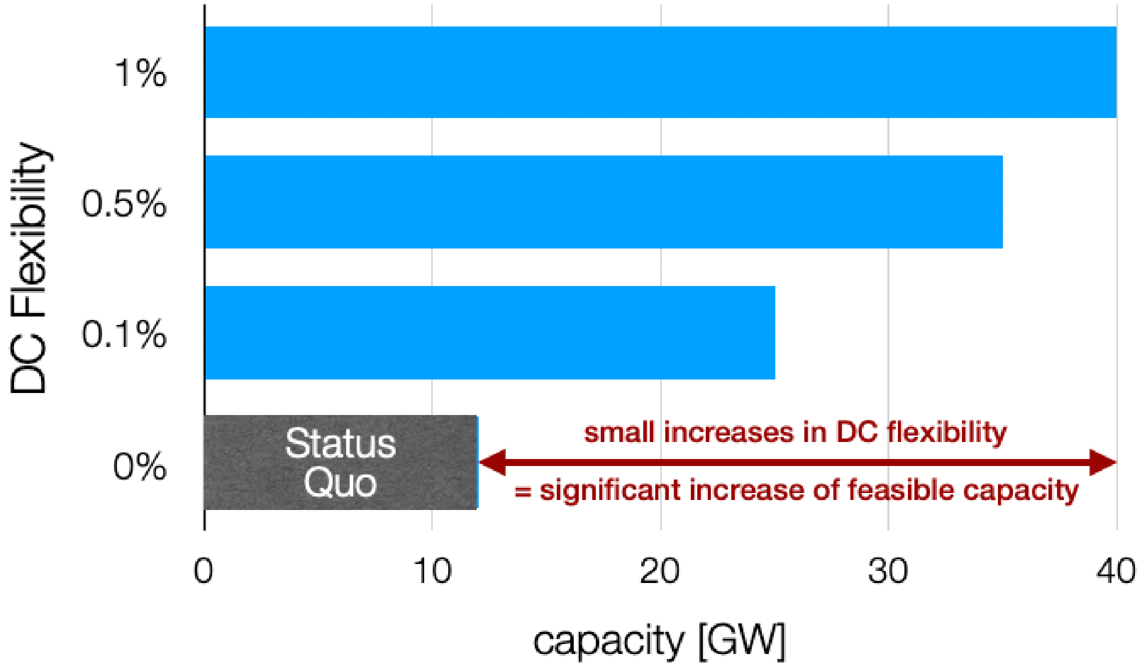

Figure 2.9: DC Flexibility: Shifting 0.1–1% of DC workload could make the addition of 10 to 25 GW feasible with current grid constraints

Source: IEA, 2025.

Realising this flexibility potential, however, cannot rely solely on technical capability or voluntary goodwill.

Flexibility should be contractually secured, whether through integration into redispatch mechanisms, system services, or grid support agreements, to ensure it is predictable, verifiable, and available when needed. Without such commitments, flexibility remains theoretical and cannot be relied upon by system operators in grid planning or balancing operations.

Despite the growing recognition of DCs as flexible and increasingly sustainable energy actors, critical challenges persist – foremost among them, grid congestion. As electricity demand from digital infrastructure surges, local grids in many regions are already nearing their operational limits, creating serious constraints for both the expansion of DCs and the integration of renewable energy (McKinsey, 2024; EIB, 2025). This congestion not only limits the connection of new loads and generation assets but also hinders the full deployment of flexibility potential on the system level, making it a systemic barrier to digital and energy transitions alike. The following section addresses this challenge in depth. It identifies grid congestion as the pivotal issue this report seeks to examine – both as a technical bottleneck and as a policy gap – and explores the pathways through which DCs can transition from passive demand points to active grid participants, thereby helping to alleviate the very congestion that threatens their growth.

2.6. Core Problem: Expanding DCs with Grid Congestion

Across Europe, transmission and distribution grid infrastructures are facing mounting pressure due to the rapid growth of renewables, delays in grid expansion projects, and spatial clustering of DCs. While DCs could offer flexibility potential, their current development patterns – driven by proximity to urban hubs, low-latency fibre routes, and tax incentives – are exacerbating regional grid stress. In some areas, connection queues are lengthening dramatically; in others, local moratoria on new data centre projects are being discussed or enacted. Dublin, Frankfurt, and Amsterdam already face severe congestion challenges directly linked to the concentrated growth of digital infrastructure as well as delays in grid expansion projects.

Some of the largest current and planned DCs are located in regions already struggling with limited grid headroom. This spatial mismatch risks turning digital expansion into an energy liability – unless grid constraints are consistently taken into account.

A key lever to reduce grid strain lies in the targeted siting of large, electricity-intensive loads like data centres. Rather than responding passively to siting proposals, system operators and regulators should proactively steer new DC development toward areas with available grid capacity and high renewable energy potential. This can be achieved through clear locational incentives, such as differentiated connection charges and fast-tracked permitting, or capacity market designs that reward flexible loads located near underutilised infrastructure (see more in Section 3 on Policy Approaches). These mechanisms would align private investment with system needs, easing local congestion while accelerating the integration of variable renewables.

To alleviate grid congestion not only from growing digital loads but also from renewable energy integration and electrification of other sectors, the flexibility potential of DCs must be fully harnessed. More intelligent site selection – accounting for grid capacity, renewable availability, and acceptable latency thresholds – and on-site generation can transform DCs into strategic energy assets rather than grid burdens. Doing so will require coordinated action and policy reform. As this report outlines in the following sections, addressing permitting delays, aligning investment signals, and mainstreaming integrated energy planning will be key to unlocking this potential (see Section 3). Case study 1 will illustrate this and elaborate on the issues this creates for the secure provision of sustainable energy.

Case Study 1: The Infrastructure Gap – How Current Practices Affect the Efficiencies and Economics of Electricity Provision

Providing sufficient data centre capacity will be critical for achieving the European Union's digitalisation targets[4] and ensuring European competitiveness (EC, Digital Decade, 2025 & Competitiveness 2025) Yet across many European agglomerations, the electricity grid needed to support that digital capacity is lagging behind – not only due to grid congestion or permitting

1.

bottlenecks, but also due to systemic inefficiencies in how electrical capacity is allocated, used, and reserved.

As the fast-growing and loosely regulated market of digital services is dependent on an infrastructure-heavy and highly regulated electricity market, the latter will likely struggle to keep up with the former. This creates a lag between the potential maximum peak load (IEA, 2025) demanded by DCs and the provision of the corresponding electricity infrastructure, creating an *infrastructure gap and system stability concerns*. To illustrate this, Figure 2.10 compares past and projected peak loads[1]: applied-for connection (grey line) versus provided (dark blue columns) peak load capacity, for a European metropolitan region that relies on low-latency provision of DC capacity. The gap between the provided and applied-for peak load (red arrow) needs to be addressed by regulators. Under current circumstances, electricity provision is unlikely to cater for all the applied-for peak load capacity, demonstrating that the demand for DC capacity evolves significantly faster than electricity grid developments. Such a de-phased evolution of two critical infrastructure areas would not only slow the digital transition but could also detrimentally affect the green transition, competitiveness and economic security overall (see Sections 1, 2.5, and 2.7). Consequently, regulatory interventions must strategically address the infrastructure gap by supporting and accelerating electricity infrastructure that powers the digital transition, e.g., fast-tracking applications for connector cables (see Section 3.1.2), addressing grid infrastructure bottlenecks (see Sections 2.4 and 2.6), and many more set out in this report. The combination of these policy levers could significantly reduce the infrastructure gap (see light blue and grey columns in Figure 2.11).

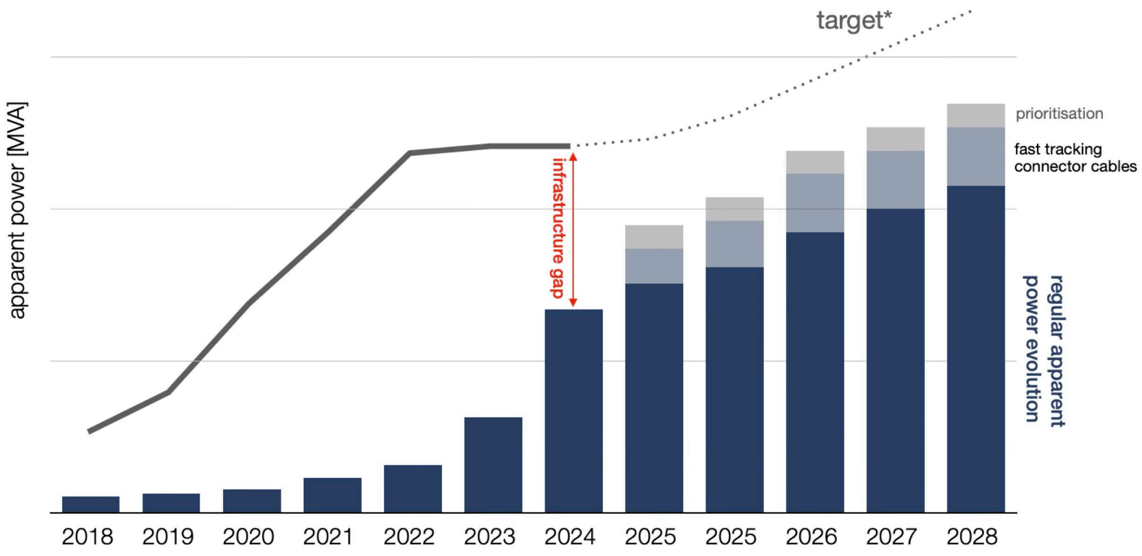

Figure 2.10: The Infrastructure Gap signifies the discrepancy between needed, utilized and contracted apparent power

Note: Peak – represented by apparent power – contracted by DCs (grey line), supplied (blue columns) and possible (light columns) in a metropolitan area.

Source: Data available to and assessed by the authors.

However, there is also a discrepancy between the applied-for and the ultimately-used peak load capacity. In high-density digital infrastructure hubs, for instance, data centres tend to apply for more capacity than they will use – sometimes exceeding peak load needs significantly. In the case of our example metropolitan area, this overcapacity can amount to one-third of contracted peak load capacity, as illustrated in Figure 2.10.

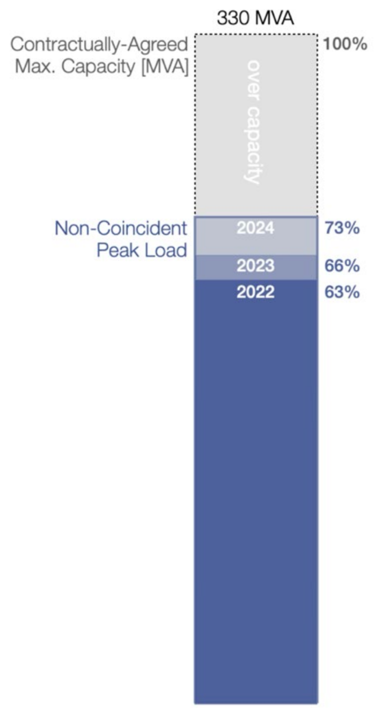

Figure 2.11: Contractually agreed (or maximum) peak load vs actually utilised peak load (blue).

Source: Data available to and assessed by the authors.

Consequently, the actual (real) infrastructure gap is narrower than the representation in Figure 2.9. While applications for safety margin are understandable as data centre operators must safeguard operability, maintain redundancy, and plan for worst-case demand overlaps, this practice has unintended consequences. It creates, for example, economic inefficiencies as DSOs and TSOs are obliged to provide the contractually agreed peak load capacity – even if it is not utilised. Unnecessary infrastructure ties up resources and slows down other critical projects (see Section 2.4 and 4).

Regulators can mitigate this by incentivising on-site electricity provision and storage by DC operators (see Section 3.1.1.2) while simultaneously reducing hurdles for such installations (see Section 3.3.2). This could reduce the number of applications for excess capacity. Moreover, a dynamic assessment of contracted capacity or the introduction of shared backup infrastructure – could help close the gap (see Section 3.5).

If orchestrated and sequenced in a holistic strategy grid and data centre development could be significantly optimised and help close the infrastructure gap as described above (also see Sections 3.2 and 3.6).

2.7. Digital Sovereignty, Tech Regulations, and DCs Demand in Europe

The increasing demand for DCs within the EU cannot be dissociated from the growing concern over digital sovereignty. Beyond the classical drivers of efficiency and latency, a new layer of political and legal rationale has emerged, even if it is largely overlooked in current policy discourses.

2.7.1. DCs as Geostrategic Assets in the Digital Value Chain

DCs have become "*final points of control*" within the digital value chain (Rand, 2025). Their location, and more importantly, the legal regime governing them, plays an important role in determining who can access, regulate, and potentially disrupt digital services. In this sense, they must now be understood as geostrategic assets whose management is deeply intertwined with questions of national and economic security, as well as of European autonomy.

The parallel with the EU's dependence on Russian gas offers a useful illustration. When critical infrastructure is subject to external control (whether pipelines or digital platforms), its ability to maintain stable operations while being resilient against geopolitical shocks diminishes considerably. In the current context, where digital systems can underpin critical economic and governmental functions, dependence on extra-European infrastructure providers, particularly in the cloud and data storage sectors, introduces a latent vulnerability.

Civil society is also increasingly concerned about digital sovereignty. For example, in France, public backlash led national energy provider EDF to abandon a potential partnership with AWS for migrating nuclear power plant-related data to the cloud (Benyahia & Labbé, 2024), and elite engineering school École Polytechnique faced reputational damages after announcing its migration to Office 365 (Laurent, 2025).

Developing sovereign DC capacity on EU territory can provide a safeguard against extraterritorial interference and ensure a continuity of service that is not contingent upon decisions taken by extra-European entities.

However, while it is an important part of the equation, the physical location of the DC does not guarantee full sovereignty over data processing. It can do so only if the data processing operation is subject to EU regulation and protected against extraterritorial laws. Full sovereignty is ensured by two components: operational sovereignty, which entails control over the infrastructure, and legal sovereignty, which entails immunity from foreign extraterritorial laws (see below).

2.7.2. Digital Regulations and the Legal Rationale for EU-Based Data Storage

In parallel, EU digital legislation increasingly introduces incentives that make local hosting of data not only desirable but, in some cases, compulsory for legal compliance. Although the EU legal texts uphold the principle of free flow of data, a growing body of law, from data protection to cybersecurity, creates a framework in which storing and processing data within the EU becomes the default, risk-averse path for many operators even if the relevance of data localisation is widely debated in academic scholarship (Chander, 2020 ; Mishra, 2016).

The legal regime governing international data transfers under the General Data Protection Regulation (GDPR) offers a particularly illustrative example of this trend. Transfers of personal data outside the EU are only permitted if the recipient jurisdiction ensures a level of protection deemed "essentially equivalent" to that offered by the GDPR[5]. This requirement has been at the centre of legal and political controversy, particularly in the context of EU-US data flows (Chander, 2020). The Court of Justice of the European Union (CJEU) has already invalidated two successive adequacy frameworks (the Safe Harbour and the Privacy Shield) in the landmark Schrems I and II rulings (CJEU, 2016 and 2020). While

[5] GDPR, Article 44.

the latest adequacy decision, adopted in July 2023 (European Commission, 2023), temporarily restored a legal basis for data flows, this precarious equilibrium has since been destabilised. Key elements of the executive order, such as the establishment of an independent oversight mechanism, have become increasingly fragile under the new US administration[6]. The comeback of President Donald Trump to office has raised substantive doubts about the future compatibility of US surveillance practices with EU law. It appears inevitable that the CJEU will once again be called upon to assess the adequacy of the US data protection framework. Activists, including Maximillian Schrems (who led the charge against the previous adequacy decisions), have already warned that the current situation is no more satisfactory than that of 2020 and argue that the adequacy decision should be annulled by the CJEU (NOYB, 2025).

If the Court were to find the new arrangements insufficient, and if alternative means of engaging in cross-border transfers with the US prove unsuitable, European companies might be compelled to halt transatlantic data transfers and require their cloud service providers to store and process data exclusively within the EU. In such a scenario, compliance with EU digital laws would depend upon access to DCs that are physically located in Europe and not subject to foreign extraterritorial laws. The mere potential for extraterritorial access by non-EU intelligence authorities could become legally disqualifying under the GDPR's rigorous standards.

A similar pattern can be observed in cybersecurity regulations. The forthcoming European Cybersecurity Certification Scheme for Cloud Services (EUCS), currently under debate, may further crystallise the role of European DCs in securing compliance. While the final text has not yet been adopted, early drafts suggest that immunity from extraterritorial access could become a prerequisite for the highest level of security[7]. Following this reasoning, demand for sovereign infrastructure, including DCs physically located and legally governed within the EU, is expected to intensify.

2.8. A Complicated Nexus: Trade-Offs between Energy Security, Economic Competitiveness, Digitalisation, and Climate Targets

In short, DCs have become emblematic of a new policy frontier where climate ambition, digital acceleration, economic resilience, and energy security intersect. Each of these goals is urgent, but in practice they often pull in opposite directions: electrifying entire sectors can strain the grid; attracting large-scale cloud investment can distort energy markets; and achieving net zero may demand unpopular constraints on growth. Lifecycle impacts – including embodied emissions and long-term material sustainability – further complicate these trade-offs, particularly as new EU frameworks begin to address circularity and embedded carbon.

[6] See Trump's removal of democrat members of the Privacy and Civil Liberties oversight Board: https://news.bloomberglaw.com/privacy-and-data-security/trump-terminates-trio-of-democrats-from-privacy-oversight-board.

[7] https://www.enisa.europa.eu/publications/eucs-cloud-service-scheme.

The previously siloed domains of ICT, energy, and industry policy can no longer afford to operate in isolation. What's needed is a paradigm shift: a move beyond static planning and one-size-fits-all regulation toward an agile, data-driven governance model. Strategic initiatives like the EU's "AI factories" exemplify this shift, aligning clean compute infrastructure with industrial policy, energy flexibility, and digital sovereignty goals.

This report argues that Europe must stop treating DCs as passive infrastructure and start treating them as assets – dynamic, distributed, and deeply embedded in the continent's energy-digital nexus. If harnessed wisely, they could serve as a cornerstone of a future that is not only smarter and greener but also more secure and competitive.

In this context, smart regulation becomes essential – not just to guide behaviour, but to evolve in step with new technologies and decentralised architectures. This means embedding feedback loops, enabling limited experimental zones, and using performance-based criteria to allow new technologies to prove their value under real-world conditions. Instead of treating regulation as a barrier or endpoint, it can function as an adaptive scaffold that supports and scales innovation responsibly. Policy will be the enabling tool for this transition, and the following section will discuss and critically assess possible policy interventions.

Case Study 2: AI as Driver for Efficiency – How Digital Intelligence Can Produce Sustainability Gains

While much attention has been paid to the environmental costs of digitalisation, less focus has been placed on the sustainability gains enabled by advanced digital technologies – particularly AI (Stern & Romani, 2025). Since as early as 2016, machine learning has demonstrated measurable benefits in real-world data centre operations. A landmark example is DeepMind's application of reinforcement learning to optimise Google's cooling systems, which resulted in a 29% reduction in energy used for cooling over the course of one year (Inderwildi & Kraft, 2022). While this example is dated, it remains a turning point, showcasing the untapped potential of AI to reduce system-level energy intensity.

Crucially, these efficiency gains have not plateaued. New applications of AI – from dynamic workload scheduling to predictive cooling, real-time power management, and AI-designed chips – continue to improve the environmental footprint of data centres. This is reflected in performance metrics from leading AI companies compared to industry averages.

As shown in Figure 2.12, the PUE of firms like Google, AWS, Meta, and Microsoft has significantly outperformed the industry average of 1.58 – achieving ratios close to 1.1. While PUE is a legacy metric and increasingly seen as insufficient to capture holistic efficiency, it remains widely reported and allows meaningful comparison. Similarly, the WUE of these companies is far below the industry average of 1.8 l/kWh, pointing to major gains in water stewardship – a critical factor in drought-prone regions.

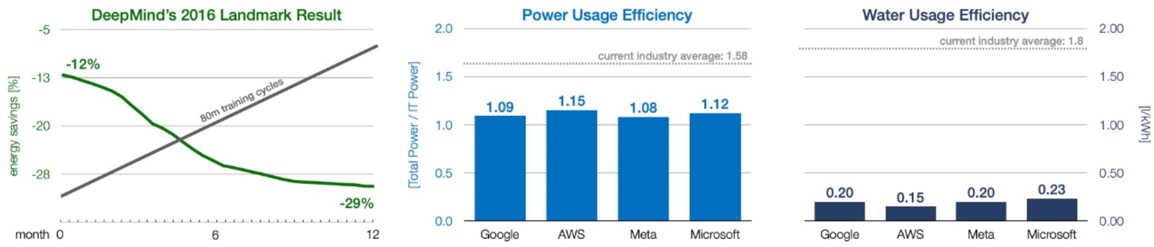

Figure 2.12: The positive impact of the AI boom

Left: DeepMind's landmark achievement on DC cooling Centre & right: PUE and WUE values, respectively, of leading AI hyperscalers vs. the industry average.

Note: Data was accumulated from the sustainability reports of the respective companies, while the industry average is based on data from the Uptime Institutes 2024 DC survey.

Sources: AWS (2024), Google (2024), Meta (2024), Microsoft (2024)

Taken together, these examples illustrate that AI is not only a driver of rising demand (EC, 2024), but also a key enabler of smarter, leaner, and more sustainable operations. When appropriately governed and strategically incentivised, AI has the potential to reinforce, rather than undermine, Europe's digital and environmental ambitions (WEF, 2025).

3. Intertwining Digital & Energy Infrastructure: Policy Approaches

The success or failure of integrating digital infrastructure with sustainable energy systems will hinge not only on technology or market dynamics, but also on policy and regulation. Well-designed policies and regulatory incentives can catalyse innovation, align stakeholder incentives, and unlock investment, whereas poorly designed ones can stifle progress, exacerbate bottlenecks, and increase fragmentation. This underscores the role of public policy and regulation as central levers in shaping the trajectory of Europe's digital-energy nexus.

Policy must navigate a complex web of partially competing objectives: fostering digital innovation and hyperscale capacity, ensuring cybersecurity and digital sovereignty, delivering affordable electricity, maintaining grid stability, and meeting stringent climate targets. One critical area of focus is the management of connection queues by systems operators, currently following a non-discriminatory 'first-come-first-served' principle, which does not allow operators to distinguish between projects based on their merits. Then, to solve the issue of congested connection queues, one must either depart from strict non-discrimination, in favour of prioritisation based on social benefits, or provide the system operator with other economic means of managing and sequencing the queue. These tensions cannot be resolved by regulation alone – they require a layered, adaptive policy toolkit.

To frame this toolkit, we introduce a four-quadrant matrix (see Figure 3.1) that categorises policy interventions by two axes: direct versus indirect influence and hard (mandatory) versus soft (incentive-based or informational) levers. This typology serves as a tool for mapping the landscape of instruments that governments and regulators can deploy. Each quadrant is illustrated with successful use cases drawn from across Europe, highlighting how different strategies – from regulation and planning to incentives and market signals – can contribute to aligning digital expansion with energy and climate imperatives.

We now analyse the role of regulation, focusing on what it is, how it must be, and under which conditions regulatory intervention is justified.

Among the various levers in the policy toolkit, regulation remains the most direct and authoritative mechanism. It establishes the binding rules that determine what DCs can build, where they can locate, how they interact with electricity systems, and under what environmental conditions they may operate. When well-calibrated, regulation provides legal certainty, accelerates infrastructure planning, and prevents harmful externalities such as land-use conflicts, grid saturation, or unchecked carbon emissions. However, overly rigid regulation can hinder innovation, delay deployment, and exacerbate regional disparities. This is particularly true in sectors characterised by rapid evolution, heterogeneity of actors, and complex system interactions – such as digital infrastructure.

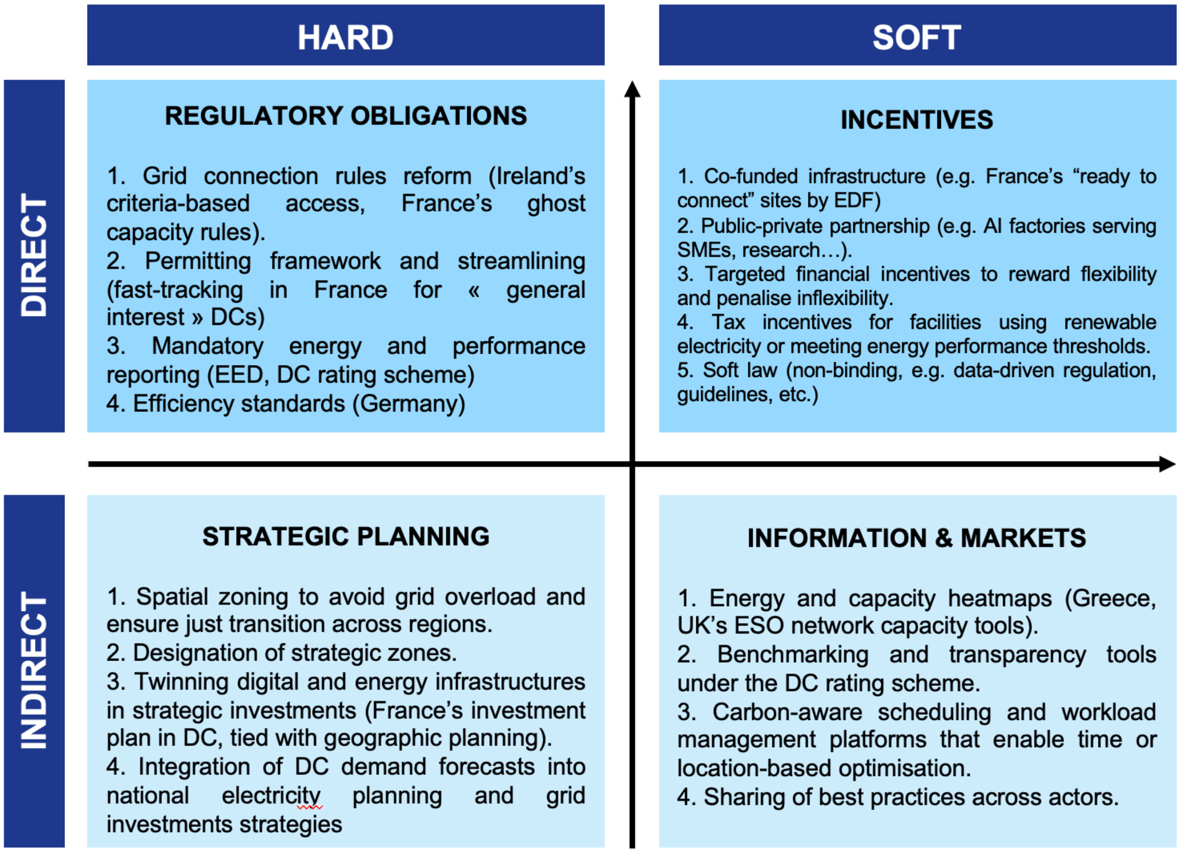

Figure 3.1: Policy Intervention Matrix for the Efficient Integration of DCs into the Electricity Grid

Source: Figure elaborated by the authors.

Regulation in this domain must be *flexible*, *adaptive*, and *proportionate* (CERRE, 2024) to evolving technological realities and to varying national and regional contexts. Imposing one-size-fits-all mandates or exemptions is often not the right solution when technologies evolve quickly over time. Exemptions and experimentations are usually well adapted for small innovative connectees, not massive loads. Effective regulatory design should build in mechanisms for periodic revision, differentiation by actor size or typology, and alignment with emerging best practices. Regulation should also be 'smart' in the sense of enabling innovation and incentivising higher standards, for instance, through performance-based thresholds.

Regulatory intervention should be reserved for specific circumstances where softer instruments prove insufficient or ineffective. These include:

- **Harmonisation needs:** where fragmented national approaches create inefficiencies, legal uncertainty, or distortions in cross-border investment (e.g., efficiency metrics). One difficulty resides in finding the right balance between harmonisation and adaptation to local specificities (e.g., it is normal that connection rules differ between different countries that face different situations).
- **Market failures:** where voluntary or market-based solutions are structurally unable to correct for systemic risks or externalities (e.g., local congestion, environmental impact).

- **Strategic alignment:** where public interest goals such as digital sovereignty, climate neutrality, or security of supply require common legal baselines.

Where these conditions are not met, preference should be given to lighter-touch tools – such as incentives, planning instruments, or market-based signals – that preserve operator flexibility and harness competitive dynamics to drive system-level outcomes.

In the following, we develop each quadrant of the policy toolkit: Regulation (3.1), Incentives (3.2), Planning (3.3) and Informational & Markets measures (3.4).

3.1. Direct & Mandatory: Regulation

In this section, we address two key regulatory issues related to DCs in Europe. The first one is how regulation is currently helping or could help accommodate DCs demand while meeting its targets (see Section 3.1.1). The second issue addressed is the fragmentation of EU legislation applicable to DCs (see Section 3.1.2). In Section 3.1.2, we'll also continue the review of EU legislation started in the 2021 CERRE report in order to identify overlaps or loopholes, and to make recommendations for a more harmonised and less complex approach to DC regulation within the EU.

3.1.1. Accommodating DC Demand: A Comparative Analysis of Regulatory Strategies across Europe and Beyond

We have conducted an original mapping and analysis of regulatory strategies aiming at accommodating DCs demand within Europe. This work resulted in the Tables 9.1-9.5, which can be found in Annex 1.

The analysis focuses on three primary areas of regulatory intervention. First, it examines grid connection rules. Second, it investigates how permitting delays (often flagged by stakeholders as a significant obstacle to deployment) can be streamlined. Finally, it surveys the implementation of energy efficiency standards and sustainability criteria applicable to DCs.

By taking a comparative perspective, the objective is to highlight effective approaches and identify shortcomings in different contexts. In doing so, the report serves as a compass for Member States seeking to refine their frameworks. The comparative analysis includes examples of strategies adopted by EU countries in different contexts, allowing policymakers to draw inspiration to address their own issues. Furthermore, the database provides EU institutions with a comprehensive overview of the current regulatory issues faced by EU Member States.

The structure of this section is as follows: the subsection 3.1.1.1 sets out the methodology used to conduct the comparative analysis and the tables 9.1 to 9.5 which can be found in Annex 1. Subsection 3.1.1.2 presents the main outcomes and policy recommendations derived from the case studies.

3.1.1.1. Methodology

The comparative analysis we conducted is based on a selection of national case studies chosen for their strategic relevance in the European DC ecosystem. The countries reviewed include France, Ireland, Germany, the Netherlands, and Greece. These jurisdictions were selected to reflect both diversity in regulatory approaches and the heterogeneity of constraints faced by DC development.

Each case study is structured around three core analytical pillars: (1) the local situation with respect to DC deployment; (ii) the public policies and legal instruments adopted in response; (iii) and the observable effects of those measures (if any). Special attention is paid to how countries regulate grid access, facilitate or delay project development, and integrate sustainability goals into their regulatory frameworks.

The selection criteria reflect distinct characteristics of national DC ecosystems. France was included for its recent legislative activity and growing emphasis on attracting foreign DC investment (109 billion euros of investments announced during the AI Summit in February 2025). Ireland offers a long-standing case of hyperscale concentration and is often cited in connection with grid stress in the Dublin region. Germany, as the second-largest DC hub in the EU. The Netherlands is included due to its policy innovation in the face of congestion in Amsterdam, including spatial zoning mechanisms. Greece introduces a different context, where the government's will to attract DC contrasts with local natural resource constraints (particularly water availability).

The main output of the analysis is a structured database compiling policy and regulatory measures observed across the selected countries, which can be found in Annex 1. While not exhaustive, it enables an inductive approach: rather than testing a predefined hypothesis, this approach allows patterns and lessons to emerge from the comparative reading of national experiences.

3.1.1.2. Lessons from the Comparative Analysis of DC Policy and Regulatory Strategies

We will first present three overarching lessons emerging from the review (General Findings), before presenting the emerging concerns regulatory frameworks will have to face (Emerging Concerns) and finishing with lessons from specific selected countries (Deep Dives on Specific Regulatory Issues).

General Findings

1. Policy and Regulatory Measures Tend to Follow Recurrent Cycles

Across the jurisdictions that were analysed, DC development appears to follow a consistent cycle in which policy incentives and regulatory frameworks evolve in response to local saturation effects (see Figure 3.2). Typically, governments initially seek to attract investment through a combination of tax incentives, public-private co-investment and a laissez-faire approach in terms of connection rules (first-come-first-served principle). This creates the conditions for the emergence of digital hubs (usually one per country, such as Ile-de-France in France, Amsterdam in the Netherlands, Frankfurt in Germany, and Dublin in Ireland), where connectivity, energy availability, and economic activity are already concentrated. As clusters expand, however, the cumulative impact on local infrastructure, especially electricity grids, becomes increasingly visible. Congestion, long connection queues, and siting conflicts begin to emerge, often triggering a wave of regulatory intervention aimed at rationing access, redirecting investment, or even freezing new development altogether.

This cycle was observed, in varying forms, in the Netherlands and Ireland, and is beginning to emerge in parts of Germany and France. In Amsterdam, for instance, the initial success in attracting DCs eventually triggered a temporary moratorium on new construction due to local grid and space constraints. Authorities have since managed to incentivise the development of DCs in other regions of the Netherlands, like the northern region. In Dublin, regulatory debates have been dominated by the need to manage a dense concentration of hyperscale facilities in a single urban area. In each case, a shift occurred from incentivisation to regulation, albeit with varying levels of coordination and foresight.

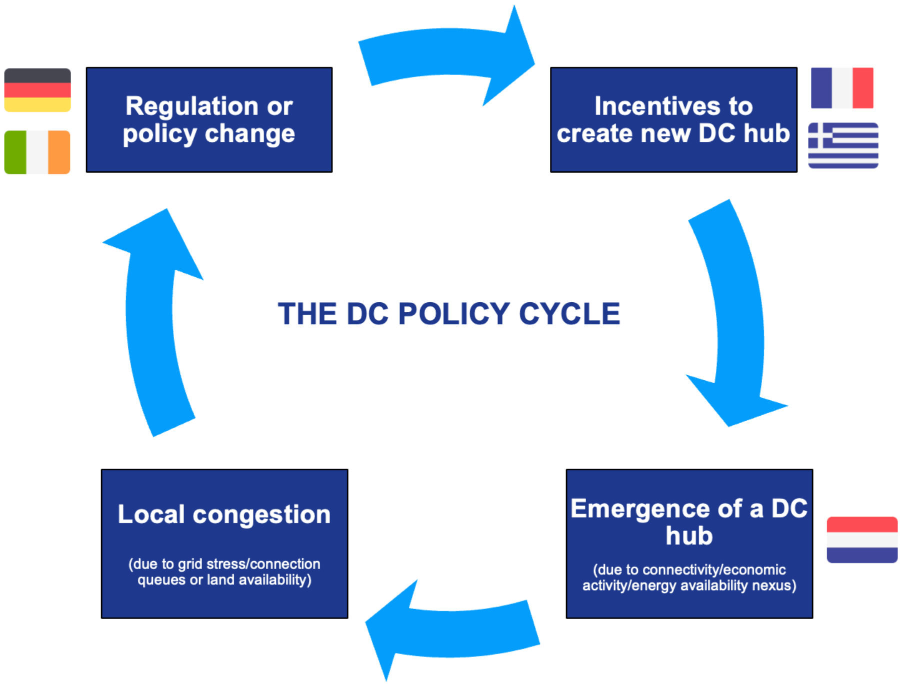

Figure 3.2: DC policy and regulatory cycle

Source: Figure elaborated by the authors.

While these cycles seem to be a natural feature of infrastructure-intensive sectors, their impact could be mitigated by better anticipatory planning.

Recommendation

Clear, stable connection rules and coordinated multi-regional planning would offer greater visibility to investors, enabling them to allocate resources more efficiently and avoid abrupt regulatory changes or temporary bans. Planning mechanisms such as heatmaps of available capacity or future-oriented zoning plans could be more widely adopted to smooth the transition between policy phases and to ensure spatial and technical diversification.

2. Regulatory Priorities Diverge across Member States

In the absence of harmonised EU-level rules specifically addressing DCs, Member States have pursued heterogeneous regulatory strategies reflecting national priorities, local constraints, existing hotspots and political preferences. This divergence introduces significant complexity for operators and investors seeking to deploy infrastructure across borders.

Some countries prioritise streamlining and permitting, offering dedicated regulatory pathways or fast-track procedures; France provides a clear example, with recent legislative initiatives leaning towards streamlining construction delays and mutualising infrastructure costs. Others, in contrast, focus on constraining development through conditional access to the grid or high energy efficiency standards; Greece illustrates this case, as water constraints feature prominently in the regulatory debate.

This diversity of approaches creates uncertainty for market participants across Europe. While healthy competition between countries to attract DC investment can positively lead to data being processed where there is capacity, the current fragmentation, complexity and opacity are not desirable for market actors to make informed decisions.

Recommendation

A more harmonised approach would enhance legal certainty, help scale up best practices and smooth the transition between the different steps in the policy cycle (avoiding temporary moratorium from which nobody benefits, for example). This does not imply a one-size-fits-all framework, which is not desirable due to different local situations, but rather grid-related EU guidance (as planned by the European Commission for Q4 in 2025) that enables learning from local experimentation and avoiding fragmentation.

The existing EU Action Plan "Digitalising the energy system" requires an update, in view of the development of a common reference framework for DC regulation that should include transparency regarding shared metrics (grid congestion, land availability, permitting delays), reporting obligations (energy efficiency metrics, renewable energy use) and permitting criteria (which could be shared between Member States, leaving implementation to the national level to take into consideration local specificities). The lack of detailed and timely data from grid companies on available connection capacity can otherwise create challenges for all new potential loads. There is also a need to enhance visibility into load demands from DCs over a longer time horizon – specifically, 5 to 10 years – to enable efficient and accurate grid planning.

Harmonisation should be flexible and dynamic to take stock of the results of local experimentation, building on the lessons from diverse regulatory paths in a 'test-and-learn' logic.

3. Streamlining DC Deployment Must be Balanced with Broader Public Interest not to Hinder Technology Adoption

Many jurisdictions have adopted measures to streamline the deployment of DCs, recognising their importance for digital transformation and economic competitiveness. These measures vary significantly in their form and intensity. In some cases, they involve soft law instruments or regulatory nudges, such as one-stop-shop administrative platforms, simplified environmental assessments, or public dissemination of energy heatmaps to guide project location (e.g., Greece). In others, streamlining takes the form of legal instruments, such as the designation of DCs as infrastructure of public interest or the creation of special fast-track procedures for strategic projects (e.g., France). All these will be running on empty if the grid connection and possibly needed upstream capacity additions do not benefit from the same streamlining as the DC itself.

While such measures can accelerate deployment, they also raise important questions of legitimacy and proportionality. Notably, the designation of DCs as 'projects of public interest' as is currently being discussed in France (see Deep Dive 1 below), must be carefully defined to avoid blanket exemptions or regulatory privilege. The public interest served by such facilities must be clearly articulated, ideally linked to broader objectives such as digital sovereignty, strategic research and innovation, or support for small and medium-sized enterprises.

One possible approach is to condition fast-track status on criteria related to the facility's expected contribution to national or European digital sovereignty, sustainability and competitiveness. This could include commitments to serve public-sector entities, allocate capacity to research institutions, or participate in public-private partnerships aimed at fostering digital innovation.

This issue is particularly relevant in the context of the European Commission's announcement of support for 'AI factories' (European Commission, 2025), which could play a role in the rollout of large-scale AI infrastructure.

Recommendation

An accelerated grid connection should not be granted solely based on economic investment, but on the added value that DCs bring to the public interest, especially regarding digital and energy ecosystems. There is no clear justification for reserving fast-tracking exclusively for DCs and not for other similar socially beneficial projects, such as housing developments, etc.

Lessons from the current regulatory landscape suggest that, while streamlining may be warranted, it should be conditioned on transparency, accountability, sustainability and clear public benefit. Otherwise, the risk is that unmoderated deployment could lead to spatial concentration, infrastructure strain, jeopardise climate targets or public backlash.

Emerging Concerns

The physical and environmental footprints of DCs are attracting growing public scrutiny. This section explores a set of emerging issues that have risen to prominence in recent years, and which are likely to shape the next phase of DC regulation. While current debates still focus largely on energy demand, permitting procedures, and connection rules, three major themes have recently surfaced and will require the attention of both national regulators and EU institutions.

1. Rise of Public Opposition to DCs (Judicial and Non-Judicial)

In several European countries, including France, Ireland, the Netherlands, Iceland, and Norway (see Case Studies Case Study 4: Strategic Location of DCs in Cool Climates with Low-Carbon Electricity – The Case of Iceland and Case Study 5: Strategic Location of DCs in Cool Climates with Low-Carbon Electricity – The Case of Norway), the social acceptability of DCs is being increasingly challenged, both in courts and through grassroots activism. These contexts reflect growing societal concerns over the environmental, social, and territorial impacts of large-scale infrastructure projects, especially in regions already under resource pressure.

France offers an emblematic example of legal disputes related to DC investments. Recent jurisprudence from the Administrative Tribunal of Versailles (2025) shows that the public is actively engaged in litigating environmental authorisations and building permits. These developments seem to indicate that DCs, like other large infrastructures, are likely to be subject to extensive litigation on environmental grounds, and courts will have to arbitrate complex trade-offs between technological development and environmental preservation.

At the same time, non-judicial disputes are also intensifying. Advocacy groups such as La Quadrature du Net (France) have launched investigations into the local impacts of hyperscaler developments, particularly in the city of Marseille, raising concerns around land use, rejection of fluorinated gases, conflicts of electricity use, and water consumption (La Quadrature du Net, 2024).

The Netherlands presents another powerful illustration. A proposed hyperscale DC in Zeewolde turned into a case study of protests against DC development. Mounting opposition from environmental groups and concerned citizens led to a public backlash, with 'Zeewolde' becoming a national political flashpoint. The controversy culminated in a parliamentary motion opposing the project and local elections were won by anti-DC candidates, forcing the plans to be abandoned in 2022 (Rone, 2024).

Beyond Europe, controversies such as Grok.ai's alleged doubling of methane-burning turbines in the US, reportedly without the necessary permits (Kerr, 2025), have intensified global scrutiny of energy-intensive digital infrastructure projects. Even recreational uses of AI have recently come under critical examination due to their environmental impact, highlighting the risk of reputational backlash that could undermine public support for digital technologies as a whole. A case in point is the controversy over people using ChatGPT to create 'Ghiblified' images or 'starter packs', which elicited public figures to caution against such activities on environmental grounds. Public awareness over these environmental concerns is rising, and activism is developing around the world[8.] The unmonitored development of global DC capacity is likely to reinforce this trend over time.

Recommendation

Involving the public in early-stage planning and regulatory choices is essential to avoid long-term opposition. Transparent communication and education about trade-offs, benefits, and mitigation strategies can foster social acceptability. EU Member States should implement participatory planning mechanisms and inclusive policy design to ensure the long-term viability of AI infrastructure deployment.

2. Debates over Carbon Accounting Methods Used by Tech Companies

A parallel debate is emerging around the credibility and consistency of the CO_2 accounting methods used by large tech companies. A recent investigation published by The Guardian (O'Brien, 2024) raises fundamental questions about the methodologies applied under the Greenhouse Gas (GhG) Protocol – a widely used international standard for corporate emissions accounting, developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)[9] in

[8] See https://www.enabledemissions.com.

[9] https://ghgprotocol.org.

the early 2000s, and now referenced in numerous regulatory frameworks. In particular, critics argue that the widespread use of 'market-based' accounting, which allows the offsetting of renewable energy certificates, masks the real emissions footprint of many DCs.

According to the investigation, emissions from DCs of large tech may have been underreported by as much as 662%. The Guardian's journalist recommends a shift toward 'location-based' accounting, which would more accurately reflect the carbon intensity of electricity actually consumed on-site. If such methods were adopted, the reported emissions from these actors could increase by a factor of 7.62. While the existing standard creates incentives for net new green energy, these discrepancies risk eroding trust in current corporate sustainability claims and may provoke calls for more robust and harmonised carbon reporting standards at the EU level.

Then, a reflection on carbon accounting methodologies should be engaged at the EU level or globally (GHG Protocol), with the following considerations as potential axes of reflection:

- Distinguish between market-based and location-based accounting in a harmonised manner (should support renewable energy generation within the same bidding zone). 100% local matching would increase guarantees of origins (GO) prices in countries with GO undersupply like Greece and Germany – improving revenue streams for renewable electricity generators (Aurora Energy Research, 2024).
- Consider temporal granularity (hourly GOs), by conducting further evidence-based research assessing the literature (Eurelectric, 2023 ; Riepin & Brown, 2022 : Riepin & Brown, 2024) and evidence from the field, like the case studies published by EnergyTag[10].
- Avoid duplicative or conflicting reporting obligations at the national and EU levels (see risks of overlapping reporting obligations in 3.1.2).

Recommendation

To prevent reputational damage and ensure environmental integrity, it is essential to crically reflect on the most suitable accounting methods for DCs' emissions. Further evidence-based research should be conducted to evaluate the consequences of adopting location-based accounting methodologies and hourly matching for transparent carbon accounting practices aside from market-based to prevent reputational damage and ensure environmental integrity.

3. Public Concerns About the Implementation of DCs in Water-Scarce Regions

Another emerging concern relates to the siting of DCs in areas already facing water scarcity. As heatwaves intensify and water stress becomes a chronic issue across several European regions, the siting of water-intensive infrastructure leads to public concerns over resource management.

At the time of writing, there is little available information on the water requirements of DCs across Europe. The Delegated Regulation (EU) 2024/1364 on the rating scheme for data centres provides for an obligation for DCs to report on total potable water input (Annex I) and water usage effectiveness

[10] https://energytag.org/case_studies/

(Annex III), to be consolidated for all reporting DCs in the European Database on DCs at Member State level and Union level (Annex IV).

Another investigation by The Guardian (Barratt, 2025) has drawn attention to planned hyperscale developments in Spain's Aragon region and in parts of Greece, regions where droughts and declining groundwater levels are already endangering agricultural livelihoods and biodiversity. In such contexts, water use by DCs, particularly for cooling purposes, becomes politically and socially sensitive. Public tolerance for this kind of resource use may decline quickly over the next few years, especially when combined with residential restrictions or agricultural limitations[11]. The risk is not only reputational for operators, but also systemic: legal or regulatory action to restrict water use would also delay DC projects or disrupt existing DCs' operations.

Policy frameworks should remain adaptable to local conditions. While technologies like air cooling or closed-loop systems can offer important water-saving benefits, their feasibility and efficiency vary based on climatic, energy, and operational parameters. Mechanically air-cooled DCs can typically be less energy efficient than water-cooled DCs, but they are more water-efficient. For instance, in hotter Mediterranean climates, some alternatives may increase electricity consumption significantly – potentially shifting the burden from water systems to energy systems. Permitting should reflect these important trade-offs to maintain accountability and to reach the best solution for each specific case.

Recommendation

Future EU and national policies should integrate water stress criteria into DC permitting and zoning frameworks. These should be context-specific and take into account regional climate resilience strategies and local resources planning. Environmental impact assessments should explicitly consider water use scenarios under different climate conditions. Where appropriate, flexible and performance-based conditionalities for technologies that minimise the DC's water needs (e.g., air-cooling or closed-loop cooling) could be introduced or best practices to be standardised and shared by industry players.

Better reporting on water usage of DCs is key to tackling this issue, which will likely be addressed by the new delegated regulation on DCs' rating scheme.

c/ Lessons from selected countries

Deep dive 1 – France: Mutualisation of Infrastructure Costs, Fight Against Ghost Capacity Reservation and DCs as Projects of Public Interest

France has emerged as a regulatory innovator in addressing grid access inefficiencies through a set of targeted reforms designed to prevent speculative behaviour, to mutualise infrastructure costs, and to strategically steer investment.

One of the country's flagship measures is the regulation of capacity reservation practices. In response to increasing speculative reservation of grid capacity by operators (also known as "ghost capacity"), French authorities introduced new rules requiring for capacity requests to be subject to periodical

[11] In 2021, Taiwan had to cut water supply in certain regions, including for agriculture : Taiwan Pei-chi, L. et al. (2021). Water supply to be cut 2 days per week in parts of central Taiwan," Focus Taiwan (24th March, 2021).

review. This policy aims to free up unused grid capacity, ensuring fairer and more efficient allocation of scarce infrastructure.

In parallel, France has introduced in its Energy Code the mutualisation of infrastructure costs, allowing for the pooling of connection infrastructure across multiple consumption sites. This not only reduces the cost burden for individual actors but also supports more coherent regional planning. Public utility EDF has complemented these efforts by preparing and promoting 'ready-to-connect' sites, which offer pre-approved, energy-optimised locations for future DCs, reducing permitting delays and enhancing investor certainty.

A recent legislative proposal seeks to allow DCs qualified as a 'project of public interest' ('*projet d'intérêt national majeur*') to benefit from streamlined permitting procedures, including a fast-track for environmental authorisation. However, this approach raises important normative questions: What criteria should determine whether a DC qualifies as a 'project of public interest'? On what conditions should such designations be granted? How can it be ensured that infrastructures qualifying for this scheme really benefit the public interest? Requirements for data sovereignty, public-private partnerships, or resource-sharing with SMEs and academia would be necessary to avoid creating a blank exemption for foreign tech companies.

Key lesson

France offers an example for an approach to managing grid demand through regulation of speculative practices and mutualised infrastructure investment. The designation of DCs as 'projects of public interest', while potentially effective, requires careful governance to maintain legitimacy and equity (see subsection a/3.).

Deep dive 2 – Germany: Allocation Rules and Energy Efficiency Standards

Germany has attempted to move beyond the traditional first-come, first-served connection model by exploring allocation rules that would better align with public interest criteria. A public consultation launched in 2023 proposed the introduction of a new allocation system. However, the consultation process proved inconclusive (DLA Piper, 2025), revealing significant divisions among stakeholders, including TSOs, DSOs, regulators, and connection requesting parties – inter alia DC operators. This episode highlights the political sensitivity of reforming connection rules in liberalised electricity markets, especially when competing objectives – such as economic competitiveness, equal access to energy, and decarbonisation objectives – must be balanced.

Germany has also taken a proactive stance on energy efficiency regulation. Even before the formal adoption of the revised Energy Efficiency Directive (EED), German authorities implemented stricter transpositions of its provisions, particularly concerning waste heat reuse and PUE reporting. While these standards had the ambition to raise the bar for environmental performance, they have also increased regulatory burdens, particularly for smaller operators (see subsection 3.4 on the limits of these indicators to effectively measure efficiency).

Key lesson

Germany's experience illustrates both the regulatory ambition and the limits of consensus-driven policymaking in this domain. While early transposition of EU directives can help steer national trajectories, meaningful reform of connection allocation mechanisms requires broader political alignment, potentially at the EU level, and stakeholder engagement.

Deep dive 3 – Ireland: Regulating Connection Rules

Ireland is at one of the most advanced stages of the DC policy and regulatory cycle. The country's long-standing role as a hub for hyperscale facilities has led to persistent congestion and sparked national concern about the sustainability of continued DC growth.

From 2022 to 2024, the Irish authorities initiated a comprehensive reform of connection rules, including a temporary *de facto* moratorium on new DC grid connections in the greater Dublin area. This was followed by a consultation on new connection criteria, including:

1. **On-site generation** (and/or storage capacity) to match the requested DC demand (on-site or local in proximity);
2. **Dispatchable generation**: contribution to grid capacity and overall system adequacy via flexibility (including demand side units – DSUs);
3. **Location** (TSOs must take into consideration whether connections demand concerns a constrained or unconstrained area); and
4. **Information gathering, reporting and transparency** from DCs to TSOs on renewable energy and emissions, market sounding by TSOs to understand DC energy appetite, publication by TSOs of information regarding local constraints, etc.

These reforms coincided with mounting public and political scrutiny. Critics argue that continued DC expansion may jeopardise Ireland's ability to meet its carbon budgets (Daly, 2025). The intersection of local environmental concerns, national climate commitments, and multinational corporate interests has turned Ireland into a testbed for the governance of DC.

Key lesson

Ireland's case demonstrates that ambitious connection rule reforms are politically viable, but only when backed by credible climate objectives, public engagement, and a clear communication strategy. The use of spatial criteria and performance thresholds could serve as a model for other congested grid areas.

Deep dive 4 – Netherlands: Zoning Regulation

After a decade of largely laissez-faire policies, the Netherlands has shifted toward a more assertive regulatory stance, especially in the Amsterdam Metropolitan Area. Following a period of uncoordinated expansion, massive electricity and land consumption, and rising public resistance, Dutch authorities began implementing a series of policy reforms in 2022. Central among these measures was the introduction of a zoning regulation to confine DC development to areas outside

Amsterdam. This strategy sought to rationalise the geographical distribution of DCs and mitigate externalities through spatial containment and energy mapping. Academia describes the Dutch case as one example of how DC have become politicised as spatial and environmental actors (Monstadt and Saltzman, 2025). Despite the new regulatory apparatus, however, challenges persist: competing land uses, limited capacity for residual heat recovery, and a lack of coherence between local and national policies continue to hamper effective governance.

Key lesson

The Netherlands highlights the importance and limits of zoning as a tool for governing DC externalities. While spatial planning provides a means to discipline growth and manage cumulative impacts, it must be embedded in broader cross-sectoral and multi-scalar coordination mechanisms.

3.1.2. A Review of EU Legislation on DCs

The EU regulatory framework applicable to DC has significantly expanded in recent years. While almost none of the major legislative instruments studied below are solely dedicated to DC, this infrastructure segment is increasingly subject to overlapping obligations under sectoral and horizontal frameworks.

This proliferation of norms introduces a level of complexity that may hinder compliance, investment, and coherent governance, particularly for operators and investors active across multiple Member States. Definitions vary, reporting thresholds differ, and the absence of a unified legal framework tailored to DC creates fragmentation. As the EU continues to pursue strategic autonomy and climate neutrality, a more coordinated and harmonised approach may be necessary to align incentives, avoid duplication, and ensure that regulations are both effective and proportionate.

We have conducted a review of the key EU legislative instruments currently applicable to DCs, assessing both their scope and the specific obligations they entail (See table 3.1).

Table 3.1: Key EU Legislative Instruments Applicable to DCs

Regulation/Directive	Scope of Application	Subject Matter & Obligations for DCs
Corporate Sustainability Reporting Directive (CSRD) – 2022		
Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting.	Applies to large companies (>250 employees or €40m turnover) and listed SMEs (phased in between 2024 and 2028). Covers both DC operators and their customers. Subject to changes in the omnibus regulation on sustainability.	Requires disclosure of ESG impacts. Energy and emissions data from DC must be included. Likely to intensify scrutiny over carbon accounting methods, particularly for cloud providers. Subject to changes in the omnibus regulation on sustainability.
NIS2 Directive (Network and Information Security) – 2022		
Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive).	Applies to *"essential and important entities,"* including cloud and DC service providers (Annex I, pt 8). **Definition of 'DC service' (Article 6, (31)):** *"'data centre service' means a service that encompasses structures, or groups of structures, dedicated to the centralised accommodation, interconnection and operation of IT and network equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control"*. **Does not cover in-house DC (recital 35).**	Requires cybersecurity risk management, reporting of incidents, and compliance with EU-level standards. Database including DC service operators to be established by ENISA. Expands scope from NIS1 and harmonises obligations across Member States. Directly applies to most hyperscalers and larger operators. Subject to national transpositions.

Regulation/Directive	Scope of Application	Subject Matter & Obligations for DCs
DORA (Digital Operational Resilience Act) – 2022		
Regulation (EU) 2022/2554 of the European Parliament and of the Council of 14 December 2022 on digital operational resilience for the financial sector and amending Regulations (EC) No 1060/2009, (EU) No 648/2012, (EU) No 600/2014, (EU) No 909/2014 and (EU) 2016/1011.	Applies to financial sector ICT service providers, including cloud and DC operators servicing critical financial institutions. **No definition of DC services.**	Introduces oversight by financial supervisors (e.g., ESMA, EBA) over third-party ICT providers. Requires robust ICT risk management, contractual transparency, and potential designation of certain operators as 'critical' for financial services. **The ICT risk management framework explicitly covers DCs and DC service (Article 6).** And recital 63: *"To address the complexity of the various sources of ICT risk, while taking into account the multitude and diversity of providers of technological solutions which enable a smooth provision of financial services, this Regulation should cover a wide range of ICT third-party service providers, including providers of cloud computing services, software, data analytics services and providers of data centre services."*
Energy Efficiency Directive – 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).	Applies to DC with ≥500 kW power demand (Art. 12). Applies directly to operators. **Defines 'DC' by referring to Regulation 1099/2008 of 22 October 2008 on energy statistics** (Annex A, point 2.6.3.1.16): *"a structure or a group of structures used to*	Mandates public reporting of energy performance metrics (e.g., PUE, renewable share, temperature). Requires information to be uploaded to a central EU database.

Regulation/Directive	Scope of Application	Subject Matter & Obligations for DCs
	house, connect and operate computer systems/servers and associated equipment for data storage, processing and/or distribution, as well as related activities".	Promotes the reuse of waste heat and energy audits.
Cyber Resilience Act (CRA) – 2024		
Regulation (EU) 2024/2847 of the European Parliament and of the Council of 23 October 2024 on horizontal cybersecurity requirements for products with digital elements and amending Regulations (EU) No 168/2013 and (EU) 2019/1020 and Directive (EU) 2020/1828 (Cyber Resilience Act).	Applies to hardware/software products with digital elements, some of which are embedded in DC infrastructure. Specifically, "*products with digital elements made available on the market, the intended purpose or reasonably foreseeable use of which includes a direct or indirect logical or physical data connection to a device or network*" (art 2). Obligations lie with manufacturers. **No definition of DC.**	Imposes cybersecurity-by-design obligations and post-market monitoring. Additional requirements for digital products critical for essential entities under NIS 2: may cover hardware in DCs (see Annex III).
Delegated Regulation on the DC Rating Scheme – 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 DCs	Applies to DC ≥500 kW (delegated act from EED). Defines common EU-wide indicators and thresholds for energy efficiency, renewable use, and heat reuse. **No definition of 'DC' but defines: 'co-location DC', 'enterprise DC', 'co-hosting DC'.** Applies to DC 'operators' (physical or legal person who manages the DC, including the	Establishes a harmonised rating scheme to assess performance based on five metrics. Intended to ensure comparability and promote benchmarking.

Regulation/Directive	Scope of Application	Subject Matter & Obligations for DCs
	building and IT services delivered, the cooling system, security, etc.)	
Ecodesign for Sustainable Products Regulation (ESPR) – 2024		
Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of Ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC.	Broader scope targeting energy-related products (e.g., servers, cooling units). Applies indirectly to DC operators through procurement and product selection.	Expands existing Ecodesign rules to include durability, reparability, and recyclability of components used in DCs. Also lays the foundation for digital product passports. Promotes circularity but introduces compliance costs for operators relying on complex equipment chains.

Four lessons can be drawn from this mapping:

5. **Risk of overlapping obligations**: Large DCs are subject to multiple legislative instruments, each with different definitions, reporting timelines, and compliance authorities. This multi-layered framework leads to legal complexity and duplicates efforts, particularly in areas like energy reporting and cybersecurity.

6. **Inconsistent thresholds and definitions**: The use of different power consumption thresholds (e.g., ≥500 kW for the EED, qualitative definitions in NIS2 and DORA) may distort market competition or allow actors to strategically avoid compliance.

7. **Simplifying reporting**: While the EED introduces an EU database for energy reporting, other legislation (CSRD, DORA) may result in parallel reporting streams. There is a need to align datasets and reduce administrative burden, especially for cross-border operators.

8. **Cybersecurity overlap**: NIS2, CRA, and DORA all touch upon digital resilience. Without careful coordination, this may result in duplicative or contradictory requirements, particularly for providers serving both private and public sectors. Further research will be needed to identify more precisely the frictions and overlaps between the texts.

Also, DC-related information reporting raises questions in terms of the confidentiality of information and the protection of business secrets. There are legitimate reasons for limiting the disclosure of sensitive DC information, especially for facilities handling nationally sensitive data. For such data and in the context of energy planning, such information should be aggregated or withheld to reduce security risks (aligned with art. 12(1) of the Energy Efficiency Directive and paragraph 12 of the Delegated Act on the Sustainability Reporting Scheme, which protects DC trade secrets and requires the information reported to be publicly available on an aggregated level. A coordinated approach between regulators, system operators, and DC operators is therefore recommended to ensure secure and effective infrastructure planning.

Recommendation

The European Commission should consider launching a **fitness check** specifically targeted at the digital infrastructure sector, as part of the omnibus package on digital or the EU Cloud and AI Development Act included in the AI Continent Plan[12]. This should assess the cumulative impact of existing legislation on DC operators and propose streamlining measures, including a **cross-regulation compliance map**, measures to support the sharing of good practices, and potentially to simplify reporting obligations if redundancies appear.

Specific attention should also be given to the administrative implications and burden for utilities that operate both regulated infrastructure and market-based digital assets like DCs. The fitness check conducted as part of the AI Continent Plan could explore mechanisms to support cross-sector planning in the energy-digital intersection.

3.2. Direct & Voluntary: Incentives

Incentive-based approaches play a crucial role in aligning data centre deployment with broader societal goals by shaping investment choices without imposing rigid constraints. These instruments directly target decision-making by providing financial or procedural advantages for operators who align with desired outcomes – such as energy efficiency, grid-friendly siting, or low-carbon power sourcing.

Common policy levers in this category include:

- tax incentives or exemptions for facilities using renewable electricity or meeting energy efficiency thresholds;
- co-investment schemes for green data infrastructure in underserved regions;
- priority access to permitting for DCs with heat reuse grid, making use of an already existing grid connection (co-location), and system flexibility capacity;
- direct subsidies or innovation funding for battery integration, modular builds, or liquid cooling technologies; and
- preferential connection queues for operators offering load flexibility or frequency response.

[12] https://ec.europa.eu/commission/presscorner/detail/en/ip_25_1013.

These measures are especially effective where market conditions alone do not internalise environmental or system-level benefits. Incentives can shift the economic calculus in favour of future-proof solutions without delaying deployment. Top priorities for market-based incentives should include:

- rewarding flexibility and penalising inflexibility;
- promoting the location of DCs in adapted regions based on their needs (latency-sensitive loads should not be incentivised to be located in remote areas and vice versa);
- promoting growth and job creation in underdeveloped or transitioning regions – such as former lignite mining areas – ensuring a socially inclusive and just transition; and
- ensuring equal treatment of DC and non-DC projects based on social benefits.

Regarding price signals, static or uniform tariffs fail to reflect the true system cost impact. Dynamic, locational grid tariffs would provide concrete incentives for DCs to behave in a grid-supportive way – both in their operational patterns and siting decisions.

Subsidising DCs is not a sensible strategy for any country, as these are assets often owned by foreign entities, create few jobs, and may deliver lower economic returns compared to other energy-intensive installations. However, while it appears that there is no reason to prioritise subsidies in the context of DC growth, this option should not be singled out ex ante as there may be reasons to do so. For example, DCs are offering to pay deep connection costs or for specific system upgrades, so subsidies can be used to indirectly raise funds for grid expansion or modernisation. Further research would be needed to determine in which conditions subsidies could be employed while complying with EU law and state aid rules.

Case Study 3: EEG Levy Reform and the Rise of Battery Storage in German DCs

In 2022, Germany implemented a major regulatory change under its Renewable Energy Act (EEG), abolishing the double charging of levies for electricity stored in batteries. This reform, aligned with the EU directive 2019/944, eliminated a longstanding barrier to the deployment of energy storage. For many operators, the previous levy structure made battery storage economically unviable unless used strictly for backup purposes. With the reform in place, batteries can serve a dual function: ensuring uptime and participating in energy markets – Figure 3.3 illustrates this by showing the increase in battery-enabled DCs and the simultaneous peak demand reduction.

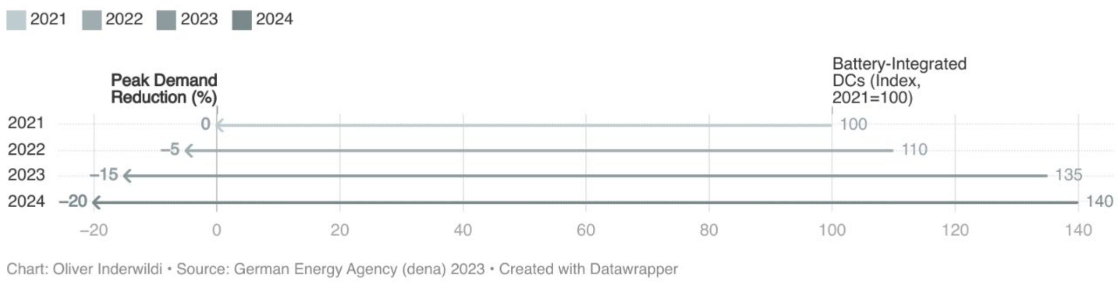

Figure 3.3: The Impact of Policy Adaptation on Battery Storage Deployment in DCs & the Resulting Reduction in Peak Electricity Demand

Note: A US strategic policy initiative supporting medium-sized DCs in demand response is projected to yield a 400 MW peak load reduction by 2030.

Source: German Energy Agency (dena) (2023); graph elaborated by the authors.

One standout example of this shift is the Master+ battery system, jointly developed by RWE and Riello and deployed at a German data centre. The initial phase included two 250 kW UPS systems and a 1.1 MW diesel generator for emergency power. The facility is now scaling up to 2 MW of battery capacity, with plans for an additional backup generator. Thanks to RWE's energy trading unit, the system participates in flexibility markets – helping stabilise the system and generate new revenue streams.

Since the EEG reform:

- Battery storage deployments in German DCs increased by 40%.
- Participating sites reported 15–20% peak grid demand reductions, thanks to intelligent load shifting and frequency regulation services.
- The Master+ system itself has proven capable of fast response and dual-purpose functionality – delivering grid support without compromising critical uptime.

This case underscores how targeted policy changes can unlock technical flexibility, lower grid strain, and support the business case for sustainable digital infrastructure.

3.3. Indirect & Mandatory: Planning

Strategic planning tools are foundational for ensuring that DC expansion does not outpace electricity grid capabilities or contradict regional development objectives. While these instruments do not mandate specific technologies or business models, they establish the spatial, temporal, and systemic boundaries within which DCs can operate. In doing so, they provide a structured framework for long-term optimisation of both digital infrastructure and electricity systems.

Key planning levers include:

- spatial zoning and regional siting non-binding guidelines based on grid capacity, cooling potential, and land availability;
- designation of 'ready-to-connect' zones with pre-approved environmental and grid capacity permits;
- regional load balancing strategies to distribute infrastructure growth more evenly;
- integration of data centre demand forecasts into national electricity planning and grid investment pathways; and
- coordination mechanisms between TSOs, DSOs, and digital infrastructure stakeholders.

Planning instruments are particularly relevant in countries with high grid congestion, limited permitting bandwidth, or politically sensitive energy markets. Unlike regulation, which operates at the micro level, planning tackles macro-level system design and enables pre-emptive mitigation of bottlenecks.

Nordic countries, particularly Iceland and Norway, have leveraged planning instruments and long-term energy strategies to attract energy-intensive computing services without straining their electricity systems. Through transparent pricing (see Section 2.2), renewable guarantees (see Section 2.1), and proactive site allocation (see Case Studies Case Study 4: Strategic Location of DCs in Cool Climates with Low-Carbon Electricity – The Case of Iceland & Case Study 5: Strategic Location of DCs in Cool Climates with Low-Carbon Electricity – The Case of Norway) – especially near hydro and geothermal assets – these countries have become global destinations for low-carbon data processing. The case examines Iceland's evolving policy approach to siting, public-private coordination, and the balance between economic development and local energy security.

Today, most major existing DC hubs are struggling with electricity supply constraints, which calls for better planning strategies, potentially combined with adaptive economic incentives. On the one hand, supply is more readily available in remote areas, but these locations often introduce latency challenges and are therefore unsuitable for workloads requiring low-latency performance. On the other hand, hyperscalers continue to prioritise urban areas and economic centres (Tier 1), despite limited grid capacity, scarce land availability, and higher costs. For workloads that are not sensitive to latency or location, it makes sense to deploy them where the electricity price is cheapest. A good example is cryptocurrency mining illustrates this principle as well, since miners are ultra-sensitive to electricity prices and largely indifferent to latency (see Case Study Case Study 4: Strategic Location of DCs in Cool Climates with Low-Carbon Electricity – The Case of Iceland). As a result, economic incentives and smart planning can help customers distribute their workloads more efficiently – placing more latency-sensitive workloads in major hubs and relocating the less sensitive ones to remote locations – thereby reducing the electricity demand in the major hubs. This is already happening today due to the limited capacity in the Tier 1 DC markets.

Case Study 4: Strategic Location of DCs in Cool Climates with Low-Carbon Electricity – The Case of Iceland

Iceland's Electricity Markets

Iceland's electricity system is distinctive: it is fully renewable and entirely isolated from other national grids. The country generates approximately 20 TWh of electricity annually, with demand expected to grow by 6.5 TWh over the next 15 years (Landsvirkjun, 2024). While there are currently no export cables, Iceland 'exports' electricity indirectly through energy-intensive industries, including aluminium and ferrosilicon production, and increasingly, DCs.

Energy-intensive users – defined as those consuming more than 80 GWh per year[13] – account for about 80% of total electricity consumption[14]. The electricity mix is over 99% renewable, primarily from hydropower (around 70%) and geothermal (30%) (IEA, 2025). Numerous wind projects are under development and may contribute significantly to future supply.

Data Centre Demand for Electricity

Iceland's data centre sector began to emerge around 2012, leveraging several strategic advantages: low-cost and stable renewable electricity, naturally cool climate, geographic location between Europe and North America, robust fibre connectivity, a well-educated workforce and ease of infrastructure development. The sector is currently dominated by three players: Verne Global, at North, and Borealis Data Centres.

By 2022–2023, data centres accounted for 5–6% of Iceland's total electricity demand, consuming 1,051 GWh in 2022, an amount roughly equal to household usage (Orkustofnun, 2024). Export revenues in 2023 amounted to 174M USD or 1.3% of total exports.

DC demand growth in recent years was driven primarily by cryptocurrency mining. However, 2024 saw a sharp (40%) decline in DC electricity use due to:

- A hydropower shortage (2024 was a particularly dry year), which affected DCs with non secured supply contracts.
- A shift in market dynamics: AI and high-performance computing began to replace cryptocurrency mining. These new workloads are more efficient in terms of energy per unit of computational value (Federation of Icelandic Industries, 2025).

[13] This is the definition of an energy-intensive consumer in the Icelandic Electricity Act (Raforkulög, 2003). This version of the definition dates from 2011, when a change was made to the law, lowering the threshold for being defined as an energy-intensive user. The change was made explicitly in order to allow DCs to be classified as energy intensive users.

[14] Aluminium production consumes about 55% of total electricity generated, some 13 TWh in 2024.

Electricity demand from DCs is expected to recover and surpass previous levels as global demand for data infrastructure – particularly AI-related activity and cloud services – continues to grow. Iceland's fundamentals make it well-positioned to benefit from this trend (Arizton Advisory & Intelligence, 2023). The Icelandic Energy Authority forecasts DC electricity demand to rise to 6% of total demand (1,400 GWh) by 2030 and to 10% (2,500 GWh) by 2038 (Orkustofnun, 2024).

Legal and Regulatory Environment

There are no data-centre-specific laws in Iceland. DCs operate under general business law, but most qualify as energy-intensive users under the Electricity Act (Raforkulög, 2003). In 2011, this law was amended specifically to accommodate investment in DCs.[15]

There are numerous special provisions in the Electricity Act applicable to energy-intensive users. Notably, energy-intensive users may connect directly to the transmission grid and are exempt from distribution charges. Transmission tariffs also vary by location: siting a DC near generation assets reduces costs, while choosing a location requiring grid upgrades leads to higher connection fees. For example, Borealis strategically located its facility in Blönduós, a town in Northwest Iceland, near a hydropower plant,[16] and others are clustered near geothermal facilities on the Reykjanes Peninsula.

These locational pricing mechanisms appear effective. According to Landsnet (2025), Iceland's transmission system has experienced minimal strain from DC growth so far.

Public Perception and Controversies

Cryptocurrency mining – and in particular, Bitcoin mining – has drawn criticism for its high electricity usage relative to its perceived social value. Environmentalists and public officials, including (then) Prime Minister Katrín Jakobsdóttir, have questioned whether crypto should be prioritised over more socially beneficial uses of renewable energy, such as food security (Financial Times, 2024). At the same time, rising electricity prices led to concerns that DCs were competing with households and SMEs for scarce renewable supply.

This negative sentiment led Landsvirkjun, Iceland's national power company, to shift away from supplying crypto miners.[17] However, as crypto activity has waned and been replaced by AI-focused services, the image of the sector has improved (Federation of Icelandic Industries, 2025).

[15] Cf. notes to the 2011 proposal to change the Electricity Act (Alþingi 2011).

[16] There is a long-standing congestion on the power line between Northwest Iceland and the Southwest, where most of the demand is located.

[17] Most generation capacity in Iceland is publicly owned, either by the state or municipalities. In particular, Landsvirkjun, Iceland's largest generation company, is fully owned by the state. Therefore, sales of electricity to DCs and other energy-intensive users inevitably become a political issue. While aluminium smelters and ferrosilicon production require substantial labour input—in particular of unskilled labour—DCs typically create

Conclusion

Iceland's clean energy, geographic position, climate and policy stability make it an attractive host for data centres. The sector is expected to expand further as AI, cloud computing, and data sovereignty concerns increase demand for secure, sustainable hosting environments.

That said, tensions around electricity prioritisation, crypto mining and environmental concerns have led to a negative public image of the sector. This has changed recently with the shift from crypto mining to AI, and the sector is expected to grow rapidly in the coming years.

Case Study 5: Strategic Location of DCs in Cool Climates with Low-Carbon Electricity – The Case of Norway

In 2021, the Norwegian Government launched a data centre strategy, aiming to become *"the world's most attractive data centre nation*" (KMD, 2021). It was expected that the industry could increase its contribution to jobs from around 2,000 at the time to more than 11,000 by 2025. While the industry has indeed grown, the current outlook is in fact not as promising as five years ago.

Norway's Electricity Market

Norway's electricity system is fully renewable and closely integrated with neighbouring countries (UK, Germany, the Netherlands, Denmark, Sweden and Finland) and hence the European system.

Annual generation is around 157 TWh (depending on inflow to hydro generating facilities) (energifakta.no). In 2024, 89.1% of generation was from hydro, 9.3% from wind, 1.5% from heat co-generation and 0.2% from solar (Statistics Norway, 2025). Net export amounted to 18.4 TWH, or 11.7% of total generation.

The Norwegian regulator, NVE, expects total generation to increase by about 30% by 2040, while electricity consumption is expected to grow by 40%, leading to a net surplus of 12 TWh, somewhat lower than today (NVE, 2024). The growth in generation is expected to be mainly associated with wind (onshore and offshore), but also from hydro and solar. The growth in energy consumption is expected to come mainly from transport (electrification), industry (including data centres), hydrogen production and the oil and gas industry (again, electrification).

Data Centre Demand for Electricity

Norway's data centre sector began to emerge during the early 2000s. However, although doubling turnover from 2010 to 2016, the sector still only accounted for only 0.03% of gross national product (GNP) in 2016 (Statistics Norway, 2019).

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fewer jobs, albeit of skilled labour. This is important in the political debate, which tends to favour job creation over, e.g., profits.

In recent years, growth has picked up, and annual electricity consumption from data centres increased from 822 GWh in 2022 to 1613 GWh in 2024, nearly a doubling (Elhub, 2025). However, the sector is still relatively small and accounts for less than 1% of the total electricity demand.

However, the importance of data centres differs across the country. Norway is divided into five price zones, and in Mid-Norway (NO3) data centres accounted for 3.7% of total electricity demand towards the end of 2024.

The advantages of locating data centres in Norway are, to a large extent, the same as those in Iceland; a low-cost and stable renewable electricity, a naturally cool climate, a robust fibre connectivity, and a well-educated workforce.

Growth of the sector is expected to continue, although at which pace is uncertain.

Legal and Regulatory Environment

There are no data-centre-specific laws in Norway. As in Iceland, data centres operate under general business law. Unlike Iceland, data centres are not treated differently from other electricity consumers.

As other electricity consumers, data centres have the right to connect to the network on standardised terms. However, they may be obliged to cover costs associated with network connections. If the data centre wants to establish its own network facilities (cables etc.) it will have to obtain a license from the regulator, NVE. The cost of network connection and network tariffs will depend on to which part of the network (and at what voltage level) the data centre connects to.

In practice, data centres take these costs into account, in addition to the fact that electricity prices vary across regions, when they decide where to locate (Elhub, 2024).

Public Perception and Controversies

The debate about data centres in Norway mirrors that in Iceland; cryptocurrency mining, as well as certain other types of data use, is drawing criticism for its high electricity usage relative to its perceived social value and a further rise of electricity prices when data centres compete with households and industries for scarce electricity supply.

An example is the establishment by Green Mountain of a data centre in Hamar in 2024 that will mainly be used by TikTok, as part of the Chinese company's strategy of migrating data processing from the US (kode 24, 2024). The establishment has been controversial because of TikTok, but also because the data centre might have blocked Ammo, the Norwegian producer of ammunition, some of which is intended for shipment to Ukraine, from expanding its production capacity. The controversy led the government to change the rules for allocating scarce network capacity, from a first-come-first-served rule to a system prioritising ´critical infrastructure’.

Conclusion

Norway seems to be an attractive location for data centres, and several new centres are currently being built or planned. It is expected that the DC electricity demand will continue to grow.

However, data centres continue to be controversial.

Although the projections of NVE describe a balanced growth of electricity demand and generation in the coming years, there are reasons to believe that the projections for generation may be too optimistic. Onshore wind power requires acceptance from local governments, and there is considerable resistance in most parts of the country, while offshore wind is turning out to be much more expensive than many had believed; it is therefore difficult to see that the growth in generation foreseen by NVE will be forthcoming. At the same time, electricity prices have become a contentious issue after the strong rise following the Ukraine war. If little or no new capacity is coming online, and the addition of new data centres puts upward pressure on electricity prices, policy changes are likely to occur.

A first sign of this change is the recent amendment to the electronic communication law that requires data centres to register with the Norwegian Communications Authority (Nkom, 2025).

3.4. Indirect & Voluntary: Information & Market Signals

Informational and market-based instruments represent a softer layer of intervention that empowers actors to make better decisions through transparency or benchmarking. These instruments are essential for operational optimisation, load shifting, and the voluntary uptake of climate-aligned practices – particularly in a sector as heterogeneous and innovation-driven as digital infrastructure.

Key tools include:

- Benchmarking frameworks and aggregated transparency on environmental performance metrics, such as under the EU DC Rating Scheme or voluntary reporting standards on energy, carbon, and water usage.
- Grid heatmaps and connection capacity visibility tools to guide site selection. In the UK, several initiatives offer interactive heatmaps displaying real-time data on grid capacity and constraints (see, for example, the heatmaps published by the National Energy System Operator (NESO)[18] or by Northern PowerGrid[19]). These tools enable DC operators to select sites with adequate grid availability when latency is not a key issue. For this to be effective, data must be shared transparently, updated regularly (ideally in real time) and of high quality.
- Carbon-aware scheduling and workload migration platforms that enable time- or location-based optimisation. For example, Google has implemented a system that shifts compute tasks to times and locations where low-carbon energy is available (Radovanovic et al., 2023). This approach effectively limits hourly capacity when the grid relies on carbon-intensive energy, postpones the execution of temporary flexible workloads to 'greener' times, and can potentially reduce the generation peak at midday. Such a solution has significant potential for broader adoption across the DC industry.
- Participation in markets for ancillary services (including, but not limited to, balancing, voltage control and inertia) and congestion management services, including via aggregators and virtual power plants. In the United States, small and mid-sized DCs are increasingly seen as underutilised assets in the transition to a more flexible energy system. Supported by the US Department of Energy (DOE)'s targets for virtual power plants and growing platform automation, strategic planning efforts have enabled smaller DCs to enrol in demand response programs. By combining battery storage with intelligent demand response participation, these centres have begun shaving local peaks, reducing blackout risk, and contributing to decarbonisation – without large-scale infrastructure investments (see Case Study 6).
- Best-practice sharing platforms and industry standards (e.g., Open Compute Project[20], ISO/IEC

[18] https://www.neso.energy/publications/beyond-2030/web-map.

[19] https://northernpowergrid.opendatasoft.com/explore/dataset/heatmapdemanddata/map/?disjunctive.substation_name&disjunctive.local_authority&location=8,53.50275,-1.32111&basemap=jawg.streets

[20] https://www.opencompute.org

standards[21]).

Though non-binding, these instruments unlock significant system value when paired with automation and digital controls. They are especially effective in enabling distributed, modular, and smaller operators to participate in grid services without extensive regulatory compliance burdens.

Case Study 6: Strategic Policy Initiatives for Peak Load Reduction in the US

As US data centre energy demand soars – expected to reach between 6.7% and 12% of total US electricity consumption by 2028 – policy attention has traditionally focused on hyperscale operators. However, recent strategic planning efforts are recognising the untapped potential of small and medium-sized DCs to support grid stability through demand response (DR) and battery storage.

The US DOE has set an ambitious goal of deploying 80–160GW of virtual power plant capacity by 2030. To achieve this, a growing share of the burden will need to be met by commercial and industrial (C&I) actors beyond traditional utilities. Strategic policy initiatives – including funding for DR automation platforms, grid-interactive incentives and streamlined enrolment processes – have enabled smaller DCs to participate effectively.

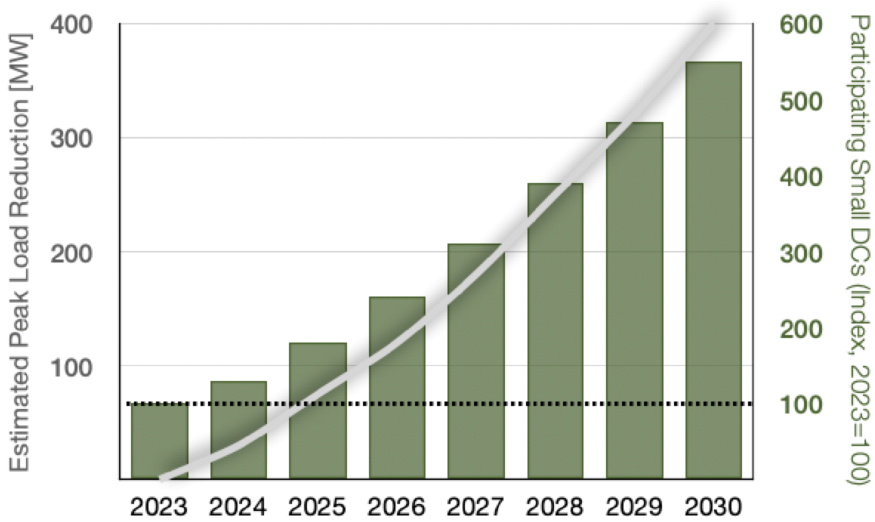

Figure 3.4: Projected Peak Load Reduction and Growth of Participating Small Data Centres (2023–2030)

Note: A US strategic policy initiative supporting medium-sized DCs in demand response is projected to yield a 400 MW peak load reduction by 2030.

Sources: [US DOE, 2023](); [USDOE, 2024]()

It is projected that the participation rate of small DCs in DR programmes will increase by more than fivefold between 2023 and 2030, while the estimated peak load reduction is expected to rise from 30 MW in 2024 to 400 MW by 2030 (Figure 3.4). This represents a fundamental shift in the paradigm, from a position of passive energy consumption to a role as flexible resources. The advent of battery-

[21] https://www.iso.org/sectors/it-technologies/data-centres

backed facilities has engendered a paradigm shift in the realm of energy management, conferring upon these entities the capability to modulate their loads during periods of peak demand, a feat previously unattainable without compromising operational continuity. This technological advancement has also endowed these facilities with the ability to export stored energy when demand surges, thereby ensuring uninterrupted service delivery. The integration of these systems is facilitated by automated DR platforms, which offer financial incentives and simplify the process.

The integration of small DCs into the VPP strategy through non-regulatory strategic planning interventions by the US is a strategy that not only expands grid flexibility but also broadens the base of digital infrastructure aligned with energy resilience and climate goals.

3.5. Next-Level Regulation: From Static Rules to Adaptive Frameworks

As set out in Section 3.1, traditional regulatory approaches, built around fixed compliance rules and ex-ante control, are increasingly mismatched with the rate of technological innovation and digitalisation and the consequent digital infrastructure development. As data centres become active participants in the energy system (Section 2.5), new regulatory models are required that can keep pace with dynamic system conditions and evolving technologies.

The EU's Better Regulation Guidelines (EC, 2021) offer a useful baseline as they emphasise flexibility, proportionality, and iterative policy learning – elements that are particularly relevant to the DC sector. Smart regulation in this context means frameworks that are risk-based, tiered, and adaptive to real-time system needs. Regulatory sandboxes, time-bound exemptions, and performance-based metrics should all be considered as tools for enabling innovation while safeguarding system stability (CERRE, 2024).

Figure 3.5 illustrates the iterative process that automatically monitors and evaluates regulatory interventions and assesses their impact, thus policy changes do not have to be initiated, but are a continuous cycle that adapts policy intervention (grey outer circle). Continuous stakeholder engagement ensures the balancing of specific needs and trade-offs between actors.

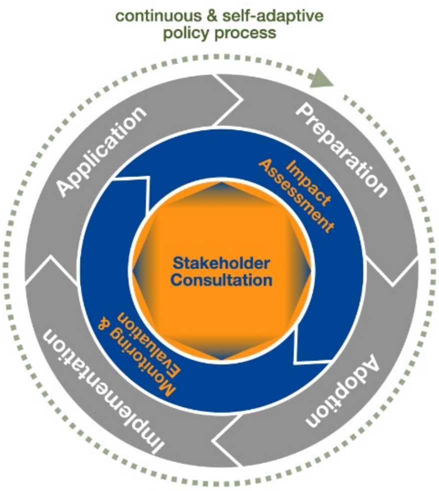

Figure 3.5: Policy cycle according to the EU Better Regulation Guidelines

Source: EU Better Regulation Guidelines (2021).

Embedding evaluation mechanisms from the outset will also ensure that rules evolve with the sector, rather than trail it. Several of the policy proposals discussed in this report could benefit from a smart regulation approach, aligned with the EU's Better Regulation Guidelines. For example, the EU Data Centre Rating Scheme (See Section 3.4) could begin as a voluntary and flexible framework, co-developed with operators and iteratively refined through real-world feedback, before becoming mandatory. Similarly, market access rules for demand-side flexibility (Section 3.3) would benefit from pilot testing and adaptive calibration, reflecting the operational realities of large-scale DCs.

Permitting and siting procedures (Section 2.4) offer another use case: introducing experimental fast-track zones or linking site approval to commitments on flexibility could help overcome bottlenecks. Additionally, as discussed in Section 2.2, AI and digital infrastructure's development trajectories are subject to fundamental uncertainty, which in turndemands active regulatory horizon scanning – a dynamic policy tool that can identify emerging technologies, assess their systemic impact, and inform timely adjustments to rules and investment signals.

Finally, definitions of carbon-free energy procurement (Section 2.5) could be co-developed in a sandbox context, with interim flexibility for innovative procurement models while robust methodologies are tested and refined. These examples all reflect the need to move beyond static compliance frameworks toward learning-based, adaptive governance structures – where evaluation and feedback are built into the policy process from the outset.

Continuous stakeholder engagement is essential to prevent unintended policy consequences – particularly in the complex interplay between the energy system and rapidly evolving digital infrastructure. As highlighted in the Introduction, the uncertainty surrounding technological trajectories such as AI, edge computing, and high-performance workloads creates major challenges for planning and policy. This interface – where a fast-moving, innovation-driven, and largely unregulated sector depends on a highly regulated and structurally slower-moving one – is especially prone to regulatory mismatches. Left unaddressed, these mismatches could undermine European competitiveness, stall the digital and electrification transitions, and compromise climate goals by limiting the realisation of sustainability benefits from new technologies.

Even smart, adaptive regulatory and policy tools must be introduced **gradually and strategically** – not imposed abruptly. They should be **sequenced and aligned** with the development pace of both the energy system and digital infrastructure to enable, rather than constrain, technological progress.

3.6. Policy Orchestration and Sequencing: The Right Levers at the Right Time

A central challenge in both digital and energy policy is not only selecting the right instruments but also sequencing them in a way that reflects market maturity, system risk, and broader strategic objectives. In the early stages of integration, regulatory clarity (as discussed in Sections 3.1 and 3.2) can help establish consistent baseline requirements, avoid fragmentation, and build trust. However, on the one hand, overly rigid or premature enforcement can stifle innovation – especially in high-growth contexts like AI and edge computing. On the other hand, overclaiming by DC companies of benefits to communities of DCs can also be detrimental if this comes at the expense of genuine job creation or new housing.

As markets mature and operational experience accumulates, policy should shift toward incentive-based instruments and market signals (Sections 3.3 to 3.5), designed to reward flexibility, resilience, and location-sensitive investments. Instruments such as capacity-based tariffs and dynamic locational signals (Section 3.6) can be gradually phased in, with flexibility to adapt based on system conditions.

At the same time, public planning tools – including anticipatory grid investment, spatial planning for DC clusters (Section 3.6), and updated cost-sharing arrangements (Section 3.7) – play a bridging role between short-term pressures and long-term structural needs. To be effective, these tools must be coordinated across jurisdictions and subject to ongoing performance review. Finally, reporting and transparency measures (Section 3.8) should evolve in tandem. Initial soft instruments (e.g., voluntary reporting) can transition to mandatory disclosure regimes once metrics are standardised and aligned with system needs.

In short, smart policy design is not static but evolutionary. The most effective approach is dynamic and staged, with each lever – regulation, planning, incentives, and market design – activated when and where it delivers the highest net benefit. This sequencing must remain agile, informed by real-world feedback and technological shifts.

Given this complex regulatory landscape and the rapid pace of technological change, policies must be as agile and adaptive as the digital infrastructure they seek to govern. The following section examines how emerging market dynamics and investment patterns are reshaping the data centre landscape, providing the economic context necessary to design effective policy interventions that align digital growth with Europe's energy and climate objectives.

4. Synthesis: How Policy Can Support the Integration of DCs into the Electricity Grid Infrastructure

Forecasting the development of technological developments is inherently difficult. History has shown time and again that technological forecasts almost never turn out to be accurate. In the case of DC integration into the electricity grid, the uncertainty extends beyond innovation trajectories to encompass a range of interdependent variables, including global economic growth, shifts in energy policy triggered by geopolitical instability or energy security concerns, the pace of electrification, and the uncertain evolution of data centre efficiency, from hardware and algorithmic advances to building and cooling design. These volatile factors compound one another. A single economic, political or technological shift can drastically alter the trajectory. If several occur at once, as during recent crises, even the most sophisticated forecasts become obsolete (see Sections 1 and 2).

Yet, despite this volatility, forward-looking analysis remains critical for strategic planning, especially for gauging where and how policy intervention can reduce risk, support infrastructure investment and align digital growth with climate and competitiveness goals (see section 3).

Against this backdrop, a near-term confidence interval and long-term scenarios for EU27 data centre electricity demand were developed using top-down and bottom-up meta-analyses. In the top-down analysis, global forecasts of data centre electricity demand were assessed for their EU27 relevance, and a weighted meta-estimation approach was used to derive proportional values. The top-down estimates extracted EU27 shares from global DC forecasts, which were complicated by varying geographic and political definitions of 'Europe'. To validate and contextualise this, a bottom-up analysis was conducted – aggregating regional (e.g., Nordics, FLAPS) and national-level projections, including those from think tanks, financial services and consultancies, to reconstruct the likely EU27 trajectory from the ground up. Comparison of both results with EU-wide approximations (e.g., by McKinsey & Co.) showed a clear convergence to deliver an 85% confidence interval for DC electricity demand in the EU27 up to the year 2030 (Figure 4.1, orange band).

Beyond 2030, three illustrative scenarios were developed; these are not to be seen as forecasts but rather visualisations of how data centre demand might evolve under different policy and market conditions.

1. *Tech-Driven Growth* (dark blue): This scenario is driven by AI acceleration and infrastructure scaling and assumes limited policy steering. Market growth outpaces infrastructure readiness, pushing electricity demand and grid capacity demand into the gridlock zone. Competition with other electrification priorities emerges. Economic and climate outcomes become volatile, which could potentially reinforce or undermine EU competitiveness and climate goals.

2. *Business-as-usual* (light blue): Demand grows steadily under the current policy and permitting regimes. Connection queues and delays act as an implicit cap, limiting blackout risk but slowing digitalisation. The EU fails to leverage the climate and productivity potential of advanced digital tools fully, resulting in competitiveness lagging behind that of more agile peers.

3. *Smart Policy* (green): This policy supports data centres as grid-supportive assets by offering location incentives, imposing energy efficiency mandates and enabling flexible grid participation. Demand continues to rise but remains below the gridlock threshold. Infrastructure expansion is synchronised with growth. This approach offers the greatest potential for climate, innovation and competitiveness benefits.

Figure 4.1 illustrates these trajectories and the trade-offs they represent. This visualisation is not a mathematical prediction, but rather a synthesis of data-backed insights from this study, integrating technical constraints, economic signals and the role of policy in shaping feasible futures.

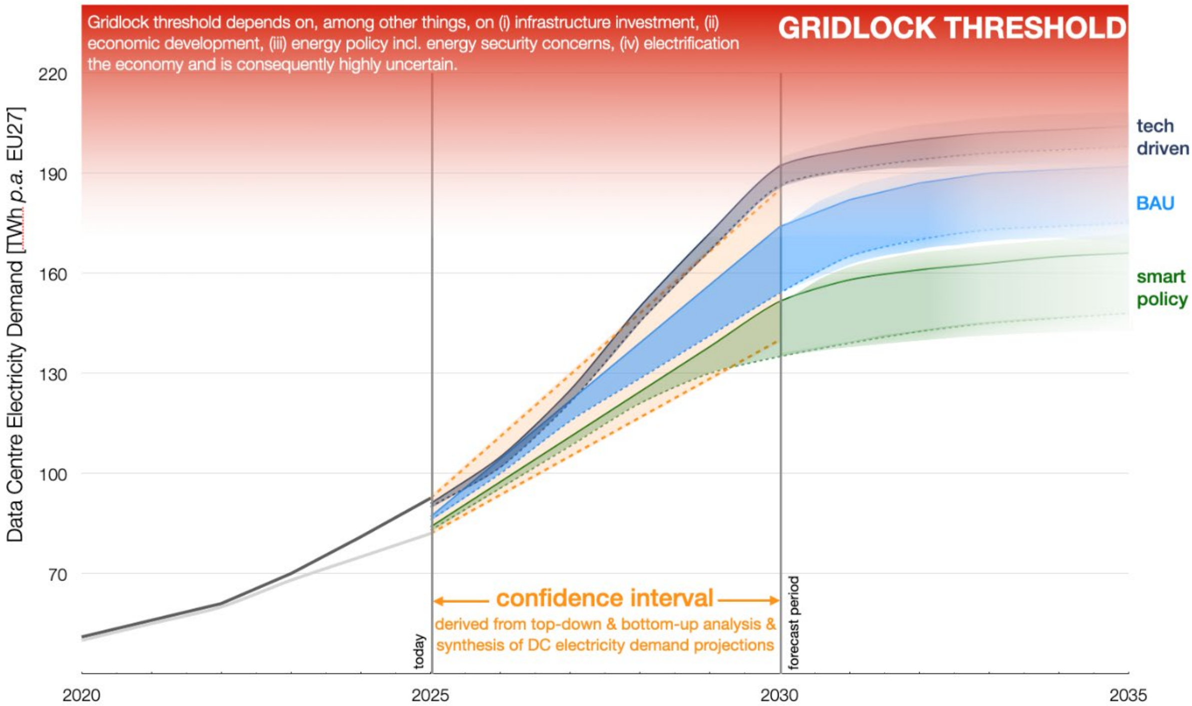

Figure 4.1: Confidence interval for the electricity demand for the EU27 to the end of the decade

Note: Visualisations of potential scenarios beyond are purely illustrative.

Source: In-house analysis and modelling based on publicly available data.

Ultimately, policymakers walk a tightrope: They must preserve energy system stability while realising the transformative potential of digital infrastructure. If sequenced and designed adaptively, policy can prevent lock-in, mitigate risk and direct innovation towards the EU's competitiveness and climate goals. Case Study Case Study 2: AI as Driver for Efficiency – How Digital Intelligence Can Produce Sustainability Gains demonstrates this potential by showing how AI-driven optimisation is already contributing to reducing emissions.

5. Conclusions

The rapid digitalisation of Europe's economy and the delivery of secure, affordable electricity are now recognised as foundational policy goals to strengthen the EU's competitiveness and its strategic autonomy. However, Europe currently faces significant headwinds in its energy policy goals.

The EU remains at a persistent disadvantage compared to other global superpowers when it comes to industrial electricity prices. Energy costs in Europe are significantly higher than those in the United States and China, key competitors in cloud infrastructure, semiconductors, and AI services. This price gap is compounded by Europe's stringent carbon pricing and emission reduction targets, which, while environmentally necessary, further raise costs for European operators. Reducing energy prices is essential for Europe to retain or attract investment in energy-intensive digital infrastructure. At the same time, energy security concerns – amplified by the energy crisis of 2022 and ongoing geopolitical tensions – have refocused European policymakers on ensuring the efficiency and resilience of electricity systems.

In this context, DCs, long seen as energy liabilities, are now being re-evaluated as potential assets to the grid. Our updated analysis confirms that DCs can play a strategic role in stabilising electricity systems through demand-side flexibility, battery storage, and carbon-aware workload scheduling.

Yet challenges remain to seeing DCs play this positive role. Electricity grid congestion is becoming a bottleneck to both digital growth, broad electrification and renewable energy integration. Many regions with high demand are already saturated or have only limited potential to further expand the grid. Strategic planning, location-aware permitting, and infrastructure co-optimisation are needed to ensure that DCs are built where capacity exists, not merely where land is cheap or demand is high. Solutions include spatial zoning, ready-to-connect zones, and prioritisation of projects that contribute flexibility or co-locate with renewable generation. Mobilising and efficiently allocating the flexibility which DCs can provide is the key to solving the congestion problem. This will be achieved by the right mix of regulatory incentives to provide and use flexibility.

It is also increasingly clear that the earlier assumption underpinning much of the policy discourse – that efficiency gains would keep pace with digital growth – no longer holds. Gains in chip performance and cooling technologies are levelling off, while emerging workloads like AI and high-resolution streaming are increasing energy intensity per operation. The rise of modular and edge computing further makes it even harder for policymakers and system operators to accurately estimate demand.

However, the outlook is not bleak – far from it. The policy toolkit is evolving. Regulatory standards are becoming more harmonised, new incentive structures are emerging, and several Member States are taking the lead in strategic planning. Flexibility pilots, carbon-aware scheduling platforms, and grid-integrated battery systems are already demonstrating results. Most importantly, progress has been made, and there is strong momentum to build upon. The data centre sector is no longer a blind spot in energy policy – it is increasingly viewed as part of the solution. To realise this potential, Europe must maintain a clear focus: enabling digital growth while safeguarding energy security and accelerating climate action. With the right mix of instruments – regulatory, strategic, and market-based – DCs can become a cornerstone of a flexible, competitive, and decarbonised European energy system.

6. Policy Recommendations

To align data centre (DC) expansion with Europe's climate, competitiveness, and energy security goals, a coordinated policy response is urgently needed. The following recommendations address the main structural barriers identified in this report. includes: the **problem** at hand; the **solution** proposed; the **benefits** it will deliver; and a **reference** to the relevant section(s) of the report where further evidence and analysis can be found.

1. Modernise Regulation

The Problem: Permitting and regulatory fragmentation across Member States slows the deployment of digital infrastructure and increases investor uncertainty. Inconsistent treatment of DCs within infrastructure and energy law leads to inefficiencies, planning delays, and potential legal contestation.

Recommendations:

- Streamline permitting for socially valuable infrastructure projects, including DCs (e.g., those supporting sovereignty, public services, or strategic R&D) and harmonise minimum efficiency and transparency standards across the EU.
- Extend fast-track status not only to DCs but also to other high-value public infrastructure.
- Permitting processes for new grid infrastructures required for the interconnection of DCs should be harmonised with the timeline for DC permitting.
- Enable Use-it-or-lose-it provisions: if the contractually agreed capacity is not fully utilised by the data centre (or any other connecting party), it may be withdrawn by the DSO/TSO (either with support by the NRA or after a predefined time frame).

How It Helps: Reduces bottlenecks and legal ambiguity; encourages sustainable, distributed DC growth aligned with public interest.

Backed by: 3.1.1 (Comparative Analysis of Regulatory Strategies) ; 2.6 (Core Problem: Expanding DCs with Grid Congestion) ; 2.7 (DCs as Geostrategic Assets) ; 10 Annex 1 (National Case Studies).

2. Enable Incentives for Grid Flexibility and Clean Energy Use

The Problem: Despite their potential, most DCs are not rewarded for offering grid flexibility or sourcing clean power. Barriers include unadjusted tariff structures, regulatory gaps in co-investment, and weak price signals for flexibility.

Recommendations:

- Design targeted incentives to support on-site battery storage, load shifting, renewable integration (e.g., via clean PPAs), and participation in flexibility markets (e.g., via flexible connection agreements) like flexible connection agreements).
- Ensure tariff design and connection fees do not penalise flexible or distributed load configurations.

How It Helps: Unlocks DCs' potential to act as programmable loads, supporting renewable integration and reducing system stress.

Backed by: 2.5 (From Liability to Asset: The Flexibility Potential of DCs) ; 3.2 (Incentives: Direct & Voluntary) ; 2.4 (Efficiency Gains Slowing) ; Case Study 2 (AI for Efficiency).

3. Integrate DCs into Spatial and Electricity System Planning

The Problem: Current spatial and energy planning frameworks often overlook DCs, leading to deployment in saturated urban grids while underutilised or renewable-rich zones remain neglected.

Recommendations:

- Include DCs in national and regional spatial planning processes and electricity system development plans.
- Use locational signals (e.g., grid heatmaps, low-carbon zones) to guide investment and relieve pressure on congested areas.

How It Helps: Promotes smart siting of infrastructure, avoids gridlock, and accelerates renewables integration.

Backed by: 2.6 (Core Problem: Expanding DCs with Grid Congestion) ; 3.3 (Planning Instruments: Indirect & Mandatory) ; 2.3 (Changing Energy Profile of Digital Infrastructure) ; 2.2 (Future Demand Trajectories).

4. Improve Transparency and Market-Based Signals

The Problem: Lack of standardised, public information on energy use, emissions, and flexibility undermines both effective planning and public trust. Many beneficial practices (e.g., carbon-aware compute, flexible scheduling) are still not incentivised.

Recommendations:

- Ensure transparent, harmonised and simplified reporting on key energy, water and carbon metrics for DCs.
- Encourage voluntary tools such as flexible connection agreements, carbon-aware scheduling, and dynamic load management – especially for hyperscalers.
- Promote the use of flexible connection agreements not only as a market-based measure to incentive demand-side response, but also to be used by network operators as a tool to dynamically allocate capacities depending on grid load conditions and to speed up the provision of grid connections.

How It Helps: Empowers regulators, operators, and the public to assess DC impacts. Facilitates system optimisation and climate accountability.

Backed by: 3.4 (Market & Informational Signals) ; 2.4 (Efficiency Metrics and New Sustainability Indicators) ; 2.8 (Trade-offs between Climate, Energy, and Competitiveness) ; Case Study 2 (AI for Efficiency).

5. Strengthen Regional and Cross-Border Coordination

The Problem: National-level policy divergences and limited TSO/DSO coordination hinder the efficient integration of DCs into the European energy system. Fragmentation leads to congestion, investment uncertainty, and missed synergies.

Recommendations:

- Promote EU-level guidance and cross-border coordination on grid codes, planning standards, and transparency obligations.
- Support regional platforms for data-sharing between TSOs, DSOs, and digital actors.

How It Helps: Reduces planning mismatches, enhances energy sovereignty, and improves resilience through shared infrastructure strategies.

Backed by: 3.5 (Next-Level Regulation: Adaptive Frameworks) ; 3.6 (Policy Orchestration & Sequencing) ; 2.7 (Digital Sovereignty & Tech Regulations) ; 2.1 (Economic Competitiveness and Energy Cost Factor).

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8. Glossary

Energy system: The full chain of energy conversion, transport, and use – across all energy carriers (e.g., electricity, gas, hydrogen, district heating water, and transport fuels such as petrol, diesel, kerosene, and biofuels).

Electricity system: The generation, transmission, distribution, and consumption of electricity – one subset of the energy system.

Electricity grid: The physical infrastructure (cables, transformers, substations) that delivers electricity from producers to users.

Demand-Side Response (DSR): Consumer-side adjustments in electricity usage in response to price signals or grid needs – central to flexibility and grid resilience.

Load: The total amount of electrical power consumed by a system or device at any given time. In energy system terms, "load" usually refers to demand – how much electricity is being used by consumers.

Peak Load: The maximum level of electricity demand recorded over a specific period (e.g., daily, seasonally). Managing peak load is crucial for grid stability, as infrastructure must be built to accommodate these rare but high-demand moments.

Grid Flexibility: The ability of electricity system actors to adjust demand or supply in response to signals such as prices, grid frequency, or system constraints. Delivered through demand-side response, storage, or distributed generation, flexibility helps balance the grid and integrate renewables.

Gridlock: In this context, a metaphor for the saturation point where grid connection queues, congestion, or permitting delays inhibit the further expansion of digital infrastructure – leading to lost economic and climate opportunities.

Locational Signals: Price or planning incentives used to steer infrastructure deployment toward regions with available grid capacity or strategic importance.

Artificial Intelligence: A broad field encompassing systems that simulate cognitive functions such as learning, reasoning, and decision-making. Large Language Models (LLMs) are a subset of machine learning, which is itself a subset of AI.

Advanced Digital Technologies: A collective term for emerging computing and communication systems that extend beyond conventional information technologies (IT). Includes artificial intelligence (AI), edge computing, high-performance computing (HPC), quantum computing, and other tools driving automation, optimisation, and digital transformation across sectors.

Hyperscaler: A large-scale cloud or digital infrastructure operator (e.g., Amazon Web Services, Google, Microsoft) with extensive global DC capacity and proprietary hardware and software systems.

Ex-ante vs. Ex-post Regulation: Ex-ante regulation sets rules before market activity occurs (e.g., permitting, technical standards), while ex-post regulation focuses on enforcement or corrective measures after the fact (e.g., penalties, audits). The balance between both shapes regulatory agility.

Regulatory Sandbox: A policy framework allowing temporary exemptions or modified rules for innovators to test new business models or technologies in a controlled environment – commonly used in fintech, now increasingly in energy.

Advanced Digital Technologies: A collective term for emerging computing and communication systems that extend beyond conventional IT. Includes AI, edge computing, HPC, quantum computing, and other tools driving automation, optimisation, and digital transformation across sectors.

EU Better Regulation Guidelines: A policy framework by the European Commission that promotes evidence-based, transparent, and proportionate rulemaking. It encourages stakeholder participation, iterative design, and regular evaluations – ensuring that regulation evolves with technological and societal change.

Load (Demand): Instantaneous power demand at a given time (e.g., peak load)

Electricity Consumption: Total energy used over time (e.g., per year, month)

Capacity (Generation / Connection): Maximum available power generation or connection capability

Apparent Power: Used in AC systems to describe combined real and reactive power (contractual load capacity)

Flexibility: Load that can be shifted or modulated (e.g., for demand response)

CO_2 (Carbon Dioxide): A greenhouse gas emitted through fossil fuel combustion and industrial processes. In energy and emissions reporting, CO_2 is often used as a shorthand for climate impact – though technically, other gases also contribute to climate change.

Carbon (vs. CO_2): The term *carbon* is often used more broadly or colloquially to describe emissions (e.g. “carbon footprint”), though it is technically not the same as CO_2. One tonne of carbon corresponds to 3.67 tonnes of CO_2. In policy and climate contexts, *carbon* usually refers to the carbon content of fossil fuels or emissions expressed in CO_2 equivalents.

Jevons Paradox: A phenomenon where increased efficiency in using a resource (e.g., energy or computing power) leads to higher overall consumption of that resource – because it becomes cheaper or more accessible. Particularly relevant in the context of AI and data centre energy efficiency.

9. Appendices

9.1. Annex 1: Comparative Analysis of Regulatory Strategies

Table 9.1: Comparative Analysis of Regulatory Strategies – France

Effects of Regulatory Measures	Regulatory Measures	Effects of Incentives	Government Incentives	Grid Connection Timeframe	Administrative Process	Current situation
2-3% of national electricity consumption [4] High demand growth concentrated around Paris region, leading to capacity constraints [4] Announcement of 109 bn € investment in AI infrastructure [1] Excess of low carbon electricity production [5] +11% of GhG emissions from DCs in 2023 + 19% of water consumption from DCs in 2023 [14]	Two-phase permit process: 1) Building permit from local authorities 2) Environmental authorisation and impact assessment for large facilities (ICPE qualification) [8]	No reliable source with precise delays' estimates, but informal sources suggest from 18 to 48 months, with significant regional variation. Up to 6-7 years depending on judicial contestations of the permits. Longer delays due to local congestion and rising connection demands from DC. [15]	Tax incentives including reduced electricity taxes for environmental standards compliance [10] Heat recovery subsidies under the "Heat Fund" from ADEME [11] 109 bn € investment plan with sites pre-selected [1] National energy provider EDF propose "ready-to-connect" sites [2]	(+) Geographic redistribution of some DC investment to regions like Hauts-de-France [1] (+) Increased adoption of heat recovery systems (e.g., Equinix PA10 DC supplying heat to local networks) [14] (+) Public investments drive DC demand in France and foreign direct investment (UAE to invest up to 40 bn €) [1] (-) Strong opposition from environmental associations (DC enter the public debate and faces contestation, as other energy infrastructures). [13]	Capacity reservation guarantees requiring milestone commitments + ex-post control by TSO [3] [6] Obligation to take measure for energy efficiency under Construction Law. 40% building energy use reduction by 2030. [9] Electricity tax rebate subject to environment performance [10] (in discussion) Project of law to simplify economic life: streamlined permitting for massive DC project qualified as "major national interest" projects. Takes the permitting for these projects to government level instead of localities. [7]	(+) Improved spatial distribution. [1] (+) DCs participating in heat recovery schemes. (-) Increased development delays and legal uncertainty resulting from additional requirements. (-) Strong opposition from environmental associations, using the legal framework to contest DCs expansion. [12] [13]

Table 9.2: Comparative Analysis of Regulatory Strategies – Ireland

Effects of Regulatory Measures	Regulatory Measures	Effects of Incentives	Government Incentives	Grid Connection Timeframe	Administrative Process	Current situation
Extremely high concentration: electricity consumption by DCs rose from 5% in 2015 to 21% in 2023 [3] Projected to reach 31% of electricity consumption by 2030 [4] Grid capacity reached critical levels in Dublin region [5] [7] De facto ban of new DCs in Dublin region until 2028, under specific connection rules [6], currently being revised [1] [2].	1) Planning permission (local planning authority), including an environmental impact assessment 2) Environmental permission 3) Electricity connection: connection agreement application with a TSO (EirGrid) [13]	EirGrid implemented a "de facto" connection moratorium in Dublin region (2021-2023), extended until 2028, in application of CRU's 2021 decision on DC connection [6] (stating that TSOs shall take into consideration whether the region is constrained or not - and Dublin still is). [7] Debate on-going on connection rules with new co-location requirements. New guidance from CRU subject to consultation. [1]	Investment incentives through IDA Ireland ; historically low corporate tax rate of 12.5% ; R&D tax credits for technology innovation [12]	(+) Attracted major hyperscalers (AWS, Microsoft, Google) (+) Dublin became Europe's largest DC hub, generated tax revenues... (-) Growing strain on national grid infrastructure, leading to major uncertainties and difficulties for grid operators, as well as stagnation in terms of DC investment/expansion	New connection policy subject to public consultation (February 2025) [1] [2] providing for connection assessment criteria prioritizing DCs based on: 1) Onsite generation (and/or storage capacity) to match the requested data centre demand (onsite or local in proximity). 2) Dispatchable generation: contribution to grid capacity and overall system adequacy via flexibility (including Demand side units - DSUs). 3) Location (TSOs must take into consideration whether connection demands concern constrained or unconstrained region) 4) Information gathering, reporting and transparency (from DCs to TSOs on renewable energy and emissions + market sounding by TSOs to understand DC energy appetite + publication by TSOs of information regarding local constraints, etc)	(+ ; expected) Increased development in regional locations. (+ ; expected) Higher adoption of onsite power generation (+ ; expected) Enhanced DC participation in grid flexibility services (+) Reduced new connections in Dublin region. New hyperscalers, like Google, DC demands are being rejected in Dublin region [8] (-) Controversy on the way environmental impacts and carbon emissions are addressed in current regulatory frameworks [10] [11] (-) Controversy on the risk of "mass exodus" of DCs without clear and workable connection rules [9]

Table 9.3: Comparative Analysis of Regulatory Strategies – Germany

Effects of Regulatory Measures	Regulatory Measures	Effects of Incentives	Government Incentives	Grid Connection Timeframe	Administrative Process	Current situation
3–4% of national electricity usage [4] [3] Frankfurt hub concentrating DC capacity (831MW), economy and tech skills [3] [5] Congestion issues: costs of managing congestion tripled between 2019 and 2022 [2]	Building permit from local planning authority Environmental impact assessment (EIA) and requirements for emissions and energy efficiency Grid capacity approval [1]	Up to 7 years in queue [2] p.94 Recent regulatory attempts to streamline process for high-efficiency facilities (failed for now due to lack of consensus and strong opposition) [11]	Renewable energy subsidies for on-site generation Reduced grid fees for facilities demonstrating flexibility Regional economic development incentives, push for establishing a new hub in Berlin Early 2025, political coalition to strengthen Germany as a DC hub (plan to accelerate planning and approval processes, facilitate integration of DC into power grids...	(+) Increasing adoption of renewable energy (88% of electricity consumed by colocation DCs comes from renewables, through PPA or on-site generation - statistics from [3]] (+) Higher industry standards for PUE. (+) Geographical diversification beyond Frankfurt. New potential hub in Berlin [6]	Consultation initiated in end-2024 regarding suitable allocation mechanisms for scarce electricity grid capacity. The German Federal Network Agency proposed the so-called repartition procedure" instead of the " first come, first served" principle. Abandoned due to lack of consensus (critics argued that allocation rules would not be adapted to local specificities) [11] Grid code amendments requiring flexibility capabilities for large connections (which would include DC) [8] Energy efficiency standards under 2023 German Energy Efficiency Act (strict transposition of the energy efficiency directive, with precise efficiency targets - 1.2 by 2026 for new DC and 1.3 for existing DC) [7] [6] [2] Germany expanded the scope of the energy reuse factor, which only accounts for reused heat and energy, requiring facilities to reach 10% in 2026 and 15% by 2028. [2] p.240; [7] All DC operators, regardless of the date of commissioning, must cover 50% of the electricity consumption in their DCs from unsubsidized electricity from renewable energies as of January 1, 2024, and 100% as of January 1, 2027. The energy used may not come from existing electricity volumes already subsidized by the German Renewable Energy Act. [9] Environmental management system and transparency over implementation plans for largest DCs (>300kW and transparency for >2.5GWh) [9]	(+ ; expected) Increased energy efficiency (+ ; expected) Increased participation of DC in flexibility (+) Growing adoption of heat reuse solutions (28% of colocation DCs utilise waste heat). [3] (-) Connection queues are still a problem in congested regions (in the absence of zoning plan)

Table 9.4: Comparative Analysis of Regulatory Strategies – The Netherlands

Effects of Regulatory Measures	Regulatory Measures	Effects of Incentives	Government Incentives	Grid Connection Timeframe	Administrative Process	Current situation
High concentration around Amsterdam. Grid capacity reached critical levels in Amsterdam Metropolitan Area [4] DC ban in 2019 in Amsterdam region, followed by policy reforms to contain DC growth [3] [4] Politicisation of the debate and major concerns about land use and water resources [3] Space issues for DC construction and grid expansion [6]	Depends on the municipal zoning plan: derogation to be authorised if data centres are not allowed under the zoning plan Municipal permit process with increasing restrictions Environmental Impact Assessment for facilities >15MW Grid connection application through grid operators [1]	Up to 10 years in queue [2] Amsterdam region implemented temporary moratorium in 2019–2020 [4]	Favourable tax structure and incentives for energy-efficient technologies Innovation Box with lower tax rate for R&D Regional development incentives.	(+) Created one of Europe's largest DC hubs (+) Restrictions and regulations have slowed growth in Amsterdam (+) Geographic redistribution to secondary locations (Middenmeer, Eemshaven, Limburg). Ex: Google 600M€ investment in Eemshaven [5] [6] (-) Growing tension between economic benefits and environmental concerns. Public acceptance issues [3]. Example: Meta killed a 200MW DC project in Amsterdam region in 2022 due to Senate's opposition [3]	2019-2020 Amsterdam moratorium followed by stricter zoning regulations Ban of hyperscale data centres (>10 Ha and >70MWh) in an interim decision of 2022 [1] [6] National Strategy on Planning (NOVI) (January 2024). Data centres may be located where (cumulatively) :- the energy demand can be met sustainably via current or future energy networks - the supply of residual heat to the district heating - they meet the market requirements for digital connectivity [6] Regional regulations. Examples: - Amsterdam policy requiring minimum PUE of 1.2, waste heat utilisation plan, sustainable energy and landscaping - Haarlemmermeer policy with strict zoning plan DC subject to environmental permits to be located in noise zoned industrial estate [1]	(+) Geographic redistribution to secondary locations (Middenmeer, Eemshaven, Limburg). Ex: Google 600M€ investment in Eemshaven [5] [6] (+) Improvement in energy efficiency (average PUE decreased from 1.67 to 1.28 from 2019–2023) (+ ; -) Slower growth rate in Amsterdam region (from 18% to 7% annually) (-) fragmented regulations across localities [6] (-) unfulfilled promises of data centres as a residual heat source [6] (-) critics over lack of transparency of the decision-making process [6]

Table 9.5: Comparative Analysis of Regulatory Strategies – Greece

Effects of Regulatory Measures	Regulatory Measures	Effects of Incentives	Government Incentives	Grid Connection Timeframe	Administrative Process	Current situation
Emerging market with ambitious growth plans Relatively low current DC capacity, with minimal grid impact (<1% of national consumption) Territory subject to water scarcity, controversies arise [5] Government effort to attract DC investment and facilitate implantation [8], also helped with lower prices of electricity due to investments in cost-effective renewables.	Compliance with the legal, urban planning and environmental regulations Notification to the competent development department of the region in whose territorial jurisdiction the data centre is located Securing grid access with utilities (requires an Environmental Impact Assessment) [7]	No reliable data found. Delays are deemed "significant" (interview). Focused efforts to accelerate for strategic projects.	Greek TSO to publish an energy map to highlight the most appropriate areas for the development and operation of such projects [8] Strategic investment incentives (Law 4864/2021 as amended by Law 5069/2023): - siting incentives: special plan for the development of strategic investments (including approval for forced expropriation) - continuous routing permission incentives: extraordinary routing to vessels for strategic projects on remote areas (incl. islands) - tax incentives for strategic investments (guaranteed stable rate, favourable taxation of profits...) - fast-track permitting for strategic projects (processed with priority) - governmental subsidies for strategic investments (portion of the costs) [8] - PPC to use land of former lignite mines. - PPC to propose available land and grid connections to DC investors.	(+) Very effective at attracting DC investments in Greece (30MW in 2019 à +150MW in 2024). (+) Efficiency of solutions to streamline permitting (package land/connection from utility). (+) Use of land from former ignite mines maximise public acceptance. (-) Potential controversy over water scarcity issues and environmental impacts [9]. This is not the case yet, as contestation is focused on wind turbines capacity (interview).	Zoning regulations: DCs can be built only in areas where such land use is permitted or not prohibited [6] Governmental effort to attract international investments in DC (Law 5069/2023 on building and construction regulations and permitted uses of land for data centres (" Law 5069"), which set in place a distinct regulatory framework for the construction and operation of data centres in Greece [8] - DCs with a capacity exceeding 200 kW (for third-party services) or 1,000 kW (for private use) are required to submit disclosure statements and comply with strict regulatory requirements. [4]	(+ ; expected) Very effective at attracting DC investments in Greece. Specifically with the streamline of connection delays. (+ ; expected) Streamlined processes for strategic projects (-) Little consideration on environmental aspects, could lead to strong public and political opposition in a distant future (-) Regulation has to keep up with the development of the DC industry, not to be a burden but a driver. Regulatory incentive (streamlining grid connection) works for attracting investment. (Interview)

All references mentioned in the table can be found in the full database available here.

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