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# RESILIENT & EFFICIENT **COMPUTING**

## Positioning Industry and Government for the Future

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## Introduction

Data centers are rapidly expanding to meet the nation's need for everything from streaming content on mobile devices to industry requirements for technology, healthcare, finance, and more. In turn, this growing demand challenges local communities and data centers to find new ways to balance quality of life while meeting the needs for real estate, energy, and other resources.

As the world leader in the data center revolution, Virginia's Loudoun County represents the perfect use case. In December 2023, MITRE is convening a collaborative, constructive discussion of the circumstances faced by Loudoun. Our objective is to encourage stakeholders to identify resilient, efficient, and sustainable opportunities to meet growing computing demand in mutually beneficial ways.

## Challenges



**National Concern.** New digital technologies are emerging daily. ChatGPT and other large language models are just one example of how critical resilient and efficient computing has become to U.S. and global security. Between 2010 and 2018, global data center (DC) computation increased by about 550%. This was impressively paired with an increase of only 6% in DC energy usage up to 205 terra-watt hours (TWh), or 1% of the global demand [1]. This success was driven by increases in DC efficiency. However, DC growth shows no sign of slowing down as our reliance on large data mature, while efficiency increases become increasingly hard-won. The U.S. hosts approximately one third of the total number of DCs around the world. Additionally, Google-owned DCs in the U.S. consumed approximately 3.37 billion gallons of water in 2021, 90% of which was potable water [2], while Microsoft increased its water consumption by 34% between FY21 and FY22 [3].



**Northern Virginia Growth.** Northern Virginia is home to the world's largest DC market, with nearly as much capacity as the second- to fifth-largest markets combined [4] [5]. Dominion Energy supplies most of Loudoun County's power. Currently, DCs account for roughly 20% of Dominion Energy's total electricity sales in Virginia [6]. Since 2019, Dominion Energy has connected nearly 70 DCs with over 2.6 gigawatts (GW) of capacity in Northern Virginia. In 2027, the demand from DCs is expected to grow by another 2.6 GW [7]. Additionally, Loudoun County may enable an additional 56 million square feet of land to be used for DC expansion within Dulles Cloud South, an undeveloped area of southeastern Loudoun [5]. This growth further increases the energy demands on the power grid.



**Load Projections.** Accuracy is critical to planning infrastructure upgrades to meet customer demand. The power demands driven by DC growth and operations are increasingly difficult to track. PJM, the regional transmission organization that coordinates the local grid, has released successive 15-year load growth projections that jump from a 1.0% to a 4.4% annual growth rate alongside a 28 to 42 GW summer peak [8]. Frequent changes in forecasts make it difficult to justify the large-scale capital investments needed to meet even the most conservative of projections.



**Quality of Life.** Northern Virginia residents and government representatives have voiced concerns regarding the planned and potential continued construction of transmission lines to service increased energy demand [9] [10].



**Water Stress.** DCs often stress existing water supply and water/wastewater infrastructure. Loudoun County currently draws its water from the Potomac River in Maryland. Previous conflicts regarding increases in Virginia's use of that water have resulted in lengthy legal proceedings that ended up at the U.S. Supreme Court [11]. Additionally, reduced water levels in the region have led to the initiation of drought operations [12]. Further challenges may force a limit, even if temporary, on the water supply for Northern Virginia or may delay water infrastructure updates necessary to support DC growth.



**Shrinking Space.** Another constraint facing the DC industry in Loudoun is the available land with proximity to electric and water utilities. The Loudoun County DC Land Use Study, released in 2022, characterizes the potential for new DC developments based on land availability, proximity to utilities, and geographical conditions. Most land adjacent to Route 7 is unsuitable for growth, while portions of eastern and southeastern Loudoun County may show potential for DC expansion. Some areas may become suitable pending utility infrastructure updates [5].

## CALL TO ACTION

The scale of DC growth in Loudoun County is an unavoidable concern. Novel and mutually beneficial solutions must be rapidly deployed to maintain the economic benefits brought to the region by the DC industry while maintaining the culture and quality of the community.

## Solution Opportunities



**Energy Optimization.** Significant energy reductions or capacity increases can be made through upgrading and optimizing DC hardware. This includes low-capital opportunities that can be implemented on a short-term timescale to increase capacity without infrastructural changes. Utilizing modeling tools, such as computational fluid dynamics and thermal imaging, to optimize air management and cooling can provide a capacity increase of 10-30% without additional energy requirements [13] [14]. IT management strategies are also valuable tools in maximizing energy effectiveness [15]. With higher capital investments, DCs can better utilize floor space and consolidate IT workloads. For example, liquid cooling can be employed through rear-door heat exchangers, direct-to-chip cooling, or immersion cooling for increasing energy reductions and efficiencies [16].



**Onsite Generation.** Localized infrastructure provides a solution for meeting the energy requirements of a growing DC demand without requiring additional public infrastructure such as power lines. Microgrid technologies will allow DCs to adopt a behind-the-meter approach, combining renewables, stationary battery energy storage

systems, thermal batteries, responsive end-use loads, and various other distributed energy resource technologies. Utilization of these technologies would allow DCs to operate autonomously and locally, thus mitigating grid disturbances, minimizing energy infrastructure in the community, and reducing carbon emissions [17] [18]. Several power production technologies could provide carbon-free local generation, including small modular nuclear reactors and green-hydrogen powered fuel cells. These technologies are not yet commercially viable; however, recent advancements have shown promise of deployable, nonvariable, and carbon-free power generation with minimal land use [19] [20].



**Water Optimization.** The Reclaimed Water Program implemented by Loudoun County will alleviate some of the strain on potable water supply caused by DC demand [21]. To reduce the burden on local utilities, many DCs have begun implementing water harvesting, treatment, and reuse measures to create more sustainable water management programs. Incentive programs for more water-efficient DC design could decrease Loudoun County's capital and operational expenditure while allowing DCs to enable the use of sustainable water management throughout their operations.

## References

- [1] Eric Masanet, “Recalibrating global data center energy-use estimates,” *Science*, vol. 367, no. 6481, 2020.
- [2] U. Holzle, “Our commitment to climate-conscious data center cooling,” Google, 21 November 2022. [Online]. Available: <https://blog.google/outreach-initiatives/sustainability/our-commitment-to-climate-conscious-data-center-cooling/>.
- [3] Microsoft, “2022 Environmental Stability Report,” 2022.
- [4] CBRE, “North America Data Center Trends H1 2022,” September 2023. [Online]. Available: <https://www.cbre.com/insights/reports/north-america-data-center-trends-h1-2022#:~:text=Atlanta%20saw%20the%20highest%20percentage%20growth%20%2840%25%29%20among,under%20construction%2C%2076%25%20of%20which%20is%20already%20released.>
- [5] Buddy Rizer, “Board of Supervisors Transportation and Land Use Committee Action Item, Loudoun County Data Center Land Study,” Board of Supervisors Transportation and Land Use Committee, Loudoun, 2022.
- [6] Dominion Energy, “Regulated Decarbonization: Q4 2022 Earnings Call,” 8 February 2022. [Online]. Available: [https://s2.q4cdn.com/510812146/files/doc\\_presentations/2023/2023-02-08-DE-IR-4Q-2022-earnings-call-slides-vTC-Final.pdf](https://s2.q4cdn.com/510812146/files/doc_presentations/2023/2023-02-08-DE-IR-4Q-2022-earnings-call-slides-vTC-Final.pdf).
- [7] D. Energy, Composer, *Dominion Energy Second Quarter 2022 Earnings Conference Call*. [Sound Recording]. 2022.
- [8] PJM Resource Adequacy Planning Department, “PJM Load Forecast Report,” 2020.
- [9] A. Harris, “Commercial developers condemn proposed Dominion power lines,” *Loudoun Times-Mirror*, 2015.
- [10] K. Sheehan, “Protect Prince William County,” 2023. [Online]. Available: <https://protectpwc.org/wp-content/uploads/2023/09/2022-PJM-RTEP-Window-3-Loudoun-County-VA-impacting-Proposals-091123.pdf>.
- [11] *VIRGINIA v. MARYLAND on exceptions to report of special master*, 2003.
- [12] J. W. Moyer, “Officials eye Potomac water levels for drought preparations,” *The Washington Post*, 1 September 2023.
- [13] A. D. Schlichting, “A Review of Commercial Technologies and Recommendations for Application to Department of Defense Systems,” The MITRE Corporation, McLean VA, 2015.
- [14] Future Facilities LTD, “Five Reasons your Data Center’s Availability, Capacity and Efficiency are being Compromised,” London, 2014.
- [15] Center of Expertise for Energy Efficiency in Data Centers, “Data Center Master List of Energy Efficiency Actions,” Lawrence Berkeley National Laboratory, U.S. Department of Energy, Berkeley CA, 2016.
- [16] “Sandia National Laboratories’ Holistic Data Center Design Integrates Energy- and Water-Efficiency, Flexibility, and Resilience,” National Renewable Energy Laboratory, Golden CO, 2023.
- [17] AlphaStructure, “Protecting data center availability with microgrids,” Boston, 2023.
- [18] S. Ferreira, M. Baggu, et al., “DOE OE 2021 Strategy White Papers on Microgrids: Program Vision, Objectives, and R&D Targets in 5 and 10 years,” Sandia National Laboratories, 2021.
- [19] The Joint Energy Institute, National Renewable Energy Laboratory, “Flexible Nuclear Energy for Clean Energy Solutions,” Golden CO, 2020.
- [20] J. Goldmeer, “Power to Gas: Hydrogen,” GE Power, 2019.
- [21] Loudoun Water, “Reclaimed Water Program.” [Online]. Available: <https://www.loudounwater.org/commercial-customers/reclaimed-water-program>.

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