GREEN GIANTS

THE HEART OF A SUSTAINABLE EUROPEAN DATA ECOSYSTEM

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SUPPORTED BY: START CAMPUS

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EXECUTIVE SUMMARY

The rapid pace of global digital transformation is driving increasing volumes of data creation, storage, and usage. This voracious data appetite–resulting from trends such as cloud computing, the rise of social media and streaming content, advances in machine learning, growth in internet-connected sensors and devices, and 5G wireless rollout–has led to surging demand for data centre capacity, which can only be expected to continue.

Historically, in Europe, the majority of data centre capacity has been built in prime business and technology centres (focused on Frankfurt, London, Amsterdam, Paris, and Dublin – the so-called FLAP-D locations). However, this approach is reaching its limits, particularly due to physical constraints on land, water for cooling and power availability.

Data centre operators are seeking new approaches to keep up with demand. We are already starting to see regional "hyperscale" facilities being built outside urban areas – located where they can take advantage of more abundant and cheaper land and proximate renewable power. But, while much has been achieved to curb the voracious power appetite of these facilities, a step change is needed if we are to continue to power our European digital transformation while at the same time meeting goals for net zero emissions. In addition, the next generation of data centres needs to be environmentally sustainable across their entire lifecycle – from design and construction, through operation, all the way to decommissioning.

As a result, we expect a new breed of regional, environmentally sustainable "Green Giant" data centres to be at the core of the future European data ecosystem. They will not only absorb much of the future growth in data processing demand, but will do so entirely powered by clean electricity. At the same time, they will support, rather than challenge, the regional energy infrastructure, for example through stimulating additional investment in renewable power and injecting much-needed flexibility into the local power grids – increasingly valuable as the proportion of renewables increases overall in Europe. Given their scale, they could also provide further benefits to the local communities, in terms of economic growth, training and other social benefits.

To build and operate such a Green Giant takes careful planning, as we will show in this paper. Sines 4.0©, a new 495MW data centre campus currently being developed in Portugal, is one exemplar of this new breed of Green Giants. It will benefit from around 1GW of dedicated renewable energy generating capacity and will be progressively built beginning in 2022 near Lisbon. The location and site–close to a decommissioned power station with many data and power connection points–will repurpose several existing and legacy infrastructure assets, enabling the planned development to deliver hyperscale capacity in a sustainable, secure and resilient way with extremely low power costs relative to alternatives located in FLAP-D cities. These lower and more stable power costs translate into a 20–25% lower overall operating cost vs a FLAP-D equivalent, and it will also provide a range of additional benefits to the local power system.

It is worth noting that, while Green Giants will provide the lowest-cost and greenest solution for bulk data storage and processing, they will not form the entire solution to the data challenge. There will always be a need for "edge" data centres placed closer to urban source of demand to support data and applications that require extremely low latency. Thus, in the future we expect to see more workload-specific approaches to data processing and storage that match specific user and application requirements. This will need to be supported by IT infrastructure strategies that seamlessly integrate multiple data workload locations across core, edge and endpoints. Given their substantial benefits, Green Giants should be at the core, meeting Europe's ever-increasing appetite for data while simultaneously overcoming the challenges in FLAP-D locations and significantly reducing climate and other environmental impacts.

The rest of this report details the opportunity for Green Giants in Europe as follows: Chapter 1 lays out the trends in data, data centres and their challenges; Chapter 2 describes "Green Giant" data centres and why we need them; Chapter 3 is a case study on Sines 4.0©; Chapter 4 outlines the potential role for Green Giants in local energy systems; Chapter 5 compares Green Giants with urban data centres and where each is best suited; and Chapter 6 concludes with why Green Giants are destined to play such an important role in the European data ecosystem.

CONTENTS

Executive summary 2

Chapter 1: 5
The challenge – sustainably powering Europe's digital transformation

Chapter 2: 12
What are Green Giants and why we will need them

Chapter 3: 16
A Green Giant case study – Sines 4.0©

Chapter 4: 18
Green Giants' additional benefits to local energy ecosystems

Chapter 5: 20
Comparing Green Giants with urban data centres

Chapter 6: 23
Building the future European data ecosystem using Green Giants

References 24

CHAPTER 1

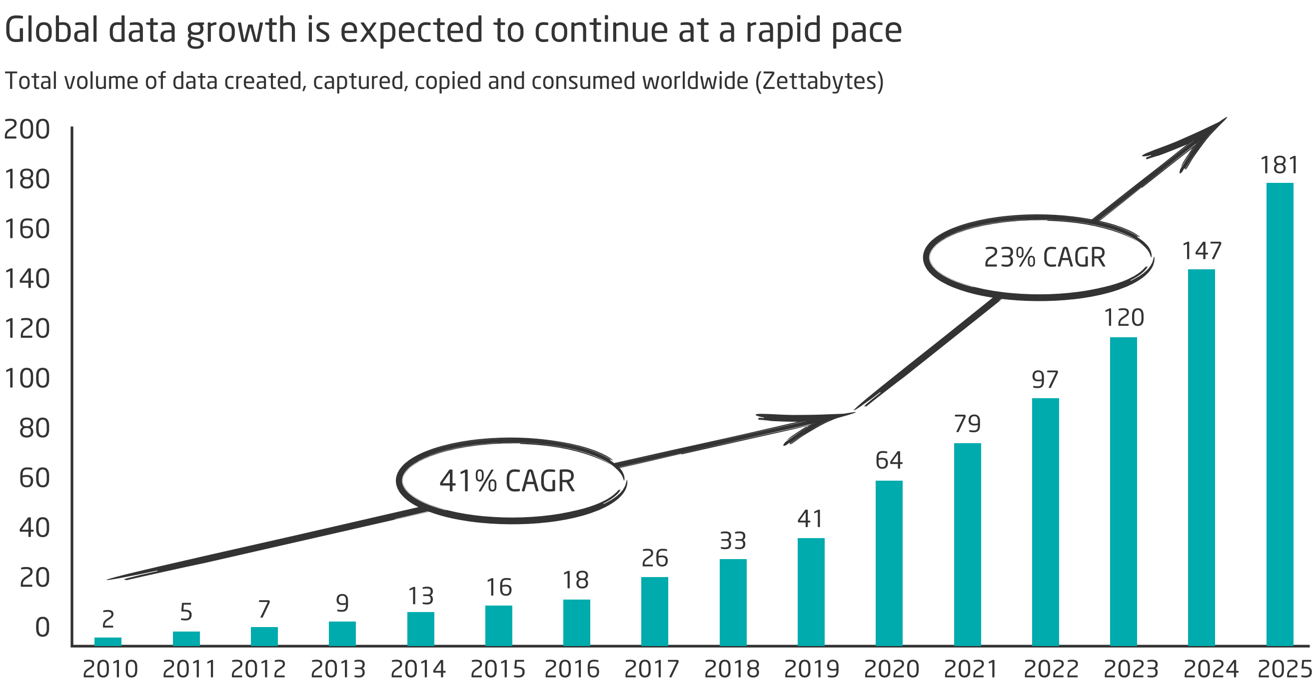
THE CHALLENGE – SUSTAINABLY POWERING EUROPE'S DIGITAL TRANSFORMATION

As Europe continues its digital transformation, there are significant challenges to be met in the near future. The unprecedented growth in data storage, processing and transmission likely to continue, as will the increase in demand for data centres to support our voracious appetite for new and expanding digital services. As we work to address the challenges with the historical ways of building out data centre capacity–in terms of the environmental impacts of energy and water use and the availability of land–we must find new ways to meet this demand.

The enormous growth in data volumes is expected to continue

The past two decades have seen unprecedented global digital transformation, fuelled by and fuelling enormous growth in data volumes, which can only be expected to continue. Several major trends–including cloud computing, increasing use of Software-as-a-Service (SaaS) platforms, the rise of social media and Over-The-Top (OTT) streaming services like Netflix–have contributed to this growth. These trends have only accelerated due to Covid-19; advances in Artificial Intelligence / Machine Learning (AI/ML), increasing connection of physical devices and sensors through the Internet of Things (IoT), Augmented Reality and the availability of 5G services are expected to drive further growth in the future. The total volume of data created, captured, copied, and consumed is expected to grow from 2 Zettabytes (ZB) in 2010 to 64ZB in 2020 and 181ZB by 2025 (IDC, 2021), as seen in Figure 1.

Figure 1: Historical and forecast data volume growth



Notes: Historical figures from IDC to 2020; forecasts from 2020 onwards estimated by Statista based on IDC growth forecasts

Source: Statista, based on IDC

To support this data growth in Europe, there has been rapid expansion in data centre capacity primarily in FLAP-D markets, but this is now reaching its limits due to availability of land, power and water for cooling

We have seen significant investment in worldwide data centre capacity to support this data demand growth. In Europe, the business centres of Frankfurt, London, Amsterdam, Paris, and Dublin (FLAP-D) have historically attracted most data centre[1] investment, due to their business importance and desire for companies to have data centres as close as possible to end users in order to reduce latency. To give a sense of scale, at the beginning of 2021, it was estimated that there is around 2,000MW[2] of colocation and managed service[3] data centre supply in FLAP-D markets (CBRE, 2021) (JLL, 2020), with additional capacity as part of enterprises and from cloud providers.

Table 1: Main current types of data centres

Data centre type	Description
Enterprise	• A data centre that is built, owned, and operated by the same organisation; optimised for their end-users • Most often housed in/on an organisation's premises ("on-premises")
Colocation	• An organisation rents space within a data centre owned by others and located off company premises • The "CoLo" data centre hosts the infrastructure (building, cooling, bandwidth, security etc.), while the organisation provides and manages the IT components (servers, storage, and firewalls etc)
Managed Service (or "hosted")	• A data centre that is managed by a third party (or a "managed services provider") on behalf of an organisation • The organisation leases the equipment and infrastructure rather than buying it
Cloud	• An off-premises form of data centre where data and applications are hosted by a cloud services provider such as Amazon Web Services (AWS), Microsoft (Azure), Google (GCP), IBM Cloud or another public cloud provider • "Hyperscale" data centres are typically associated with this type of data centre

Source: (Cisco, 2021), (CEN/CENELEC/ETSI, 2020)

[1]Data centres store, process and disseminate data and applications for end users. They are facilities that house large numbers of high-performance computers, as well as networking equipment and communications links, and allow computing to be performed at scale and with efficiency. They may be built, owned, and operated by the user, or various service providers

[2]Data centre capacity is commonly referred to in power terms – the energy supply to power the servers and other networking equipment within a data centre in megawatts (MW)

[3]See Table 1 for a description of the main current types of data centres today; largely distinguished by differences in the development, ownership and operation of the building & facilities and IT equipment

However, there are now increasing and significant site selection constraints on several FLAP-D markets, which are causing data centre operators to seek alternative locations for their data centres (see Table 2). Limited land availability and high costs are creating challenges for data centre operators to secure sites to expand. Data centres consume large amounts of electricity to power their servers and cooling. The availability of uninterrupted, affordable, and scalable power via urban grid connections is becoming increasingly challenging, given that many grids were not designed to support such concentrated, power-hungry applications. Operators are also finding it difficult to secure enough qualified staff, given competition with other technology or it related jobs in major urban centres.

Table 2: Typical data centre site selection factors and current challenges in FLAP-D markets

Data centre site selection factor	Description	Challenges in FLAP-D markets
Land and surroundings	Access to sizable sites at reasonable prices that have conducive climate, seismic activity, accessibility	Physical land and urban licencing constraints in prime locations (London, Frankfurt, areas of Paris); high costs of development sites (e.g., brownfield land with data centre consent trading for >2x residential)
Power	Access to reliable, scalable, and affordable power	Limited availability of power capacity; power shortages in main markets (Amsterdam, West London, parts of Dublin)
Connectivity	Access to reliable, robust, and scalable network connections that provide high bandwidth and low latency	Not usually an issue – data connectivity is generally straightforward to add
Water	Access to sufficient water to support data centre cooling requirements	Often reliant on potable water supplies, which can be strained by volumes required for data centres in urban locations
Skilled labour	Access to skilled labour force of sufficient quantity	Shortfall of skilled labour in the industry, exacerbated by competition from cloud providers in metropolitan locations
Local stakeholders	A supportive local environment that recognises benefits brought (e.g., tax revenue, high-quality jobs, clean operations, improvements to local infrastructure)	Previous sites have not delivered as many jobs as authorities had expected; data centres competing with office space which bring much higher number of jobs per unit of space

Sources: (Data Center Frontier, 2020), (Hagaseth, 2020), (Liebreich Associates, 2021)

We are seeing an increasing desire for hyperscale data centres

While there is no strict definition of "hyperscale" data centres, the term is typically associated with the cloud data centres operated by organisations such as Amazon, Microsoft, Google, Facebook, Apple, Alibaba, Tencent, Baidu, IBM and Oracle. These hyperscale data centres today are typically very large in size–in terms of number of servers (>5,000), power requirements (>50MW) and physical space (>10,000 square feet) (BMC, 2018)–and are based on architectures designed for scalability and energy efficient operating versus smaller data centres. For example, most traditional enterprise data centres commonly report an average Power Usage Effectiveness (PUE)[4] between ~1.7-1.8 while Google hyperscale data centres report a PUE of ~1.1 (Data Center Frontier, 2019) (Google, 2021).

As of today, there are a total of 595 hyperscale data centres globally, out of a total of >6,100 data centres, of which approximately 20% (116) are in Europe with the bulk of the remainder in North America (43%) and APAC (32%) (Synergy Research, 2021). Hyperscale data centres now account for around 50% of all installed servers, up from 21% in 2015 (PWC, 2021), with most new data centre demand expected for these types of sites (CBRE, 2021) (JLL, 2020). Thus, the number of hyperscale data centres is expected to grow at 7.2% CAGR to around 780 by 2024 (Synergy Research, 2021). To support this, European hyperscale cloud investment is expected to grow from €8.7B per year in 2019 to €50B by 2024 (Cushman & Wakefield, 2020).

Many of the hyperscale data centres of the future are likely to be located outside of urban areas, taking advantage of a shift to using "Edge + Core" approaches to data workloads

Given the enormous need for new data centre capacity and the increasing constraints in urban areas in terms of access to space, power and other resources, data centre operators are increasingly looking for options outside of the traditional FLAP-D markets (Data Center Frontier, 2019) (Cushman & Wakefield, 2020) (Hagaseth, 2020). These solutions take several forms, including expanding to additional cities and taking advantage of "Edge + Core" architecture to shift less time- and latency-sensitive workloads to locations further away from urban areas (see Table 3 for a description of the different locations for data generation, processing and storage today).

We expect to see an accelerating shift to the latter approach, where very time- and latency-sensitive data processing and storage is being done closer to end users in smaller "Edge" data centres and less time-sensitive work being done in the "Core" data centres, to take advantage of scale efficiencies, without sacrificing overall end-user performance (see Figure 2) (IDC, 2018).

These larger–typically hyperscale–Core data centres are already increasingly being located outside of major urban areas, where they can take advantage of cheaper land, have access to strong connectivity and source renewable power more easily.

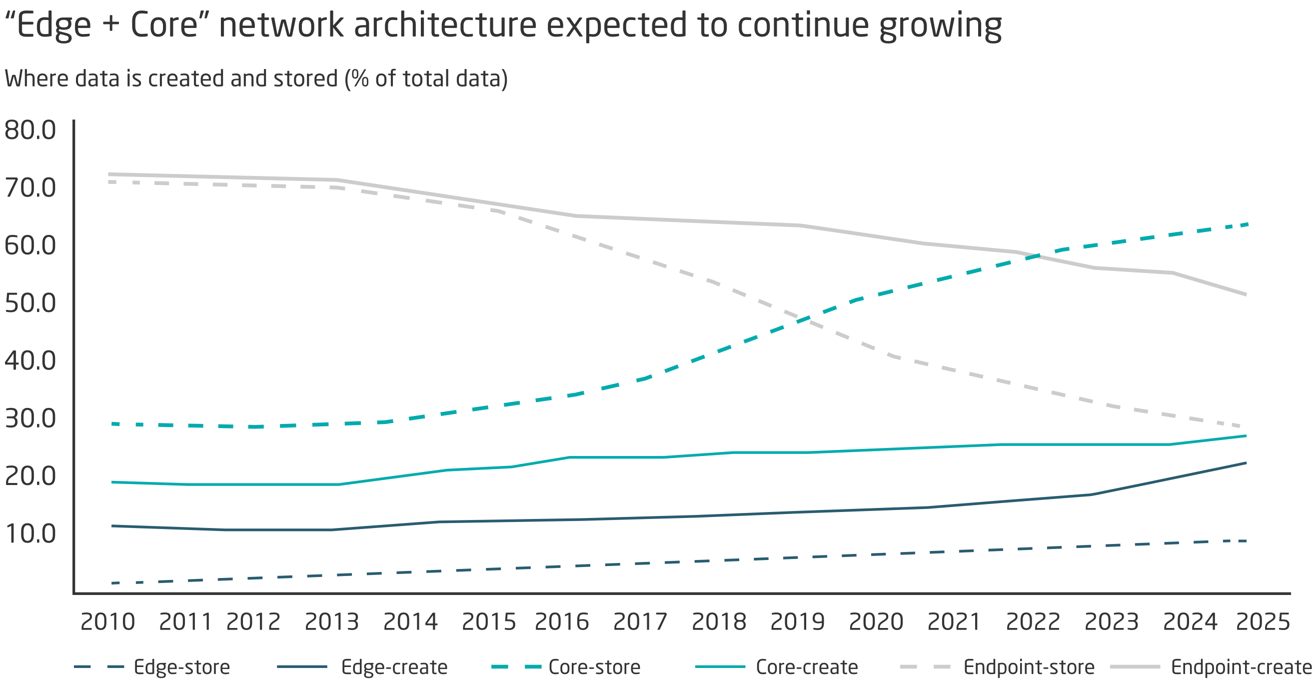
[4]Power Usage Efficiency (PUE) is defined as the power entering the facility divided by the power used to support the IT load. A PUE of 1.0 is considered "perfect" efficiency

Table 3: Locations where data is generated, processed, and stored today

Location	Description
Core	• Designated computing data centres in the enterprise and cloud providers – includes larger Enterprise and Cloud data centres, and hyperscale data centres • Play a critical role in providing centralised storage, processing and analytics, service delivery
Edge	• Servers and appliances that are not in Core data centres – includes server rooms, servers in the field, cell towers and small data centres located regionally and remotely • Located near the final user of the data (e.g., a person on their smartphone) to reduce latency and improve the user experience
Endpoints	• End-use devices at the edge of the networks • Includes PCs, smartphones, tablets, connected devices, AR/VR, IoT, vehicles etc.

Sources: (IDC, 2018)

Figure 2: The shifts in data creation and storage locations over time



Source: IDC (December 2018)

Data centres must move beyond energy efficiency to become holistically environmentally sustainable[5]

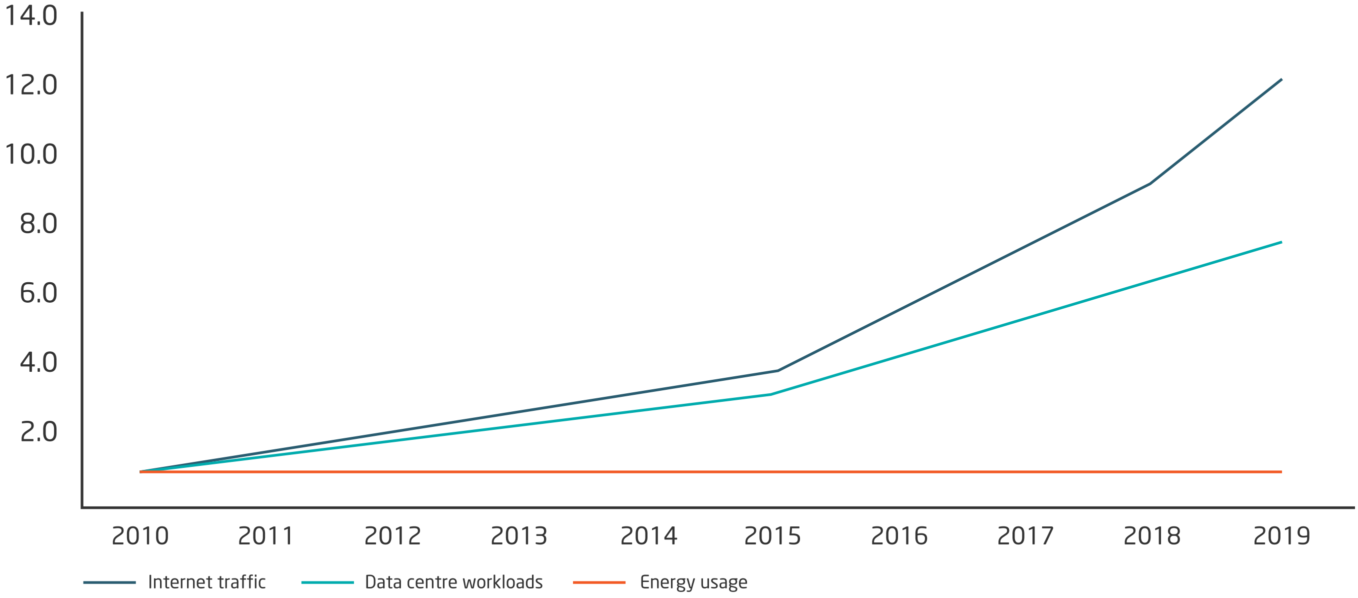
Data centres are intensive resource users, in their construction and particularly in operation. They may already account for up to 200 TWh of electricity per year globally, or ~1% of total electricity demand (IEA, 2020), and generate around 0.3% of the world's carbon emissions (Jones, 2018). For an individual data centre, power may represent 30-50% of operating costs, with cooling being the major power consumer at 35-40% (DatacenterDynamics, 2020) (Matteo Manganelli, 2021).

In recent years, data centre operators have made impressive energy efficiency gains, which have meant that total data centre energy consumption has stayed relatively flat–contrary to predictions of soaring power demands that were common a decade ago–while overall workloads have increased over seven times (see Figure 3) (IEA, 2020). This has been achieved through improved efficiency of IT equipment and data centre facilities (e.g., chip design, power infrastructure, cooling systems), largely led by the hyperscale cloud data centre operators like Amazon, Google, and Microsoft (Data Center Frontier, 2021).

Figure 3: Global data centre energy usage versus workloads and internet traffic

Data centre energy usage has stayed relatively flat despite enormous traffic growth

Global trends in internet traffic, data centre workloads and data centre energy use, 2010-2019 (Index, 2010 = 1.0)



Source: IEA (June 2020)

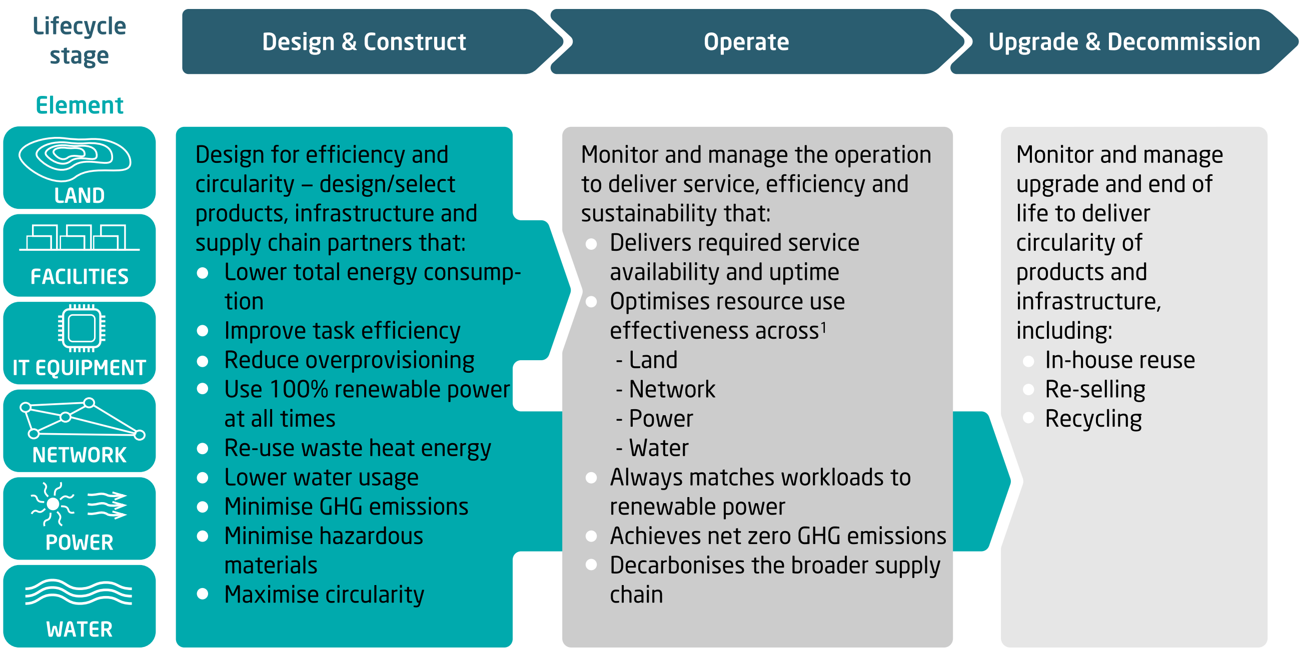
[5]Here we focus on Environmental Sustainability over the lifecycle of the data centre. We are not looking here at the Social and Governance elements required for a comprehensive ESG evaluation.

Many of the largest data centre operators have pushed further, aiming to use mostly renewable power[6] for their data centres – the hyperscale operators are leading the way, followed by the larger colocation data centre operators and managed service providers (Data Center Frontier, 2021), making them some of the largest corporate purchasers of renewable energy in the world (IEA, 2020). However, this is far from universal among data centre operators. Also, even though operators may cover 100% of their annual energy demand via renewable Power Purchase Agreements (PPAs) or Renewable Energy Certificates (RECs), this does not mean that they are using renewable power at all times of the day, every day of the year. Furthermore, meeting operating power demand with renewables is not sufficient for data centres to be considered fully sustainable over their entire lifecycle (see Figure 4).

Customers are pressuring data centre operators to do more and are increasingly wanting contractually binding commitments to efficiency and sustainability. In a recent survey, 30% of customers wanted demanding and contractually binding efficiency and sustainability commitments, with a further 44% expecting at least some efficiency and sustainability commitments in their contracts (Data Center Frontier, 2021). Google, for example, is expecting suppliers to work with them to achieve their goal of 24/7 carbon-free energy by 2030 (Google, 2020). European regulators are also considering binding environmental targets for data centre operators, particularly around carbon emissions.

Figure 4: A potential framework for considering data centre environmental sustainability

Data centre environmental sustainability considerations over the life cycle



Note: 1. Several groups consider potential to expand current data centre focus on Power Usage Effectiveness (PUE) to cover equivalent measures for Land, Network and Water

Sources: CEN/CLC/ETSI Joint Coordination Group Green Data Centres (2020); Datacenter Frontier (2020 & 2021); IDB (2020); Kass, S. and Ravagni, A., (2019); Schneider Electric (2021); Liebreich Associates

[6] Renewable power, here and through the rest of the paper, most commonly means wind and solar power, and it may also include geothermal and hydropower. This is distinct from other measures like "carbon-free energy" that Google has uses, which may also include nuclear power and, in certain circumstances, biomass (Google, 2021).

CHAPTER 2

WHAT ARE "GREEN GIANTS" AND WHY WE WILL NEED THEM

As demands for environmental sustainability becomes more widespread and more challenging, the approach to building hyperscale data centres needs to change. We will need a new breed of "Green Giant" data centres that have sustainability built into their site selection and embedded across their lifecycle.

European data centre operators must now focus on developing "Green Giants"

As a vision for the future, the next generation of hyperscale data centres will be "Green Giants" that deliver Tier 3-4 data centre requirements sustainably over their lifecycle, as in Figure 4. They will achieve this by:

- Being sufficiently large (>100MW) to generate economies of scale across multi ple elements and justify the investments to deliver the required services levels in an environmentally sustainable way
- Being located outside urban centres, at sites with appropriate characteristics as in Table 2, and with substantial expansion potential
- Being in regions with potential for large scale, low cost renewable power (preferably of two or more different types, to reduce supply variability and improve resilience), and with meaningful proportion of direct/private wire connection to the site–either onsite or nearby–to lock in low-cost power prices
- Being located within an electricity market with sufficient renewable power to supplement local supply and enable 24/7, hour-by-hour matching with workloads
- Securing additional renewable power for the region through direct investment or by stimulating investment (e.g., through long-term PPAs), to avoid displacing other renewable energy users
- Providing power resilience through zero-carbon power storage (e.g., batteries, hydrogen, compressed air, liquefied air storage, pumped hydro), avoiding the need for diesel generators
- Being close to key nodes of national power grid, allowing easy access to grid capacity and higher reliability of supply
- Deeply integrating into the regional energy ecosystem, and using their scale to provide ancillary services (e.g., reserve sharing, grid balancing) and/or monetise excess heat output (e.g., sharing with industrial customers)
- Employing or reusing existing infrastructure–including facilities, energy, cooling–and natural site features, such as a cool/cold climate
- Being designed and operating in a way that optimises resource use effectivness and sustainability across land, network, power, and water
- Being designed and built for environmental circularity from the outset

These characteristics are also included in Figure 5.

Figure 5: A checklist for potential Green Giant data centres

Green Giant data centre characteristics

- Large in size (>100 MW)
- Located outside urban centres, at sites with appropriate characteristics as in Table 2, and with substantial expansion potential
- Located in regions with potential for large scale cheap renewable power (two or more types), and with meaningful proportion of direct/private wire connection to the site – either onsite or nearby
- Have connection to sufficient renewable power to move to 24/7, hour-by-hour matching with workloads
- Secure additional renewable power for the region through direct investment or by stimulating investment (e.g., through long-term PPAs)
- Provide power resilience through zero-carbon power storage (e.g., batteries, hydrogen, compressed air, liquefied air storage, pumped hydro)
- Located close to key nodes of national grid power
- Deeply integrated into the regional energy ecosystem, providing ancillary services (e.g., reserve sharing, grid balancing) and/or monetising excess heat output (e.g., sharing with industrial customers)
- Exploit or reuse existing infrastructure–including facilities, energy, cooling–and natural site features
- Designed and operate in a way that optimises resource use effectiveness and sustainability across land, network, power and water
- Designed for environmental circularity, built in from the start

Sources: Liebreich Associates

Building and operating a Green Giant is particularly challenging, and few have/will achieve it in the near future. Green Giants will be an important part of the global solution to sustainably meeting the data growth challenge. And, while Europe has historically lagged behind North America in building hyperscale data centres, it now has an opportunity to ensure the next generation are Green Giants. Indeed, there are several European data centres that appear to be heading in the right direction[7]:

- Apple: Viborg (Denmark)
- Facebook: Odense (Denmark), Clonee (Ireland), and Luleå (Sweden)
- Google: St Ghislain (Belgium), Hamina (Finland), Dublin (Ireland) and Eem-
- shaven (Netherlands)
- Vantage Data Centers: Newport (Wales)
- Sines 4.0© (see case study below)

In each case, they have taken care to consider sustainability through all stages of construction, development, operation, upgrading and decommissioning. They are built in a way that is modular and expandable and have 100% of their total

[7]The largest known Colocation, Managed Service and Cloud data centres in Europe >50MW were considered against the vision criteria for Green Giants based on available external information. Therefore, this list may not be comprehensive and/or may overstate their sustainability credentials

power usage covered by installed/purchased renewable power–although they are not yet matching usage on an hour-by-hour basis–and seek to maximise energy efficiency during operation. Several of them repurpose existing infrastructure and provide excess heat back to the local communities and are supporting additional renewable energy investment through long-term PPAs with regional power companies. Obviously, owning and operating the data centre can make it easier to build a Green Giant, but this cannot limit us in future.

Lifecycle environmental considerations for all data centres

All aspects of data centre environmental performance must be considered across the full lifecycle of the facility. As previously mentioned, the historic focus has been on energy efficiency and, latterly, renewable energy mix. However, this is not sufficient if we consider the enormous growth in data centres expected, against the backdrop of increasing importance and customer pressure for sustainability.

Truly sustainable infrastructure is "planned, designed, constructed, operated, and decommissioned in a manner to ensure ... environmental (including climate resilience) ... sustainability over the entire lifecycle" (IDB, 2018). It integrates, restores, and preserves the natural environment, including biodiversity and ecosystems, supports the sustainable and efficient use of natural resources (energy, water, and materials) and limits all types of pollution.

In shifting to this lifecycle view, we must consider the pros and cons of choices regarding all elements in the data centres' construction, operation, and decommissioning as in Figure 4.

The design and construction phase plays the decisive role in deciding the operational efficiency and ability to upgrade and decommission data centres effectively. This has been demonstrated by the hyperscale data centre operators, particularly in the US, where companies like Facebook have rethought every element of the data centre design for operational efficiency and upgrading/decommissioning at their newer data centre facilities (Facebook, 2021).

In the design and construction phase, sustainability requires early collaboration between teams (e.g., Design, Technology, Sustainability, Operations, Procurement and Finance) to minimise the environmental impact of construction and create data centres with lower operational impact. For example, Design and IT Architecture collaboration is essential in seeking to integrate cleaner technologies into the building and facilities for IT equipment power and cooling systems. We must also consider waste stream accountability and the ability to re-use or recycle materials over the entire lifecycle. Data centres that are designed for peak environmental sustainability seek lower total energy consumption, improved task efficiency, to always use renewable power, recycle waste heat, minimise water usage and greenhouse gas (GHG) emissions and avoid the use of hazardous materials. During operation, it is essential to monitor and manage the operation to deliver the required service levels in a way that optimises resource use effectiveness across land, network, power, and water. This must go beyond the most common measures of data centre effectiveness (power- and water usage effectiveness) and consider whether the land is being efficiently and sustainably used and preserved as well as whether the network and communications infrastructure is fit for purpose and scale. They will also seek to match all workloads to renewable power on an hour-by-hour basis, achieving net zero emissions during operation, and work with partners to decarbonise the full supply chain.

CHAPTER 3
A GREEN GIANT CASE STUDY – SINES 4.0©

To further illustrate what we mean by a Green Giant data centre, we consider the case study of Sines 4.0©, which will be progressively developed in Portugal over the next six years.

start campus is developing a data centre for hyperscale in Sines, Portugal, with up to 495MW of capacity

Taking over a site neighbouring a decommissioned coal-fired power station at Sines, near Lisbon in Portugal, start campus and its backers[8] are taking advantage of the existing infrastructure and strategic location to develop a secure, 100% green and low-cost powered shell campus–Sines 4.0©–designed for hyperscale. With initial capacity planned beginning in early 2023, and expansion up to 495MW capacity by 2028, Sines 4.0© will be one of the largest data centre facilities in Europe.

Sines 4.0© will be a Green Giant and overcome many of the challenges faced in FLAP-D locations

Considering the typical data centre site selection criteria (Table 2), lifecycle environmental sustainability framework (Figure 4) and Green Giant characteristics (Figure 5), we can see how Sines 4.0© will achieve this:

- **Location** (land and surroundings): Sines is a regional town in an easily accessible location, being less than 1.5 hours from Lisbon, in a politically and climatically stable part of Europe. It is rarely subject to extreme weather and, given its mild climate, is resilient to natural events. Portugal is considered a very stable and safe country in southwestern Europe. The land is relatively inexpensive, compared with major European cities, and it also has significant potential for further expansion, given the site today and the surrounding available land.
- **Facilities and water:** Taking over an existing site provides immediate advantages. Much of the existing infrastructure can be repurposed, making it more sustainable from the outset. For example, using the legacy seawater cooling infrastructure from an adjacent LNG storage facility and the decommissioned coal-fired power plant means that new cooling systems do not need to be built. This natural form of cooling helps reduce the engineering PUE of the project to below 1.2. The further site development to Tier 3-4 hyperscale requirement levels is being done with sustainable materials in a modular way – each of the planned eight buildings can be built and operated independently, with its own backup power supply, cooling systems and connectivity.
- **Power:** The available power to the site will be 100% renewable, and some of the lowest cost power in Europe. Up to 1GW of solar PV is being developed on adjacent, owned land, delivered via private wire (60kV), locking in low-cost power (€ cents 3.0-4.0/kWh) over the data centre's life. Additional

[8] start campus is backed by Davidson Kempner Capital Management, a global institutional investment management firm with over $38 billion in assets under management, as well as Pioneer Point Partners, a pan-European sustainable infrastructure fund focused on energy, environment, water and green data centres.

- power requirements will be through green PPAs (delivered from the grid at 400kV), with gensets and batteries to provide resilience. There is also the potential to use excess heat and power from the site in the local industrial community.
- **Connectivity:** The site is well connected to Europe and the rest of the world through fast, fibreoptic connections. Subsea cables landing in Sines and Lisbon provide connectivity to North America, LatAm, Africa, Middle East and Asia with more developments planned soon. Existing dark fibreoptic cable networks provide connections to Europe, with low latency.
- **Skilled labour:** The team will create up to 700–1,200 jobs during ongoing operation. Many of these are expected to be filled by locals, through training programs to be developed with the local community.
- **Local stakeholders:** Both the local and regional Governments and communities are supportive of the project, with it already having confirmed status as a Project of National Interest (PIN).

These characteristics are also detailed in Figure 6 and Figure 7.

It is worth noting that the overall sustainability will be influenced by how the clients select and operate any equipment and infrastructure themselves at the site. However, the Sines 4.0© team expects to work closely with them to optimise things like matching workloads to renewable power and decarbonising the broader supply chain.

Figure 6: Sines 4.0© data centre site and location

Sines 4.0© is currently being developed in Portugal

- Sines 4.0© site located at Sines, Portugal in Southwest Europe, less than 1.5 hours drive from Lisbon
- Area covers 60 ha, with adjacent 1,500 ha owned for renewables
- Neighbouring a decommissioned coal-fired power station and other existing facilities surrounding
- Building a new data centre facilities for hyperscalers, that will have up to 495MW of capacity with 100% green energy
- First phase is expected to be ready for service early 2023

Sources: start campus

Figure 7: Sines 4.0© site elements and value proposition

Sines 4.0© will be a Green Giant data centre

Strategic location

- Southwest quadrant of Europe, with few hyperscale data centres
- Significant land available for expansion

Secure and resilient site

- Portugal considered very safe Not subject to extreme weather
- Designed to Tier 3-4 specs

Modular and scalable

- Plan for 8 buildings, each with 60MW and 32,000 m² usable space + 1 building of 15MW
- Each has own backup power supply, cooling systems and connectivity

Sines 4.0© delivers a hyperscale, secure, 100% green and low-cost powered shell campus

Supportive local stakeholders

- Project of National Interest (PIN) status confirmed
- Skilled workforce nearby

100% green energy

- Up to 1GW of solar PV on adjacent owned land, via private wire green PPAs, gensets & batteries; locking in low-cost power

Efficient cooling

- Repurposing existing, legacy cooling infrastructure and ocean water to deliver very low PUE

Highly connected

- Globally through subsea cables (e.g., EllaLink)
- Abundant terrestrial fibreoptic for low latency connection to rest of Europe

Sources: start campus

CHAPTER 4

GREEN GIANTS' ADDITIONAL BENEFITS TO LOCAL ENERGY ECOSYSTEMS

In addition to delivering massive computing workloads in an environmentally sustainable way and supporting the local communities through investment and jobs, Green Giants can make meaningful contributions to their local energy systems, supporting the broader transition to clean energy.

Stimulating additional renewable power investment in the region

While the unit costs of installing renewable power generation capacity have fallen rapidly, substantial capital outlays are still required. Green Giants can help support adding new renewable power to a region in several ways, many of which are enabled by their scale. They can directly invest to build their own renewable power capacity (e.g., building solar PV and/or wind turbine installations on their own land or in proximity), or enter into long-term agreements with third parties, which makes those parties' projects more bankable and stimulates more investment. These agreements can take many forms–including leases or Power Purchase Agreements of varying sorts (PPAs)–and the size and duration of the commitment helps generate the impetus to stimulate project development (RE-Source, 2020). We have seen this with several hyperscale players in Europe already, via their renewable PPA commitments delivering firm additional renewable generation. Importantly, the additional renewable power capacity is often more than required to serve the Green Giant and will therefore add net renewable power to the region.

The transition to more renewable power increases the demand for flexibility in energy systems

As previously mentioned, introducing significant levels of renewable power like solar PV and wind–common types of Variable Renewable Energy (VRE)–into energy grids causes issues due to their variability and uncertainty. In the transition to more renewable energy usage across Europe more system flexibility will undoubtedly be required, and providers of system flexibility will therefore be remunerated.

System flexibility can take several forms, including (NREL, 2015):

- System operating procedures and practices e.g., shifting to real-time forecasting
- Operational coordination between balancing areas e.g., reserve sharing, coordinated schedules and/or consolidated operations
- Demand response i.e., using price signals to shift demand in IT/other workloads, smart charging of electric vehicles and so on
- Storage, using batteries, pumped hydro, compressed or liquid air, hydrogen or other means

At VRE levels above around 30% of total supply, flexible demand and storage become particularly important (NREL, 2015). Europe is edging close to 20% on average, with several countries already over 20% (Spain, UK, and Germany) and 30% (Ireland, Denmark and Portugal), respectively (IEA, 2020) (IEA, 2021). And these levels are expected to continue increasing as investment in renewable energy continues, use of traditional thermal generation (e.g., coal, oil) declines and nuclear power plants are shut, in some case before the end of their potential useful lifetimes (BNEF, 2021). Therefore, today and in future, there will be a substantial need for ways to provide more energy system flexibility.

Green Giants can provide flexibility to the local energy ecosystem

Given their scale and investments they drive in infrastructure (e.g., renewable generation, storage, physical infrastructure), IT and operating/control systems, Green Giants will be able to provide meaningful flexibility into the local energy ecosystem. On the demand side, they could shift their workloads to match the availability of renewable power in the local area. They can do this by, for example, shifting non-time-sensitive workloads to times when there is lower power demand from others and high renewable power availability, or by shifting workloads to other data centres where there is excess renewable capacity (if they operate multiple data centres). Assuming they have significant power storage onsite and are drawing some renewable power from grid-connected sources, they could also use storage to power their sites in periods of lower renewable power availability. This would enable others to use the grid renewable power. On the supply side, they could use their power storage for grid balancing and reserve sharing, reducing the overall need for storage across the local energy system.

CHAPTER 5

COMPARING "GREEN GIANTS" WITH URBAN DATA CENTRES

As we consider two common types of large data centres expected in the future data ecosystem–Green Giants and Urban Data Centres–it is worth exploring some of the major differences between them and how this influences how we may use them.

Green Giants typically win on land, power and sustainability, but lose on latency

Comparing data centres is notoriously difficult – each data centre has its own specific requirements and build characteristics, and no two centres are identical. Furthermore, there are significant differences between whether you are running your own data centre versus using a colocation setup. However, we can consider a hypothetical situation for the sake of comparison: the same data centre either in an urban location like Paris or in a Green Giant like Sines 4.0© – with the same requirements and build, data traffic patterns and predominantly serving demand from Paris. Where would it make sense to build, and why?

From this hypothetical example, we expect the main areas of difference are in land, power, and connectivity (see Figure 8) and overall sustainability. In general, Green Giants have less competition in accessing key resources when compared to urban data centres, which compete against office, commercial and residential uses. Specifically, we would expect the Green Giants to be built where land is more easily available and at lower cost per square foot than their urban counterparts. That is certainly the case in the USA, and we are seeing similar trends in Europe (JLL, 2020). In terms of connectivity, we would typically expect there to be more connections available in urban areas. However, this is very site specific, and it may also be the case that there are bandwidth constraints in cities. Regional hyperscale data centres often setup their own connectivity, but typically bear the costs of doing so. We would also expect that traffic to local recipients–in this case in Paris–would be faster from the local data centre vs the regional one. When it comes to power, we see the main differences in the cost, access to power grid and availability of nearby renewables with Green Giants – something not generally possible in urban areas. Given the potential for greater flexibility in site and facility design, with the combination of these factors–such as more direct access to renewables and ability to design a site from scratch–we would also expect the potential for greater overall Green Giant sustainability.

Figure 8: Comparing similar hypothetical data centres at different locations

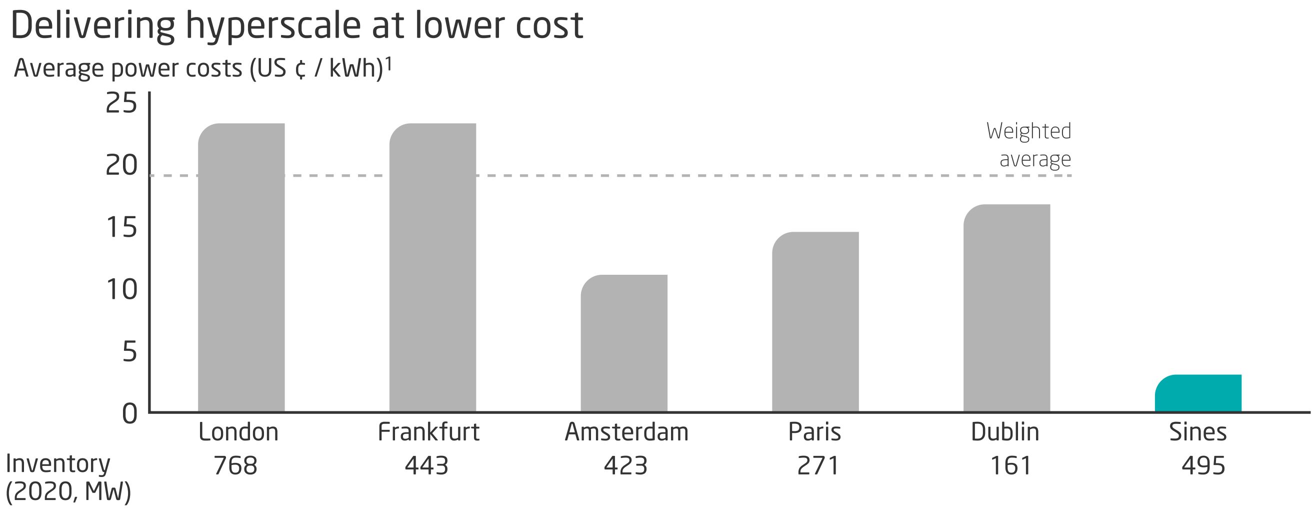
Green Giants versus urban data centres

Area	Urban data centre (e.g., FLAP-D market like Paris)	Green Giant data centre (e.g., Sines 4.0©)	Comments
Land and surroundings • Availability • Cost • Accessibility	●○○○ ●●●○ ●●●○	●●●● ●○○○ ●○○○	Physical land constraints and higher price per sq. ft. in FLAP-D locations; more accessible
Power • Availability • Cost • Renewables nearby	●●○○ ●○○○ ●○○○	●●●○ ●●○○ ●●●○	Power costs typically lower outside FLAP-D; also can be closer to renewable generation
Connectivity • Availability (# providers) • Cost • Latency/bandwidth	●●●○ ●●●○ ●●●○	●●○○ ●●○○ ●●○○	Lower latency (for local traffic) and potentially higher numbers of providers in FLAP-D locations
Water • Availability • Cost • Ability to use alt. cooling	●●○○ ●●○○ ●●○○	●●○○ ●●○○ ●●●○	Main difference in ability to use alternative cooling, where available
Skilled labour • Availability, ability to secure	●●○○	●●○○	Availability in FLAP-D locations offset by competition

Notes: more coloured dots = best scenario (e.g., higher availability or lower cost). Comparison assumes all else equal for two hypothetical data centres–the same size, equipment and other requirements, traffic patterns–except for location
Source: Liebreich Associates

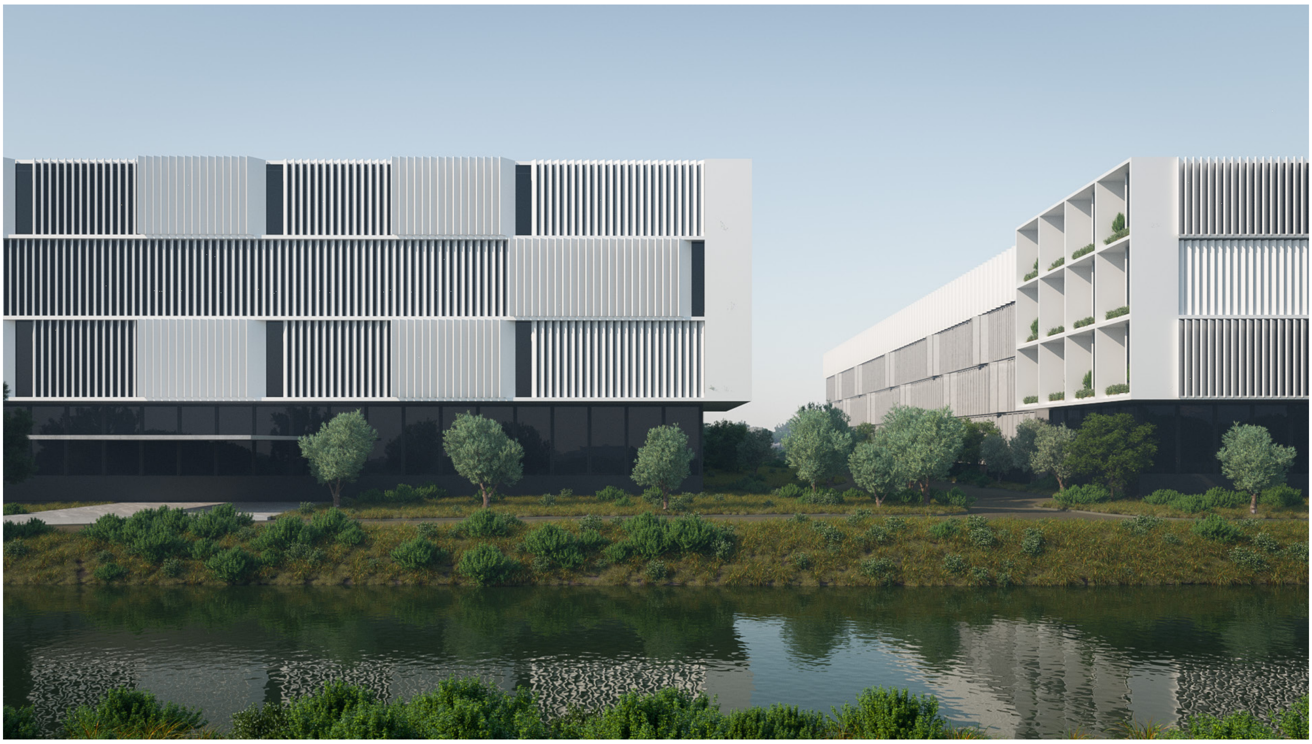
These differences can clearly have significant impacts on overall costs. Noting the aforementioned comparability challenges, if we focus on the specific component of power, we can see from Figure 9 that Sines 4.0© will have significantly lower power costs than an "average" FLAP-D location (JLL, 2020). Given that power costs are commonly 30-50% of cloud data centre operating costs, even if we consider the low-end of this range, operating with Sines-level power costs vs FLAP-D averages would reduce the overall operating costs by 20-25% versus the urban FLAP-D equivalent. It is also worth noting that the power costs can also end up being more stable over time – as Green Giants will source the bulk of their power through renewables, the nature of these investments and/or PPAs lock in power costs over a long period. This additional value can be significant, given volatility in European (thermal generation) power prices.

Figure 9: Power costs of Sines 4.0© versus FLAP-D markets



Notes: 1. Average power rates are average business energy rates for data centres in individual markets. These closely follow energy business rates but can include certain subsidies if applicable.
Source: JLL (2020), start campus

Taken together, these differences between Green Giants and urban data centres make them better suited to certain types of workloads.



CHAPTER 6

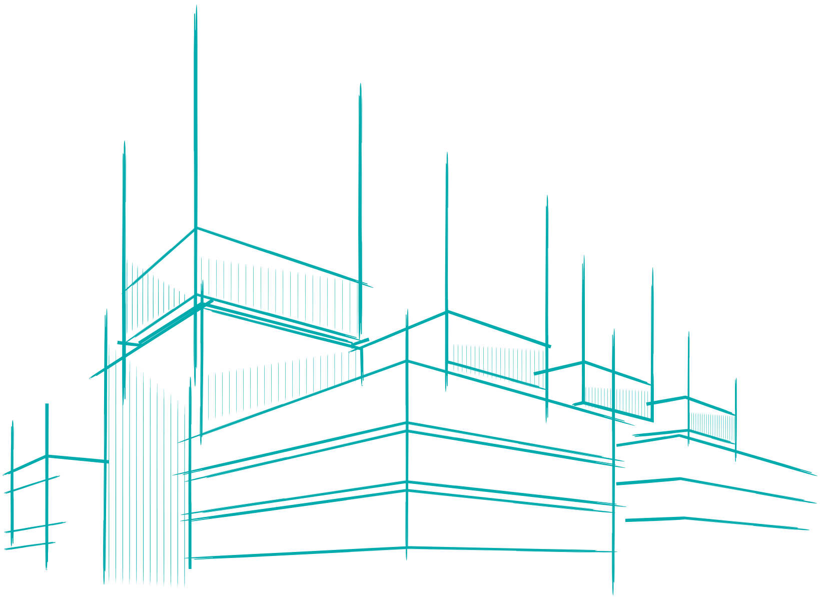
BUILDING THE FUTURE EUROPEAN DATA ECOSYSTEM USING GREEN GIANTS

As we explained throughout the paper, we expect there will be strong demand for Green Giants, and that they will deliver significant benefits to the European data ecosystem.

Delivering against the massive demand for data in an environmentally sustainable way will require a unified approach across data workload locations, with the potential for Green Giants to be at the core. By 2025, Gartner expects that 85% of IT infrastructure strategies will integrate multiple data workload locations (On-premises, Colocation, Cloud, and Edge delivery options), compared with 20% in 2020 (Gartner, 2020). Data centre operators should take the best of what Green Giants can offer–efficiency, sustainability, resilience, lower cost, benefits to their broader ecosystem etc–and integrate this into an overarching IT strategy focused on positioning workloads where they are most appropriate. This approach must take into consideration the specific application/data requirements for compliance, data protection, security, latency, resiliency, service continuity, location, availability, and performance to determine where best to undertake the work. For example, applications that require extremely low latency will remain based in Edge data centres located in urban areas closer to users, and other workloads can be shifted to Green Giants.

Moving to this workload-specific approach will likely require shifts in infrastructure, mindset, skills and technology, to ensure that the user and business outcomes are delivered in a seamless way. Managing interconnection between the various sites where workloads may be occurring–Endpoints, Edge, or Core Green Giant data centres–will be ever more important.

In conclusion, meeting Europe's ever-increasing appetite for data while simultaneously eliminating climate and other environmental impacts is certain to require the creation of a network of regional, environmentally sustainable, Green Giant data centres in Europe.



REFERENCES

- BMC. (2018, July 11). What is a hyperscale data center? Retrieved from BMC Multi Cloud Blog: https://www.bmc.com/blogs/hyperscale-data-center/
- BNEF. (2021). New Energy Outlook 2021. Bloomberg New Energy Finance.
- CBRE. (2021, August). Europe Data Centers, Q1 2021. Retrieved from https://www.cbre.co.uk/research-and-reports/European-Data-Centres-Q1-2021
- CEN/CENELEC/ETSI. (2020). Review of standardisation activities - Energy Management and Environmental Viability of Data Centres. CEN/CENELEC/ETSI Coordination Group on Green Data Centres.
- Cisco. (2021, September 6). What is a data center. Retrieved from Cisco: https://www.cisco.com/c/en_uk/solutions/data-center-virtualization/what-is-a-data-center.html#~types-of-data-centers
- Copenhagen Economics. (2020). INSIDE FINLAND: Google's European hyperscale data centres and infrastructure ecosystem.
- Cushman & Wakefield. (2020). European Secondary Markets: The Growth Story for the New Decade.
- Data Center Frontier. (2019, September). Hyperscale Data Centers. Retrieved from https://datacenterfrontier.com/wp-content/uploads/2019/09/DCF-Special-Report-Hyperscale-Data-Centers.pdf
- Data Center Frontier. (2020, September). Data Center Site Selection. Retrieved from https://datacenterfrontier.com/wp-content/uploads/2020/09/DCF-Special-Report-DC-Site-Selection.pdf
- Data Center Frontier. (2021, January). Green Data Centers. Retrieved from https://datacenterfrontier.com/wp-content/uploads/2021/01/DCF-Special-Report-Green-Data-Centers-2.pdf
- Data center models and their customers. (2018, December). Retrieved from dotmagazine: https://www.dotmagazine.online/issues/digital-infrastructure-and-transforming-markets/data-center-models
- Datacenter Frontier. (2020, December 14). The Tech Behind Microsoft's Sustainable Data Center Plan in Sweden. Retrieved from Datacenter Frontier: https://www.datacenterknowledge.com/energy/tech-behind-microsoft-s-sustainable-data-center-plan-sweden
- Datacenter Frontier. (2021, May 18). Google Moving Workloads Between Data Centers to Use Greener Energy. Retrieved from Datacenter Frontier: https://datacenterfrontier.com/google-moving-workloads-between-data-centers-to-use-greener-energy/
- DatacenterDynamics. (2020). The Future Data Centre - Trends in smart data centre design and contruction. Enterprise Ireland.
- Facebook. (2021, August 26). Embedding Circular Thinking in Data Centers. Retrieved from Facebook Sustainability: https://sustainability.fb.com/wp-content/uploads/2020/12/FB_Embedding-Circular-Thinking-in-Data-Centers.pdf
- Gartner. (2020, September 17). Your data centre may not be dead, but it's morphing. Retrieved from Gartner: Your data centre may not be dead, but it's morphing
- Google. (2020, September). 24/7 by 2030: Realizing a Carbon-free Future. Retrieved from Data center sustainability: https://sustainability.google/progress/energy/
- Google. (2021, September 17). CARBON-FREE ENERGY – Operating on 24/7 Carbon-Free Energy by 2030. Retrieved from Google Sustainability: https://sustainability.google/progress/energy/

- Google. (2021, September 29). Efficiency. Retrieved from Google Data Centers: https://www.google.com/about/datacenters/efficiency/
- Google. (2021, August). Sustainability at Google. Retrieved from Operating on 24/7 Carbon-Free Energy by 2030. : https://sustainability.google/progress/energy/
- Grant Thornton. (2018). A Study of the Economic Benefits of Data Centre Investment in Ireland.
- Hagaseth, S. A. (2020, January 29). Green Mountain Blog. Retrieved from Changing requirements in the European data center market: https://greenmountain.no/2020/01/29/european-data-center-market/
- IDB. (2018). What is Sustainable Infrastructure? A Framework to Guide Sustainability Across the Project Cycle. Technical Note.
- IDC. (2018). The Digitization of the World - From Edge to Core.
- IDC. (2021, June). Volume of data/information created, captured, copied and consumed worldwide from 2010 to 2015. Retrieved from Statista: https://www.statista.com/statistics/871513/worldwide-data-created/
- IEA. (2020, June). Data Center and Data Transmission Networks. Retrieved from https://www.iea.org/reports/data-centres-and-data-transmission-networks
- IEA. (2020). Secure Energy Transitions in the Power Sector.
- IEA. (2021). Portugal 2021 Energy Policy Review . International Energy Agency.
- JLL. (2020, December). 2020 Year-end Data Center Outlook. Retrieved from https://www.jll.co.uk/content/dam/jll-com/documents/pdf/research/jll-2020-year-end-data-center-outlook.pdf
- Jones, N. (2018, September 13). The Information Factories: Data centres are chewing up vast amounts of energy – so researchers are trying to make them more efficient. Nature, 561, 163–166.
- Matteo Manganelli, A. S. (2021). Strategies for Improving the Sustainability of Data Centers via Energy Mix, Energy Conservation, and Circular Energy. Sustainability, 13(11).
- NREL. (2015, May). Integrating variable renewable energy into the grid: key issues. Retrieved from National Renewable Energy Laboratory: https://www.nrel.gov/docs/fy15osti/63033.pdf
- NREL. (2015, September). The role of storage and demand response. Retrieved from National Renewables Energy Laboratory: https://www.nrel.gov/docs/fy15osti/63033.pdf
- PWC. (2021). BCO Network Outermost Regions workshop - Submarine connection considerations .
- RE-Source. (2020). Introduction to Corporate Sourcing of Renewable Electricity in Europe.
- Synergy Research. (2021, January). Hyperscale Cloud Market Tracker.
- ZDNet. (2020, December 15). Google promises to expand its data centers, not its carbon footprint. Retrieved from ZDNet: https://www.zdnet.com/article/google-promises-to-expand-its-data-centers-not-its-carbon-footprint/

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