Localized Air Pollution Impacts from Data Centers in Northern Virginia

Metropolitan Washington Air Quality Committee

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ISEE

Overview

- VCU-funded research, part of broader “Data Ecologies” project
- Goal: examine extent of current and potential air pollution emissions from data centers in Northern Virginia
  - » Inform local planning / permitting and state policy decisions
  - » Position VCU / ISEE as leader in data center research
- Key results: areas near clusters of data centers already experience significant emissions exposure, esp. NOx
  - » Potential for far greater exposure, allowed under DEQ air permits
  - » Exposure correlated to lower incomes, education, home-ownership

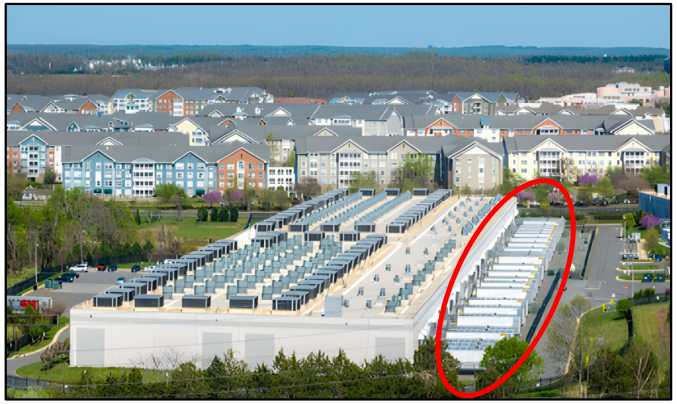
Data Centers in Virginia

- "Data Center Capital of the World"
  - » Originated with 1960s U.S. government and defense systems (ARPANET)
  - » Boom in 1990s, construction of fiber-optic networks and MAE-EAST exchange point
  - » Now hundreds of facilities at various sizes incl. many new "hyperscale"
- Concerns and Debates
  - » State tax credits dating back to 2008, current debate on continuation / reform
  - » Estimated tripling of electricity demand by 2040, challenges meeting zero-carbon goal
  - » Noise, water, air pollution, visual impacts

Amazon data center, Loudoun County (source: VCNVA)

Air Pollution from Data Centers

- Rapid increase in electricity demand = potential new fossil-fuel power plants, associated GHGs and criteria air pollution
- Use of backup generators (mostly diesel) = increased GHGs and direct air pollution impacts on nearby communities
  - » NOx, CO, Particulate Matter (PM), etc., respiratory and other health impacts



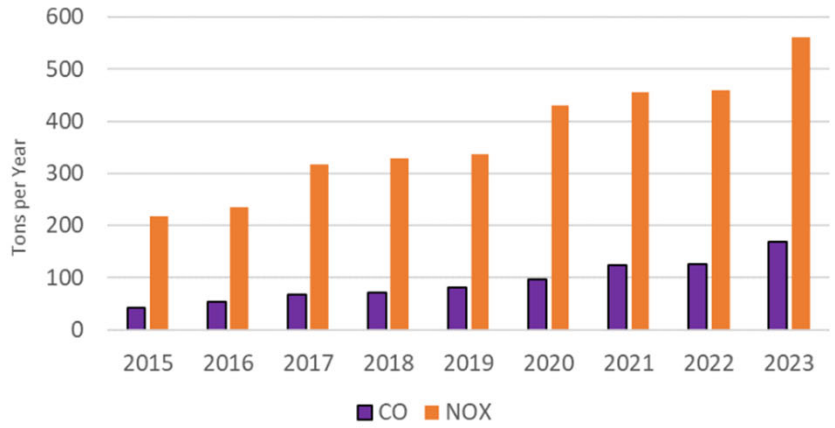
Left: location of backup-generators at Amazon site in Loudoun County (source: VCNVA)

Right: Caterpillar 3516C HD 2500KW Tier 2 Diesel Generator, type used at some Amazon facilities (source: DEPCO Power)

Air Pollution from Data Centers

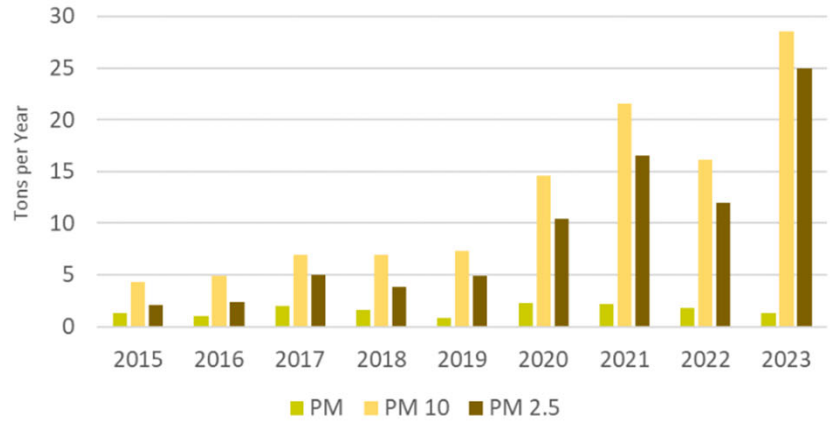
- Per the Virginia DEQ, data center air pollution in Northern Virginia has rapidly increased since 2015
- Still small percentage of overall air pollution, but reaching permitted totals would be a significant increase, esp. for NOx

Figure 1. CO and NOx Emissions from Northern Virginia Data Centers, 2015-2023



Source: Virginia Department of Environmental Quality (DEQ)

Figure 2. Particulate Matter Emissions from Northern Virginia Data Centers, 2015-2023



Source: Virginia Department of Environmental Quality (DEQ)

Scope and Approach

- Focus on Northern Virginia (Fairfax, Loudoun, Prince William counties and associated independent cities)
  - » Home to 141 of 173 DCs with active air permits (March 2026, none in ALX or ARL)
  - » Actual emissions provided by Virginia Dept of Enviro. Quality (DEQ), 2015 – 2024
  - » Potential emissions drawn from 138 DEQ air permits (downloaded June 2025)
- Estimated dispersion of emissions within 1-mile radius, concentrations at Census block-group level
- Compared to exposure from other facilities in region
- Correlations of emissions exposure > socio-economic factors

Scale of Data Center Pollution in NoVa

- The 138 permitted data centers in NoVa region have 7,338 total generators, with combined power capacity of 18.45 GW
  - » Roughly equal to entire "net-summer" power generation capacity of all Dominion Energy power stations in Virginia (Dominion, 2025 Annual Report, p. 38)
- Data center emissions compared to other notable facilities (tons/yr)

Source of Pollution	Carbon Monoxide (CO)	Nitrous Oxides (NOx)	Particulate Matter (PM 2.5)
Data centers combined total – Actual (2023)	169.3	562.0	24.9
Dominion - Leesburg Compressor Station (2022)	6.8	10.1	1.3
Dominion – Possum Point Power Station (2022)	73.0	100.0	55.9
Prince William County Landill (2022)	328.6	61.0	20.8
Fairfax County Wastewater Treatment Plant (2022)	98.1	35.9	0.0

Note: Updated 2024 data center emissions, including Vantage II facility, are 195 tons CO, 677 tons NOx, and 49 tons PM 2.5

Sources: Virginia DEQ (2025), U.S. EPA National Emissions Inventory (2022)

Caveat on Natural Gas Power Plants

- We compared pollution concentrations from data centers to the two natural gas power plants in NoVa study area
- Natural gas plant emissions vary significantly (tons, 2022):

Natural Gas Power Plant	Carbon Monoxide (CO)	Nitrous Oxides (NOx)	Particulate Matter (PM 2.5)
Doswell Energy Center (Hanover Co.)	387.37	739.46	435.68
NOVEC Energy Production (Halifax Co.)	147.03	177.06	61.03
Dominion Possum Point (Fairfax Co.)	**73.03**	**99.99**	**55.89**
Panda Stonewall LLC (Loudoun Co.)	**29.19**	**64.84**	**44.02**
Dominion – Darbytown CT Station (Richmond)	0.98	67.30	3.04
*Dominion – Chesterfield (Co.) Reliability Center**	*825.3*	*353.3*	*153.9*

Sources: U.S. EPA, National Emissions Inventory; Virginia DEQ, Dominion Chesterfield Energy Reliability Center Project

Actual vs. Permitted Emissions

- Conventional wisdom is actual emissions = @ 5% of permitted
  - » We find reported DC emissions in 2023 = @ 6 -10% of their permitted totals

Pollutant	Carbon Monoxide (CO)	Nitrous Oxides (NOx)	Particulate Matter (PM 2.5)
Actual Total (tons, 2023)	169.3	562	24.9
Permitted Total (tons per year)	2,957	9,995	1,202
Percent of Permitted*	5.7%	7.5%	10.0%

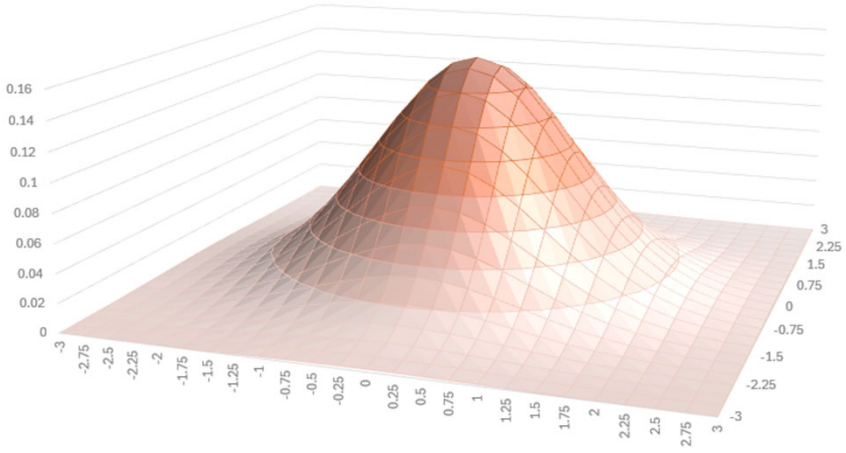
* Aggregate reported emissions from NoVa DCs in 2023 divided by aggregate of same facilities' permitted totals

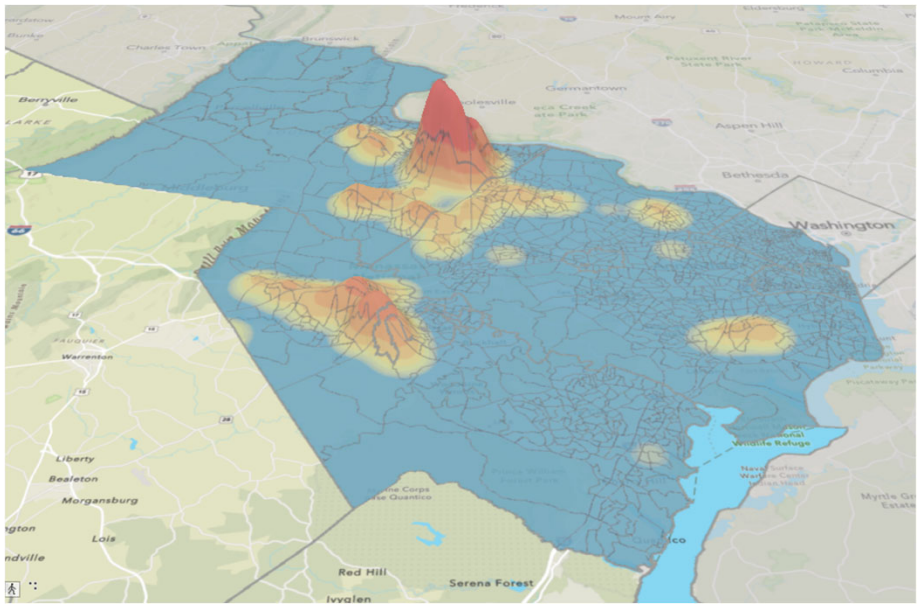
  - » But much higher in the case of some individual data centers…

Data Center Reg#	Location	CO	NOx	PM 2.5
74167	Manassas area, Prince William County	78%	78%	76%
72367	Ashburn area, Loudoun County	39%	39%	NA
73158	Sterling area, Loudoun County	41%	49%	NA
74112	Manassas area, Prince William County	30%	22%	19%

Pollution Concentrations: Methodology

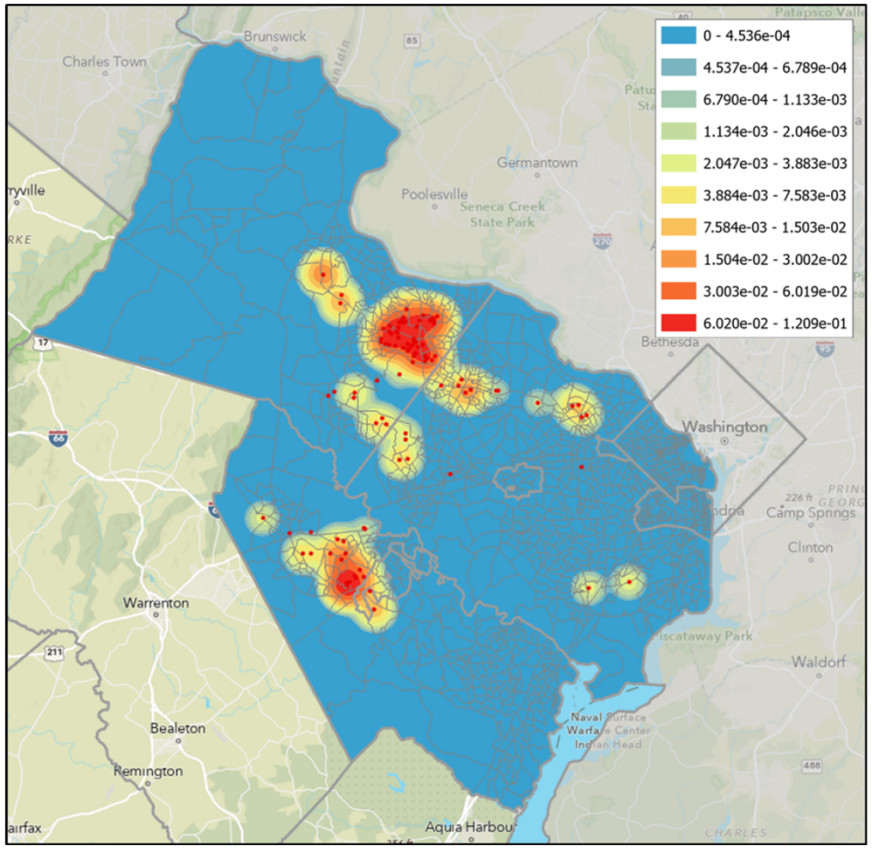
- Interpolated pollution surfaces by diffusing emissions (TPY) at each data center.
  - » Raster resolution: 330’ x 330’ (~ 100m x 100m)
  - » Bandwidth: 1-mile
  - » Gaussian kernel illustration





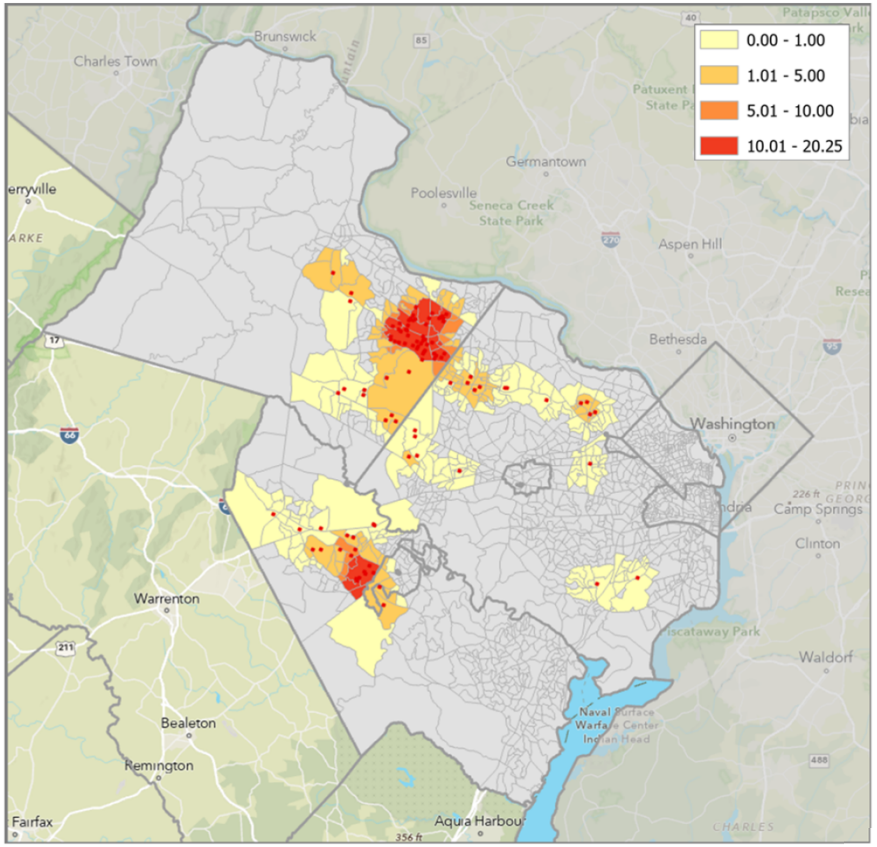
Pollution Surface to Block Groups (2023 NOx)

Figure B-2A. Diffusion Map of Nitrous Oxides (NOx) Emissions from Northern Virginia Data Centers (2023), tons per year by raster grid cells (330' x 330' resolution)



Source: Virginia DEQ data. Analysis by Virginia Commonwealth University research team.

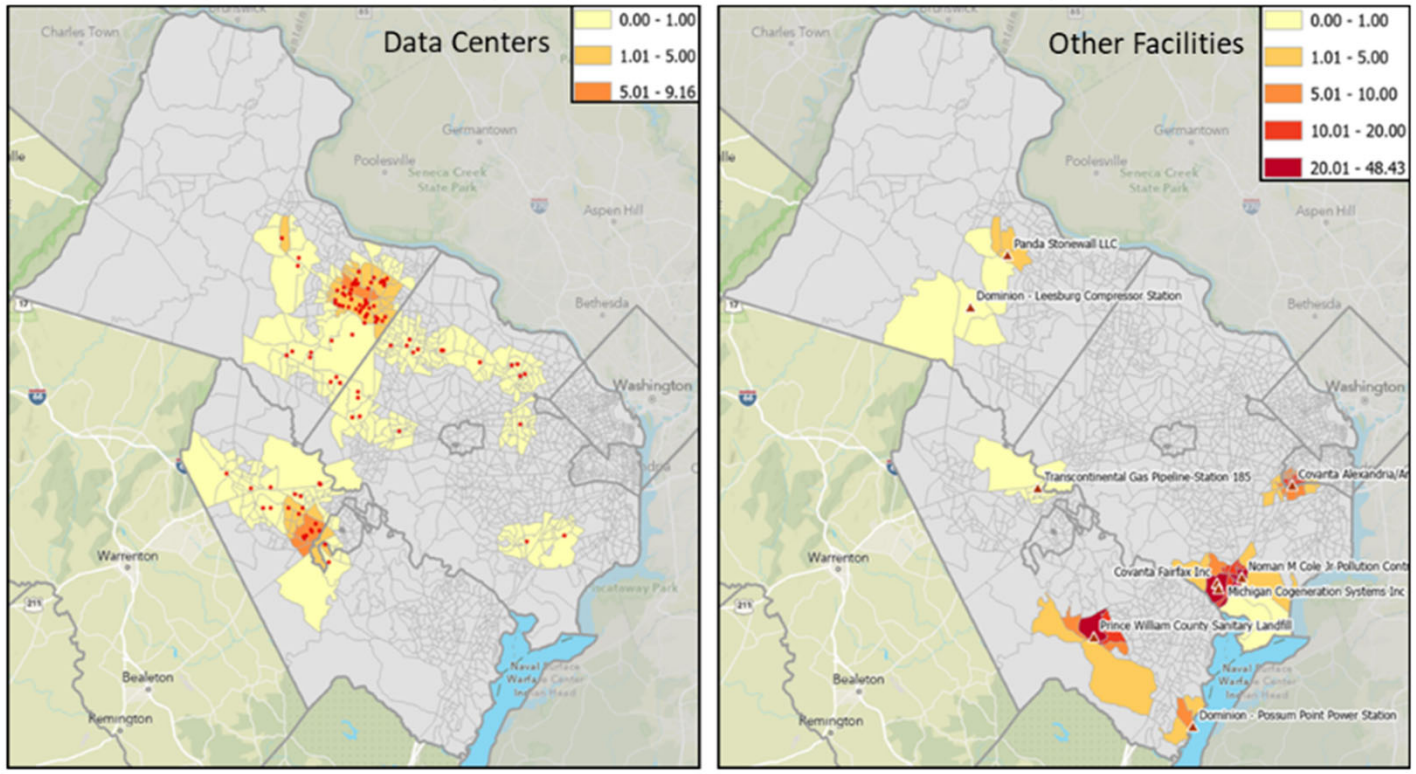
Figure B-2B. Map of Derived Total Nitrous Oxides (NOx) Emission Concentrations from Northern VA Data Centers (2023), by Census Block Group, tons per year per square mile



Source: Virginia DEQ data. Analysis by Virginia Commonwealth University research team.

Pollution Concentrations: Actual (CO)

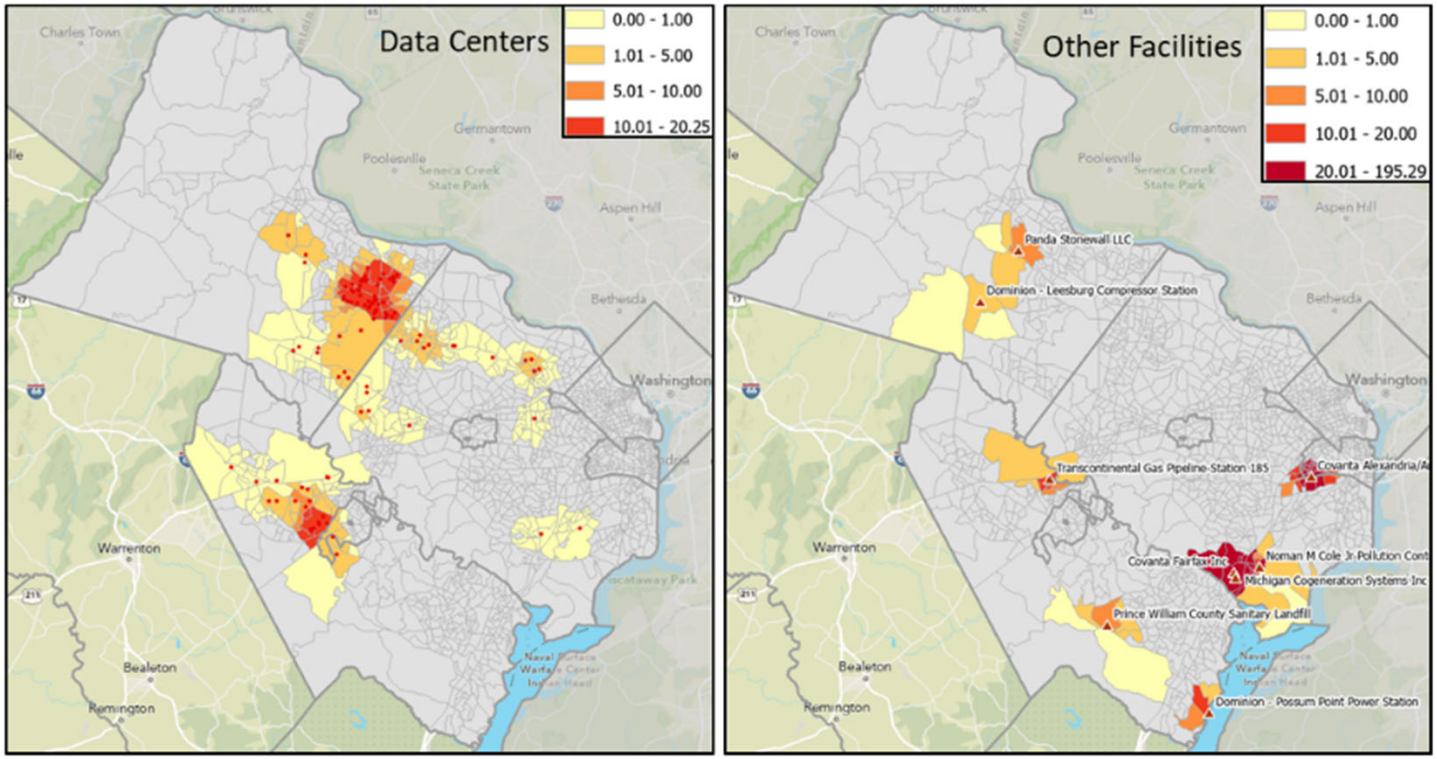
Figure 3. Concentrations of Carbon Monoxide (CO) Emissions (tons / sq. mi.) from Northern Virginia Data Centers (2023) versus Select Other Facilities (2022)



Sources: Virginia DEQ data and U.S. EPA National Emissions Inventory 2022 v2 Emissions Modeling Platform. Analysis by Virginia Commonwealth University research team.

Pollution Concentrations: Actual (NOx)

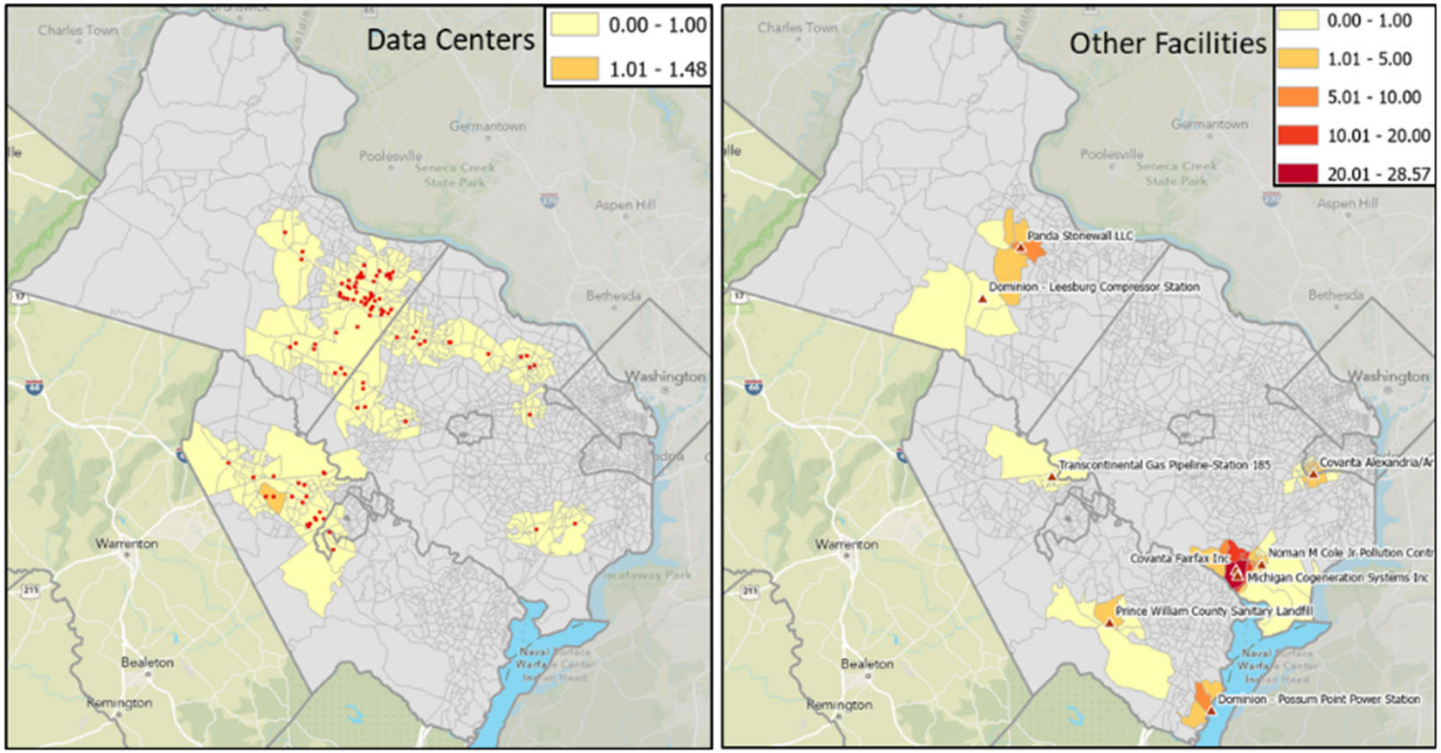
Figure 4. Concentrations of Nitrous Oxides (NOx) Emissions (tons / sq. mi.) from Northern Virginia Data Centers (2023) versus Select Other Facilities (2022)



Sources: Virginia DEQ data and U.S. EPA National Emissions Inventory 2022 v2 Emissions Modeling Platform. Analysis by Virginia Commonwealth University research team.

Pollution Concentrations: Actual (PM 2.5)

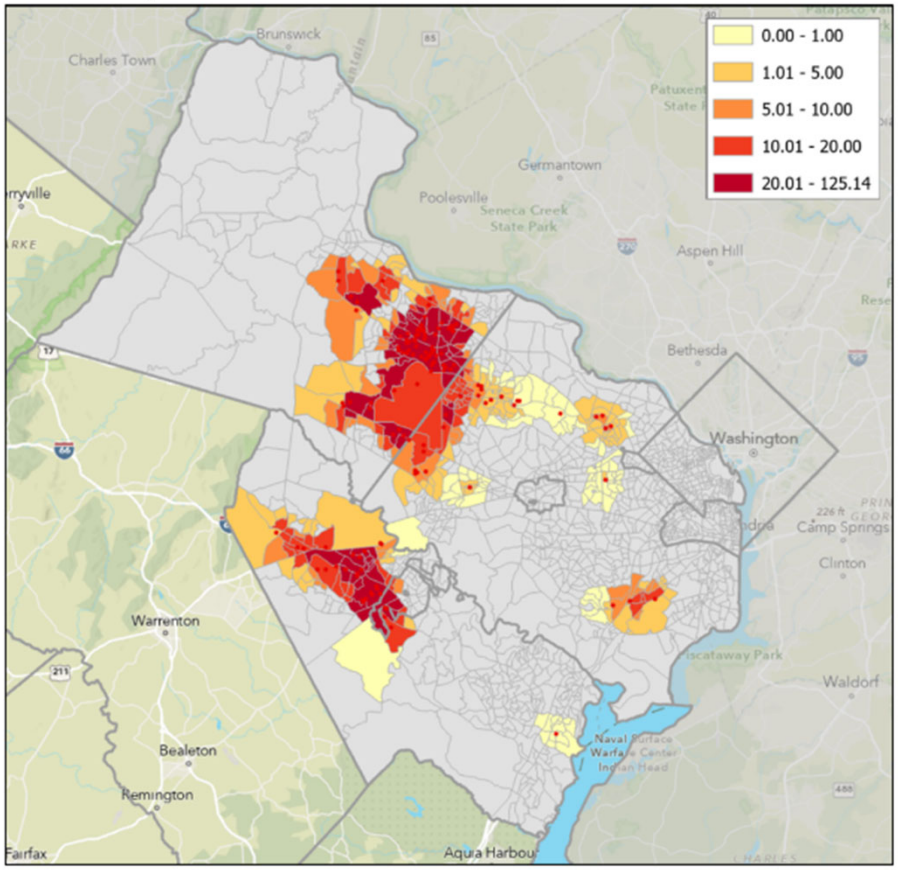
Figure 5. Concentrations of Particulate Matter (PM 2.5) Emissions (tons / sq. mi.) from Northern Virginia Data Centers (2023) versus Select Other Facilities (2022)



Sources: Virginia DEQ data and U.S. EPA National Emissions Inventory 2022 v2 Emissions Modeling Platform. Analysis by Virginia Commonwealth University research team.

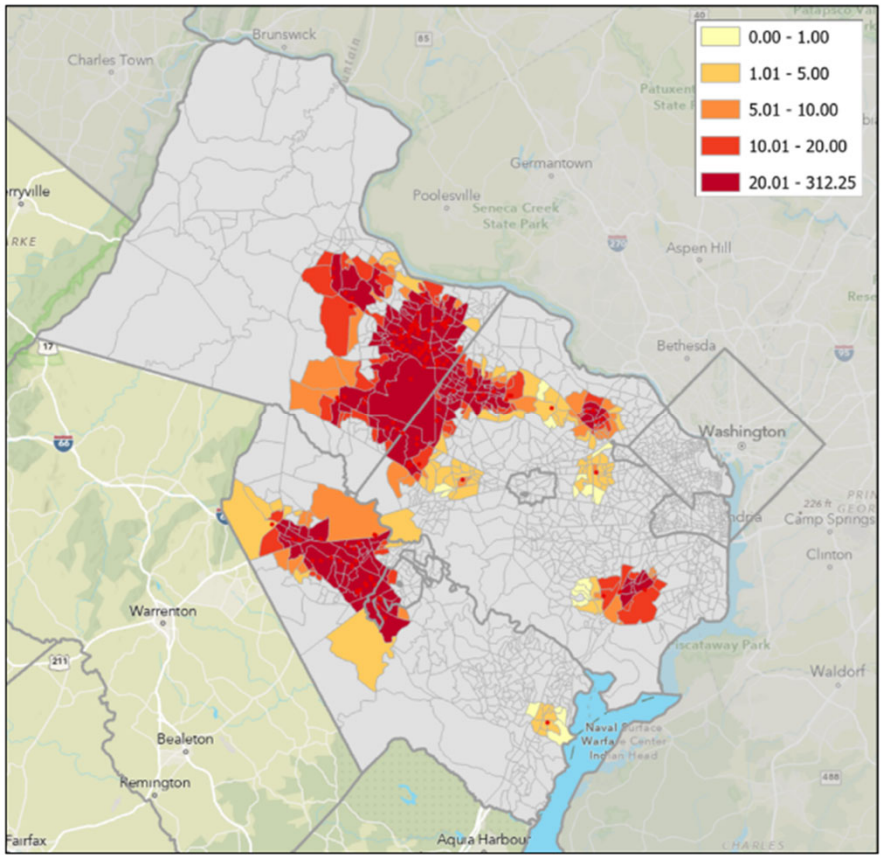
Pollution Concentrations: Potential

Figure 6. Potential Carbon Monoxide (CO) Emission Concentrations from Northern Virginia Data Centers (Maximum Allowed under DEQ Permits)



Source: Virginia DEQ (June, 2025). Issued Air Permits for Data Centers. Analysis by VCU research team.

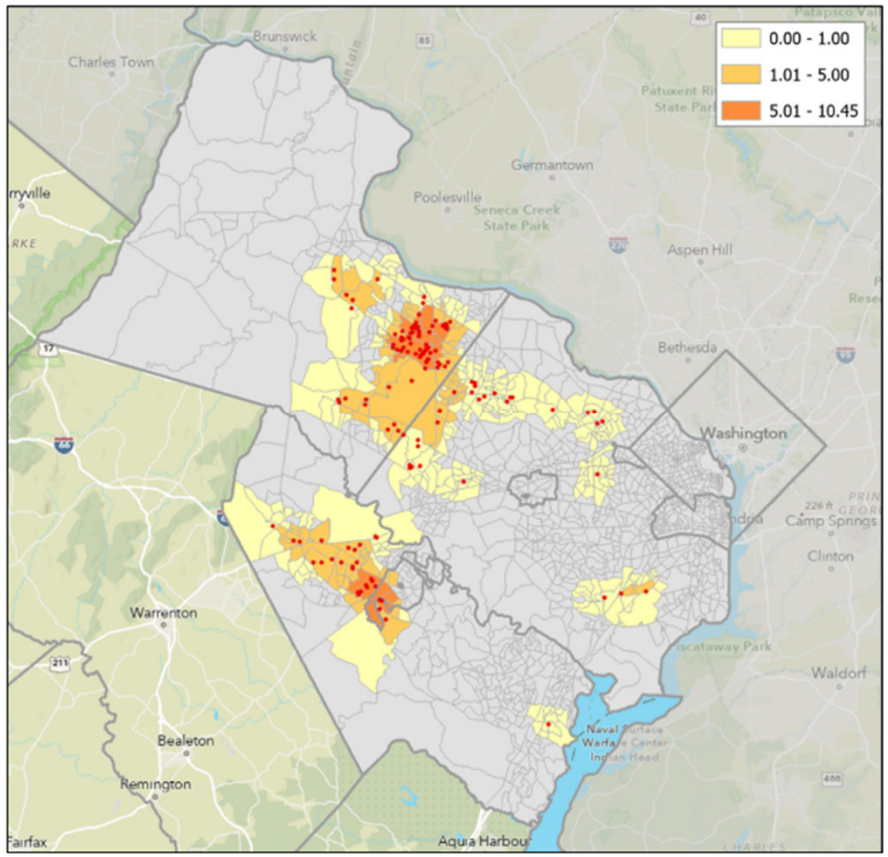
Figure 7. Potential Nitrous Oxides (NOx) Emission Concentrations from Northern Virginia Data Centers (Maximum Allowed under DEQ Permits)



Source: Virginia DEQ (June, 2025). Issued Air Permits for Data Centers. Analysis by VCU research team.

Pollution Concentrations: Potential

Figure 8. Potential Particulate Matter (PM 2.5) Emission Concentrations from Northern Virginia Data Centers (Maximum Allowed under DEQ Permits)



Source: Virginia DEQ (June, 2025). Issued Air Permits for Data Centers. Analysis by VCU research team.

Key Findings / Observations

- Concentrations of pollution exposure from actual data center operations:
  - » Are often far higher than those from a natural gas compressor station, and
  - » Can be higher than those from nearby natural gas power plants, especially for NOx
- Potential concentrations of pollution exposure from data center permits:
  - » Would be far higher than those from natural gas compressor stations or power plants, and
  - » Would be higher than most other notable facilities, except for some pollutants near concentrated municipal waste facilities

Pollution Concentrations: Correlations

- In NoVA, higher concentrations of data center pollution exposure (both actual and potential) are significantly correlated with lower socioeconomic status (income, education, homeownership), but NOT with race (% non-white)

Table 8. Correlations: Estimated Actual (2023) Data Centers Emissions Concentrations and Select Demographic Characteristics

Pollutant	Correlation Statistics	Population Density	Non-White Percent	Median HH Income	Higher Ed Percent	Home Owner Percent
CO / sq. mi.	Pearson Corr.	-0.104	0.047	**-.114***	**-.160****	-0.108
	Sig. (2-tailed)	0.06	0.39	0.041	0.004	0.051
NOx / sq. mi.	Pearson Corr.	-0.059	0.061	**-.133***	**-.158****	**-.156****
	Sig. (2-tailed)	0.287	0.265	0.017	0.004	0.005
PM 2.5 / sq. mi.	Pearson Corr.	**-.121***	0.02	-0.008	-0.098	0.022
	Sig. (2-tailed)	0.028	0.719	0.888	0.077	0.692
** Correlation is significant at the 0.01 level (2-tailed).						
* Correlation is significant at the 0.05 level (2-tailed).						

Source: Virginia DEQ data (2023). Analysis by Virginia Commonwealth University research team.

Table 9. Correlations: Estimated Potential Emissions Concentrations from Data Center Permits and Select Demographic Characteristics

Pollutant	Correlation Statistics	Population Density	Non-White Percent	Median HH Income	Higher Ed Percent	Home Owner Percent
CO / sq. mi.	Pearson Corr.	-0.051	0.064	**-.117***	**-.175****	**-.111***
	Sig. (2-tailed)	0.327	0.219	0.027	<.001	0.032
NOx / sq. mi.	Pearson Corr.	-0.018	0.051	**-.154****	**-.162****	**-.160****
	Sig. (2-tailed)	0.724	0.326	0.003	0.002	0.002
PM 2.5 / sq. mi.	Pearson Corr.	-0.074	0.056	**-.113***	**-.185****	-0.081
	Sig. (2-tailed)	0.154	0.282	0.032	<.001	0.119
** Correlation is significant at the 0.01 level (2-tailed).						
* Correlation is significant at the 0.05 level (2-tailed).						

Source: Virginia DEQ (June, 2025). Issued Air Permits for Data Centers. Analysis by VCU research team.

Conclusions / Next Steps

- Localized air pollution impacts are already significant, could be far worse if "backup" generators used more often (e.g., DOE Order No. 202-26-06; VA DEQ proposal APG-578)
- Policy around siting, use of more advanced Tier IV generators
- Future research
  - » Apply methodology to other locations (e.g., Henrico Co.), test replicability
  - » Use real-time monitoring to measure, compare emissions in data center areas
  - » Explore public health impacts, including acute vs. chronic
  - » Digitize spatial footprints of data centers, evaluate / compare land use impacts
  - » Model opportunities / challenges to replace generators with battery storage

Questions?

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