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Air Quality, Health, and Economic Impacts of the Vantage Data Center Facility

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Executive Summary

- This report evaluates the estimated public-health and economic impacts attributable to fine particulate matter ($PM_{2.5}$) emissions from the permitted on-site power system at the Vantage Data Center in Loudoun County, Virginia. The analysis reflects operation at the facility's maximum permitted annual emission limits.
- $PM_{2.5}$ is widely recognized as one of the most harmful air pollutants to human health. Extensive scientific evidence shows long-term exposure to $PM_{2.5}$ — even at levels below current federal standards — is associated with increased risks of heart disease, stroke, respiratory illness, asthma exacerbation, and premature death.
- Using the U.S. Environmental Protection Agency's COBRA health impact model, the facility's permitted emissions are estimated to result in between $53–99 million per year in health-related damages. These damages are driven primarily by an estimated 3.4 to 6.5 additional premature deaths per year across the impacted region, along with hospital admissions, asthma-related outcomes, and lost productivity.
- If annual impacts remain at this level, total estimated health damages would add up to $265–$495 million over 5 years and $1.59–$2.97 billion over 30 years (undiscounted), corresponding to approximately 17–33 premature deaths over 5 years and 102–195 deaths over 30 years. These totals reflect incremental $PM_{2.5}$ exposure affecting a large metropolitan population, where even modest increases in annual-average exposure translate into significant population-level health impacts and substantial cumulative health costs over the facility's operating lifetime.
- Geographically, the largest estimated county-level annual-average exposure increase attributable to the facility occurs in Loudoun County (0.034 μg/m³). Because of its larger population, Fairfax County accounts for the largest share of estimated total population exposure (37.7%). Elevated exposure extends beyond Loudoun into Fairfax County, the District of Columbia, and parts of Maryland.
- At the community level, the highest estimated annual-average increases occur in Sterling (0.137 μg/m³), Dulles Town Center (0.117 μg/m³), Oak Grove (0.115 μg/m³), and Dranesville (0.108 μg/m³). More than 2.5 million people live in census tracts with estimated annual exposure increases greater than 0.01 μg/m³, including 54,700 residents in tracts above 0.1 μg/m³.
- Census tracts experiencing the highest estimated $PM_{2.5}$ increases include large and diverse communities within Northern Virginia, with higher proportions of Hispanic and Asian residents relative to statewide averages and elevated Social Vulnerability Index (SVI) scores. In Loudoun County, the highest estimated exposure increases are concentrated in southeastern portions of the county, which include several areas designated as Environmental Justice communities.
- According to EPA's 2023 Air Quality Statistics, background $PM_{2.5}$ levels in the affected region are already elevated relative to national averages and are close to the current federal annual standard. Emissions from the facility would therefore add to ambient pollution levels in communities that already experience substantial existing air-quality burdens.

Introduction

This report evaluates the potential air-quality and health impacts attributable to the permanent on-site power system permitted for the Vantage Data Center facility at 22318 Glenn Drive, Sterling, Virginia. Based on Virginia Department of Environmental Quality (VA DEQ) air permit No. 74242, the facility is authorized to operate eight natural-gas simple-cycle turbines and more than fifty diesel generators, including emergency and black-start units.

Using the maximum annual emissions authorized in the permit, we quantify how this on-site power system could increase fine particulate air pollution ($PM_{2.5}$) in nearby communities in Loudoun County, Fairfax County, and the broader downwind region. We are not aware of publicly available, facility-specific analyses that translate the permitted emissions from this facility into estimates of annual-average $PM_{2.5}$ exposure burden attributable to the facility and related health damages. This report addresses that gap by providing a transparent assessment of the potential long-term public-health impacts attributable to the facility's permitted emissions.

Scientific foundation and independence

This assessment was conducted by independent scientific experts and was not prepared by or on behalf of the project proponent, permitting agency, or any regulatory authority. The analysis relies on publicly available permit documentation and peer-reviewed air-quality modeling and health-impact assessment methods. It follows established scientific frameworks used to evaluate (1) how emissions disperse and chemically transform in the atmosphere to form fine particulate matter ($PM_{2.5}$), and (2) how increases in $PM_{2.5}$ exposure attributable to the plant translate into adverse health outcomes and economic damages. The approach is consistent with methods widely applied in the academic literature and by federal agencies to assess population-level health impacts of industrial air pollution and builds on decades of statistical and epidemiological research linking long-term $PM_{2.5}$ exposure to increased risks of premature mortality and other adverse health outcomes.[1]

The analysis was conducted by an environmental health scientist and air pollution biostatistician trained at Harvard University. All assumptions, inputs, and analytical steps are documented. This report is intended to provide an independent, policy-relevant assessment of potential long-term public-health impacts attributable to the facility's permitted emissions. The analysis is focused on population-level health impacts and does not replace regulatory compliance modeling conducted as part of the permitting process.

What is $PM_{2.5}$ and why does it matter?

Fine particulate matter smaller than 2.5 micrometers in diameter ($PM_{2.5}$) is one of the most harmful forms of air pollution.[2] Because of its microscopic size (roughly 30 times smaller than

[1] Wu et al., "Evaluating the Impact of Long-Term Exposure to Fine Particulate Matter on Mortality among the Elderly"; Di et al., "Air Pollution and Mortality in the Medicare Population"; Cork et al., "Methods for Estimating the Exposure-Response Curve to Inform the New Safety Standards for Fine Particulate Matter"; Henneman et al., "Mortality Risk from United States Coal Electricity Generation."
[2] American Lung Association, "Particle Pollution."

the width of a human hair), $PM_{2.5}$ can penetrate deep into the lungs and enter the bloodstream, triggering inflammation throughout the body.[3]

A large body of scientific evidence links exposure to $PM_{2.5}$ with a wide range of adverse health outcomes, including asthma exacerbation, respiratory and cardiovascular disease, heart attack, stroke, and premature death.[4] According to major public-health assessments, $PM_{2.5}$ accounts for the majority of the roughly eight million global deaths each year attributed to air pollution, making it a leading environmental risk factor worldwide.[5] High-risk groups include children, asthmatics, and older adults with pre-existing heart and lung conditions. Many of these populations are concentrated in sensitive locations—such as schools, daycare centers, nursing homes, and residential communities—making the proximity of emission sources to these areas an important consideration.

$PM_{2.5}$ originates from both direct and indirect sources. Primary $PM_{2.5}$ is emitted directly into the air from combustion processes such as power generation, vehicle exhaust, and industrial activity. Secondary $PM_{2.5}$ forms when gases such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), and volatile organic compounds (VOCs) react in the atmosphere, often in the presence of sunlight. These reactions convert the gases into fine sulfate, nitrate, and organic particles that become part of the $PM_{2.5}$ mixture people breathe. Together, these pathways contribute to ambient $PM_{2.5}$ exposure that affect regional air quality and public health.

Importantly, there is no known safe level of exposure to $PM_{2.5}$.[6] Health risks increase continuously as exposure rises, with no threshold below which exposure is considered harmless. A large body of evidence, including national studies of more than 60 million U.S. Medicare beneficiaries employing causal inference methods, indicates that long-term increases in $PM_{2.5}$ contribute to higher mortality and hospitalization rates—even at concentrations below current federal standards.[7] In practical terms, this means that modest incremental increases in pollution can still produce meaningful population-level health impacts when large numbers of people are exposed.

Emissions Inputs and Scope of Analysis

Facility and Emissions Scope

This analysis evaluates the air-quality and health impacts attributable to the permanent on-site power system permitted for the Vantage Data Centers VA2 facility located at 22318 Glenn Drive,

[3] US Environmental Protection Agency, “Particulate Matter (PM) Basics.”
[4] Birnbaum et al., “Measuring The Impact Of Air Pollution On Health Care Costs”; Di et al., “Association of Short-Term Exposure to Air Pollution With Mortality in Older Adults”; Wu et al., “Evaluating the Impact of Long-Term Exposure to Fine Particulate Matter on Mortality among the Elderly.”
[5] Health Effects Institute and IHME, “State of Global Air Report 2025.”
[6] American Lung Association, “Particle Pollution.”
[7] Di et al., “Air Pollution and Mortality in the Medicare Population”; Wu et al., “Evaluating the Impact of Long-Term Exposure to Fine Particulate Matter on Mortality among the Elderly”; Cork et al., “Methods for Estimating the Exposure-Response Curve to Inform the New Safety Standards for Fine Particulate Matter”; Josey et al., “Air Pollution and Mortality at the Intersection of Race and Social Class.”

Sterling, Virginia (Loudoun County), under Virginia Department of Environmental Quality (VA DEQ) air permit Registration No. 74242. Based on the permit, the facility is authorized to operate multiple combustion sources, including eight natural-gas simple-cycle turbines (Ref. Nos. TG-01 through TG-08) and 51 diesel engine generator sets, consisting of 49 emergency diesel gen-sets (Ref. Nos. EG-01 through EG-49) and two black-start diesel gen-sets (Ref. Nos. EP-BS1 and EP-BS2).

Emissions inputs are based on the facility-wide annual emission limits specified in the permit, which are derived from enforceable operating limits and emission factors. These values represent maximum annual emissions and provide an appropriate basis for a bounding, screening-level analysis of potential long-term impacts. Using maximum permitted annual emission limits allows this report to characterize the potential magnitude and geographic extent of $PM_{2.5}$ impacts if the facility were operated up to its permitted limits; the analysis does not attempt to predict typical operating conditions, dispatch patterns, or short-term variability.

Pollutants Included

The permit establishes facility-wide annual emission limits (all units combined), including 56.51 tons per year (tpy) of $PM_{2.5}$, 95.00 tpy NO_x (as NO_2), 19.21 tpy SO_2, 42.87 tpy VOC, and 41.76 tpy CO.

Scope of the Assessment

The scope of this report is limited to changes in annual-average $PM_{2.5}$ exposure and the resulting health and economic effects attributable to the Vantage facility's permitted emissions. This analysis evaluates health impacts under a "full permitted operation" screening scenario, reflecting the maximum annual emissions authorized by the facility's air permit. In this report, annual-average $PM_{2.5}$ exposure refers to the population-weighted annual-average ambient $PM_{2.5}$ concentration increment ($\Delta PM_{2.5}$) attributable to the facility.

This screening approach does not assume that on-site generators operate only during emergency events. Rather, it reflects the total emissions allowed under the permit and therefore captures a bounding, full-permit emissions scenario: the potential magnitude and geographic extent of impacts if actual annual emissions approach the maximum permitted annual emission limits, regardless of the specific mix of permitted operating modes. Actual impacts would be expected to scale with actual annual emissions. The results should therefore be interpreted as illustrating the potential public-health implications of the permitted on-site power system when operated at its authorized emission levels. It is important to note that generator "tier" standards regulate emissions per hour of operation but do not directly constrain total annual emissions if operating hours increase. Accordingly, the health impacts estimated here reflect total permitted emissions rather than assumptions about specific operating schedules.

Ammonia (NH_3) emissions were not explicitly included in the primary modeling analysis. Although the permitted natural-gas turbines employ selective catalytic reduction (SCR) systems that use ammonia or urea injection for nitrogen oxides (NO_x) control, the air permit does not specify an enforceable annual emission limit for NH_3, nor does it require routine reporting of

ammonia emissions or ammonia slip rates. As a result, facility-specific NH_3 emission quantities could not be derived directly from the permit documentation. Because ammonia is a precursor in the formation of secondary fine particulate matter ($PM_{2.5}$), the exclusion of facility-specific NH_3 emissions may result in the underestimation of secondary $PM_{2.5}$ formation. Accordingly, estimated $PM_{2.5}$ exposure and associated health impacts should be interpreted as conservative with respect to ammonia-related secondary formation.

In addition to contributing to secondary $PM_{2.5}$ formation, short-term exposure to elevated ammonia concentrations can cause irritation of the eyes and respiratory tract, typically associated with localized or transient “ammonia slip” events from SCR systems. This analysis focuses on long-term, annual-average $PM_{2.5}$ formation and does not quantify short-term ammonia exposures or acute irritation effects, which are outside the scope of this assessment.

Analytical Approach and Methodology

Overview

To estimate potential air-quality and public-health impacts attributable to operation of the Vantage Data Center’s on-site power system, this analysis applies a multi-step framework that translates permitted emissions into long-term changes in ambient fine particulate matter ($PM_{2.5}$), population exposure, and attributable health and economic impacts. Emissions inputs and scope are defined in the preceding section; this section describes how those inputs are represented and evaluated within the modeling framework.

1. Source representation and release assumptions

The geographic location of the emissions source was defined using the facility location reported in the Virginia Department of Environmental Quality (VA DEQ) air permit for the Vantage Data Centers VA2, LLC in Sterling, Virginia. Facility emissions were represented as a single, aggregated elevated point source, consistent with a regional screening application of the Intervention Model for Air Pollution (InMAP). This facility-wide representation aggregates emissions from permitted gas turbines and diesel generators into a single source characterized by the maximum annual emission limits authorized under the air permit. It avoids introducing additional assumptions regarding unit-specific dispatch, operating schedules, or temporal variability, which are not required for evaluating long-term average exposure and health impacts.

Because the permit does not specify a complete set of stack geometry and exhaust parameters required for dispersion modeling, representative release parameters were derived from facility documentation and the DEQ-approved turbine stack test report. The stack inside diameter (108 inches; 2.74 meters) was taken directly from the sampling location information provided in the compliance test documentation. Exhaust temperatures used in the model (686 K) are consistent with flue gas temperatures measured during performance testing (~770–780°F). Exit velocity (20.7 m/s) was calculated from reported volumetric flow rates and stack dimensions documented in the stack test data. A representative stack height of 50 feet (15.24 meters) was assumed based on facility documentation obtained through public records and materials

accompanying the stack testing documentation. Because the air permit does not specify an enforceable stack height, this value represents a documented engineering parameter used for dispersion modeling rather than a regulatory limit.

2. Dispersion and atmospheric chemistry modeling

The analysis uses the Intervention Model for Air Pollution (InMAP) to estimate how emissions from the facility disperse and chemically transform in the atmosphere, contributing to downwind changes in annual-average $PM_{2.5}$ exposure. InMAP incorporates long-term meteorological conditions, terrain, and key atmospheric chemistry processes to estimate both primary $PM_{2.5}$ impacts and secondary $PM_{2.5}$ formation from precursor emissions.[8] Model outputs consist of gridded estimates of incremental annual-average $PM_{2.5}$ exposure attributable solely to the facility.

Why InMAP is the appropriate dispersion model

The objective of this analysis is to estimate population-level $PM_{2.5}$ exposure and attributable health impacts, including secondary particulate matter formed from precursor emissions. InMAP is a peer-reviewed, reduced-complexity atmospheric chemistry model designed specifically to estimate marginal changes in annual-average $PM_{2.5}$ exposure at regional scales, including secondary $PM_{2.5}$ formation.[9] "Reduced complexity" refers to computational efficiency rather than scientific validity; InMAP is calibrated against more complex chemical transport models and retains the processes necessary for health-impact assessment. Accordingly, InMAP is well-suited for screening-level, decision-relevant estimation of population-level $PM_{2.5}$ exposure attributable to a single source, which is the objective of this analysis.[10]

AERMOD is the EPA-preferred model for regulatory permitting and compliance demonstrations, particularly for evaluating near-field concentrations at specific receptors and shorter averaging times.[11] However, AERMOD does not simulate atmospheric chemical reactions or gas-to-particle conversion and therefore does not explicitly account for secondary $PM_{2.5}$ formation. For combustion sources, secondary formation from precursor emissions such as NO_x and SO_2 can represent a substantial—and in some cases dominant—portion of total annual-average $PM_{2.5}$ concentrations.[12] As EPA acknowledges, secondary $PM_{2.5}$ formation is chemically complex and is not represented in dispersion models that do not simulate atmospheric chemistry.[13] Because precursor emissions can form fine particles downwind over regional scales, EPA guidance emphasizes that model selection should reflect the nature of the source and its emissions.[14] When the objective is to estimate regional, annual-average

[8] Tessum et al., "InMAP."
[9] Tessum et al., "InMAP."
[10] Henneman et al., "Mortality Risk from United States Coal Electricity Generation."
[11] US Environmental Protection Agency, "Air Quality Dispersion Modeling - Preferred and Recommended Models."
[12] US Environmental Protection Agency, Integrated Science Assessment (ISA) for Particulate Matter.
[13] US Environmental Protection Agency, Guidance for PM2.5 Permit Modeling.
[14] US Environmental Protection Agency, Guidance for PM2.5 Permit Modeling.

exposure attributable to those precursors, the use of a model that incorporates both dispersion and chemical transformation is scientifically appropriate and well aligned with EPA guidance.

3. Estimating community exposure and exposure burden

We aggregated InMAP's gridded $PM_{2.5}$ exposure increments to policy-relevant geographic units, including census tracts, counties, cities, and towns. Aggregation was performed using population-weighted averaging, meaning areas where more people live contribute more to the reported exposure values than sparsely populated areas. In simple terms, we calculate the average pollution level experienced by residents, not the average pollution level across land area.

Population weights at the grid-cell level are provided internally by InMAP. For all tract-, county-, and state-level population totals and exposure burden calculations, this analysis uses 2022 American Community Survey (ACS) 5-year population estimates, ensuring consistency with authoritative demographic data.[15]

In addition to estimating the increases in average exposure, the analysis also estimates population-level $PM_{2.5}$ exposure burden attributable to the facility. Exposure burden is defined as the product of the estimated exposure increase and the number of people exposed within a given geographic area. This metric captures both the magnitude of pollution increases and the size of the affected population, providing a measure of where the facility's emissions contribute most to total population exposure. Exposure burden was calculated and reported at the county and state levels, allowing identification of the regions that account for the largest share of total facility-attributable population exposure.

4. Demographic and Socioeconomic Assessment

To characterize the populations most affected by estimated $PM_{2.5}$ increases due to the facility, this analysis includes a demographic and socioeconomic assessment using publicly available data from the American Community Survey (ACS) and Centers for Disease Control and Prevention (CDC).[16] Census tracts were grouped based on estimated increases in annual-average $PM_{2.5}$ exposure (e.g., ≥0.01 μg/m³, ≥0.05 μg/m³, and ≥0.1 μg/m³), and population-weighted averages were calculated for key demographic and health indicators.

Demographic and socioeconomic indicators—including race and ethnicity, poverty rate, median household income, median property value, and age distribution—were derived from ACS 5-year estimates. Health and vulnerability indicators include adult asthma prevalence from CDC PLACES and the CDC/ATSDR Social Vulnerability Index (SVI).[17] Results describe the characteristics of populations living in tracts experiencing different levels of estimated $PM_{2.5}$

[15] US Census Bureau, "American Community Survey 5-Year Data (2009-2023)"; CDC, "Health Outcomes."
[16] US Census Bureau, "American Community Survey 5-Year Data (2009-2023)"; CDC, "Health Outcomes."
[17] CDC, "Social Vulnerability Index."

increase. These tract-level characteristics were compared with state and national averages to assess whether estimated $PM_{2.5}$ impacts disproportionately affect lower-income or historically marginalized communities.

5. Health and Economic Impact Estimation

We estimated health impacts and associated economic damages attributable to the facility's permitted $PM_{2.5}$ emissions using the U.S. Environmental Protection Agency's Co-Benefits Risk Assessment (COBRA) tool.[18] COBRA is a nationally recognized, screening-level public-health assessment model that estimates population-level health and economic effects attributable to changes in fine particulate matter concentrations. The model applies peer-reviewed concentration–response functions linking long-term $PM_{2.5}$ exposure to outcomes such as premature mortality, hospital admissions, cardiovascular events, asthma exacerbations, and lost workdays. These impacts are monetized using standard economic valuation methods to estimate annual health-related damages.

For this analysis, we evaluated a scenario representing an industrial combustion facility located in Loudoun County, Virginia, emitting primary $PM_{2.5}$ and $PM_{2.5}$ precursor pollutants at levels consistent with the facility's permitted annual emission limits. COBRA estimates changes in health outcomes and economic damages across the contiguous United States, accounting for both the magnitude of exposure changes and the size of the affected population. COBRA is used here to address the policy-relevant question: *What is the expected magnitude of population-level health and economic impacts attributable to the facility's permitted $PM_{2.5}$ emissions?* Results represent screening-level estimates of long-term impacts rather than predictions of individual risk or regulatory compliance outcomes.

Interpretation and visualization thresholds

For visualization and summary purposes, this report uses practical exposure thresholds to help readers interpret estimated increases in annual-average $PM_{2.5}$ attributable to the facility. Maps display areas with estimated increases of 0.01 μg/m³ or greater, allowing readers to see both the full spatial footprint of emissions and areas with larger estimated increases. These thresholds are not health-based standards and should not be interpreted as distinguishing "safe" from "unsafe" conditions. Rather, they are used to facilitate clear visualization of modeled exposure changes attributable to a facility of this size. Because health risks associated with $PM_{2.5}$ increase continuously with exposure and no safe threshold has been identified, even small increments may contribute to measurable population-level impacts.

To put these estimated changes in context, long-term epidemiological studies consistently show that sustained increases of the order of tenths of a microgram per cubic meter can translate into meaningful public health effects when experienced by large populations. For example, applying a standard log-linear concentration–response relationship between long-term $PM_{2.5}$ exposure

[18] US Environmental Protection Agency, "CO-Benefits Risk Assessment (COBRA) Web Edition."

and all-cause mortality, along with the U.S. baseline mortality rate, a sustained increase of approximately 0.1 μg/m³ in annual-average $PM_{2.5}$ corresponds to roughly 0.7 additional deaths per 100,000 people per year.[19]

For reference, a sustained 0.1 μg/m³ increase in annual-average $PM_{2.5}$ corresponds to an increase in annual mortality rate comparable in magnitude to the U.S. residential building fire death rate (~0.86 deaths per 100,000 people per year).[20] This comparison is provided solely to contextualize scale using familiar population-level mortality rates and does not imply equivalence in cause, biological mechanism, timing (acute versus chronic), or preventability. This comparison is a unit-scale anchor only and is separate from the COBRA results, which directly estimate attributable cases and monetized damages using EPA's tool. Additional methodological details, assumptions, and data sources are provided in the Appendix.

Results: Estimated Air Pollution Impacts from the Vantage Data Center facility

Regional Distribution of $PM_{2.5}$ Increases

Figures 1 and 2 show the estimated increase in annual-average $PM_{2.5}$ exposure attributable to the maximum permitted emissions from the Vantage Data Center in Loudoun County, Virginia. The highest increases occur in census tracts closest to the facility, with peak increments concentrated in eastern Loudoun County and western Fairfax County.

At the regional scale (Figure 1), elevated $PM_{2.5}$ exposure extends beyond the immediate vicinity of the facility into surrounding portions of the District of Columbia and Maryland, with exposure decreasing as distance from the source increases. Figure 2 provides a zoomed-in view of the highest-exposure tracts, illustrating that the largest per-person exposure increments are localized near the facility, particularly along the Loudoun–Fairfax County border. Table 1 summarizes these regional patterns at the county level, ranking counties by their annual $PM_{2.5}$ concentration increase. Loudoun County experiences the largest average increase (0.034 μg/m³), followed by Fairfax County (0.026 μg/m³).

Regional $PM_{2.5}$ Increases in Areas with Elevated Background Pollution

Several of the highest-impact areas identified here overlap with communities that already experience elevated background $PM_{2.5}$ levels based on the most recently available EPA monitoring data. According to EPA's 2023 Air Quality Statistics, the weighted annual mean $PM_{2.5}$ concentration was 8.2 μg/m³ in Loudoun County, Virginia and 9.5 μg/m³ in Fairfax County, Virginia—near or above the current annual $PM_{2.5}$ standard of 9.0 μg/m³.[21] For the Washington–Arlington–Alexandria, DC–VA–MD–WV Metropolitan Statistical Area (MSA) as a

[19] Di et al., "Air Pollution and Mortality in the Medicare Population."
[20] U.S. Fire Administration, "Residential Fire Estimate Summaries (2014-2023)."
[21] US Environmental Protection Agency, "Air Quality - Cities and Counties."

whole, the 2023 weighted annual mean $PM_{2.5}$ concentration was 9.7 μg/m³, indicating elevated regional background levels.

This report does not assess whether the region is formally in or out of regulatory attainment, which is determined through separate federal procedures using multi-year data. Instead, the focus here is on health impacts. Research shows that $PM_{2.5}$ can affect health even at levels below current federal standards, and those standards apply to total pollution from all sources combined—not to any single facility. Even so, discussing current standards provides useful context: background $PM_{2.5}$ levels in the region are already relatively elevated compared to national averages, so additional emissions would contribute to total ambient concentrations in an area with existing pollution burdens.

Table 1. *Estimated increases in annual-average $PM_{2.5}$ attributable to the Vantage facility, summarized by county, independent city, or equivalent jurisdiction. Values represent the estimated increase in annual $PM_{2.5}$ exposure experienced by residents of each area (μg/m³). Population estimates are from the 2022 American Community Survey, rounded to the nearest 100. Counties are ordered from highest to lowest average increase.*

County / Jurisdiction	State	Population	Average annual facility-attributable $PM_{2.5}$ exposure (μg/m³)
Loudoun County	Virginia	420,800	0.034
Fairfax County	Virginia	1,145,400	0.026
City of Fairfax	Virginia	24,200	0.025
City of Falls Church	Virginia	14,600	0.02
Arlington County	Virginia	235,800	0.015
Alexandria city	Virginia	157,600	0.014
District of Columbia	District of Columbia	670,600	0.011
City of Manassas Park	Virginia	17,100	0.008
Montgomery County	Maryland	1,056,900	0.008
Prince George's County	Maryland	957,200	0.007

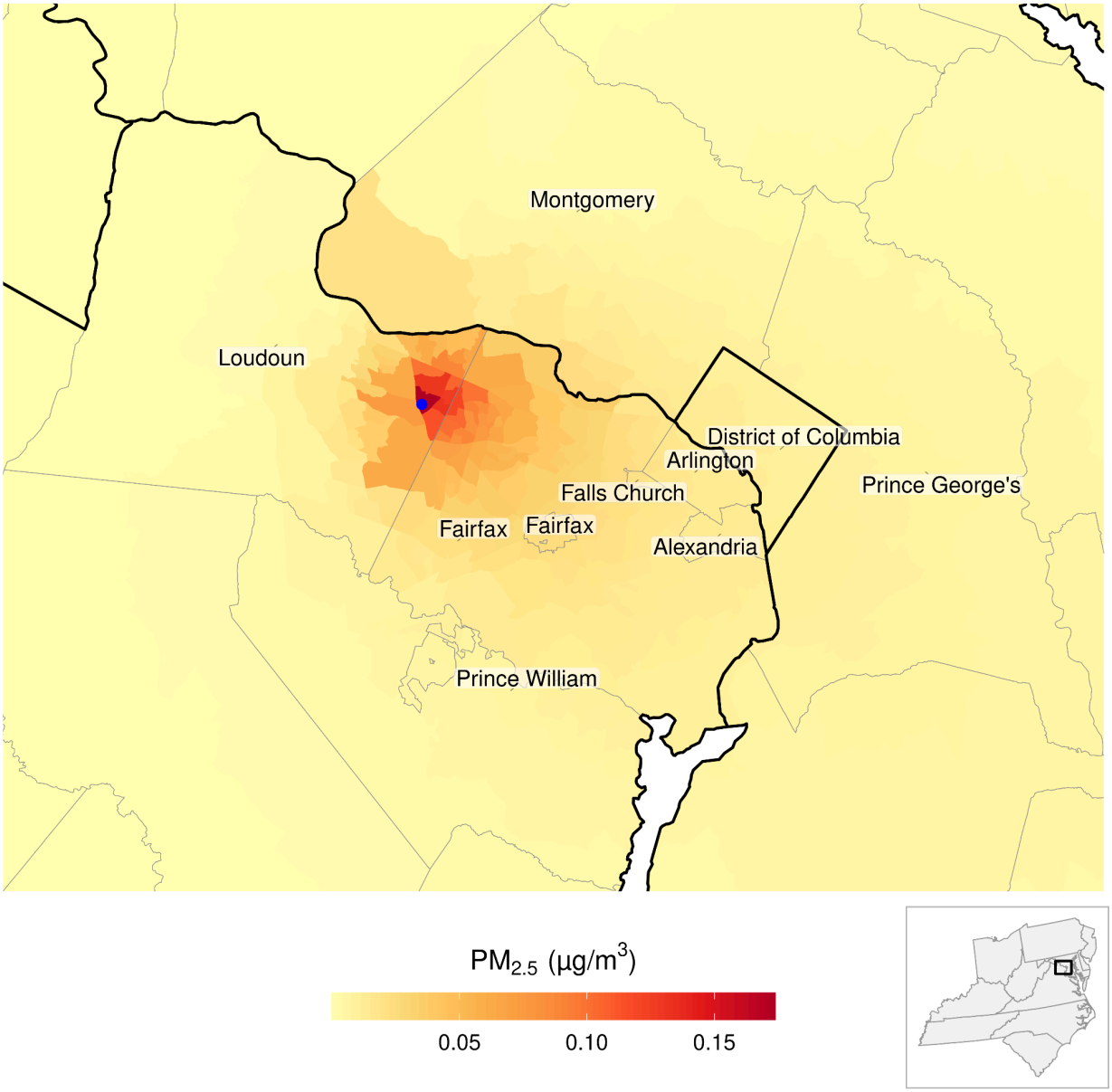

Figure 1. Estimated regional distribution of annual-average $PM_{2.5}$ increases attributable to the Vantage facility. *Colors show the estimated increase in annual $PM_{2.5}$ exposure across census tracts (µg/m³), representing the average additional pollution residents would experience due to facility emissions. The blue dot marks the facility location in Loudoun County, Virginia. County boundaries are shown for reference, and county names are labeled where at least one census tract shows an increase of 0.01 µg/m³ or greater. The inset map shows the study area's location and extent within the eastern United States.*

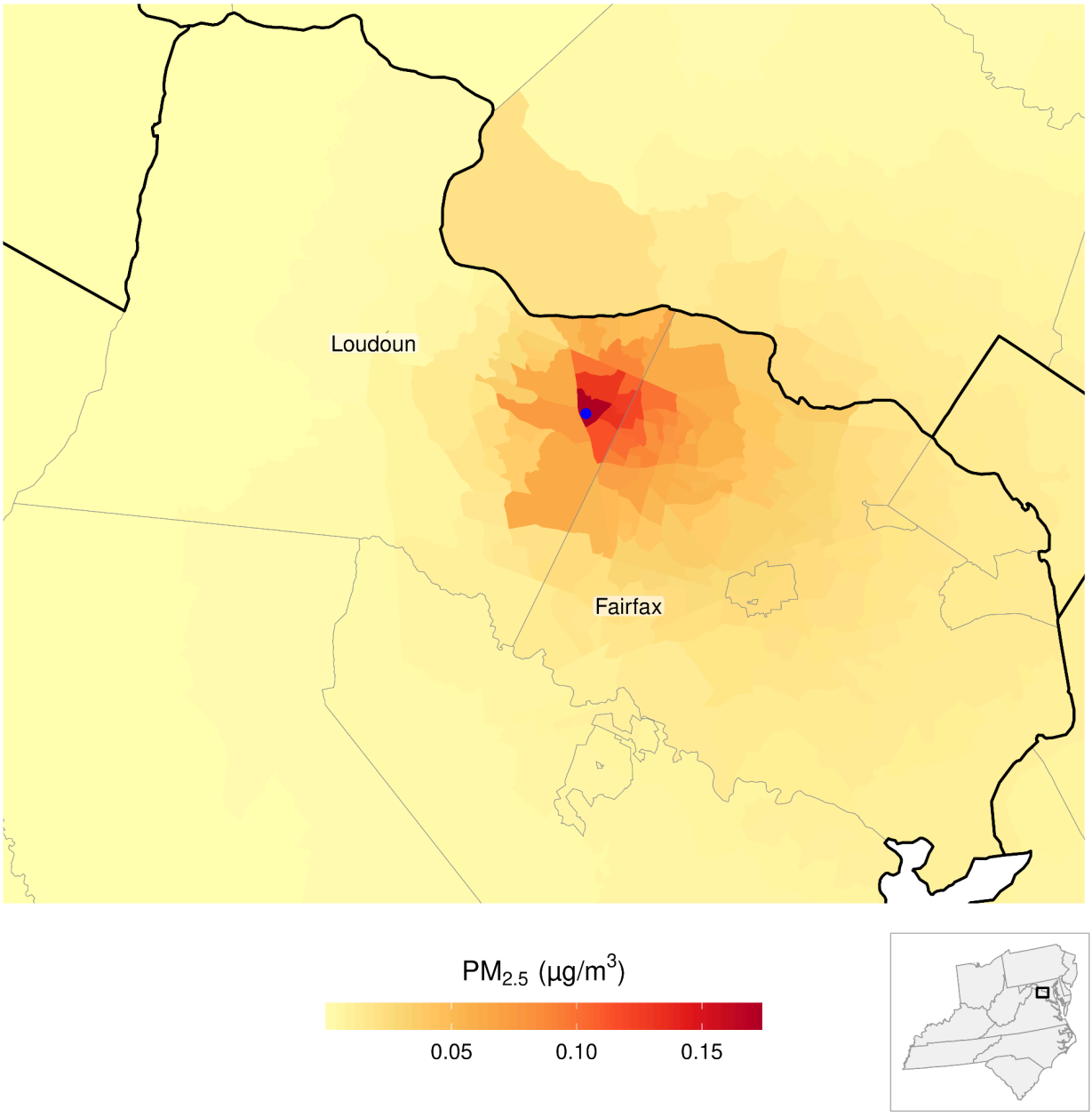

Figure 2: Zoomed-in view of census tracts with the highest estimated increases in annual-average $PM_{2.5}$ attributable to the Vantage facility. *Colors show the estimated increase in annual $PM_{2.5}$ exposure across census tracts (µg/m³), representing the average additional pollution residents would experience due to facility emissions. The blue dot marks the facility location in Loudoun County, Virginia. County boundaries are shown for reference, and county names are labeled where at least one census tract shows an increase of 0.05 µg/m³ or greater. The inset map shows the study area's location and extent within the eastern United States.*

Community-Level Exposure Patterns

While county- and census tract–level maps illustrate the broader regional dispersion of pollution, community-level results provide a clearer picture of how exposure would be experienced by residents in specific towns, census-designated places, and neighborhoods. Figure 3 presents estimated increases in annual-average $PM_{2.5}$ exposure for communities across Northern Virginia, including Loudoun County, Fairfax County, and adjacent portions of the Washington, DC metropolitan area.

The largest estimated increases in $PM_{2.5}$ exposure occur in communities located near and downwind of the Vantage facility, particularly in eastern Loudoun County and western Fairfax County. As shown in Table 2, communities such as Sterling, Dulles Town Center, Oak Grove, Dranesville, and Herndon experience the highest estimated increases in annual $PM_{2.5}$ exposure. Many of these areas are densely populated residential communities, meaning that relatively small increases in average exposure translate into measurable impacts across substantial populations.

The estimated impacts of this facility are not confined to Loudoun County. Elevated estimated $PM_{2.5}$ exposure extends into Fairfax County and surrounding communities, including Reston, McNair, Floris, and portions of the broader Washington metropolitan region. This pattern reflects both the facility's location within a heavily populated corridor of Northern Virginia and the regional transport of emissions across jurisdictional boundaries.

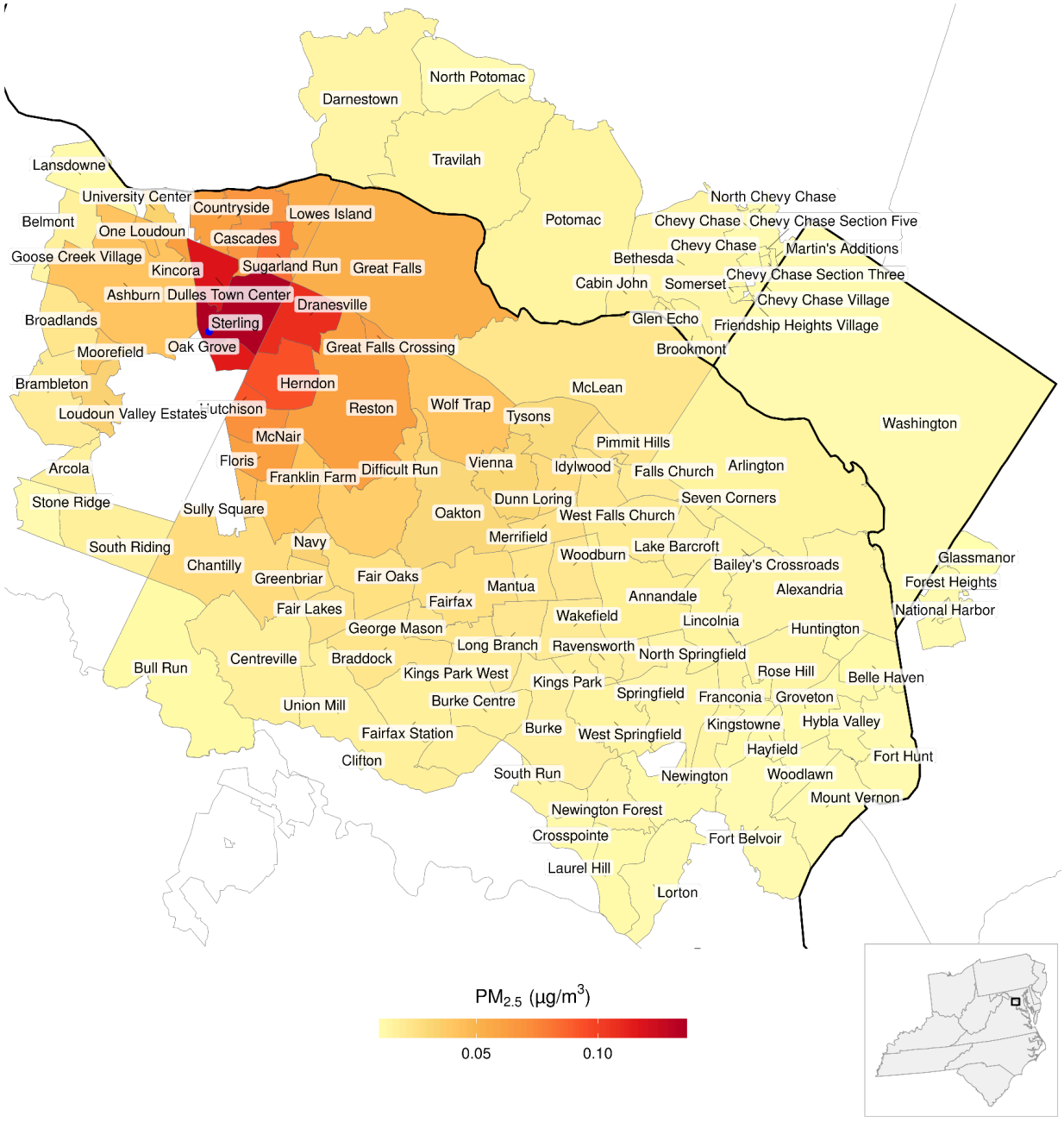

Figure 3. Estimated community-level increases in annual-average $PM_{2.5}$ attributable to the Vantage facility. *Colors show the estimated increase in annual $PM_{2.5}$ exposure (µg/m³) that residents would experience on average within each community. Communities include Census-designated places. Only communities with estimated increases of 0.01 µg/m³ or greater are displayed and labeled. The blue dot marks the facility location in Loudoun County, Virginia. The inset map shows the regional context within the eastern United States*

Table 2. *Communities with the highest increases in estimated annual-average $PM_{2.5}$ attributable to the Vantage Data Center facility. Communities include towns and small cities. Values represent the estimated increase in annual $PM_{2.5}$ exposure (μg/m³) within each community.*

Town	State	Population	Annual increase in $PM_{2.5}$ exposure (μg/m³)
Sterling	Virginia	31,100	0.137
Dulles Town Center	Virginia	5,900	0.117
Oak Grove	Virginia	2,500	0.115
Dranesville	Virginia	12,200	0.108
Herndon	Virginia	24,500	0.094
Hutchison	Virginia	6,900	0.091
Sugarland Run	Virginia	12,800	0.084
McNair	Virginia	22,200	0.069
Cascades	Virginia	12,500	0.066
Floris	Virginia	7,400	0.063
Kincora	Virginia	300	0.062
Countryside	Virginia	9,600	0.062
Reston	Virginia	62,300	0.062
Great Falls Crossing	Virginia	1,500	0.06
Lowes Island	Virginia	11,300	0.056

Population Pollution Exposure Burden and Distribution of Impacts

While understanding where estimated $PM_{2.5}$ exposure increases are highest is important, overall public health relevance also depends on how many people are exposed and where they live. To capture this, we assess population exposure burden, which reflects the combined effect of the magnitude of $PM_{2.5}$ exposure increases attributable to the Vantage facility and the size of the

exposed population. This metric identifies which counties account for the largest share of total population exposure attributable to the facility.

Table 3 summarizes the distribution of population exposure burden across the study region. Fairfax County, Virginia accounts for the largest share of the total estimated $PM_{2.5}$ exposure burden (37.7%), reflecting its large population and proximity to the facility. Loudoun County, where the facility is located, accounts for an additional 16.7% of the total exposure burden and experiences the highest average county-level estimated $PM_{2.5}$ exposure. Together, these two counties account for more than half of the total population exposure burden attributable to the facility.

The remaining exposure burden is distributed across other densely populated jurisdictions in the DC metropolitan area—including Montgomery County and Prince George's County, Maryland; the District of Columbia; Arlington County; and Alexandria, Virginia—which contribute meaningfully to the overall exposure burden despite experiencing smaller average estimated $PM_{2.5}$ exposure increases. At the state level, Virginia accounts for 67.5% of the total exposure burden, followed by Maryland at 23.2% and the District of Columbia at 8.7%.

Table 3. *Distribution of population exposure burden from estimated $PM_{2.5}$ increases attributable to the Vantage facility, summarized by county. "Share of $PM_{2.5}$ exposure burden" represents each county's percentage of the total population exposure across the study region, accounting for both the size of the $PM_{2.5}$ increase and the number of people exposed.*

County	State	Population	Share of facility-attributable annual $PM_{2.5}$ exposure burden (%)	Average facility-attributable annual $PM_{2.5}$ exposure ($\mu g/m^3$)
Fairfax County	Virginia	1,145,500	37.71	0.026
Loudoun County	Virginia	421,000	16.69	0.034
Montgomery County	Maryland	1,057,000	9.52	0.008
District of Columbia	District of Columbia	670,500	8.73	0.011
Prince George's County	Maryland	957,000	8.15	0.007
Arlington County	Virginia	236,000	4.42	0.015
Prince William County	Virginia	481,000	3.44	0.006
Alexandria city	Virginia	157,500	2.68	0.014
Anne Arundel County	Maryland	588,000	1.42	0.002

Charles County	Maryland	167,000	1.32	0.006

Demographic and Socioeconomic Profile of Exposed Communities

Table 4 summarizes demographic and socioeconomic characteristics of residents living in census tracts with higher estimated increases in annual-average $PM_{2.5}$ exposure attributable to the facility. An estimated 2.50 million people live in census tracts with estimated $PM_{2.5}$ exposure increases above 0.01 μg/m³, approximately 247,100 live in tracts above 0.05 μg/m³, and about 54,700 live in tracts with increases above 0.1 μg/m³.

Across higher exposure thresholds, affected populations exhibit distinct demographic patterns compared with statewide and national averages. Census tracts with estimated $PM_{2.5}$ exposure increases above 0.1 μg/m³ have a substantially higher share of Hispanic residents (39.8%) and Asian residents (15.7%), and a lower share of White residents, reflecting the demographic composition of several Northern Virginia communities experiencing the highest facility-attributable exposures.

Socioeconomic characteristics of higher-exposure tracts reflect a mixed profile, with higher average income levels alongside elevated social vulnerability relative to the Virginia average. Median household income and property values in these tracts exceed statewide and national averages, consistent with their location within the Washington, DC metropolitan region. It is important to note that Northern Virginia as a region has substantially higher median incomes and property values than the Virginia statewide average. Accordingly, statewide comparisons may understate relative economic vulnerability within the Northern Virginia context. Nonetheless, social vulnerability increases with higher exposure levels, with Social Vulnerability Index (SVI) scores rising to 47.8 in tracts exceeding 0.1 μg/m³, indicating greater vulnerability relative to much of the state despite above-average income levels.

Environmental Justice Designations in Loudoun County

Several communities within and near the estimated exposure area—including portions of Sterling and eastern Loudoun County—have been identified by the Commonwealth of Virginia and Loudoun County as environmental justice or energy-equity communities.[22] These designations reflect higher concentrations of low-income households and/or communities of color, as well as elevated cumulative environmental and socioeconomic burdens. Populations in these communities may face heightened vulnerability to air-pollution impacts due to baseline health conditions, housing characteristics, and differential access to mitigation resources, meaning that equivalent increases in $PM_{2.5}$ exposure may translate into disproportionate health risks for some residents.

[22] Loudoun County Government, *Energy Equity in Loudoun County: Status Report March 2025*.

Figure 4 presents the spatial relationship between estimated increases in $PM_{2.5}$ attributable to the facility at the census tract level and census block groups designated as Virginia Environmental Justice (EJ) Communities under the 2020 Virginia Environmental Justice Act. While the exposure estimates and EJ designations are defined at different geographic resolutions (tract versus block group), the figure shows that the highest estimated increases in $PM_{2.5}$ exposure in Loudoun County are concentrated in southeastern portions of the county, which also contain several areas designated as EJ communities. This spatial co-location does not imply that all EJ-designated areas experience the highest estimated increases, nor that exposure is limited to those communities. Rather, it indicates that portions of the county identified by the Commonwealth as communities of color and/or low-income communities are located within the area of greatest estimated incremental $PM_{2.5}$ increases from the facility.

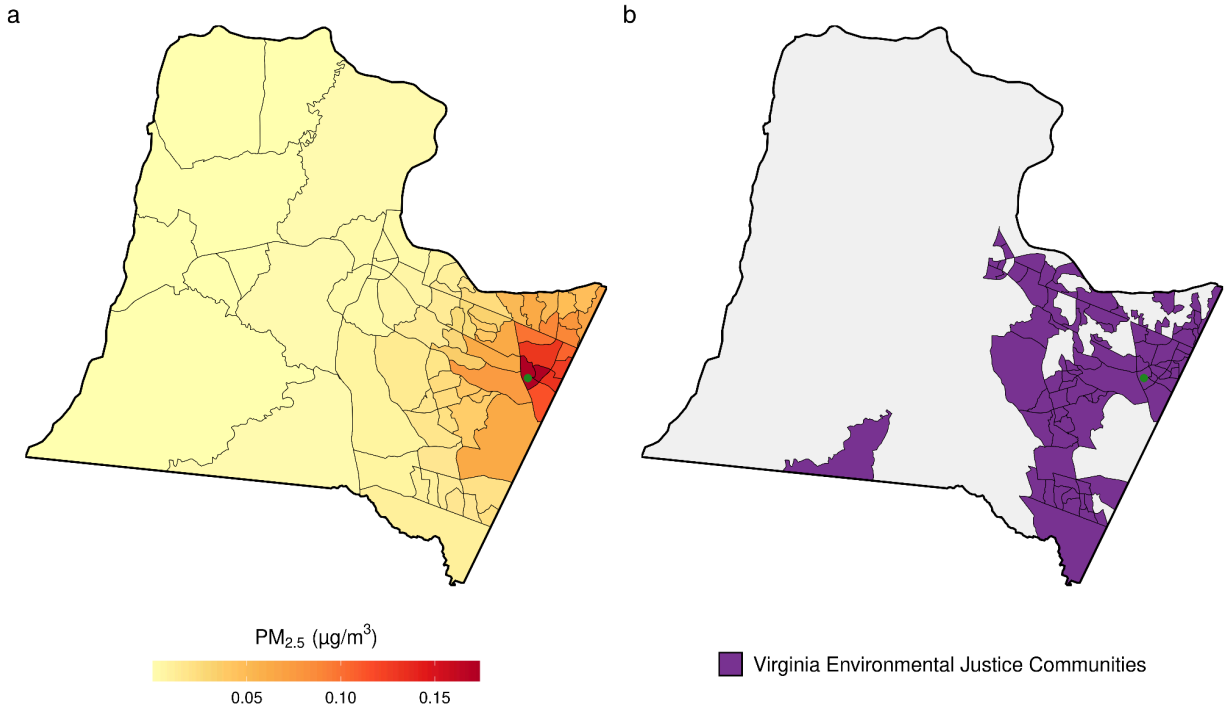

Figure 4. Estimated increases in annual-average $PM_{2.5}$ exposure and Virginia Environmental Justice (EJ) Communities in Loudoun County. *(a) Census tract–level estimated increase in annual-average $PM_{2.5}$ exposure (µg/m³) attributable to the Vantage facility. Colors indicate the estimated incremental increase in annual $PM_{2.5}$ exposure experienced on average within each tract. (b) Census block groups designated as Virginia Environmental Justice Communities under the 2020 Virginia Environmental Justice Act. The green dot marks the facility location. Estimated exposure increments and EJ designations are defined at different geographic resolutions (census tract versus census block group).*

Table 4. *Average demographic and socioeconomic characteristics of census tracts with estimated annual-average $PM_{2.5}$ exposure increases above selected thresholds*

Metric	>0.01 µg/m³	>0.05 µg/m³	>0.1 µg/m³	Virginia	National Average
Total Population Affected	2,495,800	247,100	54,700	8,624,500	331,097,600
Poverty Rate (%)	7	5.6	6.5	10.2	12.5
White (%)	55	52.7	44.4	63.5	65.9
Black (%)	13.7	8.2	7	18.9	12.5
Hispanic (%)	15.3	21.4	39.8	10	18.7
Asian (%)	16.3	18.9	15.7	6.9	5.8
Age 65+ (%)	13.6	12.3	11.1	16	16.5
Median Household Income ($)	154,200	147,600	136,000	100,600	75,100
Median Property Value ($)	726,900	595,200	501,100	389,000	281,900
SVI* (0-100)	31.4	33.6	47.8	39.9	*
Adult Asthma Prevalence (%)	9	8.7	8.9	10.1	10.5

**SVI (Social Vulnerability Index) is a CDC/ATSDR metric ranging from 0–100 that reflects community vulnerability based on socioeconomic conditions, household characteristics, minority status, and housing and transportation factors.*[23]

Health-Related Economic Impacts from the Vantage Facility

To estimate the health-related economic impacts attributable to increased air pollution from the Vantage Data Center facility, we used the U.S. EPA's Co-Benefits Risk Assessment (COBRA) model. COBRA is a nationally recognized, screening-level tool that links changes in air pollution to health outcomes using peer-reviewed epidemiological concentration–response functions. Given user-specified emissions, the model estimates annual changes in health outcomes—such as premature mortality and illness—and assigns monetary values.

For this analysis, COBRA was run using a scenario representing an industrial combustion unit in Loudoun County, Virginia emitting annual quantities consistent with permitted limits: 56.51 tons of primary $PM_{2.5}$, 19.21 tons of SO_2, 95.0 tons of NO_x, and 42.87 tons of VOCs. While COBRA estimates impacts across the contiguous United States, the majority of the projected health burden is expected to be concentrated in Virginia, reflecting regional population patterns and

[23] CDC, "Social Vulnerability Index."

prevailing downwind transport. All results represent annual impacts under continued exposure and are reported in 2023 dollars.

Using these emissions inputs, COBRA projects $53–99 million in additional health-related damages per year. The reported “low” and “high” estimates reflect alternative mortality concentration–response relationships drawn from the epidemiological literature and represent uncertainty in health risk valuation rather than differences in emissions or exposure assumptions. The majority of these damages are attributable to premature mortality, with the model estimating 3.4 to 6.5 additional premature deaths annually, corresponding to $49–95 million in monetized mortality impacts (Appendix A). Additional $PM_{2.5}$-related outcomes—including nonfatal heart attacks, respiratory and cardiovascular hospital admissions, asthma symptoms, stroke, and restricted activity days—contribute approximately $4 million per year.

COBRA also estimates health impacts attributable to ozone (O_3) formation from NO_x emissions, including asthma-related emergency-room visits, school-loss days, and additional mortality. These ozone-related impacts account for approximately $12 million per year. In total, combined $PM_{2.5}$ and ozone impacts result in estimated annual damages of $53–99 million. Of this total, $PM_{2.5}$ accounts for $41–87 million, with the remaining impacts attributable to ozone exposure.

These annual health-damage estimates can also be used to understand how total impacts would add up over time if the turbines continue operating under their permitted limits. We present annual damages as the primary result, but Table 5 shows what those annual damages would amount to over different possible operating periods. Because it is uncertain how long the on-site turbines will operate, Table 5 presents totals assuming operating lives of 5, 10, 20, and 30 years. These are not predictions about how long the turbines will run; instead, they show how total health damages increase over time if annual damages remain between $53 and $99 million.

Under these assumptions, total health damages would add up to $265–$495 million over 5 years and $1.59–$2.97 billion over 30 years. After applying a 3% discount rate to reflect the time value of money, those totals are equivalent to approximately $243–$453 million over 5 years and $1.04–$1.94 billion over 30 years in present-value terms.

Table 5. *Estimated total health damages from the Vantage facility under different operating-life assumptions. The undiscounted totals show what annual damages of $53–$99 million would add up to over 5, 10, 20, and 30 years. The discounted totals show the present value of those same annual damages using a 3% discount rate to account for the time value of money. All values are shown in millions of dollars.*

Assumed Operating Life	**Total Damages over Operating Life** ($ millions)	**Present value of total damages** (3% discount rate; $ millions)
5 years	265 million – 495 million	243 million – 453 million
10 years	530 million – 990 million	452 million – 844 million

20 years	1,060 million – 1,980 million	789 million – 1,473 million
30 years	1,590 million – 2,970 million	1,039 million – 1,940 million

Conclusion

This analysis provides a data-driven assessment of the potential air-quality, health, and economic impacts attributable to emissions from the Vantage Data Center operating at its maximum permitted annual emission limits. Fine particulate matter ($PM_{2.5}$) is a well-established contributor to adverse cardiovascular and respiratory outcomes, and extensive epidemiological evidence shows that even modest long-term increases can produce meaningful population-level health effects.

Estimated $PM_{2.5}$ exposure attributable to the facility extends across Northern Virginia and the broader Washington, DC metropolitan region, with the highest increases occurring near the facility in eastern Loudoun County and extending downwind into Fairfax County and neighboring areas. These estimated exposure increases occur in a region that already experiences elevated background $PM_{2.5}$ concentrations influenced by local sources and regional transport. In this context, emissions from the facility contribute additional pollution to communities that already experience elevated background levels.

Exposure is not confined to the immediate vicinity of the site but affects multiple towns and neighborhoods within a densely populated metropolitan corridor. Because the facility is located within a highly populated metropolitan area, relatively small increases in average $PM_{2.5}$ exposure translate into large cumulative population exposure. Exposure burden is concentrated in Loudoun County and neighboring Fairfax County, with additional contributions from other populous jurisdictions across the DC region, making population size a key driver of the estimated health impacts.

Applying EPA-standard health impact methods, the analysis estimates substantial annual health-related damages of $53–99 million, driven primarily by premature mortality, with additional contributions from cardiovascular and respiratory outcomes, asthma, and lost productivity. These damages reflect the interaction of incremental $PM_{2.5}$ exposure with a large exposed population and imply significant cumulative costs over the facility's operating lifetime.

This assessment reflects emissions consistent with operation at permitted limits and focuses on health impacts attributable to $PM_{2.5}$ and ozone formation from precursor emissions. The results indicate that operation of the facility at permitted emission limits would contribute to measurable air pollution and health burdens across surrounding communities, including populous areas and communities already experiencing cumulative environmental and socioeconomic stressors.

Appendix A. EPA COBRA Health Impact Results for the Vantage Data Center Power Facility

Estimates reflect the U.S. EPA's CO-Benefits Risk Assessment (COBRA) model applied to the Vantage facility on-site power generation in Loudoun County, Virginia, assuming annual emissions consistent with the Virginia DEQ air permit limits. Emissions include 56.51 tons of primary $PM_{2.5}$, 19.21 tons of SO_2, 95.0 tons of NO_x, and 42.87 tons of VOCs per year, reflecting facility-wide allowable emissions.

Results represent estimated health impacts across the contiguous United States, though the majority of the health burden is expected to fall in Virginia, Maryland and the District of Columbia. Estimates are reported on an annual basis and reflect EPA's standard concentration–response functions and valuation assumptions as implemented in COBRA.

Notes:

- *Note: For clarity, this table presents COBRA-estimated impacts as positive "additional" cases and positive "monetized damages." The EPA COBRA web tool reports these same changes using a negative sign convention to indicate increased adverse outcomes (i.e., negative "health benefits").*
- *For mortality outcomes, COBRA reports a range of estimates reflecting alternative peer-reviewed epidemiological concentration–response functions ("Low" and "High").*
- *All monetary values are expressed in 2023 dollars and rounded, consistent with standard COBRA output conventions.*
- *Health impacts reflect contributions from both $PM_{2.5}$ exposure and ozone (O_3) formation, with ozone-related impacts driven primarily by elevated NO_x emissions.*
- *For clarity and consistency with EPA COBRA web outputs, changes in incidence are rounded to one decimal place (or whole numbers where appropriate), and monetary values are rounded to the nearest thousand or million dollars.*

Health Endpoint	Pollutant	Change in Incidence (annual cases)	Monetary Value (annual dollars)
Mortality (All Cause)	$PM_{2.5}$ | O_3	3.4 to 6.5	$49M to $95M
Nonfatal Heart Attacks	$PM_{2.5}$	1.9	$160,000
Infant Mortality	$PM_{2.5}$	0.025	$390,000
Hospital Admissions, All Respiratory	$PM_{2.5}$ | O_3	0.38	$9,800

Emergency Room Visits, Respiratory	$PM_{2.5}$ | O_3	4.6	$7,500
Asthma Onset	$PM_{2.5}$ | O_3	15	$1.1M
Asthma Symptoms	$PM_{2.5}$ | O_3	2600	$340,000
Emergency Room Visits, Asthma	O_3	0.014	$12
Lung Cancer Incidence	$PM_{2.5}$	0.24	$10,000
Hospital Admissions, Cardio-/Cerebrovascular Disease	$PM_{2.5}$	0.4	$11,000
Hospital Admissions, Alzheimer's Disease	$PM_{2.5}$	1.1	$24,000
Hospital Admissions, Parkinson's Disease	$PM_{2.5}$	0.19	$4,600
Stroke Incidence	$PM_{2.5}$	0.19	$12,000
Hay Fever / Rhinitis	$PM_{2.5}$ | O_3	95	$110,000
Cardiac Arrest, Out of Hospital	$PM_{2.5}$	0.049	$3,000
Emergency Room Visits, All Cardiac	$PM_{2.5}$	0.97	$2,100
Minor Restricted Activity Days	$PM_{2.5}$	2800	$350,000
School Loss Days	O_3	540	$920,000
Work Loss Days	$PM_{2.5}$	470	$150,000
Total $PM_{2.5}$ Health Effects	**—**	**—**	**$41M to $87M**
Total O_3 Health Effects	**—**	**—**	**$12M**
Total Combined Health Effects	**—**	**—**	**$53M to $99M**

Appendix B. Converting estimated $PM_{2.5}$ increments to population mortality rates and selecting scale anchors

This appendix describes how estimated changes in annual-average $PM_{2.5}$ ($\Delta PM_{2.5}$, μg/m³) were translated into expected changes in all-cause mortality expressed as deaths per 100,000 people per year, and how a widely recognized public-health reference rate—the U.S. residential building fire mortality rate—was selected to contextualize magnitude. The reference rate is presented solely to assist interpretation using comparable population-level units and does not imply equivalence in cause, biological mechanism, or timing.

To estimate population-level health impacts, we applied a standard log-linear concentration–response relationship between annual $PM_{2.5}$ exposure and all-cause mortality, consistent with common practice in U.S. health impact assessment and regulatory analyses.[24] The central effect estimate used in this report assumes a 7.3 percent increase in all-cause mortality associated with a 10 μg/m³ increase in annual-average $PM_{2.5}$, based on the large national Medicare cohort analysis by Di et al. (2017).[25] This relationship has been widely used in policy-relevant assessments and reflects evidence that mortality risk increases approximately proportionally with annual $PM_{2.5}$ exposure, including at concentrations below current regulatory standards.

To convert relative risk changes into absolute population terms, we applied the U.S. all-cause mortality rate reported by the Centers for Disease Control and Prevention's National Center for Health Statistics for 2023 (922.9 deaths per 100,000 people per year).[26] For each estimated $PM_{2.5}$ increment, the relative change in mortality risk was multiplied by this baseline rate to obtain an expected change in deaths per 100,000 people per year.

Using this approach, a sustained increase of 0.1 μg/m³ in annual-average $PM_{2.5}$ corresponds to approximately 0.7 additional deaths per 100,000 people per year. These estimates represent expected population-average changes associated with persistent exposure over time and should not be interpreted as predictions of identifiable deaths in specific individuals.

To contextualize this magnitude, we use the U.S. residential building fire mortality rate as a population-level reference expressed in the same units. According to the U.S. Fire Administration's 2023 fire statistics, residential building fires resulted in approximately 0.86 deaths per 100,000 people per year when calculated using reported annual fatalities and U.S. Census population estimates.[27] This reference rate is provided solely to illustrate scale using a familiar, nationally reported mortality metric.

[24] US Environmental Protection Agency, "CO-Benefits Risk Assessment (COBRA) Web Edition."
[25] Di et al., "Air Pollution and Mortality in the Medicare Population."
[26] Centers for Disease Control and Prevention (CDC), "Deaths and Mortality."
[27] U.S. Fire Administration, "Residential Fire Estimate Summaries (2014-2023)"; US Census Bureau, "Population and Housing Unit Estimates."

Residential fire deaths are largely acute events, whereas $PM_{2.5}$-related impacts reflect chronic, population-level risk accumulated over time. The comparison is intended only to contextualize magnitude in consistent units (deaths per 100,000 people per year) and does not imply equivalence in cause, preventability, or timing.

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