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Report to the Governor and the General Assembly of Virginia

Data Centers in Virginia

2024

COMMISSION DRAFT

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Summary: Data Centers in Virginia

WHAT WE FOUND

Data centers provide positive economic benefits to Virginia's economy, mostly during their initial construction

Data centers provide positive benefits to Virginia's economy mostly because of the industry's substantial capital investment. The primary benefit comes from the initial construction of data centers. Most construction spending likely remains in the state economy because much of it goes to Virginia-based businesses providing construction materials and services.

Data centers employ fewer employees than some other industries, but data center jobs tend to be high paying. Several data center representatives indicated that a typical 250,000-square-foot data center may have approximately 50 full-time workers, about half of which are contract workers. Data center construction supports a substantially larger number of workers. Construction of an individual data center building usually takes about 12 to 18 months, and data center representatives indicated that, at the height of construction, approximately 1,500 workers are on site from various construction-related industries.

Overall, the data center industry is estimated to contribute 74,000 jobs, $5.5 billion in labor income, and $9.1 billion in GDP to Virginia's economy annually. Most of these economic benefits derive from the construction phase rather than data centers' ongoing operations. The economic benefits from the industry are concentrated in Northern Virginia, where most data centers are located, but other regions of the state also benefit because data centers are also located there, or they are home to businesses that provide materials for data center construction.

WHY WE DID THIS STUDY

In 2023, the Joint Legislative Audit and Review Commission directed staff to review the impacts of the data center industry in Virginia.

ABOUT DATA CENTERS

Data centers are specialized facilities that manage, process, and share large amounts of data. They enable the digital services that people rely on daily, including websites, electronic applications, and cloud-based platforms, such as email and media steaming. Northern Virginia is the largest data center market in the world, constituting 13 percent of all reported data center operational capacity globally and 25 percent of capacity in the Americas. Multiple factors have contributed to Northern Virginia's market prominence, including a strong fiber network, supply of reliable cheap energy, available land, proximity to major national customers, and the creation of a state data center tax incentive. The data center industry is growing rapidly in Virginia, both in established markets and newer ones. Significant new market growth is expected in counties outside of Northern Virginia and along the I-95 corridor to Central Virginia.

Data centers can generate substantial local tax revenues for localities that have them

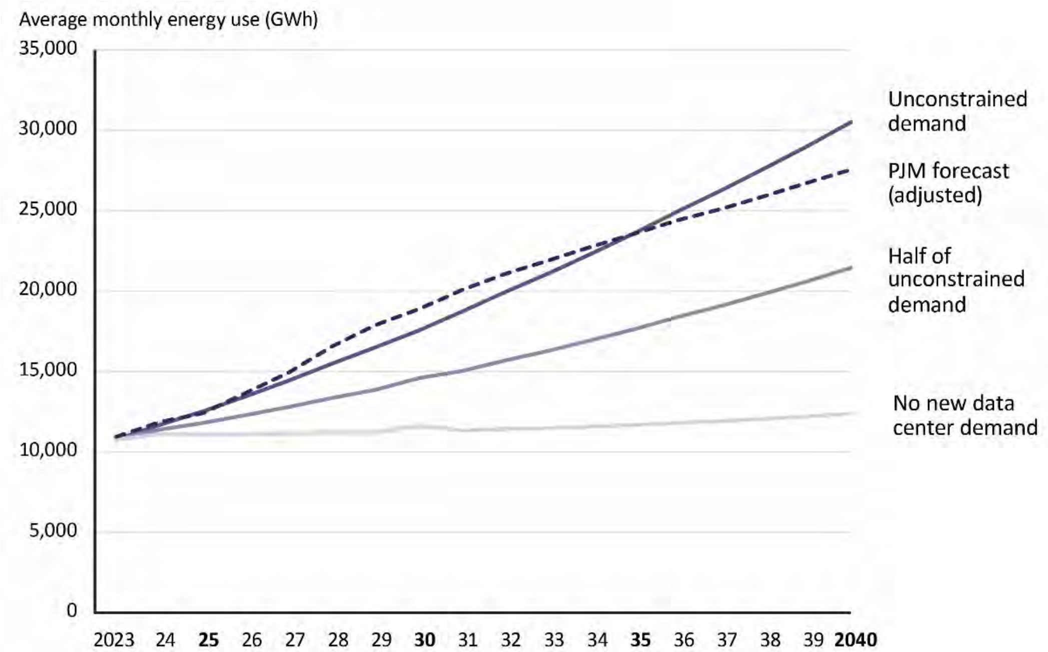
Localities with data centers can collect substantial tax revenues from the industry, primarily from business personal property and real property (real estate) taxes. The amount of local data center revenue depends on several factors, such as the size of their data center market and local tax rates. Some localities have greatly reduced their business personal property tax rates for computer equipment to try to attract data centers, but this also reduces the revenue they can collect from the industry. For the five localities with relatively mature data center markets, data center revenue ranged from less than 1 percent to 31 percent of total local revenue.

Localities in economically distressed areas of the state could benefit from data centers through increased local tax revenue, but these localities could have difficulty attracting the industry. Access to power and large, flat areas of land are key requirements for data centers, but are not available in some distressed areas, particularly in Southwest Virginia. Many distressed localities are also in rural areas that are away from data center customers and population centers, which makes it harder for them to attract the industry. However, these localities may be able to compete for data centers running certain artificial intelligence (AI) workloads, such as training. These localities could potentially become more attractive to the industry if they are able to proactively develop industrial sites suitable to data centers.

Data center industry is forecast to drive immense increase in energy demand

Modern data centers consume substantially more energy than other types of commercial or industrial operations. Consequently, the data center industry boom in Virginia has substantially driven up energy demand in the state, and demand is forecast to continue growing for the foreseeable future. The state's energy demand was essentially flat from 2006 to 2020 because, even though population increased, it was offset by energy efficiency improvements. However, an independent forecast commissioned by JLARC shows that unconstrained demand for power in Virginia would double within the next 10 years, with the data center industry being the main driver. JLARC's independent forecast largely matches the most recent forecast by PJM, which is the regional organization that coordinates generation and transmission operations for Virginia and several other eastern and midwestern states.

Data center demand would drive immense increase in energy needs in Virginia, based on JLARC's independent forecast and other forecasts

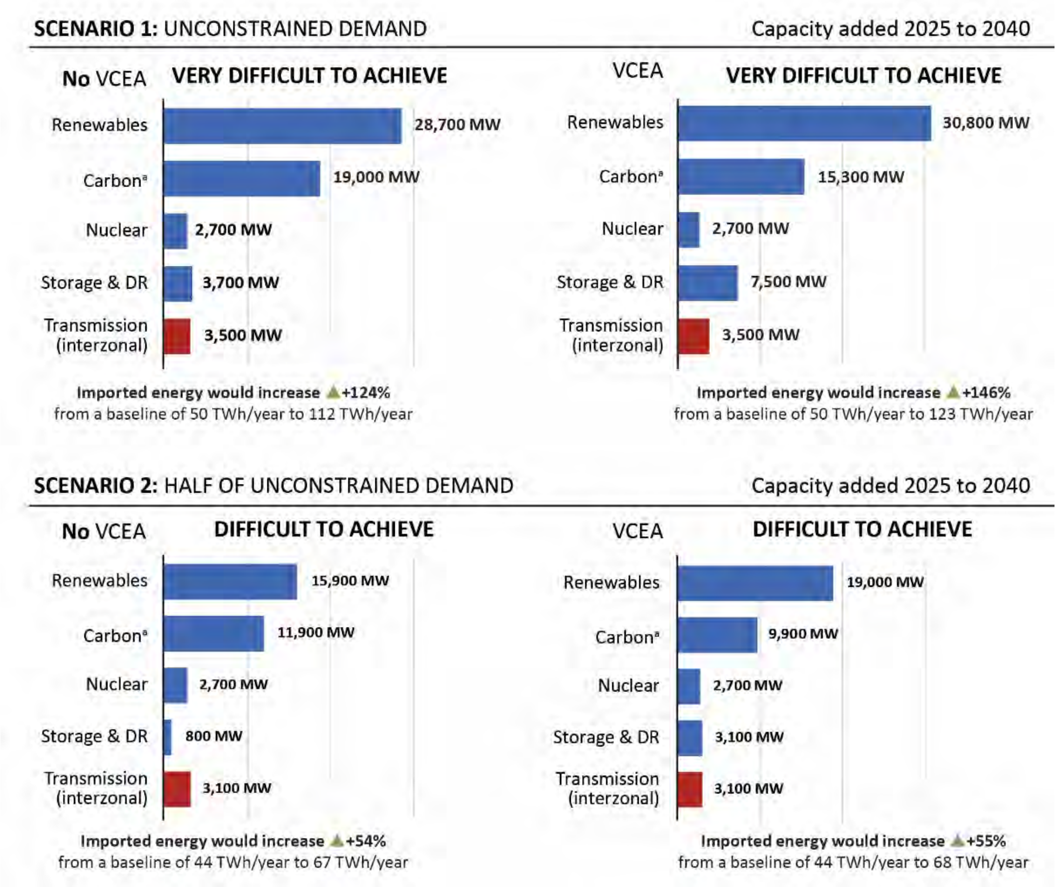


SOURCE: JLARC staff consultant analysis.
NOTE: A detailed note is provided for this figure in Chapter 3.

Building enough infrastructure for unconstrained data center demand will be very difficult and meeting half that demand is still difficult

An independent model of the energy grid commissioned by JLARC staff found that a substantial amount of new power generation and transmission infrastructure will be needed in Virginia to meet unconstrained energy demand or even half of unconstrained demand. Building enough infrastructure to meet unconstrained energy demand will be very difficult to achieve, with or without meeting the Virginia Clean Economy Act (VCEA) requirements (Scenario 1, figure). New solar facilities, wind generation, natural gas plants, and increased transmission capacity would all be required to meet unconstrained demand, and the number of projects needed would be very difficult to achieve. For example, new solar facilities would have to be added at twice the annual rate they were added in 2024, and the amount of new wind generation needed would exceed the potential capabilities of all offshore wind sites that have so far been secured for future development. Large natural gas plants would also need to be added at an equal or faster rate than the busiest build period for these facilities (2012 to 2018), depending on VCEA compliance.

Estimated generation mix needed to meet demand scenarios, with and without meeting VCEA requirements



SOURCE: E3 grid modeling analysis.
NOTE: A detailed note is provided for this figure in Chapter 3.
[a] Carbon includes natural gas, coal, and oil. Biomass facilities are counted as renewable resources, per the VCEA. However, starting in 2045, E3's grid model assumes natural gas plants would be converted to hydrogen fuel in each scenario when VCEA requirements are met.

Building enough infrastructure to meet half of unconstrained energy demand would also be difficult (Scenario 2 above). If VCEA requirements were not considered, the biggest challenge would be building new natural gas plants. New gas would need to be added at the rate of about one large 1,500 MW plant every two years for 15 consecutive years, equal to the busiest period of the last decade (2012 to 2018). If it is assumed that VCEA requirements would be met, the biggest challenges would be building enough wind, battery storage, and natural gas peaker plants. Wind generation needs would be the same as the unconstrained demand scenario. The amount of new battery storage would be several times the small amount currently in place in Virginia and a significant number of new natural gas peaker plants would have to be constructed. Both Scenarios 1 and 2 would rely on energy from as yet unproven nuclear technologies.

The state could encourage or require data centers to take actions to help address their energy impacts by promoting development of renewable energy generation, participating in demand response programs, and managing energy efficiency. However, these actions would have only a marginal impact on decreasing data center energy demand.

Existing electric utility requirements and processes help limit risks associated with system capacity and reliability

Data centers' projected energy demand increases have raised concerns about whether enough infrastructure can be built to keep pace. Currently, PJM attempts to protect regional grid reliability by requiring utilities to secure sufficient generation capacity plus a reserve margin, and the state requires utilities to develop plans that describe how generation capacity needs will be met. However, individual electric utility planning does not guarantee that the generation resources needed for the whole PJM region will be built because regional generation is not centrally planned. This is less of a concern with transmission because PJM and utility transmission owners centrally identify the impact large loads are expected to have, and how those loads can be brought on safely without causing transmission reliability problems.

If utilities are unable to build enough new infrastructure to keep pace with demand, one of the main ways they can protect grid reliability is by delaying the addition of new large load customers until there is adequate generation and transmission capacity. Utilities appear to be able to delay large load additions for transmission-related concerns, but it is less clear if they are allowed to delay adding new load because of generation concerns.

Data centers are currently paying their full cost of service, but growing energy demand is likely to increase other customers' costs

JLARC staff commissioned an independent study of electric utility cost recoveries under current rate structures to see if the data center industry is paying its share of current costs. The study found that current rates appropriately allocate costs to the customers responsible for incurring them, including data center customers.

However, data centers' increased energy demand will likely increase system costs for all customers, including non-data center customers, for several reasons. A large amount of new generation and transmission will need to be built that would not otherwise be built, creating fixed costs that utilities will need to recover. It will be difficult to supply enough energy to keep pace with growing data center demand, so energy prices are likely to increase for all customers. Finally, if utilities are more reliant on importing power, they may not always be able to secure lower-cost power and will be more susceptible to spikes in energy market prices. A typical residential customer of Dominion Energy could experience generation- and transmission-related costs increasing by an estimated $14 to $37 monthly in constant (or real) dollars by 2040 (independent of inflation). Establishing a separate data center customer class, changing cost allocations, and adjusting utility rates more frequently could help insulate non-data center customers from statewide cost increases.

Data centers create additional financial risks to electric utilities and their customers

The data center industry presents additional financial risks to electric utilities and their customers because of the sheer size of the industry's energy demand. One risk is that utilities will build more generation and transmission infrastructure than is needed if forecast demand does not materialize, or several large data centers close. This could strand utilities with infrastructure costs that would have to be recouped from their existing customer base. Another risk is particular to electric co-ops, which are not-for-profit companies that are owned by their member customers. If a data center customer delayed, disputed, or failed to pay an energy generation bill and the co-op was unable to recoup these costs from the customer, they would ultimately have to be paid by all other co-op members. A large enough bill could potentially result in a co-op defaulting and going bankrupt.

Another risk relates to data center participation in the state's retail choice program, which allows data centers and other large load customers to purchase generation through third parties rather than through their incumbent electric utility. This also has the potential to shift generation costs to other customers if enough data centers "leave" their incumbent utility for retail choice.

Data center backup generators emit pollutants, but their use is minimal, and existing regulations largely curb adverse impacts

To ensure constant operations in the event of a power outage, nearly all data centers maintain diesel generators on-site for backup power. Diesel generators emit several harmful air pollutants, such as nitrogen oxides, carbon monoxide, and particulate matter. To limit potential emissions from backup generators, the Virginia Department of Environmental Quality (DEQ) permits limit when they can be run, how long they can be run, and the maximum annual emissions each permitted site is allowed. Nearly all current data centers use "Tier 2" diesel generators, which DEQ allows to run only in emergencies or as part of routine maintenance testing.

Data center generators are run mostly only for maintenance, and most data center operators interviewed by JLARC staff reported experiencing zero to two minor outages per site in the last two years, with nearly all outages being only a few hours long. Consequently, data centers' diesel generators are a relatively small contributor to regional air pollution—in Northern Virginia, they make up less than 4 percent of regional emissions of nitrogen oxides and 0.1 percent or less of carbon monoxide and particulate matter emissions. While they make up only a small part of regional emissions, DEQ is conducting further study to ensure no harmful impacts occur locally. If the study detects any local air quality impacts, DEQ has the authority to increase protections as needed.

Data center water use is currently sustainable, but use is growing and could be better managed

Data centers require industrial-scale cooling, which is sometimes dependent on water, to manage the heat generated by their computing equipment. Most data centers use about the same amount of water or less as an average large office building, although a few require substantially more, and some require less than a typical household. The amount of water a data center uses depends on its size, computing density, and type of cooling system.

Most data centers receive their water from local water utilities, which make withdrawals from Virginia's water sources (rivers, groundwater). DEQ regulates water withdrawals, including requiring permits for large-scale withdrawals, to protect future water availability and environmental sustainability. However, while DEQ is responsible for ensuring water sustainability, there is less oversight over how available water should be shared across various uses in a locality. Virginia as a whole is relatively water rich, but water is more limited for some localities that do not have access to large amounts of surface water and are in groundwater management areas.

Localities have allowed data centers to be built near neighborhoods, but some localities are taking steps to minimize residential impacts

The industrial scale of data centers makes them largely incompatible with residential uses. One-third of data centers are currently located near residential areas, and industry trends make future residential impacts more likely.

Inadequate local planning and zoning have allowed some data centers to be located near residential areas, which sometimes causes impacts on those residents. In some cases, this occurred because local zoning ordinances did not consider data centers to be an industrial use. In addition, some localities have zoned industrial areas next to residential areas, even though land use principles state that industrial uses and residential uses should not be zoned next to each other. Local elected officials have also granted data centers exceptions that led to adverse residential impacts, such as approving rezonings that would allow data centers next to sensitive locations.

In response to increased residential opposition, some localities have taken steps to minimize the residential impacts of data centers. The three Virginia localities with the largest data center markets have taken or are considering changes to zoning ordinances to better manage future data center development, and several localities considering their first data center projects are proactively implementing planning and zoning changes to promote appropriate industry development. The effectiveness of local efforts to minimize residential impacts ultimately depends on the decisions of local elected officials when considering more restrictive zoning ordinances or individual special permit or rezoning requests.

Data center noise near residential areas presents unique challenges, and some localities are unsure about their authority to address it

The constant nature of data center noise has sometimes been a problem when data centers are located near residential areas. Data centers emit low-frequency noise that is not loud enough to damage nearby residents' hearing and rarely loud enough to violate noise ordinances. However, some nearby residents report that the constant noise generated by some data centers affects their well-being. Although noise has been a problem for some data centers, a large majority of data centers do not generate noise complaints because of their location or design.

Localities traditionally use noise ordinances to address noise concerns, but those typically target excessively loud noise from short-term sources, such as parties and barking dogs, and carry a low maximum civil penalty of $500. Noise restrictions for data centers could be more effective if included in zoning ordinances instead, but some localities were uncertain whether they have the authority to establish these restrictions in such ordinances. Zoning ordinances that establish maximum allowable sound levels for both new and existing data centers would allow localities to better account for the low-frequency noise data centers emit, prescribe a better process for measuring potential noise violations, and impose more effective penalties for addressing any violations.

Some data center companies are conducting sound modeling studies *before* building data centers, but not all Virginia localities currently require this, and some were unsure whether they had the authority to do so.

Changes to the state's data center sales tax exemption could address some policy concerns related to the industry

Since 2010, Virginia has offered an exemption to the state's retail sales and use tax to attract large-scale data centers. The exemption allows data centers and their tenants to purchase computers and other equipment, such as servers, network infrastructure, cooling equipment, and generators, without paying sales tax. Because data centers are capital intensive, the exemption is valuable to the industry (providing $928 million in tax savings in FY23), and about 90 percent of the industry uses the exemption. Data center companies report the exemption is an important factor when deciding where to locate and expand, and most of the other states that Virginia competes with for new data center developments have similar exemptions.

Because the data center exemption is a valuable incentive and used by most of the industry, it could be used to incentivize data centers to take actions to address many of the issues discussed throughout this report. There are a range of changes that could be made to the exemption, depending on the General Assembly's policy objectives.

Extend the exemption to maintain industry growth — If the General Assembly wishes to maintain data center industry growth in Virginia and the associated economic and local tax revenue benefits, it could extend the exemption. The exemption is scheduled to expire in 2035, and data center representatives unanimously reported that expiration of the exemption would negatively affect the state's ability to attract new data centers and keep existing ones. Data center companies typically consider the cost of ownership over a 15- to 20-year period when making location decisions, so to influence future site selection decisions, an extension would need to be in place well before 2035.

Allow the exemption to expire to reduce industry growth and associated energy impacts — If the General Assembly wishes to slow the data center industry's growth in Virginia because it determines that energy impacts, including increasing costs to residential and other customers, outweigh the industry's economic benefits, it could allow the exemption to expire in 2035. While the General Assembly could allow the exemption to expire only in certain regions, like Northern Virginia, that approach would be less effective in reducing overall growth in energy demand because significant growth is occurring in several counties outside of Northern Virginia and is expected to continue.

Change the exemption to balance industry growth and energy impacts — Rather than choosing between economic benefits or reduced energy impacts, the exemption could be changed to try to balance these competing impacts. The General Assembly could allow the full exemption to expire in 2035 (or end it before then) and apply a partial sales tax exemption until 2050. A partial exemption would also better align the economic benefits the state receives with the value of the exemption. Most economic benefits occur during construction, and switching to a partial exemption in 2035 would reduce the value of the exemption in later years when the economic impacts of current and planned data centers could be expected to slow. A partial exemption could also generate more tax revenue for the state.

Use the exemption to address other policy concerns related to the data center industry — If the General Assembly extends the exemption, even as a partial exemption, there are several additional options the General Assembly could implement to address concerns in specific policy areas. The exemption could be modified to address energy, natural resource, historic resource, and residential impacts.

WHAT WE RECOMMEND

This report includes multiple policy options for the General Assembly to consider depending on its policy goals for the data center industry in Virginia. The report also includes several recommendations. The following recommendations include only those highlighted in the report summary. The complete list of recommendations and options is available on page xi.

Legislative action

- Clarify that electric utilities have the authority to delay, but not deny, service to customers when the addition of customer load cannot be supported;

- Direct Dominion Energy to develop a plan for addressing the risk of infrastructure costs being stranded with existing customers, and file that plan with the State Corporation Commission;
- Expressly authorize local governments to require and consider water use estimates for proposed data center developments;
- Expressly authorize local governments to require sound modeling studies for proposed data center developments; and
- Expressly authorize local governments to establish and enforce maximum allowable sound levels for operational data center facilities using alternative low frequency metrics and zoning ordinances.

Executive action

- The Virginia Economic Development Partnership should clarify that grants under the Virginia Business Ready Sites Program can be used for potential data center sites.

Recommendations and Policy Options: Data Centers in Virginia

JLARC staff typically make recommendations to address findings during reviews. Staff also sometimes propose policy options rather than recommendations. The three most common reasons staff propose policy options rather than recommendations are: (1) the action proposed is a policy judgment best made by the General Assembly or other elected officials, (2) the evidence indicates that addressing a report finding is not necessarily required, but doing so could be beneficial, or (3) there are multiple ways in which a report finding could be addressed and there is insufficient evidence of a single best way to address the finding.

Recommendations

RECOMMENDATION 1

The Virginia Economic Development Partnership should clarify in site characterization and development guidelines that potential data center sites are eligible for grants under the Virginia Business Ready Sites Program. (Chapter 2)

RECOMMENDATION 2

The General Assembly may wish to consider amending the Code of Virginia to clarify that electric utilities have the authority to delay, but not deny, service to customers when the addition of customer load cannot be supported by the transmission system or available generation capacity. (Chapter 3)

RECOMMENDATION 3

The General Assembly may wish to consider amending the Code of Virginia to expand the Accelerated Renewable Buyers program, which allows large customers of energy utilities to claim credit for purchases of solar and wind *energy* to offset certain utility charges, to also allow customers to claim partial credit for purchases of *capacity* from battery energy storage systems based on the current PJM electric load carrying capacity rating. (Chapter 3)

RECOMMENDATION 4

The General Assembly may wish to consider amending the Code of Virginia to require that utilities establish a demand response program for large data center customers and to require that these customers participate in the program. (Chapter 3)

RECOMMENDATION 5
The General Assembly may wish to consider amending the Code of Virginia to direct Dominion Energy to develop a plan for addressing the risk of generation and transmission infrastructure costs being stranded with existing customers and file that plan with the State Corporation Commission as part of its biennial rate review filing or as a separate filing. (Chapter 4)

RECOMMENDATION 6
The General Assembly may wish to consider amending the Code of Virginia to expressly authorize local governments to (i) require proposed data center developments to submit water use estimates and (ii) consider water use when making rezoning and special use permit decisions related to data center development. (Chapter 5)

RECOMMENDATION 7
The General Assembly may wish to consider amending the Code of Virginia to expressly authorize local governments to require sound modeling studies for data center development projects prior to project approval. (Chapter 6)

RECOMMENDATION 8
The General Assembly may wish to consider amending the Code of Virginia to expressly authorize local governments to establish and enforce maximum allowable sound levels for data center facilities, including (i) using alternative low frequency noise metrics and (ii) setting noise rules and enforcement mechanisms in their zoning ordinances, separate from existing noise ordinances. (Chapter 6)

Policy Options to Consider

POLICY OPTION 1
The General Assembly could consider amending the Code of Virginia to require that, as a condition of receiving the sales tax exemption, data center companies meet and certify to an energy management standard, such as the International Organization for Standardization's 50001 standard for energy management. (Chapter 3)

POLICY OPTION 2
The General Assembly could consider amending the Code of Virginia to allow electric cooperatives to create for-profit subsidiary companies that could fulfill their legal obligation to provide energy services (retail sales) to customers with load capacity of over 90 MW. (Chapter 4)

POLICY OPTION 3
The General Assembly could consider amending the Code of Virginia to require that electric utilities establish caps on participation in retail choice that protect ratepayers from undue costs, and that such caps be approved by the State Corporation Commission through a formal case process. (Chapter 4)

POLICY OPTION 4

The General Assembly could amend the Code of Virginia to require that, as a condition of receiving the data center sales and use tax exemption, all new data center developments in the Northern Virginia Ozone Nonattainment Area use only Tier 4 generators, Tier 2 generators with selective catalytic reduction systems, or generators with equivalent or lower emission rates. (Chapter 5)

POLICY OPTION 5

The General Assembly could amend the Code of Virginia to require that, as a condition of receiving the sales and use tax exemption, data center companies meet and certify to an environmental management standard, such as the International Organization for Standardization's 14001 standard for Environmental Management Systems. (Chapter 5)

POLICY OPTION 6

The General Assembly could amend the Code of Virginia to require that, as a condition for receiving the sales and use tax exemption, data center companies conduct a Phase I historic resource study of a proposed development site, as well as a viewshed analysis when a proposed site is located within a certain distance of a registered historic site, and report the study findings to the appropriate locality prior to development. (Chapter 5)

POLICY OPTION 7

The General Assembly could amend the Code of Virginia to require that, as a condition for receiving the sales and use tax exemption, data center companies conduct a sound modeling study prior to the development of a proposed data center that is to be located within a certain distance of a residential development or area zoned for residential development and provide the study findings to the appropriate locality. (Chapter 6)

POLICY OPTION 8

The General Assembly could amend the Code of Virginia to extend the expiration date for the state's sales and use tax exemption for data centers from 2035 to 2050. (Chapter 7)

POLICY OPTION 9

The General Assembly could allow the sales and use tax exemption for data centers to expire in 2035. (Chapter 7)

POLICY OPTION 10

The General Assembly could amend the Code of Virginia to extend a partial sales and use tax exemption for data centers from 2035 to 2050. (Chapter 7)

1 Overview of the Data Center Industry

In 2023, the Joint Legislative Audit and Review Commission (JLARC) directed its staff to review the impacts of the data center industry in Virginia. Specifically, staff were directed to assess the impact of the industry on state and local revenue; Virginia's energy demand and supply; natural, historic, and cultural resources; and local residents. Staff were also directed to forecast future growth of the industry in Virginia and determine (i) how any economic benefits could be more widely distributed and (ii) if Virginia's data center tax exemption could be improved. (See Appendix A for the study resolution.)

To complete this study, JLARC staff conducted over 250 interviews with more than 150 different stakeholders, including local residents and stakeholder groups; data center companies and developers; state and local officials; electric and water utility companies; and subject-matter experts. Staff analyzed water usage and air quality and emissions data, as well as capital expenditure, employment, and tax benefit data from users of the data center tax exemption. Staff also reviewed state and local land use regulations and conducted case reviews of local data center-related zoning and permitting requests. (See Appendix B for more information on methods used for this study.)

JLARC staff contracted with two consultants as part of this study. Faculty from the Weldon Cooper Center for Public Service at the University of Virginia (Weldon Cooper Center) developed an economic impact analysis of Virginia's data center industry and an independent energy demand forecast for Virginia and its utilities. Consulting firm Energy + Environmental Economics (E3) modeled how data center growth was likely to affect future generation and transmission needs, carbon emissions, and utility costs, including how costs could be passed on to ratepayers. E3 also made additional refinements to the Weldon Cooper Center energy demand forecast.

Data centers are key hubs of the world's digital infrastructure

Data centers are specialized facilities that manage, process, and share large amounts of data. They enable the digital services that people rely on daily, including websites, electronic applications, and cloud-based platforms such as email and media streaming. These services are also critical to businesses and organizations, for example, allowing businesses to make secure transactions electronically or conduct complex computing tasks using artificial intelligence (AI). Given their essential role in daily life, business, and the economy, data centers have become a critical part of the world's digital infrastructure (sidebar).

Digital infrastructure encompasses the systems and technologies needed for the internet, online services, and other digital activities to function. This includes networks (e.g., fiber, switches), hardware (e.g., computers, servers), software (e.g., operating systems, applications), data centers, and the personnel who manage and maintain these components.

A typical, modern data center is a large industrial building filled with computing equipment, including servers, storage drives, and network hardware. Externally, these buildings often resemble warehouses or distribution centers. Data centers can vary greatly in size, ranging from smaller facilities with a few thousand square feet to large, multistory buildings exceeding one million square feet. Data centers are often located on campuses alongside other facilities or other data centers operated by the same company. In addition, many data centers have physical security measures, such as floodlights, fencing, and access controls, to protect the facility and its data.

Megawatts are units used to measure power, equivalent to one million watts. Megawatts measure the amount of energy produced or consumed at any instant, rather than total over time. A different unit of measure is used to measure the amount of energy produced or consumed over a given time period. For example, megawatt-hours describe the number of megawatts produced or consumed during an hour.

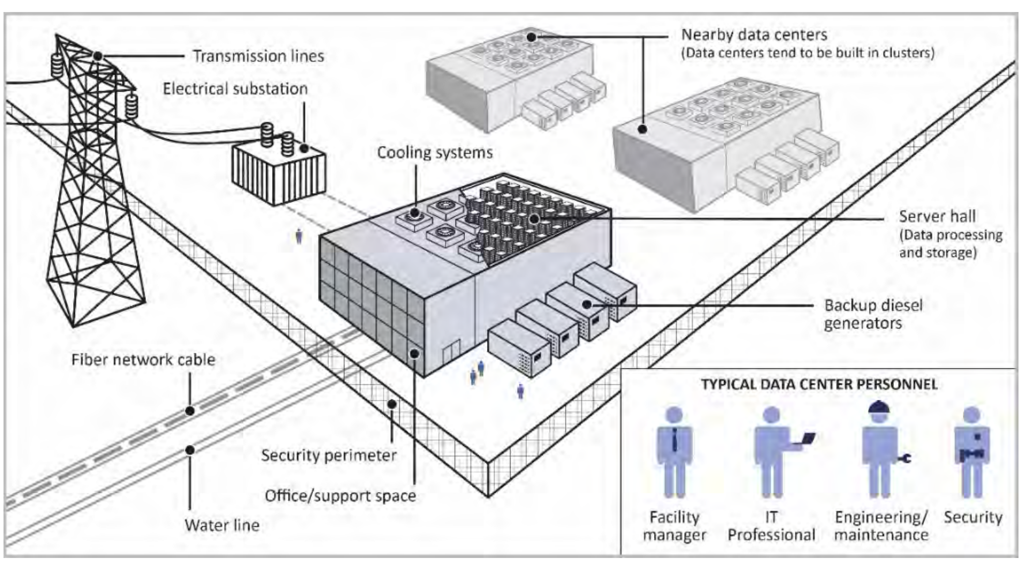
For context, **a Virginia town of 10,000 people uses approximately 10 megawatts**.

Data centers require large amounts of electricity to operate. This energy powers the computing equipment inside, as well as cooling equipment that prevents the computing equipment and building from overheating. The amount of electricity needed for a data center varies based on its size, the density and type of computing equipment, and the cooling system used. A small data center can require five to 20 megawatts of power, while a larger data center can require 100 or more megawatts (sidebar). Given the amount of electricity needed for operations, data centers often have power lines and substations connecting them directly to nearby high-voltage transmission lines. All data centers also have backup generators on-site to ensure continuity of operations if their primary power supply fails.

Data centers are operated and maintained by a skilled workforce, including technicians, electricians, and network engineers. Data centers also generally have security personnel.

Figure 1-1 illustrates the infrastructure, equipment, and personnel found in and around a typical, modern data center.

FIGURE 1-1
Common infrastructure, equipment, and personnel at a typical data center



SOURCE: JLARC staff.
NOTE: Illustrative example. Data centers may have different equipment, e.g., based on their cooling system.

There are various types of data centers, ranging from traditional enterprise and colocation facilities to newer hyperscale operations.

- Enterprise data centers are private facilities owned and operated by a single company, designed specifically to meet that company's IT and data storage needs. These are generally non-technology companies, such as banks, insurance firms, and credit card companies, that rely heavily on secure, in-house data processing and storage. Enterprise data centers are generally located on-site, such as within a corporate campus or integrated into a larger office building. Enterprise data centers are a shrinking segment of the data center market as companies increasingly rely on the cloud for their computing needs.
- Colocation data centers are facilities owned and operated by a company that leases physical space within their data center to other companies and organizations. These tenants, which include smaller technology companies, online retailers, and government agencies, house their computer equipment within their leased space and have their own staff who maintain and upgrade this equipment. Tenants rely on the data center owner to provide all other services such as power, cooling, and physical security. Colocation data centers generally serve multiple tenants—often upwards of 20 or more—which allows these companies to benefit from economies of scale.
- Hyperscale data centers are purpose-built facilities designed to serve the world's major technology companies (e.g., Amazon Web Services [AWS], Google, Meta, Microsoft), often known as "hyperscalers." These are the largest data centers with the largest operational capacity and power requirements (sidebar). Hyperscale data centers can either be owned and operated by the hyperscaler company or by a third-party that leases the facility to the hyperscaler. In some cases, the third party that owns the data center also provides services such as power, cooling, and security, while in others the hyperscaler manages all building operations. Hyperscale data centers are a growing segment of the data center market.

Operational capacity—also called "capacity"—refers to the amount of power a data center needs to operate. This includes all the power needed to run the computing equipment, cooling systems, and other building operations. Capacity is often used to describe the size of a data center. For the purposes of this chapter, capacity is measured in megawatts.

Data center industry is growing rapidly, driven by a combination of established and emerging trends

The data center industry spans markets around the world, clustering in locations that provide access to land, energy, and fiber, and are business friendly, politically stable, and at low risk from natural disasters. Many data center markets are located near key population, business, and government centers because they are close to their customers and end users. Being in proximity to customers reduces the time it takes for data to travel between the data center and the customer, ensuring fast processing, which can be critical for certain business operations, such as financial transactions (sidebar).

The time it takes for data to travel from one point to another, such as from a data center to the end user, is called "**latency**." Low latency indicates data is traveling more quickly; high latency indicates there is a longer delay. Many factors affect latency, most notably the geographic distance between the data center and user. Some tasks—such as financial transactions—are more "latency sensitive" than others, meaning they require as low latency as possible.

It also reduces time for end users to access data, which, for example, reduces buffering times and increases picture quality when streaming media.

The data center industry is dominated by a few large participants. In the U.S., four hyperscaler companies—AWS, Google, Meta, and Microsoft—are responsible for much of the data center industry. These companies operate their own hyperscale data centers, lease other hyperscale data centers, and can also be customers within traditional colocation data centers.

Data center industry is growing rapidly worldwide

The data center industry is growing worldwide, with many data centers under construction or in development. Market reports and trade literature indicate the industry has grown significantly over the past decade, with an especially rapid growth rate in recent years, particularly in the Americas. For example, a 2024 report from the real estate firm Cushman & Wakefield estimates 44,600 megawatts of data center capacity is in development worldwide. More than half (55 percent) of this capacity is in the Americas region, 30 percent is in the Asia–Pacific region, and the remaining 15 percent is in the Europe, Middle East, and Africa (EMEA) region. When completed, this growth would double existing capacity across the EMEA markets and more than double existing capacity in the Americas and Asia–Pacific markets.

The industry is growing both in terms of the number of data centers under construction as well as the size and scale of those data centers. More data centers are being built, and many of the new data centers under construction are larger and have more operational capacity. For example, the capacity of a typical data center has increased from requiring only a few megawatts of power to more than 100 megawatts.

There has also been a recent shift toward companies building data center *campuses,* rather than individual data centers, to serve the needs of hyperscalers. Such campuses can be made up of multiple parcels of land and house several data centers owned by the same entity. Collectively, the operational capacity of these campuses can reach hundreds of megawatts, and in some cases, exceed one gigawatt (i.e., 1,000 megawatts). Companies are increasingly developing data center campuses, rather than individual facilities, to consolidate operations, improve efficiency, and more easily expand capacity in response to growing demand.

Industry expected to grow for foreseeable future, though factors could shift where growth occurs

The data center industry is expected to keep growing, driven by demand for digital services, such as e-commerce, media streaming, and cloud-based applications. This trend accelerated during the COVID-19 pandemic as more people and businesses relied on these services and is expected to continue. As the economy becomes increasingly digitized, more consumers use digital services, and the number of internet-connected devices rises, the need for data storage, processing, and network capacity will continue to grow.

The recent emergence of AI is another significant driver of data center growth. AI applications, such as machine learning and data analytics, require immense computing power and storage to process large amounts of data. As businesses increasingly adopt AI tools and AI is integrated into commercial applications, the demand for data centers to support these technologies has surged and is expected to continue to grow.

AI also has the potential to reshape how and where the data center industry grows. For example, some AI workloads, such as large language model training, are not latency sensitive, allowing data centers housing these tasks to be located farther from established data center markets. Additionally, AI workloads are often much larger than typical data center demands, requiring larger facilities with more computing capacity and more power needs (sidebar).

Market constraints could also shift where the industry grows. Key factors, such as power availability, land price and availability, local opposition, and regulatory environments, are constraining the industry, especially in established markets. As these constraints grow, some markets may become less attractive for development, driving data center growth toward other locations.

AI workloads typically require more power than traditional data center tasks because they use more energy-intensive hardware. The servers conducting AI tasks often include graphics processing units (GPUs) alongside central processing units (CPUs), because GPUs are better suited to running large, simultaneous data processes required for AI applications. Since GPUs consume more power than CPUs, AI tasks are generally more energy demanding.

Northern Virginia has the largest data center market in the world, and the state's industry is growing

There are approximately 150 data center sites in Virginia, which collectively house around 340 data center buildings. These sites vary in size, ranging from a single 2,400-square-foot data center building to a campus of seven buildings that total more than 3 million square feet. In total, Virginia has over 63 million square feet of data center space on 7,200 acres of land (sidebar).

For context, **Pocahontas State Park—the largest in Virginia—covers 7,600 acres.** The entire state park system spans a total of 75,900 acres.

Virginia data center sites also vary in size in terms of operational capacity. The smallest sites require only about one megawatt of power, while some larger campuses are estimated to need 200 or more megawatts and are still growing. In total, Virginia data center sites use approximately 5,050 megawatts of power (sidebar). (This is based on the 2024 peak load forecast by Dominion Energy and Mecklenburg, Northern Virginia, and Rappahannock electric cooperatives in August 2023.)

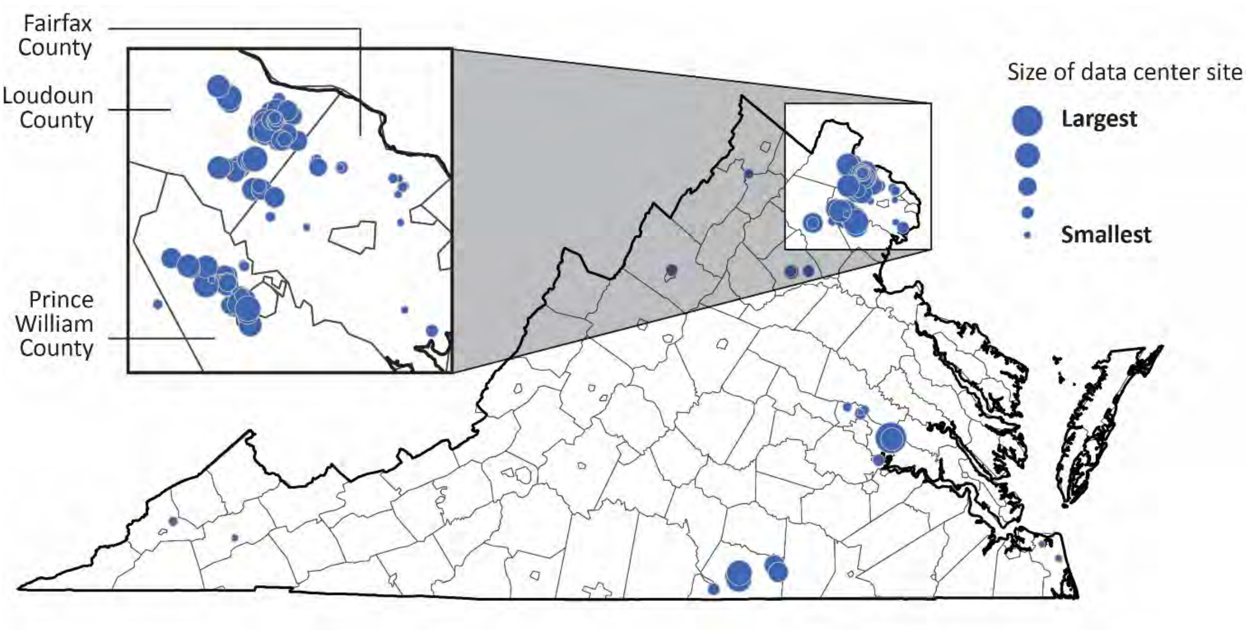
Data centers' power usage in Virginia—about 5,050 megawatts— is roughly **equivalent to the electricity needs of 2 million Virginia households** (about 60 percent of households in the state).

Virginia's data center industry is mostly concentrated in Northern Virginia, with other small clusters near Richmond and Mecklenburg

Data centers are located across the state, but 80 percent of Virginia's data center industry is concentrated in three Northern Virginia localities: Loudoun, Prince William, and Fairfax (Figure 1-2). Loudoun County alone accounts for approximately half of the state's data center industry in terms of number of sites, building square footage, and estimated energy usage. The eastern part of the county north of Dulles

International Airport has become known as "Data Center Alley" because of its high concentration of data centers. The remaining 20 percent of Virginia's data center sites are in 11 other localities, with the most notable clusters in the Richmond region and Mecklenburg County.

FIGURE 1-2
Most of Virginia's data center industry is concentrated in Northern Virginia

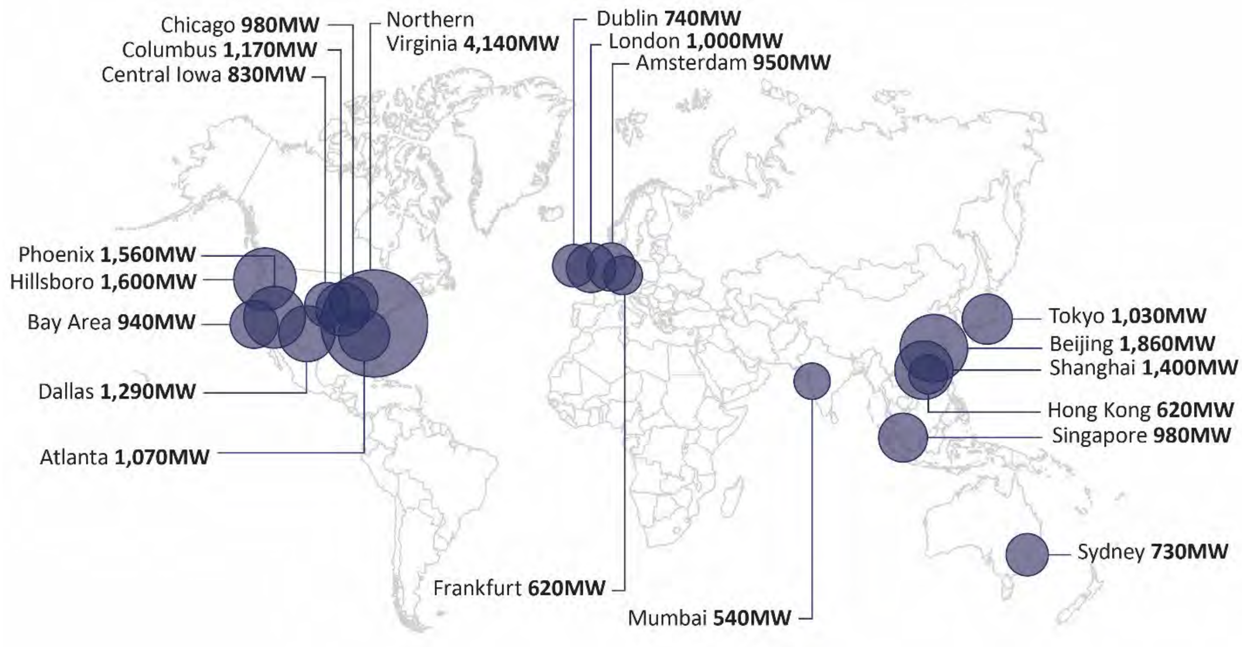


SOURCE: JLARC analysis of Virginia Department of Environmental Quality data and county property real estate records.
NOTE: Map shows one dot per data center site, which may include multiple data center buildings. Size of each site represented by size of dot, as measured by the maximum capacity (in terms of megawatts) the site is permitted to backup via diesel generators. This capacity is larger than the current operational capacity because it (i) accounts for the site's full build-out potential, which many sites have not yet reached, and (ii) includes allowances for redundancy. Data center operators report 0 to 25 percent of backup capacity is typically for redundancy.

Northern Virginia is the largest data center market in the world because of multiple factors

Northern Virginia has the highest concentration of data centers in the world and is recognized as the world's premier data center market. The exact size of the Northern Virginia data center market (in terms of the number of sites and energy demand) varies based on the sources used; however, every source indicates Northern Virginia is the global leader. According to data reported by Cushman & Wakefield, in terms of megawatts, the Northern Virginia market is more than twice the size of the next largest market in the world, Beijing, and nearly three times the size of the next largest market in the U.S., located in and around Hillsboro, Oregon (Figure 1-3). The Northern Virginia market constitutes 13 percent of all reported data center operational capacity globally and 25 percent of capacity in the Americas region.

FIGURE 1-3
Virginia has the most operational capacity of all global markets



SOURCE: JLARC analysis of Cushman & Wakefield 2024 Global Data Center Market Comparison.
NOTE: Reflects market size in terms of operational capacity as measured by megawatts. Shows 20 largest markets. "Northern Virginia" refers to an estimate of data center capacity in the traditional Northern Virginia market consisting of Fairfax, Loudoun, and Prince William counties and Manassas. The Cushman & Wakefield report also includes an estimated 560 megawatts of capacity in Culpeper and Fauquier counties and the Richmond metropolitan region.

Multiple factors have contributed to Northern Virginia's market prominence. The region's role in the early stages of the internet's development gave it a head start as a key data center hub. In the mid-20th century, early data processing companies contracting with government agencies and high-technology government labs were drawn to the region given its proximity to their federal government customers. The establishment of an internet exchange point in the 1990s further attracted major telecommunications and early internet companies to the region.

As the internet grew, a strong fiber network, supply of reliable cheap energy, and available land encouraged more data centers to locate in the region. Data centers were also drawn to the region given its proximity to major national customers, including most notably the federal government, government contractors, and technology firms that held an enormous amount of government and other data. With the rapid growth of the internet in the 2000s, it became advantageous for data centers to cluster near each other so they could share information more quickly. The high concentration of data centers also led to a burgeoning ecosystem of industry professionals, real estate developers, construction companies, and tradespeople with expertise in data centers, which continues to make the region attractive today.

The creation of a state data center tax incentive has also been a key factor in the industry's development in Northern Virginia, as well as the state more broadly. In 2010, Virginia adopted a sales and use tax exemption that exempted data centers from paying retail sales tax on computer and related equipment purchases, and the General Assembly has since expanded the exemption. (See Chapter 2 for more information about the sales and use tax exemption and its impact.)

Data center industry is growing rapidly in Virginia, both in established markets and newer ones

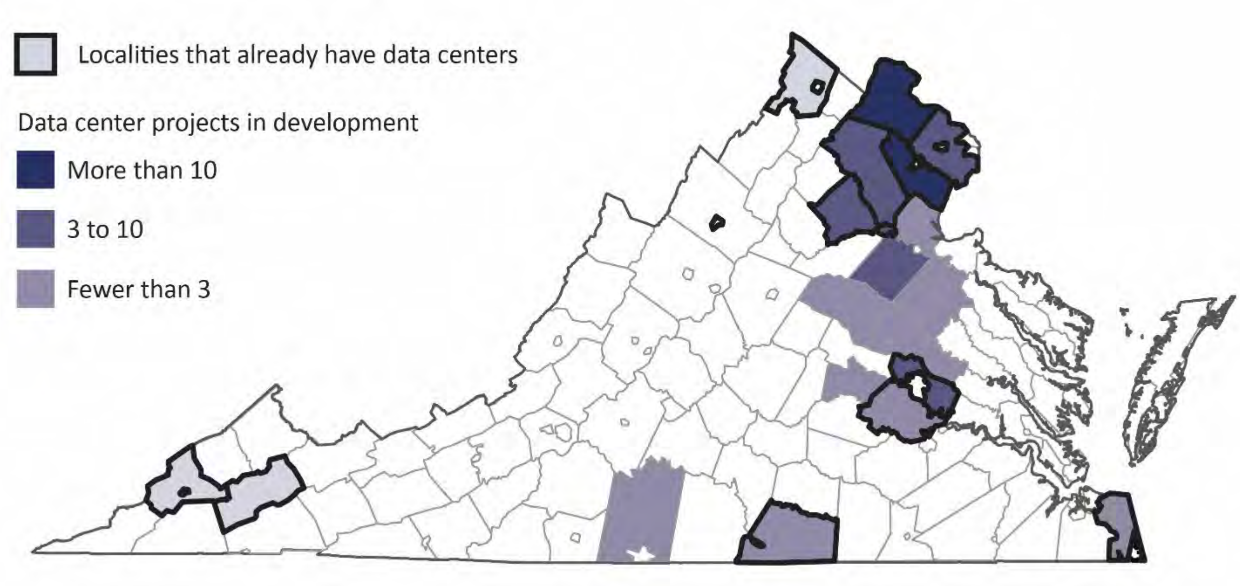
The data center industry is growing rapidly in Virginia. Since 2020, data center *space* in Virginia has more than doubled, with over a quarter of the state's existing data center square footage built in 2022 and 2023. Additional square footage has been built in 2024. A 2024 Cushman & Wakefield report underscores this trend, noting there is a record amount of data center *capacity* in development in the state. This includes 1,500 megawatts under construction and 2,900 megawatts in earlier stages of development. When this development is complete, it will nearly double the size of data center capacity in Virginia.

As of September 2024, there are at least 70 new known data center sites under active development across the state. These projects are at various stages of the development process, with more than half having received full local government approval and/or under construction. The remaining projects are at earlier stages, such as awaiting local rezoning or approval.

Much of the data center development is occurring in the established markets of Northern Virginia, the Richmond region, and Mecklenburg County. Within these existing markets, the majority of growth continues to be in Loudoun and Prince William counties, with Prince William County being the fastest-growing locality (Figure 1-4). The growth in these markets is driven by data center developers and companies building at new sites as well as expanding existing campuses.

The data center industry is also growing in new Virginia markets, most notably in counties outside of the established Northern Virginia market and along the I-95 corridor (Figure 1-4). For example, seven localities without any data centers have recently approved new campuses or have applications pending. According to stakeholders, data center development is moving into these new markets as land availability and local regulatory environments become more challenging in Northern Virginia. Additionally, AWS is leading development into localities along I-95 as part of its agreement with the state to invest $35 billion in data centers in new Virginia locations by 2040.

FIGURE 1-4
Data center industry still growing in established markets, but development starting to spread into new areas, such as along I-95



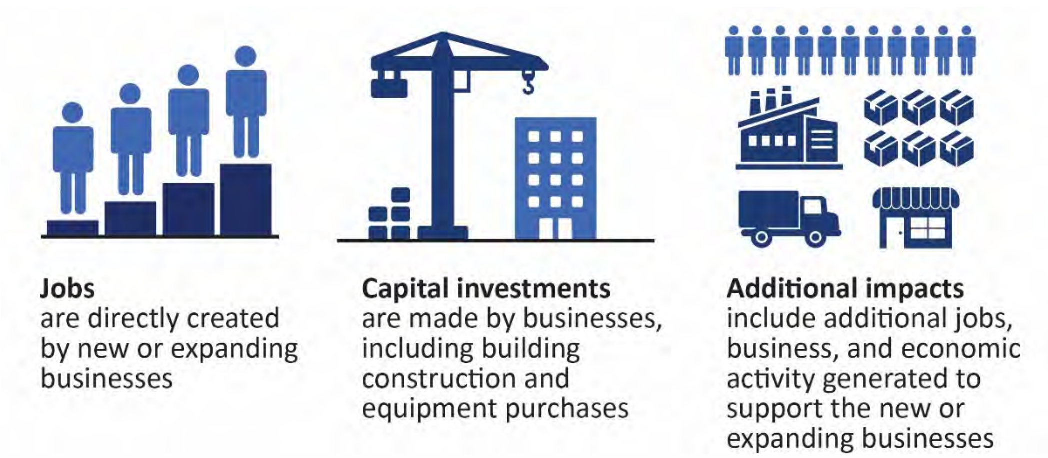
SOURCE: JLARC summary analysis as of September 2024.
NOTE: "In development" includes projects that are under construction, permitted, and/or have been approved through local rezoning or other approval processes (if applicable).

2 Economic and Fiscal Impacts

States strive to build and maintain a strong and diverse economy. A strong economy benefits the state by increasing the wealth of its citizens, helping its businesses succeed, and generating tax revenues to support state and local government operations. Tax revenues help pay for essential services like roads, schools, and public safety.

Virginia looks to improve its economy by attracting new businesses and having existing businesses expand their operations. Businesses benefit the economy directly by creating new jobs and making capital investments, such as constructing new buildings and purchasing vehicles and equipment. Business activities have many additional impacts that further economic growth, such as creating additional jobs at in-state suppliers and in the service industries that support the original business and its employees (Figure 2-1).

FIGURE 2-1
Businesses create jobs and capital investment and have additional impacts that benefit the state economy



SOURCE: JLARC staff analysis.

Data center industry provides positive economic benefits to state

State and local economic development agencies view data centers as an attractive industry. Data center companies are some of the largest and most well-resourced technology companies in the world. Though data centers directly employ relatively fewer employees than some industries, data center jobs tend to be higher paying, so jobs

Tradeable sector includes businesses that compete or export goods and services outside of where they are located. They have larger economic impacts because they bring in new revenue from outside the state instead of simply reallocating existing economic activity.

An **employment multiplier** is an estimate of the number of additional jobs created in the economy to support each job created directly by an industry.

have a higher economic impact. Data centers also meet other characteristics of a high impact industry: they are in a tradable industry sector and have a high employment multiplier (sidebar). Data centers—like manufacturers, steel producers, and transportation industries—are also capital intensive. Their facilities are enormous and require multibillion-dollar outlays for construction and equipment, which can provide substantial tax revenue for local governments and a comparatively smaller amount of tax revenue for the state (for the portion that is not tax-exempt).

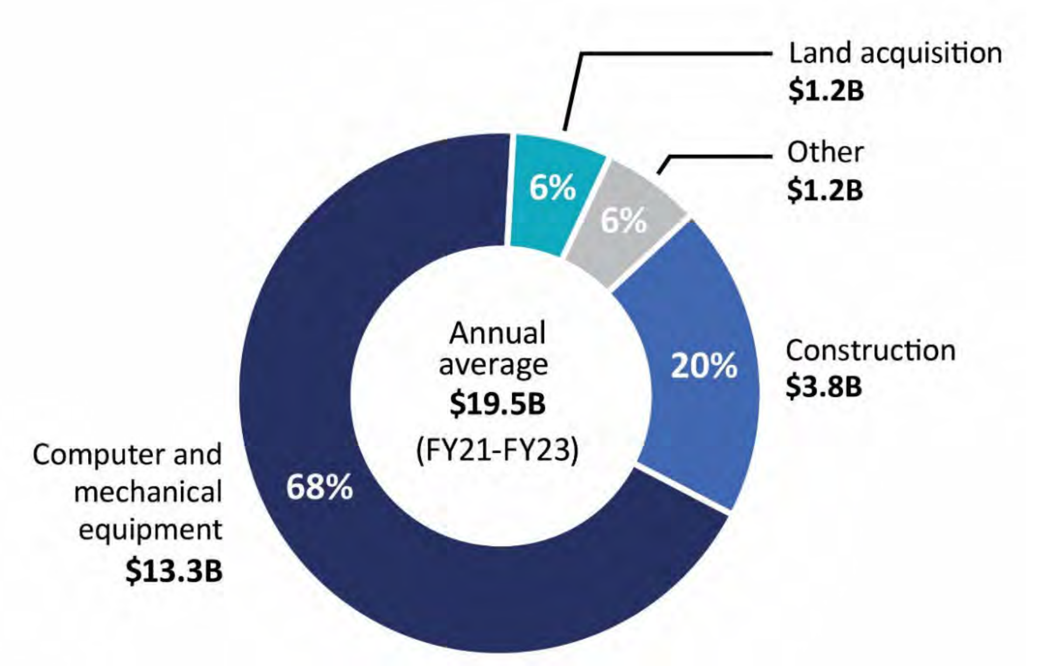
The data center industry provides secondary economic benefits to the state as well. The clustering of data centers in a region, like Northern Virginia, can have "knock on" economic effects by indirectly attracting other related technology businesses, which help create a well-trained, regional IT workforce. This clustering of data centers, related businesses, and skilled workers can further improve the region's attractiveness to additional businesses in the technology sector and other sectors.

Data center capital investment is substantial, although only a portion of it benefits Virginia's economy

Capital investment in Virginia data centers is substantial, exceeding $24 billion in FY23, and primarily consists of equipment purchases from Virginia-based and out-of-state companies. Data center investment represented 84 percent of the total capital investment across all economic development projects announced by the Virginia Economic Development Partnership (VEDP) between FY22 and FY24. However, like capital investments made by other industries, only a portion of data center capital investment benefits the Virginia economy. The primary benefit to Virginia's economy is related to data center construction, which comprises about 20 percent of total data center capital investment (Figure 2-2). Most construction spending likely remains in the state economy because much of it goes to Virginia-based businesses performing key construction services such as clearing and grading sites, erecting steel frames, installing high-voltage electrical equipment, installing industrial-scale cooling systems, and running miles of cable, conduit, and piping. Materials used in data center construction are often also sourced from Virginia businesses throughout the state.

The largest portion of data center capital investment is for IT and mechanical equipment (68 percent), and most of this spending occurs with out-of-state companies. Computer servers are the biggest equipment expense and, because there are no major computer server manufacturers in Virginia, are sourced from outside the state or the country. Some other equipment used in data centers is sourced in Virginia. For example, Virginia has suppliers of electrical and cooling equipment, raised-access floors and hot/cold aisle containment systems, and fiber infrastructure. These suppliers have recently located or expanded operations in Virginia because of the state's large data center market. Even so, a substantial amount of non-computer equipment still likely comes from out-of-state, such as the diesel generators data centers use for backup power.

FIGURE 2-2
Primary benefit of data center capital investment to Virginia's economy is from construction, which comprises 20 percent of data centers' capital investment



SOURCE: JLARC staff and Weldon Cooper Center analysis of data center capital investment between FY21 and FY23 reported to VEDP.

Data center industry supports relatively small operations workforce and sizable construction workforce, both with average or above average wages

Data centers typically employ a small number of workers for data center operations, relative to their facility size. For example, several data center representatives indicated that a typical 250,000-square-foot data center may have approximately 50 full-time workers (one employee per 5,000 square feet versus one employee per 650 square feet for some distribution centers). About half of these workers are likely direct employees of the data center company (or for colocation data centers, direct employees of the tenant). These workers include facility managers, engineers, data technicians, and facility maintenance staff. The other half are contract workers, including electricians, pipefitters, and security personnel who work full-time at the facility (sidebar).

Data centers require constant ongoing maintenance of electrical and cooling systems. Data centers have hundreds of electrical and mechanical components that must be replaced as they break down over time. Additionally, these systems can also be upgraded or configurations changed as computer equipment is upgraded and replaced.

Data center direct employees and contract workers accounted for, by JLARC staff estimates, over 8,000 full-time jobs in FY23. A data center may add new jobs each year as new facilities begin and expand operations. In FY23, data centers added more than 800 new full-time jobs.

Data center construction, however, supports a substantially larger number of workers than data center operations. Construction of an individual data center building usually takes about 12 to 18 months, and it can take five or more years to fully build out a campus. Data center representatives indicated that, at the height of construction, approximately 1,500 workers are on site building a facility and installing electrical and cooling systems and include occupations such as

- site developers and surveyors,
- equipment operators for land clearing and leveling,
- workers to erect steel building frames and concrete walls,
- electricians installing cabling, equipment, and generators, and
- pipefitters and HVAC technicians installing piping and cooling equipment.

Both data center operations and construction workers earn average or above average wages, contributing to the economic benefit of the industry. On average, data center employees and contractors earn about $100,000 per year, varying based on job role and area of the state. Many construction-related jobs do not require a college degree but are also relatively high-paying. For example, the starting salary for electricians is approximately $24 per hour, and a "journeyman" (fully trained) electrician can make approximately $56 per hour. These wages translate to $50,000 and $116,000 in annual wages, respectively, but the actual annual wages are likely higher because these workers often work over 40 hours per week and can earn overtime pay.

The growth of Virginia's data center industry has contributed to the expansion of the state's trades and construction industry. A representative from a construction supplier and contractor indicated that the data center industry is the largest construction sector right now, and data center projects are about one-third to one-half of their current projects and nearly two-thirds of their backlog. A representative of an electrical workers union in Northern Virginia indicated that, because of demand from the growing data center industry, their apprenticeship program has grown from 300 apprentices per training course to 500 in the last several years and could grow larger. A benefit of this growth is that many workers are able to stay in-state and move to another data center construction job after a project is complete, rather than moving to another state to find work.

JLARC's independent economic impact analysis was performed by staff from the Weldon Cooper Center. The analysis was conducted using economic modeling software developed by IMPLAN. The model uses an industry standard methodology but does not account for the cost of some potential externalities, such as health and environmental costs associated with increased carbon emissions, that may be associated with the industry's large energy demands. See Appendix D for additional details.

Data center industry has added thousands of jobs and several billion dollars to state's economy, mostly from construction

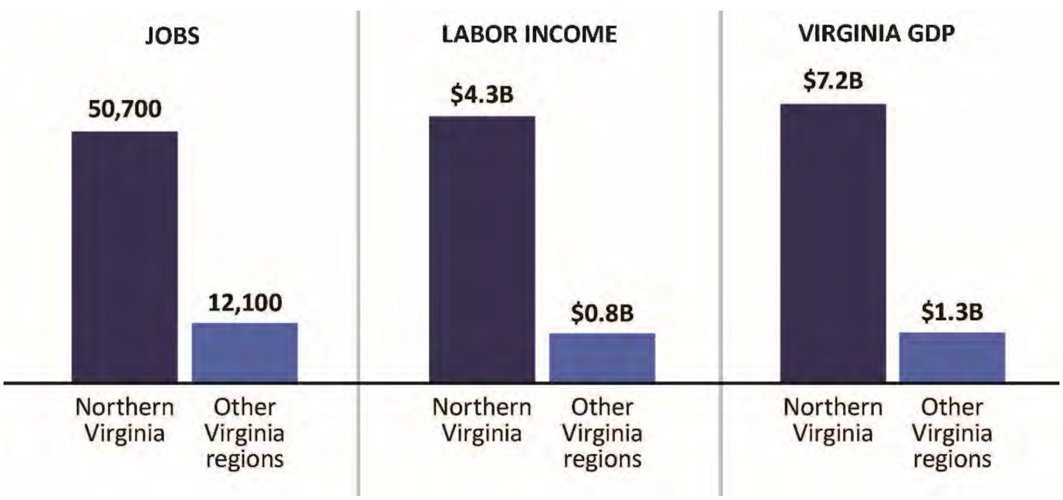
The data center industry benefits the Virginia economy because of the additional jobs and personal income created and the value it adds to the Virginia economy (i.e., Virginia gross domestic product or GDP). JLARC staff commissioned an independent economic impact analysis of the data center industry in Virginia (sidebar). The analysis estimated that the data center industry provides approximately 74,000 jobs, $5.5 billion in labor income, and $9.1 billion in Virginia GDP overall to the state economy annually, based on average spending by the industry between FY21 and FY23 (Table 2-1). These estimates are just over 1 percent of total statewide employment, income, and Virginia GDP during the last three years. Most of the economic benefits have been in the Northern Virginia region, but other regions where data centers are located or under construction, or that have businesses that otherwise support the industry, also benefited (Figure 2-3).

TABLE 2-1
Data center industry has positive economic benefits on Virginia

	Annual average based on data center capital investment and related operation spending		
Economic impact	**Construction phase**	**Operations phase**	**Total impact**
Jobs	59,000 jobs *(35,000 direct)*	15,000 jobs *(4,400 direct)*	74,000 jobs *(39,400 direct)*
Labor income	$4.3 B *($2.6 B direct)*	$1.2 B *($0.4 B direct)*	$5.5 B *($3.1 B direct)*
Virginia GDP	$6.4 B *($3.3 B direct)*	$2.7 B *($1.1 B direct)*	$9.1 B *($4.4 B direct)*

SOURCE: Weldon Cooper Center economic impact analysis of the data center industry impacts, based on data center spending between FY21 and FY23 reported to VEDP, adjusted to account for non-exempt data centers. Numbers may not sum because of rounding.
NOTE: Direct operations jobs include only data center employees and exclude contractors that work full time at data centers. Total impact includes direct impacts plus indirect and induced impacts. Average data center economic impacts presented here likely underestimate the impacts in more recent years given the growth of the industry.

FIGURE 2-3
Economic impact from data centers is concentrated in Northern Virginia



SOURCE: Weldon Cooper Center economic analysis of the annual data center industry impacts, based on data center spending between FY21 and FY23 reported to VEDP, adjusted to account for non-exempt data centers.
NOTE: Totals for Northern Virginia and other Virginia regions do not sum to statewide totals shown in Table 2-1 because the analysis does not account for impacts from activity in Northern Virginia occurring in other Virginia regions and vice versa.

Much of the data center industry's economic benefits in Virginia derive from capital spending during the construction phase rather than spending during ongoing operations (Table 2-1). Annual average spending during the construction phase is estimated to be more than three times annual operation spending, according to prior research. Data centers were estimated to contribute 59,000 jobs annually during the construction phase, accounting for 80 percent of total annual jobs resulting from data centers. This estimate includes 35,000 direct jobs, most of which were construction workers (28,000), although some were IT-related workers manufacturing and installing equipment (7,000). Another 24,000 jobs were estimated to be in supporting sectors, such as materials suppliers, and "induced jobs" in businesses that benefit from worker spending, such as restaurants and retail. The data center construction phase also accounted for most of the annual increase in total labor income (80 percent) and total Virginia GDP (70 percent) from data centers. Appendix D provides additional technical details on these and other analysis outcomes.

Because most of data centers' economic benefits are from construction, continued growth of the data center industry would be needed in Virginia to maintain the same level of economic impact. Current trends suggest continued growth is likely to happen, at least for the near future. Virginia's data center market is expected to double in the next few years based on the data center capacity currently under construction and in the early development stages.

Data centers generate substantial local tax revenues for localities that have them

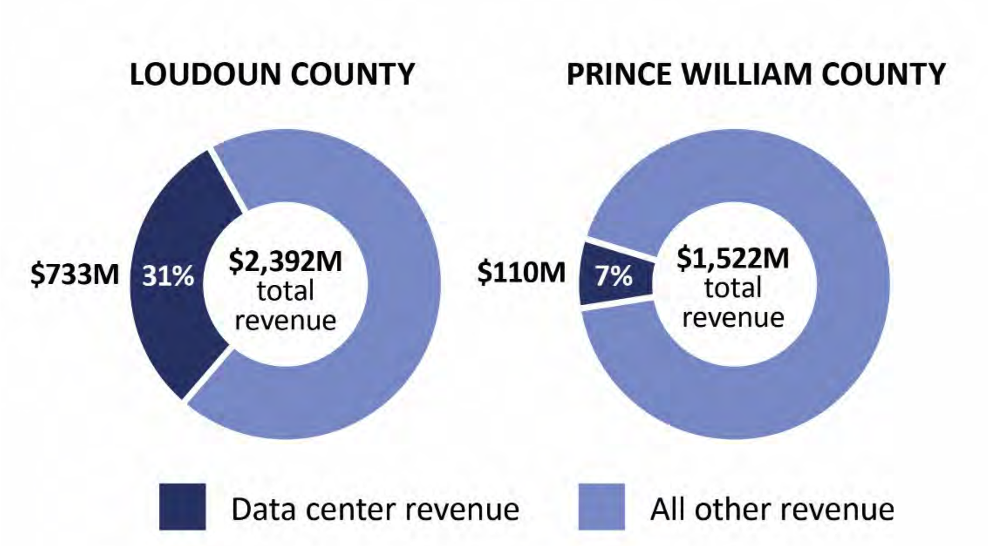
Local governments with data centers in their jurisdictions can collect substantial tax revenues from the industry. Data centers pay different types of local taxes, but the primary ones are business personal property and real property (real estate) taxes (sidebar). The business property tax, in particular, can generate substantial revenue. A single data center typically has business personal property valued in the millions, a large portion of which is computer equipment that is typically replaced every five years.

Business personal property taxes are levied by local governments on the value of property, such as furniture, fixtures, computer equipment, machinery, tools, and heavy equipment within their locality. State law allows a locality to tax certain classes of personal property at lower rates, including computer equipment for data processing.

Real property (or real estate) taxes are levied by a local government on land and improvements in their locality.

Although data center tax revenues can be substantial, the industry's share of local revenue varies. For the five localities with relatively mature data center markets (Loudoun, Prince William, Mecklenburg, Henrico, and Fairfax), data center revenue ranged from less than 1 percent to 31 percent of total local revenue. The amounts collected and percentage of local revenues vary substantially because of differences in the size and maturity of the data center markets, locality sizes and tax bases, and local tax rates and depreciation schedules. Loudoun and Prince William have the largest and most mature markets, and data center revenue accounted for 31 percent and 7 percent, respectively, of total local tax revenue (Figure 2-4). Loudoun collects substantially more revenue from data centers primarily because its data center market size is three times larger than Prince William's. Revenue estimates are not provided for all of these localities to protect taxpayer confidentiality.

FIGURE 2-4
Data center tax revenue can be substantial for local governments (FY23)



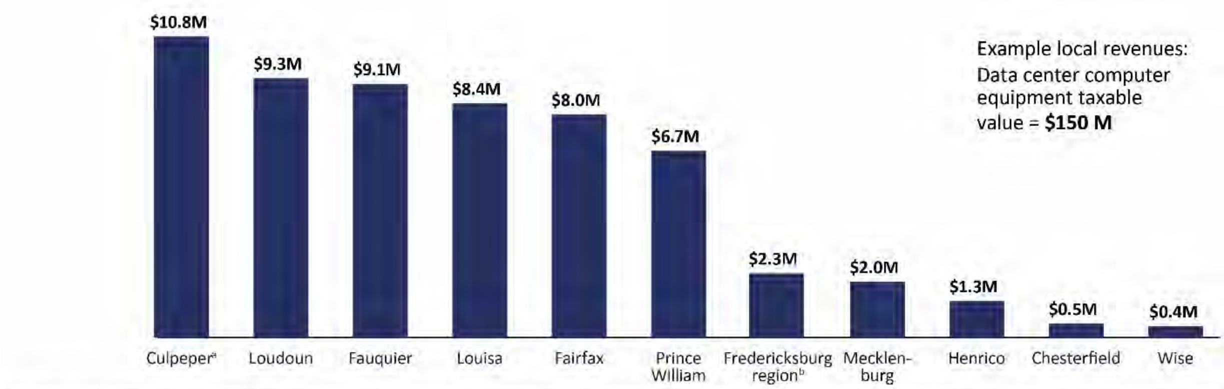
SOURCE: JLARC staff analysis of revenue collections from localities and the APA Local Government Comparative Report, FY23.

Tax rates also significantly affect the amount of revenue a locality can generate from data center developments. Some localities have greatly reduced their business personal property tax rates for computer equipment to try to attract the industry and, therefore, collect far less revenue than other localities with a higher tax rate would collect for a comparable project. For example, assuming a data center with $150 million in taxable computer equipment, counties could collect from $10.8 million to $0.4 million over a five-year period (after accounting for different tax rates and depreciation schedules) (Figure 2-5).

Even with the variation in tax revenue collections, local government staff from the five counties with the greatest data center presence indicated that data center revenue has benefited their locality. Local government staff indicated data center revenue has allowed their locality to

- lower real estate tax rates (Loudoun and Prince William),
- develop an affordable housing trust fund (Henrico County),
- establish revenue stabilization or reserve funds (Loudoun and Prince William), and
- construct new schools (Mecklenburg).

FIGURE 2-5
Some localities would collect far less revenue over a five-year period than others for the same data center development



	Culpeper[a]	Loudoun	Fauquier	Louisa	Fairfax	Prince William	Fredericksburg region[b]	Mecklenburg	Henrico	Chesterfield	Wise
Tax rate / $100	$3.50	$4.15	$3.45	1.90	$4.57	$3.70	$1.25	$0.66	$0.40	$0.24	$0.24
Depreciation rate	Slow	Moderate	Slow	Slow	Fast	Fast	Fast	Moderate	Moderate	Fast	Fast

SOURCE: JLARC staff analysis of locality property tax rates and depreciation schedules for computer equipment.
NOTE: Tax rate is the business personal property tax rate in 2024 for computer equipment. Amounts exclude real property taxes. Amounts are based on a data center with $150 million in equipment. Data center equipment is typically replaced every five years, which resets the depreciation schedule used to calculate the decline in value of equipment each year after its purchase.
[a] Culpeper provides a local tax rebate for data centers that invest at least $10 million and hire at least 10 new employees in the Culpeper Technology Zone, and therefore may reduce this amount for qualifying data centers. [b] Fredericksburg Region includes the City of Fredericksburg, Caroline County, King George County, Spotsylvania County, and Stafford County.

In addition to the revenue the industry generates, local government staff reported that data centers are an attractive industry because they impose minimal direct costs on the provision of government services compared with other industries. Data centers employ relatively few employees in comparison with other industries like manufacturing and logistics. Industries with more employees place greater demand on local roads, school systems, and other services.

Localities in distressed areas have difficulty attracting data centers

Data center developments could benefit localities in economically distressed areas of the state through increased local revenue. However, localities in these areas face several challenges in attracting data centers. To be considered, a locality likely needs to have 230kV transmission lines (the preferred voltage for modern data center campuses) and large and flat properties close to those transmission lines. These requirements could prevent many counties in distressed areas, particularly in Southwest Virginia, from being considered.

Localities in economically distressed areas that are away from population centers can also only compete for certain types of data centers. They cannot compete for data centers that need to be close to customers or require low latency, such as cloud computing and colocation facilities. However, they may be able to compete for data centers running artificial intelligence (AI) workloads, such as training models, which do not need to be near populated areas and may not require low latency. AI is expected to drive a lot of future industry growth and presents an opportunity for more remote localities.

The state could improve the competitiveness of localities in distressed areas by helping them identify, prepare, and market industrial sites that are attractive to the data center industry. Data center companies prefer to move fast once a site has been identified, so available land should have access to roads and other utilities (water, sewer) that allow construction to begin soon after selection. Company representatives said industrial sites that are shovel-ready could be particularly attractive. The primary reason Mecklenburg was successful in attracting Microsoft was because the county had already identified a site suitable for data center development when Microsoft was looking for potential Virginia locations.

The Virginia Business Ready Sites Program, which is administered by VEDP, can be used for this purpose. The program identifies and assesses the readiness of potential industrial sites and provides site characterization and development grants to local governments and regional authorities. The program is intended to develop sites to attract large employers, such as manufacturers, but it can be used to identify and develop sites for which data centers would be a "best use" and would generate a positive return on investment for the state. For example, a 150-acre site that has limited road and rail infrastructure but is located close to 230kV transmission lines might be best used as a data center instead of a manufacturing plant. To help localities in distressed areas compete for data centers, VEDP should clarify that potential data center sites can be included in VEDP's site listings and are eligible for Virginia Business Ready Sites Program grants.

RECOMMENDATION 1

The Virginia Economic Development Partnership should clarify in site characterization and development guidelines that potential data center sites are eligible for grants under the Virginia Business Ready Sites Program.

The 2020 General Assembly **lowered the eligibility requirements** for the data center exemption in distressed areas of the state to 10 jobs and capital investment of $75 million to encourage growth in these areas.

The state made changes to its data center sales tax exemption, discussed in the next section, several years ago to try to attract data centers to distressed areas of the state (sidebar). However, very few data centers have qualified for the exemption under the changes, so the changes alone may not be sufficient to overcome other challenges to attract data centers to these areas.

State's data center exemption encourages industry growth and has moderate economic benefits

Virginia, like other states, uses incentives and other strategies to try to attract specific industries that can create new economic activity. The goal of targeting specific industries is to establish industry clusters or ecosystems.

Since 2010, Virginia has offered a retail sales and use tax exemption to attract large-scale data centers. The exemption allows qualifying data centers and their tenants to purchase computers and other equipment without paying the state sales tax on the following items, namely

- computer equipment such as servers, mainframes, network infrastructure, and data storage hardware; and
- other equipment such as cabling, switches, cooling equipment, generators, monitoring systems, and similar items used to operate exempt equipment.

This report includes higher **estimates of the tax revenue impact of the data center exemption** than was reported in prior years. Data centers using the exemption are now required to report to the Virginia Economic Development Partnership their annual eligible exemption expenditures and tax benefits.

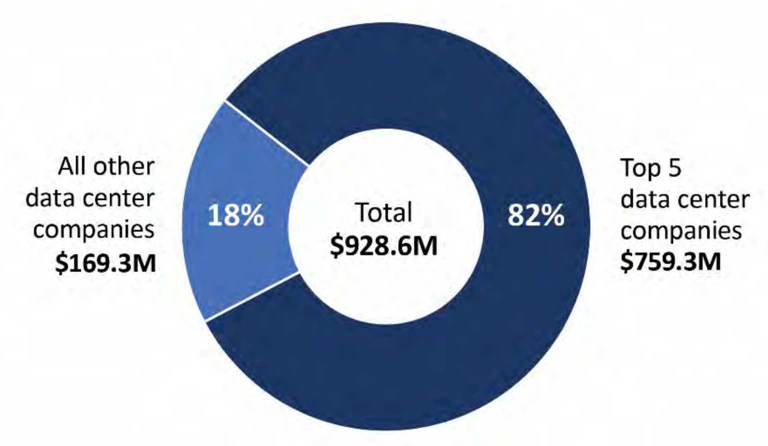
The statewide retail sales and use tax includes a 4.3 percent state share, a 1 percent local option share, and additional 0.7 percent to 1.7 percent regional share, depending on the region. In addition to collecting revenue from the local option, localities tax data center property in other ways, as described in this chapter.

Exemption provides qualifying data center companies with substantial tax reductions

Data center owners and their tenants, which can include a wide range of businesses in sectors like technology, health care, financial institutions, and retail, can claim the data center sales and use tax exemption if they meet eligibility requirements. To qualify, data centers must create a minimum of 50 jobs paying at least 150 percent of the prevailing annual average wage in the locality where the data center is located and make a $150 million capital investment. As noted above, the minimum thresholds are lower for distressed areas. Data centers and tenants reported saving $928.6 million in sales taxes in FY23 because of the exemption, including state, local, and regional portions of the tax (sidebar). The state portion of the exempted amount was an estimated $683 million, making it by far the state's largest economic development incentive, with the next closest incentive valued at $74 million.

Although approximately 30 data center companies (and their tenants, for colocation data centers) claim the exemption, most of the tax savings accrue to a small number of companies (Figure 2-6). Even so, the median savings for a data center company using the exemption was $5.4 million in FY23, and all but six companies saved $1 million or more.

FIGURE 2-6
Most of the tax savings from data center exemption go to only a few data center companies (FY23)



SOURCE: JLARC staff analysis of data center exemption information reported to VEDP.
NOTE: For colocation data centers, the tax savings is attributed to the data center owner rather than the individual tenant, because the data center owner is the "holder" of the MOU and the reporting entity.

Exemption likely affects data center location and expansion decisions

Data center companies consider several factors when determining where to locate, and state sales tax exemptions are regularly ranked among their top factors. The other top site selection factors are access to power, available land, workforce quality, customer needs, business-friendly regulatory climate, and utility and other costs. While it is impossible to precisely determine the exemption's importance in data centers' location decisions, representatives from data center companies indicated the exemption was a key consideration because it greatly reduces their costs.

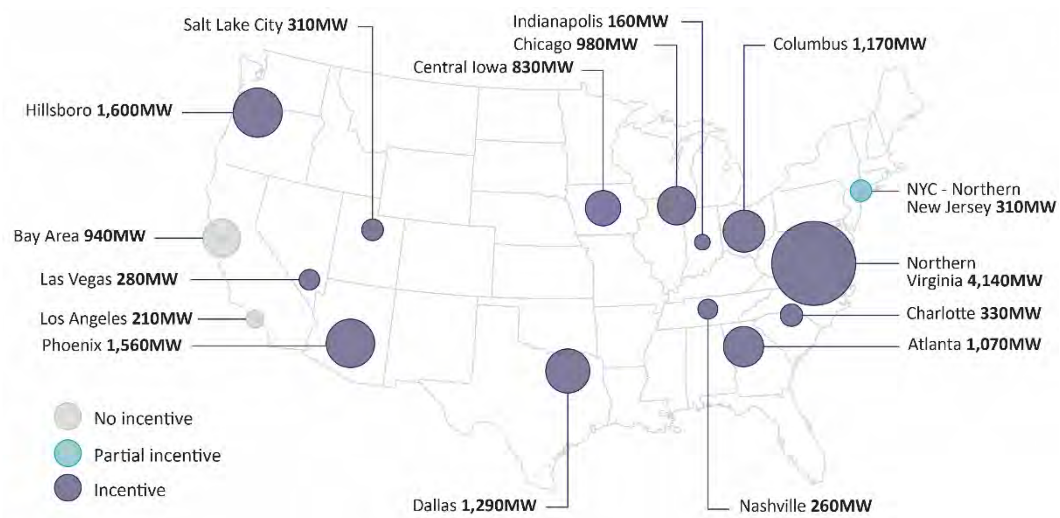
Data center companies view the exemption as important because their industry is capital intensive, and the exemption provides substantial savings on those investments. If a typical modern 250,000-square-foot data center costs $250 million to $325 million to build and equip, the exemption would provide an initial benefit of about $9 million to $15.5 million in savings (depending on the locality). Companies also save on subsequent equipment purchases, usually made every five years when data centers replace and upgrade their computer equipment. For colocation data centers, the exemption is also important for meeting customer needs, because it provides savings to tenants who purchase their own equipment.

Virginia is competing for data centers with other states that have similar exemptions

Since the late 2000s, states have increased their efforts to attract data centers, primarily by adopting sales tax exemptions. In 2008, Virginia became the seventh state to adopt a sales tax exemption. (The initial exemption applied to very few localities and is no longer in effect, but a statewide exemption was adopted in 2010.) Today, the majority of states either have a sales tax exemption for data centers (34) or do not have a sales tax (4). All states bordering Virginia provide a sales tax exemption to data centers. (See Appendix E for a map of states with a data center sales tax exemption.)

Virginia competes with other states for new data center developments, especially states that also have primary markets. Most other primary markets are located in states with exemptions, with the exceptions being markets in California and the New Jersey portion of the New York-northern New Jersey market (Figure 2-7). These two markets have a relatively small data center presence considering their proximity to major population centers, the California market's proximity to high tech firms in Silicon Valley, and the New Jersey market's proximity to the U.S. financial center in New York City.

FIGURE 2-7
All primary data center markets in the U.S. have exemptions, except for California and northern New Jersey markets, which are relatively small



SOURCE: JLARC staff analysis of Cushman & Wakefield 2024 Global Data Center Market Comparison.
NOTE: Oregon (Hillsboro market) does not have a sales tax (which has similar effect of the exemption). "Northern Virginia" refers to an estimate of data center capacity in the traditional Northern Virginia market consisting of Fairfax, Loudoun, and Prince William counties and Manassas. The Cushman & Wakefield report also includes an estimated 560 megawatts of capacity in Culpeper and Fauquier counties and the Richmond metropolitan region.

Data center exemption has moderate economic benefits and return in revenue to the state compared with other incentives

The data center exemption has moderate economic benefits and moderate return in revenue to the state compared with Virginia's other economic development incentives. (See *Data Center and Manufacturing Incentives,* JLARC, 2019.) It is rated as moderate because it is similar to the economic benefits and return in revenue for the average incentive (Table 2-2). Like most economic development incentives, the data center exemption does not pay for itself when considering just the state portion of the exemption cost and the state return in revenue.

TABLE 2-2
Data center exemption has moderate benefits compared with other incentives

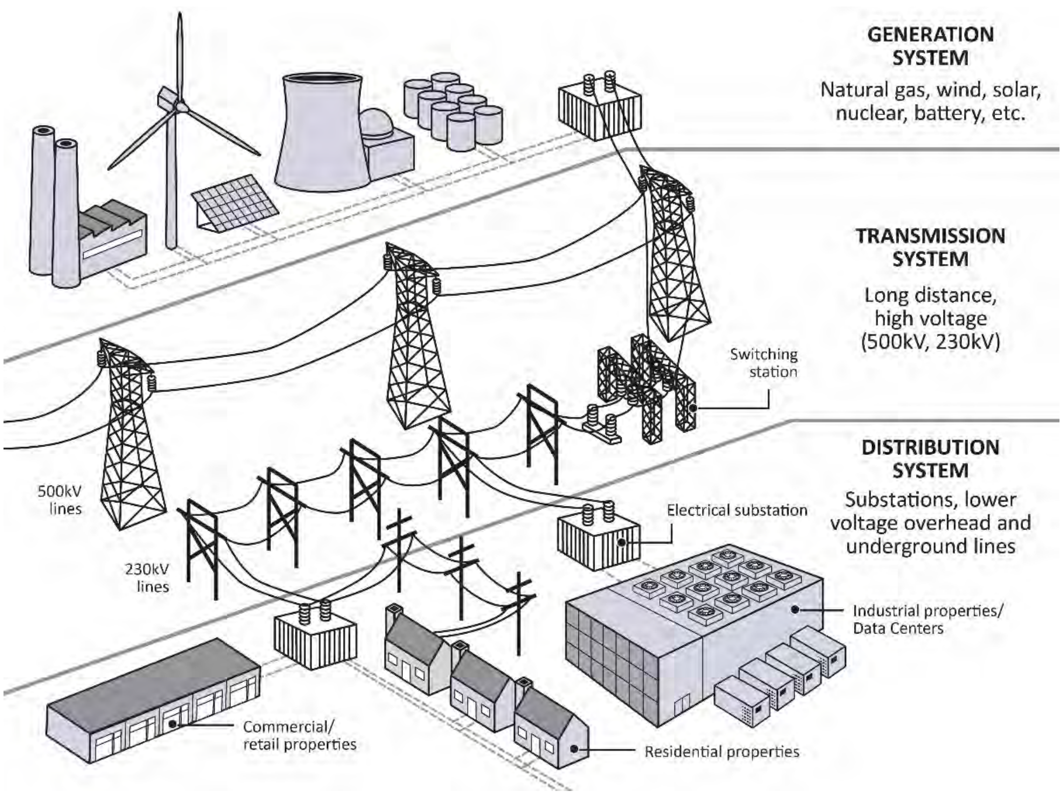
	Annual average	
	Data center exemption	**Average Virginia incentive**
Economic impact per $1 million spent on the exemption		
Jobs added	84 jobs	58 jobs
Income added	$6 M	$5 M
Virginia GDP increase	$10 M	$9 M
Impact on state revenue per $1 spent on the exemption		
Return in revenue per $1 spent	48¢	41¢

SOURCE: *Economic Development Incentives 2024*, JLARC 2024.

3 Energy Impacts

Virginia's power grid is part of the North American Eastern Interconnection, a massive energy infrastructure network that provides electricity to most states and several Canadian provinces east of the Rocky Mountains. The grid comprises three key interconnected systems: generation, transmission, and distribution (Figure 3-1). Power generation in Virginia has historically come from a few large carbon fuel and nuclear plants, but is increasingly coming from renewable sources like solar and wind. The transmission system moves power in bulk over long distances from where it is generated to the area where it is consumed. Power is then reduced to lower voltages and provided to homes, businesses, and other consumers through the distribution system.

FIGURE 3-1
Power grid is a complex network of generation, transmission, and distribution systems

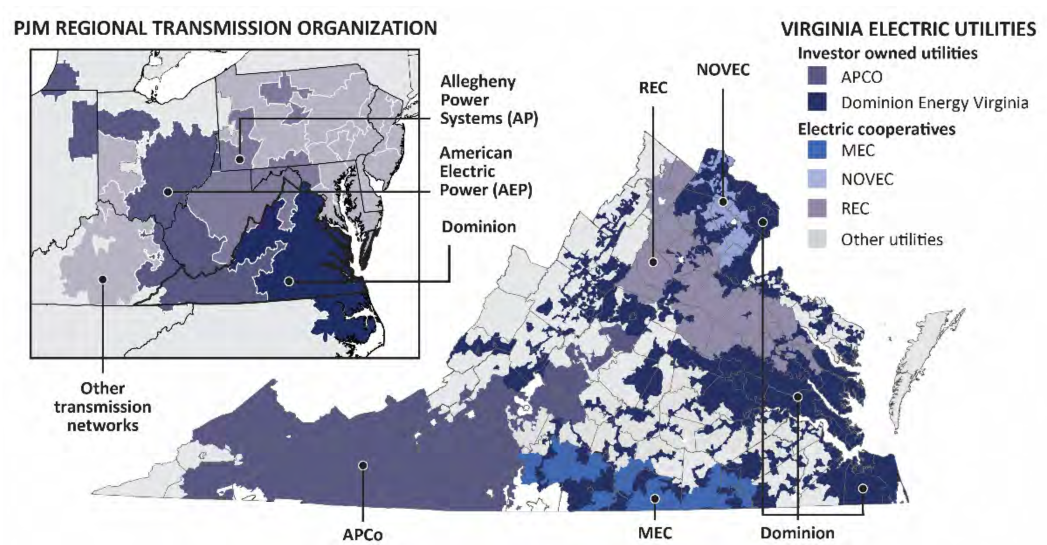


SOURCE: JLARC staff.

Within the eastern power grid, Virginia is part of the PJM regional transmission organization (Figure 3-2). PJM is a not-for-profit organization that coordinates generation and transmission operations and operates as a wholesale power market for its members, including utilities, independent power generators, and other energy companies. Within Virginia's section of PJM, the two main power utilities are Dominion and American Electric Power (AEP), which operate much of the generation and most of the transmission that serve the state. Dominion and AEP (under its subsidiary Appalachian Power Company, or APCO) are also the distribution utilities for much of the state. However, a significant portion of the state is served by 13 distribution cooperatives (the "co-ops"). Most co-ops purchase their power through another generation and transmission utility, the Old Dominion Electric Cooperative (ODEC), which operates or partially owns a few power plants, and contracts for additional power, in and outside of Virginia. The largest distribution co-op, the Northern Virginia Electric Cooperative (NOVEC), purchases its own generation and operates one power plant.

Virginia's power utilities are subject to state and federal laws and are regulated by the State Corporation Commission (SCC) and the Federal Energy Regulatory Commission (FERC). One of the SCC's key functions is to approve new generation and transmission projects. See Appendix F for more discussion of generation and transmission projects' potential impacts and how regulators and utilities try to minimize those impacts.

FIGURE 3-2
Virginia is part of PJM and relies on transmission and distribution utilities



SOURCE: PJM and SCC maps.
NOTE: MEC = Mecklenburg Electric Cooperative. REC = Rappahannock Electric Cooperative. Additional cooperatives that are not named above include A&N, BARC, Craig-Botetourt, Community, Central Virginia, Northern Neck, Powell Valley, Prince George, Southside, and Shenandoah Valley. There are also several small municipal power utilities, and the investor-owned Eastern Kentucky Power Company serves a small portion of Southwest Virginia.

Data center industry is driving immense increase in energy demand and will require enormous new infrastructure investments

Modern data centers consume substantially more energy than other types of commercial or industrial operations. For example, one of the smaller data centers recently constructed in Virginia can draw up to 18 MW of power (sidebar). This is roughly equivalent to a mid-sized automobile assembly plant, 60 large commercial office buildings, or 4,500 homes. The largest new data centers can draw from 100 to over 200 MW each, which is more than most industrial consumers. Some planned data center campuses are expected to consume well over 1,000 MW, once fully built out, which is more than the 950 MW generation capacity of the state's largest nuclear reactor.

Data center power demand is typically measured in megawatts (MW). A watt measures the amount of energy produced or consumed at any instant, and a megawatt is equal to 1 million watts. For example, a 100 MW data center can consume up to 100 MW of energy at a given point in time. Energy consumption over time is typically measured in kilowatt-hours (KWh) or megawatt-hours (MWh).

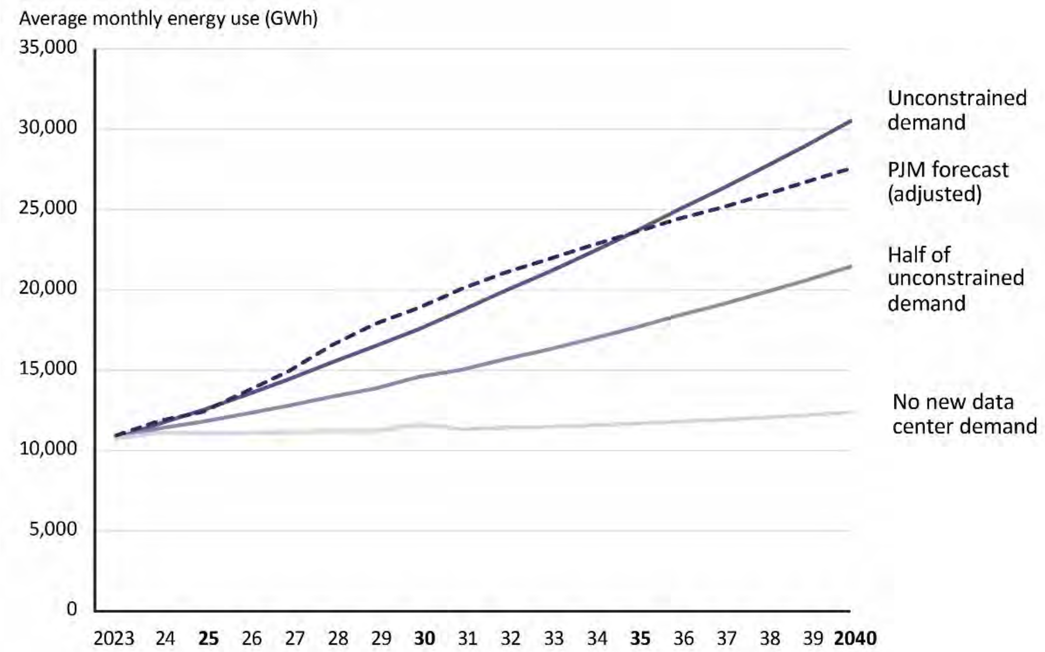
To evaluate the potential energy impacts of the data center industry, JLARC staff commissioned an independent forecast of *unconstrained* power demand growth in Virginia, based on historical data trends. The unconstrained forecast shows what demand would be before accounting for constraints like the ability to build enough energy infrastructure to meet demand. JLARC staff also commissioned an independent grid model to project what future generation and transmission infrastructure would be needed to meet (1) unconstrained demand and (2) half of unconstrained demand. The grid model also estimated infrastructure needs if there was no new data center demand, so that the effects of data center growth could be separated from other effects on the grid. The demand forecast was developed by staff from the Weldon Cooper Center for Public Service at the University of Virginia, and the grid model was developed by energy consultant Energy + Environmental Economics (E3). See Appendix B for additional details.

Data center industry is forecast to drive immense increase in energy demand

The data center industry boom in Virginia has substantially driven up energy demand, and demand is forecast to continue growing for the foreseeable future. The state's energy demand was essentially flat from 2006 to 2020 because, even though the population increased, improvements in energy efficiency offset that increase. However, by 2024, PJM forecast an unprecedented 5.5 percent year-over-year growth in the Dominion transmission zone, mainly because of increasing data center demand.

JLARC's independent forecast shows that unconstrained demand for power in Virginia is expected to double within the next 10 years, driven primarily by the data center industry's growth (Figure 3-3). Almost all of the demand growth is expected to occur in the Dominion transmission zone, which covers the Northern and Central Virginia regions, where most new data centers are being built. JLARC's forecast largely matched the most recent PJM forecast.

FIGURE 3-3
Data center demand would drive immense increase in energy demand in Virginia, based on JLARC's independent forecast and other forecasts



SOURCE: JLARC staff consultant analysis.
NOTE: Forecast is for Virginia. PJM forecast is the 2024 forecast for the Dominion transmission zone adjusted upward to account for APCO; this adjustment had no effect on the trendline shown and was done so that the forecasts could be more easily compared. JLARC's independent forecast was developed using actual, historical energy use and employed advanced statistical methods to project use going forward. While JLARC's forecast was checked against the data reported by utilities on future data center load requests, that data was not used to formulate the forecast.

The first five years of JLARC's unconstrained demand forecast are in line with the new data center load additions that are expected, based on existing utility service and data center construction agreements, data center projects that have been announced, and national energy research conducted by Lawrence Berkeley National Laboratory and the Electric Power Research Institute.

New generation and transmission infrastructure will need to be built to help address data center demand

JLARC's grid model found that a substantial amount of new generation and transmission infrastructure would need to be built in Virginia to meet unconstrained demand, or even half of unconstrained demand, and most of the new infrastructure needs would be attributable to the growing data center industry (Table 3-1). For each of the demand scenarios, the model considered the most feasible and economical approaches to meeting infrastructure needs with and without the requirements of the Virginia Clean Economy Act (VCEA). The modeling was done using industry standard approaches and tools for electric utility and state energy planning purposes. It is based on current state and federal laws and regulations. Some costs, such as the social cost of carbon, were not explicitly included in the model.

VCEA was enacted in 2020 to drive investment in renewable resources and requires the phaseout of carbon-emitting generation in the state by 2050. (See Appendix G.) VCEA requires that an increasingly larger share of the energy sold by the investor-owned utilities, Dominion and APCO, to their retail customers come from renewable and in-state generation sources. While this results in slightly more generation being built in-state than would otherwise occur, it has little effect on new transmission infrastructure needs and could increase the amount of energy that is imported from out of state. VCEA's effects on renewable and in-state generation are not as pronounced as might be expected because the requirements for utilities to sell energy from these sources do not apply to the co-ops, and a majority of projected data center growth (~60 percent) is expected to occur in co-op service territories. See Appendix H for additional details on generation capacity and energy sources expected under each scenario.

TABLE 3-1
Addressing demand from data centers would require substantial investment in new in-state generation resources and transmission by 2040

			Change from 2025 to 2040			
			Scenario 1: Unconstrained demand		Scenario 2: Half unconstrained demand	
	Current system		No VCEA	VCEA	No VCEA	VCEA
Generation resources (in-state)	36,000 MW capacity	Net increase	+54,100 MW	+56,300 MW	+31,200 MW	+34,700 MW
		Data center share	*+35,600*	*+34,300*	*+12,800*	*+12,700*
Transmission (interzonal)	8,700 MW capacity	Net increase	+3,500 MW	+3,500 MW	+3,100 MW	+3,100 MW
		Data center share	*+3,500*	*+3,500*	*+3,100*	*+3,100*
Imported energy (net)	38 TWh annual energy [a]	Net increase	+62 TWh	+73 TWh	+24 TWh	+24 TWh
		Data center share	*+79*[b]	*+92*[b]	*+41*[b]	*+43*[b]

SOURCE: E3 grid modeling analysis. Current system capacity and energy are derived from Energy Exemplar PLEXOS database.
NOTE: Generation is in-state nameplate capacity that would need to be built, which can be significantly higher than the amount of energy produced by a resource over a year (e.g., Virginia solar facilities produce at around 25 percent of nameplate capacity). The model predicts new generation capacity would still be built even without data center growth, because the grid is expected to shift to cheaper renewable energy sources and building more in-state generation to reduce reliance on imports. Transmission shows only current and additional interzonal capacity needed for power exchange between the Dominion transmission zone and neighboring zones. It does not show transmission capacity or additions *within* the Dominion transmission zone.
[a] TWh=terawatt hours. TWh are used to measure large amounts of energy consumed over time. One TWh = 1,000,000 MWh.
[b] Data center share of imported energy is larger than the net increase because, without data center demand, imported energy would decline. For example, under Scenario 1 (no VCEA), energy imports would decrease −17 TWh from 2025 to 2040 without data center demand. +79 TWh data center share −17 TWh = net increase of +62 TWh.

Building enough infrastructure to meet growing data center demand will be difficult under both forecast scenarios

Historically, utilities and other PJM members have kept up with demand by building enough new generation resources and transmission to meet demand. Utilities have been able to do this because demand has increased slowly or been relatively flat over the past several decades, but the expected increase in demand from data centers will far outpace previous energy demand growth. If utilities are unable to build enough new generation and transmission to keep pace with forecast data center demand, there are two likely outcomes: (1) they will delay the retirement of older fossil fuel plants, and less economical plants, to the extent allowed by state and federal law, and (2) they will delay the addition of new large load customers, mainly data centers, until there is adequate transmission and generation capacity to serve them. On the demand side, data centers will seek out markets where demand can be met and pursue ways of contracting for and generating their own power. While it is possible that enough infrastructure could be built to meet growing data center demand in Virginia, it would be difficult to accomplish.

VCEA financially penalizes utilities that do not comply with renewables requirements by levying deficiency payments, but in practice, utilities may choose to pay those deficiency payments if it is more economical or feasible than securing new renewable generation. Statute directs any deficiency payments collected to be used in support of job training, energy efficiency, and renewable energy programs. The costs of deficiency payments are recovered from utility customers.

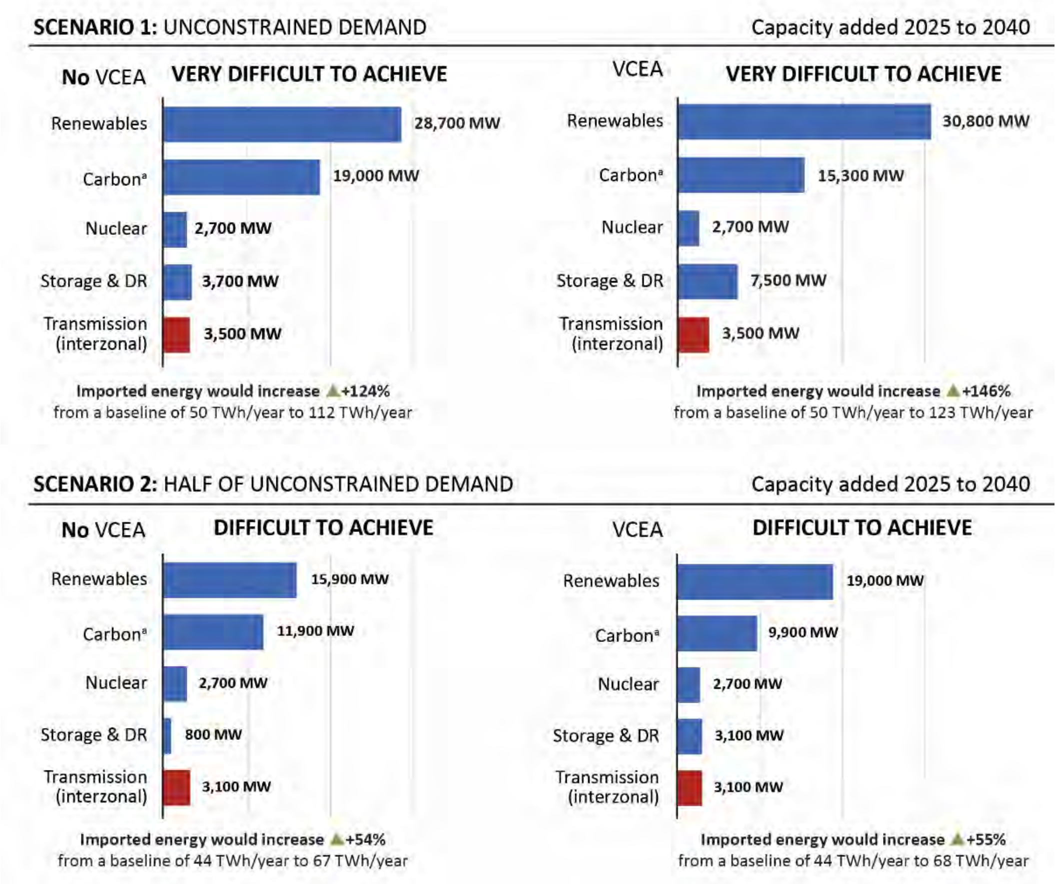
It could be especially challenging to meet demand while also fully meeting VCEA renewable requirements. Dominion's 2024 integrated resource plan indicates that it expects to meet VCEA renewable requirements for most, but not all, years between now and 2040 and expects to pay deficiency payments in some years (sidebar). In addition, in its previous 2023 plan, Dominion indicated it did not expect to meet VCEA requirements to retire carbon emitting assets that take effect in 2045. The previous plan stated: "Due to an increasing load forecast, and the need for dispatchable [i.e., easily scalable] generation, the [modeled planning scenarios] show additional natural gas-fired resources and preservation of existing carbon-emitting units beyond [the 2045] statutory retirement deadlines established in the VCEA." The revised 2024 plan does not comment on this and does not project out past 2040.

Building enough infrastructure to meet *unconstrained* energy demand will be very difficult, with or without meeting VCEA requirements (Scenario 1)

It will be very difficult to build new generation and transmission in Virginia fast enough to match unconstrained demand by 2040 (Scenario 1) and would require a massive and sustained build-out of new renewable, carbon, nuclear, and storage facilities (Figure 3-5). Build rates would have to greatly outpace what has been accomplished historically. Solar facilities would have to be added at about twice the annual rate they were added in 2024, and the amount of new wind generation needed (8,800 MW) would exceed the potential capabilities of all offshore wind sites that have so far been secured for future development (7,400 MW). New natural gas plants would have to be added at a rate of one large 1,500 MW plant almost every year (without meeting

VCEA requirements) or almost every 1.5 years (meeting VCEA requirements) for 15 consecutive years, which would be faster than the rate they were added during the busiest build period of the last decade in the state. Additional pipeline capacity may also need to be added to serve such a substantial increase in natural gas generation, which would create additional challenges. The unconstrained demand scenario would also require building more nuclear generation, presumably using new technologies.

FIGURE 3-4
Estimated generation mix needed to meet demand scenarios, with and without meeting VCEA requirements



SOURCE: E3 grid modeling analysis.
NOTE: The generation and transmission solutions generated by the model are tested to ensure they would produce a reliable system. Generation capacity is given in *nameplate* capacity, which can be significantly higher than the amount of power that can actually be expected after accounting for resource intermittency and downtime (firm capacity). The model predicts only interzonal transmission needed between PJM zones, but additional transmission would need to be built within the Dominion transmission zone. DR is demand response resources, which refer to customers who can reduce energy use during peak load events or add energy back on to the grid. The figure does not show what would need to be built if there were no new data center demand (Scenario 3). Under this scenario, the grid would be able to transition to a more renewable-based system with relatively less difficulty.
[a] Carbon includes natural gas, coal, and oil. Biomass facilities are counted as renewable resources, per the VCEA. However, starting in 2045, E3's grid model assumes natural gas plants would be converted to hydrogen fuel in each scenario when VCEA requirements are met.

To meet transmission needs, the state would have to increase interzonal capacity to the Dominion transmission zone by approximately 40 percent and construct additional transmission within the zone. Many of the new transmission lines would need to be built in densely populated regions of the state with limited options for siting new infrastructure. (Figure 3-4 shows only new interzonal transmission.)

In addition to building new in-state generation and transmission, the state would need to more than double the amount of energy imported from out of state. Consequently, Virginia would be reliant on additional generation being built at a rapid pace in other states in the PJM region and would need these other states to build sufficient generation capacity to serve Virginia's needs as well as their own.

Building enough infrastructure to meet only *half of unconstrained* energy demand will be difficult (Scenario 2)

It would likely still be difficult to build enough new generation and transmission to meet half of unconstrained demand by 2040 (Scenario 2). Meeting demand would also require a sustained build-out of new renewable, carbon, nuclear, and storage facilities. Solar facilities would have to be added at a rate of 650 to 700 MW per year, which is substantial but lower than the 1,000 MW expected to be added in 2024. New nuclear generation would also be needed.

If VCEA requirements are not considered, the biggest challenge would be building new natural gas plants. New gas would need to be added at the rate of about one large 1,500 MW plant every two years for 15 consecutive years, which would be about the same rate Dominion added these types of plants during its busiest period of the last decade (2012 to 2018).

"Peaker" plants are 50 MW to 150 MW facilities used intermittently to supplement other types of generation when there is not sufficient energy to meet demand. Historically, they have mostly operated at times when cooling and heating needs are the highest among households. However, as more solar and wind generation is incorporated into the grid, they can be used to provide energy when these renewables are not producing (alongside battery storage).

If it is assumed VCEA requirements are met, the biggest challenges would be building enough wind, battery storage, and natural gas "peaker" plants (sidebar). Wind generation needs would exceed the potential capabilities of all secured offshore wind sites in Virginia. The amount of new battery storage needed would be several times the small amount of existing battery storage in Virginia, but would be equivalent to what has already been installed in Texas and about half of California's installed capacity. A significant number of new natural gas "peaker" plants would also be needed to help balance intermittent generation from renewables.

Transmission needs would remain substantial under the half of unconstrained demand scenarios, especially in and around the Northern Virginia region, and building enough transmission capacity within a 15-year timeframe could be even more difficult than building enough generation. The amount of energy the state would need to import would increase by over 50 percent.

New infrastructure projects face several challenges that make a rapid increase in construction difficult to achieve

Under the most favorable circumstances, it takes five or more years to develop and build new generation facilities, limiting how fast they can be added to the grid. New generation projects face several challenges that could keep them from being built, including community opposition (especially to solar and natural gas projects), long lead times to procure equipment, workforce constraints, and state and federal laws that limit what new carbon-emitting generation facilities can be built. PJM data shows that only a small percentage of projects that submit applications are ever actually built (sidebar).

PJM must study and approve the addition of most new utility-scale generation to the grid. PJM's approval process became overwhelmed by small-scale renewable projects in 2022, which led to a two-year pause in approvals while PJM reformed its process. This pause may have affected the number of projects that have been built in recent years, but project success rates were already low before the pause (29 percent in 2018).

A significant portion of new generation would need to come from solar projects, which could face challenges acquiring enough land. Generally, a solar facility in Virginia needs five to 10 acres to produce one MW of power. Assuming an average need of 7.5 acres per MW, and the scenarios modeled above, JLARC staff estimated that Virginia will have about 57,000 acres of land devoted to utility-scale solar by 2025, and new projects could require from 73,000 to 165,000 additional acres by 2040, depending on the demand scenario. Utilities and independent generators could face significant challenges in acquiring and gaining local approval for this much additional land, given the resistance solar projects have already encountered in some Virginia communities.

Small modular nuclear reactors have been identified as a potential future generation source. However, none have been successfully built in the United States, only a few exist worldwide, and this technology has not yet been proven to be a viable utility generation source. They also have high up-front costs that pose a barrier to their commercial viability, and some communities may oppose them being built nearby. Other promising, emerging technologies that have not yet proven to be commercially viable at a utility scale are hydrogen generation, long duration battery storage, and floating offshore wind.

Utilities also face challenges completing the many major transmission projects that will be needed to connect generation to data center markets, including the numerous new and dispersed renewable generation facilities that are expected to be built. For example, PJM's goal is to have $3.5 billion in Virginia transmission projects that were proposed in December 2023 for Virginia, mostly to serve data center demand, to be in service by June 2027. This 3.5-year timeline is possibly unrealistic considering that major new transmission projects often take five to seven years to complete.

Demand growth raises concerns about system capacity and reliability, but existing utility requirements and processes limit risks

Federal Energy Regulatory Commission (FERC) oversees the nation's electrical grid.

North American Electrical Reliability Corporation (NERC) sets reliability standards for the grid.

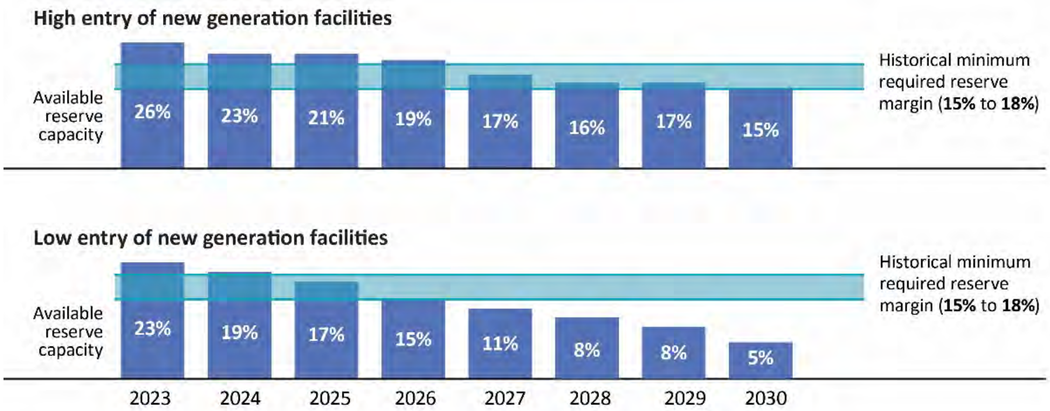
Electrical utilities in Virginia have an obligation to serve any customer within their service territory, but they are not required to provide service immediately upon request. Their foremost responsibility is to ensure the reliability of the power grid before adding any new, large customers like data centers. Federal and international bodies oversee transmission organizations and utilities and set reliability standards that PJM and Virginia utilities must follow (sidebar). The state also sets its own requirements for utilities, which the SCC is responsible for enforcing. These requirements and processes are intended to identify future reliability problems and ensure they are resolved before the grid is affected.

Generation capacity concerns are partially addressed through PJM requirements and utility planning processes, but risks remain

PJM protects grid reliability by requiring utilities to secure enough generation capacity to meet the next three years of projected customer demand, plus a reserve margin to account for peak load (i.e., high energy use) events like hot summer days. The regional PJM grid appears to have sufficient generation capacity to meet current demand without causing any system reliability concerns. However, PJM estimates the grid could run out of needed reserve capacity by 2030, even under optimistic assumptions for adding new generation (Figure 3-5). If utilities are not able to secure enough capacity to meet projected demand, they would have to delay adding new load or shed existing load to meet capacity requirements and maintain system reliability.

Although PJM sets minimum capacity requirements for utilities, there is some uncertainty in whether regional generation will be sufficient because it is not centrally planned. PJM does not plan for and identify specific generation projects that are needed (like it does for transmission), cannot direct new generation to be built, does not own or operate any generation sources (like a utility), and cannot stop a utility or independent operator from retiring an existing generation facility (although it can offer "reliability must run" payments to keep a facility open in the short term). Virginia cannot address these structural issues because PJM is federally regulated, not state regulated. PJM is aware of generation capacity concerns and is working to try and address them.

FIGURE 3-5
PJM projects available generating capacity could decline below reserve levels within a few years



SOURCE: JLARC staff analysis of PJM data and reports.
NOTE: PJM's reserve capacity projections were prepared in February 2023, using its 2023 demand forecast. PJM has since revised its demand forecast upward and in August projected a potential 1,663 MW shortfall in total capacity by 2029/2030.

At the state level, utilities protect grid reliability by planning to meet their own generation needs and PJM capacity requirements. Dominion and APCO—Virginia's two investor-owned utilities—are required to develop integrated resource plans that describe how they will meet capacity needs and submit them to SCC as part of a litigated proceeding. SCC holds public hearings to review the plans and gain perspectives from the utility, SCC staff, and other stakeholders, such as environmental groups and business interests. Despite disagreements over utility plans (sidebar), this process ensures the state's largest utilities plan to meet future generation needs and that these plans are scrutinized by regulators and stakeholders. Virginia co-ops also plan for their future generation needs, although the process is not as formal or subject to the same scrutiny. Most co-ops plan to purchase energy for data center customers from the PJM market rather than building generation to serve data center energy needs.

Stakeholders sometimes contest whether the integrated resource plans developed by utilities provide the best generation solutions for meeting future demand, or whether proposals conform to state law. For example, SCC staff recommended that Dominion's most recent 2023 plan be denied over VCEA compliance concerns, and the plan was not approved by the Commission..

Individual utility planning does not guarantee that the generation resources needed for the whole PJM region will be built, which contributes to uncertainty about the sufficiency of future capacity. Both investor-owned utilities and co-ops plan to fulfill some future share of their energy demand with energy imported from elsewhere in the PJM market and, as discussed above, there is some uncertainty in whether regional generation will be sufficient to meet that demand. Growing demand from the data center industry in other states, such as the growing Chicago and Ohio markets, could limit how much energy is available to be imported by Virginia utilities.

Transmission reliability concerns appear to be effectively addressed through existing PJM and utility planning processes

PJM and utility transmission owners centrally identify the impacts large loads are expected to have, and how those loads can be brought on safely without causing transmission reliability problems. At the project level, transmission owners like Dominion are required to study how the addition of a proposed data center (or any other large load) would affect the transmission system. These interconnection studies determine if the existing transmission system is sufficient to handle the load or if upgrades are needed to avoid violations of national reliability standards, such as excessive voltage incidents or outages. At the system level, both PJM and transmission owners must review the expected cumulative impact of demand growth on the transmission system, from proposed data centers and all other sources, and identify needed improvements (sidebar). Utilities cannot add new large loads to the grid, including from data centers, until identified transmission improvements are made. For example, if a new transmission line is needed for proposed data centers in Northern Virginia, utilities cannot add new data center loads until that line is operational.

PJM evaluates the overall transmission system through its annual Regional Transmission Expansion Plan (RTEP). Under the RTEP process, both PJM and transmission owners assess the potential impacts of expected changes in demand and generation to see if and where standards violations or other reliability concerns could occur. They then solicit or propose system improvements, such as new transmission substations and lines, to address identified problems.

Transmission planning processes appear to be working properly to protect reliability. In 2022, Dominion paused adding new data center loads in Loudoun County for three months as it worked to resolve regional transmission constraints. Since then, Dominion has incrementally added new data center loads in Loudoun to ensure new additions do not compromise the reliability of the transmission system. The utility expects the constraints that limit new load additions will not be fully resolved until 2025. Similarly, in July 2024, Dominion sent a letter to customers informing them that future large load additions to any part of the Dominion transmission zone are expected to take 12 to 36 months longer than they have previously taken so that the utility can appropriately plan for and connect the "record pace" of new load requests to the transmission system.

State could clarify that utilities can delay the addition of new, large loads if necessary to protect grid reliability

If utilities are unable to build enough new infrastructure to keep pace with energy demand, one of the main ways they can protect grid reliability is by delaying the addition of new large load customers until there is adequate generation and transmission capacity. Utilities appear to have the authority to delay large load additions for transmission-related concerns because this has already been done without legal objections. It is less clear if utilities are allowed to delay adding new load because of generation concerns. For example, representatives from one co-op utility indicated they did not believe they had the authority to provide less load than requested or delay new load additions for capacity, costs, or other reasons. The state could explicitly give utilities the authority to delay additions of new large loads if it is necessary to maintain grid reliability and avoid exceeding available generation or transmission capacity constraints.

RECOMMENDATION 2
The General Assembly may wish to consider amending the Code of Virginia to clarify that electric utilities have the authority to delay, but not deny, service to customers when the addition of customer load cannot be supported by the transmission system or available generation capacity.

Some stakeholders have asserted that the state should have a process for determining *whether* demand from large load data center customers should be met, not just *how* it should be met. In theory, the state could require evaluation of large load requests and allow requests to be denied through the existing SCC case process. However, this would be a shift in the historical U.S. electric utility paradigm and could be subject to legal challenges.

State could encourage or require data centers to take actions to help address their energy impacts, but actions would have marginal impact on demand

Virginia's growing data center industry is projected to greatly increase energy demand and will require construction of new generation and transmission infrastructure beyond what would have otherwise been built. Although regulators and utilities have requirements and processes in place to manage risks to grid reliability, new infrastructure projects can put VCEA renewable energy goals at risk, affect local communities and natural and historic resources (Appendix F), and affect customers' utility rates (Chapter 4). Data center companies could help address their energy impacts by

- promoting development of renewable energy generation,
- participating in demand response programs, and
- managing energy efficiency.

Many data center companies are already taking some of these steps, and the state could encourage or require further action. Data center companies are also exploring options for generating their own power, but it is unclear if this would address their impacts on the main power grid (Appendix I).

While these actions could have a marginal effect on data centers' energy impacts, they will not substantially reduce their energy demand or the challenges posed by growing demand.

Data centers could adopt more effective strategies for promoting renewable energy, but these would not lower their energy demand

Data center companies—including the four hyperscaler companies that account for a vast majority of the industry in Virginia—have carbon neutral policy goals that encourage investment in new, renewable generation. Some companies also directly invest in renewable energy projects in the PJM region and the development of new technologies, like small modular nuclear reactors. The scale of industry efforts is not easily quantifiable, so it is uncertain how much these efforts could help offset the industry's growing demand in Virginia.

Virginia's data center industry could be encouraged to further support investment in renewable energy and a reliable, decarbonized grid within the PJM region. The state already partially encourages this through VCEA's Accelerated Renewable Buyers program. Under the program, large customers with loads over 25 MW, which includes most data centers, can get credit for their purchases of renewable wind and solar energy made in the PJM region. Those credits go to offset what a utility charges customers for the utility's renewable generation projects, providing a financial incentive to participate. The program could be expanded to include utility-scale battery energy storage systems. Battery storage is needed because it can store and provide energy during periods when intermittent solar and wind generation is not producing power. Although battery storage systems do not count as net new generation, providing a financial incentive to invest in these resources is beneficial because of their importance in balancing loads from renewables. Any credit for using battery storage should be a partial credit per MW, based on capacity provided rather than energy consumed, and account for electric load carrying capacity (ELCC). ELCC is essentially a measure of the system energy contributions a given type of resource provides, and PJM assigns and regularly revises ELCC ratings. Currently four-hour battery storage has an ELCC rating of 59 percent for 2025/20026, meaning that a partial credit of 59 percent could be allowed for each MW of capacity purchased from battery storage resources.

RECOMMENDATION 3

The General Assembly may wish to consider amending the Code of Virginia to expand the Accelerated Renewable Buyers program, which allows large customers of energy utilities to claim credit for purchases of solar and wind *energy* to offset certain utility charges, to also allow customers to claim partial credit for purchases of *capacity* from battery energy storage systems based on the current PJM electric load carrying capacity rating.

The program could be further expanded in the future to include other renewable or non-carbon energy sources, such as hydrogen generation and small modular reactors. This could help bring more generation resources online to serve growing data center demand but would not reduce energy demand.

Demand response programs could have a more meaningful impact on energy consumption

Under demand response programs, utility customers agree to reduce their power use or send power back to the grid during peak load events. This reduces the need for additional generation and transmission to meet peak loads, and customers benefit by not getting billed higher peak load energy prices. Demand response programs are an effective way to reduce the need for new generation and transmission. As data centers become an increasingly large share of Virginia's base energy load, their participation in demand response programs could reduce the need for new infrastructure.

Data center companies in Virginia do not currently participate in demand response programs. Company representatives indicated that they have little flexibility to decrease energy use during peak load events because energy use is driven by computing activity, and computing activity is driven by customer and end user demand. From a business perspective, data center companies have strong incentives to keep facilities fully operational to meet their customer and end-user computing needs, and these typically outweigh financial incentives offered by voluntary utility demand response programs.

Despite limitations, there appear to be several viable ways that data center companies could participate in demand response programs. These include options for reducing demand during peak load events and adding energy to the grid during such events to offset a portion of their demand. Companies could

- shift some computing activity to other facilities outside of the region during peak load events,
- make operational adjustments that temporarily reduce energy use within the facility, such as small temperature adjustments for short periods, or
- install more environmentally friendly backup generators that are permitted to operate in non-emergency situations (sidebar), which could range from all generators at a facility to a subset of the generators used, or
- host battery storage systems that could serve as both a general utility and a demand response resource.

Most data centers backup generation' comes from Tier 2 diesel generators, which cannot and should not be used as a demand response resource because of their emissions (nitrogen oxides, carbon monoxide, and particulate matter). Natural gas and Tier 4 diesel generators have lower emissions and can be used for demand response under state and federal law. Backup generation is discussed more in Chapter 5.

JLARC's consultant modeled the energy impact if data centers participated in demand response programs by using battery storage or backup generators to reduce or offset the equivalent of 10 percent of their load in a peak load emergency. The model found data centers could provide 2,000 to 2,400 MW of capacity value to the grid, which would slightly reduce the need for new in-state generation and transmission. A key consideration is that these demand response capabilities would have to be in place before new generation is added to have maximum effect.

Without state direction, most data center companies appear unlikely to participate in demand response programs. The state should not require a specific demand response method because different approaches may be more or less feasible for different companies. Instead, the state could direct utilities to implement a demand response program for large data center customers, such as any customer over 25 MW, and require these customers to participate in the program. This requirement could be phased in gradually to give companies time to work with utilities on demand response solutions and participation levels (e.g., MW or percent of load a customer will commit) that are feasible for all parties. The requirement could be initially limited to investor-owned utilities and later expanded to include co-ops.

RECOMMENDATION 4
The General Assembly may wish to consider amending the Code of Virginia to require that utilities establish a demand response program for large data center customers and to require that these customers participate in the program.

Improving data center efficiency makes better use of energy but is likely to have only a marginal impact on demand

Data centers can improve energy efficiency in two primary ways. First, they can use newer and more efficient computer chips; computing activity ultimately drives almost all energy use in a data center. Second, they can improve the efficiency of their building systems, especially the cooling systems that account for most of the remaining energy use.

To promote energy efficiency, the state could encourage data center companies to meet an energy management standard, such as the International Organization for Standardization's (ISO) 50001. ISO 50001 requires organizations to set improvement goals, continually measure and evaluate outcomes, and revise policies to better achieve energy goals. An energy management standard can be fairly applied to all companies regardless of their business model. It is also preferable to requiring green building standards, such as Leadership in Energy and Environmental Design (LEED) building standards. Building standards could be required for new construction but may be unreasonable to retroactively apply to existing facilities.

The state could encourage data centers to adopt an energy management standard by making the state's sales and use tax exemption contingent on adoption. Many data center companies already set energy efficiency goals and policies, and a well-designed state incentive would complement these efforts and encourage other companies to adopt similar goals and policies.

POLICY OPTION 1
The General Assembly could consider amending the Code of Virginia to require that, as a condition of receiving the sales tax exemption, data center companies meet and certify to an energy management standard, such as the International Organization for Standardization's 50001 standard for energy management.

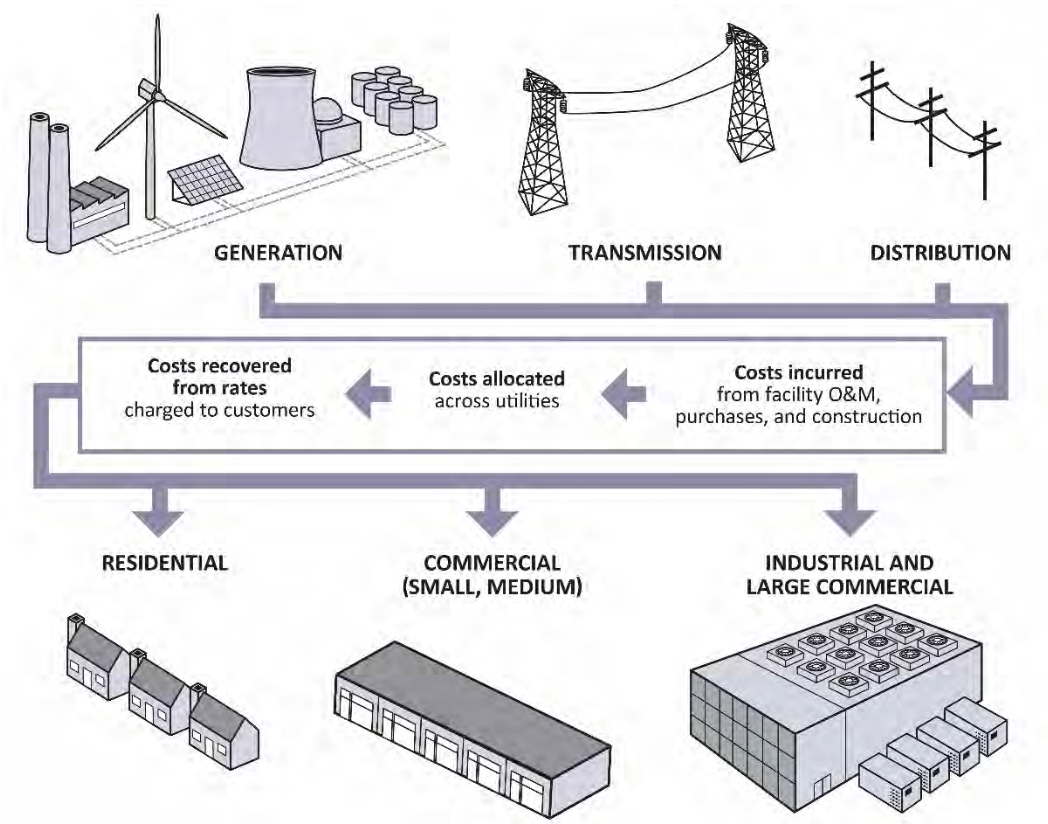
Recent legislation proposed requiring data centers to meet a specific Power Usage Effectiveness (PUE) ratio. The efficiency of cooling and other building systems in data centers is commonly measured using a PUE ratio. However, PUE does not indicate a data center's overall energy efficiency; it measures only the efficiency of cooling and other building systems that support facility operations. The data center industry has a strong market incentive to be energy efficient because energy is one of their largest operating costs. Requiring a specific and narrow requirement, like meeting a specific PUE ratio, could have unintended consequences, and could not be as widely applied as the ISO 5001. (See Appendix J for additional information on PUE.)

Energy efficiency in general is an important goal for the data center industry, but efficiency improvements are unlikely to reduce the industry's overall energy demand. Currently, the data center industry is growing fast, demand for energy exceeds the available supply, and companies want to maximize the value of their multimillion-dollar assets. Consequently, any energy saved from efficiency gains is likely to be used to perform more computing activity. One company representative noted "at the end of the day, a 200 MW data center is going to be a 200 MW data center."

4 Energy Costs

Utilities incur costs to build, operate, and maintain the energy grid and provide power to customers. These costs are ultimately recouped through rates charged to customers (Figure 4-1). The main principle underlying utility rates is that the rates charged to different types of customers should recover costs that are approximately equal to the costs of serving those customers.

FIGURE 4-1
Utilities recover costs through rates charged to customers



SOURCE: JLARC staff analysis.

Utilities group their customers into classes of similar users, based on their cost of service. While the exact customer classes vary slightly among utilities, they generally fall into three groupings:

- residential customers,
- small to medium commercial customers, and

- industrial and other large commercial customers.

Within each customer class, customers are charged three categories of rates: generation, transmission, and distribution rates. Each rate is intended to recover costs related to that part of the system. For example, generation rates recover costs associated with operating power plants, constructing new plants, purchasing energy, and securing generation capacity from third parties. Transmission rates recover the cost of building and maintaining transmission lines. Distribution rates recover costs of building and maintaining substations, street-level powerlines, and other infrastructure needed to serve end-use customers. Utility rates sometimes include "riders" or "rate adjustment clauses" specifically intended to capture the cost of new infrastructure (e.g., a generation plant) or a specific initiative (e.g., grid modernization). Some costs can also be directly assigned to customers.

The State Corporation Commission (SCC) regularly reviews and approves utility rates to ensure they are reasonable. For example, the SCC reviews Dominion's rates every one to two years, depending on the rate type. SCC reviews consider if a utility is over- or under-collecting costs by customer class and whether any changes are needed to address any allocation issues. In making its determinations, the SCC examines cost of service studies and other information presented by the utility and sometimes performs its own independent analysis. SCC's responsibilities are established in state law.

Data centers are currently paying full cost of service

JLARC's cost recovery study was performed by energy consultant E3. See Appendix B for additional details.

JLARC staff commissioned an independent study of utility cost recoveries under current rate structures to see if the data center industry is paying for its current costs (sidebar). The study focused on rates charged by Dominion, the Northern Virginia Electric Cooperative, and the Mecklenburg Electric Cooperative (the co-ops) because most existing data centers are located in their service territories. The study found that current rates appropriately allocate costs to the classes and customers responsible for incurring them, including data center customers. For example, the consultant's independently derived cost allocations for Dominion closely match the ones that the utility uses to set its rates, with only a few small differences for residential and large customer rates (Table 4-1). This finding is corroborated by SCC reviews of utility cost recoveries, especially its biennial reviews of Dominion's rates.

Utilities try to ensure data center customers pay the costs they incur in several ways. Dominion groups data centers into the same class with similar industrial and large commercial customers, charges rates based on energy and system use, and ensures recovery of costs associated with any new distribution infrastructure for data centers through contractually required minimum payments. Co-ops essentially treat data centers as their own customer class, charge rates based on energy and system use, and directly assign distribution costs for data centers to each specific customer. Co-ops take additional steps to separate the energy sources they use for data centers from the sources they use to serve the rest of co-op customers.

TABLE 4-1
Consultant's independent cost allocations closely match allocations Dominion uses to set customer rates

	Generation-related costs		Transmission-related costs	
Customer class	Independent consultant allocation	Dominion allocation	Independent consultant allocation	Dominion allocation
Residential	40%	41%	53%	55%
GS-1 (small non-residential)	5%	5%	5%	5%
GS-2 (intermediate)	14%	14%	12%	12%
GS-3 (large, secondary voltage)	15%	15%	12%	11%
GS-4 (large, primary voltage, includes most data centers)	26%	26%	18%	16%
Total	100%	100%	100%	100%

SOURCE: E3 analysis and Dominion rate schedules. Numbers may not sum because of rounding.
NOTE: GS = General Service. Table does not show churches or outdoor lighting customer classes because <1%.

Growing energy demand from data centers is likely to increase other customers' costs

Utility rates recover the cost of operating and maintaining the current system and any new infrastructure that must be built. Even though current rate structures appropriately allocate costs across customers, data centers' increased demand will likely increase system costs for all customers, including non-data center customers. This is because current utility rate structures are not designed to account for sudden, large cost increases from the construction of new infrastructure to serve a relatively small number of very large customers.

JLARC's consultant modeled the potential cost impacts of data center demand resulting from increased infrastructure needs. The model estimated costs under the two demand growth scenarios from Chapter 3: (1) unconstrained demand and (2) half of unconstrained demand, both with and without VCEA compliance. For this exercise, the model focused on cost and rate impacts in the Dominion transmission zone where most data centers are expected to be located (sidebar).

Dominion transmission zone includes the Northern, Central, and Tidewater regions of Virginia. These regions include Dominion's *distribution* service territory and the *distribution* territories of most of the state's electric cooperatives. See Chapter 3 for a map of the zone.

Generation and transmission costs are expected to increase from growing data center demand and will likely affect non-data center customers

Utility costs are likely to increase from the fixed costs of new infrastructure that will need to be built to address data center demand and the increase in prices as energy supply becomes constrained. Costs for the Dominion transmission zone could increase by an estimated $16 to $18 billion by 2040 under the unconstrained demand scenario, depending on if VCEA requirements are met. Costs could increase by $8.5 to $10 billion under the half of unconstrained demand scenario. In both scenarios, most of the projected cost increases are attributable to growing data center demand. Costs do not reflect the full up-front capital costs of building new generation and transmission infrastructure, because these costs are amortized and collected from customers over a period of 20 to 40 years. Instead, they reflect the share of capital costs that would need to be recovered from customers each year, plus operating costs and energy purchases.

Building enough generation and transmission infrastructure to meet data center energy demand would be difficult because it requires constructing enormous amounts of new infrastructure. In addition, unconstrained demand scenarios would require building infrastructure faster than has been historically possible. See Chapter 3 for additional details.

Because generation and transmission costs are passed on to customers based on their actual usage, a substantial share of these costs would be recovered from the growing data center industry. However, a share of cost increases would be borne by other customers in three ways. First, a large amount of new generation and transmission would need to be built that would not otherwise be built, creating fixed costs that utilities would recover over the next several decades. A portion of these costs would be paid by non-data center customers. Second, because it would be difficult to provide enough energy supply to keep pace with growing data center demand, energy prices would increase for all customers (sidebar). Third, if utilities are more reliant on importing power to meet demand, they may not always be able to secure lower-cost power and would be more susceptible to spikes in energy market prices. These higher overall costs are likely to affect all customers, proportional to their energy use.

Distribution cost increases are likely to be assigned mostly to data centers and not other customers

Data center loads are typically so large that they are not served from the regular distribution system and are instead connected directly to transmission lines from a substation that serves one or a few data center customers. Consequently, the main distribution costs that data centers incur are for building and maintaining these substations.

Utility rate structures appear to effectively insulate other customers from paying for distribution costs associated with data centers. Dominion recovers data center distribution costs by charging them its standard industrial and large commercial customer class rates, but it also contractually requires data centers to make minimum payments that fully recover the cost of the distribution substations built to serve them. In addition, Dominion charges data center customers directly for any "surplus" equipment (e.g., redundant connections requested by the customer). Co-ops require data centers to directly pay all costs associated with new substations as they are constructed.

There is one way that growing demand from data centers could indirectly increase distribution costs for other customers. As data center demand grows, some transmission lines could be upgraded to higher voltages to meet demand. For example, an existing 115kV transmission line could be upgraded to a 230kV line. This can require distribution-side upgrades to *all* existing substations connecting to the high voltage line, including those that serve and are paid for by non-data center customers. The cost impacts of potential substation upgrades are uncertain because they cannot easily be modeled across the system.

Residential customers could experience cost increases that current utility and regulatory rate reviews cannot fully address

Utilities recover costs, including any future cost increases, through rates charged to customers. Rates are regularly reviewed by utilities, the SCC, and the Federal Energy Regulatory Commission (FERC) to ensure costs are being properly assigned to customers (sidebar). Rate reviews ensure that system costs are being allocated in a way that best reflects which customers are responsible for incurring costs. For example, in 2019, Dominion received FERC approval to revise how transmission costs are allocated to utilities within its transmission zone, which effectively assigned a greater share of costs to large customers and reduced residential transmission costs by about 10 percent. While current rate structures will assign a larger portion of costs to data centers over time, rates are not designed to isolate other customers from cost increases driven by the expected system-transforming increase in data center demand.

Utilities regularly review their rates as required by state and federal laws.

SCC reviews and approves changes to generation, transmission, and distribution rates charged by utilities serving Virginia customers, such as Dominion and the co-ops.

FERC reviews and approves changes to how transmission costs are allocated to PJM and how transmission operators allocate cost to utilities.

Residential rates are likely to increase because of costs associated with growing data center demand

JLARC's consultant modeled how residential rates for Dominion customers might be affected by growing demand, assuming utilities and regulators use current practices to regularly reallocate costs. Dominion was chosen because of its large size and concentration of data centers. Residential rate changes were a key focus because they show how Virginia households could be affected and are indicative of how other customers, such as businesses, might be impacted.

Using the consultant's analysis, JLARC staff estimated that a typical residential customer with monthly consumption of 1,000 kWh could experience generation- and transmission-related costs increasing by an estimated combined total of $33 per month by 2040 under the unconstrained demand scenario. Factoring in VCEA requirements would increase monthly costs by four more dollars. However, building enough infrastructure to meet unconstrained demand would be very difficult. Under the half of unconstrained demand scenario, which is still difficult to achieve, the total cost is estimated to increase by around $14 per month (Table 4-2), whether or not VCEA compliance is assumed.

The rate changes shown here represent the share of generation and transmission rate increases that could be attributed to growing data center demand. Dominion's total residential bill projections, from its integrated resource plan, show much larger overall increases than the numbers reported here. Dominion's projections apply to the whole residential customer bill and include several costs that are not captured in JLARC's analysis, such as distribution costs and the cost of some additional transmission and generation projects that may not be solely attributable to data centers.

Dominion's residential bill projections are also in nominal dollars that have been adjusted upward using an inflation assumption, whereas JLARC's are held in constant (or real) 2024 dollars to show the real growth of costs that consumers will experience, independent of inflation. Dominion used a demand forecast that is similar to JLARC's unconstrained demand forecast and substantially higher than the half of unconstrained demand forecast.

TABLE 4-2
Generation- and transmission-related costs for residential customers would increase by 2040 because of data center demand (Dominion example)

	Projected increase in generation & transmission charges (not including distribution charges & some transmission costs; 2024 constant dollars)	
	2030	**2040**
Typical monthly residential generation and transmission charges (2023)	**$90**	**$90**
Scenario 1: Unconstrained demand		
- VCEA (very difficult to achieve)	+$23	+$37
- No VCEA (very difficult to achieve)	+$22	+$33
Scenario 2: Half unconstrained demand		
VCEA (difficult to achieve)	+$7	+$14
No VCEA (difficult to achieve)	+$6	+$14

SOURCE: JLARC staff analysis of E3 model results and Dominion 2024 integrated resource plan.
NOTE: Typical monthly residential charges are the sum of the amount billed to Dominion residential customers assuming typical use of 1,000 kWh. Does not include potential increases in distribution and several other charges that customers typically pay for. Does not capture the cost of the many intrazonal transmission projects that would be needed or generation projects that are not attributable to data center demand.

Utilities could help insulate customers from systemwide cost increases with new data center customer class and rate-setting approaches

Historically, adding new customers to the energy grid, even large load customers like manufacturers, has not increased costs for other customers because additions have been gradual, and the existing system has had enough capacity to serve them. However, addressing the needs of the fast-growing data center industry, even if only half of unconstrained demand is met, would require increasing generation capacity by 80-to-90 percent and transmission capacity 36 percent by 2040. Current utility rate structures are not designed to account for sudden, large cost increases from new infrastructure construction to serve a relatively small number of very large customers. New approaches would be needed to isolate residential and other customers from cost increases.

Establishing a separate data center customer class is a first step utilities could take to help insulate residential and other customers from the energy cost impacts of the industry. Utilities already have the authority to create separate rate classes with SCC approval. Creating a separate data center customer class would allow costs to be more closely allocated to data centers and provide utilities with more flexibility over how to charge rates. Co-ops essentially treat data centers as their own customer class already, so this change would only affect Dominion, which groups data centers with other industrial and large commercial customers. The General Assembly could require Dominion to establish a separate data center customer class, although historically the legislature has not set such detailed requirements in statute.

Establishing a separate data center customer class alone would not fully insulate other customers from cost impacts. Utilities, with SCC approval, would also need to establish new cost allocation methodologies that assign a greater share of generation and transmission fixed costs to the new data center customer class. For example, they could design rate structures that *directly* assign some fixed generation or transmission costs to a new data center customer class, or an increased share of those costs to the new class.

Rates may also need to be adjusted more frequently to insulate other customers from data center-driven costs. Currently, rate adjustments occur only every one to two years and can over or underestimate actual cost growth. For example, under Dominion's current biennial rate review, generation costs are reallocated and rates are adjusted every two years, based on forecast energy demand. While forecasts expect data center demand to increase, accurately forecasting the industry's rapid growth is challenging because of the many factors that can affect demand in a given year. Consequently, new rates may not fully account for shifts in how costs are being incurred across customer classes in the years in between biennial reviews. For example, if the company allocates 55 percent of costs to residential customers, but rapidly growing data center demand results in residential customers only being responsible for 52 percent of costs during the biennium, the costs recovered from residential customers could be higher than the costs they incur. This could also potentially work in the other direction, with residential customers being undercharged if costs are under-allocated based on forecasts.

Utility cost allocation and rate design are complex and highly technical, and the practicality and legality of any changes require detailed analysis to be fully understood. For this reason, utilities and SCC are in the best position to address future cost concerns through cost allocation and rate design changes. SCC is proactively looking into cost concerns from the data center industry and has scheduled a technical conference for December 2024 to explore the effects of the increasing number of data centers and other large-load customers on Virginia's utilities, ratepayers, and power grid. The conference will provide participants an opportunity to identify ways to address the cost concerns noted here and throughout this chapter.

Even if new customer classes and rate-setting methodologies are established, it may not be possible to isolate any customers from the cost impacts of higher energy prices (discussed above). In addition, energy prices in Virginia could still be affected by data center demand even if data center growth is slowed in the state, because industry growth could shift to other states in the PJM region, increasing energy prices throughout the region.

Data center growth creates additional financial risks to utilities and their customers

The growth of the data center industry presents several additional, but so far unrealized, financial risks to utilities and their customers. These risks largely result from the sheer size of the data center industry's energy demand relative to all other customers. These risks exist with the current size of the data center industry and will increase as the industry grows. Utilities have several mechanisms they use to manage financial risks from large data center customers, from planning processes to contracts, but these may not always be sufficient to mitigate the risks posed by the industry.

Data center demand could drive generation and transmission infrastructure to be overbuilt, stranding costs with existing customers

One of the main risks posed by the data center industry's rapid growth is that utilities will build more energy infrastructure than is needed if forecast demand does not materialize as expected, or one or more large data centers close. Overbuilding could strand utilities with infrastructure costs that would have to be recouped from their broader customer base. This would drive up costs for all customers, including residential and other non-data center customers. The overbuilding risk is mostly associated with generation and transmission, not distribution (sidebar). It is also more of a concern for Dominion than the co-ops, because Dominion builds generation to meet all customer needs and is responsible for transmission, whereas co-ops *purchase* most energy for their data center customers and are not directly responsible for transmission.

Distribution could be overbuilt but is less of a risk because most of these costs are fully recovered from data centers directly or through contractual minimum payment requirements.

Generation could be overbuilt if a substantial portion of the expected data center demand does not materialize, or if there is a decrease in that demand overtime. As a result, non-data center customers would pay a larger share of the fixed costs for this new generation. While it does not currently appear likely that supply will exceed demand, there is some risk because much of the data center industry is concentrated in a small number of companies. Therefore, business decisions at one company could have a substantial effect on overall demand. For example, if one of the major hyperscaler companies decided not to pursue development of new artificial intelligence (AI) products or has a line of AI products that fail to be commercially viable, then energy demand from that company could decrease substantially.

On the transmission side, there are three types of transmission lines to consider: (1) "backbone" lines that bring power into a region, (2) regional lines that move power to distribution points within the region, and (3) short extension lines that move power from main lines to serve a single distribution point, including extension lines that might be built to serve one or a few data center customers. Because transmission lines serve specific regions and distribution points, they are more at risk of being overbuilt if regional or individual customer demand does not materialize or decreases over time.

Utilities attempt to avoid overbuilding transmission and otherwise ensure costs are recovered. Dominion indicated it tries to avoid overbuilding by making transmission upgrades only as needed to meet the metered load expected from customers. For example, even if data center customers in an area have requested 2,000 MW of capacity, Dominion will only build new transmission to serve 1,000 MW if that is the forecasted metered load. One co-op utility indicated that it contractually requires data center customers to reimburse the utility for any penalties from transmission providers that may be incurred if a data center project is canceled. However, while utility actions reduce the risk of transmission costs being stranded with other customers, they do not eliminate this risk. For example, transmission costs can take up to several decades to recoup, and if a data center ceases operation before then, or it never uses the amount of energy it expected to, costs will be recovered from other customers.

Utilities could take additional steps to reduce the risk of generation and transmission costs being stranded with customers.

- Utilities could obtain contractual agreements from data centers customers to provide minimum payments that ensure the costs of major generation and transmission buildouts are not stranded with other customers. For example, AEP Ohio has proposed requiring any data center with over 25 MW of capacity to pay for at least 85 percent of the energy they expect to need, even if they use less, for at least 12 years.
- Utilities could directly assign some or all costs of smaller projects, such as transmission line extensions, to the customers or customer class for whom the line is primarily being built to serve. For example, if a two-mile transmission extension is primarily being built to serve a data center development, some or all of the project's costs could be assigned to that customer.

The state should direct Dominion to develop a plan for addressing the risk of generation and transmission infrastructure costs being stranded with existing customers. (Dominion is currently the only transmission-owning utility in the state expected to experience rapid demand growth.) The plan could adopt one or more of the approaches described above, or other approaches the utility identifies as more practical and effective. The plan could be included as part of Dominion's biennial rate review filing with SCC, or as a separate filing.

RECOMMENDATION 5

The General Assembly may wish to consider amending the Code of Virginia to direct Dominion Energy to develop a plan for addressing the risk of generation and transmission infrastructure costs being stranded with existing customers and file that plan with the State Corporation Commission as part of its biennial rate review filing or as a separate filing.

Data centers pose particular cost and financial solvency risks to electric co-ops and their customers

Virginia's electric co-ops are not-for-profit companies that are essentially owned by their member customers. Their main purpose is to provide members with reliable power at low costs. Co-ops are much smaller than the state's investor-owned, for-profit utilities—Dominion and APCO—and do not have the same financial resources or reserves as these companies.

An increasing share of data center growth is expected to occur in co-op service territories, and co-ops are statutorily obligated to serve these customers. Based on the half of unconstrained demand forecast, the industry could account for 80 percent or more of annual energy sales in three Virginia co-ops by 2030. This growth creates unique challenges for the co-ops, which must find ways to insulate themselves and other customers from the cost and financial solvency risks associated with taking on a small number of extremely large data center customers.

The main risk co-ops identified is that a data center could potentially delay, dispute, or fail to pay its energy generation bill. Co-ops purchase energy from PJM energy markets and then sell that energy to their data center customers. A weekly data center energy bill can be extremely large under normal circumstances and can be magnified by price spikes from peak load events. For example, one co-op estimated the weekly energy bill for 4,000 MW of power at data center sites expected to soon be built in its service territory could be $20 to $40 million and could range upward of $100 million under the energy price spikes that were seen in a major winter storm in 2022. PJM bills weekly, and if one or more data center customers dispute or otherwise do not pay on time, a co-op would have to cover its energy costs until they can be recouped. If the co-op was unable to recoup costs from one or more of its data center customers, the costs would ultimately have to be paid by all other co-op members, and a large enough bill could result in the co-op defaulting and going bankrupt.

Some co-ops said they were sufficiently addressing risks through their contracts with data centers, as allowed under current state law. Namely, these co-ops said the contracts allowed them to:

- perform credit checks when establishing service,
- require more frequent weekly payments for energy use, which aligns with PJM's weekly billing cycle, so they do not have to float co-op funds to pay data center bills,
- require upfront payment of deposits and pledges of collateral based on what the co-op expects it would need to cover unpaid data center bills until further action, such as terminating service, can be taken, and
- terminate service for failure to pay.

Other co-ops said they did not believe that the existing contractual and legal tools available were sufficient to fully cover all potential financial risks, especially considering data centers could soon account for the vast majority of their energy costs. They noted that current termination of service notification and dispute time periods could allow unpaid bills to continue increasing for several weeks (sidebar). They also said it can be challenging to get data center companies to agree to some contractual terms, such as committing to large collateral obligations designed to cover a large peak load event. These contractual and legal issues could be addressed at the SCC technical conference in December.

State law allows utilities to **terminate service after 10 days** of advance notice. However, customers can dispute billing issues that might lead to service termination, and co-ops indicated that **dispute resolution can take as long as 30 to 60 days**.

One co-op indicated that, even with additional contractual protections, they were still at risk if a data center company failed to meet its contractual obligations, such as if the company itself were unable to provide agreed upon payments. To address this, the co-op attempted to get SCC approval to create for-profit subsidiary companies to serve data center customers. Under this arrangement, if a data center did not pay its bills, only the subsidiary company would be affected, and the business continuity of the co-op would be assured. The SCC acknowledged the risks the co-op had identified, but did not grant the request because it did not believe it had the legal authority to allow a co-op to serve customers through a separate for-profit legal entity, among other factors. The General Assembly could amend the Code of Virginia to expressly allow co-ops to create for-profit subsidiaries to serve data centers and other large load customers. The customer size could be set at 90 MW to match the statutory threshold that already exists for the retail choice program (discussed in the next section).

POLICY OPTION 2

The General Assembly could consider amending the Code of Virginia to allow electric cooperatives to create for-profit subsidiary companies that could fulfill their legal obligation to provide energy services (retail sales) to customers with load capacity of over 90 MW.

Data center company participation in retail choice program could shift generation costs to other customers

In Virginia, most customers are obligated to purchase generation through their incumbent utility. For example, a customer in Dominion's service territory must purchase power from Dominion. The one major exception is that large load customers, including most data centers, are allowed to participate in retail choice, which allows them to purchase energy through a provider of their choice (sidebar). The goal of the program is to encourage competition and lower energy prices for industrial and other large commercial customers.

The current retail choice program was established in 2007 when Virginia's energy sector became re-regulated. Under the program, a qualifying customer can enter into an agreement to receive power from a third-party competitive service provider, which can purchase energy from the PJM market or enter into power purchase agreements with independent generators in or outside of Virginia to provide power to the customer.

Customers qualify for retail choice if they (a) exceed 5 MW and account for less than 1 percent of the utility's peak load, or (b) exceed 90 MW. The restriction that a customer cannot account more than 1 percent of the utility's load was intended to prevent customers from leaving the utility for retail choice if it could have negative cost impacts on the utility's remaining customers. The 90 MW exception was reportedly added to allow one particular industrial customer to participate in the program. At that time, very few customers exceeded the 90 MW threshold. Today, many existing data centers, and virtually all planned future ones, exceed 90 MW and are eligible to participate in retail choice.

Now that data centers make up a substantial and growing share of energy use in the state, retail choice creates two financial risks to utilities and their customers.

- Utilities are required to build or secure enough generation to meet all customer demands. If a customer leaves the utility for retail choice, the fixed cost of any recently built generation is divided among the remaining customers. For example, the costs of constructing Dominion's recent Brunswick and Greensville power stations are paid for by all of its customers. If a substantial portion of data centers leave for retail choice, a greater share of those fixed costs will be allocated to remaining customers. The risk for this potential dynamic will be compounded in upcoming years because a lot of new generation is planned to be built to serve growing data center demand.
- Utilities also indicated that, because they are legally obligated to serve any customer in their territory as a provider of last resort, they must plan for the capacity needs of current and future customers. If utilities plan and build infrastructure to serve future data center customers, and some of those customers at some point leave for retail choice, the utility will incur costs for customers who are no longer actively paying generation bills.

It is difficult to model the cost impacts of data center customers shifting to retail choice, because it is unclear how many might pursue this option. However, utilities report that only a small number of data center customers are currently participating in retail choice, so there is the potential for many more to enter the program, especially as the industry grows. Dominion estimated that if all currently eligible customers chose to participate in retail choice, including non-data center customers, the cost-shift to other customers could exceed $600 million annually (a $150 per year cost impact for a typical residential customer). That figure is likely to grow substantially as data centers make up an increasing share of the customer base.

Before returning to their incumbent utility, **a retail choice customer must provide advance written notice of five years.** However, statute allows the customer to return earlier by seeking an exemption from the SCC if its energy supplier "has failed to perform, or has anticipatorily breached its duty to perform, or otherwise is about to fail to perform," and the customer is unable to obtain service at reasonable rates from an alternative supplier.

JLARC staff identified several ways the state could manage the financial risks of retail choice to residential and other customers. The General Assembly could direct utilities to determine an overall cap on retail choice participation for their customers, such as a total amount of the utility's customer load that could be obtained through retail choice, and require the SCC to review and approve the caps. This would provide an avenue for utilities and customers to present their cases and give SCC authority to decide what is appropriate. Other alternatives to this approach include requiring exit fees for customers leaving for retail choice or directing utilities to continue directly charging them for fixed generation costs (i.e., making these "non-bypassable" charges). In addition, the General Assembly should leave in place the existing legal requirement that any customer participating in retail choice must notify the utility five years before returning (sidebar). Requiring advance notice of at least several years is important so that utilities can appropriately plan for system needs, secure needed capacity, and protect other customers from rate fluctuations.

POLICY OPTION 3

The General Assembly could consider amending the Code of Virginia to require that electric utilities establish caps on participation in retail choice that protect ratepayers from undue costs, and that such caps be approved by the State Corporation Commission through a formal case process.

Data center companies could soon have access to utility market-based pricing options that largely achieve the same goal as retail choice without shifting costs to other customers. Currently, co-ops already provide all their data center customers with market-based energy prices. Dominion has also established a small market-based rates pilot program and recently filed an application with the SCC to make the program permanent and widely available to customers. Market-based rates provide customers with potentially lower energy pricing that is similar to what they could expect to obtain through retail choice, but they remain a utility generation customer and therefore continue to help pay for fixed generation costs (instead of having these costs passed on to other customers).

5 Natural and Historic Resource Impacts

Virginia has abundant natural and historic resources, which provide economic, environmental, cultural, and educational benefits to the state. The value of these resources has long been recognized by the federal, state, and local governments. Governments have established regulatory systems intended to protect these resources and reduce the impacts that land development and other human activity have on them. The extent of natural and historic resource protections varies by resource type, with some regulatory systems providing stronger protection than others (Table 5-1). Natural and historic resource protections apply to data center operations and developments just as they apply to other commercial and industrial operations and developments (sidebar).

Data center energy demand, and its related impacts on Virginia's natural and historic resources, is discussed in Chapter 3 and related appendixes.

TABLE 5-1
Federal, state, and local regulations protect natural and historic resources from commercial and industrial operations and developments, such as data centers

	Regulatory protections			
	Federal	**State**	**Local**	**Brief overview**
Air resources				
Pollutant emissions*	●	●	○	Federal and state governments regulate harmful emissions and concentrations
Water resources				
Water withdrawals*	○	●	○	State sets and enforces water withdrawal limits and conditions
Wastewater discharges*	●	●	○	Federal and state governments regulate harmful discharge contents
Stormwater runoff*	●	●	◑	Federal, state, and some local governments regulate runoff rate and quality
Wetland and stream disturbances*	●	●	◑	Federal, state, and some local governments require impact mitigation
Land resources				
Conservation	◑	◑	◑	All government levels set aside lands for conservation, but few regulations, outside voluntary programs, protect private lands
Electronic waste				
Disposal	◑	◑	◑	No regulations require reuse or recycling, but some disposal limitations exist
Historic resources				
Preservation	◑	◑	◑	Federal, state, and some local governments regulate impacts in specific circumstances

SOURCE: JLARC staff summary of federal, state, and local regulations, staff interviews, reports, and websites.
NOTE: ● = stronger mandatory protections, ◑ = partial mandatory protections, ○ = no mandatory protections. * indicates that permits are required for potentially sizeable impacts. The responsibility or authority for a given government level to regulate impacts varies by resource.

Data center backup generators emit pollutants, but their use is minimal, and existing regulations largely curb adverse impacts

To ensure constant operations in the event of a power outage, data centers maintain on-site backup power. Data centers report that providing uninterrupted operations is extremely important to their customers, which can include banks and hospitals, who expect no outages or downtime. In Virginia, nearly all data centers use diesel generators for backup power (Figure 5-1). On average, each data center site has 54 permitted generators, but the number and electrical capacity of these generators vary widely depending on the number of data center buildings at a site, overall power and redundancy needs, and the sizes of generators used (typically one to three megawatts per unit). In total, the industry has approximately 8,000 permitted generators throughout the state.

FIGURE 5-1
Data centers rely on diesel generators for power in the event of an outage

SOURCE: JLARC photo of diesel generators at a data center in Virginia.

The federal Clean Air Act requires the U.S. Environmental Protection Agency to set **National Ambient Air Quality Standards**. These standards identify safe concentration thresholds for six pollutants—including ozone (which nitrogen oxides may form), carbon monoxide, and particulate matter—based on scientific evidence.

Diesel generators emit several harmful pollutants, so their commercial use is regulated by state and federal agencies. The main emissions are nitrogen oxides, carbon monoxide, and particulate matter. When highly concentrated in the air, these emissions can have adverse effects on public health and the environment. Exposure to high concentrations of diesel generator emissions can affect human cardiovascular, respiratory, and central nervous systems. Nitrogen oxides, which diesel generators emit in much larger quantities than other pollutants, can contribute to ground-level ozone pollution (including smog) and acid rain.

To prevent harmful concentrations, Virginia's Department of Environmental Quality (DEQ) is required by federal and state law to regulate sizeable emissions of these pollutants and enforce National Ambient Air Quality Standards (sidebar). DEQ requires diesel generators used by data centers to be permitted, primarily because of their nitrogen oxides emissions (sidebar). Moreover, DEQ monitors air quality and creates plans to maintain or attain National Ambient Air Quality Standards across the state. For instance, Northern Virginia has historically struggled to meet the standard for ozone, to which nitrogen oxides can contribute, so DEQ has stricter policies for nitrogen oxides emissions in that region.

DEQ permits are required for any new development that may annually emit over 40 tons of nitrogen oxides, 100 tons of carbon monoxide, or 10–25 tons of particulate matter, depending on the particulate matter size. Data centers using diesel generators usually meet the criterion for nitrogen oxides, but not for the other pollutants.

Data center backup generators are rarely run for prolonged periods, and emissions are unlikely to adversely affect regional air quality

Data center operators aim to have backup generator capacity for days-long outages, but in practice, the generators are rarely run for prolonged periods. Most operators reported experiencing zero to two minor outages per site in the last two years, with nearly all outages being between one and five hours long. Otherwise, generators are typically run only for limited amounts of time as part of routine maintenance (sidebar). For example, in 2023, the industry's actual emissions were only 7 percent of what permits allowed, with most emissions coming from maintenance testing.

Data center operators indicated that **maintenance testing** typically involves a short (10–30 minute) monthly test and one long (one- to four-hour) annual test. Testing of generators is staggered across a site on an individual or group basis.

On a regional level, data center emissions from diesel generators have grown substantially in recent years, but they remain a relatively small contributor to regional air pollution. Since 2015, nitrogen oxides emissions from data center diesel generators have more than doubled, carbon monoxide emissions have tripled, and particulate matter emissions are five times larger. However, these emissions make up a small part of overall emissions in the region. Based on National Emissions Inventory data, in Northern Virginia, where most data centers are concentrated, data center emissions make up less than 4 percent of regional nitrogen oxides emissions and 0.1 percent or less of regional carbon monoxide and particulate matter emissions. Overall, air quality in Northern Virginia has improved during the same time that the industry has grown, as reductions in car and other emissions have been greater than data center emission growth.

While emissions from data centers' diesel generators make up a small part of *regional* emissions, understanding whether they have adverse *local* impacts is more difficult. Because the data center industry's large clusters of diesel generators are unique, local air quality impacts are harder to assess. Diesel generators' intermittent use makes their impacts difficult to model, and no other type of development uses nearly as many generators on one site as a data center development. Additionally, air quality monitoring occurs regionally and does not effectively capture localized effects. While DEQ staff believe that data centers' intermittent use and low emissions levels are unlikely to cause adverse impacts, the agency has recently launched a three-year study that will directly monitor data center generator emissions in Northern Virginia to more fully understand their air quality impacts. If the study detects any local air quality impacts, DEQ has the authority to increase protections as needed.

Federal and state regulations limit potential emissions from backup generators, even under worst-case scenarios

The U.S. Environmental Protection Agency has established **generator tiers** based on emission rates, or the amount of a pollutant emitted by a source over a given amount of time. Data centers could use generators that are considered Tier 2 or Tier 4.

DEQ permits limit when data center generators can be run, how long they can be run, and the maximum annual emissions each permitted site is allowed. Nearly all current data centers use "Tier 2" diesel generators, which are only permitted to run in emergencies or as part of routine maintenance testing (sidebar). This restriction prevents data centers from running their generators for any other reason. Permits are issued per data center site, rather than per building or generator, and cap the total emissions allowed per site. For example, a data center campus would not be allowed to run its generators indefinitely, even in an emergency, because it would likely reach its emissions limits within a few days. Because outages are rare, data centers do not often approach their emission limits. (For information on data center generator fuel choice, see Appendix K.)

In the event of a prolonged outage that affects one or more Northern Virginia counties, any affected data centers could reach their emission maximum within a few days and potentially affect regional air quality. For example, under a worst-case scenario where all data centers in Northern Virginia reach their maximum allowed emissions, data centers would emit over 9,000 tons of nitrogen oxides in the region. That is equal to about half of what has typically been emitted annually in Northern Virginia by all sources. Such a large-scale outage could potentially result in violation of air quality standards and contribute to regional air quality issues. However, the extent of any impact would depend on weather patterns and contributions from other emissions. Such large-scale outages are rare, and air quality levels would return to normal after the event is over.

General Assembly could incentivize use of generators with lower emission rates to reduce risk of local and regional impacts during prolonged power outages

To reduce the risk of air quality impacts from data centers during a prolonged outage, the state could incentivize the industry to adopt technologies that reduce potentially harmful emissions. "Tier 4" diesel generators are designed to emit significantly less nitrogen oxides and particulate matter than the "Tier 2" generators most data centers use. Alternatively, Tier 2 generators can be equipped with selective catalytic reduction systems (SCRs). Both technologies can significantly reduce emissions of nitrogen oxides and particulate matter—reportedly by up to 90 percent—over long run times. Some newer data centers in Virginia use SCRs on their generators, and only one uses Tier 4 generators.

Without state incentives, data center companies are unlikely to change their backup power choices. Tier 4 generators and SCRs are more costly, and data center companies have expressed concerns about the extra complexity and the current availability of Tier 4 generators to meet campuswide and statewide backup power needs. The state could encourage adoption of these technologies by requiring new data centers in the Northern Virginia Ozone Nonattainment Area to use Tier 4 or SCR-equipped Tier 2 generators to be eligible for the state's sales and use tax exemption (sidebar). This requirement could be phased in over time to account for data centers that have already ordered generators or otherwise made investments that would not comply with this requirement.

The Northern Virginia Ozone Nonattainment Area includes Arlington, Fairfax, Loudoun, and Prince William counties and the cities of Alexandria, Fairfax, Falls Church, Manassas, and Manassas Park.

POLICY OPTION 4

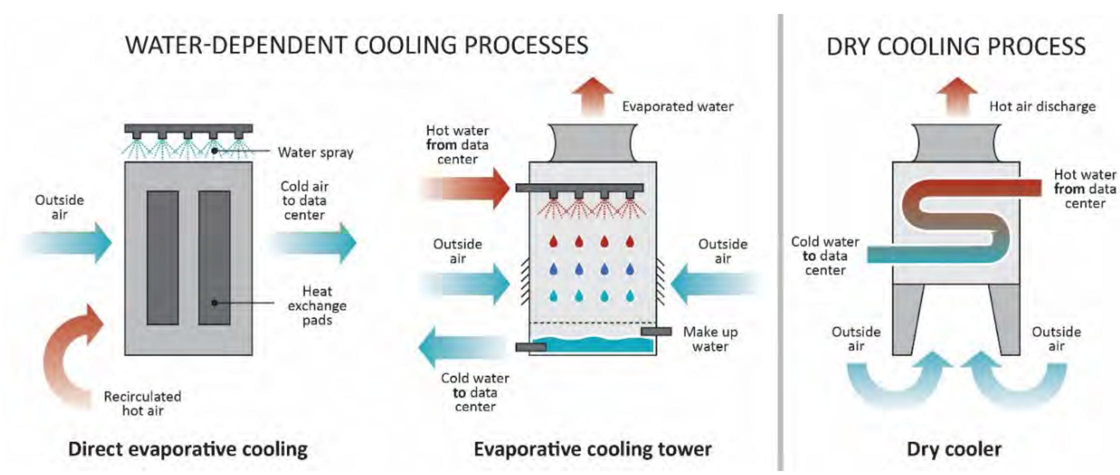
The General Assembly could amend the Code of Virginia to require that, as a condition of receiving the data center sales and use tax exemption, all new data center developments in the Northern Virginia Ozone Nonattainment Area use only Tier 4 generators, Tier 2 generators with selective catalytic reduction systems, or generators with equivalent or lower emission rates.

Data center water use is currently sustainable, but use is growing and could be better managed

Data center water use varies depending on the data center's size, computing density, and type of cooling system. Data centers require industrial-scale cooling to manage the heat generated by their computing equipment. Some cooling systems use water evaporation, and these systems typically require regular water refills to operate (Figure 5-2). Other cooling systems recirculate all or most of their water, similar to a radiator, and use relatively little water. Some data centers use a combination of cooling processes, including processes that do not require any water.

FIGURE 5-2

Evaporative cooling processes require more water than dry cooling processes



SOURCE: JLARC synthesis of interviews, government reports, and research literature.
NOTE: Depicted examples are generalizations and do not include all data center cooling processes and equipment.

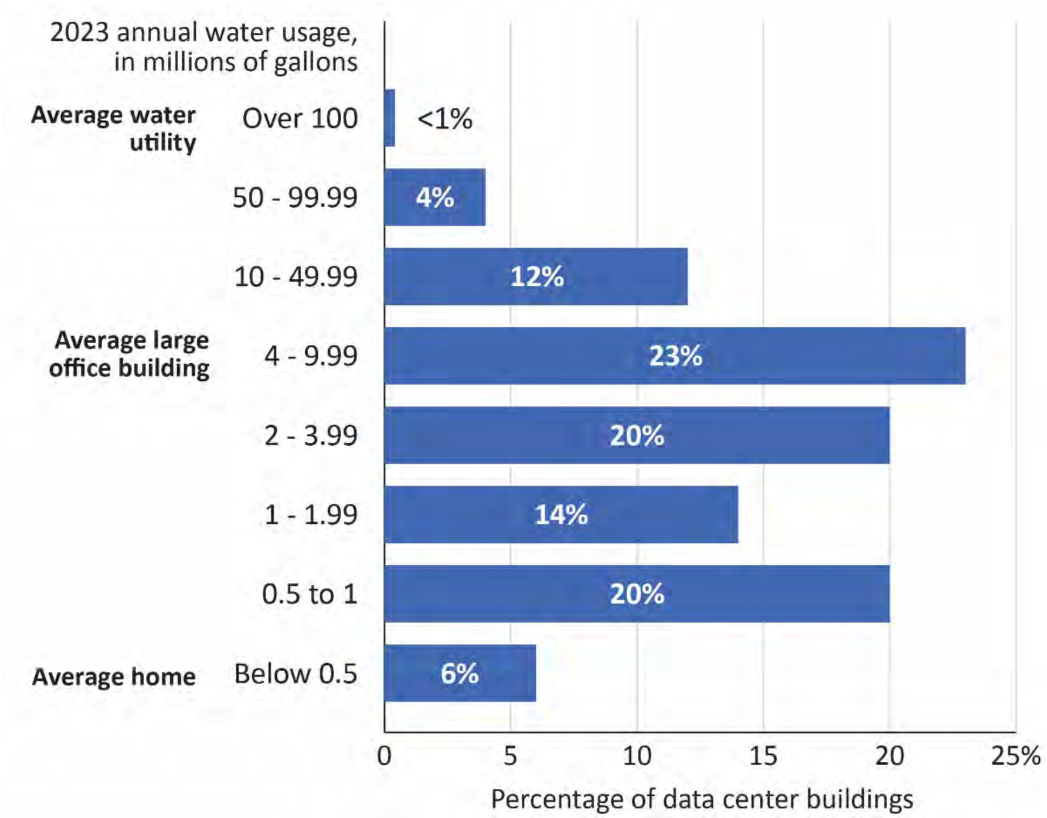
While some data centers use substantial amounts of water, most use similar or less than other large commercial and industrial water users

For comparison, **the state's largest industrial water user in 2023** used about 36.5 billion gallons of water annually.

Based on available data, most data centers use about the same amount of water (or less) as an average large office building (6.7 million gallons per year), although a few require substantially more, and some require less than a typical household (Figure 5-3). In 2023, 11 data center buildings each used over 50 million gallons, including one building that used 243 million gallons (10 percent of the industry's total use) (sidebar).

FIGURE 5-3

Annual data center building water use varied widely, but most used the same amount of water as an average large office building or less (2023)



SOURCE: JLARC staff analysis of data provided by water utilities serving Fairfax, Henrico, Loudoun, Mecklenburg, and Prince William counties and the Town of Wise. Average uses are based on federal and state water use statistics.
NOTE: Data was not available for all data centers in Virginia but was for the large majority. Water use is on a per building, not per campus, basis. Annual usage for some data center buildings is approximate because of data constraints.

Reclaimed water is wastewater that is treated, often to a non-potable standard, and re-used, such as for irrigation and industrial purposes. It reduces the need for additional water withdrawals, diverts wastewater from entering water sources, and reduces demand on potable water systems.

Cumulatively, data centers use a small share of statewide water withdrawals and a moderate share of some region's water withdrawals. In 2023, the data center industry used an estimated 2.1 billion gallons of water, with just over a third coming from reclaimed water instead of new withdrawals (sidebar). Data center water use accounted for less than 0.5 percent of total state withdrawals.

The industry's impact was also limited regionally. Most data centers are served by water utilities, and industry use made up from 2 to 21 percent of water use, after excluding reclaimed water use, at the six water utilities JLARC staff reviewed. Data centers were typically one of these water utilities' larger customers, but a data center was the single largest customer for only two utilities.

State regulates water withdrawals to ensure future water availability and to protect water ecology

To protect future water availability and environmental sustainability, DEQ regulates withdrawals from Virginia's water sources, including requiring permits for large-scale withdrawals (sidebar). Withdrawals can reduce the amount of water that is available for future use if it is withdrawn faster than it is naturally replaced. Additionally, they may affect aquatic flora and fauna, such as by reducing available habitat. Most data centers receive their water from local water utilities, which make the withdrawals. In these cases, DEQ ensures that data centers' water use is sustainable through permitting the utility's withdrawals. Only two data centers have their own DEQ withdrawal permits, and any data centers that do make their own withdrawals are subject to the same regulations as water utilities.

Withdrawal permits are required for withdrawals above 10,000 gallons per day from non-tidal surface waters, two million gallons per day from tidal surface waters, and 300,000 gallons per month from groundwaters in a groundwater management area. There are some exceptions for users that pre-date these regulations. Withdrawals that do not require permits may still require annual reporting.

To determine appropriate water withdrawal allowances, DEQ performs scientific modeling that evaluates water withdrawal impacts on future water availability and aquatic flora and fauna in that water source. Permits specify withdrawal limits and set other conditions, such as requiring the permit holder to limit withdrawals during droughts. If a requested withdrawal amount would exceed sustainable levels, DEQ would issue a permit only for a sustainable amount or add conditions to the permit that ensure sustainability. Permits must be renewed at least every 15 years, at which time DEQ reruns the water model with updated water source condition data. If growing data center demand prompted a water utility to seek a larger withdrawal than their permit currently allows, the requested permit withdrawal allowance increase would also have to be modeled by DEQ.

Data center water needs are likely to increase as the industry grows, and state and local governments could help ensure limited water resources are used effectively

While DEQ is responsible for ensuring that permitted water withdrawals are sustainable for the water source, there is less oversight over how available water should be shared across various uses. While the state as a whole is relatively water rich, water is a limited resource for some Virginia localities, such as those that do not have access to major rivers or other surface waters and are in groundwater management areas. Additionally, when local water use demand exceeds current permit or infrastructure thresholds, utilities may need to expend significant resources to meet the additional demand (sidebar). Therefore, localities should fully consider their allocation of available water. For instance, when reviewing a potential new development that may use a

Some **water utilities that serve or will soon serve data centers** have recently expanded their permits and/or infrastructure. For instance, five have requested new or larger withdrawal permits, though these expansions are not fully attributable to data centers. Water utility staff shared that data centers pay their fair share for any additional infrastructure they require.

large amount of water, a locality should consider whether the project could affect the locality's ability to meet future residential demand or pursue other types of economic development.

State could clarify localities' authority to request potential water use information from proposed developments

While any large water user has the potential to affect local water availability, water use information may be particularly helpful for zoning decisions for data center developments. Data centers can use a relatively large range of water amounts compared with other land uses. Some companies will continue to build data centers that use water for cooling, and potentially larger amounts of water as cooling needs increase. While others are moving away from water, the industry's net water use is expected to increase. In addition, because the industry is growing rapidly and typically grows in clusters, data center water use in a given locality can grow suddenly.

Localities have general statutory authority to consider water resources in their land use planning, but state law is not clear on localities' ability to require a proposed data center development to provide a water use estimate or to consider water use in their rezoning and special use permit decisions. (Rezonings and special use permits are discussed more in Chapter 6.) In interviews, local planning staff, government attorneys, and a local elected official conveyed different understandings of the law or reported being uncertain whether a locality could consider water use estimates when evaluating data center development projects. This information could be helpful for assessing a development's potential impacts, but data center developers can be reluctant to share this information because of proprietary concerns. State law should clarify localities' authority to require this information from data center developers and consider water usage in their rezoning and special use permit decisions. This clarification could potentially be extended to other development types, such as other developments with the potential to use large amounts of water.

RECOMMENDATION 6

The General Assembly may wish to consider amending the Code of Virginia to expressly authorize local governments to (i) require proposed data center developments to submit water use estimates and (ii) consider water use when making rezoning and special use permit decisions related to data center development.

Additionally, if local planning officials have this information, they should consult with their local water utility—prior to approving data center developments—on the impact these developments could have on the utility or future water availability. In some data center approvals, this information was not shared between parties. Doing so could help to ensure water use impacts are fully understood prior to approving the development.

Increasing use of reclaimed water may help reduce impacts on water resources

Some utilities offer reclaimed water systems for their customers, and using reclaimed water instead of potable water for cooling, including evaporative cooling, is generally a best practice for data centers. Reclaimed water can reduce a development's impact on water resources because it does not require additional water withdrawals and can decrease wastewater discharges. DEQ currently permits only two water utilities, including Loudoun Water, to provide reclaimed water for evaporative cooling uses.

Reclaimed systems may not be viable or available in all localities, but utilities that serve data centers should consider the option. Smaller utilities may not create enough wastewater for a reclaimed system that could sustain data center operations. Moreover, financial considerations may also limit reclaimed water use, as reclaimed systems have high capital costs. However, because of the potential benefits for water availability, utilities that serve data centers—and other large water customers—should consider the viability of using reclaimed water systems, as well as potential opportunities for data center companies to help with upfront costs.

Some stakeholders, including a data center company and several water utilities, indicated that Virginia's reclaimed water system regulations for evaporative cooling use are difficult to meet or confusing. DEQ indicated that regulatory changes, such as explicitly listing minimum standards for reclaim water use in data center evaporative cooling processes or reducing some treatment and monitoring conditions, could potentially address concerns while maintaining necessary safeguards but would require further review. DEQ is already scheduled to conclude an internal review of these regulations by September 2026 as part of its quadrennial review process, but DEQ could start this review now so that any eventual changes could be implemented a year earlier. Any potential changes DEQ identifies would need to be implemented through the standard regulatory process—including a Notice of Intended Regulatory Action and public comment period.

Data center construction has similar land and water impacts to other large developments, and state and local regulation mitigate most effects

The development of land for industrial, commercial, or residential uses, particularly "greenfield" developments, can affect Virginia's land and water resources (sidebar). Depending on the characteristics of the site being developed, the construction process may change land characteristics and uses, modify stormwater runoff patterns, and/or disturb wetlands and other waterways (Table 5-2). Such impacts can degrade air and water quality, destroy wildlife habitat, and increase flooding and erosion risks.

A development's ability to mitigate its potential impacts depends on the site, development type, and the resource. A development can mitigate overall potential impacts on these resources in three ways:

"Greenfield" development occurs on land that has not previously been developed. In contrast, redevelopment occurs on the site of a former development. A redevelopment is less likely to impact land and water resources, as any potential impacts likely already occurred during the previous development.

State-managed databases, such as the Department of Conservation and Recreation's **Natural Heritage database**, identify on-site resources that may be impacted by development.

- **avoiding** direct impacts to the maximum extent practicable, such as not constructing a building on forested land,
- **minimizing** impacts to the maximum extent practicable, such as using a retaining wall to minimize impacts to an adjacent waterway, or
- **compensating** for any impacts that do occur, such as offsetting impacts to a wetland by restoring or constructing that same type of resource elsewhere.

TABLE 5-2
Constructing new developments can result in loss of undeveloped and agricultural lands, create stormwater runoff risks, and potentially disturb wetlands

	Land resource loss	Stormwater changes	Wetland disturbances
Development action	Undeveloped and agricultural lands may be developed for industrial, commercial, residential, or other uses.	Impervious surfaces may be created to support buildings and ancillary developments.	Wetlands (including streams and other waterways) may be drained, filled, or encroached upon to maximize developable area.
Potential impact	Forests, agricultural lands, and other green spaces are lost.	Less rainwater is absorbed into the ground, increasing stormwater runoff.	Wetland areas are destroyed, diverted, or otherwise disturbed.
Effect without mitigation	Air, water, and soil quality degradation, loss of habitat, and lower agricultural production occur.	Increased flooding and erosion, water pollution, and slower groundwater recharge, occur.	Water source degradation, loss of habitat, and increased flooding and erosion occur.
Effect with mitigation	Losses are avoided, minimized, or offset by preserving, creating, or restoring lands elsewhere. [a]	Predevelopment runoff rate and quality are maintained, minimizing adverse impacts.	Disturbances are avoided, minimized, or offset by funding or implementing wetland creation or restoration. [a]

SOURCE: JLARC synthesis of interviews, government reports, and other information.
NOTE: [a] Offsetting impacts can be difficult and require significant time and space, particularly for replacing lost undeveloped and agricultural lands.

Some regions have seen substantial data center growth, but their construction impacts are similar to other large developments

Data center development has construction impacts that are similar to other large-scale developments' impacts. While comprehensive information on data centers' impacts to natural resources is not tracked, the vast majority of their development is greenfield development—although some redevelopment is also occurring.

The development pressures from data centers on undeveloped and agricultural lands statewide are not more than other fast-growing developments in Virginia. For example, the total land area of currently operating data centers is equal to about 1.4 percent of the farmland lost in Virginia between 2017 and 2022. According to land conservation experts, the current primary threat to undeveloped and agricultural lands is solar energy developments.

On a regional level, however, the share of undeveloped and agricultural land development in Northern Virginia attributable to data centers has been substantial. JLARC staff estimated that the data center industry accounted for between 20 and 30 percent of land development in Loudoun and Prince William counties from 2013 to 2021, and the amount of data center development has already increased 50 percent since then. However, these are some of Virginia's fastest-growing counties, which means that some portion of land developed for data centers likely would have been developed for other uses, such as housing, mixed-use commercial space, or distribution centers.

Data center developments have similar impacts on stormwater and wetlands as other large-scale developments, such as warehouses or shopping centers. The magnitude and significance of impacts depend on site characteristics as much as the development itself (sidebar). Therefore, impacts may be the same whether a site is developed for a data center or another land use.

Magnitude of impact depends on the change to the environment, not the development itself. For example, a small greenfield development may create more impervious surface than a large redevelopment.

Impact significance depends on the resource that is affected. For example, a given amount of water pollution may have a larger effect in a small river than a big river.

State and federal regulations require mitigation of stormwater and wetlands impacts, but land conservation is at local discretion

Federal and state regulations require stormwater management and wetland permits for sizeable impacts, regardless of development type. Stormwater permits for individual developments are usually administered by DEQ or the locality, and wetland permits are typically jointly issued by the U.S. Army Corps of Engineers and DEQ. Most data center developments require a stormwater permit because of their size, but only those that affect a wetland or other waterway require a wetland permit (which is the same for all types of development).

Stormwater management permits require developments to manage their stormwater runoff to meet water quality and quantity requirements to minimize impacts. For instance, a development would be required to install a stormwater management system, such as an on-site stormwater pond, to slow and filter its runoff. Data centers create a relatively large amount of impervious surface, and stormwater permits require management that is proportional to the addition of impervious surface and land cover changes. Some impacts may still occur even if all permit requirements are met, such as less water being absorbed into the ground or water source temperature increases, but these same impacts can occur from any developments that create large impervious surfaces or change land cover, such as a warehouse or shopping center.

Wetland permits require developments to avoid and minimize impacts to wetlands and other waterways to the maximum extent practicable and to compensate for any remaining significant impacts. Because data centers require large building footprints, they may be relatively less able to avoid or minimize impacts. However, any significant impacts that do occur require proportionate compensation, which ensures losses are replaced to the extent possible through the preservation, restoration, or creation of that resource elsewhere.

In Virginia, federal and state regulations do not require mitigation of impacts to undeveloped and agricultural lands. Localities have full discretion through their zoning laws to determine how lands that are not protected from development can be used. While localities can require, negotiate, or accept offers to conserve a portion of the existing natural landscape as part of a development, data center developments generally use most of land that is practicable and allowed to be developed. Because undeveloped and agricultural lands are difficult to replace, the primary mitigation method to protect them is to avoid or minimize development on these lands. The state could consider imposing land use restrictions to prevent or minimize the land impacts from data center development, but this would be a profound change in the state's involvement in local land use decisions, and, currently, there does not appear to be a basis for distinguishing data centers from other large developments in considering such restrictions.

State could require data centers to meet environmental management standard to receive tax exemption

The ISO 14001 standard for Environmental Management Systems is one of the most used environmental management frameworks in the world. The U.S. Environmental Protection Agency believes it helps organizations to systematically identify and reduce their environmental impacts.

Even though federal and state regulations already limit most negative natural resource impacts of data centers, the state could encourage them to meet an environmental management standard because of their large and growing presence. Environmental management standards, such as the International Organization for Standardization's (ISO) 14001 standard, require companies to proactively review and reduce their impacts to natural resources (sidebar).

Required minimum standards for specific resources could have unintended consequences, including: 1) not being viable for all data center companies, who have different operational systems and preferences, 2) not ultimately improving sustainability, such as water restrictions leading to more energy-intensive cooling, or 3) not being adaptable as the data center industry evolves, such as if new technologies shift the industry's environmental impacts.

Environmental management standards do not set required minimum standards but involve continuous improvement in operational sustainability. Required minimum standards may not be viable for all data center companies and may not be wholistically sustainable (sidebar). Environmental management standards call for companies to evaluate all of their environmental impacts and set and pursue sustainability goals. This process is repeated every few years and encourages a wholistic approach to sustainability. For instance, ISO 14001 seeks to promote organizational improvement in air emissions, water use, water discharge, waste generation, and energy consumption—all of which have been raised as concerns about data centers. (For more information on data center water discharges and waste generation, see Appendix K. For more information on data center energy impacts, see Chapter 3.)

The state could encourage adoption of an environmental management standard by making the state's sales and use tax exemption for both new and existing data centers contingent on adoption. Many data center companies already set sustainability goals and policies, and a well-designed state requirement would encourage other companies to adopt similar goals and policies. At least four other states—Arizona, Illinois, Iowa, and Washington—require data centers to meet a sustainability standard as a condition of their state data center tax incentive program.

POLICY OPTION 5
The General Assembly could amend the Code of Virginia to require that, as a condition of receiving the sales and use tax exemption, data center companies meet and certify to an environmental management standard, such as the International Organization for Standardization's 14001 standard for Environmental Management Systems.

Data center impacts on historic resources are similar to other developments, but current protections could be strengthened

Developments have the potential to negatively affect historic resources, both during and after construction. Historic resources can include sites (e.g., battlefields and cemeteries), structures (e.g., buildings), and objects (e.g., artifacts) (Figure 5-4). Impacts can vary substantially depending on the type of development being proposed, the significance of the historic resources affected, and how those resources will be affected. In many cases, a development will not adversely affect historic resources because there is nothing historically significant on the development site or located nearby.

FIGURE 5-4
Virginia has a wide range of historic resources

SOURCE: Image courtesy of the Virginia Department of Historic Resources (cropped by JLARC).

Data center developments can affect historic resources in the same ways as other large developments

Some data center developments have affected state historic resources. For instance, two data center developments have relocated or damaged cemeteries, and several have been located on historic sites, including a turn of the 19th-century residential site, a historic African American horse showground, and part of a Civil War battlefield. Additionally, several approved but not yet built data center developments have raised concerns of viewshed impacts on historic battlefields around the Northern Virginia region. Like with other development types, the total number and extent of data centers' impacts on historic resources are unknown as not all of these resources—or impacts to them—have been identified and catalogued.

Preservation experts consider data centers' impacts and risk of impact to be similar to those of other large-scale developments. Data centers have less flexibility than some other developments, like housing, to avoid building on parts of the property where resources might be located. Data center developments also require extensive grading, which can destroy buried structures and objects, and tall data center buildings are more likely to have viewshed impacts on nearby resources. However, other large-scale developments, like warehouses and shopping centers, can have the same impact. The rapid growth of data center development increases the likelihood that historic resources will be disturbed by these developments, but the same is true of other commercial and residential construction growth.

Pre-development studies help promote mitigation of impacts to historic resources

Various methods may be used to **mitigate impacts to historic resources**. For instance, developments may avoid or minimize impacts by moving building locations or lowering building heights. If historic resources cannot be avoided, they may be excavated and relocated, studied and documented before their destruction, and/or commemorated with signage. The appropriate strategy can depend on the resource, development type, and the site.

Before site development begins, sites can be studied to identify any potentially significant historic resources and determine mitigation strategies if impacts were to occur. Developers can hire experts or third parties to perform "Phase I" historic resource studies, which could include background research, physical inspection, and remote sensing, to identify historic resources that may be affected by a new development. If a Phase I study finds historic resources, Phase II historic resource studies can determine their significance and, if needed, develop mitigation approaches (sidebar). When needed, Phase III historic resource studies involve carrying out mitigation approaches, such as excavating and relocating a resource or documenting a resource. Once historic resources have been identified, developers can additionally perform viewshed analyses to determine whether a new development would be visible to these resources, potentially affecting their significance.

Phase I historic resource studies and viewshed analyses are relatively inexpensive predevelopment tools. Some data center companies reported that they conduct Phase I studies for some or all of their data center developments, and several have conducted and shared viewshed analyses as part of the local zoning approval process. Studies can ultimately save developers time and money by preventing delays or the need for design changes from unexpected discoveries after developments have been approved.

Few legal or regulatory protections exist to protect historic resources, but pre-development studies could be more strongly encouraged

While there are many layers of federal, state, and local protections for natural resources, fewer protections exist for historic resources. For private developments, federal regulations require that historic resource impacts need to be considered—studied and potentially mitigated—only if a wetland or other federal permit is required. State law only requires additional Virginia Department of Historic Resources (DHR) oversight of private developments when human remains need to be removed.

Local regulation of historic resources varies by jurisdiction, depending on local capabilities and priorities. All localities have the authority to restrict development around historic resources through their zoning ordinances, but some are better able to identify these resources than others. For instance, Loudoun requires Phase I historic resource studies for all non-residential developments and has a county archeologist who evaluates study results and makes recommendations to planning staff if additional action is needed. Most localities do not require pre-development studies and do not have an archeologist on staff. Moreover, when development and historic resource preservation goals conflict, it is up to local elected officials to make zoning decisions.

To ensure that potential impacts to historic resources are identified, the state could encourage Phase I historic resource studies for all new data center developments, as well as viewshed analyses for new developments within a certain distance of a registered historic site. To do this, the state could make eligibility for the sales and use tax exemption contingent on this work being performed for any new data center developments. For example, the state could require that, for any data center that begins construction in 2026 or later, the data center company perform a Phase I study (along with a viewshed analysis, if applicable) before the facility is constructed in order to be eligible for the exemption. Data center developers would pay for the study and report findings to localities, which would determine if any further action is required.

POLICY OPTION 6

The General Assembly could amend the Code of Virginia to require that, as a condition for receiving the sales and use tax exemption, data center companies conduct a Phase I historic resource study of a proposed development site, as well as a viewshed analysis when a proposed site is located within a certain distance of a registered historic site, and report the study findings to the appropriate locality prior to development.

Some localities may not currently have the time, expertise, or resources to review the Phase I historic resource study submissions. DHR could offer grants for localities to hire consultants or have staff available for consultation, but this would require additional funding or staff to implement. Alternatively, localities would have the option to require data centers to pay for a consultant hired by the locality to perform the review.

Some historic resource preservation experts stated that, while they would appreciate greater protections around historic resources, establishing mitigation requirements at the state level may not allow for site-specific characteristics or local preferences. For instance, prohibiting data center development near historic resources statewide, as was proposed during the 2024 legislative session, may be broader than needed—as impacts do not occur every time a development is on or near a historic resource—or could prove too restrictive given the abundance of historic resources in Virginia.

6 Local Residential Impacts

Local governments are responsible for managing land development in their jurisdictions for different residential, commercial, agricultural, and industrial uses. Localities manage development through planning and zoning to ensure developments conform with state and local laws and are grouped with appropriate types of development.

On the planning side, state law requires localities to create and update long-term comprehensive plans to support "coordinated" and "harmonious" development. These plans provide a strategic vision for development in the county but, while important for guiding local decisions, do not set any legal boundaries.

On the zoning side, localities pass zoning ordinances that set legal restrictions on development. Zoning ordinances establish conceptual *zones* (e.g., rural residential, light industrial), which have their own sets of rules and requirements for new development. For each zone, the ordinance lists *uses* that are allowed. Uses can allow different types of business operations (e.g., data center, brewery), different types of residential construction (e.g., townhouse, single-family house), and other distinct uses. Additionally, zoning ordinances can impose minimum requirements on specific uses or zones, such as maximum heights or mandatory setbacks from property lines.

Within a zone, a use can be allowed by right, allowed by special permit, or prohibited. If a use is prohibited in a zone, then a developer can seek to have the parcel rezoned to allow the use.

- **By right** uses are allowed within a zone without any special approval by the locality. For example, if data center development is a by-right use, a developer can build a data center in the zone without seeking special approval from the locality. Localities cannot require data center developers to do anything not already established in the zoning ordinance. For example, a locality could not require a by-right data center to be set back farther from nearby property lines than the ordinance already dictates.
- **Special permit** uses are allowed if approved by the locality's elected officials, e.g., a county's board of supervisors (unless they delegate this authority to the local board of zoning appeals), often following a public hearing. As part of the special permit process, the locality can make approval conditional on additional restrictions to mitigate negative impacts, such as bigger property line setbacks or lower building heights.

- **Rezoning** changes the conceptual zone a parcel falls under and therefore its allowed uses. Rezoning requests require a public hearing and approval from elected officials. Like with special permits, the locality can consider the developer's willingness to conform to additional restrictions or actions as a condition of rezoning approval.

Growing number of data centers are being built close to residential areas, causing residential impacts

This chapter focuses on data centers' impacts on residential areas. While minimizing impacts on **other sensitive uses** such as schools and parks is important, concerns of negative impacts in Virginia have primarily come from residential areas.

Land use planning principles state that neighboring property uses should be compatible with one another. These principles generally dictate that industrial uses should be far from residential and other sensitive uses because they are often incompatible (sidebar). Residential neighborhoods are generally expected to be safe, quiet, and pleasant places to live, whereas industrial facilities are often large, unsightly, and potentially noisy. For example, Loudoun County ordinances state that "industrial uses [...] are incompatible with residential uses due to the prevalence of outdoor storage and emissions of noise, odor, and vibrations."

Data centers are industrial facilities that are largely incompatible with residential uses

The industrial scale of data centers makes them largely incompatible with residential uses. A modern data center site includes one or more large, industrial buildings, similar in size and appearance to a new distribution center or a manufacturing facility, which is an abrupt contrast to a residential home.

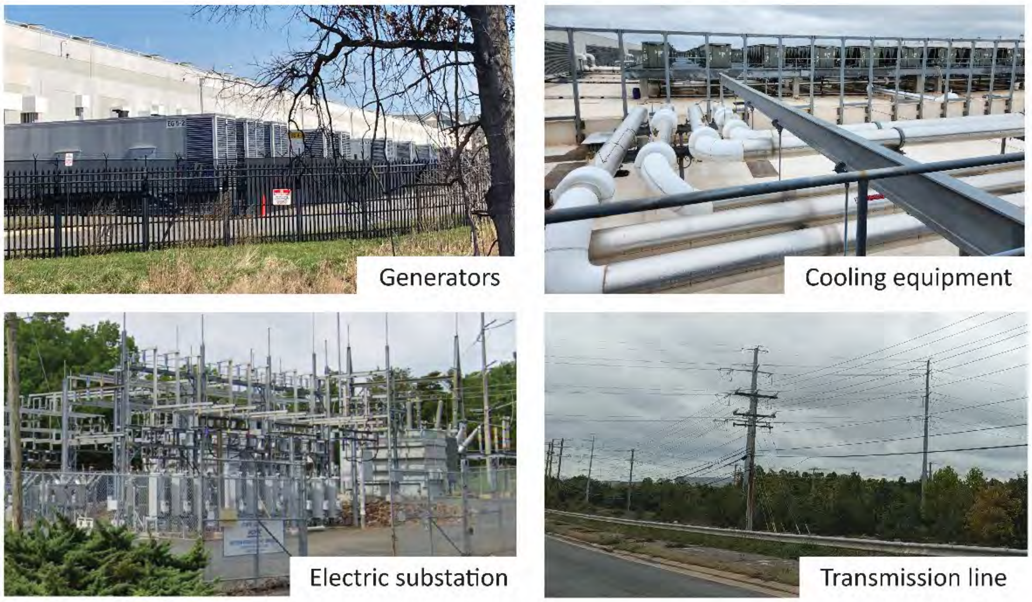
Resident descriptions of nearby data centers include:

— "a giant monolith in the wrong place"

— "a prison"

Other components of data center sites are also industrial in character and unsightly to residents who live close by (sidebar) (Figure 6-1). Trailer-sized generators (a median of 35 per site) are often lined up beside the data center building or housed in large generator sheds. Industrial-scale cooling equipment, such as chillers or water towers, often sit on the roof or outside the main building. Many data center sites are encompassed by security fences and deploy bright security lighting. Data centers also require industrial-scale electrical infrastructure. Sites will often include one or more electrical substations on or adjacent to the site, and some require above ground transmission lines extending from nearby main lines.

FIGURE 6-1
Data center buildings and sites have industrial characteristics and infrastructure



SOURCE: JLARC staff photos and Google Earth.

Homeowners in residential areas close to data centers frequently express concern that having industrial sites nearby will decrease their property values. While it is certainly possible that nearby data centers have affected the resale value of homes, there is not yet evidence of this relationship. In interviews with representatives of neighborhoods opposed to nearby data centers and other informed individuals (sidebar), almost none observed a decline in property value or speed of home sales. One commonly cited explanation was that the tight housing market in Northern Virginia decreases buyers' selectiveness and so proximity to data centers has not yet had a noticeable effect on property values.

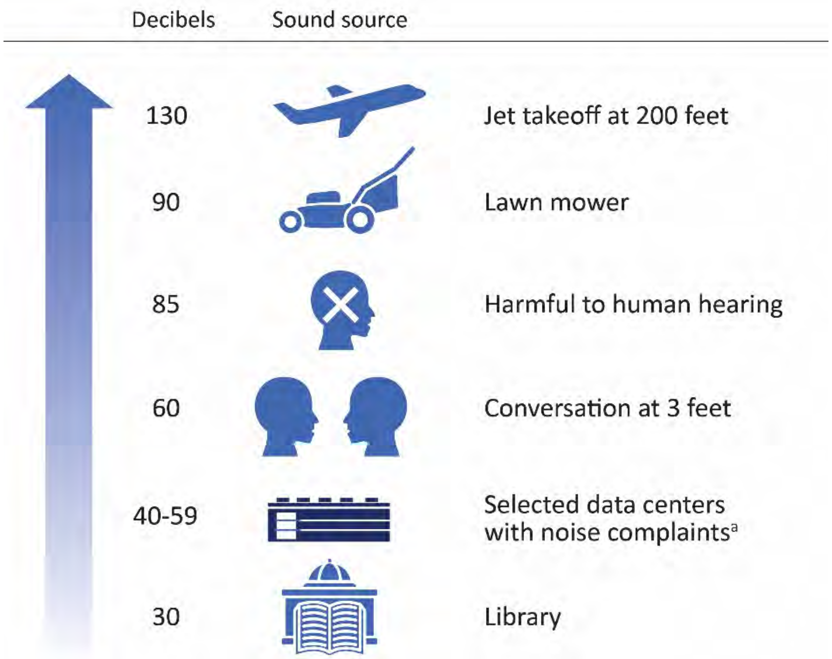
To assess data centers' impacts on property value, JLARC interviewed representatives of neighborhoods opposed to data centers proposed or recently constructed nearby, local stakeholder groups, county assessor's offices, and a local real estate agent association.

Some nearby residents report that constant noise from data centers impacts their well-being

The constant nature of data center noise has been a reported problem when data centers are located near residential areas. Whether data center noise can be heard past the facility's property line depends on its design and its type of cooling system, which can cause noise. In addition, local geography and surrounding buildings can affect how sound travels.

While some data centers have been noisy enough to cause complaints, the noise is not loud enough to damage nearby residents' hearing and rarely loud enough to violate noise ordinances (Figure 6-2). Data center noise that has prompted resident complaints ranges from an estimated 40 to 59 decibels (per JLARC's review of noise measurements of selected data centers that have prompted complaints by residents). This sound level is typically below the 55 or 60 decibel limit that Loudoun, Prince William, and Fairfax allow in their ordinances for residential areas. Rather than the volume of the noise, it's data centers' constant noise that some residents consider problematic. Data center noise is described as a constant "drone" or "hum," similar to house air conditioning systems but magnified to an industrial scale. The noise can sometimes be heard both in and outside of nearby residences.

FIGURE 6-2
Data center sound is noticeable but quieter than many common sounds



SOURCE: JLARC review of Occupational Safety and Health Administration, U.S. Centers for Disease Control and Prevention, and Federal Aviation Administration websites, and analysis of complaint data from Fairfax and Loudoun.
NOTE: The units are A-weighted decibels. [a] Encompasses measurements at locations where local staff recently measured data center noise using A-weighted decibels. Measurements are a response to complaints, so they are not representative of all data centers. Measurements indicate total sound, not the isolated amount from data centers.

Residents who have reported that data center noise is a problem have indicated that it has adversely affected their well-being. JLARC staff spoke with residents who live near data centers that have been the subject of noise complaints to learn how the noise affects them. Some residents described physical symptoms such as migraines from the facilities' constant noise. Others said that they experience health problems caused by disrupted sleep, and some residents described an inability to concentrate on tasks. A common theme was poorer quality of life, with some residents avoiding their decks and yards because the sound is louder outdoors.

Data centers are not required to reduce their noise if they are not violating local ordinances, which has made it difficult to address noise concerns. Some neighborhoods have attempted to address concerns through the county and engagement with data center companies. Residents of the Great Oak neighborhood in Prince William reported noise to county police from a nearby data center in May 2022, and as of October 2024, the issue had not been fully addressed by the data center owner to all residents' satisfaction. Residents of the Brook Haven neighborhood in Loudoun contacted the county in 2021 about noise concerns, and the data center completed an attempted solution in November 2023. In both cases, residents observed reductions in noise from the nearby facilities but emphasized it took time and repeated communications from residents to prompt action.

Data center construction sites can be especially disruptive to nearby residential areas

Because of data centers' size and scale, their construction takes a long time and is disruptive to residential areas. Construction activities typically include clearing trees, grading land, laying foundations, erecting buildings, and installing equipment. While these activities are not unique to data centers, the impacts on residents are especially large because of the projects' scope. Each building takes about 12 to 18 months to construct, and with the industry moving toward developing data center campuses, work on additional buildings often begins as soon as one is completed. Therefore, a large site could take as long as seven years to fully complete. This work requires thousands of workers on site and substantial truck deliveries of materials.

Some residents report they have been negatively affected by data centers' construction. Their concerns include loud construction noises and vehicle traffic. For example, one neighborhood's main access road was damaged by frequent use of heavy vehicles, which reportedly sometimes blocked school buses and emergency vehicles.

One-third of data centers are near residential areas, and industry trends make future residential impacts more likely

The majority of data centers are appropriately located in industrial or commercial areas and are not close to residential uses. Over 60 percent are more than 500 feet from residential-zoned properties (as measured from property line to property line, meaning the actual facility and residences are even farther apart) (sidebar). The farther away a data center is from residential areas, the less likely it is to affect nearby residents.

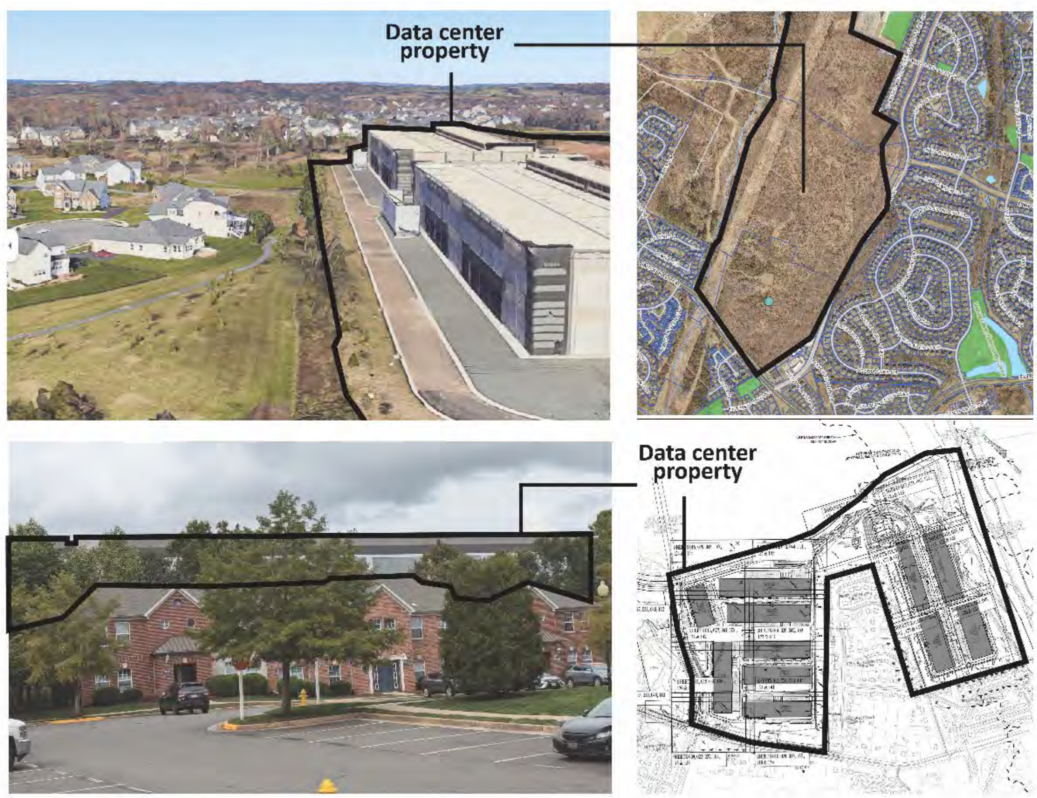
Analysis of the proximity of data center properties to residential zoning used data from eight localities that account for nearly all (93 percent) data centers in Virginia. (See Appendix B.)

A minority of data centers have generated noise complaints. At least 15 data centers (10 percent of operational data center sites) appear to have generated noise that nearby residents regard as problematic, according to resident groups and government records.

However, the number of data centers being built near residential areas is increasing. Almost one-third (29 percent) of operational data center properties in Virginia are within 200 feet of residentially zoned properties. Currently, there are several data centers being constructed adjacent to single-family homes, townhouses, and apartment complexes. Several recently approved data centers in Loudoun and Prince William will be built on land adjacent to neighborhoods, including at least two proposed developments where the property also abuts an elementary school (Figure 6-3). Other counties—such as Fairfax, Stafford, and Henrico—have also received proposals for data centers close to residential areas.

Trends in real estate availability and facility design increase the likelihood of future residential impacts. As the industry's footprint in Northern Virginia grows, the amount of land ideal for data center development is decreasing, and developers are more likely to consider locations closer to residential and other sensitive areas. Additionally, the typical data center building is becoming taller, larger, and more power-intensive, which has the potential to make their industrial characteristics more pronounced and, depending on the design, could generate more noise.

FIGURE 6-3
Some recently built or approved data centers are close to residential areas



SOURCE: JLARC site visits, Google Earth, and locality websites.
NOTE: In order, the pictures depict: (1) existing data center from the Loudoun Meadows neighborhood of Loudoun, (2) land approved for Devlin Technology Park in Prince William, (3) an existing data center next to the Regency neighborhood in Prince William, and (4) a proposed site plan for property that was rezoned to allow data centers around the Amberleigh Station neighborhood in Prince William.

Localities have allowed data centers near neighborhoods, sometimes without sufficient mitigation of impacts

Appropriate local planning and zoning decisions can reduce the risk of data center developments affecting residents. Localities need to proactively update their planning and zoning to manage data center development, because the industry is rapidly changing. As recently as 10 years ago, data centers were much smaller facilities that were similar in size and appearance to commercial office buildings. Local ordinances that continue to treat data centers as non-industrial commercial uses, which are often allowed next to residential areas, are outdated and can affect residents.

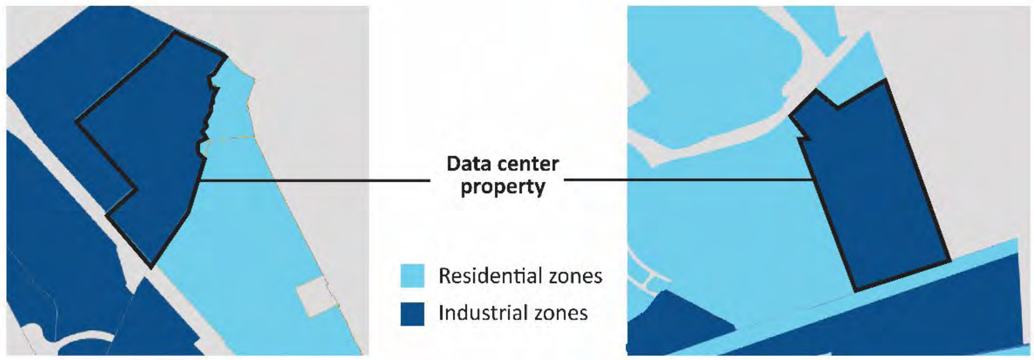
Localities need to consider which areas are appropriate for data center development, classify data centers as industrial uses in zoning ordinances, ensure data centers are not too close to residential zones, and include requirements to mitigate any potential negative impacts from data centers, such as building setbacks and height restrictions. In addition, local elected officials should adequately consider potential residential impacts when considering special permit and rezoning requests.

Inadequate planning and zoning have allowed data centers near residential areas

Data centers have sometimes been built too close to residential and other sensitive areas because local zoning ordinances did not consider them to be an industrial use. For example, until 2021, Fairfax considered a data center to be a telecommunications facility, which allowed data centers to be built in areas zoned for residential and office uses. Loudoun originally treated data centers as an office use and continues to allow by-right data center development in areas zoned for office uses in some parts of the county.

In addition, some localities have zoned industrial areas next to residential areas on their zoning maps, even though land use principles state that industrial uses are ideally separated from residential uses by buffers, such as commercial zones. For example, the Great Oak neighborhood in Prince William and the Bren Mar neighborhood in Fairfax are directly adjacent to industrial zones (Figure 6-4). This has allowed data center development by right despite being close to residences. The likelihood of residences being close to data centers has also increased because of some local decisions to rezone land to residential despite being in primarily industrial areas. If zoning maps are not reviewed and updated, more data centers are likely to be built closer to residential areas.

FIGURE 6-4
Some industrial zones border residential zones, allowing by right data centers too close to residential zones



SOURCE: JLARC review of Prince William and Fairfax geographical informational systems and planning staff reports.
NOTE: The first picture depicts an existing data center near the Great Oak neighborhood of Prince William. The second picture identifies a planned data center near the Bren Mar neighborhood of Fairfax County. Grey coloring indicates a zone that is (1) neither residential nor industrial or (2) within another locality. "Zones" refers to the official zoning classification in local ordinances.

Zoning ordinances often include requirements intended to mitigate negative impacts from businesses, but these requirements are not always sufficient. Required building height limits and property line setbacks are fundamental ways to reduce a development's impacts. For example, the property on the right side of Figure 6-4 was zoned industrial and is only subject to a setback of at least 40 feet (although the developer is voluntarily planning a larger setback). This zoning would have allowed a new data center to be built close to the property lines of two adjacent townhouse complexes. Landscaping and architectural requirements are other ways to mitigate data center impacts, but their value is limited. Newly planted trees take decades to grow, and the size and proximity of a nearby data center matters more to residents than its architecture.

Some localities' elected officials have granted data centers exceptions to requirements designed to reduce residential impacts

Local officials in Virginia have sometimes approved data center requests to build in locations that prompt resident opposition or are likely to cause impacts. These elected officials are responsible for reviewing applications for special permits and rezonings and ensuring they are compatible with the locality's long-term comprehensive plan (or amending the long-term plan). While there is no objective way to assess if officials made the "right" decision in approving a given project, there are cases where elected officials' decisions have led to impacts on residents or contradicted development strategies laid out in long-term plans. For example,

- Elected officials have approved property rezonings that allow data centers next to sensitive locations. Prince William approved rezoning from mixed residential to industrial for the Devlin Technology Park (second in Figure 6-3), which is adjacent to a school and about 80 feet from residential zoning.

- Elected officials have approved data center requests in areas that are not suitable, according to the locality's long-term comprehensive plan. In Loudoun, the board of supervisors approved the True North development even though staff recommended denial because the county's "transitional" long-term plan classification for the site does not support data centers (sidebar).
- Elected officials have exempted individual data centers from local requirements intended to mitigate negative impacts on residents. For example, Loudoun's board of supervisors allowed Aligned Energy's Relocation Drive project to exceed the zone's maximum height and square footage, despite staff recommending against the exemption because of nearby residential areas.

Local planning staff can recommend denial for several reasons. Sometimes staff may recommend denial because they believe more information from the developer is needed before a decision should be made. Other times staff may recommend denial because the proposed use is not compatible with the proposed site or there are not sufficient mitigations planned to adequately protect nearby residents.

Some localities have taken steps to minimize residential impacts, though success of these efforts rests with elected officials

Residents' opposition to data centers has grown in recent years, especially in Loudoun and Prince William. While data center projects rarely generated citizen opposition in the past, it is now more common for individuals and organized groups to speak against data center proposals at local planning commission and board of supervisors meetings. Some grassroots groups have been created to fight specific proposals for new data centers, joined by existing organizations such as regional environmental groups. These local groups often also advocate for more government restrictions on allowable locations for data centers.

Opposition to data center proposals has also emerged outside of the main Northern Virginia markets. For example, local groups contested recent proposals in Henrico County and the Town of Warrenton. However, some locations such as Mecklenburg have not encountered significant resident opposition.

Several Virginia localities are making or considering zoning ordinance changes to reduce the risk of residential impacts

Most of the Virginia localities with sizable data center markets have taken or are considering steps to better manage future data center development. Since 2019, elected officials in the three localities with the most data centers (Loudoun, Prince William, and Fairfax) have taken some steps to address residential concerns (Appendix L). For example,

- All three localities have increased the requirements for data centers to improve their appearance or reduce their visibility, for example, increasing setback requirements, requiring specific design standards for the building façade, or screening external mechanical equipment.

- Loudoun and Fairfax have reduced the number of zones allowing data centers by right.
- All three localities have taken steps to address noise, such as requiring sound studies for new projects, requiring proactive sound measuring for existing data centers, and eliminating a partial exemption in the local noise ordinance for nighttime noise from businesses (including data centers).
- All three localities recently initiated studies of their data center policies to better manage development. Fairfax's study concluded with elected officials amending their ordinances in fall 2024. Loudoun and Prince William are reviewing potential changes to their long-term comprehensive plans as part of their studies and tentatively plan to vote on study proposals in 2025.

In several of the Virginia localities that are considering or expecting their first data center projects, elected officials have proactively implemented planning and zoning changes to promote appropriate industry development. The goals of these changes are to avoid the types of residential impacts that have occurred in established data center markets. For example, in 2023, Stafford County added data center principles to its comprehensive plan, prohibited data centers in several commercial and light industrial zones, and established industry-specific standards. Culpeper County also coordinated amending its comprehensive plan and zoning ordinance relevant to data centers. Culpeper allows data centers in multiple industrial zones but provides tax incentives to encourage development in a newly designated Technology Zone with more stringent design requirements.

Localities generally have adequate expertise to make data center decisions

For the most part, local government staff possess sufficient expertise to support review and approval of data center projects. Data centers are one of many types of development that local planning, permitting, and other staff evaluate. Evaluating whether a data center project is in an allowable location, has appropriate setbacks and building height, or is proposing effective landscape screening is similar to evaluating other large commercial or industrial developments. The one exception is noise, a topic where staff from several localities would like more expertise. For example, planning staff from a locality with data center experience are uncertain whether their recently revised ordinances are the right way to prevent data center noise impacts.

Data center applications can be challenging, however, for smaller counties with less experience with the industry, given the complexity, size, and scale of data center projects. These localities have addressed challenges by reaching out to staff in other localities with more industry experience and by contracting for tasks where their expertise may be lacking, such as assessing economic impacts. For some functions, such as reviews of stormwater management plans, the Department of Environmental Quality may perform the review instead of the locality. Larger counties have sometimes used consultants as well, such as Prince William for a noise study.

Effectiveness of local efforts to minimize residential impacts ultimately depends on elected officials

The effectiveness of local efforts to minimize the residential impacts from data center development ultimately depends on elected officials. Local staff can propose well-designed zoning ordinance changes and provide sound advice on whether a special permit or rezoning request should be approved based on local development standards and the locality's comprehensive plan, but elected officials make the final decisions. As described above, elected officials in Fairfax, Loudoun, and Prince William have recently taken actions to minimize residential impacts of data centers, and several localities considering data center projects are taking actions proactively. While these actions do not guarantee elected officials will always make the "right" decisions to address impacts, they do indicate that elected officials are actively responding to residents' concerns.

State intervention does not appear warranted, but localities should consider using key practices in data center ordinances and decisions

Land use decisions are traditionally a local responsibility in Virginia, because they directly affect local residents. Land use decisions are also very site specific, and local governments are better positioned than the state to evaluate what is appropriate for a given site.

Nature of data center impacts does not appear to merit state intervention, and localities appear to be taking needed actions

Although some stakeholders have advocated for greater state involvement in land use decisions, there is not currently a compelling reason for a state role in setting local requirements for data centers or intervening in local approval decisions. State intervention should only be considered if local policies are causing significant threats to residents' health and safety or other significant harm, but that is not the case with data centers.

Furthermore, only a minority of data centers in Virginia have been reported to impose negative impacts on residents. While some localities have allowed data centers to be built in areas incompatible with residential uses, those localities now appear to be taking actions to avoid future impacts by reviewing and changing local zoning ordinances. Other localities that have not experienced negative impacts on residents yet appear to be taking proactive action to minimize impacts.

Localities should implement several practices to minimize residential impacts

Localities should implement several practices to protect residents and ensure data center development proceeds appropriately and with minimal impacts. Namely, localities should:

- classify data centers as an industrial use in their zoning ordinances;
- review the locations of zones allowing data centers by right, and adjust the zoning map if needed, considering proximity to residential areas;
- ensure that minimum requirements in the zoning ordinance adequately mitigate negative impacts on residential or other sensitive areas (e.g., setbacks, building heights), and add requirements specific to data centers as needed;
- identify optimal areas for data center development in the locality, including locations that are suitable from the county's perspective (e.g., far from residential areas) as well as the industry's perspective (e.g., large parcels, access to transmission);
- reduce the likelihood of noisy data centers (including through limiting allowable locations and requiring sound modeling) and prohibit the constant low-frequency noise of data centers from reaching residential areas; and
- require commitments from data centers making zoning requests to sufficiently mitigate negative impacts on any nearby residential areas.

Localities can take steps to mitigate data center noise, but some are unsure of authority to do so

Although only a few data centers have caused impacts to residential areas, noise is reported to be one of the most disruptive problems for residents, and data center noise concerns can be difficult to resolve. Noise impacts can be reduced by siting data centers away from residential areas and by modeling data centers' potential noise impact before they are built. Localities also need to be able to address noise that occurs after data centers are operational.

Noise concerns can be reduced by modeling data center sound impacts before a data center is built

In addition to having zoning ordinances that prevent data centers from being located close to residential areas, localities should require sound modeling for data centers proposed close to residential areas. Sound modeling predicts the sound a facility will generate once operational and provides an opportunity for building designers to assess the need for, and effectiveness of, sound reduction strategies. Localities could review study results to determine if any further action, such as sound barrier construction, should be required before approving a development project.

Sound modeling studies can also be used to establish the baseline level of noise already occurring around the proposed data center site, which can later be used to determine whether a data center has contributed to noise in the area. Many data center companies are now doing sound modeling studies for all or some of their projects, and companies explained that sound modeling prior to construction is worthwhile because reducing noise after a building is operational can be difficult and expensive.

Some localities were unsure whether Virginia law allows them to require sound modeling studies. Given this uncertainty, the Code of Virginia should be amended to clarify that local governments have the authority to require sound modeling studies by data center developers and to review and consider the results in their land use decisions.

RECOMMENDATION 7
The General Assembly may wish to consider amending the Code of Virginia to expressly authorize local governments to require sound modeling studies for data center development projects prior to project approval.

The state could incentivize sound modeling by making eligibility for the sales and use tax exemption contingent on this work being performed for any new data center developments proposed near residential areas. For example, the General Assembly could amend the law to require any data center company with a data center that is proposed to be constructed in 2026 or later near a residential area or area zoned for residential development perform a sound modeling study and provide the results to the appropriate locality in order to qualify for the exemption.

POLICY OPTION 7
The General Assembly could amend the Code of Virginia to require that, as a condition for receiving the sales and use tax exemption, data center companies conduct a sound modeling study prior to the development of a proposed data center that is to be located within a certain distance of a residential development or area zoned for residential development and provide the study findings to the appropriate locality.

Localities also need the ability to address noise issues that occur once a data center is operational

Localities also need to be able to address data centers' noise once they are operational, but local ordinances have been largely ineffective at addressing data center noise concerns. Most local noise limits are defined using "A-weighted" decibels (sidebar). This metric is designed to target excessively loud noise from sources such as parties and barking dogs. The lower frequency noise data centers emit is not fully captured in "A-weighted" decibels. Therefore, data center noise rarely exceeds the allowable limits set in ordinances, despite the constancy of the sound being problematic for residents. To effectively address data center sounds that cause resident complaints, localities could

"**Decibels**" are a pure unit of measurement of sound's volume. When measuring sound, different modifications can be used to account for various frequencies. For example, "A-weighted" decibels prioritize frequencies perceived loudest by humans and therefore reduce particularly low frequencies. "C-weighted" decibel measurements account more for low frequencies.

develop a supplemental noise limit defined using a metric that better accounts for low frequency sounds, such as "C-weighted" decibels.

Another challenge is that most localities address excessive noise in *noise ordinances*, and state law limits civil penalties for noise ordinance violations to $500 after the first offense. Stakeholders have expressed concern that this small penalty is not sufficient to affect the behavior of the large companies that own data centers. Addressing noise limits through localities' *zoning ordinances* would allow localities to better address data center noise. For example, the zoning ordinance could prescribe a process for measuring potential noise violations and penalties for not addressing them.

Some localities were unsure whether state law allows them to (i) establish maximum sound levels in alternative low frequency sound metrics and (ii) set noise rules and enforcement mechanisms in their zoning ordinances. The state should clarify that local governments have the authority to use these approaches to address data center noise.

RECOMMENDATION 8

The General Assembly may wish to consider amending the Code of Virginia to expressly authorize local governments to establish and enforce maximum allowable sound levels for data center facilities, including (i) using alternative low frequency noise metrics and (ii) setting noise rules and enforcement mechanisms in their zoning ordinances, separate from existing noise ordinances.

7 Potential Changes to Data Center Sales Tax Exemption to Address Policy Concerns

Virginia's data center retail sales and use tax exemption is a valuable incentive to data centers (providing $928 million in savings in FY23), and about 90 percent of the industry (as measured by megawatts of power) uses the exemption. The General Assembly could therefore use the exemption to incentivize the industry to take actions that help address many of the concerns discussed throughout this report.

If consideration is given to amending the exemption, two factors should be considered. The exemption was adopted primarily to attract data centers to Virginia for economic development purposes, so any changes to advance other policy goals could make it a less effective economic development tool. The exemption is also consistent with tax policy principles that generally exempt businesses' production-related inputs (in this case computer and related equipment) and therefore provides equitable tax treatment with other capital-intensive industries that have business input exemptions.

Exemption changes could encourage continued data center growth, reduced energy demand, or a balance of these priorities

The data center industry provides positive economic benefits to Virginia (Chapter 2). However, a primary concern about the growing industry is the immense increase in energy demand it will require (Chapter 3), which could increase costs to other customers (Chapter 4). The state could consider changes to the exemption to maintain data center industry growth, reduce energy demand by reducing industry growth, or attempt to balance these two competing priorities.

Extending the exemption could help Virginia maintain industry growth and associated economic and local tax revenue benefits

The data center industry provides moderate economic benefits to Virginia and can provide localities that have them with substantial tax revenues. While economic benefits are concentrated in Northern Virginia, other regions of the state also benefit. For example, data center construction benefits equipment manufacturers and material suppliers in Tidewater, Southwest, and Southside Virginia. While historically only a few localities have benefited from data center tax revenues, the industry is rapidly growing. Data center projects are under development in at least 15 localities, most of which did not previously have data centers. Therefore, from an economic development perspective, the state may want to continue attracting the industry and maintain Virginia's position as a top global data center market.

The state's data center sales tax exemption is scheduled to expire in 2035, and data center representatives unanimously reported that expiration of the exemption would have a negative impact on the state's ability to attract new data centers and keep existing ones. Some companies indicated the expiration date could start to affect site selection and expansion decisions made in the next few years, because companies typically consider the costs of data center ownership over a 15- to 20-year period when making location decisions. Companies indicated that, without the exemption, the total cost of data center ownership and operation would significantly increase. Virginia is currently competing for new data center development with several other primary U.S. markets, almost all of which have data center exemptions. Without an exemption, data center representatives indicated any new development in Virginia would be limited to only what is "absolutely necessary," and development would likely shift to other markets.

To help Virginia remain competitive, the state could extend the exemption's expiration date. To influence future site selection decisions, an extension would need to be in place well before 2035. A reasonable new expiration year would be 2050, which would match the special extension that has already been created for companies that meet certain additional criteria (sidebar). The exemption should continue to have an expiration date, because this is considered an effective practice to ensure periodic scrutiny of its need and effectiveness.

The 2023 General Assembly passed **a special data center sales tax exemption extension to 2040 or 2050** for companies that create 1,000 or 2,500 jobs (100 of which must meet above average wage requirements) and make a capital investment of at least $35 billion or $100 billion, respectively. So far, this extension applies to only one data center company, but several others may be interested in qualifying for this extension.

POLICY OPTION 8

The General Assembly could amend the Code of Virginia to extend the expiration date for the state's sales and use tax exemption for data centers from 2035 to 2050.

Extending the expiration date for the exemption, without making any other changes to it, would not address one structural issue with the exemption. Most of the economic benefits of the exemption occur during data center construction, but the exemption provides companies with substantial tax benefits in subsequent years after economic benefits have declined.

Allowing the exemption to expire could help reduce industry growth and associated energy demand

Virginia's utilities have historically been able to keep up with energy demand, but even if data center energy use grows at only half the forecasted rate, the state will need to make enormous investments in energy infrastructure. While data centers will incur much of the cost of new infrastructure investments, energy rates for all users are likely to increase. Growing energy demand could also make it more difficult for the state to meet goals set forth in the Virginia Clean Economy Act.

If the General Assembly wishes to slow down the data center industry's growth in Virginia because it determines that energy concerns outweigh the industry's economic benefits, it could allow the sales tax exemption to expire in 2035. While it is difficult to gauge the exact effect this would have, it is likely industry growth would slow and could eventually stop or even contract. If the industry contracts, it would reduce the need for future generation and transmission infrastructure but would actually increase energy costs paid by other ratepayers, who would have to share a larger portion of current systemwide costs. While the state could allow the exemption to expire only in certain localities or regions, like Northern Virginia, that approach would be less effective in reducing overall growth in energy demand. Industry growth is occurring in several counties outside of the Northern Virginia region and is expected to continue, so allowing the exemption to expire in Northern Virgina while extending it elsewhere would not address the energy impacts where much of the future industry growth is likely to occur (sidebar).

Outside of the Northern Virginia planning district, data center projects are currently under development in the counties of Caroline, Chesterfield, Culpeper, Fauquier, Hanover, Henrico, Louisa, Mecklenburg, Pittsylvania, Powhatan, Spotsylvania, and Stafford. Dominion Energy expects the Stafford area to "become another super large market" like Loudoun and Prince William counties.

If the General Assembly allowed the exemption to expire in 2035, it would need to determine how to treat the large subset of data centers that will likely qualify for the special 2040 or 2050 extension. This extension currently pertains only to Amazon Web Services, but other companies may be interested in developing agreements to use the extension. Disallowing Amazon Web Services from using the extension would likely affect its custom performance grant agreement with the state to develop multiple data center facilities throughout Virginia, which was negotiated under the assumption the company would receive the extension, and could be subject to legal challenges.

POLICY OPTION 9

The General Assembly could allow the sales and use tax exemption for data centers to expire in 2035.

Exemption could be changed to balance industry growth with energy impacts

By either extending the exemption or allowing it to expire, the state would be choosing either economic benefits or reduced energy impacts. An alternative approach is to try and balance these competing objectives. The state could do this by allowing the *full* exemption to expire in 2035 (or ending it before then) and applying a *partial* tax exemption to 2050.

The size of a partial exemption could depend on whether the state wants to emphasize economic benefits or reduced energy impacts. For example, under the current exemption, qualifying companies are exempt from paying the full 4.3 percent state share of the retail sales and use tax and local and regional portions (sidebar). Focusing on the state share, a partial exemption could require qualifying companies to pay a 1 percent sales tax, which would keep much of the exemption's value intact and would likely remain somewhat effective at promoting industry growth (but would do less to reduce energy use). Alternatively, qualifying companies could be required to pay a higher 3 percent sales tax, which would likely be less effective at promoting industry growth and so would reduce future energy use more. By choosing a higher partial tax rate, the state could risk losing some of its existing data centers, particularly in Northern

The statewide retail sales and use tax includes a 4.3 percent state share, a 1 percent local option share, and an additional 0.7 percent to 1.7 percent regional share, depending on the region.

Virginia, although this risk may be diminished by the region's many attributes that make it so attractive to the industry.

The state would need to determine if the partial exemption would apply to data centers that qualify for the existing special 2040 or 2050 extension. This extension currently pertains only to Amazon Web Services, but other companies may be interested in developing agreements to use the extension. To be most effective at addressing energy impacts, and to maintain a level playing field for competitors, the same or a similar partial exemption could also be applied to these data centers.

POLICY OPTION 10

The General Assembly could amend the Code of Virginia to extend a partial sales and use tax exemption for data centers from 2035 to 2050.

A partial exemption would also better align the economic benefits the state receives with the exemption's value. Most economic benefits occur during construction, and switching to a partial exemption in 2035 would reduce the value of the exemption in later years when the economic impacts of current and planned data centers could be expected to slow. A partial exemption would also generate more revenue for the state. For example, a 1 percent partial sales tax would have generated approximately $160 million in state tax revenue in FY23.

Exemption changes could address other policy concerns related to the data center industry

If the decision is made to extend the exemption, this report provides several options the General Assembly could enact to modify it and address concerns in specific policy areas (Table 7-1). These policy options would add new requirements, in addition to the existing requirements, for data centers to be eligible to receive the exemption (sidebar). These options could be phased in gradually to give data center companies enough time to implement them, and the General Assembly could decide to enact some but not others.

Virginia's sales tax exemption currently requires…

50 new jobs located at the data center, associated with operations or maintenance.

Jobs pay at least 150% of the prevailing annual average wage of the locality where the data center is located.

$150 million in capital investment.

Requirements are lower for data centers in economically distressed localities (10 jobs and $75 million capital investment).

The General Assembly will need to determine its primary policy goals for the industry to determine whether to add new requirements to the exemption. If some or all of these policy options were adopted, it would likely make the exemption harder to use and more complex to administer. Alternatively, the General Assembly could pass legislation *requiring* the industry to take these actions, regardless of whether they qualify for the exemption, but this approach could lead to some data centers choosing to either shut down or operate in violation of the law.

The policy options in Table 7-1 would require changes to the Memoranda of Understanding (MOUs) all data center companies are required to enter into with the Virginia Economic Development Partnership (VEDP) to receive the exemption. Current law allows all of a company's data centers in a specific locality to collectively qualify for the exemption. Therefore, the company reports data to VEDP for all of its data centers in each locality where it operates rather than by each individual data center. Policy options that apply only to new data centers might require changing MOUs to apply to each individual data center or to have addenda to the MOUs that identify the individual eligible data centers. VEDP would need to determine exactly how MOUs would need to be restructured.

VEDP would also need to determine the evidence data center companies would need to provide to qualify for the exemption, which would likely add to the complexity of administering the exemption. For example, companies could be required to provide appropriate documentation before a new data center becomes operational to qualify for the exemption. Alternatively, companies could be allowed to self-certify under the condition that documentation must be provided if requested by VEDP or Virginia Tax. VEDP would need to develop guidelines for how to implement any new compliance requirements and set forth new terms in the MOUs.

TABLE 7-1
General Assembly could modify the sales tax exemption to address energy, natural resource, historic resource, and residential impacts

Change	Issue Addressed	Policy option
Options that could apply to *all* Virginia data center operations		
Implement ISO-50001 Energy Management standard or equivalent	Energy impacts and costs	1
Implement ISO-14001 Environmental Management Systems standard or equivalent	Natural resource impacts	5
Options that could apply to *new* data centers built after a certain date		
No Tier 2 diesel generators in Northern Virginia Ozone Non-Attainment area without SCR systems	Natural resource impacts	4
Phase 1 historic resources study required, viewshed study required if near registered historic site	Historic resource impacts	6
Sound modeling (noise) study required	Residential impacts	8

SOURCE: JLARC staff analysis.
NOTE: ISO = International Organization for Standardization. SCR = Selective Catalytic Reduction systems that reduce emissions of nitrogen oxides, a major contributor to smog-forming ozone, and other harmful emissions.

Appendix A: Study resolution

Resolution of the Joint Legislative Audit and Review Commission directing staff to review data centers

Authorized by the Commission on December 11, 2023

WHEREAS, there has been substantial growth in the data center industry in Virginia, particularly Northern Virginia which has the largest concentration of data centers in the world, Southern Virginia, the Greater Fredericksburg region, and the Greater Richmond region; and

WHEREAS, growth in the data center industry is expected to continue with increasing demand from deployment of advanced and innovative technologies used by individuals, business of all sizes across all industries, government agencies, and other organizations that require the digital infrastructure that data centers provide; and

WHEREAS, data centers can bring economic benefits to localities because they can create significant economic activity during construction, they can increase property tax revenue for local governments without placing high demands on government services like schools, and the clustering of data centers can make a region more attractive to other high tech businesses and help support ecosystems of vendors, service providers, and suppliers; and

WHEREAS, concerns exist over data centers because they require large amounts of energy, which can affect the broader energy market; they may have impacts on natural, historical, and cultural resources; and some citizens have expressed opposition to having data centers located near residential areas due to concerns over issues such as noise and the adverse visual impact: and

WHEREAS, the data center sales tax exemption is Virginia's largest economic development incentive, and JLARC conducted an in-depth review of the exemption in 2019; now, therefore, be it

RESOLVED by the Joint Legislative Audit and Review Commission that staff be directed to review the overall impacts of the data center industry in Virginia and state and local policies regarding the industry. In conducting its study staff shall (i) research recent and expected trends in factors impacting data center industry growth and forecast future growth of Virginia's data center industry, taking into account how various factors may affect these projections; (ii) assess impacts of the data center industry on Virginia's natural resources, as well as historic and cultural resources, and identify potential technologies that could reduce their impacts on these resources; (iii) assess the impacts of the data center industry on current and forecasted energy demand and supply in Virginia, including how data centers will likely affect future energy infrastructure needs, energy rates paid by customer classes and whether cost allocation methods ensure no single customer class is unreasonably subsidized by other customer classes, and the state's ability to transition from fossil fuels to renewable energy sources; (iv) estimate the impact of the data center industry on local revenue and assess how local tax policies may affect data centers; (v) identify how data centers may impact local residents, including concerns such as noise pollution, decreasing property values, and the adverse visual impact; (vi) identify considerations around the construction and siting of data centers, and review how zoning and regulatory restrictions and requirements can affect data center deployment; (vii) identify guidance and assistance state agencies could provide to local governments for use in making decisions about the location and expansion of data centers; (viii) assess whether more geographically diverse data center industry growth would provide greater economic benefits to the Commonwealth, and if so, identify obstacles to attracting data centers to other areas, particularly economically distressed or rural regions of the state, and policy changes that could increase geographic diversity, such as changes in electricity policy, tax policy, and broadband infrastructure policy; (ix) compare Virginia's competitiveness in attracting data centers with other states; and (x) determine if Virginia's data center tax exemption could be improved, including whether the exemption could be better targeted, the level of benefit is appropriate given the cost, or other changes should be considered.

JLARC may make recommendations as necessary and may review other issues as warranted.

All agencies of the Commonwealth, including the Virginia Department of Energy, the Virginia Department of Environmental Quality, the State Corporation Commission, the Virginia Economic Development Partnership Authority, the Virginia Department of Taxation, and Virginia local governments shall provide assistance, information, and data to JLARC for this study, upon request. JLARC may use consultants as necessary to complete the study. JLARC staff shall have access to all information in the possession of agencies pursuant to § 30-59 and § 30-69 of the Code of Virginia. No provision of the Code of Virginia shall be interpreted as limiting or restricting the access of JLARC staff to information pursuant to its statutory authority.

Appendix B: Research activities and methods

Key research activities performed by JLARC staff for this study included:

- structured interviews with local residents and stakeholder groups, data center companies and developers, state and local officials, electric and water utility companies, and subject-matter experts;
- contracts with consultants to produce an independent energy demand forecast for Virginia and its utilities, and model how future data center growth in Virginia is likely to impact energy supply, demand, emissions, and cost;
- site visits to data centers and nearby communities;
- development of inventories of (i) operational and (ii) planned data centers;
- economic impact analysis of the data center industry (see Appendix D);
- data collection and analysis, including on data center water usage, emissions, capital expenditures, employment and tax benefits amongst users of the data center tax exemption, and data center proximity to residential areas;
- review of state and local laws, ordinances, reports, and policies relevant to energy, natural and historic resources, land use, and noise;
- review of research literature relevant to data centers, energy, natural and historic resources, and noise; and
- review of other documents, literature, and media sources.

Structured interviews

Structured interviews were a key research method for this report. JLARC staff conducted over 250 interviews with 165 different stakeholders.

Residents and stakeholder groups

JLARC staff conducted interviews with nearly 20 local residents and resident stakeholder groups, such as neighborhood associations, including those in Fairfax, Fauquier, Henrico, Loudoun, and Prince William counties. These interviews focused on the impact of data centers on local residents and communities, such as viewshed and noise issues.

JLARC staff also conducted roughly 20 interviews with state and regional stakeholders groups, including those that represent data center companies, electric cooperatives, construction tradespeople, land conversation and preservation, battlefield preservation, sustainability and the environment, and local and tribal interests. Staff interviewed the American Battlefield Trust, Clean Virginia, Cultural Heritage Partners, Data Center Coalition, Friends of the Rappahannock, Northern Virginia Technology Council, Preservation Virginia, Sierra Club, Southern Environmental Law Center, Virginia Association of Counties, Virginia Association of Soil and Water Conservation Districts, Virginia Chapter of the American Planning Association, Virginia Clinicians for Climate Action, Council of Virginia Archaeologists, Virginia Data Center Reform Coalition, Virginia Farm Bureau Federation, and Virginia, and Maryland & Delaware Association of Electric Cooperatives. Staff also interviewed representatives of the Pamunkey tribe. These interviews covered a range of topics related to the impact of data centers.

Data center companies and developers

JLARC staff conducted nearly 40 interviews with 12 data center companies and developers. These companies operate colocation and hyperscale data centers in Virginia and include industry leaders. These interviews covered a range of topics, including their data center operations in Virginia, the economic impact of data centers, data center site selection, energy issues and sustainability, and the impact of data centers on natural and historic resources, local planning, and community impacts.

State agency staff

JLARC staff conducted more than 30 interviews with state agency staff, including staff from the Virginia Department of Environmental Quality (DEQ), State Corporation Commission, Virginia Economic Development Partnership, Virginia Department of Taxation, Virginia Department of Conservation and Recreation, Virginia Department of Historic Resources, Virginia Department of Forestry, Virginia Department of Agriculture and Consumer Services, Virginia Department of Energy, Virginia Department of Housing and Community Development, and Virginia Department of General Services. These interviews covered a range of topics related to the impact of data centers, including energy issues, issues related to natural and historic resources, and economic development.

Local government staff

JLARC staff conducted more than 50 interviews with local government staff and elected officials in Caroline, Chesterfield, Culpeper, Fairfax, Fauquier, Frederick, Henrico, Loudoun, Mecklenburg, Prince William, Stafford, and Wise counties, and the town of Warrenton. These interviews covered a range of topics, including planning and zoning, economic development, environmental services, public works, historic resources, and local tax and revenue impacts.

Federal government staff

JLARC staff conducted interviews with staff at the U.S. Army Corps of Engineers, U.S. Department of Agriculture, and U.S. Environmental Protection Agency. These interviews generally focused on the impact of data centers on natural resources.

Electric companies and cooperatives in Virginia and Virginia's regional transmission organization

JLARC staff conducted more than 20 interviews with electric companies and cooperatives in Virginia, including Dominion Energy, Appalachian Power Company, and the Central Virginia, Mecklenburg, Old Dominion, Northern Virginia, and Rappahannock electric cooperatives. These interviews focused on the impact of data centers on energy demand, supply, and rates. Interviews with Dominion Energy also focused on energy transmission and generation issues.

JLARC staff also interviewed the PJM regional transmission organization, which serves Virginia. These interviews focused on energy transmission and generation in the region, as well as the impact of data centers on energy demand and supply.

Water utilities

JLARC staff conducted 15 interviews with local water utilities, including those in Caroline, Fairfax, Fauquier, Henrico, Loudoun, Mecklenburg, Prince William, Stafford, and Wise counties. These interviews focused on the impact of data centers on water utilities, planning, and availability.

Subject-matter experts

JLARC staff conducted more than 25 interviews with subject-matter experts across a range of topics related to data centers. These experts included researchers at the Cooling Technologies Research Center at Purdue University, Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, Occoquan Watershed Monitoring Laboratory, and Rutgers Noise Technical Assistance Center; experts at engineering, law, and real estate firms with experience working with data centers; and leading data center construction materials and equipment manufacturers, such as a steel fabricator and generator manufacturer.

Contracts with consultants

JLARC contracted with faculty from the Weldon Cooper Center for Public Service at the University of Virginia (Weldon Cooper Center) to develop an independent energy demand forecast for Virginia and its utilities. JLARC also contracted with consulting firm Energy + Environmental Economics (E3) to model how data center growth in Virginia is likely to affect future generation and transmission needs and whether the associated costs of system changes could be passed on to residential ratepayers. E3's work was divided into two projects: (1) grid modeling and (2) cost of service and rate impacts.

Additionally, JLARC contracted with Terance Rephann and Joao Ferreira, regional economists at the Weldon Cooper Center, to assist in the economic impact analysis. The methods used for the economic impact analysis are described in Appendix D.

Weldon Cooper Center energy demand forecast

WCC was contracted to develop an independent energy demand forecast for Virginia that accounts for the expected growth of the data center industry. WCC collected data on historical retail energy sales for Dominion Energy, Appalachian Power Company (APCO), and utilities serving the rest of Virginia. WCC collected additional data on retail energy sales to *data center* customers for the utilities that currently serve most of the Virginia data center industry: Dominion, Northern Virginia Electric Cooperative (NOVEC), and Mecklenburg Electric Cooperative (MEC). WCC also collected data on metered load forecasts for data center customers in the Rappahannock Electric Cooperative (REC). REC does not currently have any operational data center customers, but a substantial number of new, large data center campuses are planned to be built in REC's distribution service territory.

Using historical energy sales data, WCC applied advanced statistical methods to develop an *unconstrained energy demand* forecast for Virgina. The unconstrained demand forecast shows what demand would be before accounting for constraints like the ability to build enough energy infrastructure to meet demand. WCC also developed a forecast for *half of unconstrained demand* to provide a lower-growth scenario for analysis purposes. Finally, WCC developed a *no new data center demand* forecast so that the effects of the industry on energy demand could be isolated for analysis purposes. WCC's forecast made several projections, including baseload demand growth from all non-data center customers, demand growth from data center customers, and demand growth from electric vehicles. Additional details on the data and statistical methods used to develop the forecast are detailed in WCC's final report to JLARC staff.

WCC's forecasts cover the period from 2025 to 2050 because VCEA requires carbon emitting generation owned by Dominion and APCO to be retired by 2045 and for the utilities to have all energy from non-carbon emitting sources by 2045 (Dominion) or 2050 (APCO). However, because forecasts become more speculative the farther out they go, this report shows energy demand forecasts up to 2040. The energy demand forecasts for later years are detailed in WCC's final report to JLARC staff.

One of the limitations of the WCC forecasts is that historical data does not fully capture some of the trends that are likely to drive future data center growth, such as how artificial intelligence (AI) will be developed and deployed. However, the unconstrained demand forecast is within the bounds of what can be expected in the next five-plus years based on the electric service and construction agreements that utilities report having in place with data center customers. It is important to note that because forecasts were developed using actual, historical energy sales, they are not subject to distortion by speculative capacity requests from developers or data center companies.

Energy + Environmental Economics grid modeling (project 1)

E3 developed a model of the regional PJM generation and transmission grid. E3 then converted the WCC *energy* demand forecasts into *peak load* demand forecasts that estimate the highest overall power demand that would be placed on the grid each year, under different scenarios. The peak load forecast considered daily and seasonal energy use trends and weather patterns. E3 then modeled three main demand scenarios. For each of the demand scenarios, the model considered the most feasible and economical approaches to meeting infrastructure needs with and without the requirements of the Virginia Clean Economy Act (VCEA).

- Scenario 1: unconstrained demand, with and without VCEA. E3 also modeled variations where unconstrained demand and VCEA requirements could be met by using high levels of nuclear and renewable generation or by better regional coordination across PJM.
- Scenario 2: half of unconstrained demand, with and without VCEA.
- Scenario 3: no new data center demand, with and without VCEA.

E3's modeling used industry standard approaches and tools used for electric utility and state energy planning purposes. The model applied constraints on the amounts of infrastructure that could be built by 2030 using historical build rates, relaxed those constraints for 2035, and removed most constraints for 2040 and following years. Modeling was based on state and federal laws and regulations in place in 2024. For VCEA scenarios, the model followed the "letter of the law" and assumed that certain requirements—such as the Renewable Portfolio Standards and associated Renewable Energy Certificate requirements for investor-owned utilities—would not apply to electric cooperatives. This assumption has a significant impact because a majority of future data center growth is expected to occur in the electric cooperatives' distribution service territories. Societal costs, such as the social cost of carbon, were not explicitly included in the model. Additional details on the exact methods and assumptions used to develop the model are detailed in E3's final report to JLARC staff.

For each scenario, the model predicted the mix of generation and transmission capacity that would be needed to meet demand, the resulting mix of generation energy sources (including energy imports), and their associated emissions. Outcomes were developed for the Dominion transmission zone, Virginia, and the PJM region. The model also predicted system costs for the Dominion transmission zone, where most data center growth is expected to occur. Each scenario outcome was tested to ensure that the system being built would be functional and meet industry standard reliability requirements.

E3's grid modeling covers the period from 2025 to 2050 because VCEA requires all carbon emitting generation owned by Dominion and APCO to be retired by 2045 and for the utilities to have all energy from non-carbon emitting sources by 2045 (Dominion) or 2050 (APCO). However, because energy demand forecasts and generation options become more speculative in further out years, this report only shows model results up to 2040. The model's results for later years are detailed in E3's final report to JLARC staff.

Energy + Environmental Economics cost of service and rate impact analysis (project 2)

For the cost-of-service analysis, E3 examined how costs were being incurred and allocated to different customer classes under the rate structures in place at Dominion Energy, NOVEC, and MEC. The purpose of this analysis was to determine if the current rate structures were wholly recovering costs from the customers who are incurring those costs. E3's cost-of-service analysis was done using industry standard approaches and tools for electric utility planning purposes. Additional details on the exact methods and assumptions used in this analysis are detailed in E3's final report to JLARC staff.

For the rate impacts analysis, E3 focused on how changing demand could affect generation and transmission costs for residential ratepayers in Dominion's distribution service territory. Dominion was chosen because of its large size and concentration of data centers. Residential rate changes were a key focus because they show how Virginia households could be affected by growing data center demand and are indicative of how other customers, such as businesses, might be affected.

E3's analysis of rate impacts followed three steps. First, E3 estimated total costs that would be attributable to the Dominion transmission zone, under the different energy demand scenarios discussed above, using its grid model. Second, for the Dominion distribution service territory, E3 estimated how costs would be allocated to residential customers, assuming that the company regularly reallocated costs to its different customer classes using current state- and federally approved allocation methodologies. Third, E3 translated these costs into the incremental cost per kilowatt-hour that would be passed on to residential ratepayers.

E3's rate impact analysis was limited to generation and transmission cost increases that could be attributed to growing data center demand. The analysis captures the cost of transmission needed to increase capacity into the Dominion transmission zone (interzonal transmission) and to interconnect with new generation sources. A significant portion of potential future transmission costs, associated with transmission projects *within* the Dominion transmission zone (intrazonal transmission), were not captured because these projects and their costs cannot easily be predicted. The analysis did not consider potential changes to distribution rates because most increases in distribution costs from the data center industry are effectively allocated to and recovered from these customers. E3's analysis also did not consider how Dominion's allowable profit margin would factor into rate impacts.

JLARC staff converted E3's rate impact data to show how a typical residential customer, using 1,000 kilowatt-hours of energy per month, could be affected. JLARC staff's conversion included an adjustment to account for Dominion's allowable profit margin but did not incorporate several other costs that affect the total residential bill. Consequently, Dominion's total residential bill projections, from its integrated resource plan, show much larger overall increases than the numbers presented in this report. Dominion's projections apply to the whole residential bill and include several costs that are not captured in JLARC's analysis, such as distribution costs and the cost of some additional transmission and generation projects that may not be solely attributable to data centers. Dominion's residential bill projections are also in nominal dollars that have been adjusted upward using an inflation assumption whereas JLARC's are held in constant (or real) 2024 dollars to show the real growth of costs that consumers will experience, independent of inflation. The demand forecast that Dominion uses in its rate projections is similar to the WCC unconstrained demand forecast but substantially higher than the half of unconstrained demand forecast.

Site visits

JLARC staff conducted site visits to two operational data centers in Virginia, including one in Loudoun and one in Henrico. Staff conducted these site visits to better understand how data centers are designed and operated. For example, staff observed the data halls, power and cooling systems, and backup generators, and listened to noise levels throughout the facilities. Staff also spoke with a variety of personnel at the data centers, including facility operations managers and operational and maintenance staff.

Additionally, JLARC conducted multiple site visits to observe areas with data center development and neighborhoods with nearby data centers. Two of these site visits were led by stakeholder groups with extensive participation in local zoning processes and studies of data centers. JLARC visited eight neighborhoods close to operational data centers or data centers in various stages of development. At all but one of those locations, JLARC staff spoke with residents about their perspectives on the data centers. Additionally, JLARC visited a commonly used trail adjacent to a data center and visited land within Manassas National Battlefield next to property rezoned for a data center.

Data center inventories

JLARC staff developed an inventory of the operational data centers in Virginia. This inventory was used to map the presence of the industry in Virginia. The inventory was based on data provided by DEQ listing data center sites with active air emissions permits (which all Virginia data centers have for their diesel generators). This data was as of August 2024. Staff used the address field in this data to search county real estate assessment records, using these records to (i) confirm the address was associated with a data center and (ii) identify the size of the site (in terms of acres), the number of buildings on the site, when they were built, and their size (in terms of square feet). In a few instances, county records did not list the size of the building. In these instances, JLARC staff estimated the size of the building(s) on the site based on the total capacity (megawatts) of the generators permitted by DEQ.

Staff cross-referenced this information where possible, using publicly available information from data center company websites, the Existing and Proposed Data Centers map developed by the Piedmont

Environmental Council, and other websites that track the data center industry, such as Datacenter-Hawk. From this cross-referencing, JLARC staff identified a few sites that appeared to be data centers but were not associated with a DEQ permit. In these instances, JLARC staff estimated the capacity of the site (megawatts) based on the size of the building(s) listed on the site's real estate assessment record.

JLARC staff also developed a list of data center sites currently under construction, planned, or proposed in Virginia. This information was used to assess where data center growth is expected to occur in the state. To develop this inventory, staff monitored media articles announcing new and proposed data center development, such as those published by Data Center Dynamics and local news outlets. Staff also identified information about proposed data center sites by reviewing local data center-related zoning and permitting requests.

Data collection and analysis

Local data center tax revenue

JLARC staff calculated the proportion of local revenue that comes from data centers by collecting data center tax revenue from localities and comparing it to their total local revenue reported in the Auditor of Public Accounts' Comparative Report of Local Government Revenues and Expenditures for FY23.

Data center generator permit, emissions, and violations data

DEQ provided JLARC staff air permit data for Virginia data centers (who were identified by DEQ), including data center permitted generator numbers and energy capacities, maximum allowed annual emissions, and actual emissions from 2015–2023. Additionally, JLARC staff used DEQ annual point source emission data, enforcement action data (including notices or violations and any charges assessed), and National Emissions Inventory data for Northern Virginia in 2017 and 2020.

JLARC staff created summary statistics of data center permit information (such as generator numbers and maximum allowed emission) and actual emissions and examined trends across time, regions, and localities. Using a map generated through JLARC's data center inventory, JLARC staff also examined clusters of data centers and cumulative local emissions from data centers.

To understand how data center emissions compare to other industries and contribute to overall emissions, JLARC staff compared data center emission and violation data to that of other Virginia air permit holder groups from 2015–2023. Additionally, JLARC staff estimated the current and potential portion of Northern Virginia air emissions resulting from data centers using 2020 National Emissions Inventory data.

Data center water use

JLARC staff received 2023 data center water usage information from water utilities serving Fairfax, Henrico, Loudoun, Mecklenburg, and Prince William counties as well as the town of Wise. Usage was typically reported for anonymous, individual data center buildings. However, one utility shared combined data for all of their data centers buildings, and one shared all water meter data for data center companies but did not combine use by building. (Some data centers have multiple water lines.) Reclaim water use amounts were identified in the data. Two utilities shared annual usage data; three shared monthly usage data; and one shared daily usage data. Five utilities were able to share some amount of information related to data center water use trends since 2019 or later. All utilities shared their total annual customer base water usage for 2023.

JLARC staff used this data to calculate individual and cumulative data center water usage amounts, including the portion of a local utility's water that goes to data centers. JLARC also examined data center water usage seasonal trends and trends in recent years. JLARC analyzed data center water usage relative to other industries and water users in Virginia based on DEQ's 2023 Annual Water Resources reports; non-agricultural, non-public utility withdrawal data shared by DEQ; and the U.S. Energy Information Administration's 2012 Commercial Buildings Energy Consumption Survey water use statistics.

Land conversion due to data centers

JLARC estimates of land conversion due to data centers are based on data center development land area summary statistics calculated in JLARC's data center inventory. These land area amounts were compared to statewide and locality natural land losses recorded in the U.S. Department of Agriculture's 2022 Census of Agriculture state-level data and the federal Multi-Resolution Land Characteristics Consortium's National Land Cover Database Enhanced Visualization and Analysis tool.

Proximity of data centers to residential zones

JLARC staff analyzed the distance between operational Virginia data center sites and residential zoning. This analysis was limited to eight localities that account for the vast majority (93 percent) of data center sites in the state. JLARC measured the distance between each operational data center site and the nearest residential zoning using the interactive maps on localities' websites. This measurement indicates the distance between property lines, but the distance between data center buildings and homes is greater because data center buildings tend to be located away from the property line. JLARC staff captured the smallest distance to residential zoning across the multiple parcels that comprise a single data center site. JLARC focused on residential zoning because the zoning classification reflects uses of a property permissible under current local ordinances. However, this approach sometimes *overstates* the distance between a data center site and residences in situations where land is zoned residential but contains no homes. The reverse is also true; this approach sometimes *understates* the distance between data center sites and residences in situations where land contains homes but is not zoned residential. JLARC summarized the proportion of data center sites very close to residential zoning (defined as within 200 feet, which is approximately half the length of a football field) and somewhat close to residential zoning (defined as within 500 feet, which is approximately 1 ½ times the length of a football field) (Table B-1).

JLARC also analyzed the change over time in the proportion of data center sites near residential zoning. For each data center site in the analysis, JLARC identified whether the site existed in 2015 using annual DEQ data about air emission permits, which Virginia data center sites have for their diesel generators. For the group of data center sites with any generators reported to DEQ in 2015, JLARC calculated the proportion within 200 and 500 feet of residential zoning. JLARC then compared those proportions to the proportions of all data center sites within those specified distances to examine whether data center proximity to residential zoning has increased over time.

TABLE B-1
Proportion of data center sites near residential zoning varies by Virginia locality

Locality	Proportion of data center sites within specified distance of residential zoning		Total data center sites
	200 feet	500 feet	
Loudoun	24%	34%	71
Prince William	21%	21%	24
Fairfax	55%	70%	20
Henrico	38%	38%	8
Chesterfield, Culpeper, Fauquier, Virginia Beach [a]	25%	38%	8
Total	29%	37%	131

SOURCE: JLARC analysis of localities' interactive map websites and JLARC inventory of operational data centers.
NOTE: Six data center sites were excluded from the analysis because data on proximity to residential zoning was not available or reliable.
[a] These four localities are combined because the number of data center sites in each locality is very small.

Document and research literature review

JLARC staff reviewed numerous documents and literature pertaining to data centers, such as:

- Virginia state laws, regulations, and policies relevant to energy, natural and historic resources, land use, and noise;
- studies, reports, data, and other information on data center market size and forecasting data center industry growth;
- reports, presentations, and regulatory filings from Dominion Energy, electric cooperatives, and the PJM regional transmission organization, including those related to energy load, load forecasts, and transmission, generation, and distribution projects;
- research literature and stakeholder reports on natural and historic resources; data center backup power and cooling technologies; and data center, other land use, and technology impacts on natural and historic resources;
- federal, state, and local government reports, assessments, webpages, and other documents on natural and historic resources, data center, other land use, and technology impacts on these resources, land use best practices;
- local comprehensive plans, ordinances, and policies relevant to land use and noise;
- local government presentations and reports relating to data centers including documents prepared by staff, consultants, and workgroups;
- summaries of local approaches to data center regulation and recommended practices;
- documents and journal articles describing the science of sound waves, sound modeling processes, ways to reduce sound levels, and government approaches to regulating sound; and
- local, national, and international news media coverage of the data center industry.

Review of local ordinances and specific data center requests

JLARC staff conducted an in-depth examination of the way nine localities in Virginia govern data centers. The review included localities with the most existing data centers in Virginia (Loudoun, Prince William, Fairfax, Henrico, Mecklenburg), as well as several localities that have recently approved their first data centers (Caroline, Fauquier, Stafford, Warrenton). JLARC staff searched for ordinances specific to data centers, as well as other ordinances applicable to data centers due to their location or use category. The review focused on local rules regarding density (e.g., height, lot coverage), architecture (e.g., building materials), site layout (e.g., building setbacks), landscaping, and equipment screening. When specific to data centers, local rules related to environmental, water use or cooling systems, and electricity infrastructure were also identified.

Additionally, JLARC reviewed staff reports for 19 specific data center requests to local elected officials. These reports provided elected officials with information about requests for rezonings, special permits, and exceptions to local ordinances. JLARC staff reviewed reports from Caroline, Fairfax Henrico, Loudoun, and Prince William counties and the town of Warrenton. The purpose of reviewing these staff reports included learning about the types of potential positive and negative impacts from data centers, the types of conditions beyond minimum requirements that developers committed to, the standards against which local staff evaluated data centers, the frequency of data center development that was not by right, and the alignment between staff recommendations and the decision of elected officials.

Appendix C: Agency responses

As part of an extensive validation process, the state agencies and other entities that are subject to a JLARC assessment are given the opportunity to comment on an exposure draft of the report. JLARC staff sent relevant portions of the exposure draft to the State Corporation Commission (SCC), Virginia Economic Development Partnership (VEDP), Virginia Department of Environmental Quality, Virginia Department of Historic Resources, Dominion Energy, Northern Virginia Electric Cooperative, and Rappahannock Electric Cooperative.

Appropriate corrections resulting from technical and substantive comments are incorporated in this version of the report. This appendix includes response letters from the SCC and VEDP.

JEHMAL T. HUDSON
COMMISSIONER

SAMUEL T. TOWELL
COMMISSIONER

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COMMONWEALTH OF VIRGINIA

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STATE CORPORATION COMMISSION

November 22, 2024

Mr. Hal E. Greer, Director
Joint Legislative Audit and Review Commission (JLARC)
919 East Main Street, Suite 2101
Richmond, VA 23219

Dear Mr. Greer:

The State Corporation Commission appreciates the opportunity to review the draft of relevant portions[1] of the JLARC report, *Data Centers in Virginia* provided to Staff on November 13, 2024. The Commission Staff provided its high level feedback to JLARC Staff during a meeting held on Friday, November 22, 2024.

Please let us know if we may be of further assistance.

Respectfully submitted,

Jehmal T. Hudson
Chairman, State Corporation Commission

[1] Sections 3 and 4, and Appendices F, G, I, and J.

VEDP | Virginia Economic Development Partnership

November 21, 2024

Mr. Hal E. Greer, Director
Joint Legislative Audit & Review Commission
919 East Main Street, Suite 2101
Richmond, VA 23219

Re: VEDP response to the draft JLARC report, *Data Centers in Virginia*

Dear Mr. Greer:

Thank you for providing an opportunity for us to review relevant sections of chapters 1, 2 and 7 of the Joint Legislative Audit & Review Commission's (JLARC's) draft report, *Data Centers in Virginia*.

The content we reviewed provides a helpful overview of the data center industry and its importance to the Commonwealth. As the report highlights, data centers are key hubs of the world's digital infrastructure, and their concentration in Virginia has helped establish the Commonwealth as a global tech hub. We particularly appreciate your meticulous survey of the data center industry's presence in Virginia, which accounts for over 63 million square feet of data center space across 150 sites and directly employs more than 8,000 people, in addition to supporting tens of thousands of additional jobs.

Since your last comprehensive review of the industry in 2019, the geographic distribution of data centers across Virginia has changed considerably. Although many of the legacy assets are still concentrated in Northern Virginia, the industry has become an important opportunity for the entire Commonwealth. This expansion, particularly into rural areas, has been facilitated by technologies such as Artificial Intelligence, which are less constrained by latency requirements compared to other applications. Reflecting this trend, seven localities that previously lacked data centers have either approved new campuses or have pending applications, including several rural and "distressed" areas. VEDP's current project pipeline suggests that the spread of data centers across more localities is expected to continue, provided that Virginia continues to offer a competitive sales and use tax exemption.

Your report also demonstrates the significant and far-reaching impact of the data center industry. Notably, the analysis estimates that the data center industry supports an impressive 74,000 jobs, $5.5 billion in labor income, and $9.1 billion in Virginia GDP overall to the state economy annually. In particular, we appreciate that your report shines a spotlight on the significant knock-on effects of the industry that extend to virtually every corner of the Commonwealth.

VEDP strongly agrees with the report's finding that the sales and use tax exemption has been an important part of the industry's growth and continues to drive site selection and expansion decisions. VEDP has responsibility for administering, in cooperation with the Department of Taxation, this important program on behalf of the Commonwealth and is pleased to see that new data collected by VEDP is serving to strengthen transparency. Your analysis adeptly leverages this data to demonstrate the significant state and local tax revenues generated by the industry.

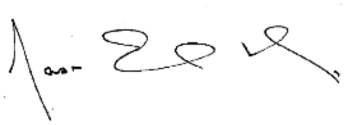
This valuable report comes at a critical juncture for the data center industry. Coming on the heels of significant growth in recent years, the industry is expected to see continued, strong growth driven by demand for digital services and the emergence of new technologies, like Artificial Intelligence. These trends raise important questions about the implications of this growth.

Your report underlines various considerations that legislators will need to balance as they think about the future of the state's support for the data center industry. You correctly point out that sustaining the growth of the industry and its critical contribution to Virginia's economy will require action on the current 2035 sunset of the data center sales and use tax exemption. Allowing the existing exemption to sunset would result in development shifting to competing markets, and those effects are likely already beginning to be felt given the long timeframes the industry uses to analyze their investments.

Nonetheless, VEDP recognizes that balancing competing interests may prompt legislators to seek out a new paradigm for support that navigates a challenging middle ground. The report is helpful in providing a number of different policy options for them to consider. In the context of thinking about these different options, we strongly agree with the report's warning that saddling an incentive program with competing policy priorities is not sound economic development practice. Furthermore, VEDP would caution against any action that could constitute a legal or moral failure to deliver on commitments to companies that have chosen to invest in Virginia and have entered into performance agreements or memoranda of understanding with the Commonwealth. This could expose the Commonwealth to legal risks and seriously undermine our credibility with prospective investors in the future.

As always, we appreciate the professionalism and engagement of JLARC staff during the project and compliment your team on its insightful analysis and reporting.

Sincerely,



Jason El Koubi
President & CEO

Appendix D: Economic impact modeling of the data center industry

Weldon Cooper Center staff conducted economic impact analyses of Virginia's data center industry using IMPLAN (IMpact analysis for PLANning) software. IMPLAN has been used in many economic impact studies and is one of the most common tools used in economic impact analysis. Models here were built using 2022 IMPLAN Pro data released in November 2023 that utilizes a 546-sector IMPLAN sector scheme (IMPLAN® model. n.d.). Tables were customized for Virginia and two of its regions using the software.

Input-output analysis using the model produces industry-specific multipliers that indicate how economic activity in one sector of the economy affects the overall state or regional economy. For this study, we were interested in how changes in the data center industry affect the state and regional economy. Outcome variables examined include total employment, state GDP, and labor income.

For estimating the impact of the industry net of the state data center exemption, the opportunity cost of state funds was accounted for by increasing government spending, equivalent to the exemption amount.

Analysis included customization of IMPLAN sector for data centers to better reflect nature of the industry

Tracking the size and growth of the data center industry is challenging because of the absence of a specific industrial classification in government statistics. Data center activity often appears merged with the primary business operations of their parent firms, making their identification difficult[i].

The North American Industrial Classification System (NAICS) code 518210—Data Processing, Hosting, and Related Services—is typically used as a proxy for data centers, but this approach introduces what is usually referred to as "aggregation bias," as this category encompasses various unrelated activities that have a far higher representation in the sector than only data centers. For instance, an analysis of Virginia's 2016 employment data for that sector (518210) reveals that only 15 percent of the total employment in the sector was data center employment, with other data centers, cloud computing, and cybersecurity-related support services making up perhaps 2–5 percent more. Indeed, most employment in this sector involves other IT services, such as document scanning and software development, particularly in federal IT contracting in Northern Virginia. (See *Data Centers and Manufacturing Incentives*, JLARC 2019).

Data center employment is also dispersed across other industries. An examination showed that only 41 percent of data center jobs were classified under data processing, hosting, and related services. Significant portions were found in sectors like "wired telecommunications carriers" (30 percent), "telecommunications resellers" (10 percent), and "all other telecommunications carriers" (4 percent). This analysis excluded many enterprise data centers and colocated firms, whose employment is often reported under other business functions, further complicating efforts to track the industry accurately.

The IMPLAN sector for data centers that corresponds to the 518210 NAICS code for data centers is "436 - Data processing, hosting, and related services." However, using this sector introduces significant bias, as data centers represent only a small portion of its total activity. More importantly, the expenditure patterns of this IMPLAN sector do not reflect the specific characteristics of data center operations. Because of this, there is a substantial mismatch between the commodity demand and value-added characteristics of the IMPLAN sector 436 and what we know of data center expenditure patterns. For instance, in 2020, IMPLAN data showed that less than 1 percent of gross output is spent on "electricity transmission and distribution" (0.68 percent) and water, sewage, and other systems (0.02 percent) even though data center industry reports estimate that electricity alone accounts for 40 percent of data center operating expenditures[ii]. Data center representatives also estimated energy accounts for about 40 percent of their operating costs during structured interviews. Similarly, employee compensation is overestimated in the IMPLAN model, accounting for 24 percent of output compared with 15 percent in industry-specific studies. This may lead to an inflation of induced economic impacts by overstating the income distributed to households.

In income distribution, little is known about other aspects of data center value added that are important for estimating activity impact, such as profit generation, distribution, and taxes paid. Indeed, data centers have the potential to contribute to local economies through tax payments, which are then reinvested via local government spending. However, IMPLAN's tax estimation methodology is quite generic and may not accurately reflect county- and state-level tax structures and exemptions. Therefore, modeling alternative tax scenarios with more realistic assumptions can help better estimate the local economic impacts of data centers.

The reliance on conventional and standardized IMPLAN sectors, particularly when key inputs are significantly misrepresented, leads to biased results in economic impact studies. Best practices in economic analysis suggest customizing expenditure patterns to more accurately reflect the unique characteristics of data center operations. Therefore, the expenditure patterns for IMPLAN sector 436 regarding electricity were increased to 40 percent and employee compensation was reduced to 15 percent. Sensitivity analysis was performed to see how changing these percentages affected results. For operational impacts, for example, customizing the IMPLAN sector to include 40 percent of electricity consumption lowers the employment multiplier for data center operations approximately 20 percent.

Analysis includes two modeling phases

This analysis was split into two phases, the construction phase (capital spending for initial development of the data center) and the operations phase (ongoing) to help policymakers better understand the industry's short-term and long-term impacts. The construction phase corresponds to the initial years of data center development and what must be put in place before a data center "works." The operations phase accounts for the impact of all the expenditures after the data center opens independent of whether they are considered capital or operational expenditures in their budget.

Construction phase

Information collected by VEDP from data centers using the exemption was used to determine amounts of capital spending by data centers to include in the analysis (Table D-1). The percentages of spending by capital spending category are consistent with other research[iii].

TABLE D-1
Initial capital spending of data centers using the exemption (by year)

Year	Land acquisition	Building and site improvements	Exempt equipment or software	Other
2021	$865 M	$3,927 M	$14,333 M	$940 M
2022	1,030	2,264	9,614	1,615
2023	1,689	5,309	16,009	1,002
Total	**$3,585 M**	**$11,501 M**	**$39,957 M**	**$3,557 M**
%	6.1%	19.6%	68.2%	6.1%

SOURCE: VEDP.

The VEDP data includes only data centers that benefited from the tax exemption. These data centers correspond to 92 percent of the data center activity in Virginia, according to DEQ records and JLARC staff analysis of locality real estate records to obtain data center square footage. Statewide, 8 percent of data centers were not included in those numbers. By region, it is estimated that only 5.45 percent of the data centers in Northern Virginia are nonexempt (94.55 percent are exempt) and 21 percent in other regions of Virginia are nonexempt. Capital spending was increased to account for the nonexempt data centers, and this new amount was assumed to be the direct impact of the industry (Table D-2).

TABLE D-2
Initial capital spending of data centers using the exemption (by region)

Year	Land acquisition	Building and site improvements	Exempt equipment or software	Other
Northern Virginia	$3,316 M	$10,638 M	$36,955 M	$3,290 M
Other regions	632	2,027	7,041	627
Virginia total	**$3,948 M**	**$12,664 M**	**$43,997 M**	**$3,917 M**

SOURCE: Weldon Cooper Center.

However, not all of this spending impacts Virginia's economy, and a critical assumption of economic impact analysis is the share of capital expenditures that are generated locally. Land acquisition is not traditionally included in impact models since this represents a monetary flow or transfer of funds that will not necessarily translate into a shock in local production. The acquisition of computer and related IT equipment is not necessarily done locally, so it should be assumed that part of this equipment comes from outside the region. This is even more true as we examine smaller geographical areas that might not include the entities associated with wholesale, transportation, and production of this type of equipment. Only building and site improvements (construction) should be included as local production. To estimate the indirect impacts, the model included 100 percent of the building and site improvements as construction (specifically IMPLAN industry sector "51 – construction of new manufacturing structures") and 25 percent of the exempt equipment and software expenditures.

The assumptions described above were used to generate indirect and induced impacts of data center capital investment in Virginia, according to average annual capital investment between FY21 and FY23

(Table D-3). Impact estimates were also produced for Northern Virginia and other regions of the state. Analysis of the results indicates that most of the impacts are construction-related (for example 80 percent of the direct employment is construction-related) rather than from manufacturing and installation of IT equipment.

TABLE D-3
Impacts of initial capital investment in Virginia and by region, annual average FY21–FY23

Impact	Employment	Labor income	Virginia GDP	Total output
Statewide				
Direct	35,110	$2,646.6 M	$3,342.1 M	$7,887.7 M
Indirect	9,945	843.8	1,504.2	2,806.8
Induced	13,992	791.9	1,570.9	2,596.8
Total	**59,047**	**$4,282.4 M**	**$6,417.2 M**	**$13,291.3 M**
Northern Virginia				
Direct	27,703	$2,368.5 M	$2,957.6 M	$6,625.6 M
Indirect	5,577	585.4	1,30.1	1,733.3
Induced	7,510	490.3	963.7	1,488.2
Total	**40,790**	**$3,444.2 M**	**$4,951.4 M**	**$9,847.0 M**
Other regions of the state				
Direct	5,761	$406.5 M	$517.0 M	$1,262.5 M
Indirect	1,584	116.6	212.5	418.0
Induced	2,106	107.3	219.6	373.4
Total	**9,451**	**$630.4 M**	**$949.2 M**	**$2,053.9 M**

SOURCE: Weldon Cooper Center economic impact analysis using IMPLAN.

The statewide results do not match the sum of the results for Northern Virginia and other regions of Virginia because, for the sake of simplicity, a multi-regional input-output model was not used. Data center investment in other regions of the state affects Northern Virginia, and vice versa, but they are not accounted for because the model accounts for the impacts in one region only.

Operation phase

As explained above, to accurately describe the impacts of the ongoing operation, the model was customized to include a better perspective of energy and labor costs. For this analysis, the model assumed that 40 percent of operational expenditures are associated with electricity consumption, and that 15 percent of the industry spending was direct labor costs.

Several adjustments were made to VEDP employment information collected from data centers. The employment information VEDP collected from data centers was used to estimate data center direct employment, statewide, in Northern Virginia, and in other Virginia regions. This number was adjusted in several ways. First, the employment number was reduced by half because the VEDP information on employment tends to boost the number of jobs as data centers can account for the jobs associated with contractors or the employees of contractors in addition to data center employees. In input-output terminology, this is an indirect impact of the industry. Several data center representatives stated that 50 percent of their jobs were associated with third-party hiring and the other 50 percent with direct jobs. Because the jobs reported by VEDP were all full time (or full-time equivalents), a factor was applied to transform these jobs to full-time and part-time employment as required by the model. Like for capital spending, employment was increased to account for the nonexempt data centers. This new amount was assumed to be the direct impact of the industry (Table D-4).

TABLE D-4
Model was adjusted to incorporate data center operating characteristics

Region	Employment	Labor income	Total output
Northern Virginia	3,426	$357.4 M	$2,382.7 M
Other regions of Virginia	947	62.0	413.1
Virginia statewide	**4,373**	**$419.4 M**	**$2,795.8 M**

SOURCE: Weldon Cooper.

The results obtained for the impacts of ongoing operation for Virginia are far less than the impacts of capital spending (Table D-5). For example, total employment impacts from a year of data center operations are estimated to be 14,817 jobs compared with total employment impacts of 59,047 jobs for a year of initial capital spending.

TABLE D-5
Impacts of data center operations in Virginia and by region, annual average FY21–FY23

Impact	Employment	Labor income	Virginia GDP	Total output
Statewide				
Direct	4,373	$419.4 M	$1,051.1 M	$2,795.8 M
Indirect	6,615	552.2	1,217.8	2,188.1
Induced	3,830	216.8	430.2	711.1
Total	**14,817**	**$1,188.4 M**	**$2,699.0 M**	**$5,695.0 M**
Northern Virginia				
Direct	3,426	$357.4 M	$956.2 M	$2,382.8 M
Indirect	4,333	441.8	963.9	1,552.5
Induced	1,966	128.4	252.5	389.9
Total	**9,725**	**$927.6 M**	**$2,172.5 M**	**$4,325.1 M**
Other regions of the state				
Direct	947	$62.0 M	$116.5 M	$413.1 M
Indirect	1,106	78.3	185.6	356.9
Induced	556	28.3	58.0	98.6
Total	**2,609**	**$168.6 M**	**$360.0 M**	**$868.5 M**

SOURCE: Weldon Cooper Center economic impact analysis using IMPLAN.

Data center industry impact

Mostly because of the impact associated with initial capital expenditures, data centers in Virginia generate 73,864 jobs per year, corresponding to almost $5,471 million of labor income, $9,166 million of Virginia GDP, and an increase in output of $18,986 million (Table D-6).

TABLE D-6
Summary of initial capital spending and operations impact statewide, annual average FY21–FY23

Impact	Employment	Labor income	Virginia GDP	Total output
Direct	39,483	$3,066 M	$4,393 M	$10,684 M
Indirect	16,560	1,396	2,722	4,995
Induced	17,822	1,009	2,001	3,308
Total	**73,864**	**$5,471 M**	**$9,116 M**	**$18,986 M**

SOURCE: Weldon Cooper Center economic impact analysis using IMPLAN.

Another aspect is that the state government could also opt to spend the exemption money on alternative sources. The alternative scenario was modeled to estimate impacts if the state would use the annual average exemption amount between FY21 and FY23 ($573 million per year) in alternative expenditures (Table D-7). These impacts were used to determine the impact of the industry accounting for the cost of the exemption. Accounting for this alternative use of the exemption amount (or opportunity cost), reduces additional jobs by about 5,000 (to 69,000 additional jobs on net) and reduces additional income and Virginia GDP by $0.4 billion and $0.5 billion, respectively, which are a small fraction of their total impacts (Table D-6).

TABLE D-7
Impacts to the state if the exemption amount was used instead for alternative government expenditures, annual average FY21–FY23

Impact	Employment	Labor income	Virginia GDP	Total output
Direct	3,534	$277.4 M	$359.1 M	$448.0 M
Indirect	403	27.7	48.3	88.5
Induced	1,197	67.8	134.5	222.4
	5,134	**$372.9 M**	**$542.0 M**	**$758.9 M**

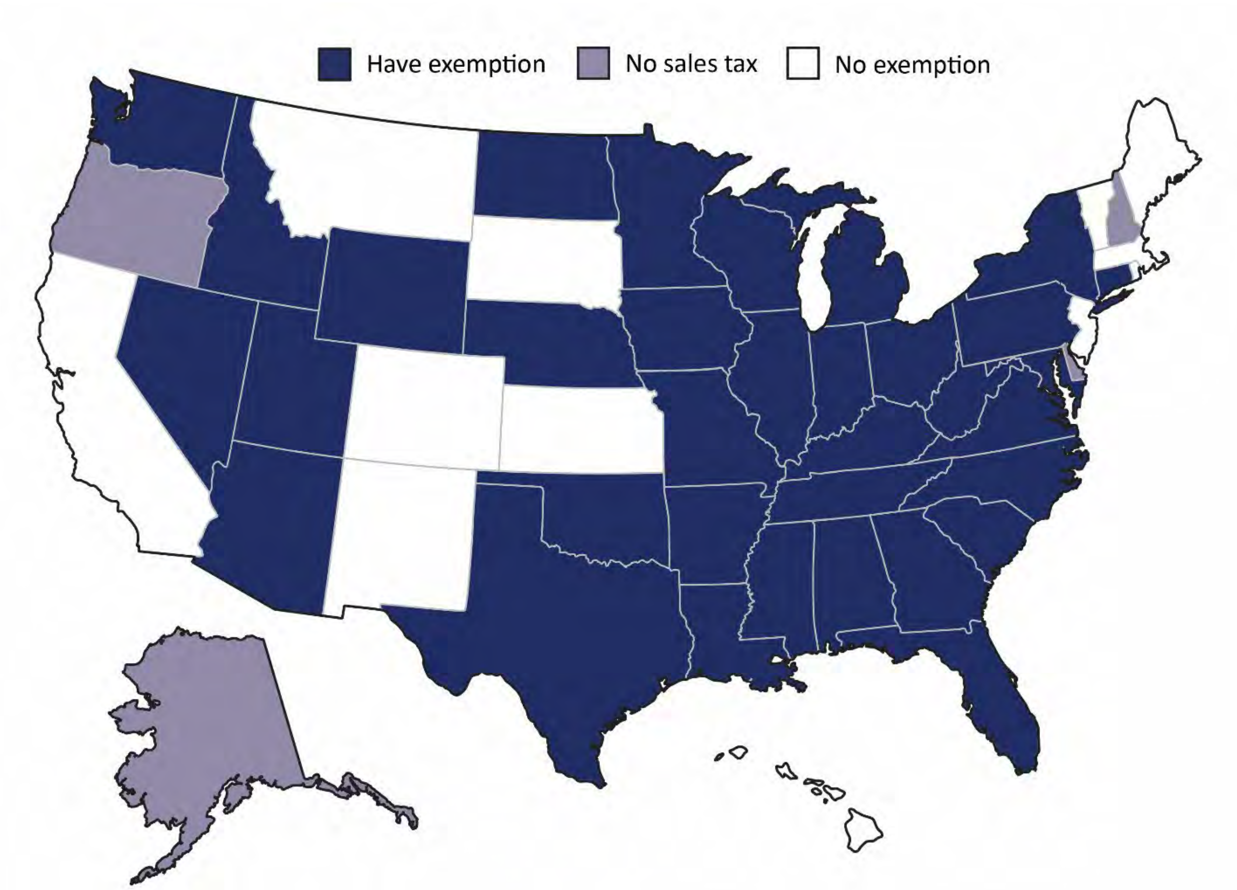
SOURCE: Weldon Cooper Center economic impact analysis using IMPLAN.

[i] Byrne, David, Carol Corrado, and Daniel E. Sichel. 2018. The rise of cloud computing: Minding your p's, q's and k's. NBER Working Paper 25188.
[ii] Day, Tim and Nam D. Pham. 2017. *Data centers: Jobs and opportunities in communities nationwide.* U.S. Chamber of Commerce Technology Engagement Center.
[iii] Day, Tim and Nam D. Pham. 2017. *Data centers: Jobs and opportunities in communities nationwide.* U.S. Chamber of Commerce Technology Engagement Center.

Appendix E: States with data center sales tax exemptions

Most states either have a sales tax exemption for data centers (34) or do not have a sales tax (Figure E-1). All states bordering Virginia provide a sales tax exemption to data centers.

FIGURE E-1
Nearly all states offer a sales tax exemption for data centers (2024)



SOURCE: State Tax Notes and JLARC staff review of state websites.

Appendix F: Energy infrastructure project impacts and regulation

Construction of new generation and transmission infrastructure can affect the communities and environments where they are built. The extent of any impacts will vary substantially for generation and transmission projects. State and local governments regulate these projects, through review and approval processes. Regulatory processes seek to minimize negative impacts but do not necessarily avoid them altogether. Utilities can implement several grid enhancing technologies to help reduce the need for major new generation and transmission projects, but this does not eliminate the need for new projects.

Construction of new generation and transmission infrastructure can have environmental impacts and is often opposed by local communities

On the generation side, a significant portion of new generation is expected to be solar, and solar facilities have large land demands that can have widespread impacts. For example, a modest 100 MW solar facility would require about 5,000 to 1,000 acres of land in Viriginia. (The rule of thumb is that 5 to 10 acres of solar can generate up to 1 MW of power.) Because of the large land demands, most solar facilities are built in rural areas. Constructing solar facilities typically involves clearing forest land or converting agricultural land to this use, which can have several environmental impacts from habitat loss to affecting stormwater runoff.

Some communities in rural Virginia have been increasingly opposed to new solar facilities, with several counties placing restrictions on solar development or outright denying projects. Community opponents site environmental concerns, impacts on local agriculture, and the effects of solar facilities' industrial appearance on the rural character of their counties. Opponents also often assert that solar facilities do not offer significant economic or other benefits to their communities.

The extent to which a solar project affects the environment and generates community opposition depends on the project. For example, a project that involves clearing 5,000 acres of forest land with multiple streams would have a more substantial environmental impact than a project that is installed on 2,000 acres of fallow pastureland. Similarly, a development located near a residential area or that is visible from the surrounding area could generate more community opposition than one that is hidden from view.

On the transmission side, new transmission lines can fragment forest habitats, create water quality risks at stream and wetland crossings, and reduce scenic quality of nearby historic and recreational resources. Communities are sometimes opposed to new or expanded transmission lines for these reasons. Communities also sometimes oppose new transmission lines because of their undesirable appearance, effect on the use of private properties that are under or adjacent to the lines, effect on the value of nearby properties, and health concerns.

Similar to the generation side, the potential environmental and community impacts of a transmission project can vary greatly from one project to the next. Generally, a "green field" project that involves acquisition of new right-of-way and construction of transmission lines where none currently exist is going to have the highest impact. A project where new lines are built in or adjacent to an existing transmission line will be less impactful, and a project where an existing line is "wrecked and rebuilt" would be the least impactful.

State and local regulation is intended to minimize the impacts of new generation and transmission projects on communities and the environment

Construction of major new generation and transmission facilities is regulated by the state to minimize impacts. Many of these projects are approved by the SCC through a formal case process to determine if a Certificate of Public Convenience and Necessity (CPCN) should be granted. The SCC considers several factors before approving a project and granting a CPCN. These factors include the potential impacts of the project on property owners, the environment, and cultural and historic resources (Table F-1). While these impacts may not be completely avoided, the process encourages the selection of projects and options that best minimize impacts without placing large cost burdens on ratepayers.

Smaller renewable generation projects (<150 MW) can be reviewed and approved by the Department of Environmental Quality through a separate "Permit by Rule" process. While this is not a litigated case process like an SCC approval, projects are reviewed to ensure they conform with the state's requirements.

Localities have some authority over generation projects and transmission and distribution substations but minimal authority over transmission lines. Generation facilities and substations are subject to the same types of local zoning processes as other land uses. Local zoning ordinances specify which zoning districts allow them, whether they require a special permit from elected officials, and whether any design standards (such as landscaping) apply. Additionally, state law requires local reviews of certain entities—including substations—before development to evaluate their alignment with the local comprehensive plan. For transmission lines, CPCN approval deems the transmission line to be in compliance with local comprehensive plans and ordinances. In effect, this means localities do not have any direct authority over most transmission line project approvals or routes. (Although localities can play a role in approving 138 kilovolt transmission lines, which exist in a few parts of the state.)

Solar and similar projects are required to attempt to coordinate an agreement with their host locality. State law requires applicants for solar or energy storage projects to notify localities of their intent to develop and to meet with the locality to negotiate a "siting agreement." This siting agreement can include conditions such as mitigating negative impacts, and if created, must receive a public hearing. However, there is no requirement for this process to culminate in a siting agreement. Failure to achieve a siting agreement does not prevent a developer from initiating the usual local zoning processes for new developments.

Localities do not have approval authority over transmission line projects but can participate in SCC cases either as respondents or public witnesses. As a public witness, a locality can submit written comments, or local representatives can provide comments in person at commission hearings. As a respondent, a locality becomes a participant in the case and can take several additional actions, such as filing for discovery (e.g., to obtain copies of utility analysis or documents supporting the application for a project), filing briefs, providing expert witnesses, and participating in cross examination of witnesses (e.g., utility staff). No matter which approach is followed, the SCC is required to hear and weigh all evidence equally.

TABLE F-1
Criteria that the SCC must evaluate before approving a project and granting a CPCN

Criteria that must be met

- Is not against the public interest [a]
- Will have no material adverse affect on system reliability
- Will have no material adverse affect on rates
- For transmission projects,
    a. the line is needed, [b]
    b. proposed method of installation is justified, [b]
    c. will avoid or minimize adverse impact on (a) scenic assets, (b) historic and cultural resources, (c) the environment, and (d) human health and safety, and
    d. why existing rights-of-way cannot adequately serve the need (presumably only applies when an expanded or new right-of-way acquisition is being requested as part of the project)

Criteria that must be considered

- Environmental impacts
- Human health and safety impacts
- Historical and cultural resource impacts
- Economic impacts, including job creation
- Improvement to service reliability
- Environmental justice considerations

Criteria that are considered, if requested

- Conformance with local comprehensive plans (locality must request) [c]
- Costs, economic benefits, and effect on construction timeline of undergrounding transmission lines (locality must request)

SOURCE: The Code of Virginia § 2.2-235, § 56-265.2, § 56-580, and § 56-46.1.
NOTE: SCC regulations provide additional information on what must be submitted to meet requirements and details what must be provided for transmission projects. SCC guidance also includes a planning and design attachment that provides detailed guidelines to applicants on how to ensure facilities protect natural and historic resources. SCC guidance provides additional information on when a transmission project requires a CPCN, based on specific characteristics. SCC guidance notes that certain transmission projects, such as reconductoring, do not require a CPCN.
[a] This is a general criterion that can be interpreted as the cumulation of all the other criteria weighed against each other. The Code declares some projects meet this goal—such as small renewable generation projects and projects in VCEA—and so do not require SCC to make a determination.
[b] Based on applicant's load flow modeling, contingency analysis, and presented reliability needs.
[c] Localities are explicitly granted right to present evidence that shows existing corridors, as designated in the comprehensive plan, can serve the identified need.

Localities also have three additional authorities under Code. First, localities can request that the SCC consider the costs, economic benefits, and effects on construction timelines of undergrounding transmission lines. Second, localities can establish transmission corridors in their comprehensive plans and provide evidence that new lines should be within those corridors, but it appears this latter authority has been rarely (if ever) used. Third, localities can establish special tax districts that pay for the additional costs of undergrounding transmission lines, although it appears this authority has never been used.

Some stakeholders have said that local governments should have more authority to determine transmission routes and, especially, when transmission lines should be buried underground. While this would make transmission projects more responsive to local needs, undergrounding transmission lines is substantially more expensive and those added costs are currently spread across all utility ratepayers. Any changes to give localities more authority to require undergrounding of transmission lines would need to be accompanied by a change in how costs are allocated to prevent local government decisions from affecting rates paid by customers who do not benefit from undergrounding projects.

Utilities can use grid enhancing technologies to help reduce the need for new generation and transmission infrastructure

Utilities use grid enhancing technologies (GETs), such as reconductoring existing transmission lines, to increase capacity of the transmission system and more effectively use existing generation. For example, Dominion reports that it uses advanced conductors for all its 230 kV reconductor and new build projects, which can increase line capacity by 50 percent. Dominion reported adding or replacing 800 miles of line with advanced conductors as of the end of 2023. Dominion also reports deploying and piloting several other GETs to improve system stability and efficiency. Utilities have an economic incentive to deploy GETs so that they can provide enough transmission capacity to serve fast-growing demand.

SCC staff indicated that, before approving a new transmission line project, they consider whether a quicker and lower-cost approach, such as reconductoring, could be used instead. Staff make this determination by looking at the project proposal, the state need, and whether reconductoring will address the need. SCC staff carry out their own power flow studies and verify thermal issues, voltage issues, and generator deliverability (if applicable).

Appendix G: Virginia Clean Economy Act

The Virginia Clean Economy Act (VCEA) was enacted in 2020 and was intended to drive investment in renewable resources and phase out carbon-emitting generation in the state by 2050. VCEA was passed when energy demand in Virginia was projected to remain relatively flat. Now that demand is growing, largely because of data centers, it will be more challenging to meet these goals than originally contemplated.

The main way VCEA intends to decarbonize generation is by requiring an increasing share of energy sold by Dominion and APCO to come from renewable sources. The share of generation from renewables—the Renewable Portfolio Standard (RPS) requirement—increases each year until it reaches 100 percent (Table G-1). The utilities can meet the RPS requirement by directly building and claiming credit for new renewable generation facilities (mainly solar and wind) and entering into power purchasing agreements with third parties that operate renewable facilities. Utilities receive Renewable Energy Certificates (RECs) for energy from these sources, which are then credited toward their RPS requirement. Utilities can also purchase RECs from the PJM market and use purchased RECs to offset energy produced through carbon generation. Starting in 2025, 75 percent of Dominion's RECs must be from in-state generation sources. VCEA financially penalizes utilities that do not comply with in-state renewables requirements by levying deficiency payments, but in practice utilities may choose to pay those deficiency payments if it is more economical or feasible than securing new renewable generation. The cost of deficiency payments is recovered from utility customers. VCEA sets aside nuclear power as a third category of generation, which in effect can be used to reduce the total amount of renewable energy required.

TABLE G-1
VCEA requires growing share of energy sold in Virginia to come from renewable generation sources, with full decarbonization by 2050

	Percentage of total power sold required to come from renewables (excluding nuclear)	
	Dominion	APCO
2021 (year one)	14%	6%
2025	26	14
2030	41	30
2035	59	45
2040	79	65
2045	100	80
2050	-	100%

SOURCE: The Code of Virginia § 56-585.5.
NOTE: Percentages are the RPS program requirements for selected years; statute sets a percentage for every year. Nuclear power is excluded from the RPS calculation. For example, if one-third of Dominion power is nuclear, then the RPS percentage applies only to the remaining two-thirds of power that is not nuclear. Renewable energy is credited toward meeting RPS requirements through the purchase and retirement of Renewable Energy Certificates (RECs). RECs can be used to offset carbon emissions.

The VCEA's RPS requirements, and their associated REC requirements, do not apply to electric co-operatives (co-ops). This has significant implications because a majority of future energy demand growth is expected to occur in the co-ops' service territories, where many new data center campuses are expected to be built. (This is based on JLARC's consultant forecasts, and is corroborated with utility forecasts, utility construction and service agreements, and JLARC staff review of data center projects that are actively under development). Unlike Dominion and APCO, state law allows co-ops to secure energy to meet their growing demand from non-renewable and out-of-state generation sources.

VCEA directs the Virginia Air Pollution Control Board to develop regulations to gradually reduce carbon emissions. VCEA states the board "may establish, implement, and manage an auction program" or "utilize an existing multistate trading system" to achieve this purpose. Initially the state entered into the Regional Greenhouse Gas Initiative (RGGI) to reduce carbon emissions. The state has since withdrawn from RGGI, although the legality of that withdrawal is being challenged in court. A recent state circuit court decision ruled that the regulatory actions the state took to remove Virginia from RGGI were unlawful, but this decision could be appealed to a higher court.

Finally, VCEA requires carbon-emitting generation in Virginia owned by Dominion and APCO to be retired by 2045. However, VCEA allows these utilities to continue operating carbon-emitting generation plants in Virginia past 2045 if taking the plant off-line "would threaten the reliability or security of electric service to customers." Utility decisions to keep plants operating past 2045 must be approved by the SCC.

VCEA also has a presumption against the SCC approving new carbon-emitting generation plants, which applies to investor-owned utilities and co-ops. However, new carbon-emitting plants can be built if the SCC determines they are needed to address threats to the reliability or security of electric service to the utility's customers.

Appendix H: Grid modeling generation capacity and energy source results

JLARC staff commissioned Energy + Environmental Economics (E3) to develop an independent grid model and project the future generation and transmission infrastructure that would be needed to meet three different demand scenarios. For each of the demand scenarios, the model considered the most feasible and economical approaches to meeting infrastructure needs with and without the requirements of the Virginia Clean Economy Act (VCEA).

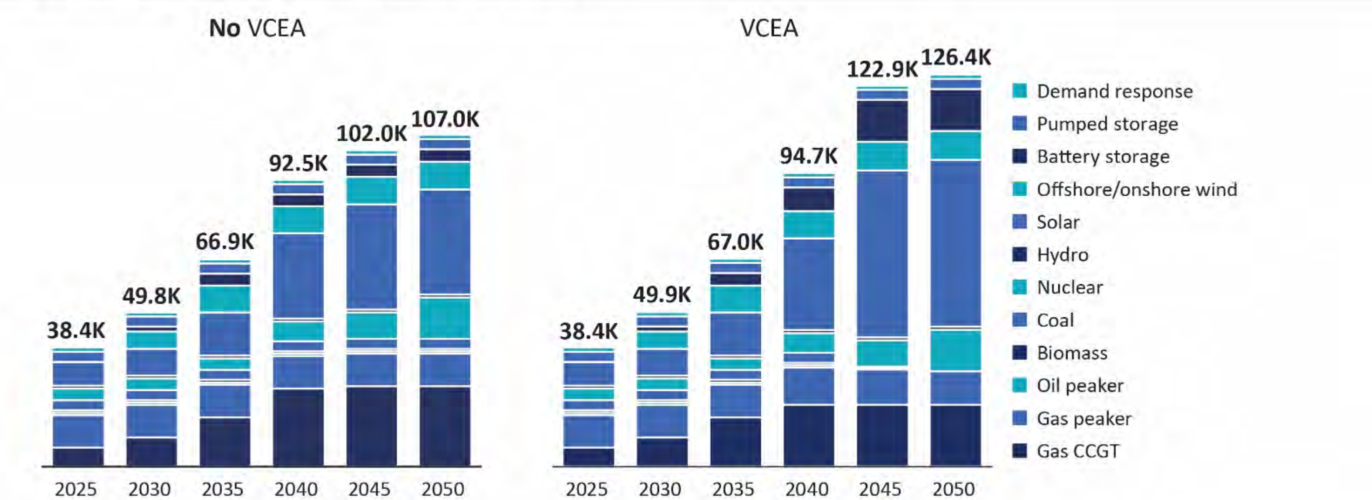
- Scenario 1: unconstrained demand, with and without VCEA. E3 also modeled variations where unconstrained demand and VCEA requirements could be met by using high levels of nuclear and renewable generation or by better regional coordination across PJM (not shown in this report).
- Scenario 2: half of unconstrained demand, with and without VCEA.
- Scenario 3: no new data center demand, with and without VCEA.

This appendix provides E3's grid modeling Virginia-level results for the (a) in-state generation capacity that would be needed to meet each demand scenario, by type of generation source and (b) the amount of energy that would be used from each type of generation source. Generation capacity is given in megawatts (MW) of nameplate capacity that would be needed, which can be significantly higher than the firm amount of capacity available from a resource. For example, Virginia solar facilities produce at around 25 percent of nameplate capacity. Generation energy is given in annual tera-watt hours (TWh) of energy used. E3's grid model assumes natural gas plants would be converted to hydrogen fuel in each scenario when VCEA compliance is assumed, starting in 2045. The model assumes that new nuclear generation will not be available until 2035. For additional discussion of E3's grid modelling methodology, see Appendix B.

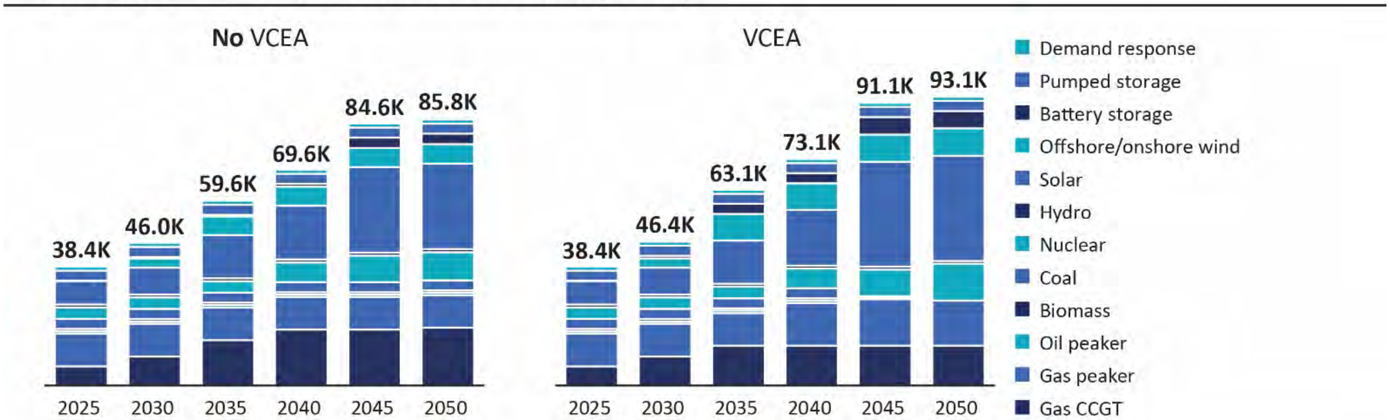
Results begin on next page.

FIGURE H-1
Generation capacity required 2025 to 2050

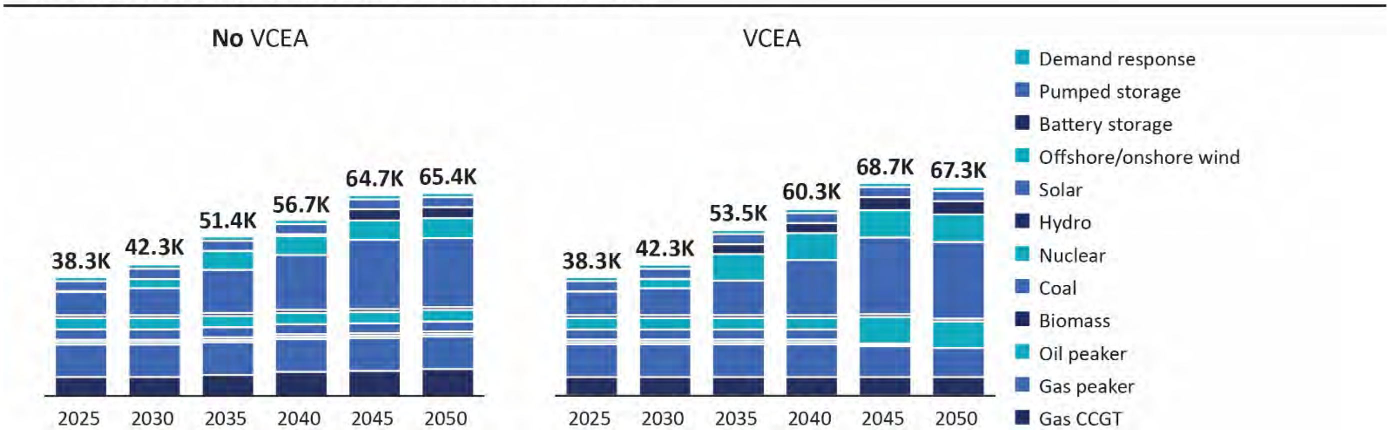
SCENARIO 1: UNCONSTRAINED DEMAND (IN MW)



SCENARIO 2: HALF OF UNCONSTRAINED DEMAND (IN MW)



SCENARIO 3: NO NEW DATA CENTER DEMAND (IN MW)



SOURCE: E3 grid modeling analysis.
NOTE: Capacity shown is nameplate capacity.

TABLE H-1
Generation capacity required 2025 to 2050, Scenario 1: Unconstrained demand (MW)

No VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	6,141	9,391	15,891	25,149	25,937	25,937
Gas Peaker	10,499	10,499	10,499	10,499	10,499	10,499
Oil Peaker	813	813	813	813	813	813
Biomass	765	765	765	765	765	765
Coal	3,230	3,230	3,230	3,230	3,230	3,230
Nuclear	3,708	3,708	3,708	6,388	8,532	13,356
Hydro	929	929	929	929	929	929
Solar	7,596	8,673	13,939	27,503	33,880	33,880
Offshore/onshore Wind	-	5,580	8,656	8,756	8,856	8,956
Battery Storage	116	1,608	3,835	3,835	4,008	4,008
Pumped Storage	3,241	3,241	3,241	3,241	3,241	3,241
Demand Response	1,354	1,354	1,354	1,354	1,354	1,354
Total	**38,393**	**49,792**	**66,861**	**92,462**	**102,043**	**106,967**

VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	6,141	9,391	15,891	19,945	19,945	19,945
Gas Peaker	10,499	10,499	10,499	11,976	11,342	10,863
Oil Peaker	813	813	813	813	316	-
Biomass	765	765	765	765	15	-
Coal	3,230	3,230	3,230	3,230	630	-
Nuclear	3,708	3,708	3,708	6,388	8,532	13,356
Hydro	929	929	929	929	929	929
Solar	7,596	8,673	13,939	29,622	53,880	53,880
Offshore/onshore Wind	-	5,580	8,656	8,756	9,216	9,316
Battery Storage	116	1,667	4,014	7,645	13,511	13,511
Pumped Storage	3,241	3,241	3,241	3,241	3,241	3,241
Demand Response	1,354	1,354	1,354	1,354	1,354	1,354
Total	**38,393**	**49,851**	**67,040**	**94,665**	**122,911**	**126,394**

SOURCE: E3 grid modeling analysis.
NOTE: Capacity shown is nameplate capacity.

TABLE H-2
Generation capacity required 2025 to 2050, Scenario 2: Half of unconstrained demand (MW)

No VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	6,141	9,391	14,626	18,021	18,021	18,605
Gas Peaker	10,499	10,499	10,499	10,499	10,499	10,499
Oil Peaker	813	813	813	813	813	813
Biomass	765	765	765	765	765	765
Coal	3,230	3,230	3,230	3,230	3,230	3,230
Nuclear	3,708	3,708	3,708	6,388	8,532	9,119
Hydro	929	929	929	929	929	929
Solar	7,596	8,673	13,939	17,340	27,589	27,589
Offshore/onshore Wind	-	2,940	6,016	6,116	6,216	6,316
Battery Storage	116	494	494	892	3,375	3,375
Pumped Storage	3,241	3,241	3,241	3,241	3,241	3,241
Demand Response	1,354	1,354	1,354	1,354	1,354	1,354
Total	**38,393**	**46,038**	**59,615**	**69,589**	**84,565**	**85,835**

VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	6,141	9,391	12,856	12,856	12,856	12,856
Gas Peaker	10,499	10,499	10,499	13,709	15,013	14,534
Oil Peaker	813	813	813	813	316	-
Biomass	765	765	765	765	15	-
Coal	3,230	3,230	3,230	3,230	630	-
Nuclear	3,708	3,708	3,708	6,388	8,532	11,854
Hydro	929	929	929	929	929	929
Solar	7,596	8,673	13,939	17,883	33,880	33,880
Offshore/onshore Wind	-	2,940	8,576	8,676	8,776	8,876
Battery Storage	116	878	3,216	3,231	5,590	5,590
Pumped Storage	3,241	3,241	3,241	3,241	3,241	3,241
Demand Response	1,354	1,354	1,354	1,354	1,354	1,354
Total	**38,393**	**46,422**	**63,126**	**73,075**	**91,132**	**93,114**

SOURCE: E3 grid modeling analysis.
NOTE: Capacity shown is nameplate capacity.

TABLE H-3
Generation capacity required 2025 to 2050, Scenario 3: No new data center demand (MW)

No VCEA

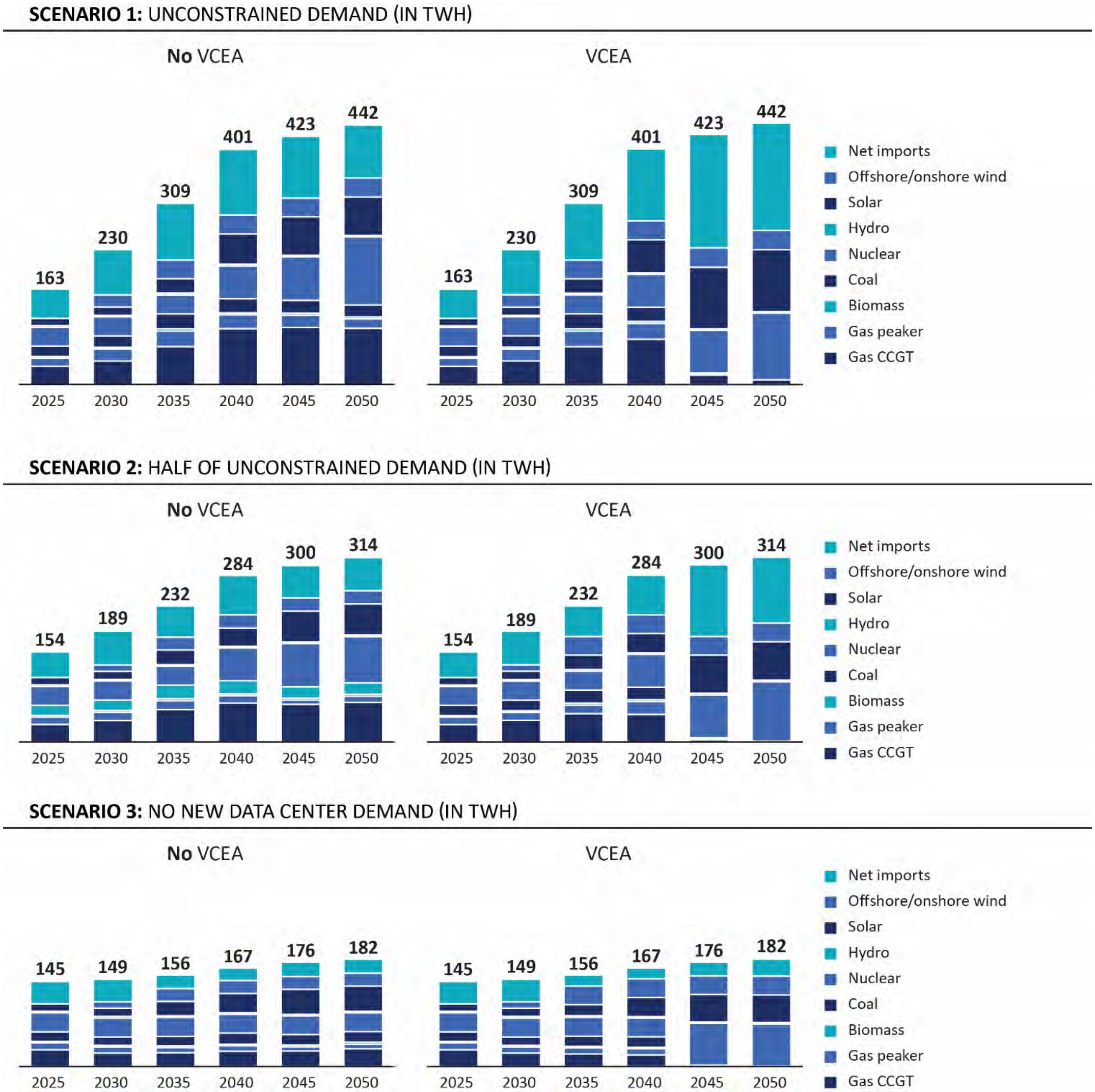
Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	6,042	6,042	6,759	7,728	8,016	8,642
Gas Peaker	10,499	10,499	10,499	10,499	10,499	10,499
Oil Peaker	813	813	813	813	813	813
Biomass	765	765	765	765	765	765
Coal	3,230	3,230	3,230	3,230	3,230	3,230
Nuclear	3,708	3,708	3,708	3,708	3,708	3,708
Hydro	929	929	929	929	929	929
Solar	7,596	8,673	13,939	17,733	22,340	22,340
Offshore/onshore Wind	-	2,940	6,016	6,116	6,216	6,316
Battery Storage	116	116	116	609	3,583	3,583
Pumped Storage	3,241	3,241	3,241	3,241	3,241	3,241
Demand Response	1,354	1,354	1,354	1,354	1,354	1,354
Total	**38,293**	**42,310**	**51,369**	**56,725**	**64,695**	**65,421**

VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	6,042	6,042	6,042	6,042	6,042	6,042
Gas Peaker	10,499	10,499	10,499	10,499	9,865	9,386
Oil Peaker	813	813	813	813	316	-
Biomass	765	765	765	765	15	-
Coal	3,230	3,230	3,230	3,230	630	-
Nuclear	3,708	3,708	3,708	3,708	8,532	8,532
Hydro	929	929	929	929	929	929
Solar	7,596	8,673	11,092	17,783	24,669	24,669
Offshore/onshore Wind	-	2,940	8,576	8,676	8,776	8,876
Battery Storage	116	116	3,216	3,216	4,313	4,313
Pumped Storage	3,241	3,241	3,241	3,241	3,241	3,241
Demand Response	1,354	1,354	1,354	1,354	1,354	1,354
Total	**38,293**	**42,310**	**53,465**	**60,256**	**68,682**	**67,341**

SOURCE: E3 grid modeling analysis.
NOTE: Capacity shown is nameplate capacity.

FIGURE H-2
Energy sources 2025 to 2050



SOURCE: E3 grid modeling analysis.

TABLE H-4
Energy sources 2025 to 2050, Scenario 1: Unconstrained demand (TWh)

No VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	31	40	65	96	98	96
Gas Peaker	14	20	27	23	21	16
Oil Peaker	-	-	-	-	-	-
Biomass	3	3	3	3	3	3
Coal	18	19	26	24	22	21
Nuclear	32	32	32	56	74	116
Hydro	3	3	3	3	3	3
Solar	13	14	25	52	66	66
Offshore/Onshore Wind	-	21	32	32	32	33
Battery Storage	(0)	(0)	(0)	(0)	(1)	(1)
Pumped Storage	(0)	(0)	(0)	(0)	(0)	(0)
DR	0	0	0	0	0	0
Net Imports	50	77	97	112	105	90
Total	**163**	**230**	**309**	**401**	**423**	**442**

VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	31	40	65	77	16	8
Gas Peaker	14	20	27	27	1	-
Oil Peaker	-	-	-	-	-	-
Biomass	3	3	3	3	0	-
Coal	18	19	26	24	2	-
Nuclear	32	32	32	56	73	114
Hydro	3	3	3	3	3	3
Solar	13	14	25	57	105	106
Offshore/Onshore Wind	-	21	32	32	33	33
Battery Storage	(0)	(0)	(0)	(1)	(2)	(1)
Pumped Storage	(0)	(0)	(0)	(1)	(3)	(3)
DR	0	0	0	0	0	0
Net Imports	50	77	97	123	194	183
Total	**163**	**230**	**309**	**401**	**423**	**442**

SOURCE: E3 grid modeling analysis.

TABLE H-5
Energy sources 2025 to 2050, Scenario 2: Half of unconstrained demand (TWh)

No VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	30	37	55	66	64	67
Gas Peaker	13	14	15	13	7	11
Oil Peaker	-	-	-	-	-	-
Biomass	3	3	3	3	3	3
Coal	17	18	23	22	19	20
Nuclear	32	32	32	56	74	79
Hydro	3	3	3	3	3	3
Solar	13	14	25	32	53	53
Offshore/Onshore Wind	-	11	22	22	23	23
Battery Storage	(0)	(0)	(0)	(0)	(1)	(1)
Pumped Storage	(0)	(0)	(0)	(0)	(1)	(1)
DR	0	0	0	0	0	0
Net Imports	44	57	54	67	56	56
Total	**154**	**189**	**232**	**284**	**300**	**314**

VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	30	37	48	47	4	2
Gas Peaker	13	14	15	22	1	-
Oil Peaker	-	-	-	-	-	-
Biomass	3	3	3	3	0	-
Coal	17	18	23	22	3	-
Nuclear	32	32	32	56	73	101
Hydro	3	3	3	3	3	3
Solar	13	14	25	33	66	66
Offshore/Onshore Wind	-	11	32	32	32	32
Battery Storage	(0)	(0)	(0)	(0)	(1)	(1)
Pumped Storage	(0)	(0)	(0)	(0)	(1)	(1)
DR	0	0	0	0	0	0
Net Imports	44	58	53	68	123	112
Total	**154**	**189**	**232**	**284**	**300**	**314**

SOURCE: E3 grid modeling analysis.

TABLE H-6
Energy sources 2025 to 2050, Scenario 3: No new data center demand (TWh)

No VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	29	23	23	26	26	30
Gas Peaker	11	10	9	10	7	8
Oil Peaker	-	-	-	-	-	-
Biomass	3	3	3	3	3	3
Coal	16	14	16	19	18	18
Nuclear	32	32	32	32	32	32
Hydro	3	3	3	3	3	3
Solar	13	14	25	33	43	43
Offshore/Onshore Wind	-	11	22	22	22	22
Battery Storage	-	(0)	(0)	(0)	(1)	(1)
Pumped Storage	(0)	(0)	(0)	(0)	(1)	(1)
DR	0	0	0	0	0	0
Net Imports	38	38	23	21	24	24
Total	**145**	**149**	**156**	**167**	**176**	**182**

VCEA

Resource	2025	2030	2035	2040	2045	2050
Gas CCGT	29	23	21	20	0	0
Gas Peaker	11	10	11	10	0	0
Oil Peaker	-	-	-	-	-	-
Biomass	3	3	3	3	0	-
Coal	16	14	17	18	2	-
Nuclear	32	32	32	32	71	72
Hydro	3	3	3	3	3	3
Solar	13	14	19	33	47	47
Offshore/Onshore Wind	-	11	32	32	32	32
Battery Storage	-	(0)	(0)	(0)	(1)	(1)
Pumped Storage	(0)	(0)	(0)	(0)	(1)	(1)
DR	0	0	0	0	0	0
Net Imports	38	38	19	19	23	29
Total	**145**	**149**	**156**	**167**	**176**	**182**

SOURCE: E3 grid modeling analysis.

Appendix I: Data center on-site generation

Instead of relying on utilities, many data center companies are looking at ways to generate their own power using on-site power generation. On-site generation can take a variety of forms, including utility-owned generation on or adjacent to a data center site, "behind the meter" generation that is owned by the data center, or a "microgrid" where the site operates its own generation and may not be connected to the larger grid. Of the current technologies available, only natural gas appears viable for on-site generation, and it can be deployed only close to pipeline infrastructure that has sufficient capacity to serve generation needs. Other technologies, such as small modular nuclear reactors, are being actively pursued by the industry as a potential future power source, but most stakeholders believe these will not realistically be available until 2035.

On-site generation is most likely to be used at new data center sites, where they can be incorporated into the site design. It appears unlikely existing sites, especially those that are fully built out, could be switched to on-site generation because of space constraints and financial considerations. Additionally, data center companies may have regulatory and public relation challenges trying to place some technologies, such as nuclear reactors, in suburban localities like Loudoun and Prince William.

On-site generation could help solve data center companies' power problems, but they may not substantially reduce generation and transmission infrastructure needs. Several data center companies indicated that they were pursuing on-site generation as a primary power source but planned to rely on the main grid for backup. Because electric utilities have an obligation to serve all customers in their service territory, they would still need to build the infrastructure necessary to provide power to these sites, even if they are only serving in a backup capacity.

On-site generation could also shift new infrastructure costs to other customers, because infrastructure costs are recaptured through utility billings, and a data center using a on-site generation would not be regularly billed for services. It is possible that utilities could reach agreements with data center companies to provide reduced or non-firm levels of service if only serving in a backup capacity, which would reduce the need for additional utility infrastructure and cost impacts on other customers. However, it is not clear whether data centers would enter into such agreements. State law could be changed to address the potential issue of stranded costs from data centers that use on-site generation, but as of today, this is not occurring and only one data center site in Virginia appears to actively rely on on-site generation for a substantial share of its energy needs.

Appendix J: Power usage effectiveness (PUE) ratios

The efficiency of cooling and other building systems in data centers is commonly measured using a Power Usage Effectiveness (PUE) ratio. For example, a PUE of 1.3 indicates that 1.0 of energy is used for computing activity, and 0.3 is used for all other building systems. A PUE of 1.0 would indicate perfect efficiency, where all energy is used for computing activity, and none is used for any other purpose. Importantly, PUE does not measure how energy efficient a data center's computing is, because energy used for computing is always set equal to 1.0. Consequently, a lower PUE does not indicate if a data center is energy efficient as a whole. PUE only measures the efficiency of cooling and other building systems that support facility operations.

The data center industry has a strong market incentive to be energy efficient because energy is one of data centers' largest operating costs. Data centers regularly upgrade their computing equipment to take advantage of newer, more powerful and energy efficient computer chips. Computer chips' performance per watt has improved annually for decades. Data centers have also made big efficiency gains with their building systems. As recently as 10 years ago, PUEs of 1.9 or above were common across smaller enterprise and colocation data centers. With the consolidation of the industry into large hyperscale facilities, large companies now report fleetwide average PUEs of 1.1 to 1.4. However, some companies may continue to have less efficient building systems because there are also strong market incentives to avoid changes that could disrupt operations, such as installing more efficient cooling systems.

At least one European country, Germany, has passed legislation requiring data centers to achieve lower PUE in the near future (1.2 to 1.3, depending on when the data center was constructed), and similar legislation has been proposed in Virginia. A PUE requirement could have two unintended consequences: (1) it could encourage more water use by the industry, because water-dependent cooling uses less energy, and could make it harder for companies that use dry cooling systems to comply, and (2) companies that operate colocation data centers may be less able to comply because they do not control operational decisions that can affect PUE calculations, such as how much computing space tenants use. A PUE requirement for existing data centers would also create fairness issues, because companies that have chosen to use cooling systems that are more water efficient but less energy efficient may be unable to comply with the requirement, solely based on the type of cooling they chose before a PUE requirement was established.

Appendix K: Additional natural resource considerations

Additional concerns about data center operations' impacts on natural resources, including their wastewater discharges, disposal of electronic waste, and diesel fuel carbon footprint, have also been raised. While significant adverse impacts to Virginia's natural resources may not occur from these, an environmental management standard, such as ISO 14001, could encourage data centers to reduce their impacts where possible. (See Chapter 5 for more information on environmental management standards.)

Because of existing regulations, data center wastewater discharges do not appear to pose ecological harms

Data centers that use water in their cooling systems typically discharge only a small portion of it, but when discharges do occur, the discharges may contain relatively large concentrations of salts, other dissolved solids, and chemical additives. Some stakeholders expressed concern that data centers and/or wastewater treatment plants do not filter out the salts and any other chemicals before discharging the water to a Virginia surface water source, contributing to the degradation of water quality.

Federal and state wastewater regulations appear to protect against these risks. DEQ requires permits for wastewater discharges from utilities and other large dischargers. These permits set limitations on the contents of discharges and require water quality monitoring to ensure that discharges do not degrade water sources. Some data centers have their own discharge permits, but most send their discharges to a wastewater utility. In either case, the permit holder must ensure any wastewater is appropriately treated before discharging it into a water source. If a wastewater utility is not capable of adequately treating discharge from a data center customer, the utility can require the data center to pretreat its discharges.

Some stakeholders were concerned that existing wastewater regulations were not sufficient to protect water resources, but any potential shortcomings would be true for other development types, so data center-specific standards are not necessary. However, a certification to ISO 14001, which requires companies to meet all environmental regulations, may encourage additional voluntary commitments from data centers to reduce any wastewater impacts.

Electronic waste faces little regulation, but existing practices divert some servers from landfills

Data centers are packed full of thousands of servers, and these servers are replaced every three to five years. Servers can contain rare and toxic materials. The process to procure these materials for use in servers can be environmentally harmful, as can improper disposal of the toxic materials. The reuse or recycling of servers and server parts can minimize environmental impacts.

Data centers, like other businesses, are not required by federal or state law to reuse or recycle electronic waste, but existing practices divert some servers from Virginia landfills. Many data center companies have sustainability goals related to electronic waste, including reusing, recycling, or donating old servers or old server parts. Additionally, not all local waste management services and landfills in Virginia accept commercial waste and/or electronic waste, which would force data centers to seek other alternatives to dispose of their old servers.

Requiring data centers to meet an environmental management standard, such as ISO 14001, would require data centers to consider any environmental impacts caused by their waste generation. This could complement existing practices and discourage disposal of data center servers in Virginia landfills, if, and where, it does occur.

Few data centers currently use diesel fuel alternatives because of supply limitations

Use of diesel fuel—the fuel commonly found in data centers' backup generators—leads to greenhouse gas emissions. Data center operators are interested in expanding the data center industry's use of alternative fuels, such as hydrotreated vegetable oil (HVO), to lower data centers' carbon footprints. These alternatives can be used in most existing diesel generators. However, while these fuel alternatives are available for and used by data centers in Europe and California, the East Coast does not have a supply chain for these fuels. This makes it more expensive and logistically challenging for Virginia data centers to use these fuel alternatives.

Some data center companies are making efforts to expand the use of alternative fuels. For instance, some have requested DEQ permit approval to use HVO in their generators—as DEQ approval of fuel choice is needed as part of emission regulations—and the industry has reached out to the Virginia Economic Development Partnership about exploring ways to attract the fuel alternative industry to Virginia to increase local availability. While a requirement to use a fuel alternative may not currently be feasible, an ISO 14001 requirement could further encourage industry efforts to review and seek opportunities to limit their carbon footprints where possible.

Appendix L: Data center planning and zoning changes in Fairfax, Loudoun, and Prince William

In recent years, the three Virginia localities with the most data centers have revised their approaches to regulating the industry and initiated studies to consider additional changes. Sites in Loudoun, Prince William, and Fairfax account for 80 percent of data centers in the state. Since 2019, all three localities have adopted changes to their ordinances or other policies relating to data centers. For example, all three localities added minimum requirements for data centers to their zoning ordinances. Additionally, all three localities began official studies of their data center policies, with Loudoun and Prince William planning votes in 2026 by their boards of supervisors in response to study findings. Table L-1 summarizes key changes by Fairfax, Loudoun, and Prince William related to data center planning and zoning processes since 2019.

TABLE L-1
Fairfax, Loudoun, and Prince William have updated data center policies since 2019

Locality	Planning and zoning actions
Fairfax	**Comprehensive zoning update with changes specific to data centers (effective 7/1/2021)** • Recognized data centers as distinct use instead of being considered a type of telecommunications facility • Prohibited data centers in residential and certain commercial zones; requires special permit in certain commercial and industrial zones if exceeds specified size • Established county's first design standard specific to data centers: requiring enclosure of equipment in certain zones **Data center study (initiated 5/9/23)** • Process included public meetings and stakeholder interviews • Produced two staff reports and a consultant report **Zoning changes (effective 9/11/24)** Board of Supervisors considered study's recommendations and implemented several rules to better manage data center development • Prohibited data centers in additional zone; converted several zones from allowing data centers by right to allowing by special permit; expanded requirement for special permit if exceeding specified size to another industrial zone • Required 200 feet between data center building and residential property; required 300 feet (or a building) between equipment and residential property • Required 1 mile between data center and Metro station • Required sound studies at two stages of new projects • Required several architectural standards (e.g., façade differentiation) of by right development, with more flexibility but the same goals for special permit developments
Loudoun	**Rewrite of comprehensive plan (adopted 6/20/2019)** Items for priority future action included performance standards for data centers **Series of meetings about data center policies by legislative committee (2022)** Initiated to review county staff research and develop process for considering changes to data center policies **Comprehensive zoning update includes changes specific to data centers (effective 12/13/2023)** [a] Goal to align zoning ordinances relevant to data centers with comprehensive plan

	• Converted two zones from allowing data centers by right to allowing by special permit; permitted data center in an additional industrial zone • Expanded applicability of data center standards (e.g., façade architecture, screening of mechanical equipment) from four zones to all locations • Created standards for data centers regardless of location including windows, main entrance features, loading bay location, and proactive sound measuring • Created standards for data centers adjacent to residential areas including separation of mechanical equipment, minimum 200-foot setback between buildings and property border, parking setbacks, time limits on generator testing, and acoustical barriers around mechanical equipment **Study of potential changes to comprehensive plan and zoning ordinances for data centers and substations (initiated 2/6/2024)** • First phase focusing on appropriate locations for data centers per the comprehensive plan and zoning ordinance, expected to conclude early 2025 • Second phase to focus on policies and zoning ordinances to implement data center standards (e.g., aesthetics, natural resources), expected to conclude 2026
Prince William	**Additional standards required in data center overlay district (adopted 6/18/2019)** • Created requirements for data centers in the data center overlay district, including for building façade and fence design, screening mechanical equipment and substations near residential areas and certain roads, and buffer yards of data centers near residential areas • To encourage data center development in the overlay, increased density allowed by right within the overlay • Adjusted borders of data center overlay on map **Comprehensive review of data center overlay (initiated 3/2/2021)** • Scope included zoning ordinance, comprehensive plan, and other formal county policies • Products included reports by county's economic development office and two consultants regarding data center industry trends, appropriate land in Prince William, and recommended standards for development • Process included public meetings and stakeholder interviews **Data center ordinance advisory workgroup (created 2/28/2023)** Responsible for continuing review of county's data center policies. Draft timeline includes Board of Supervisors vote on noise ordinance amendments in spring 2025 and vote on policy changes relevant to other topics later in 2025. **Expanded noise ordinance applicability to data centers (adopted 2/28/2023)** • Limited exemption for nighttime cooling systems to residential homes • Originally planned to sunset in a year but extended to provide time to "assess the noise impacts associated with data centers"

SOURCE: JLARC review of local ordinances, review of planning and zoning department documents, and interviews with local staff.
NOTE: Table describes significant changes since 2019 and is not a summary of current ordinances. Table focuses on planning and zoning processes and excludes changes to economic development and tax policy. Table excludes requirements limited to particular projects (e.g., rezoning commitments). "Special permit" is used for consistency, but the terminology for this process depends on the locality.
[a] Updates do not apply to certain parts of the county, which are administered under an older zoning ordinance.

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