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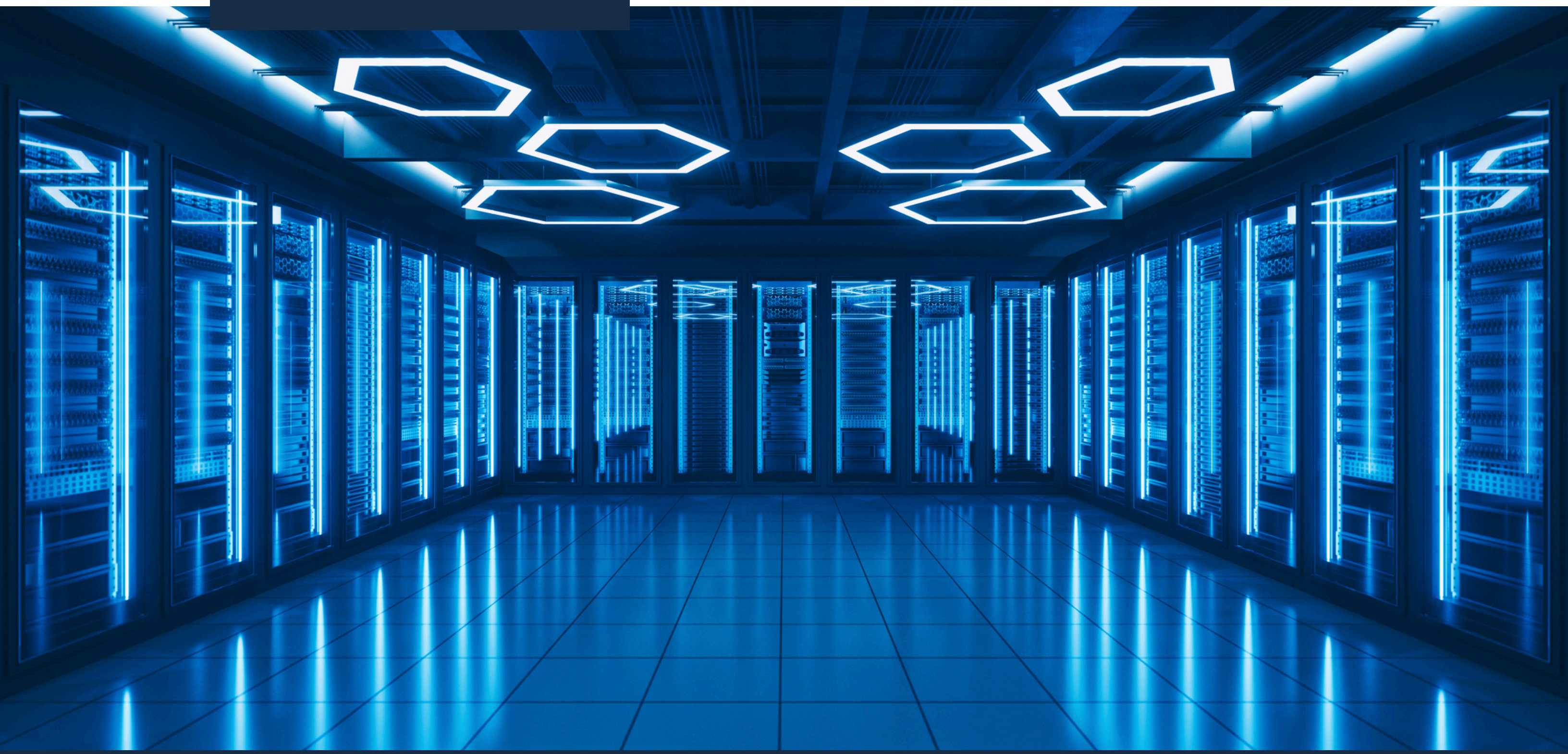
JANUARY 2026

Big Data, Data Centers, and their **Environmental Impacts**

Updated 1/27/2026



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INTRODUCTION

Large data centers are a 21st century development. The first data storage center (or mainframe computer) is reported to have been designed by the U.S. military and built at the University of Pennsylvania in 1945. Assembled using thousands of resistors, capacitors, vacuum tubes, relays, and diodes, the facility occupied 300 square feet and weighed 37 tons. Airflow and cooling were critical design considerations.[1]

The emergence of transistors in the 1960s allowed substantial reduction of the space requirements for data centers, allowing placement within office buildings and manufacturing facilities. Memory and storage capacity grew as technology improved. Over the span of less than two decades mainframes largely disappeared, being replaced by ever smaller computers, followed by the introduction of personal computers in 1981. It wasn't long before millions of these devices began interacting with one another through remote servers numbering in the hundreds or thousands residing in what came to be known as data centers.[2]

Rapid development occurred in the early 2000s with the emergence of Facebook, Amazon on-line shopping, high quality streaming of music and video and more. At about the same time propagation of high-speed wireless broadband served to decouple data from individual devices, creating the ability to access data from any device.[3] This created a market for mobile electronics that led to a rise in the number of endpoint devices. In the span of 5 years – 2018 to 2023 – the number of devices globally rose 50%, from 2.4 to 3.6 per capita.[4] On the business front, several companies began offering IT infrastructure, including computing and cloud storage functions. The entry of Amazon into this market in 2006 brought about rapid growth, with a reported 38 percent of organizations utilizing cloud services just six years later.[5] All of this translated to demand for data storage services on an almost unimaginable scale.

Exchanging email messages, streaming a favorite movie, engaging in multi-player online computer games, sharing photos on Facebook, shopping with the touch of a button, communicating via social media, searching for information on the web, seamlessly backing up computer files to the cloud – all utterly transformative to the economy and society at large. And most recently the advent of AI which promises to further revolutionize daily life. But all of this has come at a cost, a cost that has only recently gained the attention of the public: very substantial and rising environmental impacts linked to data centers.

This report examines current and projected environmental impacts of cloud computing and large data centers, highlights technologies for mitigating impacts, and identifies management strategies that businesses and individuals can utilize to reduce their electronic footprints.

1 Robertson (2024)
2 Ibid
3 Reinsel et al. (2017)
4 Sirimanne et al. (2024)
5 Robertson (2024)

DATA CENTERS, SERVERS, AND THE CLOUD EXPLAINED

A data center is a place where data is stored – encompassing the full range of information which can be accessed via the web. A data center houses hundreds to thousands of servers – computers with specialized processors designed to serve a multitude of clients simultaneously. Servers are where digital traffic is processed: social media interactions handled, on-line purchases enabled and processed, email exchanges transferred, files stored and retrieved, industrial processes monitored and controlled, and so on. What is known as the Cloud is an extensive worldwide network of remote servers that store and process data for other devices and computers and that can be accessed from anywhere via an internet connection. The system provides unprecedented access to information, with incredible speed and convenience.

Servers require power and generate considerable heat, the latter requiring robust cooling systems that often consume large volumes of water. Consequently, in addition to stacks of servers, a data center is also composed of cables, power distribution units, transformers, fiber optic tubes, air conditioners, water pipes, and more.[6] Further, web services are available 24/7 meaning that servers run continuously. And that, in turn, requires large capacity backup generators, most of which are diesel powered systems that must be ready to begin operation within seconds of an interruption of power; these are periodically run to ensure readiness when needed.

The combined effects of all of this – over 100 million servers worldwide[7] within thousands of data centers[8] and all that goes with them – are attracting increasing attention vis-à-vis high levels of energy and water consumption among other concerns.

6 Monserrate (2022)
7 Sire (2025)
8 Tilawat (2025)

TYPES OF DATA CENTERS

Data centers differ by function and size. Various sources classify types of data centers as follows[9]:

Enterprise – Data centers owned and operated by large corporations and business enterprises to provide private data storage and processing needs, or centers that serve regional needs or specialized applications. These account for about half of all data centers.[10]

Colocation – Centers that lease space to multiple organizations for housing of servers and other computing devices, in which additional data management and IT services may be provided.

Cloud – Centers owned by providers that offer services such as data storage, access, and data processing via the internet on a subscription or fee for services basis.

Edge – Facilities located close to end users that support specific functions such as autonomous driving, telemedicine, or smart cities.

Hyperscale – This type of data center is identified by size. A hyperscale center is very large, capable of handling massive processing workloads and that occupy 100,000 to several million square feet and house 5,000 to tens of thousands of servers. Any type of data center may be built to hyperscale size, with economies of scale a motivating determinant. Over half of these types of centers are operated by Amazon, Microsoft, and Google. Social media, cloud, and colocation providers are also creating facilities of this size.[11]

Data centers overall vary widely in size, ranging from enterprise or edge centers, each with hundreds of servers that might continuously require 5-20 MW, to centers of hyperscale size, a single one of which may require 50-100+ MW of power on a continuous basis.[12] To put 100MW in perspective, this is enough power to continuously provide the electricity requirements of 80,000 households[13], or 350,000 to 400,000 electric vehicles. The very largest hyperscale installations can consume over 650 MW of power.[14]

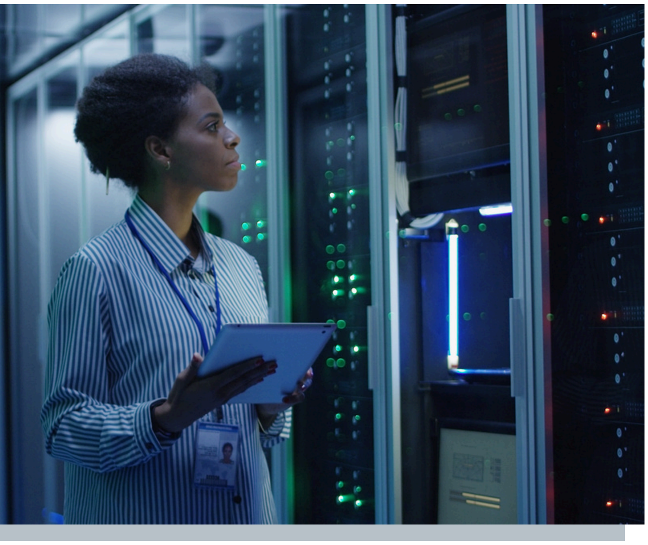
Increasingly, new data centers are being built at hyperscale size, with many of these being AI optimized. An AI optimized center contains larger, more complex, more energy-consuming servers than found in other data centers.

9 Priyadarshi (2024), Leppert (2025), Dillon (2025)
10 Aljbour et al. (2024)
11 Mahan (2025)
12 SolarTech (2025)
13 Offutt and Zhu (2025)
14 SolarTech (2025)

WHO OWNS DATA CENTERS

Most data centers of hyperscale size are owned and operated by the world's largest enterprises. Such entities include Amazon, Google, Microsoft, and Meta. Amazon and Microsoft each operate several hundred data centers around the world.

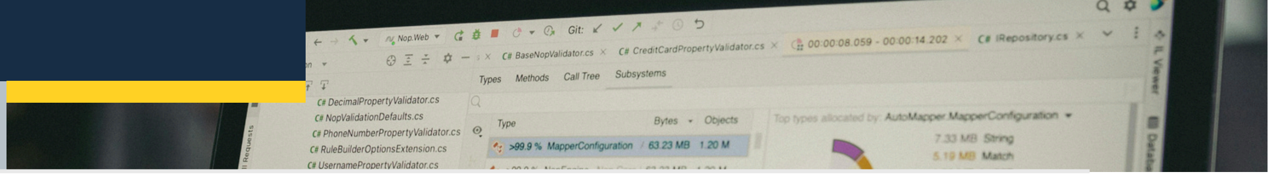
Examples of firms that operate dedicated enterprise data centers are Target Corporation, Ford Motor Company, General Motors, Intel Corporation, AT&T, Netflix, and Sony. All of these are large enterprises that have chosen to closely hold data and digital processing facilities.



There are hundreds of for-profit firms that operate colocation data centers that lease space (servers) in data centers to other companies. The largest of these include Equinix, Digital Realty, Iron Mountain, NIT Data Centers, CyrusOne, Telehouse, Centersquare, Core Site, QTS, and Switch Inc. In early 2024 these 10 companies together operated 900 data centers worldwide.[15] Competition in the data center industry is based on price, scalability, reliability, and several other factors.

Data centers are being constructed so rapidly that statistics as to numbers of centers and capacity are changing by the day. Various estimates[16] as of late 2025 place the number of data centers worldwide at 11,000-12,000. Of these the U.S. controlled 54% of capacity, a figure that encompasses centers physically located within the U.S. as well as those located in other countries but hosted by U.S. companies.[17] China (25%) and Europe (15%) also account for large shares of data center capacity consumption.[18] Despite rapid expansion of data center capacity, the vacancy rate in North American primary data center markets in mid-2025 stood at a record low 2.3%.[19]

15 Zhang (2024)
16 Neufeld (2025), Leichter (2025)
17 Neufeld (2025)
18 Net Zero Insights (2025)
19 Batson (2025)

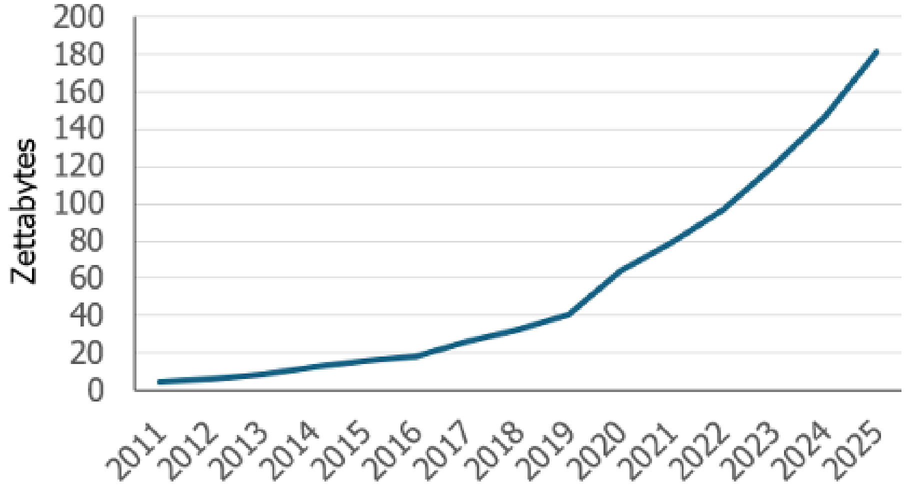


RAPID EXPANSION GAINS ATTENTION

Growth of Data

A 2010 estimate of new data created, captured, copied, and consumed globally in that year was 1.2 zettabytes (ZB)[20] up from 0.82 ZB just a year earlier.[21] By 2024 the data estimate had risen to 149 ZB, a number 124 times greater than that in 2010.[22] As reported by the International Data Center, data is growing at a compound annual growth rate of 20–43% in the U.S. (27% globally), with doubling of data creation occurring every two years within many of the largest organizations.[23] Figure 1 illustrates the rapid growth of data creation and manipulation.

Figure 1: Volume of Data Created, Captured, Copied, and Consumed Worldwide from 2010 to 2025 (2025 est.)



Source: Taylor (2025)

Rising Energy Consumption

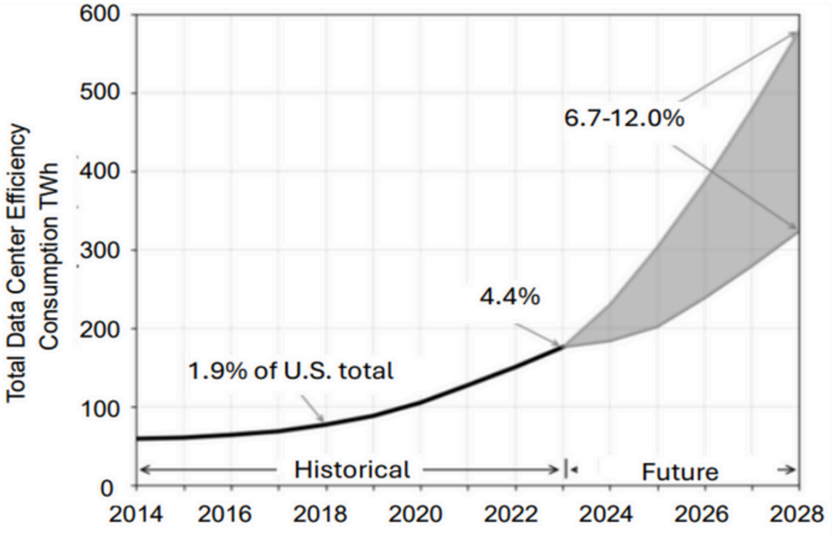
Exponential Growth

As reported by the Lawrence Berkeley National Laboratory, (LBNL) in 2024[24], energy consumption by U.S. data centers grew slowly through 2016, with energy demand reaching about 60 TWh in that year. Thereafter the rate of energy consumption accelerated due to technological advancements and increased access, reaching an estimated 366 TWh in 2025. Currently data center electricity consumption is growing at an exponential rate.

20 A zettabyte (ZB) is 1.0 trillion gigabytes
21 Miller (2010)
22 Taylor (2025)
23 Cooke et al. (2021)
24 Shehabi et al. (2024)

In 2018 U.S. data center energy use accounted for 1.9% of total national electricity consumption. By 2023 the percentage was 4.4% not counting consumption related to cryptocurrency[25] (see later section). The electrical load at U.S. data centers tripled from 2014-2024 and is projected by the LBNL to triple again by 2028, at which point data centers are projected to account for 6.7 to 12% of U.S. electricity consumption (Figure 2). The magnitude of future data center energy demand is seen as highly dependent on improvements in energy efficiency, operational standards, equipment cooling strategies, and the nature of equipment upgrades.[26]

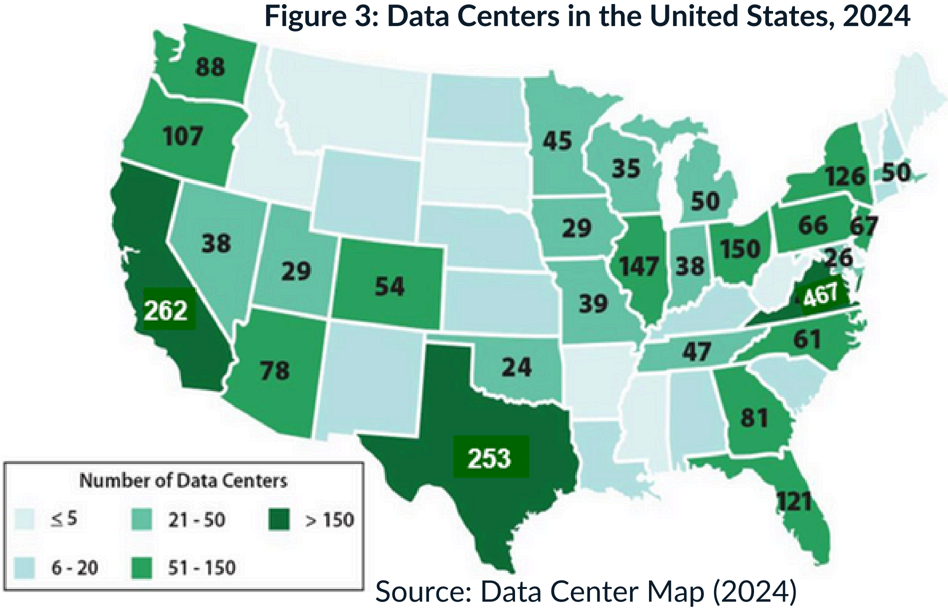
Figure 2: Total U.S. Data Center Electricity Use 2014 - 2028



Source: Shehabi et al. (2024)

The data center impact on national electricity consumption is not distributed evenly across the U.S., instead concentrated in just a few states. About half of U.S. data centers are in the states of Virginia, California, Texas, Ohio, Illinois, and New York (Figure 3), and in five states, data centers account for over 10% of electricity consumption.[27] Virginia hosts by far the greatest number of data centers, due in large part to the presence of federal agencies and military interests.

Figure 3: Data Centers in the United States, 2024



Source: Data Center Map (2024)

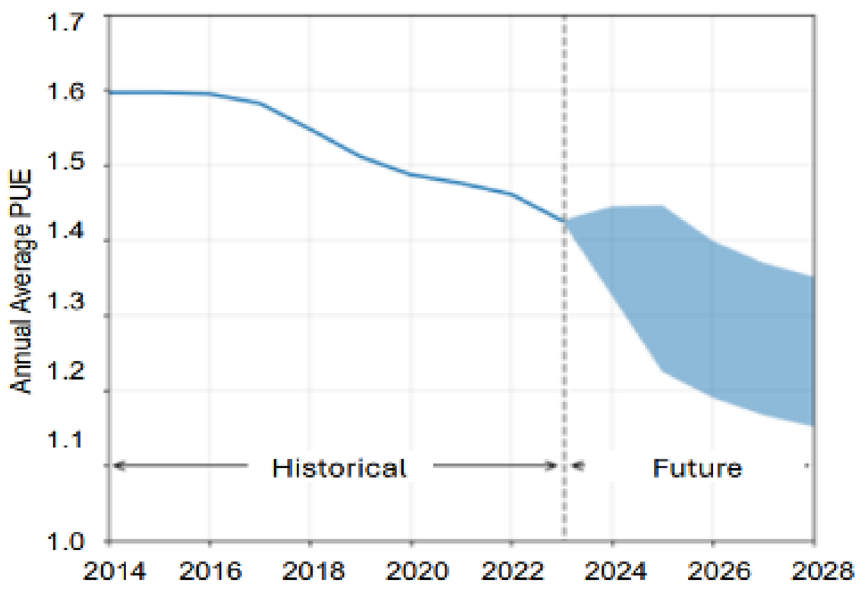
On a global scale, data centers were estimated to account for about 1.5% of electricity consumption in 2024 and projected to be about 3% in 2030.[28]

25 Ibid
26 Ibid
27 Spencer and Siddarth (2024)
28 IEA (2025)

Energy Efficiency

Power use efficiency (PUE) is a metric for gauging data center energy efficiency. PUE is calculated by dividing the total energy used by a facility by that energy used specifically for IT equipment and functions. The lower the PUE the greater the efficiency; the lowest theoretical value is 1.0. Since about 2017 considerable progress has been made in increasing the energy efficiency of data centers (Figure 4). From an industry average PUE of 2.5 in 2007 to 1.6 in 2014 and 1.43 in 2025[29], the energy efficiency improvement trend is notable. Several of the largest volume users, Google and Facebook, report PUEs of 1.10 and 1.08 respectively.

Figure 4: Annual Average PUE Across all U.S. Data Centers., 2024-2028



Source: Shehabi et al. (2024)

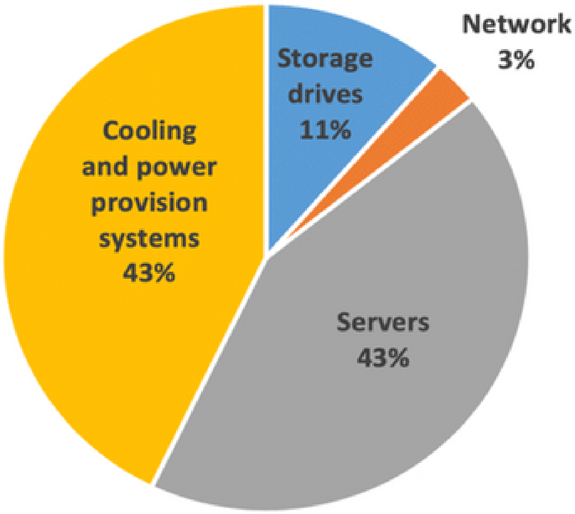
How Electricity is Used in Data Center

As much electricity is needed to cool data centers and provide cooling back-up capacity as is needed to drive servers (Figure 5). About 10-11% of data center electricity use goes to power data storage devices. Assuming continuation of exponential growth in the volume of data stored, as is forecast, this percentage is likely to grow as well. Data, once stored, tends to be stored for a very long time, requiring ongoing consumption of energy. Moreover, much of what is stored is "dark data", i.e. data that is collected, processed, and stored but not accessed or used thereafter.[30] Estimates of commercial data that is considered dark varies from 50% to 90%, depending upon the sector.[31]

29 SolarTech (2025)
30 Kez et al. (2022)
31 Tay Zar (2023)

Storage of unneeded data results in unnecessary energy consumption and related emissions. The energy cost of data transfer and storage has been determined to be 3.1-7 kWh per gigabyte, numbers that add up quickly, especially in a business environment.[32]

Figure 5: Electricity Consumption Within Data Centers by Function



Source: Massanet and Lei (2020)

Artificial Intelligence and Its Impact on Energy Consumption

The term *artificial intelligence (AI)* refers to the collective capabilities of advanced computer systems capable of performing tasks that typically require human intelligence. Examples include recognizing patterns of preferences, generating speech or images; reasoning; diagnosing problems or conditions; and even decision-making. Potential applications are almost limitless, ranging from medical care and robotic surgery to information searches, auto repair, fraud and risk detection, guidance to users of entertainment platforms, driving of autonomous vehicles, writing of code and informative articles, creating life-like images, and more.[33]

From an environmental perspective, AI is something of an enigma. On one hand it accentuates what was, before the advent of AI, an already considerable environmental impact of electronic technology[34], while on the other hand it may help to provide the answers to the most complex and daunting environmental problems faced today.[35] Regarding the latter, presented with the challenge of high energy consumption in Google data centers, the company employed the DeepMind AI algorithm to optimize cooling, resulting in reduction of cooling-related energy consumption by 40%.[36]

32 Adamson (2017)
33 ISO (2024), Coursera.org (2025)
34 Slagowski and DesAuties (2024), SolarTech (2025)
35 Dai and Clements (2024)
36 Evans and Gao (2016)

AI is reported to require more energy than traditional internet uses, tapping potentially hundreds or thousands of servers in far flung locations to generate answers.[37] And those servers require extraordinary levels of power. A traditional server[38], for example, requires 300-500 watts; a GPU accelerated server about 10 times that much. But servers in AI training clusters can each require 10,000 watts.[39]

In a 2025 report the International Energy Agency forecast a doubling of electricity demand by data centers from 2024 through 2030, with energy consumption by AI enhanced servers growing far more rapidly than for conventional servers (IEA 2025).[40] The Electric Power Research Institute (EPRI) reported AI applications accounted for 10-20% of data center power consumption in 2024.[41] LBNL predicts that by 2028 over half of data center electricity consumption will be used for AI. Moreover, power used for AI-specific purposes could rise to as much as 326 TWh, enough to power 22% of U.S. households.[42]

The two energy-demanding functions of AI models are *training* and *inference*. Training of AI models or algorithms is particularly energy intensive, potentially requiring megawatts of power for weeks or even months.[43] Training involves teaching models to utilize and interpret data sets and information sources in making predictions or decisions without the need for specific task-oriented programming. The term “inference” refers to the use of learned knowledge to generate a response to a query. Compared to training, a single inference requires considerably less energy. However, since inference happens far more often than the training phase, occurring millions or even billions of times a day, inference accounts for about 60-90% of total AI energy consumption.[44]

AI Algorithms

There are substantial differences in energy consumption by AI models depending upon the algorithm employed in a search for information, generation of an image, or other computer-aided task. A Chat GPT query requires 10-12% more energy than a Google search[45], while the least efficient image generation model consumes over 500 times the power as the most efficient.[46]

37 Kerr (2024)
38 A graphics processing unit (GPU) is capable of high-speed mathematical calculations for purposes of developing graphics and video
39 SolarTech (2025)
40 IEA (2025), Gooding (2024)
41 Aljbour et al. (2024)
42 Shehabi et al. (2024), O’Donnell and Crown (2025)
43 SolarTech (2025)
44 Aljbour et al. (2024), O’Donnell and Crown (2025)
45 SolarTech (2025)
46 Luccioni (2024)

Cryptocurrency and Energy

Bitcoin[47] is a form of digital currency that is exchanged outside of traditional banking systems and exclusively traded electronically. Expansion of the cryptocurrency supply is created through a process described as "mining".[48] "Mining" of bitcoin involves a computationally intensive process in which "miners" compete to solve a complex mathematical puzzle. With a goal of creating a new block of currency (in late 2025 a block consisted of 3.125 bitcoin with a total value of about $300,000), miners engage in what is literally a race. They compete against highly capitalized players (miners) around the world operating very powerful specialized computers. In highly energy-intensive processes, competing computers each perform tens or hundreds of millions of operations in search of a solution. The first player (miner) to find a solution "wins". Upon verification that a solution has been reached, a new block of currency is created and transactions linked to that block are enabled and confirmed.[49] The process is repeated about every 10 minutes.

The mining of bitcoin results in a large and growing environmental impact. A single bitcoin transaction, for instance, consumes the same amount of power as one U.S. household would in two and a half months.[50] Using a mining analogy, the quantity of energy required to mine the equivalent of one U.S. dollar has been found to be double the amount of energy required to mine an equivalent value in copper, gold, or platinum.[51] A 2024 estimate by the U.S. Energy and Information Administration was that cryptocurrency mining operations account for 0.6 to 2.3% of U.S. electricity consumption.[52]

A study by the United Nations University Institute for Water, Environment, and Health found that Bitcoin mining globally in 2021/2022 consumed 173.42 Terawatt hours of electricity, translating to greater electricity consumption than Pakistan and its 230 million people.[53] And the crypto market continues to grow: as of mid-October 2025 the global cryptocurrency market was over 50% larger than at mid-year 2021.[54]

47 There are many forms of digital money with about 20,000 different cryptocurrencies in circulation. Bitcoin and Etherum are the most common (Farney 2024).
48 Nambiampurath (2025), Monserrate (2022)
49 Garnett (2025), Monserrate (2022), O'Sullivan (2022)
50 Farney (2024)
51 Monserrate (2022)
52 EIA (2024)
53 Chamanara and Madani (2023)
54 Fortune Business Insights (2025)

Low Costs/Greater Use

The need for constant cooling is a major driver of the environmental impact of data centers. The choice basically comes down to using primarily either electric power or water to achieve cooling. An obvious option is to use air conditioners although their operation is relatively power intensive. Another commonly employed option is use of evaporative coolers[55] that are particularly effective in dry climates; these require only about one-third the energy as air conditioners, but at the expense of large volumes of water loss. Newer technologies (discussed later) employ liquid cooling systems designed to minimize water consumption.

In a 2022 interview on NPR the vice president at CyrusOne, a data center company, explained that the options for cooling data centers are limited. He noted that data centers "can either consume less water and use more electricity", or "use less energy and consume more water." Because "water is super cheap" he indicated that lower cost often drives the financial decision toward water cooling.[56] That the low cost of water compared to electricity drives data cost decisions was echoed by RMBJ Geo hydrologist Amy Bush who observed that "water is often the last consideration when making siting decisions," citing low cost of water relative to that of either power or land.[57]

Data centers primarily draw upon potable water from municipal or regional water utilities which can strain existing infrastructure or require expensive upgrades. Local aquifers are another common source. Alternative water sources can include use of surface water (rivers, lakes, ponds), seawater, rainwater harvesting systems, or non-potable graywater and wastewater. These alternative sources contribute less than 5% of water used by the typical data center.[58]

Water is consumed at two points in data center operation: 1) in cooling of data centers and the servers within them, and 2) in generating the electricity that data centers consume. Quantities consumed are large. For instance, a 2025 report by the Houston Advanced Research Center indicated that water consumption averages 793 gallons per MWh of electricity used in data center operation across the State of Texas.[59] An average Google data center reportedly uses 450,000 gallons of water per day, translating to over 164 million gallons annually. A hyperscale center can consume millions of gallons of water a day.[60]

55 An evaporative cooler uses liquid water that evaporates quickly in hot, low humidity environments. The phase change, from liquid to water vapor, adsorbs heat, cooling the surrounding space. Heat is carried away as water vapor is lost to the environment.

56 Copely (2022)

57 Nicoletti et al. (2024)

58 Rosenfeld et al. (2025)

59 Cook (2025)

60 CREA United (2023)

The 17 billion gallons of water used by data centers in 2023 amounted to a tiny fraction of annual water consumption in the United States.[61] Yet, the impact of water use in data centers can be significant near their locations and in regions of data center concentration, especially in areas facing water scarcity issues.

The Cooling Problem

Evaporative cooling is the most common method of data center cooling[62] and the source of greatest concern regarding water consumption. But there is another aspect to evaporative cooling that is less apparent. In evaporative systems not all water sent into the system is evaporated, instead winding up as excess water that becomes runoff. This water commonly contains biocides, corrosion inhibitors, and sometimes even heavy metals. Consequently, this runoff must be treated in some way before being released. A typical city water treatment system may not be equipped to handle such compounds.[63]

Seeking to reduce consumption of both energy and water, new systems for cooling data centers have been developed. One approach is direct-to-chip cooling involving use of cold plates placed directly on top of heat generating equipment; these are cooled by liquids that circulate, absorbing heat from the IT equipment, moving on to heat exchangers for re-cooling, and then back again through the system.[64] Cooling is efficient and focused on where heat is generated, sharply reducing water consumption while eliminating the need for cooling fans and the energy and noise they generate.[65] A downside of this approach is that data center construction is more complex and expensive than in the case of evaporative cooling. Another is that such systems can develop leaks, posing operational and environmental risks.[66]

Another method of cooling that eliminates the need for cooling water involves immersion of IT components or server systems in non-conductive fluids that have high heat transfer properties. This approach is more effective in reducing energy consumption than direct-to-chip cooling.[67] A variation of immersion cooling uses non-conductive fluids that boil when exposed to the heat of servers, carrying heat away as the fluid evaporates, later to be recovered as condensate. This is the most efficient and energy-saving system. Both of these methods of cooling, however, are significantly more expensive than simpler designs. The cost of building a fluid immersion cooling system, for example, is about 50% greater than for a direct-to-chip system, and even greater if a system employs boiling of non-conductive fluids.[68]

61 Shehabi et al. (2024), Stets (2025)
62 Burman (2025)
63 Tozzi (2025b), Ahmad (2025)
64 Ahmad (2025), Alissa et al. (2025), Bolgar (2025)
65 Device42 (2025)
66 Tozzi (2025a)
67 Ibid
68 Tozzi (2025a), Device42 (2025)

All of the newer fluid cooling systems reduce consumption of both energy and water.[69] All of these systems also pose a risk of leaks or spills of fluids that contain hydrocarbon oils and other ingredients that can include Per- and Polyfluoroalkyl substances (PFAS)[70] meaning that incorporation of biocontainment features is essential in the design of such facilities.[71] High flammability is, in addition, a concern with some of the fluids used.

Water Demand and Community Impact

A medium-sized data center can reportedly consume a quantity of water equivalent to 1,000 homes, whereas consumption by large centers may exceed that of a city of 50,000 people. The fact that AI-focused hyperscale centers are increasing in size and numbers, using large quantities of both water and energy while also driving increasing carbon emissions is a matter of rising concern.[72]

In The Dalles, Oregon residents discovered that local data centers had consumed 355 million gallons of water in 2021 – a quarter of the city's water supply – having increased 3-fold over the previous five-year period.[73] This revelation came only after a lawsuit forced city leaders to disclose water use.[74]

The state of Texas is an attractive location for data center establishment due to low land costs, tax incentives, and renewable energy access, and consequently Texas hosts more data centers than 47 other states.[75] The downside of this development is strain on the state's water resources. The Houston Advanced Research Center estimated that Texas' data center water consumption would increase 8-fold over the five-year period 2025-2030 to about 400 billion gallons annually, virtually all of which would likely come from local aquifers. Should 2030 water consumption increase to this level, data center water use would account for almost 6.6 percent of total Texas' water consumption.[76]

Bloomberg News reported in 2025 that about two-thirds of 160 new data centers built or in development over the previous three years were located in places already gripped by high levels of water stress, with over 70% concentrated in only 5 states, a list that includes Texas.[77]

69 Device42 (2025), Bolgar (2025), Alissa et al. (2025)
70 PFAS chemicals are widely used, long lasting chemicals, components of which break down very slowly over time (EPA).
71 Alissa et al. (2025)
72 Yañez-Barnuevo (2025)
73 Ahmad (2025)
74 Rogoway (2023)
75 Schlag et al. (2025)
76 Cook (2025)
77 Nicoletti and Bass (2025)

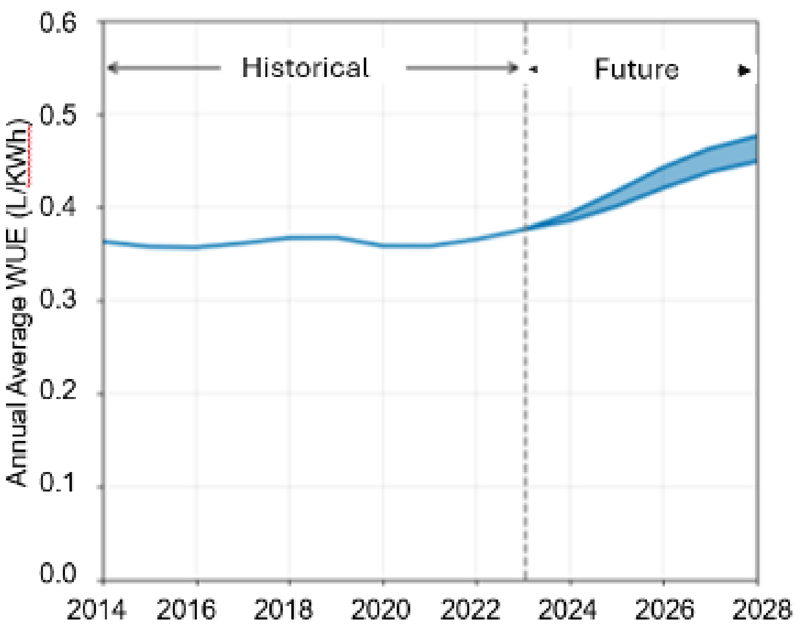
The pace of development coupled with projections of sharp increases in data center water consumption have caught the attention of state leaders and residents in many regions. Pressure is reportedly growing on state legislators to enact regulatory measures regarding data center water consumption.[78] As of early 2025 legislative bodies in Texas and at least seven other states were considering measures to address the growing environmental impact of data centers.[79]

Water Use Efficiency

A 2021 survey found that half of data center operators did not track water use at all, and only 10% of operators indicated that water use was monitored at all sites.[80] As communities have become aware of the magnitude of data center water consumption, volumes consumed and efficiency of use have gained greater attention.

The water use efficiency (WUE) metric is used to express the effectiveness of water use by data centers. Calculated by dividing water consumption (liters) by IT equipment energy consumption (kWh), WUE provides a valuable indicator of performance. Similar to power use efficiency, the lower the water WUE the more efficient the water use. But unlike the PUE, the WUE value is rising, with this trend expected to continue through at least 2028 (Figure 6). Development of hyperscale facilities and continued use of water-based cooling systems are drivers of reduced water use efficiency.[81]

Figure 6: Average Annual Site Water Use Efficiency (WUE) Across All U.S. Data Centers



Source: Shehabi et al. (2024)

Data Centers and Noise

Continuous operation of thousands of servers, air chillers, rooftop HVAC fans, switches, and routers, combined with periodic operation of backup generators (typically diesel) creates a cacophony of sound that can be disruptive to surrounding residents.

Described as a "dominant feature" of data centers is a constant low-frequency buzzing sound that can be detected miles away.[82] Nearer to data center locations (i.e. from immediately adjacent to 700-980 feet away) running of high velocity cooling fans, operation of servers, and standby equipment that combine to noise levels that exceed maximum local noise ordinance levels.[83]

There are many options for abating data center noise, including acoustic panels, soundproofing, equipment enclosures, noise zoning and use of non-fan based cooling systems.[84] However, ongoing noise issues provide testament to insufficient attention to this issue.

78 Schlag et al. (2025)
79 Hutchinson (2025)
80 Ahmad (2025), Vincent (2024)
81 Shehabi et al. (2024)
82 Noise Monitoring Services (2025)
83 Judge (2021), Lyver (2022), Richardson (2024)
84 Richardson (2024), McCabe (2025), Noise Monitoring Services (2025)

REDUCING ENVIRONMENTAL IMPACTS

Data Centers Are Here to Stay

There are many upsides to data centers: they can bring jobs, economic growth, and an expanded tax base to communities in which they are located. In addition, they enable reliable access to advanced technology, streaming of IT services, global connectivity, secure backup of files, and more from a wide array of devices. Like it or not, an increasing presence of IT and growing numbers of data centers reflect reality.

As noted previously, the services that data centers provide come at an environmental cost. Their prodigious consumption of energy and water can strain local energy and water treatment infrastructure and transmission networks, increase electricity and utility rates[85], negatively impact the quality of delivered energy in areas of data center concentration[86], and adversely impact water supplies. While there is much that the IT and data center industry could do to reduce these impacts, and steps that communities can take to minimize adverse environmental impacts, there are things that IT users can do as well. Impact reducing strategies are outlined below, organized by business/industry/large organizations, local government units, and individuals.

Data Center Impact Reducing Strategies

Business, Industry, and Large Organizations

- When considering space rental in a data center, seek a provider that has a strong sustainability commitment as demonstrated by:
  - Use of renewable energy.
  - A high level of energy efficiency (PUE closest to one).
  - Latest energy and water conservation technologies.
  - A high level of water use efficiency (lower WUE).
  - Transparent reporting/independent monitoring of water consumption, wastewater emissions.

- With respect to saving and storage of data, develop organizational protocols:[87]
  - for data storage
    - Review data storage protocols and consider a tiered approach to retention of data.
    - Delete outdated, redundant, or unneeded data, and transfer seldom accessed data to more energy efficient drives or to tape storage which requires zero energy consumption.
    - Compress files to reduce storage space and related costs

85 Kimball and Cortes (2025)
86 Nicoletti et al. (2024)
87 SolarTech (2025), Sar (2024), Alissa et al. (2025), Costenaro and Duer (2012), Cooke et al. (2021)

Local Government Units[88]

In view of the strong business and economic benefits of data centers, their large environmental footprint, the reality that virtually everyone uses data center services, and rising public opposition to establishment in their communities, it behooves local governments to become aware of the issues surrounding data center establishment and operation. A place to start is to develop a set of questions when faced with a development proposal; among the questions that should be asked are:

- What will be the scale of the proposed development?
- Will this be an AI enhanced facility?
- Is this facility intended for use in cryptocurrency mining?
- What will be the annual energy consumption?
- Will renewable energy be used?
- What technology will be employed for system cooling?
- What is anticipated annual water consumption and from what sources?
- Is generation of wastewater anticipated? If so, what are the plans for discharging?
- What provisions are being made to optimize energy and water efficiency?
- Will you commit to transparent reporting/independent monitoring of electricity consumption, water consumption, and wastewater emissions?
- If liquid cooling is to be employed, what are the plans for spill containment?
- How will backup energy be provided – generators, batteries, other?
- Are there any plans for sound abatement?

Individuals[89]

- Although an individual user constitutes a literal drop in the bucket in the big scheme of things, impacts can differ considerably based on use patterns and habits. For example:
  - Be aware that streaming media (music, video) require energy use beyond your location. Even if on an unlimited data plan, be mindful of the environmental costs and turn off when not using
  - Carbon emissions linked to high-definition streaming are about 8 times higher than when streaming standard definition.
  - For content to be viewed multiple times, downloading rather than repeatedly streaming reduces power consumption by about 75%.

88 SolarTech (2025), Device42 (2025)
89 Costenaro and Duer (2012), Adamson (2017), Santamaria (2024), Newton (2025)

- If using tabbed browsing, realize that if your computer is not in a sleep-mode there will be a continuing flow of data into the open tabs, again consuming energy beyond your location.
- Be mindful that saving a document, image, or file to the cloud triggers ongoing energy and water consumption that continues 24/7 and that storing data on the cloud is far more energy intensive than storing on an individual computer.
- Think before sending photos or files to multiple recipients. This triggers storage in multiple locations, again with perpetual consumption of energy and all that goes with it.
- Compress files before storing or when sending as email attachments.
- Unless absolutely necessary, don't include the previous e-mail thread when replying to messages, either by manually deleting all or part of included messages or by disabling automatic inclusion of message strings.

THE BOTTOM LINE

Rapid growth of the volume of data developed, captured, and stored, coupled with innovation in information sharing, streaming, social media, on-line shopping, and so on have created a need for facilities that can handle, process, and store data. The advent of AI has accentuated the need while at the same time increasing complexity, scale, and impact of data center facilities.

Data centers by their very nature consume very large quantities of energy and often of water as well. The impacts of such consumption are magnified when large scale facilities are established or concentrated such that local energy infrastructure or water supplies are strained, or when the sheer volumes of resource consumption raise concerns regarding physical and environmental sustainability. On a larger scale, concerns are focused on energy demand growth, energy consumption-related greenhouse gas emissions, and effects on already problematic fresh-water availability in some regions.

Anyone who owns a smart phone, shares photos, saves files to the cloud, or surfs the web relies on data centers. Because of this, strident opposition to their establishment is unrealistic – even hypocritical. However, that something is essential, a part of everyday life, does not mean that the environmental impacts of it should be accepted without question. In this case, the something (a data center) is associated with significant environmental costs that can be quantified and addressed in planning and design.

What is needed regarding the issue of data center establishment is an informed citizenry and leadership who are aware not only of the benefits, but also of the liabilities that data centers pose. It is also important that all parties to negotiation be aware of the options available in designing data centers for minimizing resource consumption, related impacts, and risk.

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