Greenwheel Insights

Feeding the Machine: Data centres, resources, and the environment

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Executive Summary

- **Data centres** provide the physical foundation for the digital world. **They use 1.5% of global electricity**, and new demand – driven mostly by non-AI uses – is **likely to grow data centre electricity use by 2.5x by 2030**.

- **Renewables covered 20% of data centre electricity demand in 2023**, **but more effort is needed** to drive additional, rather than drawing on existing capacity.

- **Grid constraints** are likely to **curtail new data centres** in some regions. Along with the need for sufficient and reliable electricity supply, this **may drive an increase in fossil fuel generation** – particularly gas.

- **Data centers usually have diesel generators** to provide back-up electricity. **New options, including batteries, are zero-carbon alternatives.**

- **Energy efficient cooling technologies are water intensive.** A 'hyperscale' data centre can use as much water as a mid-size town.

- **Hybrid air-liquid cooling technologies can balance electricity and water use**, but total data centre water use is set to increase significantly. Closed loop circulation, rainwater harvesting and wider watershed management activities can **reduce pressure on water resources**.

- **Data centres are also material intensive and use high volumes of copper**. New data centres in North America alone drive 1% of global copper demand. **Data centres can be designed for component and material reuse**. Material that cannot be reused may be recycled, or e-waste can be responsibility disposed of.

The following questions form the foundation of a ***framework for investors to assess the environmental footprint of companies operating data centres****.*

1. *Is the data centre sited in an area with suitable resources and connectivity?*
2. *Is the data centre designed to maximise the efficient and circular use of materials and components?*
3. *Is the cooling system designed to minimise both electricity and water intensity?*
4. *How is the company minimising its impact on freshwater abstraction and local watershed?*
5. *Is the use of zero-carbon electricity maximised, matched to demand and with additionality?*
6. *Does the data centre have a zero-carbon uninterruptable power supply?*
7. *Has consultation with local communities and other stakeholders been conducted?*

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Background

Data centres provide the physical foundation for the digital world, and are resource hungry. Their use accounts for around 1.5% of global electricity consumption and associated CO_2 emissions, with data transmission networks accounting for the same again.[i] **They also require significant volumes of water for cooling and can be material-intensive to build and refurbish**.

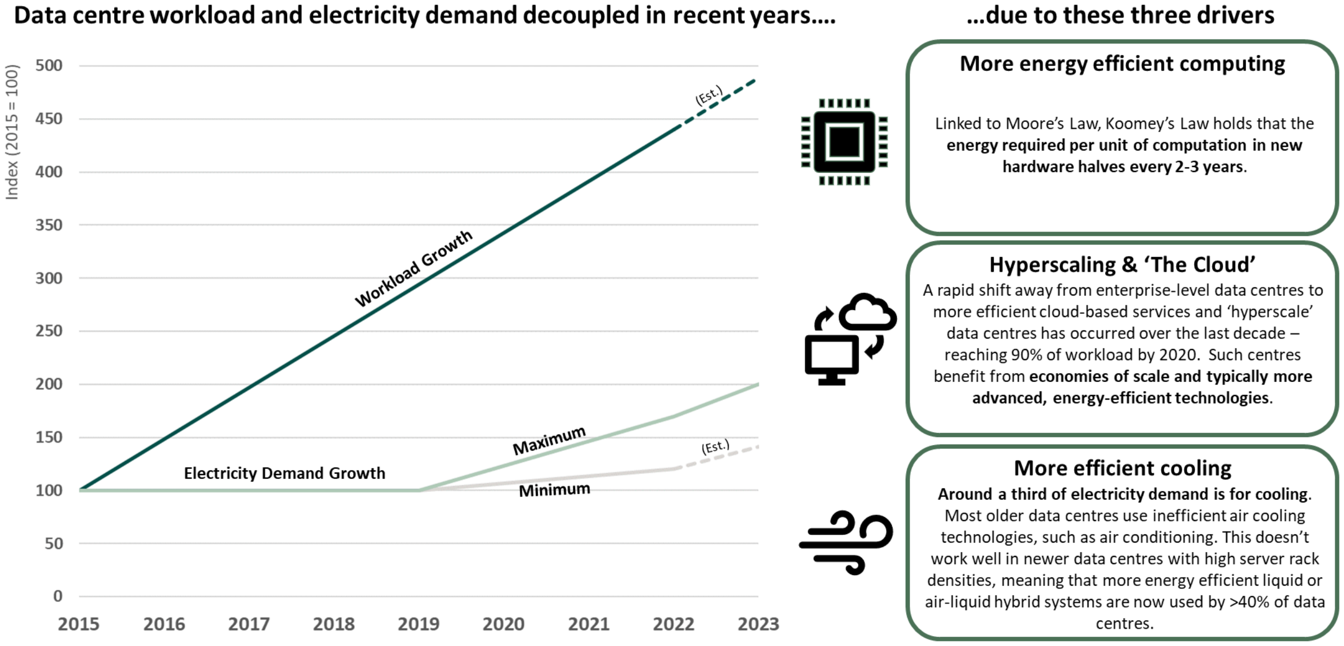
There are over 5,000 data centres in the USA - around a third of the global total, and >10x more than any other country. Germany, the UK, China and Canada round out the top 5, with 300-500 data centres each.[ii]

As artificial intelligence (AI) grows in sophistication and use, demand for data centres to deliver it will accelerate. This could have significant implications for the development of electricity systems and their CO_2 emissions, water resource security and competition, and demand for key raw materials. These factors could in turn restrict data centre development and location.

This briefing provides an overview of the resource and environmental implications of data centres. It also **provides a framework for investors to assess the environmental footprint of companies operating data centres**.

Diverging demand for computation and electricity

Despite rapid growth in data centre capacity and workloads in recent years, data centre energy use has grown modestly (excluding cryptocurrency mining). This is due to a combination of three interrelated factors, illustrated below in Figure 1.



Data centre workload and electricity demand decoupled in recent years....

...due to these three drivers

More energy efficient computing

Linked to Moore's Law, Koomey's Law holds that the **energy required per unit of computation in new hardware halves every 2-3 years**.

Hyperscaling & 'The Cloud'

A rapid shift away from enterprise-level data centres to more efficient cloud-based services and 'hyperscale' data centres has occurred over the last decade – reaching 90% of workload by 2020. Such centres benefit from **economies of scale and typically more advanced, energy-efficient technologies**.

More efficient cooling

Around a third of electricity demand is for cooling. Most older data centres use inefficient air cooling technologies, such as air conditioning. This doesn't work well in newer data centres with high server rack densities, meaning that more energy efficient liquid or air-liquid hybrid systems are now used by >40% of data centres.

Figure 1 – Data centre workload and energy use decoupling, and its drivers (2015-2023). Data Sources: IEA (2023); Goldman Sachs (2024). Workload growth and minimum electricity demand growth estimated for 2023, based on historic growth rate and maximum electricity growth rate, respectively. Graphic created by Greenwheel.

Despite a trebling in workload, electricity demand from data centres was held flat over 2015-2019 by these three factors. Electricity demand began to grow from 2020 as the efficiency gain from the shift from existing enterprise to hyperscale data centres (typically larger than 5,000 servers and 10,000 ft^2) and cloud computing became largely exhausted.

By 2023, data centre electricity demand reached 300-400TWh (excluding crypto), equivalent to electricity demand in Italy at the lower end, with the addition of the Philippines at the higher end. **Compared to all other forms of data, workload and electricity demand from AI processes is currently negligible**.

Electricity demand for cryptocurrency mining – excluded from this brief - has grown from almost negligible in 2015 to equivalent to at least 30% of data centre electricity demand for all other purposes in 2022[i], or the electricity consumption of the Netherlands.

Power Usage Efficiency (PUE) is the ratio between the total electricity used by a data centre and the power used by the IT equipment alone. **The more efficient the facility, the closer the value is to 1. The global average in 2007 was 2.5, reducing to 1.55 in 2022**[iii], due to hyperscaling, cloud computing, and more efficient cooling technologies. **Most new hyperscale new data centres have PUEs of <1.2**[iii], with some achieving <1.1.[iv]

Can this divergence continue?

Little efficiency potential from the move to hyperscale data centres and cloud computing remains. However, demand for faster response times (low latency) for some applications, such as autonomous vehicle and smart grid management, may drive an increase in 'edge' computing – smaller data centres located near the end user. Data protection and sovereignty issues may also drive an increase in edge computing.

Edge computing is less scale-efficient but can reduce electricity consumption in four ways. First, edge data centres can operate when and to the extent required, including through shifting compute demand to optimise electricity use. By contrast, hyperscale and cloud data centres operate constantly. Secondly, a larger surface area around IT equipment allows for more efficient cooling. Thirdly, heat can be recovered for use in co-located industries or heating networks. Fourth, reducing distance to end users reduces electricity demand for data transmission.[v]

More efficient cooling technologies (discussed below), **and other energy management approaches can continue to drive PUE values down toward 1**. **This will be a key driver for efficiency in the coming years**. Regulations around maximum PUE values have begun to enter force, but with highly varied ambition; as low as 1.2 in Germany and the Netherlands and 1.25 in China, but as high as 1.9 in Malaysia. The US has no regulations beyond federal government-operated data centres, and the EU requires only disclosure of energy performance from data centres from 2024.[vi]

It is likely that **the most significant factor driving the relationship between computation and electricity demand is 'Koomey's law',** which observes that the energy required per unit of computation in new hardware halves every 2-3 years, because of Moore's Law and wider improvements to system architecture.[1]

Ultimately, it is likely that **data centre workload demand growth will significantly outpace any gains in energy efficiency, increasing total electricity demand substantially.**

This is partly driven by the likely growth in AI applications. **AI requires significantly more electricity than non-AI applications, as it uses much more powerful hardware**.

AI systems use Graphics Processing Units (GPUs) rather than traditional Central Processing Units (CPUs), due to their capacity for parallel processing. Although GPUs are less electricity intensive than CPUs, their significantly higher compute capacity means that they consume far more electricity in total.

For example, a ChatGPT query uses 6-10x more electricity than a Google search.[viii] AI training is also highly electricity intensive. Estimates suggest that training ChatGPT-4 used as much electricity as 20,000 UK households use in a year.[vii]

Although AI demand will grow significantly, the primary driver of data centre electricity demand growth to 2030 is likely to be from non-AI purposes.[viii,ix]

Electricity demand for data centres is projected to grow 2.5x over 2023-2030 (Figure 2, excluding crypto) according to the IEA[ix] and Goldman Sachs[viii], with this growth equivalent to electricity used in the UK and Germany combined. Data centres would account for 3-4% of global electricity demand in 2030, and 3-8% in the USA.

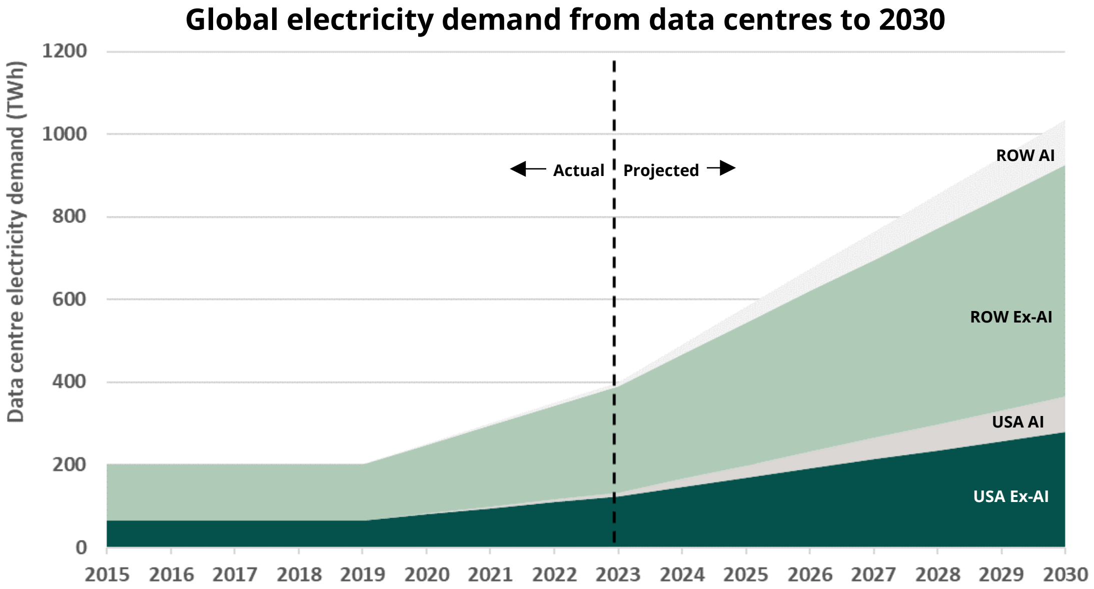


Figure 2 – Global electricity demand from data centres, 2015-2023 and estimated to 2030. Source: Goldman Sachs (2024).

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[1] Between the 1950s and 2000 a halving in electricity intensity occurred every 1.6 years, slowing to 2.6 years after 2000 due to Moore's Law (the rate of doubling in the number of transistors in an integrated circuit) decelerating and the end of Denning Scaling (power density of transistors is constant with declining size).

AI-based electricity demand grows from negligible to around 20% of all data centre demand by 2030, in both projections. **However, there is signficant uncertainty around these projections,** with the difference between the upper and lower bounds by 2030 equivalent to the **electricity consumption of Brazil**.

There are three key drivers behind such significant uncertainty (Figure 3).

Compute demand & costs

New AI hardware may have greater compute capacity and be more energy efficient, but require more electricity in total and be more expensive to install and operate. **Demand for additional compute capacity and/or budgets may be limited, constraining growth.**

Additional or cannibalistic

Some AI applications will be new and drive additional demand for computation and data centres. **Others will overlap with existing, non-AI applications, displacing existing computation and data centre demand**. The extent of this overlap in the coming years is uncertain.

Infrastructure & resource constraints

Electricity networks around the world are already under substantial pressure, and restrictions on the connection of new, large data centres may persist and grow. Land and particularly **water availability for cooling may also constrain development** in some locations.

Figure 3 – Drivers of uncertainty behind electricity demand for AI data centres. Graphic created by Greenwheel.

A boon for fossil fuels or renewables?

Most data centres are powered by their local grids... Their 'location-based' Scope 2 emissions are therefore driven by the local electricity generation mix, which is highly varied across the world.[x]

...although some data centre operators are the largest corporate procurers of renewable energy in the world. Procurement is primarily through renewable Power Purchase Agreements (PPAs) and the purchase of 'renewable guarantee of origin' certificates. This reduces their 'market-based' Scope 2 emissions. **Renewables covered around 20% of data centre electricity demand in 2023, from effectively zero in 2015.**[viii] Several major data centre owner and operators procure enough renewable electricity to cover all operational electricity demand.[i]

However, using PPAs or buying certificates does not necessarily match renewable supply to data centre demand in either time or location, **and may draw on existing rather than drive development of new renewable capacity**. **This makes the real-world decarbonisation impact unclear**.

A growing number of data centre operators, as signatories to the EU Climate Neutral Data Centre Pact, **aim to procure zero-carbon electricity procurement for all demand matched by location and hour of demand by 2030**.[xi]

Data centres are usually equipped with uninterruptable power supplies (UPS) – most often diesel generators – to provide electricity if the grid fails. As grid failures in developed economies have been uncommon, they have usually only been used – and produce emissions - in testing. Data centres in developing economies that experience greater risk of grid failure are more reliant on UPS systems, and use co-located renewables that attempt to mitigate some of this risk (e.g. South Africa).[xii] However, **the scale and consistency of data centre electricity demand means that relying solely or mostly on co-located variable renewables is not possible** in most instances.

Some data centre operators have begun testing and using alternative, low-carbon fuels and technologies for UPS systems, while yet others have been proposed as options for the future. Figure 4 presents these options in order of maturity. Depending on their characteristics, some such options could be used in place of grid electricity, for at least some of the time.

	Biofuels	**Batteries**	**Hydrogen**	**Small Modular Reactors (SMR)**
✓ **Benefits**	• Can be used with existing diesel generators • Renewable diesel (HVO) can fully replace fossil diesel • Biodiesel (FAME) is widely produced and can have very low lifecycle CO_2 emissions • Can generate power indefinitely if supply is replenished	• Maturing technology with increasing scale and decreasing costs • Can provide services to the grid for additional revenue • Zero lifecycle CO_2 if charged using renewable electricity (from grid or own supply)	• Hydrogen fuel cells and turbines are proven technology • Zero lifecycle CO_2 if using green hydrogen • Green hydrogen could be produced with on-site renewables • Can generate power indefinitely if hydrogen supply is replenished	• Provides steady, long-term electricity supply • Could replace grid electricity, reducing pressure on grids and wider electricity generation fleet • Can sell excess power to the grid for additional revenue • Very low lifecycle CO_2 emissions
✗ **Limitations**	• Renewable diesel can have similar lifecycle CO_2 emissions to fossil diesel • Biodiesel feedstock is limited in the medium/long-term, and is likely to be in high demand from other sectors. • more expensive than fossil diesel	• High capital cost for sufficient capacity • Can only be used for a limited time (can't charge while discharging)	• Green hydrogen is currently expensive, with very limited supply • Hydrogen is difficult and expensive to transport and store, so potentially unreliable for extended periods of use • If produced on site, electrolysis would need to run at high capacity, and require significant electricity and water supply, and land	• Not yet commercially available • Likely to be very expensive to build for first few years • Likely to have safety/regulatory barriers • May face public resistance in some countries/regions • If used as main source of power, other back up, so may still require active grid connection or other back-up supply.

Figure 4 – Low carbon uninterruptable power supply options. Sources include: Judge (2023); Lepineux (2023); Carlini (2023). Graphic created by Greenwheel.

Grid connection queues and capacity constraints are likely to curtail new data centres in some regions, particularly as the required size of the connection increases for dedicated AI sites. For example, **a moratorium for new data centre grid connections has been in place in Dublin since 2022**. Data centres used 17% of electricity generated in Ireland in 2022 and are expected to consume a third by 2026.[ix]

Attempts to overcome these constraints may impact local communities. For example, new grid infrastructure may be built without sufficient consultation or consent, or be completed at the expense of grid infrastructure required to supply other end users. It may also risk the stability of electricity supply to other end-users.[2]

The current inability of on-site low carbon technologies to satisfy a data centre's electricity demand, coupled with grid constraints and the need for a reliable electricity system means that **a rapid growth in data centres is likely to lead to growing electricity generation from fossil fuels – particularly gas.**

Gas power plants can be built quickly, can connect to existing gas pipelines, generate electricity on-demand, and produce half the CO_2 emissions of coal power plants. Existing gas plants on the grid may generate more for longer, and new gas capacity may be added either to the grid, or be co-located, owned and operated by data centre operators. For example**, Microsoft is constructing a gas plant to power a new data centre in Dublin**, due to the grid connection moratorium.

The extent to which these constraints put data centre renewables and emissions targets at risk, or whether these targets will curtail an increase in fossil fuel generation, is unclear. However, pressure from both directions is likely to be present.

Keeping cool is thirsty work

Traditional air-cooling approaches are energy intensive and generally unsuited to data centres with high computing loads and cooling demand, such as those supporting AI. Figure 5 (following page) illustrates key air, liquid and hybrid cooling technologies, and their implications for electricity and water use. **Current hyperscale and AI data centres largely draw on liquid and hybrid (evaporative) cooling systems**.

Water Usage Efficiency (WUE) measures the ratio of water used by the data centre to the power used by the IT equipment within the data centre. **The lower the number, the higher the water efficiency. The global average is currently 1.8L/kWh**.[xiii]

Global average WUE values for major hyperscale data centre owners and operators range from <0.2L/KWh to >1.7L/kWh, due to differences in ambient temperatures and cooling technology required.[vi,xiv] Those with the lowest values mainly use hybrid switchable systems, where the local environment is conducive.

This illustrates that while **hybrid (particularly switchable) systems can produce both water and electricity savings, their use and scale of savings available depends significantly on local environmental conditions** (e.g. cold ambient air).

Despite these low values, their large electricity and cooling demand means that **an average hyperscale data centre uses the same volume water per year as a town of around 35,000 people**.[xv] At least two hyperscale data centre operators draw around a

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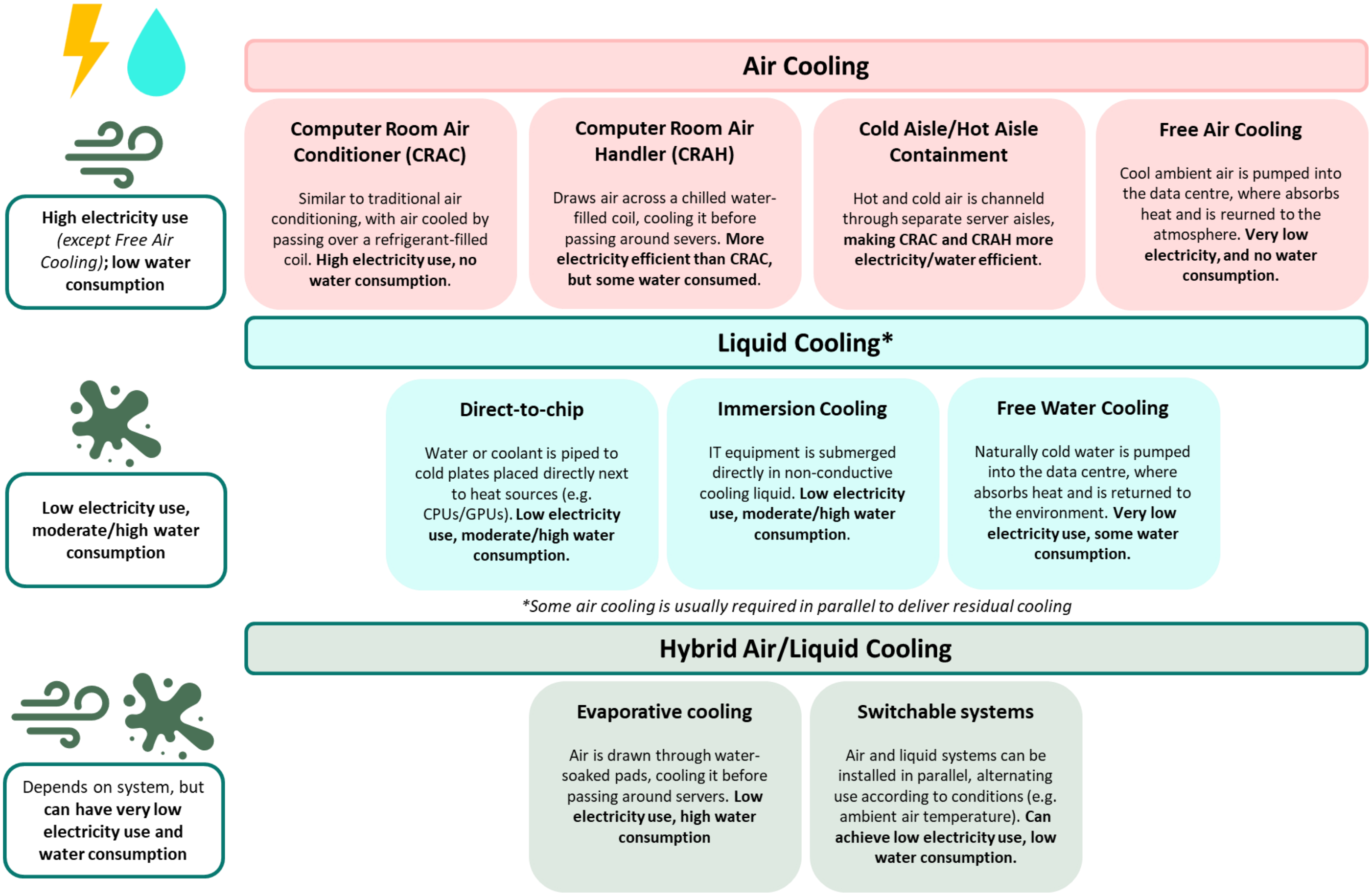
[2] See Greenwheel Briefing: "Rage against the AI machine? Impact on Communities and End-Users" for more information

fifth of their freshwater from water stressed areas.[xvi] Data centre cooling typically requires high quality water, meaning operators usually draw on potable resources.



High electricity use *(except Free Air Cooling)*; **low water consumption**

Air Cooling

Computer Room Air Conditioner (CRAC)

Similar to traditional air conditioning, with air cooled by passing over a refrigerant-filled coil. **High electricity use, no water consumption.**

Computer Room Air Handler (CRAH)

Draws air across a chilled water-filled coil, cooling it before passing around severs. **More electricity efficient than CRAC, but some water consumed.**

Cold Aisle/Hot Aisle Containment

Hot and cold air is channeld through separate server aisles, **making CRAC and CRAH more electricity/water efficient.**

Free Air Cooling

Cool ambient air is pumped into the data centre, where absorbs heat and is reurned to the atmosphere. **Very low electricity, and no water consumption.**

Low electricity use, moderate/high water consumption

Liquid Cooling*

Direct-to-chip

Water or coolant is piped to cold plates placed directly next to heat sources (e.g. CPUs/GPUs). **Low electricity use, moderate/high water consumption.**

Immersion Cooling

IT equipment is submerged directly in non-conductive cooling liquid. **Low electricity use, moderate/high water consumption.**

Free Water Cooling

Naturally cold water is pumped into the data centre, where absorbs heat and is returned to the environment. **Very low electricity use, some water consumption.**

**Some air cooling is usually required in parallel to deliver residual cooling*

Depends on system, but **can have very low electricity use and water consumption**

Hybrid Air/Liquid Cooling

Evaporative cooling

Air is drawn through water-soaked pads, cooling it before passing around servers. **Low electricity use, high water consumption**

Switchable systems

Air and liquid systems can be installed in parallel, alternating use according to conditions (e.g. ambient air temperature). **Can achieve low electricity use, low water consumption.**

Figure 5 – Key data centre cooling technologies. Sources include: ARUP (n.d.); Derrick (2023); Zhang (2024); Sheldon (2024); Yang et al (2024). Graphic created by Greenwheel.

Water use estimates increase when incorporating indirect (upstream) consumption. **In the USA, around five times more water is used in the generation of electricity used by data centres than is used by data centres directly**.[vi] Pressure on water resources also occurs upstream in the supply chain, from semiconductor manufacture to the extraction and processing of other raw materials, such as copper.[xvii]

Demand for cooling is likely to increase competition for water resources. This can threaten the rights of different stakeholders, producing conflict which can in turn threaten the operation of a data centre, or prevent its construction.[3] Significant protest movements against data centres have been seen around the world, including Ireland, the Netherlands, and Chile.[xviii] **Excessive water consumption is among the most common reasons for organisations to close data centers**.[vi]

Water demand from a data centre and its impact on local water resources can be minimised through seven complementary measures, illustrated by Figure 6. **Some direct water efficiency measures are more difficult to retrofit into existing data centres**

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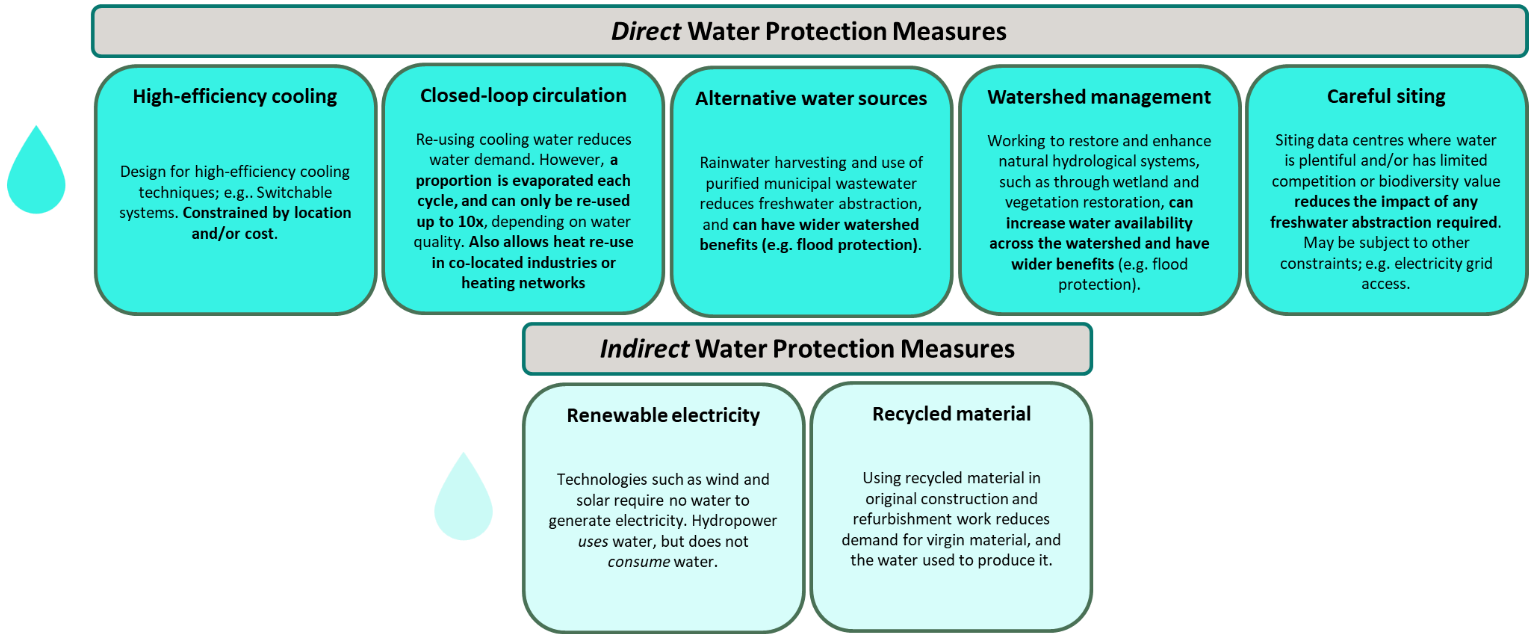
[3] See Greenwheel Briefing: "Rage against the AI machine? Impact on Communities and End-Users" for more information.

compared to new capacity, with retrofit potential specific to the data centre and its location. **However, both new and existing data centres can adopt measures to reduce their indirect water footprint**. From 2025, data centres in the EU must report water use and the reuse of waste heat in nearby facilities and heat networks.[xix] Comparable regulations are not currently found elsewhere.



***Direct* Water Protection Measures**

High-efficiency cooling

Design for high-efficiency cooling techniques; e.g.. Switchable systems. **Constrained by location and/or cost.**

Closed-loop circulation

Re-using cooling water reduces water demand. However, **a proportion is evaporated each cycle, and can only be re-used up to 10x**, depending on water quality. **Also allows heat re-use in co-located industries or heating networks**

Alternative water sources

Rainwater harvesting and use of purified municipal wastewater reduces freshwater abstraction, and **can have wider watershed benefits (e.g. flood protection).**

Watershed management

Working to restore and enhance natural hydrological systems, such as through wetland and vegetation restoration, **can increase water availability across the watershed and have wider benefits** (e.g. flood protection).

Careful siting

Siting data centres where water is plentiful and/or has limited competition or biodiversity value **reduces the impact of any freshwater abstraction required.** May be subject to other constraints; e.g. electricity grid access.

***Indirect* Water Protection Measures**

Renewable electricity

Technologies such as wind and solar require no water to generate electricity. Hydropower *uses* water, but does not *consume* water.

Recycled material

Using recycled material in original construction and refurbishment work reduces demand for virgin material, and the water used to produce it.

Figure 6 – Measures to minimise data centre water footprint and impact. Sources include: ARUP (n.d.); ING (2023). Graphic created by Greenwheel.

Many major hyperscale data centre operators have made commitments to reduce the water intensity of their data centres, and to use watershed management techniques to replenish at least as much water as they consume by 2030. However, progress is slow.[xx]

Despite the range of measures available to moderate the water footprint of data centres, the **rapid growth in demand for new data centres means that water consumed by the sector** (both directly and in thermal power generation to supply it) **is projected to grow by >50%.** For AI demand alone, water abstraction may equal half that abstracted annually in the UK by 2027 (for both direct use and power generation).[vi]

The material behind the digital

Data centres are material intensive. Significant volumes of steel and cement are used to construct their shells, the production of which produces GHG emissions equivalent to a third of the emissions from generating electricity to power the data centre.[xxi] **This is despite a significant increase in building material efficiency due to the shift to hyperscale and cloud computing**.

A wide range of other materials comprise the IT equipment, communication networks and ancillary equipment that allow the data centre to function.

Demand for copper is particularly strong. Copper is mainly used for power distribution, but also grounding, communication and more general building services such as cooling and plumbing systems. **An average hyperscale data centre requires 900-2,200 tonnes of copper**.[xxii] **Data centres constructed in 2020 in North America alone accounted for ~1% of global copper demand that year**.[xxiii]

Although building material intensity relative to compute capacity is likely to continue decreasing, copper intensity is likely to remain high.

Forecasts of additional annual global copper demand for data centre construction by 2030 vary significantly, from 200,000 tonnes[xxiv] to 1 million tonnes per year[xxv] – equivalent to ~1% and ~3% of current total global copper demand. The **production of copper and other key raw materials in the data centre value chain are highly geographically concentrated**, and many are associated with environmental and social risks.[xxvi]

Material used in data centres eventually becomes waste. Data centre buildings may last 15-20 years but severs are typically replaced every 3-5 years. This means **the rate of e-waste generation is likely to become very substantial**. Although e-waste is well regulated in some jurisdictions (e.g. the EU), only around half of US States regulate e-waste. E-waste regulation is also largely absent from most emerging economies.[xxvii]

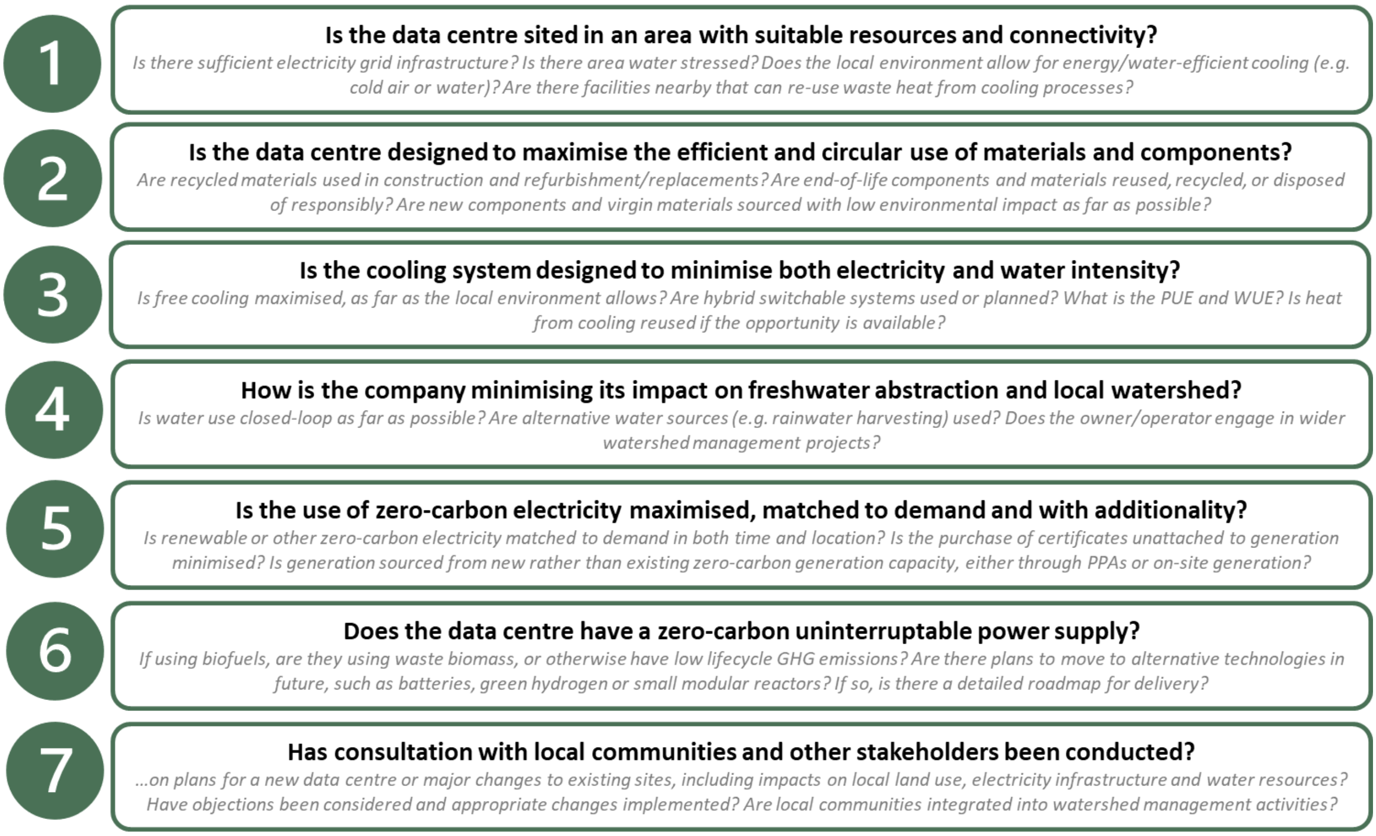
Data centres can be designed for their equipment to be reused. This is particularly the case for hyperscale data centres, which use customised components. This equipment can either be retained and used for less demanding workloads, or sold on for the same purpose, also allowing residual value to be captured. Truly end-of-life equipment can be recycled to the extent possible, or otherwise disposed of responsibly.[xxvii]

Although data centre buildings can have a large footprint, they are not sprawling. A hyperscale data centre defined as over 10,000 ft^2 – smaller than an Olympic size swimming pool. As hardware capacity continues to improve land intensity will decrease, but **the rate of demand growth will increase the total land required to support data centres**. Sites should be chosen to minimise their environmental and social impact.

What does this mean for investors?

Almost all businesses rely on data centres, but in many cases this reliance is indirect. The **data centres that underpin generic digital services are generally not considered in methodologies that measure the environmental impact of business that use them**. Their ability of businesses to engage and influence providers of generic digital services, or change provider, is also likely to be limited.

However, **business that build, own, operate or procure dedicated capacity in data centres have greater influence over their design and operation**, and the environmental impacts they carry. For these businesses and their investors seeking to minimise and manage these impacts, **the following framework of questions may be applied** (with associated questions in *italics*):



1. **Is the data centre sited in an area with suitable resources and connectivity?**
Is there sufficient electricity grid infrastructure? Is there area water stressed? Does the local environment allow for energy/water-efficient cooling (e.g. cold air or water)? Are there facilities nearby that can re-use waste heat from cooling processes?

2. **Is the data centre designed to maximise the efficient and circular use of materials and components?**
Are recycled materials used in construction and refurbishment/replacements? Are end-of-life components and materials reused, recycled, or disposed of responsibly? Are new components and virgin materials sourced with low environmental impact as far as possible?

3. **Is the cooling system designed to minimise both electricity and water intensity?**
Is free cooling maximised, as far as the local environment allows? Are hybrid switchable systems used or planned? What is the PUE and WUE? Is heat from cooling reused if the opportunity is available?

4. **How is the company minimising its impact on freshwater abstraction and local watershed?**
Is water use closed-loop as far as possible? Are alternative water sources (e.g. rainwater harvesting) used? Does the owner/operator engage in wider watershed management projects?

5. **Is the use of zero-carbon electricity maximised, matched to demand and with additionality?**
Is renewable or other zero-carbon electricity matched to demand in both time and location? Is the purchase of certificates unattached to generation minimised? Is generation sourced from new rather than existing zero-carbon generation capacity, either through PPAs or on-site generation?

6. **Does the data centre have a zero-carbon uninterruptable power supply?**
If using biofuels, are they using waste biomass, or otherwise have low lifecycle GHG emissions? Are there plans to move to alternative technologies in future, such as batteries, green hydrogen or small modular reactors? If so, is there a detailed roadmap for delivery?

7. **Has consultation with local communities and other stakeholders been conducted?**
…on plans for a new data centre or major changes to existing sites, including impacts on local land use, electricity infrastructure and water resources? Have objections been considered and appropriate changes implemented? Are local communities integrated into watershed management activities?

Figure 7 – Framework for investors to examine the environmental impact of data centres. Graphic created by Greenwheel.

Endnotes

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[i] IEA (2023)
[ii] Statista (2024)
[iii] ING (2023)
[iv] Google (2024a)
[v] Adib (n.d.)
[vi] Yang et al (2024)
[vii] Training data from Ludvigsen (2023). UK average household annual electricity use from Ofgem (2024).
[viii] Goldman Sachs (2024)
[ix] IEA (2024)
[x] Statista (2024)
[xi] CNDC (2024)
[xii] Ndlovu (2024)
[xiii] Buchholz (2023)
[xiv] Zhang (2024)
[xv] Barrowclough (2023)
[xvi] ING (2023)
[xvii] See the Greenwheel ‘Critical Materials’ series for more information.
[xviii] Lehunde (2022)
[xix] European Commission (2024)
[xx] Google (2024b)
[xxi] Swinhoe (2021)
[xxii] Man Institute (2024)
[xxiii] Venditti (2023)
[xxiv] Reuters (2024)
[xxv] Yadav (2024)
[xxvi] See Greenwheel Briefing “Rage against the AI machine? Impact on workers” for more information.
[xxvii] Powers (2023)

Key Information
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