Silicon Streams and Concrete Forests: Entitled Capacity, Resource Demand, and the Scale Mismatch in Northern Virginia Data Center Governance

Authors: Ryan S. Nisay, Christian S. Shire, Karthik Uppalapati, Enzo Garcia-Eguiluz, Nawaf Shehzad, Daniela Morales, Tyler Gorthy, Evan Giglotti, Shray Vij, Jose R. Herrera

Affiliation: Loudoun Nature Conservation Project, Virginia, USA

Correspondence: Ryan S. Nisay, Executive Director, Loudoun Nature Conservation Project. Email: Ryan.nisay@loudounnatureconservation.org

Keywords: data centers; land use entitlement; cumulative effects; energy governance; water demand; electricity load; Northern Virginia

Abbreviations:
CO, carbon monoxide
DEQ, Department of Environmental Quality
GIS, geographic information system
IEA, International Energy Agency
JLARC, Joint Legislative Audit and Review Commission
MGD, million gallons per day
MW, megawatt
NOx, nitrogen oxides
PJM, PJM Interconnection
PM, particulate matter
RPM, Reliability Pricing Model
SCC, State Corporation Commission

Preprint. Not peer reviewed.

Abstract

Northern Virginia has the largest concentration of data centers in the world, and debate over whether it can keep growing usually runs on forecasts of future demand. We instead built a facility-level inventory from county GIS records of legally entitled land, which measures the upper-bound potential of what can be built rather than a construction forecast. Loudoun and Prince William Counties have entitled 147 million square feet of data center floor area, having built approximately 49 million. At the load intensity implied by the state's own audit, the entitled total corresponds to 11,781 megawatts, 2.3 times the current load of every data center in Virginia, and to 13.2 to 14.7 million gallons of water per day, 2.3 to 2.6 times current statewide data center use. The jobs most often cited as the industry's economic benefit are primarily construction jobs that end with buildout, while resource demand lasts for each facility's life. PJM's independent market monitor attributes $16.6 billion in capacity market cost increases across two auctions to data center load. We find that data center siting regulations are active: Loudoun ended by-right data center development in 2025, and Prince William cut its data center overlay district by more than half in 2026. Every siting and water instrument in the region still applies to a single parcel or utility, and no venue evaluates the entitled total, so expansion at the entitled scale cannot be reconciled with governance as it is currently structured.

I. Introduction

Data centers are usually discussed as digital infrastructure, but they are industrial facilities that use land, electricity, and water at an industrial scale, and local governments permit them one parcel at a time with review authority that ends at the property line. Northern Virginia is where that arrangement is under the most pressure. According to the Joint Legislative Audit and

Review Commission (JLARC), 80 percent of Virginia's data center industry lies in three localities, Loudoun, Prince William, and Fairfax Counties, and the region holds 13 percent of reported global data center operational capacity and 25 percent of capacity in the Americas (JLARC 2024), with JLARC counting over 63 million square feet of data center space statewide drawing roughly 5,050 megawatts.

The new load reflects a sharp acceleration in demand for computing, much of it tied to artificial intelligence. Nationally, Lawrence Berkeley National Laboratory estimates that United States data center electricity use rose from 58 terawatt-hours in 2014 to 176 terawatt-hours in 2023, about 4.4 percent of national electricity, and projects 325 to 580 terawatt-hours by 2028 (Shehabi et al. 2024). Hyperscale operators, the large cloud companies whose own facilities drive most capacity growth, held 44 percent of worldwide data center capacity in early 2025, and Synergy Research Group projects 61 percent by 2030 as hyperscale capacity roughly triples (Synergy Research Group 2025). Globally, data centers are not a dominant driver of electricity demand growth (IEA 2025), but in Virginia JLARC finds they are the main driver of a forecast doubling of state electricity demand over a decade.

Debates over whether this growth is sustainable rely on forecasts of artificial intelligence adoption, computing efficiency, and market growth, all of which analysts dispute. Our focus in this paper is what has already been approved. Land use entitlement is public record, it does not depend on a growth assumption, and floor area that has cleared rezoning does not need another rezoning before it is built. Two counties have entitled enough floor area to more than double

Virginia's data center electrical load if it is built out, and no body with jurisdiction over the affected resource systems has assessed that entitlement as a total.

We began with the working hypothesis that expansion is conditionally unsustainable under current frameworks but could align with environmental stewardship through targeted reform and regional planning. Two findings required us to drop a common framing of the problem: local siting regulation is substantive and enforced, and backup generators are a small share of regional air pollution according to the state's own audit.

II. Methods

We built the inventory from county-published ArcGIS REST services rather than from press accounts, industry databases, or aggregated state totals, and because each county publishes its buildout data under different definitions, we recorded the source field for every quantity. For Loudoun County, we queried the Build Out Land Use map service, which reports data center floor area in three tiers for each non-residential development area (existing, in refined development plans, and permitted by zoning) as of 1 July 2025. The county's Existing Structures layer, filtered to its data center land use code, returned 223 structures with coordinates and build years but no floor area, so all Loudoun floor area figures come from the development area layer. For Prince William County, we queried the Build Out Analysis map service, which publishes a Data Center Buildings layer (246 records, 209 after excluding 37 Digital Gateway buildings) with gross, approved, permitted, and tax-assessed floor area, building status, year built, and an overlay-district flag, and a Data Center Campuses layer (75 records, 72 after excluding the three voided Digital Gateway campuses) with planned and remaining floor area, acreage, and zoning

district. Fairfax County could not be inventoried: its parcel and non-residential floor area layers have no data center classification, so data centers are recorded under generic industrial and office codes. Every two-county total in this paper is therefore a lower bound for the region, and a full accounting requires Fairfax to publish data center floor area in its own records.

Converting floor area to resource demand requires an intensity, and intensities from different sources cannot be combined safely because their numerators and denominators may describe different sets of facilities. For electricity, we used an intensity for which a single authoritative document reports both quantities: 80.2 watts per square foot, the ratio JLARC (2024) implies in reporting approximately 5,050 megawatts of Virginia data center load (from the 2024 Dominion Energy and electric cooperative peak load forecast) across over 63 million square feet of data center space. For water, where no matched pair is published, we used 90 to 100 gallons per day per 1,000 square feet, the average Fairfax Water measured at operating data centers and found comparable in Loudoun Water and Prince William County Service Authority data (Fairfax County Department of Planning and Development 2024), carrying the range by its endpoints throughout. For household equivalence, we used JLARC's own figure of 396 households per megawatt (5,050 megawatts to the electricity needs of approximately 2 million Virginia households) rather than constructing one.

Each intensity was validated against an independent aggregate before use. Applied to the combined built stock of Loudoun and Prince William, 80.2 watts per square foot yields 3,921 megawatts (78 percent of statewide data center load), while JLARC independently places 80 percent of the industry in Loudoun, Prince William, and Fairfax, a difference of two percentage

points in the expected direction because Fairfax is absent from our inventory. Applied to Loudoun's built stock, the water intensity yields 3.2 to 3.6 million gallons per day (56 to 62 percent of JLARC's statewide total of about 5.75 million gallons per day), consistent with JLARC placing approximately half the state's industry in Loudoun. To prevent citation drift across our ten-person team, Phase 1 produced eight background research documents and extracted every quantitative claim into a register of 391 claims detailing values, units, years, geography, sources, evidence tiers, source caveats, and verbatim snippets verified programmatically against the source text. We then resolved every academic citation against CrossRef, arXiv, and NCBI and checked every claim attributed to JLARC Report 598 against the full 156-page report: the check found three sourcing errors, showed that the most-cited health source in the review is an unrefereed preprint, and turned up the construction-versus-operations split reported in the results.

The inventory measures entitled and built floor area; it does not attempt to measure operating loads, metered water use, or facility emissions, and does not attempt causation for any ecological or health outcome in the study area, so the resource figures are conversions of floor area at fixed intensities rather than direct measurements. The facility lifecycle, including semiconductor manufacturing, mineral extraction, electronic waste, and supply chain labor, is out of scope because none of it can be measured at the county level, and assigning a share of a global supply chain to a Northern Virginia building would require assumptions the data cannot support. Treating the lifecycle qualitatively while quantifying operational demand would also produce the kind of incommensurable comparison we criticize in the benefit ledger. Finally, we did not

conduct ecological fieldwork, and the dose-response relationships in the discussion come from the general urbanization literature.

III. Results

Loudoun and Prince William Counties share an entitled total of 147.0 million square feet of data center floor area, with 48.9 million built and 98.1 million requiring no further rezoning (Figure 1A). The two counties are at very different stages. Loudoun's GIS layer (1 July 2025) shows 35.7 million square feet built and a further 35.1 million approved or zoned but not yet built (70.8 million total), representing a mature market with an unbuilt pipeline roughly equal to its built stock. Excluding the voided Digital Gateway, Prince William has 13.2 million square feet completed across 57 buildings, 8.9 million under construction across 30 buildings, and 42.0 million planned or pending across 122 buildings, and its campuses carry 76.2 million square feet of planned floor area across 4,058 acres, an unbuilt pipeline 4.8 times its built stock.

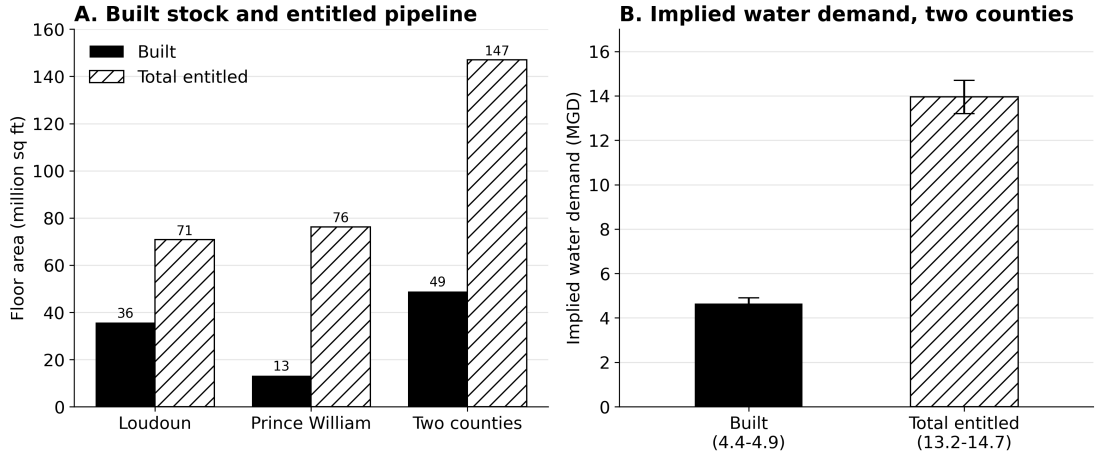


Figure 1. Built and entitled data center floor area and implied water demand. Panel A compares built floor area with total entitled floor area for Loudoun, Prince William, and the two counties combined. Panel B converts the two-county built and entitled floor area to water demand at 90 to

100 gallons per day per 1,000 square feet, with the bar at the midpoint and the whisker spanning the range. Loudoun data as of 1 July 2025; Prince William from the Build Out Analysis service, excluding the three voided Digital Gateway campuses. Fairfax County is excluded because its assessment system contains no data center classification.

The two counties also define entitlement differently: Loudoun's figure is zoned capacity and Prince William's is campus planned floor area, so the 147 million square foot total is approximate, and both definitions should be stated wherever it appears. Two patterns emerge. Facilities are growing substantially larger: in Prince William, completed buildings average 231,915 square feet and pending buildings 494,201, a factor of 2.1, and Loudoun shows the same trend, with new buildings permitted since 2023 averaging about 339,000 square feet against 234,000 for the existing stock (Loudoun County 2026), so per-facility impact estimates drawn from the existing built stock will understate what has been entitled. Data centers also dominate Loudoun's non-residential built environment, comprising 61.4 percent of existing floor area (35.7 of 58.1 million square feet) and 40.0 percent of zoned non-residential capacity, with 61 development areas (5,420 acres) carrying a data center component and data centers making up more than half of zoned capacity in areas totaling 3,434 acres. Fairfax County could not be measured at all, which we treat as a governance finding as well as a data limitation: a county that cannot identify data centers in its own records cannot report their tax contribution, floor area, or growth, or evaluate their cumulative impact.

At the validated intensities, the built stock in the two counties draws an estimated 3,921 megawatts and 4.4 to 4.9 million gallons per day, while full entitled buildout would draw 11,781

megawatts (Figure 2) and 13.2 to 14.7 million gallons per day (Figure 1B): 2.3 times the electrical load of every data center in Virginia today and 2.3 to 2.6 times current statewide data center water use. In JLARC's household terms, 11,781 megawatts equals the electricity needs of about 4.7 million households in a state with about 3.3 million, and each county's entitlement alone exceeds current statewide data center load.

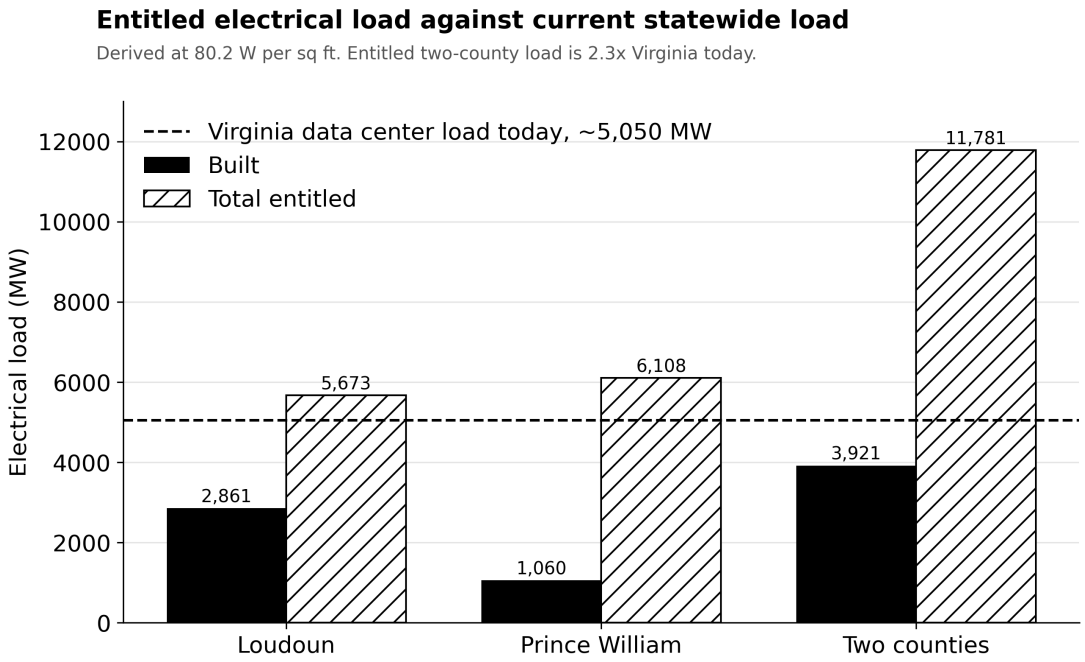


Figure 2. Electrical load by buildout tier, derived at 80.2 watts per square foot. The dashed reference line is the approximately 5,050 megawatts JLARC attributes to all Virginia data centers from the 2024 peak load forecast.

Table 1. Capacity, load, and water by county and tier

County	Tier	Floor area (M sq ft)	Load (MW)	Household-equivalents (M)	Water (MGD)
Loudoun	Built	35.7	2,861	1.13	3.2 to 3.6
Loudoun	Approved or zoned, not yet built	35.1	2,812	1.11	3.2 to 3.5
Loudoun	Total entitled	70.8	5,673	2.25	6.4 to 7.1
Prince William	Built (completed)	13.2	1,060	0.42	1.2 to 1.3
Prince William	Under construction	8.9	710	0.28	0.8 to 0.9
Prince William	Planned and pending, excluding Digital Gateway	42.0	3,364	1.33	3.8 to 4.2
Prince William	Total entitled (campus planned, excluding Digital Gateway)	76.2	6,108	2.42	6.9 to 7.6
Two counties	**Built**	**48.9**	**3,921**	**1.55**	**4.4 to 4.9**
Two counties	**Total entitled**	**147.0**	**11,781**	**4.67**	**13.2 to 14.7**

Three qualifications apply to these numbers. First and most importantly, they describe entitlement, not demand: they assume no growth rate or adoption curve and give no date for construction, and Loudoun County states that it does not expect all of its approved but unbuilt data center floor area to be built (Loudoun County 2026), so that caveat must accompany the figures wherever they are used. Second, the constant-intensity assumption errs in opposite directions for the two resources: for electricity it is conservative, because JLARC reports that the largest new data centers draw 100 to over 200 megawatts and that many under construction are larger than the existing stock (JLARC 2024), so if newer facilities draw more per square foot then 11,781 megawatts is a floor, while for water it may be generous, because cooling designs are moving toward lower water use. Third, withdrawal and consumption differ: JLARC reports that just over a third of Virginia's 2023 data center water came from reclaimed water rather than new withdrawals, which protects drinking water supply, but water routed through evaporative cooling leaves the basin as vapor instead of returning to the stream.

The industry's most-cited economic contribution (74,000 jobs, $5.5 billion in annual labor income, and $9.1 billion in annual state gross domestic product) comes mostly from construction: 80 percent of the jobs, 78 percent of the labor income, and 70 percent of the GDP (JLARC 2024).

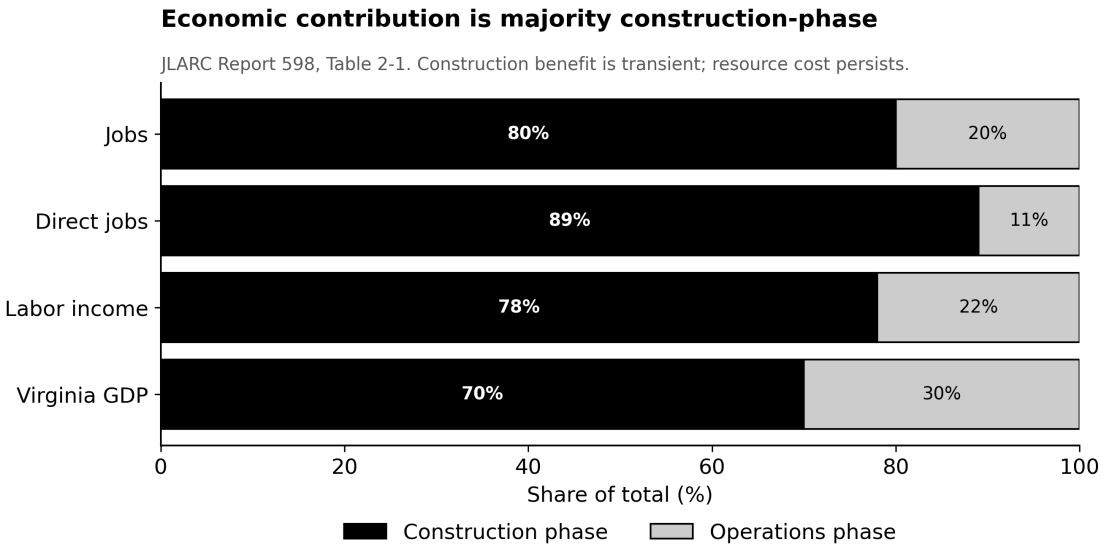


Figure 3. Economic contribution by construction and operations phase, from JLARC Report 598, Table 2-1, annual averages for fiscal years 2021 to 2023.

Table 2. Economic contribution by phase, Virginia statewide

Measure	Construction phase	Operations phase	Total	Construction share
Jobs	59,000	15,000	74,000	80%
Direct jobs	35,000	4,400	39,400	89%
Labor income ($B/yr)	4.3	1.2	5.5	78%
Virginia GDP ($B/yr)	6.4	2.7	9.1	70%

Construction benefits are temporary, while resource and infrastructure costs persist for the lifetime of a facility, so the 74,000 total should not be weighed against those costs as a standing benefit, even though it is usually quoted that way. Standing operations support 15,000 jobs

statewide (4,400 direct), and according to JLARC a typical 250,000 square foot data center employs about 50 full-time workers, roughly half of them contractors: one employee per 5,000 square feet, against one per 650 square feet for distribution centers. The whole industry is just over 1 percent of statewide employment, income, and gross domestic product. Locally, fiscal inflows vary greatly: Loudoun County collected $1.2 billion in data center real and personal property tax in fiscal 2026 (39 percent of the county budget), with $1.3 billion (40 percent) projected for fiscal 2027, while across the five Virginia localities with mature data center markets, data center revenue ranges from under 1 percent to 31 percent of total local revenue (JLARC 2024). Loudoun sits at or above the top of that range and should not be treated as typical of the region.

Table 3. Fiscal inflows by jurisdiction

Jurisdiction	Measure	Annual value	Share of local revenue	Source
Loudoun	Data center property tax, FY2026	$1.2 B	39% of county budget	Loudoun County
Loudoun	Projected FY2027	$1.3 B	40% of county budget	Loudoun County
Prince William	Data center real and personal property tax, tax year 2024	$280.2 M	About 16% of general fund tax revenue	Prince William County Department of Finance 2025
Fairfax	Data center property tax	Cannot be isolated	Cannot be isolated	No data center classification in the assessment system
Five mature markets	Range across localities	Not applicable	under 1% to 31%	JLARC 2024

Prince William's figure is the county finance department's tax year 2024 total as presented to the Board of County Supervisors (real property $130.7 million and computer and peripherals tax nearly $124 million). Because it is a share of general fund tax revenue rather than of the full budget, it does not compare directly to Loudoun's, and a higher total of $293.7 million in secondary reporting could not be traced to a county document.

The largest quantified cost of data center growth in the region falls on the regional capacity market, and the estimate comes from the market's own independent monitor: PJM's Market Monitoring Unit reports that data center load, actual and forecast, increased capacity market revenues in the 2025/2026 and 2026/2027 Base Residual Auctions by a combined $16,603,301,829, a total it expects to keep growing until the issues around large data center loads are addressed (Monitoring Analytics 2026). The monitor states that without data center growth the market would not have seen these tight supply-demand conditions or the resulting high prices, and that current conditions do not stem from organic load growth. Reliability Pricing Model revenue ran near $2.3 to $2.6 billion a year through the 2024/2025 delivery year and then rose to roughly $15 to $16.4 billion for 2025/2026 through 2027/2028, while the cleared-MW weighted average price went from $42.01 per megawatt-day for 2023/2024 to $333.44 for 2027/2028 (Monitoring Analytics 2026, Table 5-24). Nothing earlier in the series, which begins in 2007/2008, comes close. The 2028/2029 auction, whose results were released in July 2026, cleared at its $325 per megawatt-day cap with total cleared value unchanged at $16.4 billion (PJM Interconnection 2025, 2026).

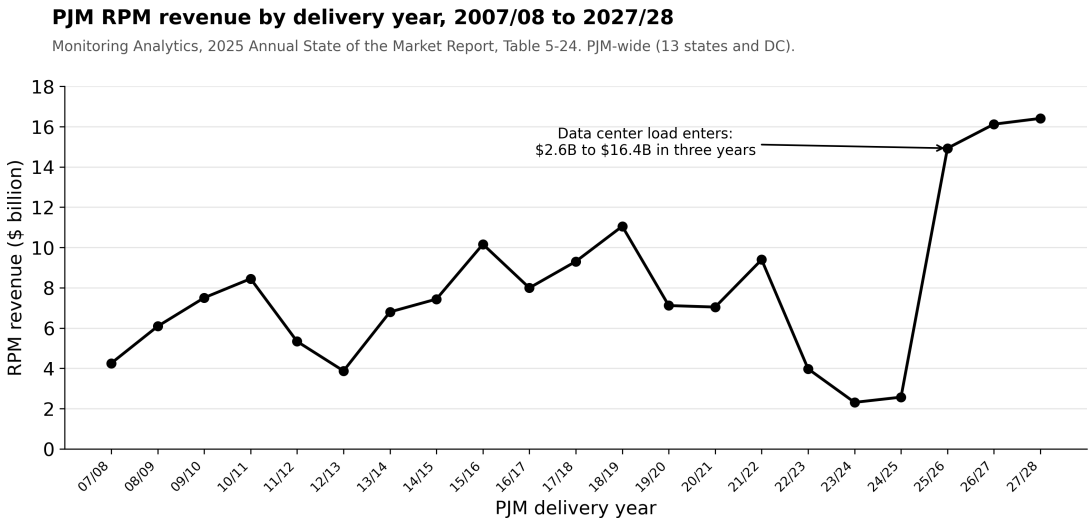


Figure 4. RPM revenue by delivery year, from Monitoring Analytics, 2025 Annual State of the Market Report for PJM, Section 5, Table 5-24. Values are PJM-wide, covering 13 states and the District of Columbia.

These costs fall across the entire PJM footprint (all or part of thirteen states and the District of Columbia), so they are not Virginia costs and should not be set beside a Virginia or county benefit figure without saying so. The Virginia-specific consumer cost is JLARC's estimate that residential customers will pay $14 to $37 more per month by 2040 in constant dollars.

Table 4. Cost lines and their evidentiary status

Cost line	Value	Scope	Source	Status
Capacity market increase attributed to data center load	$16,603,301,829 across two auctions	PJM RTO (13 states and DC)	Monitoring Analytics 2026, Section 5	Verified from source; monitor's own but-for estimate
RPM revenue by delivery year, level shift	$2.57 B (2024/2025 delivery year) to $16.41 B (2027/2028)	PJM RTO	Monitoring Analytics 2026, Table 5-24	Verified against Table 5-24
Residential bill impact	$14 to $37 per month by 2040	Virginia (Dominion)	JLARC 2024	Verified
Backup generator NOx contribution	Under 4 percent of regional NOx	Northern Virginia	JLARC 2024	Verified
Backup generator CO and PM contribution	0.1 percent or less	Northern Virginia	JLARC 2024	Verified

Data center siting in Northern Virginia is actively regulated. Loudoun County eliminated by-right data center development on 18 March 2025, so every new application not grandfathered under the amendment now needs a special exception with hearings before the Planning Commission and the Board of Supervisors, and its rural policy area (about two-thirds of county land) does not permit data centers at all. The record shows review doing what it was designed to do, which is decide whether a given parcel is suitable: between 2022 and May 2026 the Board approved 32 of 39 legislative data center applications, in July 2026 the Planning Commission unanimously recommended denial of a 325-acre rezoning, and JLARC's assessment of natural and historic resource impacts found that existing regulations largely curb adverse impacts. Prince William followed on 22 September 2026, when its Board unanimously cut the Data Center Opportunity Zone Overlay District from about 9,700 acres to about 3,650, so most new data centers outside it now need a special use permit and a public vote (Prince William Board of County Supervisors 2026). At the state level, a law effective 1 July 2026 adds a site assessment for any facility expected to draw 100 megawatts or more, covering sound at homes and schools within 500 feet and, at the locality's option, effects on water, agricultural, park, historic, and forest resources on the site and adjacent land (Code of Virginia § 15.2-2209.4). Both changes tighten review of the parcel and its immediate surroundings, and neither asks whether the corridor as a whole has reached a limit.

Table 5. Governance instruments, unit of regulation, and finding

Instrument	Unit of regulation	Jurisdiction	Finding
Special exception review	Parcel	Loudoun	By-right eliminated March 2025; 32 of 39 approved 2022 to May 2026; one 325-acre rezoning recommended for denial
Rural policy area exclusion	Two-thirds of county land	Loudoun	Data centers not permitted
Site assessment for high energy use facilities	Parcel and adjacent land	Virginia (Code § 15.2-2209.4)	Effective 1 July 2026; sound within 500 feet required, water and resource effects at the locality's option
Data Center Opportunity Zone Overlay District	District	Prince William	About 17 percent of tracked data center floor area sat outside it before the reduction; cut from about 9,700 to about 3,650 acres on 22 September 2026, with a special use permit required outside it
Rate class GS-5	Utility customer class	Virginia SCC	Effective 1 January 2027
Demand response programs	Utility customer	Virginia	Data center companies do not participate
Air permit	Facility	Virginia DEQ	Tier 2 diesel in most existing permits; Tier 4 equivalent required for applications from 1 July 2026 (HB 507, 2026)
Water withdrawal reporting	Waterworks, not end user	Virginia DEQ	Data center sales reported as a category from January 2027; facility volumes remain confidential
Groundwater withdrawal permit	Designated Groundwater Management Area	Eastern Virginia, Eastern Shore	Does not reach Northern Virginia
Watershed impervious cover budget	Basin	Does not exist	No venue holds the geography
Regional cumulative capacity limit	Corridor	Does not exist	Loudoun moved to draft a pause in September 2026 despite stating it lacks the authority

The gap between parcel review and the corridor shows up in several measurable ways. First, committed development is invisible to current-conditions review: Loudoun's 35.1 million square feet of entitled but unbuilt floor area equals its entire built stock, so any review that measures existing conditions judges each new application against a baseline that leaves out that much committed development. Second, planning instruments fail to contain expansion: in Prince William, about 17 percent of tracked data center floor area (10.7 of 64.0 million square feet) sat outside the overlay district created to channel it when we queried the county's Buildings layer, and that was before the September 2026 reduction cut the district by more than half. Third, the

grid lacks a sequencing mechanism: the regional market monitor has recommended that PJM establish a load queue so that large new data center loads are not added until there is generation to serve them, and has said PJM should not interconnect such loads if it cannot do so reliably. Fourth, the industry declines the standard mitigation: JLARC reports that data center companies in Virginia do not participate in demand response programs, with company representatives saying their load follows computing demand, even though demand response is the most frequently proposed way of fitting this load onto the grid. Fifth, Loudoun is reaching for a tool it says it does not have: the county has said it lacks the legal authority to impose a moratorium, yet in September 2026 its Board voted 7 to 1, with one abstention, to draft a resolution pausing applications for a year while it develops regulations.

Virginia public opinion on data centers reversed between 2023 and 2026 across two independent polling series. A late March 2026 survey of 1,101 registered Virginia voters by The Washington Post and George Mason University's Schar School found that the share comfortable with a new data center in their community had fallen to 35 percent from 69 percent on the same question in 2023. Support for tax breaks for data centers creating at least 1,000 jobs fell from 61 percent to 37 percent on the same wording, only 26 percent supported continuing the sales and use tax exemption for data centers meeting investment requirements against 67 percent who wanted it ended, and 57 percent said data centers were having a negative effect on home energy bills against 14 percent who said they were helping. Virginia Commonwealth University's Wilder School poll in July 2026 found 72 percent opposed to the exemption, including 73 percent of Democrats and 69 percent of Republicans.

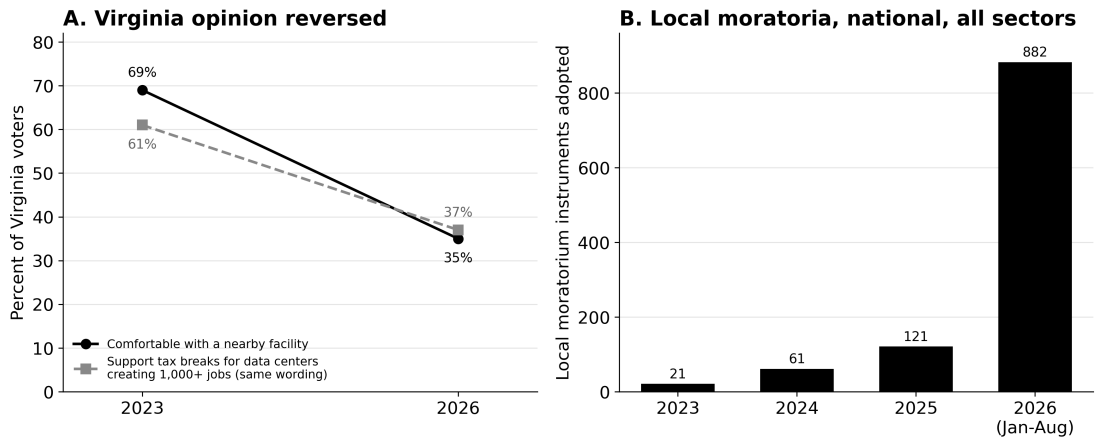


Figure 5. Panel A plots two Washington Post-Schar School questions asked with the same wording in 2023 and 2026, a two-point comparison three years apart rather than a continuous track. Panel B counts local moratorium instruments across all sectors by year of adoption from the Moratorium Nation dataset snapshot of 23 September 2026 (Bommarito 2026), with 2026 covering January through August.

The conflict has gone through three venues, and only rate regulation has produced lasting substantive change.

Table 6. Venues of conflict and their outcomes

Venue	What happened	Why it did or did not produce durable change
Litigation (Board of County Supervisors of Prince William County v. Oak Valley Homeowners Association)	The December 2023 Digital Gateway rezoning of roughly 1,790 acres was declared void ab initio for defective public notice; the Court of Appeals affirmed on 31 March 2026 and the project ended in July 2026.	Succeeded on advertising rules the General Assembly has since loosened by dropping the required interval between the two notices (Code of Virginia § 15.2-2204); residents won a right to be notified, not a right to be heard.
Moratoria (Moratorium Nation dataset; Bommarito 2026)	1,291 local instruments across 47 states by 23 September 2026: 21 adopted in 2023, 61 in 2024, 121 in 2025, and 882 in the first eight months of 2026, with most of the 2023 and 2024 instruments being New York pauses on battery storage (Bommarito 2026).	Mostly temporary pauses rather than prohibitions, typically adopted while a locality drafts standards it does not yet have.
Rate regulation (Virginia SCC, Dominion biennial review)	A GS-5 rate class for customers demanding 25 megawatts or more, effective 1 January 2027, with minimum demand charges; a 31 July 2026 order makes contributions toward transmission facilities built for new large loads mandatory and directs Dominion to develop a policy assigning such costs directly to them (Virginia State Corporation Commission 2026).	The most substantive reallocation, because cost causation is a question public utility commissions exist to answer.

Across the three venues, opponents and officials succeeded where an existing framework already had jurisdiction and a settled decision rule, and stalled where a new one would have been needed. Table 7 collects the evidence that cuts against our working hypothesis.

Table 7. Counterweight evidence

Finding	Source	Consequence
Backup generators contribute under 4 percent of regional NOx and 0.1 percent or less of CO and PM	JLARC 2024	Weakens the maximum-permitted-operation health framing common in advocacy material
Operators report zero to two minor outages per site over two years	JLARC 2024	Self-reported interview data, not metered compliance records
JLARC concludes current data center water use is sustainable	JLARC 2024	The paper disputes the entitled total, not current use
Data centers are under 0.5 percent of statewide water withdrawals; an industry-aligned estimate puts 2025 consumption at 1.4 percent	JLARC 2024; Taxpayers Protection Alliance 2026	The industry-aligned figure is the higher one, contrary to the expected direction of sponsorship bias
No measurable negative effect of data center proximity on home prices, sometimes a small positive one	Waters and Clower 2025 (GMU Schar School report); Priest 2026 (SSRN working paper)	Neither source is refereed
52 percent of Virginia voters say they would be more likely to support a local facility powered entirely by renewables with no on-site fossil generation	Stand.earth 2026 (Morning Consult survey)	Opposition is conditional on how facilities are powered, not categorical
Local siting regulation is substantive and enforced	Loudoun County; Holland and Knight 2025	The region is not ungoverned
The industry is just over 1 percent of statewide employment, income, and GDP	JLARC 2024	Cuts both ways: it limits the benefit claim and the economic-disruption claim

IV. Discussion

The governance failure documented here is specific: Northern Virginia does not lack data center regulation, but its unit of decision does not match the unit of impact, and current policy is scoped entirely to the former. Odum (1982) described this as degradation that comes from many individually reasonable decisions, none of which is the one that crosses the threshold. Duinker and Greig (2006) argue that cumulative effects assessment cannot work inside project-level review, because no single proponent can assess or manage a regional trajectory, and that regional strategic assessment is the only workable venue, while Theobald et al. (1997) show that the cumulative habitat effects of incremental development are measurable and much larger than per-project analyses suggest. Northern Virginia mirrors this structural mismatch in three ways. First,

watersheds cross jurisdictions, so no single board holds the area over which the impervious cover threshold is defined. Second, substations and transmission corridors are permitted separately from the facilities that need them, so linear infrastructure is never counted against the building footprint that drives it. Third, approved but unbuilt capacity does not appear in current-conditions review. The water system confirms the mismatch through an independent regulatory pathway, which shows the mechanism is structural rather than an artifact of one statute: withdrawal reporting attaches to the waterworks, not the end user, so even after January 2027, when waterworks begin reporting data center sales as a separate category, consumption appears only in each utility's aggregate and never by facility (HB 496, 2026), and the groundwater permit program does not cover Northern Virginia (Virginia Department of Environmental Quality, 9VAC25-610).

Whether renewable procurement, the most commonly proposed remedy, actually cleans the entitled load depends on the difference between average and marginal emissions: average emissions describe a grid's overall generation mix, while marginal emissions describe which generator runs to serve one more unit of demand, and average factors can badly misestimate the emissions consequence of a change in load (Siler-Evans et al. 2012). Data centers add a large, constant load around the clock, including hours when wind and solar output is low, so much of their added demand is met by dispatchable fossil generation even on a grid with substantial renewable capacity. Corporate procurement that matches a facility's consumption with clean generation on an annual basis, the common practice, has minimal effect on long-run system emissions, while matching on an hourly basis produces real reductions (Xu et al. 2024), so a facility's average accounting can look clean while its marginal effect stays fossil-intensive.

Because the science already supplies the units, establishing a threshold is not speculative. A watershed impervious cover budget, allocated across jurisdictions within each basin and applied to cumulative approvals rather than individual applications, follows from the impervious cover model and from the finding that stormwater mitigation cannot restore a stream past a degradation threshold (Schueler et al. 2009; Booth and Jackson 1997). Because spatial arrangement matters independently of total area (King et al. 2005), the budget would need to be spatially explicit rather than a simple acreage cap. A corridor-scale forest interior target follows from the fragmentation literature (Haddad et al. 2015; Riitters et al. 2012), and counting substation and transmission footprint against the same budget as the facilities they serve follows from the work on linear infrastructure (Forman and Alexander 1998). The market monitor's proposed load queue is the grid-side version of the same instrument, applying to the aggregate rather than to each interconnection request. What is missing is a body with jurisdiction over a watershed.

The evidence refutes a common framing while supporting a sharper, more serious one. The claim that Northern Virginia data center expansion proceeds without environmental regulation is contradicted by the siting record, the generator emissions share, JLARC's water assessment, and the property value studies. Instead, the evidence exposes a failure in which two counties have entitled floor area exceeding anything the grid or the water system is currently planned around, no venue has evaluated that total, no instrument applies to it, and the thresholds that would decide whether it is sustainable are defined at scales no existing decision-maker covers. The condition in our hypothesis therefore holds: what reconciliation requires is a venue at basin and corridor scale, not stricter parcel review.

V. Policy Implications

Three measures follow. First, entitled capacity should become a reported quantity: Loudoun and Prince William already report it and Fairfax cannot, so requiring localities to report data center floor area by tier and to classify data centers as a distinct land use in assessment records costs little and makes the other measures possible. Second, and most important, some body needs jurisdiction at basin and corridor scale, whether the instrument is a watershed impervious cover budget, a corridor forest interior target, or an aggregate load threshold, since tightening parcel review cannot address cumulative effects. Third, the sales and use tax exemption is the one instrument with statewide reach over an industry governed locally, and JLARC's own policy options already attach conditions to eligibility, from generator tiers to historic-resource and sound studies. The 2026 to 2028 budget kept the exemption without conditions and instead added an electricity consumption tax of 1.1 cents per kilowatt-hour on data centers (general fund deposits capped at $600 million a year), which raises revenue from the load without placing any condition on where or how much of it is built (Virginia General Assembly 2026).

On the grid side, endorsing the market monitor's load queue costs the Commonwealth nothing, and policy should not rely on demand response, since the industry has said its load follows computing demand and it does not participate. On the water side, reporting should reach the end user: the category reporting that begins in January 2027 moves in that direction, but individual facility volumes remain trade secrets, so consumption still cannot be measured facility by facility in the region where it is most concentrated. Finally, SB 843, filed for the 2027 session, would bar local approval of data center rezonings, special exceptions, special use permits, and site plans statewide from 1 July 2027 until it sunsets on 1 July 2030, and would bar state permits for data

center siting, interconnection, and on-site generation over the same period (SB 843, 2026). Because it reaches site plans, it would pause buildout of already-entitled floor area as well as new entitlements, but it sets no cumulative limit and expires without one, deferring the question of what total the basin and the grid can carry rather than answering it.

VI. Limitations and Open Items

Three general limits apply. First, Fairfax County is absent, so every two-county figure is a lower bound. Second, the two counties define entitlement differently, so the 147 million square foot total is approximate. Third, the resource figures are conversions of floor area rather than metered measurements, and the ecological and health relationships in the discussion come from the general literature rather than local findings.

Two limits apply to the public opinion record. First, a baseline wording caveat applies: the 2023 Post-Schar survey described the tax break as going to companies that create at least 1,000 jobs, far more than a typical data center employs, although the same wording still fell to 37 percent in 2026 and a separately worded question on the current exemption found only 26 percent support, so the direction of the shift is clear even if its size is uncertain. Second, public hearing testimony does not measure community sentiment: the Prince William Digital Gateway was approved in December 2023 after a public meeting that ran about 27 hours, and commenters at planning and zoning meetings skew toward opponents and toward older, male, longtime homeowners (Einstein et al. 2019), a skew that moving meetings online does not fix (Einstein et al. 2023), so hearing records show what concerns exist better than how widely they are shared. Local

objection is not simple proximity self-interest either, since objections track perceived impacts, trust in the developer, and procedural fairness more than distance (Devine-Wright 2009).

Two widely circulated health burden figures were left out of the cost ledger: the national figure comes from a preprint (Han et al. 2024) that is now in its fourth version and has been retitled from quantifying the public health impact of artificial intelligence to estimating the public health impact of data centers, a narrower scope and softer verb that the quoted figures may not survive, and the Virginia figure could not be traced to any source. Leaving them out does not mean the health pathway is unimportant, only that this study cannot yet quantify it.

The Prince William entitled total excludes the three Digital Gateway campuses (Digital Gateway North, Digital Gateway South, and Compass), which together carry 22.3 million square feet of planned floor area in 37 pending buildings on 1,760 acres of campus land, all outside the overlay district. The county's Data Center Campuses table still listed all three as pending when we checked it in October 2026, even though the rezonings were declared void and the project ended in July 2026. The same table does not list the Dulles South Innovation Center, whose comprehensive plan amendment the Board rejected that month, and it has been updated since our original query (99.5 million square feet across 78 campuses, against the 98.5 million across 75 we used), so the Prince William figures describe the layer on our query date. The September 2026 overlay reduction also means most planned floor area outside the new boundary will need a special use permit. Finally, one labeling discrepancy in Loudoun's published figures remains unresolved: the county's public data center page reports approximately 35.7 million square feet as approved but not yet built (as of 1 March 2026), while its GIS buildout layer gives 35,697,516 square feet as existing data center floor area (as of 1 July 2025), the same number under opposite

labels eight months apart. This paper cites the GIS field definitions, which are unambiguous, and reports the discrepancy rather than resolving it. The same county page puts Loudoun at 56.5 million square feet built or under construction as of 1 March 2026, alongside the 35.7 million approved but not yet built (Loudoun County 2026), a combined 92.2 million that exceeds the 70.8 million entitled in the July 2025 GIS layer, partly because the county issued building permits for over 10 million square feet of data center space in 2025, so the Loudoun figures in this paper are conservative.

VII. Conclusion

Loudoun and Prince William Counties have entitled 147 million square feet of data center floor area, having built 49 million, and at validated intensities the unbuilt remainder represents roughly 7,900 megawatts and 9 to 10 million gallons per day of additional demand. Local review of where these facilities go is active and enforced, so the problem is not permissiveness at the parcel: entitled capacity accumulates across parcels, jurisdictions, and regulatory systems that were each designed to evaluate something smaller, and the thresholds that decide whether the total is sustainable sit at scales no current decision-maker covers. Under current governance, no decision-maker is in a position to reconcile expansion at the entitled scale with those thresholds. Making it reconcilable would take three things: a body with jurisdiction over the basin and the corridor, reporting that makes entitled capacity and end-user water use visible, and a sequencing rule on the grid, so that someone is asked whether the total has reached a limit and not only whether each parcel is suitable.

Data and Code Availability

The facility inventories, the claims register, the capacity market revenue series, and the results tables are available from the corresponding author on request, along with the documented retrieval and validation procedure.

References

Bommarito, M. J. 2026. Moratorium Nation: a survey of data center, renewable energy, and battery storage moratoria in the United States. Working paper, SSRN 6242898, with open dataset (CC-BY-4.0), snapshot of 23 September 2026.

Booth, D. B., and C. R. Jackson. 1997. Urbanization of aquatic systems: degradation thresholds, stormwater detection, and the limits of mitigation. *Journal of the American Water Resources Association* 33(5): 1077–1090. doi:10.1111/j.1752-1688.1997.tb04126.x

Code of Virginia § 15.2-2204. Advertisement of plans, ordinances, etc.; joint public hearings; written notice of certain amendments. As amended through 2025.

Code of Virginia § 15.2-2209.4. Siting of data centers; site assessment; high energy use facility. 2026 Acts of Assembly, chapter 567 (HB 153), effective 1 July 2026.

Court of Appeals of Virginia. 2026. Board of County Supervisors of Prince William County v. Oak Valley Homeowners Association, Inc., Record Nos. 1584-25-4, 1590-25-4, and 1592-25-4. Published opinion, 31 March 2026.

Devine-Wright, P. 2009. Rethinking NIMBYism: the role of place attachment and place identity in explaining place-protective action. *Journal of Community and Applied Social Psychology* 19(6): 426–441.

Duinker, P. N., and L. A. Greig. 2006. The impotence of cumulative effects assessment in Canada: ailments and ideas for redeployment. *Environmental Management* 37(2): 153–161. doi:10.1007/s00267-004-0240-5

Einstein, K. L., D. M. Glick, and M. Palmer. 2019. *Neighborhood Defenders: Participatory Politics and America's Housing Crisis.* Cambridge University Press.

Einstein, K. L., D. M. Glick, L. Godinez Puig, and M. Palmer. 2023. Still muted: the limited participatory democracy of Zoom public meetings. *Urban Affairs Review* 59(4): 1279–1291.

Fairfax County Department of Planning and Development. 2024. *Data Centers: Report and Recommendations*. 9 January 2024. Water demand findings from Fairfax Water (Attachment 2).

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29: 207–231. doi:10.1146/annurev.ecolsys.29.1.207

Haddad, N. M., et al. 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances* 1(2): e1500052. doi:10.1126/sciadv.1500052

Han, Y., Z. Wu, P. Li, A. Wierman, and S. Ren. 2024. Health-informed computing: estimating and addressing the public health impact of data centers. arXiv:2412.06288. Preprint, version 4; originally titled "The Unpaid Toll: Quantifying the Public Health Impact of AI." Not peer reviewed; cited here only to note its exclusion.

HB 496. 2026. Water withdrawal reporting; water provided to data centers. 2026 Acts of Assembly, chapter 623, identical to SB 553; effective 1 January 2027.

HB 507. 2026. Data centers; permit requirements, emission limits for certain engine-generator sets. Virginia General Assembly, 2026 Regular Session; applies to air permit applications from 1 July 2026.

Holland and Knight (D. I. Schneider and B. B. Stolley). 2025. Loudoun County, Virginia, eliminates by-right data center development. Zoned In blog post, 4 April 2025.

International Energy Agency. 2025. *Energy and AI.* IEA, Paris.

Joint Legislative Audit and Review Commission. 2024. *Data Centers in Virginia*. Report 598. Commonwealth of Virginia, December 2024.

King, R. S., et al. 2005. Spatial considerations for linking watershed land cover to ecological indicators in streams. *Ecological Applications* 15(1): 137–153. doi:10.1890/04-0481

Loudoun County, Virginia. 2025. Data center standards and locations; zoning ordinance amendment effective 18 March 2025.

Loudoun County, Virginia. 2026. Data Centers: The Loudoun Story; adopted budget documents, fiscal years 2026 and 2027; Build Out Land Use map service, as of 1 July 2025.

Monitoring Analytics, LLC. 2026. *2025 Annual State of the Market Report for PJM, Section 5: Capacity*. Independent Market Monitor for PJM, released 12 March 2026.

Odum, W. E. 1982. Environmental degradation and the tyranny of small decisions. *BioScience* 32(9): 728–729. doi:10.2307/1308718

PJM Interconnection. 2025. *2027/2028 Base Residual Auction Report*. 17 December 2025.

PJM Interconnection. 2026. *2028/2029 Base Residual Auction Report*. 14 July 2026.

Priest, A. 2026. Not in my back yard! The effects of data centers on housing prices. SSRN working paper, February 2026. doi:10.2139/ssrn.6314620. Not refereed.

Prince William Board of County Supervisors. 2026. Zoning text amendment DPA2026-00006, Data Center Opportunity Zone Overlay District, adopted 22 September 2026.

Prince William County Department of Finance. 2025. Data center tax revenue, tax years 2012 to 2024. Presentation to the Board of County Supervisors, budget work session, March 2025.

Prince William County, Virginia. 2026. Build Out Analysis map service: Data Center Buildings and Data Center Campuses layers.

Riitters, K. H., J. W. Coulston, and J. D. Wickham. 2012. Fragmentation of forest communities in the eastern United States. *Forest Ecology and Management* 263: 85–93. doi:10.1016/j.foreco.2011.09.022

SB 843. 2026. Data centers; state permitting, local approval, moratorium, sunset. Virginia General Assembly, prefiled for the 2027 Regular Session by Sen. Russet Perry.

Schueler, T. R., L. Fraley-McNeal, and K. Cappiella. 2009. Is impervious cover still important? Review of recent research. *Journal of Hydrologic Engineering* 14(4): 309–315. doi:10.1061/(ASCE)1084-0699(2009)14:4(309)

Shehabi, A., et al. 2024. *2024 United States Data Center Energy Usage Report.* Lawrence Berkeley National Laboratory, prepared for the US Department of Energy.

Siler-Evans, K., I. L. Azevedo, and M. G. Morgan. 2012. Marginal emissions factors for the U.S. electricity system. *Environmental Science & Technology* 46(9): 4742–4748. doi:10.1021/es300145v

Stand.earth. 2026. Virginia registered voter survey on data centers, conducted by Morning Consult, April 2026, n=801. Advocacy-commissioned.

Synergy Research Group. 2025. The world's total data center capacity is shifting rapidly to hyperscale operators. Press release, 24 June 2025.

Taxpayers Protection Alliance. 2026. Analysis of Virginia data center water consumption in 2025 based on U.S. Geological Survey data, reported by R. Marchand in Cardinal News, 15 July 2026. Industry-aligned advocacy organization; not refereed.

Theobald, D. M., J. R. Miller, and N. T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. *Landscape and Urban Planning* 39(1): 25–36. doi:10.1016/S0169-2046(97)00041-8

Virginia Commonwealth University, L. Douglas Wilder School of Government and Public Affairs. 2026. Summer 2026 Commonwealth Poll, released 15 July 2026.

Virginia Department of Environmental Quality. Ground water withdrawal permitting, 9VAC25-610; water withdrawal reporting requirements.

Virginia General Assembly. 2026. Appropriation Act, 2026 to 2028 biennium, signed 30 June 2026; data center electricity consumption tax effective 1 July 2026.

Virginia State Corporation Commission. 2025. Final order, Dominion Energy Virginia 2025 biennial review, Case No. PUR-2025-00058, 25 November 2025.

Virginia State Corporation Commission. 2026. Order of 31 July 2026 on transmission cost allocation for Dominion Energy Virginia large-load customers.

Washington Post and George Mason University Schar School. 2026. Virginia statewide survey of 1,101 registered voters, late March 2026.

Waters, K., and T. Clower. 2025. Data centers and 2023 home sales in Northern Virginia. Research note, Center for Regional Analysis, Schar School of Policy and Government, George Mason University, August 2025. Institutional report, not refereed.

Xu, Q., W. Ricks, A. Manocha, N. Patankar, and J. D. Jenkins. 2024. System-level impacts of voluntary carbon-free electricity procurement strategies. *Joule* 8(2): 374–400. doi:10.1016/j.joule.2023.12.007