Air Quality Trends in North Carolina

September 2023

Air Pollutant Emissions Trends in North Carolina

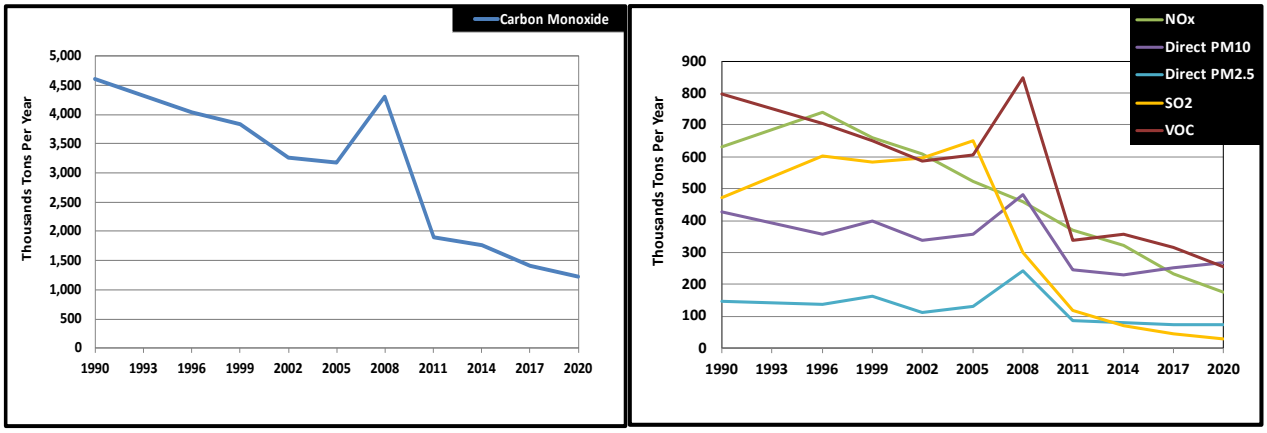
N.C. Division of Air Quality, September 2023

This report is an update to the previous report dated October 2020. For this update, criteria air pollutant emissions have been updated from 2017 to 2020 and associated ambient air concentrations have been added for 2020-2022. Air toxic emissions have been updated from 2017 to 2020. Greenhouse gas (GHG) emissions were updated by the North Carolina Division of Air Quality (DAQ) in Fiscal Year 2021-22, and this report incorporates those updates to the previous report's GHG emissions. From 2017 through 2020, North Carolina continued to show a general trend towards less air pollutant emissions. Note that the relative contribution of sector-level emissions to total emissions for a given pollutant may have changed from the previous report because of a higher reduction in pollutants for some sectors versus others.

Criteria Air Pollutants

North Carolinians are breathing the cleanest air in decades. State leaders, regulatory agencies, electric utilities, industry, and the public have significantly addressed air quality concerns in recent years. Their collective efforts are achieving impressive results to reduce tropospheric ozone and particulate matter (PM) pollution. From 1990 through 2020, statewide emissions of sulfur dioxide (SO_2) declined 94%, carbon monoxide (CO) by 73%, oxides of nitrogen (NOx) by 72%, $PM_{2.5}$ by 49%, and volatile organic compounds (VOCs) by 68%.[1]

Annual Statewide Criteria Air Pollutant Emissions*



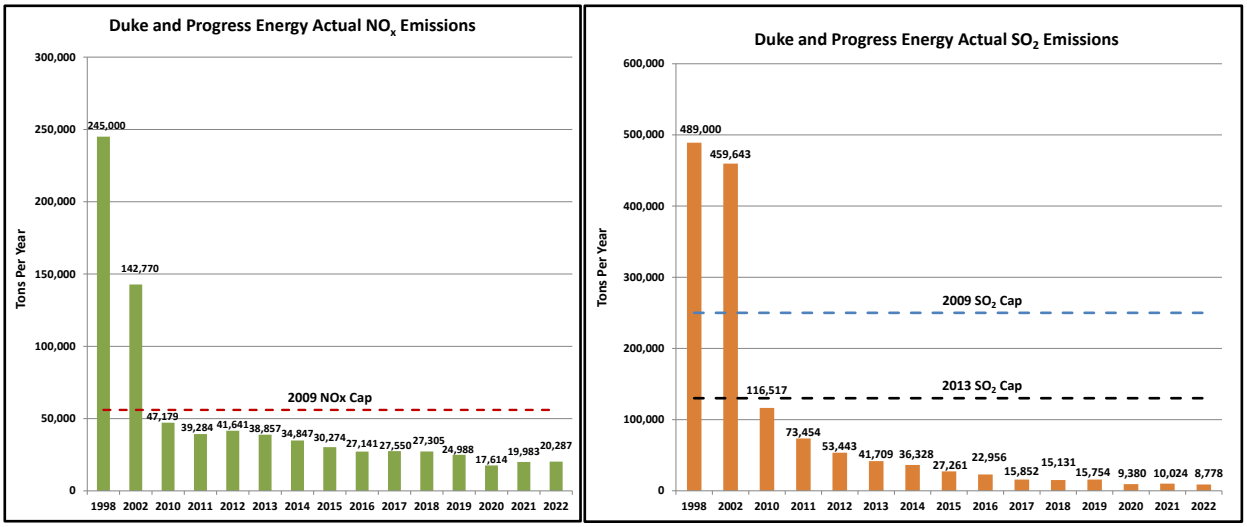
*A significant wildfire event occurred in 2008 that substantially increased CO, PM, and VOC emissions. Direct $PM_{2.5}$ and direct PM_{10} represent small particles of particulate matter with an aerodynamic diameter less than or equal to 2.5 and 10 micrometers, respectively.

For example, harmful emissions from coal-fired electricity generating units (EGUs) operating in North Carolina were significantly reduced following passage of the Clean Smokestacks Act in 2002 (see the following "Clean Smokestacks Act Emissions Reductions" charts). From 2002 through 2022, coal-fired EGUs subject to this legislation reduced total NOx and SO_2 emissions by 122,484 tons (86%) and 450,865

[1] For criteria air pollutants, facility and county level emissions data are obtained from EPA's "National Emissions Inventory (NEI)," available from https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei, accessed September 2023.

tons (98%), respectively. The state's coal-fired EGUs are equipped with state-of-the art air pollution control technology stems and since 2005, many EGUs in the state transitioned to natural gas for electric power generation. North Carolina has also has continued to increase its renewable energy capacity under the Southeast's only Renewable Energy and Energy Efficiency Portfolio Standard. While coal accounted for 96% of North Carolina's total fossil-fueled electricity generation in 2005, this figure dropped to only 20% in 2022, accounting for about 11% of total generation for the state.[2] In 2022, North Carolina was fourth in the nation for solar photovoltaic capacity, accounting for about 9% of total generation in the state.[2,3]

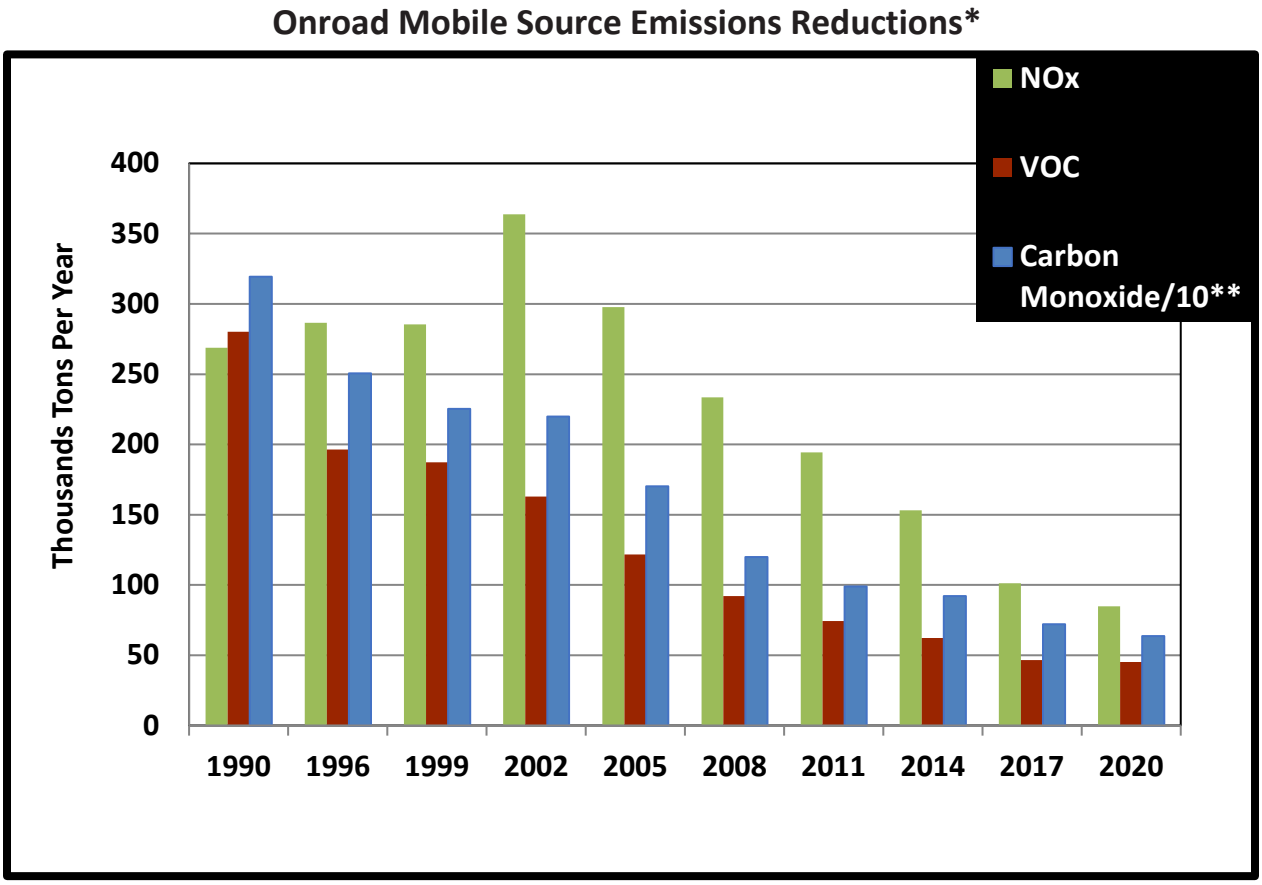
Clean Smokestacks Act Emissions Reductions



Transportation emissions associated with passenger vehicles and trucks have also declined significantly (see the following "Onroad Mobile Source Emissions Reductions" chart). From 1990 through 2020, CO, NOx, and VOC emissions have declined by 80%, 69%, and 84%, respectively. The decline in onroad emissions is associated with several EPA promulgated regulations that have been phased in over time, starting with the federal Tier 1 emissions standards from 1994-1999, national low-emissions vehicle standards from 1999-2003, Tier 2 emissions standards from 2004-2010, heavy-duty vehicle standards from 2007-2010, and Tier 3 vehicle emissions and fuel standards from 2017-2025. As a result of these standards, newer low-emitting vehicles are replacing older higher-emitting vehicles. Additionally, vehicles are now using low-sulfur fuels, and emissions controls on vehicles are more technologically advanced - thus longer lasting and less prone to malfunctions or failures. Combined, these changes have led to North Carolina's vehicle fleet being cleaner today than ever before. Emission reductions are expected to continue in future years from these and federal standards expected to be promulgated for new vehicles.

[2] U.S. Energy Information Administration, "Electricity Data Browser," available from https://www.eia.gov/electricity/data/browser/, accessed July 2023.

[3] U.S. Energy Information Administration, "Electric Power Annual, Table 4.7.B. Net Summer Capacity Using Primarily Renewable Energy Sources and by State, " accessed from https://www.eia.gov/electricity/annual/html/epa_04_07_b.html, accessed July 2023.



** The NOx emissions spike in 2002 is attributed to EPA adjusting the onroad emissions model.*
*** CO emissions represented in this chart were divided by a factor of 10 for comparability purposes.*

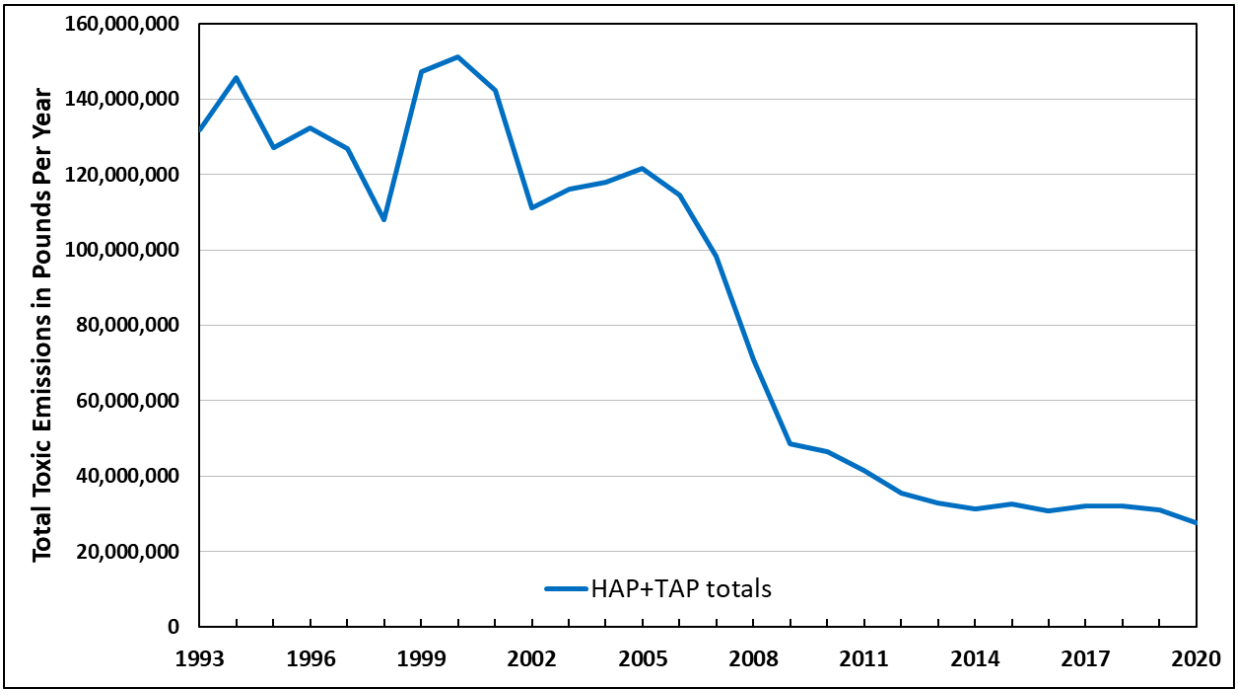
Air Toxics

Over the past few decades, industry implemented several measures to reduce their hazardous air pollutant (HAP) and toxic air pollutant (TAP) emissions as required under the Federal National Emissions Standards for Hazard Air Pollutants and NC's Air Toxics program, respectively. These include upgrading processes with advanced valve seals, leak detection systems, and state-of-the-art control technologies. Where practical, the use of hazardous chemicals in manufacturing processes has been eliminated or reduced. As a result, HAP and TAP emissions have declined significantly over the past 28 years (see the following "Statewide Air Toxic Emissions Changes 1993-2020" chart). From 1993 to 2020, HAP and TAP combined emissions have declined by more than 100 million pounds which is a 79% decrease. It is important to note that the number of HAPs and TAPs for which emissions are reported to the DAQ vary from year-to-year due to economic fluctuation in demand for products, process changes or improvements, and permitted facility population. For example, emissions were reported to the DAQ for 236 pollutants in 2017 and 221 pollutants in 2020.

Additionally, the state is working alongside the Secretaries' Science Advisory Board (SAB), U.S. Environmental Protection Agency (EPA), and academic researchers to understand the impact that air

emissions of emerging contaminants such as per- and poly-fluoroalkyl substances (PFAS) have on the state's environment and public health. This process involves building an understanding of the types of industrial sources that may emit PFAS and the amount and type of PFAS chemical released into the atmosphere. Due to the limitations in available scientific information, DAQ is working with DEQ's multi-media team and the research community to characterize the fate and transport of emissions released, the effect of the deposited pollution on water and land quality, and associated health risks to humans and aquatic life.

Statewide Air Toxic Emissions Changes 1993-2020



HAP = Federal hazardous air pollutants.
TAP = North Carolina-specific toxic air pollutants.
Source: North Carolina point source inventory.

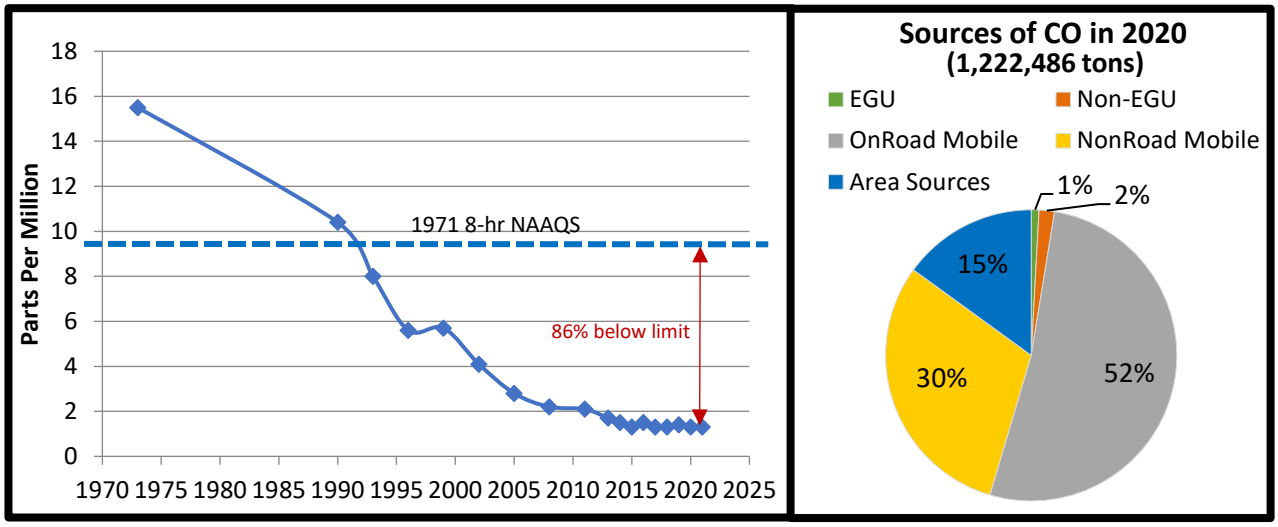
Ambient Air Improvements

Air quality and visibility substantially improved across North Carolina. Before 2009, extensive portions of North Carolina had tropospheric ozone levels exceeding the health-based standard. The areas previously designated by EPA as not meeting air quality standards included more than 30 counties in the Charlotte, Fayetteville, Rocky Mount, Triad, and Triangle metropolitan areas, and the Great Smoky Mountains National Park. Today, all areas of the state qualify as attaining the National Ambient Air Quality Standards (NAAQS) for criteria pollutants established by EPA for the protection of public health and the environment. The subsequent charts show ambient concentration trends and 2020-year emissions for CO, lead (Pb), SO_2, nitrogen dioxide (NO_2), ozone, PM, and visibility improvements (established as public welfare targets).

Carbon Monoxide

Improvements in vehicle exhaust controls, catalyst design, and fuel control systems have contributed to significant reductions in ambient CO concentrations. New cars, trucks, and buses are about 99% cleaner for common pollutants (such as CO, NOx, PM, and VOCs) compared to 1970 vehicle models.[4] North Carolina no longer has any CO maintenance areas, and all areas of the state are attaining the 1971 8-hour NAAQS.

Statewide 8-hour Carbon Monoxide Levels

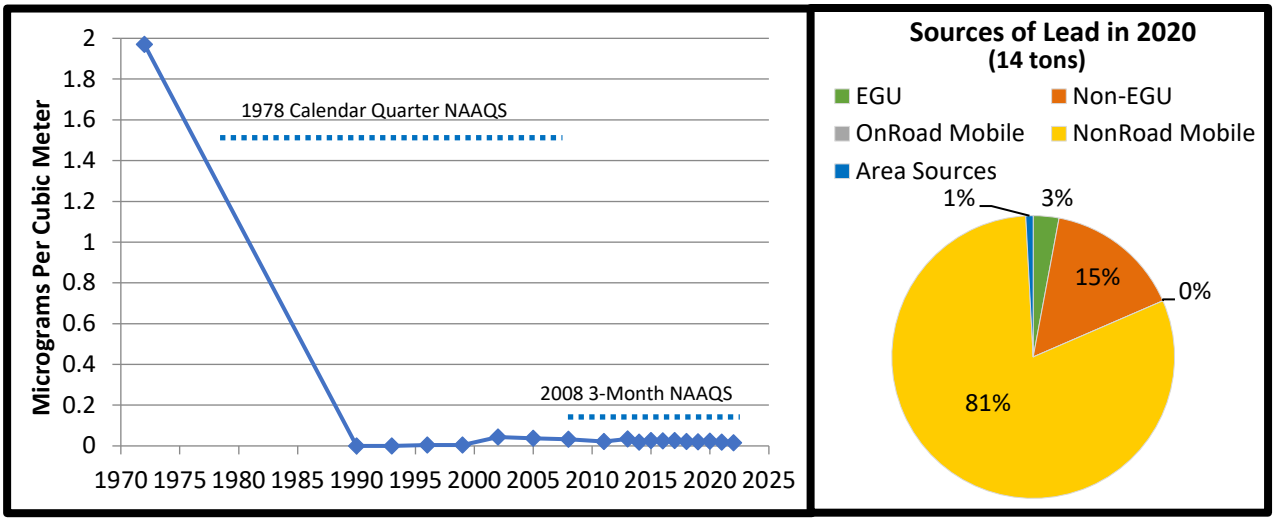


Lead

The phase-out of lead in motor vehicle gasoline pursuant to the Clean Air Act has led to dramatic reductions in airborne lead pollution and its adverse health effects. North Carolina is in statewide attainment of the 2008 lead NAAQS. In April 2016, North Carolina discontinued monitoring for lead. The measured lead design value was zero, so the EPA no longer required North Carolina to monitor for lead to demonstrate compliance with the standard. However, as part of the chemical speciation network, North Carolina monitors for lead in fine particles at several locations throughout the state. The maximum measured fine particle lead value for each year is shown in the following chart.

[4] U.S. EPA, "History of Reducing Air Pollution from Transportation in the United States," https://www.epa.gov/transportation-air-pollution-and-climate-change/accomplishments-and-success-air-pollution-transportation, accessed August 2020.

Statewide Lead Concentrations

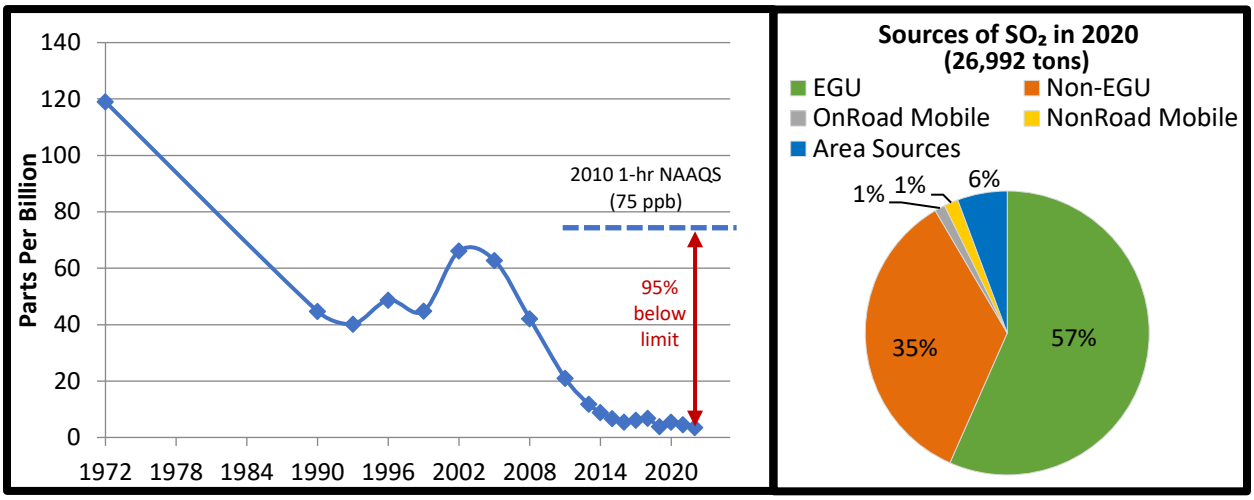


Sulfur Dioxide

Lower sulfur content in fuel,[5] state-of-the-art scrubbers, and the increasing use of natural gas-fired combined-cycle EGUs and renewable energy have led to substantial reductions in SO_2 emissions. For the 2010 1-hour SO_2 NAAQS, on December 21, 2017, EPA designated the vast majority of North Carolina as "Attainment/Unclassifiable" as a part of its Round 3 designation action pursuant to the Data Requirements Rule.[6] Brunswick County was designated "Unclassifiable" on June 30, 2016, as part of EPA's Round 2 action.[7] In response to a request from DAQ, EPA redesigned all townships in Brunswick County to "Attainment/Unclassifiable" (based on CY2018-2020 monitoring data) effective October 28, 2021.[8] For calendar years 2017 through 2019, North Carolina completed source-oriented monitoring for three facilities (one each in Limestone Township in Buncombe County, Cunningham Township in Person County, and Beaverdam Township in Haywood County). The EPA used the monitoring results along with emissions and other data to designate these three remaining areas as "Attainment/Unclassifiable" effective April 30, 2021.[9]

[5] Since the 1960s, the sulfur content of gasoline and diesel fuel has dropped by 90% and 99%, respectively.
[6] 83 FR 1098, January 9, 2018. Designations were completed at the township-level.
[7] 81 FR 45039, July 12, 2016. Designations were completed at the township-level.
[8] 86 FR 53555, September 28, 2021. Designations were completed at the township-level.
[9] 86 FR 16069, March 26, 2021. To comply with a court-ordered deadline of December 31, 2020, the Round 4 2010 SO2 NAAQS designations action was signed by the EPA Administrator, Andrew Wheeler, on December 21, 2020. For administrative purposes only, and in compliance with requirements of the Office of the Federal Register, Acting Administrator Jane Nishida re-signed the same action on March 10, 2021 for publication in the Federal Register.

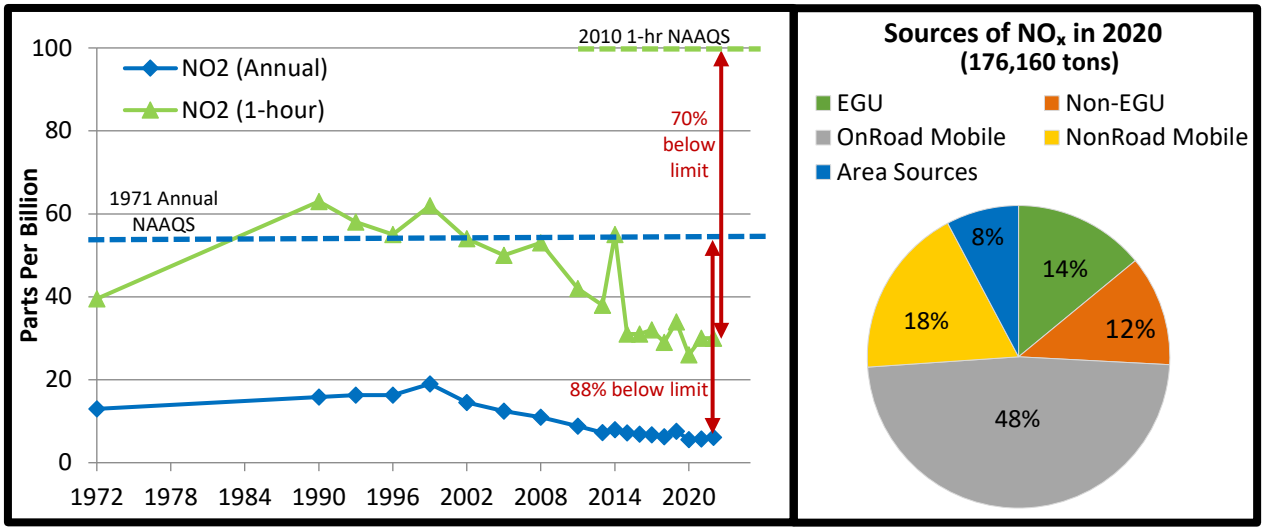
Statewide SO_2 Concentrations



Nitrogen Dioxide

Improved vehicle emission standards, fuel efficiencies, ultra-low NOx burners, selective catalytic reduction (SCR), and selective non-catalytic reduction (SNCR) emission control technologies, as well as the replacement of coal with renewable energy and natural gas generation, have contributed to substantial reductions in NOx emissions (see the following "Statewide NO_2 Concentrations" chart). North Carolina is currently attaining both the 2010 1-hour and 1971 annual NO_2 NAAQS. Currently, there are 13 coal-fired EGUs across the state that are equipped with SCR controls, while 5 EGUs are equipped with SNCR. Three EGUs equipped with SNCR controls have been retired since the last report.

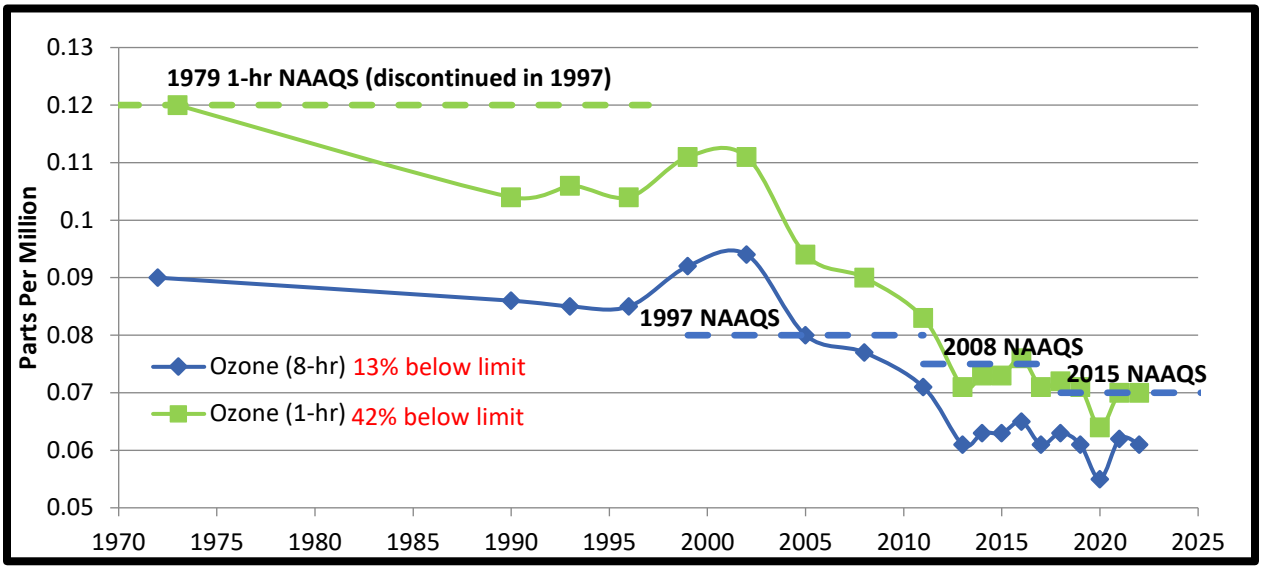
Statewide NO_2 Concentrations



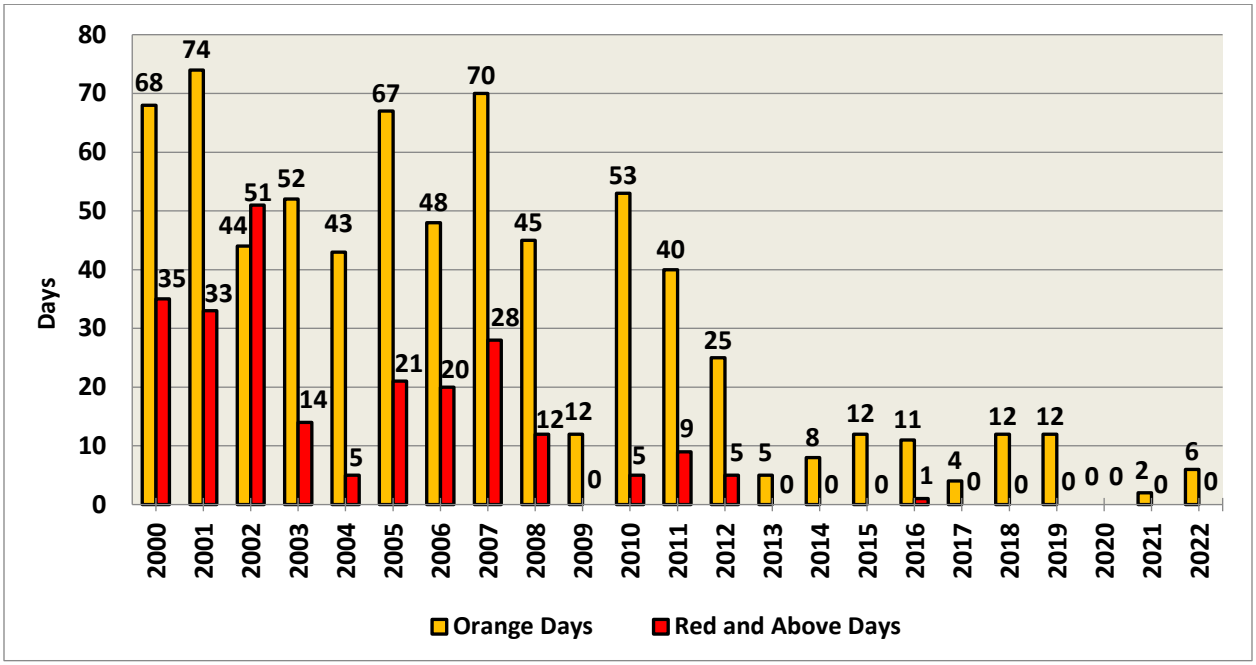
Ozone

Reductions in NOx emissions have markedly reduced tropospheric ozone formation. On October 1, 2015, the 2008 ozone standard was strengthened from 0.075 to 0.070 parts per million. On November 16, 2017, EPA designated North Carolina as attaining the 2015 ozone standard statewide. The number of ozone exceedance days in North Carolina has remained low and has only varied slightly since the more stringent standard was adopted by EPA in 2015 (see the "Statewide Ozone Exceedances (2015 Standard) chart). In the past two years, exceedance events appear to have returned to the historical norm of occurring at both urban and rural sites. The DAQ continues to evaluate each event to determine how best to minimize or eliminate exceedances in the future.

Statewide Average Ozone Concentrations



Statewide Ozone Exceedances (2015 Standard)

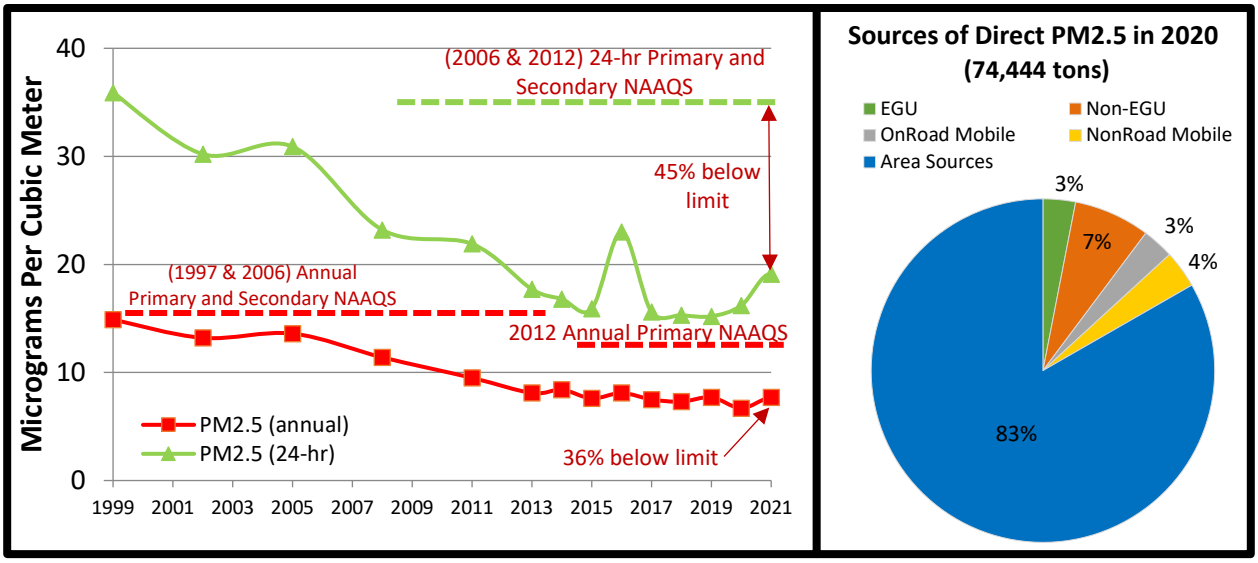


Particle Pollution

Reductions of NOx and SO_2 emissions from fossil fuel-fired EGUs, low-sulfur fuel standards, and mobile source PM have significantly lowered ambient $PM_{2.5}$ and PM_{10} concentrations across North Carolina. On January 6, 2023, EPA published a "Notice of Proposed Rulemaking for the EPA Reconsideration of the National Ambient Air Quality Standards for Particulate Matter" that proposes to revise the primary annual $PM_{2.5}$ standard. [10] However, the proposal did not include revisions to the secondary annual $PM_{2.5}$ standard, primary and secondary 24-hour $PM_{2.5}$ standards and primary and secondary PM_{10} standards. Comments were to be received by March 28, 2023. Once EPA has addressed all the comments received, the final rule will be promulgated. As of September 12, 2023, the final rule has not yet been promulgated.

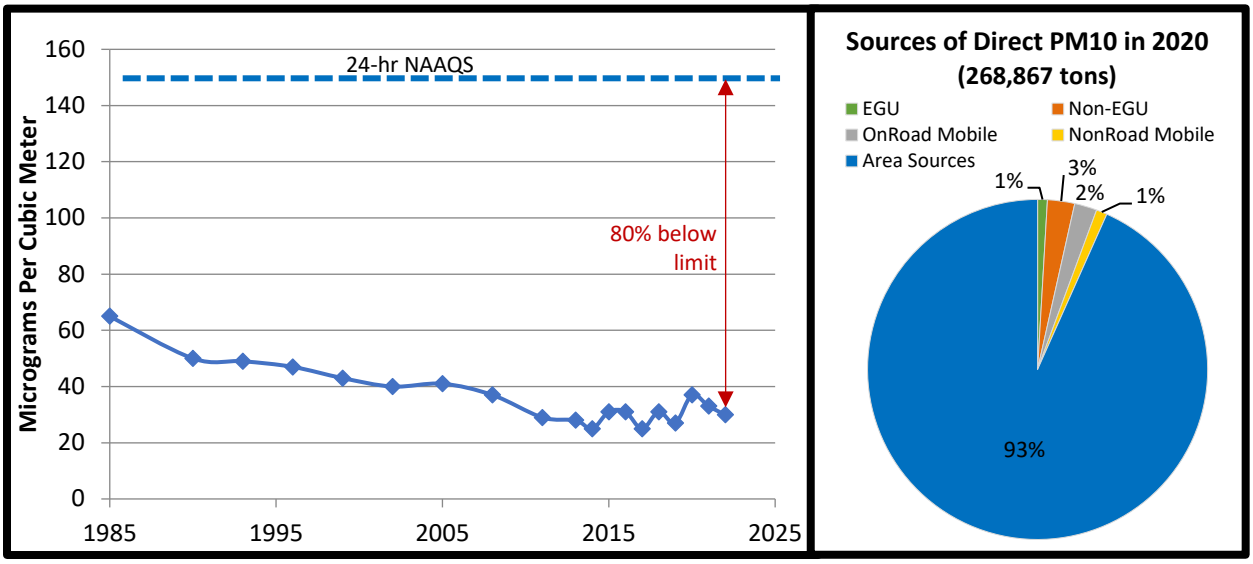
[10] U.S. EPA, "Proposed Decision for the Reconsideration of the National Ambient Air Quality Standards for Particulate Matter (PM)", https://www.epa.gov/pm-pollution/proposed-decision-reconsideration-national-ambient-air-quality-standards-particulate.

Statewide $PM_{2.5}$ Concentrations



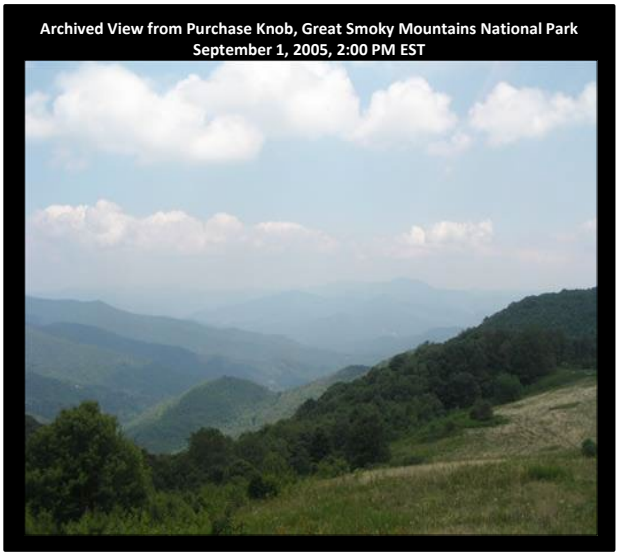
Note: To provide the most accurate method for comparing monitored values to the $PM_{2.5}$ standard, the above $PM_{2.5}$ concentration values reflect only data from regulatory monitors.

Statewide PM_{10} Concentrations



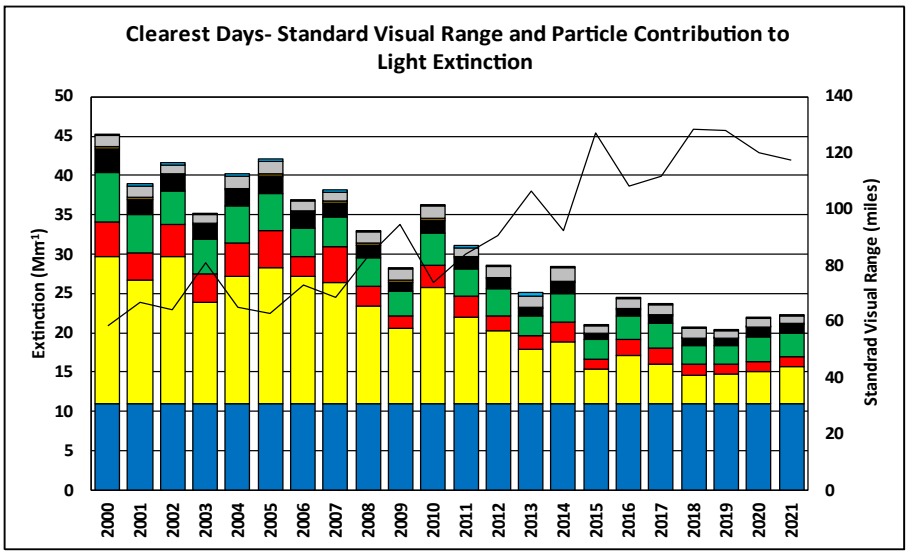
Visibility

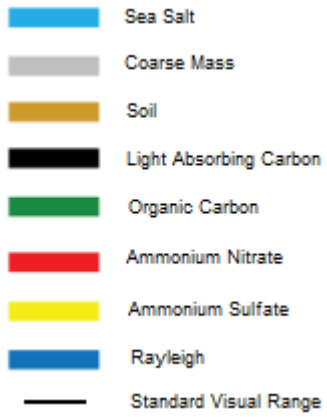
The scenic panoramas of our national and state parks are clearer due to reductions in SO_2 and NOx emissions and other air pollutants that scatter light. During hazy days, most light extinction is attributed to ammonium sulfate particles and to a lesser extent ammonium nitrate and organic carbon particles. The significant reduction of these fine particles has resulted in better visibility for North Carolina's parks and wilderness areas. For example, the following photos from Purchase Knob in the Great Smoky Mountains National Park show an increased visual range from 11.3 to 58.1 miles for days representing the median of the 20% most impaired days of 2005 and 2021, respectively.

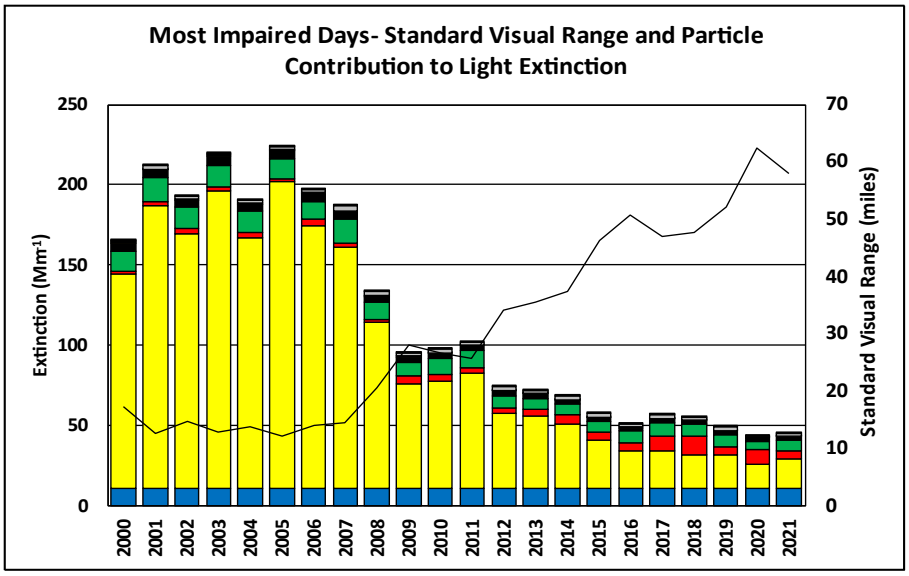


For the Great Smoky Mountains National Park, the following charts show the decline in pollutant species contribution to visibility impairment resulting in a corresponding increase in visual range for the 20% clearest and 20% most impaired days from 2000 through 2021. Note that Rayleigh represents natural light-scattering conditions. For the Great Smoky Mountains National Park, as with North Carolina's other Class I areas, significant reductions in both SO_2 and NOx emissions over the past two decades have significantly improved anthropogenic visibility impairment.[11]

[11] "Final Regional Haze State Implementation Plan (SIP) for North Carolina Class I Federal Areas for Second Planning Period (2019 – 2028)", submitted by DAQ to EPA on April 4, 2022 (includes 5-year progress report covering 2011 through 2018), https://www.deq.nc.gov/about/divisions/air-quality/air-quality-planning/state-implementation-plans-sips/regional-haze-state-sip.







The standard visual mile range on the 20% clearest days
1996: 54 miles
2000: 58 miles
2021: 117 miles

The standard visual mile range on the 20% most impaired days
1996: 11 miles
2000: 17 miles
2021: 58 miles

Note: light extinction is expressed as inverse megameters (Mm^{-1}). Light extinction values for each year represent the annual average of the 20% clearest days (top chart) or annual average of the 20% most impaired days (bottom chart) as recorded by the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitor for the Great Smoky Mountains National Park. Standard visual range (SVR) represents the greatest distance at which an observer can just see a black object viewed against the horizon sky. SVR is derived from the total light extinction value.

Greenhouse Gas Emissions Trends in North Carolina

The collective efforts of state leaders, regulatory agencies, electric utilities, industry, and the public to control criteria air pollutant emissions to achieve statewide compliance with all the NAAQS have also yielded significant reductions in North Carolina's anthropogenic GHG emissions. As shown in the following table, North Carolina's gross GHG emissions in 2018 were about 159 million metric tons of carbon dioxide

equivalent emissions (MMT CO_2e).[12,13] Accounting for carbon sinks, North Carolina's net GHG emissions in 2018 are estimated at about 117 MMT CO_2e. From 2005 to 2018, North Carolina reduced its gross and net GHG emissions by 16% and 23%, respectively. During this same period, North Carolina's population and real Gross State Product grew by 19% and 24%, respectively.

North Carolina GHG Emissions Inventory by Source Sector (MMT CO_2e)

	Historical					Projected		
	1990	**2005**	**2012**	**2017**	**2018**	**2020**	**2025**	**2030**
Electricity Generation and Use [a]	54.55	80.15	65.61	51.29	52.32	46.83	41.08	34.35
Residential/Commercial/Industrial Combustion [b]	26.76	26.00	18.74	19.83	21.28	19.65	21.38	21.96
Transportation	40.40	59.36	56.91	57.18	57.31	49.71	52.42	49.09
Agriculture	7.06	10.65	10.56	10.53	10.52	10.51	10.47	10.44
Waste Management	6.39	8.52	9.09	8.77	8.94	9.29	10.17	11.07
Industrial Processes	1.04	3.83	5.39	7.18	7.73	8.84	11.31	12.73
Natural Gas and Oil Systems	0.86	1.17	1.28	1.35	1.37	1.40	1.47	1.55
Gross Emissions	137.04	189.68	167.56	156.13	159.48	146.23	148.31	141.18
Net Carbon Sinks – LULUCF [c]	-42.17	-37.29	-40.15	-41.58	-42.13	-42.13	-42.13	-42.13
Net Emissions	94.88	152.39	127.41	114.56	117.35	104.10	106.18	99.05
Percent Reduction in Net Emissions from 2005					**23%**		**30%**	**35%**

Note: Totals may not exactly equal the sum of the subtotals shown in this table due to independent rounding.

[a] Includes estimates of emissions from Imported Electricity that are generated outside North Carolina.

[b] Represents emissions associated with on-site fuel combustion activities in the Residential, Commercial, and Industrial sectors.

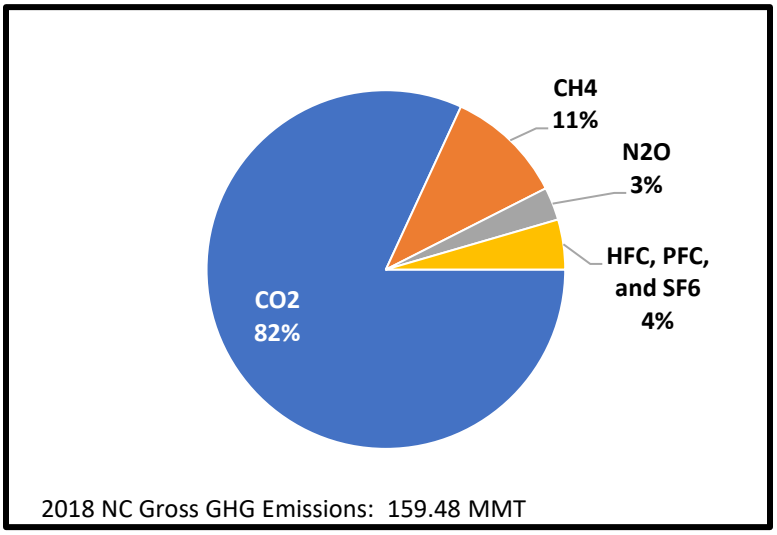
[c] Land Use, Land Use Change, and Forestry.

The six anthropogenic GHG pollutants included in the inventory are CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The following chart shows the contribution of each gas type to North Carolina's total GHG emissions in 2018. Carbon dioxide is emitted in much larger amounts than the other GHGs combined; accounting for approximately 82% of the total GHG emissions in 2018. However, the global warming potential for the other GHGs, which incorporates both atmospheric lifetime and ability to trap heat, makes them significant contributors as well.

[12] North Carolina Greenhouse Gas Inventory (1990 – 2030), North Carolina Department of Environmental Quality, Division of Air Quality, January 2022. 2018 is the last year of historic GHG emissions data. 2020 is a short-term projection of GHG emissions based on 2018 historical emissions.

[13] Emissions of each GHG pollutant are typically reported as MMT CO_2e which normalizes the emissions of the various GHG pollutants to reflect the global warming potential (GWP) of each compound using CO_2 as a baseline (DAQ uses the same GWP values as EPA in its National GHG Inventory which are the GWP values published by the IPCC's Fourth Assessment Report for a 100-year time horizon).

Percentage of North Carolina's 2018 Gross GHG Emissions by Gas Type



The primary source of CO_2 emissions is fossil fuel combustion in the transportation; electricity generation; and residential, commercial, and industrial sectors. GHG emissions from fossil fuel combustion have decreased by 21% from 2005 to 2018 due to both a shift in fuel use, from coal to natural gas and renewable energy, and increased energy efficiency. Methane emissions accounted for approximately 11% of the total GHG emissions in 2018. The primary sources of CH_4 are waste management and agriculture. Emissions from waste management and agriculture have not changed significantly since 2005, even with a growing population and economy.

The following lists key findings from both the GHG emissions inventory and from the analysis of the data used to develop the emissions for each source sector. Emissions reductions are generally expressed as the percent change in gross GHG emissions, unless otherwise stated, from the baseline year of 2005 to 2018.

- **Electricity Generation**
  - While the state's largest contributor to GHG emissions prior to 2016, Electricity Generation and Use is now the second largest emissions sector and represents 33% of all gross GHG emissions.
  - GHG emissions from electricity generation have decreased by 34% from 2005 to 2018.
  - North Carolina's electricity generation sector has undergone a transformation since 2009 including:
    1) the retirement of more than 3,000 megawatts of coal fired EGUs, which is 27% of the state's coal fleet.
    2) the increased use of natural gas combined-cycle EGUs.
    3) the passage of North Carolina legislation to promote renewable energy (e.g., North Carolina's Renewable Energy and Energy Efficiency Portfolio Standard[14] and the Carbon Plan[15]).

[14] Session Law 2007-397 (Senate Bill 3), enacted August 20, 2007.
[15] Session Law 2021-165 (House Bill 951), enacted October 13, 2021.

- Solar photovoltaic, hydroelectric, and wind power represented 10% of North Carolina's electricity generation in 2018.
- Avoided GHG emissions due to renewable energy power are estimated at 5.26 MMT CO_2e for 2018.

➢ **Transportation**

- Due to the decline in GHG emissions from EGUs, transportation is now the largest emissions sector and represents 36% of all GHG emissions.
- Emissions from the transportation sector have decreased by 3% from 2005 to 2018.
- Gasoline represents 72% of the energy input into transportation while onroad medium/heavy-duty diesel represents 16%.

➢ **Residential, Commercial, and Industrial**

- Residential, commercial, and industrial fuel combustion emissions represent over 13% of all GHG emissions.
- Residential sector emissions from total energy use have decreased by 25% between 2005 and 2018, while North Carolina's population grew by 19% over that time.
- GHG emissions from fuel combustion in the commercial sector have increased by 3% due to shifts in the economy. This is offset by a 28% decrease in emissions from electricity use by this sector.
- Industrial fuel combustion emissions have decreased by 27% from 2005 to 2018.
- GHG emissions from industrial processes have doubled since 2005.

➢ **Waste Management**

- Many large landfills in North Carolina are now collecting CH_4 and using the captured biogas as energy, resulting in 561,000 megawatt-hours of electricity generation and an additional 149,000 million British thermal units of heat input in 2017.

➢ **Land Use, Land-Use Changes, and Forests**

- Forests, natural lands, and agricultural lands sequestered an estimated 42 MMT of CO_2.
- These carbon sinks are primarily due to increases in forest stocks and storage of carbon in wood products, reflecting North Carolina's increasing sustainable management of its forests and their economic uses.