From Infrastructure to Implications: Data Center 101 for Urban Planners

February 2026 (Last Updated)

Xiaofan Liang
Assistant Professor of Urban and Regional Planning, University of Michigan

As data centers proliferate, urban planners play a key role in permitting associated land uses and anticipating their system-wide impacts on the built environment and urban life. Yet the current information landscape is fragmented across the energy, water, and regulatory sectors, with uneven quality and sometimes contradictory claims. Much of this confusion stems from insufficient attention to the diversity of data center types, local context, and infrastructure design choices. The long development timelines of data center projects, combined with rapid advances in computing, energy, and cooling technologies, also make it difficult to forecast and track impacts over time. As a result, planners often struggle to distinguish generalizable lessons from singular cases.

This white paper addresses a central question: what are data centers' implications for the urban life and built environment, and how are those implications anchored in specific data center infrastructure components? It begins by introducing major data center types, the concept of redundancy, and typical infrastructure configurations, including a visual schematic of a standard enterprise data center. It then examines the energy, water, land use, quality of life, economic, and environmental implications of data centers.

The writing draws on desktop research using high-quality sources and interviews with nine industry stakeholders, including data center developers, urban planners, elected officials, and contractors. Together, the paper provides a "Data Centers 101" mental model to help planners see the big picture and engage more confidently with data center proposals.

This white paper is a living document that can integrate further feedback and new questions you'd like to see addressed. Please email xfliang@umich.edu.

Table of Contents

TAUBMAN COLLEGE
ARCHITECTURE & URBAN PLANNING
UNIVERSITY OF MICHIGAN

1. Introduction to Data Center

A data center is a fixed, purpose-built facility (standalone or within a larger building) that houses servers, storage, and networking equipment to process, store, and transmit digital information for users and other systems.[1] They are crucial for supporting digital life, including online shopping and digital payments, video streaming, cloud document storage, navigation and ride-hailing, social media and messaging, and business operations that depend on real-time data exchange.

There are various types of data centers, and they can be classified through scales, purposes, or redundancy. Scales are typically defined by energy consumptions or square footage. The scale of the data center also has implications on its infrastructure setup. Only medium-size enterprise data centers or hyperscale data centers will require dedicated on-site transmission lines and electrical substations. By scale, four types of data centers are common.

Hyperscale data centers are the largest facilities, built to serve massive cloud/IT service workloads; they often occupy whole buildings or campuses and are typically defined by very large scale (e.g., thousands of servers, ≥100,000 sq ft, and power draw that can exceed 100 MW). These are the "cloud factories" of big tech companies like Amazon and Google.[2]

Enterprise data centers are owned and operated by a single organization to run its own IT infrastructure, rather than serving multiple external customers. These facilities can range 1-5 MW for smaller facilities and up to 100 MW with larger sites[3]; 100 MW of electric power is roughly equivalent to electricity needs of 80,000 U.S. households.[4] Non-commercial research data centers, such as the one proposed by University of Michigan and Los Alamos National Laboratory, may be considered enterprise data centers as it is governed by a single institution[5]. Despite serving public interests and research purposes, these research data centers may have similar physical footprint and built environment implications as commercial data centers.

---

[1] *Data Centers and Their Energy Consumption: Frequently Asked Questions*. (2025, August 26). Congress.gov. Retrieved January 12, 2026, from https://www.congress.gov/crs-product/R48646

[2] What is a hyperscale data center? (2025, November 17). IBM. Retrieved January 11, 2026 from https://www.ibm.com/think/topics/hyperscale-data-center

[3] *What Is a Data Center? What Are Different Types of Data Centers?* (2022, October 13). The Equinix Blog. Retrieved January 12, 2026, from https://blog.equinix.com/blog/2022/10/13/what-is-a-data-center-what-are-different-types-of-data-centers/

[4] U.S. Energy Information Administration. (2023, March 29). *EIA releases consumption and expenditures data from the Residential Energy Consumption Survey*. Retrieved January 11, 2026, from https://www.eia.gov/pressroom/releases/press530.php

[5] University of Michigan x Los Alamos Supercomputing Research Center. University of Michigan. Retrieved February 3rd, 2026 from https://research.umich.edu/research-at-michigan/lanl/

Edge data centers are smaller facilities intentionally placed closer to end users or data sources to reduce latency and improve performance for time-sensitive, data-intensive applications. These are the “neighborhood” or “local” data centers[6]

Colocation data centers are shared facilities operated by third parties where multiple organizations rent space, power, and cooling for their servers.[7] These function like a data-center apartment building or co-working space, where many tenants share the same infrastructure instead of building their own. Colocation data center can be leased to a single tenant, thereby making it effectively an enterprise data center.

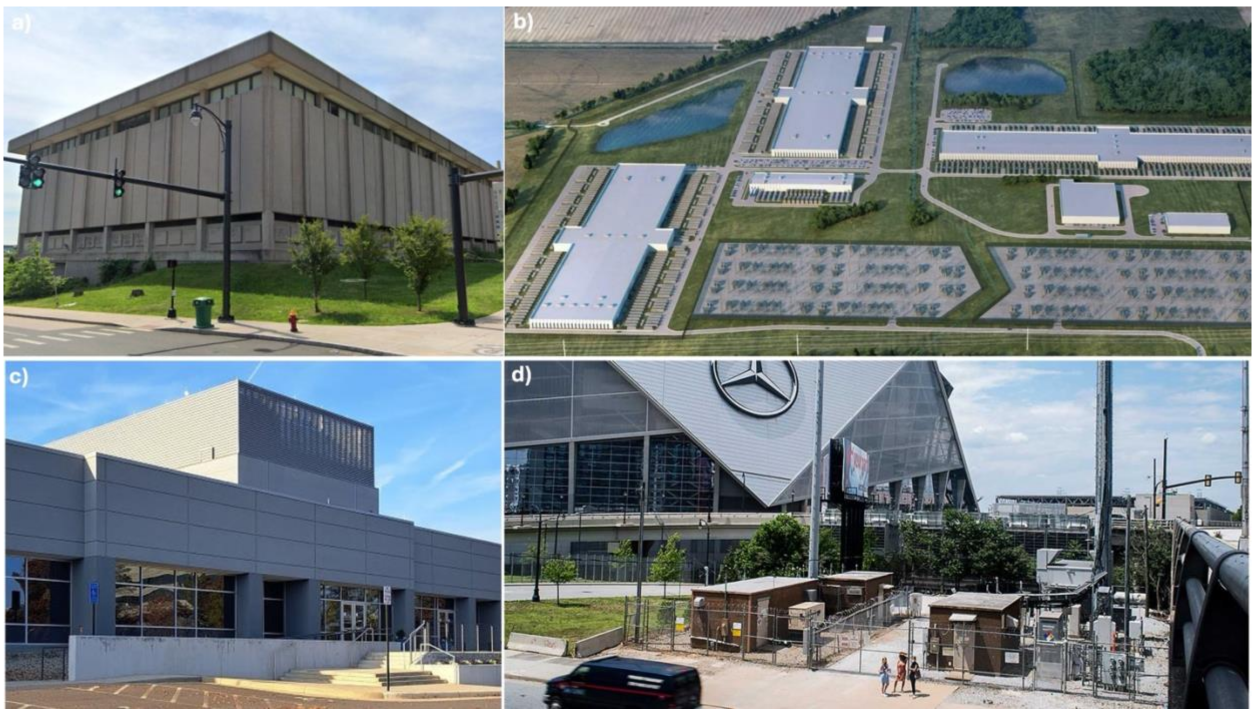


Figure 1.1: a) A vacant Bank of American enterprise data center[8]; b) A rendering of Related Digital’s planned hyperscaler data center in Saline Township, Michigan[9]; c) A CoreSite Colocation Data Center, Virginia[10]; d) An edge data center by the Atlanta Mercedes Benz Stadium in the city center.[11]

---

[6] Ibid

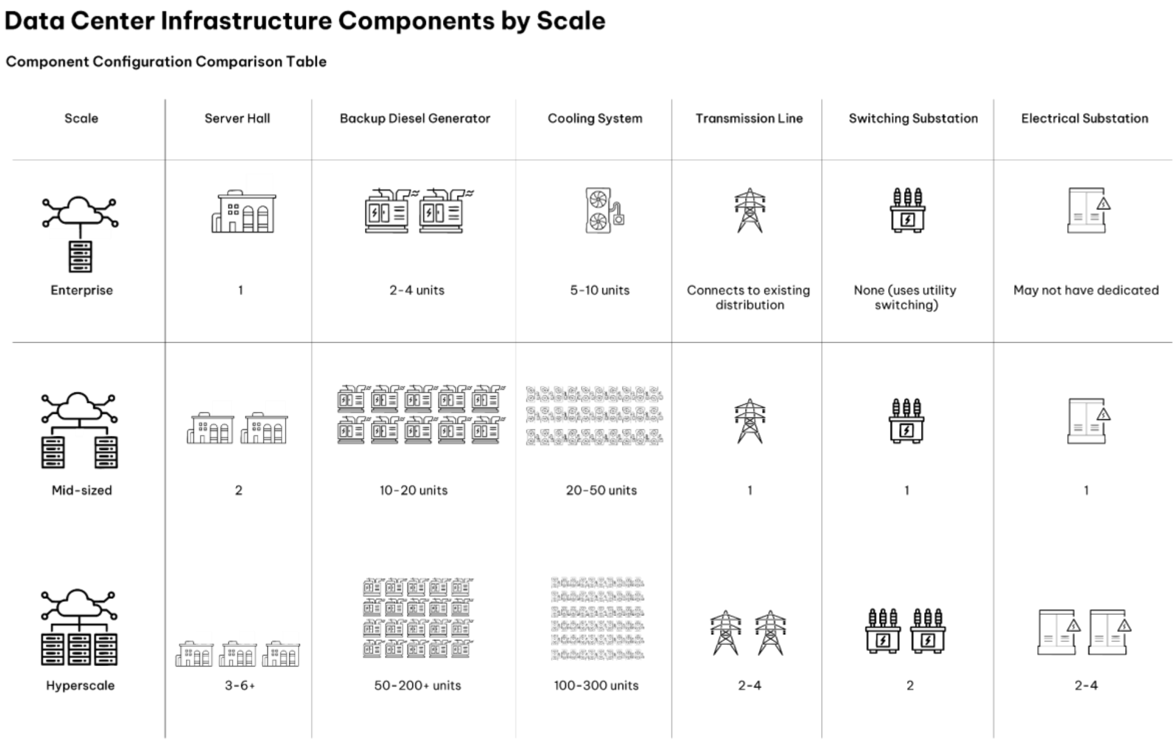
[7] Ibid

[8] Swinhoe, D. (2025, June 16). *Former banking data center in Connecticut set to be demolished after funds secured from state*. Data Center Dynamics. Retrieved January 11, 2026, from https://www.datacenterdynamics.com/en/news/former-banking-data-center-in-connecticut-set-to-be-demolished-after-funds-secured-from-state/

[9] *RELATED DIGITAL*. (n.d.). RELATED DIGITAL. Retrieved January 12, 2026, from https://www.related-digital.com/michigan

[10] Fluet, J. (2021, July 22). Data Centers Evolved: A Primer for Planners. *American Planning Association Planning Magazine*. https://www.planning.org/planning/2021/summer/data-centers-evolved-a-primer-for-planners/

[11] Ibid



Data Center Infrastructure Components by Scale

Component Configuration Comparison Table

Scale	Server Hall	Backup Diesel Generator	Cooling System	Transmission Line	Switching Substation	Electrical Substation
Enterprise	1	2-4 units	5-10 units	Connects to existing distribution	None (uses utility switching)	May not have dedicated
Mid-sized	2	10-20 units	20-50 units	1	1	1
Hyperscale	3-6+	50-200+ units	100-300 units	2-4	2	2-4

Figure 1.2: Data Center Infrastructure Components by Scale.

Classified by purposes, **data centers used for AI training and inference** have different energy and water footprints than **general purpose data centers**. AI-driven data centers often demand higher levels of electricity and cooling capacity, require larger sites, cluster more intensely, and deepen their interconnections with regional urban systems, which pushed them to the forefront of public debate. Even in long-established data center hubs such as Loudoun County, Virginia and rural counties in Oregon, interviewed local officials and planners still feel underprepared to understand, anticipate, and manage these impacts.

In design, engineering, and construction standards, data centers could also be classified by their redundancy. **Redundancy** means providing extra, independent capacity in critical systems (e.g., power, cooling, and networking), so the facility can continue operating in events of natural disaster, power outage, equipment failure, or human actions. Data centers need to run 24/7 and any down time will cost a significant financial loss to clients using the service. Power redundancy typically includes diesel generators and alternative utility feeds for power; water redundancy includes independent water towers and multiple cooling system designs; network redundancy includes additional fiber optic cables or routes; computing redundancy includes backup storage or even a second data center in a geographically diverse location.[12]

[12] Pacheco, M. (2024, January 2). *A Deep Dive into Data Center Redundancy*. TierPoint. Retrieved January 12, 2026, from https://www.tierpoint.com/blog/data-center-redundancy/

A redundancy-based standard to classify data centers uses *N* to denote the capacity required to run a facility at full load—whether for power, backup power, or cooling. Under this standard, *N+1* or *N+2* means the facility installs one or two additional units beyond what is strictly required (for example, if it needs *N* generators, it installs *N+1* or *N+2*).[13] The highest redundancy level, 2N, provides two fully independent systems, each capable of carrying 100% of the workload on its own. In general, a Tier I data center aligns with *N* redundancy, Tier II with *N+1*, Tier III (the most common) with *N+1* or *N+2*, and Tier IV (often represent high-risk data centers such as enterprise financial institutions) with *2N* and minimal downtime.

For zoning, permitting, and community engagement, the tier and redundancy system often provides the clearest signal of local, near-term impacts. Tier levels translate directly into the configuration of physical infrastructure on a site, such as the number of diesel generators, cooling plants, and electrical substations, which in turn shape land consumption, noise, air emissions, visual impacts, and emergency operations. When residents ask why a project requires multiple generators, large cooling towers, or extended testing hours, tier classification offers a standardized way to explain how reliability requirements drive infrastructure intensity and why those design choices matter locally.

By contrast, for long-range planning and infrastructure forecasting, distinctions based on data center type and function become more important. Large hyperscale or AI-training data centers need large amounts of electricity and space, so they usually locate where land is cheaper and high-voltage power lines or substations already exist, often on the urban edge or in rural areas. Smaller edge, colocation, or AI-inference data centers need to be close to people and businesses so digital services respond quickly, which means they are more likely to locate inside cities or near population centers. AI-training data centers can also expand very quickly when new computing hardware is installed, causing sudden jumps in electricity and cooling demand, as compared with inference or storage-focused facilities, which typically exhibit slower, more predictable growth patterns. This difference matters: gradual growth can be planned for, while rapid jumps are more challenging to anticipate.

2. Data Center Infrastructure

Energy Infrastructure Components

Data centers require enormous amounts of energy (electricity) to operate IT equipment and cooling systems.[14] Most large facilities need dedicated high-voltage, on-site or adjacent **transmission lines** and **electrical substations** to step voltage down for safe distribution, while

---

[13] *Uptime Institute Tier Classification System*. (n.d.). Uptime Institute. Retrieved January 12, 2026, from https://uptimeinstitute.com/tiers

[14] *Data Centers and Their Energy Consumption: Frequently Asked Questions*. (2025, August 26). Congress.gov. Retrieved January 12, 2026, from https://www.congress.gov/crs-product/R48646

smaller sites may simply connect to existing grid infrastructure without new buildouts. **Backup diesel generators** provide immediate emergency power when the grid is unavailable or unstable, because large-scale data centers can tolerate only minimal downtime.

Water Infrastructure Components

Water in data centers is primarily used for removing heat from servers and mechanical equipment while a small portion could be used for office and restroom operation. **Cooling system** choice strongly shapes local water impacts, as water demand varies widely across technologies. If designed with evaporative cooling systems, data centers often require redundant water supplies, such as on-site **independent water storage** or backup cooling strategies to manage short-term outages. These requirements drive the need for dedicated water infrastructure, including high-capacity **water lines and connections to municipal or on-site treatment systems**.

Fiber Infrastructure Components

Data centers rely on **fiber-optic cables** to move data into and out of the facility, and these cables are typically installed underground within existing road rights-of-way (ROW) for easier access and maintenance.

Land Use Infrastructure Components

Enterprise or hyperscale data centers require a large piece of industrial **land** (or agricultural land rezoned to industrial) that could exceed traditional slotting for other industrial use. The ideal land will also be close to energy and water sources, fiber backbones, and existing roadways. **Landscape screening** is a common practice to buffer visual, noise, and light disturbance to nearby residential communities.

Operation Infrastructure Components

Data Centers run 24/7 and require on-site staff. Thus, **street lights**, **parking**, and **office/support space** is necessary for employees. The **server halls** host computer equipment. The **loading bay** is near the back of the data center to offload equipment and may be used to park fuel delivery trucks. **Security perimeter** is common to prevent any disruptions to critical digital infrastructure, which can have wide-ranging consequences well beyond the site itself.

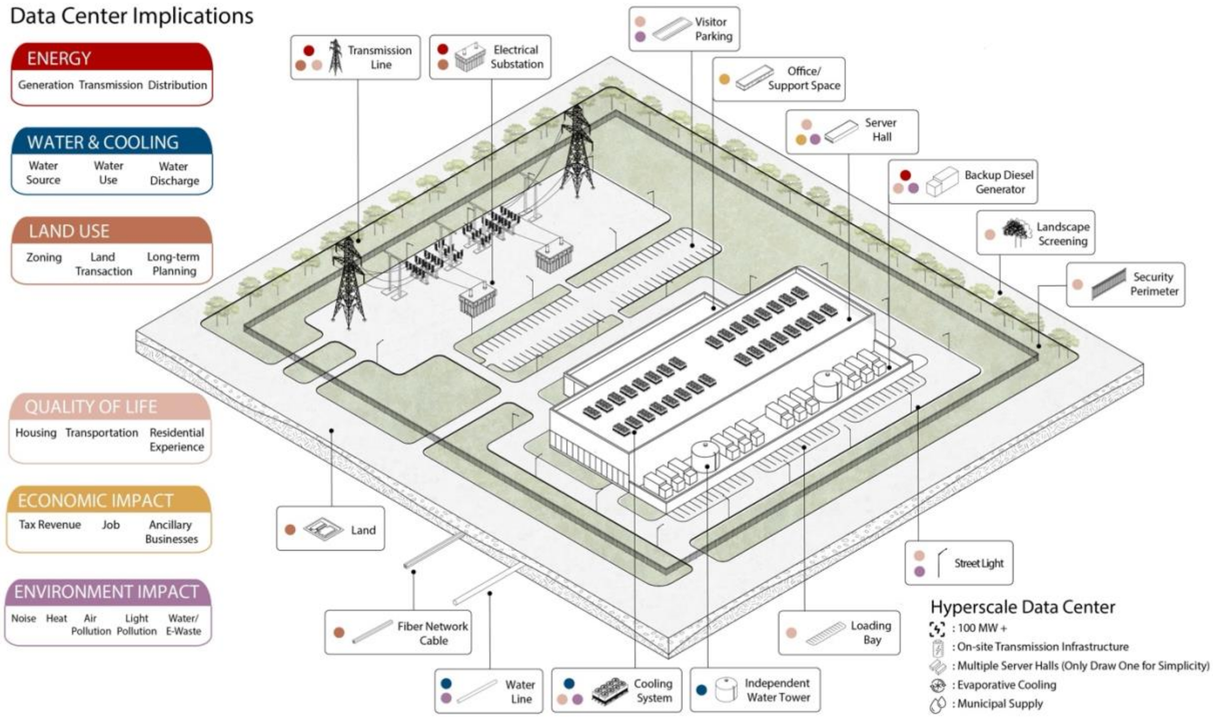


Figure 2.1: Data Center Infrastructure Components and Associated Implications. The graphic represents a stylized, simplified design of one infrastructure module for a hyperscale data center, referencing Meta's Princeville Data Center[15]. Image Credit: Yajun Dai, Matthew Wizinsky, Xiaofan Liang.

3. Energy (Generation, Transmission, Distribution)

Data centers require large, continuous electricity loads that are typically generated elsewhere and delivered via high-voltage **transmission lines**, then stepped down through on-site or adjacent **electrical substations**, with **diesel generators** providing backup power. Meeting this demand can introduce new energy-related land uses, such as renewables and microgrids, and may require permitting expanded regional transmission lines and substations. These upgrades can also raise cost-allocation concerns if capital expenditures are embedded in broader utility rates. During peak events, inflexible loads can strain system reliability. At the community scale, data center demand can tighten electricity distribution capacity for housing and electrification goals and raise community concerns around visual impacts of losing landscape characters and noise and pollution from diesel generators. For urban planners, these implications matter because they shape land-use compatibility, infrastructure investment priorities, and the fairness of who bears the costs and risks of accommodating this new form of growth.

---

[15] Zuckerburg, M. (2017, October). We are building our 11th major data center in Henrico, Virginia. Retrieved February 4th from: https://www.facebook.com/zuck/photos/were-building-our-11th-major-data-center-in-henrico-virginia-like-all-our-new-da/10104084311463881/?_rdr

3.1 How are Data Centers Powered? Power Supply and On-Site Energy Strategies

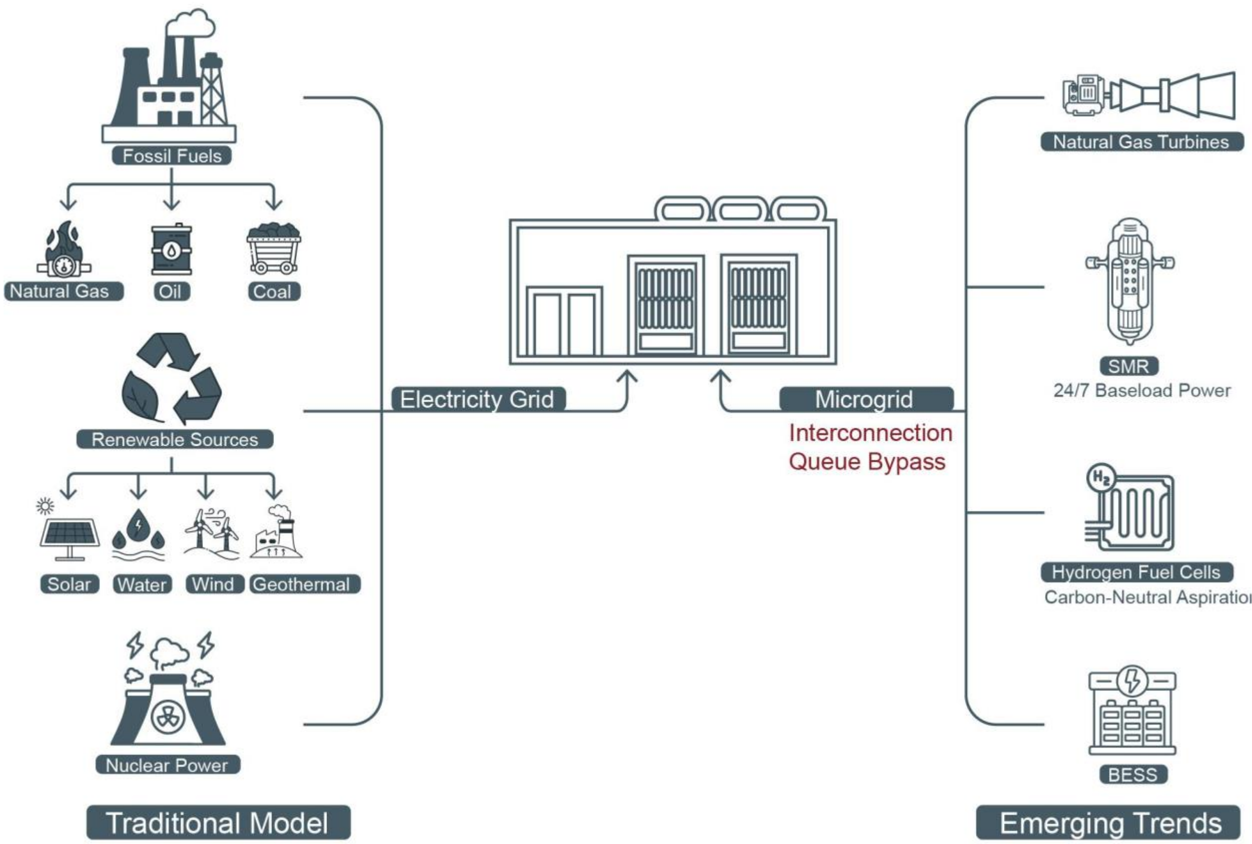


Figure 3.1: How Data Centers are Powered (Image Credit: Yajun Dai).

Energy is one of the most important factors of data center siting. Developers typically engage local utilities early to assess whether existing capacity can support a proposed facility, what upgrades may be required, and whether dedicated on-site infrastructure is needed. These factors often determine whether a site is feasible and place upper limits on facility size.

A small data center may consume 500 kilowatts (kW) to 2 megawatts (MW) at any given time, while large or hyperscale facilities can draw 100MW or more.[16] Actual demand depends on factors such as facility size, server density, cooling design (see Water-Power tradeoff at Section 4.2), redundancy requirements, and utilization rates.

---

[16] Ensuncho, M. H. (2025, July 1). *Data Centers Power Requirements*. MOST Policy Initiative. Retrieved January 11, 2026, from https://mostpolicyinitiative.org/science-note/data-centers-power-requirements/

Most data centers rely on the electricity grid for power, which draws from a mix of sources, including fossil fuels (e.g. natural gas, oil, coal), renewable sources (e.g. solar, hydro, wind, geothermal), and nuclear power. In regions where the grid is constrained, either by limited capacity or limited operational flexibility, operators may rely on fast-ramping fossil-fuel generation during peak demand, slowing local clean-energy transitions, as seen in Loudoun County, Virginia.[17] [18]

The surge in energy demands from AI data centers has outpaced grid infrastructure expansion, which then prompted major investments in on-site power generation beyond traditional grid connections. Data centers need two types of power: baseload power that supports continuous operation and backup power that ensures reliability during an emergency (see Section 1 for explanations on redundancy). Backup power typically includes uninterruptible power supplies (UPS), which provide instantaneous, short-duration power to bridge the transition from grid disconnection to on-site generation, as well as longer-duration on-site generation such as diesel or gas-fired systems.

Natural gas turbines are currently among the few viable options for providing stable, on-site (baseload or backup) power at scale for some small- to medium-sized data centers, yet the demand for the turbines is growing faster than the market could react and supply. Nuclear power, particularly through Small Modular Reactors (SMRs), has emerged as another potential source for 24/7 baseload power with high reliability and zero operational emissions.[19] [20] SMRs, typically around 300 MW per unit, could potentially be co-located with data centers to avoid long-distance transmission losses.

Hydrogen Fuel Cells and Battery Energy Storage Systems (BESS) can supply alternative short-term on-site power generation.[21] [22] Green hydrogen offers a pathway to carbon-neutral and pollutant-free operation. Biodiesel and renewable diesel could be used in diesel generators as alternative to fossil diesel. BESS stores excess power improves reliability, helps manage grid

---

[17] Halper, E. (2024, October 12). A utility promised to stop burning coal. Then Google and Meta came to town. Retrieved January 11, 2026, from https://www.washingtonpost.com/business/2024/10/08/google-meta-omaha-data-centers/

[18] Turner, M. (2025, October 20). *Loudoun County, Virginia: Data Center Capital of the World*. Retrieved January 11, 2026, from https://www.loudoun.gov/ArchiveCenter/ViewFile/Item/13979

[19] Morley, D. (n.d.). *Managing AI Build-Out in a Winner-Take-Most World*. American Planning Association Blogs. Retrieved January 11, 2026, from https://www.planning.org/blog/9319236/managing-ai-build-out-in-a-winner-take-most-world/

[20] Hiller, J. (2025, October 15). AI Data Centers, Desperate for Electricity, Are Building Their Own Power Plants. *The Wall Street Journal*. https://www.wsj.com/business/energy-oil/ai-data-centers-desperate-for-electricity-are-building-their-own-power-plants-291f5c81

[21] Turner, M. (2025, October 20). *Loudoun County, Virginia: Data Center Capital of the World*. Retrieved January 11, 2026, from https://www.loudoun.gov/ArchiveCenter/ViewFile/Item/13979

[22] Ross, B., & Vadali, M. (2024, March). *Battery Energy Storage Systems*. American Planning Association. Retrieved January 12, 2026, from https://planning.org/zoningpractice/2024/march/battery-energy-storage-systems/

interconnection constraints, and enables better use of renewable energy by storing excess power, which provides critical backup during grid disturbances.

Together, this expanding mix of generation technologies creates new governance and land-use challenges. These systems are often regulated through fragmented approval processes across energy, environmental, and land-use authorities, making cumulative impacts difficult for local governments to evaluate.[23] Increasingly, developers bundle data centers with on-site renewables and storage into microgrid-style “energy parks” to enhance redundancy and reliability, manage energy costs, and, in some cases, reduce reliance on constrained interconnection queues. While these systems can improve operational resilience, they also shift aspects of power system control and planning closer to private actors.[24]

3.2 How Do Data Centers Reshape Regional Power Systems? Bulk Power Infrastructure and Transmission-Level Impacts

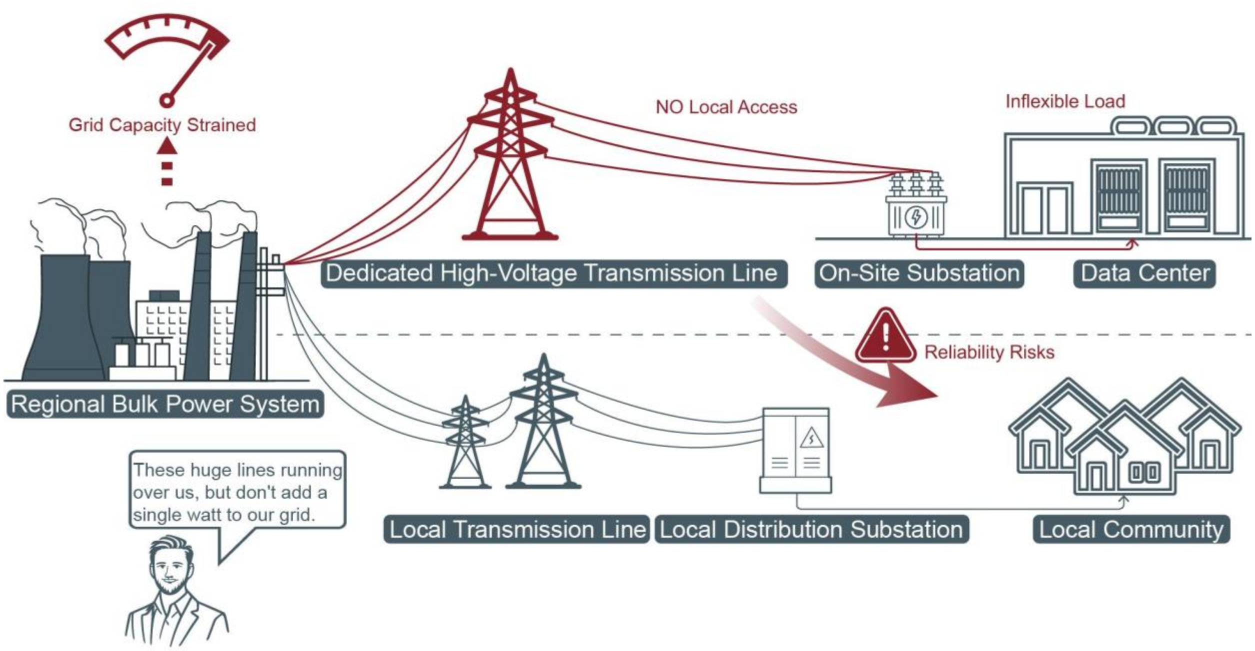


Figure 3.2: Data centers’ impacts on regional power systems (Image Credit: Yajun Dai).

Hyperscale and enterprise data centers place exceptionally large and concentrated demands on regional transmission systems. Existing grid infrastructure, interconnection processes, and

---

[23] Nichols, C. (2025, October 1). *The Physical Footprint of Artificial Intelligence*. American Planning Association. Retrieved January 12, 2026, from https://www.planning.org/publications/document/9318086/

[24] Howland, E. (2024, December 11). Google, Intersect Power to develop co-located energy parks with $20B of renewables, storage. *Utility Dive*. https://www.utilitydive.com/news/google-intersect-power-co-located-energy-park-data-center-ferc/735198/

planning timelines have struggled to keep pace with the rapid growth of AI-related electricity demand.

To serve these facilities, utilities may need to construct new high-voltage transmission lines and large on-site or adjacent substations. These facilities operate at voltages far above what residential or commercial customers can directly use, meaning the new lines built for data centers often may not expand local access to electricity even as they reshape the landscape.

Data center loads are typically large and can peak in a short timeframe and maintain high usage over hours and days. During peak demand periods, such large loads and the uncertainty in load behaviors can push transmission systems close to operational limits, reducing system flexibility and increasing the risk of cascading failures[25]. In this sense, data centers may function as regional growth constraints rather than growth catalysts, particularly in fast-developing areas.

Because outages can have major economic and system-wide repercussions, data centers may desire to be treated as "critical infrastructure," similar to hospitals or emergency facilities. Thus, it is important for local utilities and local governments to have an honest conversation with data center developers about handling outages during storms, heat waves, or cold snaps. If energy load planning was not coordinated well, prioritizing data center operation can exacerbate inequities, as reliability risks may be shifted onto other communities, which are often those already facing environmental or socioeconomic vulnerabilities.

One solution to ease data centers' strain on local gird and reduce emission is to make data center loads flexible. General purpose data centers or those that can tolerant latency are more capable to shift non-urgent compute tasks (e.g., processing a YouTube video) during grid stress while those focus on AI training are less likely to be flexible. Some industry leaders (e.g., Google) have implemented demand response practices to shift data center loads by tasks and across geography, which can help stabilize the local grid as well[26]. Flexible loads can also benefit developers and grid operators by cutting costs[27]. Another pathway is to allow data centers to use backup power generation during extreme events. For instance, a recent Department of Energy order permits data centers to deploy backup generation during winter storm fern[28], which in turn, complicates air pollution governance if diesel generators are used

[25] NERC (2025, July). Characteristics and Risks of Emerging Large Loads. *Large Loads Task Force White Paper*. https://www.nerc.com/globalassets/who-we-are/standing-committees/rstc/whitepaper-characteristics-and-risks-of-emerging-large-loads.pdf
[26] Terrell, M. (2025, October). Flexible data centers can reduce costs – if not emissions. *MIT Management Sloan School*. https://mitsloan.mit.edu/ideas-made-to-matter/flexible-data-centers-can-reduce-costs-if-not-emissions
[27] Walsh, D. (2025, August). How we're making data centers more flexible to benefit power grids. *Google*. https://blog.google/innovation-and-ai/infrastructure-and-cloud/global-network/how-were-making-data-centers-more-flexible-to-benefit-power-grids/
[28] Department of Energy (2026, January). Energy Secretary Issues Emergency Orders to Deploy Backup Generation in the Mid-Atlantic and Carolinas Following Winter Storm Fern. *DOE*.

(see Section 8.3). In reality, it is unclear how many data centers follow the load flexibility practices and there are little market incentives to do so.[29]

At the regional scale, the key challenge for local governments and planners is that transmission planning is largely opaque, centralized, and insulated from local land-use decision-making. While regional infrastructure decisions can lock in long-term spatial patterns, local governments often have limited visibility into how cumulative transmission commitments may have community impacts (see Section 6 for quality-of-life impacts).

3.3 How Does Data Center Demand Affect Local Power Delivery and Communities? Distribution Systems, Rates, and Everyday Impacts

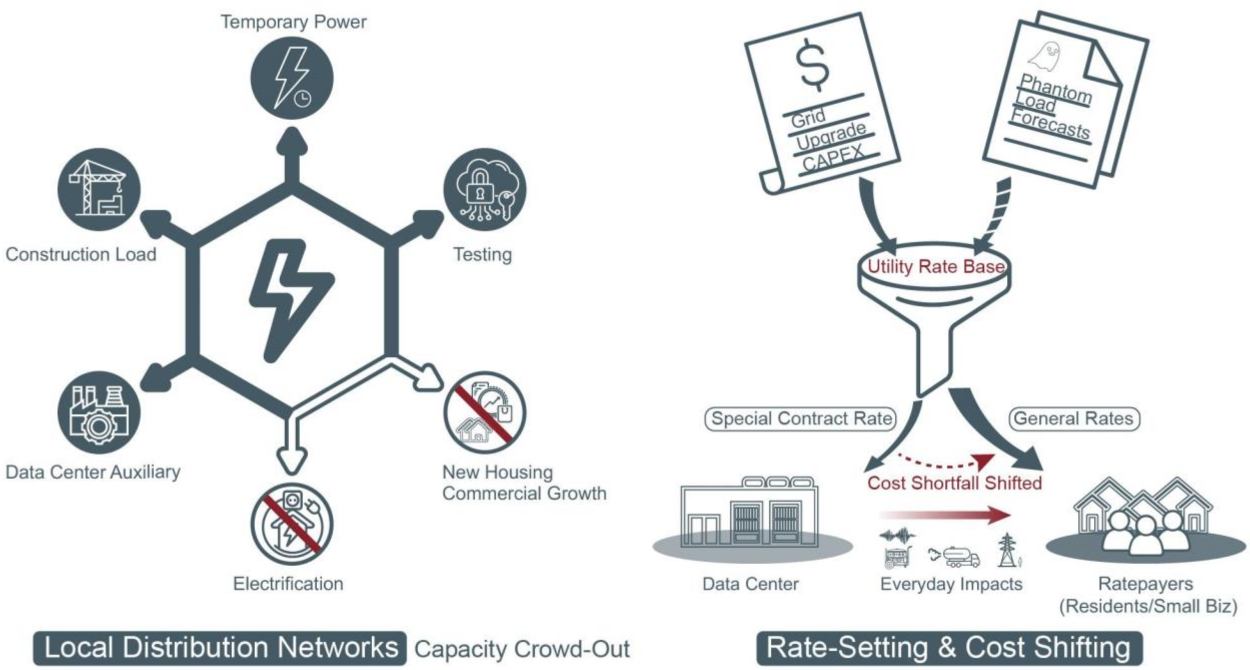


Figure 3.3: Data Centers' impact on local development and electrification and residential utility price. (Image Credit: Yajun Dai)

Data center growth can crowd out local development or delay electrification goals. Even when data centers are primarily served at the transmission level, they still interface with local distribution networks for some services (auxiliaries, construction load, temporary power, testing). A major new grid load can reduce headroom on distribution circuits, limiting capacity for

https://www.energy.gov/articles/energy-secretary-issues-emergency-orders-deploy-backup-generation-mid-atlantic-and

[29] Borenstein, S. (2025, April). Can Data Centers Flex Their Power Demands? *Energy Institute at HAAS.* https://energyathaas.wordpress.com/2025/04/14/can-data-centers-flex-their-power-demand/

new housing, commercial growth, or electrification (e.g., electric truck charging depots).[30] While similar constraints can arise from other sources of load growth, such as electrification, air-conditioning adoption in older building stock, or unanticipated neighborhood development, large data center interconnections may exacerbate these pressures in some locations. Local utilities may delay or deny new neighborhood connections if feeders are near limits, though empirical evidence on these impacts remains limited.

Data centers may affect residential electricity bills through cost-allocation and rate design, but isolating their causal contribution remains difficult. New or upgraded transmission and distribution infrastructure required to serve large loads may enter rate-setting calculations under existing Federal Energy Regulatory Commission (FERC) frameworks, in which certain capital costs are rolled into general transmission or distribution rates and shared among utility customers rather than assigned solely to the data center. Some data centers negotiate special rates outside of a rate case.[31] When the special contract rate is lower than the utility's service cost to data centers, the cost shortfall is shifted to other ratepayers classes. Data center developers are also known to produce "phantom" load forecasts, where they submit speculative or duplicate requests to connect to the electricity grid, which distorts load forecasts for utility, leading to the construction of unnecessary infrastructures which capital expenditures are ultimately shifted to other ratepayers.[32]

It is important to note that multiple factors can contribute to the rise of retail electricity prices beyond data centers, including extreme weathers and distribution investments (e.g., replacing old equipment).[33] "Many discussions of the rising electricity prices refer to wholesale market prices, which are strongly shaped by natural gas prices and weather-driven demand, not solely by load growth.[34]

On the positive side, utility companies favor data center development because they significantly expand the rate base and guarantee recovery of costs. In theory, this can help spread fixed grid costs across more customers, which may explain empirical observations such as reduced

---

[30] Westhoff, G. (2025, November 18). *Electrification 101: Enabling Truck Charging with Flexible Service Connections*. RMI. Retrieved January 12, 2026, from https://rmi.org/electrification-101-enabling-truck-charging-with-flexible-service-connections/

[31] Martin, E., & Peskoe, A. (2025, March). *Extracting Profits from the Public: How Utility Ratepayers Are Paying for Big Tech's Power*. Harvard Law School. Retrieved January 12, 2026, from https://eelp.law.harvard.edu/wp-content/uploads/2025/03/Harvard-ELI-Extracting-Profits-from-the-Public.pdf

[32] Muir, M., (2025, November 14). *'Phantom' data centres muddy forecasts for US power needs*. Large Public Power Council. Retrieved January 12, 2026, from https://www.lppc.org/news/phantom-data-centres-muddy-forecasts-for-us-power-needs

[33] Wiser, R., O'Shaughnessy, E., Barbose, G., Cappers, P., & Gorman, W. (2025). Factors influencing recent trends in retail electricity prices in the United States. *The Electricity Journal*, *38*(4), 107516. https://emp.lbl.gov/publications/factors-influencing-recent-trends

[34] Aniti, L. (2026, Feburary). U.S. wholesale day-ahead electricity prices rose in 2025 with higher natural gas prices. U.S. Energy Information Administration. https://www.eia.gov/todayinenergy/detail.php?id=67106

averaged electricity price with state-level load growth.[35] In response to cost-shifting risks, some states' Public Utility Commissions (PUCs) and Public Service Commissions (PSCs) have revised rate-setting rules to better align infrastructure costs with beneficiaries.[36] [37] For regulated utilities, the rate increase decisions do not occur unilaterally: PUCs/PSCs are responsible for reviewing and approving retail rates through formal rate-case processes, and they can reject, reduce, or require significant revisions to utility proposals. Some utilities have begun implementing separate large user rate structures for data centers.[38] Microsoft recently announced that they will cover all costs for infrastructure upgrades directly.[39]

Power-related infrastructure can also affect daily community life. Transmission corridors, substations, and backup generators can introduce visual impacts, noise, local air pollution, and truck traffic from diesel fuel deliveries during emergencies (see Section 6 and 8 for quality of life and environmental impacts).

4. Water (Water Source, Water Use, Water Discharge)

Water is central to remove heat from server operation. If a water-based cooling system is used (e.g., evaporative cooling), data centers require backup supplies from **independent water towers**. Data centers draw from municipal systems and, in some cases, groundwater sources via dedicated **water lines**, while wastewater from cooling systems are routed to local treatment plants. Because water is inherently local and cannot be transmitted across regions like electricity, large data center demands can strain regional water supplies and trigger costly infrastructure upgrades. These upgrades are often required late in the development process, placing financial and operational pressure on water utilities, especially in smaller or rural communities. For urban planners, water-related implications matter because different **cooling systems** have different energy efficiency, water uses, and environmental impacts, which then affect long-term water resource planning and infrastructure investment needs. Planners can respond by coordinating with water utilities early, requiring transparent disclosure of projected water demand, and, where appropriate, setting cooling-system standards or conditions in zoning and site-plan review to align data center growth with local water capacity and resilience goals.

---

[35] Wiser, R., O'Shaughnessy, E., Barbose, G., Cappers, P., & Gorman, W. (2025). Factors influencing recent trends in retail electricity prices in the United States. *The Electricity Journal*, *38*(4), 107516.
[36] Next Generation Energy Act (Public Utilities–Electricity Generation Planning–Procurement, Permitting, and Co–Location), H.B. 1035, 2025 Reg. Sess. (Md. 2025). https://mgaleg.maryland.gov/2025rs/bills_noln/hb/fhb1035.pdf
[37] Ohio Public Utilities Commission. (2025, July 9). *PUCO orders AEP Ohio to create data center specific tariff*. Ohio Public Utilities Commission. Retrieved January 12, 2026, from https://puco.ohio.gov/news/puco-orders-aep-ohio-to-create-data-center-specific-tariff
[38] SCC. (2025, November). In Biennial Review Ruiling, SCC creates new class for large-scale energy users. *Virginia State Corporation Commission.* https://www.scc.virginia.gov/about-the-scc/newsreleases/release/scc-issues-order-on-dev-biennial-review-2025/scc-rules-in-dev-biennial-review-case.html
[39] Smith, B. (2026, January). Building Community-first AI Infrastructure. *Microsoft.* https://blogs.microsoft.com/on-the-issues/2026/01/13/community-first-ai-infrastructure/

4.1 Where Do Data Centers Get Their Water?

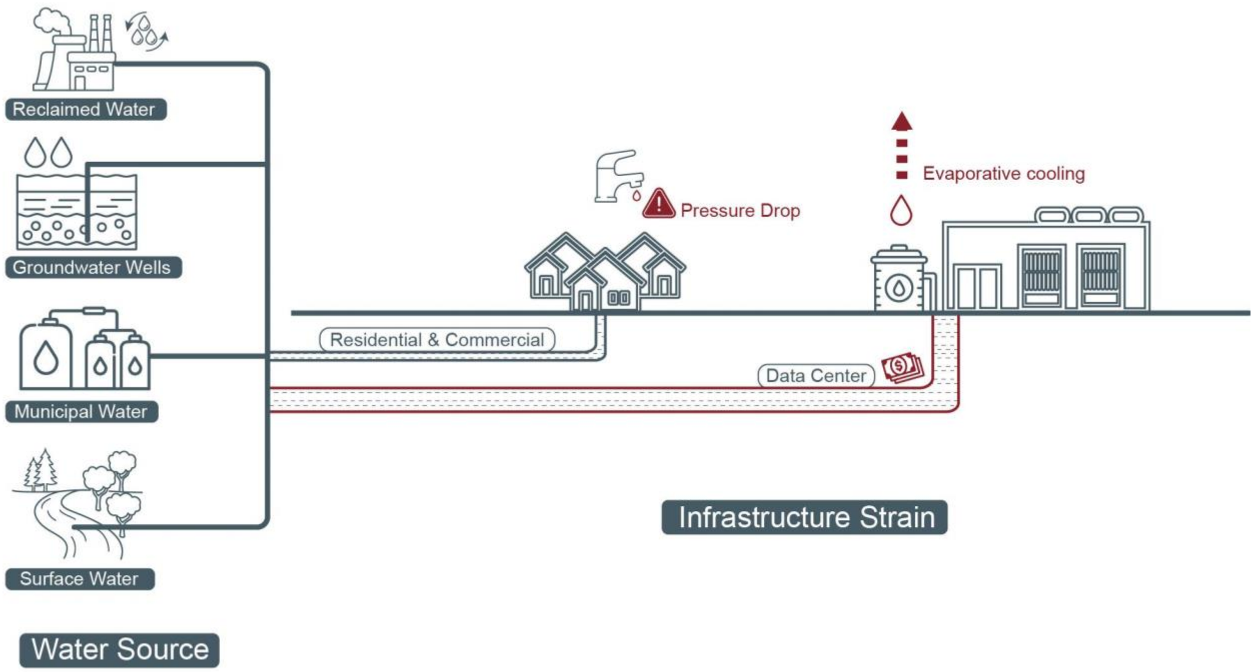


Figure 4.1: Data Center Water Sources (Image Credit: Yajun Dai).

Data centers may draw water from multiple local sources to support their cooling systems, including municipal water supplies, groundwater wells, surface waters like nearby lakes or rivers, or reclaimed water (i.e., wastewater that has been treated for reuse).[40] [41] In particular, the use of municipal reclaimed water for cooling systems is a well-established practice among large technology companies, allowing data centers to reduce reliance on limited freshwater supplies in dry areas while supporting sustainability goals.[42]

Governance of data center water use requires regional, long-term water planning and regulatory coordination. Unlike electricity where generation capacity can be expanded and transmitted across regions, water is inherently local, drawn from nearby reservoirs, rivers, lakes, or aquifers. When evaporative cooling systems are used, up to 80% of water withdrawn by data centers

[40] McCauley, P., & Scanlan, M. (2025, August 19). Data centers consume massive amounts of water – companies rarely tell the public exactly how much. *The Conversation*. https://theconversation.com/data-centers-consume-massive-amounts-of-water-companies-rarely-tell-the-public-exactly-how-much-262901

[41] Badruzzaman, M., Anazi, J., Al-Wohaib, F., Al-Malki, A., & Jutail, F. (2022, December 22). Municipal reclaimed water as makeup water for cooling systems: Water efficiency, biohazards, and reliability. *Water Resources and Industry*, *28*. ScienceDirect. https://doi.org/10.1016/j.wri.2022.100188

[42] Yañez-Barnuevo, M. (2025, June 25). *Data Centers and Water Consumption*. environmental and energy study institute. Retrieved January 11, 2026, from https://www.eesi.org/articles/view/data-centers-and-Water-consumption

evaporates and does not return to local water systems, while only the remaining portion is discharged to wastewater facilities, where reuse may be possible.[43]

Large data center water loads can affect both nearby communities and regional water systems. News reports have documented cases where data center construction coincided with reduced household water pressure, dry taps, or sediment buildup in nearby residences.[44] Although the broader social and ecological impacts of data center water use remain understudied, empirical evidence shows that data center water demand, like energy demand, peaks during hot summer periods, when regional water supplies are often most constrained, exacerbating system vulnerability.[45]

Despite water being a critical input, an interview with a regional water resource planner suggests that water utilities are frequently involved late in the data center development process. In many cases, projects advance through zoning and land-use approvals before water utilities are consulted, requiring water departments to reactively plan costly infrastructure upgrades such as upsizing transmission mains or installing booster pumps to maintain system pressure. These upgrades can entail investments of tens of millions of dollars, sometimes covered through negotiated cost-sharing or direct developer contributions.

Thus, local governments and water utilities should prepare for data center related water conversations early. Questions may involve the existing water capacity the city can accommodate, how data centers may change the forecasted regional water needs for the future, what is the amount of water lost from the rivers, what water infrastructure investments are needed, and what governance structure should be put in place to permit and check data center water uses and regulate associated environmental impacts.

This challenge is compounded by mismatches in planning horizons. Water utility master plans typically span decades, while data center lifespans and cooling technologies may change more rapidly. Utilities risk overbuilding capacity that may become underutilized if a data center relocates or shifts to less water-intensive cooling systems. While large cities may absorb such risks through existing infrastructure and diverse demand, smaller or rural utilities may face significant financial strain if forced to expand capacity on short notice and operate oversized systems long after demand declines.

---

43 Ren, S., Li, P., Yang, J., & Islam, M. (2025, March 26). *Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models*. arXiv. Retrieved January 12, 2026, from https://arxiv.org/pdf/2304.03271

44 Tan, E., & Chambers, D. (2025, July 16). Meta Built a Data Center Next Door. The Neighbors' Water Taps Went Dry. *The New York Times*. https://www.nytimes.com/2025/07/14/technology/meta-data-center-water.html

45 Scanlan, M., McCauley, P., & McLennon, D. (2025, March 5). *Inside ESG Reporting: Thirsty Data Centers Reveal Limits to Transparency*. SSRN. Retrieved January 11, 2026, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5169836

Finally, regulatory authority over large industrial water users varies widely across states. For example, a Georgia water resource planner noted that water use above 100,000 gallons per day requires permitting, giving local jurisdictions authority to meter and regulate usage. In many other states, however, comparable oversight may be absent, allowing data center developers to withdraw large volumes of water without formal reporting or approval, posing challenges for coordinated regional water planning.

4.2 How Do Data Centers Use Water?

Water demand from data centers can vary based on cooling system design. Data center cooling can be understood through three interconnected levels: how heat is removed from servers, how water or coolants circulate on the building level, and how heat is ultimately released from buildings into the environment. The choice of a cooling system also involves a fundamental trade-off between water and energy consumption. Understanding these nuances helps planners evaluate a project's real impact on water use, energy consumption, and whether the facility could provide benefits such as waste heat to the community (see Section 8.1). There are two common approaches to move heat from buildings to the outside environment.

Evaporative cooling relies on water to absorb and remove heat. When water evaporates, it carries away large amount of heat energy very efficiently. This approach consumes a lot of water. A medium-sized facility may consume up to 110 million gallons annually for cooling, comparable to annual water usage of approximately 1,000 households, while a large data center can consume up to 1.8 billion gallons, usage equivalent to a town of 10,000 to 50,000 people.[46] To make these magnitudes more legible, corporate sustainability reports sometimes compare data center water use to other water-intensive activities; for instance, the Google 2025 Environmental Report frames its total annual data center water consumption (8.1 billion gallons) as equivalent to irrigating 54 golf courses in the U.S. Southwest. [47] While such comparisons help convey scale, they do not resolve questions of local water availability, competing uses, or equity.

Water consumption increases with larger facility size, campus-scale development, AI or high-performance computing workloads (as opposed to basic data storage), and high, continuous energy demand. A significant portion of this water evaporates into the air and does not return to local water sources (i.e., up to 80% of evaporated water may be lost to the atmosphere and may not return to local rivers and lakes) [48]. While these systems can place heavy demands on local

[46] Yañez-Barnuevo, M. (2025, June 25). *Data Centers and Water Consumption*. environmental and energy study institute. Retrieved January 11, 2026, from https://www.eesi.org/articles/view/data-centers-and-Water-consumption
[47] Google. (2025). *Environmental Report*. Retrieved January 11, 2026, from https://www.gstatic.com/gumdrop/sustainability/google-2025-environmental-report.pdf
[48] Ren, S., Li, P., Yang, J., & Islam, M. (2025, March 26). *Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models*. arXiv. Retrieved January 12, 2026, from https://arxiv.org/abs/2304.03271

water supplies, they are energy-efficient, affordable, and widely used. They are most often considered for data centers located near abundant water resources.

Dry cooling rejects heat through fans, consumes minimal water, yet requires more energy to operate and works less efficiently, especially in hot weather. This system is more commonly considered for non-AI data centers in cooler, water-stressed regions, as it relies on the temperature difference between indoor and outdoor air to remove heat.

For years, most data centers chose evaporative cooling because electricity was expensive while water was cheap and abundant. Climate change, drought, and growing competition for water resources are now forcing the industry to reconsider this choice. Hybrid systems that combine evaporative and dry cooling are also becoming more popular. Whether a facility can practically use dry cooling instead of evaporative cooling at the building level depends in part on how a data center cools its servers.

At the server level, **air cooling** uses fans to blow air over servers. The heat produced through this method tends to be at a lower, near-ambient temperature, closer to the outside environment, which makes dry cooling inefficient and therefore often requires evaporative cooling systems.

Liquid cooling circulates coolant through pipes or metal plates attached directly to servers to absorb heat. **Immersion cooling** submerges entire servers in specialized cooling fluid. Both methods capture heat at higher temperatures, making dry cooling systems more feasible.

At the building level, **a closed-loop water system** refers to how these coolant flows operate, typically through sealed pipes that recirculate coolant back to the servers. When these designs are combined with dry cooling, which dissipates heat to the outside environment through air rather than water, the overall system can consume minimal water. The main trade-offs are higher electricity use, higher capital costs, and larger physical footprints, as these systems rely more on fans and mechanical equipment rather than evaporation.

In practice, data centers can use a mix of these technologies under energy and water cost tradeoff, surface climate, capital costs, or infrastructure retrofit constraints. It is possible that data centers have updated technologies at the server levels to conserve water (e.g., liquid / immersion cooling) but still use evaporative cooling systems to reject heat to the outside environment.

Rapid innovation in data center cooling technologies has produced mixed messages for local governments and communities. While some developers and local planners claim that water use is not a concern, others express ongoing uncertainty in terms of scope of work, workforce, and community capacity, particularly when projected water demand remains speculative during construction and early operation.

To address this disconnect, best practice calls for early, transparent negotiation between water utilities and data center developers, in which utilities clearly define the volume of water they can reliably supply and developers disclose expected cooling demand. Such coordination allows both parties to determine whether evaporative cooling is feasible or whether closed-loop systems are required, ensuring that cooling choices align with local water availability and reducing the risk of overcommitting scarce resources. Complementing this approach, utilities should adopt long-term master plans and support zoning ordinances that enforce limits on water-intensive cooling technologies (e.g., DeKalb County's zoning amendment mandating closed-loop systems for new data centers).[49]

4.3 What are Implications of Data Centers' Water Discharge?

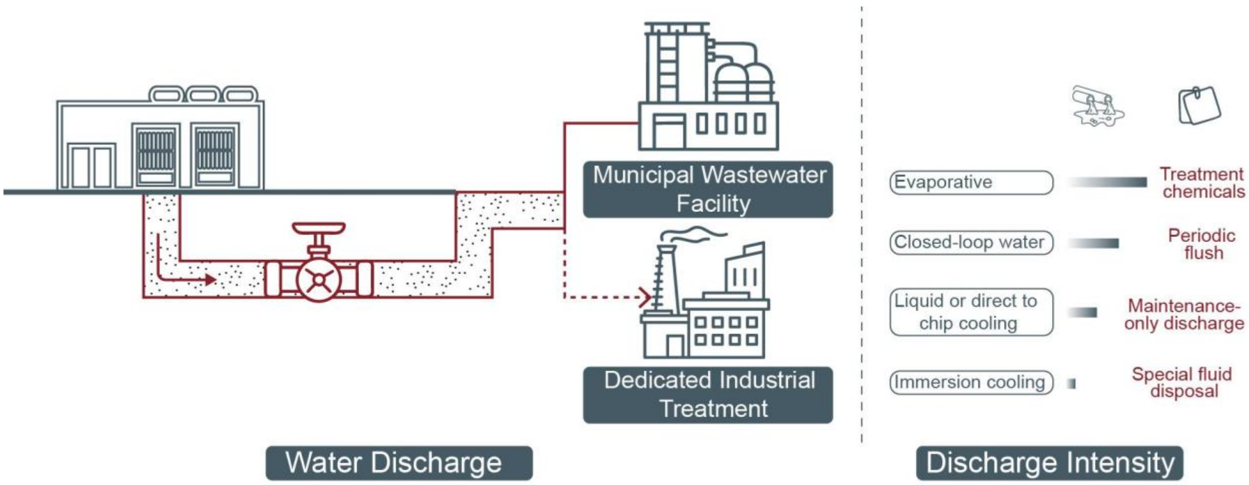


Figure 4.3: Data Centers' Water Discharge (Image Credit: Yajun Dai)

Regardless of what water-based cooling systems data centers use, periodic flushing of cooling water is required at the building level to remove accumulated minerals, chemicals, and contaminants. The volume and composition of wastewater therefore depend on both how heat is rejected to the environment and whether cooling water is recirculated in open-loop or closed-loop systems at the building level.

Evaporative systems, which rely on open-loop water evaporation to reject heat, typically discharge 20 percent of water used to the sewer system.[50] This wastewater often contains chemical additives such as biocides and anti-scaling agents used to control biological growth and corrosion.

[49] DeKalb County. (2025, December 3). *Data Center Text Amendment*. Retrieved January 11, 2026, from https://engagedekalb.dekalbcountyga.gov/data-center-text-amendment

[50] Ren, S., Li, P., Yang, J., & Islam, M. (2025, March 26). *Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models*. arXiv. Retrieved January 12, 2026, from https://arxiv.org/abs/2304.03271

Dry cooling systems, in contrast, reject heat to the atmosphere using air rather than water and generate little to no routine wastewater discharge.

Closed-loop water systems, which circulate treated cooling water within the building, release far smaller volumes but still require periodic flushing of chemically treated water that must be managed through industrial pretreatment. Because cooling water is intentionally treated to maintain system performance, it is generally unsuitable for human consumption or agricultural reuse.

At the server level, cooling technologies further influence wastewater generation indirectly by shaping how much cooling water is required at the building scale. **Liquid cooling** or **direct-to-chip cooling** reduces overall cooling water demand by capturing heat more efficiently, resulting in wastewater discharge that occurs primarily during scheduled maintenance or coolant replacement. **Immersion cooling**, which submerges servers in dielectric fluids, produces little to no routine water discharge, though the specialized fluids used in these systems require careful handling and disposal through industrial waste channels.

Depending on local discharge regulations, wastewater from cooling systems may fall under a utility's industrial pretreatment program. A water resource manager interviewed noted that many jurisdictions require data centers to obtain industrial pretreatment permits to protect public sewer infrastructure by limiting pollutant concentrations and, in some cases, requiring on-site wastewater treatment prior to discharge.

The volume and chemical composition of data center wastewater can also impose capacity and treatment challenges for local water treatment facilities, sometimes necessitating costly infrastructure upgrades. These demands can arise as early as the construction phase, leaving local governments limited time to respond. An EPA case study from Quincy, Washington documents how multiple data centers prompted the city to construct a separate industrial wastewater treatment facility so cooling-system blowdown could be treated separately from municipal sewage and then reused.[51] Despite such examples, the downstream wastewater impacts of data centers remain underexamined in the broader literature.

For data centers located in small, rural areas without access to municipal sewer and water systems, they must self-provide water supply and management system, such as drilling individual wells or extend nearby industrial facilities' water system and building on-site lagoons and septic system to manage industrial and employee wastewater (e.g., toilets, sinks, kitchens) respectively. Interviewed local planners also recite that these data centers may also apply for land application permits, allowing treated wastewater to flow to agricultural land as a positive, regulated reuse (see Section 5.2 on impacts on farmland transactions).

[51] *Water Reuse Case Study: Quincy, Washington* | *US EPA*. (2025, July 17). EPA. Retrieved January 12, 2026, from https://www.epa.gov/waterreuse/water-reuse-case-study-quincy-washington

5. Land Use (Zoning, Land Use, Long-term Planning)

Data centers require proximity to **electrical substations**, **transmission lines**, and **fiber-optic backbones**, which can introduce new **land uses** associated with these supporting infrastructures. Zoning is a key land use instrument that local governments use to regulate the built environment of data centers, their supporting infrastructure, and compatibility with nearby communities. Over time, the land-use footprint of data centers shapes not only the feasibility of individual sites but also broader questions about strategic co-location of mutually beneficial uses, land-value speculation, growth management, compatibility with surrounding development, and the long-term end use or reuse of such large, single-purpose facilities.

5.1 How are Data Centers Regulated through Zoning?

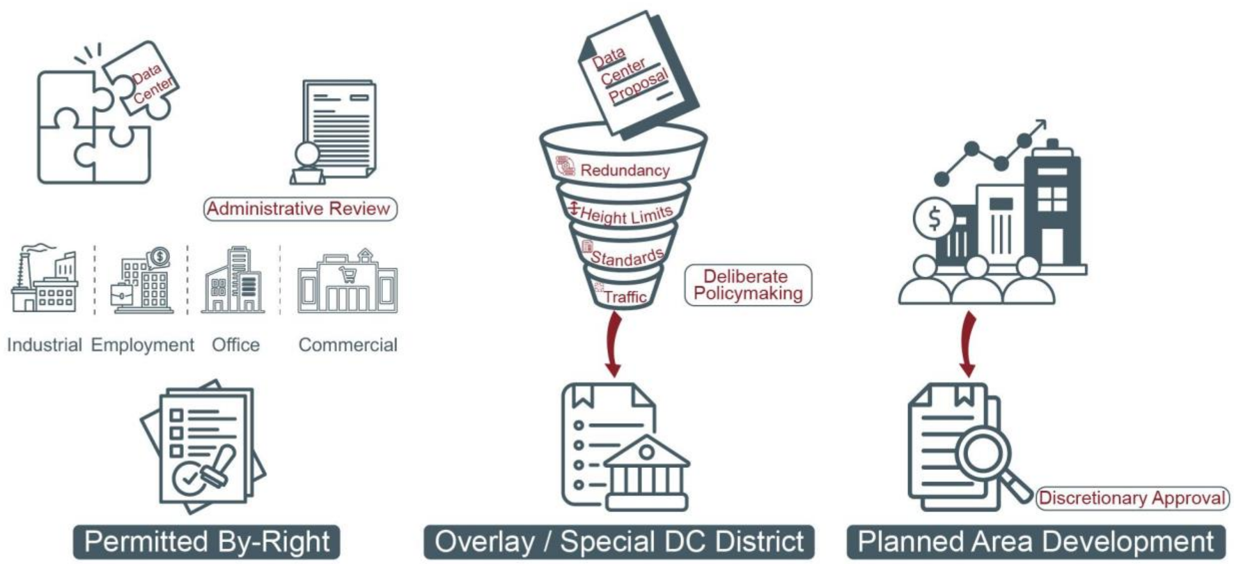


Figure 5.1: Three Zoning Approaches to Data Centers (Image Credit: Yajun Dai).

Data centers typically fall into light/heavy industrial (e.g., Hillsboro, Oregon), or employment/office/commercial zoning districts (e.g., New Albany, Ohio)[52] [53]. When zoning codes do not explicitly distinguish data centers from other industrial uses, they are often permitted by right. This means the proposal does not require discretionary approval and must be approved administratively as long as it meets objective development standards (e.g., height, setbacks). If a use is permitted by right, the city cannot deny the project based on the use itself; the review is administrative, not political.

[52] City of Hillsboro. (2024, March 5). *City of Hillsboro Community Development Code*. Retrieved January 11, 2026, from https://ecode360.com/44406061
[53] New Albany Planning Commission. (2025, March 3). *New Albany Planning Commission Meeting Agenda*. Retrieved January 11, 2026, from https://newalbanyohio.org/wp-content/uploads/2025/02/25-0303-PC-Meeting-Packet.pdf

However, data centers feature different characteristics, such as height, traffic, redundancy, and large energy and water consumption, that may not fit neatly within existing industrial categories. Whether data centers should be regulated separately from other industrial uses remains contested. As some planners noted, if a data center, a potato processing plant, and a beer factory produce similar externalities, it is not immediately obvious why zoning codes have to treat them differently. Local jurisdictions have adopted a range of approaches to regulate these characteristics more precisely.

One approach is to establish a dedicated overlay or special zoning district that explicitly governs data centers with tailored standards (e.g., Prince William County, Albemarle County, and Loudoun County in Virginia)[54] [55] [56]. This method is common in jurisdictions with a large number of data center proposals, as it streamlines by-right approval for qualifying projects. Yet defining the new district requires deliberate policymaking to ensure its standards match local infrastructure capacities and community expectations.

A second approach relies on case-by-case review through a Planned Area Development (PAD) or similar master-planned zoning designation (e.g., Chandler, Arizona)[57], or established specific zoning restrictions for data centers and require special use permits that mandate public review and council approval (e.g., Atlanta).[58] In these frameworks, developers propose customized development standards subject to discretionary approval. This approach offers flexibility and becomes increasingly popular as local jurisdictions want to exercise discretion and hold power leverages.

In places where zoning codes do not explicitly mention data centers, interpretation gaps and soft regulations may arise. For example, Santa Clara, California does not automatically permit data centers in any zoning district but notes in a planning commission opinion that they may be allowed with a use permit.[59] This ambiguity can lead to unintended consequences if planners

---

[54] Prince William County. (n.d.). *Prince William County, VA Municode Codification: Chapter 32—Zoning, Article V—Overlay Districts, Part 509—Data Center Opportunity Zone Overlay District*. Retrieved January 11, 2026, from https://library.municode.com/va/prince_william_county/codes/code_of_ordinances?nodeId=CH32ZO_ARTVOVDI_PT509DACEOPZOOVDI

[55] Albermarle County Community Development Department. (2025, July 11). *Data Center Ordinance Review*. Retrieved January 11, 2026, from https://engage.albemarle.org/data-center-regulations/news_feed/read-the-draft-ordinance

[56] Loudoun County. (n.d.). *Loudoun County Zoning Ordinance Chapter 3*. Retrieved January 11, 2026, from https://online.encodeplus.com/regs/loudouncounty-va-crosswalk/doc-viewer.aspx#secid-43

[57] Chandler, Arizona. (n.d.). *Code of Ordinances*. Retrieved January 11, 2026, from https://library.municode.com/az/chandler/codes/code_of_ordinances?nodeId=PTVIPL_CH35LAUSZO_ARTXXIIADHEARRE_35-2214DACE

[58] City of Atlanta. (n.d.). *Ordinance 25-O-1063*. Retrieved January 11, 2026, from https://atlantacityga.iqm2.com/Citizens/Detail_LegiFile.aspx?ID=37303

[59] City of Santa Clara. (2024, January 31). *Public hearing: Action on environmental impact report, general plan amendment, and use permit to allow the construction of a new four-story, 244,068-square-foot data*

are unfamiliar with data center infrastructure needs. For instance, some industrial zoning districts may not permit diesel generators, which effectively rule out data center uses because diesel generators are required infrastructure components.[60] Other jurisdictions also creatively place limits within industrial or employment districts, such as capping their cumulative total area, or only allowing data centers as secondary uses attached to another primary use, effectively prohibiting hyperscale or enterprise data centers.

Local communities can also assert their preferences by amending zoning documents to impose specific requirements on data centers, such as restricting certain types, mandating closed-loop cooling systems, or establishing enhanced setbacks near residential areas. For example, DeKalb County's zoning amendment mandates closed-loop systems for new data centers.

Local communities can also voice opposition through the rezoning public process.[61] An increasing number of data center proposals seek to rezone agricultural land into industrial use due to lower land prices and the shrinking availability of suitable industrial lands. Yet rezoning is a legislative rather than administrative action and therefore requires a public process involving City Council hearings, during which community opposition can emerge and ultimately lead to the denial of the rezoning request, and, by extension, of the data center itself. There have even been controversies in which data center developers threaten to sue local jurisdictions after rezoning denials.[62]

Data center developers typically confirm with local planners early on the zoning designation of a targeted site and assess whether rezoning is feasible. This decision is critical, as it determines the subsequent approval process (e.g., rezoning requires a public process and broader stakeholder engagement) and the design constraints for data center construction. Based on our interviews, developers ideally prefer the land to be rezoned before acquisition, but they also work closely with landowners to submit rezoning applications and, in some cases, collaborate with inexperienced jurisdictions to update zoning codes to better accommodate data centers. The specific approach to data center zoning also shapes the role of urban planners, either limiting them to "check-box" compliance with land-use standards or allowing them to exercise discretion in balancing economic development goals with community needs.

---

center with a substation at 2805 Bowers Avenue. Retrieved January 11, 2026, from https://santaclara.legistar.com/LegislationDetail.aspx?ID=6563785&GUID=DA282979-0FE8-4B1C-9650-54F48227DC96

[60] Fluet, J. (2021, July 22). Data Centers Evolved: A Primer for Planners. *American Planning Association Planning Magazine*. https://www.planning.org/planning/2021/summer/data-centers-evolved-a-primer-for-planners/

[61] DeKalb County. (2025, December 3). *Data Center Text Amendment*. Retrieved January 11, 2026, from https://engagedekalb.dekalbcountyga.gov/data-center-text-amendment

[62] Allnut, B. (2025, September 18). Data center developer takes Saline Township to court over rezoning decision. *Planet Detroit*. https://planetdetroit.org/2025/09/saline-township-data-center-lawsuit/

5.2 How Does Data Center Affect Other Land Use and Land Transactions?

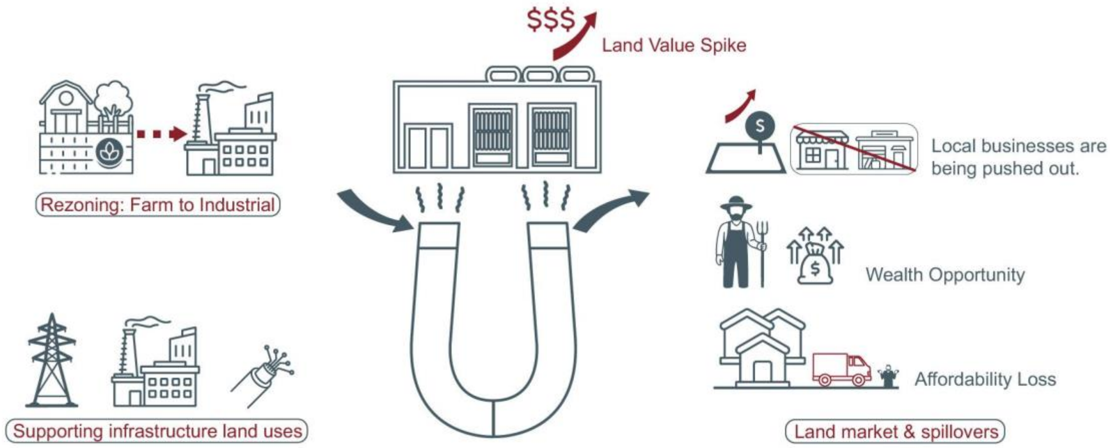


Figure 5.2: Data Centers' Impact in Land Uses and Land Transactions (Image Credit: Yajun Dai).

Data centers increasingly compete with agricultural land because farmland is cheaper and industrial land is limited. In Morrow County, Oregon, eight out of nine data centers are located outside city limits. For municipalities intent on prioritizing farmland preservation, one legal tool is to define data centers as a distinct use and explicitly prohibit them in agricultural districts, as implemented in Prince William County, VA.[63] A more likely outcome is the implementation of stricter requirements within existing regulations, as well as negotiations for agricultural preservation funds from developers, as seen in Saline Township, MI.[64] On the other hand, some municipalities, as brought up during interviews, have expanded municipal boundaries to incorporate rural agricultural land and rezone it as industrial land. However, municipalities need to consider the environmental consequences of using nearby farmland, as well as potential legal limitations in expanding the urban growth boundary based on state statute.

Data centers often induce additional power, water, fiber, and business-related land uses, such as transmission lines, electrical substations, renewable energy facilities, water storage towers, treatment plant expansions, and coordinated rights-of-way for water lines, fiber bundles, and sewers. A planner in a rural town with data centers reported spending 15–20% of their time reviewing transmission line applications alone. Interviewed developers also argue that many

---

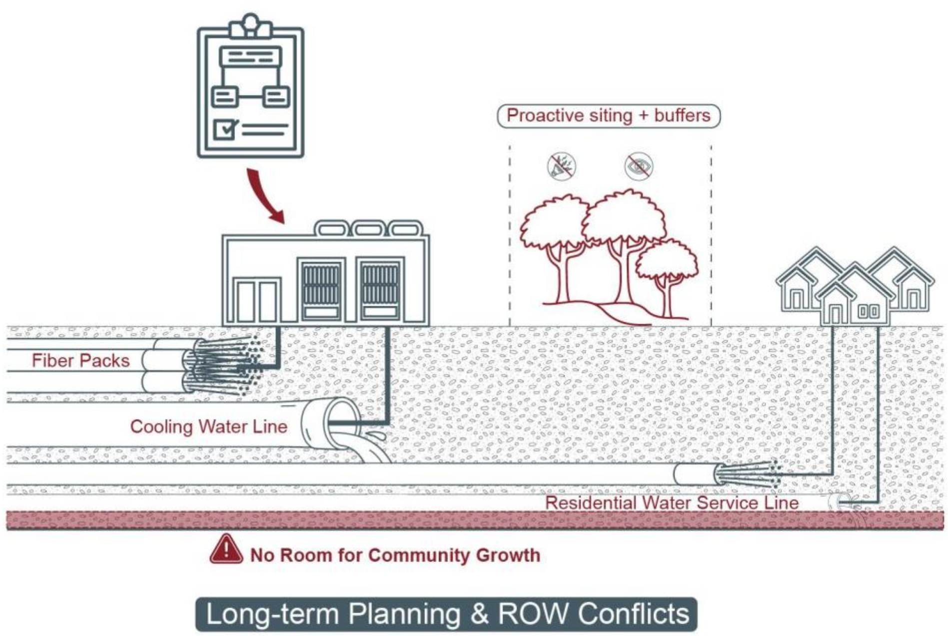
[63] Prince William County. (n.d.). *Prince William County, VA Municode Codification: Chapter 32—Zoning, Article V—Overlay Districts, Part 509—Data Center Opportunity Zone Overlay District*. Retrieved January 11, 2026, from https://library.municode.com/va/prince_william_county/codes/code_of_ordinances?nodeId=CH32ZO_ARTVOVDI_PT509DACEOPZOOVDI

[64] Allnutt, B. (2025, October 21). Saline Township settles with data center developer: 'Lesser of two evils'. *Planet Detroit*. Retrieved January 11, 2026, from https://planetdetroit.org/2025/10/saline-data-center-settlement/

data centers are located in commercial districts where fiber lines are readily available and could stimulate auxiliary business that serve the staff or the operation for data centers.

Data centers can also increase land values and thus have spilled over effects on other uses. Data center developers typically look to construct several data centers within the same general area, for both the purpose of lower latency rates between data centers and ease of working with a familiar approval process. In these targeted areas, sites of open land that are viable for data center development can see significant increase in value because of developers' willingness to pay. In Loudoun County, the data center capital of the world, viable land is selling at $6 million an acre.[65] While Loudoun is an extreme example, other areas are experiencing surging land prices. For farmers or people who own industrial land that they wish to sell, this is an incredible opportunity to build wealth, but it makes land purchases less attainable for locals or other businesses that don't have the same financial resources as data center developers. For farmers who want to purchase or rent farmlands, data centers motivate speculation on land values in farmland market. A rural town planner shared an observation that many commercial trucks for farming communities are parked on residential districts because they cannot find commercial and industrial land that they can afford due to the land price increase induced by data centers.

5.3 What Are Long-term Land Use Planning Considerations?



[65] Graham, D., & Styer, N. K. (2025, November 7). Data Center Sale Sets New Loudoun Price Record. *Loudoun Now*. Retrieved January 11, 2026, from https://www.loudounnow.com/business/data-center-sale-sets-new-loudoun-price-record/article_d392a250-e672-46c2-b2d2-f0ad3424a100.html

Figure 5.3: Long-term planning consideration on limited right-of-way headrooms due data centers' underground infrastructure (Image Credit: Yajun Dai).

A long-term challenge associated with data center development is that, given the uncertainty and rapid change in the AI industry, communities may experience a short-term oversupply of data centers, many of which could fall out of use over the long term.[66] To address the end use question, municipalities can draw inspiration from retrofitting big-box retail development or single-use, large-format buildings that have increasingly fallen out of favor in the internet age.

Solutions, particularly for enterprise or hyperscale data center proposals, typically include requiring developers to post a security bond covering demolition costs or requiring submission of an adaptive reuse plan, or both. For example, Ferndale, Washington requires developers of single-purpose structures over 50,000 square feet to either submit an adaptive reuse plan or post a bond equal to 150 percent of estimated demolition costs.[67] However, an interviewed planner raised concerns that mandatory decommissioning requirements for data centers may need to be considered carefully, as similar long-term land-use implications apply to many other industrial uses, and singling out data centers might be problematic.

Several interviewees stressed the importance of thinking ahead about where data centers *should* go long before development pressures arrive. Siting decisions made early can prevent future conflicts with residential neighborhoods, which often struggle with noise, viewshed issues, or the presence of large substations and transmission lines. Interviewed planners described the need for intentional buffers, such as parks, forests, open space, to keep high-voltage infrastructure from discouraging nearby housing.

Coordinating with power companies is also essential. As one planner noted, knowing where utilities expect to extend transmission lines in the next five or ten years helps planners understand which areas are likely to be suitable, or unsuitable, for new homes. Fiber infrastructure presents a different challenge: it is buried, expensive, and invisible to residents. Although essential to data centers, it can be hard to communicate its value to the public and elected officials.

Data centers may also strain the public right-of-way (ROW). Large water lines, dense fiber-optic bundles, and other utility corridors must all fit within limited space. One planner described a non-potable "cooling water" line built to serve several data center campuses that now occupies much of a key roadway corridor, raising questions about where future municipal water or wastewater lines will go. Similar issues arise with fiber. Data centers require high-capacity "fiber packs," which can crowd out room for community-serving utilities. In many jurisdictions, large fiber

[66] Morley, D. (n.d.). *Managing AI Build-Out in a Winner-Take-Most World*. American Planning Association Blogs. Retrieved January 11, 2026, from https://www.planning.org/blog/9319236/managing-ai-build-out-in-a-winner-take-most-world/

[67] City of Ferndale, WA. (n.d.). *Ferndale Municipal Code, Title 18 (Zoning), Chapter 18.58: Retail Design Guidelines and Standards*. https://www.codepublishing.com/WA/Ferndale/#!/Ferndale18/Ferndale1858.html

projects can also proceed through administrative ROW permits handled by public works or engineering, with limited planning commission review or public input. And there is a mismatch between what data centers need and what residents can use: data-center-grade fiber is not directly compatible with household broadband fiber. Unless communities negotiate local access or form partnerships with data centers to provide free access, those living near data centers may still struggle with slow or unreliable internet.[68]

However, data centers can be synergistic for community land use development. Some communities have converted aging malls or big-box stores into data centers, making use of structures that are otherwise hard to repurpose.[69] Others are exploring co-location models, pairing data centers with greenhouses that can use their waste heat, or placing them alongside renewable energy facilities because these uses often target the same types of land and can provide clean energies to residents in return.[70]

6. Quality of Life (Housing, Transportation, Residential Experience)

Data centers can affect nearby residents' quality of life through noise from **diesel generators** and **cooling fans**, light pollution from **24/7 security lighting**, neighborhood traffic disruptions during construction or emergency fueling activities, and visual impacts from large, windowless **server hall** buildings and expanded **transmission lines**. **Landscape screening** is a common though limited mitigation strategy to soften these visual effects. In addition, data centers can generate substantial traffic on local roads during construction, and the number drops significantly once in operation. Still, operational staff will need dedicated **employee parking** and **loading bays** for equipment. Over the longer term, local housing demand increases as construction and operations workers seek nearby living options.

---

[68] Banks, R. (2024, March 19). *Data Centers Enable Our Digital World—and Thriving Communities*. The Equinix Blog. Retrieved January 11, 2026, from https://blog.equinix.com/blog/2024/03/19/data-centers-enable-our-digital-world-and-thriving-communities/

[69] Datacenters.com. (2025, October 31). *From Retail to Racks: How Malls and Big-Box Stores Are Becoming Data Center Real Estate*. Retrieved January 11, 2026, from https://www.datacenters.com/news/from-retail-to-racks-how-malls-and-big-box-stores-are-becoming-data-center-real-estate

[70] Datacenters.com. (2024, September 19). *From Byproduct to Resource: How Data Centers are Turning Waste Heat into Valuable Energy*. Retrieved January 11, 2026, from https://www.datacenters.com/news/from-byproduct-to-resource-how-data-centers-are-turning-waste-heat-into-valuable-energy

6.1 How Might Data Centers Impact Housing?

Figure 6.1: Data centers' long term employees and temporary construction workers bring housing pressures to local communities (Image Credit: Yajun Dai).

Although data centers do not house many employees, the workforce they draw during both construction and operation requires nearby housing, food options, and neighborhood amenities. Even small facilities generate secondary employment (delivery, food services, maintenance), increasing residential demand as workers seek to live close to where they are based. This places localized pressure on housing markets in areas that were not expected to absorb significant population growth. As AI and larger computing clusters push site selection toward more remote, infrastructure-sparse locations, commuting becomes less feasible, and workforce housing emerges as a logistical constraint, one that was not typically examined in data center planning.

Data centers also introduce large, multi-year construction cycles, and tend to follow previously built out facilities (i.e., cluster in the same region). Workers initially assumed to be temporary often choose to stay permanently, gradually absorbing available housing stock. Local planners we interviewed acknowledged that the scale of this shift became apparent only over time: construction workers filled vacant units, became long-term residents as new data center phases continued to open, and contributed to sustained housing pressure that the region had not anticipated.

In places like Loudoun County, an interviewed elected official reported that power constraints and limited land availability are pushing the county to prioritize residential development over additional data centers. Residents migrating from high-cost metros (e.g., DC) intensify demand for housing in suburban counties like Loudoun, making elected officials more sensitive to housing pressures.

Data centers can also have mixed impacts on the local housing market. One study found no evidence that data centers in Northern Virginia negatively affect property values.[71] Loudoun county's 2025 budget summary reported 4.53% and 22.56% increase in residential and commercial property value due to new and expanding data centers in the county, which then contributes to extremely high housing prices.[72] [73] Another interviewee described unprecedented apartment rents in a rural town experiencing data center growth. However, it remains unclear whether these patterns generalize to regions with different market conditions and concentrations of data centers. The quality of life for residents living near data centers may also influence housing desirability. As a policy response, Henrico County, Virginia has begun directing data center tax revenues into an affordable housing trust fund.[74]

6.2 How Might Data Centers Impact Transportation?

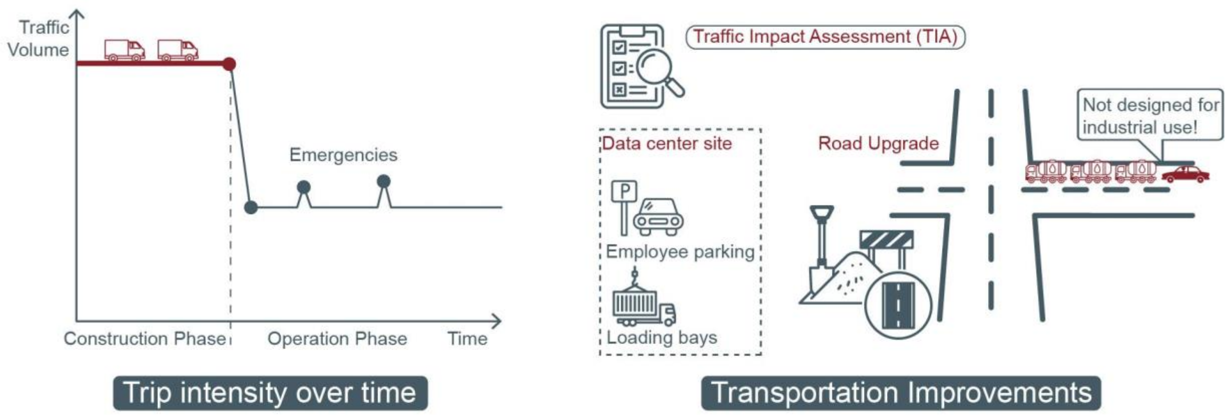


Figure 6.2: Data Center's Traffic and Transportation Infrastructure Considerations (Image Credit: Yajun Dai).

Transportation considerations tend to surface early in the data center development process. Developers told us that one of their first steps is simply looking at whether the roads are wide enough to handle heavy trucks and increased trips during construction. A regional water resource planner also noted that transportation impacts are often what first bring a proposed

[71] Waters, K., & Clower, T. (2025, August). *Data Centers and 2023 Home Sales in Northern Virginia*. Retrieved January 11, 2026, from https://cra.gmu.edu/wp-content/uploads/2025/08/NoVa_DataCenters.pdf

[72] Loudoun County. (n.d.). *Loudoun County FY 2025 Adopted Budget*. Retrieved January 11, 2026, from https://lfportal.loudoun.gov/LFPortalInternet/0/edoc/1958598/FY%202025%20Adopted%20Budget%20-%20Volume%201.pdf

[73] Chernicoff, D., & Vincent, M. (2025, February 15). *The Future of Property Values and Power in Virginia's Loudoun County and 'Data Center Alley'*. Retrieved January 11, 2026, from https://www.datacenterfrontier.com/site-selection/article/55266317/the-future-of-property-values-and-power-in-virginias-loudoun-county-and-data-center-alley

[74] Stacy, C. P. (2025, October 27). *Turning Data Center Revenues into Affordable Homes*. Retrieved January 11, 2026, from https://www.urban.org/urban-wire/turning-data-center-revenues-affordable-homes

data center to the attention of regional planning commissions, because road congestion quickly becomes a regional concern.

Data centers create intense, short-term trips during the construction period, even though they may generate few daily trips once they are operating. Interviewed rural town planners reported that residents may not immediately connect these changes to a new data center, but over time the steady buildup of congestion becomes hard to ignore.

Therefore, many local governments now require developers to submit traffic impact assessments before a rezoning or site plan can move forward. Developers typically hire national transportation consulting firms to study trip generation, access points, road design standards, and potential safety concerns. Because many local officials are not engineers, these studies often serve as the primary tool for explaining expected impacts and shaping mitigation strategies. State and county transportation departments may join the review process if a proposed site sits near a highway or a state-maintained intersection.

In practice, accommodating a data center often means upgrading local roads. New access roads may be needed, or existing ones may require infrastructure upgrades. Developers sometimes absorb these costs, but not always. When improvements extend beyond the immediate site, questions arise about who pays and who benefits. Interviewees emphasized that in remote areas, where roads were never designed for industrial-scale use, local roads could deteriorate quickly.

Parking and staging create another layer of transportation challenges. Construction sites can have hundreds of workers but only a limited number of spaces, forcing developers to secure remote parking lots and run shuttles. In places where local ordinances prohibit construction vehicles from using neighborhood streets, staging becomes even more complicated.

Transportation pressures also persist during emergencies. One developer described fuel trucks lining up along a public street during a regional power outage because generator refueling could not occur on-site, which is technically legal but nonetheless disruptive for nearby residents.

Even after construction ends, data centers continue to generate transportation activities. Large campuses may host security staff, office tenants, delivery drivers, and vendors, all of whom add daily trips. Workers may also choose to live nearby, gradually increasing residential traffic and service demand in surrounding communities.

Given these pressures, transportation improvements are increasingly written into community benefit agreements or mitigation packages. These might include sidewalks, paved shoulders, multimodal paths, safer intersections, or upgrades at key interchanges. In some cases, developers help fund improvements on road infrastructure to meet safety standards. Regional review processes, such as Georgia's Development of Regional Impact review, also flag large data center proposals early to capture regional traffic impacts.[75]

6.3 How Might Data Centers Affect Residential Experience?

Figure 6.3: Data centers' light, noise, and air pollution impacts to nearby residences (Image Credit: Yajun Dai).

Residents often become more vocal in opposing data centers once the facilities and their supporting infrastructure become visible and their effects are felt close to home. Not-In-My-Backyard (NIMBY) sentiments intensify as large transmission lines, substations, and windowless server halls appear, which many view as visually intrusive. For some residents, these structures are perceived as eyesores and as visible signs of the data center's impact on the local grid. These visual disruptions clash with landscape aesthetics, diminish rural character, and signal long-term development. These physical reminders tend to prompt communities to mobilize, question approvals, and push back more intensely.

Beyond changes in visual character, residents may experience day-to-day noise, light, air pollution, and traffic impacts at the neighborhood scale (see Section 8 for environmental impacts). Interviewed developers described receiving frequent complaints from nearby residences about noise and light. Although backup generators operate infrequently, they produce a high level of noise when activated. Fans and cooling towers operate continuously and, at scale, can create a low-frequency hum that carries beyond property lines. Light pollution can also affect nearby homes: because data centers operate 24 hours a day, security or construction lighting may unintentionally spill into adjacent yards and windows.

While air pollution and noise are regulated and mitigated through Environmental Planning Agency (EPA) and local noise ordinances, persistent disturbances can still become quality-of-

[75] Hansen, Z., & Brimmer, A. V. (2025, November 20). Data centers to get regional review, public notice on key Georgia website. *The Atlanta Journal-Constitution*. https://www.ajc.com/business/2025/11/data-centers-to-get-regional-review-public-notice-on-key-georgia-website/

life issues for neighbors. The noise and light pollution could lead to health issues where some residents reported hypertension and insomnia.[76] [77]

Developers can offer minor adjustments, such as landscape screening to soften visual impacts, redirecting lighting or generator exhaust, or informing local governments in advance when generators will be tested so they can coordinate communication with residents. In good faith, many developers do want to be good neighbors. However, as one interviewed developer explained, once a generator or cooling system has been legally permitted and installed, local governments have little authority to require substantive changes or removals, even if residents continue to raise concerns.

7. Economic Benefits (Tax Revenue, Job, Ancillary Businesses)

Data centers contribute significant tax revenues to local governments, from real estate and property taxes on infrastructure investments to business and sales taxes generated by daily operations and computer equipment in **server halls**. They also create direct and indirect jobs in **office** and site operations. The job counts tend to be higher during the construction phase than in ongoing operations. The high tax revenue per capita can be both an opportunity and a concern: while it enhances local economic output, it also raises questions about whether communities receive meaningful employment benefits, especially when these revenues are paired with generous tax breaks.

7.1 What Tax Revenue and Community Investments Do Data Centers Generate?

Data centers can bring significant tax growth. These taxes include property taxes from real estate and infrastructure investment, business taxes from operations or equipment, and sales tax on equipment purchases.[78] For instance, Loudoun County, Virginia reported $670 million in tax revenue on data centers' computer equipment alone, which constitutes 41% of all property

---

[76] Judge, P. (2021, July 22). *Chicago residents complain of noise from Digital Realty data center*. Data Center Dynamics. Retrieved January 11, 2026, from https://www.datacenterdynamics.com/en/news/chicago-residents-complain-of-noise-from-digital-realty-data-center/

[77] Monserrate, S. G., & Burrington, I. (2022, January 27). *The Cloud Is Material: On the Environmental Impacts of Computation and Data Storage*. MIT Case Studies in Social and Ethical Responsibilities of Computing. Retrieved January 12, 2026, from https://mit-serc.pubpub.org/pub/the-cloud-is-material/release/2

[78] Metropolitan North Georgia Water Planning District. (2025, October 16). *Data Center Trends in Metro Atlanta and Considerations for Local Communities*. Retrieved January 12, 2026, from https://northgeorgiawater.org/wp-content/uploads/2025/10/2025_10_16_DataCenters_Community-Considerations.pdf

tax.[79] These revenues can be used to fund community programs such as education, parks, or recreational facilities, infrastructure upgrades, sustainability initiatives and even affordable housing funds (see examples from Loudoun County, VA).[80] The large revenue inflow makes data centers attractive for elected officials and smaller, rural townships that lack public funds and economic opportunities.

Most interviewees reported that data centers generate substantial local tax revenue even after tax breaks, but these benefits remain controversial because they vary widely across states depending on tax abatement policies and local negotiation capacity. Critics often argue that the fiscal gains are far smaller than they could be.[81] In many cases, tax incentives are negotiated quietly at the state level through economic development offices without input from local planners or utilities, and smaller or less experienced jurisdictions may accept deals or sell industrial lands before they realize who they are selling to and how much more value they could have bargained. Several interviewees noted that before 2020, developers routinely expected generous tax incentives and negotiated aggressively by threatening to move to competing jurisdictions. As market demand for data center sites has grown and local opposition has risen, jurisdictions are no longer pressured to offer the steepest tax incentives.

Some data center developers may offer micro-grants or community benefits programs tailored to local needs. For instance, at Saline Township, MI, the developers offered "$2 million for a farmland preservation trust fund, $2 million for a community investment fund that can be used for community projects, township buildings, children's buildings, and maintenance of cemeteries, 5 million to invest in the fire department in trucks, facilities, and more".[82] Many local jurisdictions also include affordable housing and transportation impact mitigation requirements in their agreements (see Section 6.1 on housing-related impacts).

7.2 How Many Jobs Do Data Centers Create?

Data centers can bring jobs in different domains. The U.S. Census reported that employment in data centers have increased more than 60% nationally from 2016 to 2023. Direct jobs include

[79] Loudoun County. (n.d.). *Loudoun County FY 2025 Adopted Budget*. Retrieved January 11, 2026, from https://lfportal.loudoun.gov/LFPortalInternet/0/edoc/1958598/FY%202025%20Adopted%20Budget%20-%20Volume%201.pdf
[80] Loudoun County. (n.d.). *Data Centers - Tax Revenues and the County Budget*. Frequently Asked Questions. Retrieved January 12, 2026, from https://www.loudoun.gov/m/faq?cat=241
[81] Ramadan, L., & Brownstone, S. (2024, August 4). How a Washington Tax Break for Data Centers Snowballed Into One of the State's Biggest Corporate Giveaways. *ProPublica*. https://www.propublica.org/article/washington-data-centers-tech-jobs-tax-break
[82] Longmoore, T. (2025, October 1). Saline Township Board Approves Consent Agreement to Avoid Lawsuit, Awaits Response. *The Saline Post*. https://thesalinepost.com/g/saline-mi/n/336585/saline-township-board-approves-consent-agreement-avoid-lawsuit-awaits-response

roles involved in designing, engineering, and operating facilities.[83] Typical local positions include business support, facility managers, IT professionals, engineering and maintenance staff, security personnel, and cleaning staff.

The highest concentration of jobs occurs during construction. When construction takes place outside major metropolitan areas, these jobs often spill over into nearby regions, while operational jobs tend to remain local. However, once a data center becomes operational, the number of jobs decreases sharply. This reduction became controversial when tax incentives were justified on the premise of job creation. For example, a ProPublica investigation reported that Microsoft employed 417 people across its Washington data centers as of July 2024 while receiving $68.4 million in tax abatements in 2023, which is a stark ratio of public subsidy to jobs created.[84] Another study found that a Google hyperscale data center could support 1,500 to 2,000 full-time workers during its 18 to 24-month construction period, but only 150 to 250 full-time jobs once operational.[85] In Michigan, reporters documented that a data center near Grand Rapids provided only 74 full-time, potentially low-wage jobs in 2019, despite public claims of creating 1,000 jobs over the coming decades, raising questions about what counts as a “job” attributable to data center development.[86]

One interviewed developer argued that this post-construction job shrinkage may actually benefit smaller communities: data centers generate high tax revenue per capita while requiring only a modest workforce, reducing demands on public services and lowering the need for extensive workforce training. Although the number of permanent jobs may seem small, they can represent a meaningful increase for rural towns. Another interviewed planner noted that these jobs sometimes could be repetitive and boring yet often pay higher wages than typical local employment. At the same time, planners observed that construction workers may stay in the region, especially when multiple data center projects overlap for years, contributing to population growth, which can bring further business opportunities as well as housing pressures (see Section 6.1 for housing impacts).

[83] Foote, A., & Wilkie, C. (2025, January 6). *Data Centers Growing Fast and Reshaping Local Economies*. U.S. Census Bureau. Retrieved January 12, 2026, from https://www.census.gov/library/stories/2025/01/data-centers.html
[84] Ramadan, L., & Brownstone, S. (2024, August 4). How a Washington Tax Break for Data Centers Snowballed Into One of the State’s Biggest Corporate Giveaways. *ProPublica*. https://www.propublica.org/article/washington-data-centers-tech-jobs-tax-break
[85] Vicki, M. (2023, February 22). When do we go from here? Data center infrastructure labor, jobs, and work in economic development time and temporalities. *New Media & Society*, *25*(2). SAGE Journals. https://doi.org/10.1177/14614448221149947
[86] McVicar, B. (2019, November 22). Lawmakers gave big tax breaks to Switch data center. Are they working? *MLive*. https://www.mlive.com/news/grand-rapids/2019/11/lawmakers-gave-big-tax-breaks-to-switch-data-center-are-they-working.html

7.3 How Do Data Centers Stimulate Secondary Businesses and Regional Economic Activity?

Many data centers are built close to cities where energy, water, and fiber infrastructure are more readily available, and sometimes even within downtown districts or office parks. As a result, data center construction and operation workers generate additional demand for nearby shops, restaurants, and housing. PwC estimated that every direct job in the data center industry could lead to six additional jobs elsewhere in the economy through indirect and induced effects, though independent empirical validation of this multiplier remains limited.[87] One interviewed developer described constant hiring of outside vendors, such as HVAC contractors and Original Equipment Manufacturers (OEMs) that produce industrial chillers and backup generators to fill ongoing workforce gaps. Infrastructure expansions that support data centers, including new transmission lines and electrical substations, also create additional local work opportunities.

At the regional scale, data centers are often treated as infrastructure projects, meaning that upgrades, such as improved digital connectivity or increased demand for renewable energy, can attract other businesses and support broader economic development. Yet reporters cautioned that public policy and tax incentives must be designed strategically to ensure that potential social benefits are realized.[88] This includes prioritizing support for construction rather than ownership and ensuring that the infrastructural gains brought by data centers translate meaningfully to nearby communities.

8. Environment (Air & Heat, Water & Waste, Governance)

Data centers create layered environmental impacts. Heat from **server halls** is released through **cooling systems**. Air pollution is driven largely by **backup diesel generators** that emit PM2.5 and NOx during testing and outages, while water and chemical risks depend on how cooling systems are designed and managed. In addition, 24/7 **security lighting** can contribute to light pollution and nighttime skyglow, especially near residential areas and sensitive habitats. Over time, rapid equipment turnover in **server halls** generates substantial e-waste, potentially implicating persistent chemicals such as Pfas. Regulation is strongest for air emissions and wastewater permits, but far weaker for localized heat and light externalities, making environmental outcomes highly dependent on how these infrastructure components are designed, monitored, and governed.

[87] PwC. (2025). *Economic contributions of U.S. data centers, 2017-2023*. 2025 PwC Report. Retrieved January 12, 2026, from https://www.centerofyourdigitalworld.org/2025-impact-study
[88] Leahey, A. (2024, August 13). Tax Breaks For Data Centers Bring Few Jobs. *Forbes*. https://www.forbes.com/sites/andrewleahey/2024/08/13/tax-breaks-for-data-centers-bring-few-jobs/

8.1 How Do Data Centers Affect Thermal Conditions and Local Air Quality?

A major output of data centers' energy and water-cooling systems is heat. Most heat originates from the computers inside server halls. Understanding the heat implications of data centers therefore requires distinguishing among server-level heat generation, building-level cooling and heat transport, and environment-level heat release. Cooling technologies operate across these levels, and their combined configuration determines whether heat is concentrated, dissipated, reused, or discharged into the local environment, as well as the associated air pollution impacts (see Section 4.2 on more explanations on each cooling technology and tradeoffs with water and energy).[89]

At the server level, **air-cooling** uses fan to remove heat from computer equipment and generates relatively low-temperature waste heat that must be moved in large volumes. **Liquid cooling and immersion** cooling removes heat by bringing liquid coolants into direct contact with computer components, absorbing heat at its source with higher temperature.

At the building level, cooling systems transport heat from servers to the facility boundary and prepare it for release or reuse. **Air-based cooling systems**, common in smaller or older data centers, move heat through air handlers and exhaust it directly outdoors, functioning similarly to large air-conditioning units and creating localized warming that can raise microclimate temperatures. These systems also rely on chemical refrigerants called HFCs, which are extremely powerful greenhouse gases that contribute to global warming.[90]

Closed-loop cooling systems collect heat through a chilled-water or glycol loop within sealed pipes and transport it to outdoor heat exchangers. These systems reduce water consumption and improve energy efficiency compared to open-loop approaches, while still releasing heat to the surrounding air. Closed-loop systems are commonly used in hyperscale data centers and involve higher upfront capital costs, but they moderate both thermal discharge and air pollution relative to air-based cooling.

At the **environment level**, heat is ultimately released, or in some cases, reused through specific heat rejection technologies. **Evaporative cooling systems** reject heat using water, which is then evaporated (i.e., typically around 80%) into the atmosphere. The remaining heated water can pose a risk of thermal pollution if it is discharged directly into nearby waterbodies. In practice, however, most heated water is routed through wastewater treatment and sewage

---

[89] Yuan, X., Liang, Y., Hu, X., Xu, Y., Chen, Y., & Kosonen, R. (2023, December). Waste heat recoveries in data centers: A review. *Renewable and Sustainable Energy Reviews*, *188*. https://doi.org/10.1016/j.rser.2023.113777

[90] Honeywell. (n.d.). *Design for more efficient data centers*. Retrieved January 12, 2026, from https://www.honeywell.com/content/dam/honeywellbt/en/documents/downloads/hon-corp-design-for-more-efficient-data-centers-whitepaper.pdf

systems, where it cools significantly before discharge, resulting in minimal remaining heat and limited risk to the environment. These systems do not significantly increase local air temperature but do increase humidity and have minimal direct air pollution impacts. As a result, evaporative cooling primarily shifts thermal and environmental impacts toward water systems rather than air. They are widely used in the industry, moderately priced, water-intensive, energy-efficient, and require proper wastewater management.

Dry cooling systems, often paired with closed-loop circulation, reject heat directly to the atmosphere using fans and air-cooled heat exchangers. These systems produce moderate localized heat discharge, but minimal water use and limited air pollution. Their effectiveness depends on ambient temperatures, making them more suitable for cooler climates or water-constrained regions.

When paired with liquid or immersion cooling at the server level, building- and environment-level systems can more easily support **heat reuse**, such as supplying nearby buildings or district energy networks. Because heat is captured at higher temperatures, these systems can more easily support heat reuse for nearby buildings or facilities, reducing how much heat is exhausted outdoors. As a result, these systems generate the least external heat waste, cause minimal warming around the data center, and have negligible air pollution impacts. Although this technology is emerging and the most expensive to deploy, it is highly efficient in both water and energy use and requires appropriate disposal of spent coolants.

Beyond cooling systems, backup diesel generators are another major contributor to air pollution, emitting significant amounts of PM2.5 and nitrogen oxides (NOx) when operated. Although generators are used infrequently during outages, their cumulative impacts warrant caution. According to EPA's COBRA modeling tool, emissions from Virginia's data center backup generators impose an annual public health cost of approximately $200-300 million.[91] The air pollution could also be worsen as local policies prioritize grid resilience during extreme weather and permits more operation hours for backup diesel generators to lower demands on grid connections (see Section 8.3 for details).

8.2 How Do Data Centers Handle Wastewater and E-Waste?

For **evaporative water systems**, wastewater can contain concentrated minerals and treatment chemicals. A key public health concern is the microbial contaminant *Legionella pneumophila*, which can cause the deadly Legionnaires' disease.[92] In an interview, a developer reported

[91] Wierman, A. (2025, November 5). *Mitigating the Public Health Impacts of AI Data Centers*. Harvard Business Review. Retrieved January 12, 2026, from https://hbr.org/2025/11/mitigating-the-public-health-impacts-of-ai-data-centers

[92] Falkinham III, J. O., Hilborn, E. D., Arduino, M. J., Pruden, A., & Edwards, M. A. (2015). Epidemiology and ecology of opportunistic premise plumbing pathogens: Legionella pneumophila, Mycobacterium avium, and Pseudomonas aeruginosa. *Environmental health perspectives*, *123*(8), 749.

conducting routine testing for Legionella when evaporative cooling is used to monitor potential public health risks.

For **closed-loop or immersion cooling systems**, the water–glycol mixture and chemical coolants are fixed in sealed pipes and are typically disposed of as industrial waste rather than discharged directly into sewage systems. While wastewater risks are minimal, coolant leaks and end-of-use disposal can pose additional environmental concerns.

Data centers also generate substantial e-waste as computer equipment is upgraded every two to three years. Reporters have noted that large amounts of Pfas are used in manufacturing these components and cooling systems.[93] [94] Because Pfas chemicals do not break down in the environment, they can pose serious and long-lasting environmental health risks.

8.3 How are Data Centers' Environmental Impacts Regulated?

The largest environmental impacts of data centers involve energy and water consumption, which can have deep ecological consequences for the generation, maintenance, and distribution of these resources. At the regional scale, air pollution and waste impacts are dispersed, while at the neighborhood scale, heat, noise, and light pollution are more visible and immediate (see Section 6.3 for residential experience impact).

Environmental review requirements vary widely across states.[95] Some states require environmental impact statements that scrutinize energy demand, water use, and emissions, while others lacking such frameworks may overlook these impacts entirely. Overall, air pollution, wastewater, and noise are the most clearly regulated at federal or local levels, whereas impacts like heat and light are more ambient and difficult to isolate and quantify. Local governments and planners must therefore understand what federal law covers and what falls outside its scope, and proactively develop local approaches to address these externalities.

Air Pollution. The Environmental Protection Agency (EPA), along with state environmental agencies, regulates air pollution from data centers under the Clean Air Act, which requires permits for diesel generators and other stationary emission sources.[96] In 2025, EPA issued new guidance allowing emergency generators to operate up to 50 hours per year in non-emergency

---

[93] Perkins, T. (2025, October 4). Advocates raise alarm over Pfas pollution from datacenters amid AI boom. *The Guardian*. https://www.theguardian.com/environment/2025/oct/04/pfas-pollution-data-centers-ai

[94] Clean Water Action. (2025, March 2). *Data Centers - A Threat To Minnesota's Water*. Retrieved January 12, 2026, from https://cleanwater.org/publications/data-centers-threat-minnesotas-water

[95] Nichols, C. (2025, October 1). *The Physical Footprint of Artificial Intelligence*. American Planning Association. Retrieved January 12, 2026, from https://www.planning.org/publications/document/9318086/

[96] United States Environmental Protection Agency. (2025). *Clean Air Act Resources for Data Centers*. Retrieved January 12, 2026, from https://www.epa.gov/stationary-sources-air-pollution/clean-air-act-resources-data-centers

situations.[97] Yet evidence shows that some data centers have been able to circumvent EPA regulations to increase generator operation hours during summer peaks, raising public concerns.[98]

Waste. For data centers using evaporative cooling systems, if wastewater is discharged into a waterbody that qualifies as a "Water of the United States" under the Clean Water Act, they must obtain a permit under the National Pollutant Discharge Elimination System (NPDES). If wastewater is discharged into municipal systems, facilities must comply with the Clean Water Act's National Pretreatment Program. E-waste and specialized chemicals, such as specialized coolants and certain electronic materials, may also fall under the EPA's Toxic Substances Control Act (TSCA), which has recently expedited reviews for emerging chemicals used in data center projects.[99]

Noise. Noise from diesel generators and cooling systems is typically regulated through local noise ordinances rather than by EPA. Interviewed developers noted that noise regulation has become increasingly common, especially when data centers are located near residential neighborhoods or in downtown areas. Even though data centers may have complied with noise ordinance and produce noise below the threshold, residents may still perceive this as a quality-of-life issue (see Section 6.3 for more details on noise impacts).

Light Pollution. There is no federal regulation on light, but local governments can regulate light pollution through zoning code or site plan review such as imposing shielding, fixture, and curfew requirements to minimize light impacts on nearby residents. Some states have outdoor lighting ordinances, though not targeted toward data centers. Developers may also be willing to do minor adjustments on the facilities to reduce noise and light impacts.[100]

Heat. EPA does not regulate heat exhaust from data centers, and the ecological implications of localized heat islands or microclimate warming remain largely unknown. Most modern data centers do not discharge heated water directly into natural water bodies, so they rarely trigger Clean Water Act's thermal regulation. On the other hand, data center operators begin to explore heat export as a way to capture and reuse the waste heat generated on-site, providing nearby

---

[97] United States Environmental Protection Agency. (2025, May 1). *EPA Issues Clarification to Help Power Data Centers, Ensure U.S. Is the AI Capital of the World*. EPA Press Office. Retrieved January 12, 2026, from https://www.epa.gov/newsreleases/epa-issues-clarification-help-power-data-centers-ensure-us-ai-capital-world

[98] Piedmont Environmental Council. (n.d.). *Data Centers, Diesel Generators and Air Quality – PEC Web Map*. Retrieved January 12, 2026, from https://www.pecva.org/uncategorized/data-centers-diesel-generators-and-air-quality-pec-web-map/

[99] United States Environmental Protection Agency. (2025, September 18). *EPA Prioritizes Review of New Chemicals Used in Data Center Projects, Supporting American Manufacturing and Technological Advancement*. Retrieved January 12, 2026, from https://www.epa.gov/newsreleases/epa-prioritizes-review-new-chemicals-used-data-center-projects-supporting-american

[100] *Outdoor Lighting Ordinances - DesignLights*. (n.d.). DesignLights Consortium. Retrieved January 12, 2026, from https://designlights.org/outdoor-lighting-ordinances/

communities with a productive energy source rather than releasing it into the atmosphere.[101] Some Nordic countries have started to pair computer processing facilities with district heating systems to minimize environmental impacts.[102]

9. Contributors and Acknowledgement

Lead Author: Xiaofan Liang
Visual Guide: Yajun Dai, Matthew Wizinsky
Research, Writing, and Formatting: Samuel Sav, Katherine Cafaro, Huy Dung Lou, Chen Lyu
Interview: Samuel Sav, Katherine Cafaro

Guest Reviewers:
Shea Mckeon, Global Head of Design & Engineering Standards, Digital Realty
Rabab Haider, Assistant Professor, Civil and Engineering, University of Michigan
Tamra Mabbott, Planning Director, Morrow County, Oregon

Disclosure: This report used an AI writing assistant (ChatGPT 5.2) for light editorial support, including proofreading, improving clarity, and suggesting starting points for literature searches. All content, framing, and final edits were made by the lead author, and all references were verified against original sources.

[101] *What Is Data Center Heat Export and How Does it Work?* (2024, June 5). The Equinix Blog. Retrieved January 12, 2026, from https://blog.equinix.com/blog/2024/06/05/what-is-data-center-heat-export-and-how-does-it-work/
[102] Paulsson, L., Lundgren, K., & Pohjanpalo, K. (2025, May 13). Finland's Data Centers Are Heating Cities, Too. *Bloomberg.com*. https://www.bloomberg.com/news/features/2025-05-14/finland-s-data-centers-are-heating-cities-too?utm_source=chatgpt.com