Data Center Measure: ***Draft***

Data centers are buildings containing computer servers, storage and network equipment that provide online services and support for the digital economy such as social media, video streaming, cloud storage and increasingly artificial intelligence (AI) and quantum computing. The Metropolitan Washington region has become the world's leading hub for data centers, driven by favorable incentives and zoning policies, access to land and electric power, an extensive underground fiber optic network, and proximity to federal agencies. Loudoun County, Virginia, is home to the highest concentration of data centers globally. In 2023, data centers consumed around 25% of total building electricity use in the MSA, resulting in 10% of the region's GHG emissions.

While data centers are a key driver of rising energy demand in the region, they also generate significant economic benefits to localities, including tax revenue and job creation. Loudoun County's ~200 data centers, for instance, provide more than 12,000 jobs in Loudoun County and generate almost half of the county's property tax revenues.[1] The goal of this measure is to provide a suite of actions that localities can leverage going forward to maintain these economic advantages while addressing concerns regarding how to balance rising electricity consumption with GHG emission reduction goals. Data center owners and operators, such as Amazon, Microsoft, and Google – who collectively own over half of hyperscale data centers[2] – will be critical partners for implementing the actions outlined in this measure.

Data Center Types at a Glance

Emissions from data centers come from the use of fossil fuels to generate electricity. That electricity is either grid-supplied or generated onsite through backup power (typically diesel generators). In theory, reducing these emissions is simple: Sourcing carbon-free power for electricity supply would eliminate GHG emissions from data center operations. However, developing such resources at the pace and scale required presents a significant challenge, largely due to the high reliability requirements for data centers.

There are over 300 data centers within a 50-mile radius of Washington, DC, about 200 of which are in Loudoun County.[3] While specific data centers' energy demands may vary depending on their size, the concentration of them in the region, including the recent development of large hyperscale facilities, has led to significant increases in energy demand.

From 2010-2018, the majority of servers could be found in Internal, Edge, or Enterprise data centers. In 2023, hyperscale and colocation data centers accounted for almost 80% of data server energy use. Hyperscale data centers are built by companies that deploy internet services and platforms at massive scale and can exceed 100,000 square feet. The development of more powerful microchips in recent years has led to higher power demand in a smaller footprint, resulting in some hyperscale

- **Edge data centers** are smaller facilities that are located closer to end users at the edge of a network to provide low-latency computing.
- **Enterprise data centers** are owned or leased by a single organization and used to support that organization's IT needs.
- **Internal data centers** are integrated into larger buildings and managed by businesses with their own IT systems.
- **Colocation data centers** provide space, power, cooling, and connectivity for the servers and other hardware of multiple organizations. These facilities are also referred to as multi-tenant data centers.
- **Hyperscale data centers** are usually built by or for one organization to meet the specific technical, operational, and pricing requirements of a hyperscale customer.

facilities using hundreds of megawatts of electricity – enough to power hundreds of thousands of homes.

Hyperscale data centers are experiencing rapid growth. Distinct clusters emerge for colocation and hyperscale data center locations as data centers strategically position themselves close to their clients and cloud services users to ensure high availability and low response times. Factors such as proximity to population centers, electricity cost, network infrastructures, and local utility prices influence their location choices. Virginia hosts the highest electricity demand associated with data centers in the U.S., serving as the primary hub for both colocation and hyperscale data centers, followed by California and Texas.

Data centers are a critical partner for implementing the actions outlined in this measure, and many of the region's data centers are already applying best practices to maximize energy efficiency and manage energy demands. Currently, 44 data centers across the MSA are ENERGY STAR certified and two have been awarded Designed for ENERGY STAR status, with the majority located in Loudoun County. In addition, 24 have been certified by LEED and 5 by Green Globes. To manage costs, many colocation and hyperscale data centers are designed to be highly efficient, but may not apply for certification programs.

Status of Local Action

With the rise in proposals to develop data centers – hyperscale ones in particular – counties in the region have begun to review their zoning and permitting processes to manage data center growth and community concerns.

The furthest along is Loudoun County, where the Office of Planning and Zoning is in the process of updating the policies, standards, and locations for data center development. Phase 2 of this work, expected to be completed in 2026, will focus on establishing policy guidance and use-specific zoning standards for data centers and utility substations to address concerns related to land use, compatibility, aesthetics, infrastructure and natural and environmental resources. The County is also collaborating with the Data Center Coalition, the National Renewable Energy Laboratory, and other regional partners to build on existing successes and identify strategies to manage and reduce energy and water use by data centers.

While the regulatory environment around data centers is constantly evolving, the table below outlines ongoing processes to navigate significant data center growth in select localities.

[NOTE: This table is currently incomplete. Local jurisdictions are being asked to review and update the language in this table.]

County	Permitting Overview	Workgroups / Task Forces
Loudoun County	March 2025: removed by-right development; all new data centers require a special exception. Ongoing: Comprehensive Plan and Zoning Ordinance Amendment to update the policies and standards for data center and electrical substation uses.	None

Fairfax County	Sept 2024: adopted data center zoning ordinance amendment, which created stricter by-right standards, including size limits, noise studies, setbacks, and building aesthetic requirements.	None
Prince William County	By-right development allowed in the Data Center Opportunity Zone Overlay District (DCOZOD) (est. 2016); outside the overlay, special use permit is required. Ongoing: Review of policy proposals for enhanced design and sustainability guidelines.	Data Center Ordinance Advisory Group stakeholder workgroup is advising on ordinance revisions.
Frederick County	No revisions yet.	Data Centers Workgroup published a report with recommendations, including CDI zones and sustainability measures.
Prince George's County	No revisions yet.	Qualified Data Center Task Force established in 2025 to evaluate potential risks, community benefits, and revenue potential from data centers.

Implementation Activities and Milestones

This measure includes several actions that data centers can take to improve energy efficiency and reduce emissions from onsite backup power. Many of these actions can be encouraged by localities through the permitting process, or reporting or meeting efficiency standards. The key drivers of data center energy use are servers/IT equipment and cooling systems. The actions below are grouped into five categories: 1) IT Equipment Efficiency, 2) Building-level (cooling and power systems efficiency), 3) Onsite Clean Energy, 4) Data Tracking and Reporting, and 5) Engagement and Advocacy.

IT Equipment Efficiency

- Encourage including efficient equipment in procurement processes, such as ENERGY STAR IT equipment.
  - ENERGY STAR servers use 30% less energy than regular servers on average when power management is enabled while typically providing better performance per watt, leading to fewer servers being needed.
  - ENERGY STAR certifications available: computer servers, storage, switches/routers and uninterruptible power supplies. Many of these products can also be found on the EPEAT registry which covers additional environmental and sustainability product criteria beyond energy use.
  - Metrics used this these efforts are based in part on efficiency measurements using the Standard Performance Evaluation Corporation's (SPEC) Server Efficiency Rating Tool (SERT) for computer servers and the Storage Networking Industry Association's (SNIA) Emerald tool for storage products.
  - Sample procurement language can be found here.
- Encourage the adoption of higher utilization levels in IT hardware when possible.

- Educate customers (e.g., data center operators, facilities, IT departments) on best practices for servers/IT equipment.
- Encourage data center operators to leverage free IT equipment return and/or recycling programs offered by major IT vendors (HPE, Dell, Oracle, IBM, Cisco, etc.).

> Servers and IT equipment can drive 40% of data center power demand. Encouraging data centers to identify savings opportunities through IT equipment upgrades is a relatively straightforward method to help reduce energy demand.
>
> Reducing the IT power requirements results in a multiplier effect through savings on infrastructure power: every unit of IT power saved reduces infrastructure power to energize and cool the IT equipment. Data center owners and operators can take advantage of not only higher efficiency IT equipment, but also data center management strategies such as utilization, consolidation, and virtualization to prevent excessive IT energy consumption.

Building-level (Mechanical and Electrical)

- Encourage implementing best practices for cooling & air management, including:
    - Free air cooling through air economizers. **Direct free air cooling** uses outside air to directly cool equipment. This is very efficient but requires careful air quality and temperature management. **Indirect free air cooling** uses outside air to cool water or other fluids, which are fed into various forms of heat exchangers in the data center. This requires protecting equipment from outside environmental factors.
    - In-row, overhead, or rear door refrigerant-based heat exchangers, which are typically more efficient than traditional air cooling and can be implemented cost-effectively in traditional enterprise and colocation data center facilities.
    - Hot aisle/cold aisle arrangements, which should always be implemented when cooling with any air-based approach. Hot aisle and cold aisle containment separates the hot air released from servers from the cool air used to cool the data center.

> Servers and computer chips generate heat, resulting in significant cooling needs for the building and equipment. Cooling systems often drive 40% of date center energy demand. At the building level, data center cooling systems can be either air-cooled or water-cooled. Evaporative cooling systems use water evaporation to cool air, and while very energy efficient, consume significant amounts of water. Considerations for cooling systems include cost and complexity to implement, load availability, space configurations, future energy needs, and energy efficiency.

- Encourage onsite efficiency improvements, including:
    - Raising the chilled water temperature.
    - Evaluating chillers for replacement.
    - Encourage monitoring systems for real-time management and efficiency (including Data Center Infrastructure Management (DCIM) software), reviewing operation and efficiency on a regular basis, and staff training.
- Implement best practices for power infrastructure and uninterruptible power supplies (UPS).
- Collaborate with liquid-cooled data centers during the site selection process to consider access to recycled wastewater. Using non-potable water for data center cooling processes will limit the impact on local drinking water supplies.

Onsite Energy

Power Usage Efficiency (PUE): A metric used to evaluate the efficiency of energy usage that can be measured by *Total Facility Energy (kWh) / IT Equipment Energy (kWh)*

Water Usage Effectiveness (WUE): A metric used to evaluate the efficiency of water usage that can be measured by *Total Site Water Usage (liters) / IT Equipment Energy (kWh)*

The closer the PUE value is to 1.0, the more efficient the data center is in utilizing its power solely for IT equipment. WUE value of 0 indicates no water usage. It is important to note that additional IT equipment energy use lowers PUE, so adding more IT capacity in a data center, all else equal, can lower PUE scores while increasing energy use.

- Encourage onsite solar.
    - Given the amount of renewables needed to meet a data center's electricity demand, it is generally not feasible or cost-effective for data centers to deploy onsite solar to meet all their electricity demand. Powering a 100 MW hyperscale data center would require nearly 1,500 acres of solar -- roughly 1,100 football fields -- and that power would need to be generated 24/7 (which solar alone cannot provide). However, onsite solar could be included as part of the permitting process to provide community benefits to help meet local goals for clean energy development.
- Encourage options to reduce emissions from backup power and increase efficiency.
    - Replace diesel generators with natural gas generators.
    - Deploy Combined Heat and Powers (CHP) systems, which can increase the energy efficiency and reliability of data centers by providing a reliable power supply and efficiently utilizing waste heat. They can even be used as a primary energy generation source, turning a utility feed into a backup power option and removing the need for diesel generators and storage.
        - CHP plants can also be paired with fuel cells to realize even greater efficiencies and are capable of using hydrogen blends and/or pure hydrogen in place of natural gas if available. CHP and fuel cells can both play a primary role in microgrid deployments as they are capable of producing constant power which can allow electric grid connections to become secondary or backup electricity options and also potentially open up grid demand response or load sharing opportunities.
- Collaborate with utilities to encourage participation in demand response programs.
    - Data center load is typically not flexible enough to participate, but they could host grid-scale batteries onsite to provide grid services. Options like on-site CHP plants mentioned above or future development of nuclear small modular reactors may allow for new forms of interactivity between data centers and the electric grid.
- Conduct feasibility studies for district energy.
    - District energy systems carry hot water, steam, and/or water through a network of insulated pipes to provide energy for nearby buildings. Through district energy systems, waste heat from data centers could help provide a base heat resource for nearby buildings and facilities. A district heating system could be considered in planning for new data center campuses.

Data Tracking and Reporting

- Encourage data center operators to implement metering/monitoring systems to track water and energy consumption and benchmark their performance. Key metrics to do so are power usage effectiveness (PUE) and water usage effectiveness (WUE).
  - Leverage Maryland and DC BEPS reporting requirements to track data center energy consumption and emissions.
- Encourage data centers to achieve ENERGY STAR certification and track certifications over time.
- Encourage existing data centers to conduct comprehensive energy assessments to identify key areas of energy use.
- Encourage data centers to report the amount of renewable energy directly tied into operations, either through on-site installations or off-site power purchase agreements within same service territory.

Engagement and Advocacy

- Implement new policies in localities where applicable:
  - Establish policy guidance and use-specific zoning and permitting standards/ordinances for new data centers and utility substations to address concerns related to land use, compatibility, noise, aesthetics, infrastructure and natural and environmental resources.
  - Require reporting of PUE where able, and set maximum PUE design targets for new data center builds and retrofit/operating targets for existing data centers.
  - Educate locality staff, providing background materials on data centers to support discussion related to planning and zoning changes.
- Coordinate between localities to advocate for changes at the state, regional, and federal level.
  - Add select data center items to legislative agendas.
  - At the state level, track Virginia's and Maryland's legislative agendas and coordinate regional advocacy to support select bills, especially around data reporting and tracking of energy and water use.
  - At the state level, intervene as appropriate in utility proceedings related to ratepayer impacts from meeting data center energy demand.
  - At the broader regional and federal level, identify opportunities to participate in PJM or Federal Energy Regulatory Commission (FERC) stakeholder discussions.
  - Support local jurisdictions with data driven decision-making (e.g., including data center estimates in future community-wide GHG inventories).
  - Continue exploring partnership opportunities with the Data Center Coalition for anonymized and aggregated data collection.

Key Implementing Agencies and Partners

Regulating Agencies

- **Federal Energy Regulatory Commission (FERC):** Regulates electricity and transmission of electricity in interstate commerce, the development of reliability standards and national energy infrastructure, including natural gas pipelines and more.

- **Virginia State Corporation Commission, Maryland Public Service Commission:** The regulatory bodies that acts as a State Public Utility Commission and regulate utility rates.
- **State Air Emission Regulators**: VA's Department of Environmental Quality (DEQ), Maryland's Department of the Environment (MDE), and D.C.'s Department of Energy and Environment (DOEE) play key roles in issuing water permits, requiring certifications, or conducting environment impact assessments for data centers, as well as issuing air quality permits for fossil fuel-powered backup generators. In Maryland and D.C., these agencies also implement the building energy performance standards.

Implementing Agencies

- **Federal government agencies:** Several federal agencies play a role in developing best practices for and certifying data centers. EPA's ENERGY STAR program certifies data centers that meet high standards for energy efficiency and provides resources on efficient equipment. DOE works with national laboratories, including Lawrence Berkeley National Laboratory and the National Renewable Energy Laboratory, to conduct research on data center energy use and identify solutions and best practices.
- **Local government and regional agencies:** Localities, COG, and the Northern Viriginia Regional Commissions (NVRC) play an important role in facilitating regional coordination, leading community engagement and outreach, and compiling GHG inventory data. Local planning and zoning departments play a key role in managing and regulating data center development, including updating policies and standards for data center uses.
- **Data center owner and operators.** Data center owners and operators make key facility development, operation, and maintenance decisions, and are responsible for ensuring facility reliability and security. This group ultimately decides how their data centers are designed, if they include any of the above efficiency improvements, and what data is collected and/or reported.
- **Data Center Coalition:** The Data Center Coalition (DCC) is the membership association for the data center industry that advocates for investments to support data center development and builds partnerships with key stakeholders.
- **Electric, water, and gas utilities:** Utilities are responsible for supplying the energy and water data centers use for their operations.

Authority to Implement

Data center owners, operators, and developers have the authority to implement all actions related to data center operations and development.

The District of Columbia and counties in Maryland have the authority to implement data tracking and reporting requirements for buildings. Under their respective Building Energy Performance Standards (BEPS) programs, some data centers will be required to report their energy use and emissions data starting in 2025. However, Virginia law does not currently allow local governments to establish BEPS or related energy tracking policies unless there is a state policy in place. Localities in Virginia could encourage the use of energy efficiency and data tracking by expediting permit approvals for data centers whose designs and commitments meet certain requirements, absent legislative action at the state level requiring reporting on energy usage from data centers.

Geographic Coverage

This measure applies to the full MSA, but it reduces GHG emissions in counties where data centers are or will be present.

Quantified GHG Reductions [Draft]

2025 – 2050 cumulative GHG emission reductions: 2.8 $MMTCO_2e$

This measure only quantifies potential reductions from cleaner electricity supplied by the grid and does not include an assessment of the impact of cleaner backup power due to a lack of available data. The total electricity consumed by data centers is held constant between the BAU and CCAP implementation scenario.

Funding Sources

Example potential funding sources include:

- U.S. DOE Grid Resilience and Innovation Partnerships (GRIP) Program grants
- Inflation Reduction Act tax credits for onsite renewables at data centers
- The Maryland Energy Administration offers grant programs to data centers located in or being constructed in the state with a minimum data floor facility size of 2,000 square feet to support projects that reduce electrical usage and improve PUE.

Sample Metrics for Tracking Progress

The following metrics can only be reported if information is able to be collected from data centers:

- PUE
- WUE
- % of year using free air cooling when applicable
- % of electricity offset by clean energy procurements
- Amount of onsite solar hosted by data centers

COG and localities can collaborate to collect the following metrics:

- Energy use from data centers covered by BEPS (only applies to MD/DC)
- Number of data centers achieving various energy efficiency certifications (e.g., ENERGY STAR)
- Data center electricity GHG emission estimates to incorporate into local and regional greenhouse gas inventories.

Appendix: Data Center Background Information

A data center is a facility that houses and supports computer systems and related infrastructure, enabling storage and processing of digital data. It contains various components, including servers, storage devices, networking equipment, power systems, cooling systems, and physical security measures. The following background information is compiled from multiple resources, including:

- Lawrence Berkeley National Lab's (LBNL) Center of Expertise for Energy Efficiency in Data Centers https://datacenters.lbl.gov/
- Graphics from: LBNL *2024 United States Data Center Energy Usage Report*, December 2024
- "As generative AI asks for more power, data centers seek more reliable, cleaner energy solutions" Deloitte

Data Center Types

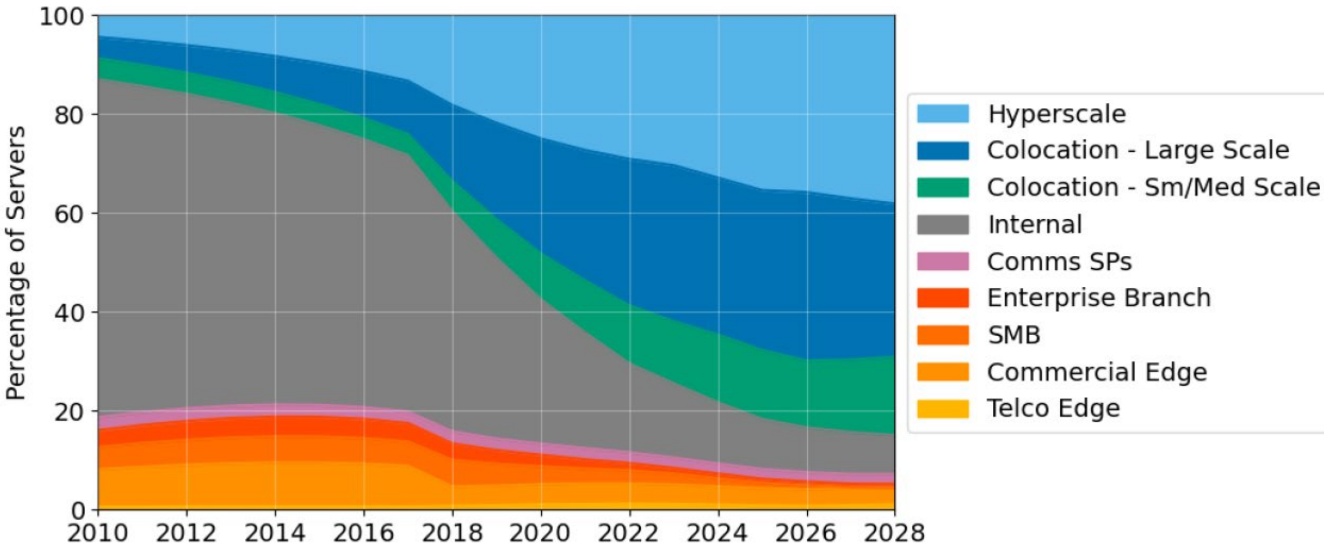
There are multiple ways to categorize data centers, including based on IT equipment, ownership (internal vs service provider), or the facility space type. Different space types can have varying operational characteristics and cooling systems. The LBNL report categorizes them by space type: small, with an average square footage of less than 150; midsize, with an average square footage of 2,700 – 6,900; or large-scale, with average square footages of 11,000 for the colocation space types and 30,000 for hyperscale facilities.

Hyperscale data centers are experiencing rapid growth, with Amazon, Microsoft, and Google collectively owning more than half of them. Distinct clusters emerge for colocation and hyperscale data center locations. These data centers strategically position themselves close to their clients and cloud services users to ensure high availability and low response times. Factors such as proximity to population centers, electricity cost, network infrastructures, and local utility prices influence their location choices.

According to the latest estimates, Virginia hosts the highest electricity demand associated with data centers in the U.S., serving as the primary hub for both colocation and hyperscale data centers, followed by California and Texas. Figure 1 shows the estimated distribution of data centers by type in the U.S.

- **Edge data centers** are smaller facilities that are located closer to end users at the edge of a network to provide low-latency computing. They offer the same services as a traditional data center but have a smaller footprint.
- **Enterprise data centers** are owned or leased by a single organization and used to support that organization's internal IT needs. Enterprise data centers can be a full-capacity data hall built for a specific customer within a colocation data center or an on-premise data center built by an organization. Enterprise facilities are built to suit that organization's needs.
- **Internal data centers** are typically integrated into larger buildings and managed by businesses with their own IT systems.
- **Colocation data centers** provide space, power, cooling, and connectivity for the servers and other hardware of multiple organizations. The organizations that rent space at these facilities are known as tenants. Space in a colocation data center is often leased by the rack, cabinet, cage or room. These facilities are also referred to as multi-tenant data centers.
- **Hyperscale data centers** are usually built by or for one organization to meet the specific technical, operational, and pricing requirements of a hyperscale customer.

Figure 1. Distribution of Servers by Data Center Type



Data Center Power Use

Demand Drivers

The key drivers of data center energy use are servers/IT equipment, and cooling systems. Other infrastructure elements such as storage systems, network devices, lighting, power distribution units, and uninterruptible power supplies represent smaller sources for electricity demand.

The energy used for **cooling** can represent a significant portion of a data center's total power consumption, sometimes nearly equaling the power utilized by the computing equipment. These systems are essential to manage the heat generated by the servers and other hardware.

The power consumption of **servers** varies based on their workload, with higher processing power demand leading to increased energy usage. The increasing power density of processing chips results in higher energy demand and heat per square foot compared to other data center designs. AI and hyperscale data centers are experiencing server rack power requirements exceeding 30 kW today, which is expected to continue rising. Rack power is the amount of power used per rack and illustrates the density of computing resources in a data center. Liquid cooling solutions are generally cost-effective or necessary at rack power densities greater than 20-40kW.

Large/AI Data Center Power Demand Breakdown

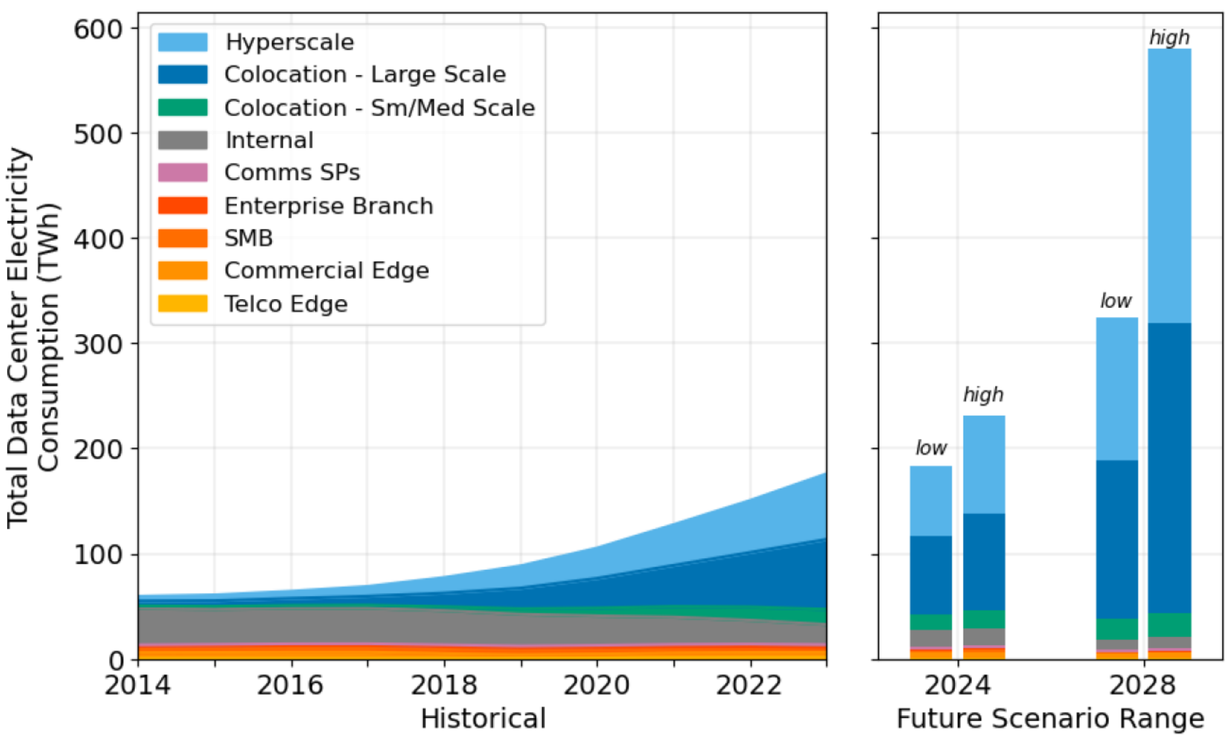
- **Servers and IT equipment** can drive 40% of power demand
- **Cooling systems** often drive another 40% of energy demand
- **Storage, lighting and other infrastructure:** Internal power conditioning systems represent 8-10% of data center's energy use, while network and communications equipment and storage systems comprise another 10%, and lighting usually takes just 1-2%

Hyperscalers are the most energy intensive data centers, with servers operating on average 50% of the time. When used for AI training, server utilization can reach 80%. Colocation and other small/medium size data centers typically see 15-30% average server operating times. Figure 2 shows the total annual electricity use by data center space type and by component, highlighting the demand from servers/IT equipment. In 2023, hyperscale and colocation data centers accounted for almost 80% of server energy use. The total range of energy use growth for 2024 and 2028 will be highly dependent on the quantity and operation of AI servers.

Reducing the IT power requirements through energy-efficiency improvements cascades through the data center and results in a multiplier effect through savings on infrastructure power: every unit of IT power saved reduces infrastructure power to energize and cool the IT equipment. Many energy efficiency opportunities involving IT equipment such as servers, network, and storage remain untapped. Data center owners and operators can take advantage of not only higher efficiency IT equipment, but also data center management strategies such as utilization, consolidation, and virtualization to prevent excessive IT energy consumption.

Encouraging data centers to identify savings opportunities through IT equipment upgrades is a relatively straightforward method to help reduce energy demand. LBNL has compiled a comprehensive list of energy efficiency actions data centers can take to improve energy management across IT equipment, cooling & air management, monitoring & controls, environmental conditions, and power (UPS, lighting).

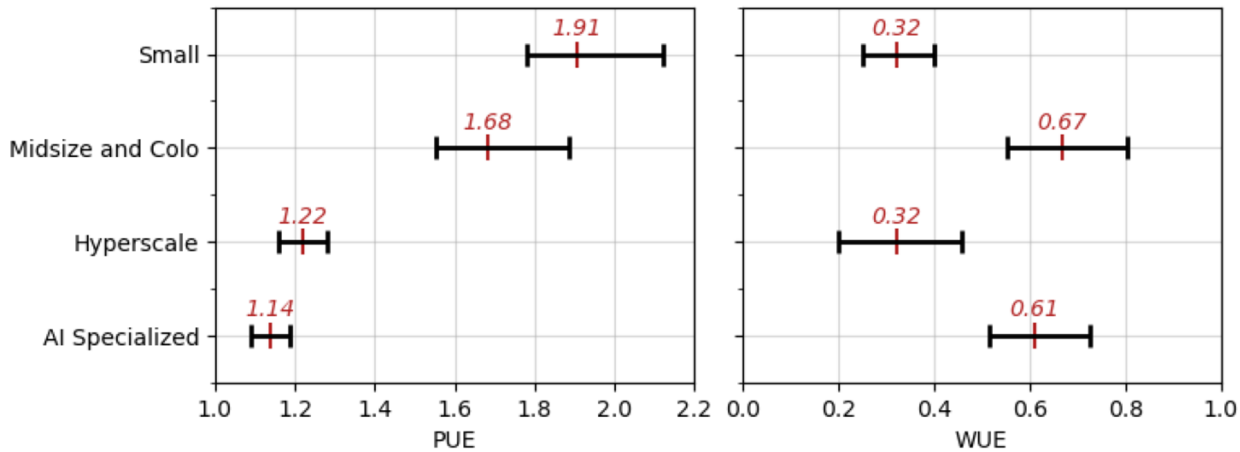
Figure 22. Total Data Center Electricity Use 2014 - 2023, Projected 2024 and 2028 by Space Type and by Equipment Type



Measuring Data Center Efficiency

Figure 3 shows the range of calculated PUE and WUE metrics across data center types considering their location and cooling system type. The average PUE was 1.4 in 2023. The closer the PUE value is to 1.0, the more efficient the data center is in utilizing its power solely for IT equipment, without wasting much on other infrastructures. The LBNL report estimates the average PUE will decline to 1.15 – 1.35 by 2028, driven by the shift to more efficient hyperscale and colocation facilities, combined with the increase in liquid-cooled (efficient) AI servers. However, this shift will also increase the average WUE, growing from 0.36 L/kWh today to 0.45 – 0.48 by 2028.

Figure 33. PUE and WUE by Data Center Type, 2023



Data Center Cooling Technologies

LBNL estimated the nationwide distribution of cooling systems by data center space type (Figure 4), which illustrates the use of liquid/water cooling technology in medium/large data centers, and almost exclusively for hyperscale and AI data centers. Data centers typically cool computing equipment by blowing cold air over the components using a water-cooled fan coil or by directly cooling the computing equipment with cool water.

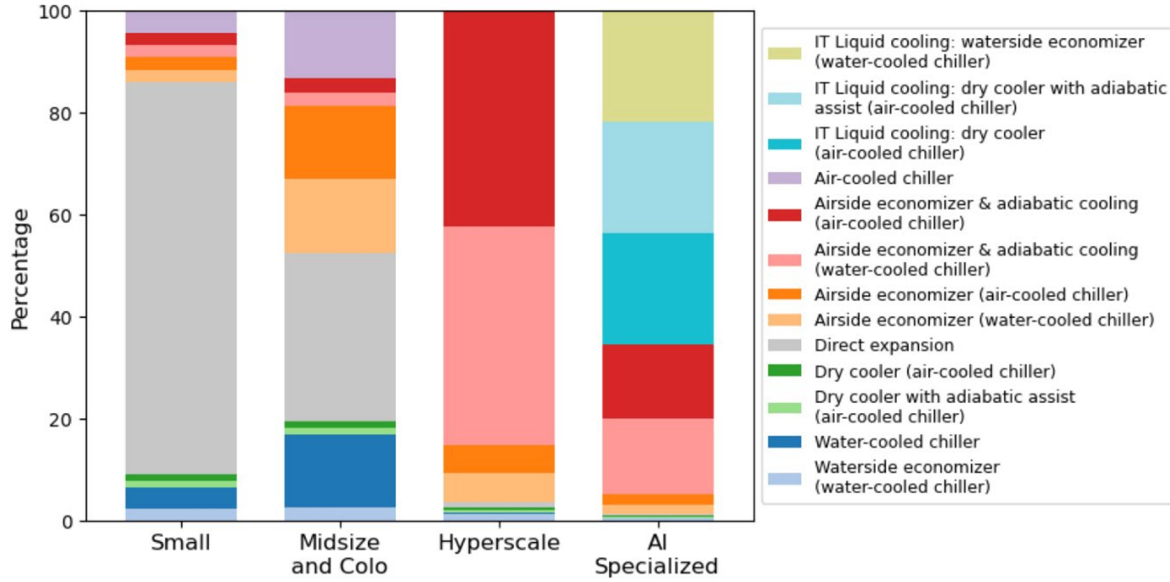
Data Center Cooling & Air Management

Efficient and well-planned air management strategies are crucial for enhancing energy efficiency. Typically, air distribution involves mixing cooled air with air that has been heated by IT equipment. This can pose challenges in directing cool air precisely where it is needed, resulting in an inefficient cooling system. Effective management of cold and hot air streams is essential not only for optimizing the cooling infrastructure but also for maintaining the IT equipment's thermal environment. Improved air management can significantly reduce energy consumption and operational costs, as cooling demands constitute one of the largest energy expenditures in data centers.

Compared to air cooling, liquid cooling delivers up to 40% in energy savings, leading to lower PUE values (see Figure 3). For many small and medium-sized data centers, with server loads under approximately 10-15 kW power density per rack, air cooling remains a viable option. However, as power densities increase, air cooling presents certain drawbacks, including elevated cooling costs, risks of performance throttling due to thermal issues, and limited scalability. Although liquid cooling solutions generally incur higher initial costs compared to air-cooled IT equipment within standard racks, these costs may be substantially offset by the enhanced energy efficiency and potential capital savings associated with liquid cooling near the heat source. Liquid cooling also provides opportunities for utilizing waste heat to warm adjacent offices or contribute to district heating systems.

Currently, liquid-cooled rack designs are bespoke and used in standalone data centers. LBNL has identified a goal of a liquid cooled rack specification that could accommodate multiple vendors and provide a reusable infrastructure for multiple refresh cycles with a variety of liquid cooled servers/suppliers. Note: Immersion cooling (submerging IT equipment in non-conducting fluid) is still being explored but typically voids IT hardware warranties at this time.

Figure 4. Data center cooling systems distributed by space category, 2023



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