environmentanalyst

Corporate Guide: Delivering Sustainable Data Centres

November 2025

Introduction

Welcome to our Corporate Guide on Delivering Sustainable Data Centres. This guide brings a wealth of experience from environmental and sustainability consultants who have been advising data centre clients globally.

Global investment in data centres is surging on the back of rapid expansion of AI, big data analytics, and growth of large-scale computing and data-storage systems. Investment – by the likes of Amazon, Microsoft, Google, Meta, Apple, Alibaba and Tencent – is expected to reach nearly $300bn 2027 and more than $1tr by 2029.

By 2030 it is expected that data centres globally will use double the amount of electricity they did in 2022, reaching up to 1,050TWh/year.

This level of investment and energy demand will require careful and considered strategies and planning. The demand for land, energy, water, nature conservation and the needs of local communities will have to be balanced with the rewards of delivering big tech.

Operators face a complex set of risks that need to be factored into investment and design decisions.

The next few years will be critical, and this guide aims to introduce the big issues and explain how companies involved in delivering data centres can navigate the path to growth sustainably and with resilience.

The opening chapter, authored by **Ramboll**, highlights the importance of thorough planning and strategic site selection to ensure the long-term success and efficiency of projects. Selecting the right site for a hyperscale data centre is complex but crucial, it says. By carefully evaluating various factors, stakeholders can ensure long-term success and efficiency of projects.

Designing energy-resilient data centres from the outset is an important starting point. In the second chapter, **Bentley Systems** describes how the next generation of data centres will look very different to today's. The company says they will be increasingly autonomous, flexible and low-carbon, functioning not as isolated power users, but as integrated parts of smart, distributed energy systems.

The third chapter focuses on water use. Ramboll outlines why water is a critical utility for data centre developers and what considerations they need to make. It looks at potential solutions to water provision, and how local communities need to be involved.

Ramboll also provides the fourth chapter on the growing recognition that biodiversity and nature-based solutions (NbS) are critical to future-proofing data centre development and operations. It demonstrates how integrating biodiversity and NbS into data centre projects is a strategic investment.

Turning to the built data-centre, in chapter five, **Arup** looks at whole life carbon emissions, especially embodied carbon from materials and equipment. By taking action early the consultant says organisations can meet the challenge of tackling embodied carbon throughout an asset's lifetime.

In chapter six, Bentley Systems outlines how digital twins can be used to provide dynamic, real-time representations of physical assets, systems or environments, enabling data centres to be monitored and performance optimised, to improve efficiency, sustainability, and transparency with stakeholders.

Addressing community opposition to data centres is tackled in the last chapter, as Arup challenges the sector to change its narrative, by addressing gaps in knowledge. It says there is an opportunity to also create tangible benefits for communities and wildlife – and for data centres to become a preferred development partner for planning authorities worldwide.

Thank you to all of our contributors for sharing their expertise throughout this guide. We hope you find the content valuable and welcome your feedback. To get involved with future guides, or suggest topics for us to cover, please get in touch.

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Contents

Credit: Ramboll

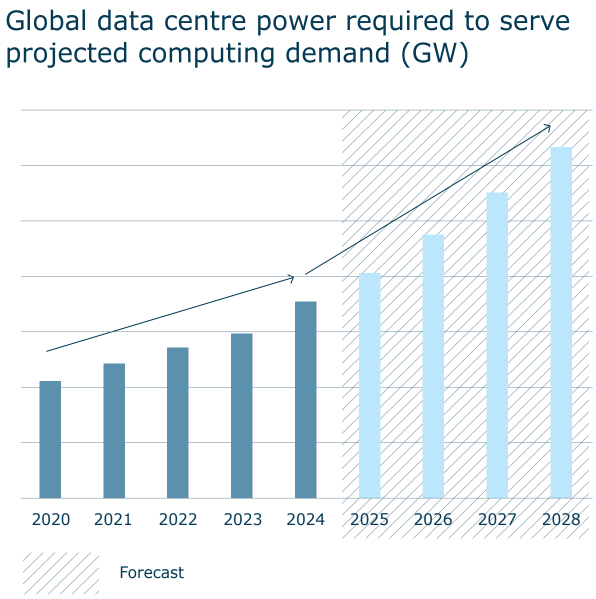
Chapter 1: The importance of site selection

Selecting the right location for hyperscale data centres is an essential step in the development process. The chosen property can significantly impact the overall success, especially as AI-powered solutions continue to develop, driving unprecedented growth of hyperscale data centres (see **Figure 1**).

Careful site selection is crucial. Neglecting early-stage assessments can hinder progress, often causing delays during the pre-acquisition phase. Without due diligence, commercial decisions become uncertain, making it challenging to evaluate land opportunities. In worst-case scenarios, this can lead to time and resources being wasted on unfeasible sites. Site selection due diligence can help to avoid time and cost intensive design changes at later planning stages that could have been addressed already at an early stage.

Effective site selection requires a thorough evaluation of technical, environmental/regulatory, and social aspects for the desired location.

Global demand for data centre power continues to be in the high growth mode and key players are investing massively in the sector to meet the need



Rapid growth ahead — **16%**
Demand for data centre computing power is surging and expected to grow at 16% CAGR from 2023-2028

Gen AI's role in growth — **65%**
While GenAI presents the fastest growing workload segment with a 65% CAGR from 2023-2028, traditional enterprise workloads will continue to represent the majority – roughly 55% in 2028 – of the data centre power demand

Clients — **60%**
Hyperscalers will generate around 60% of the industry's growth from 2023-2028 and increase their share of global demand for data centre power from 35 to 45%

Regional dynamics — **18%**
The US share of global data centre demand will grow with a 18% CAGR from 2023-2028 and will continue to be the largest market for installed capacity

Sources: 2025 trends in datacenter services & infrastructure, S&P Global Research 2025; Breaking barriers to data center growth BCG 2025; How AI's transformative impact on data centers is driving unprecedented industry growth, innovation and global expansion, Data Center Frontier 2025

Figure 1.

Technical considerations

1. Power

Reliable and abundant power supply is the backbone of data centres. Sites must have access to a stable and scalable power grid or on-site power generation to support both current and future energy demands. Evaluating the proximity to power plants and substations, along with the availability of renewable energy sources, can enhance sustainability and cost-efficiency. Developers must thoroughly assess power reliability and redundancy to prevent downtime.

Power needs for data centres are substantial. A typical hyperscale cloud data centre can consume **between 30 to more than 100 megawatts (MW)**, depending on its size and services. In contrast, AI data centres, which require more processing power for complex computations and machine learning tasks, can demand upwards of 200 MW. Based on Ramboll's project experience, hyperscale clients are looking at power supply up to 600 MW. This significant demand underscores the importance of selecting sites with robust and reliable power infrastructure.

Innovative solutions for both off-site and on-site power are being developed, including **microgrids**, battery energy storage systems (BESS), small modular nuclear reactors (SMR), hydrogen fuel cells, and natural gas fired power plants. Ramboll's experience in the data centre industry shows that clients are increasingly open to alternative and hybrid solutions for their growing power supply needs.

2. Connectivity

Connectivity is the lifeline of a data centre. Evaluating the availability of high-speed and reliable broadband providers is essential to ensure reliability. Proximity to major network hubs and fibre routes can significantly impact latency and performance, especially for cloud data centres. For AI data centres, latency is less critical.

> Developers must thoroughly assess power reliability and redundancy to prevent downtime.

3. Security

Both physical and cyber security are crucial for data centres. Sites should provide robust physical security measures like surveillance, access control, and perimeter security. Developers should assess proximity to emergency services and law enforcement agencies. Cybersecurity infrastructure, including secure network connections and data protection measures, is essential to safeguard sensitive information.

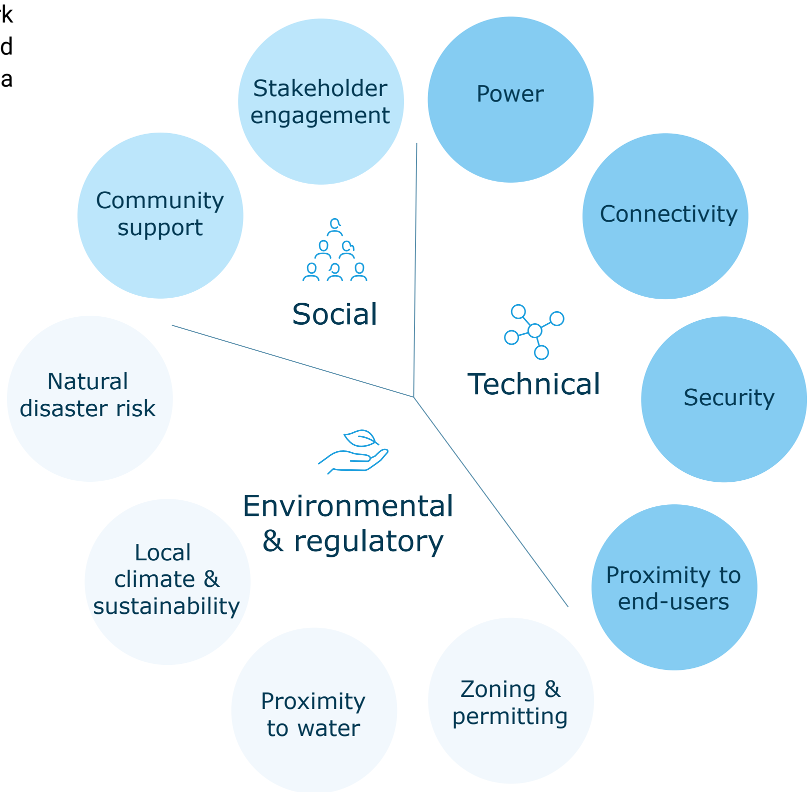
4. Proximity to end-users and industry ecosystems

The location of a cloud data centre should be strategically chosen to minimise latency and enhance connectivity for end-users. Proximity to major urban centres, business districts and industry clusters significantly improves performance and accessibility. Being near industry ecosystems facilitates collaboration and integration with other businesses and technology providers.

Hyperscale data centres are typically built in metropolitan or capital regions, such as Frankfurt, London, Amsterdam and Paris (FLAP markets), and Arlington, Virginia, but also increasingly in secondary regions in Southern Europe, some other US States and Asia-Pacific.

As latency is less critical for AI data centres, there are further opportunities in other regions like Northern Europe. Developers can consider sites in more remote areas and benefit from advantages like consistent temperatures, higher water availability, better off-heat infrastructure, and abundant renewable energy.

Data centre siting considerations



Environmental and regulatory considerations

1. Zoning and permitting

Zoning regulations and permitting processes are foundational to the development of data centres, ensuring compatibility with surrounding environments. Zoning laws define where data centres can be built, often as industrial or special-use facilities, and impose restrictions on building height, setbacks, air and noise levels to protect community interests. Developers must navigate these rules early in the planning phase to avoid costly redesigns or rejections.

The permitting process involves securing various approvals, including building, planning, environmental, and utility permits, and requires time. These are essential to meet structural, safety, and environmental standards. Permitting processes, including environmental impact assessments, are key factors in site selection, affecting the speed to operation. Thus, understanding and complying with permitting frameworks is crucial.

In Europe, **Directive (EU) 2024/2881**, issued in October 2024, focuses on air quality and clean air, with specific stipulations for data centres. It must be transposed into national legislation by December 2026 and will influence site selection, technical design and costs by stipulating chimney heights, setting limits on air pollution, and potentially influencing operation time.

In the US, new air and noise regulatory legislation, like **Virginia's SB 1046**, mandate strict noise abatement measures, including baseline acoustic studies, ongoing noise monitoring, and public notification of generator use. These regulations reshape site selection strategies, requiring developers to consider long-term compliance and mitigation costs. Cities like Phoenix have already **adopted specific zoning and noise ordinances**, signalling a trend toward localised regulation. Early engagement with local authorities and communities, along with proactive environmental planning, is essential for successful data centre deployment.

> Early engagement with local stakeholders is essential for building trust and securing approvals

2. Proximity to coolant infrastructure and water

This point is closely interlinked with climate change and resilience strategies. Data centres generate substantial heat, necessitating efficient cooling systems for optimal performance. Proximity to coolant infrastructure, such as chilled water plants, can save costs. Access to abundant and sustainable water sources is essential for water-based cooling systems. Evaluating the availability and sustainability of these resources is vital for long-term operational efficiency, especially in drier regions and where water is a valuable resource and local policies or national water strategies may affect major water users.

3. Local climate and sustainability considerations

The local climate significantly impacts the operational efficiency of a data centre. Cooler climates reduce cooling costs by utilising natural air for optimal temperatures, while warmer regions incur higher energy costs due to constant artificial cooling. Understanding the local climate and its impact on operational expenses is crucial for site selection.

4. Natural disaster risk

Assessing natural disaster risk is essential when selecting a site. Data centres should be located in areas with minimal risk of earthquakes, floods, sea level rise, severe storms, fires, droughts, and other severe weather events. A comprehensive risk assessment ensures the site's resilience against disruptions. Building data centres in low-risk zones safeguards infrastructure and ensures uninterrupted operations. A recent detailed natural disaster risk assessment undertaken by Ramboll revealed that certain geographical regions are unsuitable for hyperscale data centres due to climate risks. Additionally, evaluating the resilience of supply infrastructure, site accessibility in case of flooding, and the robustness of power infrastructure such as transmission lines and masts, is critical during site selection.

Social considerations

1. Community support

Community support and local political dynamics are increasingly pivotal in determining data centre project success. As hyperscale and AI-driven facilities expand, they often face resistance from local communities concerned about environmental impact, air and noise emissions, land use, and energy consumption.

This phenomenon, known as **data centre NIMBYism** ('not in my back yard'), has led to the delay or cancellation of projects worth billions of dollars in the US alone. Opposition is particularly strong in northern Virginia, which hosts more data centres than any other state. According to **Inside Climate News**, $900 million in proposed data centre projects have been blocked in Virginia, with an additional $45.8 billion in projects experiencing delays.

2. Stakeholder engagement

Early engagement with local stakeholders through transparent communication, public consultations, and community benefit programs is essential for building trust and securing approvals. Regions with supportive local governments, especially those transitioning from coal or industrial economies, are more likely to welcome data centres as part of broader economic revitalisation strategies. Building partnerships with municipalities and aligning with local development goals can foster goodwill and smooth the path for long-term operations. For example, Microsoft's positive relationship with the municipalities in North Rhine-Westphalia (see news articles in **German** and **English**) showcases the impact. Ramboll's experience indications that a positive relationship with local authorities can be the final determining factor in being awarded a site.

Best practices and tools for optimal site selection

Successful site selection involves a combination of strategic planning, analytical tools, and stakeholder collaboration. The following processes and tools can aid in identifying the optimal site for a data centre:

1. **Geospatial analysis:** Use geographic information systems (GIS) to analyse spatial data and identify suitable sites.

2. **Due diligence:** Conduct thorough assessments covering environmental, power and technical aspects.

3. **Cost-benefit analysis:** Determine the most cost-effective option by analysing construction, operational and energy expenses.

4. **Stakeholder engagement:** Collaborate with local authorities and community stakeholders to gather insights and ensure alignment.

5. **Sustainability assessment:** Evaluate the environmental impact and alignment with sustainability goals.

Key takeaways

- Reliable power and connectivity are essential.
- Early engagement and compliance with regulations can prevent delays.
- Assessing the local climate and natural disaster risks ensures site resilience.
- Community support is pivotal for project success.
- Use strategic processes and tools for effective site selection.

These points highlight the importance of thorough planning and strategic site selection to ensure the long-term success and efficiency of hyperscale data centre projects. Selecting the right site for a hyperscale data centre is complex but crucial. By carefully evaluating various factors, stakeholders can ensure long-term success and efficiency of their projects.

This chapter was authored by Dr Andrea Merkle, Director, Global Environment & Health Data Centre Sector at Ramboll.

Chapter 2: Designing energy-resilient data centres

Introduction

Global data centre demand is accelerating at a pace not seen before, largely driven by the expansion of artificial intelligence and high-performance computing. These workloads require dense clusters of servers and intensive cooling, placing significant strain on electricity supply and local infrastructure.

Current estimates suggest that data centres account for about 1% of global electricity use, and the International Energy Agency says this could double by 2026. The IEA projects that carbon dioxide emissions from data centres – based on the energy consumption – will peak at approximately 320m tonnes/year by 2030 and decline to 300m tonnes by 2035.

Operators and policymakers must address the rising need for these facilities while maintaining secure and sustainable energy use, and minimising negative effects associated with their construction and operation. Energy resilience is essential, addressing cost, uptime, sustainability, regulatory compliance and community acceptance.

Several digital tools offer practical pathways to achieving this. Digital twins, building information modelling (BIM), and advanced energy management platforms enable data centre leaders to model energy flows, test infrastructure designs under stress conditions, and optimise operations in real time. Embedding these solutions early is critical to ensuring that new and existing facilities remain both resilient and future-ready.

The energy resilience challenge

The rapid scaling of digital infrastructure is colliding with limits in grid capacity and natural resources. For operators, this creates a complex risk landscape that must be factored into investment and design decisions.

In many regions, transmission and distribution capacity has remained static for decades, while new energy-intensive data centres add sudden, large loads.

> Embedding these solutions early is critical to ensuring facilities remain resilient and future-ready.

The US Department of Energy (DOE) estimates that data centre load growth has tripled over the past decade and is projected to double or triple by 2028. In Europe, electricity demand from data centres is projected to rise by 150% between 2024 and 2035, according to the energy think tank **Ember**. And in the APAC region, especially in China, Singapore and Malaysia, the **IEA** expects demand to double by 2030.

Existing energy infrastructure is not prepared for this scale of sudden growth, causing grid congestion. Interconnection waiting times can, at times, exceed ten years.

High electricity demand drives up data centres' use of water for cooling. This strains relationships with local communities, especially in water-scarce areas. Regulators now require operators to prove efficiency and sustainability before approving new projects.

The need for large amounts of water and power increases their carbon footprint, making energy resilience more important. Air cooling alternatives are less energy efficient.
Locating data centres close to communities or sensitive areas raises concerns, as choosing the right site often means balancing grid access and water supply with potential environmental and social impacts.

Areas with abundant green power may lack adequate grid capacity. Regions with strong connectivity may face severe water stress and pushback from local stakeholders.

Siting also affects climate risk exposure. As these risks grow, their proper consideration helps to mitigate threats like higher cooling demands from rising temperatures and direct hazards to data centre uptime from flooding, wildfires and storms.

Data centre energy management is dependent on cost dynamics, which are currently shifting due to new rate structures that penalise peak time demand, while incentives for large energy users are being reduced.

At the same time, reliance on backup fossil fuels is becoming more expensive and less socially acceptable. Rising operational costs and reputational risks place further pressure on operators to integrate renewables, storage and advanced energy management.

Principles of energy-resilient design

Designing for energy resilience requires an integrated approach that balances operational continuity with cost-efficiency, lifecycle sustainability and community acceptance. The principles that follow provide a framework to future-proof data centre infrastructure across the lifecycle.

Efficiency by design
Reducing baseline demand remains the most effective strategy for resilience. By adopting low-power IT equipment, consolidating workloads and optimising power distribution from the planning stage onwards, energy intensity can be lowered significantly.

Electrical resilience refers to the process of maintaining accurate voltage regulation and minimising harmonics, which contribute to equipment protection and reduced overall energy loss.

Modern data centres can also be designed to adjust their electricity demand dynamically, reducing loads or shifting non-critical workloads during periods of grid stress. This flexibility alleviates pressure on electricity networks, particularly in areas with variable power generation like wind energy and high peak demands. In this way, data centres can act not only as energy consumers, but as stabilising partners for the wider grid.

Energy efficiency also directly reduces water use and carbon footprint. Water-efficiency can be further improved using recirculating systems. And non-potable water minimises dependence on drinking water and lessens environmental impact.

> Energy-resilient data centres are flexible, allowing operators and suppliers to adjust their operations for cost-effective and sustainable outcomes.

Energy diversification and flexibility
Relying on a single grid connection exposes operators to outages, congestion and volatile energy costs. Past grid failures have shown how overdependence on one energy source or line can create systemic vulnerabilities.

To minimise risks, robust designs incorporate various power sources - like on-site renewables, off-site agreements and hybrid backups - and use multiple transmission lines or substation components to avoid single points of failure.

In some areas, geothermal energy provides stable, low-carbon power year-round, supporting intermittent resources like wind and solar. Groundwater cooling also enables heat captured from data centres to be stored and used for heating in colder seasons.

Energy flexibility may be also described as a bidirectional system that extends beyond data centre boundaries. Alignment with local energy systems provides an opportunity for waste heat reuse, for example, in district heating, which turns a liability into a community asset. This helps reduce operational emissions, improves return on investment (ROI) and community acceptance.

Scalable and modular builds
With ongoing uncertainty in load growth, data centre owners should prioritise flexible, modular designs that support expansion with minimal environmental and community impact.

Unpredictable AI and digital service needs increase the risk of both wasted capacity and shortages. Modular builds let operators add resources gradually, match spending to actual usage, and easily integrate new technologies like advanced storage or hydrogen backup. This may permit faster grid interconnection by incrementally increasing the power demands.

Digital solutions as enablers

Energy-resilient data centres are flexible and adaptable to changing conditions, allowing operators and suppliers to adjust their operations for cost-effective and sustainable outcomes.

Given the complexity of this, they are increasingly dependent on the intelligent use of software and data. Digital tools make it possible to test resilience before construction, run multiple scenario simulations, and optimise operations in real time to demonstrate value to regulators and communities.

Digital twins and advanced planning tools enable the modelling of site layouts, grid integration and energy-water trade-offs. They also facilitate interoperability testing across systems and assessment of various power supply options.

A case study from Google's Nevada data centres shows how modelling tools can support sustainable power solutions. Geospatial analysis tools support resilient design by enabling teams to assess terrain, water stress, renewable resources and community effects.

Scenario analysis extends this by comparing costs, emissions and resilience outcomes before ground is broken, giving decision-makers a comprehensive view of trade-offs.

CASE STUDY

Geothermal innovation powering Google's data centres

In Nevada, Google partnered with Fervo Energy to pioneer next-generation geothermal power for its data centres. By combining Seequent's subsurface modelling with Fervo's fibre-optic sensing and advanced drilling, the project delivered a reliable, low-carbon baseload supply. This innovation also demonstrates that geothermal energy can now be sourced beyond traditional tectonic boundaries, expanding opportunities to power data centres sustainably in more regions.

During operations, a data-centric approach supports real-time monitoring of system parameters, cooling and airflow optimisation, predictive maintenance and stronger information management.

These insights feed into resilience modelling, where facilities can stress-test their performance against extreme weather, grid volatility and failure scenarios. A Missouri case study shows how using digital twins enabled quick repairs of a flood-damaged transmission tower, demonstrating the benefits of digital solutions in infrastructure maintenance.

CASE STUDY

Digital twins safeguard power resilience

Exo Inc used Bentley's iTwin Capture and Power Line Systems applications to create a digital twin of a flood-damaged transmission tower in Missouri. Drone surveys enabled rapid modelling and structural analysis without de-energising the line, ensuring hospitals retained power during the pandemic. The digital approach saved four to six weeks, avoided dangerous fieldwork, and demonstrated how digital twins strengthen grid resilience against ageing infrastructure and environmental threats.

Digital platforms also enable grid interaction modelling, optimising storage, microgrid operation and demand-response participation. Visualisation tools improve transparency with stakeholders, building trust and accelerating approvals.

A case study from Finland demonstrates how AI-driven forecasting, when combined with digital twins, can enhance operations by predicting demand and system behaviour. Smart visualisation also improves understanding of the latter and fosters better cooperation among stakeholders.

CASE STUDY

AI-driven digital twin optimizes heating networks

Silo AI leveraged Bentley's iTwin Platform to create Silo Flow, a digital twin and AI-based optimization service water and district heating networks in Finland. By consolidating scattered data, the tool predicts leaks, prioritizes maintenance, and optimizes heat balance, cutting fuel use and lowering supply temperatures. Such smart infrastructure management demonstrates how digital twins can enhance energy resilience and efficiency in urban utilities—capabilities equally vital for supporting energy-intensive facilities like data centres.

Challenges and risks
While digital solutions offer powerful and practical ways to support energy-resilient data centres, they also introduce new challenges that must be managed carefully.

Digital twins, monitoring platforms and forecasting tools are only as effective as the data input. Data and interoperability gaps keep systems siloed, as incompatible standards from different vendors hinder integration across design, operations and utilities.

The financial case can also be complex. High capital costs, training and ROI uncertainty discourage some operators from adopting advanced digital tools. Advanced digital design tools add upfront costs. But they lower expenses during development and operations by improving processes and reducing rework.

While benefits like reduced downtime, efficiency gains or faster permitting are real, they may be difficult to quantify in advance, particularly for smaller operators with limited budgets.

Regulations add complexity. Inconsistent policies and rules across regions - such as for data-sharing and grid interconnection - create uncertainty for multinational operators and slow compliance and adoption.

Greater connectivity also introduces cybersecurity risks. As infrastructure becomes more digital, the attack surface expands, requiring stronger defences against intrusion, manipulation of control systems or data breaches.

Core practices for digital-enabled energy resilience
While digital tools are effective at diverse solutions to any challenges associated with energy resilience, their adoption requires planning and awareness of boundary conditions, requirements and prerequisites.

Key core practices for successful implementation of digital solutions in data centre energy management are presented in Figure 1.

Step 1. Define resilience objectives Whether beginning from the design phase or operational stage, set clear priorities such as uptime, renewable energy integration, water usage and carbon emissions limits to guide the digital strategy.
Step 2. Collaborate with utilities early Address interconnection, capacity, and flexibility, explore synergies and co -develop solutions that support clean, reliable power.
Step 3. Integrate digital solutions from the outset Embed digital strategy and data management from the earliest planning stages to optimize collaboration, optimization and efficiency in all life cycle stages. This is especially important for scalable projects that may be fully constructed over several years.
Step 4. Build operational visibility and intelligence Implement real-time monitoring, interoperability, and predictive maintenance to improve efficiency and reliability.
Step 5. Make resilience an ongoing process Utilize digital tools for forecasting and monitoring to connect design with operations. Regularly test systems against weather, grid issues, and equipment failures, using the results to enhance daily functions and plan future growth.
Step 6. Strengthen community and stakeholder trust Use transparent data and visualization tools to demonstrate efficiency and community benefits.

Figure 1. Key steps to effectively implement digital solutions throughout the data centre lifecycle.

Looking forwards

The next generation of data centres will look very different to today's. They will be increasingly autonomous, flexible and low-carbon, functioning not as isolated power users but as integrated parts of smart, distributed energy systems.
By interacting dynamically with utilities and renewable generation, future-ready facilities will help stabilise electricity networks while ensuring their own operational resilience.

Reusing waste heat and circular water management are expected to become industry standards, transforming resource challenges into benefits for local communities.

Facilities that supply heat to adjacent districts or use near-closed-loop water systems will not only reduce their environmental footprint, but also enhance their social licence to operate.

At the heart of this transformation will be software-defined energy management. Digital twins, AI forecasting and smart-grid interfaces will make it possible to coordinate demand, storage and renewable supply in real time.

Energy-resilient data centres are therefore not just a technical ambition but a cornerstone of sustainable digital infrastructure, enabling the growth of AI and the cloud while aligning with global net-zero goals.

This chapter was kindly authored by Saila Vicente, Sustainability Manager, Dave Lewis, Solution Manager, Nicole Pearson, Director, Industry Marketing, and Rodrigo Fernandes, Director, Sustainability at Bentley Systems.

Chapter 3: Managing and reducing water consumption in data centres

Power, cooling, physical security, and network connectivity are all core design considerations for data centres. Water is a critical utility when used for cooling. There may also be competing demands on the resource, from local communities, for example. A number of issues are therefore key to effective water management of centres, including resilient operations, sustainable use and environmental compliance.

As the number of data centres rapidly expands, projects are entering increasingly complex, and circular, local water cycles (see Figure 1). The affected water and wastewater treatment utilities have an existing customer base (including residential and other industries), an active investment strategy for infrastructure, and established organisational capacity and anticipated schedules for development.

When water is proposed for cooling at new data centres, key factors include:

- Shortest time to delivery of water and wastewater services
- Best use of community water resources
- Waste management
- Operational complexity and reliability of water systems (on-site and off-site)
- Impact on energy consumption, depending on the cooling method

To be successful, a new centre will be sensitive to these concerns, in addition to the external stakeholders that provide the regulatory permissions and community support that underpin a ‘licence to operate’.

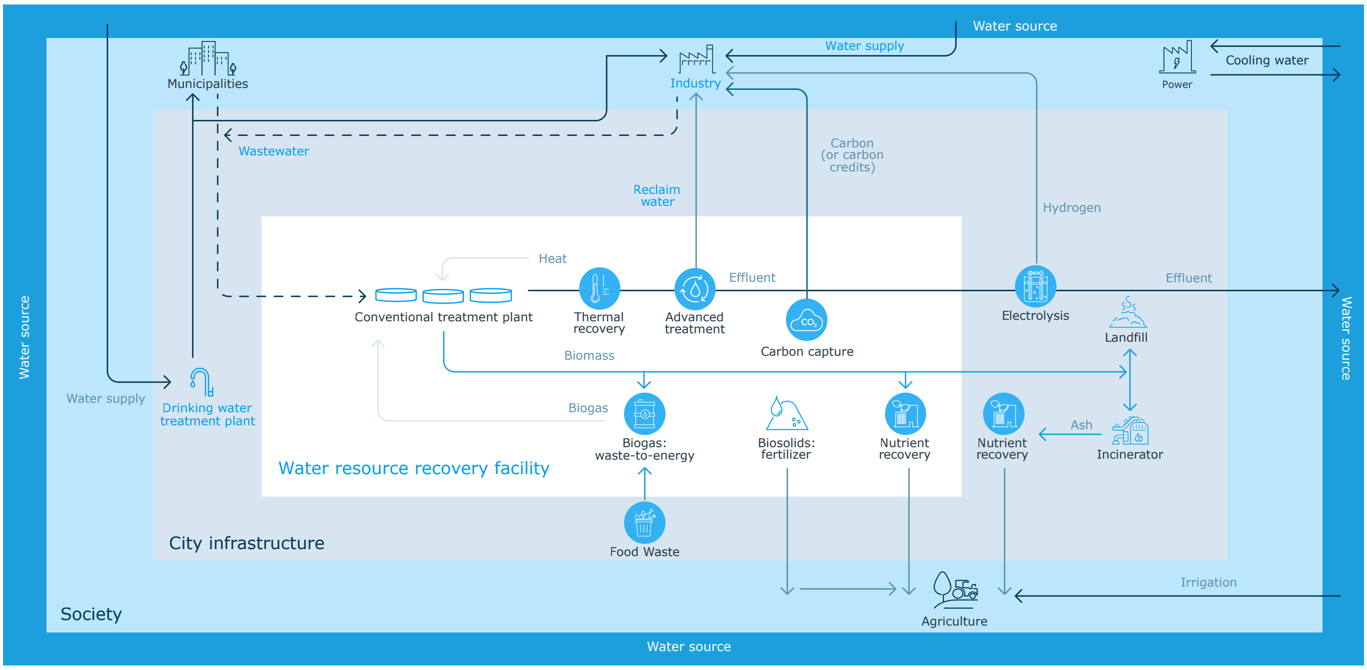


Figure 1. Integrated urban water cycle

Water supply

Adequate volume from a reliable source is key to supply, since acceptable quality is achievable via treatment, if needed. Factors affecting reliability include:

- Type of water source
- Location
- Demand

Satisfying water demand on the peak design day, often involves building significant on-site storage to align security of supply with the high reliability and redundancy expected of the rest of the data centre operations. This increased focus on equipment redundancy, process resilience, and ease of operation and maintenance carries through to the water and wastewater treatment systems on-site.

Common water sources are:

- Groundwater
- Surface water
- Potable water
- Reclaimed water (wastewater treatment plant effluent)

Groundwater and surface water supplies are usually the most abundant. Potable and reclaimed water have the best and worst water quality, respectively. Reclaimed water usually requires the most treatment, but does have particular positive features related to its relative scarcity, versus groundwater and surface water. Reclaimed water-treated wastewater effluent is always available as a source. It is not seasonal, increases over time and there is little competition for its use. (Reclaimed water can be designated as industrial water in utilities to reflect the desired use.)

The location of a water source is important, because it can impact the practicality and cost of infrastructure to supply the centre and convey wastewater from it.

A key consideration is local availability and competing demands on the source. For example, potable water near urban areas may be perceived to be, or is actually, limited due to priority use for drinking water. Similarly, groundwater could be vital to rural agriculture and therefore abstraction for industry viewed as threatening supplies for the higher beneficial use – ie food production – whether or not it is true.

Rainwater harvesting is not included here because it is rarely utilised as the primary source of cooling for data centres. However, it can be used to support sustainable design, as discussed below. The idea is attractive. But there are challenges of storage (perhaps across seasons) on space-constrained sites, adequate volume and quality, entailing treatment to substitute for another source.

Seawater is also a potential cooling source. But it presents unique treatment and construction material challenges, which are beyond the scope of this discussion.

> Water is a critical utility for data centre developers, and its importance is only increasing as data centres expand in size and geographic reach.

Water for cooling

The means of removing heat from a data centre, like most facilities, typically involves multiple steps of transfer from one medium to another. In the final step, all the heat is expelled to the outside air.

The first step is extracting heat from the computing equipment. Until recently, this has been achieved using air-moving overheat sinks within the equipment. This is then drawn over a refrigerant or water-based cooling coil located near, or just outside, the data centre computing area.

The recent trend is for a medium denser than air due to ever-increasing power densities. The preferred fluid is quickly becoming water or liquid refrigerant that absorbs heat directly from the equipment heat sinks and takes the place of large volumes of air. This liquid cooling still needs to find a way to transfer heat to the exterior of the building. The traditional refrigerant and water-based cooling systems remain the preferred means of doing this.

There are several common technologies used for cooling that range in complexity and energy use, only some of which use water. They are:

1. Free air cooling
2. Evaporative (or adiabatic) cooling (direct or indirect)
3. Mechanical cooling or chillers (air or water cooled)

Free air cooling uses ambient air. This is cool enough naturally to absorb heat, as it is forced through the process and exhausted out of the building. Adiabatic cooling uses air cooled by evaporation to extract heat directly or from a second medium adjacent to the process and then exhausted to the building exterior.

Chilled water uses mechanical refrigeration, which employs compressors to 'lift' the rejected heat's temperature above outdoor ambient conditions, where it is finally expelled.

Cooling systems may employ various combinations of these methods that ultimately trade between power and water consumption, depending on local conditions and available resources. In general, colocation data centres prefer chilled water (mechanical) systems as they allow lower space and humidity conditions, while hyperscale data centres will often use evaporative (adiabatic) cooling systems, operating at higher temperature and humidity ranges. Thus, hyperscalers will consume more water due to size and cooling technology but relatively less energy than mechanical cooling.

Choice of cooling technology and operational efficiency are based on a range of factors, including:

- Local climate
- Data centre size
- Internal layout (eg rack density)
- Balancing power and water availability and reliability
- Operational decisions, such as temperature and humidity of operations

For example, the impact of climate on cooling technology suitability is shown in Figure 2.

Zero-water technologies include free air cooling and air-cooled chillers. More water use occurs with evaporative media and chillers using water via cooling towers. These technologies have a different energy profile. There can be a significant energy/carbon footprint, when using those with the lowest water use. A summary of relative complexity, water and energy use is provided in Figure 3.

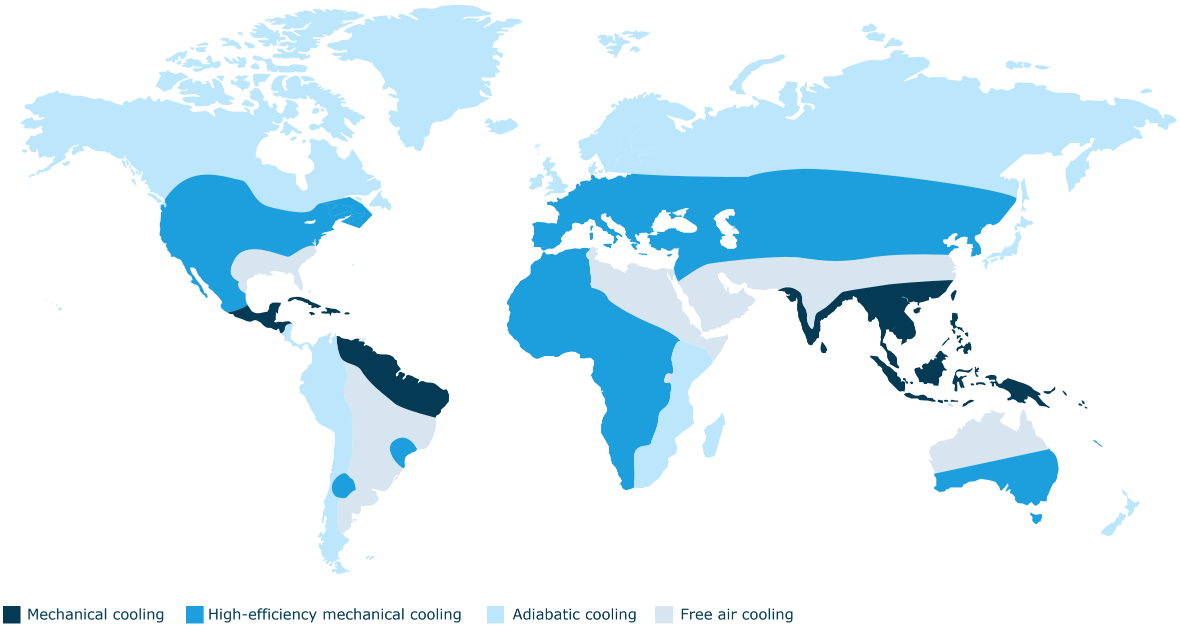


Figure 2. The impact of climate on cooling technology

Range of complexity, water & energy use

Cooling approach	Type of system	Typical application	Relative complexity	Relative water use	Relative energy use	Limitations
Free-air	Free-air	Large air handling units	Low-Medium (large ductwork)	Zero	Very Low	Ambient temperatures (Climate)
Adiabatic	Direct evaporative cooling (DEC)	Large external units	Medium (seasonal water needs)	Low to moderate (depending on climate)	Very Low	Climate, Humidity control
	Indirect evaporative cooling (IDEC)	Large external units	Medium (seasonal water needs)	Slightly more than DEC	Low	Climate, Humidity control
Chilled water	Air-cooled	External plants	Low (simple to operate)	Zero	High	None (High power usage)
	Water-cooled with cooling towers	Internal	High	Very high	Medium	None (High power usage)

Figure 3. Range of complexity, water and energy use

Several other cooling methods are not included here, because they are not widely used. They are intended for specialised applications or earlier stages of development, including immersion and direct-to-chip cooling.

It is important to note, for cooling, the demand for water is more seasonal, compared with other industrial uses. A conceptualised description of seasonal water use is provided in Figure 4 below. In addition to estimating annual consumption, it is critical to understand the number of days of operation and the potential peak demand.

Water discharge

Water used for cooling is most often cycled up in cooling towers. This not only reduces the volume extracted (versus once through cooling) but also diminishes the water quality. This is due to the addition of chemicals to inhibit corrosion or prevent biofouling, or through cycling-up the concentration of constituents, such as conductivity, or salt, by often three to six times the incoming water quality. This wastewater is often referred to as cooling tower blowdown.

This water often requires treatment before it can be returned to the environment. The constituents of concern will be determined by the incoming water quality, where the wastewater is being discharged (ie surface water, land, evaporation pond, municipal sewer) and the site-specific regulations. For some sites, this treatment plant will include flow attenuation tanks because of either sewer hydraulic limitations or a small receiving waterbody. Freshwater quality standards are the most stringent since they affect ambient conditions; therefore a direct discharge to receiving water may require treatment for metals and dechlorination.

Sustainable design

The data centre industry has committed to water stewardship, by reducing use. Some operators are also incorporating watershed replenishment projects. The adoption of such efforts, and metrics to assess progress, are relatively recent compared with other industries, such as the beverage sector that helped to pioneer this approach over the past two decades. Across this fast-growing and rapidly changing sector, stewardship activities, priorities and objectives vary. In time, as in other industries, they will align towards best practices.

The data centre industry tracks several sustainability metrics, including water use effectiveness (WUE) and power use effectiveness (PUE). Both assess efficiency with respect to total information technology (IT) power consumption.

It is critical to consider trade-offs between the two, since facilities can improve their WUE by using mechanical cooling or their PUE by using evaporative cooling. WUE can be a valuable metric for evaluating operational efficiency. But it is important to understand the full water and energy context. Another consideration may be the water use relative to other industries in a watershed.

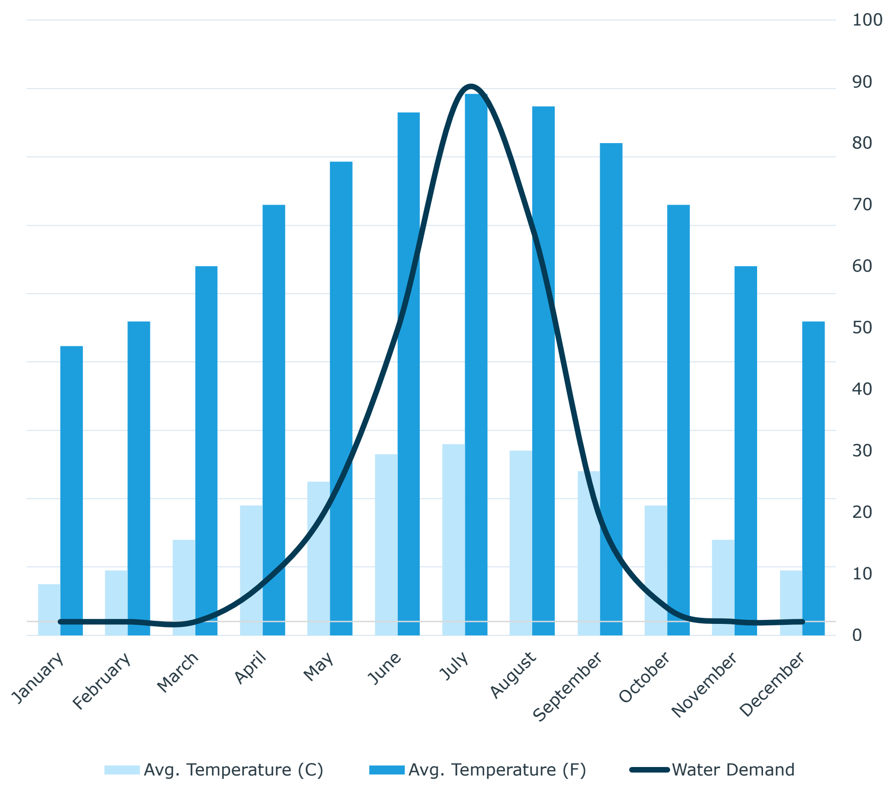


Figure 4. Seasonal water use representation

For sustainable design, data centres can minimise the direct use of water and improve resilience, with the following design and/or operational strategies:

To reduce water consumption:

- Optimise use of cooling water to where and when needed
- Utilise energy-efficient water treatment processes that minimise chemicals
- Maximise the cycles of concentration in cooling towers
- Treat and reuse spent cooling tower blowdown
- Recycle water treatment waste
- Utilise constructed wetlands to gain co-benefits from cooling tower blowdown water discharge
- Harvest rooftop rainwater to offset other water sources
- Recharge or replenish aquifers, using (treated) cooling tower blowdown water
- Implement or design for future use of reclaimed water

To increase system resilience:

- Build-in redundancy for critical facilities
- Ensure a back-up supply of cooling water
- Provide on-site supply water storage and treatment
- Undertake pre-settling and direct filtration to reduce coagulant chemical use
- Attempt zero liquid discharge of cooling tower blowdown water

Finally, the project delivery method can also be a key tool for increasing sustainability and resilience. For example, greater focus on alternative sources will shift attention towards reclaimed municipal wastewater effluent for industrial water supply. These reclamation projects involve public-private partnerships between data centre developers and public water utilities to find water solutions that bring value to both parties and the local communities, and deliver the required infrastructure.

Another partnership opportunity is leveraging existing water infrastructure at utility brownfield sites. These approaches provide a win-win, by reducing the impact on other local water resources, while providing the data centre with a reliable and resilient feed supply.

Conclusions

Water is a critical utility for data centre developers. Its importance is only increasing as the centres expand in size and geographic reach. Sustainable resource management and coordination with utility owners are essential to the future of the industry.

Key considerations include competing uses for potable water (drinking, fire protection, sanitation), public opposition to its use for planned growth, and the increasing availability of treated wastewater effluent from growing communities.

Harvested rainwater can be appealing, but is typically supplementary and space intensive. A balanced approach – combining reclaimed water, on-site storage, raw water, potable supply and/or harvested rainwater – is often best. Disposal of spent cooling water can be as challenging as securing a reliable water source, depending on quality and quantity; therefore, planning for disposal is equally important.

Working with local communities is crucial to sustainable, resilient water solutions. Public-private partnerships with water utilities can align data centre needs with community goals. By prioritising reclaimed municipal wastewater effluent and other alternative sources, they create mutually beneficial outcomes: reducing pressure on traditional water sources, enhancing local water security, and delivering the infrastructure needed for reliable operations.

This chapter was authored by Patrick J Campbell, water lead for data centres and Rachel Schwaab, water master planning & design for data centres, at Ramboll.

Chapter 4: Embracing biodiversity and nature-based solutions

Many data centre leaders prioritise sustainability topics like carbon neutrality and water stewardship. However, there's growing recognition that biodiversity and nature-based solutions (NbS) are critical to future-proofing development and operations. Integrating biodiversity into planning reduces environmental impact and can streamline permitting by avoiding impacts to sensitive habitats and protected species. NbS help mitigate natural hazards and strengthen ecosystem services such as flood control, temperature regulation, and soil stability. These strategies can also improve community acceptance, support employee well-being, and boost mental health and productivity.

Forward-thinking technology companies adopt NbS to minimise land disturbance, preserve sensitive habitats, and restore native ecosystems. Others do so for stormwater management, reduced cooling demands, and improved landscape connectivity. These approaches benefit nature while mitigating operational, regulatory, reputational, and climate-related risks.

As interest grows among investors, regulators, and the public, new expectations are shaping how data centres are planned. Designing with biodiversity and NbS in mind is becoming part of broader efforts to improve performance and long-term site resilience. This chapter provides practical guidance for identifying and mitigating biodiversity-related risks and highlights opportunities to enhance regulatory compliance, operational efficiency, and community support through the integration of nature-based solutions across site selection, design, construction, and operations.

The relationship between biodiversity and NbS

NbS use natural systems to address environmental, social, and operational challenges (**Figure 1**). They protect, sustainably manage, and restore ecosystems. For data centres, NbS include restoring native habitats, designing green buffers and habitat corridors, managing water through wetlands or bioswales, or reintroducing natural landforms to regulate temperature or reduce erosion. In many cases, NbS can offer the same site functions as engineered solutions, while saving money and providing additional benefits for people and the environment.

These approaches are based on functioning ecosystems, which depend on the variety and interaction of plants, animals, and microorganisms. Thus, biodiversity supports the services that NbS are designed to provide. For example, native plants improve soil stability and water retention, and diverse habitats attract pollinators that contribute to landscape health. In this two-way relationship, investing in NbS supports local biodiversity, and biodiversity contributes to the performance of these solutions. Biodiversity strengthens nature-based design, and nature-based design can protect or restore biodiversity on the site and in the surrounding area.

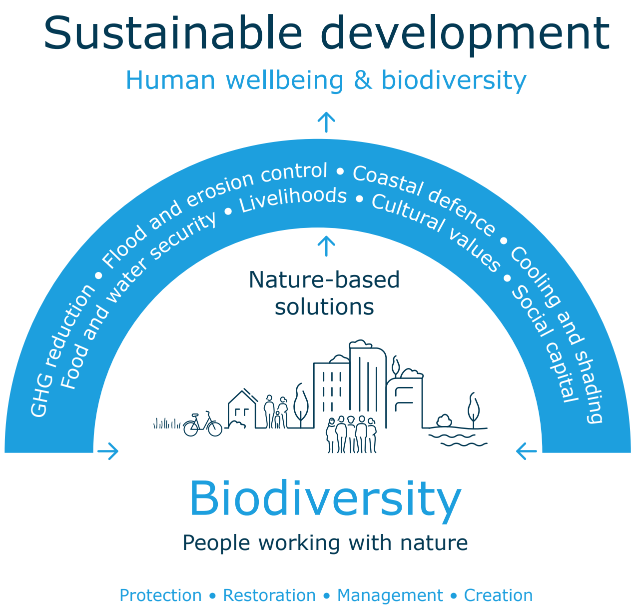


Figure 1. NbS can tackle challenges on data centre sites, with biodiversity and social benefits. Image adapted from IUCN 2016.

Managing impacts through avoidance, minimisation, and meaningful restoration

One of the most effective ways to protect biodiversity is to **avoid** causing damage in the first place (**Figure 2**). When planning a new data centre, this might mean selecting a site with less ecological value, adjusting layouts to preserve priority habitats, and scheduling construction activities to avoid sensitive periods for wildlife. Integrating biodiversity considerations into site selection helps avoid permitting delays, ensures compliance, and prevents community objections and litigation, while benefitting from the ecosystem services of the existing habitat.

Impacts that can't be avoided should be **minimised**. Careful site planning decisions can minimise biodiversity impacts on site, for example by reducing the building footprint and overall development footprint, strategic site layout and equipment configurations, or through intentional planning for materials staging.

If impacts can't be avoided or minimised, the next step is to **restore**. That might involve restoring disturbed areas, replanting native species, or applying NbS to rehabilitate ecosystems. Although restoration is valuable, it's often more expensive and less effective than prevention.

Companies aiming for net gain or no net loss of biodiversity – such as those subject to biodiversity net gain (BNG) regulatory requirements – may need to **offset** impacts to achieve their target. Importantly, offsets should be considered a last resort, only after all avoidance, minimisation, and restoration efforts are exhausted.

> Integrating biodiversity and NbS is critical for future-proofing development and operations.

Partnering with nature at every development stage

Integrating biodiversity considerations and NbS throughout each stage of the data centre lifecycle – from site selection to operations (and eventually decommissioning/facility repurposing) – can reduce environmental risks, improve permitting outcomes, and unlock long-term performance benefits. The following sections provide practical guidance on how nature-based strategies can be applied to align with regulatory expectations, support business continuity, and earn community support.

1. Site selection

Biodiversity and NbS can influence projects before design work begins. Site selection shapes the scale and type of impact on nature and communities, and determines opportunities to reduce risk, minimise disturbance, simplify approvals, or create environmental benefits.

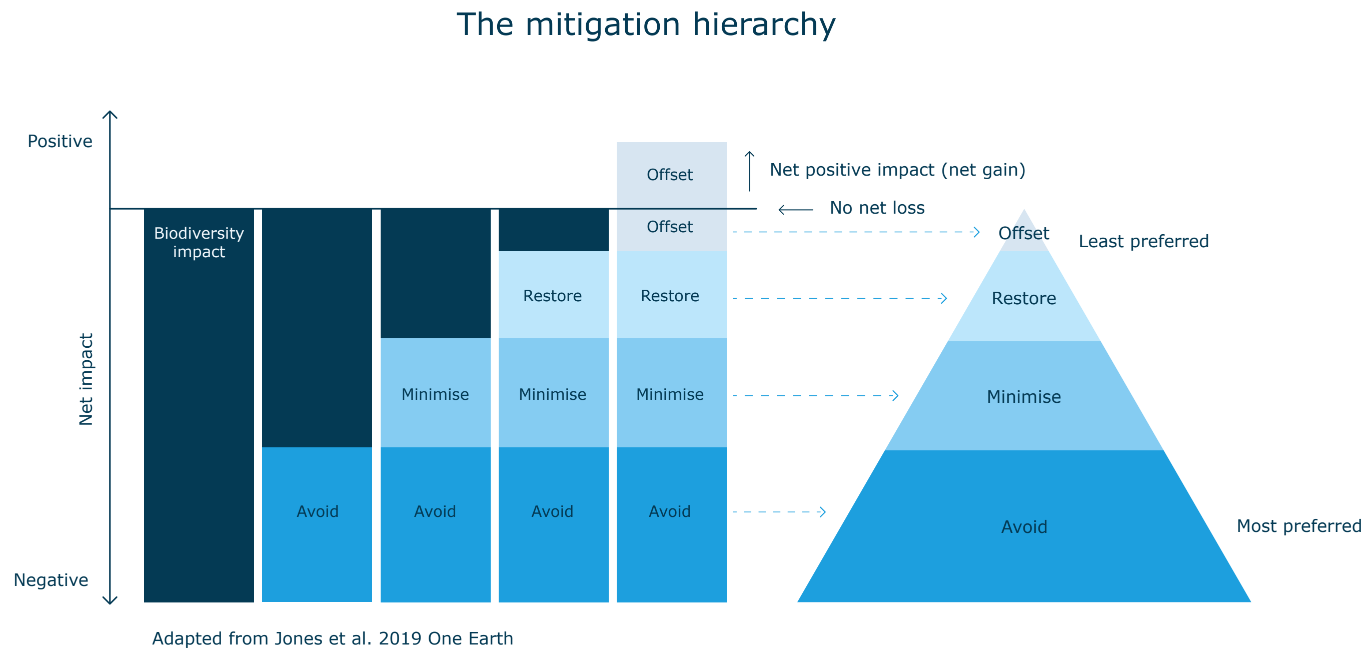


Figure 2. The mitigation hierarchy structures site decisions around biodiversity.

Habitat loss is one of the main drivers of global biodiversity decline. The choice to develop a previously undisturbed area results in permanent impacts to species and ecosystems, and early screening reduces that risk. Biodiversity metrics, screening tools, and conservation maps can show whether a proposed site includes species or habitats that are rare, threatened, or part of a broader ecological corridor, making it possible to avoid locations where impacts would be difficult or costly to offset.

Early screening can identify sites with lower biodiversity value, such as degraded land, converted farmland, or previously developed parcels, which often have fewer environmental and permitting constraints, and more flexibility for incorporating NbS.

Thoughtful site design including restoration of surrounding habitat can also bring measurable ecological benefits, making it easier to achieve biodiversity net gain or no net loss. When baseline biodiversity is low, small investments in restoration can compensate for losses on site.

2. Site layout and design

Thoughtful planning and design reduces risk and enhances value. Early consideration of biodiversity helps identify constraints, improves layout efficiency, and guides the integration of NbS. Even sites with low biodiversity value may contain small but significant features such as wetlands, patches of native vegetation, or areas supporting protected species. Early identification of these features – often revealed through due diligence activities like habitat mapping or wetland delineation – allows for layout adjustments that minimise disturbance. Designing around these environmental 'hotspots' can prevent costly redesigns, reduce permitting delays, build trust with reviewing agencies, and lower compliance costs.

Biodiversity metrics provide a transparent way to quantify these values and compare site options, ensuring decisions are consistent, science-based, and aligned with the mitigation hierarchy. They help guide site selection and layout to minimise ecological impact, streamline permitting, and support long-term resilience.

> Designing with nature can improve community acceptance and support employee well-being.

Biodiversity-friendly design directly improves site resilience and operational reliability. For example, in flood-prone areas, bioretention stormwater basins planted with native species can improve water infiltration and storage capacity, reducing the load on engineered drainage systems. Similarly, planting deep-rooted native trees or grasses helps stabilise slopes, prevent erosion, and encourage excess moisture absorption. These measures both safeguard infrastructure and reduce long-term maintenance needs.

Traditional infrastructure can be replaced with innovative, nature-based alternatives that address site challenges and strengthen environmental and social performance. For example, instead of a conventional ditch, a bioswale planted with native species can manage runoff while filtering pollutants, providing habitat, and improving aesthetics. Forested buffers can be positioned not just as habitat, but as multi-functional features offering visual screening, noise attenuation, site security, and cooling. These alternatives benefit operations while also addressing common community concerns.

Designing with nature and aligning projects with regional environmental priorities can build trust with regulators and communities, resulting in streamlined permitting, shorter review periods, and increased collaboration and transparency.

3. Construction

Integrating biodiversity and NbS during construction minimises disruption and supports compliance. Construction is a critical phase where simple measures can reduce harm and enhance on-site ecosystem function.

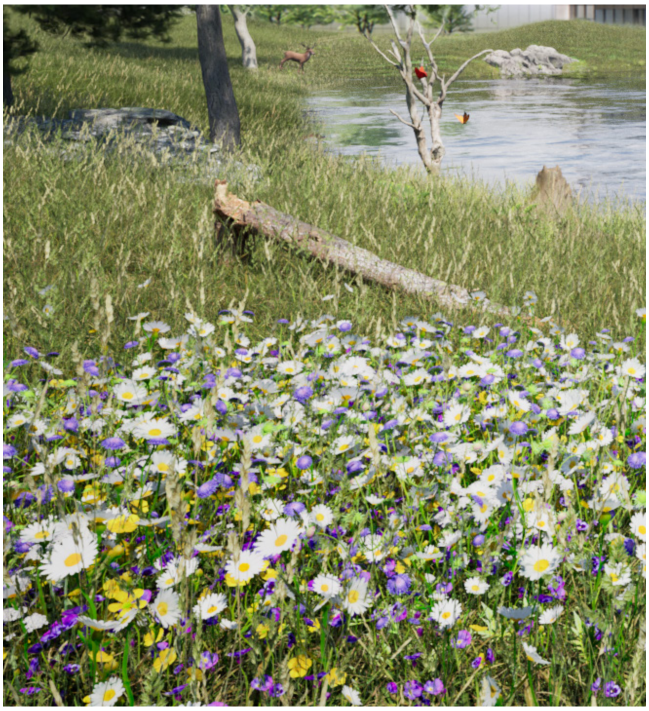
Nature-positive construction methods such as limiting vegetation clearance, controlling erosion, and managing pollution help maintain healthy ecosystems. Erosion control tools like silt fences and bioretention systems can prevent sediment runoff from entering nearby water bodies, preserving aquatic life and water quality. Buffer zones planted with native species reduce the spread of dust and noise, supporting surrounding habitats and making construction less disruptive for neighbours. Timing construction around breeding seasons protects wildlife, demonstrates environmental responsibility, and helps avoid costly delays.

Sourcing and disposing of construction materials also carries ecological implications. Opting for repurposed materials reduces demand for raw resource extraction, a key driver of habitat loss. Recycling construction waste supports circular economy principles, helping to conserve ecosystems well beyond the project site. These decisions, often seen as cost-saving or carbon-reducing, also contribute meaningfully to biodiversity protection throughout the supply chain.

4. Operation

Data centre operations offer opportunities to align performance with nature. Sustainable operational practices, such as using renewable energy, water-efficient cooling, and waste heat recovery, reduce pressure on local ecosystems. Technologies like air-cooling, water recycling systems, and heat reuse networks improve resource efficiency and help avoid environmental impacts tied to energy and water abstraction.

NbS like green roofs and living walls can moderate building temperatures and reduce energy use while providing habitat for pollinators and birds. Rainwater harvesting systems offer a low-impact water source for landscaping, reducing dependence on municipal supplies. Wildlife-friendly features like bird-friendly window treatments reduce avian collisions, and pollinator gardens support bee populations critical to ecosystem health.



Credit: Ramboll

Engaging local stakeholders in biodiversity initiatives, such as community planting days or citizen science programs, can build trust and create shared value. These efforts support nature while strengthening the social license to operate.

Key considerations when implementing NbS

1. Tailored NbS

Success depends on tailoring NbS to specific operational, ecological, and social contexts because site conditions vary widely: ecosystems, local biodiversity pressures, community priorities, and climate resilience needs all differ. A site-specific strategy ensures that NbS deliver meaningful benefits for both nature and business. In all cases, design biodiversity-enhancing features informed by native habitats, and use metrics to track and provide evidence improvements over time.

2. Collaboration

Engineers and technical leads play a critical role in project delivery but are often under pressure to follow tight budgets and timelines. Under these constraints, project teams tend to default to standardised designs and established practices, which can limit consideration of biodiversity integration and NbS. Positioning these strategies as opportunities, rather than add-ons, helps demonstrate how they can streamline permitting, minimise redesigns, and enhance long-term operational resilience. Framing NbS as solutions that deliver both ecological and functional value encourages buy-in and creates space for more innovative, cost-effective project outcomes.

3. Monitoring and management

Nature and site conditions change over time, making ongoing monitoring and adaptive management essential to ensure that NbS continue to perform as intended. This includes tracking ecosystem health, assessing biodiversity outcomes, and adjusting practices to respond to evolving environmental or operational conditions. Although NbS often require less maintenance than conventional alternatives, proactive management remains critical – especially in the early years.

Key takeaways

Integrating biodiversity and NbS into data centre projects is not just good for the environment, it is a strategic investment. These strategies help mitigate risks like permitting delays, flooding, and public opposition, while unlocking operational efficiencies, regulatory advantages, and long-term cost savings (**Figure 3**, on next page).

By working with nature, companies can improve return on investment by reducing lifecycle costs, enhancing site performance, and protecting the natural capital that underpins business operations. In doing so, data centres become more future-ready, resilient, and capable of delivering sustainability commitments with lasting financial and reputational value.

Economic

- Avoid costly delays and redesigns
- Streamline permitting and compliance
- Lower costs by conserving nature upfront vs. restoring later
- Enable land reuse and reduce footprint
- Elevate branding and market perception
- Strengthen sustainability credentials

Social

- Gain social licence to operate
- Build community trust and buy-in
- Support employee well-being and retention
- Encourage cross-discipline collaboration

Environmental

- Boost site resilience (eg flooding, heat, erosion)
- Protect biodiversity and ecosystem health
- Enhance visual screening and reduce noise impacts
- Improve water quality and landscape function
- Increase nature capital and ecosystem services
- Improve water management and conservation

Figure 3. Summary of benefits and risk mitigation opportunities

This chapter was authored by Rachel Esbenshade, Sustainability Engineer at Ramboll.

Chapter 5: Meeting the embodied carbon challenge

Data centres form the digital backbone of the modern economy and play a critical role in our daily lives. The industry is expanding rapidly, driven by AI and cloud demand. But this growth comes with environmental impacts that we must rebalance, so data centres contribute positively to our planet.

Embodied emissions, especially embodied carbon from materials and equipment, are becoming the dominant footprint as electricity grids decarbonise. By taking action now, organisations can meet the challenge.

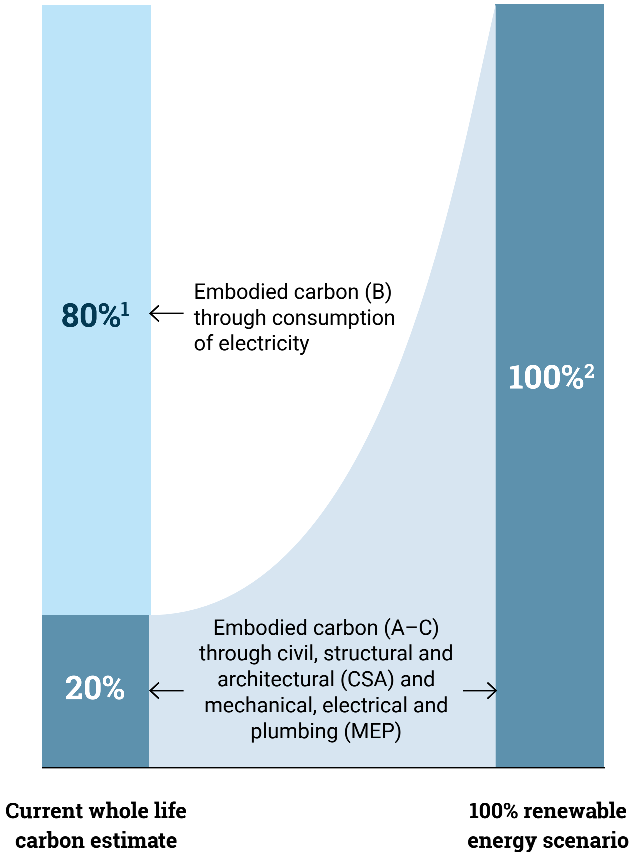
Data centre players have made huge progress in reducing operational carbon – the carbon dioxide or equivalent (CO_2e) greenhouse gas emissions generated through the asset's day-to-day use – by improving energy efficiency, coupled with lower carbon electricity.

However, less progress has been made on embodied carbon – the CO_2e emissions generated in producing and constructing the asset, replacing components over its lifetime, and end-of-life emissions.

Why focus on embodied carbon?

Arup analysis shows that, currently, most emissions from data centres – around 80% – relate to operational energy use. However, as electricity grids decarbonise and more data centres are powered entirely by renewables, embodied carbon will become the primary source.

Reducing these emissions will be essential for data centre players to achieve decarbonisation goals and future-proof their assets amid tightening regulations, growing client expectations, mounting public pressure and stricter reporting requirements.



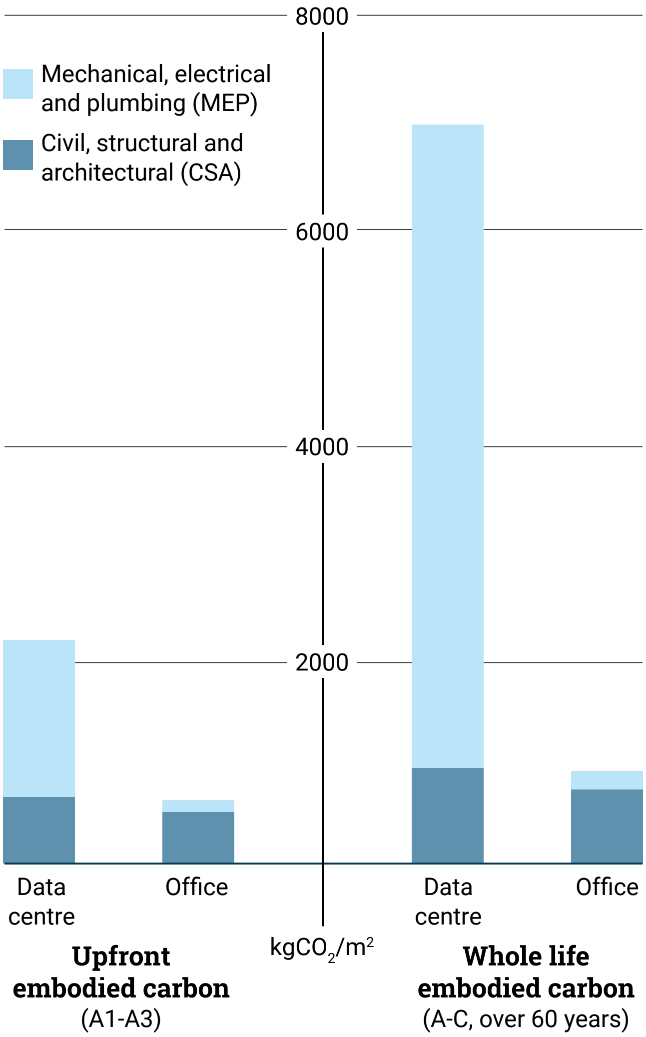
1 Based on electricity use only.
2 There would still be a small amount of operational carbon, due to fuel use on site.

Figure 1: Typical balance of operational and embodied carbon in UK data centres, assessed by Arup

The largest contributors to the embodied footprint of data centres are mechanical, electrical and plumbing (MEP) systems and civil, structural and architectural (CSA) elements. On average, MEP represents 70% of upfront embodied carbon and 88% of whole life embodied carbon.

Yet, MEP is often excluded from whole life carbon assessments, due to its complexity. This is the biggest embodied carbon challenge that data centres face. Without understanding its impact, we cannot effectively decarbonise or meet the 1.5°C target set by the Paris climate accords.

While CSA tends to be the dominant embodied footprint for offices and other buildings, Arup analysis shows that, for data centres, MEP emissions can be up to seven times larger. This is driven by the extensive MEP systems in data centres, which are often replaced multiple times over a building's lifespan.



Office data is based on Whole Life-Cycle Carbon Assessments Guidance published by the Greater London Authority. It includes structure, fittings, finishes and MEP.

Figure 2: Proportion of embodied carbon from MEP and CSA in data centres and offices

Big opportunities: three key actions you can take

1. You can't manage what you don't measure

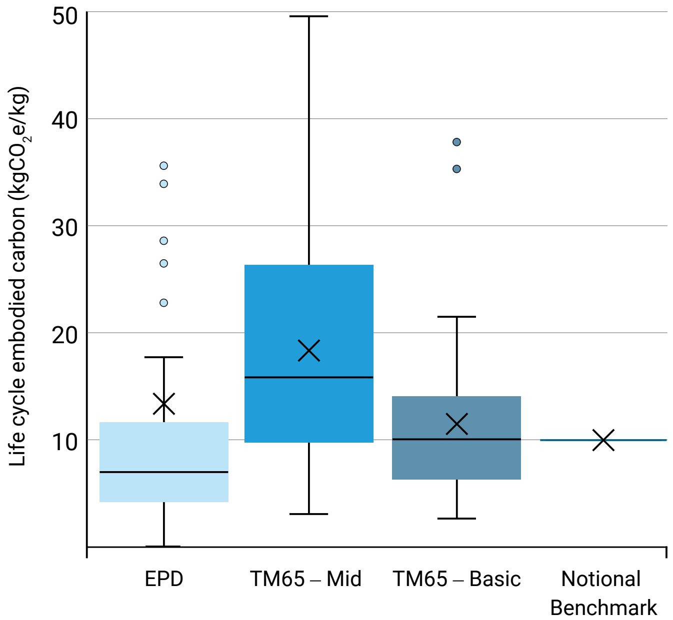
First, data centre developers must calculate the embodied emissions from MEP systems. They will then be able to identify carbon hotspots to prioritise action.

The industry is already calling for Environmental Product Declarations (EPDs) – the gold standard for accuracy. However, product-specific EPDs are difficult for MEP equipment, with systems combining many components from different factories, sizes and product lines.

We cannot wait for EPDs. We need MEP manufacturers to provide simpler materiality information for their products now: on the main materials, place of manufacture and weight. We can then use standardised methodologies, such as CIBSE TM65, to estimate emissions.

An Arup review for CIBSE revealed that, whether you use EPDs, CIBSE TM65 or a notional benchmark of 10kg of carbon per 1kg of MEP equipment, carbon hotspots will usually be correctly identified.

Although we saw variations across methodologies – for example, emissions from basic TM65 reports averaged 36% higher emissions than EPDs – all methods produce results in the right order of magnitude.



Life cycle embodied carbon based on A1–A4, B3, C2–C4 stages only. (A5, B2, B4–B7 and refrigerant impacts B1 and C1 not included.)

Figure 3: Comparison between EPDs, CIBSE TM65 estimations and notional benchmarks

Client specific guidance documents' outlining assumptions will improve consistency. Progress can then be tracked from concept designs through to completion and different projects compared. Data must also be reported transparently and include sources, so users can assess data quality and benchmark against EPDs. This will support standardisation across the industry, improving comparisons across products and projects.

Currently, many manufacturers are hesitant to share their environmental data for fear of unfair benchmarking against competitors, with everyone using different methodologies.

Ultimately, we want full accuracy through EPDs and a common industry standard adopted by all manufacturers – but we cannot wait for perfection. We need to act now to reduce carbon as quickly as possible. With the data centre industry's track record for pushing boundaries, its focus on MEP emissions could be transformative for the entire built environment.

> Questioning norms often leads to significant carbon and cost savings for data centre developers

Maintenance is a big opportunity all round. Arup research shows that extending the usual lifespan of equipment by just 5% – which can be achieved through good maintenance – can reduce whole life carbon of the MEP systems by 20%.

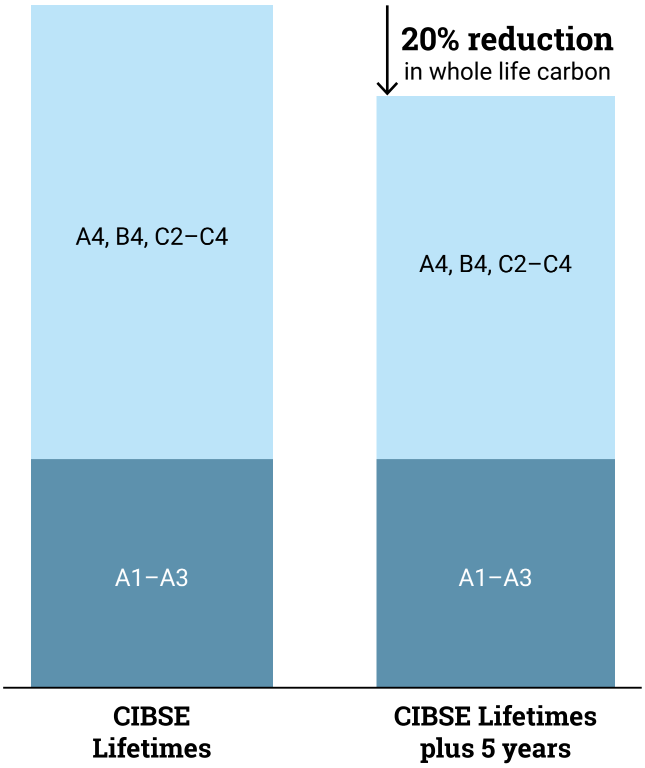


Figure 4: Typical balance of operational and embodied carbon in data centres

2. Challenge the status quo

In our experience, questioning norms often leads to significant carbon and cost savings for data centre developers.

For instance, one standard approach for duct banks is cast-in-place concrete. However, there are lower carbon alternatives – from direct bury, where soil conditions and overhead traffic allow, to trenches with lids, replacing high cement concrete with lower carbon flowable fill.

It is worth exploring the detail. For example, stainless steel pipe is more carbon intensive by mass than typical carbon steel pipes. But, given its increased strength and lighter weight per unit length, it could be the better choice from a carbon perspective.

Similarly, data centres often use heavier grade pipework than required, specifying Schedule 40 pipe by default. Instead, check what pressure ratings are actually needed and embed good maintenance regimes. Thinner walled pipes will last the lifespan of the building, when well maintained.

3. Influence supply chains to enable change at scale

In addition to engaging with manufacturers to gain EPDs and materiality information for their products, encourage your suppliers to set their own decarbonisation goals. When they cut carbon in their products, everyone benefits.

Influential data centre players could also go directly to materials producers. The biggest MEP emissions typically relate to base metals, such as steel, aluminium and copper. If manufacturers decarbonised those at source, savings would percolate not only through the data centre industry but also across the broader built environment.

For instance, copper is a major MEP component and one of the world's most recyclable metals. Yet, because existing recycling networks mix it with other metals, it ends up with too many impurities for data centre applications. If copper conductors were collected separately, manufacturers might be able to supply high-purity, low-carbon, recycled copper for cabling and electrical conductors.

Best practice for tackling embodied carbon hotspots

Arup analysis means we now have a good understanding of the key contributors to embodied carbon in data centres.

Most emissions come from metals embedded in mechanical and electrical equipment, MEP pipework and cabling, and the superstructure. Electrical equipment dominates upfront carbon. Server racks also have a dramatic whole life impact, due to their high precious metal content and complex manufacturing processes.

Here is how circularity can tackle embodied carbon hotspots across data centres.

1. Build nothing

Wherever possible, **retrofit and improve existing facilities**. In assessing different buildings that could potentially be repurposed as data centres, we have often found that the necessary modifications make it less carbon-intensive to deconstruct and rebuild. However, always explore retrofit for small facilities or specific upgrades, as these often yield positive results.

Following a feasibility study by Arup, EMC² is retrofitting its Ireland Centre of Excellence to dramatically improve energy efficiency, introducing free cooling technologies.

This will reduce annual carbon emissions by 7,000 tonnes.

2. Build for long-term use

Workable actions to keep assets at highest value as long as possible include:

- Standardisation for adaptability and reuse, prioritising server racks which can account for as much whole life carbon as MEP systems.
- Water-based cooling systems, which have longer lifespans than direct expansion (DX) refrigeration plants and use less refrigerant. They can also be sized slightly smaller, which, in turn, allows electrical systems to be downsized and potentially even the building itself.
- Manufacturer design for reuse. For instance, pipe manufacturers could supply pipes that can be bolted together, taken apart and reused when layouts change, or recycled at end-of-life.
- Leasing models for specific components or systems, with continuous monitoring and optimisation to extend lifespan.
- Take-back and end-of-life programmes with vendors, focusing on repetitive units such as fan coil assemblies, dry air coolers and water-cooled chillers, as well as large equipment like generators, transformers, switchgear and uninterruptable power supplies.

> By retaining ownership, the company ensures systems are efficiently operated, maintained and upgraded over time. This extends asset life, reduces waste and avoids premature replacements.

Kaer offers a cooling service for data centres. By retaining ownership, the company ensures systems are efficiently operated, maintained and upgraded over time. This extends asset life, reduces waste and avoids premature replacements.

3. Build efficiently

Opportunities to increase materials efficiency include:

- Optimising structural column grids and spans to significantly reduce steel and concrete use: Arup recently reduced superstructure carbon by 35% on a data centre project by optimising slab span.
- Using prefabrication to reduce waste and speed up construction.
- Dematerialising racking, pipework and duct banks: insulation could be removed in some pipes and thinner pipes used in some areas, saving materials and costs.
- Re-evaluating fundamental design criteria and building form: moving heavy rooftop plant to ground level can reduce structural embodied carbon by up to 40%. Tailoring structural loading for specific areas can significantly reduce steel and concrete use, thereby lowering embodied carbon and costs.
- Designing MEP systems layout for efficiency.

Working with a data centre client, Arup reduced embodied carbon by 15% on a live project, from initial concepts to final designs, by increasing materials efficiency and using those less carbon-intensive.

4. **Build with the right resources**

Priorities in switching to less carbon-intensive materials include:

- Working with construction partners to use the best low-carbon concrete mixes: apply more aggressive reductions in low-risk areas, like ancillary structures, and more conventional mixes in high-risk areas, such as data hall floors. Several hyperscalers are collaborating to test novel materials and accelerate advancement of low-carbon concrete.
- Reusing structural steel: this can reduce upfront carbon emissions by up to 97% compared with virgin steel.
- Engaging with vendors to influence decisions in metal manufacturing: the first step is asking for greater transparency on the carbon impact of products made primarily of steel, aluminium and copper.
- Using mass timber to replace concrete slabs in floor and roof decks: several data centre developers are exploring this for ancillary and administrative areas, or as cladding.
- Using bio-based instead of fossil fuel-based materials to reduce and potentially sequester carbon: when specifying bio-based insulation, consider fire resistance, durability, maintenance, availability, construction speed, cost and other performance requirements.

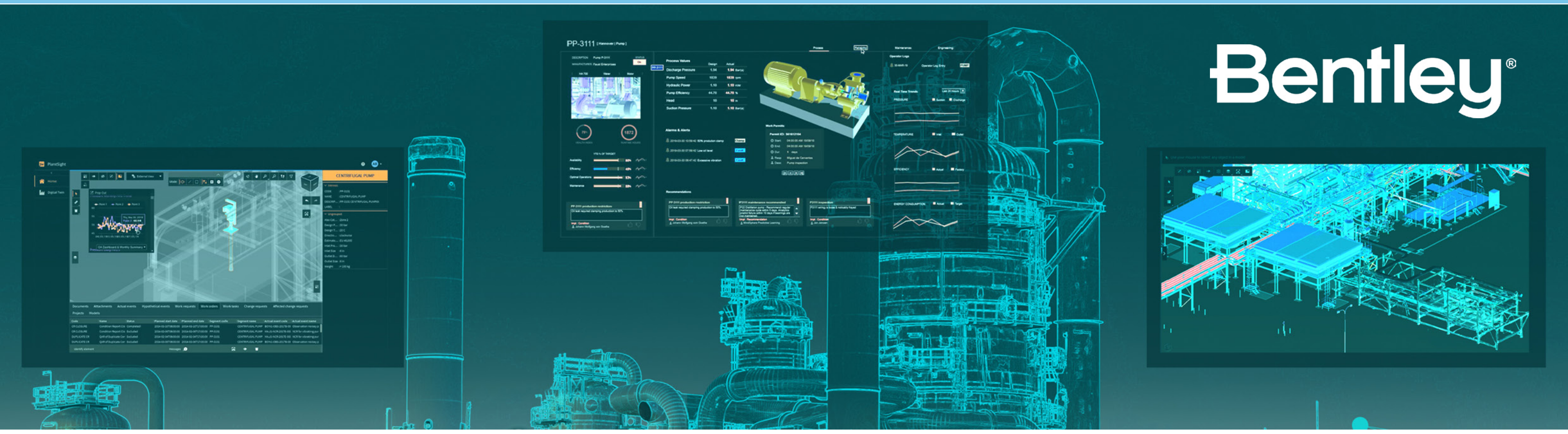
Microsoft is building its first data centres with wood to slash carbon emissions. More here.

Together, we can work towards a more sustainable future for data centres

At Arup, we have worked for many years with data centre clients to measure and reduce carbon emissions. We recently published a guide on Circular Thinking for Data Centres, based on real-life projects. This outlines how circularity strategies can reduce whole life carbon and future-proof facilities.

With thoughtful design and a commitment to sustainability, data centres can contribute positively to the environment and balance meeting our technological needs with respecting planetary boundaries.

This chapter was authored by David Davies, Associate Director at Arup.



Chapter 6: Integrating digital twins for operational efficiency

Introduction

Data centres are the backbone of the digital economy, powering cloud services, artificial intelligence and global communications. Their rapid growth has made them critical infrastructure, but also one of the fastest increasing consumers of electricity and water worldwide.

According to the International Energy Agency, in 2024, global electricity consumption from data centres was estimated at around 415TWh, roughly 1.5% of global demand. Forecasts suggest this could double by 2030.

The strain extends beyond electricity. Depending on cooling technologies and operational practices used, a hyperscale facility can consume 3-5m gal/day of water (at the upper end this is similar to what 50,000 US citizens consume, based on US Geological Survey data).

In regions already facing water stress, this has sparked community pushback. Governments in the US, Ireland and the Netherlands have put moratoria on new construction, highlighting that community approval is as crucial as technical success.

Demand for data centres is being fuelled by the surge in AI workloads and high-performance computing. This growth underlines the need for strategies that enhance operational efficiency while reducing environmental impacts.

One promising answer lies in digital twin technologies: dynamic, real-time representations of physical assets, systems or environments that evolve alongside their real-world counterparts. By combining data from various sources, digital twins enable operators to monitor, predict and optimise performance, improving efficiency, sustainability, and transparency with stakeholders.

This is particularly important for data centres, which are in a constant state of change. Throughout their design, construction, commissioning and operation, developers and operators must adapt to evolving requirements within the limitations of space and resources.

> Digital twins provide a single, integrated view of servers, cooling systems, power distribution and environmental conditions.

Core functions of digital twins in data centres

Originally developed in industries such as aerospace, defence and manufacturing, digital twins are now increasingly applied in critical infrastructure. For data centres, they provide a single, integrated view of servers, cooling systems, power distribution and environmental conditions.

Importantly, the role of the digital twin evolves over time. A digital model created during the design phase becomes a true 'twin' — a virtual replica of a physical asset —once it is connected to live operational data.

As more layers of information are integrated, the twin evolves into a powerful tool for long-term adaptation and resilience (see Figure 1).

- **Design and planning (digital model, pre-build):** Even before the first drawing is produced, digital models are critical in site selection, helping to assess climate conditions, grid availability and water resources.

  This ensures efficiency, sustainability and resilience are considered from the outset, while also building trust with local communities. Once a location is identified, high-fidelity design models allow operators to test decisions virtually.

Computational fluid dynamics and airflow modelling can optimise server placement and room layouts, while power flow simulations highlight weaknesses in distribution networks.

- **Operations and optimisation (true digital twin, in use):** Data centres demand near-perfect availability while keeping power usage effectiveness (PUE) as low as possible. A digital twin enhances this by unifying data from building management, cooling and power infrastructure into a single real-time model.

  Built on open standards, it provides continuous visibility of temperature, airflow, humidity, water use and power loads. Operators can track metrics like PUE, water usage effectiveness (WUE) and carbon intensity, applying AI to predict failures, optimise performance, and strengthen the safety case for critical infrastructure.

- **Expansion and resilience (resilient twin, future growth):** As demand rises, the twin evolves further into a platform for long-term strategy. Scenario modelling enables teams to test expansion strategies virtually, avoiding overbuild or bottlenecks, while stress-testing resilience against extreme weather or grid instability.

  Increasingly, these capabilities support not only insurers and investors but also regulatory compliance, because operators must demonstrate performance against energy, water and carbon reporting requirements. In this way, the digital twin becomes a living asset, ensuring today's facilities remain adaptable, efficient and climate-ready for tomorrow.

Operational intelligence

Operational efficiency is defined in day-to-day performance, by keeping servers, cooling and power infrastructure running at maximum output with minimum waste. Digital twins enhance this by continuously synchronising data across systems, giving operators a unified view of performance.

Success is evaluated by uptime, reliability, and metrics like PUE, WUE and carbon intensity. When integrated into operations, these metrics become standard outputs rather than compliance burdens.

From monitoring to optimisation
Data centres operate as highly interdependent systems, where even small inefficiencies can cause higher costs, wasted energy and unnecessary emissions. Digital twins go beyond monitoring to predictive optimisation, using AI and machine learning to simulate 'what if' scenarios, anticipate failures, and fine tune responses before issues escalate.

Predictive maintenance is another key application. Instead of relying on fixed schedules or waiting for failures, operators can forecast when equipment is likely to degrade and intervene at the right time.

This extends asset life, minimises downtime, and keeps systems running at peak efficiency. Twins can also simulate failure and recovery scenarios, allowing teams to rehearse responses to power surges, cooling breakdowns or other disruptions, without risking live operations.

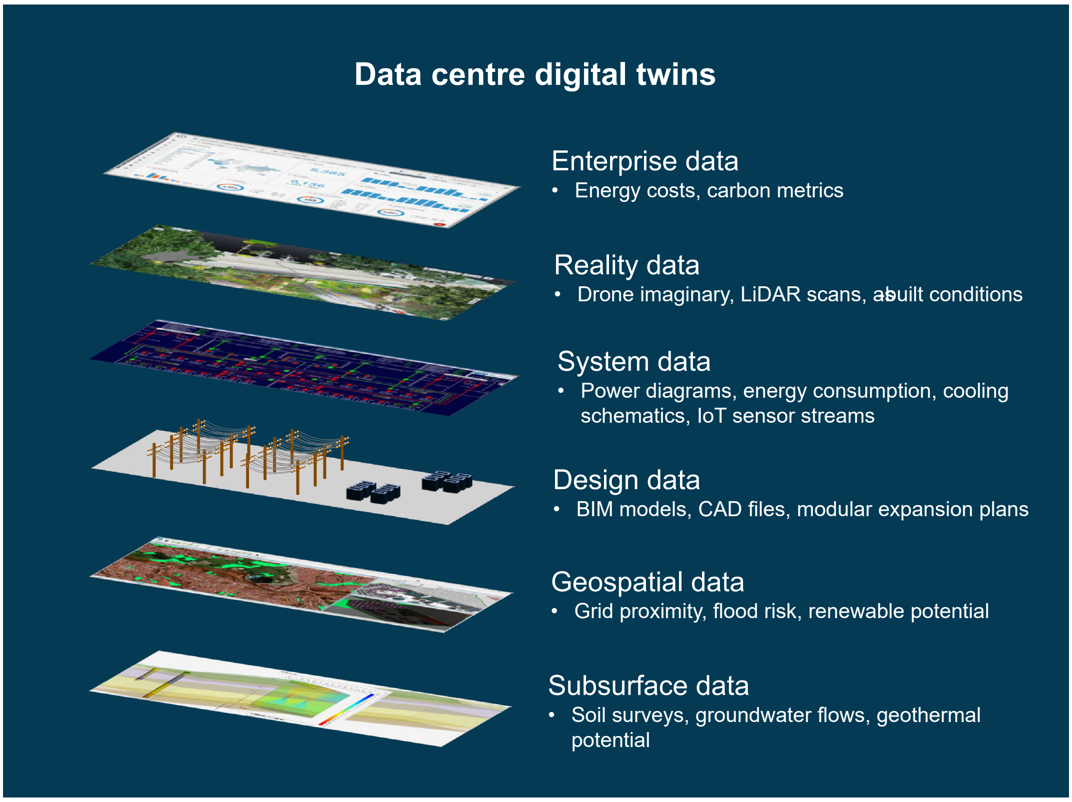


Figure 1. Digital twins are virtual models of physical assets with several data layers.

Spatial awareness and integration
Spatial intelligence is emerging as a powerful tool to enhance the operational efficiency of data centres.

By embedding internet of things (IoT) sensor data, BIM models and environmental information into advanced 3D geospatial platforms, operators gain not only technical insights, but spatial awareness of how their facilities interact with surrounding infrastructure and ecosystems. This enables better planning, stronger risk management, and more transparent communication with regulators, communities and stakeholders.

Importantly, efficiency now extends beyond the walls of the data centre itself. Digital twins allow operators to model how facilities connect to wider infrastructure, such as capturing and distributing surplus heat through district heating networks or supporting nearby industrial processes.

Across many regions, new data centres are designed for integration, serving as technology hubs while advancing local sustainability targets. By reusing otherwise wasted energy, they help cut fossil fuel reliance and benefit surrounding communities. They can also improve resilience through local micro-distribution centres that balance supply and demand.

Planning growth and resilience with digital twins
As demand grows, scenario modelling within the twin enables modular, future-focused expansion while avoiding bottlenecks. Equally, climate resilience is now non-negotiable. Twins can model how heatwaves, flooding or water stress will affect cooling, water supply or grid stability, allowing operators to plan adaptation strategies in advance.

Twins will also be pivotal in preparing data centres for zero-carbon operations and more autonomous management. By linking to smart grids, they can model renewable energy, storage and variable demand, and provide pathways for emerging technologies such as liquid cooling, hydrogen backup systems or on-site microgrids.

Long term, digital twins may underpin autonomous facilities that self-optimise, self-heal and continuously adapt.

Sustainability and compliance integration
Improving operational efficiency directly supports sustainability goals. Optimised cooling cuts electricity demand and water use, while smarter load management lowers carbon intensity.

Digital twins also automate data capture, aligning with sustainability frameworks. This not only makes compliance easier but also builds trust with investors, regulators and communities.

Case study examples from Lithuania's Kaunas University of Technology campus scale twin and Sabesp, a Brazilian utility, show how large, complex systems can consolidate energy and water reporting across multiple assets.

> Aligning design, build and operate phases requires integrated procurement routes, shared data standards, and collaborative platforms.

Applied to data centres, the same approach helps shift from reactive maintenance to proactive optimisation, driving measurable progress toward efficiency, resilience and sustainability targets.

Challenges and risks

As with any transformation, adopting digital twins in data centres brings challenges. The hurdles of data quality, interoperability and integration of legacy systems persist, while the highly connected nature of these platforms heightens cybersecurity risks, requiring strong governance and monitoring.

A key issue stems from fragmented procurement and responsibility. Facility design and construction are typically handled by separate teams from those managing IT and operations. This leads to poor data handovers, siloed systems and missed opportunities to build in digital twin capabilities from the outset.

Aligning design, build and operate phases requires integrated procurement routes, shared data standards, and collaborative platforms.

Data quality and system interoperability are challenges, particularly in legacy systems. Digital twins introduce cybersecurity risks due to their connectivity and real-time data use, which requires strong oversight.

Organisational and cultural barriers also hinder adoption — facilities and IT teams work separately, and digital skills or sustainability expertise may be lacking. Early return on investment (ROI) is hard to demonstrate, even though long-term gains are evident.

Overcoming these challenges requires systems thinking, seeing data centres not in isolation, but as part of wider infrastructure ecosystems. Digital twins support this by unifying data, simulating scenarios, and enabling continuous optimisation.

Case study examples

Direct, public examples of data centres using full digital twin implementations are still emerging. However, valuable lessons can be drawn from analogous projects in related domains that highlight the impact of real-time monitoring and simulation on large, complex systems.

Two examples illustrate how twin technology improves efficiency and resilience, in ways directly relevant to data centre operations:

- **Campus energy management:** At Kaunas University of Technology, Lithuania, a campus-scale digital twin was introduced to manage a diverse portfolio of academic buildings. By bringing together IoT sensor data and building management systems into a single 3D platform, the twin enabled real-time monitoring and predictive analytics across heating, cooling and electricity networks (Figure 2).

  Facilities teams could test retrofits, adjust schedules or simulate new control strategies virtually, evaluating their impact on energy demand before implementation.

  This approach not only reduced consumption but improved resilience and planning capacity. The Kaunas experience shows how digital twins can move from pilot projects to large-scale deployment, providing a model for data centres aiming to optimise cooling, airflow and overall energy efficiency.

- **Water network optimisation:** The Brazilian utility, Sabesp, applied a water digital twin platform to manage one of the world's largest and most complex water supply networks (Figure 3).

  By integrating thousands of sensors monitoring flow, pressure and quality, the twin provided real-time visibility into leaks, inefficiencies, and overall system health.

  Through simulation and AI-driven analytics, Sabesp was able to forecast demand surges, identify and repair leaks more rapidly, and optimise pump operations to lower both water losses and energy use.

  This success illustrates the power of continuous monitoring and predictive control. For data centres, the lesson is clear: digital twins can be used to manage cooling and water systems more sustainably, improving WUE, reducing costs and safeguarding resilience.

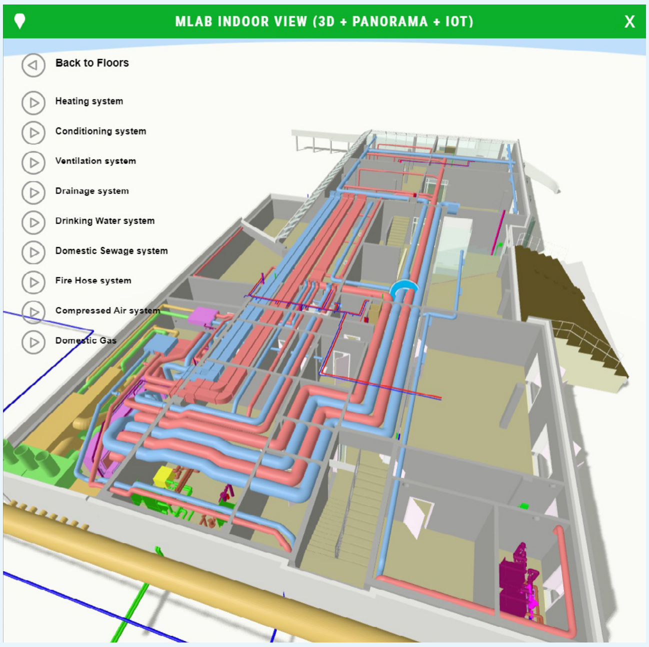


Figure 2. Kaunas University of Technology used digital twins for managing a variety of academic buildings.

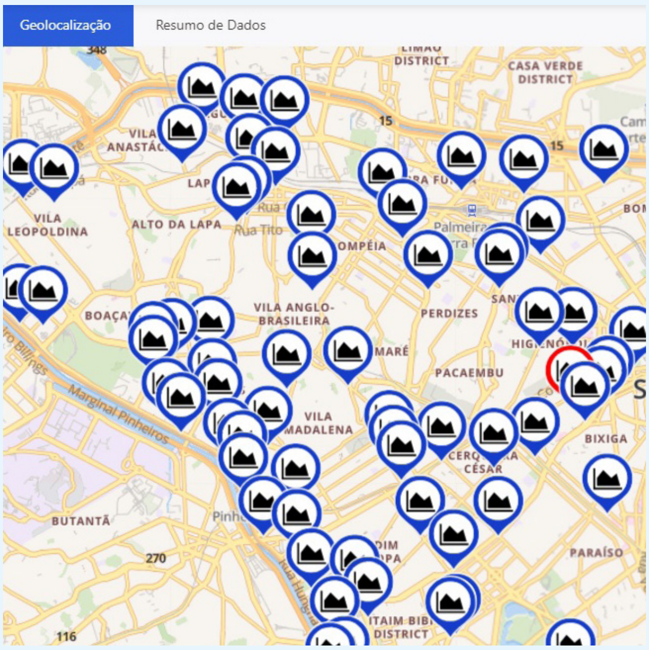


Figure 3. SABESP's water digital twin in Brazil streamlines complex water supply management.

Implementation roadmap

Adopting digital twins requires more than recognising potential — it demands a clear roadmap. Figure 4 outlines five steps for implementing a digital twin during any stage of a data centre's lifecycle: define objectives, ensure data readiness, pilot, scale, and continuous improvements.

The case example from Kaunas shows the value of phased rollout, while the Sabesp digital twin underscores the importance of comprehensive sensor networks. Together, they reinforce the effectiveness of staged adoption that is applicable anywhere in the lifecycle.

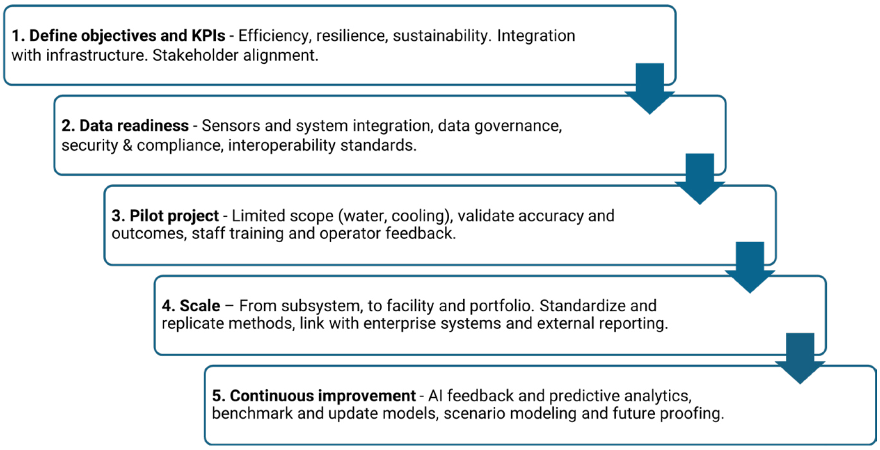


Figure 4. Roadmap for integrating digital twins into data centre operations.

Conclusion

Data centres are no longer hidden infrastructure. They are now in the public eye, as both enablers of the digital economy and major consumers of energy and water. The rise of AI and high-performance workloads is intensifying pressure on grids and resources, making efficiency, resilience and transparency essential.

Digital twins offer a practical way forwards. By combining real-time data with predictive models, they optimise performance, cut waste, and support informed planning. They also streamline ESG reporting, building trust with regulators, investors and communities.

Challenges remain, from legacy systems to governance gaps. However, the opportunity is clear. With open, interoperable approaches and responsible AI, data centres can become more efficient, resilient, and integrated with wider ecosystems.

For owners, operators, regulators and stakeholders alike, the message is simple: efficiency is the new baseline. Those who act now to embrace digital twins as a foundation for sustainable growth will be best placed to deliver the low-carbon, future-ready data centres the world demands.

This chapter was kindly authored by Stefan Mordue, Senior Manager, Education Programs & Partnerships, Saila Vicente, Sustainability Manager, and Rodrigo Fernandes, Director, Sustainability at Bentley Systems.

Chapter 7: Affected neighbours: Positive impacts on local communities and wildlife

As the data centre industry prepares for unprecedented expansion, it has a unique opportunity to transform relationships with affected neighbours. By considering local communities and wildlife right from the start – even before acquiring a site – the sector could unlock significant benefits for both itself and those living nearby.

Every community relies on data centres. They form the backbone of our digital world, powering everything from social media and online banking to government services and global communications.

Unlike other infrastructure, however, the benefits of having one on your doorstep are not always obvious, sometimes causing local opposition. There is a huge opportunity for the industry to change this, creating tangible benefits for communities and wildlife, and potentially becoming the preferred development partner for planning authorities worldwide.

Why aren't data centres always welcomed by neighbouring communities?

While transport infrastructure improves local connectivity and energy facilities power neighbouring homes, data centres serve as critical infrastructure for entire digital networks, rather than specifically for surrounding communities.

Moreover, they tend to bring fewer jobs and services to an area than developments, such as offices, retail destinations and leisure facilities, which directly boost regional economies and improve people's quality of life.

Data centres also continue to have notable environmental impacts through their consumption of energy and water. They often occupy large areas of land, with the potential to negatively affect local biodiversity and flood management, as well as people's access to green spaces and scenic views.

Collectively, these factors are causing some developments to fail in the planning and permission stages.

How could data centres overcome these challenges?

All developments – including data centres – exist within a social, environmental and economic context. Here are three fundamental shifts to drive change:

1. **Think about community and wildlife from the start**

   At Arup, we have seen the limitations of the traditional approach, where public engagement often does not begin until well into the planning process – usually after selecting the location, consulting investment agencies, assessing site suitability and preparing the planning case.

   By then, data centres may face local objections that are hard to resolve.

   We believe the due diligence stage is the ideal time to ask: 'How can we improve things while becoming your neighbour? How can we benefit local wildlife and climate resilience?'. These questions are as important as whether there is enough energy and water supply.

   Some major housing developers now bring together project teams including ecologists before acquisition to embed them, early, into the site selection process. This helps the developer to avoid important areas for people and wildlife and prevent purchasing land that results in unexpected local challenges.

   Embedding community and wildlife considerations at the outset creates opportunities for enhancement, making the mitigation hierarchy of 'avoid, minimise, restore and offset' central to the project. Critically, this can also speed up the planning process.

2. **Treat nature as a stakeholder**

Nature is critical to the future of our planet and influences every aspect of our lives, from the food and water we consume to our health and wellbeing. Yet, we have lost 70% of the abundance of our wildlife in the last 50 years. One million of the planet's plant and animal species face probable extinction. Three quarters of the planet's land surface has been significantly affected by human activity. Given that 55% of the world's GDP – equivalent to $58tn – is moderately or highly directly dependent on nature, this matters to every business.

Once a developer has avoided the areas important to wildlife, enhancing existing ecosystems can deliver a range of local benefits or nature-based solutions. These are central to how data centres could solve many of the challenges they face in communities.

Tangible benefits include promoting community wellbeing by increasing access to green space, boosting local ecosystems and growing resilience to climate change through flood protection and natural cooling. Data centres could lead a global shift by valuing green and blue infrastructure alongside grey, therefore giving nature a voice, from planning through to operation.

3. **Consider the wider landscape**

Data centres do not exist in isolation. Even big campuses represent only a small part of wider urban and rural catchments and ecosystems. To create resilient places, we must address issues across the whole area, not merely at individual sites.

This calls for new forms of collaboration between property owners, infrastructure providers and planning authorities. Together, they can create the right balance of infrastructure – green, blue and grey – to reduce flood risk, lower water demand, provide cooling, enhance air quality, boost biodiversity and promote wellbeing.

Data centres have an important role to play within this integrated system of the future, strengthening the resilience of communities and the centres themselves.

> To create resilient places, we must address issues across the whole area, not only at individual sites

How can data centres create positive local impacts?

Here are eight workable examples:

1. **Grow community spaces:** By going beyond landscaping, socially valuable and accessible green spaces can be created around data centres that promote health and wellbeing. When co-created with communities, these spaces can be enjoyed for physical activity and social interaction in areas including playgrounds, cycle paths and walkways. A wealth of research shows the benefits of nature for both physical and mental health. Landscaping can also turn a data centre's impact on local views into a positive one.

   One of the largest global technological companies is planning to develop a +200 MW hyperscale data centre campus in Spain, applying a positive-impact mindset. The development of the campus will deliver a +50 hectare public park, which was co-designed with the nearby communities. The design, which will achieve a 20% biodiversity net gain, enhances the cultural heritage of the locality and provides places to gather, exercise, play and enjoy nature. The project will compensate 100% of the energy and water consumption with renewables and water restoration projects.

2. **Boost biodiversity:** More and more data centres are investing to enhance biodiversity across their sites and contributing to nature strategies for the wider area. This includes providing diverse habitats for target species, connecting green corridors and monitoring biodiversity. The delivery of such habitats tangibly boosts their wildlife value, avoiding mown lawns and lollipop trees, and creating semi-natural habitat resources that provide structural diversity for a range of species.

   CyrusOne's plans for a new 90MW data centre campus in London include planting 670 trees and creating 72,800m^2 of public green space, along with woodland walks, cycle paths, mixed meadows and grassland. This will deliver 71% biodiversity net gain – seven times higher than the 10% required by UK regulations.

3. **Decrease flood risks:** By incorporating sustainable urban drainage systems (SUDS) and contributing to water management strategies for the wider area, data centres could actively decrease local flood risk and enhance climate resilience.

   Water is a key issue for many data centres and communities, particularly in regions facing water stress. While the industry is already factoring this into site selection and innovating to improve efficiency, a catchment-wide approach is needed. This will require different stakeholders to come together to create a resilient system for homes, food production, manufacturing, data centres and other essential sectors.

An **Arup-led data centre project** incorporated an attenuation (holding) pond that mitigates the impact of storms by storing water during heavy rainfall, gradually filtering and releasing it. The pond also provides valuable ecosystem services through native planting, varied depths for wildlife shelter and habitats for aquatic life.

4. **Generate local renewable energy:** Data centres that incorporate solar, wind or green hydrogen can share surplus power with neighbouring communities. Excess heat from servers can also be captured and recycled to provide heating for the local community. This remains complex to establish and operate but has been successful in several locations worldwide.

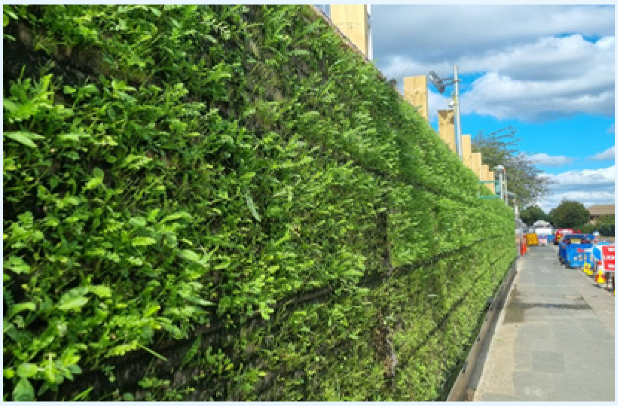
   Old Oak and Park Royal Development Corporation in London will be the first of its kind to recycle waste heat from large computer systems storing internet data to supply heating for the local community.

5. **Improve connectivity for rural internet consumers:** Local homes and businesses should benefit from the fast and robust internet connections that data centres develop for their own operations.

6. **Develop science/digital hubs to attract other start-ups:** Data centre campuses can be planned as part of larger hubs for other tech and scientific organisations and businesses, boosting the local economy. They can also develop training centres and support local skills strategies.

7. **Maximise construction opportunities:** While the construction phase is temporary, a few years can seem a long time for those living alongside it. There is already a lot of good practice in mitigating impacts like noise and dust, as well as prioritising local workers and suppliers for opportunities. With its track record of innovation, the data centre industry could lead the way in ensuring local communities and wildlife benefit from construction.

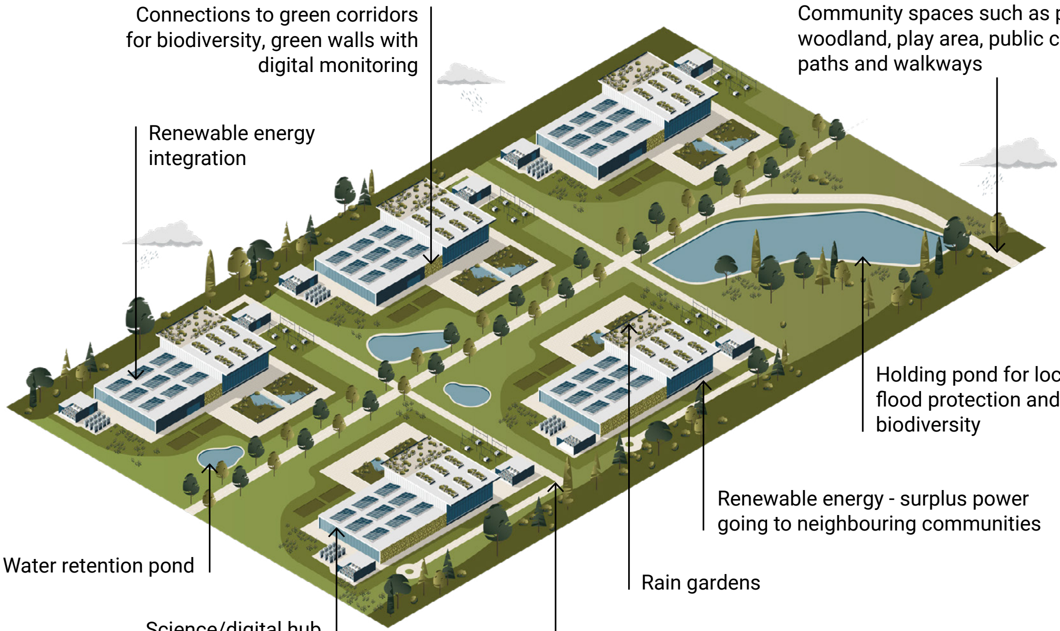
   Vertical Meadow has created a living cladding system for buildings and a wrap for site hoardings, using native wildflowers to support local biodiversity. This adds visual interest for the community and a species-rich habitat, as well as incidental sound insulation.



Vertical Meadow wrap on a data centre

8. **Digital monitoring:** Deploying sensors, satellite data and AI to track the effectiveness of solutions would not only give communities tools to verify that commitments are being met, thereby building trust, but also generate insights to shape future developments, highlighting what works well and what needs rethinking. The information could potentially be shared with the local community so that they can input to and access the data on local wildlife, taking an active role in mapping the recovery of nature.

   Arup's data centre clients are already fitting bio-acoustic sensors in green walls to monitor visiting bird and bee species and to share this information publicly. Experts are also using photos to assess the biodiversity quality of an environment. Similar digital tools could assess flood resilience and be made available to people to use via their smartphones.



A data centre campus that balances technology, community and nature

Of course, all the suggestions here need to work commercially, as well as socially and environmentally. **Our experience shows** they do not necessarily add significantly to total project costs. And the commercial upsides are a de-risked development and a shorter timeline to operations.

It is worth noting that many of the interventions listed above can overlap – the green space for people can screen the site and support wildlife, while decreasing flood risk.

Looking ahead, we see data centres as integral components of wider masterplans that incorporate community spaces and nature-based solutions. Those in cities may have fewer landscaping and amenity options, but the listen-first ethos still holds true. Here, the offer might be local educational initiatives or other tech sector opportunities.

The fastest line through

As the data centre industry expands at pace, some clients – looking for the fastest line through – have chosen not to embed social and environmental initiatives, only to have to retrofit them later. This is usually more expensive, takes longer and is less successful.

Starting the process with public engagement improves the planning journey. Data centres are at the forefront of the digital world. Innovation is in their DNA. By leveraging their digital capabilities and creativity, they can drive change.

The era of the anonymous black box – the 'UFO landing' development approach – is coming to an end. A more socially angled approach to data centre development offers a better way forward for everyone. After all, people are part of nature and nature is part of the local community, and both are essential for successful functioning data centers.

This chapter was authored by Tom Butterworth, Director, UKIMEA Nature Lead and Neil Harwood, Associate Director at Arup.