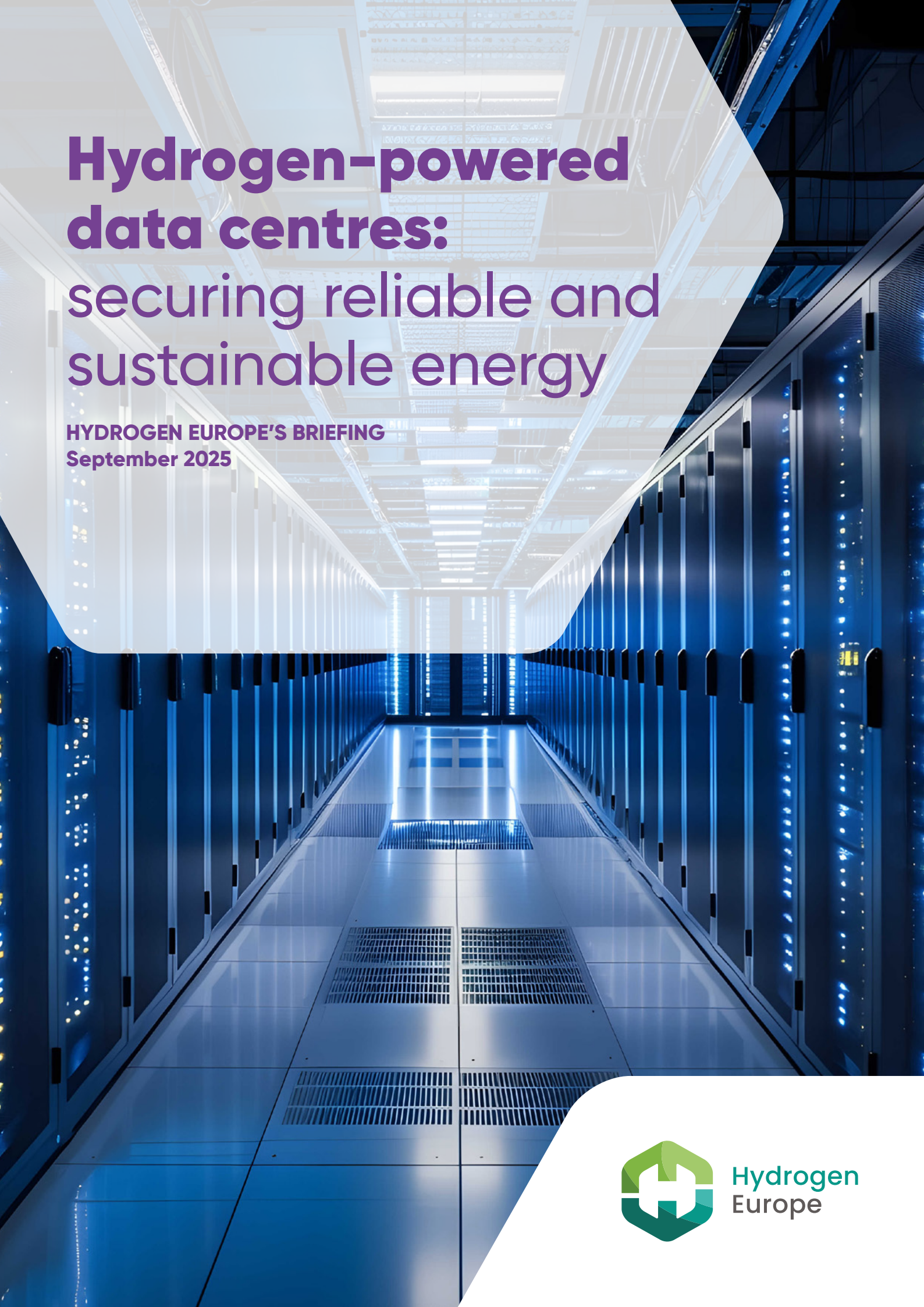
Hydrogen-powered data centres: securing reliable and sustainable energy

HYDROGEN EUROPE'S BRIEFING
September 2025



Hydrogen Europe

IN COLLABORATION WITH:

EUROPEAN DATA CENTRE ASSOCIATION

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01

Data Centres and the challenge of rising energy demand in the AI era

Once regarded as mere technological facilities, **data centres (DCs) are now at the forefront of Europe's critical infrastructure amid growing digitalisation and security needs.** The new geopolitical circumstances are bringing to light the importance of data sovereignty: Citizens and businesses demand that their data be stored within Europe, and under the jurisdiction of the EU and its Member States' laws[1]. Artificial Intelligence (AI) and DCs are increasingly intertwined. DCs provide the infrastructure for AI development and deployment, while AI is transforming DC operations.

On one hand, **AI will bring multiple benefits to the energy sector:** from enhanced asset and grid operation to more precise weather forecasting, better predictive maintenance, and image recognition across numerous applications[2] – all of which will help maintain Europe's competitive edge. However, on the other hand, the current spike in AI development could create a bottleneck for energy access, production and transport given its high demand for electricity and grid infrastructure.

In this context, **the European Union is committed and determined to become a global leader in Artificial Intelligence,** as showcased by the AI Continent Action Plan[3], that aims to at least triple the EU's DC capacity within the next five to seven years and build large-scale AI computing infrastructure, including 13 AI factories and 5 AI gigafactories.

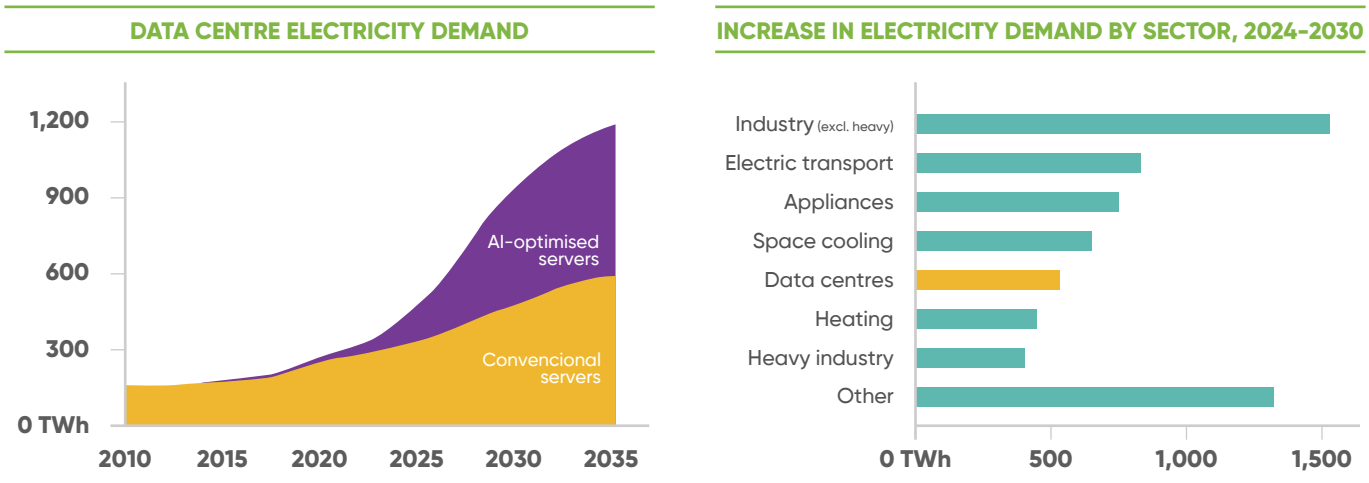
Digital infrastructure is undoubtedly the key element for technological sovereignty. **However, digital infrastructure comes with its associated energy supply needs.** As stated by the Affordable Energy Action Plan (AEAP) *"Data centres could increase strain on the energy system and drive-up energy prices, especially considering data centres' capacity to outbid other energy consumers for access to energy[4]".*

Due to their massive power consumption and rapid growth, DCs have the potential to either significantly strain power systems and hamper climate goals or, if effectively integrated, enable the net zero transition.

As of 2024, **Europe had over 1,400 DCs[5], with a total power demand of 96 TWh[6] (3.1% of Europe's total power demand).** By 2030, this could rise to 150-200 TWh (equivalent of 25 GW of DCs and about 5% of total European power consumption) depending on AI rate of adoption and expansion[7].

According to the IEA, **the major contributor to doubling DC energy demand is the increase of AI-optimised service hardware[8],** and preliminary studies from Morgan Stanley show that power demand from generative AI will increase globally at an annual average of 70% through 2027, mostly from the growth of AI-associated DCs[9].

Figure 1: DC electricity demand by type of servers. Source: IEA[10].



1 / European Data Protection Board, accessible here.
2 / IEA, AI for energy optimisation and innovation, accessible here.
3 / AI Continent Action Plan, accessible here.
4 / EC, Action Plan for Affordable Energy, accessible here.
5 / Savills, "European DCs - Navigating the new data-centric frontiers", accessible here.
6 / ICIS, accessible here.
7 / McKinsey, The role of power in unlocking the European AI revolution, accessible here.
8 / AI-Optimized Hardware is a term that refers to computer hardware that is specially designed or adapted to perform AI tasks more efficiently and effectively than general-purpose hardware.
9 / Morgan Stanley, Powering the AI Revolution, accessible here.
10 / IEA - EUSEW session, Can AI be efficient and sustainable? Going beyond energy efficiency, accessible here.

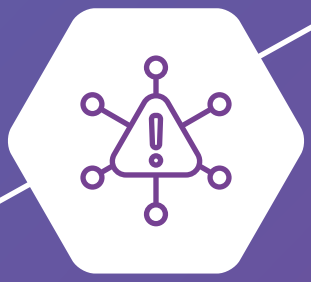
Data centres' electricity demand will more than double by 2030 and almost triple by 2035, driven by AI. Data centres are among the key contributors to electricity demand growth.

One signal of this rise in energy demand by DCs is that DC operators are leading the corporate renewable energy Power Purchase Agreement (PPA) push[11]. The reason is that, as electricity prices are still coupled with gas prices, their future evolution is hard to assess, and this price volatility can have a strong impact on cash flows. Hence, DCs are increasingly signing long-term PPAs, as those not only allow to hedge electricity prices for 15-20 years, but also help decrease scope 2 emissions - which is an important sustainability aspect for most digital and cloud service providers

The challenge is that even if electricity production is secured, the major bottleneck lies in energy delivery: today, the European electricity grid cannot deliver clean electricity at the required scale, price, speed, and reliability. In the following sections, this paper will explore why AI and growing digitalisation can introduce bottlenecks in the energy system, and how we can mitigate them using clean back-up power solutions like hydrogen.

Given the significant benefits that AI and digitalisation offer for the energy transition – as well as for Europe's broader resilience and strategic autonomy – it is essential that Europe adopts a balanced approach to ensure clean energy supply to DCs while managing the competition for energy access between DCs and industrial decarbonisation.

11 / Energy and AI Special Report, IEA, accessible here (Box 2.4).



02

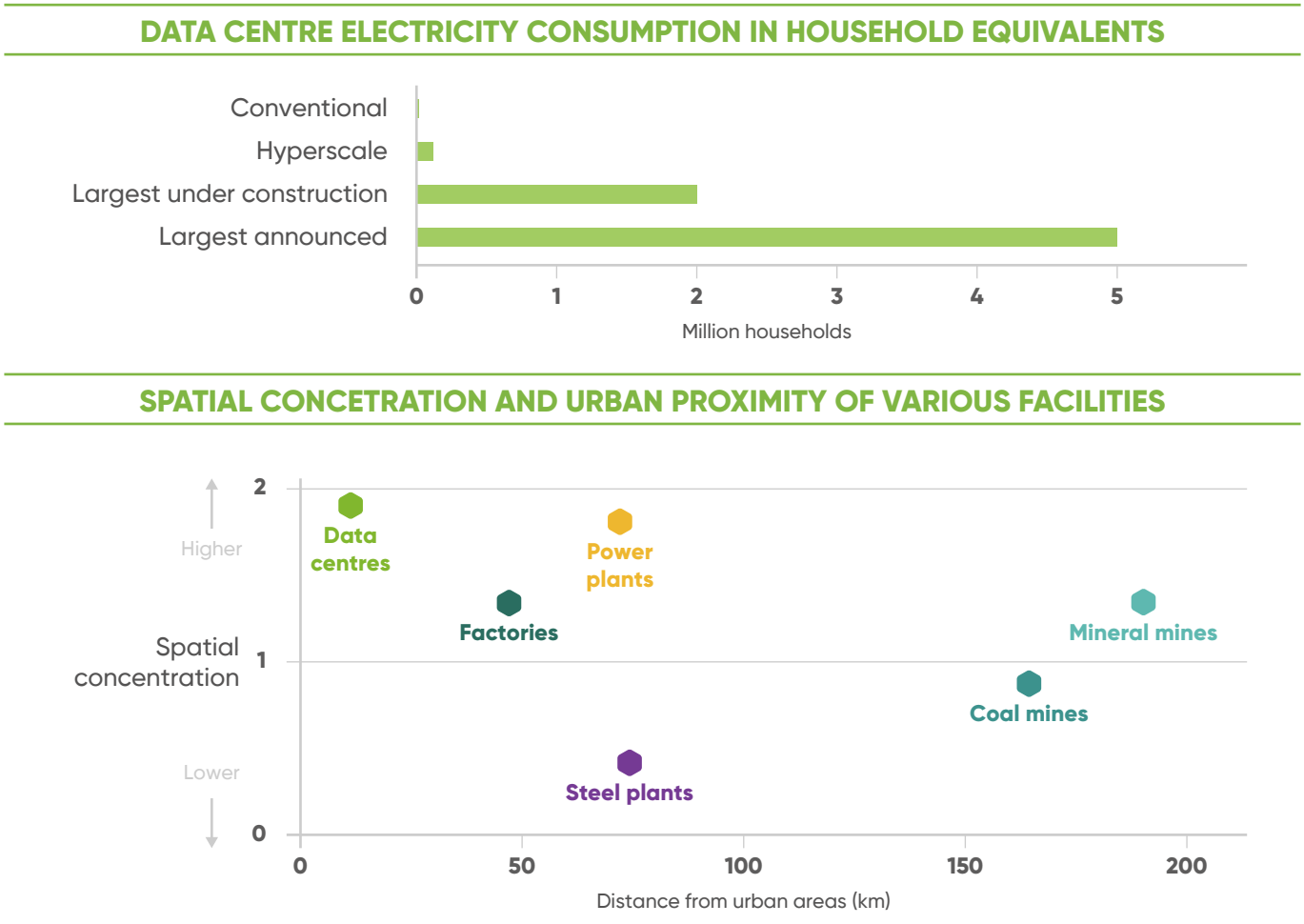
Power struggles: data centres and the grid connection crisis

2.1 High energy demand and congestion issues

Not only did the rise of AI-driven DCs create additional clean energy demand and drive up energy prices, but they also contributed to grid connection bottlenecks. AI-focused DCs can draw as much electricity as power-intensive factories such as aluminium smelters (~500MW).

Given the premium placed on low latency in traditional DCs, such as video streaming and web hosting, DCs tend to cluster close to final demand and population centres.

Figure 2: DC annual electricity consumption in household electricity consumption equivalents and the spatial concentration of various facilities versus proximity to urban areas. Source: IEA[12].



Data centres tend to be geographically concentrated and located around cities; a 100 MW data centre can consume as much electricity as 100,000 households.

12 / Energy and AI Special Report.

DCs in Europe are predominantly located in the FLAP-D markets (Frankfurt, London, Amsterdam, Paris, and Dublin), which are **already suffering from grid congestion issues[13].** In these regions where DCs are concentrated, the share of electricity demand going to DCs is disproportionately high: in 2023, data centres consumed 33% to 42% of all electricity in Amsterdam, London and Frankfurt – and almost 80% in Dublin[14]. On top of that, it takes an average of 7-10 years to connect a DC to the grid in these legacy hubs[15], and Member States are starting to place limits to DCs growth:

Examples of DC grid connection issues in Europe

Germany

Grid connection queues for new DCs can be up to 7 years long[16]. Frankfurt has confined new DCs to specific city zones, where DC providers are struggling to find suitable land and sufficient power capacity to continue their growth within city limits[17]. As a result, DCs in Germany are planning its own fossil fuel plants, citing slow grid connections[18].

Ireland

DCs consume around 20% of the metered electricity supply and this is expected to go as far as to 90% given current growth trajectory[19]. In Dublin, the electricity supply is so constrained that it is more feasible to connect hyperscale DCs to gas power plants than to reinforce the grid. In 2023, Microsoft was given permission to build a 170MW gas-fired power plant for its DCs development[20]. The move sparked public backlash, as many saw it as a step backwards for decarbonisation efforts – and settting a precedent of what can happen in other European countries.

Spain

The Aragón region is facing a significant grid capacity allocation challenge caused by massive DCs expansion: 3,500 MW of grid connection requests from DCs that the grid is unable to host (equivalent to 11% of Spain's new electricity demand)[21]. DCs connection queues can be between 5 – 7 years[22].

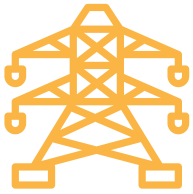
Netherlands

In 2021, the Netherlands restricted hyperscale DCs projects sizes to 70 MW and to just two locations in the country[23].

13 / Germany's grid congestion costs for 2024 were 2.78 billion Euros with 9.3 TWh of renewable energy curtailed Bundesnetzagentur, accessible here.
14 / Greenpeace, ENVIRONMENTAL IMPACTS OF ARTIFICIAL INTELLIGENCE, accessible here.
15 / EMBER, Grids for data centres: ambitious grid planning can win Europe's AI race, accessible here.
16 / Energy and AI Special Report, IEA, accessible here (Table 2.4).
17 / Energy & Infrastructure Insights — Data Centres in Frankfurt: A City Fit for the Future?, interview with Oliver Schiebel, CEO of Mainova WebHouse, accessible here.
18 / Data centres in Germany planning own fossil fuel plants, citing slow grid connections – report, accessible here.
19 / IEA, Understanding the AI and energy nexus, accessible here.
20 / Microsoft granted permission to run its Dublin DC on gas, DC Dynamics, accessible here.
21 / Given the limited grid capacity, Red Eléctrica is holding public tenders to allocate access, adding uncertainty and potential delays for these energy-intensive projects. El Periodico de Aragon, accessible here.
22 / Energy and AI Special Report, IEA, accessible here (Table 2.4).
23 / Locations: Eemshaven and Middenmeer. Source: Stibbe, "Increasing control of DC locations", accessible here.

Being less latency-sensitive than traditional data centre workloads, AI training is leading to the development of DCs outside existing clusters. DCs growth is expected to soar outside FLAP-D markets, particularly in the Nordics and some clusters in the South of Europe, where DCs demand growth will nearly double the rate of traditional FLAP-D market leaders (+110% vs. +55%) by 2030[24].

In conclusion, long lead times for renewable and grid infrastructure, coupled with interconnection queue, can make power access for DCs more critical than electricity prices[25].



In fact, developers are often willing to pay a premium just to secure fast deployment[26]. Private wire connection via behind-the-meter generation and storage could speed up projects by avoiding the need for grid connection, as well as potentially reduce electricity prices due to avoidance of network charges and ancillary services payments.

2.2 The flexibility challenge

Moreover, according to the IEA **fully grid-connected data centres are only around 1% flexible[27]**. Although, there is potential for more by batching of AI queries and different execution schedules that align with electricity prices, grid congestion, and on-site generation, more research is needed on how adjustable these loads are over seconds, minutes, or hours.

Due to the inflexibility of DCs, System Operators are planning them as firm loads and they build grid capacity for peak demand. However, DCs rarely operate at full capacity – except during extreme weather or usage spikes that last for approximately 3-5 hours. As a result, adding even modest amounts of storage and flexibility could potentially unlock massive amounts of grid capacity across Europe[28]. The IEA estimates that if European DCs offered just 30 hours of flexibility annually, the grid capacity available for them could more than double[29]. To unlock this flexibility, on-site back-up generation and storage are critical.

2.3 Balancing Act: data centres and grid stability

Even if sufficient grid capacity was available, other challenges persist: DCs can have a variable load profile - especially those ones specialised in AI - due to fluctuating computation loads from servers and cooling systems. This load profile raises concerns for electricity System Operators, as they're already facing increased grid stability issues due to higher shares of variable and inverter-based renewable energy sources in the system[30]. Indeed, some early reports are stating that DC operation modes may affect power quality and create harmonic distortions[31].

24 / EMBER, Grids for data centres: ambitious grid planning can win Europe's AI race, accessible here.
25 / Carbon leakage in AI driven data center growth?, German Environment Agency, accessible here.
26 / Morgan Stanley, Powering the AI Revolution, accessible here.
27 / Energy and AI Special Report, IEA, accessible here (2.6.3 Data centre operational flexibility)
28 / More studies need to be done on how much grid capacity can be liberated by adding flexible DC behaviour. A recent study in the US showed that at 0.5% flexibility or curtailment of the new data center load, one could add up to 98 gigawatts of new data centers across the US. See Podcast: Catalyst with Shayle Kann – interview with Tyler H. Norris Jam Ph.D. Student, Nicholas School of the Environment, accessible here.
29 / The IEA model assumes that in "80% of the hours of grid stress, more than half of the usual grid electricity supply to the data centre would still be available. In 50% of these hours, around four-fifths of the grid capacity would be available". IEA analysis here.
30 / Understanding the impact of non-synchronous wind and solar generation on grid stability and identifying mitigation pathways, accessible here.
31 / EPRI, Utility Experiences and Trends Regarding Data Centers: 2024 Survey, accessible here. Bloomberg, AI needs so much power, it's making yours worse, accessible here.

DCs variable load profile

On average, DCs operate at only 30% of their maximum capacity, though peak loads can spike up to 90% during periods of high user activity. Demand tends to follow a diurnal cycle, with nearly double the user activity during daytime hours compared to nighttime. Furthermore, usage spikes due to the "flash-crowd effect" can cause sudden surges in load. Such situations have been previously observed during breaking news, viral social media posts, limited-time offers or live-streamed events. This effect tends to be more present for AI-focused data centres.

Given the concerns of System Operators for safeguarding grid stability, it is likely that **stricter technical connection requirements - quite cost and time-consuming to fulfil – will likely be introduced**[32]**.** This can further encourage hyperscale DCs to explore off-grid solutions or reinforce their connections with on-site (or behind-the-meter) power generation and storage.

Moreover, **grid stability concerns go both ways:** DC industry's uptime requirements can reach up to five 9s or 99.999%, meaning DCs cannot be down for more than 5.25 minutes per year[33].

As a result, when a DC experiences a disturbance, it may be prompted to switch to backup power to avoid power interruption, removing a large amount of load from the grid. These situations can be more common than expected: globally, network issues caused 54% of DCs downtime[34].

This potential for DC load loss can be challenging for grid operators and planners, especially as power capacities increase. A grid disturbance may cause a DC to suddenly remove a large load from the grid. This may trigger a short feedback loop, where the initial disturbance prompts a response that causes further instability on the grid.

2.4 Back-up power solutions

To remedy grid unreliability, DCs can use backup solutions. DCs connected to the grid in areas with high stability (e.g, Western Europe), might run on backup power for a few hours per year, during grid outages, voltage fluctuations, or maintenance. In other areas, this can be longer thereby requiring more sophisticated solutions.

HyFlex™ Hitachi data centre hydrogen power designed to replace diesel generators.

Source: here.

32 / A situation that electrolysers, heat pumps and electric vehicles are already experiencing. See: ACER Recommendation 03-2023 on reasoned proposals for amendments to the network codes on requirements for grid connection of generators and on demand connection, accessible here.
33 / Slunk, "What Is Five 9s in Availability Metrics?" accessible here.
34 / With over two-thirds of outages costing more than $100,000. On top of that, the number of outages lasting over 48 hours is rising. See: Uptime Intelligence, Annual outages analysis 2023, accessible here.

The setup for data centres backup power can be distinguished as follows:

Operation	Technology	Characteristics
Short term storage (seconds to minutes)	Uninterruptible Power Supply (UPS) with batteries	First line of defence during outages
Medium term storage (hours)	Diesel generators **Fuel cell generators**	Standard backup for most DCs
Long term storage (days to weeks)	**Gas turbines or fuel cells**	Less common, growing trend as DCs struggle to secure grid capacity
Independent operation (future trend)	**Onsite renewable energy + batteries + hydrogen**	Mix of real-time generation with short term and long-term storage

Retrofitting diesel backup with renewable diesel such as HVO (hydrotreated vegetable oil) is currently underway, but generator manufacturers are already exploring a broader range of e-fuels (such as e-methanol, for instance) that could replace diesel with minimal system modifications.

Fuel cells could substitute diesel generators in new data centres to provide clean back-up capabilities, reducing scope 1 emissions and eliminating local air pollution. In these configurations storage remains crucial as backup systems may lie dormant for days, weeks, or even months.

Beyond fuels, next-generation data centre designs are introducing Active/Active power distribution paths[35], which integrate multiple independent power sources, load balancing, and fault-tolerant redundancy. These architectures allow data centres to dynamically switch between grid and onsite resources, reducing dependency on long-duration storage while significantly increasing operational flexibility.

In the future, as electricity access becomes even more scarce, DCs will develop through "sustainable energy islands" or micro grid environments to secure reliable, around-the-clock power. They will play a central role in the development of Net Zero Digital Energy Hubs: integrated infrastructures that deliver 24/7 clean energy at competitive costs, within realistic timelines, while supporting overall grid resilience. This shift will require large volumes of clean fuels to comply with sustainability criteria, balance variable renewable generation, and ensure a safe and uninterrupted energy supply. Hydrogen and/or its derivatives will have a significant role to play in this equation.

35 / Active/Active power distribution paths refer to a configuration in which power is distributed across multiple paths simultaneously, with each path actively providing power to the load. These provide a higher level of redundancy compared to single-path configurations, as multiple independent power sources and Power Distribution Units (PDUs) are actively delivering power to the load. See: Datum: The lifeline of data centres, accessible here.

03 Hydrogen and data centres nexus

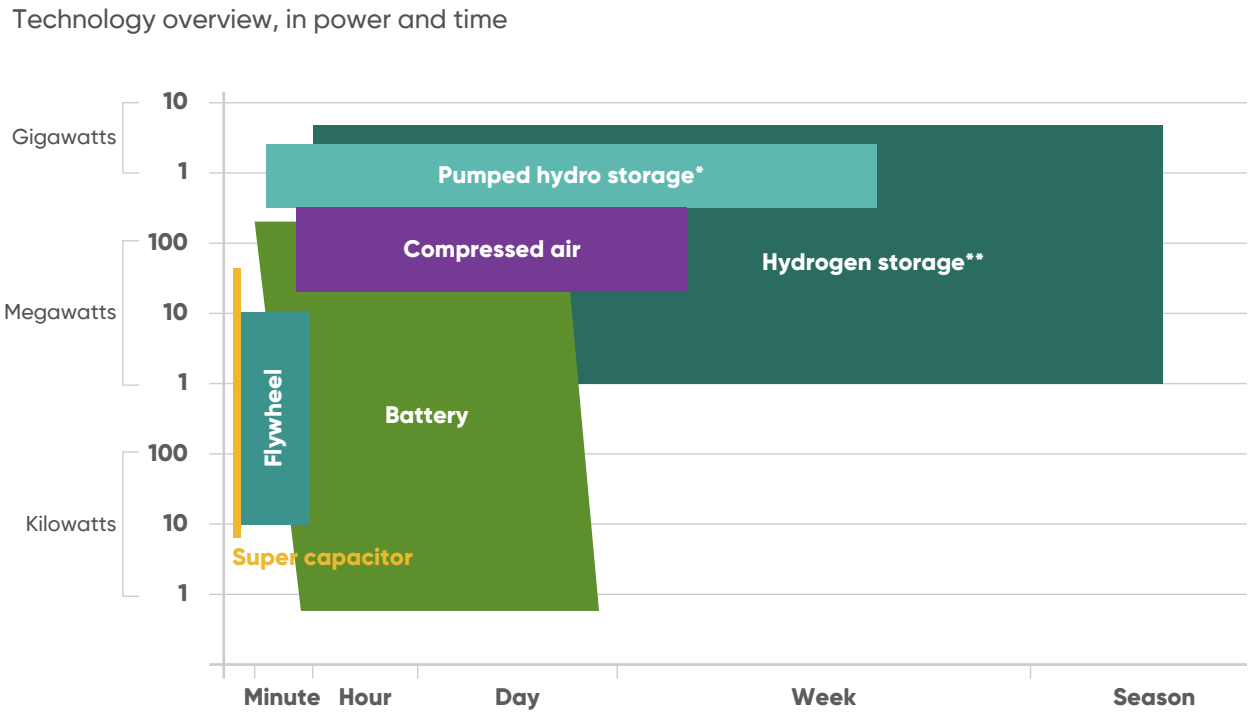
3.1 How can hydrogen support data centres needs?

Operating in island mode requires high volumes of long-term energy storage to address battery limitations and the variability of renewable energy sources, while ensuring a constant supply of energy. Hydrogen can play a crucial role in Net Zero Digital Energy Hubs by storing excess renewable electricity in molecules and later converting it into electric power and heat through turbines or fuel cells (for electricity and heat in combined heat and power systems).

When moving to longer energy storage timeframes, hydrogen stands out as the most techno-economically proven solution[36]. Only clean molecules like hydrogen and e-methane can provide clean power at peak capacity from days to months. This unique capability can compensate for efficiency losses during the conversion of hydrogen back to electricity.

Figure 3: Hydrogen storage capabilities Source: IEA[37].

HYDROGEN CAN BE STORED FOR MONTHS WITHOUT LOSING MUCH OF ITS POWER



*Limited capacity (<1% of energy demand)
**As hydrogen or Synthetic Natural Gas (SNG)

36 / Low-cost hydrogen in the future European electricity system – Enabled by flexibility in time and space, accessible here.
37 / IEA Technology Roadmap - Hydrogen and Fuel Cells, accessible here.

INNIO to deploy "hydrogen-ready" island mode engine power plant

Current micro-grid environments are opting for natural gas turbines as backup power, waiting for hydrogen to be scaled up. In Ireland, INNIO will deploy a 60 MW "hydrogen-ready" island mode engine power plant to support another hyperscale DC in the country[38].

Microsoft and ESB launched in 2024 a groundbreaking green hydrogen pilot to decarbonise Dublin DCs

Microsoft[39] and ESB[40] are testing hydrogen fuel cells to convert stored hydrogen to electricity to supply 250 kW of clean energy to Microsoft's Dublin campus for an eight week-period. This initiative aims to replace diesel generators and demonstrate hydrogen's potential in decarbonizing DCs.

3.2 How much hydrogen will data centres need?

Beyond power infrastructure and storage, a key challenge is ensuring that DCs are supplied with additional clean energy that matches their load profiles and rising demand. As outlined before, hydrogen will be essential in enabling reliable and dispatchable clean supply. While in the short term, availability of clean hydrogen for long-duration storage is still a challenge in itself, the question remains: **how much energy will DCs actually require?**

SCENARIO-BASED CALCULATION OF HYDROGEN NEEDS FOR A DATA CENTRE

Assuming that 25 GW of DC capacity will be built (220 TWh), we estimate the hydrogen usage in 2 use cases, with each a 25 - 50% range of adoption:

1

ONLY THE BACK-UP FUNCTION:
Few hours/year by substituting diesel generators, which would be 1% of operational time, equivalent to 7.3 hours per month

2

BACK UP + GRID INTERACTION:
Configuration in which hydrogen helps deliver 24/7 clean power in the Net Zero Energy Hubs (powered by a combination of renewables, batteries, and clean fuels). Hydrogen will provide in average about 10% of the yearly load, or 2.4 hours per day.

Each scenario can have 50% or 25% adoption, meaning that 50% (or 25%) of the newly build data centres would use 100% hydrogen as fuel to generate the power for the number of hours assumed in the lines above.

38 / "INNIO's Jenbacher engines to power 60 MW hyperscale DC power plant in Ireland", accessible here.
39 / Microsoft announces pioneering green hydrogen pilot project with ESB, accessible here.
40 / ESB Hydrogen Cell FastTrack, YouTube video accessible here.

The expected clean hydrogen supply by 2030 – without considering the potential DC demand – **is between 2.5 and 4.4 million tonnes of H_2/year (Mt H_2/y)[41].**

NEW DATA CENTRES BUILT TO 2030 (estimated at 25GW)

		Only Back-up: 1% oper. time 7.3 hour per month		Back-up + grid intteraction: 10% 2.4 hour per day	
	Hydrogen use				
	Data centre H_2 adoption	**25%**	**50%**	**25%**	**50%**
	Mt/H_2 needed	0.03	0.07	0.33	0.66
		Percentage of total expected clean hydrogen production in Europe			
Europe clean H_2 production scenario	**High 4.4 Mt H_2/y**	**0.7%**	**1.5%**	**7%**	**15%**
	Low 2.5 Mt H_2/y	**1.3%**	**2.6%**	**13%**	**26%**

Only back-up

In the "only back-up" scenario, hydrogen demand from data centres would represent just 0.8% to 2.7% of the projected European clean hydrogen production. Already delivering 2.5 Mt of hydrogen can present a challenge depending on the data centre location, renewable energy availability, and presence or lack of hydrogen infrastructure. The 2.5 Mt could already act as a lever for hydrogen production projects and alleviate grid connection bottlenecks for DCs.

Back-up + grid interaction

Under the "back-up + grid interaction" scenario, additional demand from data centres could reach 8% to 27% of European clean hydrogen production. In this case, data centres would emerge as a highly relevant demand driver for hydrogen. This combined scenario would significantly increase hydrogen's role in the energy system.

When DCs are integrated in Net Zero Digital Energy hubs, they represent a significant and relevant offtaker for the green hydrogen industry, that could consume close to 30% of the currently expected clean hydrogen production.

Hydrogen can be harnessed to power our digital lives. If scaled successfully, it could provide new ways of advancing sustainability in the DCs' sector and beyond. However, without an appropriate regulatory framework, Europe risks falling behind on sovereignty, resilience and decarbonisation goals.

41 / Clean Hydrogen Monitor 2024, Hydrogen Europe.

3.3 What is needed to make it happen?

DCs can constitute a significant off-taker for hydrogen – and that will require an adequate political and financial framework at the EU level. Currently, the European Commission is planning to integrate their DCs energy perspective in the following initiatives:

1. Grids package to address permitting, expansion, and digitalisation of DCs (Q4 2025)
2. Introducing a DC green label for energy efficiency and performance standards for DCs (Q1 2026)
3. Electrification Action Plan to support/acknowledge AI deployment (Q1 2026).

All of the above should enable us to have:

- **Grid access framework:** A suitable regulatory framework for access to the electricity grid – in a way that balances grid access competition of DCs with other essential high electricity demand sectors and decarbonisation solutions such as hydrogen production and renewables is needed.
- **Better mapping**: Improve mapping using granular data on AI computation hubs, grid congestion and their associated energy demand. This will allow for better balancing of needs between local industry, DCs, and hydrogen infrastructure.
- **Incentives for co-location of storage assets with DCs:** Policies and market design should support and incentivise the co-location of data centres with on-site clean power generation and storage, optimising grid use and reducing stress on constrained hubs.
- **System integration:** Integrate DC granular load impacts with system integration considerations in the **Ten-Year Network Development Plans (TYNDP) and the Offshore Network Development Plan (ONDP).** Hydrogen infrastructure can connect areas with high-RES abundance to DCs locations – especially in FLAP-D markets, where land scarcity and limited RES capacity constrain on-site generation. This approach reduces pressure on local grids while optimising cross-sectoral energy flows.

Specific measures foreseen in the **Clean Industrial Deal and the Affordable Energy Action Plan (AEAP)** should provide regulatory and financial foundations for hydrogen powered DCs, to support their green transition and resilience.

- Hydrogen should be one of the key components of the **Strategic Roadmap for Digitalisation and AI for the Energy Sector in 2026,** as envisioned in the AEAP.
- Also, the **tripartite contracts for affordable energy** between public sector, including financial institutions, clean energy developers and energy-intensive industry could be applied to DCs. This would allow to guarantee offtake for clean hydrogen and clean energy supply to DCs through streamlined administrative process enabled by public authorities.
- In line with the AI Continent Action Plan, **energy supply for digital infrastructure should be fast tracked and included under the InvestAI facility** that aims to mobilise €200 billion, to drive private investment in gigafactories[42]. Public-private agreement models should support these developments, with hydrogen infrastructure integrated into these frameworks.

42 / EU launches InvestAI initiative to mobilise €200 billion of investment in artificial intelligence, accessible here.

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