Assessment of Air Monitoring Capacity Around Dominion's Proposed Chesterfield Energy Reliability Center Site

Chesterfield County, VA

Loren Hopkins, Ph.D.

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EXECUTIVE SUMMARY

DOMINION'S PLAN FOR AIR QUALITY DATA IS INSUFFICIENT

Virginia Electric and Power Company dba Dominion Energy Virginia ("Dominion") proposes to build the Chesterfield Energy Reliability Center ("the gas plant"), a new, 1,000-megawatt, simple-cycle gas plant (with four 250-megawatt combustion turbines) at the same location as the Chesterfield Power Station. Dominion has operated the Chesterfield Power Station, using various combinations of oil, coal, and gas for over 70 years. Environmental Protection Agency ("EPA") data identify this area as, compared to the rest of the state, disproportionately overburdened with respect to fine particulate matter ("PM2.5") and toxic releases to air.[1] The EPA data also identifies that 44 percent of the population within three miles of the site are people of color. These nearby communities have experienced air pollution from Dominion's coal plant, along with other pollution from other sources still operating today.

Dominion's proposed new gas plant would further add to that burden. The plant would emit multiple air pollutants that have been linked to adverse health effects in amounts sufficient for the Virginia Department of Environmental Quality ("DEQ") to regulate the facility as a major source under the Clean Air Act. PM2.5, which has been shown to be harmful to humans at any level of exposure and linked to a variety of adverse health outcomes, is of particular concern—the proposed gas plant would emit about 61 tons per year more PM2.5 than the Chesterfield Power Station prior to Dominion retiring the last of its coal units in 2023. The harms from emissions of these pollutants, moreover, are cumulative—that is, the increases in pollutants from the proposed gas plant would occur on top of the air pollution that already exists in the area, making it more likely that the additional emissions from the plant will cause adverse health effects in the surrounding communities.

Because of the cumulative nature of pollution's impact on air quality and, by extension, human health in the area, Dominion and state and local regulators cannot accurately assess the potential health impacts of the proposed gas plant without a reliable analysis of the existing ambient air quality at the site before the plant is built and operational. In my opinion, Dominion has not proposed a viable plan to establish baseline air pollution levels in the communities near the proposed site before construction. Without this information, the Board of Supervisors cannot accurately assess the Chesterfield Energy Reliability Center's impacts on public safety, health, or welfare, and DEQ, in turn, cannot assess "the character and degree of injury to, or interference with, safety [or] health"[2] for the surrounding area.

This report evaluates the feasibility of Dominion's proposal to use existing air monitor data to determine the current ambient air quality around the site it has proposed for the Chesterfield Energy Reliability Center project. I examined the capabilities and locations of the existing air monitors in the area that generate publicly available data. Based on my review of this information, I conclude that Dominion cannot obtain an accurate determination of existing air quality in the communities near the proposed site relying on the existing network of state air monitors for three main reasons:

1. The air monitors with publicly available data in the area are neither close enough nor directionally oriented to accurately measure concentrations of pollutants around the site proposed for the Chesterfield Energy Reliability Center.

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[1] Available at EPA, *EPA EJScreen*, https://ejscreen.epa.gov/mapper/ (discussed below in greater detail).
[2] Va. Code 10.1-1307.E; *see also* 9 VAC 5-170-170.

2. The existing air monitors do not all measure the same pollutants or measure ambient air concentrations according to the same time intervals, and the existing data contain considerable gaps.
3. Even using the data that are available, a statistical analysis indicates that there is a source (or sources) in the area that is already emitting harmful pollutants—but with the available data, it is impossible to determine the precise location for that source (or sources), meaning it is also impossible to determine what effect the source (or sources) could have on the background concentrations at the proposed site.

These uncertainties are significant and point to the need for Dominion to install and utilize its own air monitors near the facility and the community, or to identify existing, privately owned air monitors that would be appropriate.

RECOMMENDED ACTION

To understand the effect of an increase in pollution from the proposed Chesterfield Energy Reliability Center, Dominion must determine existing concentrations of harmful pollutants in the communities near the proposed site by collecting (and making publicly available) accurate ambient air quality data. My recommendations are as follows:

- To accurately measure the current ambient pollutant concentrations and monitor concentrations in the future if the gas plant is constructed, Dominion, at a minimum, must install or identify an air quality monitor or monitors located in the communities near the proposed facility.
- At least one monitor should be located in the direction which is predominantly downwind of the proposed site so that it measures concentrations from the site. Ideally, monitors on both the upwind and downwind side of the facility are preferred so that the monitor pair can be used to define the contribution from the site (i.e., by subtracting the concentrations upwind and downwind in the same hour).
- The monitor(s) should provide concentration data for all of the pollutants the proposed gas plant will emit.
- Since the gas plant will emit ozone precursors, the monitor(s) should also provide concentration data for ozone, which poses a risk for the same health effects of concern associated with PM2.5.
- All monitoring data should be provided on an hourly basis, not a 24-hour basis, so that hourly exposures can be assessed by wind direction (e.g., the one-hour PM2.5 National Ambient Air Quality Standards ("NAAQS") cannot be evaluated with 24-hour data).
- The monitor(s) should measure wind direction so that the concentrations can be interpreted as upwind or downwind of the facility.

I also recommend that Dominion complete a robust baseline study of community health that, at a minimum, assesses current rates of asthma attack, asthma incidence, cardiac events, stroke, diabetes, and cancer in communities near the proposed site. Both existing pollution levels and existing community health information are needed to inform community members and decision makers about the cumulative impacts that vulnerable communities may face as a result of their proximity to the proposed Chesterfield Energy Reliability Center.

ASSESSMENT OF AIR MONITORING CAPACITY

BACKGROUND

The gas plant that Dominion proposes to build in Chesterfield raises environmental justice concerns. The site[3] is located in an area EPA has identified with high Environmental Justice index values (EJ index[4]) for PM2.5 and toxic releases to air. At a one-mile radius, each of these is above the 90th percentile (statewide); at a three-mile radius, toxic releases to air is above the 80th percentile (statewide).

Dominion's proposed gas plant would emit multiple air pollutants of concern, including carbon monoxide ("CO"), volatile organic compounds ("VOCs"), particulate matter ("PM"), particulate matter with diameters that are generally 10 micrometers and smaller ("PM10"), nitrogen oxide ("NOx"), and sulfuric acid ("H_2SO_4"). These pollutants have all been linked to adverse respiratory health effects. Health risks from increased emissions of PM2.5, however, present a particular concern. PM2.5 concentrations are linked to many adverse respiratory health effects (including acute events such as asthma attacks), along with cardiac arrest and stroke.

While increases in any of these pollutants could cause harm to people living in the immediate vicinity of the plant, CO, VOCs, and PM2.5 are projected to increase by amounts that would subject the plant to regulation as a major source under the Clean Air Act ("CAA").[5] To be clear, any of these pollutants can cause harm at levels below the CAA's thresholds.[6] But an increase of such a magnitude, as indicated in Dominion's air permit application,[7] is particularly concerning, especially with respect to PM2.5, which is small enough to penetrate deep into the lungs.

These increases, moreover, would not happen in a vacuum. The adverse health effects noted above can all be triggered by other pollutants that are already in the air; the added emissions from the gas plant would have a cumulative effect. Again, PM2.5 is of particular concern for this project, because EPA's EJScreen[8], an environmental justice mapping tool, identifies EJ index values above the 80th

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[3] Dominion now appears to be proposing to build the CERC at 500 Coxendale Road, rather than its initial proposal of 1201 Battery Brooke Parkway. The figures that follow are given for the second proposed location at 500 Coxendale Road.

[4] EPA assigns EJ index values using EJScreen, an environmental justice mapping tool. *See* EPA, *What is EJScreen?*, https://www.epa.gov/ejscreen/what-ejscreen. EJ index values combine demographic factors with a single environmental factor (here, PM2.5) into a cumulative indicator value for a given census block group. A higher value generally indicates higher percentages of people of color/low income and a higher amount of whichever pollutant is being evaluated. EPA calculates this figure by multiplying the environmental indicator for a census block group by the demographic indicator (i.e., low income, people of color) for the same census block group. https://www.epa.gov/ejscreen/ej-and-supplemental-indexes-ejscreen#:~:text=An%20EJ%20index%20combines%20demographic,The%20people%20of%20color%20populations.

[5] *See* Application at 4.2.1 ("As discussed in Section 3.5 and presented in Table 3-8, the proposed CERC project will result in both a significant emission increase and a significant net emissions increase for CO, VOC, PM2.5 and GHGs, and the project is subject to PSD as a major modification for these pollutants."). In fact, EPA recently revised the NAAQS for PM2.5 overall to 9 $\mu g/m^3$ to provide increased public health protection. *See* EPA, *National Ambient Air Quality Standards (NAAQS) for PM-Rule Summary*, https://www.epa.gov/pm-pollution/national-ambient-air-quality-standards-naaqs-pm.

[6] *See, e.g.*, EPA, AMERICA'S CHILDREN AND THE ENVIRONMENT (3d ed.) 1 (2015), https://www.epa.gov/sites/default/files/2015-10/documents/ace3_criteria_air_pollutants.pdf (last visited Apr. 18, 2024).

[7] Dominion Energy, Air Permit Application for the Chesterfield Energy Reliability Center ECT No. 230413-0700 Revision 1 (July 2023) ("Application") at 4.2.1.

[8] EPA, *What is EJScreen?*, https://www.epa.gov/ejscreen/what-ejscreen.

percentile[9] in the state for PM2.5 in the area where Dominion has proposed siting the gas plant. Such a high concentration of PM2.5 makes it more likely that additional emissions from the proposed plant will cause severe health effects in the surrounding communities.[10] EJScreen captures data from various time frames; thus, given the concerning concentrations of PM2.5 identified for the area, a more detailed analysis of the area's pollutants should be undertaken.

Other non-pollutant related stressors, such as having low income, may make the community more vulnerable to these health events which are then exacerbated by pollution. For example, those with low income may not seek routine health care or maintain routine medications compared to others. In a vulnerable community, cumulative impacts must be considered to understand the effect of increases in pollution. Census tract level or ZIP code level information is needed to evaluate the rates of these health events in the proposed site area.

In this respect, to accurately project the plant's health impacts, Dominion must not only complete a robust baseline study of community health (e.g., current rates of asthma attack, asthma incidence, cardiac events, stroke, diabetes, and cancer), but must also determine the existing concentrations of harmful pollutants at the site.

EXISTING AIR MONITOR DATA IS INSUFFICIENT FOR AN ACCURATE BASELINE ASSESSMENT OF AIR QUALITY AT THE PROPOSED SITE

In its air permit application, Dominion proposes to use "existing air monitor data"[11] to evaluate baseline conditions in the ambient air. The existing data, however, cannot give an accurate sense of the baseline for three reasons. First, the air monitors with publicly available data in the area are neither close enough nor directionally oriented to accurately measure concentrations of pollutants around the proposed site. Second, the air monitors do not all measure the same pollutants or measure ambient air concentrations according to the same time intervals, and the existing data contain considerable gaps. Third, even using the data that are available, a statistical analysis (discussed below) indicates that there is a source (or sources) in the area that is already emitting harmful pollutants—but with the available data, it is impossible to determine that source's (or sources') precise location, meaning it is also impossible to determine what effect it could have on the background concentrations at the proposed site. These uncertainties are significant and point to the need for Dominion to utilize air monitors near the facility and the community. These monitors should provide hourly federal reference method ("FRM") quality data for air pollutants and meteorology to ensure accurate measurements of preconstruction concentrations of existing air pollutants.

[9] Available at EPA, *EPA EJScreen*, https://ejscreen.epa.gov/mapper/.

[10] While these data may have included pollution from the Chesterfield Power Station (closed May 2023), the proposed CERC would, if running entirely on gas during normal operation, startup, and shutdown, increase PM2.5 emissions by an estimated 69.01 tons per year *more* than what the coal plant had emitted. *See* Application, Table B-9, Table B-11, at 168-70 [in PDF].

[11] *See* Application at 4-7.

Location of the Air Monitors

According to publicly available data,[12] the closest monitors in the area surrounding the site are the Math-Science, Beach Road ("Beach"), and Shirley monitors, approximately 12, 11.5, and 7.52 miles from the site, respectively (Figure 1, below). None of these monitors fall within a three-mile radius of the proposed site, and so cannot reliably measure concentrations in the immediate area; conversely, because they are relatively far away, these monitors *can* pick up concentrations from other sources that will not necessarily impact the proposed site.

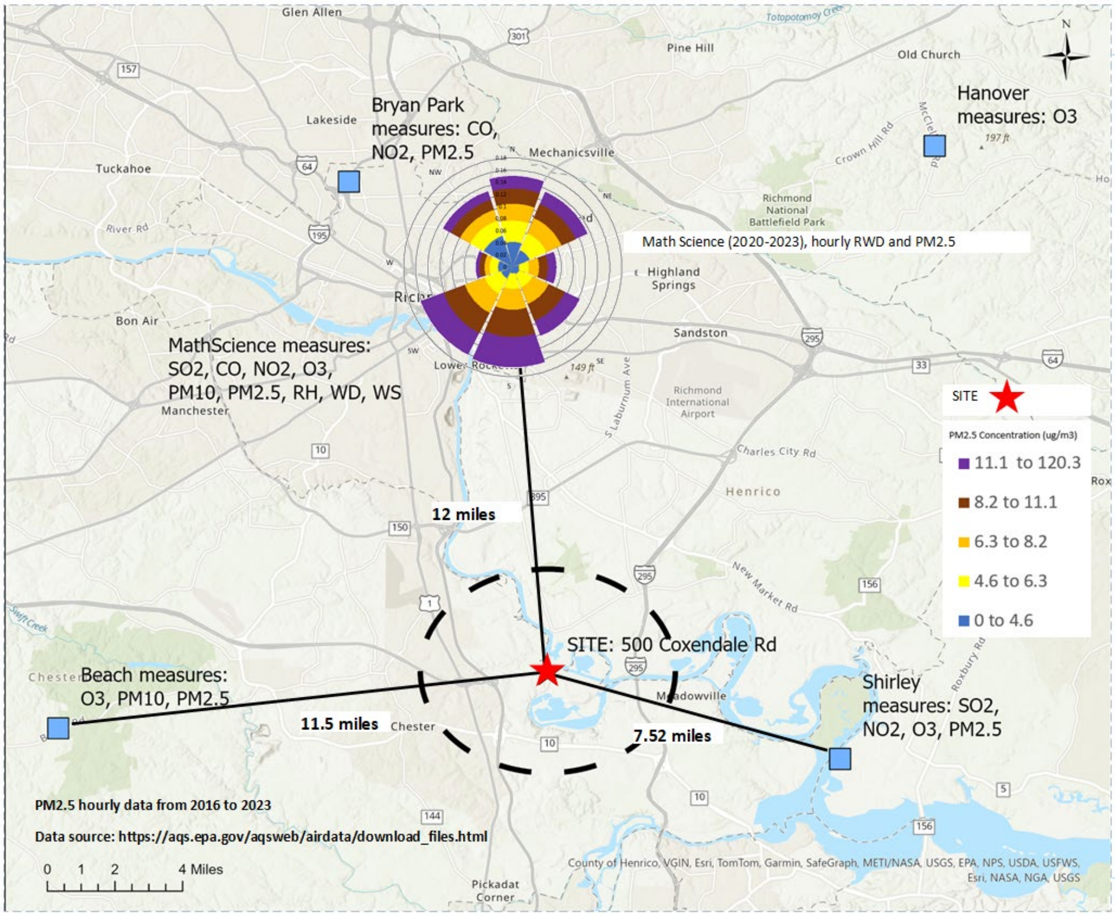

***Figure 1**: Map depicting proposed site, area air pollution monitors, and concentration wind rose of PM2.5 (2020-2023) at Math-Science with predominant wind direction S and SSW.*

The wind rose in Figure 1 depicts two things at the Math-Science monitor: the direction of the wind and the concentrations of PM2.5 for each direction.[13] The wind rose shows the directions of the wind in much the same way that a pie graph shows "slices"—the larger the "slice," the more time the wind blows in that direction. Here, for example, the largest sections of the wind rose are those roughly south and southwest; these two sections account for roughly a quarter of the wind rose, so we know the

[12] EPA, Air Data, Pre-Generated Data Files, https://aqs.epa.gov/aqsweb/airdata/download_files.html#Raw.

[13] EPA explains how to read a wind rose in this document: https://www.epa.gov/sites/default/files/2019-01/documents/how_to_read_a_wind_rose.pdf. The concentration wind rose is a variation of the wind rose EPA uses as an example, where the windspeed is replaced with concentration.

wind blows either from the south or southwest about 25% of the time. The colored segments of each "slice" show what percent of the time the wind has a given concentration of PM2.5. The wind rose above shows that when the wind is blowing south or southwest (the two largest "slices"), PM2.5 concentrations are usually between 8.2 and 120.3 μg/m^3 (purple and maroon), and almost never lower than 4.6 μg/m^3 (blue).[14]

Shirley is the closest air monitor to the proposed site, but its spatial orientation is not in-line with the predominant wind direction needed to measure concentrations representative of the site (i.e., is not often downwind of the site area). According to the resultant wind direction data collected at Math-Science between 2020 and 2023, the predominant wind direction is south and southwest and then north, northeast and northwest. In fact, from Figure 1, we can see that the proposed site (starred) is not in-line between the upwind monitor (Math-Science) and either of the two downwind monitors (Beach or Shirley). As a result, measuring the difference in concentrations of pollutants between the upwind and downwind monitors does not tell us much, if anything, about the background concentrations at the site itself.

EXISTING DATA

The data that the three monitors have collected are not consistent enough for a reliable comparison. In addition, Beach only began measuring hourly PM2.5 in December 2023, which means there is not enough data to analyze (and in any case it is not available to download at present[15]). Table 1 lists the pollutants measured by each of the nearest monitors, the timeframe measured, and the duration of the measurements.

***Table 1**: Air pollutants measured by Virginia DEQ at sites surrounding the proposed plant. "AQS" stands for air quality system. "Partial" indicates that data for only part of the time frame examined, 2016-2023, are available.*

Monitor	Math-Science	Shirley	Beach Road
AQS	51-087-0014	51-036-0002	51-041-0004
PM2.5 (hourly)	2020-2023 (partial)	2023 (partial)	NA
PM2.5 (24 hr)	2016-2023 (partial)	2016-2023 (partial)	2016-2023 (partial)
NO_2 (hourly)	2016-2023 (partial)	2016-2023 (partial)	NA
NO_2 (24 hr)	2016-2023 (partial)	2016-2023 (partial)	NA
Ozone (hourly)	2016-2023 (partial)	2016-2023 (partial)	2016-2023 (partial)
Ozone (8hr)	2016-2023 (partial)	2016-2023 (partial)	2016-2023 (partial)
CO (hourly)	2016-2023 (partial)	NA	NA
CO (24 hr)	2016-2023 (partial)	NA	NA
Wind Direction (hourly)	2016-2023 (partial)	NA	NA

NA=not available

[14] On February 7, 2024, EPA strengthened the National Ambient Air Quality Standard (NAAQS) for PM2.5 by lowering the primary annual PM2.5 standard from 12 μg/m^3 to 9 μg/m^3. EPA did not, however, change the 24-hour PM2.5 standard of 35 μg/m^3. *See* EPA, National Ambient Air Quality Standards (NAAQS) for PM, https://www.epa.gov/pm-pollution/national-ambient-air-quality-standards-naaqs-pm (last visited June 2, 2024); EPA, Final Rule to Strengthen the National Air Quality Health Standard for Particulate Matter Fact Sheet 2 (2024), https://www.epa.gov/system/files/documents/2024-02/pm-naaqs-overview.pdf (last visited June 2, 2024).

[15] As of May 2, 2024.

The closest air monitor to the proposed plant, Shirley, has limited PM2.5 data available on an hourly basis, does not have windspeed or wind direction data, and does not measure CO. The two monitors whose transect comes closest to intersecting the location of the proposed site, Math-Science and Beach, are also not directly comparable. Beach does not measure hourly or 24-hour CO, hourly or 24-hour NO_2, or wind direction. The lack of wind direction data is a particular problem because without it, there is no way to tell where the concentrations of each pollutant being measured are coming from, which makes it impossible to predict how those concentrations will affect the air around the proposed gas plant site.

STATISTICAL ANALYSIS

As discussed above, the publicly available data are not complete or comparable enough to accurately predict background concentrations of pollutants at the site of the proposed plant. However, even using the data that are available, a statistical analysis of the 24-hour PM2.5 concentrations measured at Beach and Math-Science indicates that Math-Science PM2.5 is significantly higher than Beach. Although the proposed site is not exactly in-line with wind from the south-southwest flowing over Beach across the site to Math-Science, that transect is the closest pair of monitors in line with the predominant wind direction to provide insight on what might be expected at the site. When evaluating the concentrations when the wind is from the south-southwest, Beach would be upwind of the proposed site and Math-Science downwind. I found that Math-Science has statistically higher concentrations of PM2.5 than Beach. This indicates that there is a source between the Beach and Math-Science monitors causing increased concentrations at the Math-Science monitor. However, as discussed above, because of the gaps in the data from these two monitors—particularly wind direction—it is impossible to know precisely what that source is or how (or whether) it would impact the ambient air quality at Dominion's proposed site.

To complete the analysis, I used EPA's ProUCL[16] software to run a two-sample t-test with unequal variance.[17] This test compares the averages (sample means) of two samples of data and determines whether the difference between them is statistically significant (e.g., likely not the result of chance). If there are no differences between the concentrations at the monitors, then the average levels should be approximately equal. In this case, I tested if the mean concentration of PM2.5 recorded at Math-Science was lower than the mean concentration of PM2.5 recorded at Beach from 2016 through 2023. The test computes a value (t_0) that represents the difference between the two means while considering the standard deviation and the sample size.[18] To interpret the result, t_0 is compared to a

[16] ProUCL is a statistical software program that EPA has noted includes statistical methods and tools to address many environmental applications. *See, e.g.*, https://www.epa.gov/land-research/proucl-software.

[17] The particular test I used is called the Welch-Satterthwaite (unequal variance) two-sample t-test. This test often applies in situations like the one we have here, where each sample has a different number of data points in it (e.g., 850 from Math-Science compared to 141 from Beach).

[18] Standard deviation measures the distance of the data from the sample mean (e.g., how spread out the data are). The t-test considers the distance between the sample means we are comparing as well as how spread out the data are from each mean to assess the probability that the data from each monitor are measuring the same concentrations, all part of the same distribution of concentration where the concentrations overlap, or if the data are measuring two different distributions of concentration data, two distinct sets of concentrations, not overlapping.

critical t value (which the software calculates based on the number of data points and the confidence level, which here was 95% [p>0.05]). The critical t value is a number that defines the threshold of significance for this kind of statistical test. If t_0 is greater than the critical t value, that means that the mean of whatever "population" the first sample came from is greater than the mean of the "population" the second sample came from, and that the difference is statistically significant.

Here, the "population" that sample 1 (Math-Science) comes from would consist of the concentration of PM2.5 for every hour of every day from 2016 through 2023 that the Math-Science monitor could measure; the "population" for sample 2 (Beach) would be the concentration of PM2.5 for every hour of every day, 2016 through 2023, that the Beach monitor could measure. Obviously, it is impossible to obtain all of that information. The "samples," therefore, are the data we do have—specifically, 850 distinct measurements of PM2.5 concentrations from Math-Science (sample 1) and 141 distinct measurements from Beach (sample 2). The average (mean) concentration for sample 1 was 7.508 μg/m^3, while the mean concentration for sample 2 was 6.701 μg/m^3. The value for t_0 was 5.313 compared to a critical t value of 1.646, meaning that, with the 95% confidence coefficient I applied, we can be 95% confident the "population" (e.g., the hourly PM2.5 concentrations for all of 2016 through 2023) at Math-Science is higher than the "population" at Beach; in other words, the air that Math-Science measures has, on average, higher concentrations of PM2.5 than the air that Beach measures. The test result indicates that the distribution of concentrations at Math-Science is statistically different and higher than the distribution of concentrations at Beach with less than a 5% chance of being wrong. This 5% chance is represented by a p value; with a confidence coefficient for 95% (0.95), a p value less than 5% (0.05) indicates an extremely low probability that the test results occurred coincidentally instead of being caused by a real difference between the two samples. As shown in Appendix A, the p values I obtained were consistently so small that they appear in the spreadsheet as 0.000.

In 2023, smoke from the Canadian wildfires increased the PM2.5 concentrations in the air for much of Virginia over several days during the summer. Because of this external influence, I ran the same two-sample t-test for the data without any of the measurements from 2023. The conclusion remained the same: the Math-Science monitor recorded a statistically higher concentration of PM2.5 than Beach. The results of both tests (2016 through 2023 and 2016 through 2022) are shown below in Appendix A.

These analyses show that the higher concentrations of PM2.5 at Math-Science are not due to coincidence, but rather some source (or sources) between the two monitors that is emitting PM2.5. The presence of this source (or sources) makes it difficult to determine a background concentration of PM2.5 at the proposed site even with the data that is available, because there is no way to know where the source is. Without knowing where the source between Math-Science and Beach is located in relation to the proposed site, we cannot know how or whether emissions from this source affect the amount of PM2.5 that is already in the air at the proposed site.

The Welch-Satterthwaite two-sample t-test uses the equation $t_0 = \frac{(\overline{x}-\overline{y})}{\sqrt{\frac{s_x^2}{n}+\frac{s_y^2}{m}}}$, where $\overline{x}$ and $\overline{y}$ are the sample means for samples 1 and 2, s is the sample standard deviation, and n and m represent the sample size or number of data points in each sample.

Conclusion

Accurately measuring the current ambient pollutant concentrations requires, at a minimum, a monitor located near both the community and the facility. In addition to accurate air quality data, baseline community health data must be collected. Without these two critical bodies of information, any evaluation meant to identify potential human health impacts from the operation of the proposed gas plant in Chesterfield will be ill-informed and should not be relied upon.

APPENDIX A: STATISTICS AND ANALYSES

Statistical comparison of PM2.5 concentrations by monitor-Math-Science to Beach (2016 to 2023)

t-Test Sample 1 vs Sample 2 Comparison for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.2 2/7/2024 2:22:47 PM
From File	daily_pm25_MathShirleyBeach_2016to2023.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference (S)	0.000
Selected Null Hypothesis	Sample 1 Mean <= Sample 2 Mean (Form 1)
Alternative Hypothesis	Sample 1 Mean > the Sample 2 Mean

Sample 1 Data: pm25_24h_math

Sample 2 Data: pm25_24h_beach

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	2152	850
Number of Missing Observations	770	2072
Number of Distinct Observations	850	141
Minimum	0.9	0.6
Maximum	52.65	50.9
Mean	7.508	6.701
Median	6.875	6.1
SD	3.933	3.676
SE of Mean	0.0848	0.126

Sample 1 vs Sample 2 Two-Sample t-Test

H0: Mean of Sample 1 - Mean of Sample 2 <= 0

Method	DF	t-Test Value	Critical t (0.05)	P-Value
Pooled (Equal Variance)	3000	5.160	1.645	0.000
Welch-Satterthwaite (Unequal Variar	1656.8	5.313	1.646	0.000

Pooled SD 3.862

Conclusion with Alpha = 0.050

Student t (Pooled) Test: Reject H0, Conclude Sample 1 > Sample 2

Welch-Satterthwaite Test: Reject H0, Conclude Sample 1 > Sample 2

Statistical comparison of PM2.5 concentrations by monitor-Math Science to Beach (except 2023)

t-Test Sample 1 vs Sample 2 Comparison for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.2 2/7/2024 2:48:06 PM
From File	daily_pm25_MathShirleyBeach_2016to2023 excerpt.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference (S)	0.000
Selected Null Hypothesis	Sample 1 Mean <= Sample 2 Mean (Form 1)
Alternative Hypothesis	Sample 1 Mean > the Sample 2 Mean

Sample 1 Data: pm25_24h_math
Sample 2 Data: pm25_24h_beach

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	1942	765
Number of Missing Observations	615	1792
Number of Distinct Observations	751	135
Minimum	0.9	0.6
Maximum	33.2	32.2
Mean	7.345	6.531
Median	6.821	6
SD	3.347	3.118
SE of Mean	0.0759	0.113

Sample 1 vs Sample 2 Two-Sample t-Test

H0: Mean of Sample 1 - Mean of Sample 2 <= 0

Method	DF	t-Test Value	Critical t (0.05)	P-Value
Pooled (Equal Variance)	2705	5.809	1.645	0.000
Welch-Satterthwaite (Unequal Vari	1493.9	5.991	1.646	0.000

Pooled SD 3.284
Conclusion with Alpha = 0.050
Student t (Pooled) Test: Reject H0, Conclude Sample 1 > Sample 2
Welch-Satterthwaite Test: Reject H0, Conclude Sample 1 > Sample 2

Statistics of 24-hr PM2.5 by year (ug/m^3)

year	N Obs	Variable	N	N Miss	Minimum	Mean	Maximum	Std Dev	Coeff of Variation	95th Pctl	Upper 95% CL for Mean
2016	366	pm25_24h_math	356	10	1.0	7.0	18.4	3.2	44.9	13.4	7.3
		pm25_24h_beach	49	317	1.8	7.3	14.2	2.9	39.8	12.3	8.0
		pm25_24h_shirley	124	242	1.7	6.5	15.2	2.9	44.0	11.9	6.9
2017	365	pm25_24h_math	261	104	1.0	7.2	17.9	3.2	44.4	12.5	7.5
		pm25_24h_beach	122	243	0.9	7.2	16.1	3.2	45.3	12.5	7.6
		pm25_24h_shirley	122	243	1.1	7.0	17.0	3.0	42.7	11.8	7.4
2018	365	pm25_24h_math	124	241	1.5	7.0	18.3	3.3	47.5	14.0	7.4
		pm25_24h_beach	117	248	1.7	6.6	16.9	3.0	46.3	13.1	7.0
		pm25_24h_shirley	110	255	1.5	6.5	17.4	3.0	45.8	12.9	6.9
2019	365	pm25_24h_math	112	253	2.1	6.9	19.6	3.2	45.5	12.0	7.4
		pm25_24h_beach	117	248	1.7	6.7	14.3	2.9	43.3	11.8	7.2
		pm25_24h_shirley	116	249	2.0	6.6	17.6	3.1	46.5	12.3	7.1
2020	366	pm25_24h_math	366	0	0.9	6.9	19.6	3.0	42.7	12.3	7.2
		pm25_24h_beach	118	248	0.6	5.6	13.0	2.5	45.8	10.2	6.0
		pm25_24h_shirley	118	248	1.0	5.6	12.3	2.6	46.8	10.5	6.0
2021	365	pm25_24h_math	359	6	2.5	8.4	33.2	4.1	48.6	15.8	8.7
		pm25_24h_beach	120	245	2.3	7.0	32.2	4.1	57.7	14.1	7.6
		pm25_24h_shirley	116	249	2.2	6.9	32.6	4.1	58.7	12.7	7.6
2022	365	pm25_24h_math	364	1	1.6	7.4	17.3	3.1	41.7	13.2	7.7
		pm25_24h_beach	122	243	1.2	5.8	13.3	2.4	41.1	10.0	6.2
		pm25_24h_shirley	117	248	1.8	5.8	14.5	2.6	44.0	10.1	6.2
2023	365	pm25_24h_math	210	155	1.6	9.0	52.7	7.3	80.5	22.7	9.8
		pm25_24h_beach	85	280	1.6	8.2	50.9	6.7	82.0	18.9	9.5
		pm25_24h_shirley	178	187	2.4	9.1	55.8	7.6	83.7	26.3	10.0

Appendix B: EPA References for the Association Between Pollutants to be Emitted/Precursors and Acute Health Effects

NO_x/NO_2
Asthma:
https://www.epa.gov/no2-pollution/basic-information-about-no2
"Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms."

PM/PM10
Asthma:
https://www3.epa.gov/region1/airquality/pm-human-health.html
"Health effects may include cardiovascular effects such as cardiac arrhythmias and heart attacks, and respiratory effects such as asthma attacks and bronchitis."

Cardiac Arrest and Stroke:
https://www.epa.gov/air-research/air-pollution-and-cardiovascular-disease-basics
"For the population as a whole, however, short -and long-term exposure has been shown to increase hospitalizations for serious cardiovascular events such as coronary syndrome, arrhythmia, heart failure, stroke, and sudden cardiac death, particularly in people with established heart disease."

OZONE
Asthma:
https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution
"[Aggravates] lung diseases such as asthma, emphysema, and chronic bronchitis."

Stroke:
https://www.epa.gov/sciencematters/study-examines-if-long-term-exposure-ozone-impacts-cardiovascular-system
"researchers found a strong correlation between increasing ozone concentrations and carotid artery injury as measured by thickening of the carotid artery and the build-up of plaque in the artery's wall. When the walls of carotid arteries thicken, or plaque builds up, the risk for stroke increases. They found an increase in carotid artery thickness of 5.6 micrometers with a 3 parts per billion increase in the mean annual ozone concentration."

Cardiac Arrest:
https://www3.epa.gov/airnow/airaware-2014/day2.html
"People with cardiovascular disease (your heart and blood vessels) are at risk from particle pollution, which can contribute to heart attacks, strokes, cardiac arrest, and congestive heart failure. Ozone can also harm the heart. And both particle pollution and ozone can increase the risk for premature death."