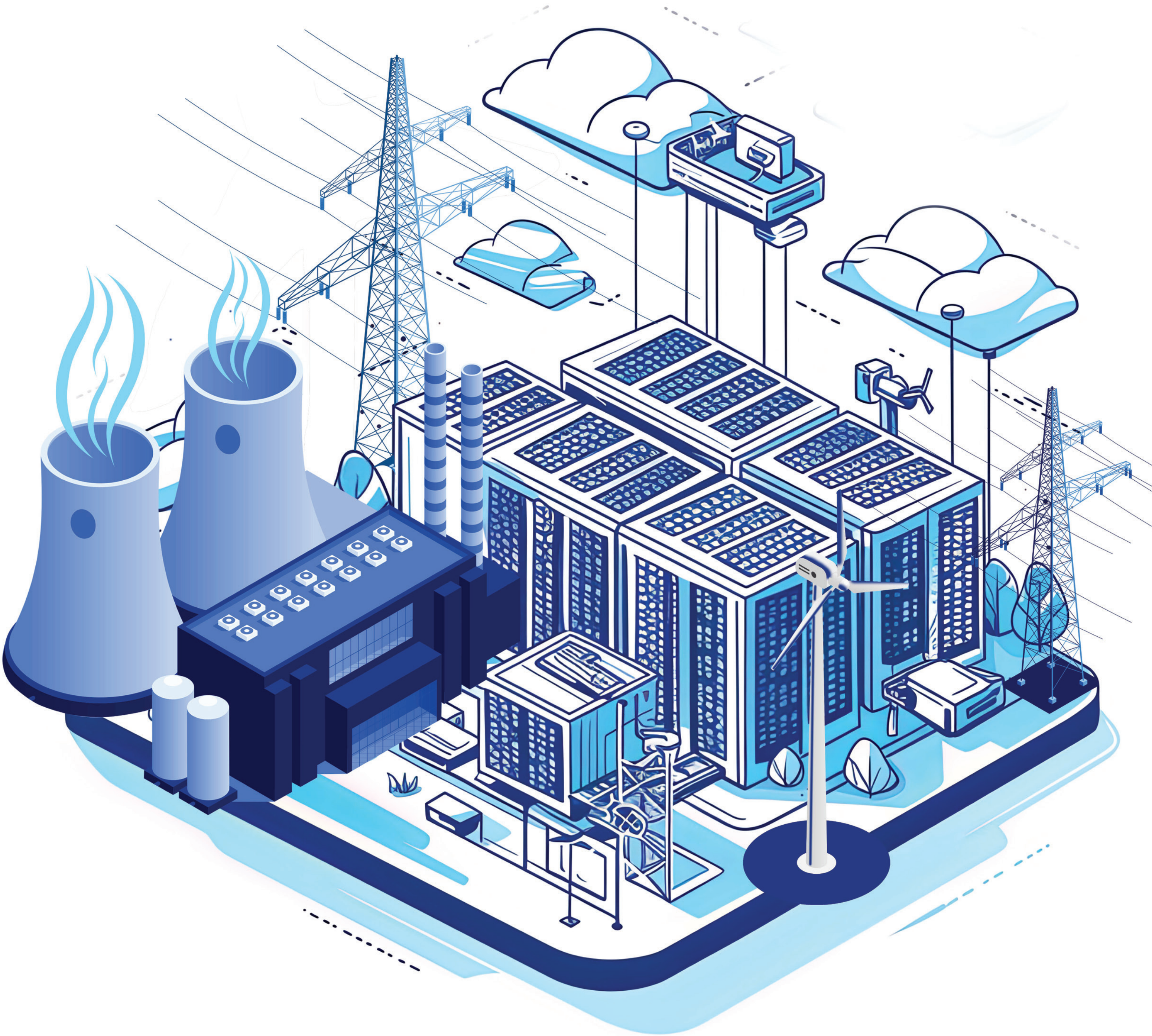
The Consumption of Energy by Data Centres

Implications for the Global South

Lydia Powell • Akhilesh Sati



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Executive Summary

Key Takeaways

THE ERA OF STAGNANT growth in electricity demand in the Global North is forecast to end with the emergence of additional large electricity loads arising from the promotion of domestic manufacturing, growth in electric vehicle adoption, revival of the cryptocurrency industry, and the increase in data centres (DCs) that power the generation and use of artificial intelligence (AI). Among these drivers, the growth in electricity consumption by DCs is projected to be the fastest and largest, driving demand for gigawatts of electricity generation capacity.

THE DRIVERS OF INVESTMENT in DCs across the world include historical context, availability of infrastructure, fibre links to the rest of the world, availability of land and electricity at competitive rates, and proximity to DC clients and owners. In 2024, the United States (US) accounted for over 50 percent of DCs in terms of numbers and power consumption, followed by Asia with 30 percent and Europe, the Middle East, and Africa, the remaining 20 percent.

THE GLOBAL SOUTH, EXCLUDING China, accounted for 50 percent of the world's internet users, but it has less than 10 percent of global DC capacity. The Global South is currently a net exporter of data and a net importer of knowledge generated from the data processed by Global North DCs. To reverse this pattern, the Global South must invest in cutting-edge data infrastructure and promote high-level skill development.

THE GLOBAL SOUTH HAS A small share of the economic gains from hosting DCs. To attract DC investment, countries in the Global South should position themselves as low-cost locations with competitively priced land and energy resources and stringent but fair environmental regulations.

ELECTRICITY CONSUMPTION BY DCs accounted for about 1.5 percent of global electricity consumption in 2023. The US, Europe, and China contributed to around 85 percent of global electricity consumption from DCs. Overall, conventional fuels accounted for about 56 percent of electricity consumed by DCs in 2023. In the future, power generators could increase generation from conventional fuels, nuclear, or renewables, depending on demand and policy support. In all scenarios, due to rising marginal costs of electricity supply, the increase in generation is not likely to be proportional to economy-wide demand growth, which may drive up electricity prices.

WHILE GHG EMISSIONS FROM DCs remain below 1.5 percent of the total energy sector emissions in 2023, DCs are among the fastest growing sources of emissions. In North America and Europe, grids average roughly 0.3-0.5 kg CO_2 per kilowatt-hour of carbon intensity owing to rising gas, nuclear and renewable shares. In China and India, where grids are coal-dominated, grid intensities are of 0.5-0.6 kg CO_2 per kilowatt-hour or higher.

CONCERN THAT AI-DRIVEN DEMAND for DCs could accelerate climate change is overstated, as is the expectation that AI will solve the GHG emissions problem, among other human problems. Given that available atmospheric space for GHGs is limited, additional energy demand from the Global North to power DCs may enable appropriation of the shrinking atmospheric space for GHG emissions, crowding out development-related space for GHG emissions that the Global South needs.

AN INCREASE IN GHG EMISSIONS from the Global North may also hike the pressure on the Global South to accelerate reduction of emissions to accommodate additional emissions from the Global North. This issue must be raised at multilateral climate negotiation platforms to ensure equitable distribution of available atmospheric space for GHG emissions.

Contents

Executive Summary 5

I. Introduction 8

II. The Geography of Data Centres 11

III. Data Sovereignty 15

IV. Energy Demand from Data Centres 18

Manufacturing
Artificial Intelligence Training
Operations
Regional and National Energy Consumption Shares
Data Centre Energy Mix
Emissions Footprint

V. Conclusions 32

VI. Policy Recommendations 36

I.

Introduction

Demand for terawatt hours of additional electricity from data centres in the Global North will decrease affordability of fuels for electricity generation and crowd out development carbon space of the Global South.

In 2023, electricity generation in the United States (US), which accounted for 15 percent of global electricity generation, declined by 1 percent. In the decade ending in 2023, electricity generation declined by 0.4 percent.[1] In Europe, which accounted for 12.7 percent of global electricity demand in 2023, electricity generation declined by 2.4 percent, and in the decade ending in 2023, electricity generation declined by 0.6 percent.[2] Electricity generation also declined in Japan, Taiwan, and South Korea, the industrialised high-income countries of the Asia Pacific.[3] Overall, electricity generation declined by 1.5 percent in OECD (Organisation for Economic Co-operation and Development) countries in 2023, while electricity generation increased by 5.1 percent in non-OECD countries.[4]

The era of stagnant growth in electricity demand in OECD countries (or the Global North) is forecast to end with the emergence of new large electricity loads arising from the promotion of domestic manufacturing, growth in electric vehicle (EV) adoption, revival of the cryptocurrency industry, and the increase in data centres (DCs) that power the generation and use of artificial intelligence (AI).[5] Among additional demand drivers, electricity demand from DCs is the fastest growing. This alone is likely to increase irrespective of policies and mandates for the energy transition, as DC electricity consumption is driven primarily by commercial and popular demand for data and AI services. As electricity demand from AI-based outcomes increases exponentially with the complexity of the task, the demand growth for electricity from DCs is likely to be unprecedented.[6]

According to the International Energy Agency (IEA), rising DC electricity use, linked in part to the growth of AI, is likely to have primarily local impacts.[7] This may be true in the short term, but in the longer term, when the share of energy consumed by DCs increases, it is likely to hike the price of traded primary energy forms such as natural gas and coal. Additionally, it will increase GHG emissions from energy production and use across the world. The economic benefits (efficiency and productivity gains) and environmental costs of energy use by DCs are likely to be unevenly distributed between the Global North and the Global South.

If DCs remain concentrated in the Global North as they are today, energy demand from the Global North will increase, compromising energy security and affordability for the Global South. Additional energy demand from the Global North may also enable appropriation of the shrinking atmospheric space for GHG emissions, crowding out development-related atmospheric space for GHG emissions that the Global South needs. An increase in carbon emissions from the Global North may also heighten the pressure on the Global South to accelerate the reduction of emissions to accommodate additional emissions from the Global North. However, AI that depends on DCs could also accelerate breakthroughs in low-emission energy innovation, manage the electricity grid to facilitate more renewables, and enhance the profitability and speed of electrification programmes in the Global South. Given the impact of AI, enabling conditions and scalability are not well-known, the expected benefits on the scale projected may not materialise. If so, the expected rise of DC GHG emissions will represent a social cost. The development goals of the Global South will be compromised if the Global South is expected to bear a disproportionate share of the social cost. The economic benefits of DCs, particularly higher economic growth and job creation, may accrue largely to the Global North.

This report seeks to understand how the projected growth of energy consumption by DCs and the consequent increase in GHG emissions will be distributed between the Global North and the Global South. It will answer the following questions: (1) Will geography determine the location of DCs? If so, will countries in the northern hemisphere that host most of the technology companies have an advantage? Will cooler climates and low energy prices attract most of the DC investment? What will this mean for the Global South? (2) Will data sovereignty decide the location of DCs? Will this force DCs to be located in countries that are otherwise not favourable? (3) Will companies, rather than countries, decide the location of DCs? If commerce drives decisions on DC location, will it create opportunities for the Global South as low-cost locations, thus redistributing some of the economic benefits?

II.

The Geography of Data Centres

The Global South accounts for over 50 percent of internet users but less than 10 percent of data centre capacity. Most of the economic benefits of hosting data centres will accrue to the Global North while the Global South will bear a disproportionate share of the environmental costs.

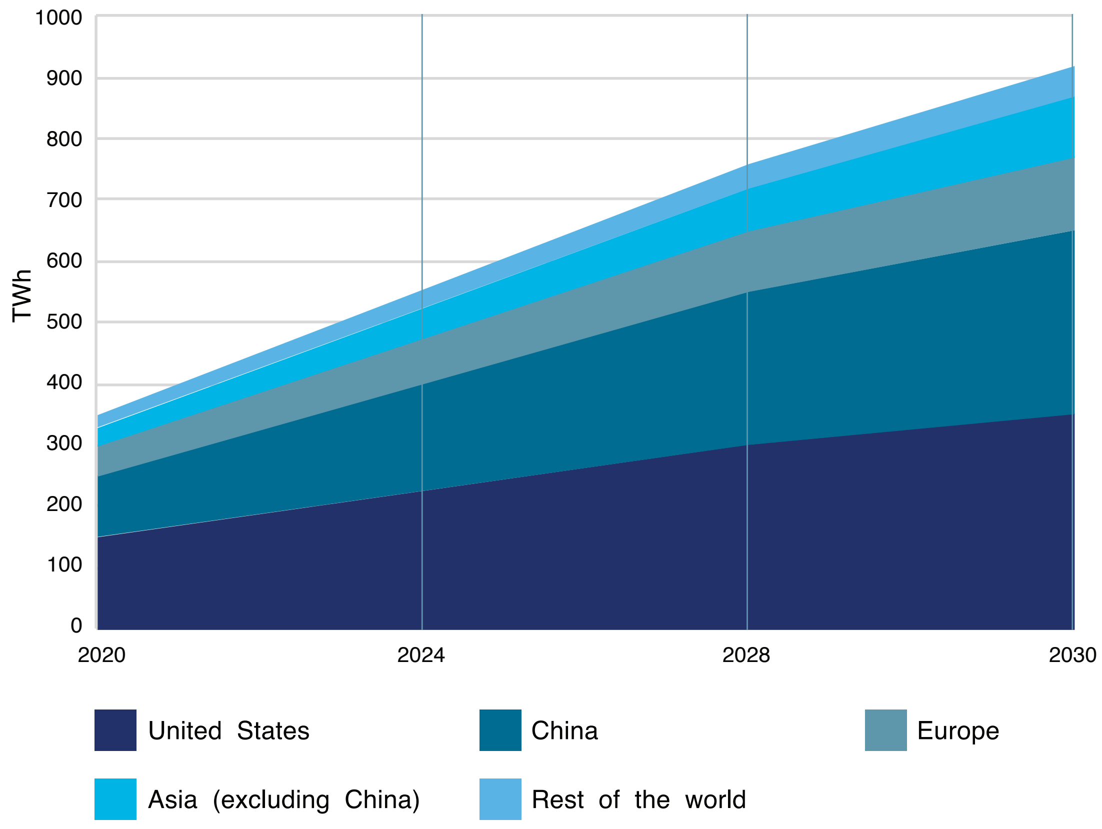
According to available data, there are more than 11,000 DCs registered worldwide in 2024.[8] The US accounted for over 50 percent of DCs in terms of numbers and also in power consumption, followed by Asia, which accounted for 30 percent, and Europe, the Middle East, and Africa, which accounted for the remaining 20 percent.[9] DCs are more spatially concentrated than other energy-intensive economic activities such as steel production.[10] Companies tend to build DC buildings close together so that they can share power grids and cooling systems, and transfer information efficiently, both among themselves and to users.[11]

In large economies like the US, China, and Europe, DCs accounted for around 2-4 percent of total national electricity consumption in 2023.[12] Electricity consumption by DCs has surpassed 10 percent in at least five US states.[13] In the US state of Virginia, which is home to the largest concentration of DCs in the world, electricity consumption by DCs matches that of the tens of thousands of residential homes, potentially driving up tariffs for residents and straining the area's power infrastructure beyond its capacity.[14] Virginia attracted DC firms by providing tax breaks and other incentives, leading to clustering. According to one study, DCs accounted for one-quarter of Virginia's electricity use.[15] The square footage of server-filled DCs in Virginia is now estimated to be roughly equivalent to the floor space of eight Empire State buildings.[16] In Ireland, DCs account for more than 20 percent of the country's electricity consumption, with most of them situated in Dublin.[17]

Factors that contributed to the development of Virginia and Dublin as DC hubs offer clues on the likely geographical distribution of DCs in the future. The concentration of DCs in Northern Virginia has a historical context. The Advanced Research Projects Agency (ARPA), an arm of the US defense department, funded the development of the Advanced Research Projects Agency Network (ARPANET) in Virginia in the late 1960s.[18] It was the first public packet-switched computer network that linked computers at Pentagon-funded research institutions over telephone lines.[19] Many of the protocols used by computer networks today were developed for ARPANET, and it is considered the forerunner of the modern internet.[20] In the 1990s, the metropolitan area exchange-East Point, part of the MCI (a US telecommunications company acquired by Verizon Communications) and its role in developing the internet was founded in Virginia, thanks to the presence of AOL (America Online) and other ISPs (internet service providers).[21] Half of the world's internet traffic passed through the network by 1997, and companies like AOL and Verizon established a vast fibre backbone and network hubs there.[22]

Virginia's strategic location on the US East Coast, closer to the national capital, made it ideal for serving government, defence, finance and technology clients.[23] In addition, Virginia's abundant flat land—exposed to few natural disasters—and reliable electricity supply, with a tariff below the national average, favoured DC construction.[24] State and local governments aggressively courted DCs with tax breaks for investments above a threshold that created attractive employment opportunities.[25] As a result, Northern Virginia has evolved into a 'DC alley' with hundreds of operating DCs for internet, social media, and financial firms.[26] A state-commissioned review in 2024 noted that although DCs bring economic benefits, their growth could double electricity demand in Virginia within 10 years, with a potential increase in tariffs for consumers.[27]

Figure 1: Electricity Consumption by Data Centres: Share by Country/Region 2020-30



Source: International Energy Agency[28]

Dublin has emerged as Europe's premier hyperscale DC hub, primarily driven by government policies for attracting investment and the creation of jobs since the 1990s.[29] Towards this goal, Ireland positioned itself as a technology gateway between the US and the European Union (EU). While the country offered no DC-specific tax breaks, a low corporate tax regime of 12.5 percent and research and development credits attracted multinationals.[30] Investment in fibre-optic and telecom infrastructure with multiple undersea cable landings to the US, UK, EU, and other parts of the world made Dublin a transatlantic internet node.[31] Early investment in national backbone networks enabled the rapid growth of DC capacity.[32] The European Commission's state aid rules allowed certain "energy intensive" users low electricity tariffs, which made Dublin a favoured investment destination.[33] Dublin's temperate, cool climate was advantageous for cooling servers in DCs.[34] Ireland's EU membership and skilled English-speaking workforce added to its attractiveness.[35] By the 2010s, Dublin was a natural landing point for transatlantic cables and cloud services.[36] These firms co-located their EU headquarters and cloud infrastructure in Ireland, creating a powerful cluster effect.[37] Each new large DC in Dublin attracted more infrastructure and specialised firms, reinforcing Dublin's status as a European DC capital. The city currently hosts dozens of hyperscale centres (large DCs), roughly 5 percent of the world's capacity run by multinational e-commerce, social media, and financial firms.[38] By one account, Ireland now hosts roughly 25-30 percent of all European data storage.[39]

The drivers of investment in Virginia and Ireland, leading DC locations in the US and EU, respectively, show that historical context, investments in infrastructure including fibre-optic cable connections to the rest of the world, availability of stable and low-tariff electricity, and proximity to clients or owners of data centres attract investment in DCs. In the Global South, excluding China, few companies that generate internet traffic and AI services are comparable in scale and scope of US-based companies. Affordable land, cheap power, availability of digital infrastructure and favourable policies are essential for DC development, and this is leading to the concentration of DCs. Half of the capacity under development in the US is being built in locations that already have over 1 GW of installed capacity.[40]

While around two-thirds of the global population reside in the Global South, excluding China, these countries account for less than a third of global electricity generation, underscoring the energy challenge in attracting DC investment.[41] In the Global South, excluding China, only around 60 percent of the population currently have access to reliable Internet, and households spend on average 10 times more of their income on fixed broadband than in the Global North.[42] Though the Global South (excluding China) account for 50 percent of the world's internet users, the South has less than 10 percent of global DC capacity.[43] In some countries in the Global South, local populations can experience severe power scarcity, even as new DC investments intensify competition for local energy demand.[44] For many low-income economies in the Global South, attracting DC investment is difficult as they face electricity supply challenges that complicate local hosting. Dependable electricity is non-negotiable for any data infrastructure.[45] In regions with frequent outages, maintaining a DC often demands costly backup power systems, making overseas hosting or cloud services more appealing for businesses.[46]

III.

Data Sovereignty

Data sovereignty could be a factor driving investment in data centres in the Global South. This may lead to data centres being built in sites that are not economically and environmentally favourable, leading to overcapacity.

Data nationalism, along with laws enacted to protect national data, are driving investment in DCs in some parts of the world. The global landscape of data protection laws has expanded remarkably over the past four decades.[47] From the time Sweden passed its pioneering Data Act in 1973, the number of countries with comprehensive data privacy laws has grown to 144 by 2025, covering approximately 82 percent of the world's population.[48] The laws typically cover both private and public sectors, establish data protection authorities, and align with international agreements.[49] While European countries initially led this trend, the majority of data privacy laws are now found outside Europe.[50] This global proliferation of data protection laws has implications for international data flows and privacy standards worldwide. Data sovereignty may also influence the location of DCs.

The EU's General Data Protection Regulation (GDPR) is a comprehensive data protection law that applies to all member states.[51] It governs the processing of personal data and grants individual rights over their data. Enforcement is carried out by national data protection authorities.[52] GDPR restricts data transfers to countries outside the EU unless they ensure an adequate level of data protection.[53] Mechanisms like standard contractual clauses (SCCs) and binding corporate rules (BCRs) facilitate such transfers.[54] The region's robust legal framework provides clarity and consistency, which can be appealing to DC investors. However, strict compliance requirements and the potential for prohibitive fines necessitate careful planning by investors.[55]

The US lacks a comprehensive federal data protection law akin to the EU's GDPR and instead relies on sector-specific regulations.[56] Additionally, the Clarifying Lawful Overseas Use of Data (CLOUD) Act allows US law enforcement to access data stored by US-based companies, even if stored overseas. Enforcement is decentralised, with various federal and state agencies overseeing compliance.[57]

The CLOUD Act's extraterritorial reach has raised concerns internationally, particularly in the EU, about potential conflicts with foreign data protection laws.[58] Efforts like the EU-US data privacy framework aim to address these concerns, but legal contestation persists. Despite challenges, the US offers a mature infrastructure and a business-friendly environment, making it attractive for DC investments.[59] However, the lack of a unified data protection law and the CLOUD Act's provisions may pose challenges for companies handling international data.[60]

China has enacted several laws governing data protection, such as the Cybersecurity Law that focuses on network security and data localisation, the Data Security Law that classifies data and imposes controls based on its importance, and the Personal Information Protection Law that regulates personal data processing and cross-border transfers.[61] Enforcement is stringent, with authorities conducting inspections and imposing penalties for non-compliance.[62] The revised State Secrets Law further expands the scope of protected information, increasing operational complexity for foreign businesses. Cross-border data transfers are tightly regulated.[63] Companies must undergo security assessments, obtain certifications, or use standard contracts. According to experts, China offers a vast market and has made efforts to attract foreign investment, but its stringent data laws and regulatory complexities can pose challenges for DC operations.[64]

India's Digital Personal Data Protection Act (DPDPA) of 2023 governs digital personal data processing. It outlines obligations for data fiduciaries and rights for data principals.[65] The DPDPA establishes a data protection board to oversee compliance. However, enforcement mechanisms are still developing, and the board's effectiveness remains to be seen.[66] Initially, the DPDPA proposed strict cross-border data transfer restrictions. The final version adopts a 'blacklist' approach, allowing data transfers to all countries except those specifically restricted by the government.[67]

The US lacks a unified data protection law that may lead to legal complexities. However, the concentration of the world's largest companies in the communication, information, social media, financial services, and AI sectors, along with the offer of mature infrastructure, has led to the concentration of DCs in the US.[68] This is in contrast to the EU, which has not attracted comparable investment in DCs, though it provides a robust and consistent legal framework for data protection.[69] Strict compliance requirements of data protection may have inhibited investment in DCs in Europe by data and AI-based companies.[70] China is emerging as the world's second-largest DC location despite stringent data laws, as it presents a vast domestic market for data and AI services, along with companies that offer data and AI services competing with US-based providers.[71] India is also developing as a formidable player with a growing digital economy, though the country's regulatory landscape is still evolving. In the short term, data sovereignty is likely to be one of the factors determining investment in DCs, especially in the Global South.[72] This could lead to overcapacity as DCs may be constructed in locations that are not economically and environmentally favourable, with negative implications for global GHG emissions.

IV.

Energy Demand from Data Centres

Long and complex artificial intelligence (AI) queries consume more than 40-watt hours of electricity, which is more than 20 times the electricity consumed when using 10-watt bulb for 5 minutes. Increase in the efficiency of electricity use in data centres may reduce costs and consequently increase use of AI applications. This rebound effect will wipe out gains in efficiency of data centres.

Manufacturing

The manufacturing of hardware for DCs and AI is energy-intensive, but along the life cycle, manufacturing accounts for less energy than the operation phase.[73] The most energy-intensive part is the manufacture of chips used in graphics processing units (GPUs) as well as in server storage.[74] The production of chips is highly concentrated geographically.[75] More than 70 percent is located in East Asia.[76] Currently, the global semiconductor industry is estimated to consume more than 100 terawatt hours (TWh) of electricity per year, equivalent to around 1 percent of global industrial electricity demand.[77] However, the impact is much higher in certain geographies.

Most semiconductors are used for other purposes, but DCs and especially AI, are expected to be the key drivers of semiconductor demand in the years to come. The high share of coal-fired electricity generation in many important manufacturing countries in Southeast Asia could lead to a high emission footprint.[78] The construction of DCs and the transport of intermediate materials in the supply chain have a minor impact on the hardware footprint. DC construction, including the materials required, accounts for less than 2 percent of data centre life-cycle emissions.[79]

Artificial Intelligence Training

The costs of the rapid development and adoption of large language models (LLMs) in the US, China, Europe, and across the globe have two main components: a large, fixed cost for training the model on large quantities of data, and variable costs for operating and responding to user prompts.[80] As substantial computational resources are required during both stages, electricity consumption represents a critical input for companies delivering AI services. The total training electricity consumption of the large frontier AI models was about 1,700 GWh (1.7 TWh).[81] This is equivalent to around 0.001 percent of global electricity consumption from all sources, or 0.1 percent of the global electricity consumption of DCs during these years.[82]

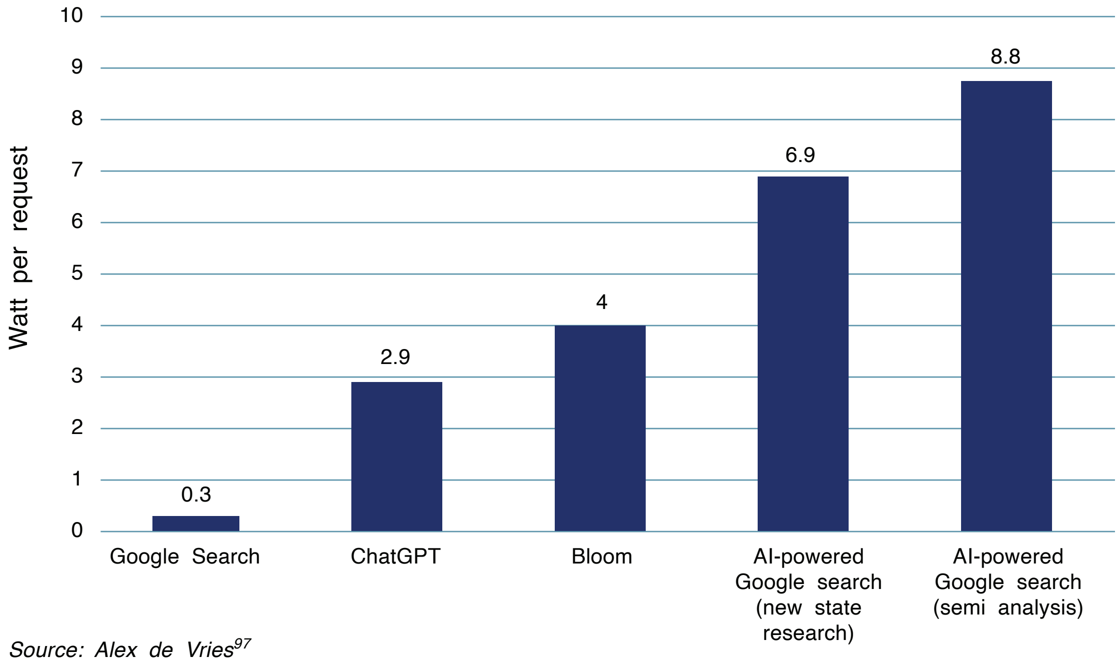
Operations

Typically, the DC operator builds the facility, secures the water and power supply, and ensures security. DCs use different information technology (IT) devices to provide services, all of which are powered by electricity.[83] The customer brings in the chips and IT equipment that go into the racks and uses the facility. The customer often leases the facility for an extended period of time.[84] Servers provide computations and logic in response to information requests, while storage drives house the files and data needed to meet those requests.[85] Network devices connect the DC to the internet, enabling incoming and outgoing data flows. The electricity used by these IT devices is ultimately converted into heat, which is removed from the DC by cooling equipment that also runs on electricity.[86] Heat is the waste product of computation, and if left unchecked, it can ruin the workings of digital civilisation. Heat from DCs is therefore relentlessly abated to keep the digital economy going.[87] On average, servers and cooling systems account for about 86 percent of direct electricity use in DCs, followed by storage drives (11 percent) and network devices (three percent).[88]

Operations consume the highest share of electricity in the DC lifecycle. With reasonable and somewhat pessimistic assumptions, a ChatGPT query consumes around 0.3 watt-hours (Wh) for a typical text-based question, though this increases substantially to 2.5 to 40 Wh for queries with very long inputs.[89] This amount of 40 Wh is more than twice the average electricity consumption of a typical US household per minute and is more than 20 times the electricity consumed while using a 10-Watt light bulb for five minutes.[90]

According to studies, the increase in energy use by DCs has not been in direct proportion to the increase in DCs use, owing to substantial efficiency gains in energy use by DCs since 2010.[91] Worldwide energy use of DCs grew from 153 TWh (terawatt hour) in 2005 to between 203 and 273 TWh by 2010, which was about 1.1 to 1.5 percent of global electricity use.[92] By 2018, global DC workloads and compute instances increased more than sixfold, whereas DC internet protocol (IP) traffic increased by more than tenfold.[94] DC storage capacity increased by an estimated factor of 25 over the same period. However, since 2010, electricity use per computation has decreased by a factor of four, largely owing to processor efficiency improvements and reductions in idle power.[95] At the same time, the watts per terabyte of installed storage has dropped by an estimated factor of nine owing to storage-drive density and efficiency gains.[96]

Figure 2: Electricity Consumption Per Request



Source: Alex de Vries[97]

Growth in the number of servers has slowed considerably owing to the fivefold increase in the average number of compute instances hosted per server (owing to virtualisation), alongside steady reductions in DC power usage effectiveness (PUE, the total amount of energy used by a DC divided by the energy used by its IT equipment).[98] In 2018, global DC energy use rose to 205 TWh, or around 1 percent of global electricity consumption.[99] This represented a 6-percent increase from 2010, whereas global DC compute instances increased by 550 percent over the same period.[100] Expressed as energy use per compute instance, the energy intensity of global DCs decreased by 20 percent annually since 2010.[101]

Greater use of server virtualisation software that enables multiple applications to run on a single server has reduced the energy intensity of each hosted application.[102] As most compute instances have migrated to large cloud- and hyperscale-class DCs, which utilise ultra-efficient cooling systems, energy efficiency has improved substantially.[103]

Higher rack density exacerbates the cooling demands within DCs because concentrated computing equipment generates substantial heat.[104] Traditional methods, such as air-cooling used in low-cost DCs (mostly in the Global South), struggle to dissipate the heat generated by densely packed racks.[105] Since cooling typically accounts for roughly 40 percent of an average DC's electricity use, DC operators in the Global South can offset the energy needs of higher computational power by shifting to liquid cooling.[106] Liquid cooling boasts significant power reductions, as high as 90 percent, while improving computational capability and space requirements.[107] Liquid cooling is gradually becoming cost-competitive with conventional solutions, so operators will face a lower cost barrier to entry in the near future. While DCs with traditional rack densities will maintain air-cooled setups, wider adoption of liquid cooling in facilities with high rack densities will grow in the future.[108]

In the Global North, the technology needed for DCs to recover their excess heat and transport it to off-takers is well established, and the adoption of liquid cooling provides an opportunity to increase the amount of heat recovered.[109] Air-cooled systems often require a heat pump to upgrade the heat to a usable temperature, but liquid cooling systems can provide higher-temperature heat – from 40°C (Celsius) to 80°C—which can directly supply existing district heating networks in the Global North.[110] Efficiency gains lead to an increase in consumption, reducing but not completely negating the expected savings due to the rebound effect captured by the Jevons paradox—when increased consumption fully offsets, or even surpasses, the expected savings from improvements in efficiency.

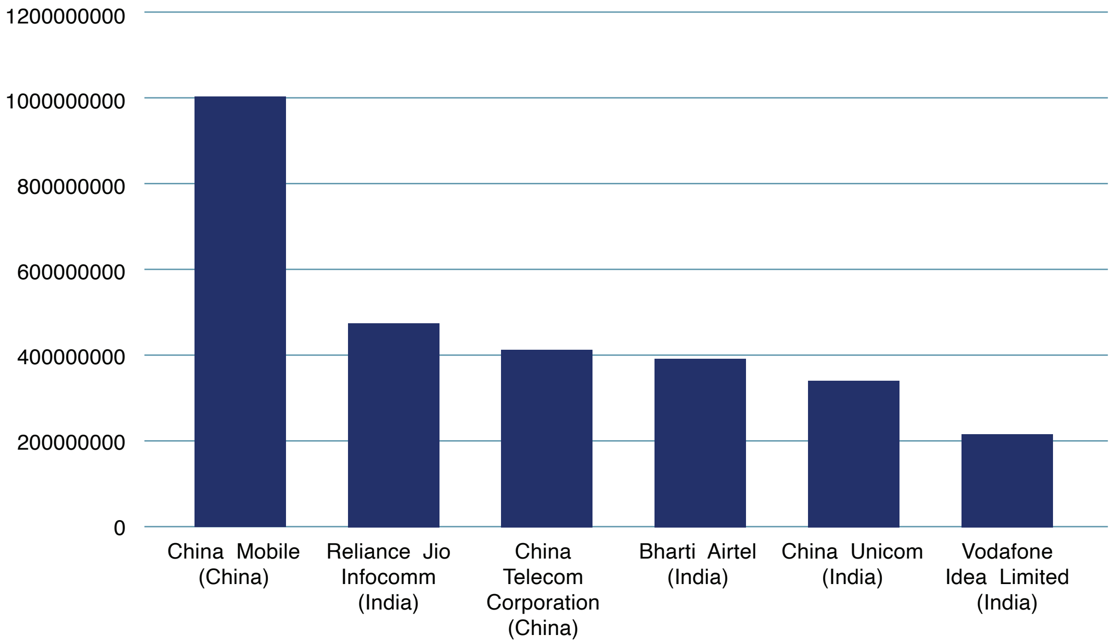
Companies are exploring options for moving AI inference applications to edge DCs and end-user devices.[111] Decentralised learning that underpins this shift enables AI models to be trained using edge devices such as smartphones and laptops. Instead of bringing the data to a central server, decentralised learning brings the model training to the data source.[112] Early studies have shown the potential for decentralised learning to reduce energy use and emissions associated with AI training.[113] This is advantageous for use cases where fast response or low latency is critical.[114] Research points out that on-device AI inference may also be important for operational resilience in situations where network connectivity is poor or when handling large volumes of data such as video analysis.[115] On-device AI inferencing offers improved data privacy by avoiding the transfer of sensitive data to centralised data centres. The cooling challenge does not exist for decentralised learning, as the heat is distributed across billions of users; it is crucial to consider it when estimating the cost of centralised training.[117] Even under worst-case assumptions, decentralised learning does not produce more emissions than traditional DCs. Even though GPUs or TPUs (tensor processing units) are getting more efficient in terms of computational power delivered by the amount of energy consumed, the need for strong and energy-consuming cooling remains—thus the decentralised learning advantage only grows.[118]

According to the IEA, device manufacturers are increasingly integrating AI acceleration hardware such as neural processing units (NPUs) into laptops and smartphones, to facilitate on-device AI inferencing.[119] However, when compared to large DCs, edge devices compromise on computation, storage and power, limiting the type and size of the AI models they can run. Given the computational and energy constraints of smartphones and laptops, these models are compressed and optimised to have fewer parameters, require less memory, and use less power, and often involve trade-offs between efficiency and accuracy.[120] The power consumption of an NPU on a smartphone was estimated to be around 0.5 W, around 80 percent lower than the central processing unit (CPU).[121] Laptops typically consume between 20 W and 60 W during active use, making any incremental energy consumption from AI inference (1 W to 5 W) relatively small. With smaller and more optimised models at the edge, the shift towards AI inference at the edge is likely to reduce energy use in DCs with only a limited increase in energy use by devices.[122] This shift of inference tasks to edge devices can potentially also help electricity systems by distributing power demand across different locations and time zones. An important consequence of this development is the decentralisation of both, computation and energy consumption by digital devices. This may reduce the competitive advantage in territorialising DCs.

There is a negative side to decentralising computation through smart devices. On-device AI capabilities and minimum hardware requirements for increasingly prevalent AI-powered applications could accelerate device replacement cycles in the near term.[123] This could reverse the slowing of turnover rates over the past decade, with average replacement cycles for smartphones reaching 3.5 years.[124] The impacts of widespread generative-AI adoption on data traffic and the energy use of data transmission networks are highly uncertain. According to one study, most of the traffic increase from AI will be due to video-based generative interactions using smartphone cameras, smart glasses, or extended reality devices to engage their environment or ask questions to a video-based large language model.[125] It also predicts that most of these AI workloads will be executed in the cloud in real time or pre-rendered to generate hyper-personalised content.[126] Some medium-complexity AI workloads may migrate to smartphones, mitigating some traffic growth.[127] However, the extent to which increased data traffic would affect network energy use is uncertain. Recent studies have demonstrated that fixed and core networks generally use the same amount of energy regardless of data traffic.[128] This shift could potentially carry benefits for the Global South, which dominates in terms of numbers of device users.

For example, the Global South (including China) dominates mobile telephone subscriber numbers. Smart mobile devices could emerge as the primary channel for AI applications in the future.[129] Among the top six mobile telephone companies in terms of subscriber numbers, three are Chinese and three are Indian, with a total of over 2.8 billion subscribers, accounting for over 34 percent of the world's population.[130] DCs that capture the data and information flows from these devices facilitate the export of information to the Global North but also enable the import of knowledge processed from the information gathered from the Global South. This replicates the historical pattern of the Global South exporting raw material (data) to the Global North that converts to knowledge (AI), and exports it back to the Global South.

Figure 3: Mobile Telephone Subscribers: Top 6 Providers

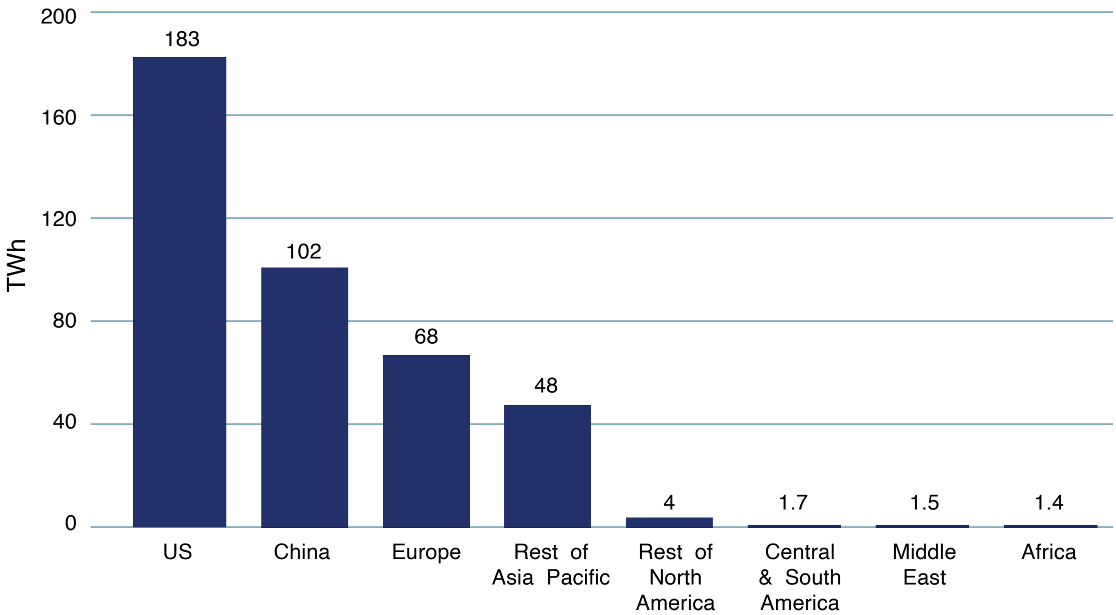


Source: Theglobaleconomy.com[131]

Regional and National Energy Consumption Shares

When the COVID-19 pandemic shut down the world in 2020, initially, demand for DCs accelerated because of the rise in the use of mobile communications, social media, and e-retailing, as well as the use of apps like Zoom.[132] Currently, DC investment is driven by demand for AI services.[133] Electricity consumption from DCs has grown by 12 percent per year over the last five years, to consume 1.5 percent of global electricity consumption in 2024.[134] Important drivers of the increase were the growth of cloud computing, the shift to online media consumption, the wider use of social media platforms, and the rise of AI, which increased the demand for high-performance computing, facilitated by the rise of accelerated servers.[135] Though AI-related electricity consumption of DCs is difficult to estimate, the IEA provides an electricity consumption of accelerated servers as a proxy for the share of AI in total electricity consumption from DCs.[136] Accelerated servers accounted for 24 percent of server electricity demand and 15 percent of total DC demand in 2024.[137]

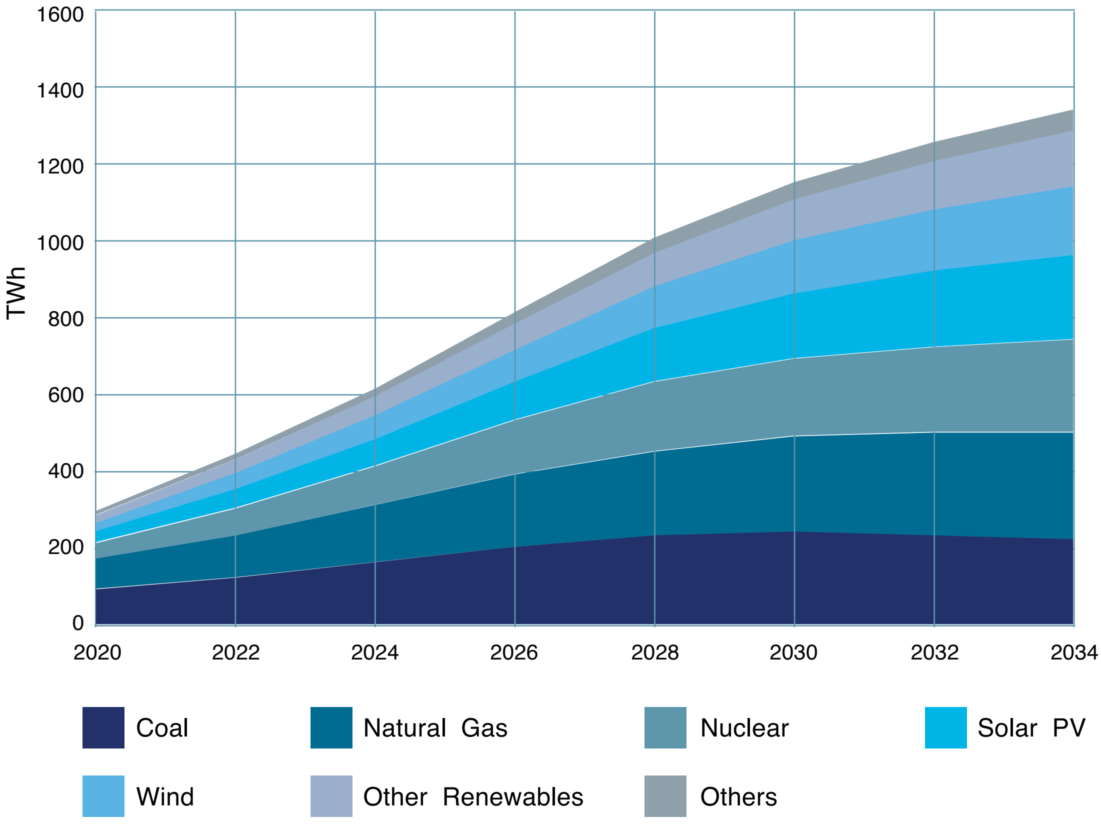
Figure 4: Data Centre Energy Consumption by Region



Source: International Energy Agency[138]

DCs in North America consumed over 187 TWh of electricity or about 45 percent of total electricity consumption by DCs in 2024.[139] The US alone accounted for most of the electricity consumed by DCs in North America at 183 TWh or 44 percent of the global total electricity consumption from DCs.[140] DCs in the Asia Pacific consumed about 150 TWh of electricity, accounting for about 36 percent of the global total electricity consumption by DCs in 2024.[141] China alone consumed 102 TWh of electricity, accounting for about 24 percent of global electricity consumption from DCs.[142] DCs in Europe consumed about 68 TWh of electricity or about 16 percent of the global total.[143] In 2023, electricity consumption by DCs was the twelfth-largest, exceeding the electricity consumption of large economies like France.[144]

Figure 5: Energy Consumption by Data Centres: Share by Fuel



Source: International Energy Agency[145]

The US, Europe, and China account for around 85 percent of global electricity consumption from DCs today.[146] In the US, electricity consumption from DCs grew by around 12 percent per year between 2015 and 2024.[147] DCs accounted for more than 4 percent of US electricity consumption from all sources in 2024.[148] In China, DCs started to expand from 2015 onwards, with electricity demand growing by 15 percent per year between 2015 and 2024—more than twice the rate observed between 2005 and 2015.[149] Over the same period, electricity consumption across all sectors grew at an annual rate of around 7 percent. As of today, DCs in China account for approximately 100 TWh of electricity consumption, roughly equivalent to that of EVs in China.[150] According to the IEA, China's DC electricity consumption increased by 20 percent since 2015.[151]

DCs accounted for slightly less than 2 percent of Europe's electricity consumption, a share that is higher than China's at 1.1 percent, according to the IEA. However, in absolute terms, Europe's consumption is lower, at an estimated 70 TWh in 2024. Its share of global electricity consumption of DCs has decreased over the past decade.[152] In Japan, the IEA estimates that DCs accounted for less than 20 TWh of electricity consumption (about 2 percent of Japan's total consumption, on a par with Europe).[153] Many regions in the Global North, particularly cities such as Amsterdam, have imposed moratoriums on DC construction to limit land and energy use.[154]

The Southeast Asian DC boom began in the early 2000s in Singapore. In 2000, Singapore's telecom companies set up small DCs on the island, working in conjunction with some of the Singapore's larger real estate businesses.[155] They also helped set up the first connection cables in the area.[156] The growth of the DC industry in Singapore outpaced its ability to provide sufficient amounts of water and power.[157] In 2019, the country placed a moratorium on new DC buildings.[158] DC developers moved to either Malaysia or Indonesia, where power and water were more plentiful but they have situated their campuses close to Singapore as they can utilise the island nation's fibre cable connections to the rest of the world.[159] The pace and urgency of DC demand saw industry hotspot Singapore relax its moratorium, with 300 MW of additional power being made available "in the short term," while more capacity could be allocated for companies that use low emission energy.[160] The case of Singapore illustrates that DC investments can move geographically in search of locations that offer energy, water and light regulation.

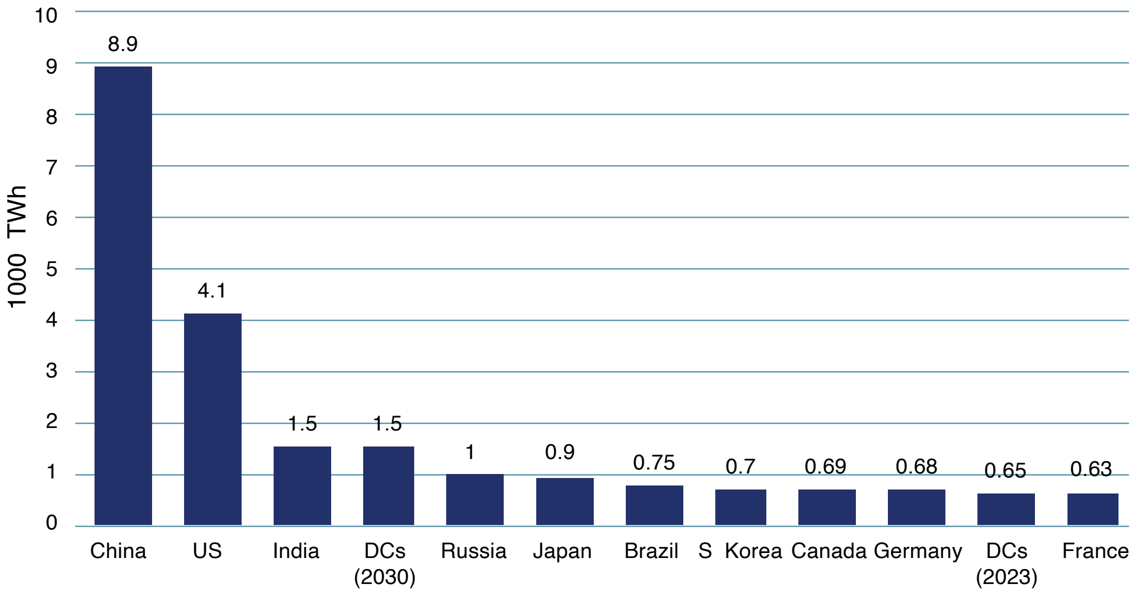
DCs in India are estimated to utilise around 9 TWh of consumption in India or about 0.5 percent of total consumption, as estimated by the IEA.[161] As of June 2024, India had 2 GW of total installed DC capacity in operation, together consuming electricity equivalent to 6.5 million Indian households.

India has the largest DC capacity in the Global South, excluding China.[162] India's total installed DC capacity has doubled in only four years, and over 2 GW of further maximum designed capacity is in the pipeline and planned to come online over the next two years.[163] Some states in India have announced 100 percent exemption on electricity duty and transmission charges for 10 years for new DCs.[164] The government's IndiaAI Mission, with a budget of US$1.2 billion, consists of several objectives, including the development of an AI computing ecosystem with over 18,000 GPUs to support AI start-ups and research.[165] Electricity consumption from DCs is contributing to India's electricity demand growth at a time when the country is already among the world's fastest-growing electricity markets. Coal fuels about 75 percent of electricity generation in India today, providing much of the firm power to the grid, and the dominance of coal in the mix is likely to continue beyond 2030.[166]

But India is still "significantly underpenetrated" with just 1MW of DC capacity per million users, compared with 51MW in the US and 4MW in China.[167] 40 percent of shared DC capacity in India was taken up by international cloud service providers, with the rest used by businesses.[168] Of these, the financial sector was responsible for approximately 90 percent of consumption.[169] This is despite the fact that the country generates about 20 percent of global data, but uses just three percent of DC capacity. It is among the cheapest DC locations in the Global South at around US$80 per kilowatt per month, compared to nearly US$200 in Indonesia.[170]

By 2030, the US is expected to see the largest absolute growth in DC electricity consumption, followed by China and Europe.[171] Under current trends, the IEA estimates that electricity consumption from DCs is set to increase by around 945 TWh by 2030, more than doubling from the 2024 level.[172] According to the IMF (International Monetary Fund), by 2030, AI-driven global DC electricity consumption could hit 1,500 TWh, conceivably making it comparable to India's current total electricity consumption, the third-highest in the World.[173] This projected electricity demand from AI by 2030 is around 1.5 times higher than expected demand from EVs, another emerging source of electricity demand growth.[174]

Figure 6: Electricity Demand from DCs Vs. Top Electricity Consuming Countries



Source: International Monetary Fund[175]

In all regions, due to rising marginal costs of electricity supply, the increase in generation is not likely to be proportional to the economy-wide demand growth, which will drive up electricity prices.[176] Taking into account the investment costs of increased generation, along with transmission and distribution infrastructure, the IMF projects electricity prices to increase by 8.6, 3.6, and 5.3 percent in the US, Europe and China, respectively, by 2030. AI-driven electricity demand could increase gas prices by 9 percent in Asia and Europe and by 7 percent in the US by 2026.[177] One study projects electricity demand to increase by 9 percent in the US, driven by DCs, with a 19 percent rise in electricity costs.[178] Demand for compute and electricity from AI service providers is subject to heightened uncertainty. This poses a risk of delaying crucial energy investments, potentially resulting in underinvestment and escalating energy prices.

Data, intelligence, crypto, and DC industries are likely at a Cambrian explosion stage, with different firms trying out a variety of approaches. This experimentation may be spiking energy use in the near term, but not all of these approaches are likely to succeed. With sectors maturing and their players consolidating, energy demand growth may slow down.[179]

Data Centre Energy Mix

Nearly all DC energy is electricity, and consequently, growth in electricity demand from this sector is a key driver of overall power system growth, especially in the Global North. DCs are essentially grid-powered, so their operational energy-source breakdown mirrors the evolving global grid mix. The fuel mix supplying that electricity, therefore, determines their energy-source breakdown. In 2023, coal, natural gas and oil comprised roughly two-thirds of world electricity generation, while renewable sources (wind, solar, hydro, biomass) provided about a third.[180]

In 2023, coal, with a share of about 30 percent, was the largest source of electricity for DCs, with the highest contribution found in China.[181] Renewables (wind, solar PV and hydro) accounted for about 27 percent of the electricity consumed by DCs globally. Natural gas was the third-largest source, meeting 26 percent of the demand, followed by nuclear with 15 percent.[182] Overall, conventional fuels accounted for about 56 percent of electricity consumed by DCs in 2023. However, regional and national shares of DC electricity consumption vary. For example, 57 percent of the electricity supply in Virginia—home to the largest concentration of DCs in the world, is derived from natural gas, and 30 percent from nuclear power.[183]

Several countries have mandated minimum energy performance standards for DCs.[184] These performance standards specifically focus on the PUE (Power Usage Effectiveness), or the ratio between the power consumption of the whole facility against the consumption of the IT equipment.[185] On the supply side, Chinese AI companies have achieved breakthroughs in algorithmic efficiency that could reduce the electricity demand from DCs.[186] However, demand could rebound on account of lower costs, increasing overall electricity requirements. The IEA is optimistic about the increase in the share of renewable energy consumption in the DC energy basket. However, the growth of renewable energy could slow down in the US, which currently hosts the largest share of DCs, due to policy changes and uncertainty, supply chain constraints, and volatility in commodity prices.

Emissions Footprint

The emissions footprint of a given DC depends on the fuel mix of the local grid. Most academic and industry studies agree that operational energy use dominates the lifecycle emissions footprint of DCs; embodied impacts from manufacturing and construction are relatively small by comparison.[187] The operational electricity demand from DCs is projected to double or triple by 2030.[188] This implies a substantial increase in GHG emissions if grids do not reduce emissions. Asia's DC electricity demand is projected to soar, but much of the power there comes from coal and gas, making emission intensity a major concern.[189] Projections by the IEA and others note that meeting the Paris climate goals would require halving data-centre emissions by 2030, implying a more aggressive shift to low-emission power. In response, technology companies routinely sign renewable energy power purchase agreements (PPAs) with renewable power generators and commit to improving PUE.[190] While renewables like wind and solar are intermittent and cannot always match real-time demand, especially when split-second latency and uptime are critical. This explains why natural gas and nuclear are regaining prominence in grid planning to meet DC electricity demand.[191] Smaller DC operators might find it difficult to procure low emission energy due to slow growth in renewables.[192] Therefore, the appeal of natural gas for DC on-site power generation for primary and backup purposes is growing as natural gas manages intermittency and offers a lower emission alternative to coal or oil-powered generators.[193] The DC industry's natural gas lock-in may delay efforts to reduce emissions, prolonging dependence on conventional fuels.[194] Even though a lot of companies are devoted to the emission offsetting scheme, this approach still contributes to a net increase in the absolute rate of global GHG emission growth in the atmosphere.[195]

Nuclear power is emerging as a low emission dependable source of energy for DCs.[196] According to estimates by Goldman Sachs, 85-90 gigawatts (GW) of new nuclear capacity would be needed to meet all of the DC power demand growth expected by 2030 (relative to 2023), but less than 10 percent will be available globally by 2030.[197] In the US alone, big tech companies have signed new contracts for more than 10 GW of possible new nuclear capacity in 2024, and Goldman Sachs sees potential for three plants to be brought online by 2030.[198] DC operators are willing to pay what is labelled a low emission reliability premium to secure low emission dependable energy sources.[199] Adding a price of US$100/tonne for carbon dioxide meaningfully offsets the premium.[200] The US$100/tonne carbon price will increase the cost of the natural gas-combined cycle to US$91/MWh, based on historically reported gas-fired power emissions intensity, compared to US$87/MWh for a near 100 percent renewable energy solution including offsite solar or wind power and battery storage, and US$77/MWh for a large-scale onsite nuclear generator.[201]

Investments by data and information companies help de-risk projects for institutional capital, transforming new and early commercial low emission-energy technologies, such as small modular nuclear reactors (SMRs), and advanced geothermal and tidal power, into more traditional infrastructure assets.[202] However, mechanisms like long-term corporate PPAs secure low corporate pricing by guaranteeing stable energy prices years in advance for technology companies, who are then able to promote their commitments to reduce emissions by purchasing renewables.[203] Close coordination between DC developers and electric companies regarding power needs, timing, and flexibility, as well as electric supplies and delivery constraints, is also growing.[204] Dominant energy policy allows private technology companies to exploit the growing renewable energy market, with costs such as high energy prices socialised to billions of ordinary customers who have minimal public support. The information age may thus favour unregulated utilities. The utilities' ability to capture rising electricity prices without regulatory constraints positions them for potentially outsized gains.[205]

The current US president has signed an executive order to use coal resources to power DCs.[206] The US coal sector has argued that coal plants are needed to ramp up power generation to meet the demand from DCs and maintain grid reliability.[207] Power generators in the US are not optimistic about the future of coal in the US, as natural gas holds more promise in terms of availability, affordability and sustainability.[208] If the effort to revive coal in the US succeeds, it may have positive economic consequences for coal-dominant economies in the Global South, such as hosting DCs at lower costs with negative costs passed on to the environment. This opportunity, if accompanied by conditions such as the installation of carbon capture and storage infrastructure, could lead to economic benefits for the Global South at relatively low environmental costs.

DCs in the Global South, particularly in Asia and East Asia, have higher emissions per MWh than those in the Global North, even before considering location-based renewable procurement. In North America and Europe, grids average roughly 0.3-0.5 kg CO_2 per kWh (kilogram carbon dioxide per kilowatt hour) owing to rising gas, nuclear and renewable shares. In China and India, whose grids are coal-dominated, there are grid intensities of order 0.5-0.6 kg CO_2/kWh or higher.[209] Under current energy policies, GHG emissions are expected to increase by 5.5, 3.7 and 1.2 percent in the US, Europe and China, respectively, with a global average increase of 1.2 percent by 2030. In cumulative terms, this translates into a global GHG emissions increase of 1.7 Gt (gigatonnes) between 2025 and 2030, which is similar to Italy's energy-related GHG emissions over a 5-year period.[210] Overall, AI is expected to increase global GDP at the cost of GHG emissions. Based on a median social cost of carbon (SCC) estimate of US$39/tonne of carbon, the additional social cost of 1.3 to 1.7 Gt of carbon-equivalent emissions is about US$50.7 to US$66.3 billion.[211] While additional emissions will have global impacts, the cost of addressing the emission challenge will fall on the host country.[212]

The share of DCs in aggregate emissions may appear small but DCs are among the few sectors, along with road transport and aviation, that see an increase in their direct and indirect emissions by 2030.[213] Projections by the IMF show that the use of AI improves sectoral productivity, resulting in higher output from the IT sector. This would increase demand for all inputs, including electricity, especially in the US, Europe and China. Total electricity supply is expected to increase by 8 percent in the US, 3 percent in Europe and 2 percent in China.[214] Power generators could increase supply by increasing conventional fuel, nuclear or renewable-based generation, depending on demand and policy support. While these emissions remain below 1.5 percent of the total energy sector emissions in this period, DCs are among the fastest-growing sources of emissions.[215] At this stage of technological progress, concerns that AI could accelerate climate change appear overstated, as are expectations that AI will solve the GHG emission problem, among others.

V.

Conclusions

The virtual data economy concentrated in the Global North has a large material footprint. By 2030, data centre electricity consumption will match India's electricity consumption in 2024. The unanticipated capture of developmental carbon space from the Global South by additional electricity consumption by data centres deserves to be discussed in multilateral climate platforms.

Geography is a key factor in determining the location of DCs. The presence of digital and data technology companies in the Global North, particularly in the US, has led to the concentration of DCs in the US. Cooler climates, legacy IT infrastructure, and favourable policies add to the attractiveness of particular regions, such as Northern Virginia and Dublin, in attracting investment in DCs. DC investment in the Global South, excluding China, is far behind investment in DCs in the Global North. Data sovereignty plays a role in influencing the location of DCs, but it is less significant than the location of DC owners and clients, or the availability of land and energy at competitive prices. Data protection laws can enable DCs to be located in countries that are otherwise not favourable, but this could lead to overcapacity and waste of scarce resources such as land and energy. Companies, rather than countries, have a greater influence on locating DCs, as control of the data economy is almost entirely in private hands. Perversely, this could create opportunities for the Global South as low-cost DC locations, which will enable profit maximisation by digital technology companies while also redistributing some of the wealth created.

AI may be virtual, but its energy demands and consequent GHG emissions are very real.[216] However, the binary portrayals of AI and its DCs as utopian or apocalyptic for the Global South may be inaccurate. It is unlikely that AI will create a utopian world that is wealthy, environmentally sustainable, and equal; it is equally unlikely that it will confirm the Malthusian prospect of a mostly poor, dirty, and unequal world.[217] Like most industrial revolutions, the data revolution may benefit a few at the expense of many. Given the uncertainty in expectations and outcomes, the Global South must exercise caution in passively consuming optimistic narratives on the data economy generated by the Global North.

The development of DCs and AI services is shifting influence on critical decision-making on issues such as the choice of energy source from countries to corporations.[218] Though the State plays a supportive role, its influence is subordinate to that of the corporation. For example, the revival of fortunes for natural gas and nuclear power in the Global North is driven primarily by companies investing in power generation from these primary sources to power DCs. In the Global North, nuclear capacity installations were stagnant or falling either because the markets sought a high premium on the risk involved— as in the US— or because the society voted against it, as in Europe. The revised narrative over nuclear power, shaped by data, social media and e-commerce firms investing in DCs, is now overwhelmingly positive. This trend may lead to a lack of democratic accountability, giving rise to a culture of experimentation amongst technology giants, as has already been seen in the mass experiments conducted on users by various online services.

The first wave of the IT revolution that began in the 2000s involved labour-intensive tasks, such as programming, that led to the outsourcing of specific labour-intensive tasks to the Global South. This redistributed some of the wealth generated by the first wave of the IT revolution. The current wave of data digitisation and AI revolution is capital-, technology- and resource (land and energy)-intensive. Unless countries in the Global South position themselves as low-cost locations with competitively priced land and energy resources, their share of the economic gains from hosting DCs will be limited. To minimise the negative environmental externalities, such as GHG emissions from DC energy consumption, and economic externalities such as an increase in the price of energy, countries in the Global South may have to impose stringent energy efficiency standards without compromising the cost-competitiveness of their DCs.

A further risk posed by energy consumption by DCs in the Global North is what Morozov has termed 'solutionism': the application of engineering solutions to problems that are long-term and structural, and social.[219] For example, the argument that AI will solve the problems of energy demand and GHG emissions that the technology itself initiated is essentially the application of solutionism.

Informational and data capitalism may become the new norm for the field of international development.[220] Under this paradigm, countries across the Global South will be expected to harness this intertwined relationship between the twin energy and AI transitions to not only accelerate their participation in AI advancements and propel the energy transition but to also ensure that these advancements are carried out sustainably, driving co-benefits domestically.[221] However, the data economy, driven by multinational corporations, may not offer anything new in terms of the far-reaching structural change that is necessary to 'solve' real-world problems such as disease and poverty in the Global South.

The data economy and its demand for natural resources to power DCs have led to social narratives that portray DCs as powerful tools and infrastructure of multinational digital capitalism.[222] Industry groups endeavour to make DCs essential. While acknowledging them as necessary infrastructure, social theorists question the basis of the DC business model that depends on the uninterrupted growth of digital data, making the material footprints of digital and the attendant energy and land usage inextricable from the business interests of the companies. DCs thus become energy silos, wherein the companies that run them siphon public energy, innovating their efficiencies, and profiting off energy transitions.[223] Big technology companies control and profit from what is ostensibly a transition administered through public energy systems, albeit in response to global regulations with planetary climate aspirations.[224] This could lead to a form of climatological imperialism in which the Global South is tasked with rehabilitating the Global North by offering scarce land, energy and GHG emission space to support the data economy.[225] The scarce and limited atmospheric space that would have accommodated development emissions will now have to accommodate additional GHG emissions from the data economy, whose benefits are concentrated in the Global North.

VI.

Policy Recommendations

- The Global South needs to balance the necessity of appropriating the efficiency and productivity gains in using AI and in hosting DCs while minimising the economic costs, such as increase in electricity tariff and an increase in GHG emissions. Towards this goal, the Global South can attract investment in DCs by imposing strict mandates on energy and emissions performance standards without compromising on its locational competitiveness.

- The Global South needs to raise the issue of additional electricity demand from DCs in the Global North, potentially appropriating the Global South's fair share of development carbon space in multilateral climate platforms. It must seek acknowledgement and compensation for the unanticipated capture of developmental carbon space from the Global South.

- The Global South is currently a net exporter of low-value information and a net importer of high-value knowledge (AI). To reduce the import of knowledge, the Global South must promote AI innovations and invest in resource-efficient high-end DCs. Simultaneous investment in the training and education of personnel in AI and related high-level skills is critical for the Global South to become a net exporter of high-value knowledge.

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