Loudoun County, Virginia: Data Center Capital of the World

"A Strategy for a Changing Paradigm"

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Author's Preface

The opinions and recommendations in this paper represent those of the author alone and in no way represent those of any other Board member, the Loudoun County Board of Supervisors or Loudoun County Staff. Furthermore, these opinions and recommendations have no legal authority nor are they in any way legally binding on any Loudoun County employee.

Summary of Updates Since January 1 Edition

- Notes a March 18, 2025 vote by the Loudoun County Board of Supervisors ending "by right" data center development in Loudoun County, VA.
- Discusses the viability of microgrids as elements of a national, distributed energy network, but acknowledges their limited application in Loudoun County due to available land constraints.
- Identifies microgrid elements that do have applicability in Loudoun County.
- Discusses in more detail the role of Small Modular Reactors (SMR) and Advanced Nuclear Reactors (ANR) in establishing future, national power grid resilience.
- Identifies critical, short-term restraints on the deployment of SMRs and ANRs due to their production of higher levels of nuclear waste, their creation of new and previously unknown types of nuclear waste, and a requirement for onsite storage due to a lack of a national nuclear waste storage policy. These limitations make them unsuitable for deployment in Loudoun County.

Executive Summary (citations included in applicable main body text)

- Loudoun County, VA, and particularly "Data Center Alley" in eastern Loudoun, has the highest concentration of data centers in the world with approximately 200 data centers built and 117 in the development pipeline. There has not been a single day in 14 years when a data center was not under construction in Loudoun County. We have more data centers than the next six U.S. markets combined. Each day, seventy percent of the world's email traffic passes through Loudoun County.

- Two source documents guide and regulate Loudoun County's approval and placement of data centers: the Comprehensive Plan and the Zoning Ordinance. The Comprehensive Plan is a guide and details the Board of Supervisors' vision for land development over the next 20 years in the county. It is not legally binding. The Zoning Ordinance provides the legal basis for the Comprehensive Plan and is legally binding. Each parcel of land under the zoning ordinance allows certain types of development "by right," meaning such development does not need legislative approval from the county

Board of Supervisors. Much of Loudoun County's data center development has been "by right."

- Key developmental milestones:
    - Late 1990's: U.S. government's Advanced Research Project (ARPA) establishes the Metropolitan Area Exchange-East (MAE-East) as a national internet hub. Extensive underground fiber optic network is laid giving Loudoun County the lowest (fastest) latency rates for moving data from point A to point B in the world. This latency advantage exists to the present day and represents a significant market advantage for data centers located in Loudoun's "Data Center Alley."
    - CY 2000: Loudoun County Zoning Administrator determines data centers should be treated as office parks, thereby making any data center development "by right" on land parcels that permit office parks.
    - CY 2003: First mention of data centers in the Zoning Ordinance.
    - CY 2008: Loudoun County Economic Development launches an aggressive marketing campaign touting our low latency rates to attract data centers to the county. "Data Center Alley" is born.
    - CY 2019: County Comprehensive Plan updated fully for the first time in 18 years. Incorporates a wide range of data center performance criteria.
    - CY 2022: A landmark year marking the start of a new era of constrained power for the worldwide data center market. After ten years of slightly declining power demand within the Dominion Energy service area, PJM, the northeast Regional Transmission Organization, of which Dominion Energy is a member, recognizes an impending exponential increase in power demand from Loudoun County's "Data Center Alley." Dominion Energy immediately imposes power constraints on "Data Center Alley" which remain in effect today. Loudoun County, VA becomes the constrained power "canary in the mine" for the world data center community.
    - CY 2023: Loudoun County Zoning Ordinance updated for the first time in 20 years to align with the 2019 Comprehensive Plan. This increases local legislative oversight of data center applications, thereby limiting "by right" development for the first time.
    - CY 2024: Joint Legislative Audit Review Committee releases long-awaited data center report to the Governor and General Assembly.
    - CY 2025: The Loudoun County Board of Supervisors ends "by right" data center development in Loudoun County at a March 18th, 2025 Board meeting.[21]
- From 2018-2023, largely before the dawn of Artificial Intelligence (AI), Loudoun County's energy use increased 240%, from 1.0 Gw to 3.4 Gw of power consumption. Using a simple linear extrapolation over the next five years, without accounting for a likely tenfold increase in power required by AI, Loudoun will need 11.56 Gw of power. An independently commissioned Kimley-Horn report has confirmed this estimate almost

exactly, estimating 11.59 Gw of power will be needed by 2028. Loudoun County is currently receiving about 9.3 Gw of power, though only a portion of that reaches "data center alley." PJM and Dominion Energy plan to bring an additional 6.3 Gw into Loudoun County by 2028 to meet Loudoun's growing power demands, but it is unclear how much of this additional power will reach "Data Center Alley." None of this development addresses the vast increase in power demand anticipated for AI.

- Demand for data processing is growing exponentially worldwide. With that increase in demand for data processing comes a concomitant exponential increase in demand for electricity by the world's data centers. The electric utilities serving Northern Virginia (PJM; Dominion Energy) will be unable to build sufficient grid infrastructure to meet the growing demand for power by the region's data centers. This conclusion, originally stated in the preface below in July 2024, was similarly arrived at in the December 2024 JLARC data center report to the Virginia Governor and General Assembly.

- The rapid increase in data center sector demand for power has resulted in a significant increase in constituent resistance to more data centers in their communities. It has also caused both PJM and Dominion Energy to slow or cancel the decommissioning of fossil fuel generation plants throughout the region. Given that the most recent U.N. climate change report indicates 2024 was likely the warmest year on record, this delay or cancellation of fossil-fuel plant decommissioning will likely add to community resistance to more data center development.

- The three key stakeholder groups critical to developing a new strategic paradigm for energy consumption amidst a worldwide data revolution are the data center sector, the electric utility sector and the constituent sector, represented by local, state and federal elected bodies. Heretofore, these groups have rarely collaborated. Systematic collaboration and communication between and among these groups will be essential going forward.

- Certain realities must be acknowledged if we are to successfully meet Loudoun County's energy challenges:

    - The 135-year-old paradigm of power generated by large, remote power plants and transmitted over hundreds of miles of transmission lines to end-user distribution locations will not solve Loudoun County's unique energy challenges.

    - The utilities will likely continue to slow or halt fossil fuel generation plant decommissioning. This will lead to increased community pressure on elected officials to oppose data center development and increased market pressure on data centers to develop onsite, regional or distributed energy networks with a greater reliance on low-carbon or carbon net-zero power.

    - Solar and wind power alone will not be sufficient to solve Loudoun County's data center energy needs.

    - Halting data center construction in Loudoun County will not solve the problem. AI will drive up energy demands for our existing data centers far in excess of Dominion Energy's and NOVEC's (Northern Virginia Electric Cooperative) capacity to meet that demand.

- Immediate steps available to PJM and Dominion Energy to begin to address rising power demand are 1) reconductoring new and existing transmission lines, and 2) considering the development of a regional High Voltage Direct Current (HVDC) network for the exclusive use of the Loudoun County data center sector.

- If, as this paper and the JLARC study predict, the power grid infrastructure in Loudoun County—even with its planned expansion—will be insufficient to meet the future energy demand of the county's data center market, there are only three possible future scenarios by which that demand can be reduced to manageable levels:

  Scenario #1: Government-Imposed Energy Consumption Constraints. In this scenario, the Commonwealth of Virginia, the power utilities or both artificially constrain the energy use of high-energy consumers to ensure grid stabilization for all Virginia energy consumers. This scenario would likely cap continued data center development in Loudoun County and cause new data center development to take place in locations with much lower power constraints.

  Scenario #2: Technological Breakthrough. A technological breakthrough occurs significantly reducing the power needed by AI and cloud-based computing. Such a development would stabilize the power grid and could enable the power utilities to meet the stabilized infrastructure needs of the industry. This scenario could lead to significant stranded costs.

  Scenario #3: Industry Conversion to Onsite Power. Faced with exponential market demand and possessed with almost unlimited resources to meet that demand, the data center industry rapidly develops the capacity to generate onsite, local or distributed energy power (microgrids) for its operations and, in so doing, significantly reduces its reliance on the regional power grid. Such a development would stabilize the grid and could enable the power utilities to meet the stabilized infrastructure needs of the industry. (Widespread microgrid development in Loudoun County is unlikely due to geographic constraints.) Additionally, this scenario could lead to significant stranded costs.

- In the future, the three scenarios will likely occur simultaneously but in varying and fluctuating degrees based upon market and grid infrastructure conditions. The utilities have already begun delaying additions of large loads to the grid, and the JLARC study recommends codifying this in state code to allow delays for generation limits in addition to transmission limits (scenario #1). Meanwhile, new GPU chips are emerging that use significantly less power (scenario #2), and we already have examples of data centers in Loudoun County building advanced microgrids to reduce their dependence on grid power (scenario #3). All three scenarios will continue to develop for the foreseeable future.

- Stranded costs occur when a regulated utility, required by law to meet the energy demand of its customers, is forced to build new infrastructure to meet predicted, future demand for energy. If at any time during the infrastructure buildout process the predicted demand is not realized, stranded costs occur. The regulated utility has incurred the costs of the buildout, but the reduced consumer demand can no longer defray those costs. The utility must then absorb the costs or pass them on to residential

and small commercial customers. A tool to insulate the utilities from stranded costs is the imposition of preemptive tariffs on high-energy consumers.

- While the 2024 JLARC study concludes it will be very difficult to meet the data center sector's unconstrained energy demand, it offers only two broad approaches to reduce that demand: 1) utilities should be allowed to delay large energy load additions to the grid while local jurisdictions impose performance standards to increase energy efficiency, and 2) the state should use the sales tax exemption to incentivize greater data center energy efficiencies. These approaches represent an acceptance of scenario #1 above as the only way to decrease energy demand. Approach #1 is occurring already due to physical grid infrastructure limits that will exist for the foreseeable future. Approach #2 would fail to achieve data center energy efficiencies sufficient to adequately reduce stress on the power grid and would cause data centers to leave the Commonwealth.
- Microgrids generally comprise up to five key components:
    - A major power consumer (e.g. data center)
    - A baseload power source (onsite power capable of meeting the major consumer's power needs 24/7/365)
    - A backup power source (e.g. generators, gas turbines, batteries, etc.)
    - A connection to the regional power grid (optional)
    - A demand response management system to manage microgrid power sources and determine when and how the microgrid will interface, if at all, with the regional power grid
- There are currently six types of onsite power sources capable of practical application within the next five years:
    - Backup diesel generators
    - Battery Energy Storage Systems (BESS)
    - Natural gas turbines
    - Green hydrogen fuel cells
    - Blue hydrogen fuel cells
    - Small Modular Reactors/Advanced Nuclear Reactors (more than 50 variations)
- Only natural gas turbines are immediately capable of delivering baseload, onsite power.
- Small modular reactors have the highest capacity factor (ability to deliver maximum power for the longest duration) and solar power has the lowest.
- Small Modular Reactors and Advanced Nuclear Reactors have the highest potential for delivering maximum, carbon net-zero power, but require at least 10 acres to produce 300 Mw. They also create new types and larger amounts of nuclear waste than traditional light-water reactors. These two factors would likely prohibit their use in

Loudoun County with its very dense data center community located near residential areas.

- The data center industry is facing historic market demand and possesses virtually unlimited resources to meet that demand. History suggests that any market experiencing these two forces simultaneously will derive its own market-based solution. Loudoun County, through constant collaboration with the data center sector and local utilities, should strive to anticipate in what direction its data center community will choose to move. Towards that end, the county should develop precise performance standards to 1) shape and manage future data center development, and 2) create significant incentives/disincentives to effect environmentally friendly and energy efficient design changes to existing data centers.

Preface

I was elected to the Loudoun County Board of Supervisors in November 2019 and took office in January 2020. For my entire tenure, our bipartisan Board has had to deal with two enduring and overarching issues: data center growth and housing. While the need for attainable housing in Loudoun County, the wealthiest county in America,[1] remains a critical issue, the explosion of data center growth in the past two years, both unprecedented and accelerating, has created urgent policy issues I believe our Board must now address.

This paper is intended to form the factual basis for a new policy regarding data center growth in Loudoun County. Stated simply—based on the data, logic and conclusions offered herein—the existing paradigm of power generation, transmission and consumption this nation has relied on for more than a century is simply not capable of providing sufficient power to Loudoun County data centers (and very likely Prince William County data centers) going forward. The demand from that sector of our market environment is too high, and that demand is accelerating rapidly to historic levels. This same conclusion was reached by the December, 2024 JLARC data center report submitted to the Virginia Governor and General Assembly:

> "Data center demand would drive immense increase in energy needs in Virginia, based on JLARC's independent forecast and other forecasts. Building enough infrastructure for unconstrained data center demand will be very difficult and meeting half that demand is still difficult."[2]

I suspect the data center sector and the power utilities will not agree with several of my conclusions expressed in this paper, and I both respect and value their feedback. However, having done the research on this issue, I believe we have all been considering these changes within the context of our historic organizational paradigms. The data centers' imperative is to meet market demand, and that's their focus. Dominion Energy and PJM, the Regional Transmission Organization (RTO) for the northeast power grid, are required by law to provide power to all customers, and that's their focus. And the Board of Supervisors is an elected body responsible for making land-use decisions and encouraging economic growth, and that has

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[1] Ibeh, Kemi. "The Wealthiest County in the U.S. Is Not Where You Think." Fodor's Travel. January 23, 2024. https://www.fodors.com/world/north-america/usa/virginia/experiences/news/heres-where-the-wealthiest-u-s-county-actually-is

[2] Joint Legislative and Audit Review Commission. "Data Centers in Virginia, Commission Draft." Report to the Governor and the General Assembly of Virginia. December 9, 2024, pg. ii-iii. https://jlarc.virginia.gov/pdfs/reports/Rpt598-2.pdf

been our focus. But the post-COVID world since 2022 has seen a seismic increase in demand for data representing not an evolution, but a revolution of technological change now very likely to overwhelm our existing power infrastructure. Essentially, we've invented the airplane but just realized we haven't yet invented runways. This level of systemic change demands new paradigms at almost every level if we are to avoid an involuntary and likely painful landing.

This paper offers a summary of how we got here, presents data to capture the magnitude of the change we are all facing, acknowledges what I believe are the new realities of our current and future data center environment, and proposes the key elements of a new policy going forward. I do not consider the ideas presented or the policy elements I'm proposing the only viable answers to the historic challenges we now face. But my overarching responsibility, and I believe the responsibility of the Loudoun County Board of Supervisors, is to protect the quality of life of our citizens, even if the decisions we make are controversial, politically fraught and decidedly unpopular. My purpose here is to start a conversation based not on our ungrounded hopes but on our fact-based needs. That is the only basis upon which we can, collectively and collaboratively, formulate a transformational strategy for Loudoun County. We are the nexus for the world data center community. We have both a profound responsibility and an historic opportunity to redefine and permanently reshape the digital world and the power infrastructure it relies on. And we must act now.

Introduction

As of this writing, Loudoun County, Virginia—and more precisely, eastern Loudoun County comprising approximately 30 square miles—is home to about 200 data centers. A recent independent analysis by consultant Kimley-Horn indicates there are another 117 data centers in Loudoun County's development pipeline, with presumably many of them "by right," not requiring approval by the Loudoun County Board of Supervisors.[3] Combined with the rest of Northern Virginia, we have three times more than the second highest concentration in America.[4] In 2022, Dominion Energy forecasted Loudoun County would require about 3.4 Gw of power in 2023[5], up from just 1 Gw in 2018[6]. That's a 240% increase in the need for electricity in Loudoun County in five years. Stated another way, in 2023 we were expected to use 3.4 times as much power as we did in 2018. If we apply just a linear extrapolation of that growth rate in power demand over the next five years—and that is probably an unrealistically conservative growth rate based on the preponderance of growth trends in power demand—that means by 2028 Loudoun County will require about 11.56 Gw of power. The independent analysis by Kimley-Horn arrived at an estimate of 11.59 Gw of power needed by 2028.[7]

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[3] Kimley-Horn staff report to the Loudoun County Transportation and Land Use Committee. "Power Transmission Evaluation of Loudoun County, Virginia." October 17, 2024, item #9, Atch. 2, pg. 4. https://www.loudoun.gov/3432/Transportation-and-Land-Use-Committee

[4] United States Data Centers: Top 10 Locations in the USA - Dgtl Infra

[5] "Dominion Energy 15-Year Data Center Plan." Slide #2. https://sdc.pjm.com/-/media/committees-groups/subcommittees/las/2023/20231018/20231018-item-03a---dominion-large-load-request.ashx

[6] Abdulsalam, Sami. "Dominion Northern Virginia Area Immediate Need." Slide #2, "Data Center Alley Area Load Growth and Transmission System." Slide #3, "Dominion 2022 Load Forecast." Data interpolated from data center load forecast line (orange). June 7, 2022. https://www.pjm.com/-/media/committees-groups/committees/teac/2022/20220712/item-08---dominion-northern-virginia---immediate-need.ashx

[7] Op. Cit.

Regarding actual data center construction growth, in 2018 we had about 13 million sq. ft. of permitted data centers in the county. In 2024, we had about 43 million sq. ft. of data centers permitted.[8] That's a 231% increase in six years. Moreover, we now have an additional 47 million sq. ft. in the pipeline (application being reviewed or site plan submitted).

By every metric, the rate of data center growth in Loudoun County over the past 20 years has been among the highest of any community in the world, and that rate has accelerated exponentially since 2022. All indications suggest that growth will be accompanied by a commensurate increase in demand for power, unless outside factors—governmental action, technological breakthroughs or increased use of onsite power—reduce the demands on the regional power grid to manageable levels.

Our county is at the edge of the frontier in data center development. The lessons we have learned as a community can serve as invaluable roadmaps for communities across the nation, ranging from those contemplating their first data center, to those with modest growth, to those with an established and thriving data center community.

At the same time, because of our uniqueness, many of the challenges we now face have no corollary outside of Loudoun County. Yes, our journey can be instructive to other communities still in the early to moderate growth cycles, but many of the issues our data center community, our utility companies and our local elected leaders are now facing have never before been encountered.

Three Key Stakeholder Groups

There are three core stakeholder groups in Loudoun County with an urgent interest in developing a comprehensive strategy for future data center sector growth: the data center community, the core utilities (electricity, gas, water), and local government representing our citizens who benefit from the data produced by our data centers.

> **Data Centers.** This group involves not just data center owners and land developers, but the land-use attorneys representing them, construction companies, unions who provide labor, non-union laborers, and a wide range of corollary businesses that benefit from the construction, growth and increased impact of data centers on our society. All the members of this stakeholder group are primarily focused on enabling data centers to meet the rapidly increasing demand for data processing in our society. **Their market imperative is to continue to grow.** There are two broad types of data centers:
>
> > **Hyperscale (Enterprise) Data Centers.** Hyperscale (100 Mw or more) or enterprise data centers are generally owned and operated by a single owner and are extremely large with very high power demands. According to an August article in *Enterprise Storage Forum,*[9]a hyperscale data center is any data center with more than 10,000 sq. ft. of space and more than 5,000 servers. However, by this standard, just about every data center in Loudoun County, including most of our legacy data centers,

[8] Yearly data provided by the Loudoun County Commissioner of Revenue.

[9] Vyas, Kashyap. "Hyperscale Data Centers vs. Colocation Data Centers." Enterprise Storage Forum. August 24, 2023. https://www.enterprisestorageforum.com/cloud/hyperscale-vs-colocation/#:~:text=Hyperscale%20data%20centers%20meet%20enterprise%20data%20needs%20by,essential%20resources%2C%20allowing%20for%20cost-effective%20expansion%20and%20management.

would be considered hyperscale. For the purposes of this paper, I will distinguish between the two based on function. An enterprise data center is usually owned by a single entity and is designed to process enormous data loads at scale for just that entity or perhaps a handful of partners. According to a major colocation data center owner I talked to recently, hyperscale or enterprise data centers require significantly more power than colocation data centers as defined below. This trend is likely to accelerate significantly as hyperscale/enterprise data centers pick up more and more of the generative AI load worldwide.[10]

Colocation Data Centers. Colocation data centers are owned by a company that leases data rack space to tenant companies. It's a shared-space data center often hosting hundreds of clients who own and operate their own servers and infrastructure in an ideal data processing environment. The power requirements of a colocation data center have historically been much less than hyperscale/enterprise data centers. While this is likely to remain true, AI is also going to significantly increase the power demands of colocation data centers.[11]

Core Utilities. Though services like internet, phone, cable T.V. etc. can be considered utilities, for the purposes of this discussion, we will limit our focus to just the core utilities of electricity, water and gas. The principal core utility and the one facing the most urgent current demand in Loudoun County due to accelerating data center growth is power (electricity). However, our other two utilities could play increasingly important roles in the future. Submerged data racks using water cooling could significantly lower data center power needs but increase demand for closed, reclaimed water systems. Use of onsite gas-generated electricity is a viable future option and one already being used in Loudoun County. Rapid growth in these sectors would also require more resources. But this paper's principal focus will be on power. There are two major players and one currently minor player in the Loudoun County power space:

Dominion Energy. Dominion Energy is the largest supplier of electricity in the Commonwealth of Virginia and the predominant electricity provider in Loudoun County. It is an investor-owned utility and, **because we are a regulated state, is required by Virginia law to provide power to every customer it serves.** This is a critical point underlying the entire issue of data center growth in Loudoun County and will be addressed later.

PJM. According to the PJM website, "PJM is a Regional Transmission Organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia."[12] PJM monitors and regulates all the power companies in the northeast region, including Dominion Energy, to ensure the stability and resiliency of the entire northeast power grid. Northern Virginia, and specifically Loudoun County, are among PJM's largest customers due to our data centers. Approximately 60% of the PJM grid is carbon dioxide-producing, and about 40% is carbon-net-zero energy with about 82% of the carbon-net-zero portion being

[10] McKinsey & Company. "AI power: Expanding data center capacity to meet growing demand." October 29, 2024. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-power-expanding-data-center-capacity-to-meet-growing-demand

[11] Ibid.

[12] https://www.pjm.com/about-pjm

nuclear.[13] As we will note later in this paper, that ratio could change significantly in the years ahead.

Northern Virginia Electric Cooperative (NOVEC). According to their website, "NOVEC is a distribution electric cooperative. NOVEC purchases wholesale power through the PJM marketplace."[14] As stated, NOVEC's principal function is to distribute electricity purchased by wholesale providers such as Dominion Energy. Generally, they provide power to residential customers and commercial businesses not powered directly by Dominion. At present, they are not a major player in the data center space in Loudoun County, but that could change in the near future as well.

Local Elected Officials Representing the Community. In Loudoun County, the senior elected body charged with land-use planning is the nine-member Board of Supervisors (BOS). The BOS works for the citizens of Loudoun County and must be responsive to their needs and concerns. No individual Supervisor may act alone; all proposed actions by the BOS require at least five votes to be implemented.

Regarding the BOS's role in land-use issues, the extent of BOS involvement in the decision-making process for land development depends on what type of land development is proposed. There are generally two types: "by right" and legislative.

"By Right." Every parcel of land in the county has permitted uses, and if a landowner decides to develop one of those permitted uses, s/he is not required to obtain BOS approval to develop that land unless they wish to change a "by right" use or add a new use.

Note: Loudoun County ended "by right" data center development by a 7-2 vote at a March 18, 2025 Board of Supervisors meeting. All new data centers in Loudoun County (except for 22 data centers "grandfathered" at the March 18th meeting) now require Board of Supervisors approval.

Legislative. If the landowner decides to modify the use of the land beyond what's permitted "by right," s/he must submit a legislative application to county staff and obtain final approval from the BOS.

The Roles of the Comprehensive Plan and the Zoning Ordinance. Key to understanding the planning environment within which these three stakeholders have been operating throughout the period of rapid data center growth is the relationship between the Loudoun County Comprehensive Plan and the Zoning Ordinance. Stated simply, the Comprehensive Plan is the Board of Supervisors' vision of how land should be developed in the county (plus the transportation infrastructure needed to support that vision). The Zoning Ordinance is the legally binding code landowners must abide by when developing their land, and it is used to implement the vision outlined in the Comprehensive Plan. The Comprehensive Plan is not legally enforceable; the Zoning Ordinance is.

These two documents should always be in alignment and updated every five years. Yet Loudoun County went from 2001 to 2019 without a complete update of its Comprehensive Plan and from 2003 to 2023 without a corresponding update of its Zoning Ordinance. These two decades precisely aligned with the growth, from inception to maturity, of the data center sector in Loudoun County,

[13] https://en.wikipedia.org/wiki/PJM_Interconnection
[14] https://www.novec.com/About_NOVEC/index.cfm

the largest such sector in the world today. The BOS finally updated the Comprehensive Plan in 2019, but due to COVID, it took four more years to update the Zoning Ordinance in December 2023. These four years of misalignment between the Comprehensive Plan and the Zoning Ordinance occurred just as data centers began exercising their "by right" development options. Additionally, PJM, Dominion, and Aurora Energy, a leading global advisor to energy investors, mark 2022 as the year data center power demand began increasing rapidly.[15] This plan/ordinance misalignment could not have occurred at a worse time and seriously limited the Board's ability to manage data center growth as envisioned in the Comprehensive Plan.

How We Got Here: A Timeline of the Growth of the Loudoun County Data Center Sector

The following is a timeline of key events shaping the proliferation of data centers in Loudoun County:

- 1993 Update of 1972 Zoning Ordinance: No mention of data centers.
- 1990s (latter half): Metropolitan Area Exchange-East established in Loudoun County; AOL HQ comes to Ashburn in 1997 and expands on existing fiber optic network.
- 2000 Loudoun County Zoning Administrator determination: data centers are viewed as similar to office buildings in the 1993 Zoning Ordinance. Office parks are a hot trend.
- 2001: General Plan (land use) updated.
- 2003: Revised 1993 Zoning Ordinance passed to match the 2001 General Plan: First Mention of Data Centers in the Zoning Ordinance.
- 2008: Loudoun County Economic Development initiates marketing strategy to actively recruit data centers to build on land specifically permitting data centers.
- 2014: Zoning Ordinance Amendment (ZOAM) addressing data center sight, setback, sound.
- 2019: General Plan updated (land use).
- 2022: May-July: The Loudoun County Transportation and Land Use Committee (TLUC) holds a series of three meetings to inventory current and potential locations of data centers, obtain staff recommendations about how best to manage data center growth, and to determine the best process to implement a future data center Comprehensive Plan Amendment (CPAM)/Zoning Ordinance Amendment (ZOAM) to codify those managerial changes. Dominion announces new 500/230 Kv Wishing Star-Mars transmission line.
- 2022: July: PJM informs Dominion Energy it has underestimated power infrastructure needs. Dominion Energy informs "Data Center Alley" it will have less power available for at least five years. The power "constrained area" is created until new power lines can be built by 2027.[16] [17] PJM announces a new 500 Kv line from Doubs-Aspen.[18]

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[15] https://auroraer.com/company/about/

[16] RTO Insider LLC. "PJM Orders Dominion 'Immediate Need' Projects to Serve Load Jump in 'Data Center Alley'." June 16, 2024. https://www.rtoinsider.com/30472-pjm-orders-dominion-immediate-need-projects-load-jump-data-center-alley/

[17] Abdulsalam, Sami. "Data Center Planning and Need Assessment Update." PJM. January 10, 2023. https://www.pjm.com/-/media/committees-groups/committees/teac/2023/20230110/item-04---data-center-load-planning.ashx

[18] PJM. "Transmission Expansion Advisory Committee (TEAC) Recommendations to the PJM Board." PJM. Dec. 11, 2023. Slide 44, last entry in table. https://pjm.com/-/media/committees-groups/committees/teac/2023/20231205/20231205-pjm-teac-board-whitepaper-december-2023.ashx

- 2023: Dominion Energy announces a new 500/230Kv transmission line along Route 7 in Loudoun County.[19] This line, the southern Wishing Star-Mars line and a third Golden-Mars line will be connected to form a loop to "Data Center Alley."
- 2023: Dec: Zoning Ordinance Rewrite (ZOR) to align with the 2019 Comprehensive Plan is approved by the BOS. This zoning ordinance rewrite established new, more restrictive construction and performance standards for data centers and attached Special Exceptions (SPEX) to data centers being built on Research and Development Park or Office Park land.
- 2023: Dec: PJM announces acceptance of a NextEra proposal to build a new 500Kv transmission line through western Loudoun County.[20] Public resistance is significant, and PJM later decides to build this line in existing right-of-way.
- 2024: Mar: The Loudoun County Board of Supervisors denies the construction of a 4.9 million sq. ft./600 Mw data center next to a residential neighborhood but approves the application when the applicant reduces its size to 1.3 million sq. ft., the "by right" permitted size, and retains the environmental proffers from the larger application.
- 2025: Mar: The Loudoun County Board of Supervisors ends "by right" data center development in Loudoun County by a 7-2 vote at a March 18, 2025 Board meeting.[21]

It's important to note here the strategy initiated in 2008 by the Loudoun County Economic Development Department had the full support of the Loudoun County Board of Supervisors and proved to be enormously successful.

- There has not been a single day in the past 15 years when a data center was not under some type of initial construction or expansion in Loudoun County.
- Loudoun County now has about 200 data centers, more than any other community on Earth.[22] An additional 117 data centers are in the development pipeline.[3]
- Loudoun County's data center market is greater than the next six U.S. markets combined.[23]
- In 2021, "Data Center Alley" in Loudoun County, VA hosted 70% of the world's internet traffic (current estimates now place that figure at 65%).[24]

And the reasons why the Loudoun County BOS fully supported this program are easy to discern:

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[19] Kirby, Jess. "Lansdowne residents oppose Route 7 transmission line proposal." Loudoun Times Mirror. Oct. 5, 2023. https://www.loudountimes.com/news/lansdowne-residents-oppose-route-7-transmission-line-proposal/article_46190288-639f-11ee-9908-7722c63f7ffd.html

[20] Kirby, Jess. "PJM advances proposal for transmission line in western Loudoun." Loudoun Times Mirror. Dec. 13, 2023. https://www.loudountimes.com/0local-or-not/1local/pjm-advances-proposal-for-transmission-line-in-western-loudoun/article_c0202122-99e3-11ee-9896-b71271fc88fc.html

[21] Loudoun County Board of Supervisors business meeting minutes, March 18, 2025. file:///C:/Users/mike.turner/Downloads/Item%2007%20Data%20Center%20Standards%20&%20Locations%20CPAM-ZOAM%20Phase%201.pdf

[22] Zhang, Mary. "United States Data Centers: Top 10 Locations in the USA." Dgtl Infra. April 11, 2024. https://dgtlinfra.com/united-states-data-centers/

[23] Vogelsong, Sarah. "Virginia Has the Biggest Data Center Market in the World. Can It Also Decarbonize Its Grid?" Inside Climate News. May 24, 2024. https://insideclimatenews.org/news/24052024/virginia-data-center-market-electricity-demand/

[24] Woolridge, Ginger. "How Ashburn, VA became the Colocation Mecca known as Data Center Alley. Lightyear. Nov. 12, 2021. https://lightyear.ai/blogs/ashburn-colocation-data-center-alley

- Enormous tax revenue: In FY2025, Loudoun County estimates about $895M in data center real and personal property tax revenue. The county's entire operating budget is projected to be $940M.[25]
- As a result of data center tax revenue, Loudoun County has the lowest real property tax rate in NOVA; about 25% lower than our neighbors.[26]
- A data center costs the county $0.04 per $1 of tax revenue received, whereas normal businesses cost about $0.25 per $1 of revenue.[27]
- Data centers put very few cars on the road.
- Data centers put very few kids in schools.

Thus, with the full and enthusiastic support of the Board of Supervisors and the visionary foresight of the Loudoun County Department of Economic Development, Loudoun County capitalized on its unique geography (Washington, D.C. and Dulles Airport), its role as a high-tech digital incubator and home of the internet, and its extensive fiber-optic infrastructure touting the lowest latency rates in the industry to become ground zero for historic digital development. Until 2022, though Dominion and the Department of Economic Development had cautioned for years infrastructure would have to be built to accommodate the rapid increase in demand for power, the future looked relatively unconstrained.

Then, in 2022, PJM informed Dominion Energy that Dominion's infrastructure predictions were significantly underestimating the growing power needs of Loudoun County's data center sector. In response, Dominion Energy established what is now known as the "constrained area" in Loudoun County and informed the data center sector they would have significant power constraints until 2027 when new transmission lines could be built. This deadline has now been pushed back to June 1, 2028.[28] This marked the start of a sobering new reality in Loudoun County: the rapid growth of three competing forces affecting the data center community and the larger Loudoun County community.

Three Accelerating, Co-Dependent, Conflicting Trends

There is no question three co-dependent, conflicting trends are going to dominate the Loudoun County data center landscape for the foreseeable future: 1) Rapidly increasing demand for data 2) Rapidly increasing demand for power to process that data 3) Rapidly increasing local community resistance to changes in quality of life, changes to neighborhoods, and the proliferation of overhead transmission lines.

Increasing Demand for Data. As shown below, the years between 2016-2024 have seen staggering data center growth in Loudoun County:[29]

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[25] Loudoun County FY2025 Appropriations Resolution; Commissioner of Revenue. Available on request.

[26] "City of Alexandria Revenues." City of Alexandria. 2024. Pg. 7-19 table. https://www.alexandriava.gov/sites/default/files/2023-02/Section%2007%20Revenues%20FY24.pdf

[27] Northern Virginia Technology Council. "The Impact of Data Centers on Virginia's State and Local Economies 5th Biennial Report." April, 2024. Pg. 7. https://info.nvtc.org/acton/attachment/45522/f-1c3915e6-b8b1-4914-818e-9fae14877a3d/1/-/-/-/-/2024%20NVTC%20Data%20Center%20Report.pdf

[28] Kirby, Jess. "Dominion files SCC application for Route 7 transmission lines." Loudoun Times Mirror. April 8, 2024. https://www.loudountimes.com/0local-or-not/1local/dominion-files-scc-application-for-route-7-transmission-lines/article_85f0c24c-f607-11ee-b165-e343f9408d14.html

[29] Data provided by the Loudoun County Commissioner of the Revenue, May 31, 2024.

- In 2016, 8.8 million sq. ft. of permitted data center floor space
- In 2017, 10.1 million sq. ft. (14.7% increase)
- In 2018, 13.1 million sq. ft. (29.7% increase)
- In 2019, 18.3 million sq. ft. (39.7% increase)
- In 2020, 21.5 million sq. ft. (17.5% increase)
- In 2021, 26.4 million sq. ft. (22.8% increase)
- In 2022, 28.1 million sq. ft. (6.4% increase)
- In 2023, 31.9 million sq. ft. (13.5% increase)
- In 2024, 43 million sq. ft. (34.8% increase; 47 mil. sq. ft. in the application pipeline)

This steady increase in data center square footage is the result of the growth of our society's dependence on social media, "smart" device technology, personal computing and communication, and a host of other data-dependent advancements our society has come to depend on. And now, Artificial Intelligence (AI) is expected to increase the demand for data exponentially again. A January 2024 article by a major data center realty company suggests consumers and businesses will generate twice as much data in the next five years as was generated in the previous ten.[30] That's a statement with staggering implications. The article provides a stark prediction of the speed and magnitude of growth in the data center sector and also illustrates convergence of the three conflicting growth trends:

> "With the growing demands of AI, data center storage capacity is expected to grow from 10.1 zettabytes (ZB) in 2023 to 21.0 ZB in 2027, for a five-year compound annual growth rate of 18.5%[1]. Not only will this increased storage generate a need for more data centers, but generative AI's greater energy requirements – ranging from 300 to 500+ megawatts – will also require more energy efficient designs and locations. The need for more power will require data center operators to increase efficiency and work with local governments to find sustainable energy sources to support data center needs."[31]

Increasing Demand for Power

Growth in data center power demand in Virginia is increasing at a rate far exceeding Dominion Energy's capacity to provide it. A January 2024 Data Center Dynamics article projected data center power consumption will double by 2030.[32] This trend is magnified in Loudoun County because of our unique data center load. In a May 2, 2024 article, Bloomberg reports that Northern Virginia data center developers are now asking Dominion Energy for the energy equivalent of several nuclear reactors' output. In a recent quarterly earnings call, Dominion Energy's CEO Bob Blue stated that Dominion Energy is now receiving requests from data center

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[30] Steele, Kimberly. "Growth of AI creates unprecedented demand for global data centers." Jones Lang LaSalle IP, Inc. January 31, 2024. https://www.us.jll.com/en/newsroom/growth-of-ai-creates-unprecedented-demand-for-global-data-centers

[31] Ibid.

[32] Gooding, Mathew. "Newmark: US Power Consumption to Double by 2030." Data Center Dynamics. January 15, 2024. https://www.datacenterdynamics.com/en/news/us-data-center-power-consumption/#:~:text=While%20the%20hyperscalers%20typically%20need,up%20from%2017GW%20in%202022.

campus developers for "several gigawatts" of power.[33] This is a staggering increase in data center power demand in just a few years. Below is a summarized timeline of actual power usage in Loudoun County since 2018, the year we first reached approximately 1 Gw (1,000 Mw; a megawatt is one million watts) of power consumption in "Data Center Alley."[34]

- 2018: 1 Gw (chart interpolation)
- 2019: 1.5 Gw (chart interpolation)
- 2020: 1.6 Gw (chart interpolation)
- 2021: 2.0 Gw (chart interpolation)
- 2022: 2.8 Gw (actual)[35]
- 2023: 3.4 Gw (forecast)[36](This is a 240% increase, or 3.4X increase, in five years.)

If we assume a linear growth rate over the next five years similar to the previous five years, Loudoun County will demand 11.56 Gw of power by 2028. As mentioned earlier, an independently commissioned Kimley-Horn report has confirmed this estimate almost exactly, estimating 11.59 Gw of power will be needed by 2028.[3] But Artificial Intelligence (AI) is raising power demand much faster than a simple linear rate. As the use of AI grows, the need for more computing power within existing data centers means the demand for power within those walls is going to increase commensurately. According to an article in Data Center Knowledge, the average data rack power usage in a typical hyperscale data center today is 6-12 Kw. Because of their much higher reliance on Graphics Processing Units (GPUs) within the data rack, AI applications are going to increase that data rack power consumption to 40-60 Kw.[37] An October, 2024 McKinsey & Company report states the new Nvidia GB200 GPU AI chip could increase data rack density to 120 Kw per rack, a tenfold increase in the power required per rack.[10] This increase will affect both new data centers and existing data centers as well as both hyperscale/enterprise data centers and colocation data centers. This means that, using a base year of 2023 and 3.4 Gw of power consumption, by 2028, Loudoun County could easily require as much as 20-30 Gw of power due to AI demands. Put more bluntly, it is unlikely PJM and Dominion are going to be able to build enough grid infrastructure to meet Loudoun County's future energy needs. Moreover, we could stop building data centers today, and that would not stop a significant increase in existing data center demand for more power in the near to mid-term. As noted previously, the JLARC data center study arrived at the same conclusion.[2]

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[33] Saul, Josh. "Data Centers Now Need a Reactor's Worth of Power, Dominion Says." Bloomberg. May 2, 2024. https://www.bloomberg.com/news/articles/2024-05-02/data-centers-now-need-a-reactor-s-worth-of-power-dominion-says?utm_source=website&utm_medium=share&utm_campaign=email

[34] Abdulsalam, Sami. "Dominion Northern Virginia Area Immediate Need." Slide #2, "Data Center Alley Area Load Growth and Transmission System." Slide #3, "Dominion 2022 Load Forecast." Data interpolated from data center load forecast line (orange). PJM. July 12, 2022. https://www.pjm.com/-/media/committees-groups/committees/teac/2022/20220712/item-08---dominion-northern-virginia---immediate-need.ashx

[35] Dominion Energy. "Dominion Energy 2023 15-Year Data Center Plan." Slide #2. https://sdc.pjm.com/-/media/committees-groups/subcommittees/las/2023/20231018/20231018-item-03a---dominion-large-load-request.ashx

[36] Ibid.

[37] Kleyman, Bill. "Data Center Rack Density Has Doubled. And It's Still Not Enough." Data Center Knowledge, April 15, 2024. https://www.datacenterknowledge.com/cooling/data-center-rack-density-has-doubled-and-it-s-still-not-enough

A disturbing, unintended consequence of this growth has also emerged. A recent New York Times article addressed an industry trend to slow or shelve plans to decommission legacy fossil fuel power plants in an effort to meet demand. According to this article, by 2030, power demands by the nation's data centers could triple.[38] A February 2023 report by PJM shows the RTO planning to retire about 40 Gw of old power plants by 2030 while expecting about 11 Gw of new orders by that same date.[39] Obviously much higher demands for power could significantly alter this plan. These trends have very serious implications for our efforts to meet our climate change goals. In 2023, global temperatures increased 1.3 degrees centigrade.[40] Six global tipping points will be reached at a 1.5-degree rise.[41] A 2024 U.N. report predicts 2024 will be the hottest year in history.[42]

It is fair here to note the data center community is pursuing very aggressive sustainability goals, goals that are far more aggressive than many other business enterprises. Unfortunately, by relying on power provided exclusively by the utility companies, their lofty sustainability goals are going to be negatively impacted if the utility companies continue this trend of postponing or even reversing the decommissioning of fossil-fuel power plants.

Recognizing this rapid growth in demand, and mindful of the legal requirement to provide power to all consumers in a regulated state, PJM, in the summer of 2022, advised Dominion Energy it would need to significantly increase its transmission infrastructure to handle the projected load in Loudoun County and to specifically address the urgent power constraints in "Data Center Alley." First, they needed to get power from the existing Loudoun north/south main transmission line to "Data Center Alley" to relieve the constraint. Then, they needed to bring additional power into Loudoun County from the north and south and connect it to the main north/south line to address the rapid growth in aggregate Loudoun County power demand.

To tackle the first and more urgent challenge, Dominion announced it would build a closed loop connecting the north/south main transmission lines to "Data Center Alley" in eastern Loudoun. Dominion is now planning a new 500/230 Kv line from the Wishing Star to Mars substations in the southern part of the county and a 500/230 Kv line between the Aspen and Golden substations in the northern part of the county. The loop will be completed with the addition of a third 500/230 Kv line connecting the Golden substation in the northern portion of the loop to the Mars substation in the southern part of the loop. Again, these three lines don't add new power from outside the county, and they won't be built until 2028 at the earliest. They do not, by

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[38] Plumer, Brad and Popovich, Nadja. "A New Surge in Power Use is Threatening U.S. Climate Goals." The New York Times. March 14, 2024. https://www.nytimes.com/interactive/2024/03/13/climate/electric-power-climate-change.html

[39] PJM. "Energy Transition in PJM: Resource Retirements, Replacements & Risks." PJM. February 24, 2023. https://www.pjm.com/-/media/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx

[40] Harvey, Chelsea; Weiss, Zia and E&E News. "The State of the Planet in 10 Numbers." Scientific American. November 20, 2023. https://www.scientificamerican.com/article/the-state-of-the-planet-in-10-numbers/

[41] Singh, Inayat. "At current rates, 5 key climate tipping points are already possible, new study warns." CBC. Sept. 11, 2022. "Climate Tipping Elements" graphic. https://www.cbc.ca/news/science/tipping-point-climate-change-paris-agreement-1.6577630

[42] UN News. "2024 to become the hottest year on record." United Nations. December 30, 2024. https://news.un.org/en/story/2024/12/1158621

themselves, address the enormous future increase in demand projections expected for all of Loudoun County as a result of our high concentration of data centers.

To address this future demand and bring more power into the county, in December 2023 PJM accepted a proposal from NextEra, a Florida-based power company, to run a new 500 Kv line from an existing east/west line in West Virginia south through the heartland of western Loudoun County agriculture to connect to the north/south main transmission line. This proposal encountered fierce resistance from Loudoun citizenry, the BOS and environmental groups. As a result, in August 2024, PJM announced it would route the new line through the existing north/south right-of-way.[43] Dominion later announced it would build a second 500 Kv line in the existing right-of-way and is also planning to run a new 500 Kv line from the south to connect to the main Loudoun County line. These three new lines will increase the aggregate size of the Loudoun power grid.

The table below provides an inventory of the main transmission lines of the current Loudoun grid and then adds the three new lines to the mix. To understand the table, one must understand how much power each type of line can deliver. According to several sources, as a rough planning factor, depending on distance, a 500 Kv line can normally deliver between 1.0-1.5 Gw of power and a 230 Kv line can deliver about 500 Mw of power.[44] However, I've revised these power estimates based on recent conversations with Dominion Energy. According to their team, they've increased the amperage to 5,000 amps on 500 Kv lines and 4,000 amps on 230 Kv lines. Watts=Volts x Amps, so, by increasing the amps on these lines, more power can be delivered. With the increased amps, a 500 Kv line can now deliver an average load of about 2.1 Gw, and a 230 Kv line can deliver about 750 Mw. The table below shows the estimated power now being delivered into Loudoun County and projected with the new lines:

Current Lines Bringing Power Into Loudoun County:[45]

- From the north: (1) 500 Kv line = 2.1 Gw; (2) 230 Kv lines = 1.5 Gw
- From the south: (2) 500 Kv lines = 4.2 Gw; (2) 230 Kv lines = 1.5 Gw
- Total currently coming into Loudoun = **9.3 Gw**, but not to "Data Center Alley"

Planned new lines by 2028 at the earliest:[46]

- Aspen/Golden (north E/W line; planned completion date June 1, 2028), Wishing Star/Mars (south E/W line), Golden/Mars line (eastern N/S connector for Aspen/Golden and Wishing Star/Mars). These constitute the closed loop to "Data Center Alley" but add no new power to the Loudoun grid
- New power from the north, Mid Atlantic Resiliency Link (MARL): (1) 500 Kv line = 2.1 Gw; Doubs/Aspen (1) 500 Kv line = 2.1 Gw

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[43] Ferguson, Sheila. "Western Loudoun Power Line." Loudoun Wildlife Conservancy. Aug. 28, 2024. https://loudounwildlife.org/2024/08/western-loudoun-power-line/

[44] Power Engineers. "500 kV AC/DC Extra-High Voltage Transmission Project." Power Engineers. 2024. https://www.powereng.com/library/500-kv-acdc-extra-high-voltage-transmission-project

[45] Open Infrastructure Map. https://openinframap.org/#13.17/39.07107/-77.5192

[46] Tesfa, Nebiat. "PJM Regional Transmission Expansion Planning (RTEP) Process." PJM. December 8, 2023. Slide presentation, slide 17. https://www.pjm.com/-/media/committees-groups/stakeholder-meetings/ipsac/2023/20231208/20231208-item-02-1-pjm-regional-transmission-expansion-planning-process.ashx

- New power from the south, Morrisville-Wishing Star line: (1) 500 Kv line = 2.1 Gw
- Total new Loudoun grid power planned: **15.6 Gw** (existing 9.3 Gw + 6.3 Gw new lines)

Yet as we saw earlier, with the advent of AI, Loudoun could easily see its power demand rise to as much as 20-30 Gw by 2028, far more than will be available through the above buildout schedule. While Dominion and PJM will likely assert this demand can be met by more infrastructure construction, I believe the data indicates these new transmission lines will not keep pace with the rapid increase in future demand in Loudoun County.

Nor have we addressed the 30 million sq. ft. of data centers recently approved in Prince William County immediately adjacent to Loudoun County's southern border. If we assume a 1 million sq. ft. data center will request from Dominion about 150 Mw of power, the Prince William County campus will require about 4.5 Gw of power. And the lines delivering this added power will almost certainly come through Loudoun County.

Increasing Community Resistance

Prior to 2022, the proliferation of data centers in Loudoun County was largely confined to land parcels intended for data center construction, and they were largely accepted by our citizens. The BOS received occasional complaints about the loss of green space, the visual impact of massive data center buildings, the noise these facilities made both with cooling fans and backup diesel generators, and the environmental impact associated with extremely large power consumption, but this pushback was largely generalized. Our citizens also understood and accepted that Loudoun County data centers kept our real property tax rates about 25% lower than our Northern Virginia neighboring jurisdictions.

But in 2022, the Board of Supervisors began sensing real community resistance to more data centers in Loudoun County. At about that time, data center companies had started running out of industrial land to build on and had begun to exercise their "by right" options to build on parcels they had bought years earlier zoned for office parks, research and development parks and industrial parks, many of which are located near residential neighborhoods. This began to create real tensions between communities, Supervisors and the data center sector. For example, in 2019, there were no data centers in Ashburn District (the community of Ashburn actually encompasses two districts: Ashburn and Broad Run). As of this date, four hyperscale data centers are being planned or constructed in the Ashburn district, all "by right" and all across the street from residential communities.

Community resistance increased dramatically when in 2023, Dominion Energy announced it would need to construct four new overhead transmission lines to relieve the power constraints in the county and specifically in "Data Center Alley." The previously mentioned Aspen/Golden line would run along Rte. 7, a heretofore unthinkable routing Loudoun County Boards for the previous 25 years had sworn would never happen. Earlier in 2023, Dominion Energy had already announced development of the Wishing Star/Mars line in southern Loudoun, but that line would run through a flood plain away from houses and drew little community response. Then a new line would connect the new Golden substation in the north to the new Mars substation in the south to close the loop to "Data Center Alley." Finally, a fourth line, a so-called "green field" transmission line—the previously mentioned MARL line—would run through western Loudoun

County between the Potomac and Leesburg cutting across active farmlands, wetlands, tree conservation areas and through the historic village of Waterford. The public outcry was both immediate and predictable. As a result of that outcry, communities along Route 7 launched a year-long resistance movement to force Dominion to bury the 500/230 Kv line along Route 7, and a western coalition of citizens successfully pressured PJM to relocate the route of the new MARL line into the existing right-of-way coming into the county from Maryland. In October 2024, the State Corporation Commission announced it would not require Dominion to bury the Aspen/Golden 500/230 Kv line along Route 7.

Thus, between 2022-2024, community resistance to more data centers, more overhead transmission lines, more substations and more consumption of fossil fuel energy reached unprecedented levels and began to have a major impact on BOS decision-making. As discussed earlier, in March of 2024, for the first time, the BOS voted 5-4 to deny a major data center application to build a 2.9 million sq. ft. data center. The applicant resubmitted the application scaled down to 1.3 million sq. ft., the "by right" permitted size, and, to their credit, retained a substantial environmental package in the application. That scaled down application passed by a vote of 6-3. But that application marked the first time a major, new data center application was denied by the BOS.

The "by right" growth of data center construction since 2022 in Loudoun County has proven to be particularly problematic for the BOS. As a result, in late 2023, the BOS took steps to require BOS review of some of these types of parcels and will likely require oversight of all data center construction in the near future. But since 2022, "by right" construction has proliferated as land specifically intended for data centers became scarce.

This trend came to an abrupt end on March 18, 2025 when the Board of Supervisors, in a 7-2 bipartisan vote, ended all "by right" data center development in Loudoun County. With the exception of 22 data centers "grandfathered" with the vote, all new data center development in Loudoun County must receive Board of Supervisors approval.[21]

To be clear, no one is to blame for this confluence of these three conflicting trends. The speed with which the entire data center environment has evolved is staggering, and each of the stakeholders has, heretofore and understandably, responded to that change largely within their respective silos and process paradigms.

BOS Focus. From the BOS point of view, prior Loudoun County Boards and the Department of Economic Development saw an opportunity to get in on the ground floor of revolutionary technology likely to bring enormous economic growth to our community. It would enable us for almost 20 years to lower taxes even though our population growth was the highest in Virginia for that entire period.

Data Center Focus. Similarly, the data center community was and is simply responding to revolutionary changes in the market and historic demand for data.

Utility Focus. And that demand for data has translated into an insatiable demand for power. The energy utilities are required by law to provide sufficient power to their customers even if demand for that power is increasing at an unprecedented rate. Asked at public meetings, including Board of Supervisors meetings, if they will be able to meet growing demand, they always assure their audiences they will—because the law requires them to.

Facing the New Realities

However we got here, we're here now. Going forward, it is incumbent upon all stakeholders—the data center community, Dominion Energy/PJM and the Board of Supervisors—to develop a strategy based on the new realities we face, a strategy that protects the quality of life of every Loudoun County citizen and reflects the tough choices we are clearly going to have to make. Based on the facts thus far presented, I believe the following are some obvious new realities we, as a Board, must address:

1. **In the author's opinion, as evidenced by PJM documents citing load violations existing since 2022 and Dominion's establishment of a "constrained area," the Loudoun County electric grid is now significantly oversubscribed, and planned new powerline construction will likely lag behind rapidly increasing power demand for years to come. This is conclusion was also reached by the JLARC study released in December 2024.**

   To be clear, "oversubscribed" does not mean the power grid is insecure; it means large customers with existing Electric Service Agreements (ESAs) will be power constrained—likely for years—by Dominion Energy until sufficient grid infrastructure is built to handle the contracted load. In its 2024 Integrated Resource Plan,[47] Dominion Energy illustrates how it constrains customer load below the contracted ESA amount for as much as seven years. In a letter to at least one large customer on August 22, 2024, a senior Dominion official confirmed this by stating, "However, the size and quantity of large scale requests requiring supporting backbone expansion results in an extension of planning analysis and project execution lead times. Therefore, we expect the typical duration of the planning and execution process for large (greater than 100 MW) DP [Delivery Point] requests within the Dominion Energy transmission zone (DOM Zone) to increase by 12 to 36 months [from the current 3-4 years to 4-7 years]."[48]

2. **Halting new data center construction will not solve the problem.**

   Even if all new data center construction is halted immediately, the oversubscription of the power grid in Loudoun County will continue as our dependence on AI—requiring up to a tenfold increase in processing power within existing data centers—proliferates throughout the world.

3. **"Data Center Alley" rapidly rising power demand will slow the retirement of fossil fuel power plants throughout the PJM/Dominion service area.**

   This is the only way PJM/Dominion can meet the increasing demand, because the majority of power being delivered to Loudoun County data centers is derived from fossil fuels. This could be slowed somewhat if PJM/Dominion accelerate their conversion to carbon-net-zero fuels in response to aggressive data center programs demanding the utilities do just that, but the net result of these competing trends is difficult to predict.

4. **Community resistance is going to rapidly increase.**

   Thus far proposed are the new 500 Kv MARL line entering Loudoun from the north along the existing north/south corridor, a second 500 Kv line from Doubs to Aspen in the north, a new

[47] "Virginia Electric and Power Company's Report of Its 2024 Integrated Resource Plan." Case No. PUR-2024-00184; Docket No. E-100, Sub 204. Pg. 14

[48] August 22, 2024 email from Dominion Energy official to a large Delivery Point customer. Available upon request.

Morrisville/Wishing Star 500 Kv line coming into Loudoun from the south, and the closed loop to "data center alley" comprising the new Aspen/Golden line proposed along Rte. 7 in the north, the new line from Golden-Mars through "Data Center Alley," and the Wishing Star/Mars line closing the loop in the south. But as previously stated, this loop adds no new power, and these won't be enough. A second line down Rte. 7 is probably next up. After that, Dominion will have likely used the last available routing to "Data Center Alley" that won't require using eminent domain. The next available routes along the W+OD Trail or the Dulles Greenway will require the use of eminent domain to obtain the necessary right of way. Community resistance will build accordingly. If incumbent elected officials are then voted out of office, they will be replaced by other elected officials with a mandate to vehemently oppose the data center and utility sectors.

5. **Burying 500 Kv transmission lines delivering AC power is possible but challenging and expensive; burying 500 Kv High Voltage DC (HVDC) lines is much easier and more efficient, however HVDC lines are most appropriate for very long distances.**

   As stated earlier, in October 2024, the Virginia State Corporation Commission denied the citizens' petition to underground the new 500/230Kv line from Aspen to Golden substations. Undergrounding a 500 Kv AC line has only been done once in the U.S. In 2013, an underground 500 Kv line was constructed traversing 3.7 miles through Chino Hills, CA. The project took three years and cost $224 million (not including the seven years of court battles).[49] Underground lines transmitting AC power must be insulated, usually with oil, and buried in a concrete tunnel, require much higher power transmission to deliver the same energy due to energy losses underground, are much harder and take longer to repair, and are not practical over long distances.[50] Undergrounding HVDC is now a viable alternative, loses very little power when buried, is used in many locations around the world and accepts renewable energy additions to the grid more easily.[42] While HVDC generally only makes sense for transmission over very long distances, the unique circumstances in Loudoun County, with its very high concentration of data centers within a relatively small geographic area, may offer an opportunity to develop a separate HVDC regional grid for the exclusive use of Loudoun County data centers. This would offer two, major advantages: 1) it would create an entirely separate grid for data centers enabling a separate Dominion billing structure for data center users exclusive of residential and other commercial users, and 2) because HVDC is a more efficient means of transmitting carbon net-zero power, it would facilitate the transmission of carbon net-zero power (solar, wind, etc.) from numerous sources directly to "data center alley"

6. **Solar and wind are not viable alternatives for Loudoun County data centers.**

   a. **Solar.** The average solar panel has a capacity factor (explained below) of about 23%. That means, due to clouds, darkness and other external factors, solar panels only deliver about 23 percent of their peak capacity in a year. It requires about 10 acres of

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[49] Nisperos, Neil. "Edison about to flip the switch on controversial power line project through Chino Hills." Daily Bulletin. October 30, 2016. https://www.dailybulletin.com/2016/10/30/edison-about-to-flip-the-switch-on-controversial-power-line-project-through-chino-hills/

[50] XcelEnergy. "Overhead vs. undergrounding. Information about burying high-voltage transmission lines." XcelEnergy Information Sheet. 2021. https://www.transmission.xcelenergy.com/staticfiles/microsites/Transmission/Files/PDF/Projects/CO/Avery/Transmission-CO-Avery-Substation-Overhead-Vs-Underground-Info-Sheet.pdf

land to generate 1 Mw of power.[51] Loudoun County has about 200 data centers that used about 3.4 Gw of power in 2023. That usage level would require 34,000 acres of solar panels. If power demand in Loudoun County for the next five years grows at the same rate as the previous five years (this does not account for AI growth), the county will be using 11.56 Gw of power in 2028. That would require 115,600 acres of solar panels. The entire landmass of Loudoun County is about 333,000 acres.

b. **Wind.** As an illustrative, Vineyard Wind, a 62-turbine wind farm being built off the coast of Martha's Vineyard, will generate 806 Mw of electricity when complete.[52] At completion, this offshore wind farm will generate enough power to power 400,000 homes in the local area. It would meet the power needs of about 10 of Loudoun County's 200 data centers.

7. **The 135-yr. old paradigm of power generated by large, remote power plants and transmitted across hundreds of miles of transmission lines will no longer work for Loudoun County's globally unique needs.**

   Given the above power demand projections and the time required to build new power infrastructure, it seems highly unlikely our traditional approach of delivering power to a consumer market as large and growing as Loudoun County can safely and effectively serve our needs.

Only Three Possible Scenarios Exist to Reduce or Stabilize Future Data Center Power Demand

If, as this paper and the JLARC study predict, the power grid infrastructure in Loudoun County—even with its planned expansion—will be insufficient to meet the future energy demand of the county's data center market, there are only three possible future scenarios by which that demand can be stabilized to manageable levels:

Scenario #1: Government-Imposed Energy Use Constraints. In this scenario, the Commonwealth of Virginia, the power utilities or both artificially constrain the energy consumption of high-energy consumers to ensure grid stabilization for all Virginia energy consumers. Such constraints are already in place in Loudoun County and are likely to remain in place for the foreseeable future. As stated earlier, Dominion Energy has already extended the planning and execution time for delivering requested power to large consumers from 3-4 years to 4-7 years. In the author's opinion, this extended delay for full-power access will likely only increase. The JLARC study tacitly acknowledges this trend in its recommendation #2:

> "The General Assembly my wish to consider amending the Code of Virginia to clarify that electric utilities have the authority to delay, but not deny, service to customers

[51] Arthur, Luke. "Understanding Solar Farms." Simple Solar. May 3, 2024. https://getsimplesolar.com/how-many-acres-solar-panels-produce-1-megawatt/#:~:text=To%20make%20one%20megawatt%20(MW,they%27re%20supposed%20to%20make.

[52] Vineyard Wind. "Avangrid, CIP Announce First Power from Nation-Leading Vineyard Wind 1 Project." Vineyard Wind. January 3, 2024. https://www.vineyardwind.com/press-releases/2024/1/3/cip-avangrid-announce-first-power-from-nation-leading-vineyard-wind-1-project

when the addition of customer load cannot be supported by the transmission system or available generation capacity. (Chapter 3)"[53]

Like many aspects of the Loudoun County data center environment, I believe these de facto power constraints are a harbinger of what's to come globally for the data center market. We are the "canary in the mine." Data center power constraints were hardly mentioned in large data center conferences I attended in 2023. Now, they are a key topic in virtually every major data center conversation. Artificial caps on available power for data centers will likely become the norm as utilities struggle to achieve their core mission mandate, grid resiliency for all customers. This reality establishes the foundational argument for two subsequent market evolutions: 1) continuing technological advancements requiring less power within data centers, and 2) the development of microgrids to reduce data center dependency on the grid.

Scenario #2: Technological Breakthrough. Technological breakthroughs are now on the near horizon that are likely to significantly reduce the power needed by AI and cloud-based computing. Such developments will initially reduce strains on the power grid and give the power utilities time to adjust to meet the growing infrastructure needs of the industry. For example, a July, 2024 article in Windows Central discusses the newly emerging chip technology called computational random-access memory (CRAM) that would reduce generative AI's power consumption by 1000-fold potentially achieving a 2,500 percent energy savings.[54] Note: this scenario could lead to significant stranded costs (discussed below). As discussed below, such technological breakthroughs would likely be iterative and provide only temporary relief.

Scenario #3: Industry Conversion to Onsite Power. Faced with exponential market demand and possessed with almost unlimited resources to meet that demand, the data center industry will likely develop the capacity to generate onsite power through microgrids for its operations and, in so doing, significantly reduce its reliance on the regional power grid. Such developments could eventually stabilize the grid by allowing an industry-wide, demand response system to develop. The JLARC study specifically recommends a change to state code requiring data centers to participate in demand response systems that would enable data centers to shift their loads on the grid to stabilize grid resiliency.[55] This would better enable the power utilities to meet the more predictable infrastructure needs of the industry. This evolution has already begun in Loudoun County (see below). Note: this scenario could lead to significant stranded costs (see below).

Likely Future: All Three Scenarios Occur Simultaneously and Energy Demand Still Grows

The three scenarios will likely occur simultaneously but to different degrees based upon market conditions. The utilities have already begun delaying additions of large loads to the grid, and the

[53] Joint Legislative and Audit Review Commission. "Data Centers in Virginia, Commission Draft." Report to the Governor and the General Assembly of Virginia. December 9, 2024, pg. xi. https://jlarc.virginia.gov/pdfs/reports/Rpt598-2.pdf

[54] Okemwa, Kevin. "This breakthrough tech could solve Microsoft's AI power consumption woes and is 1,000x more energy-efficient." Windows Central. July 29, 2024. https://www.windowscentral.com/software-apps/this-breakthrough-tech-could-solve-microsofts-ai-power-consumption-woes-and-is-1000x-more-energy-efficient

[55] Joint Legislative Audit Review Commission. "Data Centers in Virginia, 2024: Report to the Governor and General Assembly of Virginia." Pg. 38-40. https://jlarc.virginia.gov/pdfs/reports/Rpt598-2.pdf

JLARC study recommends codifying this in state code to allow delays for limited generation or transmission capacity (scenario #1). Meanwhile, new GPU (AI) chips are emerging that use significantly less power (scenario #2), and we already have examples of data centers in Loudoun County building advanced microgrids to reduce their dependence on grid power (scenario #3). All three scenarios will continue to develop for the foreseeable future.

But even as these three scenarios evolve in varying degrees and temporarily reduce demand on the power grid, data centers will adjust, increase data processing density to fill the space created by the efficiencies, and once again operate at maximum capacity using all the power available to them. The JLARC study acknowledges this critical point. They quote one data center representative who succinctly captures the phenomenon known as Jevon's Paradox[56]:

> "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.'"[57]

And so, in its continuing quest for more power, the data center industry will evolve in order to meet market demand. The utilities will begin to artificially cap that demand, as they eventually must do to preserve grid resiliency (scenario #1), the data industry will produce ever more energy-efficient chips (scenario #2), and data centers will strive to become less reliant on grid power by developing microgrid, onsite/communal/distributed energy baseload, backup and stored power (scenario #3).

I believe the development of onsite microgrid power will reshape the national power grid going forward, though due to geographic constraints and our very dense data center market, its applicability in Loudoun County will be limited. As access to grid power becomes more and more constrained and chip efficiencies constantly evolve, a comprehensive demand response system will become the core of a regional and even nationwide distributed energy system. This is the heart of the new energy paradigm. Local, regional and national demand response systems will enable onsite power sources to stabilize hourly grid operations.

Assessment of the 2024 JLARC Data Center Study[58]

The 2024 JLARC study concurs with the basic premise of this white paper, namely that it will be either "very difficult" or "difficult" to build sufficient infrastructure to meet the projected energy demands of the data center industry. Unfortunately, the study's underlying premise and all its recommendations and policy options represent a tacit acceptance of scenario #1 above as the only possible way to reduce the energy demands of the data center sector.

Of the study's eight recommendations, six deal with data center siting or locally imposed performance standards to improve energy efficiencies. Yet the study plainly states improved performance measures would have a limited impact on decreasing data center sector energy demand:

> "Improving data center efficiency makes better use of energy but is likely to have only a marginal impact on demand."[59]

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[56] Wikepedia. "Jevon's Paradox." https://en.wikipedia.org/wiki/Jevons_paradox

[57] Ibid, pg. 41.

[58] Joint Legislative Audit Review Commission. "Data Centers in Virginia, 2024: Report to the Governor and General Assembly of Virginia." https://jlarc.virginia.gov/pdfs/reports/Rpt598-2.pdf

[59] Ibid, pg. 40

One recommendation suggests allowing utilities to delay but not deny data center construction to protect the grid. This is already occurring; the change would simply legally codify the practice. It also doesn't reduce increasing energy demand.

Finally, the one remaining recommendation addresses stranded costs (see below).

Of the study's ten policy options, eight suggest the General Assembly should use the state sales tax exemption as an incentive to encourage data centers to use less energy. The study acknowledges such actions could have significant, unintended consequences on the data center sector. In fact, this option would have a devastating impact on Loudoun County's economy:

> "If the General Assembly wishes to slow down the data center industry's growth in Virginia…it could allow the sales tax exemption to expire…. 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.[60]

In short, the entire study essentially recommends two broad approaches: 1) local governments should use performance standards to improve energy efficiency, measures it acknowledges will have only a limited impact on reducing sector energy consumption, or 2) state government should use the state sales tax exemption to incentivize greater energy efficiency, precisely the type of artificial government intervention described in scenario #1, to reduce sector energy demand. Very brief mention is made of either technological breakthroughs (scenario #2) or onsite/communal power generation through microgrids (scenario #3) as ways to significantly reducing demands on the regional power grid.

Stranded Costs

As mentioned above, scenarios #2 and #3 could easily result in what the utility industry refers to as "stranded costs." Stranded costs occur when a regulated utility, required by law to meet the energy demand of its customers, is forced to build new infrastructure to meet predicted, future demand for energy, and, at some time during the infrastructure buildout process, that predicted demand is not realized. The regulated utility has incurred the costs of the buildout, but the consumer demand no longer justifies those costs. The utility must then absorb the costs or pass them on to residential and small commercial customers.

Normally, this is not a major challenge as historically, energy demand has been both relatively stable and predictable over time. For example, PJM charts illustrate that energy consumption between 2007-2017 in the Dominion service area decreased slightly, presumably due to realized efficiencies.[6] In such a stable market, predicting future energy demand, while a complex process, is relatively straightforward.

Since 2022, however, energy demand in Northern Virginia and particularly in Loudoun County, has increased rapidly and exponentially making it extremely difficult to accurately predict future power demand. Despite the turbulence in the marketplace, because Virginia is a regulated state, the investor-owned utilities must plan to build that infrastructure even though the predicted demand may never be realized.

Such is the case with scenarios #2 and #3. If PJM and Dominion Energy build billions of dollars of new generation and transmission infrastructure to meet what at present appears to be enormous

[60] Ibid, pg. 88-89.

future demand, and data centers subsequently find a way to process data using far less energy or move heavily towards microgrids and onsite power generation, the costs to the utility companies of that new infrastructure become "stranded" because demand for grid energy has dropped The Virginia State Corporation Commission specifically addressed the issue of stranded costs at its December 16, 2024 technical conference.[61]

One way to insulate utility companies from stranded costs is to allow the utilities to charge major energy consumers an upfront tariff to absorb the cost of the infrastructure development should demand suddenly drop. This tool was used in May, 2024, when AEP Ohio filed a plan with the Public Utilities Commission of Ohio to require data centers to commit to a 10-year plan to make monthly payments equal to 90% of the cost of the energy they said they needed even if they ultimately didn't use that much energy.[62] It is highly likely the Virginia State Corporation Commission is considering just such a tariff structure.

Strategies for the Future

Clearly there is no "silver bullet" to meet these complex challenges, especially in Loudoun County. Any approach will require the thoughtful integration of a range of options to meet the growing demand for more power from the data center sector in ways that do not drastically and negatively impact the quality of life of our residents or the stability of our economy. Obviously whatever strategies are developed will be policy decisions for the Board of Supervisors to make by a majority vote.

Offered below are some suggested options by the author and as such are entirely subjective and debatable. They will likely generate considerable discussion, hopefully based upon the factual foundation thus far provided. It seems clear however that, over the next ten years, unless the data center industry undergoes a major technological transformation enabling it to significantly reduce its power consumption, the Board of Supervisors will likely be faced with a repeating binary choice:

1) Accept the traditional paradigm of AC power generated at massive, remote power plants, transmitted over hundreds of miles of overhead transmission lines, then delivered to customers, including Loudoun's data centers with their historic demand for power. The likely result will be a significant threat to Loudoun County's power grid resiliency and a lattice of overhead transmission lines throughout Loudoun County, or;

2) Reject that 135-yr. old power infrastructure paradigm and facilitate the data center sector's market-driven move to a radically new power delivery model and market environment. Large power consumers will find ways to reduce their power needs while simultaneously generating low or carbon-net-zero power onsite or locally to enable them to participate in a demand response system and deliver surplus power onto the regional power grid as part of a nationwide distributed energy network. This is precisely the model the Department of Defense (DoD) has adopted. In a recent update to Title 10,

[61] Pamploni, Hanna. "State Leaders Grapple with Infrastructure, Generation Costs." Loudoun Times Mirror. December 31, 2024. https://www.loudounnow.com/news/state-leaders-grapple-with-infrastructure-generation-costs/article_ebb47fac-c7b1-11ef-808d-df584e150bf9.html?utm_source=loudounnow.com&utm_campaign=%2Fnewsletter%2Foptimize%2Fdaily-headlines%2F%3F-dc%3D1735676910&utm_medium=email&utm_content=read%20more

[62] AEP Ohio. "AEP Ohio Files Plan to Secure Grid Resources for Data Centers, Protect Residential Customers." AEP Ohio news release, May 13, 2024. https://www.aepohio.com/company/news/view?releaseID=9539

DoD has directed all Services to make select military bases and critical installations energy independent and resilient through the use of onsite, sustainable energy generation, including long-term energy storage and nuclear and hydrogen power generation. This program is now being implemented worldwide.[63]

Here, then, are some possible strategies for consideration:

1. **PJM/Dominion Energy: Increase Transmission Capacity.**

   a. **Near Term: Reconductoring.**

   The 2025 session of the Virginia General Assembly passed a law requiring all new transmission lines in Virginia to use advanced conductors (transmission lines). Dominion has advised they now plan to replace their existing lines with advanced conductors and use advanced conductors for all new lines in Loudoun County. They will use Aluminum Conductor Steel Supported (ACSS) line. Depending on other upgrades, this will cost about 35% more than the cost of the current type of conductor in use for the past 100 years. ACSS conductors can increase line capacity by 50-100%, are the cheapest of the new alternatives and are proven technology. This type of conductor has been in use since the 1970's but is still considered an "advanced conductor" option because of the capacity increase.

   While there are several other advanced reconductor options, the most common new alternative to ACSS is Aluminum Conductor Carbon Core (ACCC) conductors. Developed around 2003, this would also increase capacity by about 100%. It's a lighter line and delivers increased capacity, but is prone to breakage during installation, has had some recent, unforeseen challenges, has challenges in icing conditions and costs about three times more than ACSS conductors.[64]

   The newly reconductored lines would eventually be overtaken once again by rising demand, but, if combined with other measures, could be a valuable tool in building a new energy transmission paradigm.[65]

   b. **Long-Term: Create a High Voltage Direct Current (HVDC) Parallel Loudoun Power Grid**

   Another very theoretical option but one that may have unique advantages for Loudoun County involves creating an entirely separate High Voltage DC power grid for data centers in Loudoun County. This could start with a very limited pilot project within "data

[63] TITLE 10 / Subtitle A / PART IV / CHAPTER 173 / SUBCHAPTER I / § 2911. May 31, 2024. https://uscode.house.gov/view.xhtml?req=(title:10%20section:2911(b)%20edition:prelim)

[64] Idaho National Laboratory. "Advanced Conductor Scan Report." Idaho National Laboratory. Dec. 2023; revision April, 2024. https://inl.gov/content/uploads/2024/02/23-50856_R8_-AdvConductorszScan-Report.pdf

[65] Plumer, Brad. "The U.S. Urgently Needs a Bigger Grid. Here's a Fast Solution." The New York Times. April 9, 2024. https://www.nytimes.com/2024/04/09/climate/electric-grid-more-power.html

center alley." Data centers are beginning to look seriously at converting their entire internal operation to DC power, and it is likely several in Loudoun County already have.[66]

The National Renewable Energy Laboratory (NREL), a Department of Energy laboratory, is exploring the expanded use of HVDC transmission lines in more multiple connection environments.[67] Recent technological advances now make the use of HVDC transmission lines a real alternative to the present AC-power dependent U.S. power grid. HVDC transmission lines are currently used in many countries. An HVDC transmission line is far more efficient in transmitting high-voltage power across long distances, experiences much less power loss through transmission, can be buried underground much more easily and with little loss of power, and is much better suited to allowing a grid to accept power from renewable and onsite sources.[68]

What if PJM, Dominion Energy, the Commonwealth of Virginia and Loudoun County collaboratively proposed to DoE and NREL the creation of a national pilot project to create a separate HVDC power grid in Loudoun County specifically to deliver HVDC power directly to Loudoun County data centers, the highest concentration of data centers in the world? DoE could provide funding (likely several billion dollars) to build the six new lines already being planned for Loudoun County as advanced conductor, HVDC lines. Meanwhile, data centers could begin planning to fully convert to internal DC power by 2028, the projected completion date for some of the new lines. At completion of the pilot project, Loudoun County would have two separate power grids, an AC grid for residences and normal-sized commercial customers, and a DC grid exclusively for data centers.

This is obviously theoretical, but if PJM and Dominion must build these lines anyway, why not make the project a national pilot project and incorporate state-of-the-art technology throughout the pilot project? This would include using all advanced conductors to double line capacity and using largely buried HVDC transmission lines to distribute DC electricity directly to data centers.

The advantages of this admittedly bold concept would be significant:

1) The existing AC power grid in Loudoun County would immediately stabilize as data centers were moved off that grid;

2) A large infusion of DoE funding would relieve PJM and Dominion Energy of the burden of financing the currently planned infrastructure upgrades, a burden existing residential and commercial customers will undoubtedly have to bear;

3) Two separate grids would facilitate two separate billing systems for Dominion Energy, thereby relieving residential/small commercial customers from having to

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[66] Howard. "Direct Current (DC) Power: Is It the New Normal for Data Centers?" FS. June 1, 2022. https://community.fs.com/article/direct-current-dc-power-is-it-the-new-normal-for-data-centers.html

[67] NREL. "On the Road to Increased Transmission: High-Voltage Direct Current." NREL.gov. June 12, 2024. https://www.nrel.gov/news/program/2024/on-the-road-to-increased-transmission-high-voltage-direct-current.html

[68] Berthou, Andreas. "The Benefits of High-Voltage Direct Current (HVDC) Power." EE Power. October 19, 2020. https://eepower.com/technical-articles/the-difference-that-dc-makes/#

help pay the added infrastructure costs associated with the growing power consumption by the data centers;

4) A significant portion of the new HVDC power grid could be buried near sensitive areas;

5) The new HVDC grid would be much more adaptable to the incorporation of onsite data center microgrids with multiple DC power sources such as natural gas, battery backup, hydrogen fuel cells and distant solar/wind inputs.

2. **Loudoun County:**

   a. **Create Performance Standards Requiring New Data Centers to Conserve Energy and Develop Microgrids.** We must insist new data centers adhere to rigorous energy-conserving performance standards while incorporating essential microgrid elements into their campus designs enabling them to significantly lower their projected power load on the regional grid.

   b. **Create an Incentive/Disincentive Program to Encourage/Require Existing Data Centers to Operate More Sustainably and Reduce Community Impact.** While retrofitting existing data centers to incorporate microgrids may, at present, be impractical, steps can be taken to reduce emissions, reduce noise levels and improve viewsheds. It may also be possible in the near future to incorporate several microgrid elements on existing data center campuses.

   The planning objective for both new and existing data centers should be to demonstrate a commitment to the Loudoun County Board of Supervisors to reduce their load on the grid and their impact on the surrounding community over time.

   Loudoun County's highly dense data center environment is unique in the data center world today. This means we are literally on the frontier of a new digital age. The county's key stakeholders are now faced with a simple binary choice: lead, through innovation and imagination, or wait and react too little, too late to a rapidly expanding traditional power grid infrastructure inappropriate for Loudoun County's needs and unable to solve our unique demand challenges.

What is a Microgrid?

A microgrid generally consists of five elements: 1) a major power "load" or consumer such as a data center, 2) an onsite or nearby communal baseload power source (power delivered continuously to sustain normal, daily operations), 3) an optional backup power source to supplement the baseload power source during times of grid instability or to store excess power, and 4) connections to the utility power grid enabling upload of excess power or operation of the microgrid independently in "island" mode, and 5) a system to manage all elements of the microgrid and determine if, when and how the microgrid should interface with the regional power grid.[69]

If we accept the premise the traditional power grid infrastructure serving the nation, by itself, will ultimately not be able to meet the unprecedented aggregate nationwide increase in demand for power—and some may not accept that premise—then the only viable national-scale alternative is a distributed energy network. Such a distributed energy network would offer nationwide power grid

[69] NREL. "Microgrids." https://www.nrel.gov/grid/microgrids.html

resiliency and redundancy in much the same way information stored in “the cloud” is continuously available through any smart device and not susceptible to any single device failure.

A distributed energy network would comprise thousands of microgrids around the country continuously generating baseload power for their onsite customers, storing energy for periods of grid instability, and uploading excess energy to the national grid when available to increase grid resiliency. These microgrids could be as large as data-center scale microgrids generating hundreds of megawatts of power, smaller scale microgrids to provide backup power to large consumers or even tiny, point source microgrids such as individual electric vehicle charging stations whereby your personal vehicle, once fully charged, begins to discharge onto the local power grid.

The Challenges of Developing Microgrids in Loudoun County

Though the solution for the national power grid may be the development of a nationwide distributed energy network through microgrids, such a solution has limitations for widespread deployment in Loudoun County. While I believe the development of a nationwide distributed energy grid infrastructure is highly likely, such a model presents significant challenges in Loudoun County for one reason: land. Our 200+ data centers are packed into about 30 square miles of real estate in eastern Loudoun County, and “data center alley” is literally a zero-lot-line checkerboard of data centers built on just about every square meter of space. My research suggests microgrids capable of generating the baseload power many of our data centers would require would likely need land that simply isn’t available.

However, even with that limitation, an organic evolution within the industry is now gaining momentum in Loudoun County. The Board recently learned of a “by right” natural gas microgrid operating in Loudoun County in “island” mode (not connected to the power grid but operating autonomously) that has been under development for the past two years. Because it was “by right,” the application did not come before the Board. In August 2022, the company was forced to develop this microgrid when, after signing a billion-dollar land lease for its property, Dominion Energy informed the landowner it would not be able to provide power for several years. The site is now operating eight natural gas turbines with Selective Catalytic Reduction (SCR; see below) units attached and is in full compliance with federal EPA, Virginia DEQ and Loudoun County emission and noise regulations. They plan to expand the concept to a second campus soon. Similarly, another company recently submitted an application to build a 750 Mw data center campus in Loudoun County powered, at least in part, by blue hydrogen fuel cells (see below).

Thus, while fully autonomous, carbon-net-zero, baseload microgrids may not be immediately feasible for many Loudoun County data centers, several microgrid elements could be adapted and applied to our existing data centers as transitional steps moving us to a distributed energy, fully carbon-net-zero data center environment in the future. For example, the natural gas generators in the example above have SCR units attached. These SCR units reduce Nitrogen Oxides (NOX), inhalable Particulate Matter (PM2.5), and Hydro-Carbons (HC) to Tier IV Final EPA emission standards, the strictest standards in the industry. If Loudoun County were to create incentives or require, through new performance standards, existing data centers to replace their 4,000 diesel generators with either Tier IV diesel generators or natural gas generators, the county would experience a significant reduction in CO2, PM2.5, NOX and HC emissions and noise levels. With this in mind, let’s examine the various onsite power generation options either available now or being developed in the near future.

In researching this paper, I encountered a common theme among many I talked to when I raised the issue of carbon-net-zero onsite power production. Many believe such onsite power production is still purely theoretical and that practical demonstrations of this technology are years away. I was one of those people. What I have learned, however, is that there are several working installations delivering onsite power with the potential to provide the Loudoun County data center sector with various options for a viable way forward.

Potential Onsite Power Sources for Loudoun County

Given the current state of our technology, here are the six sources of onsite power that could be tailored to meet Loudoun County's unique microgrid challenges: (I include Small Modular Reactors (SMR) and Advanced Nuclear Reactors (ANR) because, while largely unproven and likely not practical in Loudoun County, they offer the most efficient carbon net-zero solution, and there is global interest in their rapid development) :

Power Source Type	Baseload Capacity	Carbon-Net-Zero	NOX, PM2.5 Free
Diesel Backup Gen. w/SCR		**Tier IV**	**Tier IV**
Battery Energy Storage Sys.		✓	✓
Natural Gas Turbine w/SCR	✓	**Tier IV**	**Tier IV**
Green Hydrogen Fuel Cells		✓	✓
Blue Hydrogen Fuel Cells			
SMR/ANR	✓	✓	✓

Below are the pros and cons of each power source:

Battery Energy Storage Systems (BESS).[70] A battery energy storage system captures energy from various sources and stores it for later use. These are most often used to capture renewable energy produced, for example, from solar or wind installations, but they can be used to store energy from any source. They are typically used as backup power to augment a continuous power supply.

Advantages: Carbon-net-zero; no pollution; no noise.

Disadvantages: Not a source of sustainable, baseload power; lithium for batteries is becoming scarcer, and the fire hazard requires new suppression methods. However, illustrating how fast technology is advancing new microgrid options, one company I spoke with will, by early 2025, be offering BESS in the form of 40 ft. trailers each capable of storing 10 Mw using a waste-recycled substance called graphene.

[70] ABB. "What Are Battery Energy Storage Systems?" https://electrification.us.abb.com/battery-energy-storage-systems-bess-basics

Natural or Renewable Gas.[71, 72] Natural gas (local pipeline) power generation is not carbon-net-zero and is a fossil-fuel derived energy source. If used to generate baseload power without active emission controls, it has significant CO_2, NOX, PM2.5, HC and CO emissions. These can be significantly mitigated (by at least 90%) through the use of Selective Catalytic Reduction (SCR) mentioned earlier, a modification that should be mandatory in Loudoun County. Renewable natural gas (RNG or "biomass" gas) is waste gas produced by organic waste, captured, and delivered to the microgrid. Since the waste gas would otherwise be released into the air, using waste gas to run generators can reduce the net CO_2 emissions even considering the CO_2 released in burning the gas. It too may use SCR to reduce emissions.

> **Advantages:** Biomass or renewable natural gas may reduce total CO_2 emissions by capturing and using waste gas that would otherwise be released into the atmosphere; natural gas has lower carbon emissions than diesel and these are significantly reduced by the use of SCR; it can provide sustained, baseload power; it can rely on existing gas lines; it could replace Loudoun's 4,000 diesel backup generators; a gas microgrid design could easily accommodate a different energy source (hydrogen fuel cells, nuclear) in the future.
>
> **Disadvantages:** Even with SCR, gas turbines run on fossil fuel, create some emissions, and create sustained noise levels requiring mitigation; they could easily oversubscribe the gas grid with widespread use; **Important Note for Loudoun County:** Natural gas turbines can deliver onsite, baseload energy today by tapping into local Loudoun County natural gas lines. It may be the quickest, cheapest option for onsite baseload power for our data centers and could quickly become their local option of choice if not regulated. However, it is essential the county mandate the use of SCR for all natural gas turbines in the county to significantly mitigate emissions. Also, baseload turbines would run 24/7/365, and the one existing natural gas microgrid in the county has a noise level of 65db at the property boundary directly across the street from a residential neighborhood. Our zoning ordinance would have to be changed reducing that noise level to at least 55db at the sending property line.

Hydrogen Fuel Cells.[73] Hydrogen is present in abundance throughout nature, but it is rarely available in a free form. Instead, it is usually part of the chemical makeup of other energy sources such as oil, gas, biomass or even water. Through a process called reforming, hydrogen molecules are stripped off these compounds, passed through an electrolytic membrane and combined with oxygen. This process produces an electrical charge with a byproduct of water. The source of the hydrogen and the method used to strip off the hydrogen molecules determine the classification of the type of hydrogen. About 95% of hydrogen production in the U.S. is accomplished through natural gas reforming[74].

Note: Only green hydrogen is carbon-net-zero and fully pollutant free. Blue hydrogen and gray hydrogen "reform" natural gas (methane, a highly potent greenhouse gas) to obtain the

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[71] https://enchantedrock.com/the-advantages-over-diesel/
[72] https://www.sapphiregassolutions.com/renewable-natural-gas/
[73] https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technology-basics
[74] U.S. Department of Energy. "Hydrogen Production Natural Gas Reforming." https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

hydrogen molecules but create CO_2 emissions which must be captured and stored. Carbon Capture and Storage (CCS) is a nascent technology with significant infrastructure obstacles and environmental impacts.

Renewable Hydrogen ("Green Hydrogen"): The hydrogen source is water (H_2O), and the reforming process is done using electricity from sustainable sources such as solar or wind.

Decarbonized Hydrogen ("Blue Hydrogen"): Natural gas is reformed to separate hydrogen from the methane leaving carbon dioxide. The carbon dioxide is then captured through Carbon Capture and Storage (CCS). This type of hydrogen is up to 99% carbon-net-zero in the fuel cell itself, but CCS as required by the reforming process presents significant technological issues.

Traditional Hydrogen ("Gray Hydrogen"): Uses the same natural gas reforming process except the carbon dioxide is not captured.[75] This has major environmental impacts and should not be used in Loudoun County.

The use of hydrogen fuel cells for anything other than backup power for data centers is likely many years away.

Advantages: Green hydrogen is carbon-net-zero; hydrogen fuel cells make no noise and emit no pollutants; could replace diesel backup generators as a cleaner source of backup power

Disadvantages: Hydrogen fuel cells are not practical as a baseload power source because they generate too little power for use at utility scale; unless the system uses green hydrogen, the gas reforming process has all the disadvantages of unfiltered natural gas as a power source; utility scale fuel cells are largely theoretical and will be for some time.

Small Modular Reactors (SMR) and Advanced Nuclear Reactors (ANR). A micro nuclear reactor is a small nuclear reactor capable of producing up to 20 Mw of electricity independently. An SMR/ANR is similar but is capable of producing 20-300 Mw of electricity.[76] There are more than 50 designs for SMR/ANRs. These reactors can be cooled by light water, the existing technology, or by gas, liquid metal or molten salt.[77]

Advantages: Carbon-net-zero; 93 percent capacity factor (see below); essentially noiseless; no pollutants; relatively small footprint

Disadvantages: Other than the few, traditional, light-water SMRs being developed, the majority of new ANRs produce much higher quantities of nuclear waste and

[75] Shell Oil Company. "Blue Hydrogen Production." https://www.shell.com/business-customers/catalysts-technologies/licensed-technologies/refinery-technology/shell-blue-hydrogen-process.html#:~:text=Blue%20hydrogen%20is%20a%20common,and%20autothermal%20reforming%20(ATR).

[76] Idaho National Laboratory. https://inl.gov/trending-topics/microreactors/

[77] DoE, Dept. of Nuclear Energy. https://www.energy.gov/ne/advanced-small-modular-reactors-smrs

entirely new types of nuclear waste not yet fully evaluated for their storage risk.[78] Moreover, there is no national repository for nuclear waste, meaning the waste produced by these new SMR/ANRs would be stored locally. Finally, while all current nuclear reactors in the country use 5 percent enriched uranium, the new ANRs propose using High Assay Low-Enriched Uranium (HALEU) which enriches the uranium 5-20 percent, a largely untested and unproven level of enrichment[79]; community resistance would be extreme; there is an extended licensing process; SMR/ANRs are at least two years from construction; they are extremely expensive.

Nuclear Fusion. On December 17, 2024, Commonwealth Fusion System, associated with the Massachusetts Institute of Technology, announced plans to build the world's first nuclear fusion power plant in Chesterfield County, VA. The plant is planned to produce 400 Mw of power by the early 2030's.

Nuclear fusion has been largely theoretical for decades. It combines atomic nuclei from isotopes of hydrogen derived from sea water or lithium to release enormous amounts of energy. This is the process our sun uses. The energy released is completely clean, and the process produces no nuclear waste. The singular disadvantage of fusion is that it requires enormous heat to combine the isotope atomic nuclei. In 2022, after 70 years of experimentation, scientists were able to create a fusion reaction for the first time that produced more energy than it needed to create the reaction.

Given the developmental timeframe, I believe the data center sector will be well along the way to meeting its energy needs long before nuclear fusion becomes a practical reality.

Capacity Factor: Choosing A Microgrid Energy Source

A key metric used to determine what type of microgrid is appropriate for any given application is the capacity factor of the power source used in the microgrid. The U.S. Energy Information Administration (EIA) defines the capacity factor of an energy source as:

Capacity factor: The ratio of the actual electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full power operation during the same period. [80]

An example illustrates this ratio. Suppose we have an energy source that can generate a maximum of 10 Mw of electricity at its peak operating power. If that energy source operates at peak power for one hour, it is generating 1 megawatt hour (1 MWh) of electricity. There are 8,760 hours in a year. We determine that energy source's historic capacity factor by dividing how many hours in a year that energy source actually operated at full capacity by the total hours in the year. If that 1 Mw energy source actually only delivered an average of .5 Mw per hour for 8,670 hours in a year, it has a

[78] Krall, Lindsay, McFarlane, Allison, Ewing, Rodney. "Nuclear Waste from Small Modular Reactors." PNAS. May 31, 2022. https://www.pnas.org/doi/full/10.1073/pnas.2111833119?trk=public_post_comment-text

[79] Dept. of Energy. "What is High-Assay Low-Enriched Uranium (HALEU)." Office of Nuclear Energy. December 3, 2024. https://www.energy.gov/ne/articles/what-high-assay-low-enriched-uranium-haleu

[80] U.S. Energy Information Agency. "Glossary." U.S. EIA. https://www.eia.gov/tools/glossary/index.php?id=Capacity_factor#:~:text=Capacity%20factor%3A%20The%20ratio%20of,operation%20during%20the%20same%20period.

capacity factor of 50%: (.5 Mw x 8,760 hours) / 8760 total possible hours = .50 or a 50% capacity factor. Similarly, if that same energy source delivered its maximum power for only 4,380 hours in a year, that too would be a capacity factor of 50%.

U.S. EIA keeps track of the average capacity factors associated with each of the various types of energy sources now available for use in microgrids. The higher the capacity factor, the greater the amount of time that energy source can deliver its maximum possible power. Below is a chart depicting the annual capacity factors for various energy sources in 2023:[81]

2023	Geothermal	Hydroelectric	Nuclear	Biomass	Gas	Solar	Wind
Capacity Factor	70%	34.2%	93.1%	50.6%	61.7%	23.3%	33.5%

As shown, nuclear power is, by far, the most efficient power source presently available for use in microgrids. It's capable of delivering its maximum power 93.1 percent of the time throughout any given year. It is not weather dependent and not subject to significant external constraints. Solar, on the other hand, only delivers its maximum rated power about 23.3% of the time due to weather, length of day, and many other external factors. Thus, a utility-scale solar farm rated at 100 MW will only be able to deliver about 23 MW on average throughout the year.

Natural gas microgrids using SCR offer a relatively low emission option with a fairly high capacity factor of 61.7%. They are good candidates for replacing diesel backup systems and may prove to be a viable transitional source of microgrid power in situations where the power grid is constrained such as in Loudoun County.

Geothermal microgrid applications are geographically dependent and largely theoretical at present.

Strategy Implementation: Creating a New Paradigm for Loudoun County

Based on the foregoing analysis, what then might a new paradigm for Loudoun County look like? At present, diesel generators, BESS, and possibly hydrogen fuel cells are only best suited for backup power. Given the large number of diesel generators being used in the county, we should, in the near term, incentivize or require a sector-wide transition to Tier IV diesel generators or Tier II generators with SCR units attached. This is one of the recommendations of the JLARC study.[82] Natural gas turbines incorporating SCR and significant noise mitigation could operate as either backup or baseload power and represent a very viable microgrid option for data centers facing power grid constraints. Loudoun County should immediately develop performance standards and zoning requirements for all of the above microgrid component systems.

Nationally, SMR/ANRs, while likely 3-7 years away, are the only viable long-term option for carbon-net-zero, baseload, onsite power generation, but they are simply not viable until the significant nuclear waste issue is addressed and resolved. They will also face significant community resistance. Given that the only alternatives to SMR/ANRs will be more power lines, gas turbines or a

[81] U.S. Energy Information Administration. "Table 6.07.B. Capacity Factors for Utility Scale Generators Primarily Using Non-Fossil Fuels" Electric Power Monthly. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b

[82] Op. Cit., pg. 60

continuously constrained power grid, the greater Loudoun County community—and indeed, the Commonwealth of Virginia—have some very challenging discussions ahead.

Yet even within these practical constraints, we can still identify and provide to the data center community a set of desired data center characteristics based on Loudoun County's unique power grid environment. As technological advances occur, data centers can be encouraged, through a series of tax incentives, or required, through changes to our Comprehensive Plan or Zoning Ordinance, to organically shift away from grid over-reliance towards greater power independence. Such a model would guide future data center development and incentivize existing data centers to strive to incorporate as many desired characteristics as possible. The result could be transformational sector change. If successful, we could become a world pioneer ushering in a new age of data center design supported by a transformed national power grid. At the same time, we could create a thriving new green business market here in Loudoun County.

The following is a proposed list of desired attributes for Loudoun County data centers:

Practical, Immediate Improvements Possible Through Incentives (Existing Data Centers)/Performance Standards (New Data Centers):

1. **Tier IV or Tier II/SCR Backup Generators**
2. **Maximum of 55 Db Noise Levels at the Sending Property Line with Pre-/Post-Construction Noise Studies**
3. **Minimum of 500' Setback from Property Line Facing Residential**
4. **Significant Visual Screening**

Desired Attributes (All Data Centers):

5. **Microgrid Elements in Site Plan**
6. **Low Carbon or Carbon Net-zero Power (baseload and/or backup)**
7. **Leadership in Energy and Environmental Design (LEED) Gold Certified or above buildings**
8. **Green Building Initiative "Green Globe" Rating of Three or Higher**
9. **Total Usage Efficiency of 1.15 or Less (TUE=IT Usage Efficiency x PUE)**
10. **Liquid-submerged Data Racks**
11. **Waste Heat Reuse Systems (District Energy)**

Summary

While the challenges are great, implementation of a strategy incorporating some or all the elements above would accomplish several urgently needed objectives. It would:

- **Establish Loudoun County as a Green Data Center Environment.** Loudoun County could become a role model for communities around the world seeking to host green data centers in their community or to transform the data center markets they already have.
- **Enable Decommissioning of Fossil Fuel Power Plants.** If implemented for all data centers throughout Virginia, this strategy could substantially reduce the pressure on Dominion Energy and PJM to slow the process of decommissioning fossil fuel plants and enable them to meet their climate change goals. Note: data centers are only one part of the puzzle, albeit the largest piece in Loudoun County. The rapid proliferation of electric

vehicles will also contribute to the pressure on the grid, but in Loudoun County the power demand of data centers very likely far exceeds the demand from electric vehicles.

- **Increase Loudoun County's Power Grid Resiliency.** Incentivizing data centers to develop autonomous microgrid elements will increase grid resiliency and reduce the threat to residential and other commercial users posed by rapidly increasing demands on our power grid. It would also help keep rates low for non-data center customers. "Peak shaving" by having numerous microgrids operate in "island mode" during peak power demands would help stabilize the grid. Nationally, microgrids could also constitute a major source of distributed energy.
- **Create a New Loudoun County Market for a Burgeoning Green Microgrid Industry.** Just as the sector's rapid growth over the past twenty years led to an economic boom in Loudoun County, transforming Loudoun County's data center industry to a wider use of microgrid elements, especially "green" microgrid elements, could have similarly beneficial business revenue effects. Such a change could attract green industry companies to the county and have a significant, positive multiplier effect on Loudoun County's entire business environment by diversifying our tax revenue with a host of complementary businesses supporting the transformation.

Challenges

Without question, there are major challenges implementing this strategy. Here are a few:

- Will Dominion Energy eventually cap available power to data centers? Such a physical constraint will drive greater innovation within the data center community.
- Though widespread adoption of microgrid designs is probably impractical in Loudoun County, can the Board of Supervisors create a legislative environment encouraging data centers to adopt various microgrid design elements into their planned and existing campuses?
- Can the Loudoun County Board of Supervisors react quickly enough to shape the outcomes of the rapid change taking place in the energy environment?
- Will Dominion Energy allow point source power generation in its market?
- It will take 12-18 months to implement a formal CPAM/ZOAM change. Will BOS votes prior to this codified change reflect a willingness to implement the new strategy?
- What form will incentives/requirements/disincentives take to effect the needed changes in the Loudoun County data center environment?

Likely Future Scenarios

Based on my experience as a County Supervisor and my understanding of the issues addressed herein, let me suggest some likely near- to midterm developments:

- **More Grid Infrastructure.** Of necessity, PJM and Dominion Energy must continue to aggressively pursue their regulated legal requirement to expand and enhance their infrastructure to accommodate increased power demand. This means Loudoun County will likely see more overhead transmission line proposals in the near term. Given that

the SCC recently denied a community advocacy effort to bury the Aspen/Golden 500/230 Kv transmission lines, it is unlikely any similar effort in the future will be successful. Pressure to build new lines will only be alleviated by stabilizing large consumer demand on the grid. This will only be possible through three simultaneous occurring conditions: 1) artificially imposed power constraints, 2) technological advancements significantly reducing AI power requirements, and 2) rapid development of data center microgrids or microgrid elements making data centers less grid dependent.

- **Continued Power Constraints for Major Power Consumers.** With a five-year infrastructure buildout likely, Loudoun County data centers will be power constrained until at least 2029, and that assumes a predictable increase in demand. The growth of AI and its attendant power demands could vastly complicate that problem. As we have already experienced here in Loudoun County, this is going to create an organic industry push to develop onsite microgrids to reduce data center dependence on the grid. This transition is likely to happen relatively quickly, and therefore the Loudoun County Board of Supervisors must act now to assert and maintain managerial oversight, through land-use planning and new zoning requirements, of this sector-wide evolution.

- **Development of Natural Gas Turbine Microgrids.** Natural gas turbines with Selective Catalytic Reduction are the most practical, near-term microgrid solutions to a constrained power grid environment. Given that one has already been built and another is likely within a year, more widespread use of this transitional solution to grid constraints seems likely. However, microgrid technology is advancing so fast, any type of microgrid evolution is possible. The Loudoun County Board of Supervisors must ensure it has continuous visibility over this rapidly evolving sector in the years ahead.

- **Increasing Community Resistance.** More overhead power lines and more data centers requiring those power lines has increased community opposition to further data center growth in Loudoun County to an unprecedented level. Given the historic increase in global demand for data, which is not going to abate any time soon, such resistance only serves to heighten the challenges we face. It is clearly in our collective best interest to avoid a proliferation of overhead power lines throughout Loudoun County. The fastest way to ease the pressure on the utility companies required by law to build more infrastructure is to stabilize the load on the grid.

The list of challenges is no doubt long and complex. But the stakes of the game have never been higher for our county. Our task is not to fight the changing environment. Our task as Loudoun County's elected governing body is to learn how our environment is changing and adapt to the changes in a way that preserves our quality of life and protects the people we work for. I believe we're up to the task.