2022 Air Quality Trends Report

March 2023

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NOACA: Planning For Greater Cleveland

Northeast Ohio Areawide Coordinating Agency

The Northeast Ohio Areawide Coordinating Agency (NOACA) is a public organization serving the counties of and municipalities and townships within Cuyahoga, Geauga, Lake, Lorain and Medina (covering an area with 2.1 million people). NOACA is the agency designated or recognized to perform the following functions:

- Serve as the Metropolitan Planning Organization (MPO), with responsibility for comprehensive, cooperative and continuous planning for highways, public transit, and bikeways, as defined in the current transportation law.
- Perform continuous water quality, transportation-related air quality and other environmental planning functions.
- Administer the area clearinghouse function, which includes providing local government with the opportunity to review a wide variety of local or state applications for federal funds.
- Conduct transportation and environmental planning and related demographic, economic and land use research.
- Serve as an information center for transportation and environmental and related planning.
- As directed by the Board, provide transportation and environmental planning assistance to the 172 units of local, general purpose government.

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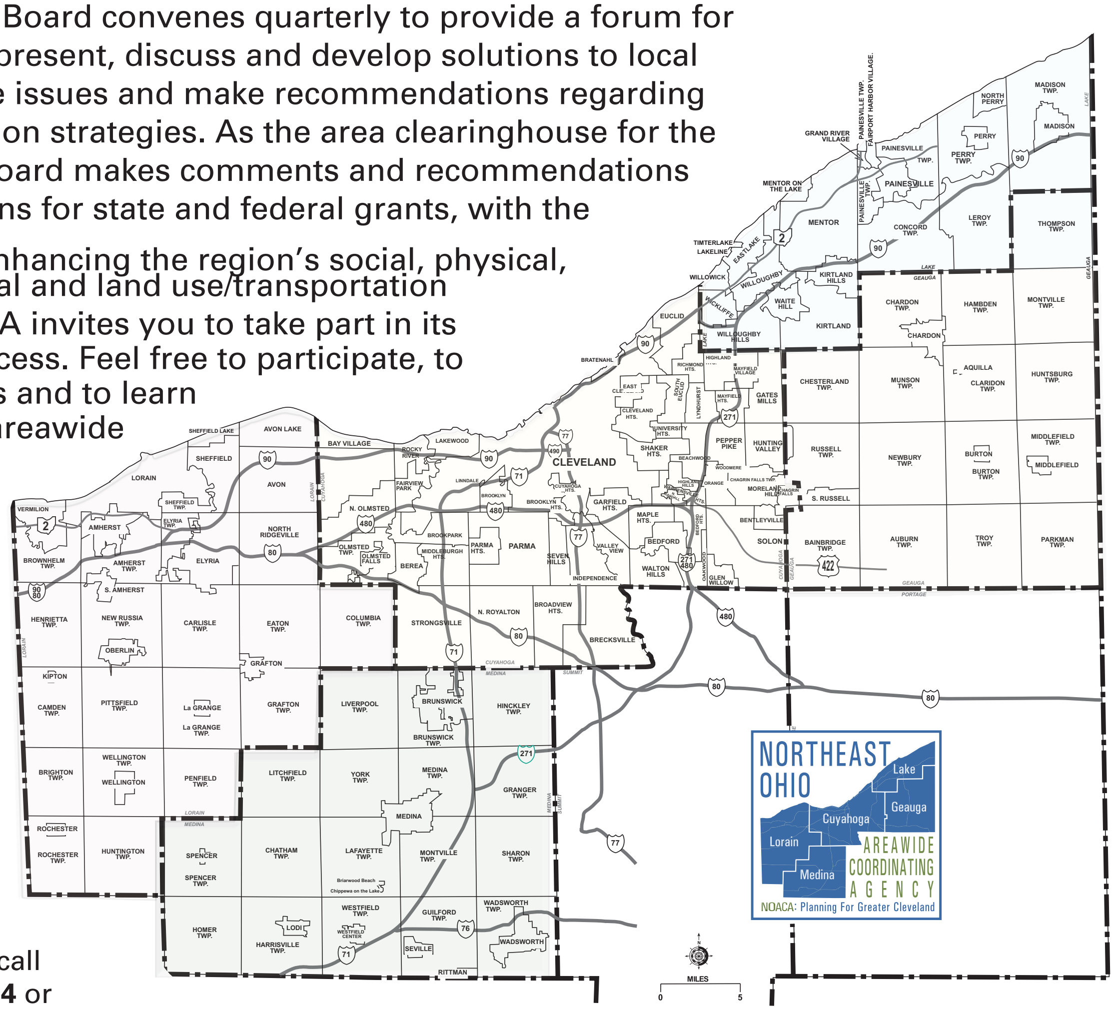

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Air Quality Trends and Attainment Status for Northeast Ohio: CY2021

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ABSTRACT

This report presents information on air quality trends in Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit counties for the six criteria pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. These are the pollutants for which the Clean Air Act requires the United States Environmental Protection Agency (U.S. EPA) to establish National Ambient Air Quality Standards (NAAQS). The NAAQS are the maximum allowable ambient concentrations for each pollutant. The primary NAAQS are intended to protect people by preventing adverse health impacts from excessive pollution concentrations. The report also includes sections on the link between transportation and air quality, as well as on climate change and greenhouse gas (GHG) emissions. Data are generally reported under some form of nonattainment classification for the pollutant under discussion. The nonattainment areas and the associated U.S. EPA attainment dates are also discussed with updates through calendar year (CY) 2021, as of the time of printing this report.

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In 1970, the United States Congress amended the federal Clean Air Act (CAA), leading the U.S. Environmental Protection Agency (U.S. EPA) to create and enforce federal limits for six so-called criteria air pollutants—ozone, particulate matter (coarse and fine), carbon monoxide, sulfur dioxide, lead, and nitrogen dioxide. These limits, known as the National Ambient Air Quality Standards (NAAQS), protect human health and public welfare.

This document summarizes the most current data on air quality in eight counties in Northeast Ohio (Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit), which constitute the NOACA air quality planning area. As the report demonstrates, while air quality has generally improved throughout the region, portions of Northeast Ohio remain in nonattainment for one of the six NAAQS. Additionally, this report examines the links between transportation and air quality (Section 3), as well as greenhouse gas emissions and climate change (Section 6).

NAAQS Attainment Status Summary:

1. **Ozone (Section 5.1):** On April 30, 2018 U.S. EPA designated Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit Counties as a marginal nonattainment area for the 2015 Eight-hour NAAQS of 70 parts per billion (ppb). The region failed to meet its attainment date of August 3, 2021, therefore U.S. EPA raised the designation to moderate nonattainment on October 7, 2022.

2. **Particulate Matter (Section 5.2):** Cuyahoga County was redesignated as a maintenance area for PM_{10} on January 10, 2001. In January 2013, U.S. EPA strengthened the annual $PM_{2.5}$ NAAQS to 12 micrograms per cubic meter (µg/m^3). Cuyahoga and Lorain counties were redesignated as maintenance areas effective April 12, 2019.

3. **Sulfur Dioxide (Section 5.3):** On August 5, 2013, U.S. EPA designated Lake County as a nonattainment area for the 2010 One-Hour sulfur dioxide NAAQS of 75 ppb. U.S. EPA redesignated the county as a maintenance area on May 14, 2019 (84 FR 21253).

4. **Carbon Monoxide (Section 5.4):** Cuyahoga County remains in maintenance status for the 1971 carbon monoxide NAAQS, while all other counties are in attainment.

5. **Lead (Section 5.5):** On May 31, 2017 (82 FR 24871), U.S. EPA redesignated a portion of Cuyahoga County as a maintenance area for the 2008 lead NAAQS of 0.15 µg/m^3.

6. **Nitrogen Dioxide (Section 5.6):** All counties in Northeast Ohio are in unclassifiable/attainment for the 2010 One-Hour nitrogen dioxide NAAQS of 100 ppb.

Air Quality Trends: Northeast Ohio's historic reliance on manufacturing, heavy industry, coal-fired electricity generation, and single-occupancy vehicles has contributed to the region's legacy air pollution. Air quality has improved significantly in Northeast Ohio in recent years (see Section 4); however, as U.S. EPA continues to strengthen the NAAQS to protect public and environmental health, the region is still not in compliance with all EPA standards. Transportation remains the primary driver of Northeast Ohio's air quality issues. On-road vehicles generate the largest share (31.6%) of criteria pollutant emissions. Additionally, ozone (O_3) and fine particulate matter ($PM_{2.5}$) levels have declined by smaller margins than other pollutants. Accordingly, the region still has much work to do to address the dual threat of air pollution and climate change.

1. Introduction

In 1970, the United States Congress passed its first round of amendments to the existing federal Clean Air Act (CAA), significantly reforming the way that the United States regulates air quality and pollution. The CAA (40 C.F.R. § 50), which was last amended in 1990, requires the U.S. EPA to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. The CAA identifies two types of national ambient air quality standards. Primary standards protect public health, including the health of sensitive populations such as asthmatics, children, and the elderly. Secondary standards protect public welfare against decreased visibility and damage to animals, crops, vegetation, and buildings.

Table 1: Summary of National Ambient Air Quality Standards (2021)

Pollutant (final rule cite)		Primary or Secondary Standard	Averaging Time	Level	Form
Carbon Monoxide (76 FR 54294, August 31, 2011)		Primary	Eight-Hour	9 ppm	Not to be exceeded more than once per year
			One-Hour	35 ppm	
Lead (73 FR 66964, November 12, 2008)		Primary & Secondary	Rolling 3-month average	0.15 $\mu g/m^3$	Not to be exceeded
Nitrogen Dioxide (75 FR 6474, February 9, 2010) (61 FR 52852, October 8, 1996)		Primary	One-Hour	100 ppb	98th percentile, average over three years
		Primary & Secondary	Annual	53 ppb	Annual mean
Ozone (80 FR 65291, October 27, 2015)		Primary & Secondary	Eight-Hour	70 ppb	Annual fourth-highest daily maximum eight-hour concentration, averaged over three years
Particle Pollution (78 FR 3085, January 13, 2013)	$PM_{2.5}$	Primary	Annual	12 $\mu g/m^3$	Annual mean, averaged over three years
		Secondary	Annual	15 $\mu g/m^3$	Annual mean, averaged over three years
		Primary & Secondary	24-Hour	35 $\mu g/m^3$	98th percentile, averaged over three years
	PM_{10}	Primary & Secondary	24-Hour	150 $\mu g/m^3$	Not to be exceeded more than once per year, on average over three years
Sulfur Dioxide (75 FR 35520, June 22, 2010) (38 FR 25678, September 14, 1973)		Primary	One-Hour	75 ppb	99th percentile of One-Hour daily maximum concentrations, averaged over three years
		Secondary	three-hour	0.5 ppm	Not to be exceeded more than once per year

Source: U.S. EPA, www.epa.gov/air/criteria.html (accessed February 15, 2023).

In response to the CAA, U.S. EPA created NAAQS for six principal pollutants, called the criteria pollutants because the NAAQS are based on human and environmental health criteria. The current NAAQS are listed in Table 1 above. Units of measure are parts per million (ppm) and parts per billion (ppb) by volume and micrograms per cubic meter of air ($\mu g/m^3$).

Under the CAA, U.S. EPA must periodically revisit these standards. Section 109(d)(1) states that, effective December 31, 1980, U.S. EPA must complete a thorough review of each NAAQS every five years. If appropriate, U.S. EPA must revise the standards to protect public health and the environment.[1] The CAA also called for the creation of an independent scientific review panel—the Clean Air Scientific Advisory Committee (CASAC)—to complete this review and advise the U.S. EPA Administrator.[2] Once U.S. EPA, in concert with CASAC and other stakeholder groups, completes its scientific review for a given NAAQS, the agency undertakes a rulemaking process, ultimately setting a new standard for the pollutant. The CAA stipulates that U.S. EPA must set standards that "allowing an adequate margin of safety, are requisite to protect the public health."[3] U.S. EPA most recently completed this process when it strengthened the existing NAAQS for ground-level ozone (O_3) to 70 ppb from 75 ppb on October 26, 2015 (80 FR 65291).

Within two years of the promulgation of a new NAAQS, U.S. EPA must determine whether regions comply with the standard. Taking input from states and tribes, U.S. EPA designates whether areas meet the standard (attainment areas) or do not meet the standard (nonattainment areas). U.S. EPA typically bases its final area designations on the following five factors:[4]

1. Air quality data
2. Emissions and emissions-related data
3. Meteorology
4. Geography/Topography
5. Jurisdictional Boundaries

Within 18 to 36 months of the designation, states must submit State Implementation Plans (SIPs) for all nonattainment areas within their borders. The Ohio EPA is responsible for developing SIPs, in coordination with appropriate agencies within the nonattainment area and based upon public input. Once approved by U.S. EPA, these SIPs identify the means by which the nonattainment area will come into compliance with the NAAQS by its specific attainment date.[5] For certain pollutants, like O_3, the attainment date is based upon the severity of the nonattainment area's designation. These dates can range from three years for the least severe areas (Marginal) to 20 years for the most severe areas (Extreme).[6] Once a nonattainment area has attained the relevant NAAQS, U.S. EPA will redesignate it as a "Maintenance" area.[7] For all maintenance areas in Ohio, the Ohio EPA must develop a 10-year Maintenance Plan, which identifies the necessary measures to ensure that the area will remain in attainment of the NAAQS and avoid backsliding.[8] Once an area is designated nonattainment for a given NAAQS, it can never be in attainment; it will remain in maintenance status until the NAAQS is rescinded.

[1] 42 Code of Federal Regulations (C.F.R.) §7409(d)(1).
[2] Ibid., (d)(2).
[3] Ibid., (b)(1).
[4] U.S. EPA, "Area Designations for the 2020 Annual Fine Particle ($PM_{2.5}$) Standard: Designations Guidance and Data," https://www3.epa.gov/pmdesignations/2012standards/techinfo.htm (accessed February 15, 2023).
[5] 42 C.F.R. §7502(a)(2).
[6] Ibid., §7511(a)(1).
[7] Ibid., §7407(d)(3)(E).
[8] U.S. EPA, "Area Designations for the 2012 Annual Fine Particle ($PM_{2.5}$) Standard."

2. National Ambient Air Quality Standards (NAAQS) Attainment Status in Northeast Ohio

This section summarizes information on air quality within the NOACA air quality planning area (Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit counties).

Table 2: Attainment Status for NAAQS in Northeast Ohio (2021)

Pollutant	**Recent Trend Direction**	**Designated Attainment Status**	**Counties in Nonattainment**	**Major Contributing Sources**
Ozone (Eight-Hour)	Stable	Nonattainment (Marginal)	Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, Summit	Automobiles, Industry, Utilities, Solvents, Paints, Other Fossil Fueled Engines
Coarse Particulate Matter (24-Hour)	Stable	Maintenance	None	Automobiles, Industry, Construction Sites, Tilled Fields, Unpaved Roads, Stone Crushing, and Wood Burning
Fine Particulate Matter (24-Hour)	Decreasing	Maintenance	None	Automobiles, Industry, Construction Equipment, Ships, Trains, Road Salt, Dirt, and Burning of Wood
Fine Particulate Matter (Annual)	Decreasing	Maintenance	None	Automobiles, Industry, Construction Equipment, Ships, Trains, Road Salt, Dirt, and Burning of Wood
Carbon Monoxide (One-Hour)	Stable	Maintenance	None	Automobiles, Non-Road Vehicles, Steel Mills, Other Combustion Sources
Carbon Monoxide (Eight-Hour)	Stable	Maintenance	None	Automobiles, Non-Road Vehicles, Steel Mills, Other Combustion Sources
Sulfur Dioxide (One-Hour)	Decreasing	Maintenance	Lake	Electric Utilities and Other Industrial Combustion Sources
Nitrogen Dioxide	Stable	Unclassifiable/ Attainment	None	Automobiles, Electric Utilities and Other Industrial, Commercial, and Residential Combustion
Lead	Stable	Maintenance	None	Metal Processing Plants

Source: U.S. EPA, *Green Book*, https://www.epa.gov/green-book (accessed February 15, 2023).

2.1 Attainment Status Summary for Northeast Ohio

1. **Ozone (O_3):** On May 21, 2012, U.S. EPA designated Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit counties as a marginal nonattainment area for the 2008 ozone NAAQS of 75 ppb (77 *Federal Register* (FR) 30088). U.S. EPA redesignated the region to maintenance on January 6, 2017, based upon 2013-2015 monitor data (82 FR 1603).

   On October 26, 2015, U.S. EPA strengthened the eight-hour ozone NAAQS to 70 ppb (80 FR 65291). EPA designated Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit counties as a marginal nonattainment area on April 30, 2018 (83 FR 25776).[9] Because the region did not meet the standard by the August 3, 2021 attainment date, U.S. EPA bumped the region up to moderate nonattainment on October 7, 2022.

2. **Particulate Matter:**
   - Coarse Particles (PM_{10}): Cuyahoga County was redesignated as a maintenance area for the 1987 PM_{10} NAAQS, effective January 10, 2001 (65 FR 77308).

   - Fine Particles ($PM_{2.5}$): In December 2009, U.S. EPA designated Cuyahoga, Lake, Lorain, Medina, Portage and Summit counties as nonattainment areas for the 2006 24-hour $PM_{2.5}$ NAAQS of 35 µg/m^3 (74 FR 58688). U.S. EPA redesignated Ashtabula Township and Cuyahoga, Lake, Lorain, Medina, Portage, and Summit counties from nonattainment to maintenance on September 18, 2013 (78 FR 57270).[10]

     U.S. EPA strengthened the annual $PM_{2.5}$ NAAQS to 12 µg/m^3 on January 15, 2013 (79 FR 3085). Both Cuyahoga and Lorain Counties were designated as nonattainment areas effective April 15, 2015. However, Cuyahoga and Lorain Counties were redesignated as maintenance areas effective April 12, 2019 (84 FR 14881).

3. **Carbon Monoxide (CO):** Cuyahoga County remains in maintenance status for CO, a designation promulgated on July 12, 1993 (58 FR 37453). The rest of Northeast Ohio is in unclassifiable/attainment status.

4. **Sulfur Dioxide (SO_2):** On August 5, 2013, U.S. EPA designated Lake County as a nonattainment area for the 2010 one-hour sulfur dioxide NAAQS of 75 ppb. U.S. EPA redesignated the county as a maintenance area on May 14, 2019 (84 FR 21253).

5. **Lead (Pb):** On May 31, 2017 (82 FR 24871), U.S. EPA redesignated a small area in Cuyahoga County as a maintenance area for the 2008 lead NAAQS of 0.15 µg/m^3.[11] The rest of Northeast Ohio is in unclassifiable/attainment status.

6. **Nitrogen Dioxide (NO_2):** All counties in Northeast Ohio are in unclassifiable/attainment for the 2010 one-hour NO_2 NAAQS of 100 ppb (77 FR 9532).

[9] Based on the recommendations of Ohio EPA, U.S. EPA did not include Ashtabula County as part of the 2015 O_3 nonattainment area, as it had in the past. Both agencies agreed that Ashtabula County does not contribute to the formation of O_3 pollution at the locations in excess of the NAAQS.
[10] In its nonattainment designation for the 2006 $PM_{2.5}$ NAAQS, U.S. EPA listed Ashtabula County as unclassifiable/attainment. However, when it redesignated Northeast Ohio to maintenance status in 2013, the Agency included Ashtabula Township in the maintenance area.
[11] Please refer to page 50 of this report for a description of the lead maintenance area.

2.2 Air Quality Index (AQI)

The AQI is an index used to report daily air quality in a given region. The AQI expresses how clean or polluted a region's air is and what the associated health effects may be for a person living in that region. The AQI focuses on the potential health effects a person may experience within hours or days of breathing polluted air. The U.S. EPA calculates the AQI for five of the six criteria air pollutants: O_3, $PM_{2.5}$, CO, SO_2, and NO_2.

AQI values range from 0 to 500. The higher the AQI value, the higher the concentration of a pollutant in the air and the greater the potential health impacts. The 2021 AQI trends are provided in this report (see Section 5). The figure below shows the relationship between AQI and NAAQS.

Table 3: Air Quality Index and Corresponding NAAQS Concentrations

AQI Level	O_3 (ppb)	$PM_{2.5}$ (µg/m^3)	CO (ppm)	SO_2 (ppm)	NO_2 (ppm)
Good (0-50)	0-54	0-12.0	0-4.4	0.00-0.034	0- 0.053
Moderate (51-100)	55-70	12.1-35.4	4.5-9.4	0.035-0.075	0.054-0.1
Unhealthy for Sensitive Groups (101-150)	71-85	35.5-55.4	9.5-12.4	0.076-0.185	0.101- 0.36
Unhealthy (151-200)	86-105	55.5-150.4	12.5-15.4	0.186-0.304	0.361- 0.649
Very Unhealthy (201-300)	106-200	150.5-250.4	15.5-30.4	0.305-0.604	0.65-1.244
Hazardous (> 300)	> 201	> 250.5	> 30.5	> 0.604	> 1.244

Source: U.S. EPA, *Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI)*, https://www.airnow.gov/sites/default/files/2020-05/aqi-technical-assistance-document-sept2018.pdf (accessed February 15, 2023).

3. Mobile Emissions and Transportation Conformity

Mobile emissions, those that stem from the transportation sector, account for a significant share of air pollution in the United States, particularly in urban areas. According to U.S. EPA, mobile sources make up the majority of nitrogen oxides (NO_x) emissions and the largest share of carbon monoxide (CO) emissions nationwide.[12] Prior to the U.S. ban on leaded gasoline, mobile sources also accounted for the vast majority of airborne lead.[13] Traffic-related air pollution (TRAP) can be particularly harmful for human health for two key reasons. First, TRAP emission sources are in close proximity to where people live. TRAP emissions also occur at a lower height, making them easier to inhale than emissions from smokestacks.[14] Second, TRAP can contain pollutants that are particularly harmful for human health. Black carbon, which makes up a significant share of mobile particle pollution, can be up to 16 times worse for human health than $PM_{2.5}$ generally.[15]

U.S. EPA has implemented a number of regulations to reduce mobile emissions since the passage of the CAA. These include restrictions on the amount of pollution vehicles can emit per mile, such as the Tier 3 Motor Vehicle Emissions and Fuel Standards (79 FR 23414), and vehicle fuel economy requirements, chiefly the corporate average fuel economy (CAFE) standards.

To ensure that federal transportation investments neither worsen air quality, nor interfere with a region's ability to attain and maintain the NAAQS, the 1977 Clean Air Act Amendments (CAAA) introduced the concept of transportation conformity. Under this provision, a region's transportation plans, programs, and projects must not create new NAAQS violations, increase the frequency or severity of existing NAAQS violations, or delay a region's attainment of the NAAQS.[16] Under existing law, metropolitan planning organizations (MPOs) such as NOACA, must demonstrate their 20-year long-range transportation plans (LRTPs) and three-year transportation improvement programs (TIPs) conform to the NAAQS. This process is known as a conformity determination.[17]

When developing SIPs, MPOs work in coordination with state officials to create a motor vehicle emissions budget (MVEB) that details the portion of total allowable emissions allocated to on-road mobile sources, such as cars, trucks, and buses. MVEBs define the total level of on-road emissions that an area can generate while still meeting the goals laid out in the SIP.[18] Through its conformity demonstration, NOACA must prove that projected on-road mobile emissions within the region will not exceed the MVEB contained in the SIP.

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[12] U.S. EPA, "Air Pollutant Emissions Trends Data," https://www.epa.gov/sites/production/files/2018-04/national_tier1_caps.xlsx (accessed February 15, 2023).

[13] U.S. EPA, "Basic Information about Lead Air Pollution," https://www.epa.gov/lead-air-pollution/basic-information-about-lead-air-pollution#how (accessed February 15, 2023).

[14] Transport & Environment, *Don't Breathe Here: Beware the Invisible Killer* (London: Transport & Environment, 2015), https://www.transportenvironment.org/sites/te/files/publications/Dont_Breathe_Here_exec_summary_FINAL.pdf (accessed February 15, 2023).

[15] World Health Organization (WHO), *Reducing global health risks through mitigation of short-lived climate pollutants* (Geneva: WHO, 2015), http://www.who.int/phe/publications/climate-reducing-health-risks/en/ (accessed February 15, 2023).

[16] 42 C.F.R. §7506 (c)(2).

[17] Federal Highway Administration (FHWA), *Transportation Conformity: A Basic Guide for State and Local Officials* (Washington, D.C.: FHWA, 2010), https://www.fhwa.dot.gov/environment/air_quality/conformity/guide/ (accessed February 15, 2023).

[18] Ibid.

If a region fails to meet this requirement, it may be classified as “in a conformity lapse.” If a region fails to address a conformity lapse, the Federal Highway Administration (FHWA) may impose restrictions on the area. These restrictions can include the freezing of federal transportation funding, in the most extreme cases. To date, NOACA has never experienced a conformity lapse. Both NOACA’s current LRTP, *eNEO2050*, and its current TIP, which covers state fiscal years (SFY) 2021-2024, conform to the requirements laid out in the region’s SIPs.[19]

[19] NOACA, *eNEO2050* (Cleveland, NOACA, 2021), https://www.eneo2050.com/ (accessed February 15, 2023).
NOACA, *SFYs 2021-2024 Transportation Improvement Program* (Cleveland, NOACA: 2020), https://www.noaca.org/home/showpublisheddocument?id=25165 (accessed February 15, 2023).

4. Air Quality and Public Health

As noted earlier, the CAA requires U.S. EPA to set NAAQS that "are requisite to protect the public health." This statement alludes to the substantial public health burden that air pollution poses. Air pollution is connected to a host of health issues, including respiratory illnesses (e.g. asthma, bronchitis, and emphysema); pre- and neonatal health risks, including low birthweight, premature birth, and infant mortality; stroke; heart disease, including heart attacks; behavioral conditions, such as attention deficit hyperactivity disorder (ADHD); cognitive issues, including IQ decrements and dementia; lung cancer; and premature death.[20]

According to the World Health Organization (WHO), ambient air pollution was responsible for 4.5 million deaths worldwide during 2019.[21] While the majority of these premature deaths occur in the developing world, the U.S. bears a major health burden from air pollution. To quantify these impacts for Northeast Ohio, NOACA utilized U.S. EPA's Co-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool. To develop these estimates, staff created a scenario using 2016 as the analysis year and zeroed out emissions from all sources. Table 4, below, details the total costs and certain public health impacts of pollutants emitted in the NOACA region during 2016.

Table 4: Public Health Impacts of Air Pollutant Emissions in the NOACA Region (2016)

Type of Impact	Incidence	Total Cost (2016 $)
Mortality (low estimate)	639 deaths	$6.8 billion
Mortality (high estimate)	1,439 deaths	$15.3 billion
Infant Mortality	4 deaths	$41.2 million
Nonfatal heart attacks (low estimate)	60 heart attacks	$9.9 million
Nonfatal heart attacks (high estimate)	546 heart attacks	$89.8 million
Respiratory Hospital Admissions	136 admissions	$4.9 million
ER Visits for Asthma	284 visits	$159,913
Minor Restricted Activity Days	381,132 days	$33.1 million
Lost Work Days	63,606 days	$12.7 million
Asthma Exacerbations	12,975 attacks	$952,894
Total Health Costs (low estimate)[a]	$6.9 billion	
Total Health Costs (high estimate)[a]	$15.5 billion	

[a] Total costs do not include all health impacts and are therefore greater than the sum of the individual impacts included in this table.
Source: NOACA estimates using U.S. EPA's COBRA model

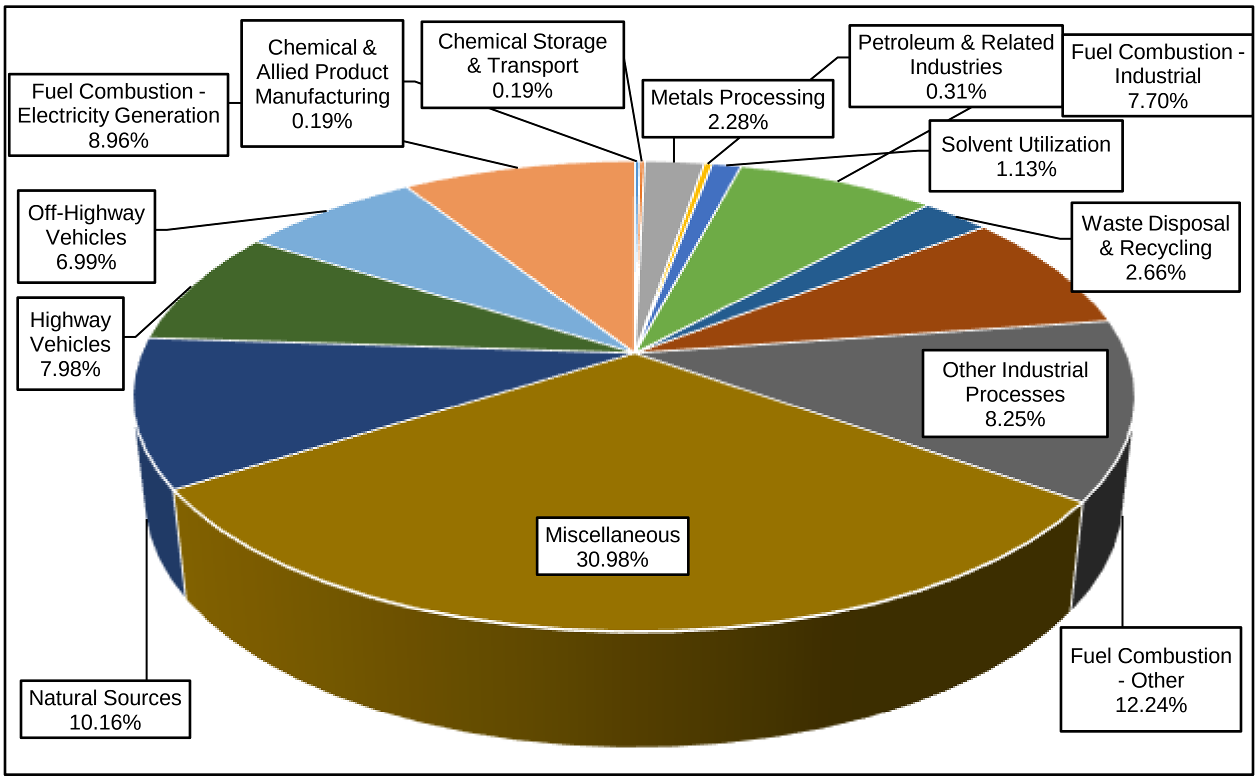
[20] For further information on the public health effects of air pollution, consult the U.S. EPA's *Integrated Science Assessments* on the criteria air pollutants at https://www.epa.gov/isa (accessed February 15, 2023).
[21] R. Fuller, et al, "Pollution and health: a progress update." *The Lancet Planetary Health* (2022), https://doi.org/10.1016/S2542-5196(22)00090-0 (accessed February 15, 2023).

Combined, all sources of pollutant emissions in the NOACA region caused total health costs of $6.9-15.5 billion during 2016. These emissions were responsible for 639-1,439 premature deaths, 60-546 heart attacks, and 12,975 asthma attacks. Manmade emissions within the NOACA region inflicted $6-14 billion in total costs and were responsible for 575-1,294 premature deaths, equal to 91% of total costs.

Figure 1 breaks down the share of health impacts by sector. Miscellaneous sources were responsible for the largest share of emissions and associated impacts, accounting for 31% of total costs ($2.1-$4.8 billion, 198-446 premature deaths). Highway and off-highway vehicles – the fifth and sixth highest polluting sectors, respectively – caused a combined $1-2.3 billion in damages and 96-215 premature deaths, equal to 15% of the total costs of air pollution emissions in the region. Figure 2 shows the breakdown of public health impacts by county.

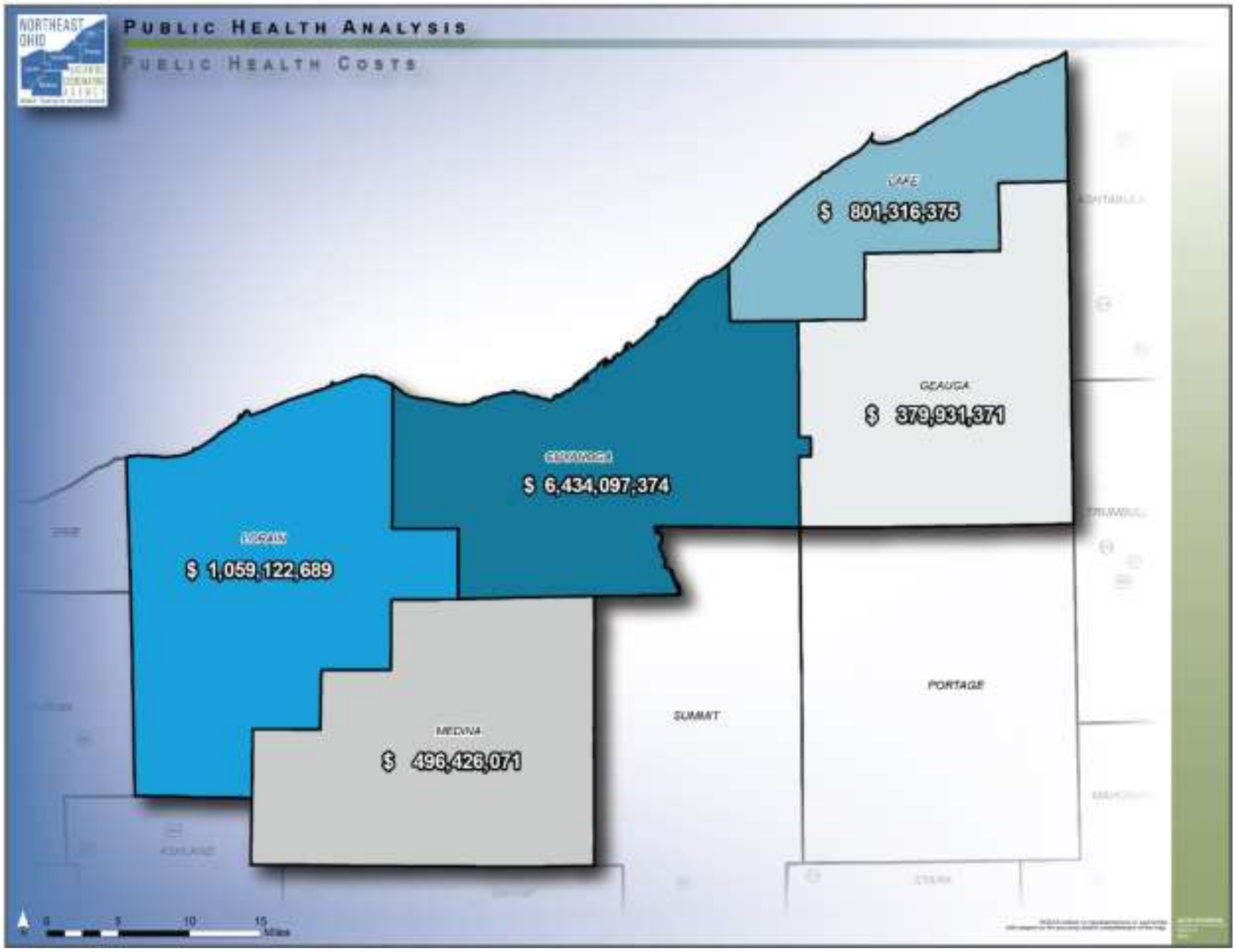
Because air pollution does not respect borders, Northeast Ohio residents also bear the impacts of pollution emitted from upwind sources. As a result, pollution from all sources in the U.S. were responsible for $10.4-22.8 billion in total costs and 962-2,119 premature deaths in Northeast Ohio during 2016. These totals are equal to 4.4-9.7% of total mortality in the region that year. Air pollution was also responsible for 6.3% of infant mortality.

Figure 1: Share of Public Health Impacts from Air Pollutant Emissions by Sector in NOACA Region (2016)



Source: NOACA estimates using U.S. EPA's COBRA model

Figure 2: Distribution of Public Health Impacts of Air Pollutant Emissions in NOACA Region by County (2016)



Source: NOACA estimates using U.S. EPA's COBRA model

Air pollution places a substantial burden on the region; nevertheless, that burden is not borne equally, and it plays out through existing structural inequities. There is a clear connection between land-use patterns and individual exposure to air pollution. The durability of land-use patterns prolongs the impacts of land-use decisions for decades. The Interstate Highway System disproportionately harmed low-income and minority neighborhoods, displacing thousands of families and damaging local economic and cultural networks.[22] Consequently, racial minorities are three times more likely to live in neighborhoods adjacent to the most heavily trafficked roads.[23] Highway construction literally cemented racial segregation through physical barriers such as urban freeways.[24]

Communities of color are also more likely to be near locally unwanted land uses, such as landfills and hazardous waste facilities. Decision makers often site these facilities in areas with higher concentrations of racial minorities because such areas exhibited lower land values and local residents had less power to block such decisions.[25] The result is a disproportionately negative impact from air pollution on low-income and minority communities. In Northeast Ohio, racial minorities are exposed to 10.2% more $PM_{2.5}$ than the regional average, while white residents are exposed to 5.2% less, a 15.4% disparity. This gap is even larger for emissions from both passenger vehicles (16%) and heavy-duty vehicles (19.2%).[26]

Since its passage in 1970, the CAA has significantly enhanced air quality in the U.S. From 1970 to 2021, ambient concentrations of the six criteria air pollutants declined by 73% nationwide, even as the economy grew by 272% and vehicle miles traveled (VMT) rose by 111%.[27] Table 5, below, illustrates the change for each of the criteria pollutants from 1980 to 2021. This decline in pollutant concentrations has also reduced the associated health burden of air pollution. In 1997, U.S. EPA concluded that, from 1970 to 1990, the CAA prevented approximately 205,000 premature deaths and generated $22.2 trillion in economic benefits.[28] U.S. EPA also concluded that 1990 CAAA prevented 230,000 premature deaths by 2020.[29]

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[22] D.N. Archer, "'White Men's Roads through Black Men's Homes': Advancing Racial Equity through Highway Construction," *Vanderbilt Law Review* 73, no. 5 (2020), 1259-1330.

[23] G.M. Rowangould, "A census of the US near-roadway population: Public health and environmental justice considerations," *Transportation Research Part D* 25 (2013), 59-67.

[24] K.M. Kruse, *White Flight: Atlanta and the Making of Modern Conservatism* (Princeton, NJ: Princeton University Press, 2004). D. Kerr, *Derelict Paradise: Homelessness and Urban Development in Cleveland, Ohio* (Amherst, MA: University of Massachusetts Press, 2011), 107-108.

[25] P. Mohai & R. Saha, "Which came first, people or pollution? Assessing the disparate siting and post-siting demographic change hypotheses of environmental injustice," *Environmental Research Letters* 10 (2015), 11508.

[26] C.W. Tessum, D.A. Paolella, S.E. Chambliss, J.S. Apte, J.D. Hill, & J.D. Marshall, "PM2.5 polluters disproportionately and systemically affect people of color in the United States," *Science advances*, 7, no. 8 (2021), eabf4491.

[27] U.S. EPA, "Air Quality Trends," https://www.epa.gov/air-trends/air-quality-national-summary (accessed February 15, 2023).

[28] U.S. EPA, *The Benefits and Costs of the Clean Air Act, 1970 to 1990—Retrospective Study* (Washington, D.C.: U.S. EPA, 1997), https://www.epa.gov/sites/production/files/2015-06/documents/contsetc.pdf (accessed February 15, 2023).

[29] U.S. EPA, *Benefits and Costs of the Clean Air Act 1990-2020, the Second Prospective Study* (Washington, D.C.: U.S. EPA, 2011), https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1990-2020-second-prospective-study (accessed February 15, 2023).

Table 5: Change in Criteria Air Pollutant Concentrations for USA (1980-2021)

Pollutant Type	1980-2021	1990-2021	2000-2021	2010-2021
Carbon Monoxide (CO)	-87%	-79%	-65%	-26%
Lead (Pb)	-98%	-98%	-93%	-85%
Nitrogen Dioxide (NO_2) (annual)	-67%	-61%	-53%	-29%
Nitrogen Dioxide (NO_2) (one-hour)	-64%	-54%	-40%	-22%
Ozone (O_3) (eight-hour)	-29%	-21%	-16%	-5%
PM_{10} (24-hour)	n/a[a]	-32%	-36%	-5%
$PM_{2.5}$ (annual)	n/a[a]	n/a[a]	-37%	-14%
$PM_{2.5}$ (24-hour)	n/a[a]	n/a[a]	-33%	-2%
Sulfur Dioxide (SO_2) (one-hour)	-94%	-91%	-85%	-74%

[a] Not available for this pollutant during this timeframe.

Source: U.S. EPA, "Air Quality – National Summary," https://www.epa.gov/air-trends/air-quality-national-summary (accessed February 15, 2023).

Table 6, below, charts the change in concentrations of the criteria air pollutants from 1990 to 2021 in the Akron, Cleveland, Columbus, and Cincinnati metropolitan areas. Air quality has improved dramatically in Ohio since 1990; however, this rate of improvement has slowed since 2010, mirroring the national trend.[30] While the overall downward trajectory has continued, there are annual variations in the concentrations of various pollutants, including increases in certain pollutants from one year to the next. Northeast Ohio has directly benefited from the long-term decreases in pollutant levels. A 2015 analysis found that, since 1970, air quality improvements associated with the CAA have extended the average life expectancy of people within the region by 2.3 years.[31]

More recent reductions in pollution concentrations have also improved public health. According to a study from the Natural Resources Defense Council, air pollution reductions tied to the 1990 CAAA prevented 2,153-4,308 premature deaths in the NOACA region during 2020. This number will increase to 2,565-5,132 by 2030.[32] These improvements have had other clear benefits, as well. Due to regulations on tailpipe emissions, transportation-related NO_2 pollution has fallen considerably. As a result, the number of childhood asthma cases in the NOACA region fell by 42.6% from 2000 to 2010.[33]

[30] Z. Jian et al, "Unexpected slowdown of US pollutant emission reduction in the past decade," *Proceedings of the National Academy of Sciences* 115, 20 (2018), 5099-5014.
[31] M. Greenstone, "The Connection Between Cleaner Air and Longer Lives," *The New York Times*, http://www.nytimes.com/2015/09/25/upshot/the-connection-between-cleaner-air-and-longer-lives.html?_r=1 (accessed February 15, 2023).
[32] J. Price, S. Gulati, J. Lehr, and S. Penn, *The Benefits and Costs of U.S. Air Pollution Regulations* (Cambridge, MA: Industrial Economics, Inc., 2020), https://www.nrdc.org/sites/default/files/iec-benefits-costs-us-air-pollution-regulations-report.pdf (accessed February 15, 2023).
[33] R. Alotaibi, M. Bechle, J.D. Marshall, T. Ramani, J. Zietsman, M.J. Nieuwenhuijsen, and H. Khreis, "Traffic related air pollution and the burden of childhood asthma in the contiguous United States in 2000 and 2010," *Environment International* 127 (2019), 858-867.

Table 6: Change in Criteria Air Pollutant Concentrations for Ohio Metropolitan Areas (1990-2021)

Pollutant Type	Metropolitan Area	1990-2021	2000-2021	2010-2021
Carbon Monoxide (CO)[a]	Cleveland	-69%	-38%	-67%
	Cincinnati	-60%	-73%	-40%
Nitrogen Dioxide (NO_2) (one-hour)[a]	Cleveland	-44%	-20%	-9%
	Cincinnati	-56%	-38%	-35%
Ozone (O_3) (eight-hour)	Akron	-26%	-21%	-12%
	Cleveland	-19%	-15%	-11%
	Columbus	-28%	-30%	-17%
	Cincinnati	-33%	-25%	-13%
PM_{10} (24-hour)[b]	Cleveland	-27%	-27%	-24%
	Cincinnati	+96%	+154%	+202%
$PM_{2.5}$ (annual)	Akron	n/a[c]	-35%	+82%
	Cleveland	n/a[d]	-37%	-12%
	Columbus	n/a[c]	-42%	-29%
	Cincinnati	n/a[c]	-39%	-23%
Sulfur Dioxide (SO_2) (one-hour)[d]	Akron	-97%	-97%	-87%
	Cleveland	-80%	-74%	-72%
	Cincinnati	-84%	-73%	-51%

[a] Not available for the Akron or Columbus metropolitan areas for this pollutant.
[b] Not available for the Akron metropolitan areas for this pollutant.
[c] Not available for this pollutant during this timeframe
[d] Not available for the Columbus metropolitan areas for this pollutant.

Source: U.S. EPA, "Air Quality Statistics Report," https://www.epa.gov/outdoor-air-quality-data/air-quality-statistics-report (accessed February 15, 2023).

5. Trends for the Six Criteria Air Pollutants in Northeast Ohio

This section details the trends for each of the six criteria air pollutants in Northeast Ohio. It includes information on the properties of the pollutants, their effects on public health, their formation, and their major sources within the region. This section also provides further detail on the region's attainment status for each pollutant, as well as information on the air quality monitoring network operating within Northeast Ohio. Data on Tier 1 emissions sources and quantities are from U.S. EPA's *2017 National Emissions Inventory*, the most recent year for which data are available.[34]

As noted in Section 4, air quality has improved dramatically within the NOACA air quality planning region over the past four decades. However, because this rate of improvement has slowed and the U.S. EPA has continued to strengthen several of the NAAQS to reflect new scientific evidence on the impacts of air pollution, portions of the eight-county area remain in nonattainment for O_3. Transportation is the primary driver of the region's air quality issues, with on-road vehicles representing a plurality of total criteria pollutant emissions. Two of the pollutants most closely tied to mobile emissions –O_3 and $PM_{2.5}$—are closely linked to mobile emissions. Ambient levels of these pollutants have fallen by a smaller margin than the other pollutants of concern since 1990, as documented in Table 6 in the previous section. Accordingly, transportation infrastructure and modal choice continue to be intricately linked to the quality of the region's air. Given the importance of O_3 and $PM_{2.5}$ to air quality in Northeast Ohio, the first two sections of this section focus on these two pollutants. The discussion then shifts to SO_2; the final three sections examine CO, Pb, and NO_2.

5.1 Ground-Level Ozone (O_3)

Properties: Ground-level, or tropospheric, ozone (O_3) forms when ultraviolet radiation in the atmosphere splits nitrogen oxide (NO_x) into nitric oxide (NO) and an oxygen atom (O). This oxygen atom is then able to join with an oxygen molecule (O_2) to form O_3. Volatile organic compounds (VOCs) play an important role in this process, as they help facilitate the continual production of O_3 in the atmosphere.[35] Accordingly, NO_x and VOCs are called O_3 precursors. Motor vehicle exhaust, industrial emissions, and chemical solvents are the major anthropogenic sources of these precursors. Although they often originate in urban areas, winds can carry these precursor chemicals hundreds of miles. Additionally, O_3 production takes several hours, so that maximum O_3 concentrations typically occur downwind from primary emissions sources. In Northeast Ohio, the prevailing winds are southwest to northeast, meaning that O_3 precursor emissions from Cuyahoga and Summit Counties often form O_3 in Lake and Geauga counties. While urban areas are typically VOC-limited (that is, O_3 production is more contingent upon the availability of VOC emissions), most rural areas are NO_x-limited.[36]

O_3 can irritate the respiratory system, causing coughing, irritation in the throat, or a burning sensation in the airways. It can reduce lung function, with feelings of chest tightness, wheezing, or shortness of breath. O_3 can aggravate asthma and trigger asthma attacks. People at a greater

[34] U.S. EPA releases the NEI every three years, on a three year delay. The 2020 NEI should be available in March 2023.
[35] U.S. EPA, *Guideline on Ozone Monitoring Site Selection* (Research Triangle Park, NC: U.S. EPA, 1998).
[36] U.S. EPA, *Final Ozone NAAQS Regulatory Impact Analysis* (Research Triangle Park, NC: U.S. EPA, 2008), 2-1, http://www.epa.gov/ttnecas1/regdata/RIAs/452_R_08_003.pdf, (accessed February 15, 2023).

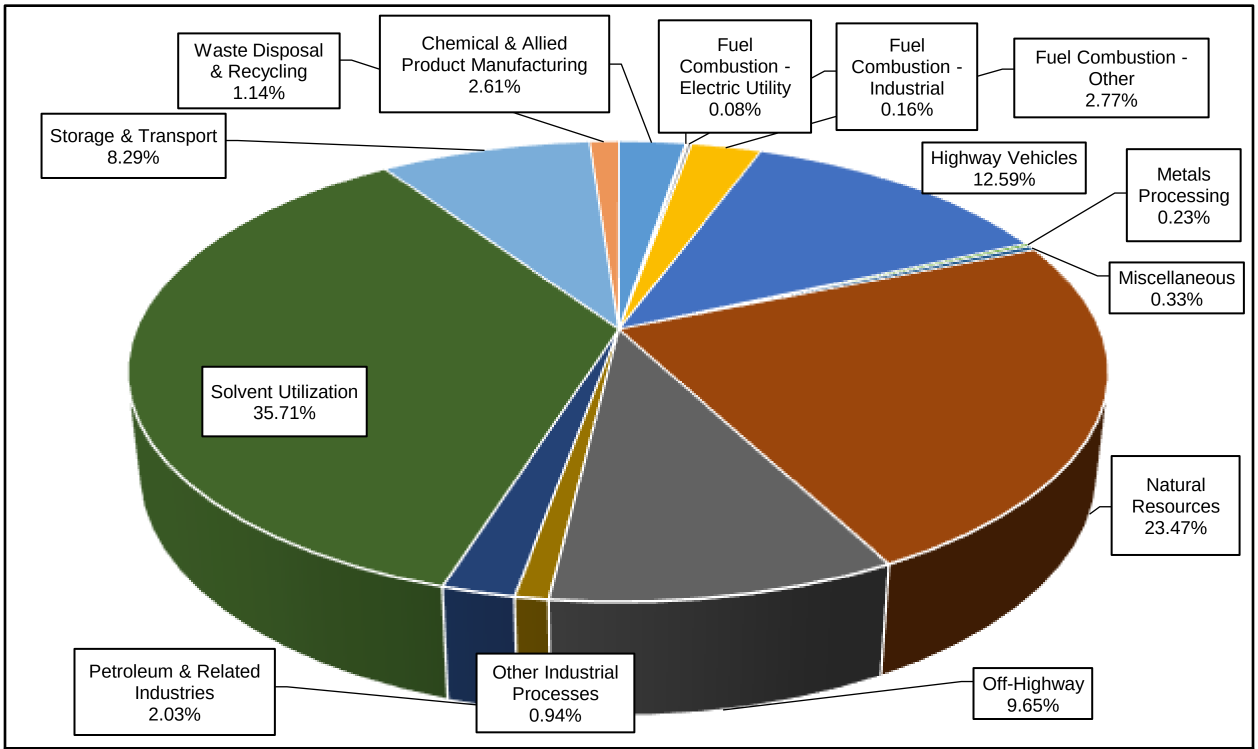
risk from ground-level O_3 are those with respiratory conditions, such as asthma and emphysema, and children and adults who are active outdoors.[37]

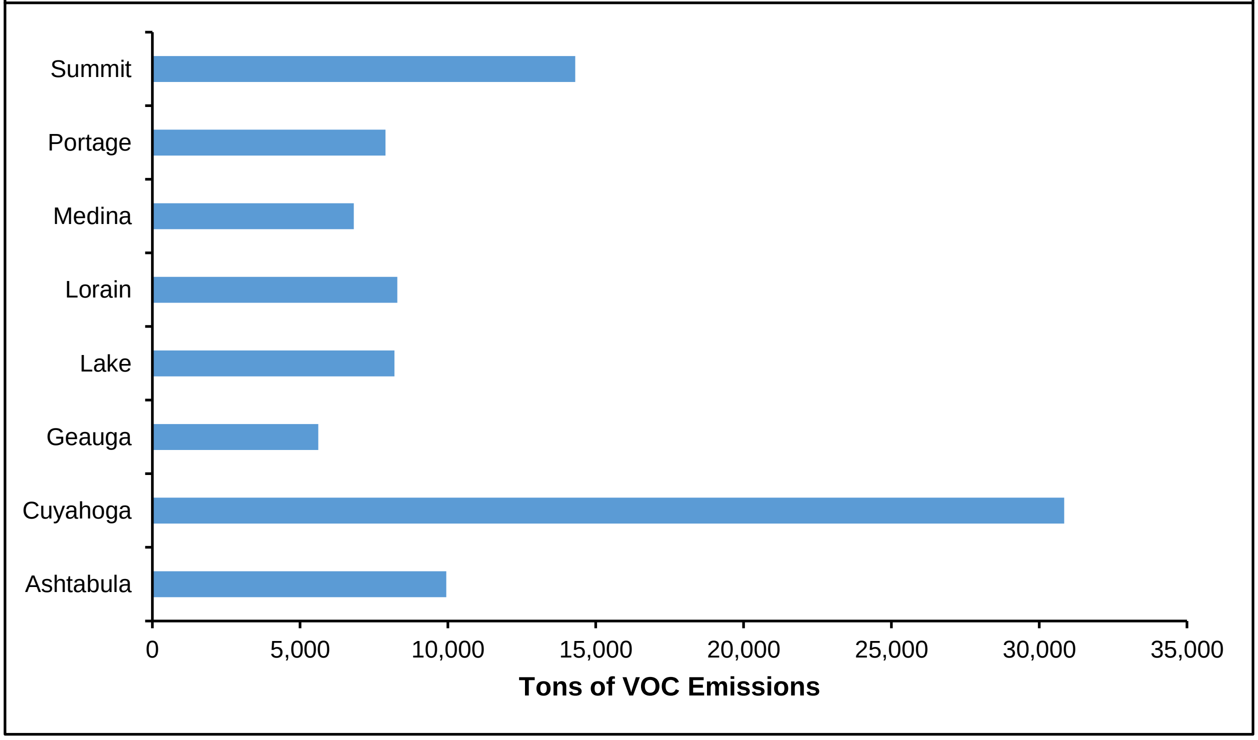
Ground-level O_3 levels are highest in cities with high levels of automobile traffic during daylight hours in the summer months. Decreases in atmospheric NO_x and VOCs generally result in decreases of O_3 formed under a given set of conditions.[38] Because the actual ambient O_3 concentration is strongly dependent upon weather conditions (including maximum daily temperatures, cloud cover, wind speed, and wind direction), reductions in O_3 concentrations based on reductions in precursors are difficult to predict until sufficient data have been accumulated to allow for the removal of weather effects. As the O_3 NAAQS has tightened, it has become more difficult to forecast O_3 formation.

Sources: O_3 levels can be modulated indirectly by cutting NO_x and VOC emissions. Significant NO_x sources include cars; trucks; ships; trains; non-road equipment powered by fossil fuels; and industries, such as electric utilities, that combust fossil fuels. Significant sources of VOCs include solvents, such as dry cleaning, degreasing, and surface coatings; cars; non-road vehicles, such as aircraft, construction vehicles, lawn care equipment, and railroads; and gasoline distribution facilities. VOCs can also come from natural (biogenic) sources, including trees and other vegetation. Figure 3 breaks down the main sources of VOCs in Northeast Ohio during 2017.[39]

[37] U.S. EPA, *Smog—Who Does It Hurt? What You Need to Know About Ozone and Your Health* (Washington, D.C.: U.S. EPA, 1999), http://epa.gov/airquality/ozonepollution/pdfs/smog.pdf.
[38] However, a decrease in NO_x emissions in urban areas can actually increase O_3 levels in the short-term. This is due to a chemical process known as NO_x titration, during which exceed NO_x emissions can destroy O_3 formation in VOC-limited areas.
[39] For data on the primary sources of NO_x, consult Figure 34 on page 53.

Figure 3: VOC Emissions Inventory for Northeast Ohio (2017)



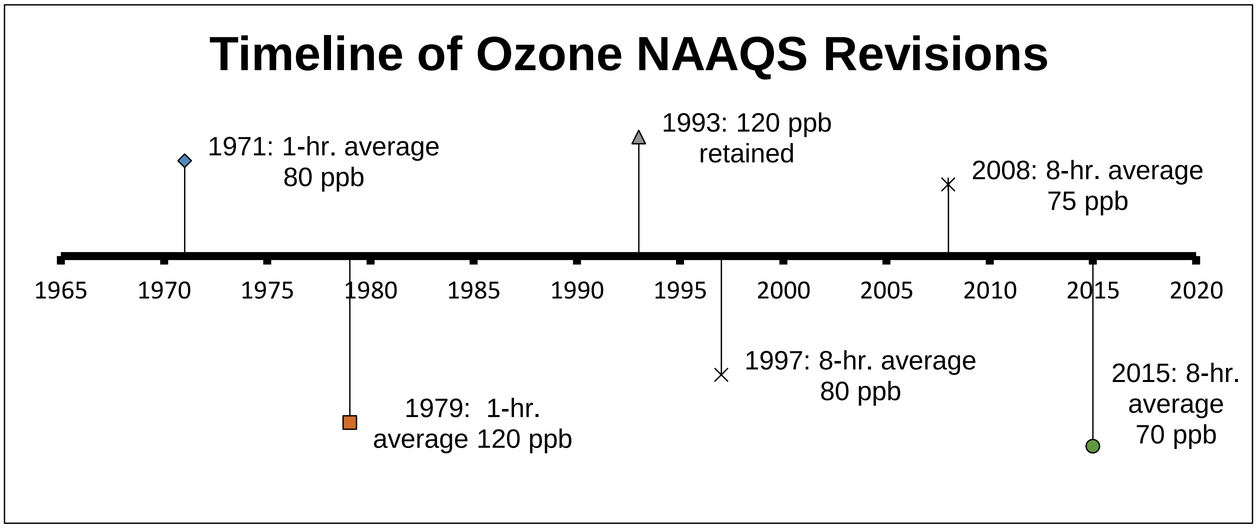


Source: U.S. EPA, *2017 National Emissions Inventory*, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data (accessed February 15, 2023).

NAAQS and Nonattainment Status: The full timeline of O_3 NAAQS revisions is shown in Figure 4. On March 12, 2008, U.S. EPA promulgated revised eight-hour primary and secondary O_3 NAAQS (73 FR 16436). The 2008 eight-hour O_3 NAAQS was 75 ppb. On April 30, 2012, U.S. EPA classified Northeast Ohio counties (Ashtabula, Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit) as a marginal nonattainment area based on 2008-2010 data. Because O_3 is readily transported throughout a region, U.S. EPA classifies the entire regional airshed as the O_3 nonattainment area even if only one monitor in one county exceeds the NAAQS. On January 6, 2017 (82 FR 1603), U.S. EPA formally redesignated the region to maintenance for the 2008 NAAQS, based upon 2013-2015 monitor data.

On October 26, 2015, U.S. EPA strengthened the existing O_3 NAAQS from 75 ppb to 70 ppb (80 FR 65291). U.S. EPA issued nonattainment designations on April 30, 2018 (83 FR 25776). Based upon monitor data from 2014 to 2016, the Agency designated Northeast Ohio (the counties of Cuyahoga, Geauga, Lake, Lorain, Medina, Portage, and Summit) as a marginal nonattainment area, a designation that took effect on August 3, 2018. The attainment date was August 3, 2021, but the region failed to meet the NAAQS in time. As a result, U.S. EPA bumped the region up to moderate nonattainment on October 7, 2022 (87 FR 60897). This designation pushes its attainment date back to August 3, 2024.

Figure 4: Timeline of Revisions to Ozone NAAQS (1971-2021)



Control Measures: The Ohio EPA is responsible for submitting SIPs for all regions within the state. Please visit the Ohio EPA website to review the relevant O_3 SIPs for Northeast Ohio: https://epa.ohio.gov/divisions-and-offices/air-pollution-control/state-implementation-plans.

In its capacity as the air quality planning agency for Northeast Ohio, NOACA plays a role in coordinating air quality monitoring, public outreach, and control efforts. Throughout the O_3 monitoring season, which lasts 245 days (March 1 to October 31), NOACA forecasts eight-hour average O_3 concentrations throughout the region. On days when ambient O_3 levels are projected to exceed the NAAQS (currently 70 ppb), the agency issues an air quality advisory, encouraging Northeast Ohio residents, particularly those who belong to sensitive groups, to modify certain behaviors (e.g., walk, bike, or ride public transit versus drive alone) and limit their time outdoors. NOACA also encourages localities to implement those recommendations that do not require a state action, such as municipal anti-idling ordinances.

Monitoring: U.S. EPA provides clear guidelines on how regions should develop their monitoring networks for O_3.[40] Northeast Ohio's O_3 monitoring network was developed to meet these requirements. There are 12 operating O_3 monitors in Northeast Ohio (Table 7 and Figure 5).

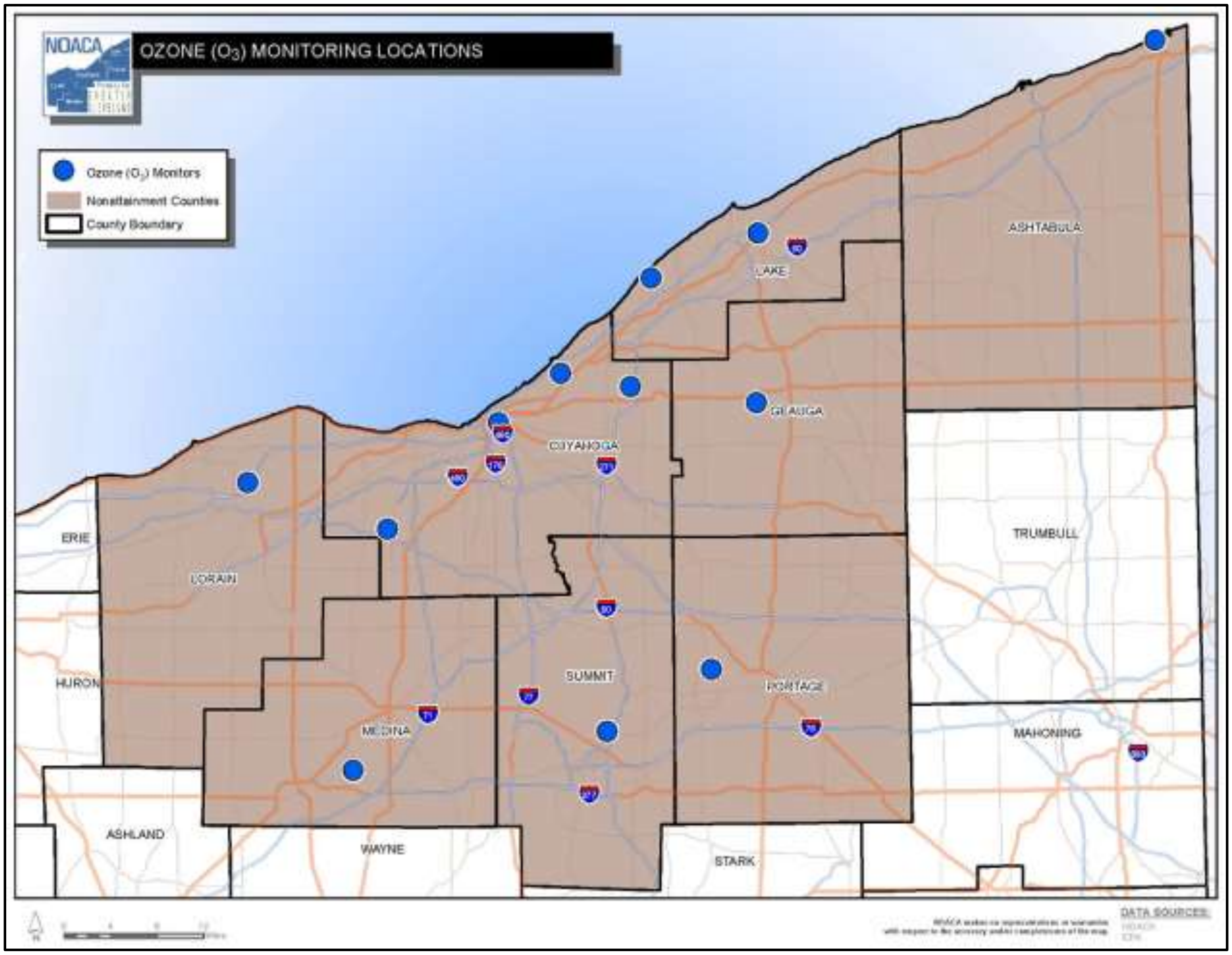
Table 7: Locations of O_3 Monitors in Northeast Ohio

Monitor	County	FIPS ID	Site ID	Latitude	Longitude	Address
1	Ashtabula	7	1001	41.95	-80.57	Conneaut Water Plant
2	Cuyahoga	35	0034	41.55	-81.57	891 E. 152 St.
3			0060	41.49	-81.67	GT Craig, E. 14th St. & Orange Ave., Cleveland
4			0064	41.36	-81.86	Board of Education, 390 Fair St., Berea
5			5002	41.53	-81.45	6116 Wilson Road, Mayfield
6	Geauga	55	0004	41.51	-81.24	Notre Dame School, Munson
7	Lake	85	0003	41.67	-81.42	Jefferson School, Eastlake
8			0007	41.72	-81.24	177 Main St., Painesville
9	Lorain	93	0018	41.42	-82.09	Fire Station, Sheffield
10	Medina	103	0004	41.06	-81.92	Ballash Rd., Lafayette Twp.
11	Portage	133	1001	41.18	-81.33	1570 Ravenna Rd., Kent
12	Summit	153	0020	41.10	-81.50	800 Patterson Ave., Akron

Source: Ohio EPA, *2021-2022 Ohio Air Monitoring Network Plan,* https://epa.ohio.gov/static/Portals/27/ams/sites/2021-2022_AMNP_Main_Report_Final.pdf (accessed February 15, 2023).

[40] U.S. EPA, *Guideline on Ozone Monitoring Site Selection*.

Figure 5: Northeast Ohio O_3 Monitor Locations



Currently, U.S. EPA oversees three pollution monitoring networks: the State and Local Air Monitoring Stations (SLAMS), the National Air Monitoring Stations (NAMS), and the Photochemical Assessment Monitoring Stations (PAMS). Each network satisfies different monitoring requirements and serves a different purpose.[41]

SLAMS monitors fulfill four roles:

- Determine the highest concentrations of a given air pollutant expected to occur in the monitored area;
- Determine the representative concentrations of that pollutant in areas of high population density;
- Determine the impact of ambient pollution levels of significant pollutant sources or source categories; and
- Determine the general background concentration levels of the pollutant.

NAMS is a broader, national monitoring network that includes a subset of SLAMS monitors in urban areas with populations of at least 200,000 people. NAMS networks must include at least two SLAMS monitors. PAMS, in turn, conduct enhanced, continuous air quality monitoring in nonattainment areas.

Under current guidelines, U.S. EPA requires that O_3 monitors be placed at the following locations:

- **Maximum exposure sites:** These are areas where the greatest population is expected to be exposed to high concentrations of O_3, typically just downwind of an urbanized area.
- **Maximum downwind concentration sites:** These are the locations farther downwind of an urbanized area where O_3 concentrations are likely to be highest, accounting for the direction of the prevailing wind and the amount of time it takes O_3 to form.
- **Upwind sites:** These are sites located upwind of the air quality monitoring area, which enables officials to track background O_3 levels and pollution entering the region.
- **Maximum emissions sites:** These are sites located immediately downwind of the main sources of O_3 precursor emissions in the region, typically near the edge of the central business district.

In its 2015 revision to the O_3 NAAQS (80 FR 65291), U.S. EPA revised its rules for both the O_3 monitoring network and the O_3 monitoring season. Previously, PAMS were required for those nonattainment areas designated as serious, severe, or extreme. U.S. EPA now requires PAMS be distributed across the country at 63 urban and 17 rural sites. Cleveland houses one of these monitors at the GT Craig site (see Table 7). This site will conduct continuous monitoring 365 days per year, though enhanced O_3 monitoring will occur only from June through August.

Trends: While Northeast Ohio has, at one point or another, been in nonattainment for each of the O_3 NAAQS, it is far from the only metropolitan area that fits this description. According to U.S. EPA, there are currently 49 O_3 nonattainment areas nationwide for the 2015 NAAQS; these areas include 203 total counties, which are home to more than 125 million people.[42] However, as Section 4 notes, the region's O_3 levels have declined by only 19% since 1990, compared to a 21% decline nationally.

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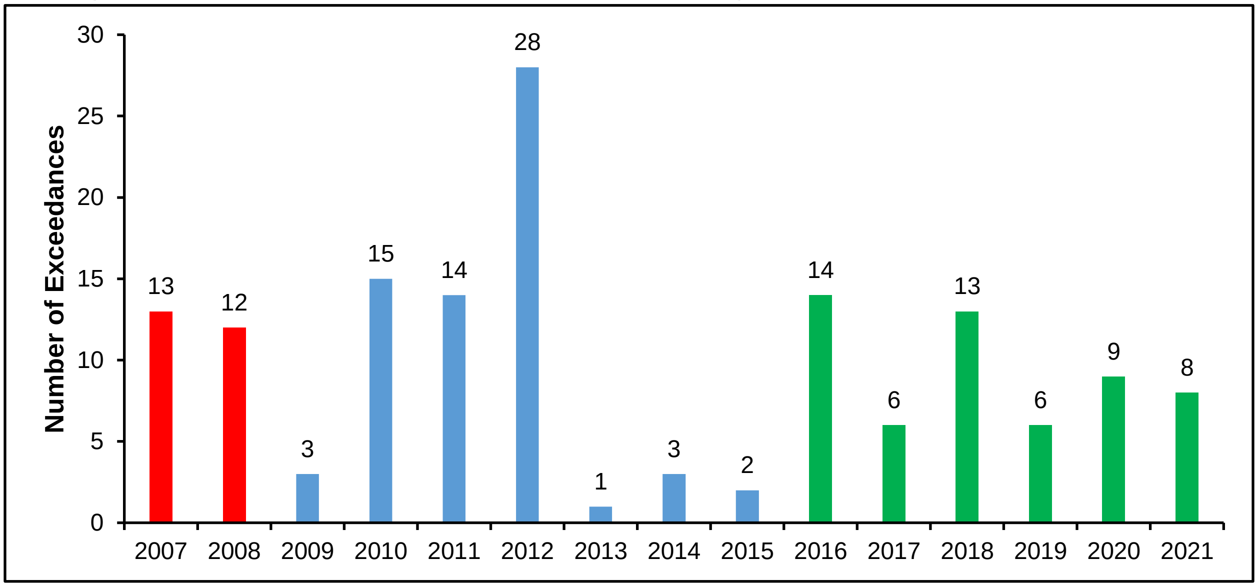
[41] Consult 40 C.F.R. §58 for additional information.

[42] U.S. EPA, "8-Hour Ozone (2015) Designated Area/State Information with Design Values," https://www3.epa.gov/airquality/greenbook/jbtcw.html (accessed February 15, 2023).

While O_3 concentrations within Northeast Ohio have declined over time, this trend has leveled off in recent years. This slow, long-term decrease is expected to continue into the future, as the U.S. EPA implements new and existing regulations, such as the Cross-State Air Pollution Rule (CSAPR, 76 FR 48208), greenhouse gas emissions standards for heavy-duty trucks (80 FR 40137), and the Tier 3 Motor Vehicle Emissions and Fuel Standards (79 FR 23414). Nevertheless, this downward trend is not guaranteed. O_3 concentrations in Northeast Ohio have actually remained flat or increased slightly in five of eight counties since 2013-2015, and climate change threatens to exacerbate this trend, as Section 6 discusses.

Figure 6 displays the number of days with eight-hour O_3 exceedances from 2007-2021 in Northeast Ohio, based upon the NAAQS in place at the time. When a monitor records an ambient pollution concentration that exceeds the NAAQS, the event is classified as an exceedance. Red bars indicate years when the NAAQS was 85 ppb; blue bars 75 ppb; and green bars 70 ppb.

Figure 6: Number of Exceedance Days for the Eight-Hour O_3 NAAQS (2007-2021)[43]

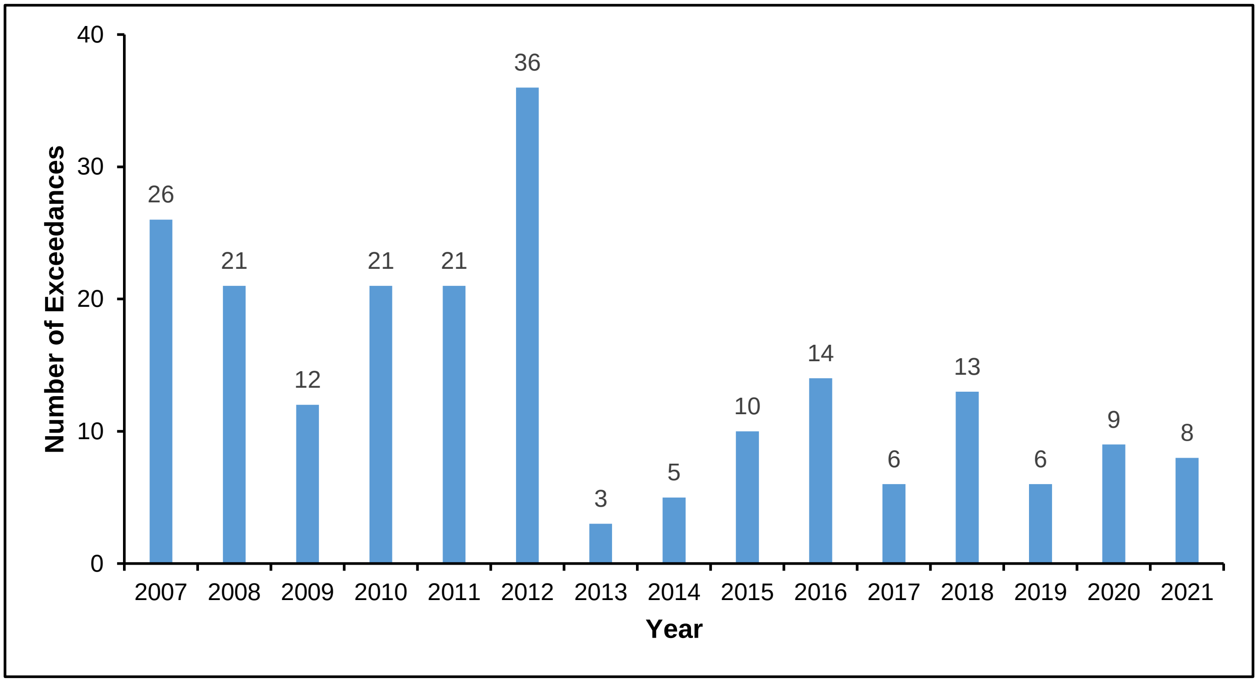


Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

O_3 exceedances range from a low of one (1) day in 2013 to a high of 28 days in 2012. Exceedance days generally decreased through 2015, but this trend has reversed since 2016. Part of this reversal is due to U.S. EPA's tightening of the O_3 NAAQS to 70 ppb from 75 ppb. Comparing the number of days on which Northeast Ohio has exceeded the current NAAQS (70 ppb) during this period further demonstrates the long-term downward trend in O_3 levels in the region. As Figure 7 shows, while the region experienced an average of 20.2 days above 70 ppb from 2007 to 2011, that average fell to just 8.4 days from 2017 to 2021.

[43] For a list of the dates when exceedance days occurred, see Appendix A: Ozone Exceedance Days.

Figure 7: Number of Exceedance Days of the 70 ppb O_3 NAAQS (2007-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

But the tighter NAAQS does not fully explain this trend. That O_3 levels have increased slightly despite continued decreases in mobile emissions highlights the challenge that climate change poses to air quality in Northeast Ohio. Hot, dry weather promotes more exceedances, while cool, rainy weather suppresses O_3 formation. Northeast Ohio was warmer than normal during 2021. The average annual temperature was 52.1ºF, well above the 1991-2010 average of 49.5ºF, which made 2021 the third warmest year on record for the region (records date back to 1895).[44] Because O_3 is contingent on weather, changing weather patterns can obscure the impact of changes in emissions levels. Controlling for average wind speed and precipitation, each 1ºC increase in maximum daily temperature is associated with a 1.3 ppb higher daily O_3 level (0.7 ppb per 1ºF).[45]

U.S. EPA bases its NAAQS on the three-year average of the fourth highest daily eight-hour O_3 values, which better accounts for long-term ambient O_3 levels to which people are exposed. Table 8, below, captures the three-year average O_3 concentrations for each of the eight counties in the NOACA air quality monitoring area from the 2009-2011 period to the 2019-2021 period. Values that exceeded the NAAQS in effect at the time are highlighted in red. Figure 8 displays O_3 levels throughout the region during this period. The black dashed lines denote the NAAQS in effect during each period. For 2019-2021, Cuyahoga (71 ppb) and Lake (73 ppb) Counties had O_3 values that exceeded the NAAQS.

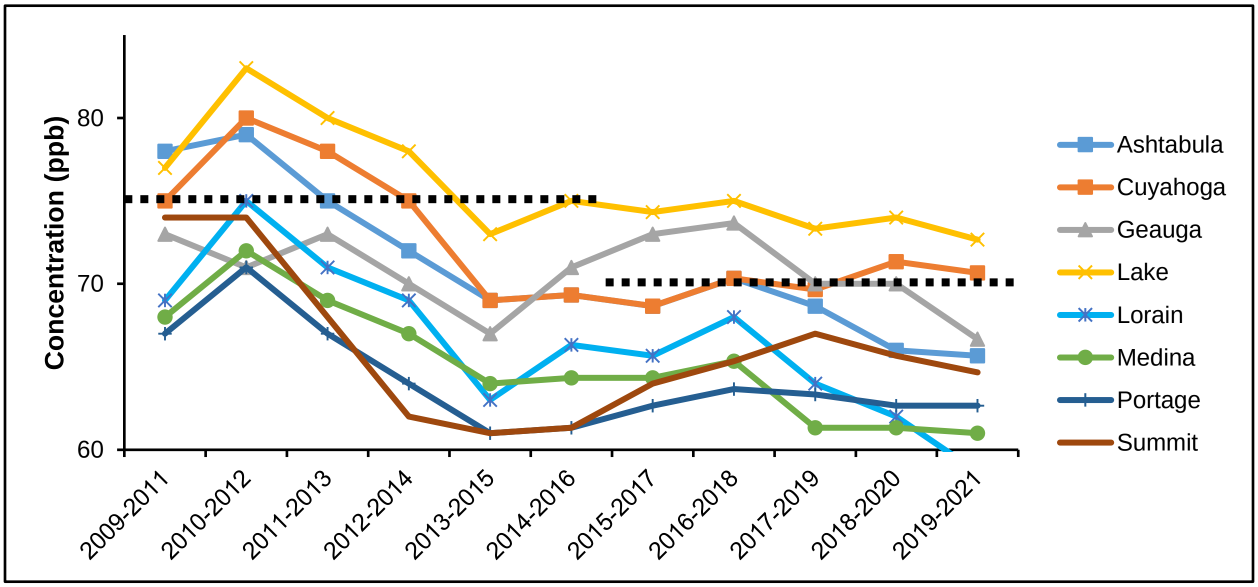
[44] NOAA National Centers for Environmental Information, "Climate at a Glance: Divisional Time Series," https://www.ncdc.noaa.gov/cag/city/time-series (accessed February 15, 2023).
[45] Based on author's estimates using O_3 monitor and meteorological data from 2000-2017.

Table 8: Three-Year Average Eight-Hour O_3 Readings in Northeast Ohio (2009-2021)[46]

	2009 - 2011	2010 - 2012	2011 - 2013	2012 - 2014	2013 - 2015	2014 - 2016	2015 - 2017	2016 - 2018	2017 - 2019	2018 - 2020	2019 - 2021
Ashtabula	78	79	75	72	69	70	70	70	69	66	66
Cuyahoga	75	80	78	75	69	69	69	70	70	71	71
Geauga	73	71	73	70	67	71	73	74	70	70	67
Lake	77	83	80	78	73	75	74	75	73	74	73
Lorain	69	75	71	69	63	66	66	68	64	62	59
Medina	68	72	69	67	64	64	64	65	61	61	61
Portage	67	71	67	64	61	61	63	64	63	63	63
Summit	74	74	68	62	61	61	64	65	67	66	65

Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

Figure 8: Rolling Three-Year O_3 Averages for Northeast Ohio (2009-2021)[47]



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

As noted in Section 2, U.S. EPA uses the AQI to translate the NAAQS for each pollutant into a normalized metric that allows individuals to gauge air quality on a given day. Figure 9 below depicts the daily AQI values for O_3 for the Cleveland and Akron metropolitan areas during 2021. Green and yellow squares denote good and moderate air quality levels, respectively, while orange squares show days in which the O_3 level exceeded the eight-hour NAAQS. As the image shows, there were eight (8) total exceedances in Cleveland-Elyria and one (1) in Akron.

[46] The monitor with the highest average in the county was used for each three-year period. The concentrations are the truncated, not rounded, values (i.e., 77.7 is listed as 77 not 78). Values highlighted in red exceeded the NAAQS in effect at the time.
[47] The dashed black lines indicate the NAAQS in effect during each period.

Figure 9: Daily O_3 AQI Values for Cleveland & Akron (2021)

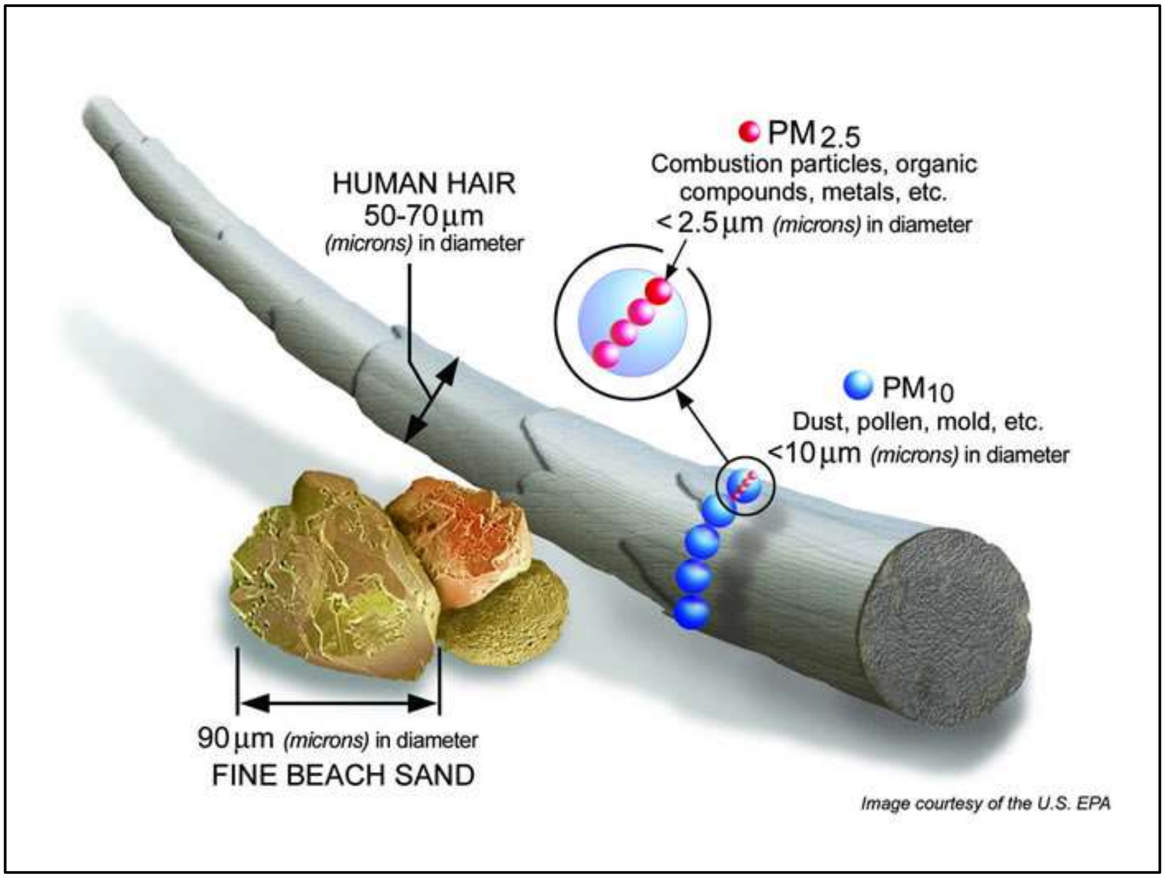
Source: U.S. EPA, "AirData Tile Plot," http://www.epa.gov/airquality/airdata/ad_viz_tile.html (accessed February 15, 2023).

5.2 Particulate Matter (PM)

Properties: Particulate matter (PM) is the term applied to both solid and liquid droplets suspended in the atmosphere. It can be emitted directly from a source (primary) or result from chemical reactions in the atmosphere (secondary). Inhalation of these particles can irritate one's nose, throat, and lung tissues. This irritation can easily create or exacerbate existing respiratory problems or even cause premature death.

U.S. EPA has focused on smaller particles in setting standards. The smaller the particle, the deeper it can travel into one's respiratory system. A subscript number generally follows references to PM. This number is the largest diameter of the particles covered by the standard or discussion. Thus, PM_{10} refers to particles less than or equal to 10 micrometers in diameter, while $PM_{2.5}$ refers to particles less than or equal to 2.5 micrometers in diameter. "Coarse" particulate matter is used to refer to PM_{10}, while "fine" particulate matter is used to refer to $PM_{2.5}$. Prior to 1987, U.S. EPA focused on total suspended particulates (TSP), which include particles approximately 25 to 45 micrometers in diameter. PM_{10} is one-seventh the diameter of a human hair, while $PM_{2.5}$ is just 1/28 of a hair's diameter (see Figure 9). Particles smaller than one micrometer, known as ultrafine particles (UFP), are also harmful to human health, but U.S. EPA has not set NAAQS for them.

Figure 10: Particulate Matter Size

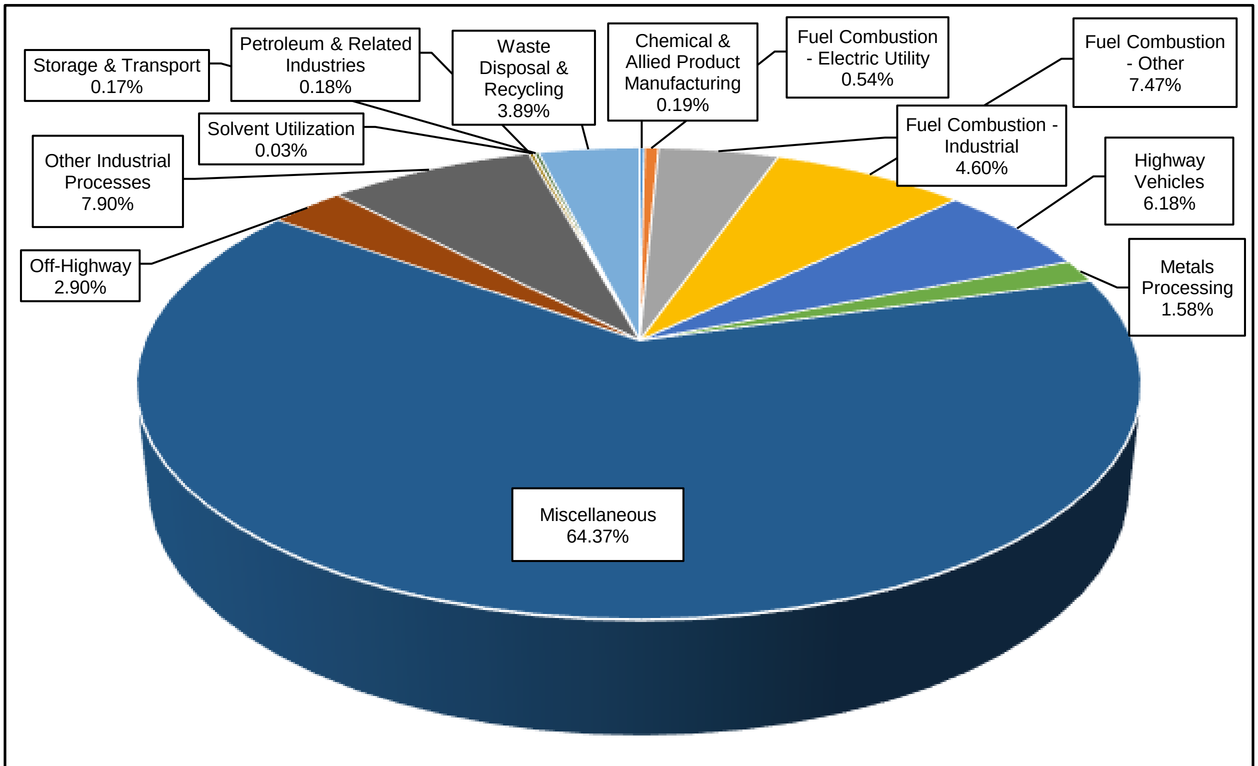


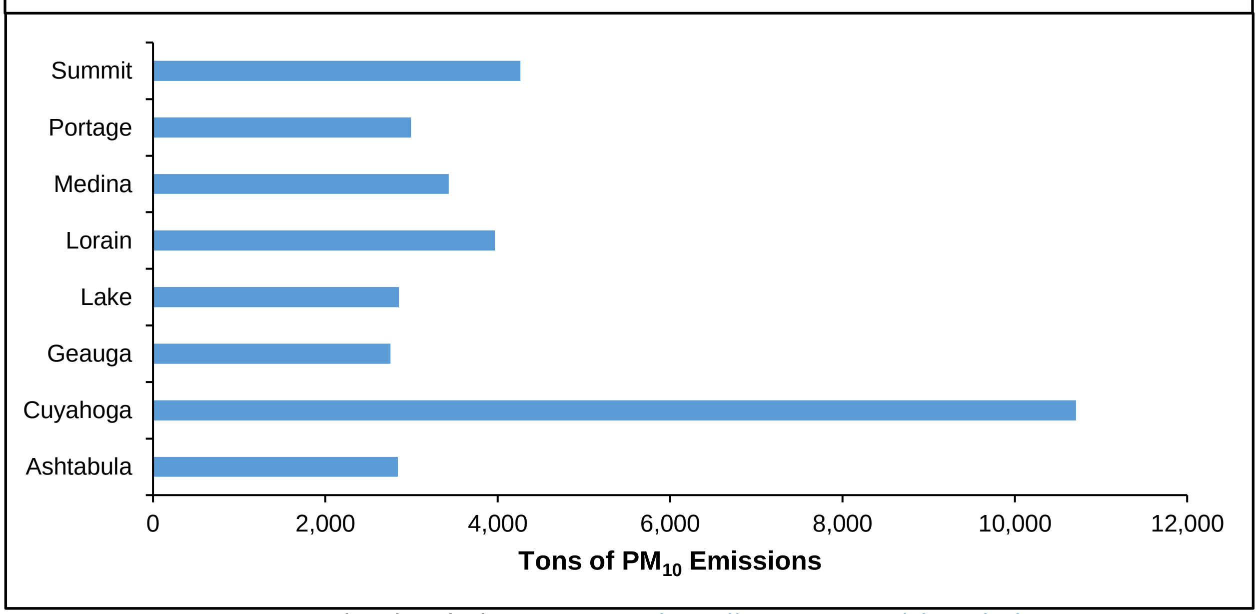
Source: U.S. EPA, "Particulate Matter: Basic Information," https://www.epa.gov/pm-pollution/particulate-matter-pm-basics (accessed February 15, 2023).

5.2.1 Coarse Particulate Matter (PM_{10})

Sources: In Northeast Ohio, PM_{10} largely comes from miscellaneous sources, such as fugitive dust emissions and the agriculture/forestry sector; industries that combust fossil fuels; gasoline and diesel-powered automobiles, trucks, construction equipment, ships, trains, and aircraft; waste disposal and recycling; and wood-burning stoves and fireplaces (see Figure 11).

Figure 11: PM_{10} Emission Inventory for Northeast Ohio (2017)





Source: U.S. EPA, *2017 National Emissions Inventory*, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data (accessed February 15, 2023).

NAAQS and Nonattainment Status: Since 2006, there has been only one PM_{10} NAAQS, a daily (24-hour) standard. U.S. EPA revoked its annual standard in December 2006 because there was insufficient health-based evidence to continue it.

The 24-hour PM_{10} NAAQS is 150 micrograms per cubic meter ($\mu g/m^3$), not to be exceeded more than once per year, averaged over three years. No county in Northeast Ohio is in nonattainment for the PM_{10} NAAQS. Cuyahoga County was redesignated as a maintenance area for PM_{10} effective January 10, 2001 (65 FR 77308).

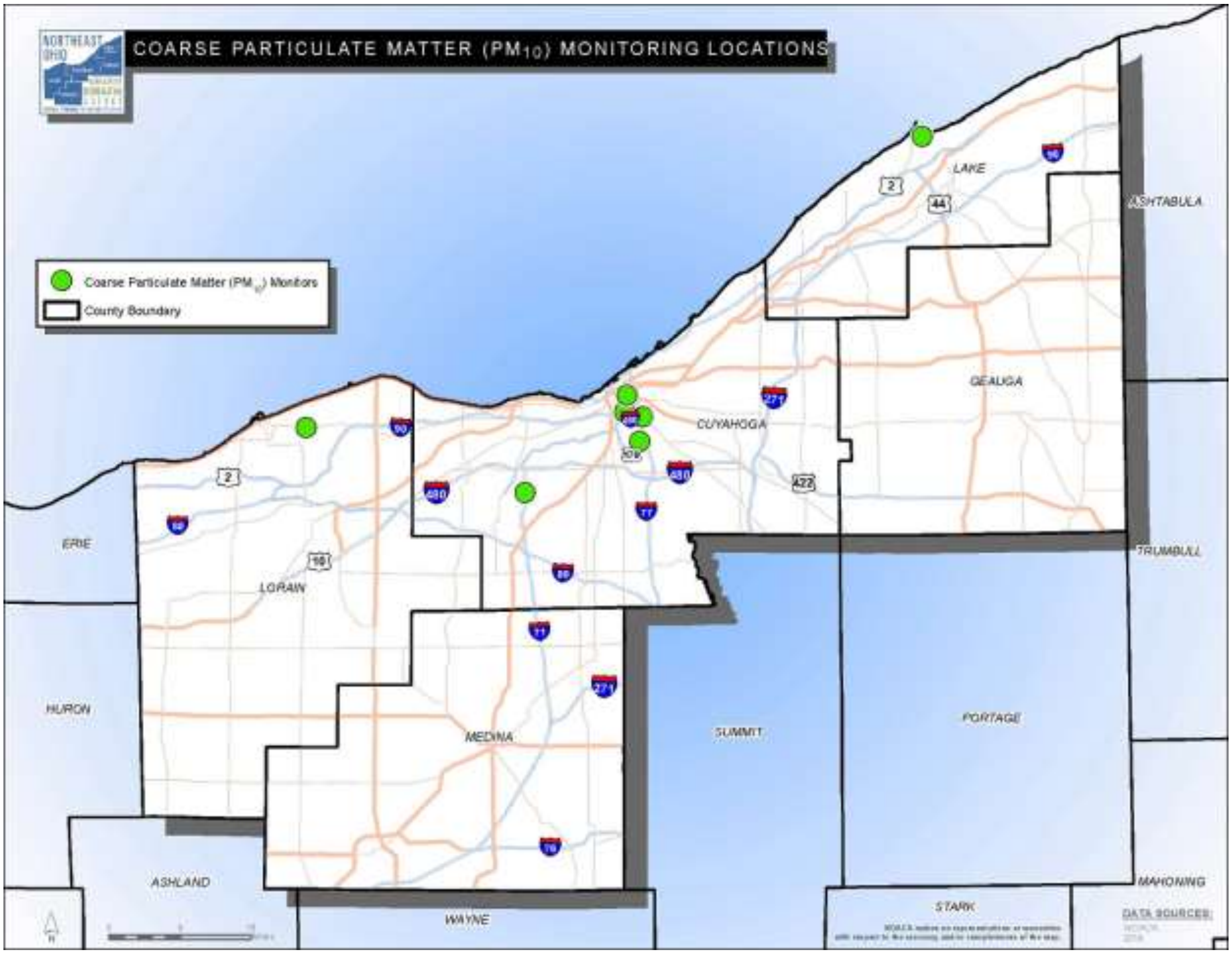
Monitors: There are seven PM_{10} monitors in Northeast Ohio (see Table 9 and Figure 12).

Table 9: Locations of PM_{10} Monitors in Northeast Ohio

Monitor	County	FIPS ID	Site ID	Latitude	Longitude	Address
1			0038	41.47	-81.68	St. Theodosius, St. Tikhon Ave., Cleveland
2			0045	41.47	-81.65	FS 13, 4950 Broadway Ave., Cleveland
3	Cuyahoga	035	0060	41.49	-81.67	GT Craig, E.14th St. & Orange Ave.
4			0065	41.44	-81.66	4600 Harvard Ave., Newburgh Heights
5			1002	41.39	-81.81	16900 Holland Road, Brook Park
6	Lake	085	0008	41.75	-81.27	Fairport High School, Fairport
7	Lorain	093	3002	41.46	-82.11	Barr School, Sheffield

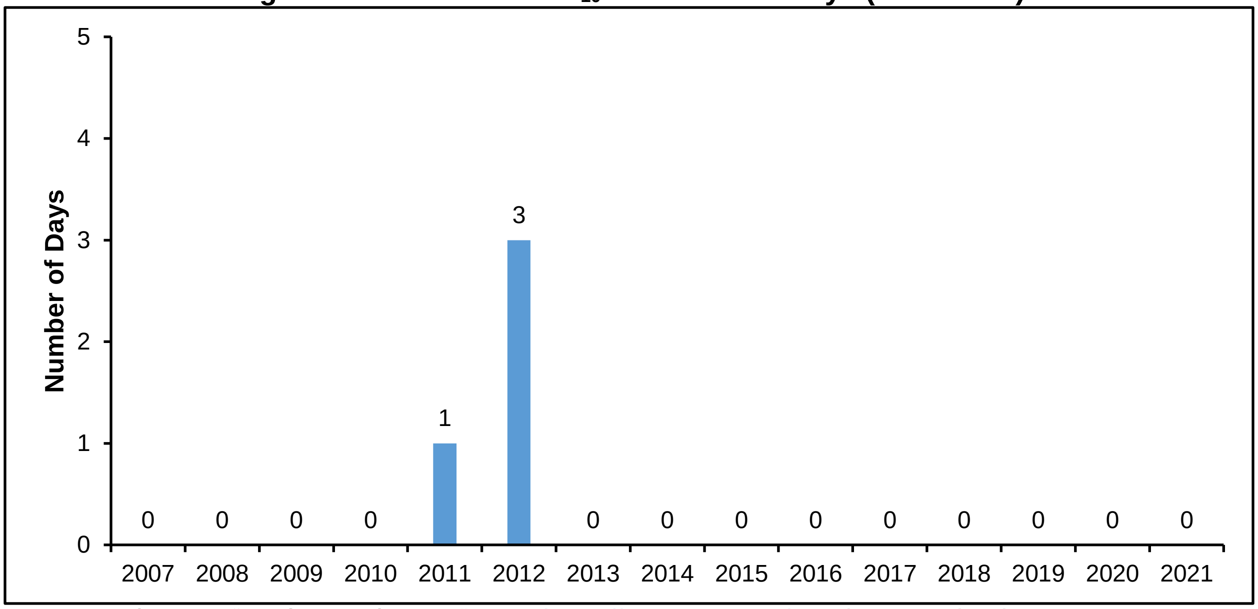
Source: Ohio EPA, *2021-2022 Ohio Air Monitoring Network Plan,* *https://epa.ohio.gov/static/Portals/27/ams/sites/2021-2022_AMNP_Main_Report_Final.pdf* (accessed February 15, 2023).

Figure 12: Northeast Ohio PM_{10} Monitor Locations



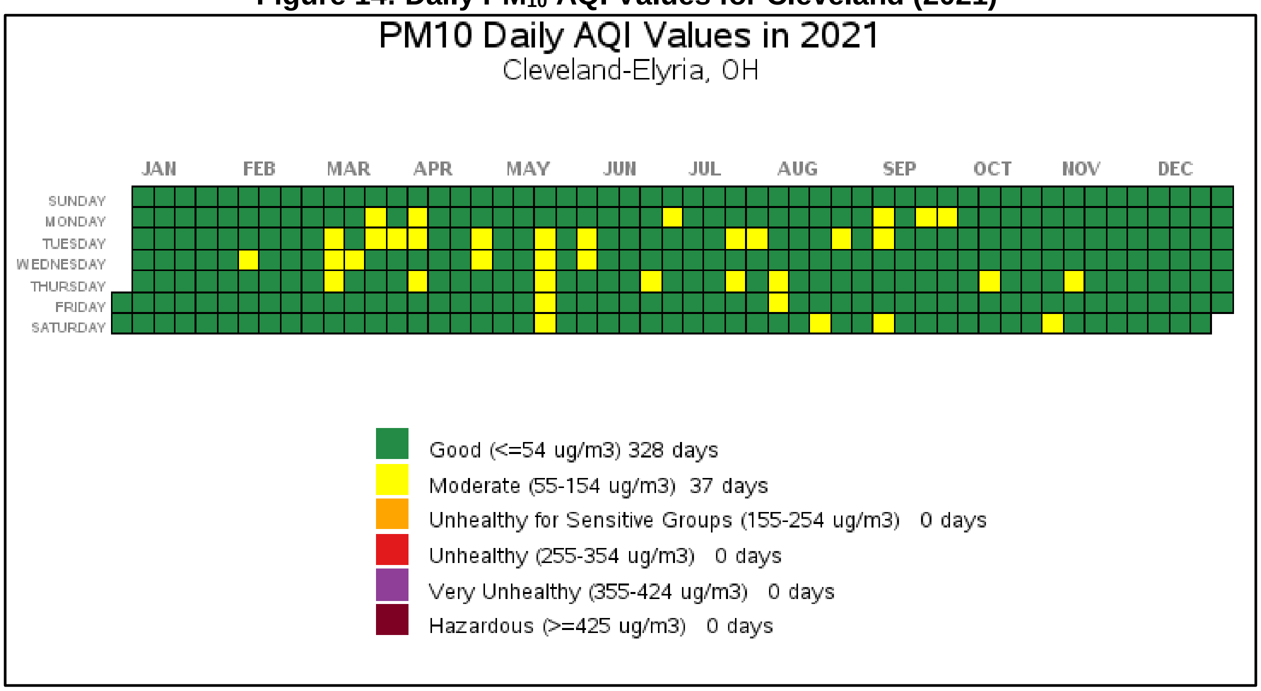
Trends: Figure 13 displays the number of PM_{10} exceedance days from 2007-2021. Northeast Ohio has consistently remained at or near zero exceedance days per year since 1996. While there were three exceedance days in 2012, the region has not registered an exceedance since that point. Figure 14 displays the 2021 daily AQI values for the Cleveland-Elyria area. As it shows, the region had 328 Good AQI Days and 37 Moderate AQI Days in 2021.

Figure 13: Number of PM_{10} Exceedance Days (2007-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

Figure 14: Daily PM_{10} AQI Values for Cleveland (2021)



Source: U.S. EPA, "AirData Tile Plot," http://www.epa.gov/airquality/airdata/ad_viz_tile.html (accessed February 15, 2023).

5.2.2 Fine Particulate Matter ($PM_{2.5}$)

Properties: $PM_{2.5}$ is a complex mixture of extremely small particles and liquid droplets. It is so small that it can be inhaled into the lungs and remain there; it may even travel into the bloodstream. Numerous adverse health effects are associated with breathing $PM_{2.5}$, including lung cancer, heart attack, stroke, and premature death. $PM_{2.5}$ is the major source of haze that reduces visibility in many parts of the United States, including the national parks. $PM_{2.5}$ affects vegetation and ecosystems by settling on soil and water, upsetting delicate nutrient and chemical balances. It also causes soil erosion and damage to structures, including culturally important objects such as monuments and statues.

Figure 15: Air Monitor Filter Before and After Trapping $PM_{2.5}$

Clean and dirty $PM_{2.5}$ monitor filters, showing six weeks' difference; Lorain County.
Source: Ohio EPA, Northeast District Office.

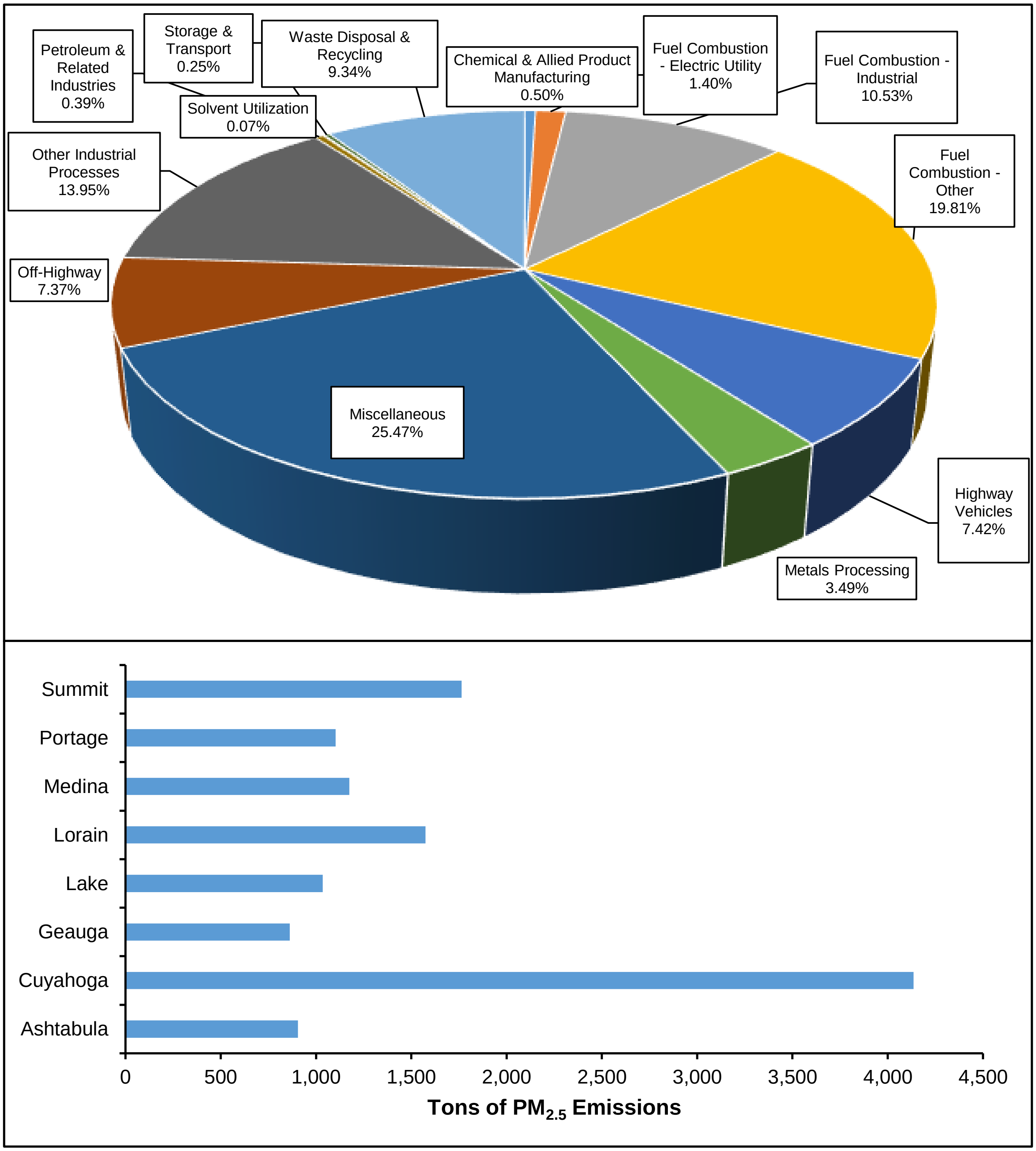
$PM_{2.5}$ is made up of a number of components, including acids, such as ammonium nitrates and ammonium sulfates; organic chemicals, including various forms of carbon; metals; and soil and crust particles. Water is also a component of $PM_{2.5}$, which ensures that ambient concentrations increase in Northeast Ohio when humidity levels are high or when fog is present. Secondary formation in the atmosphere accounts for more $PM_{2.5}$ than does primary formation (such as smoke or industrial emissions). $PM_{2.5}$ can occur year-round, ordinarily showing a bimodal distribution of high concentrations in winter and summer, with lower concentrations during spring and fall.

Sources: Direct sources of $PM_{2.5}$ include miscellaneous sources, such as fugitive dust emissions and the agriculture/forestry sector; industries that combust fossil fuels; waste disposal and recycling; wood burning; and diesel-powered trucks, construction equipment, ships, trains, and aircraft. Sulfates are more readily formed from SO_2 released by power plants from July through September, which may result in higher $PM_{2.5}$ levels.[48] Indirect sources that contribute through secondary formation in the atmosphere include agriculture (ammonia from fertilizer and manure),

[48] U.S. EPA Office of Air Quality Planning and Standards, *The Particle Pollution Report: Current Understanding of Air Quality and Emissions through 2003* (Research Triangle Park, NC: U.S. EPA, 2003), https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/190219 (accessed February 15, 2023).

electric utilities, industry, gasoline-powered cars, and diesel engines. In Northeast Ohio, road salt is also a factor during the winter. Figure 16 shows the primary sources of $PM_{2.5}$ in the region.

Figure 16: Primary $PM_{2.5}$ Emissions Inventory for Northeast Ohio (2017)



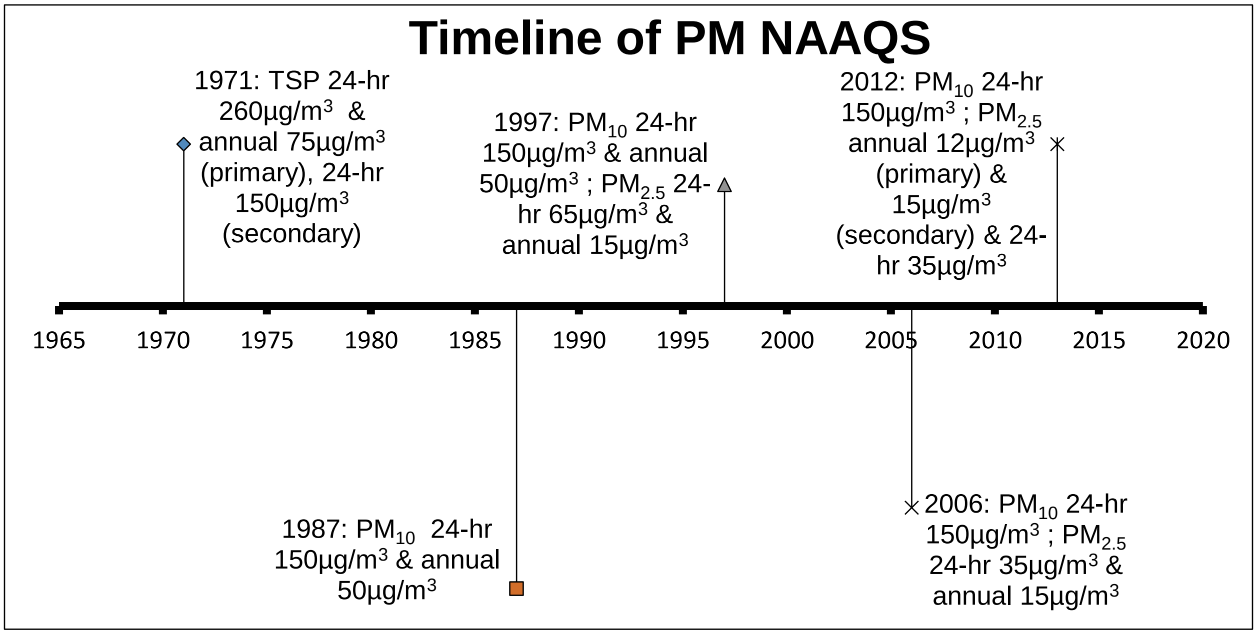
Source: U.S. EPA, *2017 National Emissions Inventory*, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data (accessed February 15, 2023).

NAAQS and Nonattainment Status: Figure 17, below, traces the changes in PM NAAQS since 1970. Monitoring for $PM_{2.5}$ began in 1999. In December 2009, U.S. EPA designated Cuyahoga, Lake, Lorain, Medina, Portage and Summit counties as nonattainment areas for the 2006 24-hour $PM_{2.5}$ NAAQS of 35 μg/m^3 (74 FR 58688). U.S. EPA redesignated Ashtabula Township and Cuyahoga, Lake, Lorain, Medina, Portage, and Summit counties from nonattainment to maintenance on September 18, 2013 (78 FR 57270), based on monitoring data.

U.S. EPA completed its 2012 revision to the $PM_{2.5}$ NAAQS on January 15, 2013 (78 FR 3085), when it issued three new $PM_{2.5}$ standards. These include two annual standards and a 24-hour standard. The primary annual NAAQS is 12 μg/m^3. The secondary annual NAAQS is 15 μg/m^3. The three-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed the annual standards. The 24-hour primary and secondary NAAQS is 35 μg/m^3. The three-year average of the 98th percentile of 24-hour concentrations at each monitor within an area must not exceed 35 μg/m^3.

U.S. EPA designated Cuyahoga County and Lorain County as moderate nonattainment areas for the annual NAAQS (80 FR 2206), a ruling that took effect on April 15, 2015. Based on 2015-2017 monitor data, the Agency redesignated Cuyahoga and Lorain Counties to maintenance status on April 12, 2019 (84 FR 14881).

Figure 17: Timeline of Revisions to PM NAAQS (1971-2021)



$PM_{2.5}$ Control Measures: The Ohio EPA is responsible for submitting SIPs for all regions within the state. The agency faced a deadline of October 2016 to submit a new $PM_{2.5}$ SIP for Cuyahoga and Lorain Counties (80 FR 2206). Please visit the Ohio EPA website to review the relevant $PM_{2.5}$ SIPs for Northeast Ohio: http://www.epa.ohio.gov/dapc/SIP/pm2_5.aspx.

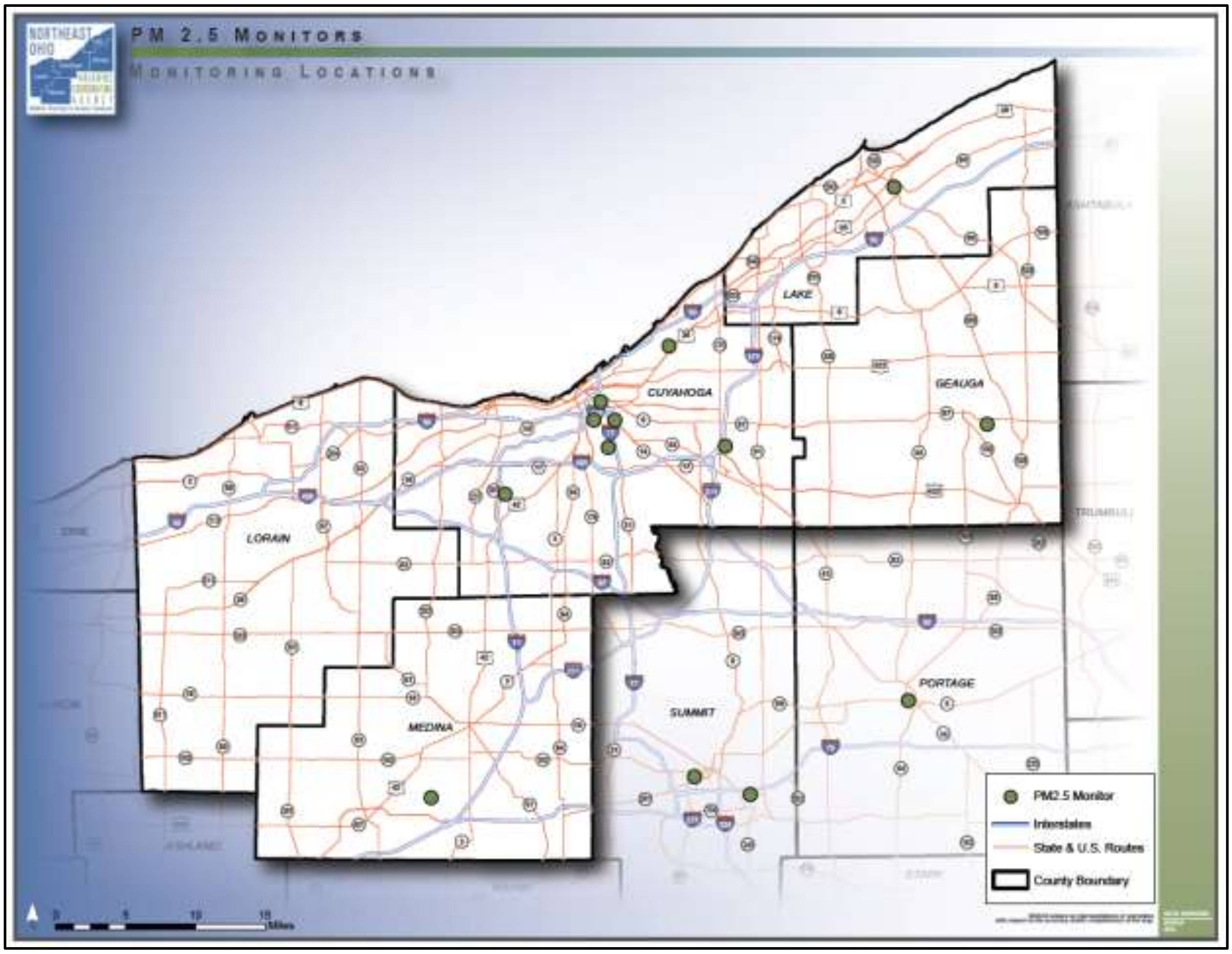
Monitors: There are 13 $PM_{2.5}$ monitors in Northeast Ohio (see Table 10 and Figure 18).

Table 10: Locations of $PM_{2.5}$ Monitors in Northeast Ohio

Monitor	County	FIPS ID	Site ID	Latitude	Longitude	Address
1	Cuyahoga	035	0034	41.55	-81.57	891 East 152nd St., Cleveland
2			0038	41.47	-81.68	St. Theodosius, St. Tikhon Ave., Cleveland
3			0045	41.47	-81.65	FS 13, 4950 Broadway Ave., Cleveland
4			0060	41.49	-81.67	GT Craig, East 14th St. & Orange Ave., Cleveland
5			0065	41.44	-81.66	4600 Harvard Ave., Newburgh Hts.
6			0073	41.44	-81.49	2506 Emory Rd., Warrensville Hts.
7			1002	41.39	-81.81	16900 Holland Road, Brook Park
8	Lake	085	0007	41.72	-81.24	177 Main St., Painesville
9	Lorain	093	3002	41.46	-81.11	Barr School, Sheffield
10	Medina	103	0004	41.06	-81.92	Ballash Rd., Lafayette Twp.
11	Portage	133	0002	41.16	-81.23	531 Washington Ave., Ravenna
12	Summit	153	0017	41.06	-81.46	East High School, Akron
13			0023	41.08	-81.54	642 W. Exchange St., Akron

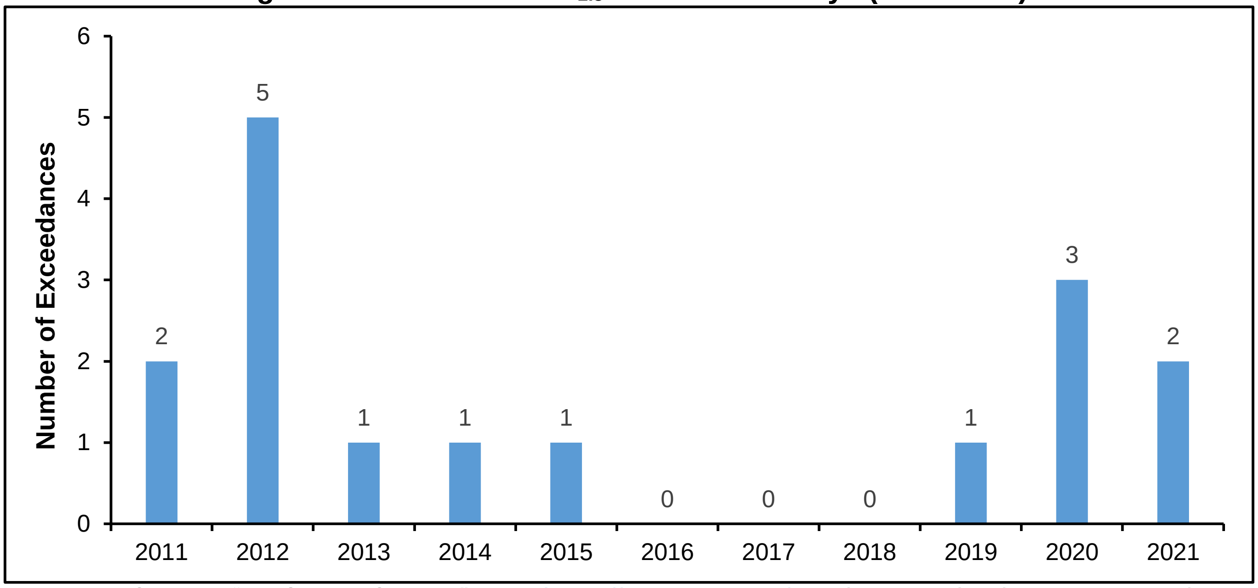
Source: Ohio EPA, *2021-2022 Ohio Air Monitoring Network Plan,* *https://epa.ohio.gov/static/Portals/27/ams/sites/2021-2022_AMNP_Main_Report_Final.pdf* (accessed February 15, 2023).

Figure 18: Northeast Ohio $PM_{2.5}$ Monitor Locations



Trends: Figure 19 shows the number of exceedance days for the $PM_{2.5}$ 24-hour NAAQS since 2010. There were two exceedances during 2021 which occurred on July 5 and July 20. Both of these occurred at East High School (monitor 39-153-0017) in Akron. The recent increase in exceedances has occurred despite the continued decline in annual $PM_{2.5}$ levels. Much like O_3, $PM_{2.5}$ exceedances are more likely to occur on days when warm fronts cause air to stagnate, trapping pollution in place. These stagnation events are becoming increasingly common due to climate change, as discussed in Section 6.2. For a list of the dates of each exceedance and the number of exceeding monitors, please see Appendix B: $PM_{2.5}$ Exceedance Days 2007-2021.

Figure 19: Number of $PM_{2.5}$ Exceedance Days (2011-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

Table 11 shows the three-year rolling averages for annual $PM_{2.5}$, monitor-by-monitor, from 2009-2011 to 2019-2021. While the Newburgh Heights monitor (39-035-0065) recorded an annual concentration (12.6 $\mu g/m^3$) above the NAAQS during 2021, its three-year average value (11.3 $\mu g/m^3$) remained below the standard. Accordingly, no monitor has exceeded the NAAQS since 2014-2016. Table 12, in turn, lays out the three-year rolling averages for the daily (24-hour) $PM_{2.5}$ for this same period. Every monitor has met the 24-hour NAAQS since 2007-2009. Cells marked N/A in either table indicate that the monitor was not operational during that period.

Table 11: Monitor-by-Monitor Three-Year Rolling Averages for Annual $PM_{2.5}$ NAAQS[a]

Monitor[b]	ID Number	County	2009-11	2010-12	2011-13	2012-14	2013-15	2014-16	2015-17	2016-18	2017-19	2018-20	2019-21
1	39-035-0034	Cuyahoga	10.4	10.1	9.6	9.5	9.4	8.9	8.2	7.8	7.6	7.2	7.1
2	39-035-0038	Cuyahoga	13.1	13	12.4	12.2	12.1	11.4	10.6	9.9	9.6	9.2	9.5[c]
3	39-035-0045	Cuyahoga	12.3	12.2	11.5	11.3	11.2	10.6	10.1	9.5	9.4	9.1	9.3
4	39-035-0060	Cuyahoga	12.8	13.1	12.5	12.5	12.1[c]	11.3[c]	10.1	9.3	10.3	10.0	10.5
5	39-035-0065	Cuyahoga	12.7	12.7	12.1	12.1	12.4	12.2	11.7	11.0	11.0	10.8	11.3
6	39-035-0073	Cuyahoga	N/A	N/A	N/A	N/A	N/A	N/A	7.3	7.6	9.0	9.8	9.8
7	39-035-1002	Cuyahoga	10.9	10.5	9.7	9.5	9.3	8.9	8.3	7.9	7.7	7.0	8.9[c]
8	39-085-0007	Lake	10.1	9.6	9	8.7	8.5	7.9	7.4	7.0	6.9	6.6	6.5
9	39-093-3002	Lorain	9.9	9.8	9.2	9.1	8.7	8.1	7.6	7.5	7.7	7.4	7.5[c]
N/A	39-103-0003	Medina	10.9	10.3	9.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	39-103-0004	Medina	N/A	N/A	N/A	9	9.3	8.7	8.4	7.6	8.0	7.6	7.8
11	39-133-0002	Portage	10.9	10.3	9.5	8.8	8.9[c]	8.3[c]	7.8	9.0	7.4	7.3	7.3[c]
12	39-153-0017	Summit	12.6	N/A	N/A	10.6	11.2	11	10.2	9.3	8.9	9.1	9.2
13	39-153-0023	Summit	11.7	11.2	10.4	10.2	9.9	9.2	8.5	7.8	7.9	7.8	8.1

[a] Values that exceeded the NAAQS in place at the time are highlighted in red.
[b] Monitors numbered N/A are no longer in operation.
[c] Annual values that do not meet Ohio EPA completeness criteria. In order for a monitor to meet completeness criteria, at least 75% of its scheduled sample days must register valid readings for each quarter of each calendar year.

Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

Table 12: Monitor-by-Monitor Three-Year Rolling Averages for 24-Hour $PM_{2.5}$ NAAQS[a]

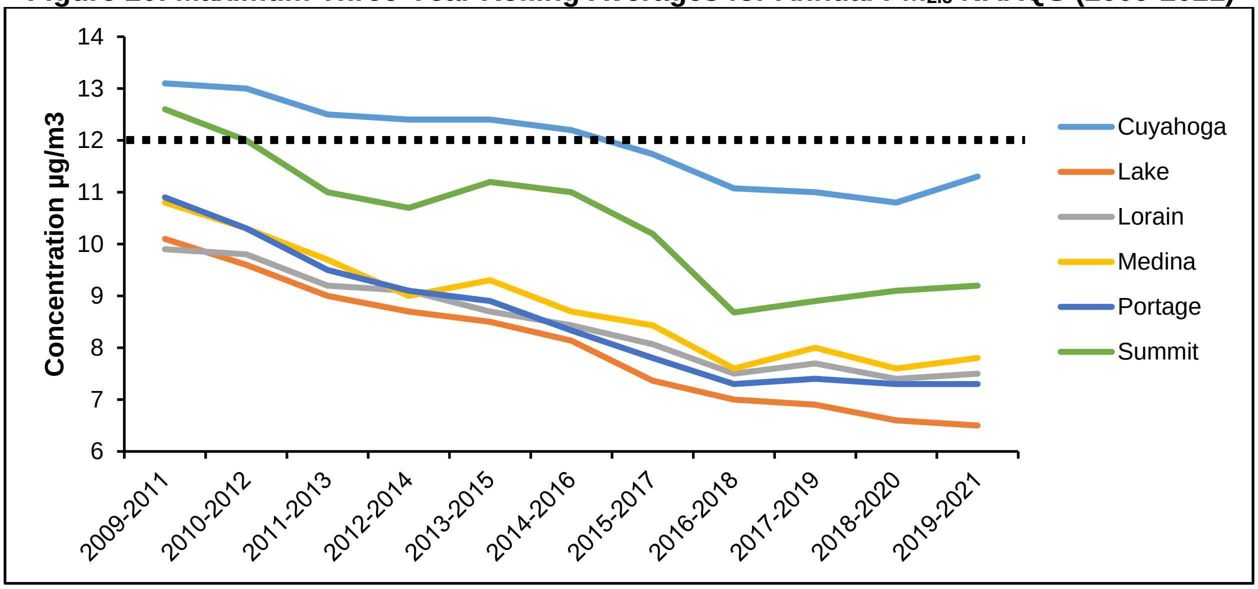
Monitor[b]	ID Number	County	2009-11	2010-12	2011-13	2012-14	2013-15	2014-16	2015-17	2016-18	2017-19	2018-20	2019-21
1	39-035-0034	Cuyahoga	24.7	23	21.9	22.1	23	20.4	18.7	17.7	17.9	16.9	16.6
2	39-035-0038	Cuyahoga	29.5	29.2	28[c]	27.2	26.7	25	23.7	23.3	23.0	23.8	23.3
3	39-035-0045	Cuyahoga	27.1	27.5	24.5	24.6	25.1	22.9	21.2	20.7	22.0	20.6	19.5
4	39-035-0060	Cuyahoga	28.8	30.3	29[c]	30.2[c]	27.7[c]	25.3[c]	21.8	23.7	25.4	25.9	25.2
5	39-035-0065	Cuyahoga	27.7	25.9	24.5	24.2	25.4	24.9	25	23.7	24.3	24.2	26.4
6	39-035-0073	Cuyahoga	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	18.6	21.2	22.9
7	39-035-1002	Cuyahoga	23.6	23.4	22.1	21.7	22.3	19.5	18.8	17.7	19.3	18.3	17.4
8	39-085-0007	Lake	N/A	23.2	20.5	19	18.8	17.4	16.6	17.0	16.8	16.7	15.2
9	39-093-3002	Lorain	23	23.2	22	21.9	22.1	20.2	18.3	16.7	18.5	19.4	20.1
10	39-103-0004	Medina	N/A	22.1	22.2	20.5	21.6	19.6	19.4	18.0	19.4	18.4	18.9
11	39-133-0002	Portage	26.3	24.4	21.6	20.3	21.2	18	17.8	16.3	17.8	16.9	15.8
12	39-153-0017	Summit	29.4	26.5	23.9	22.7	24.8	23.7	22.1	21.3	21.3	23.7	24.9
13	39-153-0023	Summit	26.6	24.9	22.9	21.9	22.9	20.2	19.1	17.7	19.8	21.8	22.5

[a] Values that exceeded the NAAQS in place at the time are highlighted in red.
[b] Monitors numbered N/A are no longer in operation.
[c] Annual values that do not meet Ohio EPA completeness criteria. In order for a monitor to meet completeness criteria, at least 75% of its scheduled sample days must register valid readings for each quarter of each calendar year.

Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

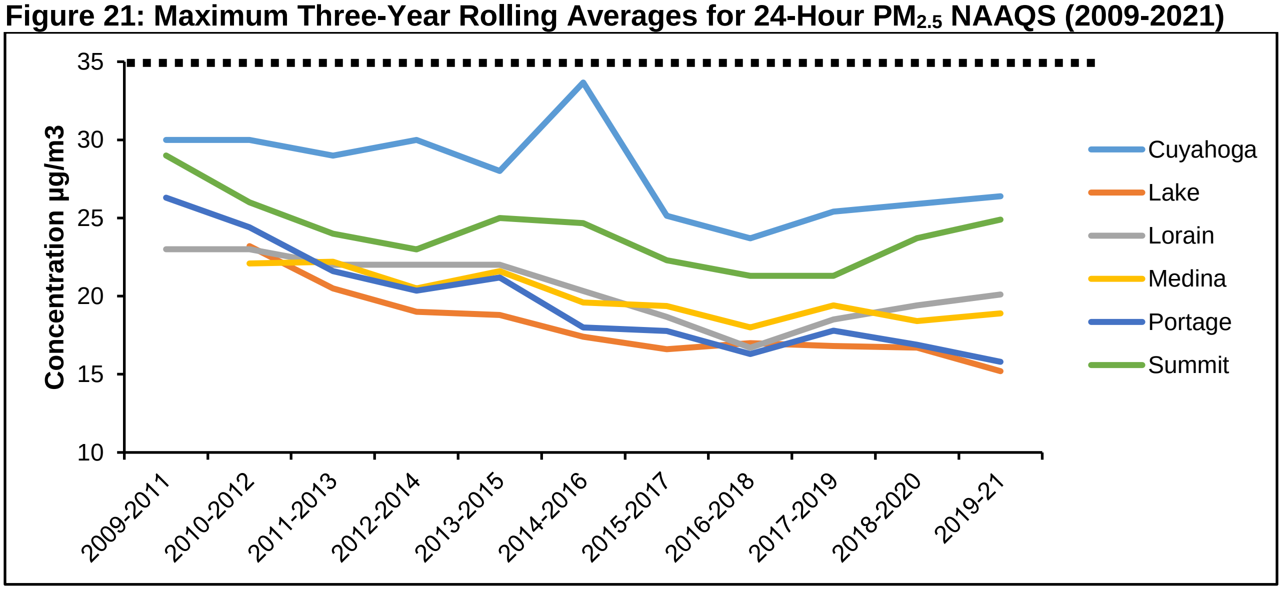
Figures 20 and 21 illustrate the information from Tables 11 and 12. The data show a clear downward trend over the past decade, most likely due to new controls on coal-fired power plants, cleaner fuels (e.g., low sulfur diesel), and alternative vehicle technologies (e.g., vehicle retrofits, repowers, replacements, and anti-idling mechanisms). The 2015-2017 three-year annual $PM_{2.5}$ levels were below 12 µg/m^3 for all counties in Northeast Ohio. U.S. EPA moved the region from nonattainment to maintenance status on April 12, 2019, based on these data. During 2021, $PM_{2.5}$ levels increased slightly throughout the region, but no monitor exceeded the NAAQS.

Figure 20: Maximum Three-Year Rolling Averages for Annual $PM_{2.5}$ NAAQS (2009-2021)[49]



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

Figure 21: Maximum Three-Year Rolling Averages for 24-Hour $PM_{2.5}$ NAAQS (2009-2021)

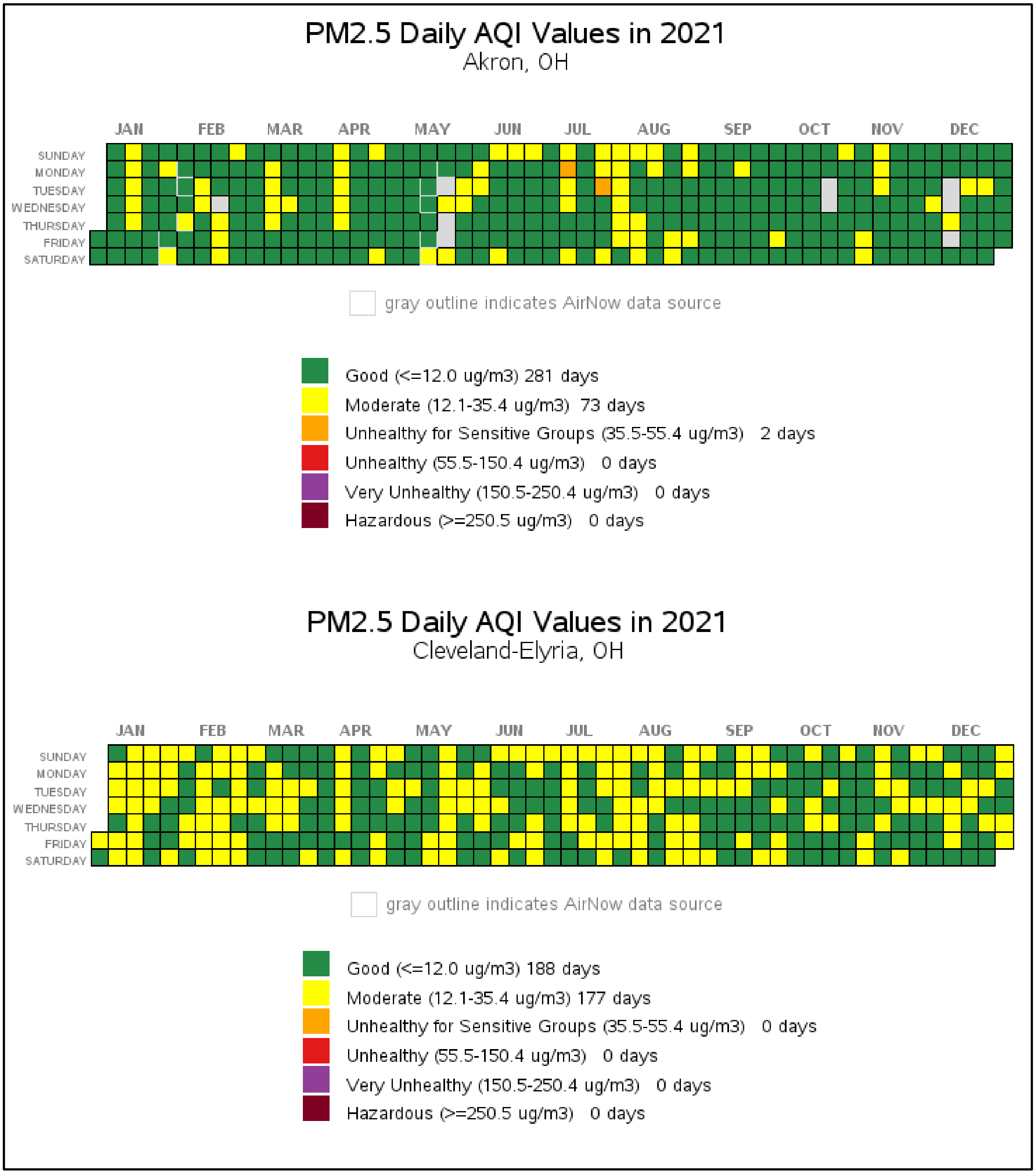


Source**:** U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

[49] Figures 18 and 19 depict the data only from the highest value monitor in each county, for each year. The dashed black lines in each chart indicate the NAAQS in effect during each period.

Figure 22 displays the 2020 daily AQI values for the Akron and Cleveland-Elyria areas. Nearly two-thirds of all days had good AQI values.

Figure 22: Daily $PM_{2.5}$ AQI Values (2021)



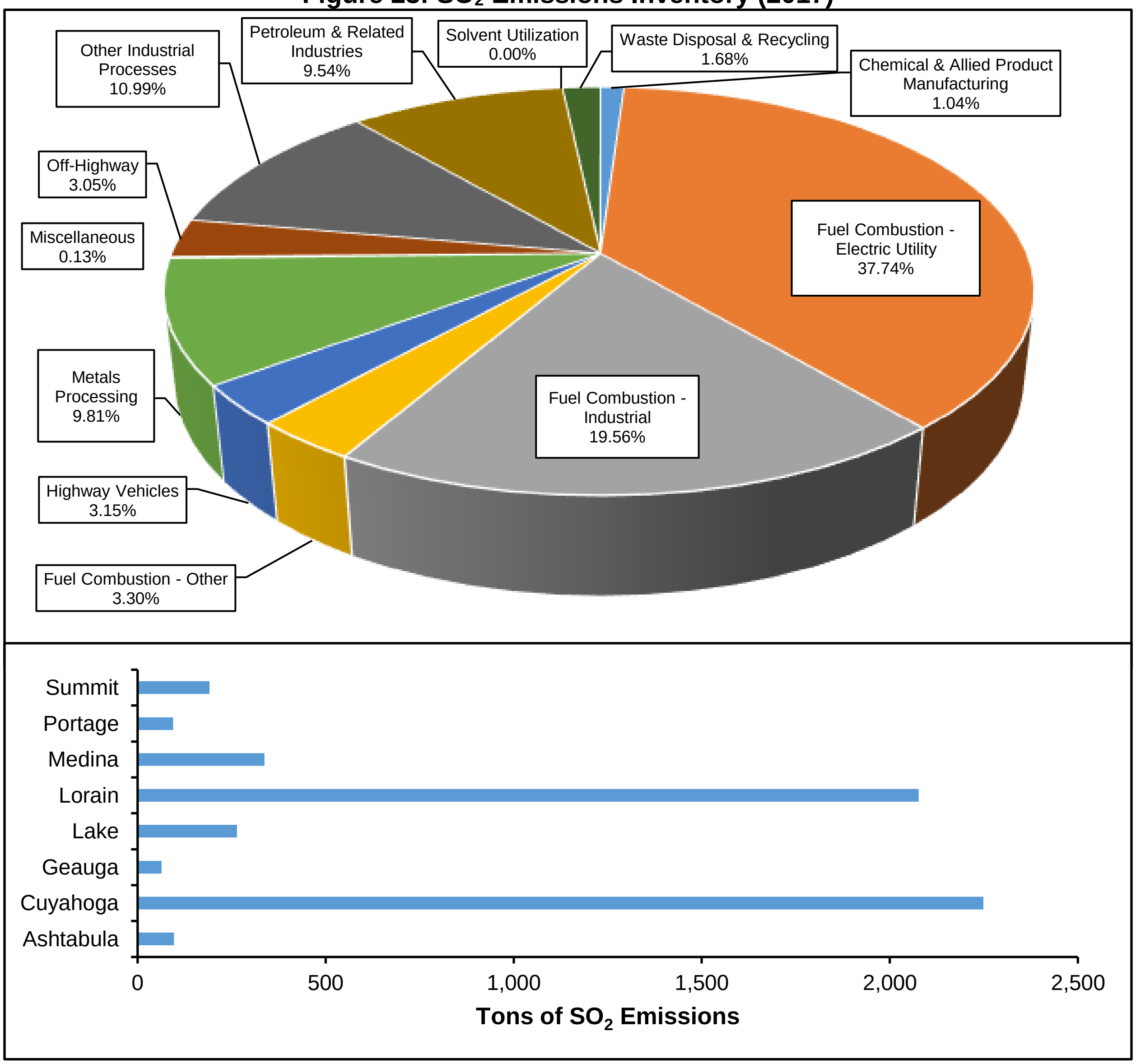
Source: U.S. EPA, “Air Data Tile Plot,” https://www.epa.gov/outdoor-air-quality-data/air-data-tile-plot (accessed February 15, 2023).

5.3 Sulfur Dioxide

Properties: Sulfur dioxide (SO_2) is released primarily by the combustion of fuels that contain sulfur as a contaminant. Like O_3, it irritates lung tissue and can exacerbate preexisting respiratory and cardiovascular conditions. It also contributes to acid rain, which deteriorates man-made structures, damages plants, and can alter pH levels sufficiently to destroy ecosystems. Moreover, SO_2 is a major source of secondary $PM_{2.5}$ formation.

Sources: Industries that burn fossil fuels and diesel are the primary contributors to sulfur dioxide concentrations. U.S. EPA has eliminated sulfur from diesel fuel, on a phased-in basis. Due to the closures of coal-fired power plants in Northeast Ohio, SO_2 emissions from the electricity sector fell 97% from 2014 to 2017, bringing the sector's share of the pollutant down from 85% to 38%.

Figure 23: SO_2 Emissions Inventory (2017)



Source: U.S. EPA, *2017 National Emissions Inventory*, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data (accessed February 15, 2023).

NAAQS and Nonattainment Status: On June 22, 2010, U.S. EPA strengthened the NAAQS for SO_2, creating a single one-hour NAAQS of 75 ppb and revoking the 24-hour and annual NAAQS. This final rule took effect August 23, 2010 (75 FR 35519). There is also a secondary NAAQS set at a three-hour average concentration of 0.5 ppm, not to be exceeded more than once per year.

Most of Northeast Ohio is currently in attainment for SO_2. Lake County was designated as a nonattainment area for the one-hour NAAQS on July 25, 2013 (78 FR 47191). Based upon 2015-2017 monitor data, U.S. EPA redesignated the county to maintenance on May 14, 2019 (84 FR 21253).

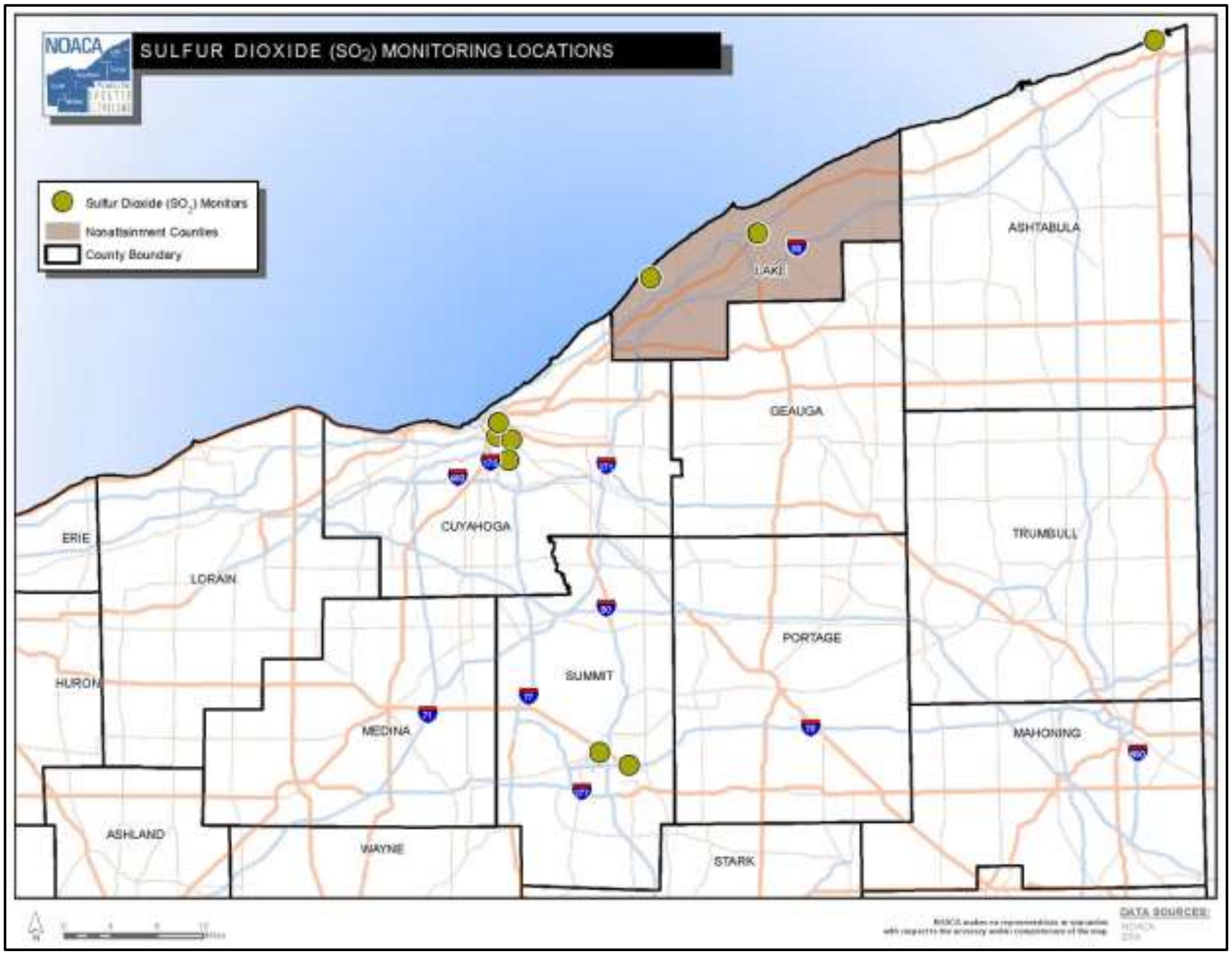
Monitors: There are nine SO_2 monitors in Northeast Ohio (see Table 13 and Figure 24).

Table 13: Locations of SO_2 Monitors in Northeast Ohio

Monitor	County	FIPS ID	Site ID	Latitude	Longitude	Address
1	Ashtabula	007	1001	41.95	-80.57	Conneaut Water Plant
2	Cuyahoga	035	0038	41.47	-81.68	St. Theodosius, St. Tikhon Ave., Cleveland
3			0045	41.47	-81.65	FS 13, 4950 Broadway Ave., Cleveland
4			0060	41.49	-81.67	GT Craig, E. 14th St. & Orange Ave., Cleveland
5			0065	41.44	-81.66	4600 Harvard Ave., Newburgh Hts.
6	Lake	085	0003	41.67	-81.42	Jefferson School, Eastlake
7			0007	41.72	-81.24	177 Main St., Painesville
8	Summit	153	0017	41.06	-81.46	East High School., Akron
9			0025	41.08	-81.51	199 S. Broadway, Akron

Source: Ohio EPA, *2021-2022 Ohio Air Monitoring Network Plan,* https://epa.ohio.gov/static/Portals/27/ams/sites/2021-2022_AMNP_Main_Report_Final.pdf (accessed February 15, 2023).

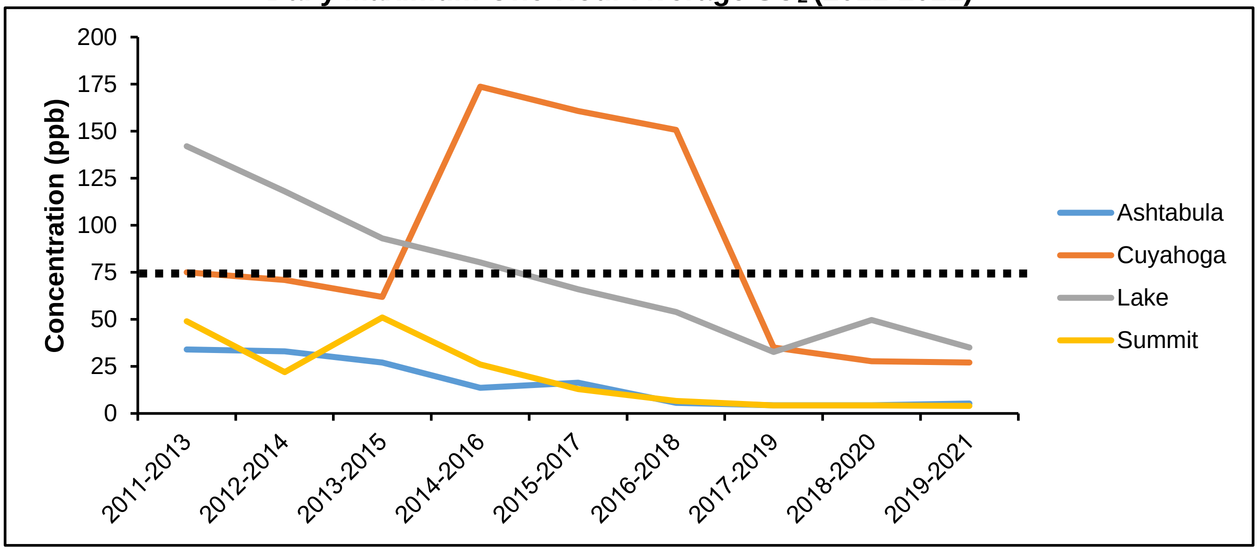
Figure 24: Northeast Ohio SO_2 Monitor Locations



Trends: For 2021, the maximum three-year average of the 99th percentile of the daily maximum one-hour average occurred at monitor 39-085-0007 in Lake County (35 ppb). The spike in Cuyahoga County's concentration, shown in Figures 25 and 26, stems from fugitive emissions in the Industrial Flats during February 2016. Fugitive emissions are accidental or unintended releases of vapors or gases from equipment due to mechanical or operating errors. However, this event did not put the county into nonattainment, and it has met the NAAQS since that point.

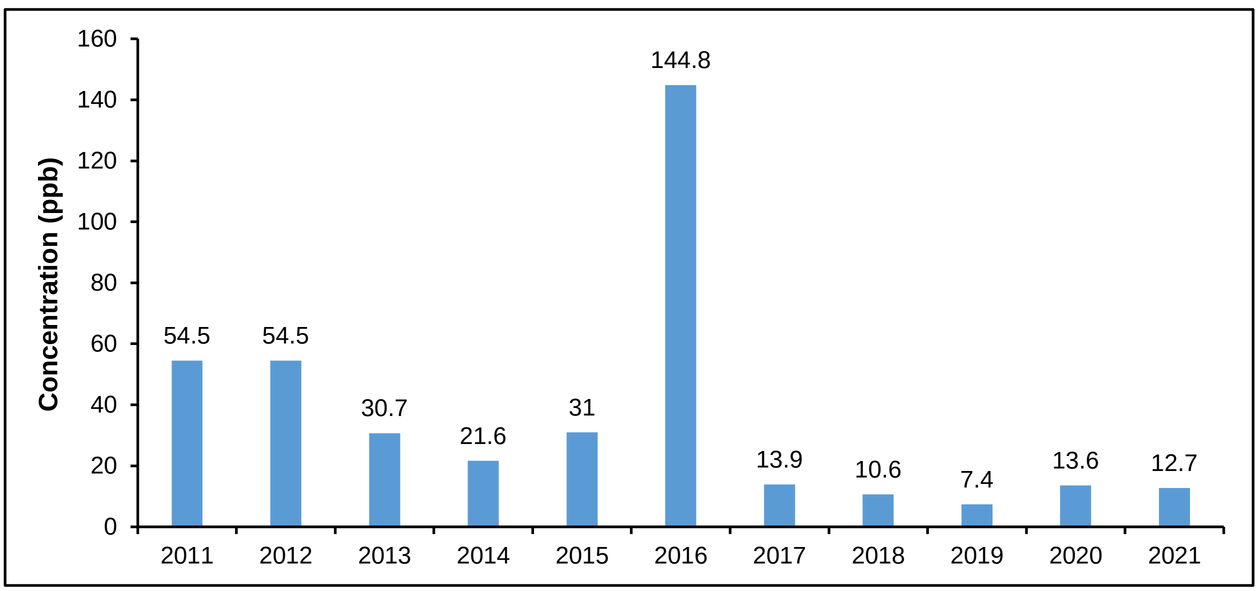
Lake County's SO_2 levels continue to decline, and they remained below the 75 ppb standard for the fourth year in a row. This kept the county in compliance with the NAAQS, and U.S. EPA redesignated it to maintenance status on May 14, 2019 (84 FR 21253). Figure 26 shows the second maximum 24-hour concentration for all SO_2 monitors in the region. In 2021, the highest concentration was at monitor 39-035-0038, located in Cleveland.

Figure 25: Three-Year Average of the 99th Percentile of Daily Maximum One-Hour Average SO_2 (2011-2021)[50]



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

Figure 26: Second Maximum 24-Hour SO_2 Concentration (2011-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

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50 The dashed black line indicates the NAAQS in effect during this period.

5.4 Carbon Monoxide

Properties: Carbon monoxide (CO) forms whenever a fuel is burned incompletely due to insufficient oxygen. It enters the bloodstream during normal respiration and leads to insufficient oxygen delivery to body tissues. Depending on its concentration, health effects can include increased discomfort for those with cardiovascular ailments, visual impairment, reduced work capacity, and even premature death.[51]

Sources: Primary sources of CO in Northeast Ohio include motor vehicles and steel mills. Passenger cars produce far less CO per vehicle than they did 40 years ago, due to the widespread adoption of the catalytic converter.[52] As Figure 27 shows, in Northeast Ohio, highway and off-highway vehicles are the largest sources of CO in Northeast Ohio.

NAAQS and Nonattainment Status: There are two primary NAAQS for carbon monoxide. The one-hour NAAQS is an average concentration of 35 ppm that cannot be exceeded more than once per year. Additionally, the eight-hour NAAQS is an average concentration of 9 ppm that cannot be exceeded more than once per year.

No part of Northeast Ohio is in nonattainment for carbon monoxide. Cuyahoga County was designated as nonattainment for carbon monoxide from 1978 to 1994 and is now in maintenance. The Ohio EPA, with NOACA's assistance, completed a maintenance plan update in 2003. On January 28, 2011, U.S. EPA proposed to retain the existing NAAQS for CO. Hence the rest of the region is expected to remain in attainment under the current NAAQS for the foreseeable future.

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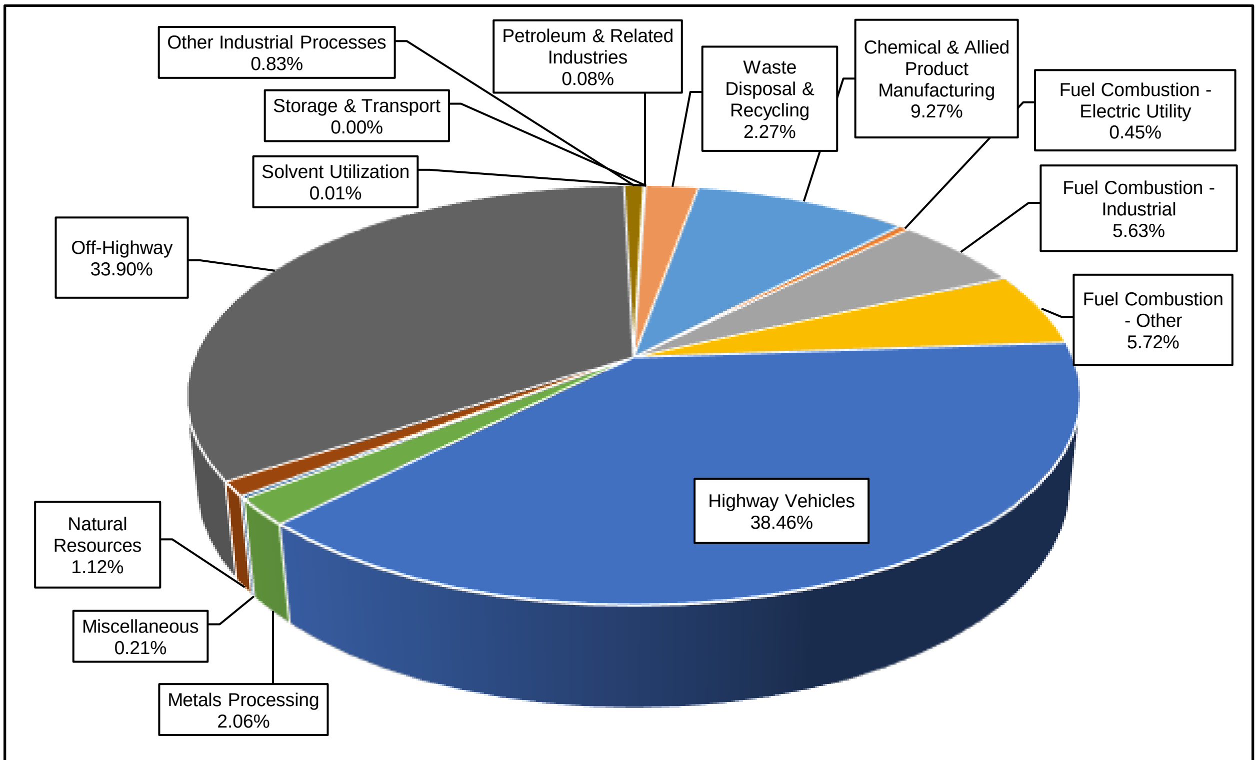
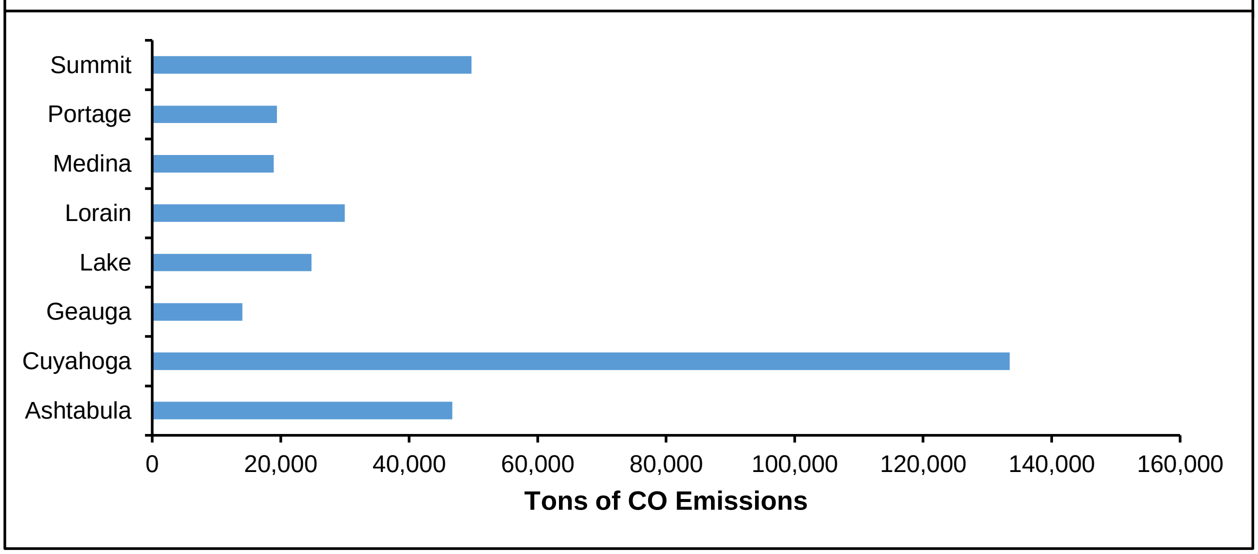
[51] U.S. EPA, "Carbon Monoxide," http://www.epa.gov/airquality/carbonmonoxide/index.html (accessed February 15, 2023).
[52] U.S. EPA Office of Mobile Sources, "Automobiles and Carbon Monoxide," http://www.epa.gov/oms/consumer/03-co.pdf (accessed February 15, 2023).

Figure 27: CO Emissions Inventory for Northeast Ohio (2017)





Source: U.S. EPA, *2017 National Emissions Inventory*, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data (accessed February 15, 2023).

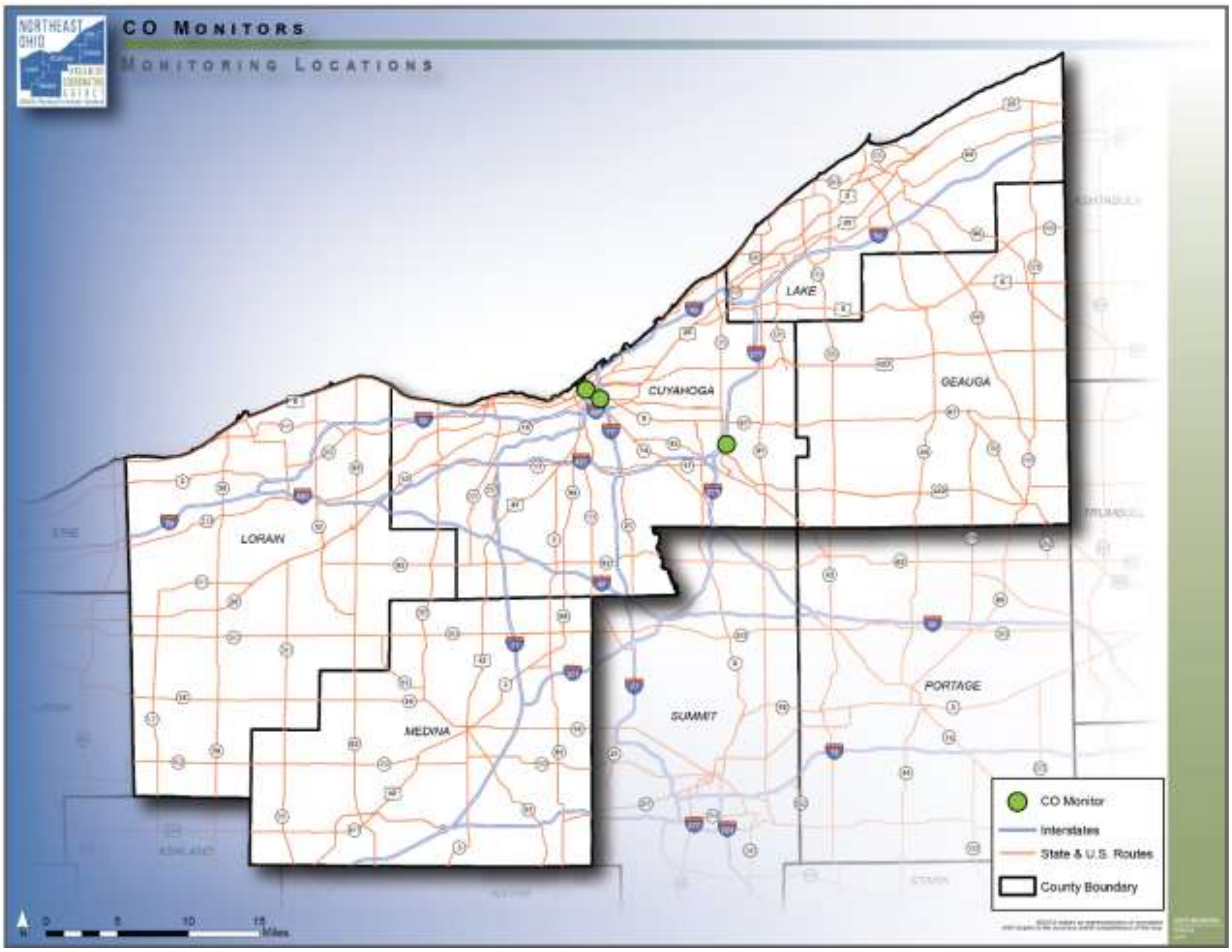
Monitors: There are three operating CO monitors in Northeast Ohio (see Table 14 and Figure 28).

Table 14: Locations of CO Monitors in Northeast Ohio

Monitor	County	FIPS ID	Site ID	Latitude	Longitude	Address
1	Cuyahoga	035	0051	41.50	-81.69	Galleria, E.9th St. & St. Clair Ave., Cleveland
2			0060	41.49	-81.67	GT Craig, E.14th St. & Orange Ave., Cleveland
3			0073	41.44	-81.49	26565 Miles Rd., Warrensville Hts.

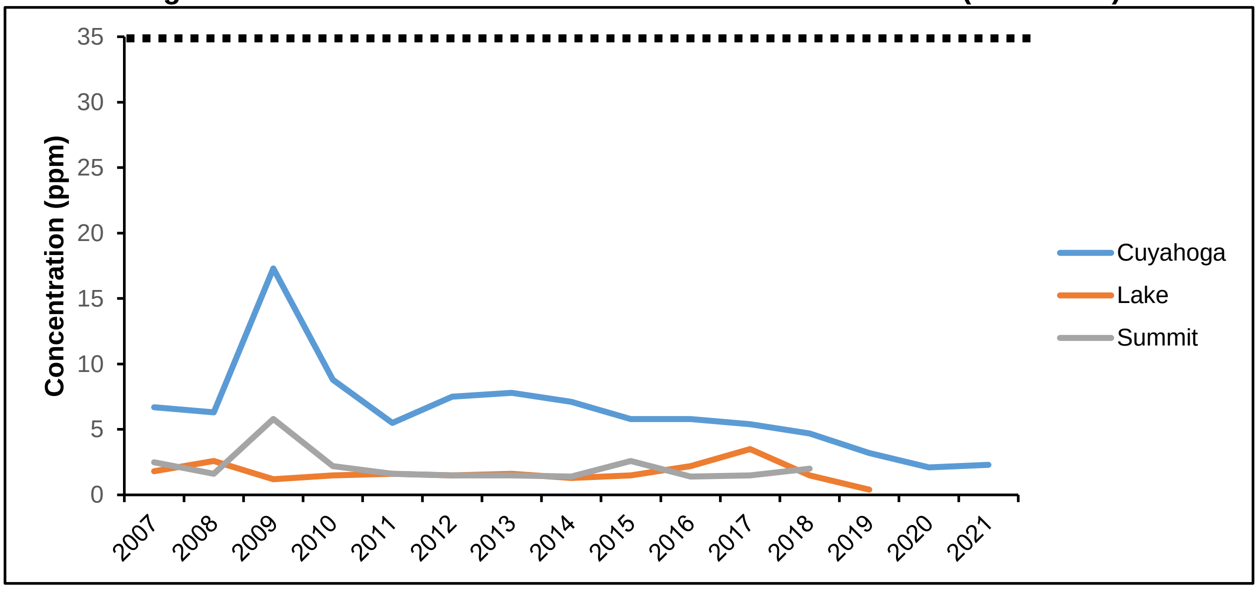
Source: Ohio EPA, *2021-2022 Ohio Air Monitoring Network Plan,* https://epa.ohio.gov/static/Portals/27/ams/sites/2021-2022_AMNP_Main_Report_Final.pdf (accessed February 15, 2023).

Figure 28: Northeast Ohio CO Monitor Locations



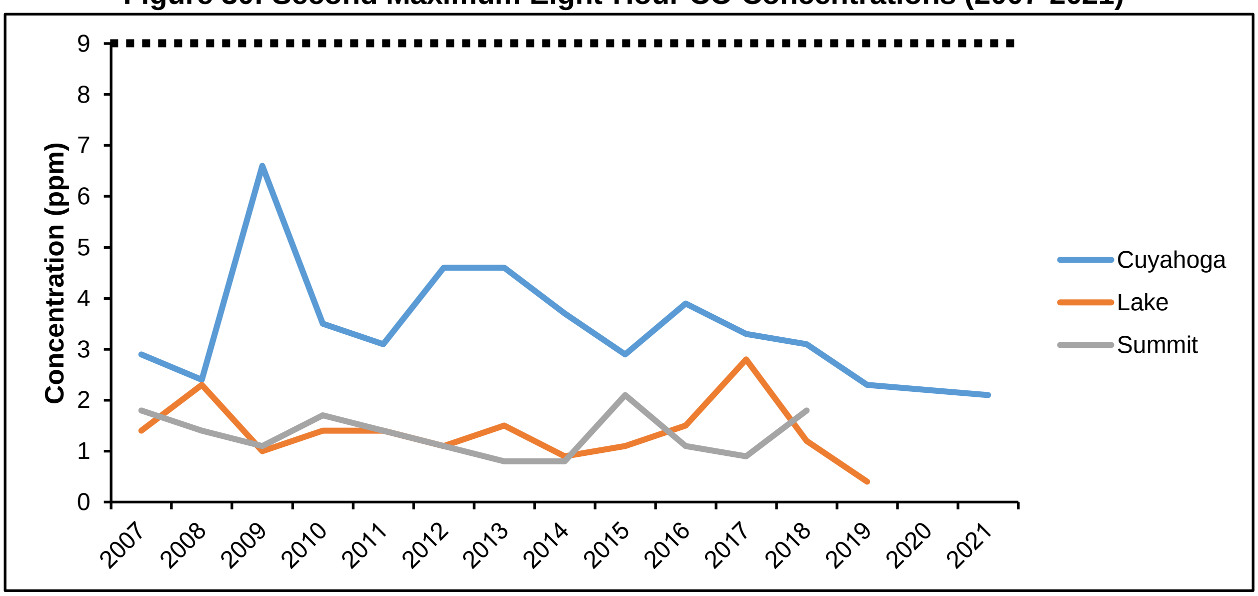
Trends: Figure 29 displays second maximum one-hour concentration data for CO, while Figure 30 displays the second maximum eight-hour concentration data. Both figures show data for Cuyahoga, Lake, and Summit Counties, though only Cuyahoga currently has operating monitors. The dashed black line shown within each figure indicates the NAAQS.

Figure 29: Second Maximum One-Hour CO Concentrations (2007-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

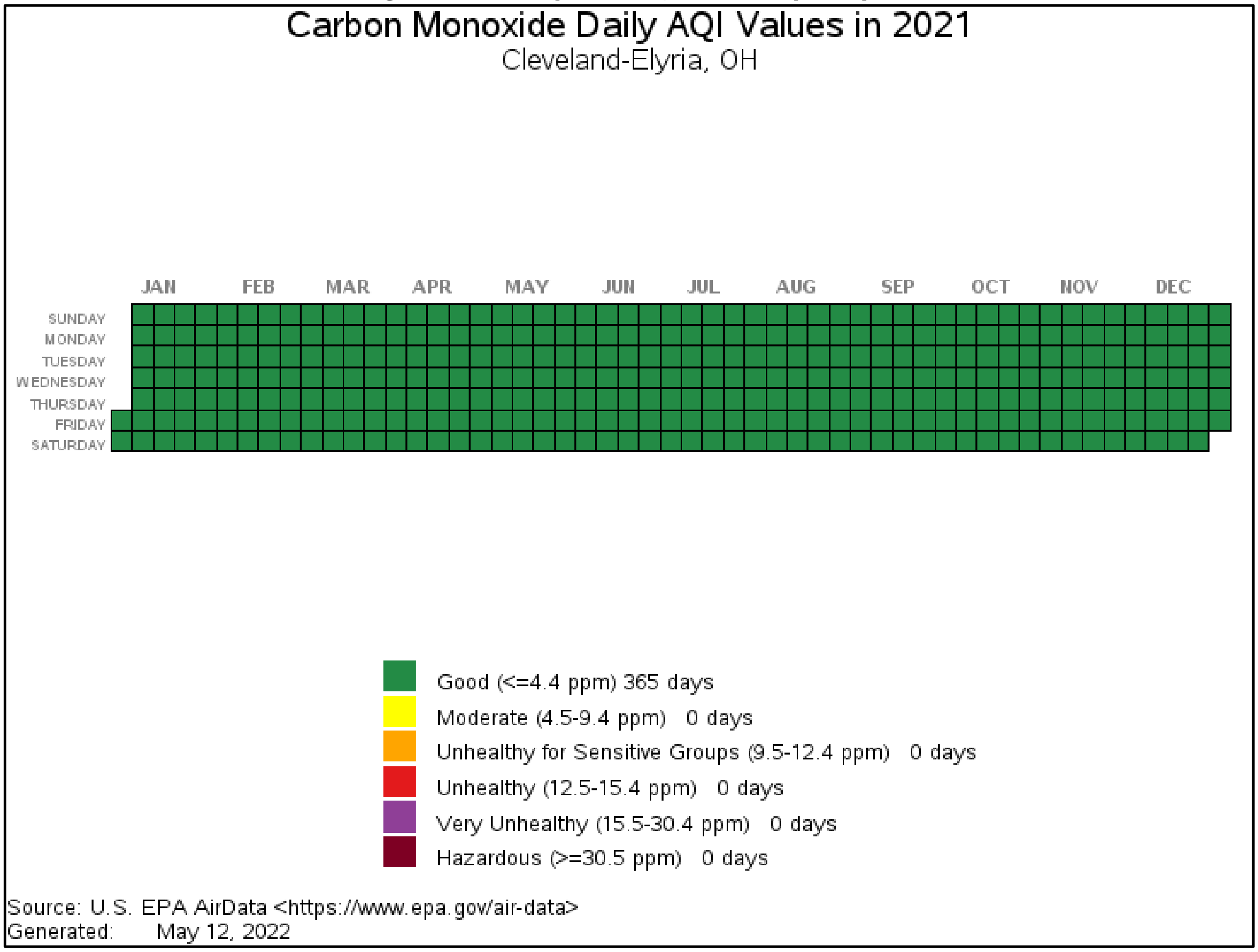
Figure 30: Second Maximum Eight-Hour CO Concentrations (2007-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

CO concentrations fluctuate slightly from year to year, but they remain well below both the one-hour and eight-hour NAAQS. As Figure 31 shows, Northeast Ohio registered good AQI values for CO every day during 2021.

Figure 31: Daily CO AQI Values (2021)[53]



Source: U.S. EPA, "Air Data Tile Plot," http://www.epa.gov/airquality/airdata/ad_viz_tile.html (accessed February 15, 2023).

5.5 Lead

Properties: Lead (Pb) exists in its elemental form in the atmosphere and, in Northeast Ohio, in the ground, where particles from leaded gasoline and lead-based paint have settled. Pb accumulates in the body and can damage kidneys, liver, the nervous system, and other organs.

Sources: Historically, leaded gasoline was the primary source of Pb emissions, although in Cleveland a single source, Master Metals, was responsible for large amounts of fugitive lead emissions. Master Metals is now defunct, and a comprehensive environmental remediation has been performed at its former site.

U.S. EPA began efforts to phase out the use of lead in gasoline in the early 1970s, but it was not until December 31, 1995, that the use of leaded gasoline in on-road vehicles was officially banned. Lead additives are still used in off-road engines. Lead-based paint is also no longer manufactured, but it remains in a large number of older buildings throughout the region. Only metal industries and

[53] U.S. EPA rounds all concentrations to the first decimal place. Accordingly, EPA rounds down all values below 9.5 ppm, while those greater than or equal to 9.5 are rounded up and treated as an exceedance.

battery manufacturers remain significant contributors to atmospheric Pb pollution. In Northeast Ohio, the primary source of Pb pollution has been the area surrounding the Ferro Corporation in Cleveland's Industrial Flats.

NAAQS and Nonattainment Status: On November 12, 2008, U.S. EPA strengthened the primary NAAQS for Pb by lowering it from 1.5 µg/m^3—a level set in 1978—to 0.15 µg/m^3 (73 FR 66964). U.S. EPA designated the portions of Cuyahoga County that surround the Ferro Corporation as a nonattainment area for Pb on November 16, 2010, based on data from 2007-2009 (FR 76 72097). This designation was effective as of November 22, 2011, with an attainment date set for December 31, 2015. U.S. EPA defined the nonattainment area as the "portions of Cuyahoga County that are bounded on the west by Washington Park Boulevard/Crete Avenue/East 49th Street, on the east by East 71st Street, on the north by Fleet Avenue, and on the south by Grant Avenue."[54] The rest of Cuyahoga County, and all other counties in Northeast Ohio, are unclassified/attainment areas.[55]

Based upon 2012-2015 monitoring data, U.S. EPA determined that Cleveland had attained the 2008 Pb NAAQS. U.S. EPA formally redesignated Cleveland as a maintenance area for the 2008 Pb NAAQS on May 31, 2017 (82 FR 24871), and this action took effect on July 31, 2017.

[54] 40 C.F.R. § 81.336 (2010).
[55] Ohio EPA Division of Air Pollution Control, *Ohio's 2008 Lead Standard: Second Round of Recommended Designations* (Columbus, OH: Ohio EPA, 2010), http://www.epa.ohio.gov/portals/27/SIP/lead/2008_Lead_Standard_Updated_Recommendated_NA_Areas-FINAL.pdf (accessed February 15, 2023).

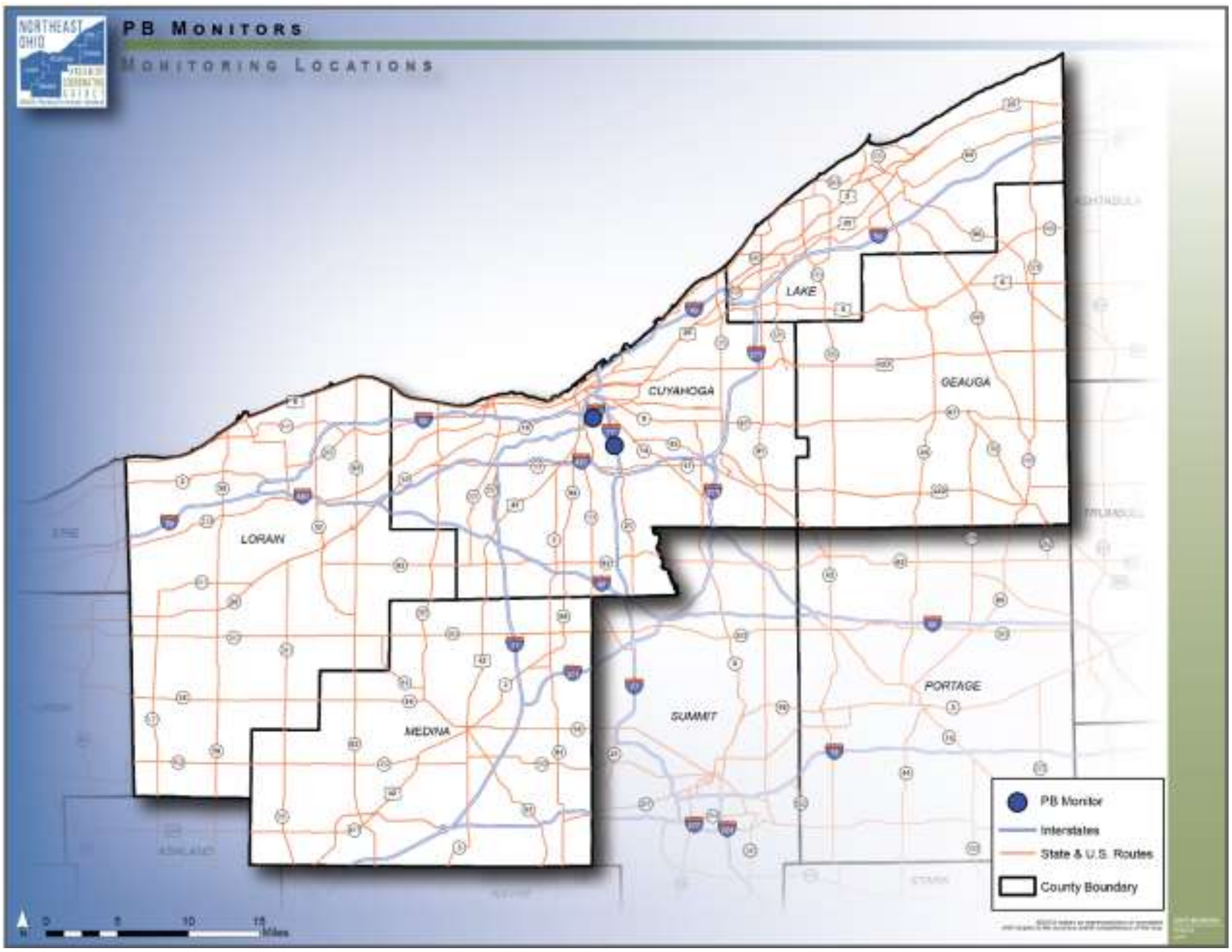
Monitors: There are two operating Pb monitors in Northeast Ohio, both in Cuyahoga County (see Table 15 and Figure 32).

Table 15: Locations of Pb Monitors in Cuyahoga County

Monitor	County	FIPS ID	Site ID	Latitude	Longitude	Address
1	Cuyahoga	035	0038	41.47	-81.68	St. Theodosius, St. Tikhon Ave., Cleveland
2			0049	41.44	-81.65	Ferro Corp., East 56th St., Cleveland

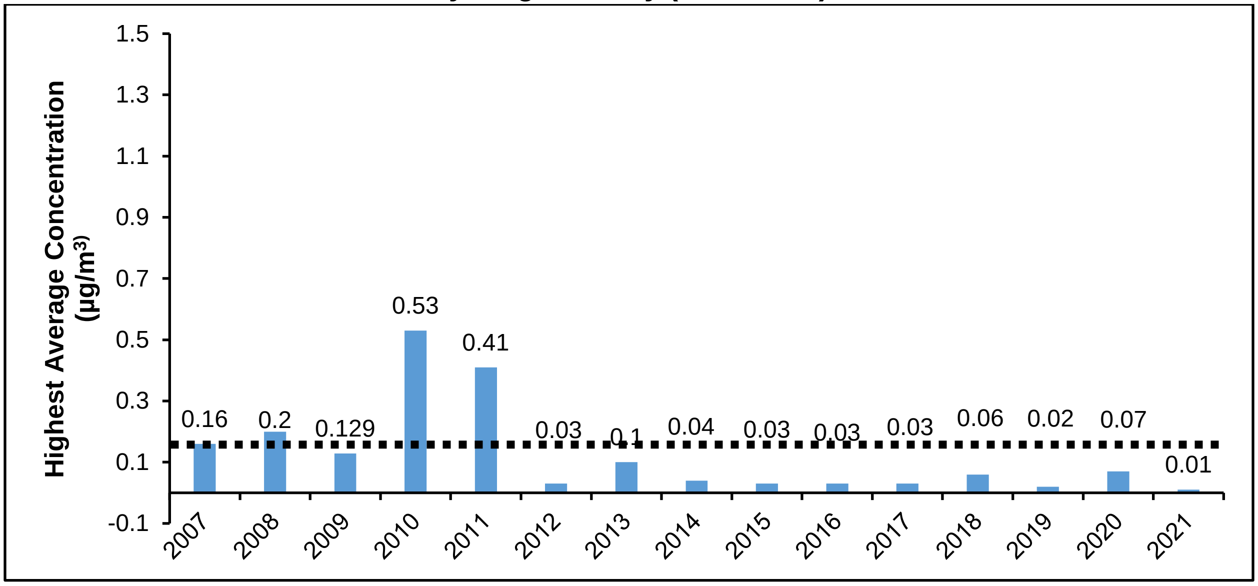
Source: Ohio EPA, *2021-2022 Ohio Air Monitoring Network Plan,* https://epa.ohio.gov/static/Portals/27/ams/sites/2021-2022_AMNP_Main_Report_Final.pdf (accessed February 15, 2023).

Figure 32: Northeast Ohio Pb Monitor Locations



Trends: Figure 33 displays three-month average Pb concentrations. The highest average in 2021, a three-month concentration of 0.01 µg/m^3. This concentration remains well below the NAAQS levels.

Figure 33: Highest Three-Month Average Pb Concentrations in Cuyahoga County (2007-2021)[56]



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

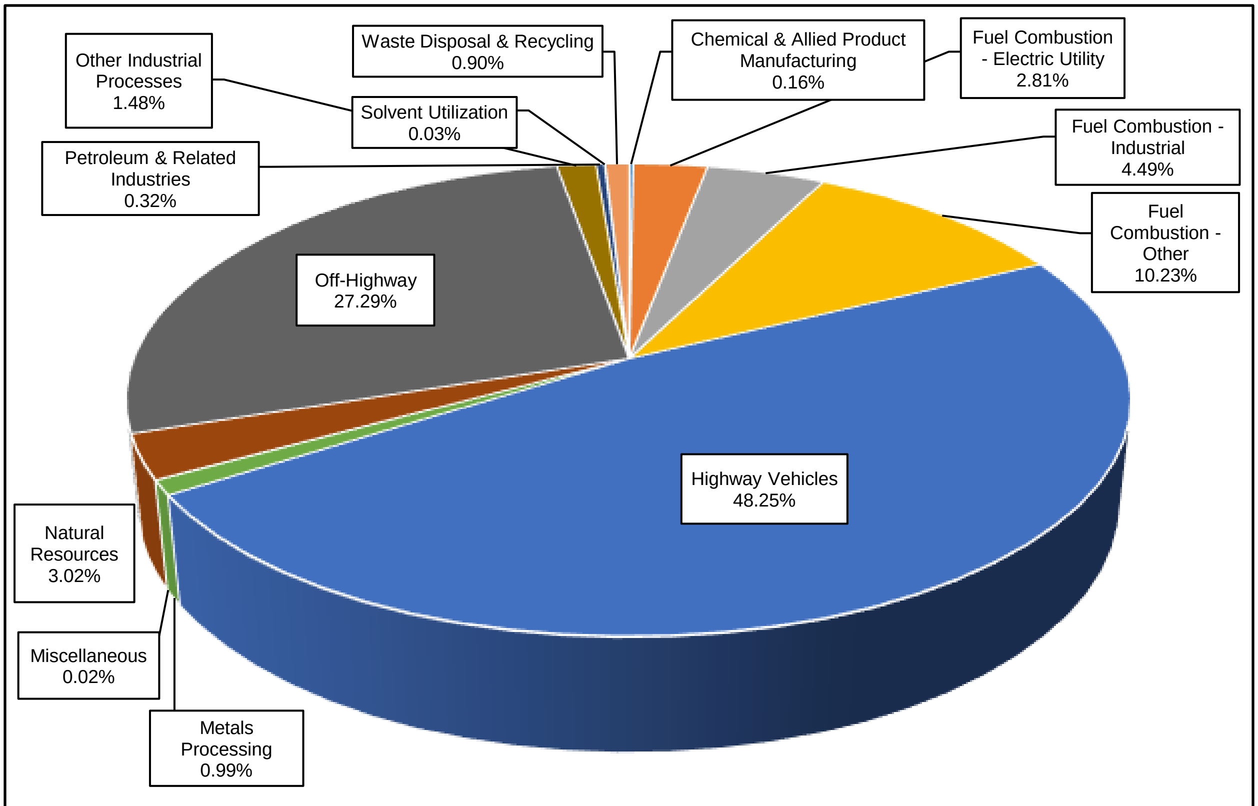
5.6 Nitrogen Dioxide

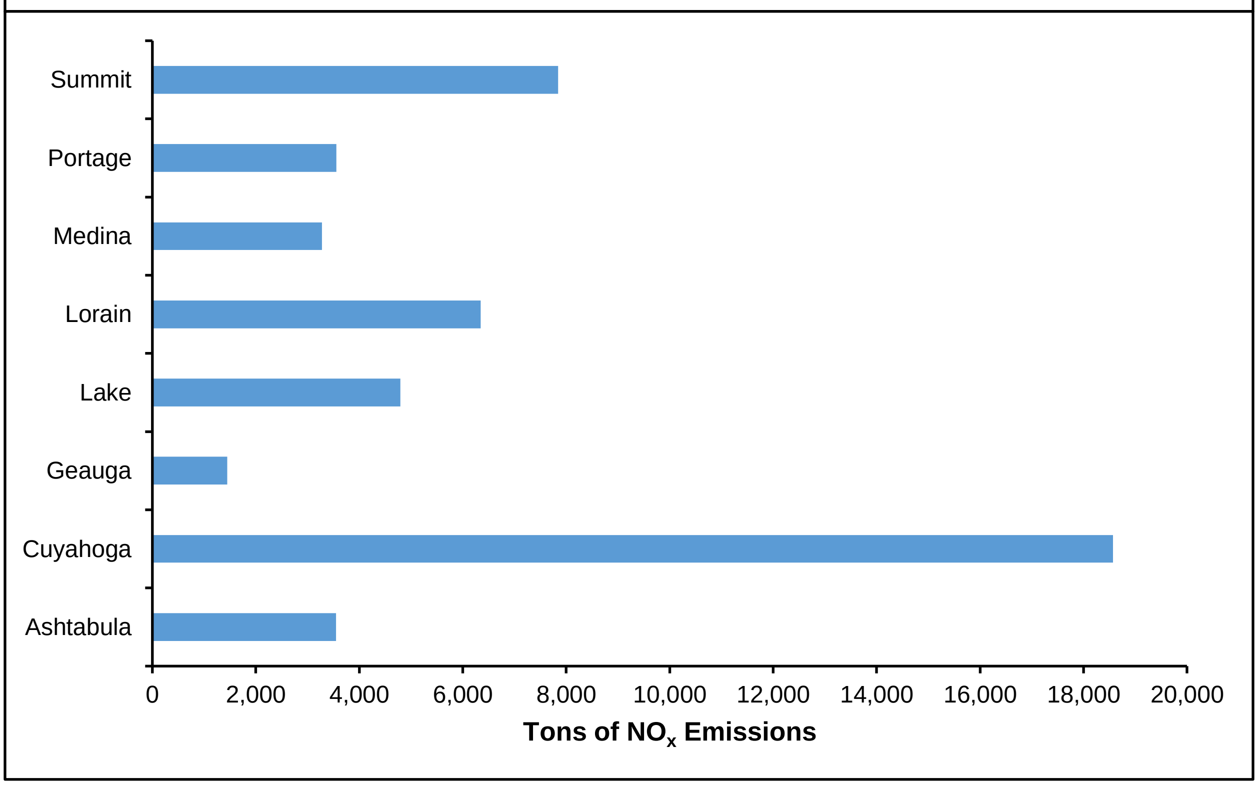
Properties: Nitrogen dioxide (NO_2) is formed by the oxidation of nitric oxide (NO) in the atmosphere. NO_2 is one of a family of compounds known collectively as nitrogen oxides (NO_x). NO_2 is a reddish-brown gas. It is readily apparent around urban areas during hot, stagnant weather. On its own, NO_2 is dangerous, as it can worsen respiratory conditions and reduce one's resistance to lung infection. It also plays a major role in O_3 formation, secondary $PM_{2.5}$ formation, climate change, and stratospheric ozone depletion. Accordingly, actions that reduce NO_2 emissions also tend to reduce emissions from other members of the NO_x family, improving overall air quality.[57]

Sources: High-temperature combustion processes release NO_2. Figure 34 shows the source sectors of NO_x in Northeast Ohio, which includes NO_2. The largest source of NO_x is highway vehicles, followed by off-highway vehicles and fossil fuel combustion, including electricity generation and industrial facilities.

[56] The dashed black line indicates the NAAQS in effect during this period.
[57] U.S. EPA, "Nitrogen Dioxide," http://www.epa.gov/airquality/nitrogenoxides/index.html (accessed February 15, 2023).

Figure 34: NO_x Emissions Inventory for Northeast Ohio (2017)





Source: U.S. EPA, *2017 National Emissions Inventory*, https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data (accessed February 15, 2023).

NAAQS and Nonattainment Status: Effective January 22, 2010, there are two primary NAAQS for NO_2: an annual arithmetic mean of 53 ppb and a one-hour standard of 100 ppb. To attain the NAAQS, the three-year average of the 98th percentile of the daily maximum one-hour average at each monitor within an area must not exceed 100 ppb.

No portion of Northeast Ohio is designated as in nonattainment for NO_2. Cuyahoga County is the only county monitoring for this pollutant within the region. U.S. EPA designated all areas as unclassifiable/attainment for the new standard on February 12, 2012 (77 FR 9532).

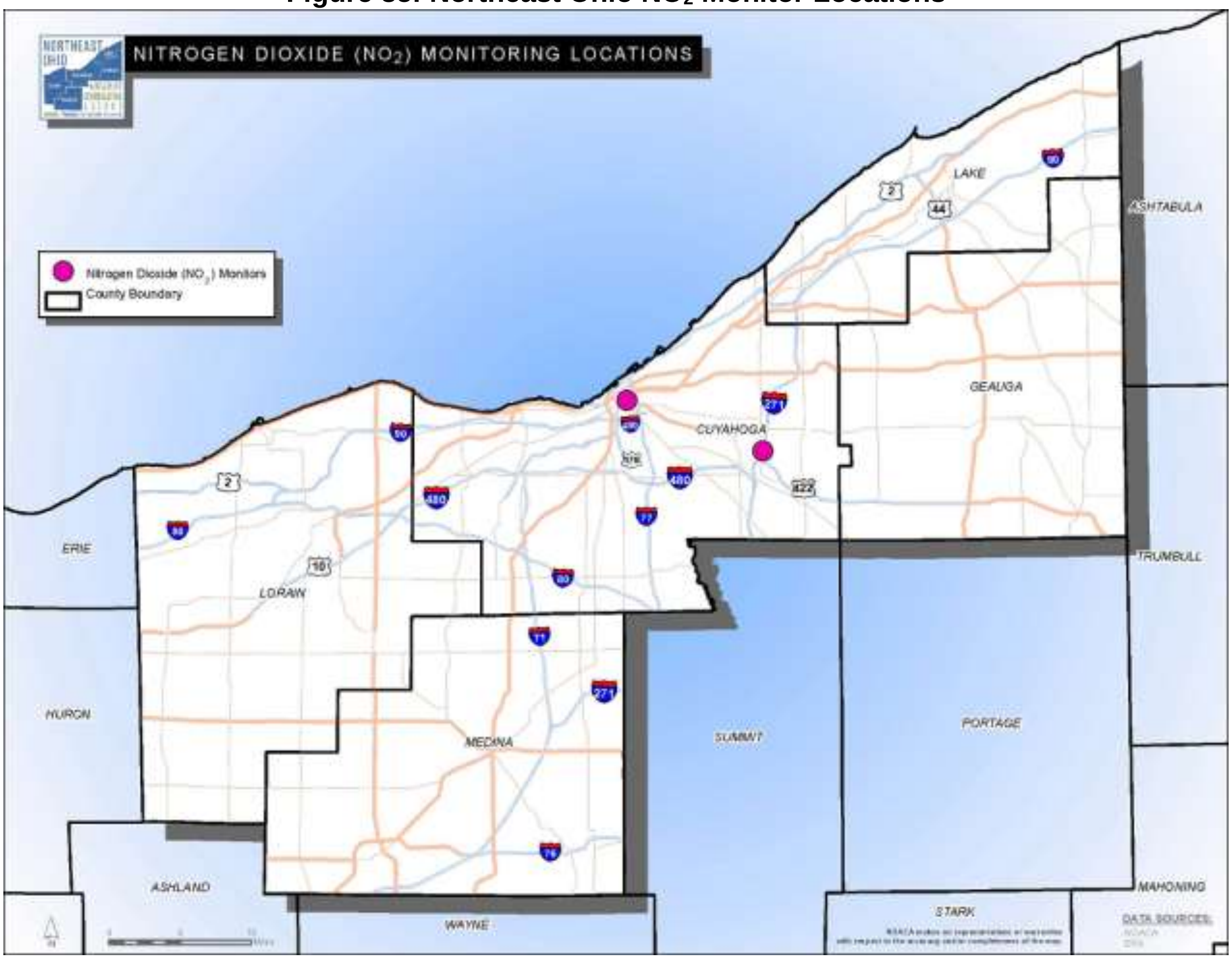
Monitors: There are two monitors for NO_2 in Northeast Ohio, both in Cuyahoga County (see Table 16 and Figure 35).

Table 16: Locations of NO_2 Monitors in Northeast Ohio

Monitor	County	FIPS ID	Site ID	Latitude	Longitude	Address
1	Cuyahoga	035	0060	41.49	-81.67	GT Craig, East 14th St. & Orange Ave., Cleveland
2			0073	41.44	-81.49	Cleveland NR, 26565 Miles Rd., Warrensville Hts.

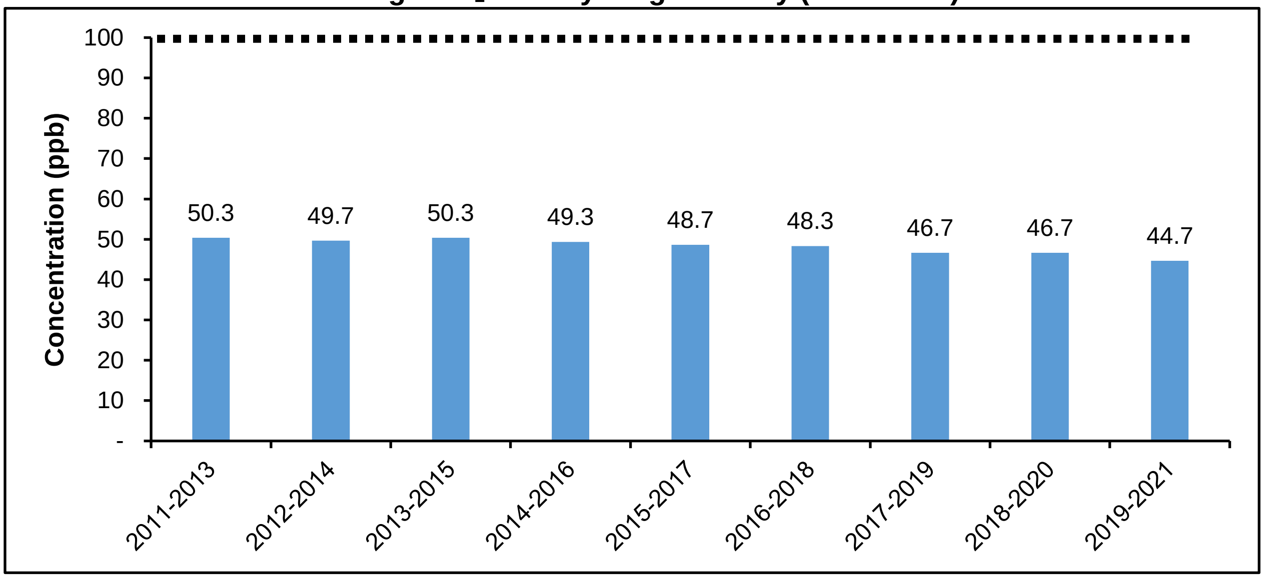
Source: Ohio EPA, *2021-2022 Ohio Air Monitoring Network Plan,* https://epa.ohio.gov/static/Portals/27/ams/sites/2021-2022_AMNP_Main_Report_Final.pdf (accessed February 15, 2023).

Figure 35: Northeast Ohio NO_2 Monitor Locations



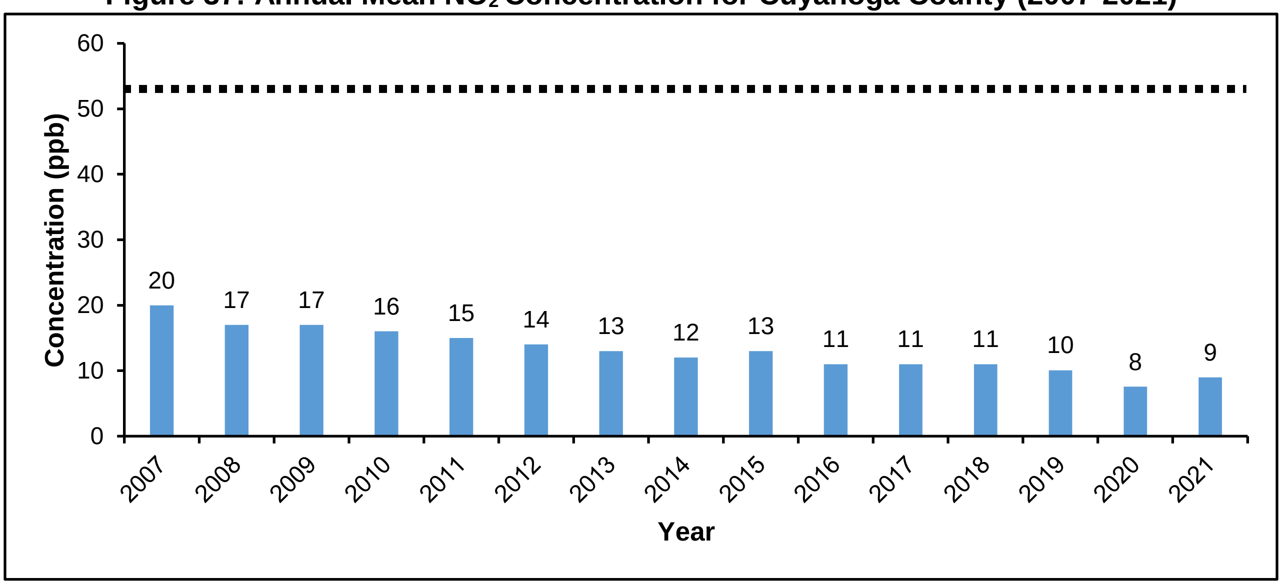
Trends: Figure 36 displays the three-year average of the 98th percentile of the daily maximum one-hour average (100 ppb NAAQS). Figure 37, in turn, shows the annual mean concentrations for NO_2 in Cuyahoga County (53 ppb NAAQS). NO_2 levels decreased over the past 15 years, though that progress has largely stalled in recent years.

Figure 36: Three-Year Average of the 98th Percentile of the Daily Maximum One-Hour Average NO_2 for Cuyahoga County (2011-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

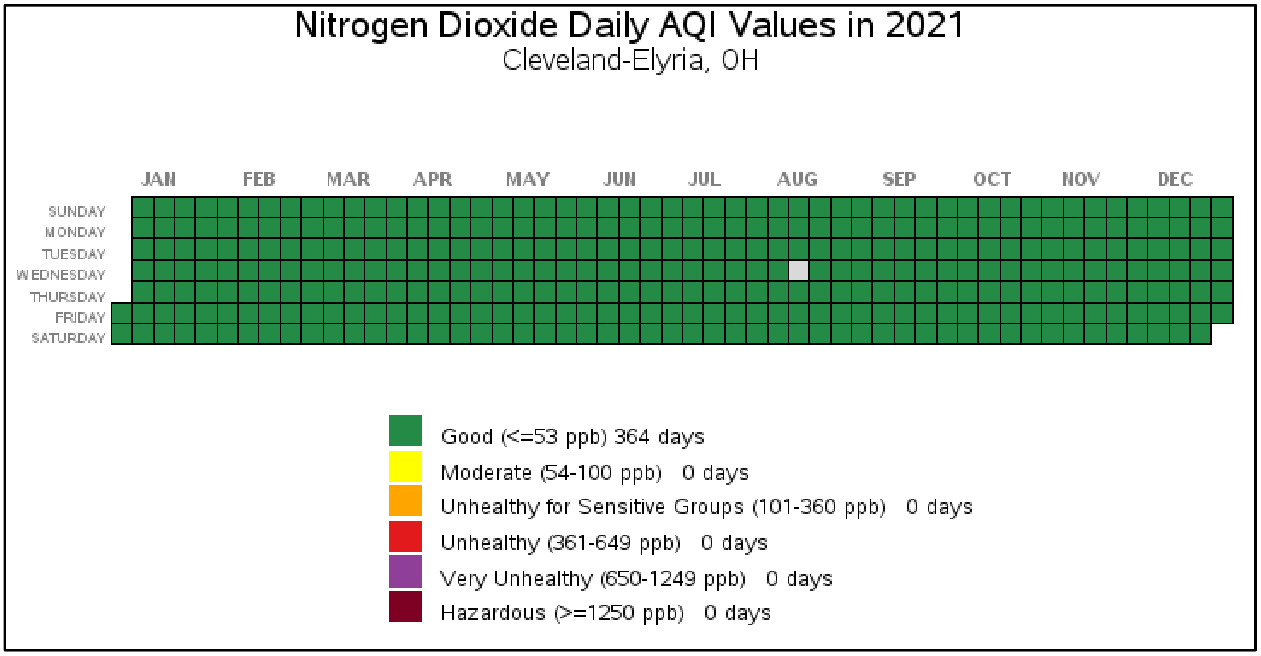
Figure 37: Annual Mean NO_2 Concentration for Cuyahoga County (2007-2021)



Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).

Figure 38 shows the daily AQI values for NO_2 in Northeast Ohio during 2021. As it illustrates, the region had 364 Good AQI days for NO_2.

Figure 38: Daily NO_2 AQI Values (2021)[58]



Source: U.S. EPA, "Air Data Tile Plot," https://www.epa.gov/outdoor-air-quality-data/air-data-tile-plot (accessed February 15, 2023).

58 Gray boxes in the tile plot indicate that no data are available for that day.

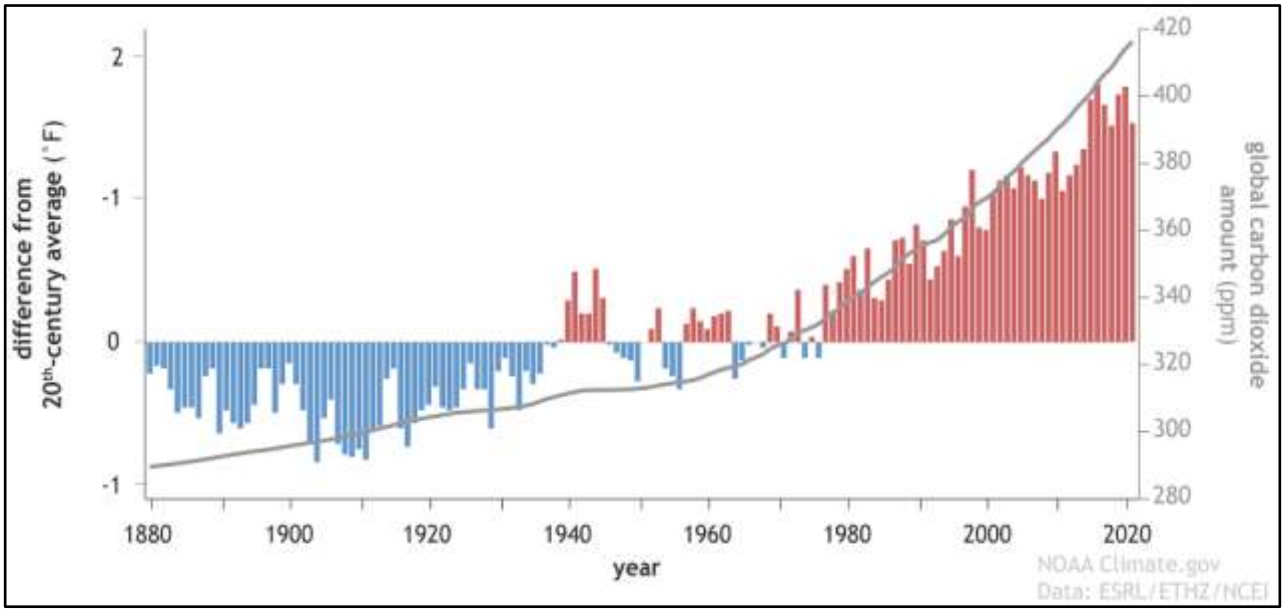
6. Climate Change and Greenhouse Gas Emissions

Climate change is a global phenomenon that includes any significant change in the climate that lasts for extended periods of time. Global warming, which refers to the observed increase in average global surface temperatures over the past several decades, is one facet of climate change.[59] Other components include changes in precipitation, wind patterns, the cryosphere, and extreme weather events. Over the past century, humans have released large amounts of CO_2 and other greenhouse gases (GHGs) into the atmosphere. Most of these emissions have come from the combustion of fossil fuels, such as coal, natural gas, and oil; however, land-use changes, such as deforestation and agriculture, are also major contributors, both due to direct emissions and the elimination of carbon sinks (which pull carbon out of the atmosphere and sequester it) such as forests. According to the Intergovernmental Panel on Climate Change (IPCC), human activities have increased atmospheric concentrations of GHGs to their highest levels in at least 800,000 years, and humans are the dominant cause of changes to the global climate since the mid-20th century.[60]

GHGs act like a form of atmospheric insulation, trapping energy in the atmosphere and increasing global temperatures. GHGs allow ultraviolet radiation from the sun to enter the atmosphere; however, because they trap infrared radiation, they prevent a portion of that energy from escaping back into space. Though GHGs make up a tiny fraction of the composition of the atmosphere (0.04%), they can significantly affect the global climate. As a result, global average surface temperatures have increased by approximately 1ºC since 1880.[61] Figure 39, below, shows the strong correlation between the increase in CO_2 concentrations and global temperatures.

[59] U.S. EPA, "Climate Change: Basic Information," https://19january2017snapshot.epa.gov/climatechange/climate-change-basic-information_.html (accessed February 15, 2023).
[60] Intergovernmental Panel on Climate Change, *Global warming of 1.5˚C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (Geneva: IPCC, 2019), https://www.ipcc.ch/sr15/ (accessed February 15, 2023).
[61] Ibid.

Figure 39: Atmospheric CO_2 and Earth's Surface Temperature (1880-2021)



Source: R. Lindsey, "If carbon dioxide hits a new high every year, why isn't every year hotter than the last?" https://www.climate.gov/news-features/climate-qa/if-carbon-dioxide-hits-new-high-every-year-why-isn%E2%80%99t-every-year-hotter-last (accessed February 15, 2023).

GHG Control Measures: Although CO_2 is not a criteria air pollutant, U.S. EPA has taken steps to regulate GHG emissions under the Clean Air Act. In its 2007 ruling in *Massachusetts v. EPA,* the U.S. Supreme Court ruled that GHGs, including CO_2, are pollutants covered by the Act.[62] The Court ordered the U.S. EPA to determine whether GHGs contribute to air pollution and pose a threat to human health. U.S. EPA issued its "endangerment finding" on December 7, 2009, ruling that GHGs exacerbate air pollution and threaten human health and welfare (74 FR 66496). Research demonstrates that taking steps to mitigate GHG emissions can help improve air quality and public health. One study found that the air quality benefits associated with cutting GHG emissions can offset the costs of implementing these regulations by orders of magnitude.[63]

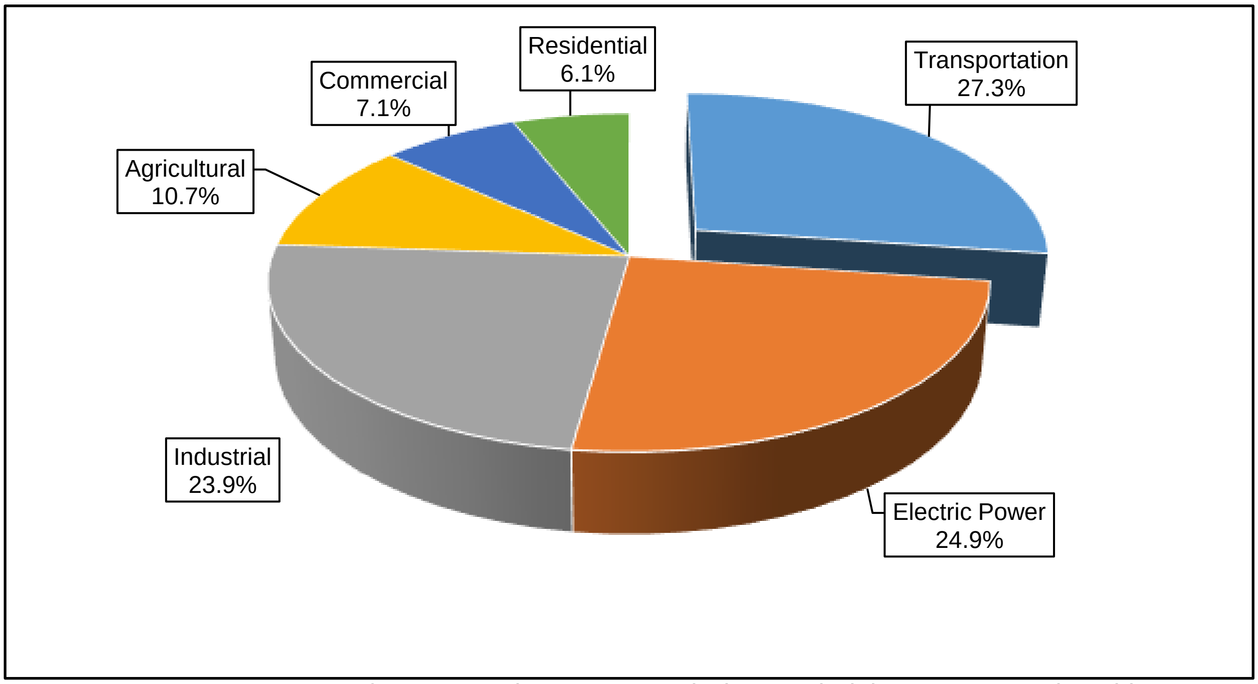
In December 2015, leaders of 196 countries adopted the Paris Agreement, which commits the international community to hold the increase in global temperatures "to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C."[64] To remain below 2°C, global GHG emissions must decline 25% and 70% by 2030 and 2050, respectively (compared to 2010 levels), and reach net zero by 2070.[65] To meet these benchmarks, emissions will need to decline by approximately 2.7% and 7.6% per year to keep warming below 2°C and 1.5°C, respectively.[66]

[62] *Massachusetts v. EPA*, 127 S. Ct. 1438 (2007).
[63] T.M. Thompson, S. Rausch, R.K. Saari, and N.E. Selin, "A systems approach to evaluating the air quality co-benefits of US carbon policies," *Nature Climate Change* 4 (2014), 917-923.
[64] United Nations Framework Convention on Climate Change (UNFCCC), *Paris Agreement,* Dec., 12, 2015, FCCC/CP/2015/10/Add.1.
[65] IPCC, 12.
[66] United Nations Environment Programme (UNEP), *Emissions Gap Report 2021* (Nairobi: UNEP, 2021), https://wedocs.unep.org/bitstream/handle/20.500.11822/36990/EGR21.pdf (accessed February 15, 2023).

Sources: GHG emissions have increased dramatically in recent years. Nearly half of all manmade GHG emissions generated since 1750 were released over just the past four decades.[67] Global GHG emissions reached 48.9 gigatons of CO_2 equivalent ($GtCO_2e$) in 2018, up from less than 33 $GtCO_2e$ in 1990.[68] Electricity generation and heat accounted for the largest share (31.9%) of emissions, followed by transportation (16.9%), manufacturing (12.6%), and agriculture (11.9%). Emissions from electricity/heat and transportation rose by 81.4% and 79.2% from 1990-2018, respectively.

In the U.S., the electric power sector released 1,482.2 million metric tons of CO_2 equivalent ($MMTCO_2e$) in 2020, accounting for 24.9% of total emissions (see Figure 40).[69] But transportation makes up a larger share of GHG emissions in the U.S. than it does globally—the sector generated 1,627.6 $MMTCO_2e$, equal to 27.3% of emissions. Transportation sector emissions rose by 6.6% from 1990 to 2020; however, this increase in emissions was smaller than the 36% increase in VMT, as a result of improved vehicle fuel economy during that period.[70]

Figure 40: Share of GHG Emissions by Sector – United States

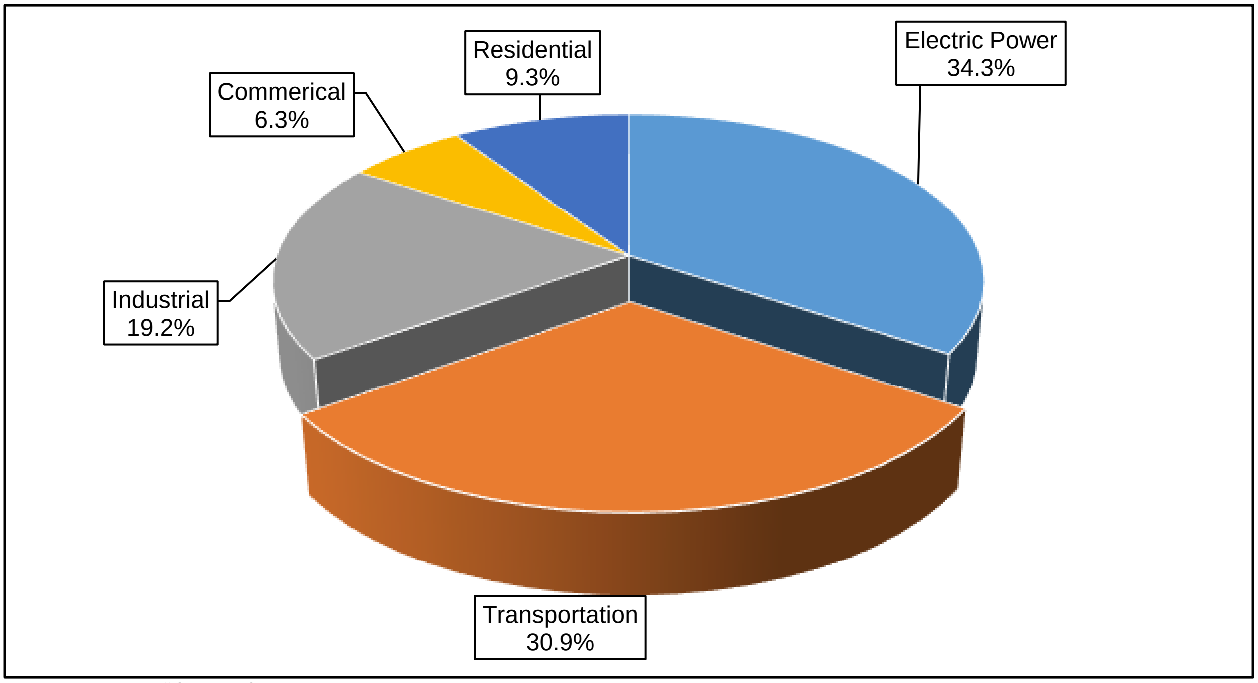


Source: U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020* (Washington, D.C.: U.S. EPA, 2022), https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf (accessed February 15, 2023).

[67] IPCC, 4.
[68] Climate Watch, "Historical GHG Emissions," (Washington, DC: World Resources Institute, 2021), https://www.climatewatchdata.org/ghg-emissions (accessed February 15, 2023).
[69] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020* (Washington, D.C.: U.S. EPA, 2021), https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf (accessed February 15, 2023).
[70] Ibid.

According to the U.S. Energy Information Agency (EIA), the transportation sector made up 30.9% of total GHGs in Ohio, second only to the electric power industry.[71] Due in large part to Ohio's reliance on coal-fired power plants, this sector makes up a greater share of total GHGs in the state (34.3%) than it does nationally (24.9%).[72] Nevertheless, while GHG emissions from electricity generation fell by 39.1% in Ohio from 1990 to 2019, transportation sector emissions actually increased by 8.7%. Figure 41 breaks down GHG emissions in Ohio by economic sector.

Figure 41: Share of GHG Emissions by Sector – Ohio



Source: EIA, "State Carbon Dioxide Emissions 2019," http://www.eia.gov/environment/emissions/state/ (accessed February 15, 2023).

[71] Energy Information Agency, "State CO_2 Emissions 2018," http://www.eia.gov/environment/emissions/state/ (accessed February 15, 2023).
[72] Ibid.

GHG emissions from the transportation sector include CO_2, methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). While CO_2, CH_4, and N_2O are emitted from the combustion of fossil fuels, HFCs are released by leaks from and the disposal of vehicle air conditioning units.[73] Each of these gases can store a different amount of heat energy per unit. The relative ability of each GHG to contribute to global warming is known as its global warming potential (GWP). As Table 17 shows, CO_2 makes up the largest share (96.6%) of GHG emissions from the transportation sector in the United States. Because CO_2 is the most common GHG, officials express GHGs, based upon their GWP, in tons of CO_2 equivalent (TCO_2e).

Table 17: Global Warming Potential of Transportation Sector GHGs

Greenhouse Gas	Global Warming Potential	Percent of Transportation Sector GHG Emissions[a]
CO_2	1	96.6%
CH_4	25	0.1%
N_2O	298	1.1%
HFCs	124 to 14,800[b]	2.2%

[a] Values may not total 100% due to rounding.
[b] This value expresses the range of GWPs for each of the HFCs relevant to the transportation sector.
Source: U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.

[73] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020* (Washington, D.C.: U.S. EPA, 2021), https://www.epa.gov/sites/production/files/2021-04/documents/us-ghg-inventory-2021-main-text.pdf (accessed February 15, 2023).

6.1 Transportation Sector Greenhouse Gas Emissions in Northeast Ohio

Transportation accounts for 25.5% of total GHG emissions in Northeast Ohio.[74] Transportation sector GHG emissions vary by county. NOACA used U.S. EPA's Motor Vehicle Emissions Simulator (MOVES), version 3, in emissions rates mode to model on-road GHG emissions during 2021 for the five-county NOACA region.

Table 18 displays each county's relative share of emissions, along with its percentage of the region's total population. Regionally, transportation accounted for nearly 8.1 $MMTCO_2e$ last year, a 42.1% increase from 2020. This change was due regional VMT returning to pre-pandemic levels following a 30% reduction during 2020.

Unsurprisingly, Cuyahoga County, which has the largest population, has consistently generated more GHGs than any of the four other counties in the area. In 2021, Cuyahoga County accounted for 57.3% of total emissions, lower than its share of the regional population (60.2%). The four other counties generated a larger share of GHGs than their share of regional population; the largest disparity occurred in Medina County, which generated 11.4% of GHGs but is home to just 8.8% of the population.

Figure 42 illustrates the breakdown of GHG emissions by county. As Table 18 shows, Northeast Ohio residents produced 3.9 tons of on-road CO_2e per capita during 2021, up from 2.8 in 2020. The per capita totals ranged from a low of 3.7 tons per capita in Cuyahoga County to a high of 5.1 tons per capita in Medina County.

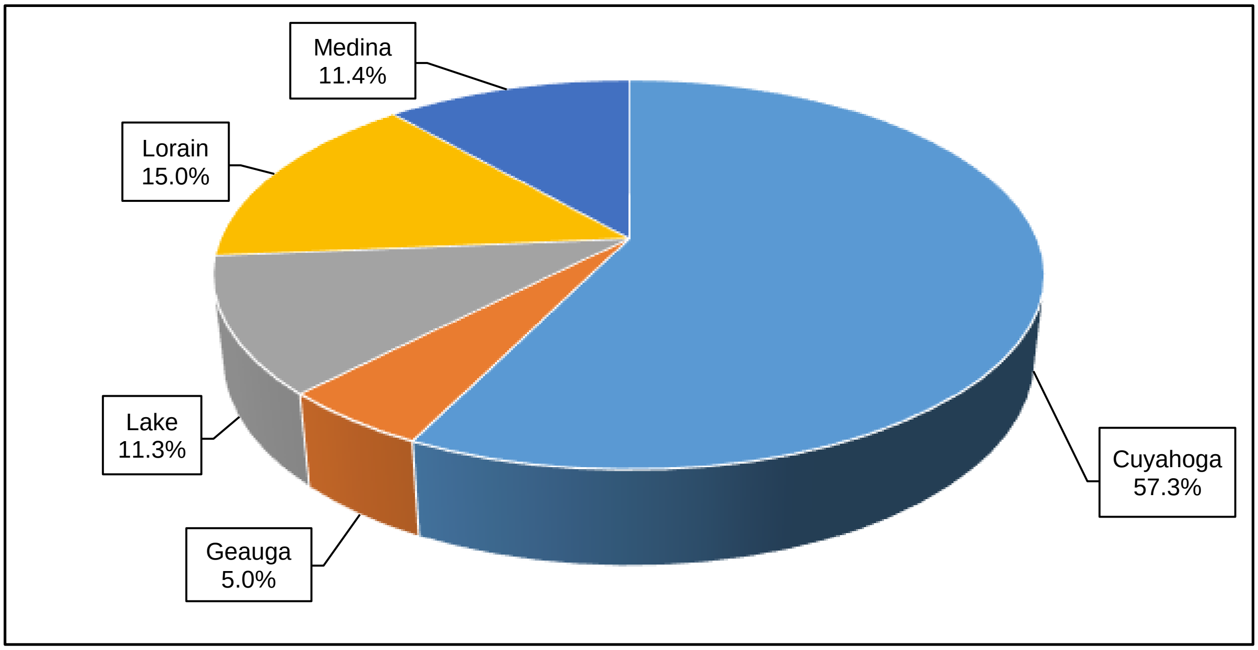
Table 18: Population & On-Road GHG Emissions in Northeast Ohio

County	2021 Population[a]	% 2021 NOACA Population	2021 GHG Emissions ($MTCO_2e$)[b]	% 2021 NOACA GHG Emissions	GHG Tons Per Capita[b]
Cuyahoga	1,249,387	60.2%	4,660,306	57.3%	3.7
Geauga	95,565	4.6%	407,287	5.0%	4.3
Lake	232,023	11.2%	916,715	11.3%	4.0
Lorain	315,595	15.2%	1,220,435	15.0%	3.9
Medina	183,092	8.8%	930,569	11.4%	5.1
Totals	2,075,662		8,136,312		3.9

[a] U.S. Census Bureau, "2021 American Community Survey 1-Year Population Estimates."
[b] GHG totals are depicted in metric tons of CO_2e. One metric ton is equal to 1.102 US tons.
Source: NOACA estimates using MOVES3.

[74] NOACA & ICLEI – Local Governments for Sustainability USA, *NOACA Regional Greenhouse Gas Inventory: 2018 Baseline* (Cleveland: NOACA & ICLEI USA, 2022), https://www.eneo2050.com/_files/ugd/9911f1_2a9358afc9544d67bf02994253b093db.pdf (accessed February 15, 2023).

Figure 42: Share of On-Road GHG Emissions in Northeast Ohio by County (2021)



Source: NOACA estimates using MOVES3.

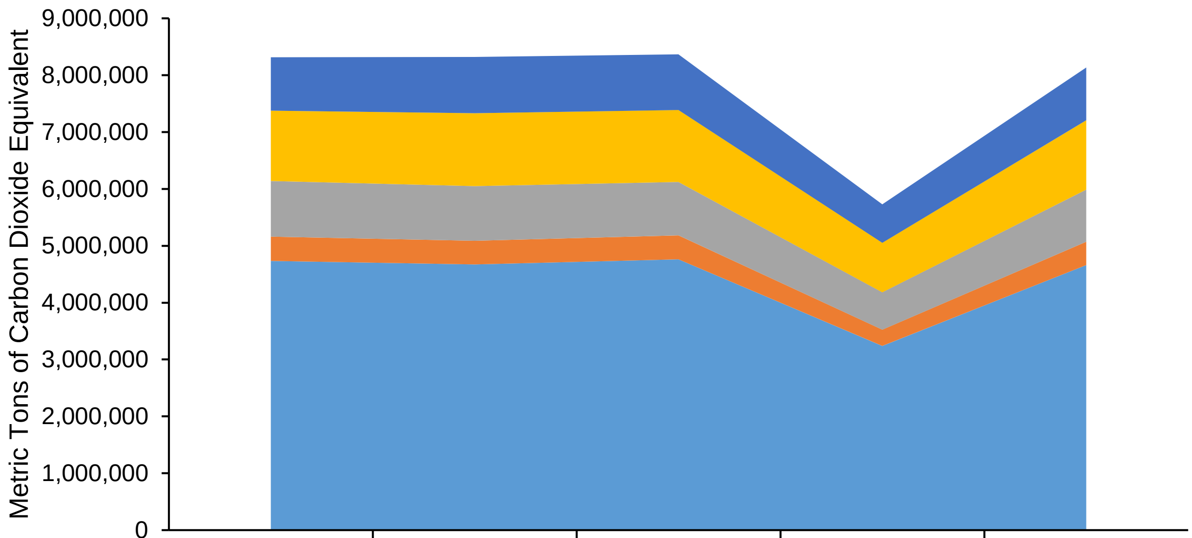
Within Northeast Ohio, light-duty vehicles, which include passenger cars and light-duty trucks, such as sport utility vehicles (SUVs), account for the vast majority of transportation sector GHGs (74.4%) and the largest share of vehicles (93.3%) (see Table 19). While medium- and heavy-duty trucks make up just 3.6% of total vehicles, they generated 23% of total GHGs. Combined, motorcycles and buses account for just over 2.3% of total on-road GHG emissions.

Table 19: Northeast Ohio On-Road GHG Emissions by Vehicle Type

Vehicle Type	2021 GHG Emissions ($MTCO_2e$)[a]	% 2021 GHG Emissions[b]	% 2021 Vehicle Population
Light-Duty Vehicles	6,072,172	74.6%	93.3%
➢ Passenger Cars	2,445,871	30.1%	49.5%
➢ Light-Duty Trucks	3,626,301	44.6%	43.8%
Motorcycles	578	0.01%	2.9%
Buses	189,211	2.3%	0.2%
Medium- and Heavy-Duty Trucks	1,874,352	23%	3.6%

[a] GHG totals are depicted in metric tons of CO_2e.
[a] Values may not total 100% due to rounding.
Source: NOACA estimates using MOVES3.

Figure 43: On-Road GHG Emissions in the NOACA Region (2017-2021)



	2017	2018	2019	2020	2021
Medina	940,757	991,103	977,032	674,483	930,569
Lorain	1,237,666	1,283,200	1,264,484	871,094	1,220,435
Lake	978,039	959,596	941,674	657,262	916,715
Geauga	426,942	416,096	421,189	284,108	408,287
Cuyahoga	4,733,814	4,672,654	4,762,083	3,239,634	4,660,306

Source: NOACA estimates using MOVES3.

Figure 43 illustrates on-road GHG emissions in the NOACA region from 2017 to 2021. Emissions increased slowly from 2017 to 2019, before falling dramatically (31.6%) during 2020 due to COVID-19 travel restrictions. Though emissions rose again during 2021, they remained 2.2% and 2.8% below 2017 and 2019 levels, respectively. The largest reduction by county occurred in Lake County, where GHGs fell by 6.3% from 2017 to 2021, while the smallest decrease (1.1%) was in Medina County. While on-road GHGs have not yet returned fully to pre-pandemic levels, the region is not on track to meet the goals of the Paris Agreement, as outlined in Section 6.0.

6.2 Impacts of Climate Change on Air Quality in Northeast Ohio

Air pollution contributes to climate change. Multiple criteria air pollutants are also GHGs. Both O_3 and $PM_{2.5}$, which are highly potent GHGs, are known as short-lived climate pollutants, which drive both poor local air quality and global warming. Black carbon (a species of $PM_{2.5}$), for instance, has a global warming potential of approximately 3,200 over a 20-year period.[75] According to the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), mitigating these short-lived climate pollutants could reduce future global warming by 0.5°C.[76]

Climate change may, in turn, degrade air quality in Northeast Ohio. Ground-level O_3 forms most readily on calm, warm summer days. Climate change appears to be making these stagnant air days more common, as Cleveland experienced eight more stagnant summer days per year, on average,

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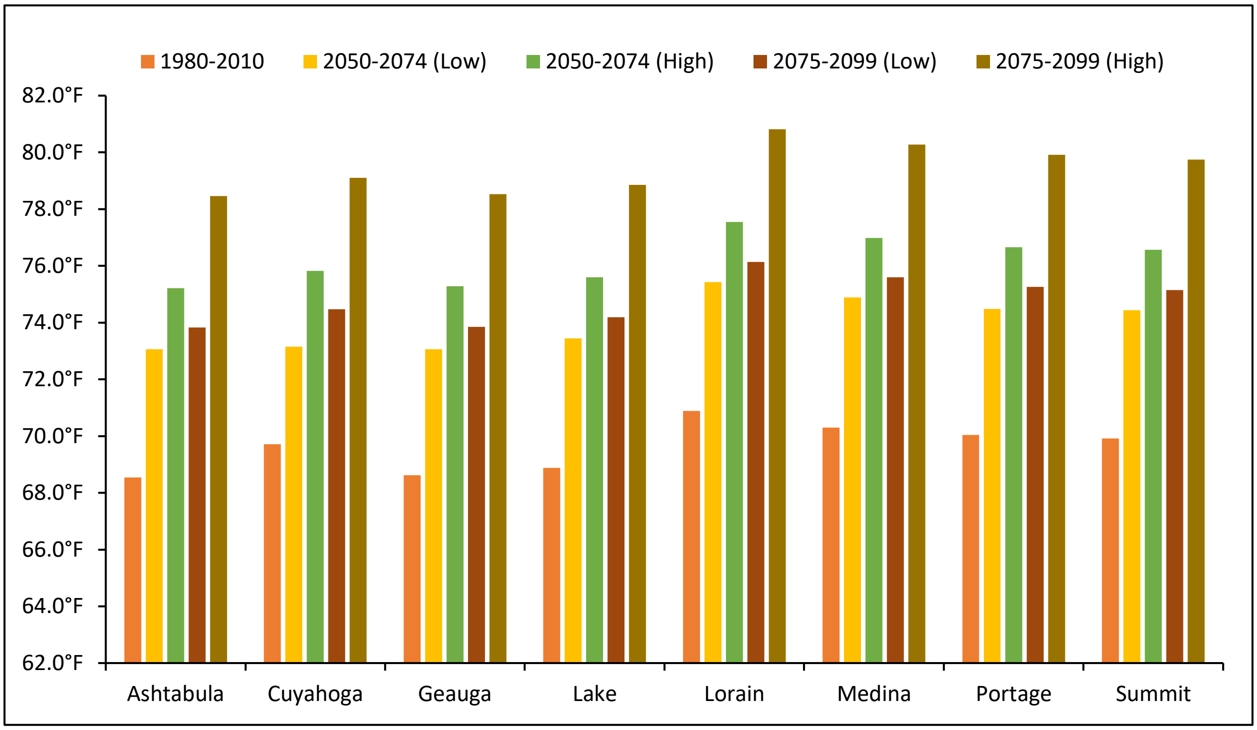
[75] WHO, *Reducing global health risks*, 29.

[76] UNEP & WMO, *Integrated Assessment of Black Carbon and Tropospheric Ozone* (Nairobi: UNEP & WMO, 2011), https://wedocs.unep.org/rest/bitstreams/12809/retrieve (accessed February 15, 2023).

since 1973.[77] This trend will continue in the coming decades. From 1980 to 2010, Northeast Ohio experienced roughly nine days per year when ambient air temperatures exceeded 90°F.[78] This number will increase significantly over the next several decades, as the region's maximum annual daily temperature is projected to rise 2.8-4.4°F by 2050 and 5.8-9.7°F by 2099.

Figure 44: Projected Maximum Daily Temperatures by County (March-October)



Source: USGS, "National Climate Change Viewer," https://www2.usgs.gov/landresources/lcs/nccv.asp (accessed February 15, 2023).

As Figure 44 shows, maximum daily temperatures during the ozone season (March-October) in the eight-county air quality planning area may increase 4.4-5.2°F by 2050-2074 and 5.2-9.8°F by 2075-2099, compared to the 1981-2010 baseline. In the latter, most extreme case, summer temperatures would exceed 92°F on a daily basis.[79] Northeast Ohio may experience 29 to 34 days over 90°F per year by 2050, a number that may jump to 40-85 by the end of the century.[80]

Such increases in ambient temperatures would make it more likely for ground-level O_3 to form, effectively offsetting some of the benefits of continued emissions reductions. However, this relationship is not necessarily linear; some research suggests that temperatures above 95°F can

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77 Climate Central, "Stagnant Summer Days on the Rise in U.S.," http://www.climatecentral.org/news/stagnant-summer-days-on-rise-19280 (accessed February 15, 2023).
78 National Oceanic and Atmospheric Administration (NOAA), "NOAA's 1981-2010 Climate Normals," https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data l (accessed February 15, 2023).
79 Projections are drawn from the U.S. Geological Survey's "National Climate Change Viewer," which produces downscaled climate projections based on global climate models from the IPCC.
80 U.S. Federal Government, "U.S. Climate Resilience Toolkit," http://toolkit.climate.gov (accessed February 15, 2023).

actually suppress further ozone formation.[81] U.S. EPA estimates that climate change may increase daily eight-hour maximum ozone levels by 1-5 ppb in 2030.[82] As noted earlier, each 1°C increase in daily maximum temperatures in Northeast Ohio is associated with a 1.3 ppb (0.71 per 1°F) increase in daily O_3 concentrations. From 2000-2020, there were 287 days when maximum daily eight-hour O_3 concentrations were 66-70 ppb in the region, an average of nearly 14 per year. If the O_3 level increases by 5 ppb – which seems possible, given projected temperature increases – that could lead to a significant increase in exceedance days in Northeast Ohio this century. The public health impacts of this increase could be substantial; according to one study, a long-term, 3 ppb increase in O_3 levels is equivalent to smoking for 29 years or aging three years.[83]

The effect of climate change on $PM_{2.5}$ in Northeast Ohio remains more ambiguous. Change in temperature and precipitation patterns are already contributing to an increase in the frequency and intensity of wildfires in the western U.S.[84] This increase in fire activity may periodically degrade air quality in Northeast Ohio. The region will also see a significant increase in the number of hot summer days, which are conducive to $PM_{2.5}$ formation.[85] Nevertheless, while there may be an increase in the number of individual days with elevated $PM_{2.5}$ levels in the region, U.S. EPA projects that annual $PM_{2.5}$ will continue to fall due to increases in precipitation.[86]

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[81] L. Shen, L.J. Mickley, and E. Gilleland, "Impact of increasing heat waves on U.S. ozone episodes in the 2050s: Results from a multimodal analysis using extreme value theory," *Geophysical Research Letters* 43, no. 8 (2016), 4017-4025.

[82] U.S. Global Change Research Program (USGCRP), *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment* (Washington, D.C.: USGCRP, 2016), 74-75, https://s3.amazonaws.com/climatehealth2016/low/ClimateHealth2016_FullReport_small.pdf (accessed February 15, 2023).

[83] M. Wang, et al, "Association Between Long-Term Exposure to Ambient Air Pollution and Change in Quantitatively Assessed Emphysema and Lung Function," *JAMA* 322, no. 6 (2019), 546-556.

[84] J.S. Melillo, T.C. Richmond, and G.W. Yohe, eds., *Climate Change Impacts in the United States: The Third National Climate Assessment* (Washington, D.C.: U.S. Global Change Research Program, 2014), 177-178, http://nca2014.globalchange.gov/ (accessed February 15, 2023).

[85] Risky Business Project, 13.

[86] U.S. EPA, *Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts* (Washington, DC: U.S. EPA, 2021), https://www.epa.gov/system/files/documents/2021-09/climate-vulnerability_september-2021_508.pdf (accessed February 15, 2023).

7. Conclusion

As this report demonstrates, air quality remains an important issue in Northeast Ohio. While the region's air quality has improved considerably since the passage of the 1970 CAA, portions of the eight-county NOACA air quality planning area remained in nonattainment for the 2015 O_3 NAAQS during 2021. Additionally, transportation is a leading source of GHG emissions throughout the region, and its share may become even larger as the region continues to shift away from coal for electricity generation.

In its capacity as both the regional air quality and transportation planning agency, NOACA continues to collect information on regional air quality, educate the public on air quality and its linkages to transportation, and strive to increase transportation choice within the region (i.e., reduce single-occupancy vehicle trips). The agency operates or implements a number of programs to serve these goals, such as Gohio Commute, the Commuter Choice Awards, air quality advisories, the Congestion Mitigation for Air Quality Improvement (CMAQ) Program, the Signal Timing and Optimization Program (STOP), and the Transportation for Livable Communities Initiative (TLCI). These programs further the agency's vision to build a multimodal transportation system that enhances quality of life in Northeast Ohio. For more information on these programs, visit noaca.org.

For More Information

More criteria pollutant data is available from the following agencies:

- U.S. EPA: https://www.epa.gov/outdoor-air-quality-data
- Ohio EPA: www.epa.ohio.gov/dapc/airohio/index.aspx
- Cleveland Division of Air Quality: http://www.clevelandhealth.org/network/air_quality/air_quality.php
- Akron Regional Air Quality Management District: http://www.araqmd.org/
- Lake County General Health District: https://www.lcghd.org/

NOACA thanks the above agencies for their assistance with this report, as well as for their tireless efforts to collect meaningful, accurate air quality data for Northeast Ohio.

Appendix A: O_3 Exceedance Days 2000-2021

Year	Eight-Hour Ozone NAAQS	Exceedance Date	No. of Monitors Exceeding the NAAQS	Highest Monitor
2000	**85 ppb**	May 31, 2000	1	93 ppb (Ashtabula)
		June 1, 2000	1	89 ppb (Geauga)
		June 9, 2000	10	106 ppb (Ashtabula)
		June 10, 2000	9	101 ppb (Ashtabula)
		July 13, 2000	2	94 ppb (Summit)
		July 28, 2000	1	87 ppb (Lake)
	Total	**6 days**		
2001	**85 ppb**	May 3, 2001	5	99 ppb (Geauga)
		May 4, 2001	5	92 ppb (Geauga)
		June 13, 2001	5	91 ppb (Cuyahoga)
		June 14, 2001	7	100 ppb (Lake)
		June 15, 2001	1	87 ppb (Geauga)
		June 19, 2001	10	105 ppb (Ashtabula)
		June 26, 2001	1	86 ppb (Ashtabula)
		June 27, 2001	3	102 ppb (Ashtabula)
		June 28, 2001	6	103 ppb (Portage)
		June 29, 2001	4	105 ppb (Ashtabula)
		July 15, 2001	1	94 ppb (Ashtabula)
		July 16, 2001	1	89 ppb (Geauga)
		July 17, 2001	6	101 ppb (Geauga)
		July 18, 2001	4	108 ppb (Summit)
		July 19, 2001	2	87 ppb (Lorain)
		July 20, 2001	2	96 ppb (Geauga)
		July 22, 2001	1	87 ppb (Geauga)
		July 24, 2001	1	87 ppb (Geauga)
		July 31, 2001	3	100 ppb (Summit)
		August 1, 2001	9	102 ppb (Geauga)
		August 2, 2001	2	97 ppb (Geauga)
		August 6, 2001	1	90 ppb (Geauga)
		August 7, 2001	1	92 ppb (Geauga)
		August 9, 2001	1	91 ppb (Lake)
	Total	**24 days**		
2002	**85 ppb**	June 9, 2002	7	99 ppb (Summit)
		June 10, 2002	5	100 ppb (Portage)
		June 11, 2002	3	92 ppb (Ashtabula)
		June 20, 2002	7	104 ppb (Lake)
		June 21, 2002	6	108 ppb (Ashtabula)
		June 22, 2002	9	103 ppb (Lake)
		June 23, 2002	8	107 ppb (Ashtabula)

Year	Eight-Hour Ozone NAAQS	Exceedance Date	No. of Monitors Exceeding the NAAQS	Highest Monitor
		June 24, 2002	6	105 ppb (Summit)
		June 25, 2002	8	114 ppb (Geauga)
		June 30, 2002	4	96 ppb (Ashtabula)
		July 1, 2002	5	100 ppb (Summit)
		July 4, 2002	1	92 ppb (Ashtabula)
		July 8, 2002	7	117 ppb (Geauga)
		July 13, 2002	3	101 ppb (Summit)
		July 14, 2002	9	103 ppb (Summit)
		July 15, 2002	9	112 ppb (Summit)
		July 17, 2002	10	115 ppb (Lake)
		July 18, 2002	7	103 ppb (Lake)
		July 21, 2002	2	101 ppb (Geauga)
		July 26, 2002	1	87 ppb (Geauga)
		July 31, 2002	3	94 ppb (Lake)
		August 1, 2002	7	115 ppb (Geauga)
		August 4, 2002	5	100 ppb (Lake)
		August 10, 2002	11	115 ppb (Geauga)
		August 11, 2002	9	122 ppb (Geauga)
		August 13, 2002	7	107 ppb (Geauga)
		August 21, 2002	1	90 ppb (Geauga)
		September 7, 2002	3	93 ppb (Lake)
		September 8, 2002	10	110 ppb (Geauga)
		September 9, 2002	9	113 ppb (Lake)
		September 10, 2002	8	104 ppb (Lake)
	Total	**31 days**		
2003	**85 ppb**	June 23, 2003	10	120 ppb (Geauga)
		June 24, 2003	7	123 ppb (Portage)
		June 25, 2003	9	112 ppb (Lake)
		July 3, 2003	8	99 ppb (Ashtabula)
		August 15, 2003	1	93 ppb (Geauga)
		August 20, 2003	1	95 ppb (Geauga)
		August 21, 2003	1	89 ppb (Ashtabula)
		August 25, 2003	1	91 ppb (Geauga)
	Total	**8 days**		
2004	**85 ppb**	May 12, 2004	1	88 ppb (Ashtabula)
		May 13, 2004	1	88 ppb (Ashtabula)
		July 2, 2004	1	87 ppb (Summit)
		July 3, 2004	1	87 ppb (Summit)
		August 2, 2004	2	87 ppb (Geauga)
		August 3, 2004	1	86 ppb (Portage)
	Total	**6 days**		
2005	**85 ppb**	June 7, 2005	2	89 ppb (Ashtabula)

Year	Eight-Hour Ozone NAAQS	Exceedance Date	No. of Monitors Exceeding the NAAQS	Highest Monitor
		June 8, 2005	3	103 ppb (Lake)
		June 9, 2005	1	95 ppb (Lake)
		June 21, 2005	2	86 ppb (Geauga)
		June 24, 2005	5	94 ppb (Lake)
		June 25, 2005	2	104 ppb (Ashtabula)
		June 26, 2005	3	94 ppb (Medina)
		June 27, 2005	10	118 ppb (Lake)
		June 29, 2005	1	86 ppb (Portage)
		July 10, 2005	6	95 ppb (Ashtabula)
		July 11, 2005	5	101 ppb (Medina)
		July 12, 2005	3	95 ppb (Lake)
		July 20, 2005	2	90 ppb (Geauga)
		August 1, 2005	1	91 ppb (Lake)
		August 2, 2005	2	93 ppb (Portage)
		August 3, 2005	3	89 ppb (Geauga)
	Total	**16 days**		
2006	**85 ppb**	May 29, 2006	1	86 ppb (Ashtabula)
		May 30, 2006	2	99 ppb (Ashtabula)
		June 16, 2006	1	90 ppb (Cuyahoga)
		June 17, 2006	1	99 ppb (Ashtabula)
		July 16, 2006	1	90 ppb (Ashtabula)
	Total	**5 days**		
2007	**85 ppb**	April 22, 2007	1	87 ppb (Cuyahoga)
		May 23, 2007	1	103 ppb (Cuyahoga)
		May 24, 2007	4	95 ppb (Ashtabula)
		May 30, 2007	1	89 ppb (Summit)
		May 31, 2007	3	98 ppb (Ashtabula)
		June 17, 2007	1	90 ppb (Summit)
		June 18, 2007	1	89 ppb (Summit)
		July 10, 2007	1	90 ppb (Ashtabula)
		August 1, 2007	2	92 ppb (Summit)
		August 2, 2007	1	89 ppb (Summit)
		August 28, 2007	1	86 ppb (Summit)
		August 29, 2007	2	92 ppb (Ashtabula)
		September 6, 2007	1	92 ppb (Ashtabula)
	Total	**13 days**		
2008	**75 ppb**	April 18, 2008	5	82 ppb (Geauga)
	New	April 19, 2008	1	78 ppb (Ashtabula)
	NAAQS	May 30, 2008	2	83 ppb (Geauga)
		June 12, 2008	5	83 ppb (Cuyahoga)
		July 7, 2008	1	76 ppb (Lake)
		July 18, 2008	2	81 ppb (Ashtabula)

Year	Eight-Hour Ozone NAAQS	Exceedance Date	No. of Monitors Exceeding the NAAQS	Highest Monitor
		July 28, 2008	3	81 ppb (Ashtabula)
		July 29, 2008	5	88 ppb (Cuyahoga)
		August 21, 2008	5	85 ppb (Cuyahoga)
		September 2, 2008	4	80 ppb (Medina)
		September 3, 2008	8	92 ppb (Summit)
		September 4, 2008	7	85 ppb (Cuyahoga)
	Total	**12 days**		
2009	**75 ppb**	May 20, 2009	2	79 ppb (Lake)
		May 21, 2009	4	86 ppb (Lake)
		June 25, 2009	3	88 ppb (Lake)
	Total	**3 days**		
2010	**75 ppb**	April 15, 2010	6	87 ppb (Geauga)
		May 27, 2010	3	82 ppb (Summit)
		June 18, 2010	1	79 ppb (Lake)
		July 3, 2010	1	80 ppb (Lake)
		July 4, 2010	2	85 ppb (Ashtabula)
		July 6, 2010	4	88 ppb (Ashtabula)
		July 7, 2010	4	83 ppb (Ashtabula)
		July 8, 2010	6	89 ppb (Lake)
		August 2, 2010	2	81 ppb (Geauga)
		August 9, 2010	2	85 ppb (Lake)
		August 10, 2010	1	77 ppb (Lake)
		August 29, 2010	3	78 ppb (Lake)
		August 30, 2010	4	80 ppb (Lake)
		August 31, 2010	1	78 ppb (Ashtabula)
		October 10, 2010	1	80 ppb (Geauga)
	Total	**15 days**		
2011	**75 ppb**	June 4, 2011	4	86 ppb (Cuyahoga)
		June 6, 2011	2	78 ppb (Cuyahoga
		June 8, 2011	4	87 ppb (Ashtabula)
		June 30, 2011	1	76 ppb (Summit)
		July 1, 2011	5	85 ppb (Summit)
		July 6, 2011	7	90 ppb (Lake)
		July 10, 2011	2	78 ppb (Cuyahoga)
		July 12, 2011	2	78 ppb (Lake)
		July 20, 2011	4	88 ppb (Lake)
		July 21, 2011	1	78 ppb (Lake)
		July 22, 2011	1	82 ppb (Cuyahoga)
		September 1, 2011	1	79 ppb (Lake)
		September 2, 2011	2	80 ppb (Lake)
		September 3, 2011	3	77 ppb (Cuyahoga)
	Total	**14 days**		

Year	Eight-Hour Ozone NAAQS	Exceedance Date	No. of Monitors Exceeding the NAAQS	Highest Monitor
2012	**75 ppb**	May 15, 2012	1	76 ppb (Cuyahoga)
		May 19, 2012	5	88 ppb (Cuyahoga)
		May 20, 2012	3	83 ppb (Cuyahoga)
		May 21, 2012	3	83 ppb (Cuyahoga)
		May 25, 2012	3	82 ppb (Lake)
		May 28, 2012	1	76 ppb (Cuyahoga)
		June 9, 2012	6	84 ppb (Cuyahoga)
		June 10, 2012	6	93 ppb (Ashtabula)
		June 15, 2012	2	79 ppb (Cuyahoga)
		June 16, 2012	1	76 ppb (Cuyahoga)
		June 20, 2012	3	83 ppb (Cuyahoga)
		June 21, 2012	2	81 ppb (Ashtabula)
		June 28, 2012	11	108 ppb (Lake)
		June 29, 2012	3	82 ppb (Lake)
		July 6, 2012	2	88 ppb (Lake)
		July 7, 2012	7	94 ppb (Cuyahoga)
		July 12, 2012	5	89 ppb (Cuyahoga)
		July 13, 2012	2	76 ppb (Cuyahoga, Lake)
		July 22, 2012	2	77 ppb (Lake)
		July 26, 2012	1	77 ppb (Lake)
		July 31, 2012	1	77 ppb (Lake)
		August 2, 2012	3	87 ppb (Cuyahoga)
		August 3, 2012	5	92 ppb (Lake)
		August 8, 2012	2	76 ppb (Cuyahoga)
		August 24, 2012	5	89 ppb (Lake)
		August 25, 2012	1	78 ppb (Lorain)
	Total	**26 days**		
2013	**75 ppb**	June 21, 2013	4	86 ppb (Cuyahoga)
	Total	**1 day**		
2014	**75 ppb**	April 21, 2014	2	78 ppb (Lake)
		May 26, 2014	2	76 ppb (Lake)
		June 28, 2014	1	79 ppb (Lake)
	Total	**3 days**		
2015	**75 ppb**	May 8, 2015	4	79 ppb (Ashtabula)
		July 29, 2015	1	80 ppb (Geauga)
	Total	**2 days**		
2016	**70 ppb**	April 18, 2016	3	77 ppb (Geauga)
	New	May 24, 2016	6	82 ppb (Geauga)
	NAAQS	May 25, 2016	5	83 ppb (Lake)
		June 2, 2016	1	72 ppb (Geauga)

Year	Eight-Hour Ozone NAAQS	Exceedance Date	No. of Monitors Exceeding the NAAQS	Highest Monitor
		June 10, 2016	2	74 ppb (Cuyahoga)
		June 11, 2016	6	80 ppb (Lake)
		June 19, 2016	1	72 ppb (Lake)
		June 22, 2016	2	73 ppb (Geauga)
		July 7, 2016	2	74 ppb (Lake)
		July 12, 2016	1	71 ppb (Lake)
		July 21, 2016	1	74 ppb (Lake)
		July 23, 2016	1	76 ppb (Lake)
		September 22, 2016	1	76 ppb (Geauga)
		September 23, 2016	2	74 ppb (Geauga)
	Total	**14 days**		
2017	**70 ppb**	May 16, 2017	3	72 ppb (Lake)
		June 10, 2017	5	75 ppb (Lake)
		June 11, 2017	1	72 ppb (Lake)
		June 13, 2017	6	83 ppb (Lake)
		July 19, 2017	4	84 ppb (Lake)
		July 27, 2017	2	73 ppb (Lake)
	Total	**6 days**		
2018	**70 ppb**	May 17, 2018	2	72 ppb (Lake)
		May 25, 2018	5	80 ppb (Cuyahoga)
		May 28, 2018	4	73 ppb (Cuyahoga, Geauga)
		May 29, 2018	2	73 ppb (Cuyahoga, Geauga)
		June 16, 2018	2	75 ppb (Cuyahoga)
		June 17, 2018	2	76 ppb (Lake)
		June 29, 2018	4	78 ppb (Cuyahoga, Lake)
		June 30, 2018	1	73 ppb (Lake)
		July 9, 2018	2	72 ppb (Geauga)
		July 10, 2018	2	72 ppb (Geauga)
		July 13, 2018	1	71 ppb (Cuyahoga)
		July 14, 2018	4	76 ppb (Lake)
		July 15, 2018	6	80 ppb (Cuyahoga)
	Total	**13 days**		
2019	**70 ppb**	June 27, 2019	2	72 ppb (Cuyahoga)
		June 28, 2019	3	75 ppb (Lake)
		June 29, 2019	1	71 ppb (Lake)
		July 10, 2019	4	76 ppb (Geauga)
		July 13, 2019	3	73 ppb (Summit)
		August 4, 2019	1	72 ppb (Lake)
	Total	**6 days**		

Year	Eight-Hour Ozone NAAQS	Exceedance Date	No. of Monitors Exceeding the NAAQS	Highest Monitor
2020	**70 ppb**	June 9, 2020	1	74 ppb (Cuyahoga)
		June 21, 2020	1	72 ppb (Cuyahoga)
		July 3, 2020	2	73 ppb (Lake)
		July 6, 2020	1	72 ppb (Summit)
		July 7, 2020	2	75 ppb (Lake)
		July 8, 2020	6	83 ppb (Cuyahoga)
		July 9, 2020	5	81 ppb (Cuyahoga)
		July 18, 2020	2	72 ppb (Cuyahoga)
		August 10, 2020	1	75 ppb (Lake)
	Total	**9 days**		
2021	**70 ppb**	May 18, 2021	2	72 ppb (Lake)
		May 19, 2021	1	71 ppb (Lake)
		May 20, 2021	2	75 ppb (Lake)
		May 21, 2021	1	71 ppb (Lake)
		June 5, 2021	1	71 ppb (Lake)
		July 27, 2021	1	72 ppb (Lake)
		July 28, 2021	1	72 ppb (Cuyahoga)
		August 24, 2021	2	77 ppb (Lake)
	Total	**8 days**		

Source: U.S. EPA, “Air Quality System” data, https://www.epa.gov/aqs (accessed February 15, 2023).

Appendix B: $PM_{2.5}$ Exceedance Days 2007-2021

Year	24-Hour $PM_{2.5}$ NAAQS[1]	Exceedance Date	Number of Monitors Exceeding NAAQS	Highest Monitor (Readings in $\mu g/m^3$)
2007	**35 $\mu g/m^3$**	May 24, 2007	7	42 (Cuyahoga)
		September 6, 2007	9	43 (Lake)
		September 21, 2007	5	41 (Lake)
		December 26, 2007	1	37 (Cuyahoga)
	Total	**4 days**		
2008	**35 $\mu g/m^3$**	January 28, 2008	5	41 (Cuyahoga)
		February 24, 2008	7	44 (Summit)
		March 10, 2008	2	39 (Cuyahoga)
		July 29, 2008	7	40 (Cuyahoga)
		September 3, 2008	1	37 (Cuyahoga)
		September 21, 2008	1	40 (Summit)
	Total	**6 days**		
2009	**35 $\mu g/m^3$**	February 9, 2009	1	37 (Cuyahoga)
	Total	**1 day**		
2010	**35 $\mu g/m^3$**	February 2, 2010	1	35.3 (Summit)
		February 3, 2010	1	36.6 (Summit)
		March 8, 2010	1	35.8 (Summit)
		March 9, 2010	10	52.6 (Cuyahoga)
		July 7, 2010	1	36.9 (Summit)
		August 3, 2010	1	38.9 (Summit)
		October 11, 2010	1	35.1 (Summit)
		November 20, 2010	1	36.3 (Summit)
	Total	**8 days**		
2011	**35 $\mu g/m^3$**	January 6, 2011	1	38 (Cuyahoga)
		September 2, 2011	1	36 (Cuyahoga)
	Total	**2 days**		
2012	**35 $\mu g/m^3$**	May 25, 2012	1	49 (Cuyahoga)
		May 27, 2012	1	37 (Cuyahoga)
		November 9, 2012	1	37 (Cuyahoga)
		November 17, 2012	2	37 (Cuyahoga)
		November 21, 2012	2	46 (Cuyahoga)
	Total	**5 days**		
2013	**35 $\mu g/m^3$**	June 21, 2013	1	43 (Cuyahoga)
	Total	**1 day**		

Year	24-Hour $PM_{2.5}$ NAAQS[1]	Exceedance Date	Number of Monitors Exceeding NAAQS	Highest Monitor (Readings in μg/m³)
2014	**35 μg/m³**	February 13, 2014	1	37 (Cuyahoga)
	Total	**1 day**		
2015	**35 μg/m³**	March 10, 2015	2	39 (Cuyahoga)
	Total	**1 day**		
2016	**35 μg/m³**	N/A	0	N/A
	Total	**0 days**		
2017	**35 μg/m³**	N/A	0	N/A
	Total	**0 days**		
2018	**35 μg/m³**	N/A	0	N/A
	Total	**0 days**		
2019	**35 μg/m³**	November 19, 2019	1	38 (Cuyahoga)
	Total	**1 day**		
2020	**35 μg/m³**	July 5, 2020	5	61.8 (Lorain)
		November 8, 2020	1	42.9 (Cuyahoga)
		December 9, 2020	1	37.1 (Cuyahoga)
	Total	**3 days**		
2021	**35 μg/m³**	July 5, 2021	1	36.7 (Summit)
		July 20, 2021	1	36.3 (Summit)
	Total	**2 days**		

Source: U.S. EPA, "Air Quality System" data, https://www.epa.gov/aqs (accessed February 15, 2023).