North Carolina Conservation Network

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NORTH CAROLINA STATE OF THE ENVIRONMENT

2025 / TECHNICAL DOCUMENT

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FRONT MATTER

About the State of the Environment

This report assesses trends in North Carolina's human and natural environments. It is organized around 46 goal statements that we think can draw broad support across the political spectrum – "Drinking water is (should be) safe"; "Residents (should) have long lives and good health"; "Electric power (should) be reliable." Our trajectories towards or away from these goals are measured by 114 indicators. We've tried to select indicators that measure real-world outcomes: not how many dollars government has spent, or how many grants or permits it has issued, but how often drinking water violates health standards; how long North Carolinians live; how often the power goes out. Some indicators are important but lack reliable data series. We label these as data gaps.

North Carolina is blessed with a strong university system, built through committed investment of public funds over decades. In our discussions of goals and indicators, we've made an effort to cite relevant research, especially from the last five years, and especially published by researchers based in or studying North Carolina. No doubt our literature searches have missed relevant studies and findings; we hope researchers reading this will share their results with us to cite in future iterations of the State of the Environment.

The discussion of each goal follows a consistent format: we name the indicators tied to the goal and state their directional trends, and list policy solutions that could help the state achieve the goal. The policy solutions are collected in an appendix at the end of the report. But the solutions are nearly an afterthought; the focus of this report is the condition of the state we share.

The discussion of each indicator also follows a standard format. A 'top line' briefly explains the indicator and its trend. An 'about' section discusses the indicator in greater depth, explaining what it shows, and usually including a chart or graph that lays out the data for the last ten years, or less if the data series is shorter. We discuss relevant history, official reports, and academic research in this section as well. Many indicators finish with a 'recent developments' section that notes key changes in policies or new scientific findings from the last five years.

We offer two notes about data limitations. In the interest of protecting their employees from exposure to COVID-19, many institutions stopped collecting data for part or all of 2020. Generally, most data series resumed by mid-2021. But some data series – for example, freshwater fish sampling, which follows a fish-year rotation across dozens of streams – still suffer from the lost year. Substantively, several data series show odd dips that track economic contraction during and recovery from the pandemic. For ten-year series, we think the availability of data before 2002 and after 2021 has allowed us to largely iron out temporary effects, although the pandemic placed a few indicators on a distinctly new trajectory.

For most indicators, annual data ends in late 2023. That means that the trends do not account for changes in direction in 2024. For example, after a few good years, 2024 was a truly terrible year for North Carolina agriculture. More broadly, none of the impacts of Hurricane Helene in western NC show up in the data. With long data series, one anomalous year would likely not change an overall trend. But some changes wrought by Helene are more fundamental and will cast a longer shadow. We've tried to address those key changes narratively as 'recent developments.'

How to use the State of the Environment

We have designed this report to be used in five ways:

- First and foremost, it is an assessment of where North Carolina is and where we're headed. To get a top-line perspective, you can study the mandala, discussed below under 'overarching trends', which boils all 46 goals and 114 indicators down into a circle. Or you can consider the top five challenges we identify for North Carolina's environmental future, discussed below under 'five drivers'.

- Second, it is a reference. For any particular topic – energy efficiency; exposure to microplastics – you can keyword search the document to find the indicators where that topic is discussed. Or, you can skim the goals and indicators for topics that look interesting or relevant and jump to those.

- Third, we hope you will use this document as a jumping off point to find and follow current and evolving research. We've looked for the best and most down-to-earth scientific studies we could find tied to our goals and indicators, especially studies with a North Carolina focus. We've linked to reports, studies, and journal articles in the footnotes.[1]

- Fourth, for readers looking for solutions, the policy appendix is a springboard. No doubt each policy proposal has pros and cons; this report does not attempt to weigh those. Rather, the policies listed following each goal and gathered in the appendix reflect the collective aspirations of North Carolina's environmental and conservation organizations, as well as a few ideas that no one has actively proposed in North Carolina but seem to us worth exploring.

[1] If you're a person who reads footnotes, this is for you. For the sake of brevity and ease of use, we've invented our own citation format. News articles and reports are hyperlinked by their titles; we've relied on digital object identifiers (DOI) for peer-reviewed journal articles that provide them. For web resources, we've included a one- or two-word description before the title – 'blog post', 'interactive map' – so you know what you're getting before you click through, and the link is attached to the descriptive word. Links break – DOIs last longer than most – but if a link breaks for a web resource, we recommend that you use the Wayback Machine to find it. State legislation and statutes can be found at the NC General Assembly website; the texts of state rules are in the NC Administrative Code online. Sources cited more than once are given the full cite the first time, with an italicized [*Short Name*] provided in brackets. If you're looking at a footnote and see an italicized name, the full cite is somewhere earlier in the report. Do a keyword search of the italicized name to find the full citation, which will include the DOI or other link. By convention, *ibid* means the information comes from the same page in the same source cited in the previous footnote; *idem* means it came from the same source but not the same page.

- Finally, NC Conservation Network keeps a list of advocates across North Carolina's environment and conservation organizations working on the problems identified in this report. Given staff turnover, the list changes rapidly enough that it doesn't make sense to include it in the published text – but we have it. If you need to connect with advocates working on a particular topic or problem, please contact us; we'll point you to the right people.

What we found: overarching trends

Reality is complex, but too much information is overwhelming. To make sense of our data, we've boiled the 46 goals and 114 indicators down to 19 categories and 7 supercategories. They are all shown here, in what we've come to call 'the mandala'.

What we found: five drivers of North Carolina's future

We identified five areas that will shape North Carolinians' ability to live healthy and safe lives in our state. These areas are broad and interact with indicators from all through the report.

The human exposome. The exposome consists of everything a person is exposed to, from the air they breathe, to the water they drink or swim in, to the dust on their skin from the furniture and clothes they buy, to the social and built environments that surround them. A suite of indicators reflect air, water, and toxic pollution (indicators 12.1 – 19.3); others capture the built environment (indicators 21.1 – 24.3). Together, these drive common health outcomes (indicators 20.1 – 20.5).

What the trends in the exposome add up to: we've made much progress over the last 30 years in reducing exposures to conventional pollutants. Smog and particulates are rarer; rivers don't run red or green depending on the daily industrial releases upstream. In that sense, the major federal pollution control programs delegated to North Carolina – the Clean Air Act, the Clean Water Act – have worked. But as science improves, evidence of toxicity at low doses has piled up for a long list of chemicals whose release into air and water is unregulated, or that are used freely in consumer products. Moreover, the practice of only regulating toxics once health impacts can't be ignored has established a treadmill of regrettable substitutes: regulators work for years to address a known threat, but by the time standards are in place, polluters have shifted to release a different product or byproduct that is equally dangerous but not yet regulated. Finally, we've learned that several kinds of pollutants don't go away: PFAS, and plastics, which break into smaller and small pieces, now found around the world and in every human organ system. Exposures to these unregulated and emerging contaminants are headed in the wrong direction, with dire implications for human health.

Growth patterns. North Carolina is loved for its rural and natural landscapes, from the mountains to the sea. We're fortunate to have new North Carolinians flocking here from across the nation and around the world, bringing skills and vision with them. But the particular form our growth takes on the land today – sprawling outwards from metropolitan areas – threatens our rural landscape and our agricultural sector. It also drives higher greenhouse gas emissions from the transportation sector, longer commute times that damage residents' health, and increases in stormwater runoff that degrades rivers and estuaries.

We choose future development patterns through the land use and transportation policies we adopt. A different set of choices could promote compact development, lower total housing and transportation costs for residents, lower infrastructure costs for governments to serve their residents, lower carbon emissions, and protect North Carolina's rural landscapes for the future. Innovative policies and programs rooted in equity would result in better economic opportunities and higher quality of life for all North Carolinians, including lower income residents and members of communities that haven't enjoyed the benefits of growth to date.

Adaptation and the impacts of ongoing disasters. In September 2024, the remnants of Hurricane Helene devastated western NC, washing away or burying houses, roads, railroads, factories, workshops,

water and sewer plants, and farm fields. Beyond loss of life, the worst impact, the storm destroyed an enormous amount of wealth in a 24-hour period. Such a loss – in kind if not in scale – occurs every time a major storm brings flooding, storm surge, or landslides to one or another part of the state. And those disasters are happening more frequently now, as a warmer atmosphere carries more water and dumps it in more intense storms over our communities and landscapes.

Predicting climate doom has become a cottage industry; we're not interested in that. But economic historians with a very long field of view have studied the challenges that shifts in the climate have presented our civilization in the past.[2] One of the impacts of more frequent disasters is that – other choices aside – we have to spend more resources repairing and replacing lost buildings, infrastructure, businesses, and human resources, just to maintain our current quality of life. Fortunately, we can make choices – building back more resiliently, investing in hazard mitigation before disaster strikes – to reduce the recurring drain on our resources. History also shows that when societies fail to make those investments, the recurring losses are felt by everyone, but most keenly by those living on the economic margins. Smart adaptation policies are an investment in our common good.

North Carolina's energy transition. The cause of increased storms, flooding, and higher storm surge is climate change, driven by human emissions of carbon dioxide and other planet warming gases. This is now beyond serious scientific debate. There are multiple paths to reducing carbon emissions; all require a transition to 'clean' sources of energy and away from coal and gas. The chief obstacle to that transition is not the cost of energy efficiency or renewables, or the availability of technologies; it is a set of legal and institutional structures that suppress competition in energy generation and reward our energy-generating monopolies for the money they spend, not the efficiency and quality of the electric service they provide. Because this report focuses on outcomes, it is neutral with respect to the institutions. But the impacts of past and current energy policy choices show up in several indicators: rising atmospheric concentrations of CO2, rising temperatures, rising sea levels (indicators 1.1 – 1.3); efficiency of new housing stock (indicator 28.1); energy affordability, reliability, and spillover effects (indicators 39.1 – 42.2). To date, implications of other sources of energy aren't showing up in our data, but we discuss them where appropriate: wood pellet harvesting under timber volume (indicator 6.2), animal waste biogas (indicator 11.2), and land used for solar farms (indicator 42.1).

Annual greenhouse gas emissions dropped with coal plant closures in the state in the 2010s (indicator 2.1), proof that progress is possible as long as we hold fast to commitments made towards a carbon neutral future and phase out expensive, polluting energy generation. The crucial forum for decisions about energy policy in North Carolina is the NC Utilities Commission. There, stakeholders of all kinds engage with and make cases for an energy landscape that is affordable for ratepayers today, and resilient, robust, and cost effective for ratepayers in the future.

Household economic outlook. One core measure of well-being is household economic health. That's a function of household income and job opportunities (indicators 26.1 – 26.4), and also housing costs

[2] Bruce Campbell, The Great Transition: Climate, Disease, and Society in the Late-Medieval World, 2016; Geoffery Parker, Global Crisis: Warm Climate Change and Catastrophe in the Seventeenth Century, 2013.

(indicators 27.1 – 27.2), access to medical care (indicator 21.1), transportation options (indicators 30.1, 30.2, 33.1, 33.2), energy affordability (indicator 39.1), and water rates (38.1). In general, North Carolina's households have done well over the last four years, despite the pandemic, and despite tight housing markets in several metro areas. We think that is in part a marker of robust metropolitan economies drawing new residents from across the country and around the world. It is also a reflection of federal and state policies: tax credits during the pandemic, and expansion of Medicare to afford health coverage to 600,000 more North Carolinians.

While the general trajectory has been strong, opportunities are not equally distributed. In the early 2000s, local and state elected officials spoke often about 'two North Carolinas', urban and rural. Our data suggests three: urban centers, exurban, and rural, with blurry boundaries, but different patterns of expense and opportunity in each. To capture this, we include a number of maps that don't show trends but do show important geographic disparities. Where the data allows, we share breakouts for several indicators by race and ethnicity as well. Racial and ethnic disparities usually reflect the deep-rooted legacy of historic racism, embedded in land uses and property values, and in the capacity of local governments to fund public goods based on property taxes. When evaluating trends, we've tried to take a consistent approach: if an indicator is getting better for the 'average' North Carolinian, but racial or ethnic disparities are getting worse, it isn't getting better for the state. In a just, healthy North Carolina, we want to see averages improving *and* racial disparities narrowing over time.

Hurricane Helene Recovery

In September 2024 – six months ago – Hurricane Helene brought historic rainfall, strong winds, and tornadoes to western NC, and left deadly flooding and landslides in its wake. More than 100 people died in North Carolina alone, making it the most lethal tropical system on record in North Carolina.[3] The NC Office of State Budget and Management has estimated the overall damage and needs at more than $59.6 billion across the state.[4] Recovery will require building back better and preparing for future extreme weather.

The quantitative data in the report does not include Hurricane Helene's impact on the natural or built environments. However, discussions of Helene damage and recovery are included in the "recent developments" sections of the indicator discussions. It's also worth noting that the path to recovery and resilience is in effective policy design and implementation. The State of the Environment's policy appendix does not have a Helene specific section, because recommendations for Helene recovery are already reflected in the broader resilience recommendations (M1 though M8).

[3] Corey Davis and Katie Dello, blog: The Weather Year in Review: Heat, Helene, and Weather Whiplash in 2024, North Carolina State Climate Office, January 2025.
[4] NC Office of State Budget and Management, Hurricane Helene Recovery: Revised Damage and Needs Assessment [*Helene DNA 2.0*], December 13, 2024.

OUR CHANGING CLIMATE

North Carolina faces a number of challenges to our environment and public health; of these, the in-state impacts of human-driven global climate change loom largest. North Carolina cannot stop climate change and its impacts alone, but we can do our part to cut emissions and stabilize the rate of change.

Goal 1: Key drivers and effects of climate change in NC slow or stabilize

Trend: Negative

Climate change is driven by emissions around the world and has enormous momentum. Yet, North Carolina can have an outsized influence on our world's future. Our state economy, $767 billion dollars in 2023, is the 11th largest state economy in the United States.[5] Viewed as a separate country, North Carolina would have the 23rd largest economy in the world, ahead of Belgium, Argentina, Ireland, and Sweden.[6] In 2020, North Carolina emitted an estimated 139.45 million metric tons (MMT) of carbon dioxide equivalents (CO2e),[7] or 13.16 tons CO2e per resident (gross emissions). That is below the US per capita rate of 14.2 tons for 2020 but about three times the global rate of 4.5 tons per year.[8] We have more emissions to trim, and more capacity to trim them, than most nations of the world.

In 2019, we began this report noting that we looked forward to the years when key climate indicators stabilize. Although nations around the world have made progress since 2019 in cutting greenhouse gas emissions, all three indicators of climate baselines – global CO2 concentrations, global temperatures, and the rate of sea level rise – are still trending in the wrong direction.

Solutions: To improve climate outcomes, North Carolina should J1, expand the use of renewable energy generation and storage; J2, expand energy efficiency; J3, decline to invest in new gas infrastructure; J4, minimize new natural gas pipelines; J5, modernize the grid to support electrification, especially in the transportation sector; J6, invest in statewide ZEV charging infrastructure; J7, distribute available federal funds to support under-resourced communities; K1, invest in non-highway modes of transportation; K4, integrate carbon reduction and equity into transportation planning; and H2, divert food from landfills to composting. In addition, A6, investing in wetland and forest conservation, offers a way to boost carbon sequestration. To protect North Carolinians from the impacts of rising temperature, North Carolina

[5] US Bureau of Economic Affairs, 2023 Gross Domestic Product by State (SAGDP1), April 11, 2024 (data through 2023).
[6] International Monetary Fund, World Economic Outlook Database, October 2023.
[7] NC DEQ, North Carolina Greenhouse Gas Inventory, 1990-2050, January 2024, Table 1-1, at 14. Factoring in ongoing sequestration from natural and working lands yields a net emission of 91.77 MMT for 2020. The 2020 numbers reflect a temporary drop in economic activity during the pandemic. Official data are delayed for several years, so there are no estimates of actual emissions since 2020. The Inventory predicts gross GHG emissions for 2025 of 147.65 MMT, and net emissions of 100.41 MMT.
[8] Climate Watch, Global Historical Emissions, per capita GHG emissions for 2020, U.S. and World, data source: Global Carbon Project, Supplemental data of Global Carbon Budget 2023 (Version 1.1), 2023, https://doi.org/10.18160/gcp-2023.

should D3, adopt a heat protection standard for workers; J7, spend out IRA dollars in underserved communities; J10, establish state energy assistance for low income households; and L5, protect urban tree canopy.

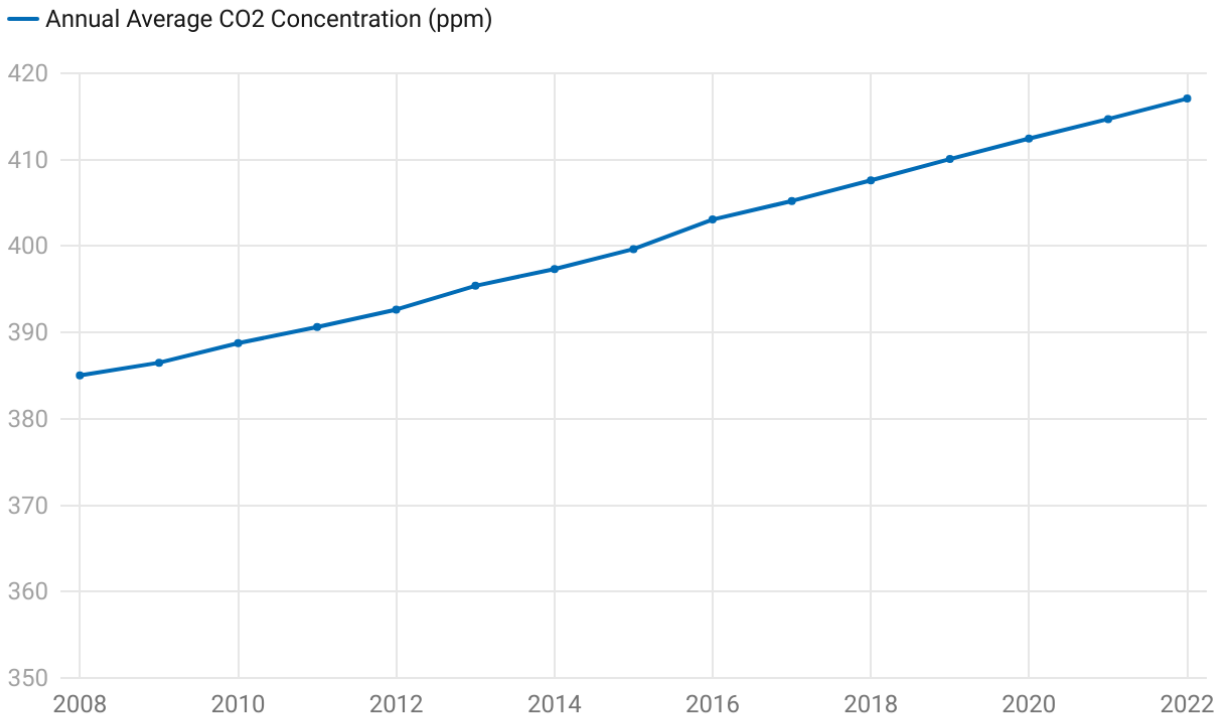
Indicator 1.1: Global average atmospheric CO2 concentrations

Top line: Carbon dioxide stays in the atmosphere for years, so even as global annual emissions have nearly leveled, the concentration of CO2 in the air has continued to rise – we are still adding it faster than natural processes can remove it. The harms of climate change are a direct result of the concentration of CO2 in the atmosphere, so that's a bad trend.

About atmospheric CO2 concentrations: Anthropogenic climate change is driven by emissions of multiple different gases, but excess carbon dioxide is by far the greatest contributor to global warming. Because CO2 belongs to a global atmospheric pool, we examine a data source outside of North Carolina: the National Oceanic and Atmospheric Administration's (NOAA) Global Monitoring Laboratory, which tracks the global atmospheric average CO2 concentration.[9]

[9] X. Lan, et al., Trends in globally averaged CO2 determined from NOAA Global Monitoring Laboratory measurements, version 2024-04, https://doi.org/10.15138/9N0H-ZH07.

Figure 1.1: Atmospheric CO2 Concentrations Per Year (ppm)



Source: NOAA Global Monitoring Laboratory • Created with Datawrapper

Although global carbon emissions fell temporarily during the height of the COVID-19 pandemic, the atmospheric concentration of CO2 continues to rise. Since the 2019 State of the Environment, warnings and calls to action have continued to pile up from climate scientists and international bodies. The Intergovernmental Panel on Climate Changes, in the Summary for Policymakers of its 2023 Synthesis Report, noted that "Observed increases in well-mixed GHG concentrations since around 1750 are unequivocally caused by GHG emissions from human activities over this period." Further, "[i]n 2019, atmospheric CO2 concentrations (410 parts per million) were higher than at any time in at least 2 million years (high confidence), and concentrations of methane (1866 parts per billion) and nitrous oxide (332 parts per billion) were higher than at any time in at least 800,000 years."[10]

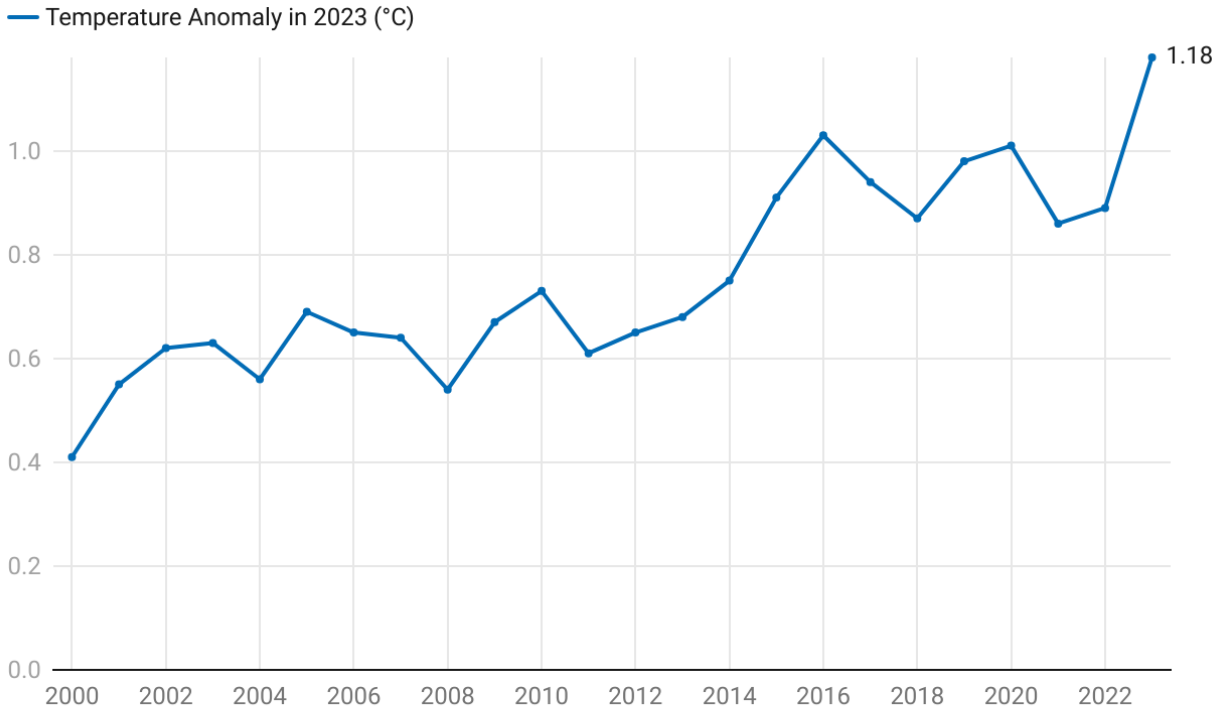
Because it takes time for CO2 to leave the atmosphere, even cutting annual net CO2 emissions to zero ('net zero') will not immediately stop continued warming, but it will slow it. Failing to reach net zero quickly buys a future with increasing climate disruption and economic and human loss. We discuss trends in emissions from North Carolina's major source sectors below, under indicators 11.1 (agriculture), 29.1 (transportation), and 41.1 (energy).

[10] IPCC, Summary for Policymakers, A.1.3, in Climate Change 2023: Synthesis Report, Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [*IPCC 2023 Summary for Policymakers*], 2023, at 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001.

Indicator 1.2: Global annual average temperature increases

Top line: Our indicator for global temperature increase is the difference between the current annual average global temperature and the annual average temperature of the Earth across the 1900s. A wealth of data indicates the global average temperature continues to climb, placing vulnerable populations at greater risk of adverse health effects, among other impacts. Ecological communities are also threatened by rising temperatures. This is a harmful trend.

Figure 1.2: Difference between Actual and Average Global Temperature (°C) is Rising



Source: NOAA National Centers for Environmental Information, Climate at a Glance: Global Time Series • Created with Datawrapper

About rising global temperatures: Climate change manifests, among other impacts, in warmer average temperatures. Temperatures vary seasonally over much of the world and can vary widely from day to day at any specific location. To detect a signal amid all that noise, scientists use a large set of samples to estimate the global annual average temperature. Global surface temperatures have increased faster since 1970 than in any other 50-year period in the last 2000 years.[11] Every year since 2000 has seen an average annual temperature greater than the previous century, with the 'anomaly' – the departure from the average for the 1900s – growing from 0.41 degrees Celsius in 2000 to 1.18 degrees Celsius for

[11] *IPCC 2023 Summary for Policymakers*, at A.1.1.

2023.[12] A key recent regional study found that wet-bulb globe temperature, a metric that better reflects stress on the human body than standard thermometer temperature, has increased in North Carolina and across the southeast, especially near the coast and in inland cities with extensive pavement (Raleigh-Durham and Charlotte).[13]

Rising temperatures will affect everyone, but some populations bear disproportionate risk, including seniors, children, people in poverty, immigrants, and those who are socially isolated. Rural populations may be especially vulnerable to heat, depending on the number of mobile homes and the labor intensity of local agriculture.[14] In urban areas, heat related illness is associated with decreased vegetation (greenness).[15] A study of North Carolina temperature and mortality data from 2000 to 2016 did not find an urban-rural difference in mortality in response to extreme heat; it is harmful to residents everywhere.[16]

National and state level studies have explored the relationship between heat exposure and birth outcomes, showing that heat exposure correlates with worse pregnancy outcomes.[17] Mothers living in urban areas with low greenness and mothers living in rural areas with high greenness both face higher risk of pre-term birth when exposed to extreme heat.[18] Extreme outdoor heat and energy poverty (see indicator 39.1, energy affordability) together create unsafe exposures indoors, contributing to income-based disparities in birth outcomes.[19] A North Carolina study also shows that pregnant women face significant increased risk of severe mental illness during heatwaves.[20]

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[12] NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, retrieved on April 11, 2024.

[13] Kyle Wodzicki et al., Heat Stress Metrics, Trends, and Extremes in the Southeastern United States, Journal of Applied Meteorology and Climatology, October 2024, 63 (10): 1137, https://doi.org/10.1175/JAMC-D-24-0009.1, at 1145. This paper also evaluated three common algorithms for translating readily available climate data to wet-bulb globe temperature – harder to measure directly – and found that the Liljegren algorithm works best in North Carolina.

[14] Margaret Kovach et al., Area-level risk factors for heat-related illness in rural and urban locations across North Carolina, USA, Applied Geography, June 2015, 60:175, https://doi.org/10.1016/j.apgeog.2015.03.012.

[15] National Integrated Heat Health Information System, webpage: About Urban Heat Islands, visited September 8, 2024. See also American Planning Association, webpage: Urban Heat Resilience, visited September 8, 2024.

[16] Hayon Michelle Choi et al., Temperature-Mortality Relationship in North Carolina, USA: Regional and Urban-Rural Differences, Science of the Total Environment, September 2021, 787, https://doi.org/10.1016/j.scitotenv.2021.147672.

[17] Bruce Bekkar et al., Association of Air Pollution and Heat Exposure With Preterm Birth, Low Birth Weight, and Stillbirth in the US. [*Bekkar et al.*], JAMA Network Open, June 2020, 3(6), DOI: 10.1001/jamanetworkopen.2020.8243.

[18] Ji-Young Son, et al., Exposure to heat during pregnancy and preterm birth in North Carolina: main effect and disparities by residential greenness, urbanicity, and socioeconomic status, Environ Res., March 2022, 204 (Pt. C), DOI: 10.1016/j.envres.2021.112315.

[19] Gabriella Meltzer et al., Indoor Temperature and Energy Insecurity: Implications for Prenatal Health Disparities in Extreme Heat Events, EHP, March 2024, 132 (3), https://doi.org/10.1289/EHP13706.

[20] Sarah Ulrich et al., Mental health disparities among maternal populations following heatwave exposure in North Carolina (2011–2019): a matched analysis, The Lancet, January 2025, https://doi.org/10.1016/j.lana.2025.100998 (Acute heatwaves were associated with a 13% higher risk of severe mental illness among pregnant women; prolonged exposure to moderate-intensity heatwaves was associated with 37% higher risk).

Recent developments: In early September 2024, a collaborative of federal agencies, the National Integrated Heat Health Information System (NIHHIS) released the National Heat Strategy, outlining a series of priority actions for federal agencies to prepare for extreme heat waves.[21] The NIHHIS website – Heat.gov – includes a number of mapping and data tools, guides for heat resilience planning, and lists of funding opportunities.[22] At roughly the same time, the Occupational Safety and Health Agency (OSHA) published a proposed new federal standard intended to prevent heat illness among indoor and outdoor workers.[23] In January 2025, the World Meteorological Organization confirmed that 2024 was the hottest year yet of the 21st century, and that the global annual average temperature anomaly exceed 1.5 degrees Celsius for the first time, a bad sign.[24]

Indicator 1.3: Rate of sea level rise

Top line: The Atlantic Ocean is rising relative to North Carolina's coastline. As a result of climate change, the rate of that rise has continued to accelerate over the last five years. This is very much a trend in the wrong direction.

About sea level rise: As global temperature increases, thermal expansion of the oceans and melting of ice reserves is accelerating the speed of sea level rise.[25] In our 2019 report, we cited the National Oceanic and Atmospheric Administration (NOAA)'s 2017 analysis, which estimated a rise of global mean sea level of around 34 cm (13.4 in) by 2050 as an intermediate scenario among a wide range of possible outcomes.[26] In 2022, based on an additional five years of research, NOAA issued updated estimates, noting that "multiple lines of evidence" allow greater confidence in the agency's new 2050 estimate: 30 cm (11.81 in) global rise with as much as an additional 5 cm (1.96 in) from regional conditions along the North Carolina coast.[27]

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[21] National Integrated Heat Health Information System (NIHHIS), National Heat Strategy, 2024 – 2030, September 2024.

[22] NIHHIS, website: Heat.gov, visited September 8, 2024.

[23] 89 F.R. 70698, Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings Rulemaking, August 30, 2024. The OSHA webpage on the proposed rule is here. The comment period closed January 14, 2025, and an informal public hearing has been scheduled for June 16, 2025.

[24] World Meteorological Organization, press release: WMO confirms 2024 as warmest year on record at about 1.55° C above pre-industrial level, January 10, 2025; Raymond Zhong and Bred Plumer, 2024 Brought the World to a Dangerous Warming Threshold. Now What?, New York Times, January 9, 2025.

[25] Sea level rise at a given location reflects a combination of factors, including global average rise, changes in local ocean currents, and ongoing geologic elevation or subsidence. The northern sections of North Carolina's coastline are subsiding, independent of climate change, resulting in higher relative sea level rise there. See, P.L Barnard et al, Future coastal hazards along the U.S. North and South Carolina coasts, November 2024, https://doi.org/10.5066/P9W91314 (including estimates of vertical uplift and subsidence along the North Carolina coast); see also, Jennifer Allen, Sinking land could exacerbate coastal flooding: Study, Coastal Review, March 20, 2024.

[26] NOAA, Global and Regional Sea Level Rise Scenarios for the United States, NOAA Technical Report NOS CO-OPS 083, January 2017, at 23 and 25.

[27] NOAA, Global and Regional Sea Level Rise Scenarios for the United States: Updated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines, NOAA Technical Report NOS 01, 2022, at 60.

NOAA's 2021 analysis also tightens the focus on the local impacts of sea level rise: "By 2050, the expected relative sea level will cause tide and storm surge heights to increase and will lead to a shift in U.S. coastal flood regimes, with major and moderate high tide flood events occurring as frequently as moderate and minor high tide flood events occur today. Without additional risk-reduction measures, U.S. coastal infrastructure, communities, and ecosystems will face significant consequences."[28]

In North Carolina, NOAA tracks tide and water level data at several gauges along the coast. These gauges aren't just measuring sea level rise; they're also showing that the *rate* of sea level rise keeps accelerating. For example, the gauge at Wilmington is experiencing the slowest rise of all the North Carolina gauges at 2.73 mm/year as of 2024 – but that is up from 2.56 mm/year in 2021, and up from 2.30 mm/year in 2019.[29] Similarly, the Oregon Inlet gauge is currently experiencing a rise of 5.56 mm/year, up from 5.32 mm/year in 2019.[30] Sea level rise is accelerating; that is a harmful trend.

We don't include a separate indicator built around ocean acidification, but excess carbon emissions and increasing concentrations in the atmosphere also change the ocean by acidifying it. This poses a threat to multiple habitats and species along our coast, and around the world.[31] Economic risks from acidification include harm to North Carolina's $30 million oyster industry, discussed under indicator 3.1, water quality for shellfish.[32]

Recent developments: The collapse of beach houses in Rodanthe into the Atlantic Ocean draws media attention on a regular basis; debris from the houses spreads up and down the coastline and burdens Hatteras National Seashore.[33] The problem is not limited to Hatteras; a 2020 state analysis identified more than 750 oceanfront structures at risk.[34] In September 2024, an interagency workgroup on threatened structures released a list of proposals to address the problem, ranging from funding to relocate or simply remove threatened structures, to state and local regulatory approaches.[35] In October 2024, the NC Coastal Resources Commission's Science Panel finalized its 2024 Sea Level Rise Science Update, finding that under all climate models, North Carolina can expect roughly a foot of sea level rise by 2050, with the speed of the rise after that determined by near-term emissions reductions.[36]

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[28] *Ibid.*
[29] See, NOAA, Wilmington, NC station ID 8658120.
[30] See, NOAA, Oregon Inlet Marina, NC station ID 8652587.
[31] Emily Hall, et al., Acidification in the U.S. Southeast: Causes, Potential Consequences and the Role of the Southeast Ocean and Coastal Acidification Network [*Hall et al.*], Frontiers in Marine Science, July 2020, 7 (548), https://doi.org/10.3389/fmars.2020.00548.
[32] Frank Graff, Oysternomics: New Report Highlights Economic Impact of Oysters in North Carolina, PBS North Carolina, January 5, 2024 (wild and farmed shellfish contributed $31.7 million to the state economy in 2022).
[33] Catherine Kozak, Superintendent 'disappointed,' unsurprised by 7th collapse, Coastal Review, August 22, 2024.
[34] Gareth McGrath, New report looks for solutions for the hundreds of threatened homes along the NC coast, Wilmington Star News, September 5, 2024.
[35] NC DEQ, Managing Threatened Oceanfront Structures: Ideas from an Interagency Workgroup, August 2024.
[36] NC Coastal Resources Commission Science Panel, North Carolina 2024 Sea Level Rise Science Update, October 2024; Jennifer Allen, Science panel applies 2022 seas level report projections to NC, Coastal Review, October 28, 2024.

The last five years have seen an explosion of research into the process and ecological impacts of sea level rise on terrestrial ecosystems along the North Carolina coastline. A 2024 review article, authored by a who's who of respected North Carolina coastal and freshwater ecologists, offers an excellent overview of the stages that coastal habitats will pass through, from forest to marsh to open water.[37] That transition is already happening; over the last 35 years, 32% of the Alligator River Wildlife Refuge – North Carolina's largest coastal wildlife refuge – has changed land cover, much from 'forest' to 'ghost forest', with changes accelerating following hurricanes or during drought.[38] Because forests (and organic soil wetlands) hold a lot of carbon, this transition has the potential to greatly increase North Carolina's greenhouse gas emissions.[39] That research helped underpin North Carolina's successful application in 2024 for a $421 million Climate Pollution Reduction Grant to conserve and restore pocosins and salt marsh, discussed under indicator 6.3 below.

Other research has noted that sea level rise rates appear significantly higher along some freshwater rivers than suggested by NOAA's buoys and calculations. A study of sea level rise in the New River Estuary found rates triple those at Beaufort.[40] A 13-year study in the Waccamaw National Wildlife Refuge in South Carolina, upstream from the mouths of the Waccamaw and PeeDee rivers, found dramatically higher rates than those measured along the coast.[41] The authors suggest this reflects increased volumes of freshwater flowing down the river as a result of more intense rainfall upstream. We suspect this is a facet of 'compound flooding', discussed below in the context of disaster resilience, indicator 36.3.

Well before sea level rise threatens most buildings along the coast, it will interfere with drinking water wells and septic systems. Drinking water on several barrier islands is pumped from lenses of fresh groundwater that are replenished by rain; sea level rise is gradually squeezing these. Wells where the islands are narrowest and sea level rise is fastest are most vulnerable.[42] A recent economic analysis

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[37] Kiera O'Donnell, et al., Saltwater intrusion and sea level rise threatens U.S. rural coastal landscapes and communities, Anthropocene, March 2024, 45, https://doi.org/10.1016/j.ancene.2024.100427.

[38] Emily Ury, et al., Rapid deforestation of a coastal landscape driven by sea-level rise and extreme events, Ecological Applications, April 2021, 31 (5), https://doi.org/10.1002/eap.2339. But see also, Dan Chapman, Where war looks lost, Mother Nature fights climate change, Coastal Review, January 17, 2024 (discussing $27.5 million Inflation Reduction Act grant to build nature-based solutions to slow forest and wetland loss).

[39] Gillian Gundersen, et al., Long-Term Sediment, Carbon, and Nitrogen Accumulation Rates in Coastal Wetlands Impacted by Sea Level Rise, Estuaries and Coasts, March 2021, 44: 2142, https://doi.org/10.1007/s12237-021-00928-z; Lindsey Smart, et al., Quantifying Drivers of Coastal Forest Carbon Decline Highlights Opportunities for Targeted Human Interventions, Land, July 2021, 10: 752, https://doi.org/10.3390/land10070752; Melinda Martinez, dissertation: State Changes in Coastal Wetlands: Anticipating Transitions and Evaluating the Role of Ghost Forests in Regional Greenhouse Gas Emissions, 2021.

[40] NOAA, A Decade of Water Level Changes along the New River Estuary in North Carolina, USA, NOAA Technical Memorandum NOS NCCOS #258, November 2021.

[41] Thomas Williams and Thomas O'Halloran, Relative Sea Level Rise in the Winyah Bay-Waccamaw River Tidal System Over the Last Thirteen Years, Journal of South Carolina Water Resources, May 2023, 9 (1): 29, https://open.clemson.edu/jscwr/vol9/iss1/4.

[42] Nicholas Fiori and William Anderson Jr, The impact of sea-level rise on saltwater intrusion for barrier-island aquifers in North Carolina, Continental Shelf Research, July 2022, 244: 104789, https://doi.org/10.1016/j.csr.2022.104789.

found that tourists' efforts to avoid a brackish taste in drinking water could cost barrier island economies as much as $232 million annually by 2040.[43] Sea level rise also raises the cost of wastewater management. A 2024 study found that currently, about 14% of Dare County – islands and mainland – may have enough separation between the surface and the groundwater table to allow safe use of conventional septic systems. By 2060, that's likely to drop to 5%, and to 2% by 2100.[44] Many residents are already adapting incrementally to sea-level rise, while acknowledging that will only work for so long.[45] Increased water and wastewater costs will likely prompt some homeowners to sell their homes and move, although a drop in house prices could trap others in place.[46]

Eventually, some coastal communities will be inundated. In general, North Carolinians oppose armoring the coast, and a 2020 study found the general public is much more likely to support taxes that pay for beach nourishment when it is combined with a retreat strategy than when it is combined with a beach armoring strategy.[47] A study of policies that have actually been adopted found that communities that chose armoring tended to have higher home values, higher household incomes, greater population densities, and lower racial diversity. Buyouts (a retreat strategy) were correlated with lower home values, lower household incomes, and lower population density, and high racial diversity.[48] For now, coastal property values continue to rise, thanks to public investment in beach nourishment projects and

[43] J.C. Whitehead et al., Sea-Level Rise, Drinking Water Quality and the Economic Value of Coastal Tourism in North Carolina, Water Resources Research, October 2024, 60 (11), https://doi.org/10.1029/2023WR036440.
[44] Michael O'Driscoll, et al., Rising groundwater levels in Dare County, North Carolina: implications for onsite wastewater management for coastal communities, Journal of Water and Climate Change, July 2024, 15 (8): 3666, https://doi.org/10.2166/wcc.2024.735.
[45] Brianna Castro, Ad Hoc Adaptations to Climate Change in Coastal Communities, Qualitative Sociology, August 2024, 47: 413, https://doi.org/10.1007/s11133-024-09577-7.
[46] Dennis Guignet et al., Sea-level rise, groundwater quality, and the impacts on coastal homeowners' decisions to sell, Journal of Housing Economics, December 2024, 66, https://doi.org/10.1016/j.jhe.2024.102028.
[47] Craig Landry et al., Economic Values of Coastal Erosion Management: Joint Estimation of Use and Existence Values with recreation demand and contingent valuation data, Journal of Environmental Economics and Management, September 2020, 103, https://doi.org/10.1016/j.jeem.2020.102364. See also, Keith Bollt et al., master's project: Examining Local Policy Responses to Changing Hazards in Coastal North Carolina, April 2020 (cataloging local policies).
[48] A.R. Siders and Jesse Keenan, Variables shaping coastal adaption decisions to armor, nourish, and retreat in North Carolina, Ocean and Coastal Management, January 2020, 183, https://doi.org/10.1016/j.ocecoaman.2019.105023; See also, Michelle Covi et al., Sea level rise hazardscapes of North Carolina: Perceptions of risk and prospects for policy, Ocean & Coastal Management, October 2021, 212, https://doi.org/10.1016/j.ocecoaman.2021.105809 (comparing discussions in Dare County and Washington County). For another example of a strong local reaction to the concept of buyouts, see, Trista Talton, Math May Favor Buyout of North Topsail, Coastal Review, July 2, 2019.

tax advantages for high-income property owners.[49] But modeling suggests values will fall rapidly as total inundation approaches.[50]

Goal 2: On track to net zero GHG by 2050

Trend: Negative

This goal has a single indicator: total annual greenhouse gas (GHG) emissions from North Carolina. Because emissions are falling, but neither far nor fast enough, we count this as a mixed trend this year.

Solutions: Along the same lines of Goal 1, to reduce our greenhouse gas emissions, North Carolina should J1, expand the use of renewable energy generation and storage; J2, expand energy efficiency; J3, decline to invest in new gas infrastructure; J4, minimize new natural gas pipelines; J5, modernize the grid to support electrification, especially in the transportation sector; J6, invest in statewide ZEV charging infrastructure; J7, distribute available federal funds to support under-resourced communities; K1, invest in non-highway modes of transportation; K4, integrate carbon reduction and equity into transportation planning; and H2, divert food from landfills to composting. In addition, A6, investing in wetland and forest conservation, offers a way to boost carbon sequestration.

Indicator 2.1: Progress towards the goal of net zero GHG emissions by 2050

Top line: North Carolina is making progress towards the carbon reduction goals articulated by former Governor Roy Cooper, but is not on track to meet them without substantial additional investments and state policy changes, so we rate this trend as showing inadequate progress.

About greenhouse gas emissions: North Carolina cannot solve climate change by ourselves – but we can do our part. Most of the indicators in this report are purely directional, asking whether specific concerns are getting better or worse. For GHG emissions, the direction of the trend isn't sufficient. Emissions are falling; the question is whether they are falling fast enough to avoid crossing devastating planetary boundaries. There are several ways to measure that, all with some degree of uncertainty:

- The Intergovernmental Panel on Climate Change (IPCC) recommends keeping global average temperature change to under 1.5 degrees C (2.7 degrees F), because the odds of irreversible impacts increase above that threshold. Achieving that will require GHG emissions reductions of

[49] Jordan Branham et al., A Wrench in the Machine, Journal of the American Planning Association, November 2022, 90 (1): 18, https://doi.org/10.1080/01944363.2022.2119156 (the federal Coastal Barrier Resources Act, which denies subsidies for development in certain risky areas, is effective specifically because development doesn't make economic sense without the subsidies).

[50] Dylan McNamara et al., Policy and market forces delay real estate price declines on the US coast, Nature Communications, March 2024, 15 (2209), https://doi.org/10.1038/s41467-024-46548-6.

43% from 2019 levels by 2030, and 60% from 2019 levels by 2035.[51] Translated into North Carolina's framework, that is a 52% reduction from 2005 levels by 2030 and a 67% reduction from 2005 levels by 2035.

- The United States does not have a set of reduction targets adopted as federal law. The Biden-Harris administration articulated a portfolio of targets that included reducing US greenhouse gas emissions by 50% from a 2005 baseline by 2030 and achieving a 'net-zero economy' by 2050.[52]

- In SL 2021-165 (H951), the NC General Assembly established targets for the electric-generation sector of a 70% reduction from 2005 levels by 2030, and 'carbon neutrality' by 2050.[53] The legislation does not address emissions from other parts of the state economy and does not count sequestration provided by the state's natural environments.

- In two executive orders (EO 80 and EO 246), Governor Roy Cooper articulated a trajectory of reductions for the state as a whole: 40% below 2005 levels by 2025; 50% below 2005 levels by 2030; and net zero by 2050.[54]

For this indicator, we track North Carolina's progress against the targets articulated in EO 80 and EO 246 because they are state specific and cover all sectors of the state's economy. Both the US Environmental Protection Agency (EPA) and the NC Department of Environmental Quality (NC DEQ) maintain greenhouse gas inventories to track reductions; they differ in minor ways.[55] Throughout this report, we cite both but rely on the EPA estimates for North Carolina, because that allows for direct comparison with EPA's data for other states. It also matches the accounting protocols of the IPCC, allowing for comparisons with other countries' data as well.

Unfortunately, the data indicates that North Carolina is not on track to hit the state emissions reduction targets. For 2021, four years out from the 2025 target, EPA's most recent data suggests that North Carolina's gross GHG emissions had declined by just 20% since 2005. This is not really a surprise; a

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[51] IPCC, AR6 Synthesis Report: Climate Change 2023, Summary for Policymakers, 2023, at 21. Various researchers have converted the 1.5 degree target into a 'global carbon budget' and attempted to allocate emissions on that basis. If one includes historic emissions – something most of the world is inclined to do – the United States has already overspent our share of the global carbon budget. NOAA, blog post: Does it matter how much the United States reduces its carbon dioxide emissions if China doesn't do the same?, Climate Q&A, August 30, 2023; Andrea Thompson and Amanda Montañez, blog post: Wealthy countries have blown through their carbon budgets, Scientific American, April 5, 2023.

[52] The White House, webpage: President Biden's Historic Climate Agenda, visited July 25, 2024. See also, Umair Irfan, Joe Biden's enormous, contradictory, and fragile climate legacy, Vox, July 23, 2024.

[53] SL 2021-165 (H951), Energy Solutions for North Carolina.

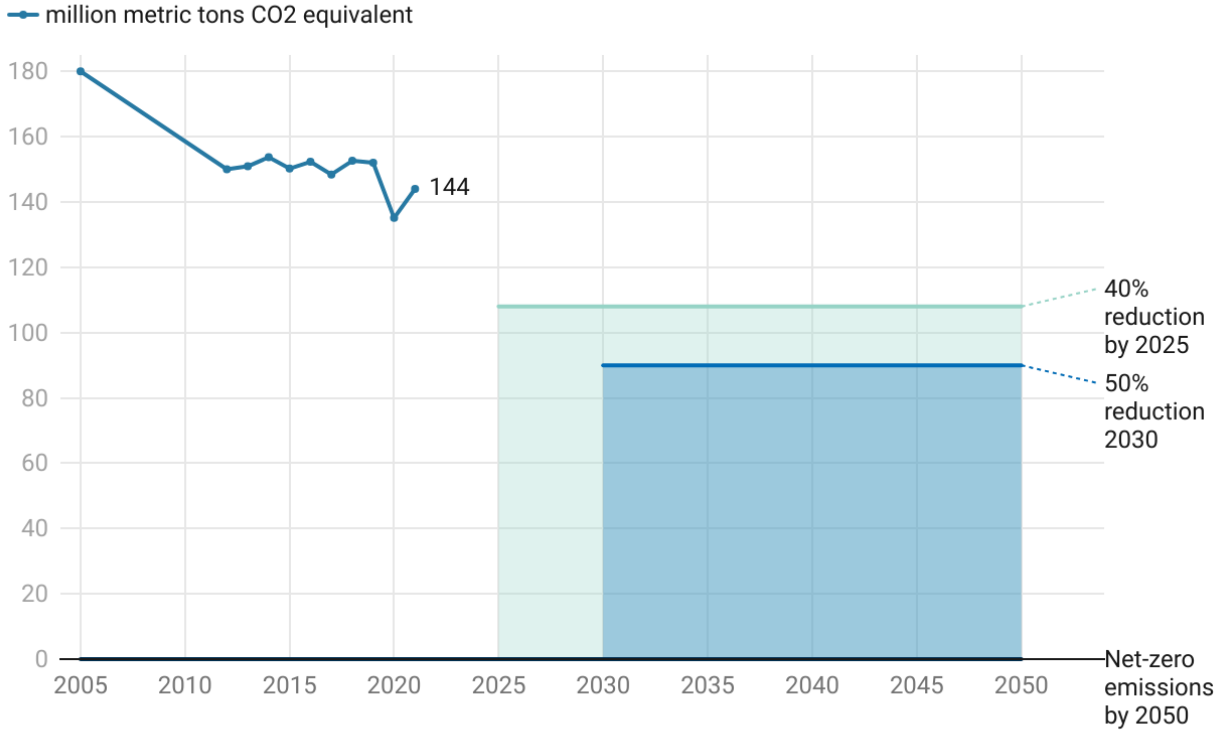
[54] Executive Order 80 (EO 80), North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy, October 29, 2018 (2025 goal); Executive Order 246 (EO 246), North Carolina's Transformation to a Clean, Equitable Economy, January 7, 2022 (2030 and 2050 goals).

[55] NC DEQ, Greenhouse Gas Emissions Inventory (1990-2050), January 2024 [*NC Greenhouse Gas Inventory*]; US EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2022, April 2024; US EPA, web database: Greenhouse Gas Inventory Data Explorer, updated August 18, 2023.

February 2023 analysis by the NC Governor's Office suggested that the state's then-current emissions path would deliver 37% reductions by 2025, 46% reductions by 2030, and 60% reductions by 2050.[56] The report outlined three different baskets of policies that could allow North Carolina to hit the net zero target by 2050: electrification of buildings and transportation; displacement of fossil fuels with decarbonized fuels; and substantial investments in carbon sequestration. North Carolina's state legislature has not enacted any of the proposed policies since then, so there is little reason to expect North Carolina's trajectory has improved. We rate this indicator as showing inadequate progress.

Figure 2.1: Gross State-Level GHG Emissions Will Not Meet State Emissions Reduction Goals

Gross GHG excluding emissions and removals from Land Use, Land-Use Change, and Forestry (LULUCF)



Source: US EPA, Greenhouse Gas Inventory Data Explorer: North Carolina, 1990 - 2021 • Created with Datawrapper

While we address several of the sectoral emissions trajectories under separate indicators, looking at them together is revealing. As a result of the closure of coal-fired power plants, GHG emissions from the power generating sector dropped in the 2010s; meanwhile, as growth in North Carolina has continued to sprawl, emissions from the transportation sector have continued to climb. We address these

[56] Office of Governor Roy Cooper, North Carolina Deep Decarbonization Pathways Analysis [*Deep Decarbonization report*], February 2023, at 13.

respectively under indicators 41.1 (power sector) and 29.1 (transportation). Building efficiency is addressed under indicator 28.1, and emissions from agriculture under indicator 11.1.

Table 2.1: North Carolina GHG Emissions by Economic Sector, MMT CO2 eq.

	Transportation	Electric power industry	Industry	Commercial	Agriculture
2005	55	77	18	10	12
2012	50	58	13	12	12
2013	51	57	14	12	12
2014	52	58	13	12	11
2015	53	53	13	13	11
2016	55	52	14	14	12
2017	56	48	14	13	12
2018	57	49	14	14	12
2019	58	47	14	14	12
2020	52	38	14	13	12
2021	57	41	14	13	11

Gross emissions total presented in this table excludes emissions and removals from Land Use, Land-Use Change, and Forestry (LULUCF).

Source: US EPA, Greenhouse Gas Inventory Data Explorer: North Carolina, 1990 - 2021 • Created with Datawrapper

NC DEQ's estimates of gross emissions track EPA's estimates fairly closely, but the state also estimates the annual sequestration of carbon in wetlands, forests, and other working lands: between 45 and 48 MMT CO2e per year. Sequestration isn't driving reductions, but, if you remove it from the state's annual gross emissions, North Carolina's 2005 starting point looks smaller, and the progress we have made looks a bit larger, a 32% reduction by 2021, which is how the state inventory portrays the record.[57] Natural and working lands are making a contribution to net emissions reductions; we discuss the role of wetlands, including peatlands and saltmarsh, under indicator 6.3.

If there's a bright spot to North Carolina's GHG emissions reductions to date, it is that the state has achieved them while growing the economy and the state's population. North Carolina's gross annual per

[57] *NC Greenhouse Gas Inventory*, at 1 and 69.

capita GHG emissions have dropped from 20.8 metric tons (t) CO2e in 2005 to 13.6 t in 2021. That's below the national average of 14.9 t, but still several times the global average of 4.7 t per person.[58]

NORTH CAROLINA'S WATERS

This section surveys trends in the health and sustainability of North Carolina's waters: coastal (Goal 3), freshwater (Goal 4), and underground (Goal 5). The four indicators we rely on for the coast – closures of shellfish waters, extent of submerged aquatic vegetation, shoreline management, and fish populations – all point in the wrong direction. The picture for inland surface waters and groundwater is better, despite data gaps and reasons for caution.

Goal 3: North Carolina's coasts and estuaries are healthy, resilient, and home to abundant fish and shellfish populations

Trend: Negative

When asked in polls what we love about our state, North Carolinians routinely point to our coasts. The state's 20 coastal counties are home to roughly 800,000 people, 7% of the state's population.[59] For those of us who live there, the coast is home, work, and daily community. For many more, our coasts are associated with family trips, memories of beaches, swimming, and fishing, and a culture of slower time, seafood, and salt water. Yet, parts of North Carolina's coastline face heavy growth pressures, even as sea level rise and more extreme storms challenge existing infrastructure and communities.

The guiding document for managing North Carolina's coastal resources is the Coastal Habitat Protection Plan, first adopted in 2005, with strategic updates in 2010, 2016, and an amendment in 2021.[60] The document identifies six habitat types that are under particular pressure and are also vital to the region's economy, culture, and quality of life: the water column, shell bottoms, submerged aquatic vegetation, wetlands, soft bottom, and hard bottom.[61] A joint 2017 study by North Carolina Sea Grant and the Nicholas Institute at Duke University found that North Carolina's coastal environment – termed the 'ocean economy' in the report – contributed $2.1 billion to state GDP in 2013, and over 43,000 jobs.[62]

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[58] Our World in Data, website: Per Capita CO2 emissions, updated June 20, 2024 (but data cited is for 2021). For comparison, the global per capita average of 4.7 t is in the ballpark of the national figures for Argentina (4.2 t), Chile (4.3 t), France (5.2 t), the United Kingdom (4.7 t), and Denmark (4.9 t).

[59] Calculated from OSBM, webpage: 2023 Certified County Population Estimates, July 1, 2024.

[60] NC DEQ, NC Coastal Habitat Protection Plan, 2021, 2016, 2010, 2005. By statute, NCGS 143B-279.8, the plan must be approved by the NC Coastal Resources Commission, the NC Environmental Management Commission, and the NC Marine Fisheries Commission.

[61] NC DEQ, DCM, webpage: Coastal Habitat Protection Plan, visited October 9, 2024.

[62] Jane Harrison et al., North Carolina's Ocean Economy: A First Assessment and Transitioning to a Blue Economy, UNC-SG-17-02, January 2017.

The six habitats underpin this economy and are thus of vital economic and social as well as environmental importance.

Between them, the four indicators we track in this section, as well as indicators in other parts of this report, cover most of the six habitat types or major threats to them. Shellfish closures (indicator 3.1) indicate problems with water quality, especially polluted runoff. Bulkheads lower the coast's resilience, reflecting wave energy back into vulnerable seagrass beds and soft bottom, while living shorelines (indicator 3.2) offer protection for retreating wetland vegetation as the sea rises. Submerged aquatic vegetation (indicator 3.3) is one of the six habitats. Fish stocks (indicator 3.4) reflect the changing state of biodiversity in our waters. (The status of forested coastal wetlands and salt marshes is discussed under indicator 6.3, wetlands). The living shoreline/ bulkhead ratio is a data gap; the other three indicators all show negative trends, adding up to a negative trend for this goal overall.

Solutions: To protect our coast, North Carolina should C1, expand oyster mariculture; C2, promote living shorelines over bulkheads; C3, improve maintenance of coastal stormwater measures; C4, implement the Coastal Habitat Protection Plan; and A5, enact state wetlands protections.

Indicator 3.1: Percentage of shellfish waters open to harvest

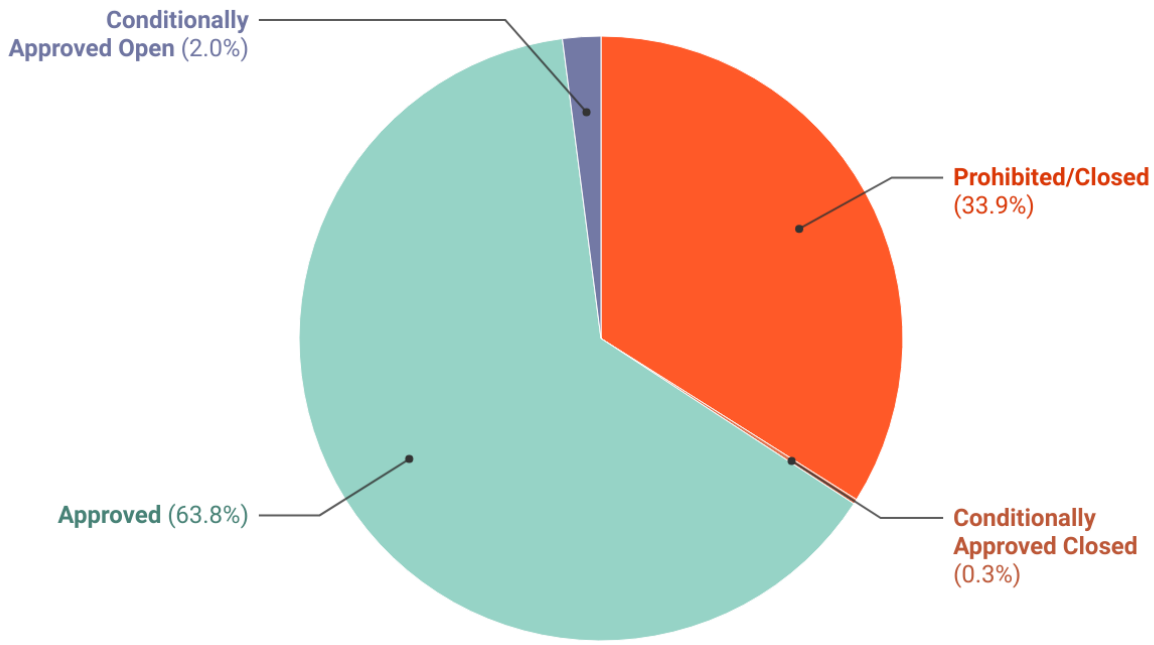
Top line: As sea level rises, estuaries are more likely to be contaminated by stormwater runoff. As a proxy for coastal water quality, this indicator evaluates the change in relative areas closed to shellfish harvesting by the state Division of Coastal Management. The data shows that overall, more shellfish waters have been closed to harvesting over time, indicating a negative trend in coastal water quality.

About shellfish waters: North Carolina needs clean coastal waters to sustain our commercial and recreational fisheries, attract tourists to beaches, and support a high quality of life for residents. Bacteria present a particular problem, presenting a threat to swimmers and to the shellfish industry, since oysters are filter feeders that take in dirty water and can become contaminated with fecal bacteria that make them unsafe to eat and illegal to harvest and sell. For decades, the state has sampled shellfish for bacteria; that data is a key source for understanding trends in coastal water quality.[63] Researchers have found that bacteria are carried into coastal waters in higher concentrations by stormwater runoff.[64] Over time, as sea level rises, more frequent inundation of stormwater infrastructure seems likely to increase bacteria contamination of our estuaries.[65] The indicator we use to evaluate coastal

[63] Natalie Chazal et al., Assessing the utility of shellfish sanitation monitoring data for long-term estuarine water quality analysis, Marine Pollution Bulletin, June 2024, 203, https://doi.org/10.1016/j.marpolbul.2024.116465.
[64] See, for example, Charles Humphrey, Jr. et al., Assessment and Mitigation of Fecal Bacteria Exports from a Coastal North Carolina Watershed, Hydrology, July 2023, 10 (7): 156, https://doi.org/10.3390/hydrology10070156 (two-year study of Boat House Creek in the White Oak basin found most samples exceeded EPA thresholds for bacteria, and were carried into the creek by stormwater runoff from developed surfaces).
[65] M. M. Carr et al., Fecal Bacteria Contamination of Floodwaters and a Coastal Waterway from Tidally-Driven Stormwater Network Inundation, GeoHealth, April 2024, 8 (4), https://doi.org/10.1029/2024GH001020.

water quality is the trend in the relative areas Division of Coastal Management (DCM) has closed to shellfish harvesting because of pollution from stormwater runoff.

Figure 3.1: 2023 Status of Shellfish Waters



Source: Shared by staff from Shellfish Sanitation and Recreational Water Quality Section, NC DEQ Division of Marine Fisheries • Created with Datawrapper

North Carolina classes all shellfish waters in one of four categories based on a running five years of data: approved (open except in emergencies); conditionally approved open (default open, but is closed temporarily after rains); conditionally approved closed (default closed, but is occasionally opened when extended dry weather makes it safe); and prohibited (always closed).[66] For the purposes of this indicator, we count conditionally approved open waters as open, and conditionally approved closed waters as closed. Over the course of the last 10 years, there have been sharp spikes in the acres of closed shellfish waters to a relative high in 2017 and to a smaller extent in 2020 and 2022.[67] These spikes reflect decisions by the state agency, driven by legislative budget cuts, to administratively close waters to shellfishing in order to redirect limited water sampling resources. The FY18-19 budget bill included a special provision to re-establish a northern coastal laboratory so these acres can eventually be sampled

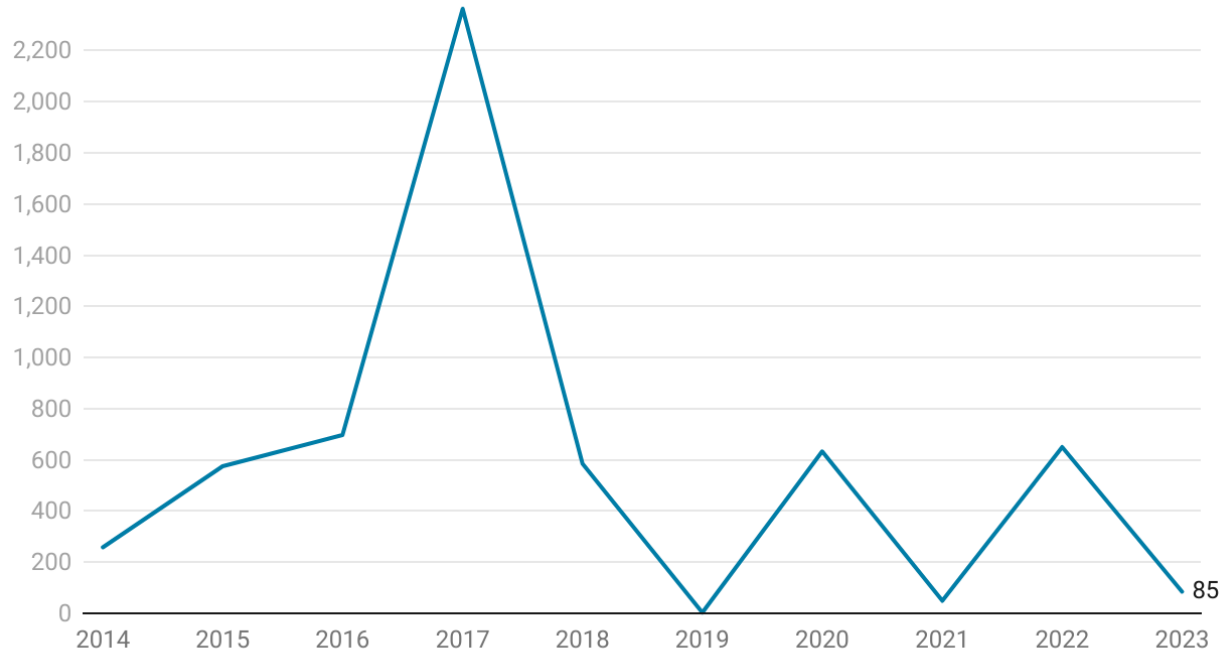
[66] North Carolina follows the guidelines of the Interstate Shellfish Sanitation Conference, published by US Food and Drug Administration, National Shellfish Sanitation Program, Guide for the Control of Molluscan Shellfish - 2023 Revision. The protocols for managing shellfish beds start at page 43; the four part classification of beds is at 49. FDA updates these guidelines every year; the full series is available here.

[67] Data received through email from Andrew Haines, Shellfish Sanitation and Recreational Water Quality Section, NC DEQ Division of Marine Fisheries, May 2024.

and reopened.[68] Setting aside the administrative closures, the overall trend shows gradually declining coastal water quality taking a toll on the shellfish resource, a negative trend.

Over the longer term, North Carolina shellfish have been identified as particularly vulnerable to ocean and estuarine acidification.[69] Better managing runoff pollution would help our shellfish endure changes in water acidity.

Figure 3.1: Net Change in Closed Shellfish Waters (acres)



For readability, this chart omits the 2015 administrative designation of over 314,710 acres as closed, but retains that year's net closure of 575 acres for actual conditions.

Source: Shared by staff from Shellfish Sanitation and Recreational Water Quality Section, NC DEQ Division of Marine Fisheries • Created with Datawrapper

Recent developments: State and federal elected leaders, scientists, businesses, and advocates have elevated oyster restoration as a priority for North Carolina's coast. A stakeholder process hosted by the NC Coastal Federation published versions of a 'North Carolina Oyster Blueprint' in 2003, 2008, and 2015.[70] An updated edition was released in April 2021, with goals running through 2025.[71] In the

[68] SL2018-5 (S99), Appropriations Act of 2018, Joint Conference Committee Report, at D6.
[69] *Hall et al.*
[70] NC Coastal Federation, Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action 2003-2008; NC Coastal Federation, The Oyster Restoration and Protection Plan for North Carolina, A Blueprint for Action 2008-2014, December 2008; NC Coastal Federation, The Oyster Restoration and Protection Plan for North Carolina, A Blueprint for Action 2015-2020, March 2015.
[71] NC Coastal Federation, The Oyster Restoration and Protection Plan for North Carolina: A Blueprint for Action, 2021-2025, April 2021. A shorter summary is here.

meantime, partners succeeded in restoring nearly 140 million oysters by 2020, with the capacity to filter 7 billion gallons of water every day.[72] Responding to a mandate from the NC General Assembly, in 2018 the NC Policy Collaboratory published a strategic plan focused on leasing and other legal reforms needed to promote shellfish mariculture as an industry in coastal waters.[73] Reform legislation was signed into law in June 2019 and has been gradually implemented by the NC Marine Fisheries Commission in the years since.[74] Today there are just under 500 shellfish leases covering a little less than 2,500 acres in North Carolina's estuaries.[75] Since 2020, the NC Coastal Federation has been working towards the goal of restoring 500 acres of protected oyster sanctuaries in Pamlico Sound.

Indicator 3.2: Ratio of living shorelines: bulkhead projects

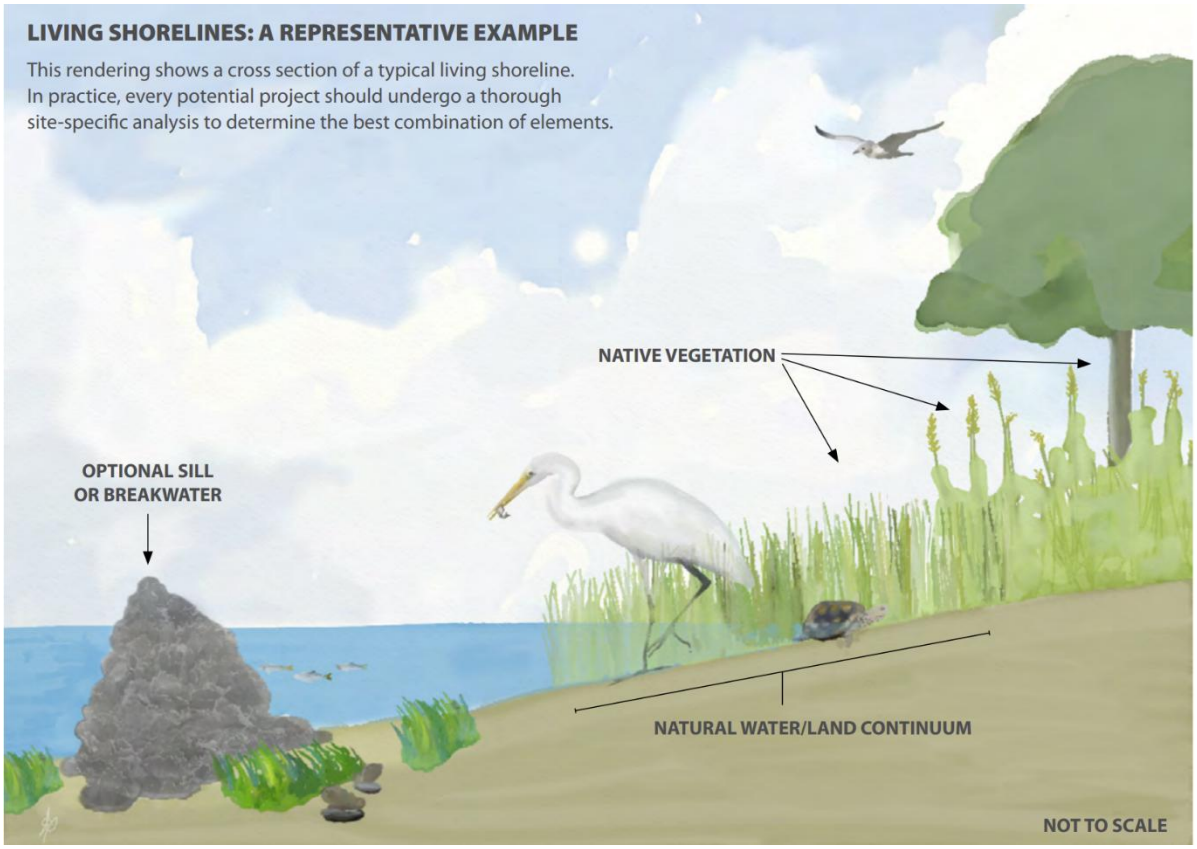


Image from Restore America's Estuaries. 2015. Living Shorelines: From Barriers to Opportunities. Arlington, VA. Used with permission.

[72] NC Coastal Federation, webpage: 50 Million Oyster Initiative, visited Sept. 5, 2021.
[73] NC Policy Collaboratory, North Carolina Strategic Plan for Shellfish Mariculture: A Vision to 2030, 2018. A short policy brief on the strategic plan is here.
[74] Kirk Ross, Cooper Signs Shellfish Aquaculture Bill, Coastal Review, June 24, 2019.
[75] NC DEQ, Division of Marine Fisheries, webpage: Shellfish Lease and Franchise, Table 1: Shellfish Lease Type and Total Number and Acreage In North Carolina, visited January 18, 2025.

Top line: Living shorelines are better for the health of the estuary and will protect estuarine shores from sea level rise longer than bulkheads. But while the absolute number of living shoreline projects has grown, it's become nearly impossible to estimate either the relative length of bulkheads and living shorelines along North Carolina's estuaries, or the annual changes. We label this a data gap, but note that a modest investment of state resources could provide a data series with real value for managing North Carolina's coast.

About bulkheads and living shorelines: As sea level rises, property owners are tempted to protect their properties for a time by reinforcing them against storms and waves. However, hard surfaces – armoring or bulkheads – reflect wave energy back into the near-shore environment, increasing erosion nearby and wiping out undersea vegetation.[76] North Carolina has been a leader among Atlantic Coast States in resisting beach armoring, but landowners along the sounds have had an easier time getting permission to install bulkheads. There is a better alternative: 'living shorelines', a mixture of wood, rock, or oyster shell slopes with marsh grasses growing on and around them.[77] Living shorelines absorb rather than reflect wave energy, and a robust literature has confirmed that they are effective at slowing erosion.[78] Research into coastal impacts from Hurricanes Florence and Matthew found that living shorelines resisted erosion better than bulkheads and natural shorelines, and needed less repair.[79] Living shorelines provide fish habitat comparable to natural shorelines, and, over time, can match natural shoreline's ability to trap carbon, nitrogen, and phosphorus.[80] Additional research has found that living shorelines are much cheaper than bulkheads to install and to maintain.[81]

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[76] Samantha Burdick, master's thesis: Effects of Bulkheads on Salt Marsh Loss: A Multi-decadal Assessment Using Remote Sensing, 2018.

[77] Laura Exar, master's thesis: An Analysis of Material Use in Living Shorelines, April 25, 2024.

[78] *Salt Marsh Action Plan*, at 8. See also, NOAA, website: Understanding Living Shorelines, June 19, 2017; Mariko Polk and Devon Eulie, Effectiveness of Living Shorelines as an Erosion Control Method in North Carolina, Estuaries and Coasts, July 2018, 41: 2212, https://doi.org/10.1007/s12237-018-0439-y.

[79] Mariko Polk et al., Coastal resilience surges as living shorelines reduce lateral erosion of salt marshes, Integrated Environmental Assessment and Management, January 2022, 18 (1): 82, https://doi.org/10.1002/ieam.4447 (Florence and natural shorelines); Caster Smith, et al., Living shorelines enhanced the resilience of saltmarshes to Hurricane Matthew (2016), Ecological Applications, April 2018, 28 (4): 871, https://doi.org/10.1002/eap.1722 (Matthew and bulkheads).

[80] Carter Smith et al., Living Shorelines Equal or Outperform Natural Shorelines as Fish Habitat Over Time: Updated Results from a Long-Term BACI Study at Multiple Sites, Estuaries and Coasts, September 2024, 47: 2655, https://doi.org/10.1007/s12237-024-01429-5 (fish habitat); Amanda Guthrie, Ecological equivalency of living shorelines and natural marshes for fish and crustacean communities, Ecological Engineering, March 2022, 176, https://doi.org/10.1016/j.ecoleng.2021.106511 (fish and shellfish habitat); R. M. Chambers, Comparison of nutrient accrual in constructed living shoreline and natural fringing marshes, Ocean & Coastal Management, January 2021, 199, https://doi.org/10.1016/j.ocecoaman.2020.105401 (capture of carbon, nitrogen, and phosphorus).

[81] Rachel Gittman and Steven Scyphers, The cost of coastal protection: A comparison of shore stabilization approaches, Shore & Beach, 2017, 85:4, at 19; see also, Sarah Ball Gonyo et al., The Cost of Shoreline Protection: A Comparison of Approaches in Coastal New England and the Mid-Atlantic, Coastal Management, March 2023, 51 (2): 145, https://doi.org/10.1080/08920753.2023.2186091 (study of projects in Mid-Atlantic and New England found living shorelines are cheaper than bulkheads).

In 2019, to track the trends for North Carolina's shoreline, we used an imperfect substitute: an estimate of the ratio of linear feet of bulkheads permitted annually to linear feet of living shorelines built annually. We found that the Wilmington District of the US Army Corps of Engineers had authorized 5,651 linear feet of bulkheads in 2018, while conservation advocates had installed 3,098 linear feet of living shorelines, for a ratio of 0.548. More recent data has not been reported in linear feet, so for this update we are comparing the number of authorized projects.

In 2023, the Wilmington District authorized 19 bulkhead projects and only 6 Living Shoreline Projects, an improvement compared to the 2020 ratio, 24 authorized bulkhead projects to 3 living shoreline projects. Although it is good to see the number of living shoreline projects grow, there is not enough information to assign a trend. Ultimately the best indicator will be the miles of 'hard' vs 'soft' shoreline along North Carolina's coast. A 2022 survey of coastal states reported that North Carolina and New Hampshire had the least hardening as a percentage of shoreline length (8%), but that doesn't capture a trend, and data are inconsistently updated.[82] Researchers have demonstrated the feasibility of assessing the prevalence of bulkheads and living shorelines based on satellite photographs of North Carolina's central coast, but there is no estimate for the coast as a whole.[83] So, we label this indicator a data gap this year. This is one area where a modest investment of resources could establish a data series with profound value for state resource management.

Why haven't living shorelines been more widely deployed? A 2021 study, data from a 2014-2016 coastwide survey of waterfront residents, found that bulkheads tended to be clustered, and that many respondents said they know wetlands are valuable, but chose bulkheads over living shorelines because their neighbors had bulkheads.[84] In a 2023 survey of property owners along the Neuse in Craven County, roughly 90% of respondents said they have observed bluffs along the estuary retreating, but lean towards installing bulkheads and riprap rather than living shorelines.[85] Both bulkheads and living shorelines have mostly been built in higher income communities; deployment is not correlated with vulnerability to inundation.[86] Changes in state rules in 2019 made it easier for individual landowners to install a living shoreline.[87] But for projects longer than 500 feet, bulkheads are still much easier to get

[82] Riordan Correll-Brown et al., Shifting Baselines May Undermine Shoreline Management Efforts in the United States, Policy and Practice Reviews, January 2022, 4, https://doi.org/10.3389/fclim.2022.719109. The 2024 NC Salt Marsh Action Plan includes an estimate that 826 miles (6.5%) of North Carolina's shoreline is hardened, but that is ultimately based on 2012 aerial imagery, now over a decade old. *Salt Marsh Action Plan*, at 8.

[83] Hannah Sirianni et al., Shoreline classification maps and ground truth data for the Neuse River Estuary, North Carolina, Scientific Data, January 2024, 11 (103), https://doi.org/10.1038/s41597-024-02954-5.

[84] Rachel Gittman et al., Reversing a tyranny of cascading shoreline-protection decisions driving coastal habitat loss, Conservation Science and Practice, July 2021, 3 (9): e490, https://doi.org/10.1111/csp2.490.

[85] Hannah Sirianni, Bluff retreat in North Carolina: harnessing resident and land use professional surveys alongside LiDAR remote sensing and GIS analysis for coastal management insights, Anthropocene Coasts, May 2024, 7 (11), https://doi.org/10.1007/s44218-024-00043-z.

[86] Nicholas Fairbairn and Kathryn Lienhard, master's thesis: Determining Living Shoreline Distribution in North Carolina: A Mixed Methods Study, Spring 2023.

[87] Jennifer Allen, Living Shoreline Permitting Made Easier, Coastal Review, March 1, 2019 (discussing Coastal Resources Commission revision to 15A NCAC 7H .2700 to create a general permit for riprap sills).

permitted.[88] A recent analysis from the Nicholas Institute at Duke University offers a set of recommendations for simplifying permitting for living shorelines to make them a more viable alternative.[89]

Indicator 3.3: Area of submerged aquatic vegetation.

Top line: North Carolina has the second largest acreage of submerged aquatic vegetation (SAV) on the East Coast, but that acreage is steadily decreasing. Sediment and excessive nutrients flowing into the estuaries have reduced water clarity, starving the undersea grasses for light. While efforts are underway to establish ongoing monitoring, the best data currently available shows a decrease in acreage from the early 2000s to the mid-2010s, so we're counting this indicator as trending in a negative direction.

About SAV: North Carolina's 2016 Coastal Habitat Protection Plan described submerged aquatic vegetation (SAV), one of six vital coastal habitat types, as 'underwater gardens'.[90] The CHPP's 2021 Amendment notes that SAV "is critical for healthy fisheries, such as shrimp, blue crab, red drum, and flounder"; SAV also helps slow waves, stabilize shorelines, clean estuarine waters, and sequester carbon.[91] A 2016 analysis estimated the annual economic value of the ecosystem services provided by healthy SAV at $7,700 per acre.[92] A more recent analysis has suggested that a 5% loss in SAV would impose an economic loss of $8.6 million in 2019 dollars.[93]

SAV requires shallow, clear, sediment-free water, protected from strong waves.[94] SAV is composed of a variety of species; the balance between them in any given location reflects the species' different tolerances for salinity, water depth and turbidity.[95] Overall, the scientific literature consistently identifies

[88] See, for example, Matthew Shudtz, Overview of Living Shoreline Permitting and Regulatory Review in North Carolina, Georgia, Florida, and Mississippi, IRIS in Focus, September 2024 (discussing case study of effort to permit a two-mile long living shoreline at Marine Corps Air Station Cherry Point).
[89] Chloe Wetzler et al., Challenges and Solutions to Permitting Living Shoreline Projects, Nicholas Institute CC BY-NC-4.0, November 2024. See also, Shana Jones and J. Scott Pippin, Towards principles and policy levers for advancing living shorelines, Journal of Environmental Management, June 2022, 311, https://doi.org/10.1016/j.jenvman.2022.114695 (concluding that the most effective policies to promote living shorelines are targeted prohibitions on bulkheads where erosion is modest, where there are 'gaps' between existing seawalls, and/or where a maximum percentage (10% to 25%) of the shoreline is already armored).

[90] NC DEQ, NC Coastal Habitat Protection Plan, 2016, at 25-26.
[91] NC DEQ, Coastal Habitat Protection Plan 2021 Amendment [*CHPP 2021 Amendment*], 2021, at 3 and 60.
[92] NC DEQ, NC Coastal Habitat Protection Plan Source Document [*CHPP Source Document*], 2016, at 90.
[93] Sara Sutherland, et al., Economic Valuation of Submerged Aquatic Vegetation in the Albemarle-Pamlico Estuary, 2021, at 4.
[94] US Army Corps of Engineers, Environmental Factors Affecting Coastal and Estuarine Submerged Aquatic Vegetation (SAV), 2021, at 5 - 10; *CHPP 2021 Amendment*, at 43.
[95] Noah Gwynn, master's thesis: The Effects of Salinity, Depth, and Turbidity on Submerged Aquatic Vegetation (SAV) Abundance in Eastern North Carolina, May 2021.

light penetration as the driver of SAV abundance and distribution.[96] The largest threat to SAV across the coastal zone is turbidity in estuarine waters, caused by a combination of sediment and algal growth in the water column. That algal growth is fed by excessive nitrogen and phosphorus from nearby coastlines and, transported by rivers, from further inland.[97] Large construction projects, such as NCDOT's proposed Mid-Currituck Bridge, can have locally significant impacts as a result of direct physical displacement and shading of SAV.[98] Other sources of physical disturbance include certain fishing gear; dredging; marina siting and use (propeller scarring); and hardening of shorelines with bulkheads that reflect wave energy back onto estuarine bottoms.[99] Climate change is expected to worsen these threats, with sea level rise deepening the estuaries (which means less light will reach the bottom), heavier rains increasing transport of inland pollution to the estuaries, and stronger waves battering seagrass in the sounds.[100]

North Carolina has the second-largest acreage of SAV on the East Coast, but it is likely that this represents a loss of as much as 50% of the historic extent.[101] In 2019, we quoted the CHPP's analysis, based on data from 1981-2011, that North Carolina had 196,000 acres of SAV.[102] In 2021, based on data 1981-2015, scientists estimated that North Carolina had just over 191,000 acres of SAV.[103] This appears to reflect new information from a 2013 aerial survey, showing a loss of over 5,600 acres of SAV.[104] Worse, the data suggests a much larger area of continuous seagrass beds became patchy by 2013. Declines were highest in regions of the coastline with dense residential and commercial development.[105] We rate this updated information as showing a trend in the wrong direction.

[96] Natasha Biarrieta, master's thesis: SAVE Currituck Sound: Submerged Aquatic Vegetation Evaluation in Currituck Sound, NC [*Biarrieta*], May 2020; see also Reid Corbett et al., SAVE Currituck Sound: Submerged Aquatic Vegetation Evaluation in Currituck Sound, NC, NCDOT Project 2018-05, June 2020.
[97] *CHPP 2021 Amendment*, at 82-86.
[98] *Biarrieta*, at 59.
[99] *CHPP 2021 Amendment*, at 89-90.
[100] *CHPP 2021 Amendment*, at 86-87. See also, Colleen Brown et al., 20-year water quality analysis reveals spatial variability and long-term changes at North Carolina's Masonboro Island National Estuarine Research Reserve, Estuarine, Coastal, and Shelf Science, December 2024, 309, https://doi.org/10.1016/j.ecss.2024.10893.7 (over the last two decades, major storms have brought weeks of low oxygen and low salinity in their wake); Hans Paerl et al., Recent increases of rainfall and flooding from tropical cyclones (TCs) in North Carolina (USA): implications for organic matter and nutrient cycling in coastal watersheds, Biogeochemistry, June 2023, 164: 257, https://doi.org/10.1007/s10533-021-00770-2 (storm related discharges account for more than 50% of annual carbon, nitrogen, and phosphorus loads into the estuaries).
[101] *NC CHPP Source Document*, at 97.
[102] *NC CHPP Source Document*, Table 4.3, at 89.
[103] *CHPP 2021 Amendment*, Table 4.5, at 89
[104] Don Field, et al., Metric Report: Extent of Submerged Aquatic Vegetation, High-Salinity Estuarine Waters (Revised), May 2021.
[105] *Ibid*, at 13.

Recent developments: CAMA 2021 amendments identify multiple strategies to conserve and restore SAV.[106] The CHPP Steering Committee holds periodic meetings and receives updates on the implementation of the CHPP 2021 Amendment recommendations.[107]

The Albemarle-Pamlico National Estuarine Partnership (APNEP) conducted additional SAV surveys in 2019-2020. In 2021, APNEP folded SAV into its Integrated Monitoring Plan, rotating among four sub-regions annually rather than the entire region every six or seven years.[108] Research conducted by the UNC Institute of Marine Sciences for APNEP has derived chlorophyll-a and turbidity thresholds that are protective of SAV in high salinity and low salinity zones of the Albemarle and Pamlico estuaries.[109] The study found that in high-salinity habitats, a threshold annual median value of 15 ug/L of chlorophyll-a and turbidity of 5 NTU would provide sufficient water clarity. Achieving that would require numeric water quality standards of 30 ug/L of chlorophyll-a and 10 NTUs for turbidity, well below current state water quality standards of 40 ug/L for chlorophyll-a and 25 NTU for turbidity.[110]

Indicator 3.4: Populations of 25 fish species

Top line: In 2023, more fish stocks were evaluated as depleted, and the number of stocks considered recovering or viable did not change. The COVID-19 pandemic interrupted sampling in 2020 and 2021, but based on the available data, we assign this indicator a negative trend.

About fish stocks: Given the importance of saltwater fish for recreational and commercial fishing, state and federal fisheries managers take great effort to track stocks. Saltwater fish depend on a wide variety of habitats, ranging from estuarine marshes for reproduction, to hardshell or rock bottoms, to seagrass beds or reefs. State and federal agencies classify the status of each species as depleted, of concern, unknown, recovering, or viable for a sustained fishery.[111] Their data tracks changes in the distribution of 21 species (including various subpopulations) and one species complex.[112]

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[106] *CHPP 2021 Amendment*, at 96-97.

[107] The CHPP Steering Committee does not have its own website, but announcements, agendas, and minutes of Steering Committee meetings can be found here on the NC DEQ website.

[108] APNEP, Program Evaluation Narrative, 1 July 2017- 30 September 2022, March 2023, at 5.

[109] Nathan Hall, Evaluation of water clarity metrics for protection of submerged aquatic vegetation in the Albemarle-Pamlico Estuarine System, March 2022.

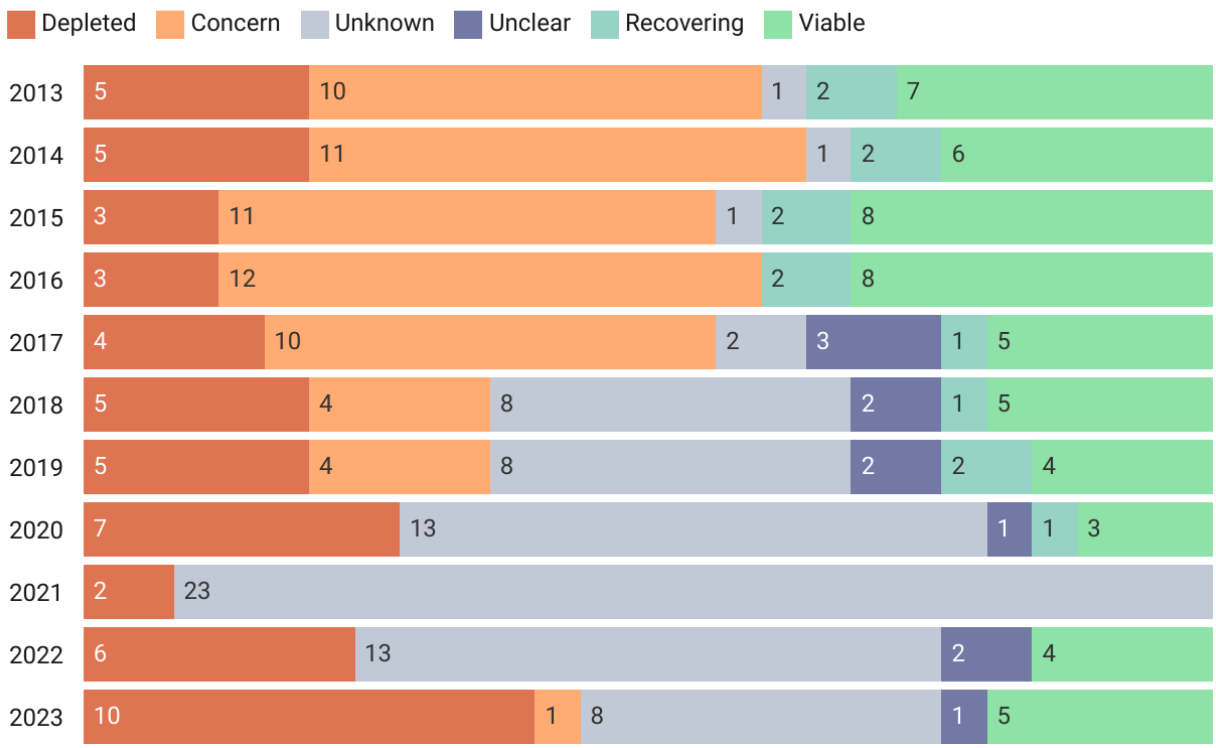
[110] *Ibid*, at 8. The study determined that the model will need to be recalibrated to provide meaningful targets for low salinity SAV.

[111] *CHPP Source Document*; Atlantic State Marine Fisheries Commission, ASMFC Stock Status Annual Overviews (2013-2023), available here; NC DEQ DMF, 2023 FMP Review, August 2024; NC DEQ DFM FMP Annual Updates (2013-2023), available here.

[112] The various species, populations, and complexes managed by NC DEQ DMF are: Bay scallops, Blue crab, River Herring (Albemarle), Striped bass (Albemarle), Striped bass (Central/southern), Striped bass (Ocean), Shrimp, Southern Flounder, Spotted Seatrout, Striped Mullet. Species, populations, and complexes managed jointly by state and federal entities are: American Shad, Atlantic Croaker, American Eel, Atlantic Menhaden, Black Drum, Black Sea Bass (N. of Hatteras), Black Sea Bass (S. of Hatteras), Bluefish, Gag, Oysters, Red Drum, Reef Fish (Snapper-Grouper Complex), Spot, Summer Flounder, and Weakfish.

The COVID-19 pandemic disrupted several sampling programs in 2020 and portions of 2021. Since sampling and management returned to normal in 2022 and 2023, more species have been categorized as depleted, with no change in stocks categorized as recovering or viable. This is a bad trend. Research suggests that, beyond questions of overfishing and habitat management, climate change is putting pressure on key species, some through warmer water temperatures and others through ocean acidification.[113]

Figure 3.4: Status of 25 Fish Stocks, 2013 - 2023



Source: NCDEQ 2016 Coastal Habitat Protection Plan - Source Document, Atlantic State Marine Fisheries Commission (ASMFC) Stock Status Annual Overviews (2013-2023), NC DEQ DMF - 2023 Fisheries Management Plan Review, NC DEQ DMF FMP Annual Updates (2013-2023) • Created with Datawrapper

Recent developments: The state Division of Marine Fisheries (DMF) and the North Carolina Marine Fisheries Commission (MFC) are responsible for managing marine and estuarine fisheries within the state's waters. Since 1997, DMF has prepared an annual Fishery Management Plan for review and adoption by the Commission to maintain consistent and sustainable fish stocks for both commercial and recreational fishing. DMF limits fishing seasons, sets minimum size limits, and defines creel limits for

[113] Stephen Midway et al., Southern Flounder: Major Milestones and Remaining Knowledge Gaps in their Biology, Ecology, and Fishery Management, Reviews in Fisheries Science & Aquaculture, May 2024, 32 (3): 450, https://doi.org/10.1080/23308249.2024.2341017 (warmer temperatures are likely interfering with the sex balance of the southern flounder population); *Hall et al.* (ocean acidification threatens blue crab and shellfish populations); NOAA, A Climate Vulnerability Assessment for Fish and Invertebrates in the United States South Atlantic Large Marine Ecosystem, August 2023, especially pages 28 – 31.

individual fish species in amendments to management plans. In the case of the Southern flounder, for example, DMF limited the 2022 recreational fishing season to just one month, with a restriction of one fish per person per day.[114] In 2021, the recreational flounder season was only two weeks (four fish per fishermen per day).[115] Commercial licensees were allotted 70% of the total harvest and recreational licensees were allotted 30%. The management plan proposed to reset the allocation each year to reach 50/50 split of the fishery by 2026, with overharvesting deducted from the allowed catch in subsequent years. As a result, in 2024 there was no recreational season for Southern flounder.[116] The decision was politically controversial and has led the MFC to propose moving the 50/50 split date up to 2025.[117]

Goal 4: North Carolina's waters support a full complement of animal and plant species, and ecological communities

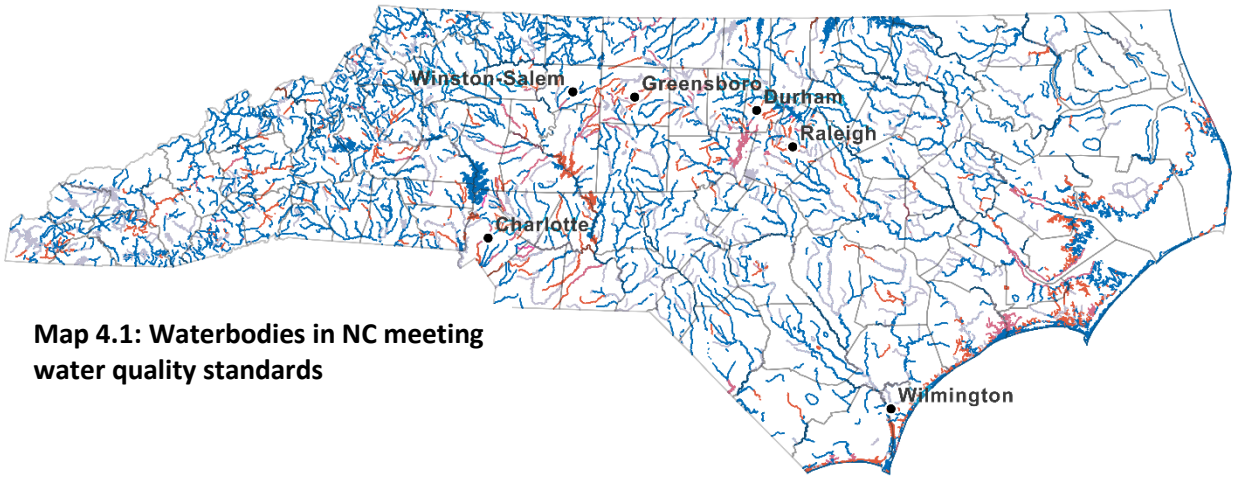
Trend: Positive

We rely on three indicators to track trends in surface water quality and river health. First (indicator 4.1), we consider the percentage of water bodies supporting their designated uses as fish habitat, recreational waters, or drinking water sources. Second, we consider trends in the health of benthic organisms (indicator 4.2), many of which are particularly sensitive to fluctuations in water quality. Finally, we examine the degree to which river flows have been altered (indicator 4.3) by withdrawals and impoundments. Comprehensive data is lacking for flow alteration, but experts working on river flows have identified a pattern of significant improvements over the last ten years, discussed in more detail below. Altogether, although many waters are threatened by pollution, we rate North Carolina as showing some progress in restoring the health of our rivers and lakes.

Solutions: North Carolina can improve surface water quality and flows through all the water solutions, G1 – G14; and also through F3 curbing air emissions of PFAS. Authorizing local governments to adopt water-neutral growth ordinances, L6, is a key step to managing surface water flows sustainably.

[114] DMF, N.C. Southern Flounder Fishery Management Plan Amendment 3, June 2022.
[115] DMF, press release: 2021 recreational flounder season announced, March 4, 2021.
[116] Martha Quillin, NC won't allow recreational flounder fishing this year. What does that mean for anglers?, The News & Observer, June 2024.
[117] Gareth McGrath, Frustrated fishermen: NC recreational anglers go political in fight over flounder closure, Star News, June 30, 2024; Brenna Flanagan, Local rep, fishermen call on state to improve fishery management after flounder season cancellation, Port City Daily, August 11, 2024; Staff report, Draft plan would evenly shift southern flounder catch quotas, Coastal Review, March 14, 2025.

Indicator 4.1: Percentage of waterbody segments 'fully supporting' their assigned uses



Map 4.1: Waterbodies in NC meeting water quality standards

Map shows waterbodies in North Carolina that meet water quality standards (blue), do not meet standards but have a cleanup plan (purple), or are impaired without a plan (red), from NC DEQ's 2022 list of impaired waters. Created using data from NC DEQ, Division of Water Resources.

Top line: Every two years, North Carolina submits an 'Integrated Report' to the EPA that summarizes water quality data from across the state. For the last several cycles, only about 12% of all waterbodies have met all quality standards (other than mercury contamination). We count this stability as a positive trend but note that monitoring has some significant spatial gaps, with the majority of water segments going untested, as shown in the table below. Also, degradation that may result from recent rollbacks to wetlands, stormwater, and wastewater rules has not yet had time to show up in the data.

About water quality assessments: The federal Clean Water Act aims to keep our rivers, lakes, and estuaries fit for all the ways we use them and – at a minimum – safe for fish and wildlife. To that end, state environmental managers regularly test the quality of surface waters across the state, dividing waterbodies and rivers into 'segments' to better indicate where problems are. North Carolina has identified over 13,000 segments, but the state only collects data on between 3,000 and 4,000 of these in any given 5-year period.[118] The state is required to report the results of those tests to the US EPA every other year in a document called the 'Integrated Report'. The Integrated Report, based on the rolling previous five years of data, identifies waters that are not meeting water quality standards (these are called 'impaired') and describes the condition of all other waters as well. In any given five-year span,

[118] NC DEQ, DWR, Consolidated Report on Basinwide Water Resources Management Plans & Hydrologic Models, November 1, 2024, at 8; NC DEQ, DWR, Annual Report to the General Assembly Environmental Review Commission, July 2017 to June 2018, at 22.

many waters are not sampled, and many smaller streams have never been checked. Still, the list of impaired waters is the most comprehensive indicator we have of the health of our surface waters.

In 2019, we presented data from the 2018 impaired waters list as a baseline and did not assign a trend. For this update, we compare data from the 2018, 2020, 2022, and 2024 lists, as per Table 4.1. All waters in the state are listed as impaired for mercury in fish tissue, so we exclude that from our analysis of trends, as otherwise that blanket impairment would mask all other improvements or declines in water quality. The percentage of waterbody segments supporting their uses varies from biennium to biennium, but has stayed stable, which we count as positive.

Table 4.1: Waterbody Segments Fully Supporting Assigned Use is Stable Over Time

	2014	2016	2018	2020	2022
Met all quality standards (other than mercury contamination)	1,713	1,735	1,676	1,701	1,718
Not meeting standards, with clean up plan	148	160	153	185	187
Not meeting standards, no clean up plan	1,113	1,151	1,162	1,223	1,212
No data	9,718	9,678	9,690	9,767	9,816
Percentage of segments that fully support their assigned uses	**12.8%**	**12.9%**	**12.5%**	**12.5%**	**12.6%**

Source: Data request to DEQ, DWR, Modeling and Assessment Branch. • Created with Datawrapper

Recent developments: The leading causes of impairment in North Carolina's waters are turbidity (from suspended sediment), chlorophyll-a (from excessive nitrogen and phosphorus pollution), low dissolved oxygen (from too much organic waste entering our rivers), and bacteria.[119] Most wastewater treatment plants adhere to their permit limits, though some poorly maintained wastewater systems suffer from frequent pipe breaks and spills.[120] Major sources of pollution include runoff from ongoing development,

[119] See, NC DEQ, DWR: interactive map: NC 2022 Integrated Report, visited September 4, 2024.
[120] See, Delaney Eyermann, Sewer overflows in north Carolina reflective of aging infrastructure, growing population & extreme weather events, WRAL, May 20, 2024; NC DEQ keeps an online map of reported sanitary sewer overflows, NC DEQ, interactive map: NC DWR Sanitary Sewer Overflow Reports, visited April 4, 2025.

developed landscapes, hog waste sprayfields, and poultry manure land application fields.[121] Over the last five years, the state legislature has repeatedly weakened requirements for developers to control runoff from new development, and has prevented DEQ from requiring even modest improvements of animal agriculture.[122] At the same time, more intense rain events – a manifestation of climate change – are flushing more pollution from uplands into our rivers, lakes, and estuaries. River advocates in nearly every basin can point to specific streams or river segments that have been harmed by these changes, but the biennial statewide assessment is not so fine-grained and has yet to reflect these losses.

Near future: Given the crucial role natural wetlands play in filtering out pollutants, the loss of state and federal wetlands protections (discussed under indicator 6.3) is likely to degrade inland and estuarine water quality over time. A decision by the state legislature to restore some measure of wetland protections could head off those impacts.

Indicator 4.2: Number of waterbody segments impaired for benthic health

Top line: 'Benthic' communities are the made up of organisms that live on the bottom of streams: crayfish, mussels, worms, and aquatic insect larvae. Data across the last four assessment cycles indicates a slow but steady increase in the number of stream segments with degraded benthos. That's a negative trend.

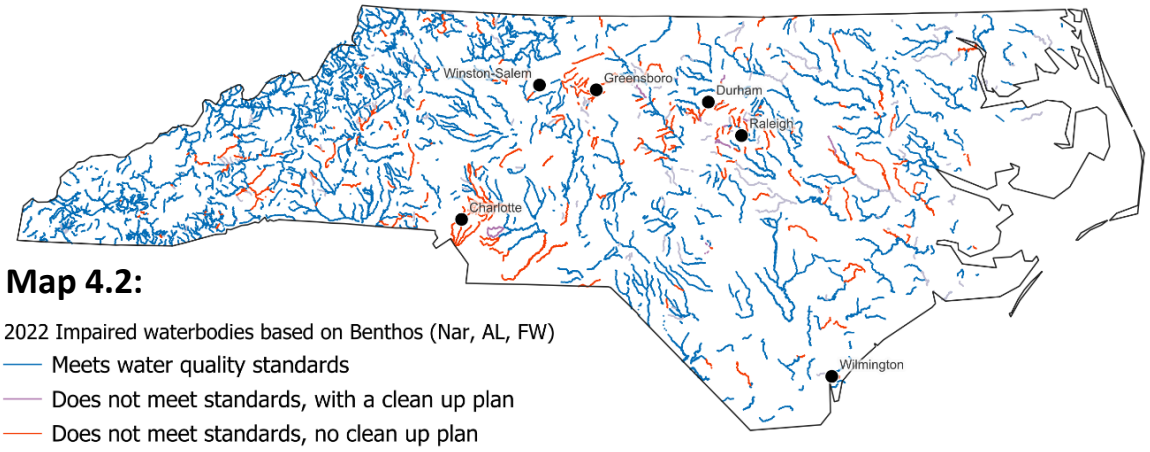
About benthic health: A key indicator of a stream's biological health is the vitality and diversity of the organisms that live on the bottom – the 'benthic' life, which also comprises the base of the aquatic and nearby terrestrial food web. State scientists assess benthic health along with sampling for other water quality data, and segments of streams, rivers, lakes, and estuaries can be labelled as impaired for poor benthic communities.[123] Indeed, some 303 of the segments listed as impaired in 2022 were listed for benthic impairment.[124] Many of those have been so listed for years.

[121] NC DEQ, DWR, Consolidated Report on Basinwide Water Resources Management Plans & Hydrologic Models, November 1, 2024 (discussing the draft plans for the Yadkin Pee-Dee, Broad, and Cape Fear basins); NC DEQ, DWR, White Oak River Basin Plan, 2021; NC DEQ, DWR, Pasquotank River Basin Plan, 2021; NC DEQ, DWR, Chowan River Basin Plan, 2021.

[122] Adam Wagner and David Raynor, NC Lawmakers have steadily changed rules, added protections that help poultry industry, Charlotte Observer, December 8, 2023 (deference to animal agriculture); Lynn Bonner, Overriding Gov. Cooper's vetoes, the NC legislature makes it harder to vote, easier to pollute, NC Newsline, October 11, 2023 (stormwater rules, animal agriculture); Kirk Ross, Fine Print in budget worries environmental advocates, Coastal Review, December 12, 2021 (waiver of 401 certification).

[123] NC DEQ, Benthic Macroinvertebrate Community Assessment Program: Quality Assurance Project Plan, 2017.

[124] NC DEQ, 2022 Integrated Report Online Map, filtered by parameter, visited May 2024.



Map created using data from the 2022 Integrated Report from NC DEQ, Division of Water Resources.

The map above shows segments considered impaired based on benthos outcomes in 2022. Runoff from the cities and roadways of the Piedmont crescent has scoured local streams (purple and especially red), devastating stream health in those watersheds. Healthy streams (blue) are clustered in the mountains and the Sandhills, and a few are scattered across other rural counties. In fact, recent academic research confirms high quality benthic communities in the mountains.[125] For this indicator, we consider the total number of segments listed as impaired for poor benthos, across the 2018, 2020, 2022, and draft 2024 assessment cycles, as per table 4.2 below, which shows a steady increase in the number of impaired segments, a negative trend. Benthic impairment is the second most commonly exceeded parameter and the rate of change outpaces other water quality criteria.

Table 4.2: Number of Water Segments Listed Impaired for Benthic Impairment is Rising

Year ▲	Number of Segments
2018	267
2020	277
2022	303
2024	313

Source: NC DEQ Integrated Report Draft 2024, Integrated Report Online Maps 2022-2018 • Created with Datawrapper

Recent developments: Just as water quality is threatened when stormwater is poorly managed, so is benthic health. Increased runoff can scour the life from streambeds, giving rise to 'urban stream

[125] Sierra Benfield and Shem Unger, Assessment of lotic macroinvertebrate assemblage in the Oconaluftee River basin in Cherokee, North Carolina, Aquatic Sciences and Engineering, 2023, 38(4), https://doi.org/10.26650/ASE20231285476

syndrome'.[126] Most state stormwater rules and local ordinances require detention and release of stormwater. That can lower peak flows downstream, but if the stormwater is released rather than being retained on site, the total volume of runoff remains high relative to natural conditions, and erodes stream banks and beds, destroying benthic habitat. For that reason, retention of stormwater to match a site's pre-development volumes of runoff is better. In 2007, Congress required this pre- and post-development 'hydrologic matching' for federal facilities.[127] State rules allow hydrologic matching as a target for stormwater management, but to date, no state program has required new development to meet a hydrologic matching standard.

Last fall, Hurricane Helene damaged many streams in western North Carolina, blowing out streambanks and burying many habitats in silt.[128] It may be months before scientists have a sense of the lasting impacts of the landslides, flooding, and debris on benthic health – but it is likely that many of North Carolina's highest quality streams will take years to recover.

Indicator 4.3: River flows are not excessively modified

Top line: Objective data is lacking on trends in modification of river flows, but the restoration of flows in the context of dam relicensing over the last decade leads us to rate river flows as trending in the right direction for this update.

About river flows: River flows – high and low – are a key determinant of river health.[129] Thanks to state legislation enacted in 2010, North Carolina's Department of Environmental Quality (DEQ) models flows, withdrawals, and discharges in 11 of the state's 17 river basins.[130] As a result of the same legislation, a team of scientists studied North Carolina's waters and concluded that the cumulative removal of more

[126] Anthony Joseph Roux, dissertation: An Examination of the Impact of Urbanization on Stream Biodiversity and Ecosystem Function [*Roux*], 2022; Roger von Haefen et al., Estimating the benefits of stream water quality improvements in urbanizing watersheds: An ecological production function approach [*von Haefen et al.*], PNAS, April 2023, 120 (18), https://doi.org/10.1073/pnas.2120252120.

[127] US EPA, webpage: Stormwater Management for Federal Facilities under Section 438 of the Energy Independence and Security Act, updated June 24, 2024, discussing PL 110-140 (2007), §438.

[128] Connor Griffin, 'Drastically different': How Helene upended ecology and habitat of Western North Carolina, Asheville Citizen-Times, October 25, 2024; Lindsey Liles, What Helene Means for Trout Fishing – and Other Aquatic Life – in Western North Carolina, Garden & Gun, October 29, 2024.

[129] For a recent overview, see Luke Bower et al., Quantifying flow-ecology relationships across flow-regime class and ecoregions in South Carolina, Science of the Total Environment, 2021, 802, https://doi.org/10.1016/j.scitotenv.2021.149721.

[130] SL2010-143, codified at N.C. Gen. Stat. § 143-355(o). The state has models for the Broad, Cape Fear, Catawba, French Broad, Lumber, Neuse, New, Roanoke, Tar-Pamlico, Watauga, and Yadkin-PeeDee basins. Michelle Raquet & Neela Sarwar, presentation: Overview of Basin Planning & Hydrologic Models, EMC Water Allocation Committee, May 8, 2024, slide 14. The state lacks models for the Hiawassee, Little Tennessee, and Savannah basins because there are insufficient stream gauges in those mountain watersheds. It lacks models in the Chowan, Pasquotank, and White Oak in part for lack of data, and in part because significant portions of those basins are tidal-influenced, and the existing models have not been adapted to handle tides.

than 10% to 20% of river flows would jeopardize river health.[131] That has not been translated into any regulatory requirement. One logical way to bridge from the scientific conclusions to monitoring trends would be for agency staff periodically to run each of the 11 models, updated to include new withdrawals and transfers, to determine whether any river segments in those 11 models experience more than 10% or 20% cumulative flow alteration under low-flow conditions. However, that is not built into the agency's current workplan. Moreover, the hydrologic models are not kept current; some are approaching a decade old and have not been updated.

In the absence of a periodically updated assessment or index of flow alteration, we fall back on the observations of experts in the field. Over the last decade, the continued increase of impervious surface around North Carolina's metropolitan areas has altered some local flow patterns for the worse. But, on a larger scale, numerous dams have passed through the Federal Energy Regulatory Commission's (FERC's) dam relicensing process over the same period.[132] Thanks to the steady engagement of river advocates, many of these relicensing processes have resulted in improved dam release protocols and flow management to protect in-stream species and uses. Thus, we rate the overall trend for the last decade positive.

Since FERC licenses last 30 to 50 years, and most of North Carolina's dams have already passed through relicensing, we do not expect relicensing to sustain improvement in this indicator over the next decade.

Recent developments: The 2013 scientific report on ecological flows noted that coastal rivers function somewhat differently than piedmont and mountain rivers. In response, the Albemarle-Pamlico National Estuary Project (APNEP) convened an 'ecological flows action team' to study coastal rivers. That team published a pilot study of the Trent River in 2022, finding that reductions in river flow could pave the way for saltwater intrusion, which could drive significant changes in vegetation and fish habitat at even very small increases in salinity (2 to 6 parts per trillion).[133] The APNEP management plan for 2025-2030 includes continued work to identify the river flows needed to sustain the health of the estuary.[134]

Goal 5: Ground water resources are being used sustainably

Trend: Positive

Over the last two decades, scientists and water managers have become increasingly explicit about the link between groundwater and surface waters: many kinds of wetlands are pathways for groundwater

[131] North Carolina Ecological Flows Scientific Advisory Board, Recommendations for Estimating Flows to Maintain Ecological Integrity in Streams and Rivers in North Carolina, November 2013.
[132] Twelve of North Carolina's 22 FERC-licensed dams have had their licenses renewed since 2010; only one more, the Spencer Mountain dam on the South Fork of the Catawba, is up for relicensing before 2030. FERC, excel file: Active Licenses, October 7, 2024.
[133] Michael O'Driscoll et al, Developing Coastal Plain Ecological Flow Guidance in the Albemarle-Pamlico Basin: Trent River Study, December 2023. See especially the discussion of policy implications, pp.81-83.
[134] APNEP, Comprehensive Conservation and Management Plan, 2025-2030, January 17, 2025.

recharge, and groundwater supplies the base flow for most of our streams and rivers during drier months of the year. So, although we include separate goals for surface and groundwater, the two are part of a single hydrological system.

Across the nation, American communities are withdrawing groundwater – for agriculture, industry, and residential uses – faster than it can naturally recharge.[135] North Carolina is generally blessed with abundant rainfall and groundwater resources, but there are limits to how much groundwater can be sustainably withdrawn. Moreover, climate change is expected to increase evapotranspiration and decrease shallow groundwater storage.[136] For this goal, we track two indicators: groundwater levels in the Coastal Plain, as represented by conditions in the two aquifers under the greatest stress from heavy use; and well levels across the state generally. State and federal scientists collect data on groundwater levels across the state. Data from the coastal aquifers is assessed regularly, and shows stable levels, with some warning signs for the future; data from the Piedmont and mountains are not systematically assessed. Nonetheless, shortages do not appear to be looming, so we assign this goal a positive trend for this update.

Solutions: To maintain and improve the health of ground water, especially as people move to the state, North Carolina should G2, conduct periodic and systematic analysis of groundwater levels. We can also mitigate sources for groundwater contamination by G8, improving land application of municipal wastewater; G11, establishing a permanent septic repair fund for low-income households, and E3, banning fire-fighting foams.

Indicator 5.1: Groundwater levels in the Central Coastal Plain Capacity Use Area are stable

Top line: thanks to effective state regulation, levels of crucial coastal aquifers are stable, and we rate this as a positive trend – though growth in parts of the region will put increased pressure on the resource over time.

About the coastal aquifers: In the late 1990s, scientists and water managers realized that overpumping was dropping water levels in two economically vital aquifers in the North Carolina coastal plain. The Cape Fear and Black Creek aquifers are two of a series of water-bearing rock layers, arranged like a layer cake under a 13-county region of eastern NC. Given declining water levels, users depending on these aquifers were on track to pump their wells dry. Worse, overpumping the aquifers could cause the porous rock to condense, permanently reducing its capacity to store water. Hoping to forestall a crisis, in 2003 the NC Environmental Management Commission (EMC) established the Central Coastal Plain

[135] Leonard Konikow, Groundwater depletion in the United States, 1900–2008, 2013, U.S. Geological Survey Scientific Investigations Report 2013−5079. *See also*, Mira Rojanasakul, Christopher Flavelle, Blacki Migliozzi, and Eli Murray, America is using up its groundwater like there's no tomorrow, New York Times, December 29, 2023.
[136] Laura Condon, et al., Evapotranspiration depletes groundwater under warming over the contiguous United States, Nature Communications, 2020, 11:873, https://doi.org/10.1038/s41467-020-14688-0.

Capacity Use Area (CCPCUA), requiring users pumping from these two aquifers to cut their withdrawals by 25% in 2008, another 25% in 2013, and – if necessary to stop further declines – a final 25% in 2018.[137]

Our indicator is the stability of water levels in the Cape Fear and Black Creek aquifers. By 2018, DEQ found that water levels had stopped dropping and even recovered a bit.[138] Some users reduced their water use; some communities switched to other aquifers or invested in new infrastructure to withdraw surface waters.[139] Overall, the CCPCUA is a regulatory success story, and the trend for this indicator is positive.

Recent developments: DEQ's last free-standing report on the CCPCUA was issued in 2019; since then, the agency has folded information on the status of water levels into the agency's overall Groundwater Management Branch annual reports.[140] In November 2021, the EMC unanimously readopted the CCPCUA rules with minor changes to provide authority for the ongoing permits and conditions.[141]

Over time, two factors will put increasing pressure on the coastal aquifers and on the regulatory system that protects them. State hydrogeologists are monitoring saltwater intrusion on the eastern edge of the aquifers, where sea level rise could force brackish groundwater up into the zone that communities are using.[142] In addition, a number of coastal plain communities continue to increase in population. As those new residents become customers of local water systems – or sink wells of their own – cumulative withdrawals could once more tip the crucial aquifers into an imbalance.

Indicator 5.2: Percentage of groundwater wells in state network with declining levels for more than 3 years in a row

Top line: While North Carolina has substantial data on groundwater levels in the Piedmont and mountains, it cannot be easily manipulated to yield a view of trends. We do not assign a trend to this indicator.

About Piedmont and mountain groundwater levels: Most of North Carolina's other groundwater resources are not so well studied as those in the Central Coastal Plain Capacity Use Area. In the Piedmont and the Mountains, groundwater is typically pumped from fractures in bedrock. State

[137] 15A NCAC 02E .0501 - .0507.
[138] NC DEQ, DWR, Ground Water Management Branch, Central Coastal Plain Capacity Use Area Assessment Report, June 2018.
[139] NC DEQ, DWR, Ground Water Management Branch, Central Coastal Plain Capacity Use Area Status Report, September 2019. *See also*, Stephanie DeVries, presentation: CCPCUA: A water withdrawal permit program for sustainable groundwater use in the Coastal Plain Aquifer, EMC: Water Allocation Committee, March 13, 2024.
[140] See, for example, NC DEQ, DWR, Groundwater Management Branch, Monitoring Well Network 2023 Annual Report, November 2023. All branch reports are housed at North Carolina Groundwater Publications.
[141] 15A NCAC 02E .0500 et seq.
[142] *Idem*, at 22-26. See also, Kristen McSwain et al., Hydrogeology, hydraulic characteristics, and water-quality conditions in the surficial, Castle Hayne and Peedee aquifers of the greater New Hanover County area, North Carolina, 2012–13, U.S. Geological Survey Scientific Investigations Report 2014–5169, September 2014.

hydrogeologists have been slowly expanding the network of groundwater monitoring stations. The network now consists of 699 wells at 235 locations, heavily weighted to the Coastal Plain.[143] In theory, one could track the percentage of these wells that show steady declines over several years not accounted for by drought. In fact, state staff watch this data for odd signals, to identify places where shortages may be looming. However, distinguishing the signal from the noise for each well takes regression analysis, and the state does not conduct or publish those systematically. Our efforts to obtain bulk download of annual data to conduct the analysis ourselves have been unsuccessful. This is not a true data gap – the data is robust – but we cannot draw any conclusions about it.

Goal 6: Landscapes support economy and quality of life

Trend: Mixed

Over the last four hundred years, North Carolina's natural landscapes have experienced enormous changes, accelerated by development patterns over the last four decades. Rapid land conversion has increased pressure on forests and wetlands that provide raw materials, support carbon sequestration, keep pollution out of our water supplies, and sustain biodiversity and human health. This goal values conservation of open spaces, forests, and wetlands. We evaluate the state's trajectory based on three indicators that are underpinned by federal data: the National Land Cover Data (NCLD) from the US Geological Survey, and forestry data from the US Forest Service (USFS). North Carolina has continued rapidly to lose open space to urban development, but through 2023, enjoyed modestly positive trends in the volume of live trees, presenting a mixed trajectory overall. It is worth noting, however, that Helene destroyed an enormous volume of live trees in western NC. Also, our data does not reflect wetland losses following the June 2023 US Supreme Court *Sackett* decision and the repeal of independent state wetland protections by the NC General Assembly three weeks later.

Solutions: North Carolina can protect and conserve our landscapes for human uses by A1, restoring dedicated funding for the natural resource trust funds; A2, funding the Parks & Recreation Trust Fund; A3, funding the Agricultural Development & Farmland Preservation Trust Fund; A4, investing in floodplain restoration and reconnection; A5, enacting state wetlands protections; A6, conserving peatland, salt marshes, and forests; J8, curbing wood pellet facilities; K4, using carbon reduction and equity criteria in transportation planning; and B4, encouraging farmland protection plans.

Indicator 6.1: Loss of open space

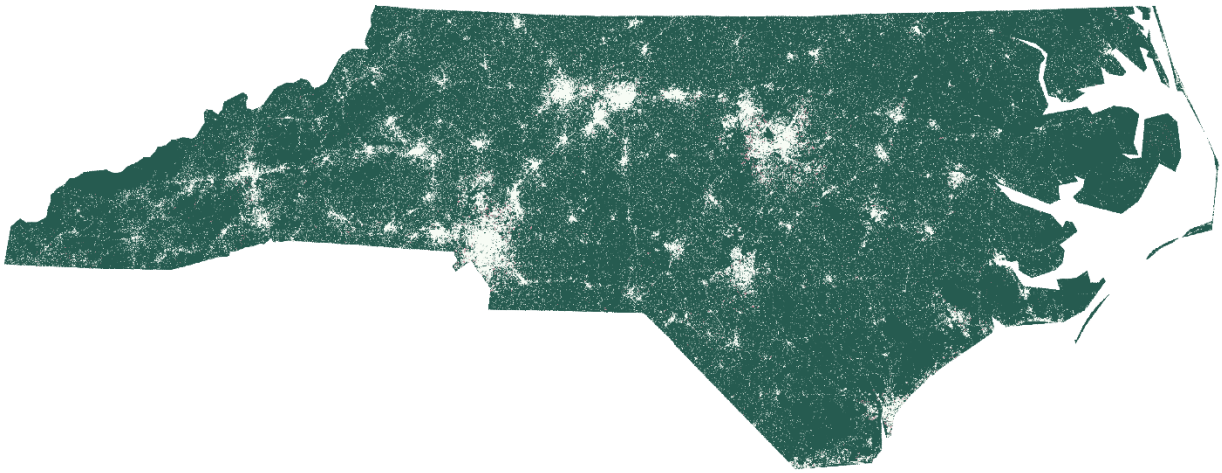
Top line: North Carolina retains much natural beauty, but in recent decades, as the population of the state has grown rapidly, the area paved over for roads, neighborhoods, and commercial buildings has

[143] NC DEQ, Division of Water Resources, Groundwater Management Branch Monitoring Well Network 2023 Annual Report, November 2023.

grown faster still, eating away at North Carolina's open space and rural landscapes. This is a negative trend.

About loss of open space: The spatial footprint of the average North Carolinian is increasing, even as there are more and more of us. While growth has many benefits, the loss of open space has both direct and indirect costs. This indicator measures the rate of loss of open space. When we drafted the 2019 State of the Environment, the most recent data was the 2011 National Land Cover Dataset (NLCD), and we declined to assign a trend to this indicator. Since then, the US Geological Survey has released the 2013, 2016, 2019, and 2021 NLCDs, and the layers are comparable across the full time series, allowing for a powerful view of recent changes in open space across North Carolina.

Map 5.2: Developed land in NC 2011 and 2021



This map depicts developed land per 2011 NLCD in white, developed land per 2021 NLCD in purple, and undeveloped land as green. White and purple areas include all four classifications of developed land from the National Land Cover Classification Legend and Description.

An analysis of National Land Cover Data indicates that developed land in NC expanded by 30% from 2011 to 2021. 'Medium intensity development', which includes residential subdivisions of single-family homes, grew fastest. This is faster than projected just a decade ago. A 2014 paper calculated land use changes across North Carolina from 1992 to 2001, validated against 2006 land cover, and projected trends to the year 2030. That study predicted 20% increase in developed land and a 17% decrease in forest land from 1992 to 2030.[144] Low density urban development outside of urban cores poses risks to local flora and fauna, ecosystems, and humans alike; it also feeds the expansion of impervious surface (indicators 7.2 and 7.3). In contrast, studies have confirmed the benefits of open space: wildlife

[144] Sayem Zaman and Manoj Jha, Modeling of future land cover change in North Carolina using Markov chain and cellular automata model, American Journal of Engineering and Applied Sciences, January 2014, 7 (3): 295, doi:10.3844/ajeassp.2014.295.306.

management areas in the state support the economy on the local and state levels,[145] and access to greenspace benefits mental health in both rural and urban neighborhoods in North Carolina.[146]

Indicator 6.2: Volume of live trees

Top line: The total area of forest in North Carolina has declined over the last decade – a reflection of continued loss of open space – but the volume of live trees, a reflection of the age of the forest (and an indicator of the carbon it stores) has continued to rise. We count that as a positive trend, saving a more nuanced discussion of the ecological health of North Carolina's forests for indicator 7.1, the area of non-intensively managed forestlands.

About timber on the landscape: As of 2021, North Carolina had roughly 18.70 million acres of forest.[147] Roughly 2.2 million acres (11%) are owned by the federal government; another 1.2 million acres (6%) are owned by the state. The other 15.3 million acres (83%) are in private ownership, indicating how crucial wise private management of forests is for the well-being of the state. NC State Extension estimates that North Carolina's forest sector – including forestry, sawmills, furniture mills, and pulp and paper mills – directly contributed $25.8 billion to the state's economy in 2022 and employed just under 74,000 North Carolinians.[148] North Carolina's forests are also a key location for outdoor recreation, which contributed $14.6 billion to the state's economy in 2022 and employed roughly 146,000 people.[149]

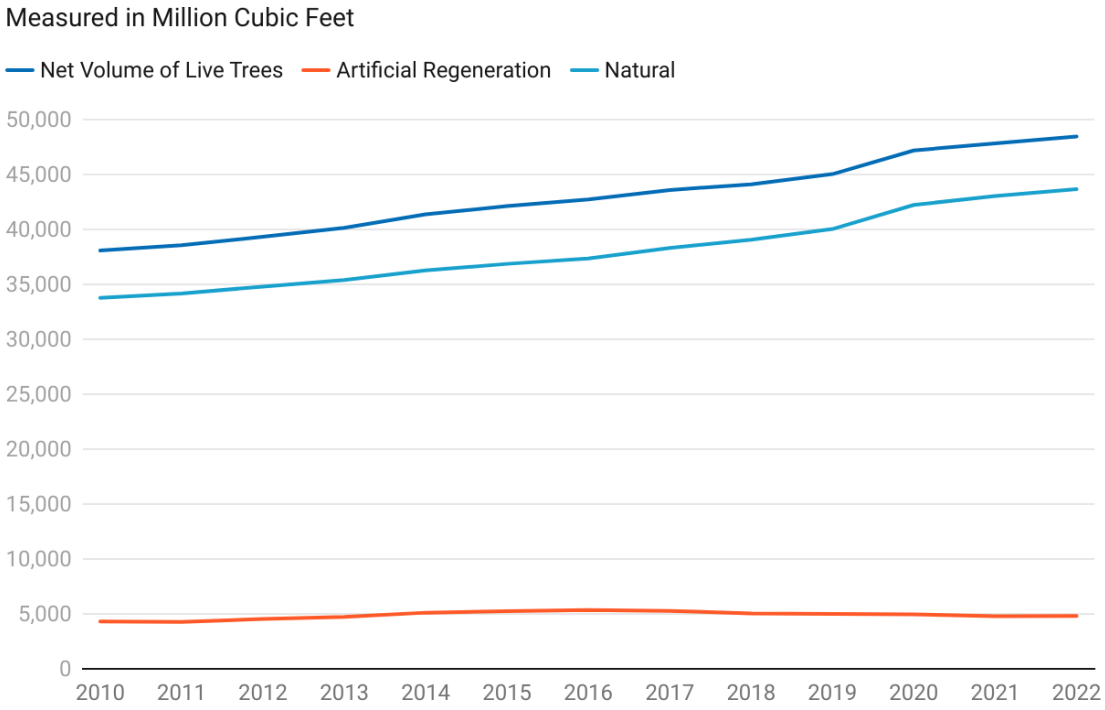
Forests are vital for water supply. Over 45% of all surface water in North Carolina originates on state and private forestlands, and roughly 57% of North Carolinians rely for at least some of their water supply on that water.[150] Forests are important for water quality as well as quantity; drinking water intakes downstream from heavily forested watersheds enjoy higher raw water quality than intakes downstream from agricultural and developed landscapes.[151] At the end of 2024, the USFS Southern Research Station released an analysis projecting the impacts of climate change and grow patterns on the future water supplies provided by forests across the Southeast. In general, under most climate scenarios North Carolina is better off than other southern states, but we face increased risk of floods and landslides from

[145] William Casola, et al., Economic contributions of wildlife management areas in North Carolina, Forest Policy and Economics, July 2022, 140, https://doi.org/10.1016/j.forpol.2022.102747.
[146] Sophia Ryan, et al., Spatial Analysis of Greenspace and Mental Health in North Carolina, Journal of Health Promotion and Maintenance, July/September 2023, 46(3): 181, *DOI:*10.1097/FCH.0000000000000363.
[147] USDA Forest Service, factsheet: Forests of North Carolina 2021, 2022. That is roughly 100,000 acres less than the 18.81 million acres estimated in 2016.
[148] NC State Extension, factsheet: Economic Contribution of the Forest Sector in North Carolina, 2022, June 3, 2024.
[149] U.S. Dept. of Commerce, Bureau of Economic Analysis, factsheet: Outdoor Recreation Satellite Account, 2022 – North Carolina, visited June 17, 2024.
[150] Ning Liu et al., Quantifying the role of State and private forest lands in providing surface drinking water supply for the Southern United States, 2020, Gen. Tech. Rep. SRS-248, https://doi.org/10.2737/SRS-GTR-248, at 119.
[151] Peter Caldwell et al., Forested watersheds provide the highest water quality among all land cover types, but the benefit of this ecosystem service depends on landscape context, Science of the Total Environment, 2023, 882: 163550, http://dx.doi.org/10.1016/j.scitotenv.2023.163550.

intense rains. The report also notes the potential for expanding areas of impervious surface in North Carolina's mountains and Piedmont to damage groundwater recharge in the coming decades, reducing key summer surface water flows.[152]

North Carolina's forests are an important storehouse of carbon. When burned or harvested, wood releases carbon into the atmosphere; growing trees absorb and sequester it. A recent paper evaluating land use data from 1986-2010 concludes that conversation of forestland to developed landscapes in North Carolina's urban counties released significant amounts of carbon – but in the state as a whole, these emissions were offset by absorption in growing forests.[153] North Carolina's most recent official greenhouse gas inventory estimates that forest lands sequester 47.52 MMT CO2e annually.[154] The inventory notes that an expert panel estimated in 2020 that this annual rate of sequestration could be boosted by an additional 10 to 20 MMT CO2e through targeted reforestation and conservation.[155]

Figure 6.2: Net Volume of Trees on Forest Land



Source: USDA Forest Service, Forest Inventory and Analysis Program, May 2024 Forest Inventory EVALIDator web-application • Created with Datawrapper

[152] Peter Caldwell et al., Southern Forest Outlook: Water, Southern Research Station General Technical Report SRS-276, December 2024.
[153] Weishu Gong et al., Carbon fluxes from contemporary forest disturbances in North Carolina evaluated using a grid-based carbon accounting model and fine resolution remote sensing products, Science of Remote Sensing, June 2022, 5: 100042, https://doi.org/10.1016/j.srs.2022.100042.
[154] NC DEQ, North Carolina Greenhouse Gas Inventory (1990-2050), January 2024, at 34.
[155] NC DEQ, NC Climate Risk Assessment and Resilience Plan, Natural and Working Lands Action Plan [*Natural and Working Lands 2020*], June 2020, at 20.

The indicator we use to measure the amount of forest on the land is the volume is live trees. Our 2019 report used a different but related indicator, 'biomass of living trees', but that is not consistently reported. The USFS estimates the volume of live trees for each state using rolling surveys; in North Carolina, those cover between 10% and 20% of 5,726 sample plots in the state each year.[156] This method smooths variations from year to year. As the chart suggests, North Carolina has experienced a steady increase in the volume of live trees over the last decade, even as the total acreage of forest has shrunk by roughly 100,000 acres and the total number of trees has declined. Those are also important trends, addressed through indicator 6.1, loss of open space, and indicator 7.1, the extent of non-commercial forestlands. But, as noted above, the volume of live trees is both important as an economic resource and as an indication of carbon storage, so we recognize this indicator as trending in a good direction.

Recent developments: a particularly controversial aspect of forestland management in North Carolina has been the growth of the wood pellet industry. The field has been dominated by Enviva, which has opened four facilities in North Carolina in environmental justice communities. Neighbors have complained about noise, truck traffic, and billowing sawdust.[157] Forest advocates have argued that cutting forest for wood pellets is ecologically destructive, economically wasteful (compared to other potential uses of the timber), and a net source of carbon emissions rather than a sustainable energy source.[158] In early 2024, Enviva ran into financial difficulties, then filed for bankruptcy, but the North Carolina facilities continued to run.[159] The company exited bankruptcy in October 2024 with American Industrial Partners Capital Fund as the new largest shareholder, leaving bondholders in other states holding the bag, and with communities around the plants still complaining about harmful impacts.[160]

Also in the last five years, North Carolina has included forestlands in its state-led policies to support natural and working lands. The multi-agency 2020 NC Natural & Working Lands Action Plan laid out of series of recommended policies to conserve working farms and timberlands as well as natural forests and wetlands.[161] Strategies endorsed in the Plan included conserving forests through easement and acquisition; reforming tax policy to reward keeping land in forest; investing state funds and private philanthropy to restore as much as 5.1 million acres of forest; and investing in technical assistance and

[156] USDA Forest Service, Forests of North Carolina, 2022: FIA annual snapshot, December 2024; USDA Forest Service, Forest Inventory and Analysis Program, Forest Inventory EVALIDator web-application, Version 2.1.2, visited May 13, 2024.
[157] NC DEQ, webpage: Wood Pellet Industry Permitting Actions and Information, visited September 4, 2024; Melba Newsome, North Carolina Trees Are Feeding Europe's 'Clean Energy' Revolution, The Assembly, January 25, 2023; Environmental Integrity Project, Dirty Deception: How the Wood Industry Skirts the Clean Air Act, April 26, 2018.
[158] NRDC, blog: Carbon Capture Can't Fix the Climate Impacts of Forest Biomass Power, January 17, 2024; Joby Warrick, How Europe's climate policies led to more U.S. trees being cut down, Washington Post, June 2, 2015.
[159] Gareth McGrath, What does wood-to-energy giant Enviva's bankruptcy mean for Noth Carolina?, StarNews, March 20, 2024; Lisa Sorg, Enviva declares bankruptcy, operates four wood pellet plants in NC, NC Newsline, March 13, 2024.
[160] Enviva emerges from bankruptcy as AIP becomes largest shareholder, Bioenergy Insight, December 9, 2024; Robert Slavin, Wood pellets burn Enviva muni bondholders in bankruptcy, The Bond Buyer, January 2, 2025; Justin Catanoso, New survey puts human face on pollution caused by U.S. wood pellet mills, Mongabay, October 24, 2024.
[161] *Natural and Working Lands 2020*.

market development for high-value wood products.[162] A 2022 progress report lists nearly all of the significant forestry recommendations as 'ongoing'.[163] In early 2024, Governor Roy Cooper's Natural and Working Lands executive order, EO305, called for state agencies to implement Plan strategies and layered on the additional goal of restoring or reforesting 1 million new acres of forests and wetlands by 2040, measured against a 2020 baseline.[164] Based on the 2024 NC Natural and Working Land Progress Report, published in October 2024, the annual rate of new lands protected between 2020 and 2024 was close to 38,000 acres/year.[165] The statewide annual rate of protection will need to increase by 35% to meet the goal of protecting one million new acres by 2040.[166]

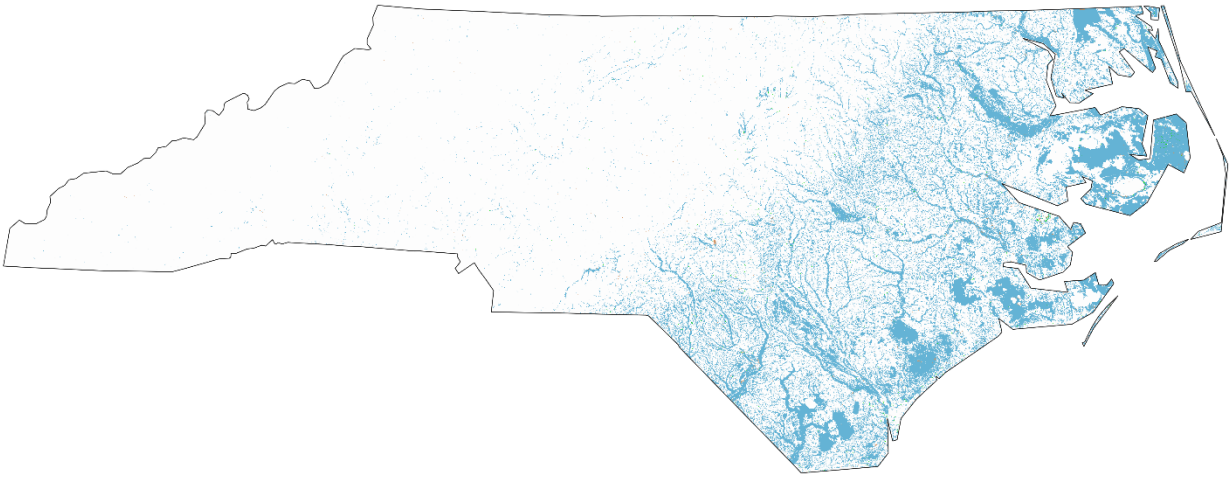
Hurricane Helene no doubt reduced the volume of live trees on forestland in western North Carolina. Across the four states it traversed – Florida, Georgia, South Carolina, and North Carolina – Helene is estimated to have destroyed $1.8 billion worth of timber.[167] Yet, 82% of that was in Georgia, where saw timber, selling for $35/ tonne before the storm, dropped in value by 90%.[168] The NC Forest Service estimates that 822,000 acres of timberland in North Carolina suffered 'some level of damage' from the storm, an estimated $214 million, distributed 78% to private lands, 21% to public forests, and 1% to parks.[169] The worst hit counties were Mitchell ($41 million in lost timber), Yancey ($27.4 million), and Buncombe ($19 million); those estimates do not count urban trees.[170] The NC Forest Service estimate was based on a day of overflights shortly after the storm; the USFS Southern Research Station has offered a more comprehensive and nuanced perspective of damage based on analysis of pre- and post-storm satellite photos using its High Resolution Forest Mapping (HiForm) tool.[171] Analysts working with that data have reached an estimated of total damage of closer to 540,000 acres, with large blow-downs and patchy areas of severe damage limited to a more modest 200,000 acres.[172] For a sense of relative scale, if every tree in those 200,000 acres was destroyed, that would amount to a loss of just over 1% of North Carolina's forest acreage. So while its impacts were locally significant, we think Helene is not likely to have substantially changed the trajectory of timber volume in the state.

[162] *Idem*, 30-38.
[163] Natural and Working Lands Steering Committee, Annual Report from the Stakeholder Committee, March 2022.
[164] Executive Order 305 (EO 305), An Order to Protect and Restore North Carolina's Critical Natural and Working Lands, February 12, 2024.
[165] North Carolina Natural and Working Lands Action Plan 2024 Progress Report [*NWL Progress Report*], October 2024, at 12.
[166] Idem, 12.
[167] Grant Blankenship, Hurricane Helene knocked a massive hole in Georgia's timber industry [*Blankenship*], Georgia Public Broadcasting, November 14, 2024.
[168] Amanda Land, blog post: The Impacts of Hurricane Helene on Future Pine Sawtimber Supplies, Forisk Consulting, February 14, 2025; *Blankenship*.
[169] NC DACS, NC Forest Service, North Carolina Forest Damage Appraisal Hurricane Helene, October 2024, at 2.
[170] *Idem*, at 3.
[171] USFS, Southern Research Station, HiForm, web presentation: 2024 Hurricane Helene in the southern Appalachians, December 17, 2024.
[172] Nick Holshouser, Hurricane Helene Forest Damage Overview, December 2024.

Indicator 6.3: Wetlands not in federal ownership

Top line: There are two major sources that track wetlands trends across the nation, but they suffer from delay and lack sensitivity. Analysis using National Land Cover Data shows little change in wetlands from 2011 to 2021, but wetlands protections changed significantly on the national and state level in 2023, and the current trajectory of wetlands loss in North Carolina is murky. We assign this indicator no trend.

Map 6.3: Change in wetlands, 2011 and 2021



This map depicts woody wetlands and emergent herbaceous wetlands per 2011 NLCD in blue and non-wetlands in white. To visualize change over time, using data from the 2021 NLCD, woody and emergent herbaceous wetlands that were lost are orange, wetlands gained are green.

About wetlands: Wetlands serve a multitude of functions, cleaning water, recharging groundwater, absorbing floods, and providing habitat for fish and wildlife. Scientists generally distinguish between palustrine (fresh) and estuarine (brackish) wetlands. Isolated inland wetlands are particularly important habitat for amphibian, bird, and plant species.[173] Wetlands play a crucial role in filtering pollution and keeping it out of streams, lakes, and rivers; a recent study of a wetland in the Falls Lake watershed found it reduces phosphorus loadings by 85% and *E. coli* bacteria by 57%.[174] Small, ephemeral isolated

[173] Southern Fire Exchange, factsheet: Prescribed Fire Management of Ephemeral Wetlands of Southern Pine Communities for Amphibian Conservation, November 2024 (amphibians); Jackson Barratt Heitmann et al., Geographically isolated wetlands have higher alpha diversity than surrounding uplands in pine savanna ecosystems, Research Square pre-print, under review, January 2024, https://doi.org/10.21203/rs.3.rs-3827765/v1 (birds and plants).

[174] Charles Humphrey et al., Evaluation of Phosphate and E. coli Attenuation in a Natural Wetland Receiving Drainage from an Urbanized Catchment [*Falls watershed wetland*], Hydrology, May 2024, 11 (6): 74, https://doi.org/10.3390/hydrology11060074. See also, Curtis Richardson and Neal Flanagan, Water quality and wetland vegetation responses to water level variations in a university stormwater reuse reservoir: Nature-based approaches to campus water sustainability, Science of the Total Environment, October 2024, 948, https://doi.org/10.1016/j.scitotenv.2024.174616 (finding that a constructed wetland in Jordan Lake watershed downstream from Duke University campus reduced annual nitrogen, phosphorus, and total suspended solids by 58% to 85% depending on the intensities of storms during the year).

wetlands are particularly effective at controlling nutrient pollution.[175] When acting as filters, wetlands can themselves receive too much runoff and be degraded by pollution and excessive volume.[176]

A function of certain types of wetlands, recently gaining more appreciation, is their ability to sequester carbon that would otherwise be released to the atmosphere and contribute to climate change. Wooded peatlands in eastern NC store enormous volumes of carbon; a recent study estimates that re-wetting them could reduce carbon emissions, providing – with systematic investments across the Southeast – as much as 2.4% of the annual nationwide target for emissions reduction.[177] Yet other research indicates (also discussed under indicator 1.3), that sea level rise threatens these organic soil wetlands as far as 12 miles (20 kilometers) in from the estuaries.[178] A study of satellite photos of the Albemarle Pamlico peninsula from 1985 to 2021 found that 77% of the peninsula has had stable or increasing vegetation, but 22% has lost cover, divided evenly between gradual decline (10%) and abrupt decline (11%).[179] As forest is lost, much of this forested wetland may become salt marsh – but another recent study found that of all the National Wildlife Refuges along the South Atlantic coast, only two, the Currituck NWR in North Carolina and the Waccamaw NWR in South Carolina, are gaining marsh elevation fast enough to stay ahead of sea level rise.[180] In more settled stretches of the coast, as seas rise, estuarine marshes are likely to get squeezed against land-side development and eventually disappear if paths are not protected for the marshes to retreat inland.[181]

In the previous iteration of this report, we relied on the USDA's Natural Resource Inventory (NRI) to estimate North Carolina's remaining acreage of wetlands on non-federal lands. The NRI data is not a perfect representation of what is on the ground but was at the time the most robust state or federal wetland data series. NRI data suggests that the acreage of North Carolina's estuarine wetlands has not changed much over the last 25 years, but that development pressures have resulted in the steady loss of

[175] Frederick Cheng et al., Disconnectivity matters: the outsized role of small ephemeral wetlands in landscape-scale nutrient retention, Environmental Research Letters, January 2023, 18, https://doi.org/10.1088/1748-9326/acab17.

[176] *Falls watershed wetland*, at 22, 23. A. Jack Kurki-Fox and Michael Burchell, Characterizing ambient nutrient concentrations and potential warning levels for surface water in natural forested wetlands in the Piedmont and Coastal Plain of North Carolina, USA, Ecological Engineering, December 2021, 172, https://doi.org/10.1016/j.ecoleng.2021.106395 (forested wetlands); Anett Trebitz and Alan Herlihy, Wetland water quality patterns and anthropogenic pressure associations across the continental USA [*Trebitz and Herlihy*], Wetlands, December 2023, 43 (107), https://doi.org/10.1007/s13157-023-01754-8 (isolated and streamside emergent wetlands).

[177] Curtis Richardson et al., Annual carbon sequestration and loss rates under altered hydrology and fire regimes in southeastern USA pocosin peatlands, Global Change Biology, November 2022, 28 (21): 6370, https://doi.org/10.1111/gcb.16366.

[178] Maricar Aquilos et al., Hydrologic Perturbation Is a Key Driver of Tree Mortality in Bottomland Hardwood Wetland Forests of North Carolina, USA, Forests, January 2025, 16 (1), 39, https://doi.org/10.3390/f16010039.

[179] Melinda Martinez et al., Detecting Trajectories of Regime Shifts and Loss of Resilience in Coastal Wetlands using Remote Sensing, Ecosystems, October 2024, 27: 1060, https://doi.org/10.1007/s10021-024-00938-5.

[180] Micelle Moorman et al., Will They Stay or Will They Go — Understanding South Atlantic Coastal Wetland Transformation in Response to Sea-Level Rise, Estuaries and Coasts, June 2023, 47: 2011, https://doi.org/10.1007/s12237-023-01225-7.

[181] *Salt Marsh Action Plan*, at 15; Anne Smiley, dissertation: Nitrogen Processing in Urban Coast Environments: Assessing Resilience Amidst a Changing Climate, May 2024.

freshwater wetlands. Roughly 90% of the remaining non-federal wetlands are described as 'forest' by the NRI.[182]

The US Fish and Wildlife Service developed the National Wetland Inventory (NWI) in the 1970s, and the most recent data published shows little change in wetlands in the state, confirming our analysis of the National Land Cover Database's landcover data. A report by the NC Division of Water Resources compared 2020 NWI spatial data to field delineations of wetland and non-wetland areas collected in 2001-2019 to assess the accuracy of NWI for the state.[183] The results were mixed: the NWI drastically underestimated wetland acreage in the Blue Ridge and slightly underestimated acreage in the Mid-Atlantic Coastal Plain, but overestimated wetland acreage in the Piedmont and moderately overestimated in the Southeastern Plains. Results also suggested that NWI was "largely unreliable" for wetlands under an acre, a serious problem for estimates in the central Piedmont and western Blue Ridge areas, where many wetlands are very small.[184]

Recent developments: For the last 50 years, most wetlands have been protected under the Clean Water Act: private actors could drain or fill them with a permit, but were asked to avoid and minimize impacts to the extent possible. In June 2023, the U.S. Supreme Court decision in *Sackett v. EPA* sharply limited federal Clean Water Act jurisdiction over wetlands to those that, in the words of the opinion, have 'a continuous surface connection' to traditionally navigable waters.[185] The majority opinion explicitly looked to the states to pick up the slack, deciding which additional wetlands to protect for the good of the state.[186] Three weeks later, having taken no time to study the issue, North Carolina's General Assembly enacted S.L.2023-63 (S528), the 2023 Farm Act, stripping existing state protections for all wetlands no longer protected by the federal Clean Water Act.

The combination of *Sackett* and the 2023 Farm Act has left a significant share of North Carolina's wetlands without regulatory protection from ditching and draining.[187] Some fraction of wetlands are protected incidentally from certain impacts by other statutes – for example, wetlands located downstream from a construction site may be protected from sedimentation because the state sediment and erosion control statute applies to all land disturbing activities with more than an acre of impacts – but there are no other regulatory protections for wetlands as wetlands. It is worth noting that wetlands that have lost protection are not immediately destroyed; the impact of lost protections is likely to be felt gradually, in increased flooding or incrementally worse water quality over time, as projects upstream

[182] USDA, 2015 Natural Resources Inventory: North Carolina Wetlands, September 2018.
[183] NC DWR, DEQ. National Wetlands Inventory (NWI) Accuracy in North Carolina, August 2021.
[184] *Idem*.
[185] Sackett v. EPA, 598 U.S. 651, 2023, at 27.
[186] See, *Sackett* at 17 ("the [Clean Water Act] expressly 'protect[s] the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution' and 'to plan the development and use … of land and water resources.'")
[187] B. Alexander Simmons et al., A Murky Ruling Threatens the Fate of Millions of US Wetlands, Wetlands, April 2024, 44 (47), https://doi.org/10.1007/s13157-024-01801-y (estimating jurisdictional losses of 27% to 47%); Adam Gold, How wet must a wetland be to have federal protections in post-Sackett US?, Science, September 2024, 385 (6716): 1450, https://doi.org/10.1126/science.adp3222 (estimating jurisdictional losses of 19% to 91%, depending on subsequent judicial and agency interpretations).

are no longer required to mitigate their impacts. A new trajectory will likely take several years to show up in the NRI's sampling. The heaviest impacts will show up as loss of freshwater (palustrine) wetlands, since coastal wetlands are more likely to remain jurisdictional.

On a bright note, the last two years have seen significant steps to protect coastal wetlands from continued loss to sea level rise. First, in May 2023, the South Atlantic Salt Marsh Initiative (SASMI) rolled out its Marsh Forward, a regional plan for conserving salt marsh in the face of rising seas.[188] This was followed by the release of a North Carolina specific plan, the North Carolina Salt Marsh Action Plan, in May 2024.[189] Finally, in July 2024, US EPA awarded the Atlantic Conservation Coalition, a consortium of four states and non-governmental organizations, a $421 million Carbon Pollution Reduction Grant to protect and restore high-carbon coastal habitats, peatlands, and forests.[190] The project is expected to protect and restore 33,000 acres of peatlands and coastal marsh in North Carolina and Virginia, and reforest 55,000 acres in North Carolina, among other goals. The lead state agency for this project is the NC Department of Natural and Cultural Resources; key non-governmental partners include the Nicholas Institute at Duke University, the Nature Conservancy, and the NC Coastal Federation.[191]

Goal 7: Landscapes provide healthy habitat

Trend: Mixed

Beyond providing services directly useful to people, North Carolina's landscapes provide vital habitat for fish and wildlife. The next four indicators all provide measures of the health of terrestrial and aquatic habitats: non-intensively managed forests (indicator 7.1); total impervious surface (indicator 7.2); the percentage of small watersheds with minimal impervious surface (indicator 7.3); and the percentage of known biodiversity hotspots that are under some kind of protective management (indicator 7.4). The overall share of impervious surface has grown, and the number of watersheds with damaging levels of impervious surface has worsened as well, both of which are negative trends. Both the terrestrial indicators – the retention of non-commercial forests and the management of known biodiversity hotspots – are positive trends. Overall, the trend for this goal is mixed.

Solutions: There is much overlap with solutions for goal 6. To protect the ecological functions of terrestrial and aquatic habitats, solutions include A1-A3, funding the natural resource trust funds, and

[188] SASMI, Marsh Forward: A Regional Plan for the Future of the South Atlantic Coast's Million-Acre Salt Marsh Ecosystem, May 2023.
[189] NC Coastal Federation, North Carolina Salt Marsh Action Plan [*Salt Marsh Action Plan*], May 2024; New plan details strategy to save, restore NC's salt marshes, NC Coastal Review, May 15, 2024.
[190] US EPA, webpage: Inflation Reduction Act: States of North Carolina, Maryland, and South Carolina, and the Commonwealth of Virginia, updated July 23, 2024; see also, Adam Wagner, 'What nature intended it to be': NC lands historic EPA grant to fight climate change, News & Observer, July 25, 2024.
[191] Duke University, Nicholas Institute for Energy, Environment & Sustainability, webpage: Project: Atlantic Conservation Coalition, visited January 22, 2025; The Nature Conservancy, webpage: Saving North Carolina's Peatlands, updated November 4, 2024; NC Coastal Federation: webpage: Salt Marsh, visited January 22, 2025.

A4, floodplain reconnection. Protecting, A5, and conserving, A6, wetlands is essential to providing habitat. In addition, C3, improving maintenance of coastal stormwater control measures; G5, strengthening stormwater management; G7, funding community conservation assistance; K4, avoiding induced sprawl; and L4, eliminating parking minimums, would greatly help aquatic habitats.

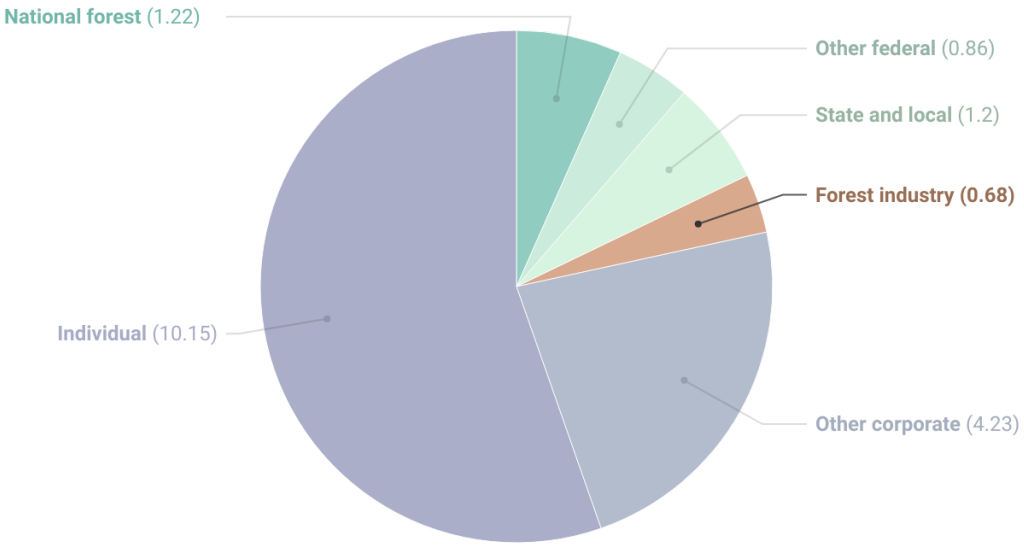
Indicator 7.1: Extent of non-intensively managed forests

Top line: The extent of non-intensively managed forests has remained stable, which is positive.

About non-intensively managed forests: North Carolina is known for its tall pines and diverse native trees. It has roughly 18.7 million acres of forestlands, but a little under a million of that is intensively managed commercial timberland. Intensively managed commercial timberlands provide ecological services that cleared and developed land would not, such as absorbing rainfall, recharging aquifers, and releasing oxygen – but they are mostly monocultures, and do not sustain diverse and resilient ecological communities. This indicator tracks non-commercial forest acres. The vast majority are held by small, private landowners. Some of these acres may be ecologically degraded; it is likely most are not being managed closely for any particular purpose. Nonetheless, this indicator offers an upper bound on the acreage of natural or semi-natural forests in the state.

Figure 7.1: Forest Acreage Not In Commercial Production in 2022

In Millions of Acres



Source: USDA Forest Service, Forest Inventory and Analysis Program, Forest Inventory EVALIDator web-application • Created with Datawrapper

The forest acreage is so large that the US Forest Service doesn't try to assess it all in one year. Instead, each year, the agency updates a portion of the records. In effect, that means that each annual estimate is a smear of results from the last three years, a sort of rolling average.

The data has not changed much in the past few years; North Carolina's non-commercial timberland acreage has hovered around 17.5 million acres for the last 10 years. That land is owned by a combination of federal, state, and local governments, non-timber corporations, and – larger than all other categories combined – private landowners. Because this land area appears stable, we evaluate this as a positive trend.

Recent developments: As noted under indicator 6.1, Hurricane Helene damaged hundreds of thousands of acres of forest in western North Carolina. Virtually all of that was on private (78%) or public (21%) forestlands. There's been little written to date about the likely ecological impact of the destruction, but foresters in the region have noted the potential for widespread soil disturbance from the storm to open the door to invasive species.[192] Looking just at the public lands in the Nantahala and Pisgah National Forests, the US Forest Service estimated that Helene caused 'moderate to catastrophic damage' to 187,000 acres of forest, roughly 20 percent of the forests' total acreage.[193] One effect of that damage is to rewind large acreages of forest to 'early successional habitat'; in December 2024, environmental advocates asked the US Forest Service to revise forest management plans for the Nantahala and Pisgah National Forests to take account of the storm's impact.[194]

Indicator 7.2: Statewide impervious surface

Topline: As North Carolina population grows, the state's total cleared and paved surface has grown faster. That's bad for the health of our rivers and estuaries, so we mark this as a negative trend.

About total impervious surface: Developing a natural landscape doesn't just remove the habitat on the site; it also significantly changes what happens to rainfall. On undeveloped land, rain soaks into the ground and is transpired by trees or moves slowly through the soil to feed nearby streams. The degree to which undeveloped land absorbs rainfall depends on soil type, but in nearly in all cases some rainfall infiltrates the soil. In contrast, when rain hits the hard surfaces of a developed landscape – pavement, roofs, patios, compacted gravel – it promptly runs off, carrying whatever pollutants are lying around. The resulting runoff flow is larger in volume and moves faster than it would in a pre-development environment, causing more erosion and flooding downstream. This relationship has been documented

[192] EcoForesters, webpage: Hurricane Helene Information & Resources, visited March 3, 2025.
[193] USDA, USFS, press release: USDA Forest Service releases update on Helene's impact to ecosystem, infrastructure, November 1, 2024.
[194] Center for Biological Diversity, press release: Forest Service Urged to Update N.C.'s Nantahala-Pisgah Forest Plan in Wake of Hurricane Helene, December 18, 2024.

by researchers across the state.[195] Runoff also degrades nearby isolated and streamside wetlands.[196] We rely on the United States Geological Survey's National Land Cover Database (NLCD) to estimate impervious surface and evaluate the degree to which we have altered the natural hydrologic system through development.

NCCN's analysis of the 2011 NLCD showed 13% of the state was made up of surfaces that are impervious to some degree, and analysis of the 2023 NLCD showed 15% was impervious. That's a 15.4% increase, even as the state's population grew by just 12.2% over the same period. We're not just paving over more surface, we're paving over more surface per North Carolina resident.[197] That's a bad trend.

Indicator 7.3: Percentage of watersheds that remain relatively undegraded

Topline: Not only has North Carolina gained impervious surface overall, we also have more watersheds where the percentage of impervious surface, though low, has passed critical thresholds that trigger degradation of streams and rivers. That's a direct consequence of land development on the urban fringe and is a negative trend.

About impervious surfaces and watershed health: The previous indicator tracks impervious surface as a percentage of total state land cover, but that impervious surface isn't evenly distributed. That distribution matters because it doesn't take much impervious surface in a watershed to do a lot of damage: when impervious surface exceeds 7% of the area of a watershed, water quality in the watershed begins to decline rapidly. By the time a watershed reaches 20% impervious surface, increased runoff largely destroys habitat for bottom-dwelling species, severely degrading the streams.[198] So the overall health of North Carolina's aquatic ecosystems depends not just on how much impervious surface the state has, but also how many watersheds have been pushed over the very low threshold that triggers stream degradation.

To get a better sense of the distribution and extent of degradation, this indicator tracks changes in the percentage of HUC-12 watersheds that have less than 5% and 10% impervious cover, comparing the 2011 and 2021 versions of the National Land Cover Dataset (NCLD). There are 1748 HUC-12 watersheds in North Carolina, so each one covers a relatively small area. We chose to analyze imperviousness within

[195] Sarah Praskievicz, Impacts of land use metrics on urban stream health: Buffalo Creek, North Carolina, USA, Applied Geography, February 2022, 139, https://doi.org/10.1016/j.apgeog.2022.102637 (Piedmont); Adam Gold et al., The Effects of Urbanization and Retention-Based Stormwater Management on Coastal Plain Stream Nutrient Export, Water Resources Research, July 2019, 55 (8): 7027, https://doi.org/10.1029/2019WR024769 (Coastal Plain). Wastewater infrastructure that accompanies impervious surface also plays a role; see, Joseph Delesantro, dissertation: Urbanization Controls on Non-point Source nutrient Loading along the rural to Urban Gradient of the North Carolina Piedmont, November 2021.

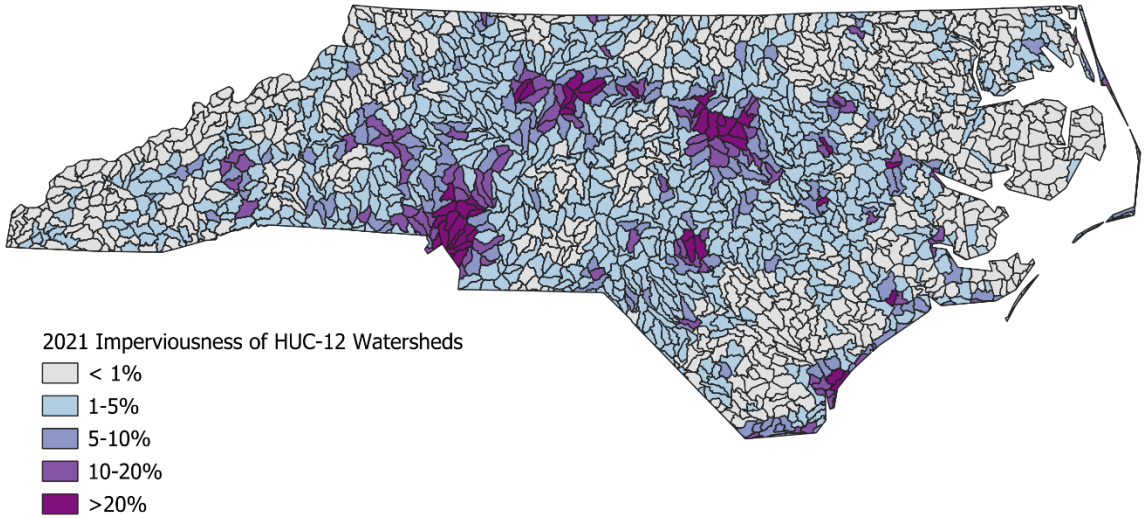
[196] *Trebitz and Herlihy*.

[197] The state population grew from 9.66 million (2011) to 10.84 million (2023).

[198] *Roux*; Christopher Elvidge et al., Global Distribution and Density of Constructed Impervious Surfaces, Sensors, September 2007, 7 (9): 1962, https://doi.org/10.3390/s7091962.

these smaller units because using too large a watershed can mask concentrated areas of impervious surface that are degrading substantial lengths of streams or rivers.

Map 7.3. Impervious surface percentages in each small watershed, 2021



In our analysis of the 2011 NLCD, reported in the previous iteration of the State of the Environment, 89% of HUC-12 watersheds had less than 5% impervious surface, and 95.4% had less than 10% impervious surface. The 2021 analysis showed that at least 105 watersheds tipped over the lower threshold for degradation: only 83% of HUC-12 watersheds had less than 5% impervious surface, and 92% had less than 10% impervious surface. Most concerningly, the number of HUC-12 watersheds with greater than 20% impervious surface more than doubled between 2011 and 2021, from 1% to 2.6% respectively. We evaluate this as a negative trend. In the map above (map 7.3), the more color-saturated the watershed, the greater the percentage of impervious surface. Watersheds with the highest levels of imperviousness are clustered in a crescent that runs from Charlotte through the Triad to the Triangle, and around Fayetteville and along the coast.

Recent developments: In the last five years, multiple researchers have studied the impacts of increasing impervious surface in mountain watersheds.[199] That focus makes sense since – as map 7.3 suggests –

[199] Riley Westman and Katherine Martin, Urbanization results in highly dynamic, degraded benthic macroinvertebrate communities in North Carolina streams, Research Square preprint, November 2024, https://doi.org/10.21203/rs.3.rs-5417973/v1 (finding that urbanization changed stream life significantly over 20 years, replacing diverse native species with a few pollution-tolerant species); Kelsey Solomon et al., Effects of low-density development on stream biota: Evidence for biotic homogenization from an assemblage perspective, Ecological Indicators, November 2024, 168, https://doi.org/10.1016/j.ecolind.2024.112753 (finding that native diatoms in mountain streams start disappearing even at low levels of development; native finfish survive longer, but at reduced levels); Jon Calabria et al., Effect of curve numbers on family benthic index in headwater streams in western North Carolina, USA, Environmental Challenges, April 2022, 7, https://doi.org/10.1016/j.envc.2022.100521 (finding that natural soil permeability interacts with impervious surface to influence benthic health; the healthiest streams are in watersheds with permeable soils and not much development).

these are some of the least disturbed watersheds remaining in the state, and a key refuge for plant and animal diversity. Unfortunately, as noted under Indicator 4.2, benthic health, Hurricane Helene hit streams across western North Carolina hard. It will take a while for initial scientific reports on these impacts to emerge, and even longer for peer reviewed studies, but it is likely that watersheds with minimal impervious surface have a leg up on recovery compared to those that suffer excess runoff and pollution on an ongoing basis.

Indicator 7.4: Biodiversity hotspots protected

Top line: The percentage of natural lands under some form of federal, state, or private easement protection or management has remained consistent between 2019 and 2024, which we consider a positive trend.

About protection for biodiversity hotspots: North Carolina's Natural Heritage Program tracks the location and condition of known valuable 'natural areas', including high quality examples of ecological communities and habitat for rare species. The program also tracks places under private or public management providing some protection for these features. This indicator is the percentage of 'natural area' acres – land known to have special value – that are under protective management. To calculate this, staff scientists at the Natural Heritage Program compared the managed lands data set (not including areas not based on land rights or county/municipal properties) to the natural lands data set using GIS analysis. Areas of less than 2 acres were disregarded to reduce mismatching between data layers, and the sum of the overlap was calculated with a statistics tool.[200] Based on NHP data as of July 2024, out of 3,121,315 acres of natural areas, an estimated 2,154,604 acres, or 69%, are under some form of federal, state, or private easement protection or management. In 2019, that percentage was calculated to be 70.2%. Ultimately, we want more natural lands to be under some form of protection or management, but for now we consider the stability of this indicator a trend in the right direction. This indicator does not reflect the additional importance of connectivity of habitats; we'd love to find a way to incorporate such a metric in the future.

Goal 8: North Carolina's landscapes support a full complement of animal and plant species, and ecological communities

Trend: Negative

The next three indicators attempt to characterize, through a selection of species of interest, the strength and wellbeing of North Carolina's biodiversity. By tracking species associated with specific habitats and

[200] Analysis received through email from Michael Schafale and Mitchell East, NC Natural Heritage Program, NC Department of Natural and Cultural Resources, July 2024, based on North Carolina Natural Heritage Program Biotics Data.

ecological communities, these indicators collectively suggest the extent to which North Carolina's living systems are thriving alongside the state's dynamic growth. Indicator 8.1 considers avian species; indicator 8.2 tracks freshwater fish; and indicator 8.3 considers the overall availability of data on species population trends. Both quantitative indicators show some gains, but more declines; overall, North Carolina's species diversity and abundance is suffering.

Solutions: Policies which improve the quality of habitats in North Carolina will result in better outcomes for this goal. See solutions listed for goals 3 and 4, and goals 6 and 7. In addition, North Carolina should, I1, publish and implement the recommendations of the 2025 Wildlife Action Plan, the ten year update of the 2015 Wildlife Action Plan. To protect pollinators and the species that depend on them, North Carolina should E4, ban neonicotinoid pesticides.

Indicator 8.1: Avian diversity and abundance.

Top line: Out of ten bird species selected as proxies for distinct habitat types across North Carolina, six have declining populations. There are some bright spots in bird conservation, but overall, this is a negative trend.

About avian diversity and abundance: Birds are an essential part of healthy ecosystems, critical to pollination, insect control, forest generation, seed dispersal, and many other ecological processes. Over 460 species of birds call the diverse habitats of North Carolina home for some part of the year. North Carolina is a part of the Atlantic Flyway, one of the major routes that migratory birds travel, and birds rely on key habitat features during their stopovers in the state.[201] To simplify and standardize trend analysis, Audubon North Carolina has identified 10 species that range across different habitats, and whose population trends over time offer a window not just on the wellbeing of those species, but also the broader habitats and ecological communities of which they are a characteristic part. For each species, the table below names its characteristic habitat and the most recent annual trend in the species' estimated population in North Carolina. The table also includes projected vulnerability to climate change for each species.

The Audubon climate change vulnerability status is derived from Audubon's 2019 Survival by Degrees: 389 Species on the Brink which modeled how climate change will impact habitats of 604 species under three different climate scenarios. Species that may lose more of their suitable range are determined to be more vulnerable to climate change; birds designated highly and moderately vulnerable are at risk of losing more than half their current range. The report identifies 204 different species of birds native to North Carolina that are threatened by climate change.[202]

[201] Pine Island Audubon Center, A Critical Sanctuary Along the Atlantic Flyway

[202] Audubon North Carolina, factsheet: Survival By Degrees: 204 Bird Species at Risk in NC, January 2020.

Table 8.1: Population of 10 diagnostic species

Worsened Improved

Species	Habitat	2019 Birds and Climate Report	Trend Calculation	Monitoring
Brown-headed Nuthatch	Coniferous Forest	Highly vulnerable	1.26	Breeding Bird Survey, Nest Box project, Climate Watch
Wood Thrush	Deciduous Forest	Highly vulnerable	-3.18	Breeding Bird Survey
Hooded Warbler	Deciduous Forest	Moderately vulnerable	0.07	Breeding Bird Survey
Prothonotary Warbler	Deciduous Forest	Neutral	-0.39	Breeding Bird Survey
Eastern Meadowlark	Grassland	Moderately vulnerable	-3.13	Breeding Bird Survey
Eastern Whip-poor-will	Open/Ag	Highly vulnerable	-4.92	Nightjar Survey
Chimney Swift	Urban/Suburban	Neutral	-2.87	Breeding Bird Survey, Audubon Swift Project
American Oystercatcher	Marsh/Estuarine	Neutral	-5.30	Audubon Survey, Colonial Waterbird Census
Brown Pelican	Coastal	Neutral	3.50	Audubon Survey, Colonial Waterbird Census
Piping Plover	Coastal	Moderately vulnerable	12.50	Audubon Survey, Piping Plover Census

Source: Calculated by staff at Audubon NC using data from the national Breeding Bird Survey, USGS. • Created with Datawrapper

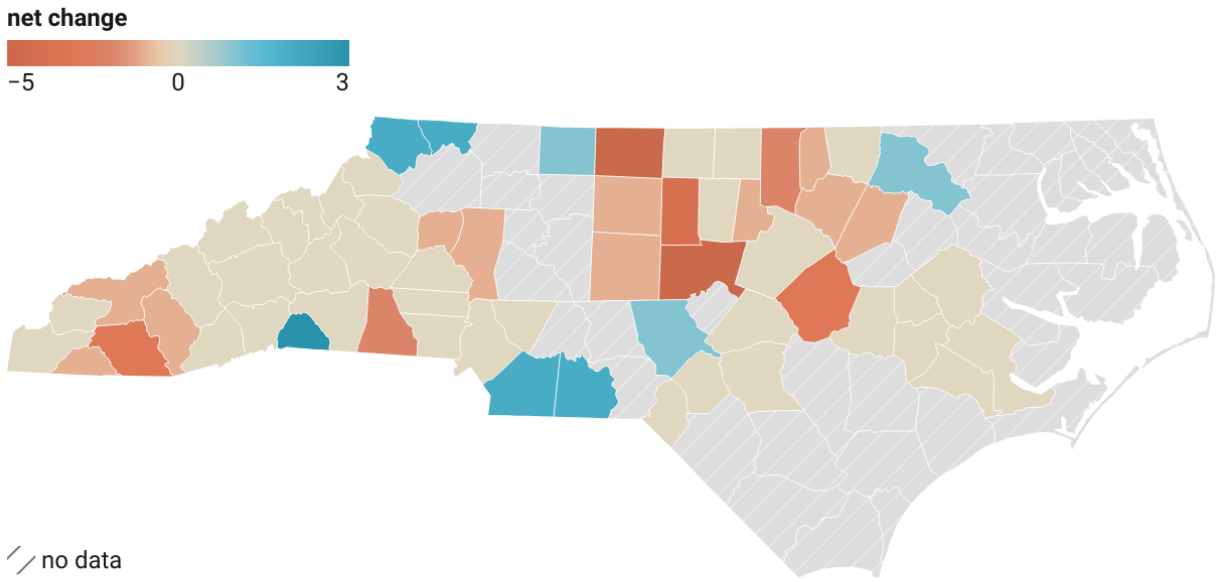
The most recent data (Table 8.1) shows a mix of population increases and decreases.[203] While a 2% increase or decrease from year to year may seem small, it can build to a substantial change if the trend continues over time. For the purpose of tracking the health of North Carolina's biodiversity, not just individual species, we want to see improvement for a substantial majority of populations. Given that the most recent data shows that six of the 10 selected bird species have seen a negative trend, we evaluate the data as showing inadequate progress towards sustainable bird populations across a variety of ecological communities.

[203] Annual population trends were calculated in June 2024 by Curtis Smalling, Director of Conservation, Audubon North Carolina, on the basis of monitoring data from several sources: Brown-headed Nuthatch: Breeding Bird Survey (BBS), Nest box project, Climate Watch; Wood Thrush: BBS; Hooded Warbler: BBS; Prothonotary Warbler: BBS; Eastern Meadowlark: BBS; Eastern Whip-poor-will: Nightjar Survey; Chimney Swift: BBS, Audubon Swift Project; American Oystercatcher: Audubon Survey (AS), Colonial Waterbird Census (CWC); Brown Pelican: AS, CWC; Piping Plover: AS, Piping Plover Census.

Indicator 8.2: Net change at fish community assessment sites.

Top line: We use fish sampling data from NC DEQ as a proxy for freshwater aquatic biodiversity more generally. Although the data is messy, and shows both improvements and declines, the overall trend for freshwater fish diversity and abundance is more negative than positive.
About freshwater fish communities: We use freshwater fish communities as a proxy for aquatic diversity more broadly. Many other types of species inhabit these environments, including mussels, crayfish, and amphibians; but none have as much data as fish populations. Freshwater fish are among the top predators in the aquatic food web, and some species are themselves eaten by mammals, birds, and people. Healthy fish populations, both in abundance and in diversity of species in the habitats that support them, are a sign of healthy aquatic habitats. In some cases fish diversity seems to directly influence the diversity of other aquatic species.[204] Scientists estimate that the state is home to 234 native freshwater species, with another 24 introduced species that are now naturalized.[205] As a study of 61 years' worth of data from North Carolina's New River suggests, aquatic communities have become increasingly homogenized over time, supporting fewer distinct species, with the most common species expanding their range.[206]

Map 8.2: Net Change in Fish Community Assessment Sites



Source: NC DEQ's Fish Community Data Assessment with data through December 2021 • Created with Datawrapper

[204] Tamara Pandolfo et al., Thermal Threats to Freshwater Mussels: An Empirical Stream Assessment, Diversity, January 2024, 16: 37, https://doi.org/10.3390/d16010037.
[205] NC Biodiversity Project, List of the Freshwater Fishes of North Carolina, retrieved September 2024.
[206] Logan Sleezer et al., A new composite abundance metric detects stream fish declines and community homogenization during six decades of invasions, Diversity and Distributions, August 2021, https://doi.org/10.1111/ddi.13393.

When we last published the State of the Environment in 2019 two freshwater fish were listed as endangered under the federal Endangered Species Act (Cape Fear Shiner, and the Roanoke Logperch). A third freshwater fish, the Carolina Madtom, has since been listed as endangered under the federal Endangered Species Act.[121] There are still two freshwater species listed as threatened (Spotfin chub and Waccamaw Silverside), and two anadromous fish that migrate between fresh and saltwater are listed as endangered (Atlantic and Shortnose Sturgeon).[207] North Carolina's Wildlife Resources Commission (WRC) lists another 8 species as endangered and 12 as threatened under state law.[208]

We track trends in freshwater fish populations using data collected by NC DEQ's Fish Community Data Assessment. Starting in 1990, the program has sampled at roughly 960 sites, almost all road crossings and other access points where state scientists can use backpack electroshock equipment to stun and count fish.[209] Each time a site is visited, staff use a consistent protocol to assign it a value representing an index of biotic integrity.[210] Non-swamp sites are rated excellent, good, good-fair, fair, or poor, or are recorded as having insufficient data for a ranking (though such streams tend to have lower index scores). The protocol applies in the mountains, the Inner and Outer Piedmont, and the Sandhills, but not in coastal waters.

For this evaluation, we sifted the data for sites tested twice between 2009 and 2021. In most cases, the measurement was 5 years (one basinwide cycle) previously; in some, 10 years (skipping a cycle, meaning the site was not sampled at the 5 year mark). This screen reduced the data to 198 pairs of assessments. We then tallied whether the assessed quality improved, remained the same, or declined between visits. Of the 198 pairs, 73 sites suffered a decline, 74 were the same, and 51 improved. For purposes of this report, we mapped the net spatial distribution of those improvements and declines by county. Counties are shaded by the strength of net change in testing sites from red to blue; beige counties had no change; counties striped black and white had no data. Most of the counties with available data showed no change; where counties saw a change, it was negative more often than positive – so the trend for the state as a whole is negative. The regions with the most severe degradation align with the furthest exurbs of North Carolina's largest cities, where new development is spreading impervious surface across the landscape, changing flows and degrading stream habitat.

Indicator 8.3: Diversity and abundance of other species

Top line: Data on the health of species and ecological communities across North Carolina is limited and provides little basis for assigning a trend, so we label this a data gap. However, changes in rainfall, flooding, and temperature are expected to shift the range of many species and assemblages of species

[207] US Fish & Wildlife Service, Eastern North Carolina's federally protected plants and animals, retrieved September 2024.
[208] NC Wildlife Resources Commission, Protected Wildlife Species of North Carolina, October 2021, at 3 and 5.
[209] NC DEQ, website: Fish Community Data Assessment, visited January 19, 2024.
[210] NC DEQ, Standard Operating Procedure Biological Monitoring: Stream Fish Community Assessment Program, 2013.

faster than they can keep up through natural migration.[211] Continued habitat fragmentation from North Carolina's sprawling growth patterns also presents a threat to species.[212]

About species diversity and abundance: Biodiversity has instrumental value in the health of ecosystems and economy, as well as intrinsic value.[213] Unfortunately, data on the health of most species and ecological communities in North Carolina is limited and collected only sporadically.[214] Most species-specific studies provide snapshots rather than time-series data. North Carolina's main official analysis of species and ecological community trends is the North Carolina Wildlife Action Plan, released every ten years. The most recent version was published in 2015.[215] An addendum in 2020 updated the status of various animal species, and an addendum in 2022, overwhelmingly supported by public comments, added plants to the list of Species of Greatest Conservation Need (SGCN).[216] The NC Wildlife Resources Commission is slated to develop and publicly release the next ten-year update in 2025, at which point it may be possible to compare how many species have moved on or off the list of species of greatest concern and assign a trend. For the moment, we mark broader trends in species abundance and diversity across North Carolina as a data gap.

While we record this as a data gap, ongoing scientific research offers a lot of reasons to be concerned. One of those reasons is insect populations. Insects play critical roles in the food web, pollinating plants, cycling nutrients, and acting as a food source for other species. Yet, studies suggest strongly that spraying of neonicotinoids and pyrethroids, in both agricultural and developed landscapes, is destroying bee populations.[217] Climate change – and sprawling growth patterns that drive habitat losses and changes in microclimates – are likely to compound those declines.[218] A 2018 study in Raleigh found that

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[211] Mark Urban, Climate change extinctions, Science, December 2024, 386 (6726): 1123, https://doi.org/10.1126/science.adp4461; see also, Elaina Hancock, blog post: Climate change extinction risk, UConn Today, December 10, 2024 (interviewing the study's author).

[212] See, for example, Ashley Graham et al., Woodland Box Turtle (*Terrapene carolina carolina*) Abundance Declines with Increasing Urban Land Use in the Piedmont, Ichthyology & Herpetology, November 2022, 110 (4): 705, https://doi.org/10.1643/h2022001; C. Rhett Jackson et al., Water supply, waste assimilation, and low-flow issues facing the Southeast Piedmont Interstate-85 urban archipelago, JAWRA, May 2023, 59 (5): 1146, https://doi.org/10.1111/1752-1688.13130 (growth threatens aquatic species in the Piedmont); Selina Ruzi et al., Bee species richness through time in an urbanizing landscape of the southeastern United States, Global Change Biology, December 2023, 30 (1), https://doi.org/10.1111/gcb.17060 (195 species of bees missing from collections of bees in Wake County over last two decades, a period of rapid urban expansion).

[213] Rebecca Chaplin-Kramer et al., Wildlife's contributions to people, Nature Reviews Biodiversity, January 2025, 1: 68, https://doi.org/10.1038/s44358-024-00006-9.

[214] One powerful tool for identifying what is known about species is NatureServe Explorer, available through NatureServe, interactive map: NatureServe ExplorerPro, visited March 22, 2025.

[215] NC Wildlife Resources Commission, NC Wildlife Action Plan, 2015, available at NC Wildlife Resources Commission, webpage: Wildlife Action Plan, visited December 19, 2024.

[216] NC Wildlife Resources Commission, 2020 Addendum to the 2015 NC Wildlife Action Plan, 2020; NC Wildlife Resources Commission, North Carolina Protected Plant Species and Plan SGCN Evaluation Methodology White Paper, SGCN Plant List, and Public Comments, 2022.

[217] Laura Melissa Guzman et al., Impact of pesticide use on wild bee distributions across the United States, Nature Sustainability, August 2024, https://doi.org/10.1038/s41893-024-01413-8.

[218] Jeffrey Harvey et al., Scientists' warning on climate change and insects, Ecological Monographs, November 2022, 93 (1): e1553, https://doi.org/10.1002/ecm.1553.

bee abundance declined by 41% for each degree Celsius of urban warming.[219] A broader 2023 study at Duke Forest found that each Celsius degree of warming was associated with 20% decline in arthropod abundance; the pattern of declines suggested the major driver was a warmer winter rather than a hotter summer.[220]

Recent developments: For this indicator, we're ultimately more interested in the health and diversity of North Carolina's natural ecosystems as a whole than the status of any one species. That said, some species are in much better shape than others. The US Fish & Wildlife Service (USFWS) lists 68 species known to occur in North Carolina as threatened or endangered, including 7 mammals, 7 birds, 7 reptiles, and 1 amphibian.[221] Since 2016, the USFWS has used Species Status Assessments to organize and evaluate data on the health of listed species and species under consideration for listing.[222] Academic and agency scientists have wrestled with how to adapt this process to address the long backlog of species that are struggling but have no federal or state protections. Scientists have generally recognized the threats posed by climate change and urban growth patterns, and the need to protect assemblages of species, not just individual species.[223]

Meanwhile, over the last five years, spurred onwards by petitions for listing and occasional lawsuits brought by advocates, USFWS has proposed to add individual species to the federal Threatened & Endangered Species list. As of the end of 2024, USFWS had 60 species proposed for listing nationwide, but only a handful are known to occur in North Carolina.[224] These include the tricolored bat, the green floater (a freshwater mussel), the monarch butterfly, and the eastern hellbender.[225] It's worth noting that Hurricane Helene severely damaged habitat in the range of several protected or candidate species, including the hellbender and the Appalachian elktoe freshwater mussel.[226]

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[219] April Hamblin et al., Wild bee abundance declines with urban warming, regardless of floral density, Urban Ecosystems, January 2018, 21:419, https://doi.org/10.1007/s11252-018-0731-4.
[220] Jacquelyn Fitzgerald et al., Abundance of spring- and winter-active arthropods declines with warming, Ecosphere, April 2021, 12(4): e03473, https://doi.org/10.1002/ecs2.3473.
[221] USFWS, webpage: Environmental Conservation Online System (ECOS), visited December 20, 2024.
[222] USFWS, Species Status Assessment Framework, August 2016; USFWS, factsheet: Species Status Assessment Framework, August 2016.
[223] Reed Noss et al., Improving species status assessments under the U.S. Endangered Species Act and implications for multispecies conservation challenges worldwide, Conservation Biology, December 2021, 35(6): 1715, https://doi.org/10.1111/cobi.13777.
[224] USFWS, webpage: Environmental Conservation Online System (ECOS), visited December 20, 2024.
[225] 87 Fed. Reg. 56381 (September 14, 2022), Tricolored Bat; 88 Fed. Reg. 48294 (July 26, 2023), Green Floater; 89 Fed. Reg. 100662 (December 12, 2024), Monarch Butterfly; 89 Fed. Reg. 100934 (December 13, 2024), Eastern Hellbender.
[226] Will Hofman, Rare hellbender salamander in Western NC faces calamity from Helene's floods, Asheville Citizen-Times, October 19, 2024; Gray Pandolfi et al., Riparian land-use and in-stream habitat predict the distribution of a critically endangered freshwater mussel, Hydrobiologia, March 2022, 849: 1763, https://doi.org/10.1007/s10750-022-04826-8.

Goal 9: Agriculture is economically viable and rewarding for farmers

Trend: Mixed

North Carolina agriculture is something of a chameleon. It has at times been presented as an economic behemoth, with agriculture and agribusiness providing 16% ($103.2 billion) of the state's gross state product and employing 16% (736,000 people) of the workforce in 2021.[227] Yet, that calculation includes manufacturing that uses fibers (from North Carolina or elsewhere), agricultural chemical production, and food stores and restaurants. The actual income attributed to farming and forestry is 2.9% ($17.8 billion) of the state's economy and about 3.3% of total employment (150,000 jobs).[228] Those farms hold a crucial part of the state's cultural and economic heritage and are stewards of millions of acres of land. Their continued success is the focus of this goal.

To evaluate this goal – that agriculture remain economically viable and attractive to farmers – we examine three indicators: net farm income per acre (indicator 9.1); net number of farms and farm acres in use (indicator 9.2); and the acreage held by farms taking advantage of policies designed to keep land in agriculture (indicator 9.3). The results for these indicators are mixed.

Solutions: There are undoubtedly solutions beyond the scope of this report, but NC can support the economic viability of North Carolina agriculture by A3, funding the Agricultural Development and Farmland Preservation Trust Fund; A4, investing in floodplain restoration; B1, increasing agricultural cost share funding to improve water quality and habitat benefits of working lands; B2, expanding incentives for private woodlots; and B4, adopting local farmland protection plans. Cross-industry solutions include also B3, promoting farm to school initiatives; K4, avoiding induced sprawl in transportation planning.

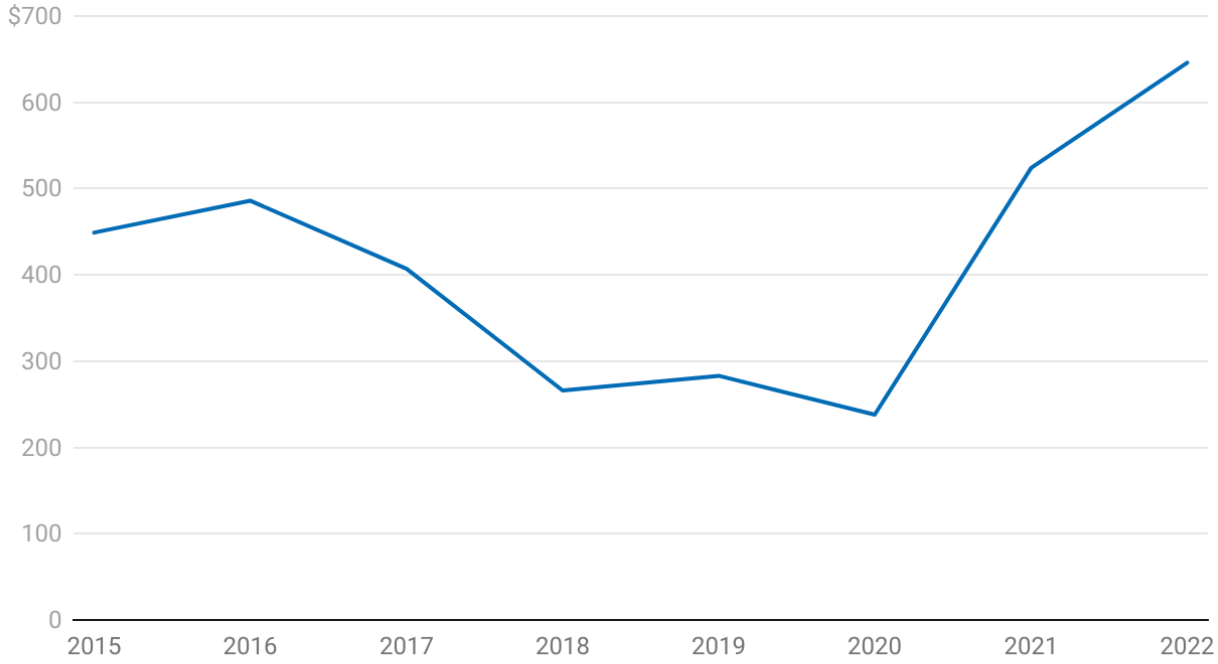
Indicator 9.1: Net farm income per acre

Top line: We track farm income per acre because it is a basic driver of whether farmers can make a living. Over the last decade, net farm income measured in real dollars (so, controlling for inflation) dipped and then surged to higher levels. The data we have, ending in 2022, shows a positive trend – but largely as a result of climate-charged weather disasters, the bottom dropped out for North Carolina agriculture in 2024, described as 'the worst year on record'. Given that, and the uncertainty about what it will take for farm income to bounce back, we assign this indicator a yellow flag.

[227] NC State University, factsheet: Agriculture and Agribusiness, May 2023.
[228] *Ibid*; see also, NC State University, factsheet: Economic Contribution of the Forest Sector in North Carolina, 2022.

Figure 9.1: Net Farm Income per Acre

Adjusted for inflation, expressed in 2024 dollars



Source: U.S. Department of Agriculture, Economic Research Service. Farm Income and Wealth Statistics. • Created with Datawrapper

About farm profitability: A basic determinant of whether farming remains economically viable is whether farmers can reliably make enough money to cover costs, manage debt, and support their families.[229] We use data on net farm income and farm acres from the USDA Economic Research Service to calculate net farm income per acre, adjusted to real 2022 dollars (the most recent year of available data). [230] In 2019, farm income had been volatile but falling for years, so we assigned this indicator an unfavorable trend. However, between 2020 and 2022, real income per acre increased significantly. That's a positive trend, but 2024 was awful statewide, not just as a result of Helene-driven losses in the mountains.[231] Both the US Congress in late 2024 and the NC General Assembly in early 2025 moved to

[229] For more depth and a national perspective on farmer profitability and other measures of 'success', see Emily Burchfield et al., The State of US Farm Operator Livelihoods, Frontiers in Sustainable Food Systems, February 2022, 5: 795901, https://doi.org/10.3389/fsufs.2021.795901.

[230] USDA, Economic Research Service, Farm Income and Wealth Statistics, February 7, 2024; USDA, Economic Research Service, Farms and Land in Farms, 2015-2022.

[231] Jane Winik Sartwell, 'Worst' year ever for farms in North Carolina, Carolina Public Press, November 25, 2024; Galen Bacharier, North Carolina agricultural leaders outline a bleak landscape post-Helene, NC Newsline, December 11, 2024.

provide direct financial assistance to farmers to offset some losses, but that doesn't address longer term trends in profitability, which we assign a yellow flag for this update.[232]

Even during good years, growth has not been evenly shared across the agricultural sector. Over the last five years of data (2018-2022), total crop receipts increased by 8%; receipts for 'meat animals' (which includes swine) increased by 22%; but receipts for poultry/eggs increased by 67%, nearly $4 billion in real 2022 dollars.[233] That reflects the massive expansion of the poultry industry in North Carolina, also discussed under indicator 11.3, phosphorus soil levels.[234]

An estimated 6% of farmers in North Carolina are 'socially disadvantaged', the term USDA uses for farmers of color.[235] Roughly 5% of North Carolina farms are run exclusively by women; another 35% are run jointly by men and women.[236] Roughly 11% of North Carolina farms are considered 'low resource' farms, meaning they had low gross farm sales and low household income two years in a row.[237] There is some evidence that socially disadvantaged, women, and low resource farmers have difficulty accessing agricultural support programs.[238] In North Carolina, those farmers may be at particular risk of leaving farming and selling property that is then developed or otherwise lost as working lands.

Recent developments: In the last few years, as North Carolina has begun to wrestle in earnest with stronger storms and more intense floods, one strategy that has emerged is the possibility of paying farmers to let their lands flood at rare intervals to spare downstream cities.[239] Studies have suggested this could bring income to farmers and protection to downstream communities, but we are only just reaching the stage of on the ground pilot projects, and 'water farming' and other payments for assisting in climate mitigation or adaptation are not yet reflected in farm income statistics.

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[232] Colin Campbell, $475 million for crop losses? N.C. House Republicans aim to aid farmers after 'unprecedented' year, WUNC, February 26, 2025; NC State University, American Relief Act of 2025: Economic Assistance for North Carolina Crop Producers, NC State Economist, February 2025.

[233] USDA, National Agricultural Statistics Service, Statistics by State: North Carolina, Section 2, Income & Prices, table: Value Added to the North Carolina Economy By the Agricultural Sector, at 30. Data as of August 31, 2023.

[234] North Carolina set a new record for egg production in 2021 and for commercial broilers in 2022. USDA/NC DACS, 2023 North Carolina Agricultural Statistics, Livestock, Dairy and Poultry, Record Highs and Lows, at 34.

[235] USDA Economic Research Service, An Overview of Farms Operated by Socially Disadvantaged, Women, and Limited Resource Farmers and Ranchers in the United States, February 2024, Figure 3, at 11.

[236] *Idem*, Figure 12, at 24.

[237] *Idem*, Figure 22, at 36. North Carolina has one of the highest percentages of low resource farmers, but it is worth noting that, nationally, 76% of farms had low gross farm sales but not low income, making lack of off-farm income rather than farm sales a key distinction for low resource farmers.

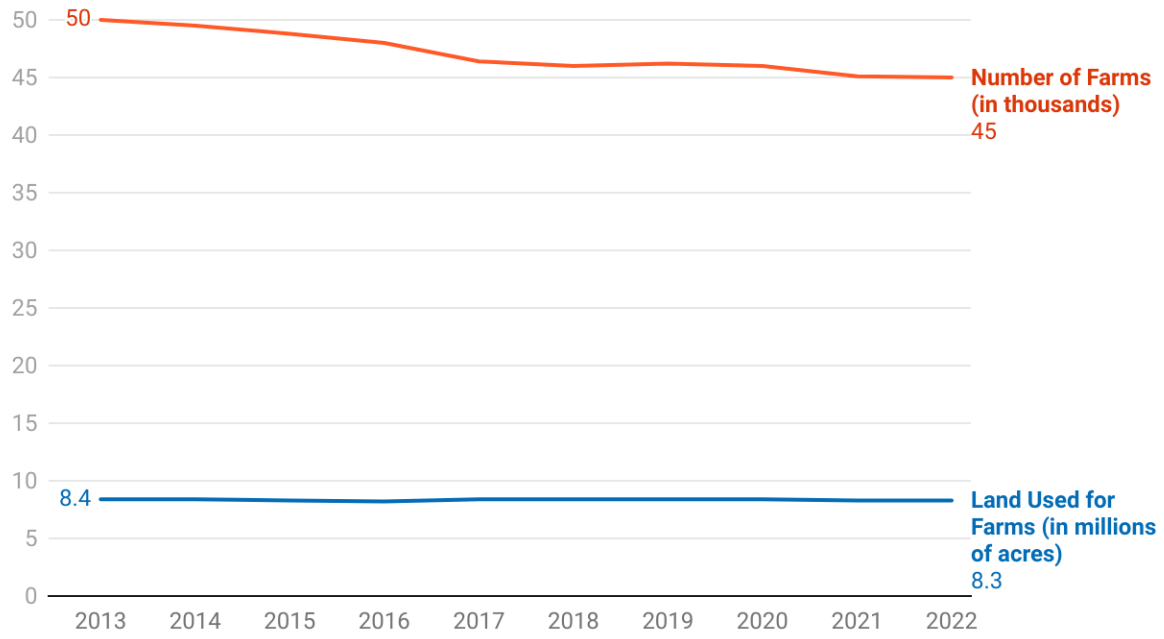
[238] *Idem*, at 47; Darren Dodson, master's thesis: Exploring the Role of Farm Tourism Microentrepreneurship in Supporting Black Agrarianism in North Carolina, at 108 – 111.

[239] *See*, Meredith Hovis, dissertation: The Floodwise Pilot Program: Leveraging Nature-Based Solutions for Flood Mitigation and Resiliency in Rural, Eastern North Carolina, 2022; Meredith Hovis et al, Determining the costs, revenues, and cost-share payments for the "floodwise" program: Nature-based solutions to mitigate flooding in eastern, rural North Carolina, Nature-Based Solutions, March 2022, 2, https://doi.org/10.1016/j.nbsj.2022.100016.

Indicator 9.2: Numbers of farms and acres in farm and agricultural use

Top line: The number of farms continues to decline steadily, although the acreage in agricultural use is declining much more slowly. Both are trends in the wrong direction for the long-term health of the sector and the state.

Figure 9.2: Numbers of Farms and Acres in Farm and Agricultural Use



Source: USDA, Economic Research Service, Number of Farms, 2013-2022; Acres of farmland, 2013-2022. • Created with Datawrapper

About numbers of farms: A healthy agricultural sector needs farmland to stay in active use, rather than being abandoned or developed. USDA's National Agricultural Statistics Service (NASS) provides annual estimates of the numbers of farms and acreage of land in farms. The data for North Carolina indicates that over the last decade, the state has lost 10% of its farms, dropping from 50,000 to 45,000.[240] Meanwhile, the acreage in agricultural use has declined by only 1%, from 8.4 million acres to 8.3 million acres.[241] From that one might conclude that the majority of farms ceasing production are small in acreage, or that their land is being bought at least in part by existing farms that continue to farm it. Either way, the trend is one of increasing concentration and a loss of family farms; we regard that as a bad trend.

[240] USDA, Economics, Statistics, and Market Information System, Farms and Land in Farms, 2013-2022.
[241] *Idem*. USDA's Natural Resources Inventory, based on a different dataset, estimated that North Carolina lost a similar acreage (100,000 acres) of prime cropland from 2007 to 2017. USDA, NRI dashboard: Prime Farmland, data from NRCS Natural Resources Inventory, 2017.

Recent developments: In 2022, the American Farmland Trust offered a projection of farmland loss in each state through 2040 under three scenarios: 'better built cities', 'business as usual', and 'runaway sprawl'.[242] Projected losses of remaining farmland for North Carolina range from 6.4 to 11.6%; the critical difference is how much of the state's predicted growth is housing in new, low density subdivisions (more loss) as opposed to densification of urban area (less loss).[243] NC Agriculture Commissioner Steve Troxler drew on the AFT analysis for his 2024 State of Agriculture address, sounding the alarm on farmland loss.[244]

Despite that concern, the NC General Assembly has taken relatively few actions in recent years to keep land in agriculture. The legislature has appropriated modest funding for farmland preservation – more on that under indicator 9.3, below – and individual legislators have complained loudly about solar farms in rural counties. Yet, as AFT notes, solar farms account for a tiny share of land conversions, only a fraction of the area converted to low density development. In general, state legislators over the last decade have favored building interests over local governments, for example by making annexation much more difficult, and by supporting efforts of neighborhoods on the urban fringe to de-annex. Cumulatively, these policies promote faster sprawl, a trend we discuss under indicator 34.2, patterns of residential growth, below.

Well behind the impact of human growth patterns, many acres of cropland in eastern North Carolina are threatened by rising seas and saltwater intrusion.[245] USDA has identified five stages of salinization in the Southeast; by stage 2, recurring episodic salinity, soils cannot sustain sensitive crops.[246] On the one hand, we don't want to lose farmland, though there's only so much land managers can do to keep salt at bay; and on the other, as sea levels rise, it will be crucial to help salt marshes retreat inland, often on to former agricultural fields, or we will lose the functions and benefits of the salt marshes as well.[247] Ultimately, the only way to stop loss of cropland to saltwater intrusion is to halt climate change.

Indicator 9.3: Acres of farmland preserved in North Carolina.

Top line: Multiple state and local policies and programs work to keep farmers on the land. While the programs would certainly benefit from more investment, they are collectively protecting and conserving farmland, moving this indicator in the right direction.

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[242] American Farmland Trust, Farms Under Threat 2040, June 2022.
[243] *Idem*, at 28-29, 57.
[244] Laura Leslie, Troxler: NC farms under threat from rapid growth, WRAL, February 1, 2024; John Hart, NC risks losing 1.8 million acres of farmland, Farm Progress, February 8, 2024.
[245] David Boraks and John Upton, Rising seas, salt water threaten coastal farms, so farmers adapt, WFAE, June 13, 2022; Sarah Kaplan, Ruined crops, salty soil: How rising seas are poisoning North Carolina's farmland, Washington Post, March 1, 2019.
[246] USDA, Forest Service, Identification, Mitigation, and Adaptation to Salinization on Working Lands in the U.S. Southeast, July 2021, at 13-14.
[247] See, for example, PBS North Carolina, clip: State of Change: Fighting Saltwater Intrusion in the Blacklands, April 19, 2023.

About farmland preservation: Several programs currently help preserve farmland in North Carolina:

Voluntary agricultural districts. The NC Department of Agriculture calculates that as of December 2022, 90 of the state's 100 counties had county ordinances for Voluntary Agricultural Districts (VAD). Of those, 37 had 'enhanced' VAD programs, meaning that landowners could make a 10-year irrevocable commitment to keep the land in agriculture with default renewal and priority for various incentive payments. Statewide, as of December 2022, 10,895 farms were enrolled in VAD programs, covering 899,931 acres of farms and forests.[248]

Farmland protection plans. Tier one, two, or three counties that prepare a 'farmland protection plan' enjoy a significant reduction or elimination of their required local match for state farmland preservation grants.[249] NCDA estimates that 67 counties have farmland protection plans, with another two counties in the process of updating or adopting theirs.[250] That leaves 31 counties with no plan. To qualify as a farmland protection plan, a plan must inventory a county's agricultural activity, identify challenges to family farms, list opportunities and plans for the county to support farms, include an implementation schedule, and identify potential funding sources.[251]

Farmland protection easements. The Agriculture Development and Farmland Preservation Trust Fund (ADFPTF) was established by state statute in 2005. As of the end of 2023, the program had secured 212 easements and protected nearly 32,000 acres of farmland; that's 71 easements and over 12,000 acres over the five year period since 2019.[252]

Agricultural present use value. North Carolina also provides a tax incentive to landowners who commit to keep land in farming, horticulture, forestry, or wildlife management. Known as 'present use value', the state law directs counties to assess property taxes on enrolled farmland at a lower rate.[253] If landowners withdraw property from the program for development, they must pay a penalty of several years' worth of back taxes at the full market rate. This may be the single most effective strategy for keeping land in agriculture, but the data for this program is kept at the county level, and focuses on the value rather than the acreage covered, so is not readily available for inclusion here.

Based on the data that is available for voluntary agricultural districts and agricultural easements, we assess this indicator as moving in the right direction.

[248] NC Department of Agriculture, webpage: County Info and Statewide Summaries, updated December 2022; the requirements and privileges associated with Enhanced VADs are described at NCGS 106-743.1 – 743.5.
[249] NCGS 106-744(c2).
[250] NCDA, website: County Info and Statewide Summaries, visited June 19, 2024.
[251] NCGS 106-744(e).
[252] American Farmland Trust, Farmland Information Center, factsheet: 2023 Status of State PACE Program, 2023.
[253] NCGS 105-277.2 through 277.7. For a detailed discussion of the program and its variations from county to county, see, NC State Extension, web resource: Present use value, the basics of agricultural and forest use property tax, 2021.

Goal 10: Agricultural production is environmentally sustainable

Trend: Positive

Movement towards greater sustainability can take multiple forms, including setting sensitive lands aside to serve as conservation buffers, adopting practices that protect wildlife, reducing fertilizer and pesticide use, or moving towards fully organic methods. This goal is primarily focused on North Carolina crop agriculture; as indicators, we consider the rate of soil erosion (indicator 10.1, a flawed proxy for soil health); the extent of conservation practices (indicator 10.2); and the value of organic farm receipts (indicator 10.3, an imperfect proxy for sustainable farming revenues more generally). All three indicators are positive, adding up to a positive trend for the environmental sustainability of North Carolina's crop agriculture for the period covered by our data.

Solutions: There is overlap in policies aimed at economic viability (goal 9) and those meant to improve environmental sustainability: A3, funding the Agricultural Development and Farmland Preservation Trust Fund; A4, investing in floodplain restoration; B1, increasing agricultural cost share funding to improve water quality and habitat benefits of working lands; B2, expanding incentives for private woodlots; and B4, adopting local farmland protection plans. In addition, by E4, banning the use of neonicotinoid pesticides, we can protect essential pollinators. Cross-industry solutions include also B3, promoting farm to school initiatives; K4, avoiding induced sprawl in transportation planning.

Indicator 10.1: annual rate of soil erosion.

Top line: Historians taking a long view of civilizations' rise and fall often point to soil health as an underlying driver. Unfortunately, the data for tracking soil health across North Carolina is narrow and updated infrequently. Existing data suggests we have made gradual progress in reducing soil erosion over decades, which we count as a positive trend. That said, climate change will reverse some of these gains, and we'd also like to find an indicator that offers a broader perspective on soil health than just erosion.[254]

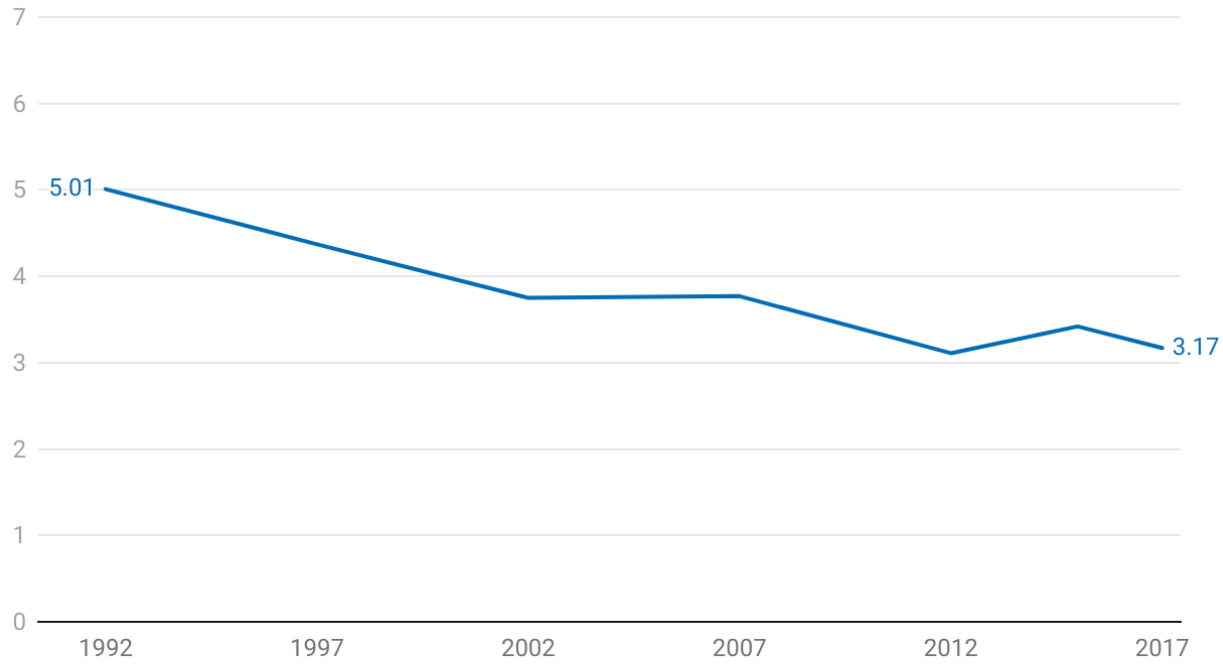
About soil erosion: In 1938, in the midst of the Dust Bowl, USDA soil scientist Charles Kellogg wrote an essay on the history of the discipline for the USDA Yearbook of Agriculture. "All life depends on the soil," Kellogg wrote, "there can be no life without soil and no soil without life; they have evolved together."[255] Concern for soil health underlies a strong tradition of conservation in America. Soil health is complex,

[254] For work towards a broader metric of soil health, see, Alan Franzluebbers, Texture and organic matter associations with soil functional properties in crop and conservation land uses in North Carolina, Soil Science Society of America Journal, August 2023, 2: 449, https://doi.org/10.1002/saj2.20620; Jordon Wade et al., Rigorous, empirical, and quantitative: a proposed pipeline for soil health assessments, Soil Biology and Biochemistry, July 2022, 170, https://doi.org/10.1016/j.soilbio.2022.108710; Charlotte Norris et al., Introducing the North American project to evaluate soil health measurements, Agronomy Journal, April 2020, 112 (4): 3195, https://doi.org/10.1002/agj2.20234.

[255] Charles E. Kellogg, Soil and Society, 1938 Yearbook of Agriculture, at 864.

and researchers have compiled long lists of the characteristics that contribute to soil health, as well as suggestions for how best to measure them. The simplest measure of soil sustainability, however, is the rate at which soil is lost to wind or water erosion.

Figure 10.1: Estimated annual water-driven soil erosion from NC cropland (tons/ acre-year)



Source: Center for Survey Statistics and Methodology, Iowa State University, using USDA, NRCS, Land Use and Cover Inventory Database. • Created with Datawrapper

For this indicator, we track the rate of water-driven soil erosion on North Carolina cropland, estimated by the US Department of Agriculture's Natural Resources Inventory (NRI). Unfortunately, the underlying data is somewhat dated: it was collected 1982-2017, released in 2020, and added to an online mapping tool in 2023.[256] In North Carolina, the data shows a striking decline in estimated erosion from 1982 to 2007, and only minimal change since then. NRI generated its estimates "based upon the cropping conditions, management practices, and inherent resource conditions that occur at each NRI sample site," so it seems likely that the decline reflects growing adoption by farmers of conservation tillage practices.[257] We view the reduced erosion as positive trend.

Recent developments: While the NRI trend line is good, it is less clear how long it will last – or whether North Carolina's gains may already be being reversed. One of the expected consequences of climate change is greater volumes of water in the atmosphere, resulting in more intense rainfall. Scientists have

[256] USDA, 2017 Natural Resources Inventory Summary Report [*2017 NRI Summary*], September 2020; USDA, NRI dashboard: Cropland Soil Erosion, data from NCRS Natural Resources Inventory, 2017.
[257] *2017 NRI Summary*, at 5-1.

already documented that happening in North Carolina over the last 20 years.[258] Unfortunately, one direct consequence of more concentrated rain events is greater soil erosion; researchers have projected a potential global increase in rates of soil erosion of 30% to 60%, depending on how quickly emissions drop and warming slows.[259] The model the NRI applied to its survey sites has not been adjusted for changing intensity of rainfall; indeed, other federal agencies are leading that process and expecting to produce revised rainfall frequency curves in 2025. So the NRI trend line does not reflect the upward pressure that more intense rains are placing on erosion rates.

Beyond rates of erosion, interest has grown in recent years in the capacity of healthy soils to sequester carbon. Research in North Carolina suggests that such traditional conservation practices as restoring forests, grassland strips, and no-till agriculture – all methods counted under the next indicator, 10.2, conservation practices – sequester much more carbon in the ground than conventional-till cropland can hold.[260] Farmers may pursue these practices for their wildlife benefits or to control phosphorus and nitrogen; but they help reduce agriculture's net carbon emissions as well. Healthy soils on well-managed pastureland also sequester carbon at a faster rate than conventional croplands.[261]

Indicator 10.2: Value of conservation practices.

Top line: Since a low point in 2014, the federal Natural Resources Conservation Service has paid farmers increasing total amounts to implement sustainable conservation practices on their lands. This is only a rough measure of the impact of conservation practices on the state's farmland and natural resources, but it is a positive trend.

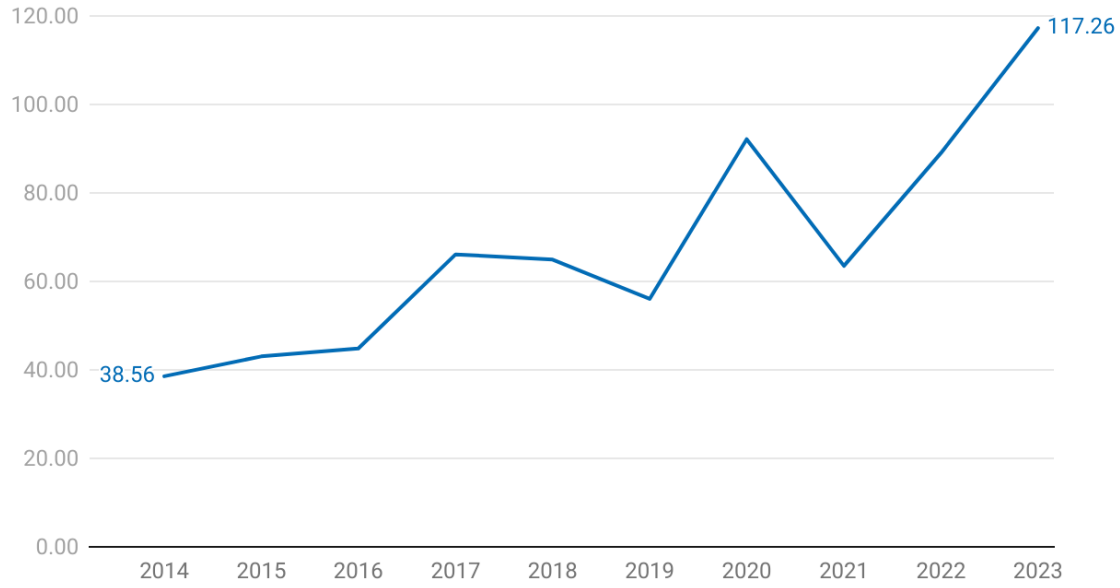
About conservation practices: Many North Carolina farmers participate in programs that pay them to implement various sustainable practices on their farms, ranging from restoration of riparian buffers, to letting sensitive lands lie fallow, to fencing livestock out of streams, among others. One key conservation practice has been conservation tillage, in which farmers minimize soil disturbance to protect the soil

[258] Bill Hunt, Presentation to Regional Resiliency Workshop: Upper Coastal Plain COG, November 12, 2019; Jungho Kim et al., Assessment of the standard precipitation frequency estimates in the United States, Journal of Hydrology: Regional Studies, December 2022, 44, https://doi.org/10.1016/j.ejrh.2022.101276.
[259] Pasquale Borelli et al., Land use and climate change impacts on global soil erosion by water (2015-2070), PNAS, July 2020, 117 (36): 21994, https://doi.org/10.1073/pnas.2001403117.
[260] Alan Franzleubbers, Soil organic carbon and nitrogen storage estimated with the root-zone enrichment method under conventional and conservation land management across North Carolina, Journal of Soil and Water Conservation, March 2023, 78 (2), https://doi.org/10.2489/jswc.2023.00064.
[261] Alan Franzleubbers, et al., Soil health and root-zone enrichment characteristics between paired grassland and cropland fields in the southeastern United States, Grassland Research, January 2024, 2 (4): 299, https://doi.org/10.1002/glr2.12066.

from erosion. Conservation tillage has been shown to significantly improve retention of carbon, nitrogen, and inorganic nutrients in the soil across the Southeast.[262]

Figure 10.2: Value of NRCS Conservation Practices in North Carolina

Measured in Millions of Nominal Dollars



Source: USDA-NRCS, Financial Management Modernization Initiative (FMMI), RCA Data Viewer • Created with Datawrapper

Typically, a participating farmer signs a contract or time-limited easement and then receives a stream of incentive payments for a period of years. Across the nation, conservation practices tend to be implemented at a lower rate on land farmed by renters rather than owners; in North Carolina, rented land makes up a substantial fraction of the total farmland in the Coastal Plain, especially north of the Neuse River.[263] Minority farmers are underrepresented in agricultural conservation programs for a suite of reasons, including lack of land ownership, limited resources to pay the landowner share of cost-share

[262] Alan Franzluebbers, Soil-test biological activity associates with soil aggregation characteristics under different land uses in North Carolina, Soil Science Society of American Journal, August 2022, 86 (6): 1639, https://doi.org/10.1002/saj2.20474; Bhupinder Farmaha et al., Cover cropping and conservation tillage improve soil health in the southeastern United States, Agronomy Journal, August 2021, 114 (1): 296, https://doi.org/10.1002/agj2.20865; Alan Franzluebbers et al., Multispecies cover cropping promotes soil health in no-tillage cropping systems of North Carolina, Journal of Soil & Water Conservation, May 2021, 76(3): 263, https://doi.org/10.2489/jswc.2021.00087.

[263] Peggy Petrzelka et al., Advancing understanding of conservation practices on rented land, Journal of Soil and Water Conservation, March 2021, 76 (2): 35A, https://doi.org/10.2489/jswc.2021.0209A.

programs, and challenges of managing property that has been passed down over the years without clear title to a large and scattered family (heirs property).[264]

This indicator tracks the total annual value of the various practices. We track total value rather than acreage because some of the most valuable practices do not take much physical space. This is not an ideal indicator, because levels of spending reflect funding decisions by the U.S. Congress as well as the choices of North Carolina farmers. Yet, the indicator does offer a sense of the degree to which conservation practices are implemented across the landscape. Over the last decade, annual payouts in North Carolina have risen substantially, from $39 million in 2014 to $117 million in 2023.[265] This increase is a positive trend.

Indicator 10.3: Acreage of and sales from certified organic farms.

Top line: Certified organic farms account for a small fraction of North Carolina's total agricultural sector. That said, the number, acreage, and sales of certified organic farms in North Carolina have grown substantially over the last decade. We count this as a positive trend.

Table 10.3: Acreage of and sales from certified organic farms in North Carolina

Year	# farms	# acres	$ sales (million)
2014	200	22	67
2015	203	29	82
2016	247	32	145
2019	347	43	370
2021	335	39	308

Source: USDA, NASS, 2014-2021 Certified Organic Survey • Created with Datawrapper

About organic and sustainable farms: Many farms choose to be environmentally sustainable without seeking formal organic certification, a process that takes three years and then requires ongoing documentation.[266] There are many degrees of sustainability that are not captured by a farmer's choice

[264] Kayla Stukes, master's thesis: Minority Landowners' Participation in Conservation Programs: Understanding Barriers and Opportunities, May 2023.
[265] USDA-NRCS, Financial Management Modernization Initiative (FMMI), RCA Data Viewer, 2014-2023.
[266] USDA, Economic Research Service, Organic Situation Report, 2025 Edition [*2025 Organic Situation Report*], February 2025; USDA, NRCS, Conservation Activities in Organic Farming Systems, Technical Note 12, April 2024.

whether to be certified as organic. While statistics on certified organic farms thus underestimate the scale of sustainable farming in the state, they offer the most readily available official snapshot of highly sustainable operations. The data are collected annually by the National Agricultural Statistics Service as part of the National Organic Survey.

Between 2014 and 2021, the most recent year of data, the number of certified organic farms in North Carolina rose from 200 to 335. As shown in the chart, total acreage in certified organic production rose from 21,600 acres to 38,900 acres, and sales rose from $66.9 million to $308 million (not adjusted for inflation).[267] These trends are all positive, and in something of a contrast to the national trends, where a decline in organic pastureland and rangeland production, driven in part by drought in California, has reduced total organic farm acreage.[268] It's also worth noting that, with a relatively modest number of farms and acres in certified organic production, North Carolina punches well above our weight in sales; that likely reflects the contribution of 99 certified organic North Carolina farms that raise eggs and chickens.[269]

Goal 11: Animal agriculture is a good neighbor

Trend: Negative

This goal assesses the impacts agriculture has on the surrounding environment and communities. In practice, this means animal agriculture. Largely, row crop farmers in sensitive watersheds have aggressively reduced their nitrogen and phosphorus pollution while also implementing best practices to protect the health of the land.[270] In contrast, animal agriculture is primarily carried out using industrial techniques that have significant and poorly managed impacts on surrounding communities.

Animal agriculture is a huge part of North Carolina's agriculture sector. In 2020, animal agriculture in North Carolina accounted for an estimated $6.61 billion in receipts, 66% of the $10.03 billion in total receipts for the sector.[271] Of the top ten agricultural commodities in North Carolina, animals account for the top three.

From a sustainability perspective, animal agriculture is a critical part of North Carolina's economy. It is essential that the industry be a good neighbor, protecting the state's air and water as it operates. The indicators below show a sector that falls far short of that goal.

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[267] USDA, National Agricultural Statistics Service, 2014, 2015, 206, 2019, 2021 Certified Organic Survey, all available for download here.
[268] *2025 Organic Situation Report,* at 3.
[269] USDA, National Agricultural Statistics Service, 2021 Certified Organic Survey, at 125-126.
[270] See, for example, NC Department of Agriculture, 2018 Annual Progress Report (Crop Year 2017) on the Neuse Agricultural Rule (15A NCAC 2B.0238), 2018.
[271] USDA, Economic Research Service, Cash receipts by state, commodity ranking and share of U.S. total, 2017.

Solutions: North Carolina should, G13, transition swine farms away from sprayfields; and G14, require dry-litter poultry operations to obtain state permits.

Table 11: Agricultural commodities in North Carolina

Rank in NC	Commodity	Percent of state receipts	NC rank nationally
1	Broilers	28.7%	2
2	Hogs	19.1%	3
3	Turkeys	8.0%	1
4	Miscellaneous crops	6.6%	6
5	Soybeans	5.5%	17
6	Chicken eggs	5.0%	6
7	Corn	4.7%	19
8	Tobacco	3.9%	1
9	Sweet potatoes	3.7%	1
10	Cotton lint, Upland	2.7%	7

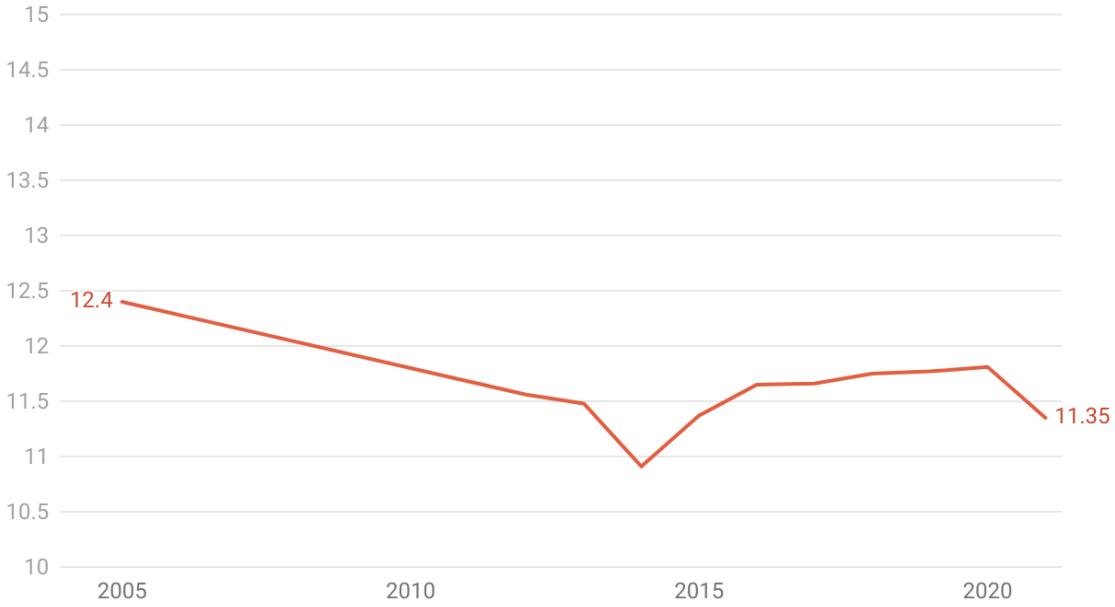
Source: USDA, Economic Research Service, Cash receipts by state, commodity ranking and share of U.S. total, 2017. • Created with Datawrapper

Indicator 11.1: Greenhouse gas emissions from agriculture

Top line: Greenhouse gas emissions from North Carolina's agricultural sector have remained virtually static over the last decade, and are only modestly down (1.05 million metric tons (MMT), or 8%) from the 2005 baseline. This is well short of state reduction targets (40% by 2025, for example), even as there are ways to significantly reduce methane emissions from animal agriculture. So, we rate this as showing inadequate progress.

Figure 11.1: Gross GHG emissions from North Carolina agriculture

in millions of metric tons of CO2 eq.



Note: Vertical axis begins at 10 MMT CO2e

Source: US EPA, Greenhouse Gas Inventory Data Explorer. • Created with Datawrapper

About greenhouse gas emissions from agriculture: Agriculture in North Carolina counts for less than 8% of the state's greenhouse gas emissions – in 2021, 11.35 million metric tons (MMT) of CO2 equivalents (CO2e), out of gross state emissions of 144 MMT.[272] Much of these emissions occur in the form of methane, which has 25x the warming impact of CO2, and nitrous oxide (N20), which has 298x the warming impact of CO2.[273] The bulk (65%) of the agricultural sector's GHG contribution comes from animal agriculture, both manure management and 'enteric fermentation' – livestock farting and burping. EPA statistics count emissions from stationary agricultural machines and farm equipment as 'industrial' and 'transportation', respectively, so those are not included in the sector estimate.[274] North Carolina's own inventory presents the components of agriculture emission in a slightly different format with a similar result.[275]

What would it mean for North Carolina's agricultural sector to meet a 'net zero by 2050' target? In 2019, EPA estimated that, using technically feasible measures, non-CO2 GHG emissions from the agricultural

[272] US EPA, Greenhouse Gas Inventory Data Explorer: North Carolina, 1990 – 2021, visited July 25, 2024.
[273] RTI International, Global Non-CO2 Greenhouse Gas Emission Projections & Marginal Abatement Cost Analysis: Methodology Documentation, September 2019, EPA-430-R-19-012, at 2-2. See also, US EPA, web report: U.S. State-level Non-CO2 Greenhouse Gas Mitigation Potential: 2025-2050 [*Non-CO2 mitigation potential report*], visited July 30, 2024.
[274] US EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022, at 62.
[275] *NC Greenhouse Gas Inventory*, at 67- 69.

sector could be reduced by 15% from what they would otherwise be by 2030.[276] That translates to a 17.4% reduction from North Carolina's 2005 baseline. Working from the EPA analysis, state officials estimate it will be possible to reduce methane and N20 emissions from animal agriculture by 59% by 2050.[277] That still leaves a gap to reach net zero; it would presumably be offset by increased sequestration of carbon in the soil through wetland restoration, forestland restoration, and incorporation of biochar into agricultural soils.[278] Even then, it is likely that some other sectors will need to overcontrol to offset unavoidable emissions from agriculture.

Recent developments: North Carolina has a statutory requirement that electric generating utilities obtain 0.02% of the sector's aggregate sales from hog waste.[279] In October 2019, DEQ's North Carolina Clean Energy Plan spoke hopefully but nonspecifically of the potential for swine biogas to reduce methane emissions from animal agriculture.[280] Buoyed by federal and state interest, biogas proponents in December 2021 released a report estimating that, in theory, North Carolina's swine waste could generate 28 billion cubic feet (bfc) of gas per year, equivalent to 17 trillion British thermal units (Btu) annually.[281] The report also made implicitly clear that relatively little biogas development makes economic sense in the absence of taxpayer or ratepayer subsidies.

Currently, North Carolina has a relative handful of swine-waste-based biogas projects. Optima KV, launched in 2018, gathers gas from digesters on five farms. Optima TH, launched in 2020, gathers gas from the wastewater ponds at Smithfield Foods' Bladen packing plant. The gas from both projects is scrubbed and injected into Piedmont Natural Gas pipelines, with the waste impurities flared. A third project, Align RNG, a joint venture of Dominion Energy and Smithfield Foods to collect gas from 19 farms, received a state permit in June 2021 and reached a settlement with environmental advocates in November 2021.[282]

As directed by the NC General Assembly's 2021 Farm Act, in June 2022, NC DEQ finalized three general permits – for swine, cattle, and poultry – for existing concentrated animal feeding operations (CAFOs) that want to build a digester.[283] Environmental advocates added the biogas permits to a 2021 complaint

[276] *Non-CO2 mitigation potential report*, at 6.
[277] *Deep Decarbonization report*, at 69.
[278] See, for example, John Horowitz and Jessica Gottleib, The Role of Agriculture in Reducing Greenhouse Gas Emissions, ERC Economic Brief 15, September 2010.
[279] NCGS §62-133.8(e).
[280] NC DEQ, NC Clean Energy Plan, October 2019, at 26-27.
[281] Sameer Parvathikar et al., Biogas Utilization in North Carolina: Opportunity and Impact Analysis, December 2021.
[282] NC DEQ, press release: Air permit issued for Align RNG biogas processing facility, January 6, 2021; CleanAIRE NC, press release: Settlement sets new limits, improves monitoring on gas project to better protect community, September 29, 2021.
[283] SL2021-78 (S605), 2021 Farm Act, §11; NC DEQ, webpage: 2022 Digester System General Permits, June 30, 2022. See also, Cameron Oglesby, NC releases general biogas permit despite environmental justice concerns, Southerly, July 22, 2022.

filed with EPA alleging discriminatory impacts from swine farms to communities in eastern North Carolina.[284]

The 2022 state budget, SL 2022-74 (H103), section 10.3, appropriated $1.5 m in nonrecurring funds for cost share assistance for the NC Dept. of Agriculture to help swine farmers install anaerobic digesters, up to $100,000 per project. To be eligible, farmers are required to have at least a 10 year contract to sell the gas. In early 2024, the state legislature extended these funds until June 30, 2026, suggesting uptake has been slow.[285] Late in 2024, the NCGA added an unrelated provision to a Helene relief bill, giving biogas operations triple credit against Duke Energy's statutory requirement to purchase electricity generated from swine waste.[286]

Separate from the question of the economic viability of biogas, researchers continue to refine estimates of how much swine biogas can reduce GHG emissions. As in the case of gas pumped from the ground, leaks in the production and distribution system for biogas can – and already likely do – release significant amounts of methane into the atmosphere.[287] Existing models tend to underestimate emissions, and to achieve significant reductions biogas systems need special components that are not currently required under state or federal law.[288]

In its 2022 biennial report, the NC Energy Policy Council – which generally supported biogas expansion – noted concerns about air and water pollution from biogas, and added,

> Management systems and add-on treatment technologies to address nutrient loading, odor, and pathogens than reduce methane emissions and risks to nearby ecosystems and communities should be supported with (1) demonstration projects, (2) dedicated funding mechanisms to enable farms to add any necessary technologies, (3) appropriate policy mechanisms, and (4) meaningful involvement of affected community on matters related to equity, biogas production, and transport of waste and biogas.[289]

None of that has happened to date.

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[284] Letter, Southern Environmental Law Center to EPA Administrator Michael Regan and Civil Rights Compliance Acting Director Anhthu Hoang, December 22, 2022. More generally, see US EPA, webpage: External Civil Rights Docket, updated July 30, 2024, 05RNO-21-R4.
[285] SL 2024-1 (S508), §4.16.
[286] SL 2024-57 (S382), Disaster Relief-3/ Budget /Various Law Changes, §3F.3. The 'swine set aside' is codified at NCGS 62-133.8.
[287] Semra Bakkaloglu et al., Methane emissions along biomethane and biogas supply chains are underestimated, One Earth, June 2022, https://doi.org/10.1016/j.oneear.2022.05.012.
[288] Nathalia Vechi et al., Methane emissions from five Danish pig farms: mitigation strategies and inventory estimated emissions, Journal of Environmental Management, May 2022, 317: 115319, https://doi.org/10.1016/j.jenvman.2022.115319.
[289] NC Energy Policy Council, 2022 Biennial Report, November 16, 2022, at 30, footnote 24.

Indicator 11.2: Annual volume of swine waste dependent on sprayfields for disposal

Top line: The number of swine dependent on sprayfields for waste disposal has gradually declined by 1.5 million hogs, or about 15%, over the last five years. A reduction in the volume of sprayed hog waste is a positive trend. Unfortunately, the reduction is purely a result of lower numbers of swine being raised, rather than farms transitioning to environmentally sound waste management. As a result, there's no guarantee that the volume of sprayed waste won't increase again in the future.

About swine waste disposal: North Carolina has nearly 2,000 hog farms raising over 8 million hogs annually, with the epicenter of swine production concentrated in Duplin, Sampson, and Bladen Counties. The vast majority of those farms dispose of their waste through a lagoon and sprayfield system: waste is washed from barns containing thousands of hogs into pits in the ground, and then the liquid from those pits is pumped and sprayed onto dedicated fields. In theory, waste is applied at a rate that allows plants on the sprayfields to absorb nitrogen and phosphorus, while the water component of the waste can either evaporate or soak deep into the ground. In practice, to keep open-air lagoons from overflowing in eastern North Carolina's wet climate, many farmers have to spray even when sprayfields are saturated or the weather is too cold for uptake of nutrients.[290] As a result, large volumes of waste run off sprayfields into surrounding creeks and sloughs and make their way into eastern North Carolina's rivers and estuaries.[291]

The scientific literature documents a variety of public health and environmental harms. Rural parts of North Carolina in the upper quartile of exposure to hogs have 21% more occurrences of acute gastrointestinal illness than rural areas without high exposure to hogs.[292] Communities in the upper third of hog exposure have a 21% higher rate of urinary tract infections.[293] Fecal microbes and antimicrobial resistance are more common downstream from commercial hog operations than in watersheds without those operations.[294] Private groundwater wells also suffer, especially in hot weather; a study of nearly 50,000 samples of water from drinking water wells across the state found

[290] See, for example, Noel Gollehon et al., Estimates of Recoverable and Non-Recoverable Manure Nutrients Based on the Census of Agriculture - 2012 Results, June 2016; and Database of Estimates by 6-digit HUC. Across four watersheds in North Carolina's Coastal Plan (Tar-Pam, Neuse, Whiteoak, and Cape Fear), the database identifies 1654 farms with insufficient farm acres to absorb the nutrients generated by the farm's animals. The database does not distinguish between poultry and swine farms.

[291] Stephen Harden, Surface-Water Quality in Agricultural Watersheds of the North Carolina Coastal Plain Associated with Concentrated Animal Feeding Operations, 2015, U.S. Geological Survey Scientific Investigations Report 2015–5080, at 50-51, http://dx.doi.org/10.3133/sir20155080.

[292] Arbor Quist et al., Exposure to industrial hog operations and gastrointestinal illness in North Carolina, USA, Science of the Total Environment, July 2022, 830: 154823, https://doi.org/10.1016/j.scitotenv.2022.15482.

[293] David Holcomb et al., Exposure to Industrial Hog and Poultry Operations and Urinary Tract Infections in North Carolina, USA, Science of the Total Environment, December 2022, 853: 158749, at 10, https://doi.org/10.1016/j.scitotenv.2022.158749.

[294] Elizbeth Christenson et al., A watershed study assessing effects of commercial hog operations on microbial water quality in North Carolina, USA, Science of the Total Environment, September 2022, 838: 156085, https://doi.org/10.1016/j.scitotenv.2022.156085.

that concentrations of disease-causing bacteria spiked in private wells downstream from swine farms when daytime temperatures reached a high over 90 degrees Fahrenheit.[295] Nor is the impact to water quality merely local: modelling suggests that hog waste released from lagoons by Hurricane Florence in 2016 reached ocean beaches 'far down the coast, days or weeks after the storm'.[296]

Lagoons and sprayfields also contribute to airborne pollution, emitting quantities of ammonia (NH3) and hydrogen sulfide (H2S).[297] There are no state or federal regulatory limits that apply to these emissions, beyond state requirements for odor control.[298] In North Carolina, areas around swine farms have experienced faster conversion of forests, wetlands, and savannahs to cropland, likely to provide sprayfields. That conversion has a side effect of increasing local day and nighttime temperatures.[299]

The harms of the lagoon and sprayfield system are distributed inequitably. Census tracts with the densest concentrations of swine farms also have a higher percentage of Black, Hispanic, low-income, elderly, and disabled residents than the state averages.[300] Neighbors of industrial hog operations in eastern North Carolina have higher death rates from causes such as anemia, kidney disease, tuberculosis, and low birth weight than residents who live further away from such operations.[301] Life expectancy in communities near swine farms remains lower even when controlling for multiple demographic, behavioral, and socioeconomic factors.[302]

In our first report, we cited an estimate from the Environment Working Group of the annual volume of waste dependent on sprayfields in 2016: 9.5 billion gallons.[303] That estimate is almost certainly now out of date. In July 2023, NC DEQ estimated that 1,943 farms were operating under the CAFO general permit

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[295] Jacob Hochard et al., Air temperature spikes increase bacteria presence in drinking water wells downstream of hog lagoons, Science of the Total Environment, April 2023, 867, https://doi.org/10.1016/j.scitotenv.2023.161426. The authors note that most wells are not sampled in hot weather, so sampling data likely gives a misleadingly low sense of the presence of contamination and the risk to well users.

[296] Melissa Moulton et al., Modeled coastal-ocean pathways of land-sourced contaminants in the aftermath of Hurricane Florence, Journal of Geophysical Research: Oceans, March 2024, 129:3, https://doi.org/10.1029/2023JC019685.

[297] Brandon Lewis et al., Modeling and analysis of air pollution and environmental justice: the case for North Carolina's hog concentrated animal feeding operations, EHP, August 2023, 131(8), https://doi.org/10.1289/EHP11344, Table 3, (predicting concentrations of NH3 of 6.8 to 9.5 ug/m3).

[298] For odor requirements, see NCGS §143-215.10C(e)(1).

[299] Lorrayne Miralha et al., Spatiotemporal land use change and environmental degradation surrounding CAFOs in Michigan and North Carolina, Science of the total Environment, December 2021, 800, https://doi.org/10.1016/j.scitotenv.2021.149391.

[300] NC DEQ, Animal Feeding Operations General Permit Renewal: Draft Environmental Justice Report, August 3, 2023, at 9.

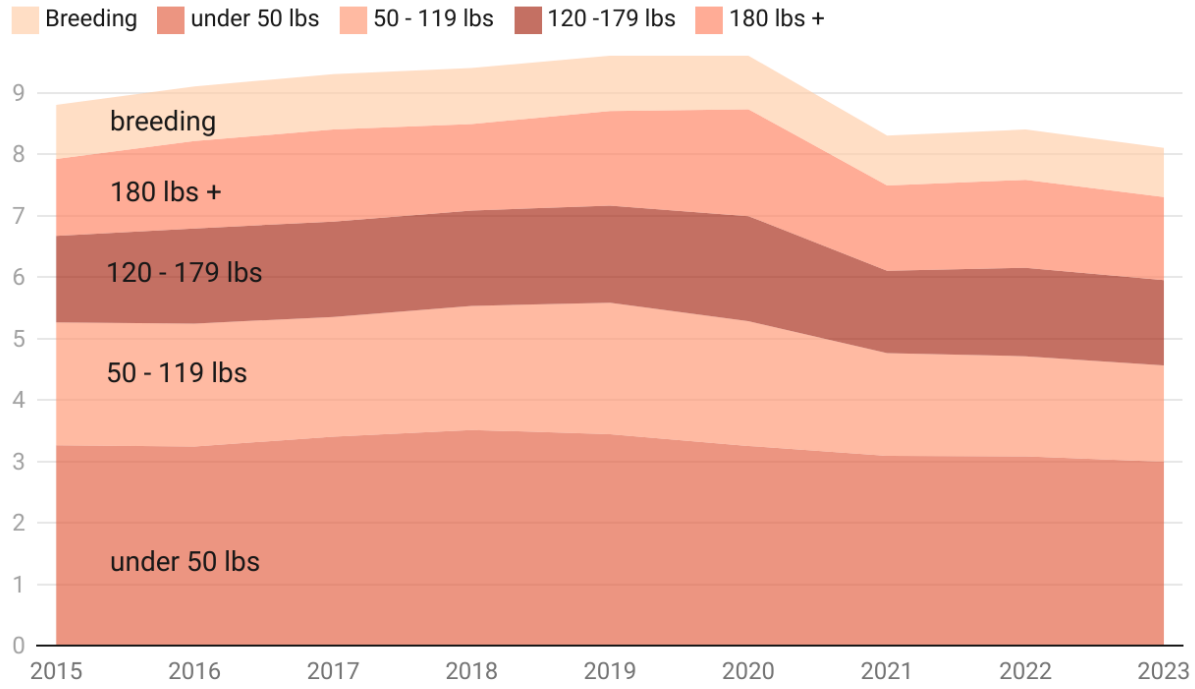
[301] Julia Kravchenko et al., Mortality and Health Outcomes in North Carolina Communities Located in Close Proximity to Hog Concentrated Animal Feeding Operations, North Carolina Medical Journal, September 2018, 79: 278, https://doi.org/10.18043/ncm.79.5.278.

[302] *Ibid.*

[303] Environmental Working Group and Waterkeeper Alliance, website: Exposing Fields of Filth, Data and Methodology, June 2016, retrieved October 27, 2021.

for sprayfields, but did not estimate how much waste they produce.[304] For this update, we would prefer to track the ongoing (steady state) weight of live animals dependent on lagoons and sprayfields. However, although that information is public, it is not published, and we were not successful in obtaining it through a public records request.

Figure 11.2: Number of hogs in North Carolina as of September 1, in thousands



Source: USDA/NC DACS quarterly Hog Reports, 2016 – 2023; data accessed via USDA, data query tool: National Agricultural Statistics Service, Quick Stats • Created with Datawrapper

Instead, we fall back on USDA's quarterly inventory of swine, using September populations – the consistent annual peak – from 2015 through 2023.[305] This data series doesn't distinguish swine dependent on sprayfields from those using other waste management practices. But, we know that large farms consistently use sprayfields, and according to the USDA Census of Agriculture, less than 40,000 hogs out of the state population of 8.1 million – that is, less than half of one percent – are on farms with fewer than 1,000 pigs.[306] So, the overall September population of swine is a good estimate of the number of swine dependent on sprayfields for waste management. Over the last five years, the number

[304] NC DEQ, Animal Feeding Operations General Permit Renewal, Draft Environmental Justice Report, August 3, 2023, at 11.
[305] USDA/NC DACS quarterly Hog Reports, 2016 – 2023; data accessed via USDA, data query tool: National Agricultural Statistics Service, Quick Stats, visited September 10, 2024.
[306] USDA, National Agricultural Statistics Service, County Data North Carolina February 2024, at 451, Table 12. Hogs and Pigs – Inventory and Sales: 2022 and 2017.

has fallen gradually, by about 1.5 million pigs. We don't celebrate the loss of sales for farmers, but the decline in the volume of waste disposed through sprayfields is good news.

We would much rather have seen the reduction in spraying accomplished through adoption of better waste management technologies. In theory, the equivalence between the total number of pigs and the number served by sprayfields should have been severed by North Carolina's 1997 moratorium on new sprayfield-dependent swine farms. Under the moratorium, new or expanding swine farms must meet five performance standards: eliminating discharges to surface and groundwater, air emissions of ammonia and odor, release of disease vectors, and contamination of soil and groundwater.[307] A ten-year process initiated by the 2000 Smithfield Agreement (signed by Smithfield Foods and then NC Attorney General Micael Easley) identified multiple waste management technologies that would pollute less. However, none were cheaper for the industry than the lagoon and sprayfield system.[308] State legislators have repeatedly blocked the Department of Environmental Quality (DEQ) from taking steps to document widespread soil and groundwater contamination around existing lagoons, and the agency has not forced farms to upgrade their waste management systems.

Recent developments: We discuss the recent history of biogas in North Carolina under indicator 11.1, GHG emissions from the agricultural sector. Here, we note that in 2020, the state legislature rewrote the terms of the 1997 moratorium to create a loophole for farms to move forward with biogas generation without installing better pollution controls.[309] That has left many residents deeply skeptical of biogas.[310] The concern is not just that this is a lost opportunity to address community concerns, but that, if systems are built without denitrification components (as some have been to date), biogas will concentrate nitrogen in the waste and make the water quality impacts of the lagoon and sprayfield system even worse.[311]

Indicator 11.3: NC soils show sustainable levels of phosphorus.

Top line: Over the last two decades, the explosion of the poultry industry across North Carolina has radically increased the over-application of phosphorus to North Carolina's soils, where it threatens soil health and groundwater and surface water quality. Concentrations of phosphorus in state agricultural soil samples have continued to rise, a bad trend.

[307] 15A NCAC 02T .1307, .1308.
[308] C.M. Williams, Development of environmentally superior technologies in the US and policy, Bioresource Technology, November 2009, 100 (22): 5512, https://doi.org/10.1016/j.biortech.2009.01.067.
[309] SL2020-18 (S315), NC Farm Act of 2019-20, §11.
[310] Cameron Oglesby, 'This plan is a lie': Biogas on hog farms could do more harm than good, Energy News Network, March 28, 2022; Aman Azhar, North Carolina's bet on biomass energy is faltering, with energy targets unmet and concerns about environmental justice, Inside Climate News, April 17, 2022.
[311] USDA, NRCS, Conservation Practice Standard: Anaerobic Digester, Code 366, August 2023, at 8 ("The digestate has increased potential for some air and nutrient emissions compared to raw manure").

About soil phosphorus levels: All animal agriculture in North Carolina – swine, chickens, turkeys – generates waste that must be managed. At its heart, this is a mass balance problem: North Carolina's leading counties for animal agriculture import massive quantities of nitrogen, phosphorus, and various metals in the form of food for animals, and export a fraction of that in the meat of the adult animals. The difference stays as waste: nitrogen, phosphorus, and such metals as copper and zinc.[312]

While North Carolina has excesses of both nitrogen and phosphorus, our imports and exports are most out of balance for phosphorus, so we use that as our indicator. Even before the massive expansion of poultry production in North Carolina over the last decade, phosphorus additions in the form of fertilizer and manure exceeded uptake (by crops) by 50% in many regions of the United States, including eastern North Carolina.[313] Yet, the vast majority of North Carolina's producers (of both swine and poultry) are not required to limit manure application based on phosphorus levels.[314] Also of note, while an individual hog produces as much as four times the waste of a human, and far more than a single chicken or turkey, the sheer number of poultry raised across the state make poultry waste a much larger source of phosphorus in North Carolina than swine.[315]

Direct information on the volume and fate of poultry litter is limited, because for two decades the state legislature has turned a blind eye to the expansion of dry-litter poultry operations, even shielding poultry farms from having to report their location to the state environmental agency.[316] However, while data on poultry manure is limited, the state does have a data source that can be used to track phosphorus concentrations in agricultural soils: soil tests conducted by the NC Department of Agriculture soil science laboratory.

The trends in measured soil phosphorus are sobering. As far back as 2000-2001, researchers found that 49% of agricultural soil samples from eastern NC were above the 'very high' threshold for phosphorus, a 'phosphorus index', or P-I, of 100.[317] By 2017-2019, the median phosphorus concentration was very high in over 36 of North Carolina's 100 counties. Moreover, in the highest poultry producing counties, over 70% of soil samples were over 150% of the very high threshold.[318] So excessive phosphorus is now a problem in more places, and where it was already a problem, it has become more intense. We count this as a bad trend.

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[312] NC State Extension, webpage: Poultry Litter as a Fertilizer Source, May 12, 2020. On copper and zinc, see, Stephanie Kulesza et al., Distribution and Fractionation of Zinc and Copper in Poultry Litters Across North Carolina, Communications in Soil Science and Plant Analysis, May 2022, https://doi.org/10.1080/00103624.2022.2072866.
[313] Robert Sabo, Phosphorus inventory for the coterminous United States (2002-2012), Journal of Geophysical Research: Biogeosciences, 2021, 126, https://doi.org/10.1029/2020JG005684, at 12.
[314] Steven Miller et al., Implications of current soil phosphorus levels for manureshed analysis in North Carolina [*Miller et al.*], Soil Science Society of America Journal, April 2024, 88 (4): 1374, https://doi.org/10.1002/saj2.20694.
[315] *Idem*, at 5.
[316] Environmental Working Group and Waterkeeper Alliance, Under the Radar, February 2019.
[317] L.B. Cahoon and S.H. Ensign, Spatial and temporal variability in excessive soil phosphorus level in eastern North Carolina, Nutrient Cycling in Agroecosystems, June 2004, 69: 111, at 116, https://doi.org/10.1023/B:FRES.0000029676.21237.54
[318] *Miller et al.*, at 8, 9.

The poultry industry is not the only source of excess phosphorus in North Carolina, but its massive expansion over the last two decades is a major driver. From 2007 to 2022, the poultry population of North Carolina's four leading poultry-producing counties (Duplin, Sampson, Robeson, and Anson) increased by 98%; the poultry population in the rest of the state (excluding those four counties) increased 27%.[319] The poultry industry in North Carolina and the region has been sharply critiqued for its treatment of farmers, workers, neighbors, and the environment.[320] Moreover, the industry has adeptly foiled meaningful oversight of its impacts to air and water or its waste management.[321]

Recent developments: Even as data indicates that many farm fields across the state are saturated with phosphorus, North Carolina scientists have also discovered that farm fields benefit from much lower concentrations than previously thought. For years, academics and extension agents in North Carolina suggested that crop fields would benefit from phosphorus fertilizers – or manure – up to a P-I index value of 100. In 2021, a team of agronomists revised that, lowering the 'critical value' for phosphorus – the concentration at which there is no benefit to adding additional phosphorus to a field – to a P-I of 50 in the coastal plain. [322] Researchers found no benefit to yields to adding phosphorus when soil levels were above a P-I of 35, and no benefit in clay-ey Piedmont soils above a P-I of 15.[323]

There is obviously a difference between the concentration at which adding phosphorus has no positive impact and the point at which it begins to cause harm. In 2003, North Carolina researchers unveiled the Phosphorus Loss Assessment Tool (PLAT), which evaluates multiple pathways by which phosphorus can leave a site and harm water quality nearby.[324] The tool recommends limiting land application of waste when P-I is 50 or higher, and advises against application of animal waste to soils with a P-I > 101. Yet many facilities are not required to apply the PLAT, and poultry waste management plans are subject to minimal oversight (and no regular soil testing), leading to the levels shown in the soil sample data. In its 2019 general permits for swine farms, DEQ included a requirement to conduct a PLAT analysis for hog-waste sprayfields with soil P-I already in excess of 400; the NC Farm Bureau challenged that provision and it has not been enforced.

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[319] Sarah Graddy and Al Rabine, blog post: Innovative EWG study uses AI to find 357M poultry on North Carolina's factory farms, Environmental Working Group, September 12, 2024; EWG, interactive map: Animal Facilities in North Carolina in 2022, visited September 17, 2024.

[320] Douglas Constance et al., The Southern Model Revisited: The Intersection of Race, Ethnicity, Immigration, and Health and Safety in Poultry Processing, Sustainability, September 2023, 15: 13945, https://doi.org/10.3390/su151813945; Megan Suggs, master's thesis: The True Cost of Chicken: Shifting the Financial Burden of Poultry Growers, April 2022.

[321] See, Gavin Off, Ames Alexander, and Adam Wagner, Big Poultry: Five takeaways from investigating North Carolina's secretive ag industry, News & Observer, December 8, 2023, part of a series, Big Poultry in North Carolina.

[322] NC State Extension, webpage: Changes in the phosphorus fertilizer recommendations for corn, soybean, and small grains in North Carolina, October 28, 2021.

[323] *Ibid.*

[324] NC State Extension, webpage: The North Carolina Phosphorus Loss Assessment Tool (PLAT), revised July 24, 2024.

Indicator 11.4: Volume of antibiotics used routinely in animal agriculture

Top line: In 2013, in an effort to slow the evolution of antibiotic-resistant bacteria, the US Food and Drug Administration (FDA) issued guidance intended to curb the routine, non-therapeutic dosing of livestock with antibiotics. Of the nearly 7 million kilograms of antibiotics given routinely to livestock nationally in 2015, the guidance eliminated about 4 million kg; but the other 3 million kg were simply reclassified as therapeutic and continued to be administered. Since 2017 when the guidance took full effect, the total annual dosing has climbed slowly from 5.56 million kg to 6.24 million kg in 2022, a 12% increase. We count that as a trend in the wrong direction.

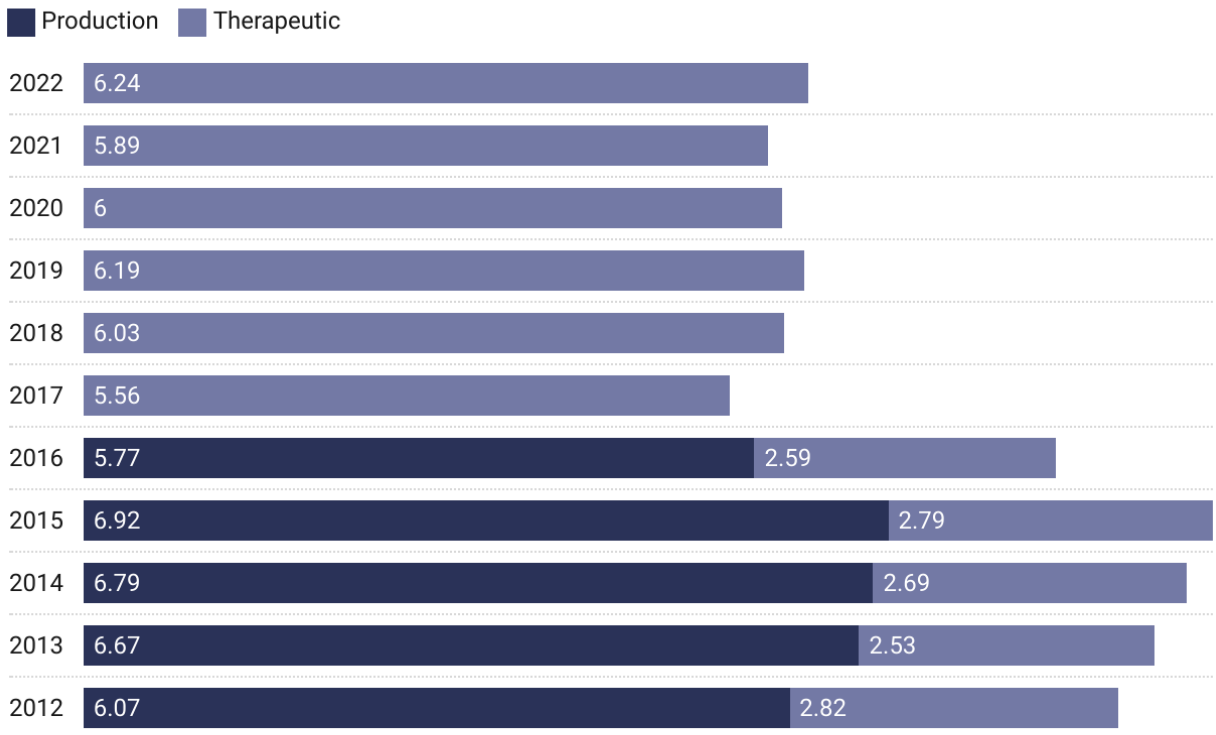
About antibiotics in animal agriculture: The federal Centers for Disease Control (CDC) estimates that every year, antimicrobial-resistant bacteria and fungi cause over 2.8 million infections and kill over 35,000 Americans.[325] Some of this antimicrobial resistance develops as a result of overprescription of antibiotics to humans.[326] The massive, routine use of antibiotics in animal agriculture also contributes to gradual increases in the resistance of dangerous human pathogens.[327] Before 2014, purchase for use in agriculture accounted for 70% of the antibiotics sold in the United States.[328] Peer-reviewed research indicates that bacteria in and spreading from these facilities develop resistance to leading antibiotics.[329] For example, in 2023, 83% of Salmonella bacteria isolated from retail chicken, and 41% of Salmonella bacteria isolated from retail ground turkey, were resistant to tetracycline.[330]

Researchers have estimated the cost of antimicrobial resistance to society as $1,500 per kilogram of one antibiotic commonly administered to broiler chickens.[331] A 2020 study of seven rural Piedmont streams and groundwater wells in areas with substantial animal agriculture found striking levels of antibiotics,

[325] CDC, Antibiotic Resistance Threats in the United States, 2019 (2019 AR Threats Report), at 6.
[326] *Idem*, at 18.
[327] Sharon Nappier et al., Antibiotic resistance in recreational waters: state of the science, Intl J. of Env. Research and Public Health, October 2020, 17:8034, doi:10.3390/ijerph17218034; Karin Hoelzer, et al. Antimicrobial drug use in food-producing animals and associated human health risks: what, and how strong, is the evidence? BMC Veterinary Research, July 2017, 13 (211), doi: 10.1186/s12917-017-1131-3. For a global perspective, see Ya He, Antibiotic resistance genes from livestock waste: occurrence, dissemination, and treatment, NPJ Clean Water, February 2020, 3 (4), https://doi.org/10.1038/s41545-020-0051-0.
[328] Pew, Antibiotics and Animal Agriculture: A Primer, February 2018 update, citing U.S. Food and Drug Administration (US FDA), 2014 Summary Report on Antimicrobials Sold or Distributed for Use in Food-Producing Animals, 2015.
[329] See, for example, Karina Yevenes, Assessment of Three Antimicrobial Residue Concentrations in Broiler Chicken Droppings as a Potential Risk Factor for Public Health and Environment, Int J Environ Res Public Health, January 2019, 16(1): 24, doi: 10.3390/ijerph16010024 (finding high quantities of tetracyclines and sulfonamides – two important families of antibiotics – in broiler litter, which is often recycled into animal feed or 'organic' fertilizer). As noted above, broilers are North Carolina's top agricultural product.
[330] US FDA, NARMS Now: Integrated Data, accessed June 27, 2024.
[331] Gabriel Innes et al., External societal costs of antimicrobial resistance in humans attributable to antimicrobial use in livestock, Annual Rev. Public health, 2020, 41:141, https://doi.org/10.1146/annurev-publhealth-040218-043954.

including several antibiotics used only on animals.[332] Although animals are dosed year-round, surface water and sediment concentrations peaked in the fall, and groundwater concentrations peaked in the winter.

Figure 11.4: Volume of antimicrobials sold or distributed for use in food-producing animals nationally, in millions of kilograms



Source: US FDA, Annual summary report on antimicrobials sold or distributed for use in food producing animals, 2013 - 2022 • Created with Datawrapper

In 2013, the US Food and Drug Administration issued guidance – which took full effect in 2017 – requiring the oversight of a veterinarian when antibiotics are given to animals. North Carolina does not track sales or use of antimicrobials within the state, so for this indicator, we track US Food and Drug Administration data on the volume of sales nationally of medically important antimicrobial drugs for use in food-producing animals.[333] The premise of the guidance was that antibiotics should continue to be used to treat actual illness in livestock, but should not be routinely fed to animals 'for production', that is, to help them gain weight. As the chart above indicates, the guidance did result in a drop in total use,

[332] Austin Gray et al., The seasonal distribution and concentration of antibiotics in rural streams and drinking wells in the piedmont of North Carolina, Science of the Total Environment, 2020, 710: 136286, https://doi.org/10.1016/j.scitotenv.2019.136286.

[333] US FDA, web report: Annual Summary Report on Antimicrobials Sold or Distributed in 2022 for Use in Food-Producing Animals, December 2023.

but growers reclassified about half of their pre-2017 'production' dosing as 'therapeutic', which is almost certainly not accurate. FDA reports that 95% of inspected facilities comply with the agency's guidance.[334] Nonetheless, since 2017, total volumes have climbed 12% to 2022. We view that as an unhealthy trend.

Recent developments: In 2018, FDA issued a strategic plan to reduce animal dosing, outlining goals for 2019-2023.[335] The goals included finalizing guidance to place all uses of medically-important antibiotics under the supervision of veterinarians, with 'appropriately targeted duration[s]' (action 1.1.6), and developing 'functional and efficient systems for collecting antimicrobial use data in animals' (action 3.1.3).[336] In April 2024, FDA issued the final guidance.[337] Improving data collection has moved slower; in August 2023, FDA invited public comment on a report outlining a possible public-private strategy to collect antimicrobial use data.[338] There's been no official word on data collection since then; ideally, it would allow state-specific analysis. We hope that the final guidance marks an inflection point, and that volumes of antimicrobials administered to animals start dropping again.

EXPOSURES

A second set of goals and indicators in this 2024 State of the Environment addresses the human exposome: the cumulative exposures that shape each person's health, including exposures to pollutants and toxic chemicals in air, water, soil, and consumer products. This marks a shift in organization from 2019, when we distributed these goals and indicators across other major categories: natural environment, human environment. This new grouping, which adds a few additional indicators, reflects a growing awareness among advocates and policymakers of how pervasive toxic exposures have become. It also reflects efforts by scientists to assess the cumulative and interactive effects of those exposures.

The concept of the exposome is now two decades old; coined in 2005, it was explicitly presented as a counterweight and complement to research on the human genome.[339] Over time, researchers have found it helpful to think about the exposome as having three components: the general external, consisting of broad social and economic conditions; the specific external, including diet and chemical

[334] US FDA, webpage: FDA-Track: Progress on FDA's Support of Antimicrobial Stewardship in Veterinary Settings, visited June 26, 2024.
[335] US FDA, Supporting Antimicrobial Stewardship in Veterinary Settings, Goals for Fiscal Years 2019-2023, September 2018.
[336] *Idem*, at 12.
[337] US FDA, Guidance for Industry (GFI) #120: Veterinary Feed Directive Regulation Questions and Answers, April 26, 2024; US FDA, CFI #120, Small Entity Compliance Guide, April 2024.
[338] US FDA, press release: FDA seeks public comment on possible framework for collecting and analyzing data on antimicrobial use in food-producing animals, August 2, 2023; Reagan-Udall Foundation, Summary Report: Establishing a Draft Framework for a Public-Private Partnership to Support the Tracking of Antimicrobial Use in Food-Producing Animals, August 2023.
[339] Christopher Paul Wild, Complementing the Genome with an "Exposome": The Outstanding Challenge of Environmental Exposure Measurement in Molecular Epidemiology, Cancer Epidemiology, Biomarkers & Prevention, August 2005, 14 (8): 1847, https://doi.org/10.1158/1055-9965.EPI-05-0456.

exposures; and the internal, the chemical signals and non-genetic processes within the body that affect other parts of the body.[340] Traditional toxicology has been fairly narrow, exposing test organisms to a single pollutant at a time to find the highest exposure with no observed effect, and looking for the specific mechanisms of the harm. That's not how humans or other living things experience the world – we're exposed to multiple pollutants at once – and so the concept of the exposome has been an important bridge for academic toxicology to respond to the way exposures actually happen.[341] It's also driven the development of multiple technical tools: wristbands to monitor exposures; non-targeted assessment to identify the various chemicals present in a mixture in air or water; high-throughput screening assays to quickly test a large number of chemicals for toxicity.[342] This section of the State of the Environment groups a series of indicators – air pollution, water pollution, and toxics – that are part of our specific external exposome. Some of their most important impacts to human health are mediated through the internal exposome, as pollutants cause our immune or endocrine systems to misfire, provoking diabetes, auto-immune disorders, or neurodegenerative diseases like Parkinson's.

The concept of the exposome does not imply any particular policy approach to limiting releases of pollution or toxic exposures. However, researchers have noted that traditional approaches to setting pollution limits – one chemical at a time, based on years of experiments to establish safe exposures – have simply been overwhelmed by the volume and variety of chemicals being manufactured and released into the world. Moreover, while humans (and other animals) have evolved to resist some natural stressors, modern society generates toxics that have never existed before. This leads some policy experts to support a precautionary approach: minimizing the manufacture and release of chemicals until they are shown to be safe, especially chemicals that do not occur in nature.

Goal 12: Outdoor air quality is good

Trend: Positive

Air pollution harms human health and wildlife, and damages crops, urban vegetation, and forests. Some of the most common air pollutants – ground-level ozone, nitrogen oxides, and particulates – cause respiratory illness and heart disease.[343] Research also indicates that air pollution contributes to

[340] Christopher Paul Wild, The exposome: from concept to utility, International Journal of Epidemiology, February 2012, 41 (1): 24, https://doi.org/10.1093/ije/dyr236.
[341] Robert Parouki et al., The Exposome and Toxicology: A Win-Win Collaboration, Toxicological Sciences, March 2022, 186 (1): 1, https://doi.org/10.1093/toxsci/kfab149.
[342] Melissa Wan et al., Exposomics: a review of methodologies, applications, and future directions in molecular medicine, EMBO Molecular Medicine, January 2025, https://doi.org/10.1038/s44321-025-00191-w; Pei Zhang et al., Defining the Scope of Exposome Studies and Research Needs from a Multidisciplinary Perspective, Environmental Science & Technology Letters, September 2021, 8 (10): 839, https://doi.org/10.1021/acs.estlett.1c00648; Roel Vermuelen et al., The exposome and health: Where chemistry meets biology, Science, January 2020, 367 (6476): 392, https://doi.org/10.1126/science.aay3164.
[343] Yongping Hao, et al., Ozone, Fine Particulate Matter, and Chronic Lower Respiratory Disease Mortality in the United States, American Journal of Respiratory and Critical Care Medicine, August 2015, 192 (3), https://doi.org/10.1164/rccm.201410-1852OC; Wayne Cascio and Thomas Long, Ambient Air Quality and

neurocognitive diseases, including autism, attention-deficit hyperactivity disorder, and adult neurodegenerative disease.[344] Beyond impacts on human health, air pollution acidifies waterbodies and disrupts nutrient movement in natural landscapes.[345]

For the goal of clean outdoor air, we consider two indicators: the number of unhealthy air days; and emissions of federally designated hazardous air pollutants. The first is generally trending well, but with interruptions from climate-driven wildfire smoke that earn a caution. For the second, measured emissions of hazardous air pollutants have dropped substantially over the last decade, although it's hard to know what's happening with unregulated air toxics. Overall, based on the available data, we think statewide trends in outdoor air quality are positive. For more local trends, it is worth looking at goal 14, focused on disparities in air quality between communities.

Solutions: North Carolina could better protect state residents from poor outdoor air by, F1, targeting air pollution "hot spots" and addressing cumulative impacts; F2, updating the state list of toxic air pollutants; F3, curbing air emissions of forever chemicals; F4, addressing transportation-related air pollution; and F5, making air permitting more transparent.

Indicator 12.1: Number of unhealthy air days

Top Line: Emissions from power plants and other stationary sources in North Carolina have declined, and cars and trucks are slowly getting cleaner, both positive trends. But smoke from wildfires driven by climate change has caused unhealthy levels of air pollution in two of the last ten years, and that's not projected to improve, so we assign this indicator a cautionary yellow flag.

The federal Clean Air Act requires states to monitor the concentration of six common pollutants in outdoor air: ground-level ozone, particulate matter, carbon monoxide, lead, sulfur dioxide, and nitrogen dioxide. Of these, ozone and particulate matter cause the greatest harm to public health in the United States today.[346]

This indicator tracks the number of 'unhealthy air days' as measured by the US EPA's Air Quality Index (AQI).[347] The AQI scales daily values of five of the common pollutants (it excludes lead), with an index value of 100 corresponding to the federal air quality standard for each. The AQI then takes the highest

Cardiovascular Health, North Carolina Medical Journal, September-October 2018, 79 (5): 306, doi: 10.18043/ncm.79.5.306.

[344] David Peden, The Unexpected Health Effects of Pollution, North Carolina Medical Journal September-October 2018, 79 (5): 309, doi: 10.18043/ncm.79.5.309.

[345] Mark Fenn et al., Setting Limits: Using Air Pollution Thresholds to Protect and Restore U.S. Ecosystems, Issues in Ecology Report #14, 2011.

[346] American Lung Association, State of the Air 2018, at 35-42.

[347] US EPA, Air Quality Index: A Guide to Air Quality and Your Health, February 2014.

of the five values for a given day, and that is the index for that day. As EPA explains, the AQI reflects actual conditions this way:

AIR QUALITY INDEX (AQI) VALUES When AQI is in this range:	LEVELS OF HEALTH CONCERN ... air quality conditions are:	COLOR ... as symbolized by this color:
0-50	Good	Green
51-100	Moderate	Yellow
101-150	Unhealthy for Sensitive Groups	Orange
151-200	Unhealthy	Red
201-300	Very Unhealthy	Purple
301-500	Hazardous	Maroon

Created with Datawrapper

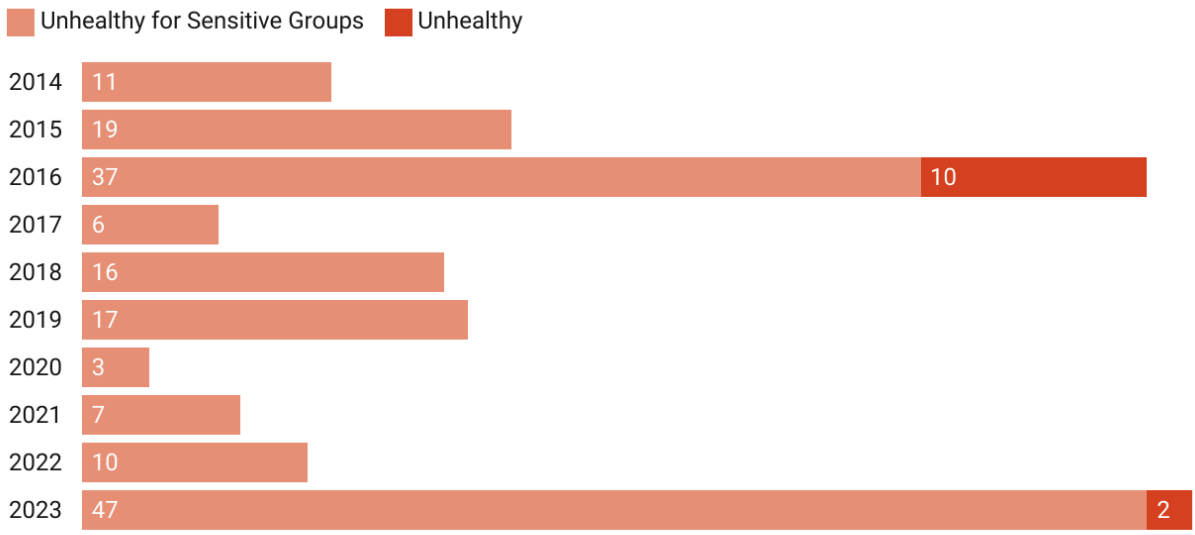
Federal law requires that the AQI be calculated and made public for all metropolitan statistical areas (MSA) with a population of greater than 350,000 residents.[348] Over the last decade, North Carolina has moved monitors among 25 different metro areas, generally moving them away from areas with consistently high air quality to collect data in communities where air quality is suspect. The network thus does not provide continuous coverage everywhere – and it has been criticized for undersampling rural communities – but it does offer a window onto statewide air quality.

For our indicator, we take the annual number of 'orange' days (unhealthy for sensitive groups) and 'red' days (unhealthy for everyone).[349] The data is volatile. Overall, ambient air quality has improved with the closure of coal fired power plants and is likely to continue improving as passenger cars and trucks are increasingly electrified. Yet, climate change is causing increased wildfires, the smoke from which can blanket the whole state, tripping multiple monitors at once, as in 2016 and 2023. Both trends are real, so for this update we assign this indicator a yellow caution flag.

[348] 40 CFR §58.50. See also, EPA, Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI), May 2024. North Carolina currently has 16 metropolitan statistical areas; eight have populations over 350,000.

[349] North Carolina's monitors have not recorded any purple or maroon days over the last decade.

Figure 12.1: Unhealthy air days annually (code orange and red)



Source: AirData Air Quality Index Summary Report. EPA. 2023. • Created with Datawrapper

Recent developments: EPA periodically reviews and sometimes revises the National Ambient Air Quality Standards.[350] In March 2019, EPA decided to leave the primary standard for sulfur dioxide (SO2) unchanged; in December 2020, EPA decided to leave the primary and secondary standards for ozone unchanged. In February 2024, EPA lowered the primary standard for annual average concentrations of small particulate matter (PM 2.5) to 9.0 ug/m3. That is good news; exposure to PM2.5 is associated with higher rates of preterm birth,[351] Alzheimer's,[352] and hospital readmission for cardiovascular patients,[353] to draw on research carried out in North Carolina. In January 2025, the NC Environmental Management Commission (EMC) incorporated the new federal PM2.5 standard into state air rules as well.[354]

As noted above, wildfire smoke accounts for spikes in the number of unhealthy air days in 2016 and 2023.[355] The 2016 wildfires were in North Carolina and nearby states; the 2023 wildfires were much

[350] US EPA, webpage: Process of Reviewing the National Ambient Air Quality Standards, updated July 24, 2024.
[351] Alison Krajewski et al., Associations between weekly gestational exposure of fine particulate matter, ozone, and nitrogen dioxide and preterm birth in a North Carolina Birth Cohort, 2003–2015, Environmental Epidemiology, November 2023, 7: e278, https://doi.org/10.1097/ee9.0000000000000278.
[352] Sung Han Rhew et al., Exposure to low-dose ambient fine particulate matter PM2.5 and Alzheimer's disease, non-Alzheimer's dementia, and Parkinson's disease in North Carolina, PLoS One, July 2021, 16(7), https://doi.org/10.1371/journal.pone.0253253.
[353] Lauren Wyatt, et al., Short-term PM2.5 exposure and early-readmission risk: a retrospective cohort study in North Carolina heart failure patients, American Heart Journal, June 2022, 248: 130, https://doi.org/10.1016/j.ahj.2022.02.015.
[354] See, NC Environmental Management Commission, January 9, 2025 meeting agenda, item II-1.
[355] Jennifer Saylor, Air Quality is Unhealthy All Over Western NC, News 13 WLOS, November 14, 2016; Canadian wildfires continue to impact air quality in North Carolina, Spectrum News 1, June 8, 2023; Karen Wynne, Wildfire smoke from Canada drifts back down to parts of NC, prompting air quality alerts, News 13 WLOS, July 17, 2023.

further afield, in Canada. EPA has a process for states to exclude 'bad air' days caused by distant wildfires beyond a state's control when calculating compliance with federal air quality standards, and North Carolina has requested that EPA designate North Carolina's 2023 exceedances of the fine particulate standard as 'exceptional events'.[356] Yet, while North Carolina has no control over distant wildfires, their particulates harm North Carolinians' health as much as those emitted locally. Moreover, since wildfires are driven by climate change, windborne smoke may become a recurring problem. The consulting group First Steet Foundation has assessed the impact of wildfire smoke on national air quality, and concluded that climate change could 'wipe away' the last two decades of air quality improvements.[357] Prescribed burning also affects air quality, though one analysis suggests that because managers can control the timing of prescribed burns, and because burns reduce fuel load that would eventually sustain more intense fires, prescribed burns provide a net improvement to air quality.[358]

Indicator 12.2: Annual releases of hazardous air pollutants (HAPs)

Top line: the federal Clean Air Act regulates the emissions of 188 'hazardous air pollutants' (HAPs). From 2013-2022, thanks mostly to the closure of several coal-fired power plants, emissions of HAPs from permitted sources declined by about 26%. 'Fugitive' emissions (leaks) of HAPs stayed virtually unchanged. There's essentially no data to track unregulated toxic air pollutants – that's a significant blind spot – but the available data shows a positive trend.

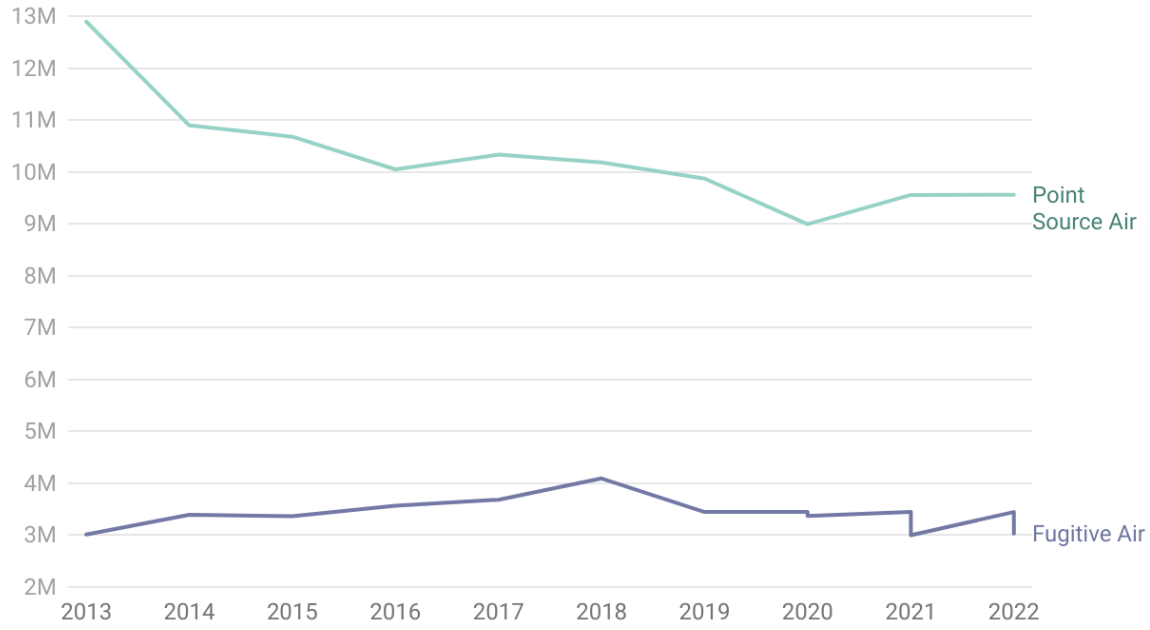
About toxic air pollution: Beyond the conventional air pollutants that contribute to unhealthy air days, federal and state laws regulate hundreds of other less universal air pollutants. Clean Air Act §112 regulates the release of 188 'hazardous air pollutants' (HAPs) from mobile and stationary sources; state law regulates the release of 91 state-listed 'toxic air pollutants' (TAPs) from stationary sources.[359] The two lists have 78 compounds in common. Unfortunately, both programs regulate lists of chemicals that were set in the early 1990s and those lists are increasingly inadequate, as many industrial processes have changed significantly since then. In addition to introducing entirely new chemicals, many emitters have changed their production processes to use and emit compounds that are not HAPs or TAPs but are chemically similar and may present similar risks to public health. With only one exception at the federal level (1-bromopropane, added in 2022) and one exception at the state level (methyl bromide, discussed below), the state and federal programs have not added additional chemicals in the last 30 years. All federal HAPs and state TAPs are on the list of chemicals for which the federal Emergency Planning and

[356] US EPA, webpage: Treatment of Air Quality Monitoring Data Influence by Exceptional Events, updated April 30, 2024; NC DEQ, Division of Air Quality, webpage: Exceptional Events Demonstration to Support Attainment Designation Recommendations for 2024 Annual PM2.5 NAAQS, visited January 20, 2025.
[357] First Street Foundation, 10th National Risk Assessment: Atrocious Air, February 12, 2024.
[358] Sadia Afrin, dissertation: Evaluating the Impacts of Prescribed Fire on Air Quality and Public Health in the Southeastern U.S., June 2021, especially chapter 4.
[359] NCGS 143-215.3(a)(1); 143-215.107(a)(1),(3),(4),(5); 143B-282; S.L.1989-168, §45; implementing rules are 15A NCAC 02D .1100 (standards) and 15A NCAC 02Q .0700 (permitting).

Community Right to Know Act requires annual reporting of releases; the data is compiled in the Toxics Release Inventory (TRI), which has a two-year lag.[360]

As shown in figure 12.2, between 2013 and 2022, net emissions of HAPs from permitted sources declined by about 26%.[361] For years, the largest category of HAPs emitted in North Carolina by volume was hydrochloric acid aerosols emitted by Duke Energy's coal-fired power plants. With the closure of many of those plants, volumes of hydrochloric acid emissions dropped substantially, accounting for 60% of the net decline over the decade. Methanol, released from pulp and paper plants, contributed another 14% of the net decline, and toluene, released by a handful of adhesive and coating manufacturers, contributed 12%. Over the same time, statewide emissions of styrene doubled, reflecting a proliferation of plastics molding facilities, including boat-building companies. Fugitive emissions – those that leak out of systems rather than passing through engineered pollution controls – accounted for about one quarter of total HAP air emissions in 2022 and were almost exactly the same absolute volume as in 2013. We would like to have seen fugitive emissions decline as well, but the overall trend is positive.

Figure 12.2: Hazardous Air Pollutant (HAP) Fugitive and Point Source Emissions in North Carolina, in millions of lbs/year



Source: US EPA, dashboard: TRI Explorer, Release Reports (HAPs), 2013 - 2022. • Created with Datawrapper

[360] Emergency Planning and Community Right to Know Act (EPCRA) §313, Toxics Release Inventory, 42 USC §11023; 40 CFR 372.

[361] US EPA, dashboard: TRI Explorer, Release Reports (HAPs), 2013 - 2022.

Recent developments: In 2021 (updated 2023), the independent newsroom ProPublica examined emissions of carcinogenic HAPs across the nation for the years 2014-2018 to provide a spatial picture of exposures to air toxics.[362] One goal of the map was to depict where risks from multiple facilities overlap, creating cumulative impacts. Such facilities are rare in North Carolina, but ProPublica identified several communities where – according to the EPA risk model the journalists used – residents likely face excess cancer risk from their HAP exposures from individual facilities. The study team also noted that highly polluting facilities are often located in communities of color, something we discuss in more detail under goal 14, 'harms of air pollution are equitably distributed'.[363] ProPublica's discussion of its method offers detailed insight into the limitations and possible sources of error in TRI data and EPA's models for estimating cancer risk.[364]

Control of toxic air pollution is one of the areas where environmental regulation most directly intersects human health. Unfortunately, federal and state programs to limit toxic air emissions have significant shortcomings, including failure to regulate toxics that aren't on the HAP or TAP lists; difficulty addressing cumulative risks even from regulated chemicals; lack of progress in eliminating leaks and other fugitive emissions; and limited resources for inspections and enforcement to ensure emissions are reported accurately and stay within permit limits. ProPublica followed up its 2021 map with a 2024 case study of a town in Kentucky that illustrates these dynamics.[365]

One notable step forward in North Carolina in the last five years is the NC Environmental Management Commission's (EMC) 2020 adoption of a new state toxic air pollution standard for methyl bromide. Methyl bromide is a colorless, volatile gas that is a mutagen and respiratory irritant, and can damage the kidneys and liver.[366] It is also a potent destroyer of stratospheric ozone (the layer that protects the Earth from the sun's UV light), and EPA worked with industry to phase out its production and most domestic uses by 2005.[367] In 2010, two emitters in North Carolina reported to the TRI that they released a total of 244,000 pounds of methyl bromide, 99% of it from DAK America's Cape Fear plant in Leland.[368] Total emissions tapered to 22,000 pounds in 2013, then dropped to 2,700 pounds in 2014 when DAK America ceased production. The single remaining North Carolina source of methyl bromide captured by the TRI is Triest AG Group, headquartered in Greenville, NC; its emissions have stayed fairly level, dropping to 1,400 pounds in the most recent year of data, 2022.[369]

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[362] ProPublica, website: The Most Detailed Map of Cancer-Causing Industrial Air Pollution in the U.S., November 2, 2021, updated August 28, 2023.
[363] Lylla Younes, Ava Kofman, Al Shaw, and Lisa Song, Poison in the Air, ProPublica, Nov 2, 2021.
[364] Lylla Younes, Al Shaw, and Ava Kofman, How we created the most detailed map ever of cancer-causing industrial pollution, ProPublica, Nov. 2, 2021.
[365] Lisa Song, The EPA has done nearly everything it can to clean up this town. It hasn't worked, ProPublica, April 15, 2024.
[366] NIH National Library of Medicine, PubChem, Compound Summary: Bromomethane, last modified May 25, 2024.
[367] US EPA, factsheet: Phaseout of Ozone-Depleting Substances: Methyl Bromide, March 4, 2024.
[368] US EPA, *TRI Explorer*, 2022 Dataset (released October 2023), visited May 31, 2024.
[369] *Ibid.*

In 2018, NC DEQ's Division of Air Quality (DAQ) became concerned that several companies planned to build facilities in North Carolina that would use methyl bromide to fumigate lumber for export.[370] The agency gathered toxicological information and consulted with the Secretaries' Science Advisory Board (SSAB, an advisory board of toxicologists), and brought a proposed emissions limit to the EMC for rulemaking. The final standard went into effect in November 2020.[371] At least two additional facilities in North Carolina are currently permitted to release methyl bromide: Ecolab's facilities at the Port of Wilmington (DAQ #6500356) and at Flowers Timber in Seven Springs (DAQ #9600280) – but neither facility has actually used methyl bromide since the adoption of the new standard.[372]

Goal 13: Indoor air quality does not threaten sensitive populations.

Trend: Data gap

The goal of safe indoor air quality has only one indicator, which we recognize as a data gap, as discussed below.

Solutions: The quality of air indoors is affected by pollution outside, so there is much overlap with solutions from goal 12. To address indoor air quality more specifically, North Carolina can F6, adopt monitoring and standards for indoor air in public buildings, and J9, unfreeze the state building code.

Indicator 13.1: indoor air quality – data gap.

Top line: Most Americans spent the majority of our time indoors – at home, at work, at school. Indoor air quality is influenced by outdoor air quality but can also include a suite of location-specific pollutants. These include secondhand smoke, radon, mold, formaldehyde, cleaning agents, and carcinogens and toxics that off-gas from carpets and furniture.[373] We have not found a dataset that tracks indoor air

[370] DAQ puts on hold methyl bromide permits, Coastal Review, July 27, 2018.
[371] 15A NCAC 02D .0546; *see also*, DEQ, press release: New state rules regulating methyl bromide use in log fumigation take effect, November 2, 2020.
[372] NC DAQ, Inspection report, DAQ #6500356, April 22, 2024, at 3; NC DAQ, Inspection report, DAQ #6500356, October 19, 2021, at 4; NC DAQ, Inspection report, DAQ #9600280, October 18, 2023, at 2.
[373] Javier Gonzalez-Martin et al., A state-of-the-art review on indoor air pollution and strategies for indoor air pollution control, Chemosphere, January 2021, 262, https://doi.org/10.1016/j.chemosphere.2020.128376; Frank Kelly and Julie Fussell, Improving indoor air quality, health, and performance within environments where people live, travel, learn, and work, Atmospheric Environment, 2019, 200: 90 – 109, https://doi.org/10.1016/j.atmosenv.2018.11.058; Tun Maung, Indoor air pollution and the health of vulnerable groups: a systematic review focused on particulate matter (PM), volatile organic compounds (VOCs) and their effects on children and people with pre-existing lung disease, Int. J. of Env. Research & Public Health, 2022, 19, https://doi.org/10.3390/ijerph19148752; Topher Sanders, ProPublica, How much formaldehyde is in your car, your kitchen or your furniture? Here's what our testing found, December 9, 2024.

quality across North Carolina, but indoor air quality is a crucial part of our environmental exposures, so we recognize it as a data gap.

About indoor air quality: Much of the historic research on indoor air quality focused on the impact of second-hand tobacco smoke, but in recent years, that topic has receded, though research on second-hand exposure to e-cigarette aerosols remains active.[374] Instead, the literature on indoor air quality increasingly discusses direct and indirect impacts of climate change. As discussed under goal 12, climate change is driving increased wildfires, resulting in worse outdoor air quality. Higher temperatures also contribute to worse formation of smog from the same level of emissions. In buildings with substantial unfiltered air exchange, outdoor pollutants degrade indoor air quality. In another indirect impact of climate change, increased intensity of rainfall and stronger storms place more properties at risk of flooding; flooded properties often suffer from mold, a significant indoor air pollutant.[375]

In an effort to increase energy efficiency, new and renovated buildings are increasingly sealed, with air exchange limited and managed through filters. Net, this likely improves indoor air quality, but it also changes the mix of pollutants to which occupants are exposed. In a sealed building, off-gassing from building materials and furniture – and biological pollutants like airborne viruses and bacteria – account for a greater share of toxic exposures.[376]

Recent developments: Over the last five years, the North Carolina General Assembly has not adopted any policies directly addressing indoor air quality. SL2023-108 (H488), Code Council Reorganization and Various Code Amendments, blocked updates to energy conservation and energy efficiency sections of the residential building code until 2031, which is likely to slow North Carolina's transition to more sealed buildings and therefore result in higher pollution exposures as well as higher energy bills for owners. EPA has had an indoor air program for years, especially focused on air quality in schools, since air quality demonstrates a correlation with student achievement and lifelong success.[377] The 2022 Inflation Reduction Act (IRA) included $32 million in new funding for indoor air quality in schools.[378] In the last

[374] Liqiao Li et al., Effects of Electronic Cigarettes on Indoor Air Quality and Health, Annual Review of Public Health, 41:363, January 2020, https://doi.org/10.1146/annurev-publhealth-040119-094043.
[375] Leela Kempton et al., Rapid Review: What impacts does increasing airtightness have on mould, condensation and measures of indoor air quality?, September 2020.
[376] Nathan Kyle Kahre, master's thesis: The Relative Value of Weatherization: Comparing Energy Savings, Monetized Health Impacts from Changes in Indoor Air Quality, and Home Improvement Costs, December 2022 (study of data from 92 North Carolina homes found that weatherization significantly improved indoor air quality); Mytien Nguyen, et al., The short-term effect of residential home energy retrofits on indoor air quality and microbial exposure: a case-control study, PLoS ONE, September 2021, 16:9, https://doi.org/10.1371/journal.pone.0230700 (weatherization increased radon and shifted the microbial community, but did not harm health)
[377] US EPA, webpage: Creating Healthy Indoor Air Quality in Schools, March 2024; see also, US EPA, Energy Savings Plus Health: Indoor Air Quality Guidelines for School Building Upgrades, October 2014, Publication No. EPA 402/K-14/001.
[378] US EPA, Notice of Funding Opportunity: Grant Funding to Address Indoor Air Pollution at Schools, February 21, 2024.

five years, EPA has also published guidelines for improving indoor air quality following single family and multifamily building renovations.[379]

The leading strategy to improve indoor air quality has been to educate people to protect themselves in their homes. Research is ongoing to develop better technologies for air filtration.[380] Strategies that reach beyond individual action include reducing toxics in building materials, furniture, and consumer products, and installing high quality air filters in schools and workplaces. The longest-term but ultimately most effective strategy is to improve building codes, both to better prevent penetration of external pollutants (particulates and mold-inducing moisture) and to reduce toxics released from building materials. Several voluntary building standards have the effect of improving indoor air quality: ASHRAE, LEED, Energy Star.[381] In 2023, a team at Johns Hopkins published a Model State Indoor Air Quality Act. The draft includes testing requirements; provisions for public notice; provisions for complaint-driven special investigations by state regulators; and incentives for building owners to improve their compliance record.[382]

Goal 14: Air pollution burden is equitably distributed

Trend: Positive

A sustainable future requires remediation of environmental injustices. In North Carolina as across the country, marginalized communities are often disproportionately affected by pollution, contributing to the cumulative burden of harm to human health caused by multiple environmental and social factors. The Clear Air Act, passed 54 years ago, has reduced overall particulate matter concentrations, but the most polluted US communities of 50 years ago are still so today.[383] Studies at the national level and in North Carolina have found that across the 2010s, the closure of coal-fired power plants improved air

[379] US EPA, Energy Savings Plus Health: Indoor Air Quality Guidelines for Single -Family Renovations, May 2021, Publication No. EPA 402K21001; US EPA, Energy Savings Plus Health: Indoor Air Quality Guidelines for Multifamily Renovations, May 2021, Publication No. EPA 402K21002.
[380] See, for example, Teresa Mata et al., Indoor air quality improvement using nature-based solutions: design proposals to greener cities, Int J. Environ Research and Public Health, August 2021, 18, 8472, https://doi.org/10.3390/ijerph18168472 (discussing advances in microalgal indoor purification systems).
[381] ASHRAE: ASHRAE, Indoor air quality guide: best practices for design, construction, and commissioning, 2009; see also, P.W. Francisco et al., Ventilation, indoor air quality, and health in homes undergoing weatherization, Indoor Air, October 2016, 27:2, https://doi.org/10.1111/ina.12325 ("indoor air quality and health improve when weatherization is accompanied by an ASHRAE residential ventilation standard"); LEED: Hannah Phillips, et al., Taking the 'LEED' in indoor air quality: does certification result in healthier buildings?, Journal of Green Building, September 2020, 15(3), https://doi.org/10.3992/jgb.15.3.55, (particulate levels in 12 LEED certified buildings were half of levels in 12 non-LEED buildings); Energy Star: US EPA, webpage: Energy Star Residential New Construction Program Requirements, visited March 22, 2024.
[382] Johns Hopkins Center for Health Security, Model State Indoor Air Quality Act, 2023; Lawrence Gostin, The model State Indoor Air Quality Act, JAMA, October 2023, 330 (16): 1525. doi:10.1001/jama.2023.17334.
[383] Jonathan Colmer et al., Disparities in $PM_{2.5}$ air pollution in the United States, Science, July 2020, DOI: 10.1126/science.aaz935

quality for everyone, but less for communities of color than for white communities, and least of all for poor communities of color.[384]

Air pollution from both stationary sources (factories, power plants) and mobile sources (cars, trucks, heavy equipment) still creates substantial disparities in local exposures. A 2019 study quantified the disproportionate burden of air pollution in the United States, finding that "on average, non-Hispanic whites experience a 'pollution advantage': they experience 17% less air pollution exposure than is caused by their consumption. Blacks and Hispanics on average bear a 'pollution burden' of 56% and 63% excess exposure, respectively, relative to the exposure caused by their consumption."[385] The disparity in impacts is also economic: a study of 1,600 facilities nationwide found that the opening of a plant that releases hazardous air pollutants leads to an 11% decline in housing values within a half mile.[386]

For this goal, we evaluate trends in the disparities in exposure to pollution from stationary sources and from mobile sources of pollution over the last five years. We've done that by calculating correlation between three metrics from the US Environmental Protection Agency's Environmental Justice screening and mapping tool (EJScreen): respiratory hazard risk, vehicle air pollution risk, and a demographic index the EPA uses to identify environmental justice (EJ) communities. This approach lacks nuance but is meant to give a loose sense of trend. As discussed below, we've found that the correlation between respiratory hazard risk and EJ communities has weakened slightly, and the correlation between vehicle air pollution and EJ communities is stable. We think this adds up to a positive trend, especially as mobile emissions should drop significantly over time in absolute terms as vehicle efficiencies improve and the transportation sector electrifies (indicators 31.1 and 31.2). One implication of the available data is that very local monitoring and targeted policy solutions will be needed to eliminate the hot spots causing enduring disparities.[387]

Solutions: North Carolina can better protect state residents by D1, protecting all North Carolinians from disproportionate burdens; F1, targeting air pollution hot spots; F2, conducting non-targeted assessments to identify unregulated air contaminants in overburdened neighborhoods; F3, curbing air

[384] Gaige Hunter Kerr et al., Increasing Racial and Ethnic Disparities in Ambient Air Pollution-Attributable Morbidity and Mortality in the United States, Environmental Health Perspectives, March 2024, 132 (3), https://doi.org/10.1289/EHP11900 (study of national trends, 2010-2019); Mercedes Bravo, Where Is Air Quality Improving, and Who Benefits? A Study of PM2.5 and Ozone Over 15 Years, American Journal of Epidemiology, April 2021, 191 (7), https://doi.org/10.1093/aje/kwac059 (trends in North Carolina, 2002- 2016); Jennifer Richmond-Bryant et al., Disparities in Distribution of Particulate Matter Emissions from US Coal-Fired Power Plants by Race and Poverty Status After Accounting for Reductions in Operations Between 2015 and 2017, American Journal of Public Health, May 2020, 110 (5): 655, https://doi.org/10.2105/AJPH.2019.305558 (air quality benefits of coal plant closures were distributed unevenly).

[385] Christopher Tessum et al., Inequality in consumption of goods and services adds to racial-ethnic disparities in air pollution exposure, PNAS, March 2019, 116 (13): 6001, https://doi.org/10.1073/pnas.1818859116.

[386] Janet Currie et al., Environmental Health Risks and Housing Values: Evidence from 1,600 Toxic Plant Openings and Closings, American Economic Review, February 2015, 105 (2): 678, https://doi.org/10.1257%2Faer.20121656.

[387] Yang Zhang, Pollution inequality 50 years after the Clean Air Act: the need for hyperlocal data and action, Environmental Research Letters, July 2021, 16, https://doi.org/10.1088/1748-9326/ac09b1.

emissions of forever chemicals; F4, addressing local impacts of transportation emissions; and J6, investing in ZEV charging infrastructure.

Indicator 14.1: Correlation between air hazards and environmental justice communities

Topline: To assess whether disparities in exposures to air toxics are getting better or worse, we check the spatial correlation of two factors over time: toxic air exposures and environmental justice characteristics. Census blocks with the greatest exposure to air pollution are slightly more likely to be home to residents of color or low income (that's bad), but over the last six years, the correlation has gotten weaker (that's good) – although this apparent trend is worth taking with a grain of salt.

About disparities in exposures to hazardous air pollutants: If disparities exist for conventional pollutants – nitrogen oxides, ozone, particulates – that is even more true for hazardous air pollutants. A recent nationwide analysis of 21 known human carcinogenic air pollutants found risks of high exposures were greater for Black and Hispanic Americans, low-income residents, and people with less than a high school education.[388] As noted under indicator 12.2, the federal list of Hazardous Air Pollutants (HAPs) was established by the U.S. Congress as part of the 1990 Clean Air Act amendments. The list has never been comprehensive, and it has become increasingly incomplete as new and existing industries have introduced new chemicals and industrial processes, but it is still the benchmark for measuring and controlling air pollution beyond the common criteria pollutants.

[388] Jessica Madrigal et al., Sociodemographic inequities in the burden of carcinogenic industrial air emissions in the United States, Journal of the National Cancer Institute, May 2024, 116 (5): 737, https://doi.org/10.1093/jnci/djae001.

Table 14.1: Respiratory Hazard Index and Demographic Index Correlation Coefficients

Year	Correlation Coefficient
2023	0.155
2020	0.196
2019	0.195
2018	0.230
2017	0.233
2016	0.265

Source: United States Environmental Protection Agency. 2016-2023 EJScreen Data Index. • Created with Datawrapper

For years up to 2017, EPA periodically issued a National Air Toxics Assessment (NATA); since then, the federal agency has issued the Air Toxics Screening Assessment (ATSA), now issued annually with a four year delay.[389] Both the NATA and now the ATSA include an index of respiratory hazard that represents to cumulative effect of all the modeled hazardous air pollutant emissions in a census tract. During the same period, the EPA developed and launched the Environmental Justice Screening and Mapping Tool (EJScreen) to better meet the agency's public health goals.[390] EJScreen includes, among many other environmental and social indicators, a justice-oriented 'demographic index' that combines measures of communities' income levels and percentage of minority residents, and the EPA Air Toxics Screening Assessment's most recent respiratory hazard index. To track the "pollution advantage" and "pollution disadvantage" in the state – the trend in distribution of health risks related to air pollution – we calculated the degree of correlation between the two indices. We used a basic Pearson correlation coefficient test to measure the strength of the relationship between the indices, using data downloaded from the EJScreen Data Index.

An equitable distribution of risk would involve an essentially random correlation between the two indices. If the correlation should become stronger over time, that would be a worrying sign. As shown in table 14.1, we observe a weak overall correlation between the indices, and it has weakened further over the last decade. This trend implies that it is possible the burden of air pollution is becoming more equally distributed. However, we acknowledge the limitations of both the data set (EJScreen relies on estimates that involve substantial uncertainty due to the size of the geographic units; environmental indicators are only screen-level proxies for actual health impacts and also include substantial uncertainty), and of our rudimentary analysis. The weakened correlation could reflect several factors,

[389] US EPA, webpage: Air Toxics Screening Assessment, updated August 8, 2024; US EPA, webpage: Previous Air Toxics Assessments, updated March 27, 2024.
[390] US EPA, webpage: EJScreen: Environmental Justice Screening and Mapping Tool, updated September 9, 2024.

including movement of white residents into redeveloping neighborhoods near emissions sources, or the closure of emissions sources in low-income and heavily minority rural communities. We regard a declining correlation between toxic air exposures and EJ communities as a positive trend, while realizing that North Carolina still has far to go to protect historically marginalized communities from air pollution.

Indicator 14.2: Correlation between vehicle air pollution and environmental justice communities

Topline: Low-income communities and communities of color in North Carolina and elsewhere are disproportionally exposed to pollution from heavy traffic. But based on a simple statistical analysis, the correlation between environmental justice communities and traffic proximity and volume has remained stable or slightly improving in North Carolina over the last five years. We consider that positive, especially given that the total burden of traffic-generated air pollution is declining.

About disparities in exposure to vehicle air pollution: Pollutants emitted directly from motor vehicles, such as particulates and nitrogen oxides, are found in higher concentrations around major roadways. As documented in a magisterial systematic review by the Health Effects Institute, exposure to these pollutants increases the risks of developing asthma, acute respiratory infections, childhood and adult cancers, and adverse birth outcomes.[391] A 2024 study in Denmark found that motor vehicle pollutants were also associated with higher risk of infertility for men, and road traffic noise was associated with infertility in women over 35 years of age.[392]

In North Carolina's urban areas, disparities in exposure to transportation emissions have historic roots in the eras of redlining and post-war highway construction that put heavily travelled routes through Black communities.[393] But modern freight transportation – especially truck traffic – has brought very local disparities into suburban and exurban communities in the present day.[394] Thanks primarily to truck

[391] Health Effects Institute, Systematic Review and Meta-analysis of Selected Health Effects of Long-Term Exposure to Traffic-Related Air Pollution, June 2022 (updated April 2023).
[392] Mette Sorensen et al., Long term exposure to road traffic noise and air pollution and risk of infertility in men and women: nationwide Danish cohort study, BMJ, September 2024, 386, https://doi.org/10.1136/bmj-2024-080664
[393] See, University of Richmond, interactive website: Mapping Inequality: Redlining in New Deal America [*Mapping Inequality*], updated August 26, 2024 (showing maps of redlined North Carolina towns and cities); Mackenzie McCausland et al., Historical redlining is associated with present-day disparities in road traffic density, ISSA Conference Abstracts, August 2024, https://doi.org/10.1289/isee.2024.0820; Deborah Archer, "White Men's Roads through Black Men's Homes": Advancing Racial Equity through Highway Reconstruction, Vanderbilt Law Review, October 2020, 73 (5), https://scholarship.law.vanderbilt.edu/vlr/vol73/iss5/1 (discussing the history of displacement of Black neighborhood by mid-century road projects); Katie Peralta Soloff, Highway construction harmed Black neighborhoods in Charlotte. Now leaders are trying to "untangle" past mistakes, Axios, October 20, 2020 (discussing historic displacement in Charlotte).
[394] Matthieu Schorung, Thibault Lecourt, and Laetitia Dablanc, Atlas of warehouse geography in the US, July 2022, halshs-03682918 (showing warehouse increases from 2012-2019 in Raleigh and Charlotte suburbs and along interstates in North Carolina generally).

emissions, warehouses increase local NO2 concentrations by roughly 20% – and a recent national analysis indicates that warehouses are disproportionately located in low-income neighborhoods and communities of color.[395] This is likely the reason that, among the various paths the United States could take to reach carbon reduction targets, those that target transportation (through vehicle electrification, discussed under indicator 29.4) have the greatest potential to reduce racial disparities in air pollution exposures.[396]

For this indicator, we follow a process parallel to that used for indicator 14.1, distribution of stationary sources of toxic air pollution: we consider the correlation between EJ census blocks and census blocks in close proximity to high volumes of traffic, a data layer created for EPA's EJScreen. From 2019 to 2024, that correlation declined very slightly from 0.2 to 0.19. That is, EJ communities do face a modestly higher level of exposure to air pollution from traffic, but the disparity has been essentially stable or narrowing slightly over the last five years. Given that the state has seen growth in population and vehicles miles traveled over the same time, and that per-vehicle emissions are gradually falling, we consider this a positive trend.

Goal 15: Public drinking water supplies are safe

Trend: Positive

North Carolinians want and expect safe drinking water. We measure progress towards this goal with two indicators: the trend in violations of safe drinking water standards, and the number of unregulated contaminants showing up in water samples collected across the state. The first shows a positive trend, and the second is a data gap for this year.

Solutions: North Carolina can better protect public drinking water supplies by A5, enacting state wetlands protections; G3, updating surface water quality standards; G4, curbing the discharge of forever chemicals; G5, building out One Water strategies for nutrient-impaired reservoirs; G6, strengthening stormwater management; G8, improving sludge management; G13, transitioning away from swine waste sprayfields; H3, reducing plastic pollution; and E1, funding lead testing and remediation.

[395] Gaige Hunter Kerr et al., Air pollution impacts from warehousing in the United States uncovered with satellite data, Nature Communications, July 2024, 15 (1): 6006, https://doi.org/10.1038/s41467-024-50000-0.
[396] Pascal Polonik et al., Air quality equity in US climate policy, PNAS, June 2023, https://doi.org/10.1073/pnas.2217124120.

Indicator 15.1: Number of drinking water violations.

Top line: In general, violations of drinking water standards are declining, so we mark this indicator as trending in the right direction. A pulse in monitoring violations in 2022 bears watching to see whether it recurs in 2025.

About drinking water violations: At any given time, the vast majority of North Carolina's public water systems are in compliance with federal Safe Drinking Water Act (SDWA) standards. When new drinking water standards are adopted, they are usually phased in over a period of years, starting with the largest systems first. Typically, heavy violators are small, poorly funded systems; many serve very small numbers of customers, such as residents of a single mobile home park. This indicator tracks the number of violations of state and federal drinking water rules, grouping them into violations of standards (the water exceeds a health standard), treatment technique violations (the utility did not carry out the water treatment process correctly), failure to monitor and report (which may or may not obscure an actual violation of standards), and a catchall category of 'other' violations. North Carolina's Public Water Supply (PWS) program, part of the Division of Water Resources in the NC Department of Environmental Quality, publishes this data for the preceding year each June.[397]

The state reports show a general trend of declines in most kinds of violations over the last decade, as shown in figure 15.1. That reflects water systems becoming accustomed to implementing the two newest federal drinking water rules, governing toxic disinfection byproducts and concentrations of lead and copper. The number of violations for the 2019 data year was unusually low, reflecting data collection garbled by the arrival of the pandemic in March 2020; the data for 2020 are correct, and in line with the overall trend. In 2022, most of the violations of standards were caused by disinfection byproducts (25), radionuclides (14), and coliform (11).[398] Most 'other' violations were inadequate public notice of system actions; most treatment violations were failures to properly treat drinking water to eliminate coliform (29). All three of these categories continued the (positive) trend of fewer violations. However, monitoring violations rose dramatically in 2022, driven by failures to test for synthetic organic chemicals (industrial solvents and pesticides, 1392), lead and copper (527), coliform (458), or inorganic chemicals (metals and nitrates, 326). Systems are only required to test for some of these once every three years, and appear simply to have missed the requirement in 2022. Monitoring violations matter, but violations of drinking water quality standards and treatment methods are more important and have continued to fall. Overall, we think public water system violations are headed in the right direction: down.

Unsurprisingly, research shows that water systems with recurring violations of health-based water quality standards are disproportionately located in socially vulnerable communities.[399] Moreover,

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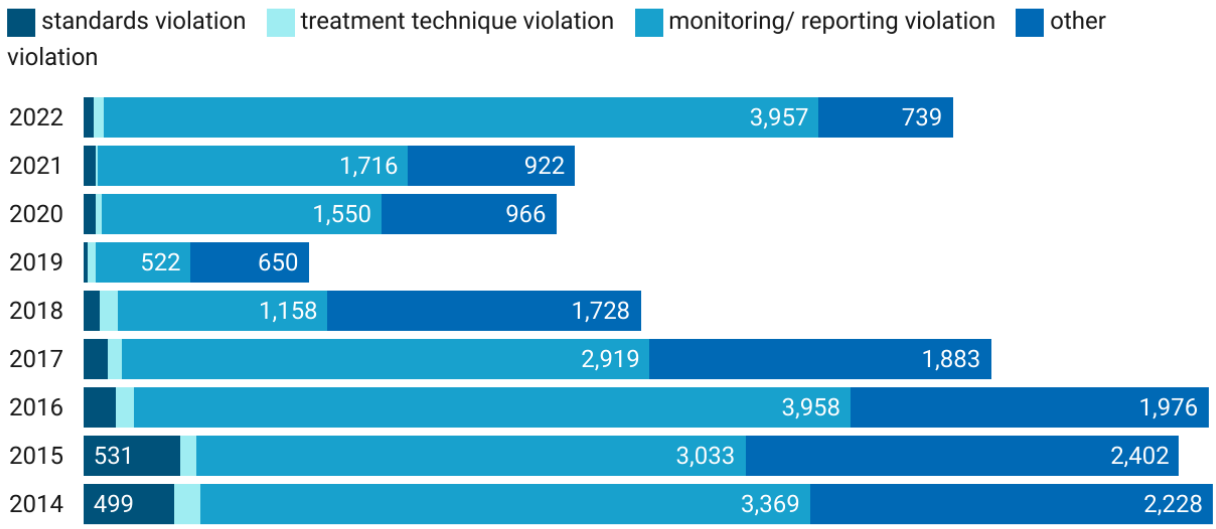
[397] NC DEQ, Public Water Supply, North Carolina's Annual Public Water Systems Compliance Report for calendar years 2014-2020.
[398] NC DEQ, North Carolina's Annual Public Water Systems Compliance Report for 2022, July 2023.
[399] Bridget Scanlon et al., Drinking water quality and social vulnerability linkages at the system level in the United States, Environ. Res. Lett., September 2023, 18: 094039, DOI 10.1088/1748-9326/ace2d9.

nationally, noncompliant water systems in counties with a higher proportion of Black or Hispanic residents take longer to return to compliance (we've not seen this analysis run specifically for North Carolina).[400] Violations can have significant long-term as well as short term consequences; a 2023 study of national compliance with bacterial standards for drinking water found that exceedances of standards are correlated with worse test scores for local students, and that those effects on student performance persist over time.[401]

Figure 15.1: Number of Public Water System Violations



Source: NC DEQ, Public Water Supply, North Carolina's Annual Public Water Systems Compliance Reports for calendar years 2014-2022. • Created with Datawrapper

Recent developments: We discuss this at greater length under indicator 19.1, PFAS in drinking water, but in April 2024, EPA finalized federal drinking water standards for six of the most common PFAS, with a compliance date of May 2029. An estimated 41% of large utilities (serving more than 10,000 residents) that draw from surface water have levels of regulated PFAS over the federal drinking water standards and will need to reduce PFAS levels by that date.[402] Failure to cut off upstream PFAS discharges will set these systems up for drinking water standard violations, or require them to invest in expensive treatment technologies paid for by their ratepayers.

[400] Junghwan Bae et al., Drinking water injustice: racial disparity in regulatory enforcement of Safe Drinking Water Act Violations, Race and Justice, July 2023, 1: 21, https://doi.org/10.1177/21533687231189854.
[401] Michelle Marcus, working paper: Testing above the limit: Drinking water contamination and test scores, August 2023, DOI 10.3386/w31564.
[402] Julie Grzyb, Chris Ventaloro, and Stephanie Bolyard, presentation: Proposed Surface Water Quality PFAS Standards, Implementation Plan, and Regulatory Impact Analysis, presentation to the EMC Water Quality Committee, July 10, 2024, at slide 20.

Indicator 15.2: Data gap – prevalence of unregulated contaminants in public water supplies.

Top line: While North Carolina's water systems are generally compliant with federal drinking water standards, it is much less clear whether they contain safe levels of unregulated contaminants.[403] EPA provides for the testing of new batches of unregulated contaminants in five-year cycles, and sometimes decides to pursue formal regulation of those. There is no lasting data series for unregulated contaminants, so we mark this as a data gap and do not assign a trend. Concern over one subset of unregulated contaminants – pharmaceuticals – peaked around 2010; we've found no recent research showing these are present at health-relevant concentrations in North Carolina drinking water, but it's also not clear that the question has been studied in a decade.

About unregulated contaminants: While most water systems comply with federal drinking water standards, many pollutants have no drinking water standard. Moreover, EPA is slow to add standards for additional pollutants. Instead, working in five-year cycles, the agency requires large water systems, and a random sample of smaller systems, to monitor – but not treat – a number of these compounds. Out of 109 chemicals (and two viruses) monitored in any of the four completed cycles, EPA has subsequently proposed new drinking water standards for just two.[404]

Each cycle is established by an Unregulated Contaminant Monitoring Rule (UCMR), which lists up to 30 chemicals for monitoring for the middle three years of the five-year cycle. For each chemical, EPA sets a 'minimum reporting level', not based on a judgment of what concentrations are safe or unsafe, but at the smallest concentration laboratories can detect.[405] Water systems that find UCMR chemicals in their water are required to let their customers know as a part of the annual 'consumer confidence reports' sent to each household.[406] We are currently in the fifth UCMR (2022-2026), which focuses on PFAS, and we therefore discuss it under indicator 19.1.[407] In the fourth cycle (2017-2021), which targeted algal toxins and pesticides, a total of 185 North Carolina water systems collected a total of 33,225 samples. Of the participating systems, 154 (83%) detected a reportable level of at least one of the UCMR4 contaminants. Contaminants showed up in a total of 8,252 samples (25%). The main contaminants were unregulated disinfection byproducts (21% of total samples), manganese (4%), and germanium (0.1%).[408]

[403] To be clear, many systems are not in compliance with the federal drinking water standards for six PFAS that will take effect in May 2029, discussed under indicator 19.1.
[404] The two chemicals EPA decided to regulate are PFOA and PFOS. US EPA, webpage: Contaminant Candidate List: Regulatory Determination 4, updated March 15, 2024.
[405] US EPA, The Fourth Unregulated Contaminant Monitoring Rule (UCMR4): Data Summary, October 20, 2018, at 3.
[406] See, 40 CFR 141.153(d)(7), describing the required elements of the Consumer Confidence Report.
[407] US EPA, webpage: Fifth Unregulated Contaminant Monitoring Rule, visited June 12, 2024.
[408] US EPA, website: Archival Data Finder for the Unregulated Contaminant Monitoring Rules (UCMR 1-4).

Since the end of the cycle, there has been no requirement for systems to continue testing most of these compounds, so there is no way to derive a trend from this data.[409]

It is worth noting that UCMR lists do not include many other emerging but unregulated contaminants that have been found in rivers and reservoirs and are not removed by conventional drinking water treatment process. These include nicotine, caffeine, birth control hormones, and many kinds of pharmaceuticals (anti-depressants, steroids, painkillers, diabetes drugs, steroids, and antibiotics, among others).[410] UCMR3 (2013-2015) did include several pharmaceutical hormones – equilin, 17beta-estradiol, testosterone – but found detections in source waters were extremely rare.[411] Academic concern and monitoring for pharmaceuticals peaked around 2010, with researchers finding widespread occurrence, but not at 'therapeutic levels'.[412] Researchers have pointed out that long-term ongoing exposure to levels much lower than therapeutic levels could present a health risk, but we lack both data and a consensus framework for assessing that risk.[413] In 2012, several federal agencies signed a Memorandum of Understanding to collaborate on addressing pharmaceuticals in drinking water; they renewed the agreement in 2022, but it is unclear what the agencies are doing.[414]

Contaminants released for discharge into surface waters can also end up concentrated in sewage sludge, also called biosolids, that is removed from wastewater during treatment.[415] Over half of sewage sludge in North Carolina is spread on agricultural fields, and another 17% is sold as a soil additive for

[409] Disinfection byproducts did become a regulated contaminant under the Safe Drinking Water Act; those trends are that covered above under indicator 15.1, Safe Drinking Water Act violations.

[410] Paul Bradley et al., Multi-region assessment of pharmaceutical exposures and predicted effects in USA wadeable urban-gradient streams, PLoS One, 2020, 15(1), https://doi.org/10.1371/journal.pone.0228214; Paul Bradley et al., Expanded Target-Chemical Analysis Reveals Extensive Mixed-Organic-Contaminant Exposure in USA Streams, Environ Sci Technol, 2017, 51:9, 4792, https://doi.org/10.1021/acs.est.7b00012. For an example of non-targeted analysis of a single urban stream, see, Imari Walker-Franklin et al., Non-Targeted Exploration of a Durham, NC, USA Freshwater Creek Reveals Temporal Trends in Polar Environmental Micropollutants, May 2024, https://dx.doi.org/10.2139/ssrn.4824412.

[411] US EPA, UCMR 3 Data Summary: 2013-2015, March 2024, at 10.

[412] USGS, webpage: Pharmaceuticals in Water, June 6, 2018 (detailing research from 2004 through 2009); Sara Rodriguez-Mozaz and Howard Weinberg, Meeting report: pharmaceuticals in water – an interdisciplinary approach to a public health challenge, EHP, March 2010, https://doi.org/10.1289/ehp.0901532 (describing a summit on the topic held in North Carolina in 2008).

[413] C.G. Daughton, Pharmaceutical Ingredients in Drinking Water: Overview of Occurrence and Significance in Human Exposure, February 2010; Alistair Boxall et al., Pharmaceuticals and personal care products in the environment: what are the big questions?, Environmental Health Perspectives, May 2012, 120 (9): 1221, https://doi.org/10.1289/ehp.11044.

[414] MOU-225-22-015, Memorandum of Understanding on Sustainability of Federal Collaboration on Pharmaceuticals in Drinking Water Between the US EPA Office of Water and USDA and US DHHS Food and Drug Administration (FDA) and US DOI US Geological Survey (USGS), May 2022.

[415] Elizabeth Pozzebon and Lars Seifert, Emerging environmental health risks associated with the land application of biosolids: a scoping review, Environmental Health, August 2023, 22 (57), https://doi.org/10.1186/s12940-023-01008-4.

landscaping and gardening use.[416] Unregulated contaminants in land-applied sludge have been measured leaching back into streams and river, and can also seep into nearby groundwater, threatening the safety of groundwater wells, the focus of the next indicator.[417]

Goal 16: Private groundwater wells are safe

Trend: Data gap

This goal – that drinking water in private wells is safe, free from bacteria and chemical contamination – has a single indicator, and that is a data gap.

Solutions: North Carolina can improve the quality and safety of private well water by, E3, banning PFAS-containing fire-fighting foams; F3, curbing air emissions of forever chemicals; G4, curbing the discharge of forever chemicals; G8, improving the management of sewage sludge; G11, establishing a septic repair fund; G13, requiring swine farms to transition away from sprayfields; H4, addressing past contamination; and H5, preventing future contamination.

Indicator 16.1: Percentage private drinking wells with unsafe groundwater.

Top line: Roughly one quarter of North Carolina residents depend on private wells for their drinking water.[418] Since 2012, state law has required that residents obtain a permit from their county health department before constructing, repairing, or abandoning a well.[419] New private wells must be tested for bacteria and a suite of inorganic contaminants, but the results of those tests are not generally publicly available. North Carolina does not require that wells be periodically tested, although experts at the UNC Gillings School of Public Health recommend that drinking water wells be tested annually for bacteria, every two years for metals, and every five years for pesticides and volatile organic compounds.[420] In effect, there is no public data series to indicate trends in the quality of private well water than North Carolinians are drinking. This data gap presents a serious threat to public health.

About private well water quality: As noted in the top line, North Carolina requires modest testing of private drinking water wells when they are first constructed, but not thereafter. Moreover, the

[416] Robert Forbes, The Changing Landscape of Biosolids Management in North Carolina Over the 21st Century's First Two Decades, Proceedings of the Water Environment Federation, May 2023, 10.2175/193864718825158783, at 6. The distribution in 2018 was: land applied, 53%; soil additive, 17%; incinerated, 21%; buried in landfill, 9%.
[417] Detlef Knappe and Erin Baker, Novel Mass Spectrometry Approaches for the Identification of Pesticides and Per- and Polyfluoroalkyl substances in North Carolina Drinking Water Sources, WRRI Report No. 512, January 18, 2024.
[418] USGS, Estimated Use of Water in the United States in 2015, Circular 1441, 2018, at 23 (Table 6: Domestic water withdrawals and deliveries, 2015).
[419] NCGS §87-97. Construction of wells with a designated capacity of 100,000 gallons/day or more is regulated by the NC Environmental Management Commission, NCGS §87-88; these are typically industrial or public drinking water utility wells.
[420] UNC, Gillings School of Public Health, webpage: All About Well Testing, visited October 30, 2024.

requirement of testing for new wells was enacted in 2006 and phased in between 2008 and 2012; millions of private wells currently in use predated the testing requirement and may never have been sampled. Well users tend to take groundwater quality for granted; as one recent study puts it, "The majority of well users do not perform routine maintenance or water testing, and, in spite of this, many believe that their water is safe to drink."[421] That is true even though, nationally, over half of private wells would not meet federal drinking water standards if they were subject to them.[422]

Industrial contamination of groundwater is a problem. Perhaps most famously, Chemours has directly and indirectly contaminated groundwater across a large region of southeast North Carolina, also discussed under indicators 19.1 an 19.2.[423] A striking 2023 paper found evidence in Coastal Plain wells – both in the surficial aquifer and deeper 'confined' aquifers usually thought to be cleaner – of non-naturally occurring contaminants, including pharmaceuticals, food additives, and aromatic hydrocarbons.[424] Some of this contamination appears to have reached deeper aquifers through surface flooding of groundwater wells. Across most of the state, industrial contamination of groundwater is more often discovered long after the fact, as a result of site assessments undertaken when the property that is the source of contamination changes hands.

More widespread testing of wells would benefit public health, but policymakers have resisted taking that step for several reasons. First, well owners of limited means would need financial help to do anything about contamination, such as cleaning it up or installing filters.[425] Some residents worry that their homes could lose value if contamination were publicly known. Some regions of the state have groundwater with naturally elevated concentrations of contaminants – arsenic, manganese, hexavalent chromium, vanadium, uranium.[426] Several of these occur over large geographic areas and at

[421] Kory Wait et al., Disparities in well water outreach and assistance offered by local health departments: a North Carolina case study [*Wait et al.*], Science of the Total Environment, July 2020, 747, https://doi.org/10.1016/j.scitotenv.2020.141173, at 6.
[422] *Ibid*, at 6. A 2023 study of private wells in four coastal plain counties found that water in 67% of wells exceeded federal or state standards or health goals. Andrew George et al., Drinking Water Disparities in North Carolina Communities Served by Private Wells, Environmental Justice, June 2023, https://doi.org/10.1089/env.2022.0100.
[423] Matthew Prensky, What we've learned so far after a year of PFAS well testing around Wilmington, Wilmington StarNews, February 21, 2023; NC DEQ, map: PFAS Residential Well Sampling, Fayetteville Region, October 10, 2022; NC DEQ, map: PFAS Residential Well Sampling, Lower Cape Fear Region, October 10, 2022. Sampling was expanded further in August 2024. NC DEQ, webpage: Well Sampling Information for Lower Cape Fear Area Residents, visited March 19, 2025.
[424] Hayden Rudd et al., Vulnerability of wells in unconfined and confined aquifers to modern contamination from flood events, Science of the Total Environment, November 2023, 901, https://doi.org/10.1016/j.scitotenv.2023.165729.
[425] Claire Mullany and Michele Okoh, A Drop in the Bucket: North Carolina's Neglected Problem of Private Well Water Contamination, North Carolina Civil Rights Law Review, 2023, 3, https://scholarship.law.unc.edu/nccvlrts/vol3/iss1/2.
[426] NC DHHS, webpage: Well Water & Health, Maps by Contaminant Name, visited October 30, 2024; Rachel Coyte et al., Occurrence and distribution of hexavalent chromium in groundwater from North Carolina, USA, Science of the Total Environment, April 2020, 771:135135, https://doi.org/10.1016/j.scitotenv.2019.135135 (hexavalent chromium); Lauren Eaves et al., Analysis of the novel NCWELL database highlights two decades of co-occurrence of toxic metals in North Carolina private well water: public health and environmental justice implications [*Eaves et*

concentrations presenting a greater risk to residents than anthropogenic contamination, but with even fewer programs available to assist homeowners. The lack of state-mandated or funded testing for private wells has thus remained a stubborn data gap for years, even as North Carolina has become a national outlier in the large number of our residents drinking private well water.

Inequities in the outreach and services provided by different county health departments create a different problem. County health departments have varied levels of staffing, charge wildly different fees, and many keep records solely on paper in the county office, making it difficult to assemble a statewide picture of risks facing well owners.[427] The historical exclusion of neighborhoods of color from access to town water systems, a process known as 'underbounding', means that the lack of protection and support for private well users is an environmental justice problem as well.[428]

Well users tend to be located in areas of concentrated reliance on septic systems. While North Carolina has invested billions in local water systems – both drinking water and wastewater infrastructure – the state has invested very little in helping private owners maintain or replace failing septic systems.[429] That means well users are disproportionately at risk from bacterial contamination from poorly maintained septic systems. Finally, flooding has presented a special risk to residents reliant on drinking water wells. Inundated wells can easily become contaminated but are routinely used by owners following disasters without being tested or disinfected.[430]

Goal 17: Surface waters are safe for recreation

Trend: Negative

Above, as a part of the section on trends in the state's land and water resources, indicators 3.1, 4.1 and 4.2 consider water quality and the health of our aquatic ecosystems. Here, we evaluate the safety of North Carolina's rivers, lakes, and coastal waters for human recreation: swimming, wading, paddling, and fishing. We track progress towards the goal with two indicators tied to the most widespread threats to recreational waters: hazardous algal blooms and disease-causing bacteria. Data sources are limited but becoming more abundant for both indicators. Algal blooms appear to be becoming more frequent,

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al.], Science of the Total Environment, March 2022, 812: 151479, https://doi.org/10.1016/j.scitotenv.2021.151479 (arsenic and manganese); Taylor Alvarado et al., Geological predictors of drinking water well contamination in North Carolina, PLOS Water, January 2024, 3(1), https://doi.org/10.1371/journal.pwat.0000194.

[427] *Wait et al.*, at 6.

[428] *Eaves et al.*, at 13. For an effort to cross-walk high concentrations of toxic metals in groundwater with communities of color or low income at the census tract level, see Noemi Gavino-Lopes et al., Developing Toxic Metal Environmental Justice Indices (TM_EJIs) for Arsenic, Cadmium, Lead, and Manganese Contamination in Private Drinking Wells in North Carolina, Water, June 2022, 14: 2088, https://doi.org/10.3390/w14132088.

[429] Will Atwater, NC focuses on helping municipal water and sewer systems, but septic owners will have to wait, NC Health News, September 5, 2024.

[430] Lisa Sorg, NC Health Officials Issue Guidelines for Thousands of Potentially Flooded Private Wells, Inside Climate News, October 4, 2024; Mira Rojanasakal and Hiroko Tabuchi, Many Wells in North Carolina Remain Unsafe After Helene's Deluge, N.Y. Times, October 25, 2024.

and water quality sampling suggests slightly increased frequency of unsafe levels of bacteria, so we think North Carolina is slipping away from rather than approaching the goal of safe recreational waters.

Solutions: North Carolina can improve recreational water quality by C3, improving maintenance of coastal stormwater practices; C4, implementing the Coastal Habitat Protection Plan; G3, updating surface water quality standards; G4, curbing the discharge of forever chemicals; G5, building out One Water strategies; G6, strengthening stormwater management; G7, expanding funding for the Community Conservation Assistance Program; G8, improving management of sewage sludge; G11, establishing a septic system repair fund; G13, requiring swine farms to transition away from sprayfields; and G14, permitting dry-litter poultry operations.

Indicator 17.1: Harmful algal blooms

Top line: there are two ways to track algal blooms in North Carolina: satellite observations and reports to the state environmental agency. Both sources of data have limitations but are likely to become more reliable with time. For now, satellite data suggests algal blooms are becoming more frequent, increasing the potential for harmful algal blooms, a negative trend.

About harmful algal blooms: Algae are a normal part of North Carolina's aquatic ecosystems. However, excess levels of nitrogen and phosphorus pollution can supercharge algal communities. When those colonies die, their decomposition can absorb much of the oxygen in the water, leading to fish kills and foul water in freshwater lakes and coastal estuaries. Algae come in many different species; excess nutrient pollution can also drive a shift in the mix of species, including an increase in species that produce chemical wastes that are toxic to humans and other animals.[431] Removing these algal toxins can be expensive for drinking water utilities. Toxic algae also present a direct threat to swimmers and boaters who come in contact with them. Such blooms are known as 'harmful algal blooms' (HABs), and their management has become an increasing challenge over the last two decades.

HABs have been identified in all parts of the state, in lakes, rivers, and estuaries, including the Chowan River,[432] Bogue Sound,[433] stormwater ponds in Wilmington,[434] drinking water reservoirs in the Triangle,[435] and parks and recreation ponds in Charlotte.[436] Traditionally, the primary health concern from HABs has been direct contact with toxins by people or pets swimming or wading; every so often,

[431] Waterkeepers Carolina, Responding to Harmful Algal Blooms: A Guide for North Carolina Waterkeepers, Government Agencies, and Water Quality Advocates, 2020.
[432] Haley Plaas et al., Harmful cyanobacterial aerosolization dynamics in the airshed of a eutrophic estuary, Science of the Total Environment, December 2022, 852: 158383, https://doi.org/10.1016/j.scitotenv.2022.158383.
[433] Madeline Mary Anderson, master's thesis: Co-occurrence of Freshwater and Marine Phycotoxins: A record of microcystin and domoic acid in Bogue Sound, North Carolina (2015 to 2020), 2022.
[434] Amy Grogan et al, Harmful Algal Blooms: A Prolific Issue in Urban Stormwater Ponds, Water, 2023, 15:2436, https://doi.org/10.3390/w15132436.
[435] Rachel Boyd, Summertime scum: Toxic algae blooms resurface at Jordan Lake, Spectrum News 1, June 28, 2022.
[436] Lauren Goyne, master's thesis: Cyanobacteria Blooms and Water Quality Parameters in Two Mecklenburg County Park and Recreation Ponds in Charlotte, NC, 2021.

newspapers report on the death of dogs following a swim in contaminated waters.[437] Research suggests that aerosolization of toxins may also be a threat where wind or waves create spray from toxin-laden waters, which could place a much larger number of North Carolinians at risk.[438] While HABs can occur by themselves, they can also interact with other forms of water pollution to pose hybrid risks.[439]

While HABs have been documented over the last two decades, there has not been a good data source for tracking trends. Traditionally, county health departments, which are overseen by the NC Department of Health & Human Services (DHHS), receive reports of HAB-induced illness and issue warnings to the public to avoid toxic waters. Meanwhile, on hearing about an algal bloom, the Department of Environmental Quality (DEQ) tries – staff resources permitting – to sample the water and identify the species of algae, to better determine whether it has a potential to release toxins. Both of these governmental responses depend on voluntary citizen reports, and are complicated by the fact that toxic HABs can be fleeting – by the time state scientists are able to reach a body of water to take a sample, the bloom and its toxins may have dissipated.

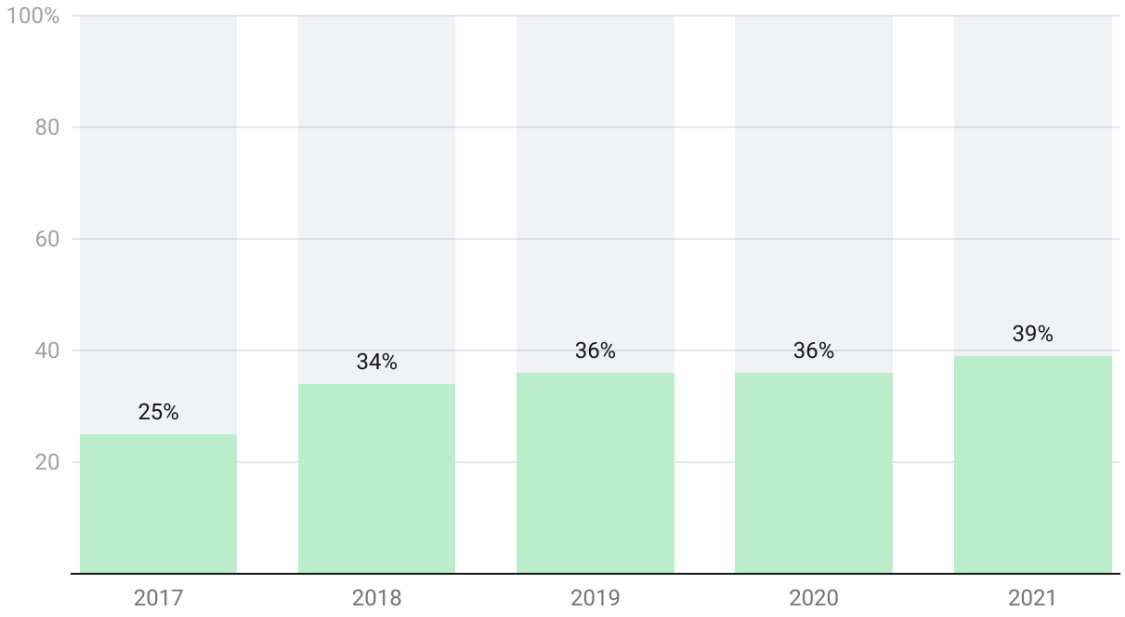
For this update, we rely primarily on satellite analysis. From 2017 through 2021, EPA used satellite photo data from the Ocean and Land Color Instrument (OLCI) to assess the frequency of cyanobacteria detections in US lakes; cyanobacteria, or blue-green algae, are a major (but not the only) source of algal toxins.[440] The OLCI data is broken out at the regional rather than the state level. As shown in figure 17.1, the percentage of weeks each year during which the average lake in the Southeast US had detectable cyanobacteria concentrations showed a steady increase, from 25% to 39% – that is, from three months to nearly five months.[441] Not shown in our chart, but the OCLI data also shows an increase in the *area* covered by cyanobacteria in US lakes. The data is very noisy, but in January 2017, 6,200 acres (49% of surveyed lake acres) was near the top of the range; by December 2021, that was near the bottom of the range.[442]

North Carolina's Fish Kill & Algal Bloom Report Dashboard is relatively new, showing data since 2021.[443] That's not really long enough to get a sense of a trend, but the data does suggest an occurrence of algal

[437] See, for example, Korie Dean, More toxic algae suspected at Jordan Lake. How to keep your pets safe, Raleigh News & Observer, July 8, 2022.
[438] Haley Plaas et al., Secondary Organic Aerosol Formation from Cyanobacterial-Derived Volatile Organic Compounds, ACS Earth and Space Chemistry, 2023, 7:1798, https://doi.org/10.1021/acsearthspacechem.3c00177.
[439] James Metcalf and Geoffrey Codd, Co-Occurrence of Cyanobacteria and Cyanotoxins with Other Environmental Health Hazards: Impacts and Implications, Toxins, 2020, 12:629, https://doi.org/10.3390/toxins12100629.
[440] Satellite data has been found to correlate well with the presence of blooms that lead state authorities to issue warnings. See, Peter Whitman, et al., A validation of satellite derived cyanobacteria detections with state reported events and recreation advisories across U.S. lakes, Harmful Algae, 2022, 115:102191, https://doi.org/10.1016/j.hal.2022.102191.
[441] US EPA, Report on the Environment: Cyanobacteria in Lakes, Exhibit 3: Frequency of cyanobacteria detections in US lakes, 2008-2011 and 2017-2021, Southeast Region. The OLCI imagery has a spatial resolution of 300 meters, so it does not pick up ponds or smaller lakes. US EPA, factsheet: EnviroAtlas: CyAN Extent and Bloom Frequency, April 2017.
[442] US EPA, Report on the Environment: Cyanobacteria in Lakes, Exhibit 2: Area covered by cyanobacteria in US lakes, 2008-2011 and 2017-2021, Southeast Region.
[443] Source: NC DEQ, dashboard: Fish Kill & Algal Bloom Report Dashboard, visited June 6, 2024.

blooms in waterbodies across the state. We hope and expect this data series will continue to improve in the coming years.

Figure 17.1: Percentage of weeks where the average lake in the Southeast had detectable cyanobacteria



US EPA, Report on the Environment: Cyanobacteria in Lakes, Exhibit 3: Frequency of cyanobacteria detections in US lakes, 2008-2011 and 2017-2021, Southeast Region.

Created with Datawrapper

Recent developments: The Clean Water Act directs states to set surface water quality standards to protect the designated uses of rivers, lakes, and estuaries, including recreational uses. To facilitate that, EPA has adopted human health criteria for a variety of pollutants. In 2019, EPA published its recommended human health criteria for two cyanotoxins released by blue-green algae: microcystin and cylindrospermopsin.[444] The agency noted that risk to human health depends on the magnitude, duration, and frequency of HABs, but suggested that at waterbody is not safe for swimming on a day when microcystin exceeds 8 micrograms per liter (ug/L), or cylindrospermopsin exceeds 15 ug/L.[445] The next step is for states to adopt surface water quality standards for recreation based on the human health criteria; those could be expressed either as concentrations of toxins, or number of algal cells per liter. Advocates have urged the NC Environmental Management Commission to do either as a part of its

[444] US EPA, Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin, May 2019, EPA 822-R-19-011.

[445] US EPA, factsheet: Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin, May 2019. One ug/L equals one part per billion (ppb), so the recommended standards are 8 ppb for microcystin and 15 ppb for cylindrospermopsin.

triennial review of surface water quality standards, but the EMC has taken no steps to adopt HAB-related water quality standards.

Indicator 17.2: bacterial concentrations

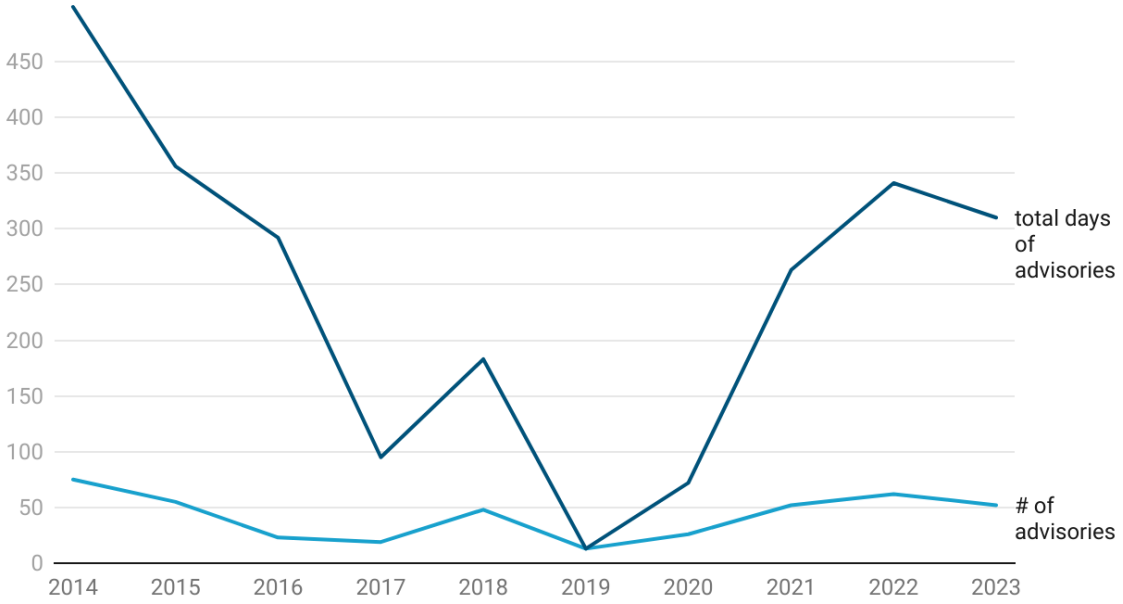
Top line: Pathogenic bacteria in recreational waters cause gastrointestinal illness. As a result of self-inflicted hurdles to sampling, the state lacks actionable data on bacteria levels in recreational waters, but sampling by river advocates suggests serious risks across North Carolina in too many waters that are supposed to be safe for swimming and boating. Some river basins are improving, but slightly more are getting worse, so we mark this indicator as trending in the wrong direction.

About bacterial concentrations: A 2018 study, based on data from 2000-2010, estimated that water pollution causes an estimated 50 million cases of gastrointestinal illness among swimmers and boaters across the nation each year.[446]

In North Carolina, coastal and inland recreational waters are monitored differently, so for this indicator, we use two data sources. Coastal waters are sampled by staff of the Shellfish Sanitation and Recreational Water Quality Program, housed in the DEQ Division of Marine Fisheries. During the swimming season, April through October, samples that exceed the state and federal standard (a running monthly average of 35 enterococci bacteria per 100 mL of water) trigger issuances of swim advisories. An advisory remains in place until the water tests below the standard.

[446] Stephanie DeFlorio-Barker, et al., Estimate of incidence and cost of recreational waterborne illness on United States surface waters, Environmental Health, 2018, 17:3, DOI 10.1186/s12940-017-0347-9.

Figure 17.2A: Number of coastal swim advisories and total days under swim advisories per year



Source: DEQ, Swimming Advisory List/ Advisory Archive • Created with Datawrapper

Over the last decade, the number of advisories – and more strikingly, the number of days that North Carolina's coastal swimming waters were under advisories – plunged and then rose again. The rise since 2017-2019 has been steep and we rate this an unhealthy trend.

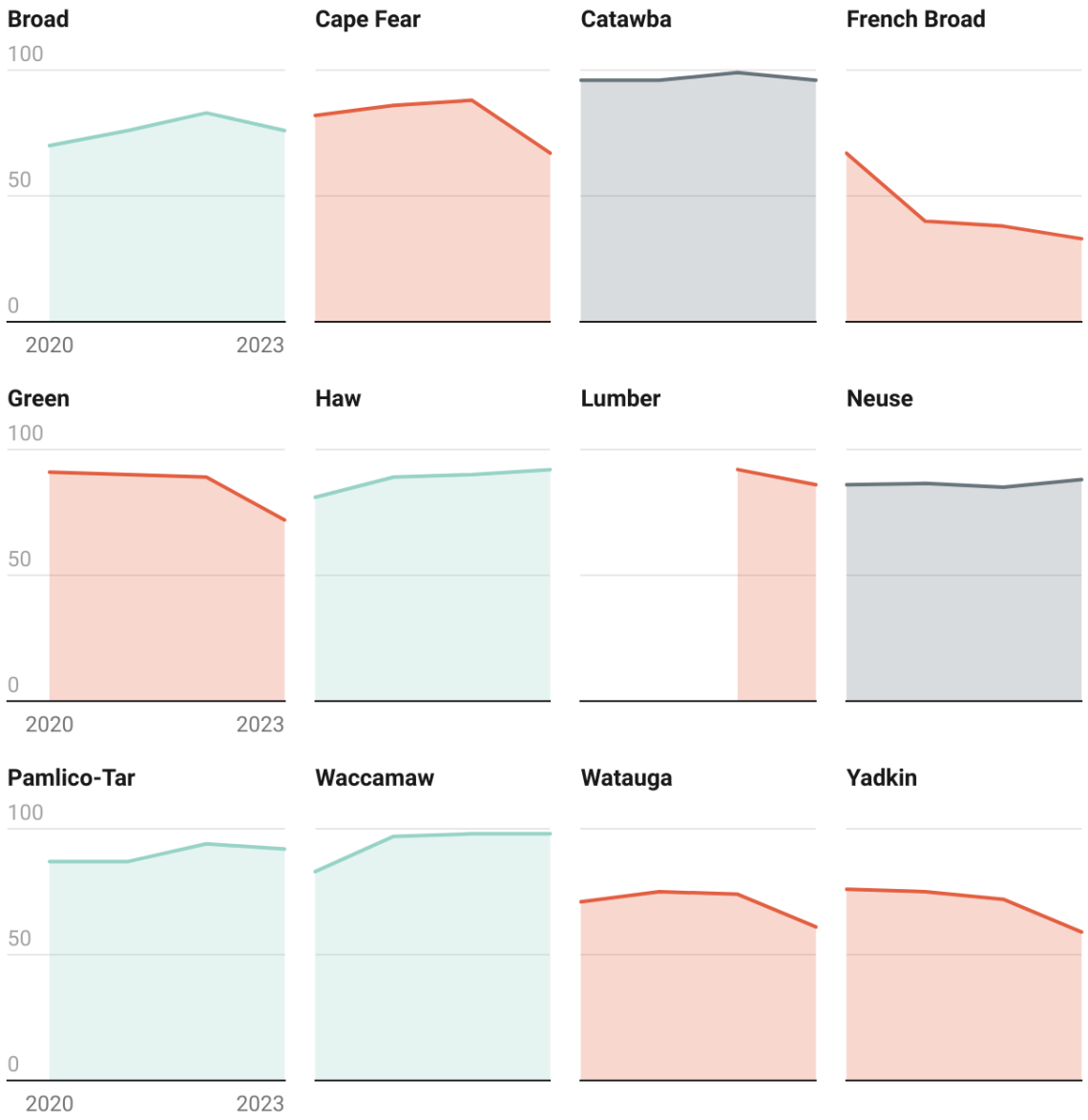
There is no comparable state program to test inland recreational waters. For those, we rely instead on the samples collected by Riverkeepers in each basin. Housed at non-governmental advocacy organizations, the Riverkeepers sample freshwater locations widely used for recreation and share the data as a public service. Each participating Riverkeeper decides the most appropriate standard for their watershed. Most use 235 MPN/100 mL of E. coli as their standard, but the French Broad Riverkeeper uses a more protective 126 MPN/ 100 mL E. coli, and some on the coast also test brackish waters against a 104 MPN/ 100 mL Enterococcus standard.[447] For that reason, it's more useful to examine each watershed's performance over time than to compare pass/fail rates across watersheds.

Riverkeepers started sampling recreational waters in their basins at different times, but advocates in at least a dozen basins have now been sampling for several years. The trends are mixed, with four basins improving, three essentially unchanged or with insufficient data to show a trend, and six declining.[448] As

[447] Waterkeepers Carolina, 2023 Swim Guide Report, 2023.
[448] Waterkeepers Carolina, 2023 Swim Guide Report, 2024; Waterkeepers Carolina, 2022 Swim Guide Report, 2023; Waterkeepers Carolina, Is it Safe to Swim? Protection Recreational Water Quality in North Carolina, 2021.

the total number of samples has doubled, the pass rate has remained fairly constant (80%) over the last two years, but with more basins declining than improving, we count this as a negative trend.

Figure 17.2B: Percentage of safe water samples in each river basin



Dan and White Oak Rivers excluded because of lack of data.

Source: Waterkeepers Carolina, Swim Guide Reports (2020-2023) • Created with Datawrapper

Recent developments: North Carolina currently protects recreational waters with a standard keyed to concentration of fecal coliform bacteria.[449] In 2012, US EPA recommended that states replace this with a standard keyed to concentrations of *Escherichia coli* (*E. coli*), which research indicates is a better measure of the potential for bacteria to make swimmers sick.[450] Most states, including those around North Carolina, have switched to *E. coli* as the freshwater standard. In 2020, the NC Environmental Management Commission (EMC) proposed to adopt *E. coli* as the standard in the mountain counties, as a possible prelude to shifting the whole state. EPA Region 4 blocked that, agreeing that North Carolina should switch to *E. coli*, but saying that the switch couldn't apply to just part of the state. Since moving to *E. coli* statewide would have required re-noticing the rule, the EMC kept fecal coliform as the statewide freshwater indicator in the final 2022 state rule, but promised to study and propose a statewide switch soon.[451] That study was completed in January 2024, and the current triennial review cycle includes a switch from fecal coliform to E. coli for all waters designated for recreation.[452]

A separate question from the species used for the standard is the sampling protocol. Bacteria in a sample begin to die off in a matter of hours. To prevent samples from showing falsely low levels of fecal bacteria, DEQ follows a protocol that disqualifies any bacterial sample not processed within six hours of collection.[453] Unfortunately, many waters in the eastern part of the state are far enough from the state lab in Raleigh that, even when sent by overnight shipment, they arrive too late to count as official samples. In counties saturated with animal waste, bacteria counts in rivers and streams are often off-the-charts – so high that the samples continue to exceed state standards many hours or days later. But because of the sampling protocol, that evidence of extreme contamination cannot be accepted by state regulators as a violation or a basis for action. The Riverkeepers' Swim Guide data follows a scientifically rigorous protocol, but avoids this perverse result, another reason we rely on it.

Goal 18: North Carolinians experience minimal unnecessary exposures to toxics

Trend: Mixed

Other goals in this section focus on air, groundwater, and surface water. This goal considers the exposome as a whole, based on four indicators: the total volume of toxics released to the environment (indicator 18.1); the prevalence of toxics in the consumer products we bring into our homes or apply to our bodies (indicator 18.2); the ubiquity of microplastic pollution, now being identified in virtually every medium and every organ system in the human body (indicator 18.3); and the extent of chronic pesticide

[449] 15A NCAC 02B .0219.
[450] US EPA, Office of Water, Recreational Water Quality Criteria, 820-F-12-058, November 2012.
[451] NC DEQ, Hearing Officer's Report, Triennial Review, 15A NCAC .0100-.0300, March 10, 2022, at 56.
[452] NC DEQ, North Carolina Study of the *E. coli* and Fecal Coliform Pathogenic Indicators for Recreational Waters - Final Report, January 10, 2024; NC DEQ, 2023-2025 Surface Water Standards Triennial Review Regulatory Impact Analysis, October 2024.
[453] NC DEQ, Surface Water Samples: Containers, Preservation and Hold Times Table, August 2021, at 1.

exposures (18.4). The total volume of toxics released to the environment in North Carolina is dropping, thanks to the closure of Duke Energy's coal fired power plants and some other changes in the landscape of in-state manufacturing. Data series are weak for toxics in consumer products, virtually absent for microplastics, and temporarily obsolete for pesticides. Yet, recent studies suggest that toxics in consumer products and microplastics represent serious threats to the health of many North Carolinians. With one indicator trending well and at least two others (consumer products and microplastics) almost certainly trending poorly but lacking strong data, we assign this goal a cautionary yellow rating.

Solutions: North Carolina can help protect residents from toxic exposures by D1, acting to prevent disproportionate burdens; E2, establishing state authority to regulate consumer products; E5, promoting green chemistry; F2, updating the state list of toxic air pollutants; F3 and G4, curbing releases of forever chemicals to air and water; H3, reducing plastic pollution; H4, addressing past contamination; and H5, preventing future contamination.

Indicator 18.1: Volume of toxic chemicals released to the environment.

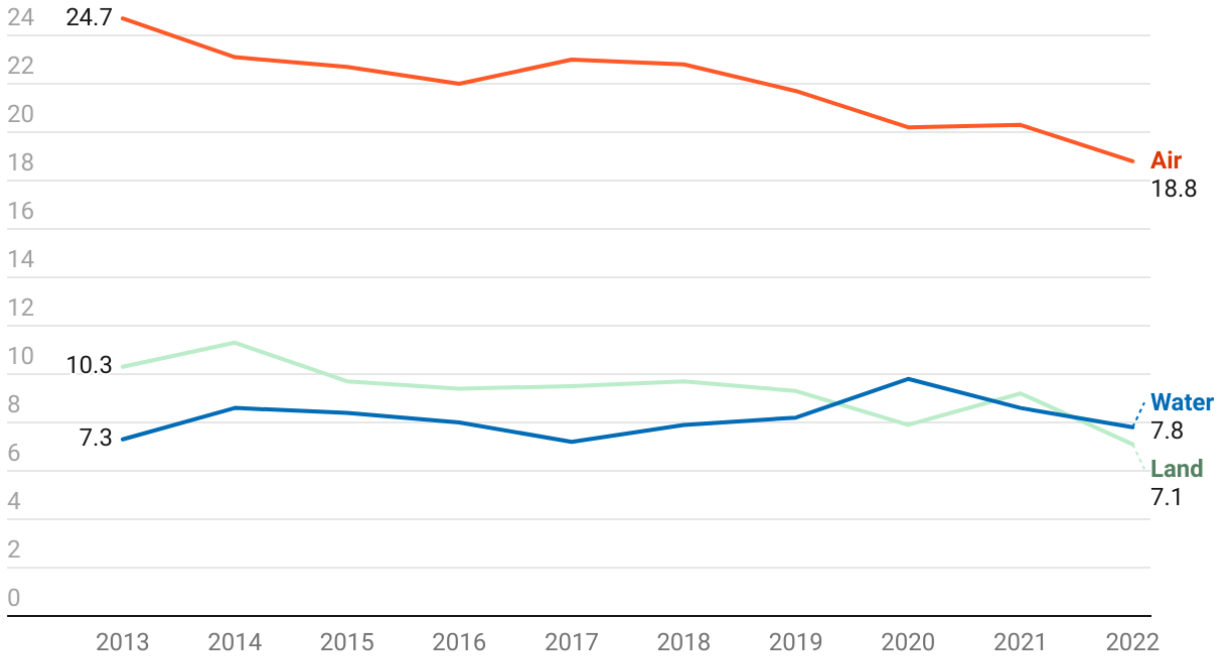
Top line: Across the last decade, as reported to EPA's Toxics Release Inventory (TRI), total on-site releases of toxic chemicals in North Carolina dropped from a high of 43 million pounds in 2014 to 33.7 million pounds in 2022. We count that as a trend in the right direction.

About releases of toxic chemicals: for this indicator, we once again turn to EPA's Toxics Release Inventory. Indicator 12.2 considered hazardous air emissions, which totaled 12 million pounds in 2022. In contrast, this indicator reports total on-site releases of all 850+ chemicals in the TRI, to air, water, and land: 33.7 million pounds in North Carolina in 2022. The downward trend in emissions since 2014 is shown in figure 18.1. In the most recent year of data, 770 facilities in North Carolina reported information about their releases and wastes. The facilities were distributed statewide, with a particularly dense band in the Piedmont, from the Triangle through the Triad and Unifour regions to Charlotte. That aligns roughly with the state's population centers.

Our analysis omits wastes sent elsewhere for disposal, because much (though not all) of that waste is shipped out of state and is less closely tied to the exposures of North Carolina residents. In 2022, that amounted to 22.6 million pounds of waste; over half, 13 million pounds, was from a single source, the Befesa Zinc smelter in Rutherford County.[454]

[454] Source: EPA, TRI Facility Report: Befesa Zinc Metal (2811WHRSHD484HI), visited May 29, 2024.

Figure 18.1: TRI Volume of Toxic Chemicals Released to the Environment, measured in millions of lbs



Source: EPA, 2022 TRI Factsheet: State - North Carolina, October 2023. • Created with Datawrapper

Indicator 18.2: annual exposures of North Carolina consumers to unsafe or untested chemicals in consumer products.

Top line: There is no data series for North Carolinians' level of exposure to or body burdens of toxics inhaled or absorbed from consumer products. However, the sheer number of unstudied chemicals in consumer products and the pervasive markers of exposure shown in recent studies of mothers, infants, and children in North Carolina, lead us to assign this indicator a negative trend.

About toxics in consumer products: When most of us think of toxic exposures, we picture ingestion of pollutants in our air and water. But in fact, substantial exposures to toxic chemicals come from products we buy and use, including personal care products, clothes, and household items. These contain a variety of chemicals, often have prolonged contact with our skin, and often shed or break down into dust that we ingest or breathe. In 2018, the NC Conservation Network published a primer explaining the multiple paths by which we are exposed to toxic chemicals, and the implications for our families' health and for public policy.[455] The challenge is complex; simply moving away from chemicals with known problems is

[455] Jessica Brandt, North Carolina and Toxics: What You Need to Know, April 2018.

not a solution if they are replaced them with 'regrettable substitutes', chemicals that turn out to be just as bad or worse.[456]

Manufacturers use many chemicals for which there is little or no publicly available health data. A 2020 survey estimated that roughly 350,000 compounds have been registered for large scale production and use over the past four decades.[457] A more recent study suggests roughly 20,000 compounds have been studied as potential pollutants; just over 14,000 are on priority lists for health studies or are close relatives of compounds on such lists.[458]

Toxic exposures can occur from chemicals that have been used for a long time but are not safe, from new uses of known compounds, and from new chemicals just being introduced into consumer products for the first time. In 2019, we framed this indicator narrowly, as just the third of those: the number of chemicals entering the stream of commerce with no toxicity testing. Implementation of the 2016 Frank Lautenburg Chemical Safety Act (discussed below) should have helped with that, but there's very little systematic data available on risks from or exposures to existing *or* new toxic chemicals.

North Carolina also lacks a data series on the levels of toxic chemicals state residents are carrying in our bodies. Data from the NHANES project of the national Centers for Disease Control (CDC) suggests that many Americans have ongoing exposures to metal pollution, compounds associated with personal care products, phthalates, polyaromatic hydrocarbons, and volatile organic compounds.[459] Individual studies of blood and urine samples show that North Carolinians have substantial exposure to toxics in consumer products. Recent studies have found that mothers using nail polish and toddlers eating from microwaved plastic dishes showed markers of phthalate exposure in their urine;[460] 95% of infants and toddlers in the UNC Baby Connectome Project had phthalate metabolites in their urine;[461] over 90% of urine samples from 303 pregnant North Carolinians over the course of their pregnancies showed phthalate metabolites.[462] Others: children in central North Carolina using hand wipes or lotions had

[456] Alexandra Maertens et al., Avoiding Regrettable Substitutions: Green Toxicology for Sustainable Chemistry, ACS Sustain Chem Eng, June 2021, 9(23): 7749, doi:10.1021/acssuschemeng.0c09435.
[457] Zhanyun Wang et al., Toward a Global Understanding of Chemical Pollution: A First Comprehensive Analysis of National and Regional Chemical Inventories, Environmental Science & Technology, 2020, 54, 2575, https://dx.doi.org/10.1021/acs.est.9b06379?ref=pdf. The authors estimate that 50,000 of these are claimed as confidential and are therefore publicly impossible to identify.
[458] Derek Muir et al., How Many Chemicals in Commerce Have Been Analyzed in Environmental Media? A 50 year Bibliometric Analysis, Environmental Science & Technology, June 2023, 57 (25): 9119, https://pubs.acs.org/doi/10.1021/acs.est.2c09353?ref=PDF.
[459] Zachary Stanfield et al., Characterizing Chemical Exposure Trends from NHANES Urinary Biomonitoring Data, EHP, January 2024, 132 (1), https://doi.org/10.1289/EHP12188.
[460] Allison Killius, master's project: Phthalate exposure and consumer product use among children in a North Carolina cohort, April 2017.
[461] Giehae Choi et al., Abstract: Phthalates and pyrethroids in infants and toddlers: concentrations, stability of repeat measures, and predictors of exposure, ISEE 2021: 33rd Annual Conference of the International Society of Environmental Epidemiology, August 2021, https://doi.org/10.1289/isee.2021.P-298.
[462] Emma Rosen, dissertation: Phthalates and Replacements: Longitudinal Assessment of Levels, Sources, and Associations with Placental Measures, August 2023, at 56.

higher levels of paraben biomarkers in their urine;[463] children in central North Carolina also tested positive for markers of exposure to brominated flame retardants from household furniture.[464] A study of newborns in North Carolina suggests exposure to indoor mixtures of PFAS, phthalates, and semivolatile organic compounds changes the infants' gut microbiota, a driver of long term health.[465]

The ubiquity of exposures suggested by these snapshot studies, the lack of reliable data series, and the share of compounds that remain unscreened for toxicity leads us to assign this indicator a negative trend.

Recent developments: Leading scientists have been sharply critical of the framework of risk management and toxics regulation in the United States.[466] The regulatory framework for controlling toxics in consumer products is a patchwork of federal and state authorities, with agencies struggling to muster the resources to implement their statutes. At the federal level, the Food and Drug Administration (FDA) has limited authority and limited resources, making cosmetics a particularly poorly managed source of risk.[467]

EPA has greater authority, but also a massively larger universe of compounds to evaluate. The key federal law, the Toxics Substances Control Act (TSCA), was upgraded in 2016 by passage of the Frank Lautenburg Chemical Safety for the 21st Century Act.[468] Under TSCA, EPA both reviews new chemicals (and new uses of known chemicals) and has some authority to screen chemicals in ongoing use to identify risks that were previously overlooked or ignored. EPA estimates that it receives 500 notices per year of new chemicals, new uses of known chemicals, and new uses of microbes.[469] Since 2016, EPA has been required to make a risk determination on each of these. As of June 2024, the agency had completed 2,108 cases, with another 430 in process. The statue also directs EPA to review industry requests for exemptions to produce new chemicals at low volumes. Since 2016, EPA has processed 2,323 of these requests, granting more than 75% of them; another 136 are in process.

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[463] Jessica Levasseur et al., Young children's exposure to phenols in the home: Associations between house dust, hand wipes, silicone wristbands, and urinary biomarkers, Environment International, 2021, 147: 106317, https://doi.org/10.1016/j.envint.2020.106317.

[464] Kate Hoffman et al., Children's exposure to brominated flame retardants in the home: The TESIE study, Environmental Pollution, July 2024, 352: 124110, https://doi.org/10.1016/j.envpol.2024.124110.

[465] Courtney Gardner et al., Exposures to Semivolatile Organic Compounds in Indoor Environments and Associations with the Gut Microbiomes of Children, Environmental Science and Technology Letters, January 2021, 8 (1): 73, http://dx.doi.org/10.1021/acs.estlett.0c00776.

[466] See, for example, Maricel Maffini and Laura Vandenberg, Science evolves but outdated testing and static risk management in the US delay protection to human health, Front. Toxicology, August 2024, 6, https://doi.org/10.3389/ftox.2024.1444024.

[467] Scott Faber, blog post: The Toxic Twelve Chemicals and Contaminants in Cosmetics, Environment Working Group, May 5, 2020.

[468] Toxics Substances Control Act, 15 U.S.C. §2601 et seq. (1976); Frank Lautenburg Chemical Safety Act of the 21st Century, P.L.114-182 (2016). Review of new chemicals and new uses is addressed by TSCA §5; review and management of existing chemicals is addressed by TSCA §4.

[469] US EPA, webpage: Statistics for the New Chemicals Review Program under TSCA, visited June 3, 2024.

EPA's review of existing chemicals with existing uses is much more limited. In 2019, EPA designated 20 chemicals as high priority for risk evaluation, and in 2020 the agency designated another 20 chemicals as low priority. As of June 2024, the agency had published draft risk assessments for five compounds, final risk evaluations for eight compounds, and final risk management rules for two compounds.[470]

Given limited federal reach and resources, some states have stepped forward to help narrow the gap. Both California and Washington state have strong and respected programs. California regulators estimate that roughly 2,500 'high volume chemicals' are produced at volumes greater than 1 million pounds per year, and that only about 45% of them have been adequately screened for impacts to people or the environment. [471] The regulators estimate that about 2,000 new chemicals enter the stream of commerce each year in the US, or an average of 7 new chemicals a day.[472] The state program does not attempt to review or regulate them all; rather, state regulators pick specific combinations of pollutants and paths of exposure to focus on for a three-year cycle. Recent areas of focus have included hair straightening products in salons (2021-2024), chemicals in nail products (2019-2023), and 1,4-dioxane in personal care and cleaning products.[473]

California also has a much older program, Prop 65, that relies on disclosure of carcinogenic ingredients rather than outright bans.[474] Originally adopted through a statewide referendum in 1986, the program directs state government to maintain a list of chemicals known to cause cancer or reproductive harm, and requires all companies manufacturing or selling products containing these chemicals to attach a warning to their product. Commenters have noted that, beyond unleashing a torrent of enforcement lawsuits against companies that fail to comply, the state statute has worked to protect the public in less obvious ways, driving transparency in supply chains and focusing the attention of other state and federal regulatory programs.[475] Researchers have crosswalked Prop 65 lists with information on volatile organic compounds (VOCs) in consumer products to get a sense of which products account for consumers' greatest exposures to toxic VOCs.[476]

The State of Washington also has one of the nation's strongest programs to block toxics in consumer products, Safer Products for Washington.[477] The state reviews and regulates compounds in five year

[470] US EPA, webpage: Ongoing and Completed Chemical Risk Evaluations under TSCA, visited June 4, 2024.
[471] California Dept. of Toxic Substances Control, webpage: Emerging Chemicals of Concern, visited June 3, 2024.
[472] *Ibid*.
[473] CA Department of Toxic Substances Control, webpage: Safer Consumer Products Research Studies, visited June 4, 2024; see also CA DTSC, Stakeholder Discussion Draft: Three Year Priority Product Work Plan (2024-2026), 2024; CA DTSC, Three Year Priority Product Work Plan (2021-2023), 2021.
[474] Proposition 65, Safe Drinking Water and Toxics Enforcement Act of 1986, California Health and Safety Code §§ 25249.5 through 25249.14.
[475] Claudia Polsky and Megan Schwarzman, The Hidden Success of a Conspicuous Law: Proposition 65 and the Reduction of Toxic Chemical Exposures, Ecology Law Quarterly, March 2020, 47 (3), https://doi.org/10.15779/Z38959C833.
[476] Kristen Knox et al., Identifying Toxic Consumer Products: A Novel Data Set Reveals Air Emissions of Potent Carcinogens, Reproductive Toxicants, and Developmental Toxicants, Environmental Science & Technology, May 2023, 57 (19), 7475, https://doi.org/10.1021/acs.est.2c07247. Categories with particularly heavy exposures include aerosol and non-aerosol household cleaners, auto care products, and caulks and sealers, among others.
[477] Toxic Pollution Law, RCW chapter 70A.350.

cycles, following four steps: prioritizing chemicals for acting; identifying consumer products that contain those chemicals; deciding whether to require notice, prohibit use of a compound, or take no action; and then adopting enforceable requirements through rulemaking. In 2023, the program adopted rules for PFAS in textile stain treatments, phthalates in flooring and personal care products, flame retardants, and phenolic compounds in laundry detergent, food and drink cans, and thermal paper. The program expects to have rules for products containing PFAS in place by the end of 2025, and to consider 6PPD, a severe aquatic toxic that is shed from vehicle tires.[478]

Indicator 18.3: North Carolinians' body burden of microplastics

Top line: There is no data series that tracks North Carolinians' exposures to or body burdens of microplastics, but the ubiquity of microplastics in our water and air, rising levels of plastics production and use, and a flood of emerging research on the harms of microplastic contamination, lead us to assign a negative trend to this indicator.

About microplastics: Among the many environmental issues discussed in this State of the Environment report, microplastics is one we expect to see explode in public awareness and policy action over the next five years. Pre-pandemic, researchers and news outlets were focused on the fate of plastic trash, large and small, in the oceans. Indeed, the term 'microplastics' seems to have burst into use between 2010 and 2015, mostly in the context of discussions of plastic in the marine environment.[479] Since then, researchers have documented microplastics in virtually every part of the global environment, multiple species of wildlife, and tissue from virtually every human organ system where researchers look – and research has begun to pile up showing harms to environmental and human health.[480]

Some microplastics – such as glitter, microbeads in personal care products, or industrial 'nurdles' – are built to be small. Those intentionally manufactured microplastics are designated as primary microplastics. However, most microplastics are secondary, forming from the weathering or breakdown of larger plastic items or fabrics.[481] Microplastics are generally defined as plastic particles up to 5 millimeters (mm). Scientists and agencies have used differing thresholds for nanoplastics; EPA describes

[478] Washington Department of Ecology, webpage: Safer Products for Washington, visited June 5, 2024.
[479] Google Ngram search, 'microplastics', conducted June 13, 2024. The adjective 'microplastic' surged between 1975 and 1990, virtual always in the context of highly technical discussions of stress on ceramics and metals in industrial contexts. For a review of the recent history of discoveries of microplastics in the human body, *see*, Huixia Niu et al., Are microplastics toxic? A review from eco-toxicity to effects on the gut microbiota, Metabolites, Juen 2023, 13:739, https://doi.org/10.3390/metabo13060739.
[480] Simon Ducroquet and Shannon Osaka, The Plastics We Breathe, Washington Post, June 10, 2024; Damian Carrington, Microplastics found in every human semen sample tested in study, The Guardian, June 10, 2024; Microplastics found in every human placenta tested, Science News, February 20, 2024.
[481] Robert Hale et al., A Global Perspective on Microplastics, Journal of Geophysical Research: Oceans, January 2020, 125(1), https://doi.org/10.1029/2018JC014719.

nanoplastics as smaller than 1 nanometers (nm), about half the width of a strand of DNA, while the State of California defines them as smaller than 100 nm.[482]

Microplastics are ubiquitous, having been found in the air, rivers, the depths of the ocean, every inhabited continent, and at the North and South Poles.[483] They are found in tap water, bottled water, and throughout the food supply.[484] In North Carolina, a 2023 study in the Neuse River found microplastics throughout the basin, but with particularly high concentrations in urban areas, and an estimated load from the watershed of 230 billion particles per year.[485] A recent study of microplastics in streams in western NC (pre-Helene) found concentrations in the upper 25% of those reportedly globally, with 90% consisting of plastic fibers.[486]

Not only are microplastics everywhere, but as researchers invent ways to see and count smaller particles, they are finding vastly more. One 2024 study found that a liter of bottled water included roughly 240,000 plastic particles; about 90% of these were nanoparticles.[487] Because the techniques pioneered in the study allowed researchers to see smaller particles, the number of total particles they found jumped by a factor of 10 to 100 over previous estimates.[488] For example, a 2019 study estimated that Americans consumed or inhaled 74,000 to 121,000 particles of plastic annually, but that's only a fraction of the 2024 count for a single 12 ounce plastic water bottle.[489] People can absorb microplastics through inhalation, ingestion in food or water, and even through the skin.[490]

Animal studies suggest that microplastics will affect organ systems in three ways: by chemical reaction (especially oxidative stress causing DNA damage); by physical obstruction; and by serving as a carrier for other toxic chemicals to ride into various parts of the body. One recent study found that over 150 plastic additives are known carcinogens, and roughly 90% of plastic additives lack any data on

[482] US EPA, webpage: Water research: Microplastics Research, May 1, 2024; California State Water Resources Control Board, Definition of 'Microplastics in Drinking Water', adopted June 16, 2020, footnote 3.
[483] Clara Leistenschneider et al., Unveiling high concentrations of small microplastics (11-500 µm) in surface water samples from the southern Weddell Sea off Antarctica, Science of the Total Environment, June 2024, 927: 172124, https://doi.org/10.1016/j.scitotenv.2024.172124.
[484] Madeleine Milne et al., Exposure of U.S. adults to microplastics from commonly-consumed proteins, Environmental Pollution, 2024, 343: 123233, https://doi.org/10.1016/j.envpol.2023.123233.
[485] J. Jack Kurki-Fox, Microplastic distribution and characteristics across a large river basin: Insights from the Neuse River in North Carolina, Science of the Total Environment, March 2023, 878: 162940, http://dx.doi.org/10.1016/j.scitotenv.2023.162940.
[486] Jerry Miller et al., Temporal and spatial variations in microplastic concentrations in small headwater basins in the southern Blue Ridge Mountains, North Carolina, USA, Environments, 2024, 11 (11): 240, https://doi.org/10.3390/environments11110240; Will Atwater, NC Health News, Nowhere to hide: Microplastics are polluting western North Carolina watersheds, December 11, 2024.
[487] Naixin Qian et al., Rapid single-particle chemical imaging of nanoplastics by SRS microscopy, PNAS, January 2024, 121(3), https://doi.org/10.1073/pnas.230058212.
[488] NIH, blog post: Plastic particles in bottled water, NIH Research Matters, January 23, 2024.
[489] Kieran Cox et al., Human consumption of microplastics, Environ. Sci. Technol., June 2019, 53 (12): 7068, https://doi.org/10.1021/acs.est.9b01517.
[490] Gregory Zarus et al., A Review of data for quantifying human exposures to micro and nanoplastics and potential health risks, Science of the Total Environment, February 2021, 756: 144010, doi:10.1016/j.scitotenv.2020.144010.

carcinogenicity.[491] Once in a mammal's body, microplastics trigger metabolic disorders, inflammation and immune responses, reproductive and developmental toxicity, and neurotoxicity.[492] Nanoplastics may also amplify the harms of other toxic exposures.[493] Although very few studies of microplastics so far use data collected from human beings, one recent study found that heart patients with higher levels of microplastics have a higher risk of later heart attack, stroke, and death.[494] As with other toxics, microplastics may pose distinct and serious threats to the health of developing infants and children.[495]

Broad scientific interest in microplastics initially grew out of research into trash accumulating in the middle of the Pacific and Atlantic oceans, and data on microplastic occurrence remains most robust for the marine environment. NOAA's Marine Microplastic Concentration dashboard gathers reported levels from multiple peer-reviewed surveys.[496] The North Carolina observations – nurdle abundance on beaches, microfiber concentrations in the offshore water column – document moderate levels of contamination. A 2020 study of two locations on the Outer Banks and two on barrier islands in Virginia found no pellets; 95% of the plastic took the form of microfibers.[497] In 2022, acting on state legislation enacted in 2018, California became the first jurisdiction in the world to require monitoring of concentrations of microplastic particles (above 1 nm in all three dimensions) in drinking water.[498] Yet, California's state agency has moved slowly to implement the requirement, and there still appears to be no public data available on microplastic concentrations in either surface or drinking water.

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[491] Sophia Vincoff et al., The known and the unknown: Investigating the carcinogenic potential of plastic additives, Environ. Sci. Technol., June 2024, 58 (24): 10445, https://doi.org/10.1021/acs.est.3c06840.

[492] Myrium Borgatta and Florian Breider, Inhalation of Microplastics – a Toxicological Complexity, Toxics, May 2024, 12 (5): 358, https://doi.org/10.3390/toxics12050358; Yangyang Peng and Qi He, Reproductive toxicity and related mechanisms of micro(nano)plastics in terrestrial mammals: Review of current evidence, Ecotoxicology and Environmental Safety, July 2024, 279: 116505, https://doi.org/10.1016/j.ecoenv.2024.116505; Scott Coffin et al., Development and application of a health-base framework for informing regulatory action in relation to exposure of microplastic particles in California drinking water, Microplastics and Nanoplastics, May 2022, 2 (1): 12, https://doi.org/10.1186/s43591-022-00030-6 .

[493] Charles Schmidt, Synergy under the Sun? Nanoplastics enhance estrogenicity of common UV-blocker, EHP, June 2024, 132 (6): 64001, https://doi.org/10.1289/EHP14939; Marina Bastante-Rabadan and Karina Boltes, Mixtures of micro and nanoplastics and contaminants of emerging concern in the environment: what we know about their toxicological effects, Toxics, August 2024, 12 (8): 589, https://doi.org/10.3390%2Ftoxics12080589.

[494] Raffaele Marfella et al., Microplastics and Nanoplastics in Atheromas and Cardiovascular Events, New England Journal of Medicine, March 2024, 390 (10): 900, DOI: 10.1056/NEJMoa2309822.

[495] Kam Sripada et al., A Children's Health Perspective on Nano- and Microplastics, Environmental Health Perspectives, January 2022, 130 (1): 015001-1, https://doi.org/10.1289/EHP9086.

[496] NOAA, National Centers for Environmental Information, map: Marine Microplastic Concentration, visited June 13, 2024.

[497] Gabrielle Dodson et al., Microplastic fragment and fiber contamination of beach sediments from selected sites in Virginia and North Carolina, USA, Marine Pollution Bulletin, February 2020, 151: 110869, https://doi.org/10.1016/j.marpolbul.2019.110869.

[498] SB1422, California Safe Drinking Water Act, 2018, codified at CA Health & Safety Code §116376; California State Water Resources Control Board, Policy Handbook Establishing a Standard Method of Testing and Reporting of Microplastics in Drinking Water, August 9, 2022. See also, Nick Cahill, article: Testing at the Source: California readies a groundbreaking hunt to check for microplastics in drinking water, Water Environment Foundation, March 17, 2023.

North Carolina has no systematic monitoring or data source for microplastic contamination in our rivers, tap water, food sources, or bodies. Yet, microplastics are all around and in us, and our understanding of the threat they present to human health is growing rapidly. Moreover, there is no reason to think North Carolinians' exposure or risk is declining; in fact, absolute and per capita plastic use continues to rise. Given that combination of factors, we assign this indicator a negative trend.

Indicator 18.4: Chronic pesticide exposure

Top line: We have found no long-term data series on chronic pesticide exposure in North Carolina. We would use the U.S Geological Survey's data series on pesticide use as a proxy, but it ends in 2019. The next update, covering 2018-2022, may be released later this year. In the meantime, we do not assign a trend to this indicator.

About pesticide exposures: In North Carolina, acute pesticide illness and injury data is collected from several sources, including physicians (as required through state mandatory reporting rules), the Carolinas Poison Center, and the NC Department of Agriculture and Consumer Services, as a part of the Pesticides and Health program within DHHS' Division of Public Health. NC DHHS reports on the frequency of acute pesticide poisoning on a five-year cycle. That data shows an encouraging decline in acute poisonings from 2007 to 2022, as illustrated in figure 18.4 below.[499] But the total number of people who experience acute poisoning is small, much lower than the number of North Carolinians exposed chronically to sub-acute doses with the potential for long term health effects – so we've chosen chronic exposure as the more relevant indicator.

Table 18.4: Acute pesticide illness and injury

	2007-2012	2012-2016	2017-2022
Occupational	233	228	129
Non-occupational	2,219	1,914	1,212

Source: NC DHHS pesticide incident surveillance data • Created with Datawrapper

One way to track likely chronic exposures is to track pesticide use. The best available data on pesticide use – an imperfect proxy for exposure – is collected by the U.S. Geological Survey (USGS), but the available data series ends in 2019. The USGS explains: "Final annual pesticide-use estimates, for approximately 400 compounds from 2018-2022, will be published in 2025. After that, preliminary

[499] NC DHHS, NC Pesticide Incident Surveillance Program, Surveillance Findings 2007-2012, July 2015; NC DHHS, NC Pesticide Illness and Injury Surveillance Program, Surveillance Findings 2012-2016, July 2018; NC DHHS, factsheet: Acute Pesticide-Related Illness and Injury in North Carolina, 2017-2021, October 2022.

estimates will be published annually and later updated with final estimates once the USDA Census of Agriculture is released (every five years)."[500] Because there is currently no publicly available data, we do not assign this indicator a trend.

Chronic exposure to agricultural pesticides is highest for farmworkers and their families, who are among the most marginalized and least protected residents in the state. In fact, agricultural labor practices differ from other industries, with children 16 and older allowed to do 'hazardous jobs', and children at younger ages allowed to do 'non-hazardous' jobs.[501] Directly handling pesticides is considered a hazardous job, but even child and adult workers in non-hazardous positions can have substantial exposure to pesticides through post-application contact with plants and soils.[502] Another complication is that many farmworkers cannot read the pesticide application labels written in English, a problem that research suggests would be only somewhat mitigated by an EPA proposal to add QR codes linking to Spanish-language information.[503] Children of farmworkers in North Carolina also show outsized chronic exposure to pesticides.[504]

The scientific literature linking chronic pesticide exposure to certain cancers (prostate, non-Hodgkin's lymphoma, leukemia, and breast cancer) is robust.[505] Pesticide exposures are similarly linked to disturbances of the body's metabolic functioning, and reproductive, immune, and nervous systems.[506] Pesticide residues on fruits and vegetables are perennial fodder for news reports; the levels are much lower than those to which farmworkers and their families are exposed on a regular basis.

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[500] USGS, National Water-Quality Assessment (NAWQA) Project, website: Pesticide National Synthesis Project: Estimated Annual Agricultural Pesticide Use, updated February 27, 2024.

[501] Thomas Arcury et al., Latinx Child Farmworkers in North Carolina: Study Design and Participant Baseline Characteristics: Am J Ind Med, February 2019, 62 (2). doi:10.1002/ajim.22938. See also, US Department of Labor, webpage: Fair Labor Standards Act Advisor: Prohibited occupations for Agricultural Employees, visited April 7, 2025.

[502] Christos Damalas and Spyridon Koutroubas, Farmer's Exposure to Pesticides: Toxicity Types and Ways of Prevention, Toxics, January 2016, 4 (1): 1, https://doi.org/10.3390/toxics4010001.

[503] Cesar Asuaje et al., Self-Reported Pesticide Application, Access to Pesticide Labels, and QR Code Use Among Agricultural H-2A Workers, North Carolina, 2024, American Journal of Industrial Medicine, February 2025, https://doi.org/10.1002/ajim.23712.

[504] Thomas Arcury et al., Pesticide exposure among Lantinx child farmworkers in North Carolina, American Journal of Industrial Medicine, May 2021, 64 (7): 602, https://doi.org/10.1002/ajim.23258.

[505] Thays Millena Alves Pedroso et al., Cancer and occupational exposure to pesticides: a bibliometric study of the past 10 years, Environmental Science and Pollution Research, October 2021, 29 (12): 17464, https://doi.org/10.1007/s11356-021-17031-2.

[506] Hugo Lamat et al., Metabolic syndrome and pesticides: A systematic review and meta-analysis, Environmental Pollution, April 2022, 305, https://doi.org/10.1016/j.envpol.2022.119288 (metabolism); Melissa Furlong et al., Preconception and first trimester exposure to pesticides and associations with stillbirth, American Journal of Epidemiology, January 2025, 194 (1): 44, https://doi.org/10.1093/aje/kwae198 (reproduction); Dazhe Chen et al., Pesticide use and inflammatory bowel disease in licensed pesticide applicators and spouses in the Agricultural Health Study, Environmental Research, May 2024, 249, https://doi.org/10.1016/j.envres.2024.118464 (inflammatory bowel disease); Angeline Andrew et al., Pesticides applied to crops and amyotrophic lateral sclerosis risk in the U.S., NeuroToxicology, December 2021, 87: 128, https://doi.org/10.1016/j.neuro.2021.09.004 (nervous system); Ray Dorsey and Bastiaan Bloem, Parkinson's Disease Is Predominantly an Environmental Disease, Journal of Parkinson's Disease, April 2024, 14 (3): 451, https://doi.org/10.3233/jpd-230357 (nervous system).

Goal 19: Releases of persistent toxics are curbed

Trend: Mixed

Some pollutants are of particular concern because they persist in the environment without breaking down, or because they bioaccumulate, or both. Most permit limits are based on the notion that pollutants will be broken down over time and neutralized, so watersheds or airsheds can absorb some ongoing levels of releases without risking ecological harm or human disease past an acceptable ceiling. Chemicals that are persistent violate that assumption – they break down very slowly – so if emitters are allowed to release them even at low concentrations, ambient concentrations will build to unsafe levels. Chemicals that bioaccumulate are worse, in that the concentrations build even faster in exposed people and wildlife than in the local environment generally.

We track North Carolina's progress towards this goal – curbing the release to the environment of persistent toxics – with three indicators. First, beyond stopping massive releases from one factory on the Cape Fear River, North Carolina has made very little progress in curbing releases of per- and polyfluoroalkyl substances (PFAS), as shown by the variety of PFAS found in drinking water samples collected in 2022 and 2023 (indicator 19.1). We don't even have good data yet to estimate the number of sites across the state that are contaminated with PFAS (indicator 19.2). Finally, on the bright side, releases of other known persistent toxics have dropped over the last decade, so we view this goal as showing mixed progress.

Solutions: North Carolina can limit releases of persistent toxics by, E3, banning PFAS-containing fire-fighting foams and destroying existing stocks safely; E5, promoting green chemistry; F3, curbing air emissions of PFAS; G3, updating state water quality standards; G4, curbing the discharge of PFAS to water; G8, improving sludge management; H4, addressing past contamination from old dumps; and H5, preventing future contamination from 'closed' landfills.

Indicator 19.1: PFAS in drinking water.

Top line: when Chemours was publicly revealed in June 2017 to be dumping massive quantities of persistent, toxic chemicals into the Cape Fear River, state regulators moved quickly to cut off the ongoing discharges, and more recently, to cut off the flow of contaminated groundwater into the river from the site. Eight years after the discovery, we know vastly more about PFAS sources and pathways of exposure, but the state has made virtually no progress halting PFAS discharges from a slew of other sources. We count this as inadequate progress.

About PFAS in drinking water: Per- and polyfluoroalkyl substances (PFAS) are a class of several thousands of synthetic chemicals. In use since the 1940s, these chemicals share the common trait of having a hard-to-break carbon-fluorine bond, making them incredibly persistent. PFAS are used to

impart stain, grease, and water resistance to consumer products such as food packaging, carpet, upholstery, outdoor apparel, and to make nonstick pans. They are also used in some firefighting foams, industrial processes (including microchip manufacturing), and specialty products like ski wax.

In June 2017, the Wilmington StarNews broke the story that, for decades, the chemical giant DuPont, followed by its spin-off Chemours, had discharged massive volumes and concentrations of PFAS into the Cape Fear River from the company's Fayetteville Works plant, upstream from the drinking water intakes of utilities in the Lower Cape Fear region.[507] Within a month, NC DEQ directed Chemours to end its discharge to the river; by 2019, the company agreed to a consent order with the state agency and environmental plaintiffs, with an addendum in 2020.[508] Among other provisions, the consent order required the company to provide water to residents with contaminated wells, and to build a wall to keep contaminated groundwater from the plant site from leaching into the river. The wall became fully operational in June 2023.[509]

Meanwhile, the NC General Assembly appropriated substantial funding for PFAS research through the UNC Policy Collaboratory, and invested in sampling by DEQ and local water utilities. In late 2021, EPA announced that its 5th cycle of the Unregulated Contaminant Monitoring Rule (UCMR5).[510] The data collection period for this cycle runs 2023-2025, during which public water systems across the nation must sample raw and treated drinking water and test for 29 PFAS and lithium.[511] Separate from UCMR5, in 2022, state regulators in North Carolina collected three months of samples from 50 large utilities, testing for 57 different PFAS analytes; and again in 2023, took one-time samples from 534 small utilities across the state, testing for the same analytes.[512] For this indicator – levels of PFAS in drinking water sources – we track the occurrence of UCMR5 PFAS in the state and federal drinking water samples, as summarized in the tables below.[513] Because EPA finalized federal drinking water standards for six PFAS in April 2024, we present that data separately.

[507] Vaughn Hagerty, Toxin taints CFPUA drinking water, Wilmington Star News, June 7, 2017.
[508] See, NC DEQ, webpage: Chemours Consent Order, visited February 17, 2025.
[509] Staff report, Chemours completes barrier wall well after deadlines, Coastal Review, June 23, 2023.
[510] US EPA, webpage: Fifth Unregulated Contaminant Monitoring Rule, updated May 16, 2024.
[511] Lithium occurs at relatively low concentrations in surface and groundwater in North Carolina; it is a more serious concern in the Southwestern and Western US. Naushita Sharma et al., Lithium occurrence in drinking water sources of the United States, Chemosphere, October 2022, 305: 135458, https://doi.org/10.1016/j.chemosphere.2022.135458
[512] NC DEQ, webpage: DEQ PFAS Sampling of Public Water Systems, visited July 26, 2024.
[513] US EPA, webpage: UCMR5 Data Finder, updated November 14, 2024.

Table 19.1A: Unregulated PFAS in UCMR5 and in state sampling

	UCMR5	State Sampling	
PFAS compound	Number of public water systems (PWS) with reportable levels (n = 201 systems)	Number of PWS with detectable levels (n = 584 systems)	Common uses
PFPeA	63	360	Breakdown products of stain- and grease-proof coatings; also used to make photographic film.
PFHxA	57	347	"
PFBA	45	321	"
PFHpA	28	266	"
6:2 FTS	8	12	PFOS replacement; also used in fire foams, chromium plating.
PFPeS	1	120	Used in fire foams.

Source: UCMR5 Data Finder, State sampling from special data request to DWR, DEQ • Created with Datawrapper

Based on the UCMR5 and other data, DEQ estimates that as many as 17% of water systems across the state (320 systems, serving 3.4 million residents) have levels of one or more of these PFAS above the new drinking water standards.[514] PFAS in our rivers and in drinking water can come from any of several sources: direct discharges from industry; discharges from municipal wastewater plants (including indirect dischargers from industries that drain their wastes into the local sewer system); leachate from landfills, often dumped into municipal wastewater systems; leaching from rural fields where wastewater utilities land apply their sewage sludge; and leaching from legacy contamination in soil and groundwater. PFAS discharges to the Cape Fear from Chemours have dropped significantly since 2017, but not from other sources, so we mark this indicator as showing inadequate progress.

[514] Rebecca Sadosky, presentation: Federal PFAS Rule & North Carolina Public Water Systems, presentation to the NC Environmental Management Commission, May 9, 2024, slide 20.

Table 19.1B: Regulated PFAS in UCMR5 and in state sampling

PFAS compound	UCMR5 Number of public water systems (PWS) with levels > drinking water standards (n= 110 systems)	NC State Sampling Number of PWS with levels > drinking water standards (n = 584 systems)
PFOS	21	136
PFOA	13	143
HFPO-DA	1	4
PFHxS	0	27
PFNA	0	3
Hazard Index	1	2

The 'hazard index' considers the sum of the concentrations of PFNA, PFHxS, GenX, and PFBS in relation to their health values. In effect, systems counted here would not violate the MCLs for PFNA, PFHxS, or GenX individually, but would violate the hazard index because of their cumulative concentrations of those and PFBS.

Source: UCMR5 Data Finder, State sampling from special data request to DWR, DEQ • Created with Datawrapper

One of the takeaways from North Carolina's experience with PFAS is the futility, from a public health perspective, of trying to control or regulate one PFAS at a time, rather than as a class. As some long-chain PFAS have become regulated, manufacturers have switched to unregulated shorter-chain PFAS that bioaccumulate less but travel further and faster through the environment and are similarly toxic.[515] Moreover, PFAS travel together, and although they rarely break down completely, they do transform

[515] Sarah Hale et al., Persistent, mobile and toxic (PMT) and very persistent and very mobile (vPvM) substances pose an equivalent level of concern to persistent, bioaccumulative and toxic (PBT) and very persistent and very bioaccumulative (vPvB) substances under REACH, Environmental Sciences Europe, December 2020, 32:155, https://doi.org/10.1186/s12302-020-00440-4.

into other toxic PFAS.[516] Many of the PFAS present in our rivers are not picked up by the targeted testing methods used for regulatory purposes (they show up in non-targeted tests). For example, a recent South Carolina study found that 38 of 40 locations tested positive for total organic fluorine, but that testing for 33 specific PFAS only accounted for about 2% of the total fluorine, and missed hot spots.[517] A recent study of PFAS in fillets from wild river fish in North Carolina found 'concerningly high' levels of 36 different PFAS, but only half of the PFAS were compounds that would be detected through regular testing methods.[518]

Finally, PFAS can transform from unstudied precursors to forms with known health harms within the human body. A recent study found 35 different PFAS in air, dust, drinking water, clothing, and on surfaces in 11 North Carolina homes; excluding PFAS in food, inhalation of volatile PFAS accounted for 65% of residents' estimated intake of PFAS.[519] Strikingly, scientists found that within the body, inhaled fluorotelomer alcohols (unregulated and without a recommended limit to protect human health) were transformed into PFOA (which has a recommended health limit), increasing adults' body burden of PFOA by 14% and a two-year old child's by 17%.[520] When a family of chemicals behaves this way, attempting to protect human health by limiting the discharge of just a few members of the family won't work; the public health challenge is to prevent or limit releases of and exposure to the class.

Recent developments: After years of relative inaction, EPA shifted into high gear on PFAS under the Biden administration. The federal agency issued a PFAS Strategic Roadmap and released an implied health value for GenX in October 2021, focused UCMR5 on PFAS in December 2021, and published a guidance memo in May 2022 on using Clean Water Act authorities to cut off PFAS discharges at the source.[521] In April 2024, EPA finalized drinking water standards – maximum contaminant levels – for six PFAS; North Carolina water utilities must comply with them by May 2029.[522] If upstream dischargers do

[516] See, for example, W. Matthew Henderson et al., Analysis of Legacy and Novel Neutral Per- and Polyfluoroalkyl Substances in Soils from an Industrial Manufacturing Facility, Environmental Science & Technology, June 2024, 58 (24), https://doi.org/10.1021/acs.est.3c10268 (describing a chain of PFAS breakdown products, from precursors to 'terminal' compounds, in soil at a former manufacturing facility).
[517] Alexandria Forster et al., Identifying PFAS hotspots in surface waters of South Carolina using a new optimized total organic fluorine method and target LC-MS/MS, Water Research, June 2024, 256, https://doi.org/10.1016/j.watres.2024.121570.
[518] Ana Boatman et al., Assessing Per- and Polyfluoroalkyl Substances in Fish Fillet Using Non-Targeted Analyses, Environmental Science & Technology, Environmental Science & Technology, July 2024, 58 (32), https://doi.org/10.1021/acs.est.4c04299.
[519] Naomi Chang et al., Exposure to per- and polyfluoroalkyl substances (PFAS) in North Carolina homes: results from the indoor PFAS assessment (IPA) campaign, Environmental Science: Processes & Impacts, November 2024, https://doi.org/10.1039/D4EM00525B.
[520] *Idem*.
[521] US EPA, PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024, October 2021; see also, US EPA, EPA's PFAS Strategic Roadmap: Three Years of Progress, November 2024; US EPA, webpage: Fifth Unregulated Contaminant Monitoring Rule, updated March 11, 2025; US EPA, memorandum: Addressing PFAS Discharges in NPDES Permits and Through the Pretreatment Program and Monitoring Programs, December 5, 2022.
[522] 89 Fed. Reg. 32532, PFAS National Primary Drinking Water Regulation, April 26, 2024; 89 Fed. Reg. 49101, PFAS National Primary Drinking Water Regulation (correction), June 11, 2024; see also, US EPA, webpage: Final PFAS National Primary Drinking Water Regulation, updated February 19, 2025.

not curb their PFAS pollution in the meantime, the cost to protect drinking water will fall on those drinking water utilities and ultimately on their ratepayers.

Unfortunately, to date, state regulatory authorities have not limited PFAS discharges by upstream polluters other than Chemours. DEQ staff began briefing the Environmental Management Commission (EMC) on proposed water quality standards in November 2023, but the Commission has never begun the rulemaking process, and in September 2024 effectively voted to stall water quality standards indefinitely.[523] Instead, commissioners have pursued a vague 'minimization' strategy that does not entail any mandatory reductions from upstream sources.[524] Meanwhile, slugs of concentrated PFAS pollution continue to be released upstream from drinking water intakes in the Haw and perhaps other rivers, and several downstream utilities have no way to remove the toxics from their drinking water.[525] Advocates have encouraged DEQ to use its existing permitting authorities under the federal Clean Water Act to curb discharges without waiting for endlessly deferred standards.

Just in the last few years, research has pointed to one likely contributor to the gap between identified PFAS and total fluorine in our rivers and drinking water: trifluoracetic acid, or TFA. This compound is very small, including just a single carbon-fluorine bond; it is a breakdown product of many other PFAS.[526] It breaks down extremely slowly, has built up rapidly in the global environment, and has been found in samples collected in homes. TFA harms mammalian livers and reproductive systems, and researchers argue that it presents a serious threat to human health and the environment.[527]

Indicator 19.2: Number of known unremediated sites with PFAS contamination.

Top line: The problem of forever chemicals is sprawling and complex, but has two main parts: how to curb their ongoing release into the environment, and what to do about PFAS contamination that is already circulating in the world around us. This indicator tackles the second question by tracking the number of known sites of PFAS contamination that have not yet been cleaned up. Private landowners

[523] Trista Talton, Update: PFAS groundwater rule OK'd for public comment, Coastal Review, September 12, 2024; Peter Castagno, Environmental Management Commission stalls PFS standards, members own stock in companies lobbying against regulation, Port City Daily, May 26, 2024; Adam Wagner, Republicans now enforcing NC water rules are delaying efforts to limit PFAS, 1,4-dioxane, News & Observer, May 8, 2024.
[524] NC EMC, Water Quality Committee, November 13, 2024 Meeting Minutes; NC EMC, Water Quality Committee, September 11, 2024 Meeting Minutes; Adam Wagner, To keep forever chemicals out of surface water, NC may just ask industry to do better, News & Observer, November 15, 2024.
[525] Samantha Hall et al., PFAS levels in paired drinking water and serum samples collected from an exposed community in Central North Carolina, Science of the total Environment, October 2023, 895, https://doi.org/10.1016/j.scitotenv.2023.165091.
[526] Miranda Willson, You've probably never heard of this 'forever chemical.' Scientists say it's everywhere, E&E News, September 12, 2024; Leana Hosea and Rachel Salvidge, Rapidly rising levels of TFA 'forever chemical' alarm experts, The Guardian, May 1, 2024; Guomao Zheng et al., Elevated Level of Ultrashort- and Short-Chain Perfluoroalkyl Acids in US Homes and People, Environmental Science & Technology, October 2023, 57 (42), https://doi.org/10.1021/acs.est.2c06715.
[527] Hans Peter Arp et al., The Global Threat from the Irreversible Accumulation of Trifluoroacetic Acid (TFA), Environmental Science & Technology, October 2024, 58: 45, https://doi.org/10.1021/acs.est.4c06189.

have only been testing for PFAS in soil and groundwater for a couple of years now, and we know no examples of PFAS contaminated sites that have been fully remediated. We have not been successful in obtaining an estimate of the number of PFAS contaminated sites in North Carolina, so we consider this a data gap and don't assign a trend in this update.[528] We would regard it as a positive trend for the state to remediate known sites faster than it discovers new ones.

About unremediated PFAS contamination: The previous indicator focuses on PFAS in drinking water, but in fact there are many paths of human exposure to PFAS. They've been found not just in river water, but also in sewage sludge, and in surface waters and drinking water wells near fields in North Carolina where sludge is spread.[529] Vegetables grown in residential gardens watered with contaminated rain or groundwater have shown unsafe levels of PFAS contamination.[530] In the Lower Cape Fear region, various PFAS have been found in different species of pets, domestic animals, and wildlife, including seabirds, fish, and alligators.[531] PFAS are found in high concentrations in landfills and landfill leachate, and have been found in groundwater surrounding landfills in the state.[532]

Chemours contaminated a large area of soil and groundwater through air emissions that then fell as rain – although a 2021 modelling study suggested that only 5% of Chemours' emissions landed within 150 km of the facility, and the rest spread further afield.[533] Air transport of PFAS remains an object of intense study but minimal regulation. A 2021 North Carolina study of ambient particulate matter across North Carolina found 34 different PFAS, with PFOS concentrations standing out. [534] That's surprising, because

[528] In March 2025, the NC DEQ, Division of Waste Management (DWM) told the Environmental Management Commission that at least 20 landfills around the state have contamination sufficient to merit additional testing of nearby private wells. See, Adam Ulishney, DWM, presentation: Update on Solid Waste Landfill PFAS Data, presentation to EMC Groundwater and Waste Management Committee, March 12, 2025. The actual list of sites contaminated by past spills, leaching, land application of wastes, and deposition of aerial emissions must be significantly larger.

[529] Shubhashini Oza et al., Surveillance of PFAS in sludge and biosolids at 12 water resources recovery facilities, Journal of Environmental Quality, July 2024, 54 (1), https://doi.org/10.1002/jeq2.20595; *Knappe and Baker*.

[530] Pingping Meng, et al., Residential Garden Produce Harvested Near a Fluorochemical Manufacturer in North Carolina Can Be An Important Fluoroether Exposure Pathway, Journal of Agricultural and Food Chemistry, November 2024, 72 (48), https://doi.org/10.1021/acs.jafc.4c06177.

[531] Jacqueline Bangma et al., Combined screening and retroactive data mining for emerging perfluoroethers in wildlife and pets in the Cape Fear region of North Carolina, Chemosphere, September 2024, 363, https://doi.org/10.1016/j.chemosphere.2024.142898; T.C. Guillette et al., Elevated levels of per- and polyfluoroalkyl substances in Cape Fear River Striped Bass (*Morone saxatilis)* are associated with biomarkers of altered immune and liver function, Environment International, March 2020, 136, https://doi.org/10.1016/j.envint.2019.105358.

[532] Fabrizio Sabba et al., PFAS in landfill leachate: Practical considerations for treatment and characterization, Journal of Hazardous Materials, January 2025, 481, https://doi.org/10.1016/j.jhazmat.2024.136685; Aleah Walsh and Courtney Woods, Presence of Perfluoroalkyl Substances in Landfill Adjacent Source Waters in North Carolina, Int. J. Environ. Res. Public Health, August 2023, 20 (15): 6524, https://doi.org/10.3390/ijerph20156524.

[533] Emma D'Ambro et al., Characterizing the Air Emissions, Transport, and Deposition of Per- and Polyfluoroalkyl Substances from a Fluoropolymer Manufacturing Facility, Environmental Science & Technology, January 2021, 55 (2), https://doi.org/10.1021/acs.est.0c06580.

[534] J. Zhou et al., PFOS dominates PFAS composition in ambient fine particulate matter (PM2.5) collected across North Carolina nearly 20 years after the end of its US production, Environmental Science: Processes & Impacts, April 2021, 23: 580, https://doi.org/10.1039/D0EM00497A.

PM2.5 lasts in the atmosphere less than 2 weeks, and PFOS production was phased out in the U.S. two decades ago, suggesting it is continuously being formed and released as a degradation product of PFAS precursors. Across the nation, average levels of PFAS in rainwater are not high, but can exceed federal drinking water standards in the vicinity of emissions sources.[535]

Our indicator is the number of known, unremediated sites contaminated with PFAS. That's not a perfect measure of the problem of existing contamination, because short-chain PFAS (like GenX and TFA) are very mobile and continue to circulate in water, plants, and the food chain. But the roster of PFAS contaminated sites does at least offer a sense of known hot spots. However, while state officials track specific instances of PFAS contamination, we've been unable to obtain a count of the total known instances of PFAS contamination in soil and groundwater, so we do not assign this indicator a trend this year. Long term, we'll measure progress by whether PFAS contamination is being discovered faster or slower than it is being cleaned up.

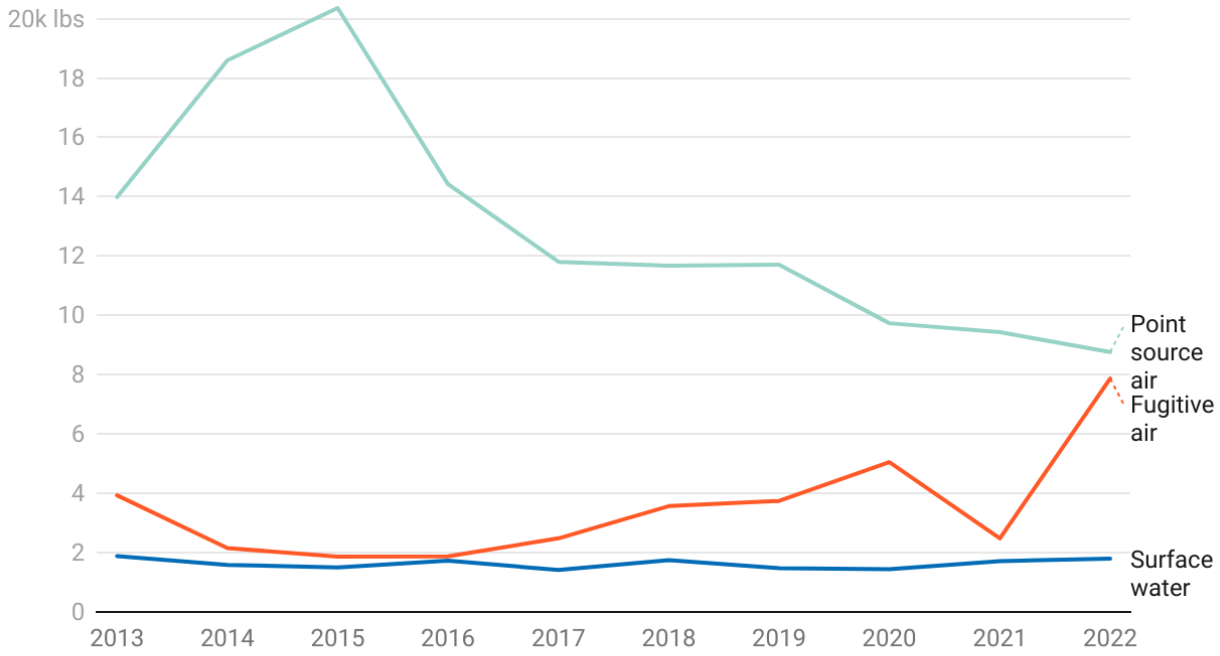
Recent developments: One of North Carolina's key environmental protections is the state groundwater rule, which prohibits the discharge of contaminants to the "land or waters" in concentrations above chemical-specific standards – or, for chemicals without adopted standards, above naturally occurring background levels.[536] These rules allowed DEQ to stop Chemours' air emissions of GenX in 2018; the compound wasn't listed as a hazardous air pollutant under the federal Clean Air Act, but because rain washed it onto the ground where it contaminated soil and groundwater, Chemours' emissions violated the groundwater rules.[537] In early 2024, DEQ staff brought proposed groundwater standards to the NC Environmental Management Commission for eight PFAS, six to match EPA's drinking water standards and two others that also occur in North Carolina and for which health information had become available.[538] In July, the EMC declined to pursue rulemaking for five of the eight and proposed to set standards for three: PFOS, PFOA, and GenX.[539] Responding to a petition from a group of landowners dealing with PFAS well contamination in Alamance County, in October 2024, DEQ issued temporary groundwater standards (interim maximum allowable concentrations, or IMACs) for all eight PFAS.[540] Under current rules, those temporary groundwater standards will last for one year, at which point the EMC must decide whether to propose permanent standards for the five not covered by the EMC's rule.

[535] Kameron Coates and Peter de. B. Harrington, Contamination levels of per- and polyfluoroalkyl substances (PFAS) in recent North American precipitation events. A review, Water Research, November 2024, 266, https://doi.org/10.1016/j.watres.2024.122390
[536] 15A NCAC 02L .0202.
[537] See, NC DEQ, press release: DEQ files new proposed court order against Chemours, June 11, 2018.
[538] NC DEQ, 2L PFAS Standards Presentation, July 2024; NC DEQ, 2L Regulatory Impact Analysis, July 2024.
[539] Trista Talton, Anger at commissions boils over during PFAS rules hearing, Coastal Review, December 5, 2024; Trista Talton, Commission members balk on 5 proposed PFAS standards, Coastal Review, July 12, 2024.
[540] NC DEQ, Public Memorandum, October 15, 2024; Adam Wagner, A Graham well was contaminated with forever chemicals. It led to a new, temporary rule, News & Observer, October 18, 2024.

Indicator 19.3: Annual releases of persistent toxics other than PFAS.

Top line: A relative handful of facilities in North Carolina account for most of the state's emissions of non-PFAS persistent toxics. Most facilities' emissions have stayed level, but as Duke Energy's coal-fired power plants have closed, their emissions have ended, gradually lowering the total annual emissions of persistent toxics – a good trend.

Figure 19.3: Fugitive air, point source air, and surface water releases of PBTs, 2013-2022 (in pounds)



Source: : EPA, TRI 2022 Dataset, October 2023, accessed via TRI Explorer, releases: Chemical report • Created with Datawrapper

About persistent toxic emissions: Among the 850+ chemicals tracked by the Toxics Release Inventory, roughly 15 non-PFAS compounds are identified as 'persistent, bioaccumulating toxics' (PBT). Eight of these are reported in North Carolina, including lead and lead compounds, mercury compounds, and polycyclic aromatic compounds.[541] The bulk of PBTs are sent to on-site landfills (coal ash), slag piles, or offsite landfills. Over the last decade, as Duke Energy has shuttered coal-fired power plants, onsite landfilling of lead compounds declined from a peak of 210,000 pounds in 2014 to 106,000 in 2022. Total onsite disposal dropped from a peak of 613,000 pounds in 2013 to 377,000 pounds in 2022; meanwhile off-site disposal has increased from 339,000 pounds to 1.2 million pounds over the same period.

[541] EPA, search form: TRI On-Site and Off-site Reported Disposed of or Otherwise Released (in pounds), for All Industries, for Persistent, Bioaccumulative, and Toxic (PBT) Chemicals, North Carolina, 2013-2022.

For our indicator, we track the much smaller amounts of PBTs that are released directly into North Carolina's air and water. Discharges of PBTs to surface water and fugitive air emissions have remained mostly constant, while permitted air emissions have declined substantially. The reduction in PBT air emissions reflects process changes at a handful of factories – SGL Carbon in Morganton, Mann + Hummel in Fayetteville, and Campbell Soup in Maxon – that reduced releases of polycyclic aromatic compounds. As best we can tell from a review of the relevant permit files, each of the reductions was driven by internal business decisions rather than any overarching state policy. Thus, while the trend is positive, it is hard to know whether it will last.

Recent developments: The 2023 closure of Blue Ridge Paper was a devastating economic blow to the Town of Canton and to Haywood County in western NC. For at least its last decade, the paper mill released upwards of 400 pounds of polycyclic aromatic toxics and 25 to 50 pounds of mercury compounds annually. As noted above, TRI data has a two-year lag; we expect the plant's closure will result in an incremental drop in PBT emissions in 2023 and beyond.

In August 2024, EPA finalized its 'Once in, Always in' rule, which applies specifically to facilities that release any of seven persistent or bioaccumulating air toxics.[542] The Clean Air Act classifies sources that release more than 10 tons of a single hazardous air pollutant (HAPs) in a year, or 25 tons of any combination of HAPs in a year, as 'major' sources.[543] Facilities that release less are classed as 'area' sources. The 'Once in, Always in' rule says that a source that reduces emissions of any of the seven compounds to convert from 'major' to 'area' source must still meet key standards that apply to major sources.[544] According to the TRI, three of the seven toxics are released in North Carolina: lead, mercury, and polycyclic aromatic compounds, in that order by weight. The largest source of lead to the air, far and away, is Fort Bragg/ Liberty, likely a reflection of vaporized ordnance. Several glass manufacturers add up to a distant second.[545]

INDIVIDUAL HEALTH

The aphorism that the greatest wealth is health has been attributed to a host of historical figures, only some of whom likely ever said anything like it. But the sentiment – that personal health is an essential component of quality of life – is intuitively true. For the first goal in this section, we consider our progress towards good health and long lives for all North Carolinians, tracked by five indicators. We've

[542] US EPA, Review of Final Rule Reclassification of Major Sources as Area Sources Under Section 112, 40 CFR Part 63, August 30, 2024. The seven compounds are alkylated lead compounds, polycyclic organic matter, hexachlorobenzene, mercury, polychlorinated biphenyls, 2,3,7,8-tetrachlorodibenzofurans and 2,3,7,8-tetrachlorodibenzo-p-dioxin.
[543] 42 U.S.C. §7412 (a)(1),(2).
[544] US EPA, factsheet: Reclassification of Major Sources as Area Sources Under Section 112 of the Clean Air Act (MM2A) – Final Action, August 30, 2024. *See also*, Maxine Joselow, EPA restores industrial air pollution rule axed by Trump, Washington Post, September 4, 2024.
[545] EPA, search form: TRI On-Site and Off-site Reported Disposed of or Otherwise Released (in pounds), for All Industries, for Persistent, Bioaccumulative, and Toxic (PBT) Chemicals, North Carolina, 2013-2022.

chosen these five – diabetes, obesity, asthma, cancer, and premature death – because they are among the health conditions that affect the most North Carolinians. They also have strong connections to environmental exposures and factors, as noted throughout this report.

The subsequent three goals describe conditions that strongly shape public health. At the beginning of the exposome goals, we noted that the concept of the exposome has three parts: general social context; specific exposures; and internal exposures. The first of these, social exposures, has been well-studied.[546] It also overlaps with a key concept from the public health world: the 'social determinants of health', the recognition that economic and social conditions are significant drivers of health outcomes for individuals and for communities.[547] Like the exposome, the concept of the social determinants of health is about two decades old, is strongly grounded in research, and has been a key tool for improving North Carolinians' lives.[548]

Goals 21 through 24 – equitable access to health care; healthy childhoods; and access to sufficient, healthy food – are all social determinants of health. Other social determinants, including economic performance, educational opportunities, and social isolation, are covered in the next section on community health. For a longer list of health indicators, it is worth looking at the North Carolina Institute of Medicine's Healthy North Carolina 2030, which details 21 health indicators, many of which reflect social determinants.[549]

Goal 20: North Carolinians have long lives and good health

Trend: Negative

[546] See, for example, Severine Deguen, Exposome and Social Vulnerability: An Overview of the Literature Review, International Journal of Research in Public Health, March 2022, 19 (6): 3534, https://doi.org/10.3390/ijerph19063534; Lola Neufcourt, Assessing How Social Exposures Are Integrated in Exposome Research: A Scoping Review, Environmental Health Perspectives, November 2022, 130 (11), https://doi.org/10.1289/EHP11015.

[547] Paula Braveman and Laura Gottlieb, The Social Determinants of Health: It's Time to Consider the Causes of the Causes, Public Health Reports, January/February 2014, 129: 19, https://doi.org/10.1177/00333549141291S206; Laura Gerald, Social Determinants of Health, NC Medical Journal, October 2012, 73 (5), https://doi.org/10.18043/ncm.73.5.353.

[548] Vibhav Nandagiri et al., blog post: North Carolina's Medicaid experiment is working. Here's how we know, Harvard Public Health, October 7, 2024 (Healthy Opportunities Pilot built around social determinants of health concept, saving state money while improving human health); Deepak Palakshappa et al., Screening for Social Determinants of Health in Free and Charitable Clinics in North Carolina, Journal of Health Care for the Poor and Underserved, February 2020, 31 (1): 382, https://doi.org/10.1353/hpu.2020.0029 (social determinants are a crucial component of effective health care at most free and charitable clinics); Health Management Associates, presentation: Social Determinants of Health and North Carolina: Medicaid and Beyond, November 2019 (addressing social determinants can reduce costs for managed care organizations and hospitals).

[549] North Carolina Institute of Medicine, Healthy North Carolina 2030: A Path Toward Health, January 2020.

Human health and the environment are intertwined. In this section we consider adverse health outcomes that are often associated with aspects of the built environment (indicators 20.1, 20.2), with environmental exposures (indicators 20.3, 20.4) or with both (indicator 20.5). We consider disparities in health outcomes by race and ethnicity throughout this report, and especially so in this section. Measured by these five indicators, North Carolina is slipping away from rather than approaching this key goal.

Solutions: Individual health is such a fundamental outcome for environmental policies that most of the policies in the solutions document will contribute to better health for North Carolinians. That said, North Carolina can especially improve health outcomes by, B3, sustaining farm to school initiatives; D1, protecting North Carolinians from disproportionate burdens; D2, sustaining Medicaid expansion and the Healthy Opportunities pilot program; D3, protecting workers from excessive heat; E1, funding lead testing and remediation; E2, regulating consumer products; F1, targeting air pollution hot spots; F3, curbing air emissions of PFAS; F4, addressing transportation-related air pollution; F6, addressing indoor air quality in public buildings; G3, updating surface water quality standards; G4, curbing PFAS discharges to water; G10, establishing a state-funded water assistance program; G11, establishing a septic repair fund; G13, require swine farms to adopt better waste management; H3, reducing plastic pollution; J7, spending out IRA dollars wisely; J9, modernizing the building code; J10, establish a state-funded energy assistance program; K4, improve prioritization of transportation projects; K5, implement Complete Streets; L1, support affordable housing; L5, encourage and protect urban tree canopy; and N3, accommodate multiple languages as government interacts with the public.

Indicator 20.1: Incidence of diabetes

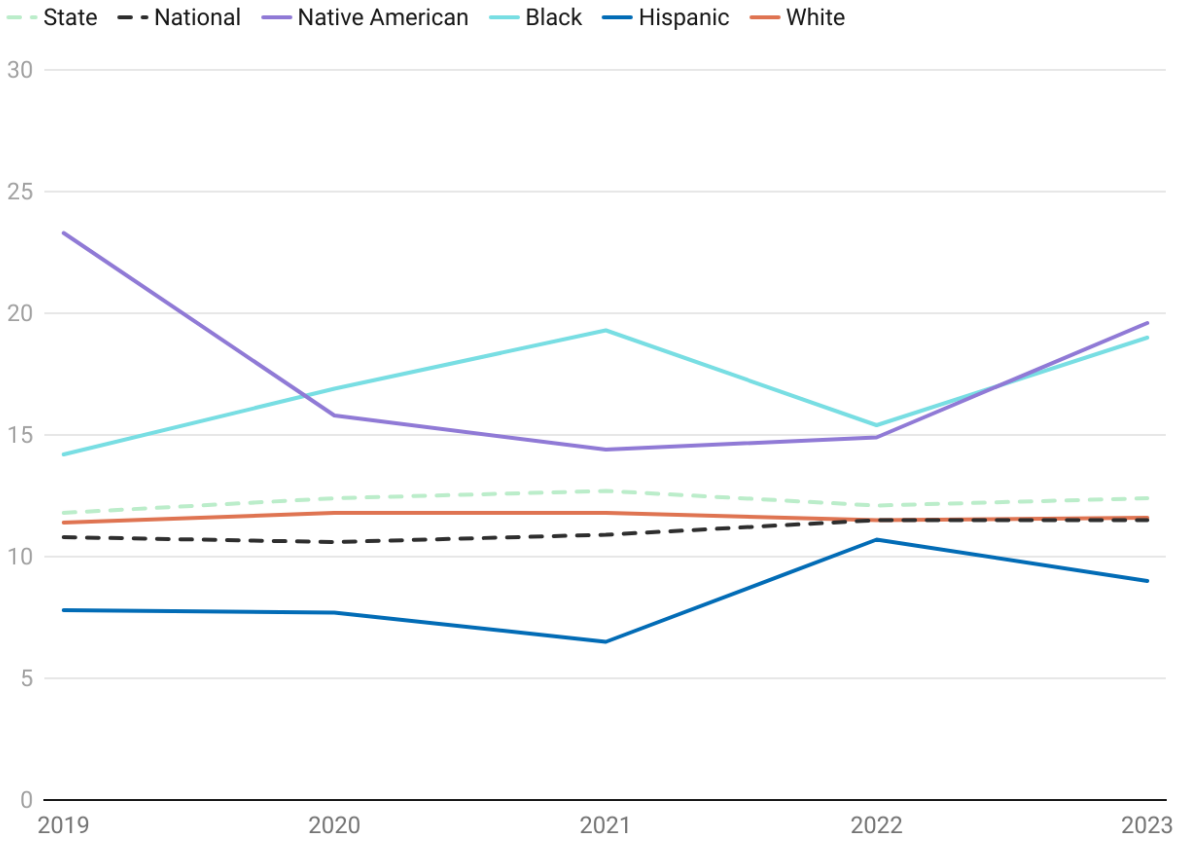
Top Line: Reflecting a broader national trend, the prevalence of diabetes in adults in North Carolina has continued to rise in the past decade. This is a harmful trend.

About diabetes: Diabetes is a chronic disease in which the body either cannot make (type 1) or cannot use (type 2) insulin effectively. Diabetes substantially increases risks of cardiovascular disease, kidney failure, and neuropathies. In the United States as a whole, over 38 million people have diabetes, with type 2 diabetes accounting for approximately 90-95% of the diagnosed cases.[550] In North Carolina, the percentage of diagnosed adults with diabetes has increased from 10.9% in 2011 to 12.1% in 2022. Racial and ethnic disparities in diabetes prevalence have persisted, as shown in figure 20.1.

[550] CDC, factsheet: Diabetes, A US Report Card, 2024.

Figure 20.1: Percent of adults told by a health professional that they have diabetes

(excludes prediabetes and gestational diabetes)



Source: Centers for Disease Control and Prevention (CDC). Behavioral Risk Factor Surveillance System Survey Questionnaire. 2019-2023 • Created with Datawrapper

Environmental exposures and modifiable lifestyle risk factors contribute to type 2 diabetes rates. These include air pollution, area-level socioeconomic level disparities, chronic stress, and sedentary habits.[551] Comparison studies of residents in urban and rural environments suggest that the built environment – specifically, whether it encourages or even allows residents to walk safely – contributes significantly to diabetes prevalence.[552] Ongoing studies are examining the relationship of diabetes and hypertension to regional walkability, access to healthy food options, and financial disparities. Studies suggest that

[551] Joline Beulens et al., Environmental risk factors of type 2 diabetes—an exposome approach, Diabetologia, February 2022, 65: 263–274, https://doi.org/10.1007/s00125-021-05618-w.

[552] Sagar Dugani et al., Burden and management of type 2 diabetes in rural United States, Diabetes/metabolism research and reviews, July 2021, 37 (5), e3410, https://doi.org/10.1002/dmrr.3410.

residents of disadvantaged communities suffer from higher rates of diabetes across all types and densities of land use.[553]

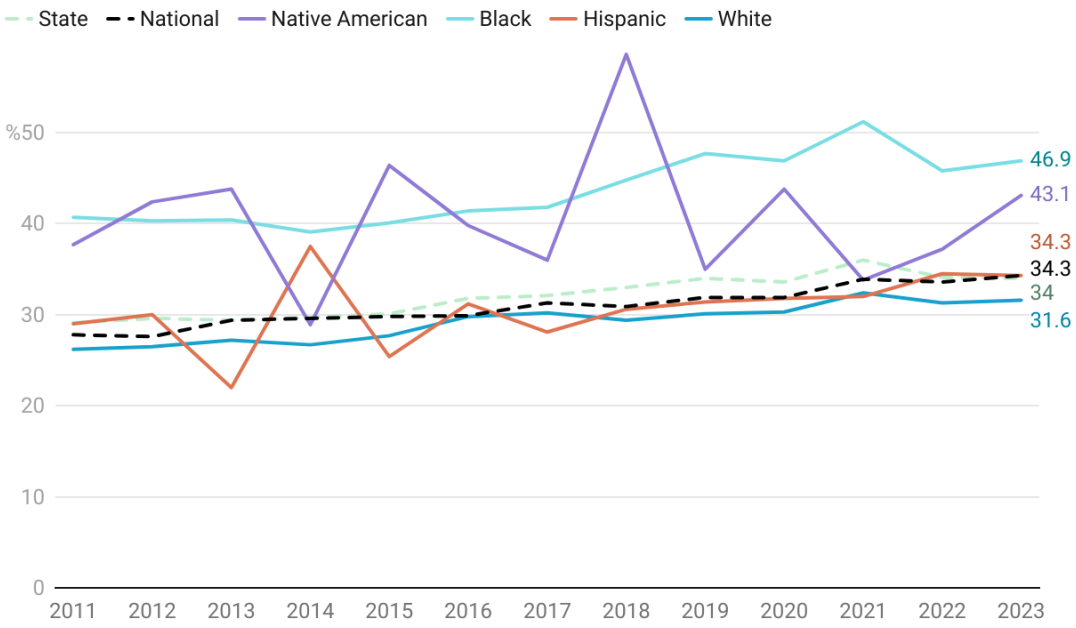
Indicator 20.2: Rate of adult obesity

Top Line: Over the last decade, obesity rates in North Carolina have risen for every racial and ethnic group except Native Americans, and have remained above the national average, although the national figure has risen towards North Carolina's. Because obesity is a significant risk factor for a variety of adverse health outcomes, we rate this as a negative trend.

About obesity rates: Obesity is a significant public health concern that contributes to a range of chronic diseases, including diabetes, hypertension, and cardiovascular disease.[554] In North Carolina, the percentage of adults classified as obese has steadily risen from 28.6% in 2010 to 34.1% in 2022, which reflects broader national trends but surpasses the national average.

Figure 20.2: Percentage of adults who are "obese"

Based on body mass index of 30.0 or higher based on self-reported height and weight



Source: Centers for Disease Control and Prevention (CDC). Behavioral Risk Factor Surveillance System Survey Questionnaire. 2011-2023 • Created with Datawrapper

[553] Jalal Uddin et al., The association between neighborhood social and economic environment and prevalent diabetes in urban and rural communities: The Reasons for Geographic and Racial Differences in Stroke (REGARDS) study, SSM, Population Health, March 2022, 17: 101050, https://doi.org/10.1016/j.ssmph.2022.101050.
[554] National Institute of Diabetes and Digestive and Kidney Diseases, webpage: Health Risks of Overweight & Obesity, May 2023.

Notwithstanding social stigma, obesity is influenced by a complex interplay of social, genetic, environmental, and behavioral factors.[555] Research suggests the built environment – the human-made surroundings within which people live, work and play – influences obesity rates through several key pathways: access to recreational facilities and green space (indicator 35.2), neighborhood walkability versus car dependence (indicator 33.1), and access to healthy food (indicators 23.1 and 23.2).[556] As far back as 2005, researchers noted that obesity in North Carolina increased even as household incomes surged, and suggested a correlation between rising obesity and rising commute times (indicator 34.1).[557] More recently, NC DHHS has underscored the impact of food deserts, areas with limited access to affordable and nutritious foods. [558]

Indicator 20.3: Prevalence of asthma

Top Line: Asthma prevalence in North Carolina has fluctuated over the past decade, with a slight increase from 2011 to 2022; it remains below the national average. The rate among White and Black adults is similar; Hispanic residents enjoy a significantly lower rate of asthma. Overall, we mark this indicator as showing no trend.

Top Line: Asthma prevalence in North Carolina has fluctuated over the past decade, with a slight increase from 2011 to 2022; it remains below the national average. The rate among White and Black adults is similar; Hispanic residents enjoy a significantly lower rate of asthma. Overall, we mark this indicator as showing no trend.

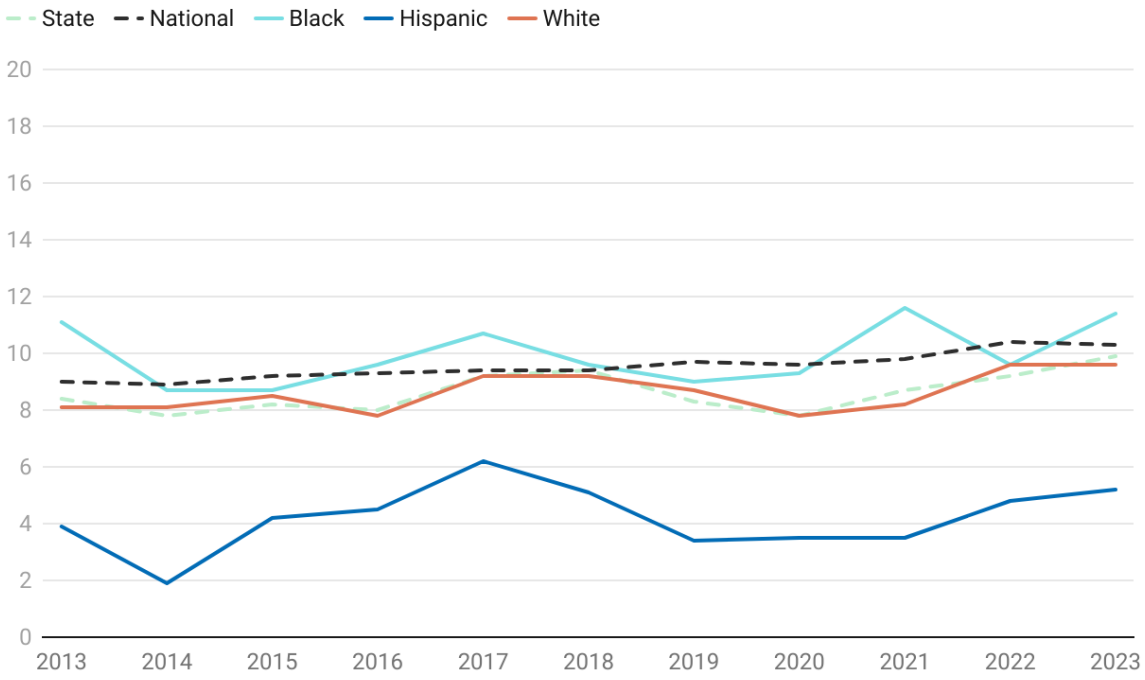
About asthma: Asthma is a chronic respiratory condition caused by airway inflammation and tightening, which can lead to episodes of breathlessness, chest tightness, wheezing and coughing of different severities.[559] Ultimately, asthma prevalence in adults can be influenced by a range of factors including genetic predisposition, environmental exposures, and socioeconomic status. Exposure to high concentrations of pollutants can worsen symptoms; particulate matter and ground-level ozone are known triggers.[560]

In contrast to several other health indicators in this report, prevalence of asthma does not show increasing racial disparities in North Carolina over the last decade: the rates for White and Black residents have converged, while the rate for Hispanic residents has remained notably lower. A national 2020 paper noted that Hispanic Americans born in Mexico have significantly lower rates than those born

[555] Alexandra Lee, et al., Social and Environmental Factors Influencing Obesity, Endotext, October 2019.
[556] Brittney Dixon et al., Associations between the built environment and dietary intake, physical activity, and obesity: A scoping review of reviews, Obesity Reviews, December 2020, 22(4), https://doi.org/10.1111/obr.13171.
[557] Selima Sultana, et al., The relationship of income, density, and commuting times on overweight/obesity rates in North Carolina, Papers and Proceedings of the Applied Geography Conference, 2005, 28, 254–263.
[558] NC DHHS, State Center for Health Statistics, factsheet: Limited access to healthy foods: Indicator brief, 2023.
[559] World Health Organization, factsheet: Asthma, May 6, 2024.
[560] Shuo Liu et al., Long-term exposure to low-level air pollution and incidence of asthma: the ELAPSE project. European Respiratory Journal, 2020, 57 (6), https://doi.org/10.1183/13993003.030992020.

in the United States; it also observed that, nationally, self-identified Black Hispanic adults suffered higher rates of asthma than white-identified Hispanic adults.[561]

Figure 20.3: Percentage of adults who have been told they currently have asthma



Source: Centers for Disease Control and Prevention (CDC). Behavioral Risk Factor Surveillance System Survey Questionnaire. 2013-2023 • Created with Datawrapper

Asthma triggers include several factors tracked by other indicators. Climate change increases the length of pollen season; we don't track that directly, but it correlates with global temperature (indicator 1.2). Ambient outdoor air quality (indicator 12.1) has broadly improved over the last decade. Substantial research ties emissions from animal agriculture to asthma on a very local level; we track hog and poultry wastes (indicators 11.2 and 11.3) rather than local air emissions, but those are correlated. Finally, asthma has a strong relationship to indoor air quality (indicator 13.1), for which there is no North Carolina data.

Indicator 20.4: Prevalence and incidence of cancer

[561] Guadalupe Marquez-Velarde, The paradox does not fit all: racial disparities in asthma among Mexican Americans in the U.S., PLoS One, November 2020, 15(11), https://doi.org/10.1371/journal.pone.0242855; see also, Torie Grant et al., Asthma and the social determinants of health, Annals of Allergy, Asthma, and Immunology, October 2021, 128(1): 5, https://doi.org/10.1016/j.anai.2021.10.002 (applying a social determinants of health framework to explain national racial disparities in asthma rates).

Top Line: Over the last ten years, the prevalence of cancer – the percentage of North Carolinians who have ever been told they have cancer (excluding skin cancer) – drifted gradually upwards, paralleling a national trend. The rates of early onset cancer diagnosis have also worsened. Both are negative trends.

About cancer: Cancer is a significant public health concern and leading cause of death across the United States. Multiple factors drive rates for different varieties of cancer, including lifestyle factors, environmental exposures, genetic dispositions, and access to screening and treatment. In North Carolina, the four most deadly cancers are lung, colorectal, female breast, and prostate cancers, according to the North Carolina Comprehensive Cancer Control Action Plan.[562]

North Carolina's cancer prevalence has tracked upwards over the last decade, from 6.4% of adults in 2013 to 8.1% in 2022. That parallels national trends, 6.7% to 8.3% over the same period. Data on cancer incidence – the rate at which new cancers are identified per 100,000 residents in the population – is collected by state health officials and reported in five year slices. The incidence of early onset cancers (diagnosed in adults between the ages of 18 and 49) is on the rise globally.[563] Although that rise may in part reflect increases in cancer screenings, there is also evidence that lifestyle and environmental risks are contributing to increased incidence of breast, colorectal, kidney, liver, and lung cancers.[564] North Carolina mirrors this trend, as shown below in the table 20.4, based on the National Cancer Institute's State Cancer Profiles.[565]

[562] NCDHHS, North Carolina Comprehensive Cancer Control Action Plan 2020-2025, December 2020.
[563] Tomotaka Ugai et al., Is early-onset cancer an emerging global epidemic? Current evidence and future implications, Nature Reviews Clinical Oncology, September 2022, 19: 656, https://doi.org/10.1038/s41571-022-00672-8.
[564] *Ibid*, 2022.
[565] National Cancer Institute, State Cancer Profiles by cancer type, Data from: National Program of Cancer Registries Policy Cancer Surveillance System (NPCR-CSS), Centers for Disease Control and Prevention and by the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program, 2017 – 2021.

Table 20.4: 2017-2021 Incidence Rates of Early Onset Cancers

Cancer Type	NC Early Onset Rate	US Early Onset Rate	NC Trend
Breast	51.1	47.3	Rising
Colorectal	8.3	8.4	Rising
Kidney/Renal Pelvis	3.8	3.7	Rising
Liver/Bile Duct	0.7	0.6	Rising

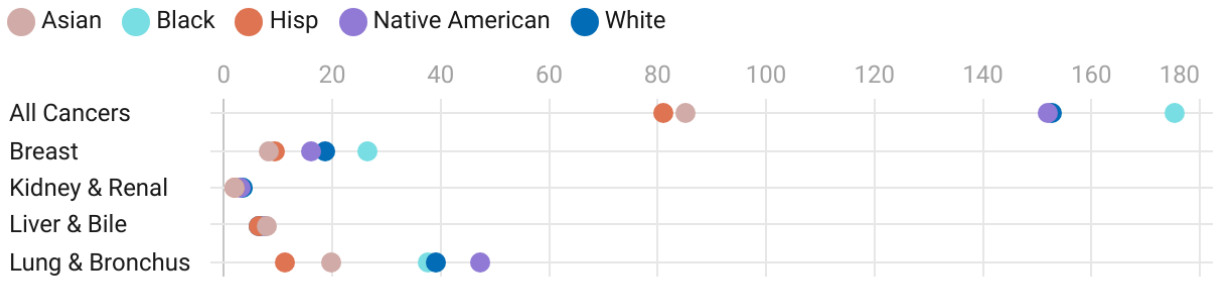
Source: National Cancer Institute, State Cancer Profiles, Data from: National Program of Cancer Registries Policy Cancer Surveillance System (NPCR-CSS), Centers for Disease Control and Prevention and by the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program • Created with Datawrapper

While some of the most common cancers are closely connected to lifestyle factors (smoking; diet), others are closely linked to environmental exposures, several of which are tracked by other indicators in this report. Conventional air pollutants, indicator 12.1, and indoor air pollution, indicator 13.1, are associated with lung cancer. Releases of air toxics, indicator 12.2; toxic chemicals generally, indicators 18.1 – 18.4, and releases of persistent and bioaccumulating toxics, indicators 19.1 – 19.3, are linked to cancers of the liver, kidney, and other distinct organ systems. Proximity to hazardous waste, indicator 45.1, and unremediated contaminated sites, indicator 45.2, raise the potential for exposures to carcinogens.

Not all the carcinogens to which North Carolina residents are exposed are man-made. Specific geologies around the state release radon, uranium, arsenic, and naturally occurring vanadium, either as gases into overlying buildings, or into groundwater that residents drink.[566] Colorless, odorless, and tasteless, radon exposure is the leading cause of lung cancer among non-smokers nationally.[567] In 77 of North Carolina's 100 counties, many homes have indoor radon air levels that exceed the national standard. Uranium, arsenic, and vanadium typically occur in groundwater. Because North Carolina lacks a state-level program to assure the safety of drinking wells in ongoing use (indicator 16.1), most of the public health response to these naturally occurring carcinogens has taken the form of scattershot local programs built by wealthier counties.

[566] For naturally-occurring contaminants in groundwater, see, NC DHHS, webpage: Well Water & Health, Maps by Contaminant Name, visited October 30, 2024.
[567] NC DHHS, website: North Carolina Radon Program. See also, Greg Barnes, N.C. gives away radon test kits, NC Health News, January 20, 2020.

Figure 20.4: 2018-2022 NC Cancer Mortality Rates



Source: National Cancer Institute, State Cancer Profiles, Data from: National Program of Cancer Registries Policy Cancer Surveillance System (NPCR-CSS), Centers for Disease Control and Prevention and by the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program • Created with Datawrapper

The last facet of this indicator considers disparate health outcomes by race and ethnicity. There are stark, persistent disparities in both cancer incidence and cancer mortality rates amongst different racial and ethnic groups. These disparities can be masked when analyzing state level data for all cancer types but are clear when looking at incidence and mortality rates by cancer type, as shown in figure 20.4. The observed disparities in cancer incidence likely reflect different exposures to environmental carcinogens, disparities in access to healthcare, or (rarely) genetic predisposition. Access to healthcare services, such as cancer screenings and preventive care, plays a role in early detection and treatment. Healthcare access disparities are more prevalent in marginalized communities and reflect disparities in income, education, and health insurance coverage, because those shape an individual's ability to seek and receive timely medical care.

The state has taken the initiative to address the disparities by creating the North Carolina Comprehensive Cancer Control Program. This program focuses on reducing cancer risks through early detection, highlighting areas for treatment accessibility, and encouraging community outreach and education opportunities. However, rising disparities suggest additional targeted efforts are needed.

Indicator 20.5: Years of potential life lost (before age 75)

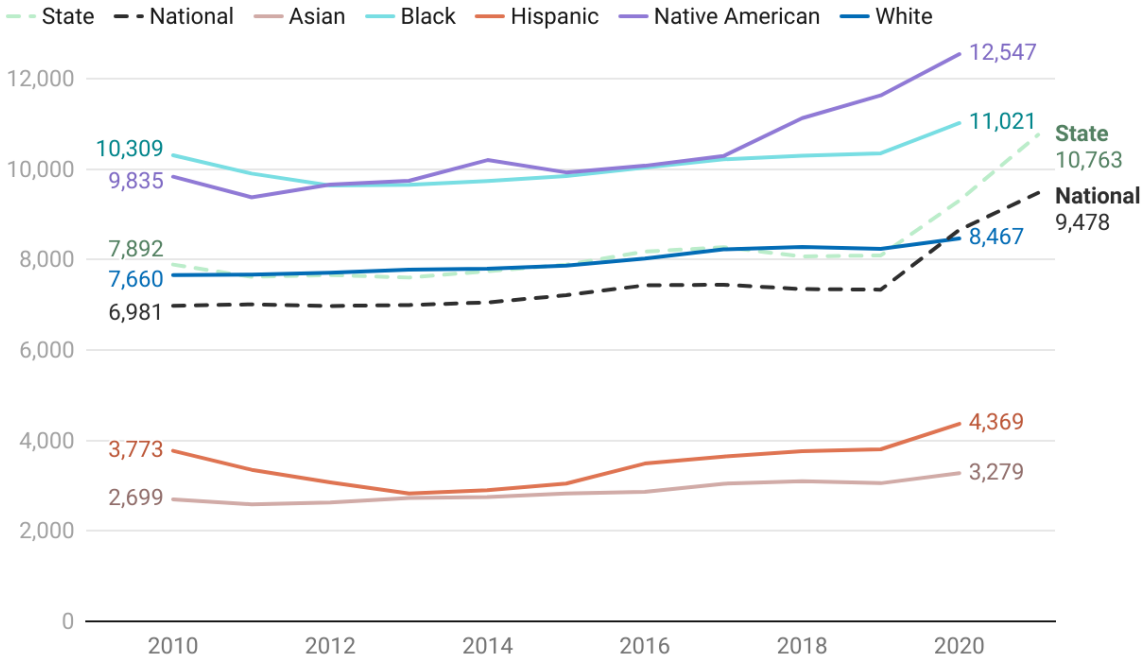
Top Line: Years of potential life lost (YPLL) measures the relative number of people dying before age 75, and weights young deaths more heavily. Over the last decade, and starting well before the COVID pandemic, YPLL has risen steadily for all racial and ethnic groups in North Carolina, and has risen faster than the national indicator. Moreover, the indicator shows substantial and widening racial disparities. This is an unhealthy trend.

About years of potential life lost: In contrast to the previous four indicators, which focus on rates of specific diseases, this indicator tracks premature deaths from all causes. Years of potential life lost (YPLL) aggregates the years by which people die short of a standard age (75 in this report) per 100,000 residents. A person who dies at 25 contributes 50 years to the count; one who dies at 35 contributes 40

years. Thus, YPLL overweights deaths among younger people compared to simple mortality counts, which tend to emphasize common causes of death with age.

Over the last decade, YPLL has risen for all ethnic and racial groups in the state, with the highest losses and fastest rise among Black and Native American residents. The rate of unintentional injury (including drug overdose deaths) and suicide have both risen steadily over the last decade and may be contributing to the rise in premature deaths overall.

Figure 20.5: Number of years of potential life lost before age 75 per 100,000 population



Data by race and ethnicity reflects a spread over the three years before the listed year, so 2014 is 2012-2014.

Source: America's Health Rankings analysis of CDC WONDER, Multiple Cause of Death Files, United Health Foundation, AmericasHealthRankings.org, Accessed 2024. • Created with Datawrapper

On the state level, in 2019, heart diseases and cancer were the two most common causes of death for all residents, regardless of race and ethnicity. Often, we discuss individual, behavioral and/or genetic risk factors for both cancer and diseases of the heart. It is important to also consider the compounding effects of social factors: studies have established that many social factors contribute to higher rates of premature deaths, including but not limited to, poverty, educational attainment, racial segregation[568], access to health care, proximity to pollution, and presence of social stressors.[569] Those factors often

[568] Sandro Galea et al., Estimated Deaths Attributable to Social Factors in the United States, American Journal of Public Health, October 2011, 101 (8), DOI: 10.2105/AJPH.2010.300086.

[569] Solmaz Amiri et al., Disparities in years of potential life lost among racial and ethnic groups in Washington state. Archives of Public Health, 2022, 80 (1), https://doi.org/10.1186/s13690-022-00969-1; David Williams et al., Racism

converge for historically marginalized communities, contributing to physiological and psychological stress, which can result in earlier onset and higher prevalence of chronic diseases.[570]

Goal 21: All North Carolinians have access to health care

Trend: Positive

We measure access to health care with a single indicator: the percentage of North Carolinians who are insured. That has risen over the last decade, so the trend is positive.

Solutions: North Carolina can help ensure that all North Carolinians have access to medical care by, D2, sustaining Medicaid expansion and the Healthy Opportunities pilot program.

Indicator 21.1: Percentage of North Carolinians with health insurance or other programmatic health coverage.

Top Line: Health care coverage is vital to creating an equitable and resilient future. Health insurance coverage is rising for all communities in the state, so we evaluate this indicator as trending in the right direction.

About access to health care: Accessible and affordable healthcare is imperative to responding to acute illnesses and to preventing or mitigating chronic conditions. In December 2023, North Carolina expanded Medicaid coverage qualifications, providing between 400,000 and 626,000 more people in the state with the opportunity to obtain insurance coverage. Research confirms that underserved and marginalized communities carry an unequal burden of climate change, toxics exposures, and environmental hazards broadly. That unequal burden puts people at risk of dealing with acute and chronic illnesses.

A 2020 study interviewed North Carolina residents from impoverished, rural, predominately Black counties with low rates of premature death, to understand community characteristics that can "moderate the negative health outcomes typically associated with social, geographic or economic disadvantages."[571] The study identified three factors: the accessibility and availability of local health

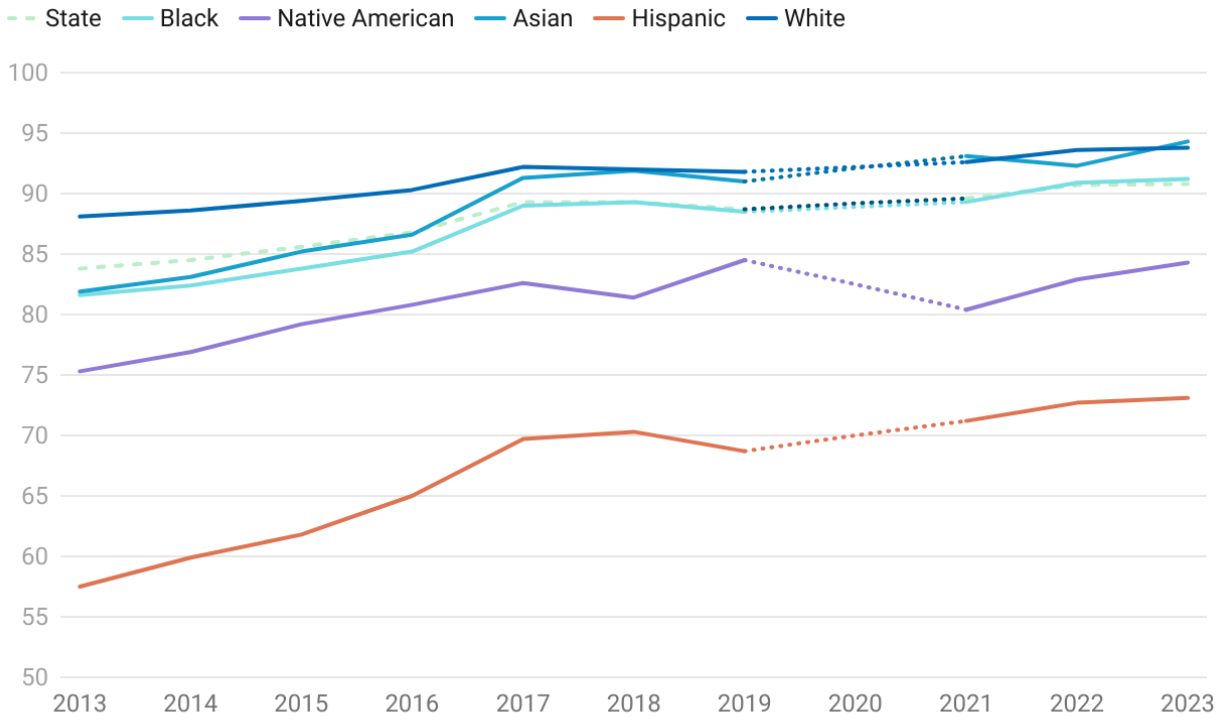
and Health: Evidence and Needed Research. Annual Review of Public Health, February 2019, 40 (1): 105, https://doi.org/10.1146/annurev-publhealth-040218-043750.

[570] For one example, see Mike Dolan Fliss et al., Measuring and Mapping Alcohol Outlet Environmental Density, Clusters, and Racial and Ethnic Disparities in Durham, North Carolina, 2017, Preventing Chronic Disease, September 2021, 18 (E89), DOI: https://doi.org/10.5888/pcd18.210127 (alcohol abundance in communities tied to higher chronic disease and early death rates; concentrations of outlets selling alcohol for off-premises consumption were more likely to be near Black and Hispanic residents and less likely to be near White residents).

[571] Rodney Lyn et al., Investigating improvements in premature death in two rural, majority-minority counties in the south, SSM – Population Health, July 2020, 11, https://doi.org/10.1016/j.ssmph.2020.100618.

care, provision of a robust emergency medical services (EMS) system, and coordination of county-funded health services targeting vulnerable populations.[572]

Figure 21.1: Percentage of North Carolinian adults with health insurance coverage



The Census Bureau did not release ACS estimates for the year 2020. Interpolated values represented by dotted lines.

Source: U.S. Census Bureau; American Community Survey, 2024 American Community Survey 1-Year Estimates (2013-2023), Table S2701 • Created with Datawrapper

Clearly, disparities persist in health coverage. However, coverage has increased across the board over the last decade, and disparities have narrowed. Coverage does not necessarily mean access. Other factors, such as availability of providers and appointments, economic barriers, and geographic barriers, can limit a person's ability to receive healthcare. The Behavioral Risk Factor Surveillance System is a national telephone survey that collects data on health behaviors, chronic health conditions, and preventative health practices. In the last decade, the percentage of North Carolina residents who said they needed to see a doctor but could not because they could not afford it has dropped. Statewide in 2012, 19% of all residents, 11% of insured residents, 49% uninsured residents responded yes, they skipped an appointment because of cost barriers. In 2022, 12% of all residents, 9% of insured residents,

[572] *Idem.*

and 38% of uninsured residents reported the same.[573] There is much work to be done to ensure all residents receive the care they need, but for now this indicator is trending in the right direction.

Goal 22: Children's development is protected in North Carolina

Trend: Mixed

Protecting children's development benefits them individually but also fosters a more productive and resilient society. Pre-natal and childhood exposures shape a child's long-term health. Social factors like educational attainment and household income can also be predictors for exposure to environmental risks. So to assess how well North Carolina is protecting children's development, we consider three indictors: the rate at which new babies are born with low birthweight, indicator 22.1; the percentage of children with high blood lead levels, indicator 22.2; and the percentage of children living in poverty, indicator 22.3. The first indicator shows a negative trend, and the other two are positive, for a mixed trend overall. It's worth noting that many other indicators not specifically focused on children have implications for children's development, including all the exposure indicators.

Solutions: North Carolina can protect children's development by, D1, protecting all North Carolinians from disproportionate burdens; D2, sustaining Medicaid expansion and the Health Opportunities pilot program; E1, funding lead testing and remediation; E2, regulating consumer products; F1, targeting air pollution hot spots; F4, addressing air pollution from transportation; F6, improving indoor air quality in public buildings; and L1, support scalable affordable housing solutions.

Indicator 22.1: Rate of low birthweight

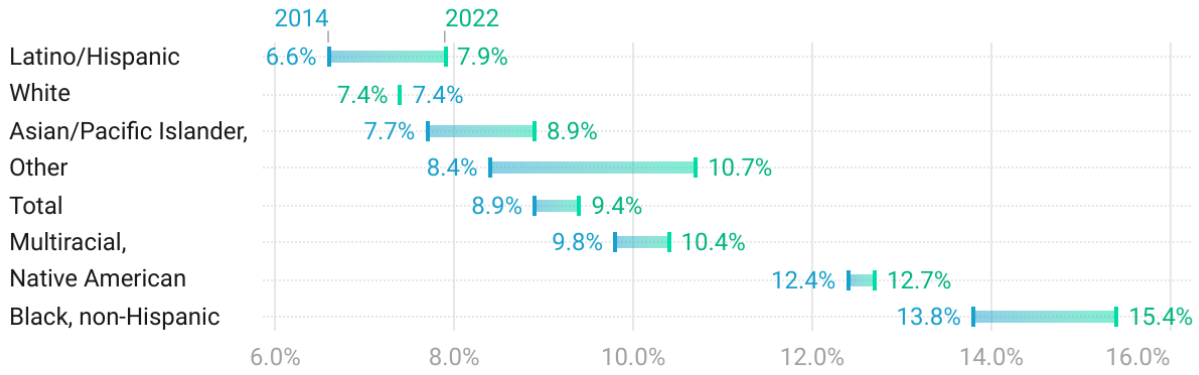
Topline: The incidence of low birthweight is rising, and disparities by race and ethnicity have stayed the same or worsened. That is a negative trend.

About low birthweight: Children born at low birthweight, defined by NC DHHS as having a weight at birth of less than 2500 grams (5.5 lbs), are at greater risk for neurodevelopmental problems, learning disabilities, and poor adult health.[574] A growing body of research links environmental exposures, such as air pollution and extreme local heat, to adverse pregnancy outcomes that include preterm births, low

[573] NCDHHS, DPH, NC State Center for Health Statistics, BRFSS Annual Survey Results, Health Care Access (2012-2022).
[574] Kate Choi and Melissa Martinson, The relationship between low birthweight and childhood health: disparities by race, ethnicity, and national origin, Annuals of Epidemiology, October 2018, 28 (10): 704, https://doi.org/10.1016/j.annepidem.2018.08.001.

birth weight, and higher infant mortality.[575] The risks of those environmental exposures are compounded by social, geographic, and economic factors.[576] This indicator relies on the State Center for Health Statistics Vital Statistics monitoring, which expresses low birthweight as a simple percentage of live births of the appropriate demographic.[577]

Figure 22.1: Percentage of babies born at a low birthweight has increased between 2014 and 2022



Source: State Center for Health Statistics, Vital Statistics, Maternal and Child Health Statistics (2014-2022). • Created with Datawrapper

Over the last decade, the percentages of low birthweight births for all North Carolinians and for all demographic groups but whites have risen. The racial and ethnic disparities are stark in the figure above: Black babies experience low birthweight at twice the rate of White or Latino babies; rates for Native American babies are also high. The scientific literature suggests that racial disparities in birthweight correlate with residential segregation, income inequality, disparate exposures to environmental toxics, and disparate levels of psychosocial stress. Because the incidence of low birthweight is generally trending up, and the racial disparities are substantial, we evaluate this indicator as showing a negative trend.

[575] See, for example, *Bekkar et al.* (air pollution and extreme heat); Bryttani Wooten, master's thesis: Extreme Temperature Exposure and Adverse Birth Outcomes for Black and White women in North Carolina, April 2023 (extreme heat using North Carolina data, 2011 – 2020); Leonardo Trasande et al., Prenatal Phenol and Paraben Exposures and Adverse Birth Outcomes: A Prospective Analysis of U.S. Births, Environment International, January 2024, 183, https://doi.org/10.1016/j.envint.2023.108378 (low birthweight associated with mother's phenol and paraben exposures).

[576] Clare Brown et al., Geographic Hotspots for Low Birthweight: An Analysis of Counties With Persistently High Rates, Inquiry, October 2020, https://doi.org/10.1177/0046958020950999.

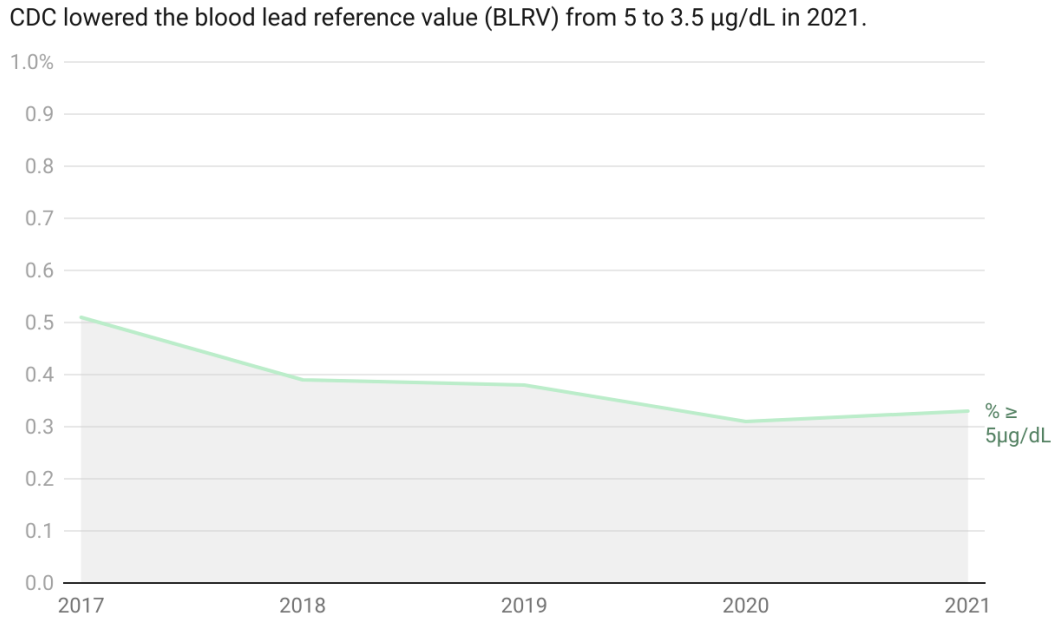
[577] NC DHHS, State Center for Health Statistics, Vital Statistics, Maternal and Child Health Statistics, Total Low Birth Weight, 2014-2022, available here.

Indicator 22.2: Percentage of children with elevated lead levels

Top Line: As a result of improved blood lead level surveillance and remediation of lead exposure sources, the percentage of children under 6 who are found to have elevated blood lead levels has fallen. This is a positive trend.

About children's lead exposure: Of all the toxics that affect North Carolina's children, lead may be the most studied. There is no safe level of lead in blood, and young children are particularly susceptible to the neurotoxic effects of lead, which can result in lasting cognitive deficits, learning disabilities, and behavioral issues.[578] High blood lead levels don't just hurt the kids who are directly exposed; North Carolina data indicates that, controlling for other factors, kids who are not themselves exposed but who have more lead-exposed peers, experience lower high school graduation rates and more suspensions and absences.[579]

Figure 22.2: Percentage of children under 6 tested for lead poisoning who had a result greater than CDC's blood lead reference value



Source: CDC, Childhood Lead Poisoning Prevention Program, Childhood Blood Lead Surveillance: State Data (2017-2021).
• Created with Datawrapper

The federal Centers for Disease Control (CDC) funds state and local health departments to run childhood lead poisoning prevention and surveillance programs. In North Carolina those programs include blood

[578] Mercedes Bravo et al., Spatial Variability in Relationships between Early Childhood Lead Exposure and Standardized Test Scores in Fourth Grade North Carolina Public School Students (2013–2016), Environmental Health Perspectives, September 2024, 132 (9), https://doi.org/10.1289/EHP13898.
[579] Ludovica Gazze et al., The Long-Run Spillover Effects of Pollution: How Exposure to Lead Affects Everyone in the Classroom, Journal of Labor Economics, April 2024, 42 (2), https://doi.org/10.1086/723175.

lead testing and reporting, blood lead surveillance, and improved care and service coordination. These efforts have been successful: the percentage of children under 6 who are found to have a significant blood lead level (BLL) has decreased, as shown in figure 22.2 above. That is a positive trend.

Children have multiple pathways of exposure to lead. The most important is dust from lead paint.[580] Studies have shown particular risk from houses built before 1980 with peeling paint, an estimated 1.7% of houses nationally.[581] Living near an industrial source is a less common risk factor; a 2021 study in Forsyth County found that children whose mothers lived within 2 km of an industrial source of lead at the time of delivery had nearly twice the risk of having a blood level greater or equal to 3 ug/ dL compared to children of mothers living further away.[582] Children are also exposed to lead through products brought or bought from global supply chains that are not subject to food and drug oversight; imported spices are one such source.[583] While lead used to reach Americans from leaded gasoline via dust and dirt on road shoulders, a 2021 study in Durham confirms that legacy contamination from paint is a far larger source of exposure today than legacy contamination from gasoline.[584]

Starting in 2014, the Flint, Michigan water crisis raised the profile of lead in drinking water as a threat. In North Carolina, municipal water supplies are generally safer than private wells. One study has found that children drinking private well water have a 25% greater chance of having elevated blood lead levels than kids drinking city water.[585] A more recent case study found that when a set of homes on well water were hooked up to city water, first-flush lead levels dropped by 92.5%.[586] The first flush is important: when lead shows up in tap water, it is often leaching from plumbing fixtures inside the house (or the

[580] Tyler Sowers et al., High lead bioavailability of indoor dust contaminated with paint lead species, Environmental Science & Technology, January 2021, 55 (1): 402, https://doi.org/10.1021/acs.est.0c06908.
[581] Veronica Garrison and Peter Ashley, Identifying Jurisdictions at Risk of Containing Housing Units With Deteriorated Paint: Results and Targeting Implications for the US Department of Housing and Urban Development, Journal of Public Health Management and Practice, November/December 2021, 27 (6): 546, https://doi.org/10.1097/phh.0000000000001191.
[582] Elizabeth Mary Kamai, dissertation: Lead and Children in North Carolina: Patterns of Lead Testing Across the State and a Case Study of Point Sources in Forsyth County, North Carolina, July 2021.
[583] Kim Angelon-Gaetz et al., Lead Levels in Spices From Market Basket and Home Lead Investigation Samples in North Carolina, Public Health Reports, January 2023, 138 (1), https://doi.org/10.1177/00333549211066152; Tanya Telfair LeBlanc et al., Perspectives on Childhood Lead Exposure Prevention: Looking Back and Looking Ahead, Pediatrics, October 2024, 154 (2), https://doi.org/10.1542/peds.2024-067808C (discussing lead in cinnamon applesauce imported into North Carolina).
[584] Anna Wade, Urban-Soil Pedogenesis Drives Contrasting Legacies of Lead from Paint and Gasoline in City Soil, Environmental Science & Technology, May 2021, 55 (12): 7981, https://doi.org/10.1021/acs.est.1c00546.
[585] Jacqueline MacDonald Gibson, Children drinking private well water have higher blood lead than those with city water, PNAS, July 2020, 117 (29), https://doi.org/10.1073/pnas.2002729117/.
[586] Jacqueline MacDonald Gibson, Effect of Community Water Service on Lead in Drinking Water in an Environmental Justice Community, Environmental Science & Technology, January 2024, 58 (3), https://doi.org/10.1021/acs.est.3c01341.

well system) – so letting the first flush pass before drinking can be an important if ad hoc way to reduce exposure.[587]

Researchers in North Carolina have ranked zip codes by risk of high blood lead level, and have recommended testing all children in the 298 zip codes (out of 808) with the highest risk.[588] Researchers in the 1990s noted a strong correlation between highly segregated communities and high lead levels, and that hasn't changed.[589] Although the state has a strong pediatric screening program, researchers think as many as 30% of children with blood levels over 3 micrograms per deciliter (ug/dL) may be missed.[590] One recent paper includes a map of hot spots of elevated blood lead levels. Looking at results on 4th grade 'end of grade' tests, it shows a clear spatial variation in impacts: for a given level of lead in blood, for example, kids in Gaston and Durham Counties seem worse off while kids in Wake and Union County seem less harmed.[591] It is unclear whether that disparity reflects differences in median household income, synergies with other environmental exposures, the presence of effective programs to counter deficits in some school districts, or some combination of other factors.

Recent developments: As scientists have documented harms from lead exposures at lower and lower levels, federal and state regulators have gradually adjusted health targets and – more slowly – regulatory targets. For many years, even as evidence of harm accumulated, the CDC maintained a blood action level of 10 micrograms/ deciliter (ug/dL). The CDC lowered that to 5 ug/dL in 2012, and to 3.5 ug/dL in 2021.[592] Over the last decade, several policy changes have brought us closer to eradicating childhood lead poisoning in North Carolina. The NC Division of Public Health offers free blood lead testing available to all pregnant women at local health departments, but often screening and testing procedures are recommended only for children "at risk of lead exposure."[593] In 2021, the NC General Assembly enacted SL2021-69 (H272), Revise Health Standard for Lead, lowering the acceptable threshold for lead in drinking water at child care centers from 15 ug/L to 10 ug/L.[594] Child care centers and public schools are now also required to test for and remove lead paint and asbestos, with support

[587] Linnea Wilson et al., Lead occurrence in North Carolina well water: importance of sampling representation and collection techniques, Environmental Research Letters, March 2024, 19 (4), https://doi.org/10.1088/1748-9326/ad2b2c.
[588] Rashida Callender et al., Identifying High-Risk ZIP Codes for Childhood Lead Exposure: A Statewide ZCTA-Level Priority List for North Carolina, North Carolina Medical Journal, March 2024, 85 (2), https://doi.org/10.18043/001c.94878.
[589] Marie Lynn Miranda, Segregation and Childhood Blood Lead Levels in North Carolina, Pediatrics, August 2023, 152 (3), https://doi.org/10.1542/peds.2022-058661.
[590] Elizabeth Kamai et al., Patterns of Children's Blood Lead Screening and Blood Lead Levels in North Carolina, 2011–2018—Who Is Tested, Who Is Missed?, Environmental Health Perspectives, 130 (6), https://doi.org/10.1289/EHP10335.
[591] *Bravo*.
[592] CDC, webpage: CDC Updates Blood Lead Reference Value, October 28, 2021. The CDC estimates that half a million children in the U.S. have a blood level at or above this health value. CDC, webpage: About Childhood Lead Poisoning Prevention, visited March 1, 2025.
[593] Council on Environmental Health, Prevention of childhood lead toxicity, Pediatrics, July 2016, 138 (1), https://doi.org/10.1542/peds.2016-1493.
[594] Fawn Pattison, blog post: Ending childhood lead poisoning in North Carolina, NC Child, October 2022.

from federal relief funds.[595] That's progress, but researchers have found that tap water samples exceeding 2 ug/dL are strongly correlated with blood lead levels above 2 ug/dL the following year among children who drink the water. In that sense, the CDC's current action level of 5 ug/L is probably not sufficient to protect children from developing unsafe blood lead levels, let along the state regulatory level of 10 ug/L.[596]

As part of the Infrastructure Investment and Jobs Act (Pub. L. 117-58, 2021), Congress appropriated $15 billion for the purpose of lead service line inventory and replacement.[597] North Carolina's portion of this appropriation has been between $60-80 million per year since FY22, with funds expected to be allocated to the state through FY26. The DEQ Division of Water Infrastructure (DWI), administering the program through the Drinking Water State Revolving Fund, has been able to fund nearly all project applications to the lead service line replacement program. These awards come as either zero-interest loans, alleviating the burden of interest on the recipient, or principal forgiveness, which allows the recipient to forego repayment altogether.[598]

Indicator 22.3: Children living in poverty

Top Line: The share of children living in poverty in the state has decreased in the last decade. This is a positive trend, although its future is uncertain.

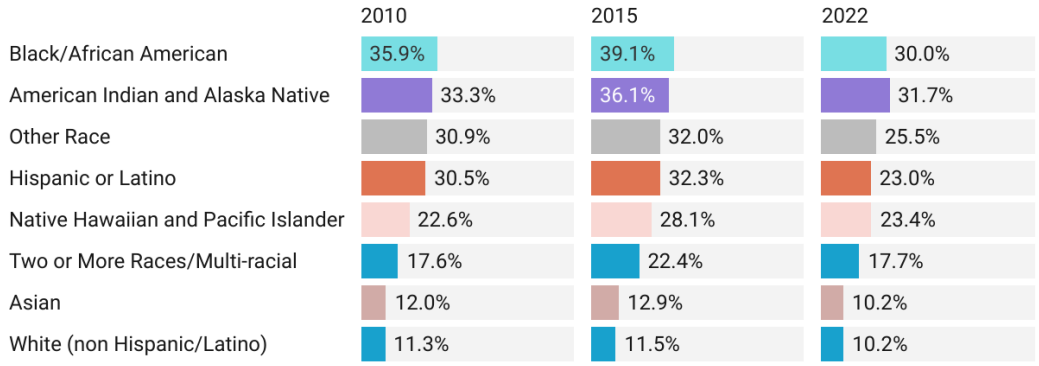
About children in poverty: Public health and child development experts speak of 'adverse childhood experiences': exposure to trauma, abuse, or neglect during childhood that is empirically connected to greater risks of physical and health problems later in life.[599] Healthy NC 2030 sets as a target that by 2030, only 18% of children should have experienced two or more adverse childhood experiences, down from 23.6% in 2020.[600] Living in poverty as a child is itself an adverse childhood experience.[601] Moreover, poverty and exposures to pollution are closely intertwined, with low-income communities facing a disproportionate burden of environmental hazards, such as excessive air pollution (goal 12), poor housing conditions (indicator 27.2), or limited access to clean drinking water (goals 15 and 16) and green

[595] See 10A NCAC 41C .1004 (requiring lead-based paint inspection/abatement) and .1005 (requiring testing and remediation of lead poisoning hazards in drinking water).
[596] Riley Mulhern et al., A new approach to a legacy concern: Evaluating machine-learned Bayesian networks to predict childhood lead exposure risk from community water systems, Environmental Research, March 2022, 204, Part B, https://doi.org/10.1016/j.envres.2021.112146.
[597] US EPA, webpage: Identifying Funding Sources for Lead Service Line Replacement, updated January 17, 2025.
[598] NC DEQ, webpage: Lead Service Line Replacement (LSLR) Funding, visited March 17, 2025.
[599] Shannon Struck et al., Adverse childhood experiences (ACEs) research: A bibliometric analysis of publication trends over the first 20 years, Child Abuse & Neglect, February 2021, 112, https://doi.org/10.1016/j.chiabu.2020.104895; Ana Austin et al., Disability and Exposure to High Levels of Adverse Childhood Experiences: Effect on Health and Risk Behavior, NC Medical Journal, January 2016, 77 (1): 30, https://doi.org/10.18043/ncm.77.1.30.
[600] *Healthy NC 2030*, at 46 – 47.
[601] Rita Hamad et al., Reducing Intergenerational Poverty – An Essential Driver of Health, JAMA Pediatrics, February 2024, 178 (4): 333, https://doi.org/10.1001/jamapediatrics.2023.6510.

spaces (indicator 35.2). Children are especially vulnerable to these hazards, and the confluence of environmental and social risks can contribute to long-term adverse outcomes.

Figure 22.3: Child poverty has improved in NC between 2010-2022

Percentage of children living in households under FPL in NC



Percentages calculated using ACS data.

Source: US Census Bureau, American Community Survey, 2010, 2015, 2022, 5 year estimates of Poverty Status in the Past 12 Months by Sex by Age by Race and Ethnicity, Tables B17001B-I. • Created with Datawrapper

Fortunately, over the last decade, the percentage of North Carolina's children living in households with incomes below the federal poverty limit has declined, with racial and ethnic disparities narrowing as well. We can attribute some of this trend to the improved economic situation in the state after the Great Recession, along with federal pandemic-era tax credits for families. This is encouraging, but progress appears to have slowed and could reverse if the economy slumps.[602]

Goal 23: All North Carolinians have access to sufficient healthy food

Trend: Positive

A healthy diet is a central determinant of an individual's overall health; we consider access to healthy foods an environmental issue because it is shaped by how we farm and how we transport food, and because diet can mediate the impact of pollution exposures.

Access to healthy foods depends on two factors: whether a household can afford to buy food; and whether, even if they can afford to buy it, healthy or fresh foods are available reasonably close by. The local food environment plays an important role in individual and community health, compounding or mitigating other environmental risks. We lack an adequate and timely data source for proximity to

[602] Jason DeBruyn, More than 1-in-6 children in North Carolina are in poverty, federal data shows, WUNC, September 15, 2023; NC Budget & Tax Center, press release: New Census Poverty Data: 1.3 Million Living in Poverty in NC, September 12, 2024.

healthy food. Thus, the trend for this goal defaults to the trend in food insecurity, which is trending positively.

Solutions: North Carolina can help ensure that residents have access to sufficient healthy food by, A3, funding farmland preservation; B3, sustaining farm to school and farm to market programs; B4, encouraging farmland protection plans; and D2, sustaining Medicaid expansion and the Healthy Opportunities pilot program.

Indicator 23.1: Household food insecurity

Top Line: The overall state rate of food insecurity has improved over the last decade and, the state's rate is better than the national rate. We consider this indicator to be improving.

About food insecurity: Food insecurity is defined by the U.S. Department of Agriculture as a household-level condition in which people have limited or uncertain access to nutritionally adequate and safe foods. It is bad for adults and even worse for infants and growing children. Food insecurity, low birth weight, and diabetes are all correlated with infant mortality in North Carolina.[603] Compared to other states, North Carolina has had an unusually high share of children in poverty and suffering from food insecurity, with substantial racial disparities.[604]

To track food insecurity, we rely on the national organization Feeding America, dedicated to closing what it calls the "food gap," the disparity between those who have access to healthy food and those who do not. Feeding America releases an annual report estimating the number of residents of each state that experience food insecurity. In North Carolina, overall food insecurity has steadily dropped over the last decade, from 18.6% of residents experiencing food insecurity to 14% in 2022, a 24% change, even as the total number of households in the state has grown.[605] According to data collected by the USDA on a 2 year rolling average, North Carolina's rate of food insecurity 2021-2023 was 10.9%, below the national rate of 12.2%.[606]

While these are the most recent available data points, it is also virtually certain that food insecurity in North Carolina has increased since then. The two-year pandemic child tax credit and expansions to federal nutrition programs were in effect in 2022; the expanded nutrition assistance expired in August 2023.[607] Following Hurricane Helene, unemployment shot up across western NC and has only gradually

[603] Lisa Cassidy-Vu et al., The correlation between food insecurity and infant mortality in North Carolina, Public Health Nutrition, April 2022, 25 (4): 1038, https://doi.org/10.1017/S136898002200026X.
[604] Gene Nichol and Heather Hunt, The Persistent and Pervasive Challenge of Child Poverty and Hunger in North Carolina, December 2021.
[605] Feeding America, Map the Meal Gap, May 2024; Feeding America, interactive map: 2022 Food Insecurity in North Carolina, May 2024.
[606] USDA, Economic Research Service using US Department of Commerce, Bureau of the Census, Current Population Survey Food Security Supplements data, State Data, 2021-2023.
[607] Brodie Smith, blog post: Food Security in North Carolina, Institute for Emerging Issues, January 22, 2024.

declined; food insecurity has undoubtedly followed the same trajectory.[608] Despite those concerns, we consider rate as improving based on the available data. Like the poverty rate, this is a trend that an economic slump could send in a much different direction.

Indicator 23.2: Access to healthy food options

Top Line: Without physical access to healthy food it is hard to build a healthy diet. However, the available data on so-called 'food deserts' – communities where there are no nearby vendors selling fresh fruits and vegetables – is now out of date, so we do not assign a trend to this indicator.

About healthy food options: Nutrition and lifestyle are well-defined modulators of chronic diseases, and both are considered essential social determinants of health that affect long term health outcomes.[609]

The US Department of Agriculture releases food desert designations every 3 to 5 years on the census-tract level, and defines a food desert as a low-income census tract that is not near a grocery store (10 miles or less for rural areas and less than 1 mile for urban areas). The USDA estimates have not been updated since 2019, but it is worth noting that in 2015, 17.5% of North Carolina residents lived in low-income, low-access areas[610] and that went up to 22.82% in 2019.[611] The 2022 Behavioral Risk Factor Surveillance System asked whether respondents found themselves unable to buy enough food within the last year.[612] Roughly 15% of respondents said that always or sometimes happens, but that's really a marker of affordability rather than physical access. With no current data on access, we do not assign a trend.

The research literature has explored multiple ways to identify and map food deserts.[613] A 2023 study of Rutherford, Guilford, and Bladen Counties (so: west, central, and east) found that food deserts were concentrated in low-income and minority communities, and were particularly clustered in urban

[608] Will Hofmann, Buncombe County unemployment drops to 6%. Still second highest in NC after Helene, Asheville Citizen Times, February 6, 2025.
[609] Bernhard Henning et al., Using Nutrition for Intervention and Prevention against Environmental Chemical Toxicity and Associated Diseases, Environmental Health Perspectives, January 2007, 115(4). https://doi.org/10.1289/ehp.9549.
[610] USDA, interactive web report: Food Access Research Atlas, State-Level Estimates of Low Income and Low Access Populations, update January 2025.
[611] Calculated from USDA Food Access Research Atlas Data Download 2019, updated April 2021, available here.
[612] CDC, Behavioral Risk Factor Surveillance System, website: 2022 Data, updated December 2, 2023.
[613] See, for example, Henry Washington et al., Examining local food deserts using visual analytics, in Christine Leitner, ed., The Human Side of Service Engineering, July 2023, http://doi.org/10.54941/ahfe1003957 (census tracts in Mecklenburg County with more residents of low income or low educational attainment are more likely to be food deserts); Anna Casey and Nicholas Pylypiw, Measuring Food Hardship in North Carolina Communities, NC Medical Journal, March 2022, 83 (2): 126, https://doi.org/10.18043/ncm.83.2.126 (based on the 2019 USDA numbers, in North Carolina, people of color make up 47% of the population of food deserts but only 28% of the population on non-food deserts).

areas.[614] On the other hand, another recent study identified 42 rural census tracts across the state as 'food insecure' as measured by a combination of income levels and lack of access to grocery stores.[615] Residents of eastern NC who identify as food insecure are more likely to identify cost as the crucial issue rather than proximity to a vendor that sells healthy foods.[616]

Recent developments: In addition to damaging many western NC households' incomes, Hurricane Helene damaged the food infrastructure, leaving a much wider swath of the mountain counties without easy access to healthy food.[617]

COMMUNITY HEALTH

Humans are social animals, and the health of our communities has enormous influence on our health as families and individuals. This section focuses on three aspects of community health. Goal 24 considers whether neighborhoods across the state are healthy and treated with respect; we don't assign a trend to two of the indicators and note concerns about the third, a slow slide to greater residential segregation. Goal 25 considers whether North Carolinians are engaged civically and politically; we are. Goal 26 examines the state economy, which has been very strong over the last five years, despite the pandemic. Overall, we see broadly positive trends in community health, with a handful of caveats. That's the best record for any of the major categories in this report.

Goal 24: Neighborhoods are thriving

Trend: Mixed

Social equity is a core component of sustainability, and it is essential to evaluate progress towards equity not just in individual outcomes, but also at the neighborhood and community level. This goal, built from three indicators, expresses the view that development should not push low-income residents into worse conditions, and that neighborhoods with many low-income and minority residents should not have to bear disproportionate environmental risks as compared to other neighborhoods. Residential segregation has slightly worsened; that's bad. We have not found a workable metric to identify whether

[614] Victoria Tanoh and Leila Hashemi-Beni, Spatial Analysis of Socioeconomic Factors Contributing to Food Deserts in North Carolina, Sustainability, May 2023, 15 (10): 7848, https://doi.org/10.3390/su15107848.
[615] Timothy Mulrooney et al., Exploring Rural Food Insecurity in North Carolina: Debunking an Urban Myth, Sociation, 2022, 20 (2): 40.
[616] Mary Jane Lyonnais et al., Examining Shopping Patterns, Use of Food-Related Resources, and Proposed Solutions to Improve Healthy Food Access Among Food Insecure and Food Secure Eastern North Carolina Residents, Environmental Research and Public Health, May 2020, 17 (10): 3361, https://doi.org/10.3390/ijerph17103361.
[617] Jane Winik Sartwell, 'Crisis within a crisis.' Food access woes growing in Western NC months after Helene, Carolina Public Press, December 19, 2024.

gentrification (displacement of communities) is accelerating or slowing, so we do not assign a trend. Toxic air releases are very weakly correlated with low income and minority communities, but that's a snapshot rather than a trend. Neighborhoods across the state are enormously varied, and over any given decade, some are on the upswing while others are in decline. Yet there are enough warning signs that we view neighborhood health in the aggregate as a mixed trend.

Solutions: North Carolina can diversify housing options by L1, supporting scalable affordable housing solutions. Other growth recommendations, L2 – L5, can improve neighborhood quality of life without triggering displacement if done wisely. Additional policies to protect neighborhoods include D1, protecting all North Carolinians from disproportionate burdens; K1, increasing spending on non-highway modes of transportation; K4, improving transportation project prioritization; and K5, implementing Complete Streets.

Indicator 24.1: Residential segregation

Top Line: Based on analysis of 2018-2022 data, Robert Wood Johnson Foundation has determined residential segregation has worsened in North Carolina overall. This is a negative trend.

About residential segregation: The current pattern of neighborhood demographics across much of North Carolina reflects the state's long racial history: three centuries of slavery and one of Jim Crow, including redlining during the New Deal and post-World War II investments that reinforced segregated living patterns.[618] Differences in inherited family wealth, implicit racial prejudice and continued (illegal) discrimination mean that many North Carolinians of color cannot buy or rent in neighborhoods where many white residents can. At the same time, many communities of color feel deep and justified pride in neighborhood history as a testament to achievement in the face of oppression.

We include trends in *de facto* racial residential segregation as an indicator for two reasons. First, segregation correlates with a variety of other social and educational disparities, including lifelong social mobility, length of life, and a host of other metrics.[619] A study of 220 US metro areas from 2001 to 2018

[618] See *Mapping Inequality*; Monica Jimenez et al., Association between historical redlining and neighborhood deprivation in North Carolina, ISEE Conference Abstracts, September 2022, https://doi.org/10.1289/isee.2022.P-0253.

[619] Ryan Gabriel et al., Race, Adolescent Exposure to Segregation, and Adulthood Residential Mobility into and out of Lower-Poverty Neighborhoods, Spatial Demography, November 2021, 9: 309, https://doi.org/10.1007/s40980-021-00090-x (social mobility); Lu Zhang et al., Association of Residential Segregation with Mortality in the U.S., 2018-2022, American Journal of Preventative Medicine, January 2025, https://doi.org/10.1016/j.amepre.2025.01.010 (mortality). For North Carolina studies offering examples of other correlates, see Margaret Sugg et al., Structural influences on psychiatric emergency department visits among racial and ethnic minority youth in North Carolina: A neighborhood-level analysis, Health & Place, November 2024, 90, https://doi.org/10.1016/j.healthplace.2024.103379 (higher levels of severe mental health conditions); Marie Miranda et al., Segregation and Childhood Blood Lead Levels in North Carolina, Pediatrics, September 2023, 152 (3), https://doi.org/10.1542/peds.2022-058661 (child blood lead levels); Susan Mason et al., Segregation and

found that communities where residential segregation increased tended to show no narrowing of racial health disparities over time.[620] Second, neighborhoods that are heavily populated with residents of color have often been targeted for the siting of facilities that pose risks to neighbors.[621] The more residential segregation we have, the greater the opportunities for environmental injustice.

To track residential segregation, we use an index calculated by the Robert Wood Johnson Foundation (RWJ). The measure reflects the degree to which the demographic distribution of census tracts within each county differs from the distribution in the county as a whole. As RWJ explains, "The index score can be interpreted as the percentage of white or non-white residents that would have to move to different geographic areas in order to produce a distribution that matches that of the larger area."[622] Also known as a dissimilarity index, this is just one of several ways to measure racial residential segregation. A rich literature debates the pros and cons of different metrics for segregation, but the data for this one is readily available, making it a practical choice.[623]

Our analysis relies on data from the most recent 2018-2022 American Community Survey of the US Census. The analysis does not assess ethnicity (segregation or integration of Hispanic or Latino residents). The index values of Black/White residential segregation vary from 10 to 76; the overall state index for segregation is 52, up from 50 from the 2019 County Health Rankings (using 2012-2016 data). We consider that a trend in the wrong direction. For comparison, from 2000 to 2020, neighborhood integration improved 'steadily and considerably' across the United States, so North Carolina's trend is an outlier.[624] Because of school assignment policies, school diversity can operate somewhat independently of neighborhood diversity. Still, a recent study found that while North Carolina's overall public school enrollment became much more diverse from 1989 to 2021, patterns of segregation intensified, with

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preterm birth: the effects of neighborhood racial composition in North Carolina, Health & Place, March 2009, 15 (1): 1, https://doi.org/10.1016/j.healthplace.2008.01.007 (preterm birth).

[620] Michael Siegel et al., Association Between Changes in Racial Residential Segregation and Trends in Racial Disparities in Early Mortality in 220 Metropolitan Areas, 2001–2018, Journal of Racial and Ethnic Health Disparities, October 2023, 11: 3782, https://doi.org/10.1007/s40615-023-01830-z.

[621] Danielle Purifoy, North Carolina [Un]incorporated: Place, Race, and Local Environmental Inequity, American Behavioral Scientist, July 2019, 65 (8), https://doi.org/10.1177/0002764219859645 (TRI releases, brownfields, landfills correlated with racial composition of census block group).

[622] Robert Wood Johnson Foundation, County Health Rankings & Roadmaps: Residential Segregation, 2018 and 2024.

[623] Another key aspect of segregation, distinct from dissimilarity, is isolation: whether members of a demographic group encounter members of other demographic groups on a regular basis. See, Robert William Pendergrass, The Relationship between Urban Diversity and Residential Segregation, Urban Science, September 2022, 6 (4): 66, https://doi.org/10.3390/urbansci6040066; and more comprehensively, Amber Crowell and Mark Fossett, Racial and Ethnic Residential Segregation Across the United States, Springer Series on Demographic Methods and Population Analysis 54, June 2023, https://doi.org/10.1007/978-3-031-38371-7.

[624] Matthew Mleckzo, Trends and Characteristics of U.S. Metropolitan Neighborhood Integration, 2000–2020, Urban Affairs Review, September 2024, https://doi.org/10.1177/10780874241278619. Mleckzo notes that despite the positive national trend, most neighborhoods remain 'persistently segregated'.

students more likely to attend schools with a higher percentage of same-race peers.[625] That's consistent with the negative trend we've found for neighborhoods.

Indicator 24.2: Gentrification of communities

Top line: The concept of gentrification is slippery; it is often used informally to mean rapid price increases in a neighborhood. What we mean by it is more specific: the experience of being forced by changing rents or property values to leave one's long-established community to relocate to a neighborhood with a poorer quality of life and less opportunity. But there's little data to evaluate how many North Carolinians have had that experience, and whether it is getting more or less common. For that reason, we discuss the available research below, but don't assign a trend to this indicator.

About gentrification: In 2019, we also did not assign a trend to this indicator. We noted that most academic definitions of gentrification were built to apply in America's largest cities. By those definitions, a total of four census tracts in North Carolina might be said to have gentrified in the decade before 2019. Yet, many residents of Raleigh, Charlotte, and other North Carolina cities would say their neighborhoods have experienced rapid redevelopment and a turnover of residents.

In the five years since our first report, the literature on gentrification has become more nuanced, with researchers defining it in a variety of ways.[626] One of the simplest is to consider a neighborhood gentrifying when the percentile of the average home value rises significantly above the percentile of the median income – that is, current residents of the neighborhood can no longer afford to buy or rent there.[627] That's a problem for housing affordability, discussed in indicators 27.1 and 27.2, but omits loss of community as a component. Researchers have suggested that gentrification can look different in mid-sized Southern US cities (Charlotte, Raleigh, Durham, Greensboro) because they start with low-density land use patterns, but the process still involves rapid increases in property values and changes in the kinds of jobs, levels of educational attainment, and median income of a neighborhood's residents. By that measure, parts of Charlotte gentrified from 2010 to 2016, with homes in traditionally Black neighborhoods being replaced with large single-family residences or luxury condos and townhomes.[628]

Some researchers focus more what happens to residents.[629] Gentrification is not, as it turns out, closely associated with evictions. Those are steadily high in low-income communities and fall in gentrifying

[625] Jennifer Ayscue et al., Can Our Schools Capture the Educational Gains of Diversity? North Carolina School Segregation, Alternatives and Possible Gains, May 2024.
[626] Nrupen Bhavsar et al., Defining gentrification for epidemiologic research: A systematic review, PLoS One, May 2020, 15 (5), https://doi.org/10.1371/journal.pone.0233361.
[627] Devin Michelle Bunten et al., Re-measuring gentrification, Urban Studies, May 2023, 61 (1), https://doi.org/10.1177/00420980231173846.
[628] Daniel Yonto and Jean-Claude Thill, Gentrification in the U.S. New South: Evidence from two types of African American communities in Charlotte, Cities, February 2020, 97, https://doi.org/10.1016/j.cities.2019.102475.
[629] Ashley Qiang et al., working paper: Displacement and Consequences of Gentrification, November 2021.

communities.[630] Does gentrification force longtime residents to move out of the community? A national analysis of gentrification across the 2010s found different answers in different types of cities, with residential mobility most strongly correlated with gentrification in college towns (Durham, Chapel Hill) and retirement destination metros (Wilmington), with a weaker response in larger southern cities.[631] Other researchers have noted that capturing gentrification as it is experienced by neighborhood residents may require data mapped at the building or parcel level rather than the census track.[632] Such studies are vanishingly rare.

Recent developments: Over the last five years, researchers have taken a particular interest in whether investments in public goods – especially greenways, parks, and transit – can trigger gentrification. An influential national study in 2019 found that park function and location, not size, were predictors of gentrification; greenway parks and parks near downtowns fostered gentrification more than others.[633] In Raleigh, greenways increased nearby property values by 4% to 12%, but it is not clear whether this contributed to gentrification.[634] More hopefully, researchers have identified strategies that can help ensure that parks benefit neighborhoods without triggering gentrification.[635] The evidence for the impact of transit is also mixed and much seems to depend on local context.[636] In Charlotte, for example, light rail appears to have helped rather than hurt existing commercial businesses in the vicinity of new stations.[637]

Indicator 24.3: Correlation of toxic chemical releases with race, income

Top Line: Toxic chemicals released into the air are known to cause harm to people and the environment. Although there is data available on the chemicals released, there is not a consistent data source which

[630] Peter Hepburn et al., Beyond Gentrification: Housing Loss, Poverty, and the Geography of Displacement, Social Forces, September 2023, 102 (3): 880, https://doi.org/10.1093/sf/soad123.
[631] Hyojung Lee and Kristin Perkins, The Geography of Gentrification and Residential Mobility, Social Forces, April 2023, 101 (4): 1856, https://doi.org/10.1093/sf/soac086.
[632] Daniel Yonto and Claire Schuch, Developing and Ground-Truthing Multi-Scalar Approaches to Mapping Gentrification, Papers in Applied Geography, July 2020, 6: 352, https://doi.org/10.1080/23754931.2020.1789499.
[633] Alessandro Rigolon and Jeremy Nemeth, Green gentrification or 'just green enough': Do park location, size and function affect whether a place gentrifies or not?, Urban Studies, July 2019, 57 (2): 402, https://doi.org/10.1177/0042098019849380.
[634] Lee Parton, Measuring the effects of public land use change: An analysis of greenways in Raleigh, North Carolina, Land Use Policy, August 2023, 131, https://doi.org/10.1016/j.landusepol.2023.106689.
[635] Alessandro Rigolon and Jon Christensen, blog post: Greening Without Gentrification, Parks & Recreation Magazine, November 2019; Alessandro Rigolon and Jon Christensen, Greening Without Gentrification, November 2019 (outlining 'parks-related anti-displacement strategies').
[636] Elizabeth Delmelle, Transit-Induced Gentrification and Displacement: The State of the Debate, in Social Issues in Transport Planning, Advances in Transport Policy and Planning, 2021, 8: 173, https://doi.org/10.1016/bs.atpp.2021.06.005.
[637] Chang Liu and Eleni Bardaka, Transit-induced commercial gentrification: Causal inference through a difference-in-differences analysis of business microdata, Transportation Research Part A: Policy and Practice, September 2023, 175, https://doi.org/10.1016/j.tra.2023.103758.

quantifies the impact on people. We have calculated a very weak positive baseline correlation between toxic releases to air and low-income communities of color in the state.

About the spatial distribution of toxic chemical releases: US EPA's Toxics Release Inventory (TRI), established by the federal Emergency Planning and Community Right to Know Act (EPCRA), requires companies that meet certain criteria to report their annual releases of specific chemicals to EPA.[638] Although the inventory does not cover all pollutants or facilities, TRI releases are significantly correlated with health risks at the county level including increased cancer hospitalization rates,[639] and higher mortality rates for cardiovascular disease.[640] As of 2023, there are 771 TRI facilities in North Carolina, and the state ranks 13th of all states and territories nationwide based on total releases per square mile.[641]

In the 2019 State of the Environment report, we cited the 2014 TRI's national demographic analysis tool, which included the percentage of residents within a mile of a TRI facility who are people of color, and the percentage who live in poverty. The analysis found that in North Carolina, out of a total state population of 9.5 million residents, roughly 1.2 million lived within 1 mile of a facility that reported releases of pollution to the TRI. Of that 1.2 million, 45% were 'minorities', and 21% were living in poverty. That contrasts with the overall state population in 2014, of which 28.5% were people of color and 17.2% were in poverty. In other words, people in poverty were a bit more likely to live near a TRI facility than the general population, while people of color were significantly more exposed than whites.

Given that recent TRI updates do not include demographic analysis of risk, for this update we have instead calculated the correlation between two indicators from the most recent version of the EPA's EJScreen Tool: the demographic index, and the "toxic releases to air" indicator, a percentile rank of average annual chemical concentrations in the air, weighted by toxicity of each chemical. The toxics releases to air index is calculated from the 2021 Risk-Screening Environmental Indicators (RSEI) Geographic.[642] Using EJScreen's 2023 data, we found the two indicators are very weakly correlated, with a correlation coefficient of 0.042. It's good news that the correlation is weak, but it is a baseline rather than a trend.

Recent developments: The concept of environmental justice offers one way to make sense of the disparate environmental burdens placed on some neighborhoods. Environmental justice is a homegrown North Carolina concept, born in Warren County from 1978 to 1982, when residents protested the relocation of PCB-contaminated soils from across the state to a new landfill in their poor,

[638] 42 USC §11023, Emergency Planning and Community Right to Know Act §313. See also, US EPA, website: Basics of TRI Reporting, June 2024

[639] Michael Hendryx and Juhua Luo, Cancer hospitalizations in rural-urban areas in relation to carcinogenic discharges from Toxics Release Inventory facilities, Int J Environ Health Res., July 2013, 23(2), doi: 10.1080/09603123.2012.708919.

[640] Michael Hendryx et al., Total and cardiovascular mortality rates in relation to discharges from Toxics Release Inventory sites in the United States, Environ Res, August 2014, 133: 36, doi: 10.1016/j.envres.2014.05.010.

[641] US EPA, 2023 TRI Factsheet: State – North Carolina, October 2024.

[642] US EPA, EJScreen Indicators Overview – Toxic Releases to Air, visited June 2024.

rural, and mostly Black community.[643] Environmental justice recognizes that communities of color and low income communities have often gotten the short end of the stick, with more sources of pollution, weaker enforcement of regulatory protections, and less investment of public dollars in local infrastructure and environmental amenities.[644] Environmental justice advocacy is, at its core, about ensuring equal rights to environmental protection in the places we live, work, play, and pray regardless of our race, color, national origin, disability, or income.

The Biden administration advanced environmental justice both directly and indirectly, integrating the concept deeply into actions tackling climate change. In his first week in office, President Biden issued Executive Order 14008, establishing both an interagency environmental justice council and advisory council with non-governmental members, and committing to direct at least 40% of the overall benefits of federal climate and clean energy investments to disadvantaged communities.[645] In April 2023, the administration followed up with Executive Order 14096, expanding the Justice40 policy to more federal agencies and publishing an environmental justice scorecard for federal agencies.[646] At US EPA, Administrator Michael Regan prioritized attention to communities overburdened with pollution, although progress was difficult and the agency stepped back after some reverses in court.[647]

In North Carolina, former Governor Roy Cooper issued Executive Order 246 in January 2022, directing each agency to establish an 'environmental justice' lead, and to develop a public participation plan to better ensure that state agencies were communicating with all North Carolinians.[648] Twenty-one months later he followed up with Executive Order 292, establishing the Governor's Environmental Justice Advisory Council (EJAC), composed of 22 members divided between agency leads and members of the public.[649] In October 2024, the EJAC offered a set of recommendations for improving the state's ability to address environmental justice concerns, ranging from improving data collection and analysis to avoiding duplication between state programs.[650]

In the early months of 2025, the second Trump Administration has rejected the concept of environmental justice, rolling back executive orders on environmental justice and protections for civil rights not just to federal EO 12898, Federal Actions to Address Environmental Justice (1994), but all the

[643] Elizabeth Blum, 'Warren County, N.C.', in The New Encyclopedia of Southern Culture: Volume 8: Environment, 2007, at 275–276.
[644] Dorceta Taylor, Toxic Communities: Environmental Racism, Industrial Pollution, and Residential Mobility, 2014.
[645] Executive Order 14008 (EO 14008), Tackling the Climate Crisis at Home and Abroad, January 27, 2021 (link at National Archives); see also, White House, blog post: Justice40: A Whole of Government Initiative, no date (link at National Archives).
[646] Executive Order 14096 (EO 14096), Revitalizing Our Nation's Commitment to Environmental Justice for All, April 21, 2023 (link at Federal Register).
[647] Lisa Friedman, EPA Chief Vows to 'Do Better' to Protect Poor Communities, New York Times, January 26, 2022; Vann Newkirk II, Why the EPA Backed Down, The Atlantic, September 23, 2024.
[648] Executive Order 246 (EO 246), North Carolina's Transformation to a Clean, Equitable Economy, January 7, 2022. The public participation plans are available at Office of the Governor, webpage: Environmental Justice, visited March 26, 2025.
[649] Executive Order 292, Advancing Environmental Justice for North Carolina, October 24, 2023.
[650] Governor's Environmental Justice Advisory Council, Final Report, October 15, 2024.

way back to Executive Order 11246, Equal Employment Opportunity (1965). The administration has frozen funding for federal grants that mention environmental justice and fired agency staff with environmental justice in their titles. Several of these actions contradict federal laws enacted by Congress and have been reversed by the courts.[651] However this plays out in the short term, overburdened communities have moral and in some cases legal claims that aren't likely to go away.

Goal 25: North Carolinians are engaged in civil society

Trend: Positive

Healthy communities depend on trust, social cohesion, and civic participation, all of which can be challenging to measure directly. To evaluate engagement in civic society, we consider indicators of social connectedness, voter registration and participation, and engagement with cultural and natural heritage sites. All these indicators have shown positive or stable trends over the last 5-10 years, adding up to positive civic engagement overall.

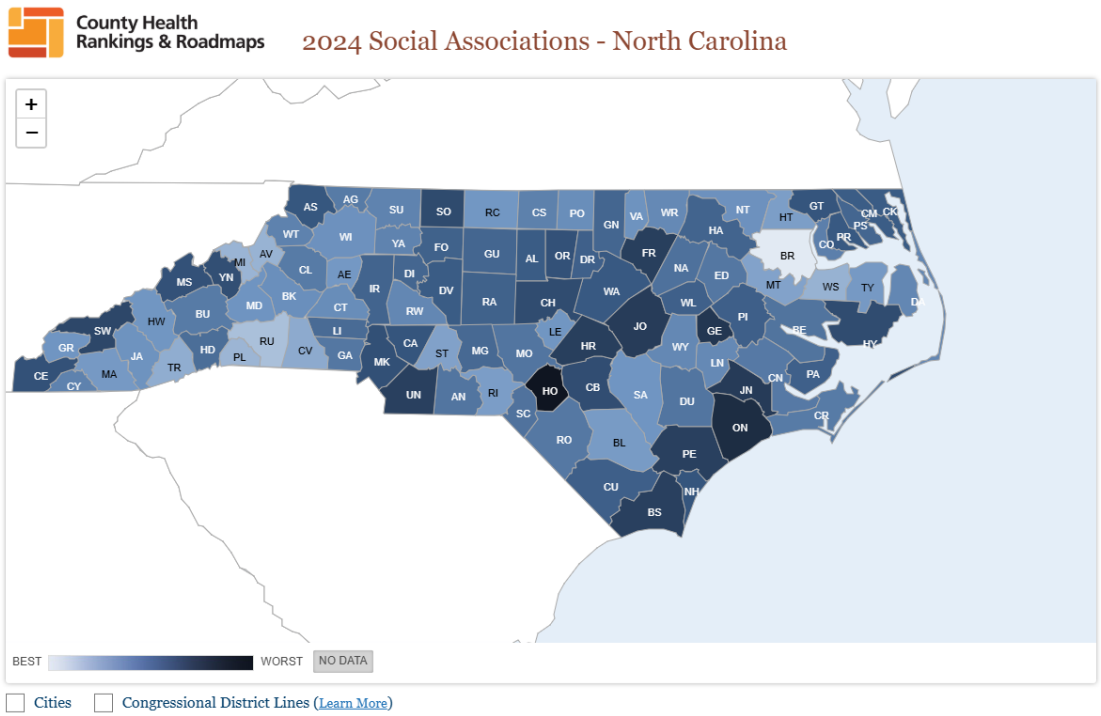
Solutions: N1, Enacting automatic voter registration; N2, enacting a nonpartisan redistricting process; and N3, accommodating multiple languages, will encourage North Carolinians to participate in civic society.

Indicator 25.1: People are connected

Top line: North Carolinians' participation in membership associations has remained consistent over the last decade and ranks higher than most other states in the country, according to an analysis from the Robert Wood Johnson Foundation. We consider this a positive trend.

About social connectedness: One way to evaluate social connectedness is to count the number of different social organizations to which state residents belong, on the premise that, apart from work and family, this is how most people know each other and build community. This indicator, compiled by the Robert Wood Johnson Foundation (RWJ), tracks the number of membership organizations in the state, calculated by adding up numbers of entities with specific North American Industry Classification System (NAICS) codes, covering civic groups, labor and business groups, certain recreational centers, and religious and professional organizations.[652]

[651] Lisa Friedman, EPA Plans to Close All Environmental Justice Offices, New York Times, March 11, 2025; Lylla Younes, The end of the EPA's fight to protect overpolluted communities, Grist, March 17, 2025.
[652] RWJ Foundation, Health Factors: Social Associations, County Health Rankings & Roadmaps, 2024.



The indicator expresses that sum as the number of membership associations per 10,000 residents. Using data from 2021, RWJ estimates a statewide value of 11.3 associations per 10,000 population, with individual counties in the state varying from 6.8 to 26.7.[653] The statewide value is virtually unchanged for the last nine years, and places North Carolina among the top tranche of states, so we count this as positive. Notably, rates are worst in the most remote mountain and coastal communities, in counties with military bases (with young, relatively transient service members), and exurban fringe counties that are experiencing a rapid build-out of commuter subdivisions.

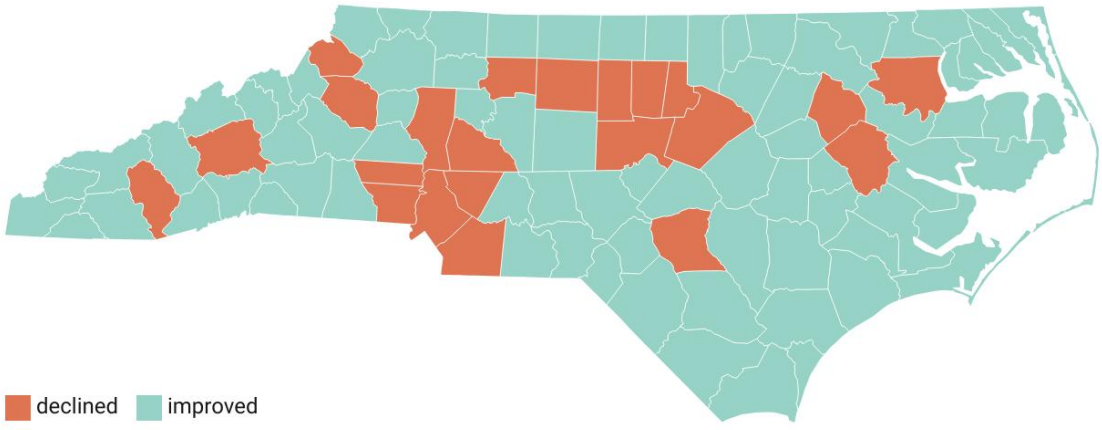
Indicator 25.2: Voter registration

Top line: Voter registration is a measure of engagement in our democracy. From 2012 through 2024, registration rose in 78 counties and declined in 22 counties; those 22 counties that saw declines are among the most populous in the state. There is also some evidence that overall voter registration was higher in 2024 than in election years past. We consider this to be a positive trend.

About voter registration: Democracy relies on the participation of citizens, and the most fundamental form of engagement is voting. This indicator tracks the percentage of individuals over the age of 18 who are registered to vote. It may include individuals who are ineligible to vote for reasons other than lack of citizenship; in North Carolina, convicted felons cannot vote while in prison, on parole, or on probation. However, voting rights are automatically restored when supervised release is completed – though, as with any other resident, the individual must register to vote.

[653] RWJ, County Health Rankings & Roadmaps, 2024.

Map 25.2: Voter registration improving or declining between 2012 and 2024



Source: NC OSMB, Percentage of Voting Age Population Registered to Vote, 2024, 2012 • Created with Datawrapper

Health researchers have noted the connections between civic and democratic engagement and health outcomes.[654] Voting helps to guide policy, programs, and resource allocations by local, state, and federal governments; voter registration is the threshold step to participate in elections. Towns and counties that are home to historically disenfranchised populations tend still, even decades after passage of the Voting Rights Act, to suffer poor environmental conditions.[655]

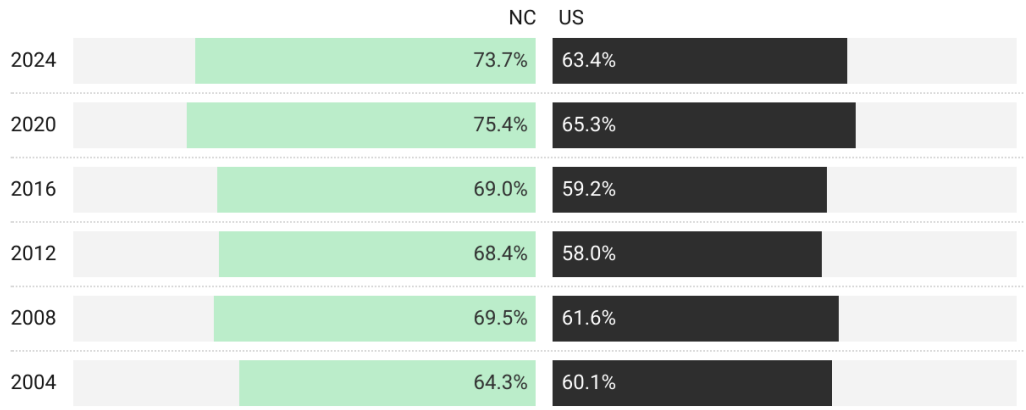
The map above compares the percentages of eligible voters registered to vote in 2012 to those registered to vote in 2024.[656] Right off the bat, it's clear that more densely populated counties saw declines in registration while less populated counties saw growth. Data on voter registration can vary from source to source, and statewide tabulations are often delayed as a result of litigation or data inconsistencies upstream. Still, based on unsophisticated analysis of data from the NC State Board of Elections, voter registration of eligible voters seems to have been higher in 2024 than in 2020.[657] Both county and state level data suggest that the rate of voter registration for eligible voters in the state is improving.

Indicator 25.3: Voter turnout

[654] Brooke Stanicki, et al, Expanding voter registration to clinical settings to improve health equity, Health Services Research, August 2023, 58 (5): 970, doi: 10.1111/1475-6773.14218.
[655] Clean Air Task Force, Understanding Disenfranchised and Underserved Communities in the U.S., November 2023.
[656] NC OSMB, Percentage of Voting Age Population Registered to Vote, 2024, 2012.
[657] NC State Board of Elections, Voter Registration Statistics Search.

Top line: Voter turnout in North Carolina significantly outpaces national voter rates and has improved over the last two decades, a positive trend.

Table 25.3: Percentage of registered voters who voted in general elections



Source: NC Data from NC State Board of Elections. US Data from UC Santa Barbara, the American Presidency Project • Created with Datawrapper

About voter turnout: A second step of political engagement, for registered voters, is turning out to vote. This indicator tracks the percentage of registered voters who actually vote, as tallied by the North Carolina State Board of Elections.[658] Participation in party primaries, particularly in midterm election years, when no US Presidential candidate is on the ballot, remains abysmally low. Voting in the general election, especially in Presidential election years, is above 70%, rising gradually from a period of apathy in the 1990s. Voter turnout in the state has been improving over the last two decades and our rates are consistently higher than national rates, adding up to a positive trend.

Indicator 25.4: Engagement with cultural and natural heritage sites

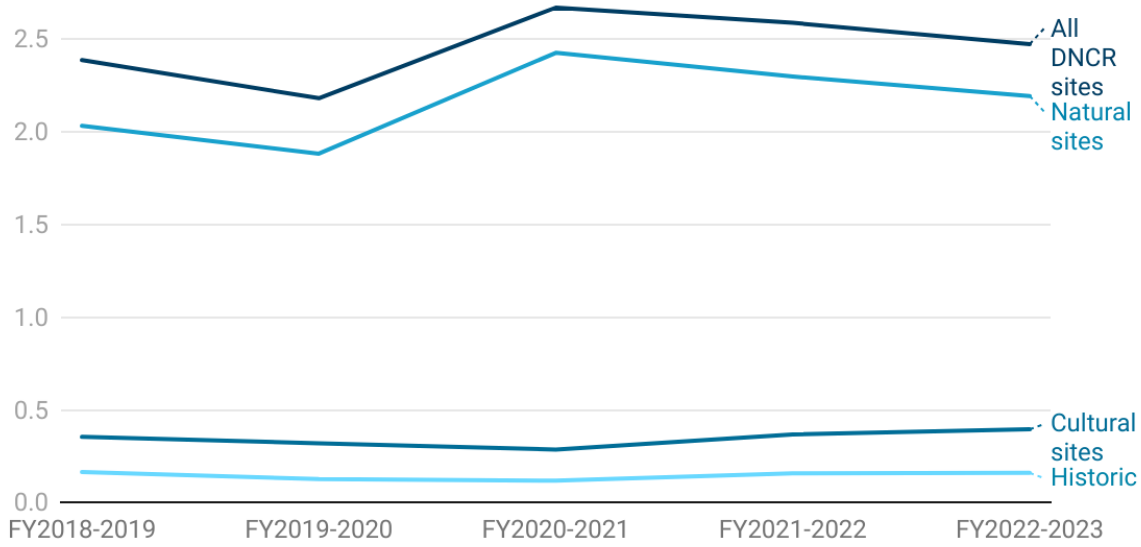
Top line: Per capita visits to cultural and natural heritage sites have rebounded since COVID-19 closures and social distancing requirements in 2020 and 2021. This is a positive trend.

About engagement with heritage sites: This indicator tracks the visitor count at the state's public historic, cultural, and natural attractions as a loose way of measuring North Carolinians' sense of attachment to state's landscape, with all its historical and cultural connections. The available data does not distinguish between visitors from within North Carolina and tourists from out of state, but we think it is still a useful signal of residents' engagement with our state identity. Historic attractions include State Historic Sites, Tryon Palace, the Roanoke Island Festival Park, and the battleship North Carolina.

[658] NC State Board of Elections, webpage: Voter Turnout, visited April 2, 2025 (North Carolina data); UC Santa Barbara, The American Presidency Project, webpage: Voter Turnout in Presidential Elections, updated February 2, 2025.

Cultural venues include the state art and history museums, and the NC symphony. Natural locations include the State Park System, the zoo, the aquariums, and the natural history museum. Altogether, state natural and cultural sites show a steady increase in annual visits, indicating a lively interest in the state's culture, history, and landscapes.[659] Not surprisingly, the data shows a dip during the COVID-19 pandemic, but visitor numbers have already rebounded and are now higher than they were pre-pandemic.

Figure 25.4: Visits to state natural and cultural heritage sites per capita



Source: By special request to NC Department of Natural & Culture Resources, July 2024. • Created with Datawrapper

Goal 26: North Carolina's economy enables broad prosperity.

Trend: Positive

Household economic wellbeing is important for many reasons. Among others, and relevant to the purposes of this report, it correlates with health and environmental outcomes. Low income residents typically face compounding challenges to their health. They are more likely to live near stationary pollution sources, breathe higher concentrations of car and truck exhaust, have to travel farther to access green space, and may have difficulty accessing health coverage or care. Conversely, families with a solid household income can afford more nutritious food and safer consumer products, may have more housing options, and be better positioned to protect themselves from environmental threats (for

[659] Data provided by NC Department of Natural & Cultural Resources, July 2024, on file.

example, buying water filters to protect themselves from drinking water contamination). We track the broad economic well-being of North Carolinians with four indicators: median household income (indicator 26.1), percentage of households in poverty (indicator 26.2), whether median income is sufficient to support a family (indicator 26.3) and distribution of educational attainment (indicator 26.4). Across the last ten years, median income shows a mixed trend, and the other three indicators are all positive, for a positive trend for this goal overall.

Solutions: Environmental policies that improve household economic outlook tend to fall in two categories. A suite of public policies directly lower the costs of housing (L1-L3), transportation (K1), energy (J1 -J3, J9 and J10) and water (G10). A slew of other policies reduce pollution exposures, improve education and job opportunities, and broaden health access, increasing opportunities for residents to enjoy materially comfortable lives free of crushing medical expenses.

Indicator 26.1: Median household income

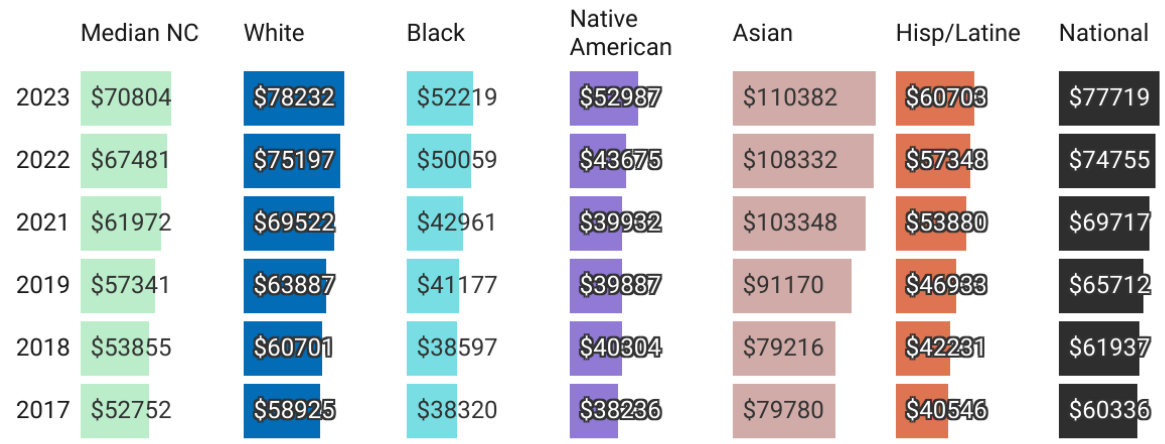
Top line: Median income has grown overall, but the improvements are felt by some residents, not all. We consider this a mixed trend.

About median household income: We track 'median' rather than 'average' household income as an indicator because median income is not skewed by the highest earners in the state. Median income varies widely by county and provides a clear look at income disparities by race and ethnicity. In 2023 the overall median household income was $70,804 in North Carolina, but the breakdown by race and ethnicity tells a more nuanced story.[660] In North Carolina, residents identifying as American Indian/Native American have the lowest household income. Not only that, but between 2018 and 2023, median household income changed the least for Native Hawaiian/Pacific Islanders and American Indians/Native Americans.[661]

[660] US Census Bureau, American Community Survey, 2023, Survey Table 1903.
[661] US Census Bureau, American Community Survey, 2018 and 2023, Survey Table 1903.

Figure 26.1: NC disparities in median household income by race and ethnicity remain consistent

Median income reported in USD



Source: US Census Bureau, American Community Survey, 2017-2023, Survey Table 1903. • Created with Datawrapper

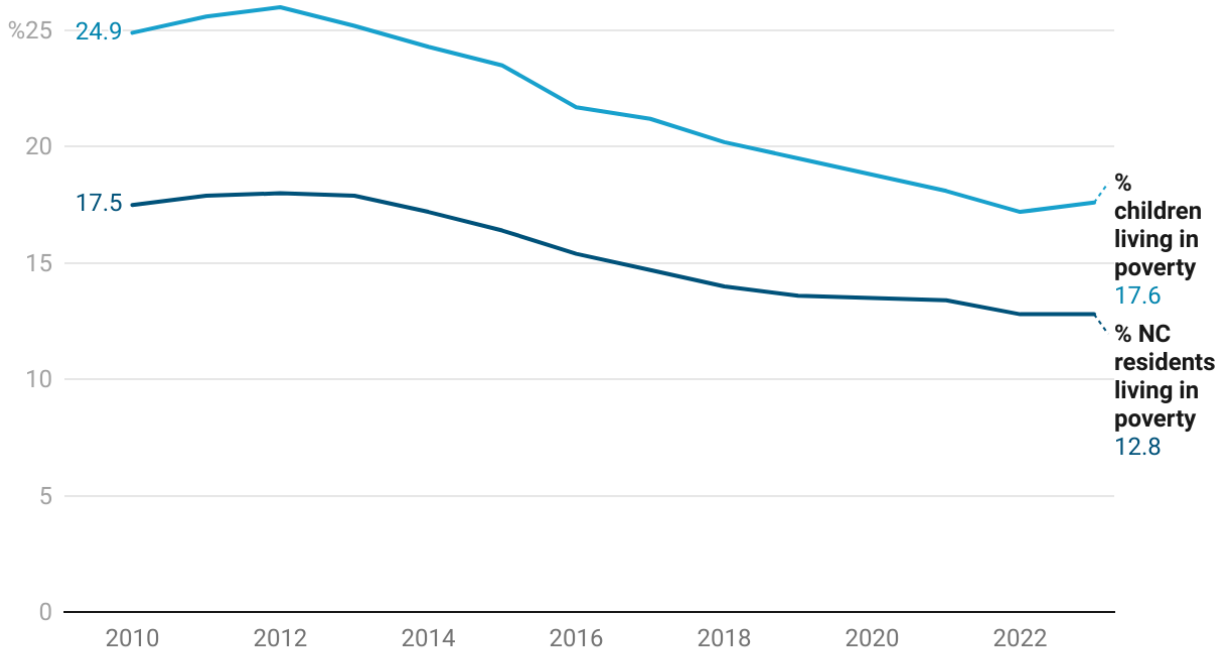
In the same period, the disparity between median household income for Black North Carolinians and white North Carolinians worsened, but the disparity between Hispanic residents (of any race) and non-Hispanic white residents improved slightly. This data shows mixed trends; overall, median income has increased, but some demographic disparities have as well. We consider this a mixed trend.

Indicator 26.2: Share of North Carolinians living in poverty

Top line: For the last decade, even as North Carolina's population has rapidly grown, the percentage of North Carolinians in poverty (incomes under the federal poverty level) has steadily dropped, from 17.2% in 2014, to 12.8% in 2023. The percentage of children in poverty is always higher, but – as noted under indicator 22.3 – that has dropped also, from 24.1% in 2014, to 17.6% in 2023. Both trends are excellent.

About people living in poverty: The federal poverty level (FPL) is determined and released annually by the Department of Health & Human Services. FPL is used to determine eligibility for certain federal and state assistance programs, families earning up to 200% of FPL are eligible for the Supplemental Nutrition Assistance Program (SNAP), and individuals or families earning 138% of FPL are eligible for Medicaid health coverage. In 2023, the FPL was $24,860 for a family of three in 2023, and $30,000 for a family of four.

Figure 26.2: Smaller share of North Carolinians live in poverty in 2023



Source: Census Bureau, American Community Survey, 2010-2023. Table S1701. • Created with Datawrapper

For this indicator, we track the estimated percentage of children and of all North Carolinians living in poverty, that is, living in households with incomes below the applicable federal poverty threshold given the size of the household. Over the last decade, the share of North Carolina households in poverty, and the share of children living in poor households, has steadily declined; that's a great trend.

Indicator 26.3: Jobs provide sufficient income

Top Line: This indicator asks, in how many counties is the median income sufficient to support a family with kids (one adult and one child, or two adults and two children)? From 2017 to 2023, more counties achieved that milestone, marking a positive trend.

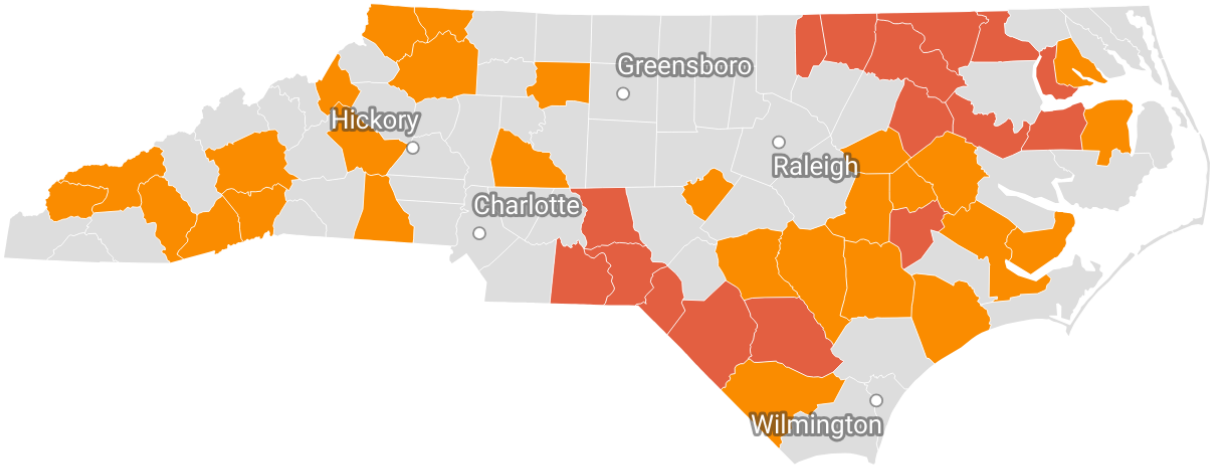
About income sufficiency: Federal poverty measures do not account for regional differences in costs of living. In 2023, the United Way of North Carolina and the Center for Women's Welfare at the University of Washington School of Social Work co-released an analysis of how much income a family must earn to meet basic needs, not just costs for housing and food, but also for child care, transportation, health care, and taxes.[662] The analysis showed that, for a single adult with a young child, or a couple with two young children, the federal poverty line is much too low. The 'sufficiency income' required is much

[662] Center for Women's Welfare, University of Washington, North Carolina Self-Sufficiency Standard, 2023, available here.

greater than what can be earned on a minimum wage, and in many counties, the calculated standard is even above median household income (MHI).

This indicator tracks the number of North Carolina's 100 counties where the sufficiency standard is at or above the median household income for the county, meaning that half of two parent households in the county (those below the median income) cannot afford to have two young children, and half of one parent households cannot afford to have one young child without some kind of government or other external subsidy. We have compared the Center for Women's Welfare's calculated sufficiency standards to data from the US Census Bureau's American Community Survey and found that in the median household income is insufficient in 44 of 100 counties in the state.[663]

Map 26.3: Median Household Income is not enough to support families with children in 44 of 100 counties, 2023



Source: North Carolina Self-Sufficiency Standard (2023) at the Center for Women's Welfare, University of Washington. & US Census Bureau, American Community Survey, 2022, 5 year estimates of Median Household Income for families with children under 18, Survey Table 1903. • Created with Datawrapper

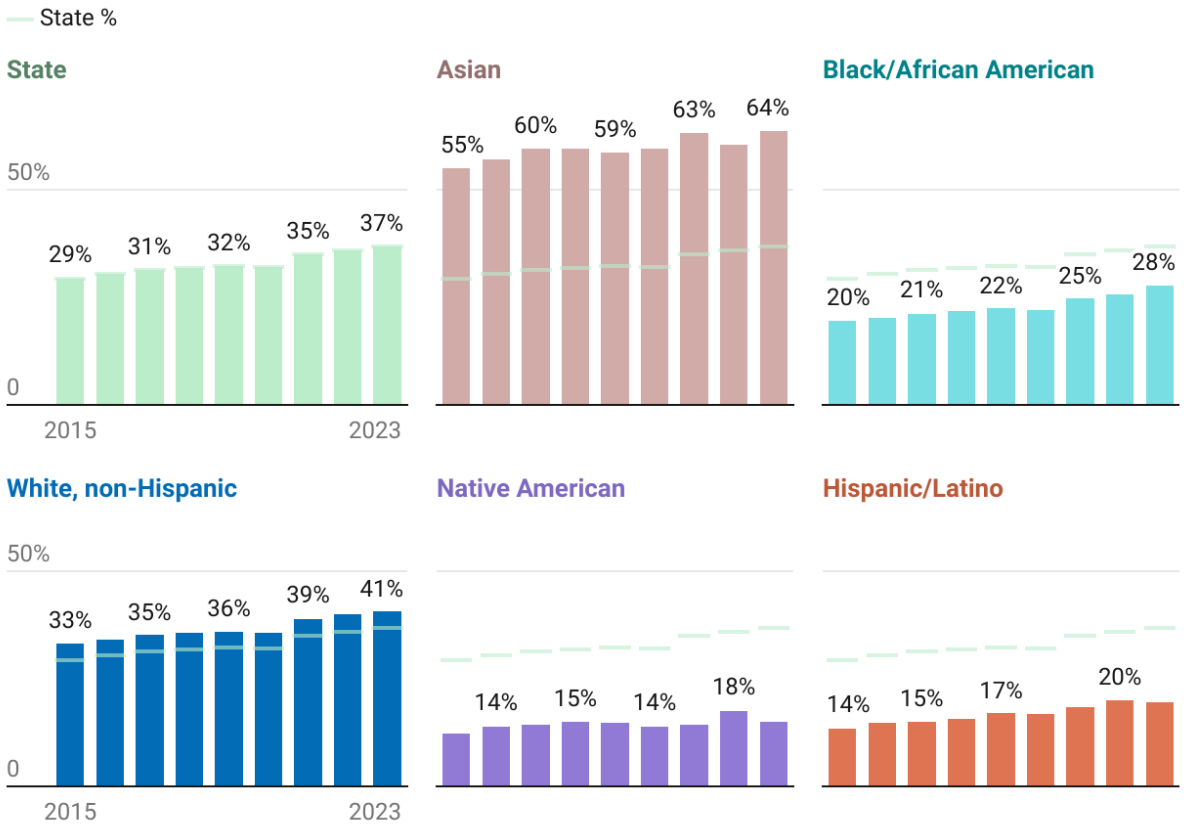
We wanted to evaluate the trend in sufficiency, so we compared counties whose MHI was insufficient in 2017 to those whose MHI was insufficient in 2023 and found that 40 counties improved, 34 maintained the same status as before, and 26 counties worsened.[664] Since most counties went from having an insufficient MHI to an MHI that can support a household with children, we consider this a positive trend.

[663] US Census Bureau, American Community Survey, 2022, 5-year estimates of Median Household Income for families with children under 18, Survey Table 1903.
[664] *2023 Self-Sufficiency Standard*; Center for Women's Welfare, University of Washington, North Carolina Self-Sufficiency Standard, 2017, January 2017.

Indicator 26.4: Educational attainment

Top Line: Educational attainment is tied to stronger earning potential, longevity, and health. Over the last decade, North Carolinians' collective education attainment has improved, and racial and ethnic disparities have narrowed, both good trends.

Figure 26.4A: Percent of residents over age of 25 with a Bachelor's degree or more



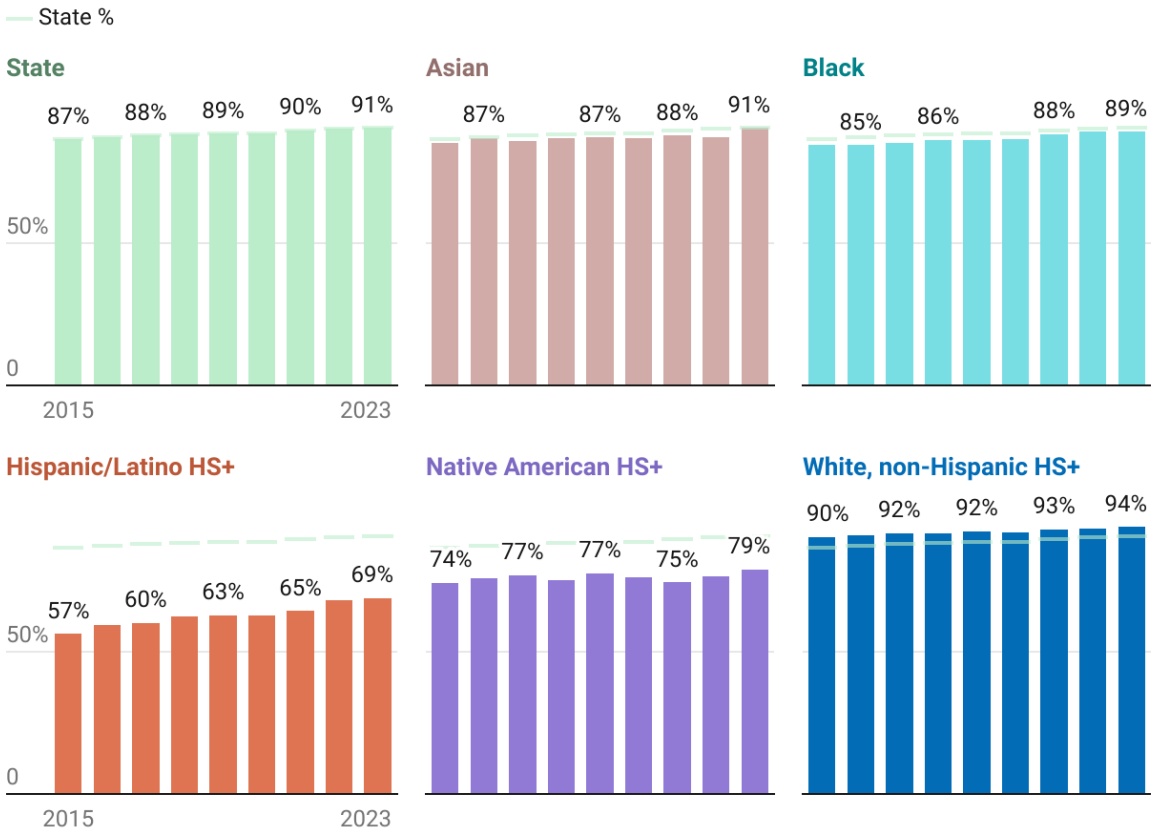
Source: US Census Bureau, American Community Survey 1-Year Estimates, table S1501, 2015-2023. • Created with Datawrapper

About educational attainment: Abundant studies have shown that adults with higher educational attainment live longer and healthier lives compared to less educated peers.[665] It's less clear exactly why, in part because both education and health are embedded in the broader social context of the country

[665] Sarah Suiter and Meredith Meadows, Educational attainment and educational contexts as social determinants of health, Primary Care: Clinics in Office Practice, December 2023, 50 (4): 579, https://doi.org/10.1016/j.pop.2023.04.007; Anjali Gupta et al., Association of educational attainment with cancer mortality in a national cohort study of black and white adults: A mediation analysis, SSM – Population Health, December 2023, 24, https://doi.org/10.1016/j.ssmph.2023.101546.

and our state. A study published in 2022 used regression models to parse the association between having a college degree and reporting favorable overall health.[666] It found that in North Carolina, economic metrics like employment and income contribute most to the relationship between education and health, as opposed to behavioral factors like weight and smoking, or demographic factors like relationship status and household size.[667] A plausible interpretation is North Carolinians with college degrees can get jobs that pay more, and higher household income in turn translates to better health.

Figure 26.4B: Percent of residents over age of 25 who've graduated high school or more



Source: US Census Bureau, American Community Survey 1-Year Estimates, table S1501, 2015-2023. • Created with Datawrapper

We track educational attainment – for all North Carolinians and broken out by race/ethnicity – using data from the US Census Bureau's American Community Survey, 1-Year Estimates.[668] The data shows that across most demographic groups, the percentage of the adults over 25 with a high school degree or

[666] Jennifer Karas Montez and Kent Jason Cheng, Educational disparities in adult health across U.S. states: larger disparities reflect economic factors, Frontiers in Public Health, August 2022, 10, https://doi.org/10.3389/fpubh.2022.966434

[667] *Idem*.

[668] US Census Bureau, American Community Survey, 1-Year Estimates, 2015-2023, table S1501: Educational Attainment.

a four-year college degree continues to rise incrementally. Even better, racial and ethnic disparities are narrowing over time. This is a good trend for North Carolinians' household economic security.

One wrinkle in the data is an artifact of the measurement process; starting with the 2020 census, the US Census Bureau started automatically categorizing people as biracial who identified themselves as Black or white and then noted they had Latin American heritage.[669] In North Carolina, that effectively quadrupled the number of residents classed as bi- or multi-racial. Because the percentage of Hispanic Americans with a high school degree trails (but is gradually catching up to) the figures for other demographic groups, the new method caused an apparent drop in the educational attainment of bi- and multi-racial North Carolinians.

BUILT ENVIRONMENT

The built environment refers to all the human-made spaces in which people live, work, and play. The decisions we make about the structures we build – where we build, how we build, how we travel between them – shape our prospects for health and economic success and impact our environmental quality. We consider 24 distinct indicators related to the built environment, spread across housing, transportation, land use, and resilience. While there are some individual bright spots among the indicators, the built environment suffers the worst overarching trend of all our major categories. That's largely the result of two factors: development decisions that are making our housing less efficient and more vulnerable to disasters; and, related, transportation investment decisions that are locking North Carolinians into long commutes and high GHG emissions.

Goal 27: North Carolinians have affordable, quality housing choices

Trend: Mixed

All North Carolinians should have access to affordable and safe housing choices, but many do not. Across the state, 28% of North Carolina households pay 30% or more of their income towards housing costs.[670] This is true not just in the state's rapidly growing urban areas, but also in rural counties that were devastated by Hurricanes Matthew and Florence in the east and Hurricane Helene in the west. As indicators for this goal, we track both a theoretical measure – how many jobs a minimum wage worker would need to hold to be able to afford a two bedroom apartment – and a practical outcome – how many renters and owners are in houses with severe deficiencies, including overcrowding. The first indicator is trending worse, the second better, for a mixed trajectory on housing overall.

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[669] US Census Bureau, press release: Improved Race and Ethnicity Measures Reveal US Population Is Much More Multiracial, August 21, 2021; Mike Schneider, Multiracial boom in 2020 census was mostly an illusion, researchers say, Associated Press, January 13, 2025.

[670] Greg Childress, 28% of North Carolina households remain burdened by housing costs, NC Newsline, January 17, 2025.

Solutions: North Carolina should L1, support scalable affordable housing solutions; L2, reform single family zoning, L3, promote transit-accessible development; and L4, eliminate mandatory minimum parking for new development, to address the rising cost of housing.

Indicator 27.1: Income needed to afford a two-bedroom apartment

Top Line: To afford the fair market rent for a two-bedroom apartment in North Carolina in 2024, without spending more than 30% of income on housing, a household must earn $52,437 annually. That equals 3.5 full time minimum wage jobs, up from 2.3 jobs in 2018. That's a negative trend.

About income needed to afford an apartment: People frequently speak anecdotally about the rising cost of living in North Carolina. To quantify and track the trend, we looked at housing data compiled by the National Low Income Housing Coalition (NLIHC). NLIHC's annual report, "Out of Reach," breaks down housing costs and barriers in each state. In 2018, NLIHC estimated that, to afford a two-bedroom apartment in North Carolina at fair market rental rates without spending more than 30% of the income on housing, members of a household had collectively to hold 2.3 minimum wage jobs.[671] Six years later, in 2024, members of a household must hold 3.5 full time jobs at minimum wage to afford a two-bedroom apartment.[672] That is 139 work hours per week at minimum wage to afford a two-bedroom in the state, a problem for many households, but especially so for households with only one working adult. In North Carolina, 35% of children live in single-parent households.[673]

Recent developments: In recent years, rents have increased across much of the state, with the North Carolina Housing Coalition estimating that 48% of renters statewide have difficulty affording their homes.[674] That figure was even higher – 53% – for Buncombe County, but in early September 2024, US Housing and Urban Development (HUD) projected that rents in the greater Asheville area would fall by upwards of 10% in 2025, a reflection of several new multifamily apartment complexes nearing completion.[675] Then Helene happened. The storm seriously damaged or destroyed an estimated 8,800 homes across western North Carolina.[676] In Buncombe County, it damaged about 7% of the housing stock to some degree, with 331 units completely destroyed and 609 suffering major damage.[677] In January 2025, HUD allocated $1.428 billion to North Carolina for disaster recovery, as well as $225

[671] National Low Income Housing Coalition, Out of Reach 2018.
[672] National Low Income Housing Coalition, Out of Reach – North Carolina 2024.
[673] U.S. Census Bureau, American Community Survey 1-year estimates, 2023, Table B23008.
[674] NC Housing Coalition, factsheet: The 2025 Housing Need in North Carolina, January 2025.
[675] NC Housing Coalition, factsheet: the 2025 Housing need in Buncombe County, January 2025; Will Hofmann, Asheville area Fair Market Rent projections decrease for 1st time in 6 years, Asheville Citizen-Times, September 5, 2024.
[676] NC Department of Commerce, Division of Community Revitalization, State of North Carolina Action Plan [*NC Helene Action Plan*], March 26, 2025, at 24. The Plan estimates that roughly 73,000 homes experienced some level of damage.
[677] Taylor Thompson, Helene worsens Buncombe County's housing crisis with over 9,000 homes damaged, WLOS, January 17, 2025.

million directly to the City of Asheville.[678] The NC Department of Commerce estimates the allocation will cover about 30% of the unmet need for repairing and rebuilding housing across the western counties.[679]

Indicator 27.2: Share of homeowners and renters in housing with moderate or severe deficiencies

Top Line: The percentage of North Carolinians living in housing with moderate or severe deficiencies – the most common deficiency being excessive cost as a share of the resident's income – has decreased slightly since 2019. That's a positive trend.

About housing quality: Available housing needs to be *safe* to live in. Our indicator tracks the percentage of owners and renters in housing with moderate or severe deficiencies. US HUD receives custom tabulations of the US Census Bureau's American Community Survey that assess the extent of housing problems and housing needs. HUD's dataset is called the Comprehensive Housing Affordability Strategy (CHAS) and uses five-year rolling averages. CHAS defines 'moderately' deficient housing as that which suffers from one or more of the following: incomplete kitchen facilities, incomplete plumbing facilities, more than one person per room, or a cost burden (ratio of housing costs: household income) greater than 30%. CHAS defines 'severely' deficient housing as that which suffers from one or more of the following: incomplete kitchen facilities, incomplete plumbing facilities, more than 1.5 persons per room, or cost burden greater than 50%.[680]

The 2019 State of the Environment report shared data from 2011-2015, during which 24% of owners and an astounding 47% of renters were in homes with moderate or severe deficiencies. The most recent data, 2017-2021, shows some improvement: 19% of homeowners and 44% of renters were in homes with moderate or severe deficiencies. Some of these suffered from lack of kitchen facilities, bad plumbing, or severe overcrowding – 1.5% and 3.1% respectively for owners and renters. But clearly, the most salient housing deficiency in the state, for owners and renters alike, is housing costs. Given the small improvement in the share of households in homes with moderate or severe deficiencies, this indicator is considered a trend in the right direction, but it also signals that many residents in our state pay too large a share of their income as housing costs, sacrificing other spending and saving.

Goal 28: North Carolina's housing is climate resilient.

Trend: Negative

[678] DR-4827-NC, 90 Fed. Reg. 4759, January 16, 2025.
[679] *NC Helene Action Plan*, at 28.
[680] U.S. Housing and Urban Development (HUD), Office of Policy Development and Research, CHAS Background, visited December 2024.

In addition to being affordable, it's crucial that housing be resilient to climate change – which is to say, built to high standards of energy efficiency, and protected from climate disasters, including flooding. We measure this with two indicators: the average energy efficiency rating for new homes; and the percentage of the housing stock in the 500-year floodplain, and therefore at relatively greater risk of flooding. Unfortunately, the energy efficiency of new buildings is reeling from state legislative rollbacks to the building code in 2023, and residential construction continues in floodplains across the state, so both indicators are looking grim.

Solutions: North Carolina can improve the resilience of our housing stock by, J9, modernizing the building code; M2, funding buyout of repetitive-loss properties; M3, keeping new development out of the floodplain; M4, keeping state-funded facilities safe from flooding; and M5, removing unsafe dams. In addition, A4, investing in floodplain restoration can help minimize damage to existing housing from future storms.

Indicator 28.1: Energy efficiency score of new houses in North Carolina

Top line: Over the last five years, the number of new homes rated for energy efficiency has grown, but the average rating has remained stubbornly poor, much weaker than what a new home matching the most recent International Energy Conservation Code (IECC) should score. We count this lack of progress as inadequate.

About energy efficiency of houses: There are two dominant energy rating systems for houses in the United States today. The Residential Energy Services Network (RESNET) was established in the 1980s, and developed the Home Energy Rating System Index (HERS Index) in the mid-1990s.[681] The HERS Index is usually understood in relation to the International Energy Conservation Code, a model building code that has changed over time to drive greater energy efficiency in buildings.[682] Under the HERS Index, a home matching the 2006 International Energy Conservation Code (IECC) has a value of 100, and more efficient houses have lower scores. RESNET itself believes that a home matching the most recent 2021 IECC standard should have a HERS score around 57.[683] A net zero house has a value of 0. The HERS Index allows for a complex, deep dive into a home's energy efficiency, and is used primarily to rate new homes (a recent estimate suggests 28% of new homes in 2023 were RESNET-rated).[684]

In 2010, the US Department of Energy (US DOE) launched a second, simpler and cheaper rating method, the Home Energy Score (HES), which ranks houses by percentile: an average house would score a five,

[681] NASEO, webpage: Home Energy Rating System (HERS), visited September 23, 2024.
[682] International Code Council (ICC), webpage: Who We Are, visited September 24, 2024; ICC, 2021 IECC Code and Commentary, August 2021.
[683] RESNET, Comments for 2021 IECC Requirement on HUD and Department of Agriculture Mortgages, August 3, 2023.
[684] RESNET, press release: RESNET Marks Milestone of Over 4 Million HERS-rated homes, January 11, 2024.

with more efficient homes inching closer to 10.[685] HES was set up to encourage home-owners to invest in home efficiency and – unlike HERS – is easy to measure in an occupied house. Not surprisingly, HES is often used by contractors selling efficiency upgrades to homeowners.

Our indicator is the average HERS Index score of rated new homes built in North Carolina. We choose it for three reasons: first, we have found no good data series for HES scores of existing homes. Second, because the HERS Index is used almost exclusively for new homes, it reflects current building trends. Third, because new homes will be around for decades, the HERS score for new homes captures choices that will shape North Carolina's efficiency landscape for a generation to come. RESNET's coverage of the market has accelerated: it took from 1995 to 2012 to rate the first million homes nationally; to 2017 to reach two million; 2021 to reach three million; and January 2024 to reach four million. The organization intends to certify a million homes a year by 2028.[686]

A 2020 study of 2014-2016 RESNET data reported that 28,757 homes were certified across those three years (less than 10,000 per year) with an average HERS Index score of 66. Annual data for the number of homes rated in North Carolina and average scores are only publicly available from 2019 on and are shown in table 28.1 below.[687] Over the five years since 2019, the number of rated homes has continued to climb, but the average score has bounced between 63 and 65. The scores are not decreasing; that is a negative trend. We hope to see average scores improve in the next few years.

Table 28.1: Average HERS Index score and numbers of new homes rated in North Carolina

Year	Average HERS	# of homes
2019	63	16,849
2020	63	16,849
2021	64	20,370
2022	63	22,068
2023	65	26,271

Source: RESNET, Annual HERS Activity by State reports. • Created with Datawrapper

[685] US DOE, Better Buildings, webpage: Home Energy Score, visited September 23, 2024; NASEO, webpage: DOE Home Energy Score Program, visited September 23, 2024; US DOE, Better Buildings, Home Energy Score Scoring Methodology, September 2021.
[686] RESNET, press release: RESNET Marks Milestone of Over 4 Million HERS-rated homes, January 11, 2024.
[687] RESNET, HERS Activity by State, 2019, 2020, 2021, 2022, 2023.

A better HERS Index score implies a direct financial benefit for the homeowner – lower utility bills, higher resale value, and, under some circumstances, lower mortgage payments.[688] It also implies better protection for human health. A 2023 study found, using Atlanta as a model, that if a heat wave and power outage were to occur for a week – not unlikely in North Carolina in the wake of a major storm – a house built to meet the 2021 IECC standard would stay at a safe temperature and humidity for the whole week, while an average existing house would remain livable for just three days.[689]

Recent developments: A 2023 study found that steadily moving North Carolina's building code from the 2010 IECC to the 2021 IECC would have saved North Carolina residents a cumulative $5.8 billion by 2030 and $10.6 billion by 2040.[690] Unfortunately, that's not what happened. Instead, in 2023, the NC General Assembly moved authority to revise building codes from the state Building Code Council to a new, developer-dominated Residential Code Council and banned updates until 2031, also blocking changes that would have made homes more resistant to storm damage.[691] Despite substantial bipartisan criticism, the state legislature made additional changes in 2024, prohibiting local governments from enacting stronger fire codes.[692]

Federal actions could someday help North Carolina homeowners in spite of the state legislature.[693] In April 2024, HUD and US Department of Agriculture (USDA) finalized new energy efficiency standards for new home construction.[694] The requirements will cover HUD subsidized apartments and starter homes with mortgages insured by the Federal Housing Administration (FHA) and USDA. The new efficiency standards track the 2021 International Energy Conservation Code (IECC, for single-family homes and multifamily buildings less than four stories) and ASHRAE Standard 90.1-2019 (for multifamily buildings with four or more stories).[695] The agencies estimate that homes that meet the standard in North Carolina will have a HERS Index of 47, reach payback of extra construction costs within 2 years, and save the homeowner more than $13,000 over the life of the home.[696] HUD and USDA cover roughly a quarter

[688] Mike Dawson, blog: Energy Efficient Home Improvements Can Increase Home Value, FreddieMac, December 18, 2019; RESNET HERS Index, webpage: Live Better in a HERS Rate Home, 2021.
[689] US DOE, Enhancing Resilience in Buildings Through Energy Efficiency, July 2023, at viii.
[690] PNNL, Impacts of Model Building Energy Codes, November 2023, Table 16. Discounted Consumer Energy Cost Savings, in 2021 dollars, at 27.
[691] Jeff St. John, North Carolina kills effort to make its building code energy-efficiency, Canary Media, August 18, 2023; Adam Wagner, New building code law bars a key inspection in most of NC. That raises risks, experts say, News & Observer, August 21, 2023.
[692] Peter Castagno, Lobbyist-written building code law could increase homeowner insurance, limit grant opportunities, Port City Daily, July 28, 2024; Peter Castagno, Firefighters raise safety concerns after lawmakers override veto of lobbyist-crafted building code bill, Port City Daily, September 13, 2024.
[693] Elizabeth Ouzts, Even with N.C.'s building code frozen, federal rule poised to boost energy-efficiency housing in the state, Energy News Network, September 19, 2024.
[694] 89 Fed. Reg. 33112, Final determination: Adoption of Energy Efficiency Standards for New Construction of HUD- and USDA-Financed Housing, April 26, 2024, available via Regulations.gov, Docket #FR-6271-N-03.
[695] *Idem*, at 33113.
[696] *Idem*, at 33124, 33137. See also, Erin Sherman, blog: Updated Home Efficiency Standards Could Affect One in Four Homes [*Sherman*], Rocky Mountain Institute, April 25, 2024 (estimating life cycle benefits of $13,775 for a North Carolina homeowner).

of new homes; the Federal Housing Finance Agency covers another 43% and has considered adopting a similar standard, but had not as of the end of 2024.[697]

Several funding streams, sometimes augmented by state matching funds, help owners of existing homes upgrade their efficiency and lower their utility bills; we discuss these under indicator 39.1, energy affordability.

Indicator 28.2: Percentage of housing stock in the 500-year floodplain

Top line: In 2019, we relied for this indicator on a dashboard maintained by the Furman Center at New York University, which estimated that 6.38% of North Carolina's housing stock was in the 500-year floodplain. But that dashboard hasn't been maintained since 2021. Eventually, the NC Flood Resilience Blueprint, discussed under indicator 36.3, may be able to estimate this. In the meantime, researchers at UNC Chapel Hill have found that from 1996 through 2017, North Carolina built ten times more houses in the 100-year floodplain than we collectively removed; that's enough to draw a red flag for this indicator.[698]

About housing and flood risk: A small fraction of North Carolina's housing stock has flooded over and over; we discuss those severe repetitive loss properties under indicator 36.1. Yet, few North Carolinians want their houses to flood even once – and as climate becomes more volatile and flooding more common, more of the state's housing stock is at risk of flooding. In North Carolina, in both the mountains and along the coast, a significant share of housing is just outside the 100-year floodplain.[699] In Hurricanes Matthew and Florence, floods damaged structures well outside the traditional 100-year floodplain. The percentage of houses in the 500-year floodplain serves as a useful signal of the scale of the risk.

In 2019, we relied on a multi-year analysis by the NYU Furman Center that estimated some 6.38% of the state's housing stock was in the 500-year floodplain. Some of the Center's research papers remain posted, but the dashboard was suspended in 2021 'to investigate and correct a data issue' with no scheduled date for restoration.[700] Good news for North Carolina: NC DEQ's Flood Resilience Blueprint Tool, as it comes more broadly online, will likely offer some capacity to measure the share of the existing housing stock at risk by jurisdiction or river basin.

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[697] *Sherman*; Tik Root, This tweak to mortgage rules could save homeowners thousands in energy bills, Grist, September 23, 2024.
[698] Miyuki Hino et al., Growing Safely or Building Risk? [*Hino et al.*], Journal of the American Planning Association, February 2024, 90:50, https://doi.org/10.1080/01944363.2022.2141821.
[699] Georgina Sanchez et al., The safe development paradox of the United States regulatory floodplain, PLoS One, December 2024, 19 (12), https://doi.org/10.1371/journal.pone.0311718, at 8, 9, and 13.
[700] NYU Furman Center, Housing in the U.S. Floodplains, May 2017; NYU Furman Center, Population in the U.S. Floodplains, December 2017; See, FloodzoneData.us, including captures via the Wayback Machine.

In the meantime, we look to three studies that paint a worrying picture. Researchers at UNC Chapel Hill have found that for every property removed from or elevated above the floodplain from 1996 to 2017 in North Carolina, builders constructed more than 10 new residences in the floodplain.[701] Moreover, the team found at least 75,000 acres of vacant floodplain land zoned for development.[702] Looking into the future, another team of researchers estimates that by 2100, storm surge could threaten areas that currently are home to between 100,000 and 133,000 North Carolinians.[703] The combination of locally heavy rain, river flooding, and storm surge is poorly modelled, but suggests an even wider range of residential properties are at risk across eastern NC.[704] Given signals of both increasing risk (wider and more frequent floods) and increasing vulnerability (more residences in the floodplain), we mark this indicator as trending in the wrong direction.

Recent developments: In September 2024, Hurricane Helene drew attention to floodplains in the North Carolina's mountain counties, where some watersheds were not mapped and many maps under-estimated flood risk. The City of Asheville evaluated its properties, determining by December 2024 that 856 parcels were in the 100 year floodplain, and over 1000, or 9% of the city's area, were in the 500-year floodplain.[705] Asheville, Waynesville, and Hendersonville – all towns with an adequate tax base and local staffing – began considering actions to reduce future risk, such as buying out at risk-properties or requiring new development to elevate two feet above the 100 year floodplain rather than just one foot.[706] It's less clear that smaller towns or rural counties have the capacity to revisit their floodplain ordinances; reducing the number of homes at risk of future flooding in these jurisdictions will require state funding and technical assistance. Communities that participate in the National Flood Insurance Program (NFIP) will need to ensure that new and rebuilt structures are out of the 100 year floodplain or elevated above it.[707] Complicating that effort, the flows in Helene were so extreme that they relocated some stream channels, moving the floodplain. Post-storm aerial photography will be used to make new floodplain maps for much of western NC; those are unlikely to be available before early 2026.

Transportation

[701] *Hino et al.*
[702] *Idem*, at 57.
[703] Jeremy Johnston, et al., Projecting the effects of land subsidence and sea level rise on storm surge flooding in Coastal North Carolina, Nature Portfolio, 2021, 11:21679, https://doi.org/10.1038/s41598-021-01096-7.
[704] Scott Curtis et al., Perceptions of risk to compound coastal water events: A case study in eastern North Carolina, USA, Progress in Disaster Science, 2022, 16: 100266, https://doi.org/10.1016/j.pdisas.2022.100266.
[705] Will Hofmann, Asheville grapples with early post-Helene floodplain policy talk; 9% of city in flood zone, Asheville Citizen Times, December 6, 2024.
[706] Sara Honosky, Asheville council will consider 1st flood protection ordinance updates since Helene, Asheville Citizen Times, January 10, 2025; Rex Hodge, Waynesville leaders propose requirement changes to new construction in flood zones, WLOS, January 23, 2025; Jennifer Heaslip, Hendersonville to revisit building standards, floodplain ordinance in wake of Helene, Asheville Citizen Times, January 24, 2025.
[707] FEMA, factsheet: FEMA Region 4 Bluesheet: Managing the Floodplain Post-Disaster, November 2024.

We think most North Carolinians – and most policymakers – can agree on three overarching goals for the state's transportation system: it should connect people to the places they need to go – jobs, schools, medical care, shopping, entertainment – efficiently and safely; it should support a robust economy and quality of life; and it should minimize harms to our environment, including emissions of climate-warming greenhouse gas emissions. The next 13 indicators track how well our transportation system is meeting those goals.

Goal 29: North Carolina's transportation system is carbon efficient

Trend: Negative

We use four indicators to measure the efficiency of North Carolina's transportation system: the total greenhouse gas emissions of our transportation sector (indicator 29.1), vehicle miles traveled (VMT) per dollar of gross state product (indicator 29.2), the carbon intensity of freight transport (indicator 29.3), and the adoption of electric vehicles (indicator 29.4). VMT per dollar has fallen; that's good. However, far from falling, greenhouse gas emissions from the transportation sector have *increased* from the 2005 baseline. We have not found any state-specific data series on freight efficiency, but truck freight is contributing to absolute increases in GHG emissions nationally and truck freight imports have increased in the state. That suggests freight emissions are headed in the wrong direction. Adoption of electric vehicles hit an initial set of targets in 2023 but is not on track to hit more aggressive targets in 2030. Overall, we rate North Carolina's progress towards an efficient, low-carbon transportation system as inadequate.

Solutions: To maximize the carbon efficiency of our transportation system, North Carolina should K1, increase the share of state spending directed to non-highway modes; K4, integrate carbon reduction and equity criteria into transportation planning; L1, support affordable housing in the urban core; L2, reform single family zoning; L3, promote transit accessible development; L4, eliminate mandatory parking minimums; and J6, invest in zero-emission vehicle infrastructure, paired with J1, expanded renewable generation and storage.

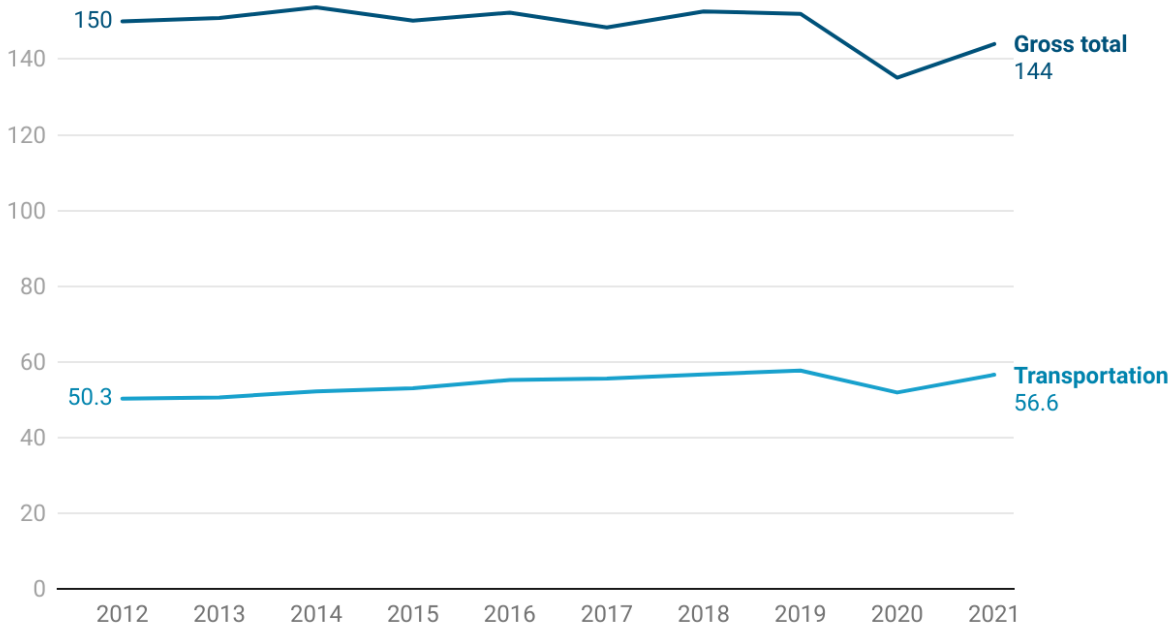
Indicator 29.1: Annual greenhouse gas emissions from the transportation sector.

Top line: the transportation sector is the largest source of North Carolina's greenhouse gas emissions, accounting for 41.7% of gross state emissions in 2021.[708] Even as emissions from other sectors have fallen, emissions from the transportation sector have *increased* slightly (2%) from the 2005 baseline, not at all on track to reach state emissions reduction targets. This is a trend in the wrong direction.

[708] US EPA, Greenhouse Gas Inventory Data Explorer: North Carolina, 1990-2021, updated August 18, 2023.

About greenhouse gas emissions from the transportation sector: As the chart indicates, by EPA's calculation, greenhouse gas emissions from the transportation sector increased slightly from 55.4 MMT CO2e in North Carolina's baseline year of 2005 to 56.6 MMT in 2021 – a 2% increase.[709] Over nearly the same period, total annual vehicle miles traveled in the state increased from 96.7 billion in 2005 to 123.1 billion in 2019;[710] improvements in the gas mileage of new cars kept total emissions from growing as quickly. Still, meeting state GHG reduction targets will require significant cuts to total emissions, not merely holding the line.

Figure 29.1: North Carolina GHG emissions from the transportation sector, MMT CO2e



Source: US EPA, Greenhouse Gas Inventory Data Explorer. • Created with Datawrapper

It is worth noting that North Carolina's official greenhouse gas inventory shows a slight (3%) *decline* in transportation sector emissions against the 2005 baseline (58.6 MMT to 55.6 MMT). That is primarily a result of the state inventory excluding ethanol, which NC DEQ considers a 'biomass fuel'.[711] Ethanol proponents argue that, when viewed with a proper life-cycle analysis, ethanol has a much lower carbon footprint that gasoline.[712] A 2021 study from Argonne National Laboratory found that corn-based ethanol reduces GHG emissions by 40% compared to a comparable amount of energy generated from

[709] US EPA, Greenhouse Gas Inventory Data Explorer: North Carolina, 1990-2021, updated August 18, 2023.
[710] NCDOT, Vehicle Miles Traveled Reduction Study [*VMT Reduction Study*], April 2021, at 9.
[711] *NC Greenhouse Gas Inventory*, at 43. The state inventory observes that "In 2005, ethanol contributed 0.39% of heat input to transportation sector motor gasoline in North Carolina, and this contribution rose to 6.88% in 2021."
[712] See, for example, Renewable Fuels Association, blog post: The Truth About Ethanol and Carbon Emissions, October 4, 2022.

gasoline.[713] (The Argonne study has been challenged by other researchers who argue that land conversions to grow feedstock crops release enough additional carbon to make ethanol worse than gas).[714] It's not clear whether NC DEQ used that ratio to calculate sector emissions in North Carolina, or simply deducted all emissions from ethanol. For this update, we rely on the EPA inventory for consistency purposes, but if we were to rely on the state inventory, given North Carolina's target of a 40% reduction, we would also rate a 3% decrease from the transportation sector as inadequate.

Recent developments: We mention the carbon reduction targets articulated in former Governor Roy Cooper's Executive Orders 80 and 246 under indicator 2.1, total North Carolina greenhouse gas emissions. Beyond setting targets, however EO 246 also directed NCDOT and other cabinet agencies to develop the NC Clean Transportation Plan (CTP), released April 2023.[715] Electrification of the transportation system, goal 32, is a major focus of the CTP; but the document also calls for NCDOT to consider ways to weigh greenhouse gas emissions and equity benefits when prioritizing projects, discussed under indicator 30.1, and to deploy federal Inflation Reduction Act (IRA) funds to drive emissions reductions from the transportation sector in North Carolina.[716]

Indicator 29.2: Vehicle miles traveled per dollar of state GDP.

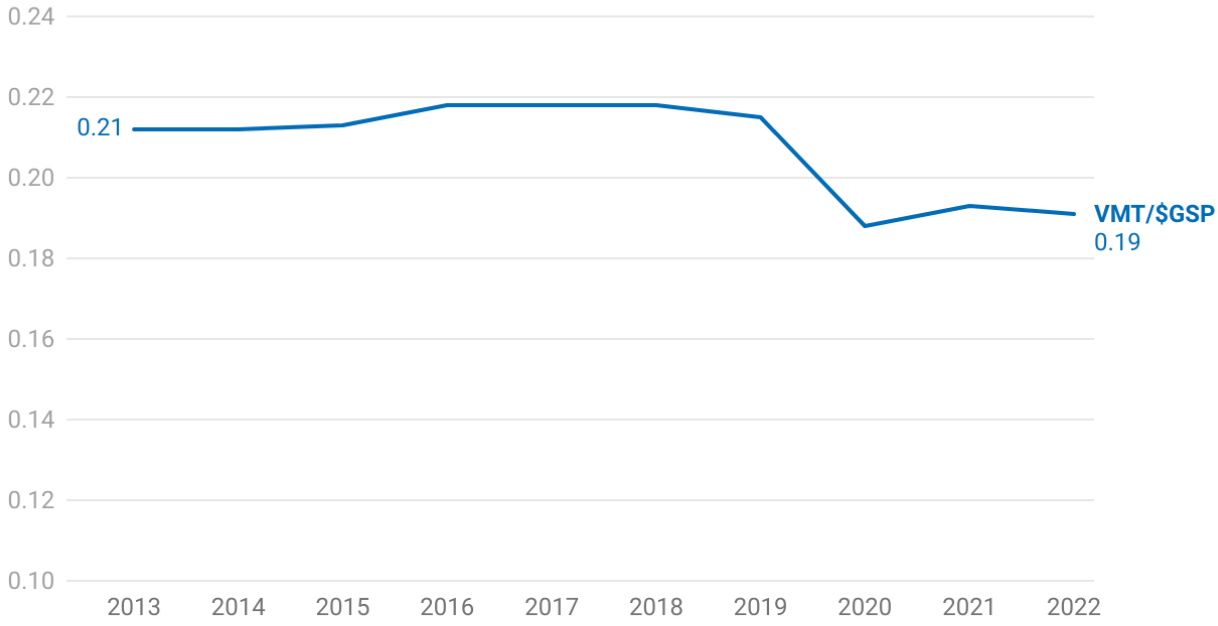
Top line: Over the last two decades, North Carolina's total vehicle miles traveled have soared, slightly outpacing the state's economy. But the pandemic appears to have reset the relationship between travel and economic activity, allowing North Carolinians to drive less to generate the same or greater wealth. That's good news for residents' quality of life, and for the environment.

About vehicle miles traveled: Vehicle miles travelled (VMT) measures the total number of miles driven by residents of a community in a given amount of time – typically, a day, a month, or a year. As noted under the previous indicator, North Carolina's annual vehicle miles travelled soared from 96.7 billion miles in 2005 to 123.1 billion miles in 2019.[717] Different ways of thinking about VMT are useful for different policy purposes. For reducing total transportation sector GHG emissions, either total VMT must drop (by people working from home or commuting to work other than by driving alone) or each mile traveled must become significantly less carbon intensive (for example, by widespread electrification of public and private vehicles). For improving quality of life for North Carolinians, per capita VMT matters; depending on population growth, lowering per capita VMT may not be enough to achieve absolute

[713] See, Michael Wang et al., presentation: Life-Cycle Greenhouse Gas Emissions Reductions of Ethanol with the GREET Model, presentation at the 2021 National Ethanol Conference, February 17, 2021.
[714] Tyler Lark et al., Environmental outcomes of the US Renewable Fuel Standard, PNAS, February 2022, https://doi.org/10.1073/pnas.2101084119.
[715] Executive Order 246 (EO 246), North Carolina's Transformation to a Clean, Equitable Economy, January 7, 2022, section 5; NCDOT, North Carolina Clean Transportation Plan [*Clean Transportation Plan*], April 2023
[716] *Clean Transportation Plan*, at 26, 29.
[717] *VMT Reduction Study*, at 9.

emissions targets, but it means that North Carolinians will spend less time trapped in their cars while commuting or running errands.

Figure 29.2: Vehicle miles traveled per dollar of gross state product, chained 2017 dollars



Source: Calculated from USDOT, Bureau of Transportation Statistics and Bureau of Economic Analysis GSP estimates. • Created with Datawrapper

For this indicator, we track VMT per dollar of state economic activity, measured as the state's gross domestic product in chained (inflation-adjusted) dollars. An increase in VMT per dollar of GDP means that residents have to drive farther to generate the same amount of total wealth for North Carolina's economy. Between 2013 and 2019, VMT per dollar of economy activity increased slightly, from 0.212 miles per dollar to 0.215 miles. But the pandemic appears to have reset the relationship, perhaps as a result of a significant fraction of post-pandemic employees working from home at least part of the time. The ratio for 2022 is 0.191 miles per dollar. On a per dollar basis, that difference translates into just 110 feet – but multiplied across the economy, it is a sizeable efficiency gain, and a good trend.

Indicator 29.3: Carbon intensity of freight

Top line: North Carolina's population growth has offset the increase in vehicle efficiency; another factor keeping transportation sector emissions high is the growth of freight. We've not found a data series that directly estimates the carbon footprint of freight transportation in North Carolina. However, national data shows that increases in freight are driving higher emissions. North Carolina specifically has seen an increase in truck traffic over the last decade. In the absence of widespread electrification of freight

transportation – discussed in the context of heavy-duty trucks under indicator 32.2 – it is safe to say the carbon intensity of freight is moving backwards in North Carolina.

About freight and GHG emissions: Fast, efficient freight is a critical part of the economy and supports our high standard of living. Nationally, growth in truck freight and pipeline are driving absolute increases in greenhouse gas emissions.[718] While North Carolina lacks carbon footprint data for freight, the federal Bureau of Transportation Statistics does track freight imports to and exports from Charlotte, the Triad, the Triangle, and the rest of the state, by mode.[719] We've aggregated these in figure 29.3. Overall, freight exports from North Carolina have stayed relatively flat over the last decade, but imports have increased, especially by truck, a much less carbon-inefficient mode than shipping or rail (table 29.3).[720]

Table 29.3: Average CO2 emissions per ton-mile of freight, by mode

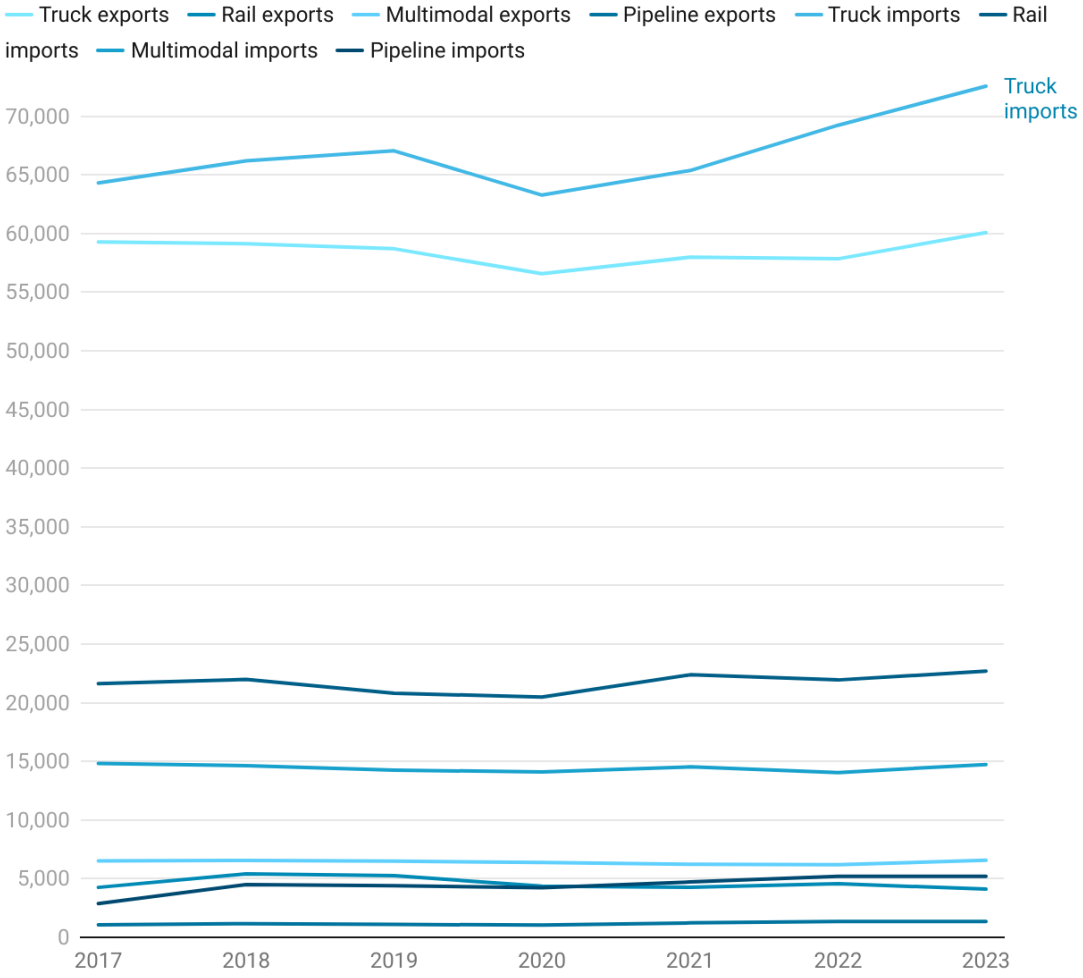
Mode	Lbs. CO2/ tmile
Air	2.57
Truck	0.40
Water	0.14
Pipeline	0.13
Rail	0.05

Source: CBO, 2022. • Created with Datawrapper

[718] USDOT, Bureau of Transportation Statistics, web database: U.S. Greenhouse Gas Emissions from Domestic Freight Transportation, 2005, 2013-2022.
[719] Bureau of Transportation Statistics, Freight Analysis Framework, FAF5 Data Tabulation Tool, visited August 30, 2024
[720] Congressional Budget Office, Emissions of Carbon Dioxide in the Transportation Sector, December 2022.

Figure 29.3: NC Freight imports and exports, major modes

Measured in million ton-miles



Source: BTS, Freight Analysis Framework, FAF5 Data Tabulation Tool • Created with Datawrapper

The spatial distribution of freight infrastructure can shape land use patterns (goal 34.2), disparities in air quality (indicator 14.2), and the density of impervious surface at the watershed level (indicator 7.3). In recent years, researchers have noted both 'logistics sprawl' – the concentration of large freight staging areas in warehouses on the urban fringe – and also the increasing use of downtown freight staging areas that allow companies to reach central business districts and urban residents.[721] One strategy that may minimize the local harms of freight in urban areas is increased use of low-emissions cargo e-bikes for 'last mile' deliveries.[722]

[721] Travis Fried and Anne Goodchild, E-commerce and logistics sprawl: a spatial exploration of last-mile logistics platforms, Journal of Transport Geography, October 2023, 112, https://doi.org/10.1016/j.jtrangeo.2023.103692.
[722] University of Washington, Urban Freight Lab, Biking the Goods, October 2023.

Indicator 29.4: Percentage of new passenger cars registered in North Carolina that are hybrid or zero-emission vehicles.

Top line: Electric vehicles (EVs) pose an opportunity for economic development as well as reduced emissions of greenhouse gases and conventional air pollutants. Zero-emission vehicles (ZEVs) achieved the goal of 80,000 registrations in 2023, two years ahead of the EO 80 target. But we are not on track to meet the expanded goal, articulated in EO 246, of have 1.25 million EVs registered in the state by 2030, with EVs accounting for 50% of new sales by that year. We assign this trend a yellow caution flag.

About ZEV passenger vehicles: Zero-emission vehicles (ZEVs) do not rely on internal combustion engines and do not directly emit exhaust gas. Most ZEVs are battery powered and must be recharged using electricity. Even when accounting for manufacturing and electric charging, ZEVs have lower greenhouse gas emissions than typical gasoline-powered vehicles.[723]

In 2022, North Carolina was among the 10 states with the highest petroleum use and total annual expenditure for motor gasoline.[724] Greenhouse gas emissions from motor vehicles increased 23% between 1990 to 2022, despite manufacturers' efforts to improve fuel efficiency and add antipollution devices.[725] A study of 30 American metro areas found that large scale uptake of EVs will significantly improve air quality, saving $440 million/ year and preventing an estimated 40 early deaths each year in the Triangle.[726] Electrification can deliver total GHG reductions even faster if electric generators avoid new fossil fuel investments, discussed under indicator 42.1.[727]

North Carolina has committed to incorporating electric vehicles in transportation plans and planning, starting with an Executive Order from former Governor Roy Cooper (EO80) in 2018 which set the goal of at least 80,000 registered zero emission vehicles (ZEV) in North Carolina by 2025.[728] The state met that goal in 2023, with 622,192 registered ZEVs.[729] The percentage of registered vehicles that were electric (ZEV) or hybrid rose from 1.72% in 2019 to 3% in 2023, a 73% increase.[730] Executive Order 246 (EO 246), issued in 2022, set a new goal of at least 1,250,000 registered ZEV in the state by 2030.[731] The order also set a target for EVs to comprise 30% of medium/heavy duty vehicle sales by 2030. North Carolina is not on track to hit either of these expanded goals, leading us to assign this a yellow caution flag.

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[723] Georg Bieker, white paper: A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars, International Council on Clean Transportation, July 2021.
[724] Energy Information Agency, webpage: State Energy Profile: North Carolina, Analysis, February 15, 2024.
[725] Maggie Davis, Fuel Efficiency Has Improved 35.4% in the Past 20 Years — Here Are the Models That Have Advanced the Most, Lendingtree, August 7, 2023.
[726] Shuai Pan et al., Impacts of the large-scale use of passenger electric vehicles on public health in 30 US. metropolitan areas, Renewable and Sustainable Energy Reviews, March 2023, 173, https://doi.org/10.1016/j.rser.2022.113100.
[727] D. R. Peters et al., Public Health and Climate Benefits and Trade-Offs on U.S. Vehicle Electrification, GeoHealth, August 2020, 4, https://doi.org/10.1029/2020GH000275.
[728] Exec. Order No. 80, 2018.
[729] NC DOT, dataset: Vehicle Registration: Monthly vehicle registration by type of vehicle, updated 2024.
[730] *Ibid.*
[731] NC Clean Transportation Plan webpage, NC DOT.

Increased uptake of ZEVs will require expanded charging infrastructure. The federal Infrastructure, Investment, and Jobs Act of 2022 (IIJA) established a national funding stream, the National Electric Vehicle Infrastructure (NEVI) program, to fund installation, operation, and maintenance of charging stations.[732] NC DOT has made nine awards to potential charging sites in the first round of the program, and has released a map showing zones for additional charging infrastructure in the future.[733] The 2022 federal Inflation Reduction Act (IRA) includes provisions for strengthening domestic manufacturing and improving the supply chain related to EVs, along with tax credits for the vehicles themselves.[734]

Apart from charging infrastructure investments, fleet purchases offer an early opportunity for state and local governments to benefit from the lower life-cycle costs of electric vehicles. To date, North Carolina's school districts have acquired 145 zero emissions school buses, purchased with a combination of grants and rebates through the EPA Clean School Bus Program with IIJA funding.[735]

Recent developments: Governor Roy Cooper's EO 271, an effort to speed North Carolina's transition to EVs by encouraging state regulators to adopt ZEV sales targets, was stopped short by a legislative budget provision in 2023.[736] In August 2024, the US Department of Transportation awarded $4 million to the City of Durham to establish 20 fast-charging stations across five locations in low- or moderate-income neighborhoods in the city, and awarded $1 million to NCDOT to install 20 Level 2 charging stations at 10 community college campuses across North Carolina.[737] The NC Department of Administration's most recent report on ZEVs in the state fleet notes that procurement remains challenging thanks to high national demand, but that multiple state agencies are building charging infrastructure, and have bought hybrid vehicles as an alternative to ZEVs when necessary.[738]

Goal 30: North Carolina's transportation system provides adequate capacity and options

Trend: Mixed

[732] NC DOE, webpage: National Electric Vehicle Infrastructure (NEVI) Funding Program, visited March 26, 2025. For a concise overview of the program, see, Dory Larsen, blog post: Unpacking the New $5B National Electric Vehicle Infrastructure Program, cleanenergy.org, February 24, 2022
[733] NC DOT, webpage: Round 1 Awards, updated November 6, 2024; NC DOT, interactive map: NC NEVI Round 2 Potential Sites, visited March 26, 2025; see generally, NC DOT, webpage: National Electric Vehicle Infrastructure (NEVI) Program, visited March 26, 2025.
[734] Electrification Coalition, webpage: Inflation Reduction Act & EVs, visited April 10, 2025.
[735] US EPA, interactive data table: Clean School Bus Program Awards, updated September 12, 2024.
[736] Executive Order 271 (EO 271), October 25, 2022; Session Law 2023-134, §12.6.(a).
[737] US DOT, FHwA, chart: Charging and Fueling Infrastructure Program Grant Recipients, August 27, 2024; US DOT, webpage: Charging and Fueling Infrastructure Discretionary Grant Program.
[738] NC Department of Administration, Motor Fleet ZEV Plan Update, November 2024.

The quality of North Carolina's transportation system turns on how the state invests its transportation dollars. Over the last decade, transportation spending has increased substantially, but NCDOT's appetite for building roads – especially massively expensive highways that both serve and induce growth on the urban fringe – has grown faster, leaving NCDOT chronically short on funds. Many residents in both urban and rural environments need options that do not require vehicle ownership. Even as patterns of demand have shifted, construction costs have risen. That has meant a bumpy ride for transportation projects and North Carolina residents.

To measure North Carolina's progress towards a transportation system with adequate capacity and flexibility to serve all users, we track three indicators. First, we consider the way state transportation funds are split among various 'modes' of transportation – highways, transit, rail, air, bike, and pedestrian. Second, we track the percentage of rural residents with non-road options for intercity travel. Finally, we consider the experience of drivers – how much time do they sit in traffic? The first shows minimal progress; the other two are improving, for a mixed picture overall. Of particular note: wasted time in traffic has declined not because of investments in more road capacity, but because since the pandemic more North Carolinians have been able to work from home, without needing to drive solo.

Solutions: Improving capacity requires K2, maintaining current infrastructure, and building out alternative options by K1, increasing the share of state spending directed to non-highway modes; K3, integrating climate adaptation into transportation planning; and K4, integrating carbon reduction and equity criteria into transportation planning. Better land use patterns would help, especially L2, reforming single family zoning; L3, promoting transit accessible development; L4, eliminating mandatory parking minimums.

Indicator 30.1: Transportation spending mode split.

Top line: Since 2015, NCDOT has prioritized most spending on new transportation capacity under the Strategic Transportation Investments (STI) law, which guides each iteration of the State Transportation Improvement Program (STIP). Revised biennially, each STIP schedules construction projects for the next ten years. In the four STIPs developed under STI (adopted 2015, 2017, 2019, and 2023), the state has programmed roughly 97% of funding for new capacity for roads and just 3% explicitly for transit, rail, ferries, airports, and bike/pedestrian infrastructure. Because many bike/pedestrian projects have moved slowly and stayed on the list cycle after cycle, it is likely that the split in actual spending is even more lopsided. This mode split has built a lot of road miles, but it has failed to build a robust, multimodal transportation system that benefits all users, so we assess its stability as a negative trend.

About funding mode split: As noted above, the state's project prioritization process drives the adequacy of North Carolina's transportation system. For decades, the choice of which projects got built reflected pork-barrel politics as much or more than actual need. In 2013, the then-new Republican majority in the state legislature boldly replaced this abuse-prone system with an 'objective' prioritization process, the Strategic Transportation Initiative Program (STIP). By statute, the STIP allocates 40% of funding for new

construction to projects of state significance (highway only); 30% to projects of regional significance (more modes, but excludes bike, pedestrian, and transit); and 30% to local projects (all modes).

On the positive side, the STIP has reduced (though not eliminated) patronage projects. On the other hand, it is extremely highway centric, thanks both to the statutory reservation of 'statewide' funds to road projects, and of NCDOT's culture, where the Highway Division remains the core of the agency and the path to leadership positions.

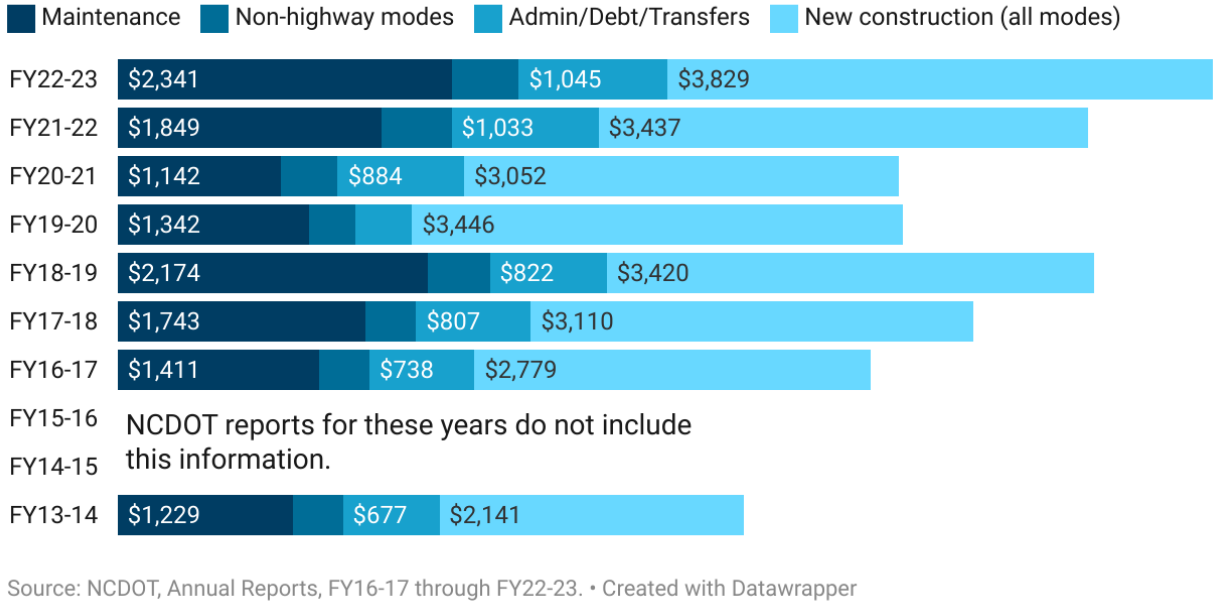
For this indicator, we track the percentage of STIP funds spent on non-highway modes: trains, aviation, ferries, public transit, and bike & pedestrian projects. Some of these are expensive investments, some cheap; they all offer much needed and lower-carbon alternatives to additional road capacity. Since 2015, the STI has been through 5 cycles of project prioritization (P3, P4, P5, P6, and P7). In each of the first four, the agency reserved a minimum of 90% percent of the regional and division 'buckets' for roads, and a minimum of 4% for other modes, with 6% to flex either direction. (In P7, the agency reserved the same 90% for roads, but committed 6% to other modes, with 4% to flex). In the first four cycles, the agency programmed and the Board of Transportation ultimately approved a list of projects that sent 95% of the regional and division budgets to roads and 5% to all other modes; P7 has not yet reached final approval.[739] Since the statewide bucket of STIP funding is reserved for highways, the total mode split in the STIP has remained 97% roads, 3% everything else, for all four completed cycles. Because the process of spending out bike and pedestrian funds is cumbersome, many bike/ped projects have stayed on the STI list without advancing. As a result, the mode split of 'actual' expenditures is probably even more lopsided than 'programmed' spending. This does not move North Carolina towards a robust transportation system offering modes to meet all user needs; we mark this as a negative trend.

Although it is not addressed by this indicator, NCDOT's overall spending also favors new construction through the STIP over maintenance and operations, as chart 30.1 (below) suggests. Each new unit of capacity implies future maintenance needs that the state is ill-equipped to sustain long term.

[739] NCDOT, Final Prologues for the 2016-2025 STIP, 2018-2027 STIP, 2020-2029 STIP, and 2024-2033 STIP, no dates.

Figure 30.1: Total NCDOT actual spending, FY16-17 through FY22-23

In millions of nominal dollars



Source: NCDOT, Annual Reports, FY16-17 through FY22-23. • Created with Datawrapper

Recent developments: As noted above under indicator 29.1, North Carolina's Clean Transportation Plan calls for NCDOT to study how to factor GHG emissions and equity benchmarks into project prioritization. Done properly, that could elevate non-road projects and modes that are carbon efficient and that can better serve low income and rural residents – but it hasn't happened yet.

Indicator 30.2: Options for intercity transportation.

Top line: One measure of the adequacy of our state transportation system is whether it gives residents good options to get from one community to another. For this update, we use a quirky indicator: the number of rural residents with some proximity to an airport, intercity bus, or rail facility. North Carolina scores quite favorably on this measure compared to other states, and the trend is also positive.

About intercity transportation: Most North Carolinians travel locally most of the time, but intercity transportation of people and goods is a crucial function of the system. For this indicator, we rely on a metric developed by the US Department of Transportation (USDOT): the percentage of rural residents with access to an airport, intercity bus, or rail facility. USDOT apparently assumes that non-rural residents already enjoy such access; we're skeptical of that. The agency defines access as living within 75 miles of a 'large or medium' airport, or within 25 miles of a small airport, intercity bus stop, or rail

facility.[740] USDOT estimates the metric for each county; for purposes of this indicator, we've aggregated the rural populations (total and with access) across all 100 counties and calculated the state percentage for the most recent three years of federal data: 2012, 2018, and 2021.

Given North Carolina's relatively dense rural population, it's perhaps not a surprise that few parts of the state are out of reach of an airport, bus stop, or rail station: a bit of the northeast, a touch of the far west.[741] Overall, from 2012-2021, USDOT calculates that access to intercity transportation increased from 92.4 of rural residents of our state to 93.7, even as the metropolitan areas grew rapidly and the total rural population stayed unchanged.[742] We rate this as a positive trend, while recognizing that the indicator isn't great – it assumes rough proximity equals access, but that's not true for a resident without a car and without much income. We hope to find a better metric for affordable access to intercity transportation in the future.

Recent developments: NCDOT uses federal dollars to subsidize service among 54 North Carolina towns and cities (and to nearby centers beyond the state's borders).[743] That's been necessary across the nation; private carriers took a big hit during the pandemic, though traffic has climbed back to 85% to 90% of pre-pandemic levels.[744] Poor intermodal connections between bus and rail in North Carolina remains a concern.[745]

Passenger rail in North Carolina connects fewer communities than intercity bus but enjoys burgeoning ridership; traffic on the Piedmont and Carolinian lines rose from roughly 468,000 in 2019 to 585,000 in 2023.[746] In December 2023, US DOT awarded $3.5 million to NCDOT to study seven potential rail corridors.[747] Last year saw a leap forward in planning and initial investment for an expanded passenger rail network: in July 2024, US Transportation Secretary Pete Buttigieg announced a $1.1 billion grant to NCDOT to build faster and more reliable rail service from Raleigh to Wake Forest and eventually to

[740] For more on US DOT's methodology, see, US DOT, webpage: Methodology for Measuring Access to Transportation in Rural Areas, visited August 16, 2024.
[741] US DOT, webpage: Access to Intercity Transportation in Rural Areas, visited August 16, 2024 (includes interactive map).
[742] US DOT, Bureau of Transportation Statistics (BTS), Access to Intercity Air, Bus, and Rail Transportation in Rural Areas, data for 2012, 2018, 2021, accessed via Data Query Tool, August 15, 2024. The figure for the United States as a whole is 85% of rural residents. US DOT, BTS, press release: 85% of Rural Residents Have Reasonable Access to Intercity Transportation; Lack of Reasonable Access Falls Disproportionately on Low-Income Households, November 14, 2023.
[743] NC DOT, webpage: Connect NCDOT: Intercity Bus, visited August 16, 2024; see also NCDOT, map: NCDOT-funded intercity bus service, FY23-24 (showing subsidized bus stops).
[744] Chadwick Institute, Back on the Bus: 2024 Outlook for the Intercity Bus Industry in the United States, February 6, 2024, at 1.
[745] *Idem*, at 7, 8.
[746] NC DOT, 2023 Annual Performance Report, February 2024, at 21. Ridership has continued to climb; see, NC Governor's Office, press release: NC By Train Ridership Continues to Set Records in First Half of 2024, July 15, 2024.
[747] NCDOT, factsheet: Corridor Identification and Development (CID), August 2024; see also, NC Board of Transportation, February 2025 meeting minutes, at 340 – 344 (update and timelines for the seven corridors), February 6, 2025.

Richmond, connecting to points north.[748] NCDOT published a feasibility study for passenger rail service to western NC in December 2023 and across southeastern NC to Wilmington in September 2024.[749] In October, USDOT awarded the NC Railroad Company a $105 million grant to support passenger and freight service on the state's main north-south rail corridor.[750] Hurricane Helene severely damaged rail lines in western NC, halting freight service and potentially delaying renewed passenger service.[751]

Indicator 30.3: Hours lost to traffic congestion.

Top line: For many drivers, a practical metric of the adequacy of the road system is the amount of time they spend stuck in traffic while commuting or running errands. It's worth noting that adding road capacity is generally an ineffective way to address congestion; it usually just induces more congestion. Better options are to provide alternatives such as transit and trains that relieve pressure on the road system, and to accommodate growth by adding density to walkable, bikeable cities. Happily, for most of the state's large and medium cities, traffic congestion appears to be less of an issue than it was before the pandemic. We rate this as a positive trend.

About hours lost to traffic congestion: NCDOT does not track traffic congestion directly but instead focuses on 'highway reliability' as a performance indicator, using as a metric the percentage of crashes that are cleared from roadways within 90 minutes.[752] That's practical from an operational perspective, but does not measure what irritates road users: delay and unpredictability. An alternative performance measure is the Level of Travel Time Reliability (LLOTTR), which measures how long an average trip takes on a congested day compared with an average day.[753] That doesn't capture the gradual creep upwards in average travel time as growth puts more commuters on the roads. But it does measure the frustration that arises when a driver can't know whether a trip will take 20 minutes or an hour.

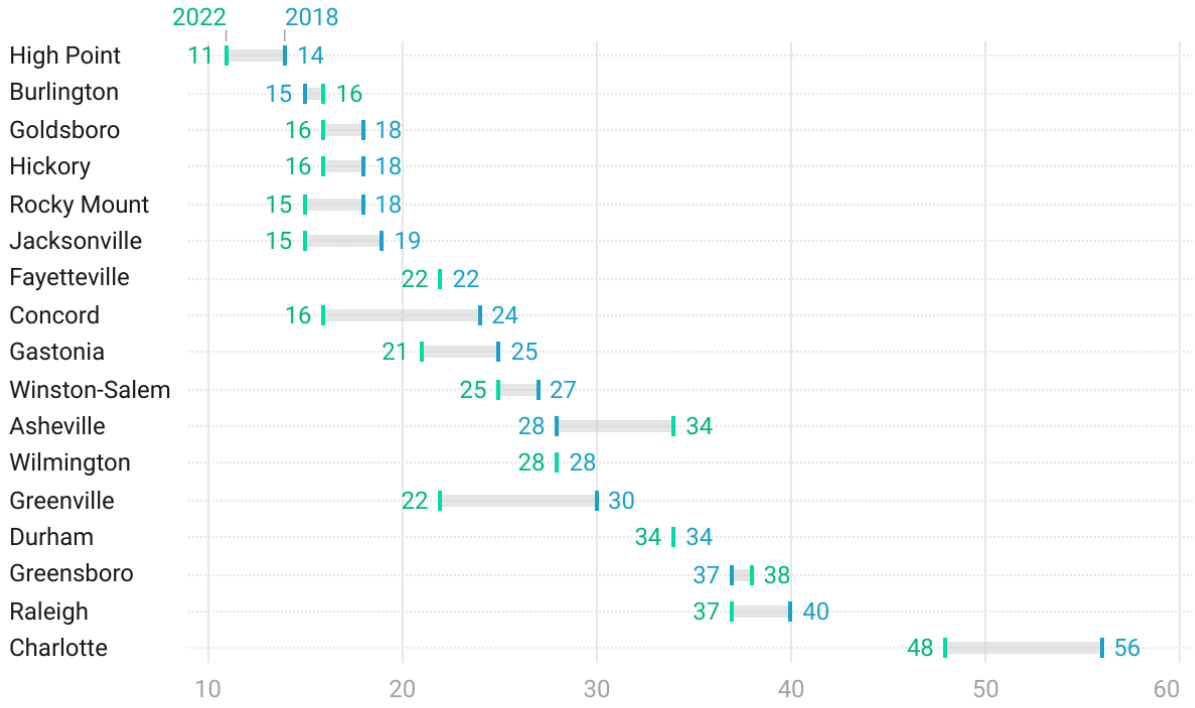
NCDOT has experimented with various models to monitor and predict travel time reliability.[754] However, there is no public data series estimating time travel reliability for North Carolina's road system statewide. The Federal Highway Administration issues an annual congestion report that considers three factors: the daily average number of hours of traffic congestion, a travel time index that measures the

[748] Richard Stradling, USDOT's Pete Buttigieg helps kick off $1.1 billion passenger rail project in Raleigh, New & Observer, July 1, 2024.
[749] NC DOT, Western North Carolina Passenger Rail Feasibility Study, December 2023; NC DOT, Southeastern North Carolina Passenger Rail Feasibility Study, September 2024.
[750] NC Governor's Office, press release: North Carolina Railroad Company Secures $105.6 Million for Transformational Rail Improvements, October 24, 2024.
[751] Jane Winik Sartwell, Getting back on track with rail in NC disaster area, Carolina Public Press, November 22, 2024; Will Hofmann, Asheville passenger rail was set to return. After Helene its future is uncertain, Asheville Citizen-Times, October 25, 2024.
[752] NC DOT, webpage: Goal: Improve Reliability & Connectivity of Transportation System, updated January 22, 2024.
[753] US DOT, FHwA, webpage: Travel Time Reliability Measures, updated June 8, 2023.
[754] US DOT, FHwA, Case study: North Carolina Department of Transportation, Implementing a Suite of Time Travel Reliability Tools in North Carolina, FHWA-HOP-21-069, June 2022.

difference between peak and off-peak travel; and a 'planning time' index that measures travel time variability.[755] However, the federal agency calculates this for just 52 metropolitan statistical areas across the nation. In North Carolina, that includes only the Charlotte metro region and the Triangle, both of which have strongly negative trends.[756]

In lieu of a better public data series, we rely on the Texas Transportation Institute's Urban Mobility Report, which provides a variety of indices and measures of congestion.[757] To be clear, this report has been sharply criticized for its bias in favor of adding road capacity as the (demonstrably ineffective) answer to congestion.[758] We think those criticisms are on point, but the metric – hours wasted in traffic annually, per driver, for drivers commuting during peak hours – still captures something drivers care about intensely.

Figure 30.3: Hours wasted in traffic annually, for drivers commuting during peak times, 2018 and 2022



Source: Texas Transportation Institute, 2023 Urban Mobility Report, Congestion Data for Your City - Visualization Map, June 2024 • Created with Datawrapper

[755] US DOT, FHwA, 2022 Urban Congestion Trends, FWHA-HOP-23-010, October 2023.
[756] *Idem*, at 3.
[757] Texas Transportation Institute, 2023 Urban Mobility Report, June 2024.
[758] Joe Cortright, blog post: 20 Reasons the New Urban Mobility Report is Fatally Flawed … Again, Strong Towns, September 4, 2019; Todd Litman, Congestion Costing Critique: Critical Evaluation of the 'Urban Mobility Report', Victoria Transport Institute, September 7, 2023.

TTI's analysis, which relies on data from the international mobility analytics company INRIX, tracks data for 17 North Carolina cities. All the cities saw major reductions in lost hours during the pandemic, but they have followed diverse paths since. Asheville residents are the only North Carolinians to face significantly more congestion than they did pre-pandemic. Several midsize cities – Burlington, Durham, Fayetteville, Greensboro, Wilmington – are nearly at the same levels. Meanwhile, the two largest cities, Charlotte and Raleigh, are below pre-pandemic levels, and congestion has fallen significantly in Concord, Greenville, Hickory, High Point, and Rocky Mount.[759] Overall, it appears that across most of the state, congestion is still below its pre-pandemic peak, which we regard as a positive trend.

Goal 31: North Carolina's roads are functional and well maintained

Trend: Mixed

The state highway system carries both freight and commuters, represents a huge historic investment, and supports much of the state's economic activity. Non-highway modes desperately need investments to increase new capacity; the highway system requires massive sums simply to tread water. A March 2025 report to the NC Board of Transportation notes that even as spending on road maintenance has climbed in inflation-adjusted dollars, purchasing power per lane mile has declined, as the funds are spread over a larger and larger universe of roads that have to be maintained.[760] Two of our indicators for this goal focus on ongoing maintenance: the percentage of lane miles in 'good' condition (indicator 31.1, we're falling short), and the percentage of bridges in 'poor' condition (indicator 31.2, trending well). The third (indicator 31.3) reflects a longer view: when storms and floods hit North Carolina, as they have and will with increasing frequencies, how resilient is our road network? We don't have a numeric indicator for this, but, based on recent investments by NCDOT in modelling and monitoring, we are confident this is improving. That said, it is still unclear how the state will pay to repair all the damage from Helene – and the storm after that, and the storm after that. Overall, the trend isn't terrible, but it also isn't sustainable, so we assess progress towards this goal as mixed.

Solutions: North Carolina should K2, prioritize spending on maintaining and improving existing infrastructure, and also, K1, build out non-highway modes, reduce the burdens on our roadways. For the longer term, North Carolina should K3, integrate climate adaptation into state transportation investments; also, M3, keeping new development out of the floodplains, would reduce the need to build roads in places they will flood.

[759] *Idem*. This is consistent with NC DOT's own analysis, see *MOPAR 2022*, at 29 – 30.
[760] Randy Finger, NCDOT, presentation: Maintenance Appropriations: Road Inventory and Purchasing Power, presentation to NC Board of Transportation, March 5, 2025, slides 6 and 11.

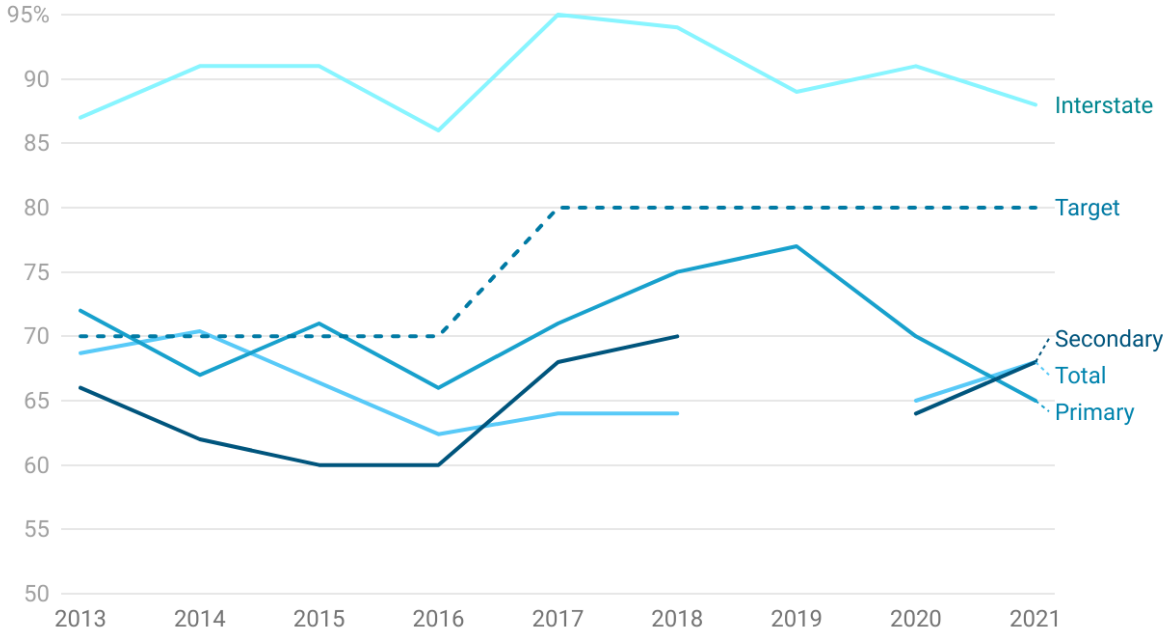
Indicator 31.1: Percentage of miles of pavement in 'good' condition.

Top line: NCDOT tracks the condition of highway pavement through an ongoing survey, and posts annual results online. In fact, the agency uses the percentage of lane miles in 'good' condition as one of its core performance indicators, with a target that 80% of miles be in good repair. While interstates in North Carolina are well above this threshold, the system as a whole seems stalled under 70%, so we mark this as a negative trend.

About road maintenance: Governments have always needed to maintain the infrastructure they've built, but over the last 15 years, asset management for state and local infrastructure has become much more systematized, at NCDOT as across the nation. The agency's vehicle for discussing its asset management is its biennial Maintenance Operations and Performance Analysis Report (MOPAR).[761] NCDOT oversees over 81,000 lane miles of pavement; the 2022 MOPAR notes that 'many system components, built in the 1950s, 1960s, and early 1970s, have either reached or are reaching the end of their service life'.[762] Failing to maintain roads properly accelerates the date at which they must be fully replaced; it also costs drivers time and money. A national nonprofit estimates that North Carolina drivers pay an average of $484 annually in additional operating costs as a result of driving on deteriorated roads.[763]

[761] NCDOT, Maintenance Operations and Performance Analysis Report (MOPAR), 2024, 2022, 2020, 2018, 2016, 2014, available here.
[762] *MOPAR 2022*, at 5.
[763] TRIP, Moving North Carolina Forward: Providing a Modern, Reliable and Sustainable Transportation System in the Tar Heel State, April 2023, at 11.

Figure 31.1: Percentage of miles of pavement in 'good' condition, by component of highway system



Axis starts at 50%

Source: NCDOT, biennial MOPARs • Created with Datawrapper

NCDOT groups roads into three tiers – interstate, primary, and secondary roads – and evaluates the pavement on each road segment as 'good', 'fair', or 'poor'.[764] The agency's own internal performance target is for 80% of lane miles to be in good condition, so we use that as our indicator.[765] While North Carolina's portion of the interstate system has stayed above that threshold for the last decade, the road system as a whole continues to fall short, dragged down by conditions on secondary roads.[766] Meanwhile, the state's future maintenance burden continues to expand as NCDOT builds new capacity, and that doesn't count the potential need to use maintenance funds to rebuild post-Helene. We assess this as a negative trend.

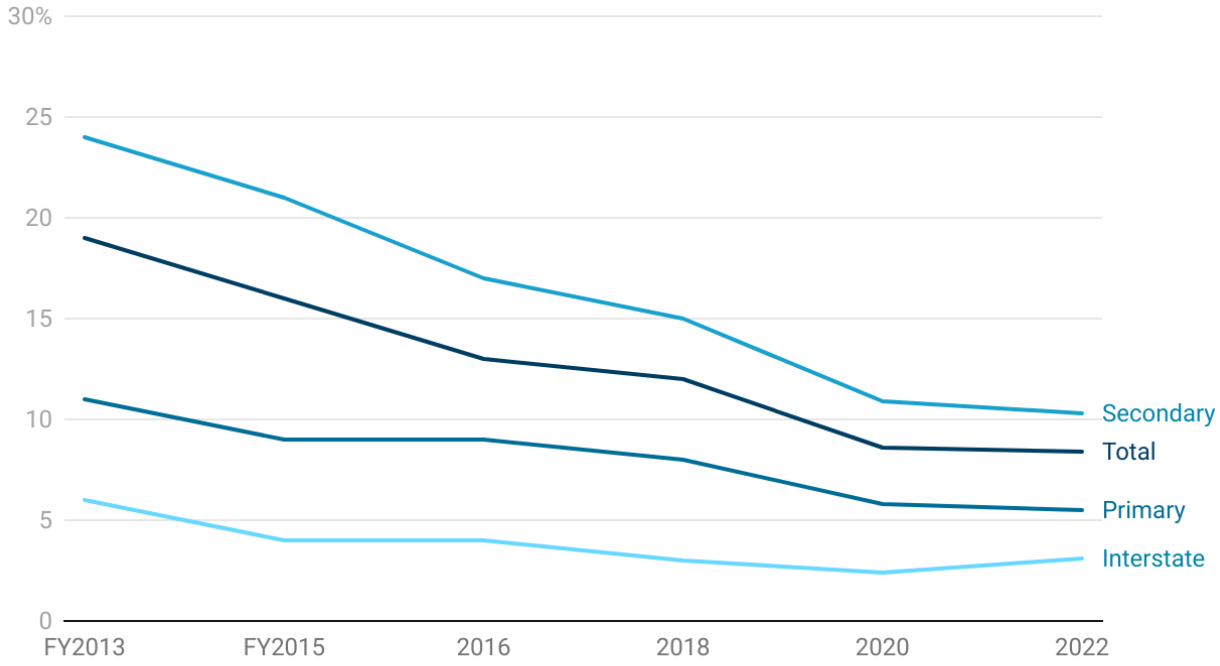
Indicator 31.2: percentage of bridges in 'poor' condition.

Top line: In addition to estimating pavement condition, NCDOT estimates the condition of bridges. Bridges in 'good' condition are deemed safe to carry typical commercial and passenger vehicles. Bridges in 'poor' condition may be physically deteriorating or unsuited for the traffic they carry. By NCDOT's

[764] NCDOT, 2023 Annual Performance Report, February 2024, at 23.
[765] NCDOT's performance target appears to have been 70% until 2016 or so; that wouldn't change our rating.
[766] *MOPAR 2022*, at 16 – 17; NCDOT, Annual Performance Reports, 2013 – 2021, available here.

estimate, the overall percentage of 'poor' condition bridges has dropped significantly over the last decade; this is a positive trend.

Figure 31.2: Percentage of bridges in 'poor' condition, by component of highway system



Source: NCDOT, biennial MOPARs • Created with Datawrapper

About bridge maintenance: NCDOT says it is responsible for inspecting and maintaining 18,600 structures that meet the federal definition of 'bridge'.[767] Bridges are inspected at least once every other year; as of January 2024, the agency estimated that 8.4% of bridges were in poor condition, needing extensive rehabilitation or replacement. A majority of these bridges were built before 1970, and they are disproportionately concentrated in the mountain counties, although there are some bridges in poor condition in every part of the state.[768] NCDOT believes it would cost $4 billion to replace all the bridges in poor condition.[769] The good news is that, thanks to targeted investment over the last decade, the percentage of bridges in poor condition has dropped by 50% or more for all components of the highway system, from interstates to primary and secondary roads.[770] This is a positive trend.

[767] NC DOT, webpage: North Carolina Bridge Information, updated February 14, 2024.
[768] Kristin Barnes, presentation: NC DOT/ Division of Highways, Maintenance Operations & Performance Analysis Report (MOPAR), Joint Legislative Committee on Transportation Appropriations, February 15, 2023, at 31.
[769] NC DOT, webpage: North Carolina Bridge Information, updated February 14, 2024.
[770] NC DOT Maintenance Operations and Performance Analysis Report (MOPAR), 2022, 2020, 2018, 2016, 2014, available here.

Indicator 31.3: Resilience of the transportation system.

Top line: In 2019, we used a makeshift measure of transportation resilience as our indicator: the amount NC DOT spends each year to fix damage from storms. Since then, the agency has taken major strides to improve the resilience of North Carolina's highway and rail networks. Hard numbers to confirm the improved resilience are not yet available, but the steps are so comprehensive and well documented that we assign this a positive trend.

About transportation resilience: In 2019, we framed resilience as 'damages avoided'. Our indicator was the amount that NC DOT spends on post-disaster reconstruction and repair. Wise investments in hazard mitigation – reducing flood risks – would lower these costs over time. Yet, there are some problems with the indicator. For one, disasters occur with uneven frequency and can have massive impacts when they do happen.[771] We tried to account for that by averaging costs over five years, but that's not long enough to smooth volatility, while a longer averaging period makes the indicator unhelpful for guiding policy. Also, direct repair costs are important, but disruption in the transportation system is more important, and repair costs don't reflect that.

For this update, we've looked for a new indicator, keying off a broader conception of resilience: how well does the transportation system keep functioning – allowing residents to get where they need to go – when North Carolina experiences powerful hurricanes or intense floods. One excellent indicator would be a measure of how continuously the most critical roads and railroads in the state provide service – or the inverse: how often critical roads and railroads are disrupted. NC DOT identified critical highway and rail segments in early 2024.[772] The analysis incorporates nine different factors, including redundancy, average daily truck traffic, tourism revenue, nearby jobs, vulnerability of residents (transportation disadvantage), proximity to transportation hubs, and proximity to hospitals, shelters, and utilities.[773] We have not seen a metric tracking closures on this subset of the system. However, the extensive steps taken by NC DOT since 2019 – discussed under 'recent developments', below – leave us certain that North Carolina's transportation system is more resilient now than it was five years ago. For that reason, we rate this indicator as showing a positive trend.

Recent developments: NC DOT has taken major steps forward over the last few years. NC DOT issued a 'resilience policy' in September 2021, announcing that the agency would take steps to identify and minimize hazards to transportation assets and the people of North Carolina, with annual documentation in an NC DOT Resilience Strategy Report.[774] Since then, the agency has worked to integrate risk and resilience analysis into operations, maintenances, and new construction.[775] Over the last five years, NC DOT has invested in a flood early warning system. Brought fully online in 2022, the system currently

[771] For example, NC DOT estimates the cost of disaster expenditures at roughly $150 million for 2020, 2021, and 2022; but twice that for 2019. NC DOT, Maintenance Operations and Performance Analysis Report [*MOPAR 2022*], 2022, at 13.
[772] NC DOT, Resilience Improvement Plan, April 18, 2024, Appendix B, Statewide Criticality.
[773] *Ibid*, at 37.
[774] NC DOT, Resilience, NCDOT Policy F.35.0102, September 27, 2021.
[775] NC DOT, 2022 Resilience Strategy Report, April 2022; NC DOT, 2023 Climate Strategy Report, October 1, 2023.

includes over 50 stream gauges allowing the agency to forecast conditions on 2,900 inland road miles, 15,000 bridge and culverts, and 11,000 miles of roads vulnerable to coastal storm surge.[776] Forecasting is not a substitute for investments to reduce flood risk and impacts, but it does reduce the chances of fatalities and improves emergency management during disasters.

The 2021 federal Infrastructure, Investment, and Jobs Act (IIJA, also dubbed the Bipartisan Infrastructure Law) included a new, resilience-oriented transportation grant program: Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT).[777] The PROTECT program, run by the Federal Highway Administration (FHwA), offers planning grants and competitive resilience improvement grants.[778] States with a Resilience Improvement Plan (RIP) incorporated in their long-range transportation plan receive a 10% reduction in non-federal cost share requirements for PROTECT project funding. NCDOT published North Carolina's RIP in April 2024; in addition to outlining critical system components as described above, the document identifies the roads, bridges, culverts, and rail segments that are the highest priority for resilience investments.[779]

One of the most vulnerable roads in the state is NC 12 on the Outer Banks; it requires frequent interventions and repairs to stay passable. Dare County and a set of local governments worked together with NCDOT to develop recommendations for the longer-term management of the highway.[780] Implementing that plan is one of NCDOT's resilience priorities, and it may offer a model for other jurisdictions to tackle resilience infrastructure problems.[781]

In September 2024, Hurricane Helene damaged transportation infrastructure throughout western NC. Flooding and landslides did an estimated $9 billion in damage to the transportation system, washing out bridges, roads, and railroads, and severing I-40 in the Pigeon River Gorge north of the Great Smoky Mountains.[782] NCDOT has estimated that North Carolina's total share of transportation recovery will be $917 million, widening the gap between what the agency would like to build and what it has funds to build; that gap is made even larger by the temporary need to front the cost of other repairs as well until federal agencies reimburse them.[783] The larger takeaway – beyond Helene recovery – is that more frequent natural disasters will require that North Carolina spend a larger fraction of its transportation budget on repairs and rebuilding, will less funds available for any kind of new capacity. Investments in resilience can help reduce but not eliminate that long-term shift in requirements.

[776] NC DOT, 2023 Annual Performance Report, February 2024, at 10; NC DOT, webpage: Flood Warning System, updated May 7, 2024.
[777] Infrastructure Investment and Jobs Act (IIJA), PL 117-58 (HR3684), 2021, section 11405.
[778] US DOT, webpage: Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT), updated August 21, 2023.
[779] NC DOT, Resilience Improvement Plan, April 18, 2024, at 52-54.
[780] Highway 12 Task Force, Highway 12 Task Force Report, February 7, 2023.
[781] NC DOT, 2023 Climate Strategy Report, October 1, 2023, at 23.
[782] *Helene DNA 2.0*, at 63.
[783] NCDOT, presentation: Hurricane Helene Recovery Financial Update and Proposed 2025 Spend Plan Amendment, presentation to the NC Board of Transportation, March 5, 2025.

Goal 32: North Carolina has safe and affordable transportation options for all residents

Trend: Mixed

Most North Carolinians commute and run errands by car, but for many – either because of youth, age, or income – driving is not an option. For others, it is a last resort. For this goal, we consider two indicators that track the degree to which North Carolinians really have accessible and affordable transportation alternatives: the percentage of workers doing something other than driving alone (indicator 33.1); and the rate of pedestrian and bicycle crashes (indicator 33.2), since safety is key to unlocking walking and cycling for most of the public. For the first, greater flexibility for some workers to work from home is positive but masks a crisis for public transit systems; for the second, pedestrian fatalities are stable and cycling fatalities increasing, a bad trend. Overall, that yields mixed results for this goal.

Solutions: North Carolina should K1, increase the share of funds spent on non-highway modes of transportation; K4, integrate carbon reduction and equity criteria into transportation planning; K5, support the robust implementation of Complete Streets; L3, promote transit-accessible development; and L5, promote and protect urban tree canopy.

Indicator 32.1: Percentage of workers not commuting alone.

Top line: For most of the last decade, the number of workers (over 16 years old) who did not commute alone to work hovered just below 20%. As a result of the pandemic in 2020, that number shot to just under 30% in North Carolina, and has remained at that level. That's almost entirely a result of more people working from home at least part of the time. It's great from a carbon reduction perspective, and likely improves people's quality of life, and so we count this as a positive trend. However, it also masks a crash in transit ridership and resulting financial pressures on public transit systems, which are a lifeline for many workers who cannot afford a car and do not have the option to work from home.

About commuting to work: A practical indicator of the availability of transportation alternatives is the number of people who use them. Alternatives to single driver commuting include carpooling, using public transit, walking, biking, personal mobility devices such as electric scooters, and working from home. For this indicator, we track the percentage of workers, 16 and older, who are commuting in some other way than driving by themselves, as reported to the US Census Bureau's American Community Survey.[784] Figure 33.1 shows the major alternatives to driving alone, including working from home. Until

[784] US Census Bureau, American Community Survey, 1 Year Estimates, 2013-2022, Means of Transportation to Work, Workers 16 and older. Data for 2020 is from the US Census Bureau, American Community Survey, 2020 1-Year Experimental Release, Table XK200801, Means of Transportation to Work.

2020, each of these alternatives were growing in absolute terms, but barely keeping up with North Carolina's population growth, so the percentage of workers not commuting by driving alone remained stalled between 18% and 20%.[785]

The pandemic changed that, instantly boosting the percentage of North Carolinians working from home; and that number has stayed high, so the total share of the workforce not commuting alone has stayed around 28%.[786] Across the economy, working from home is more widespread in the technology sector; North Carolina's strong technology sector raises the percentage of residents working from home compared to other states.[787] In addition to saving workers the time that would otherwise be spent commuting, working from home cuts greenhouse gas emissions; the effect is most pronounced for those who live further away from their offices and drive larger gasoline-powered trucks or SUVs. For these reasons, we count the overall reduction in the percentage of solo commuters as a positive trend.

[785] *Ibid.*

[786] *Ibid.* For a nuanced discussion of how various surveys measure working from home, and why they yield different estimates, see J. M. Barrero, et al., presentation: How Much Work from Home is there in the United States?, January 27, 2024.

[787] Hyunsoo Rim, Work-from-home levels reach lowest since 2020 – but remote work still dominates these industries, Forbes, June 11, 2024; Michael Burrows, Charlynn Burd, and Brian McKenzie, Home-Based Workers and the COVID-19 Pandemic, American Community Survey Reports, ACS-52, April 2023.

Figure 32.1: How North Carolinians get to work

Axis for solo-commuters is different than other 5 graphs.

Source: US Census Bureau, American Community Survey. • Created with Datawrapper

While the overall trend is good, it masks a serious problem for public transit systems. Even before the pandemic, public transit systems across the United States saw ridership drop with the advent of rideshare services (Uber and Lyft).[788] In North Carolina, the number of transit commuters rose unevenly to a peak of 55,000 in 2019, but then the bottom dropped out during the pandemic, sinking to roughly 25,000 in 2021 and 2022. At lower rates of ridership, operating and capital costs are spread over fewer fares, increasing the public subsidy needed to keep transit systems running. Nonetheless, transit

[788] Laura Bliss, Another Study Blames Uber and Lyft for Public Transit's Decline, CityLab, January 24, 2019.

remains a crucial mode of transportation for many North Carolinians. Roughly 600,000 North Carolinians of driving age do not have a driver's license, and 33.3% of workers using public transit do not own a car.[789]

Indicator 32.2: Bike and pedestrian safety

Top line: The rate at which bikes and pedestrians are involved in crashes has remained relatively stable but unacceptably high, and in recent years the rate at which bikers have died has climbed substantially. That's a negative trend.

About bike and pedestrian safety: Walking and biking account for only a small share of daily commutes and trips (see: indicator 33.1) in North Carolina today; perceived safety is a key factor in people's decision to bike or walk.[790] In fact, those perceptions have a basis in reality. Pedestrians are involved in just 1% of crashes in North Carolina but are involved in 10% of the crashes that involve serious injuries or fatalities. Risk factors for pedestrian crashes include local roads with higher speed traffic, nearby alcohol sales, nearby bus stops, and higher proportions of young or disabled residents.[791] Certain features, including lighting and crosswalks, can make sidewalks safer for pedestrians. But local governments typically provide these features, and pedestrian crashes and fatalities occur disproportionately on arterial roads, maintained by NCDOT.[792] A study of bike crash data from Mecklenburg County, 2010-2015, found that the least safe environments for cyclists were roads with no bike lanes and high speed, and with commercial, institutional, dense residential, or heavy industrial uses nearby.[793] Recent trends in the design of sport utility vehicles and pickup trucks make the threat worse; vehicles with tall, blunt front ends increase pedestrian fatality risk by 43.6%; vehicles with medium-height, blunt front ends increase risk by 25.6%.[794] The risks to pedestrians and bikers aren't just from crashes: although cycling and walking are virtually emissions-free, cyclists and pedestrians experience significantly higher exposures to pollution than people traveling in bus and car cabins.[795]

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[789] US DOT, FHwA, Highway Statistics 2022, Table DL-1C, Licensed Drivers By Sex and Ratio to Population, January 2024; US Census Bureau, 2022 American Community Survey, 1 Year Estimates, S0802, Means of Transportation to Work by Selected Characteristics: Vehicles Available. Note that 1.3% of people who said they drive to work alone also said they have no access to a car.

[790] Governors Highway Safety Association, A Right to the Road: Understanding & Addressing Bicyclist Safety, September 2017, at 23.

[791] Vikash Gayah et al., Quantification of Systemic Risk Factors for Pedestrian Safety on North Carolina, NCDOT Project 2022-11, FHWA/NC/2022-11, October 2022, at 64.

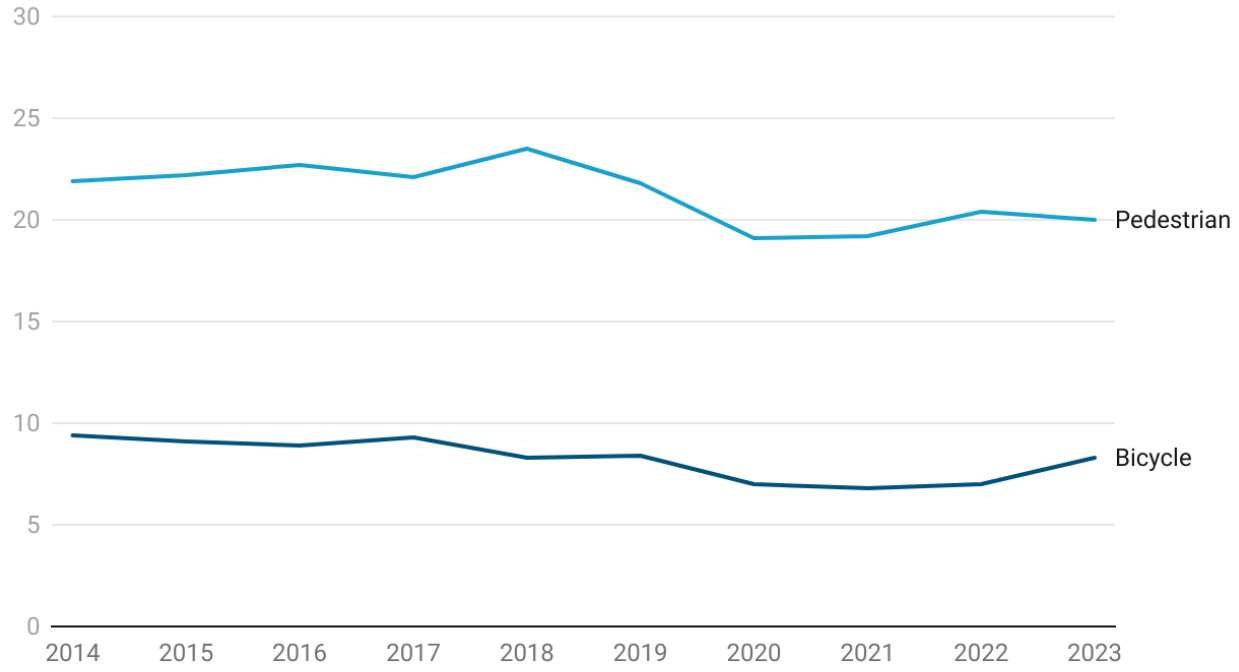
[792] NCDOT, Vulnerable Road User Safety Assessment, 2023

[793] Kanya Mukoko and Srinivas Pulugurtha, Examining the influence of network, land use, and demographic characteristics to estimate the number of bicycle-vehicle crashes on urban roads, IATSS Research, April 2020, 44 (1), https://doi.org/10.1016/j.iatssr.2019.04.001.

[794] Wen Hu et al., The association between passenger-vehicle front-end profiles and pedestrian injury severity in motor vehicle crashes, Journal of Safety Research, November 2023, 90: 115, https://doi.org/10.1016/j.jsr.2024.06.007.

[795] H. Christopher Frey at al., Quantification of Sources of Variability of Air Pollutant Exposure Concentrations

Figure 32.2: Bike and pedestrian crash rates, per 100,000 residents



Source: Crash data from Non-Motorist Crash Dashboard, NC DOT. Population data from ACS, Census. Rate calculated by NCCN. • Created with Datawrapper

Our indicator follows the crash rates for pedestrians and bicyclists since 2014, using data from the Non-Motorist Crash Dashboard developed by the NC Department of Transportation.[796] It is common practice for agencies and other organizations to use police generated crash reports to understand roadway risks and improve roadway, as we have done here, but there are limitations to this dataset. It does not reflect pedestrian and bike crashes that occur on private property, including parking lots and private roads. National studies also suggest that using crash reports alone to assess road safety may underestimate pedestrian and bicyclist crash rates, as not every crash may result in a crash report.[797] Black, Indigenous, and people of color, along with lower-income people, are disproportionately affected by pedestrian and bike injury risk and traffic fatalities regardless of transportation mode.[798]

Among Selected Transportation Microenvironments, Transportation Research Record, July 2020, 2674 (9): 395, https://doi.org/10.1177/0361198120929336.

[796] NC DOT, web dashboard: Non-Motorist Crash Dashboard, 2014-2023.

[797] Sara Doggett et al., Evaluating Research on Data Linkage to Assess Underreporting of Pedestrian and Bicyclist Injury in Police Crash Data, November 2018.

[798] Josh Roll and Nathan McNeil, Race and income disparities in pedestrian injuries: Factors influencing pedestrian safety inequity, Transportation Research Part D: Transport and Environment, June 2022, 107, https://doi.org/10.1016/j.trd.2022.103294; Matthew Raifman and Ernani Choma, Disparities in activity and traffic

The crash rates for pedestrians and bicyclists have remained stable. However, per the League of American Bicyclists, the statewide bicyclist fatality rate has increased from 21.5 fatalities per 10,000 bike commuters in 2017 to 29.4 fatalities in 2024.[799] We consider this a negative trend.

Goal 33: Walkability of North Carolina's cities

Trend: Positive

People live further away from their daily activities and often find themselves have to drive or ride in a car to get to school, to receive medical care, and to shop for their basic needs. Experts in community and city planning emphasize the importance of designing communities around the needs of residents, to reduce car use and promote walking, cycling, and public transportation.

Solutions: Improving walkability will require K1, increasing the share of funds spent on non-highway modes of transportation; K4, integrating carbon reduction and equity criteria into transportation planning; and K5, supporting the robust implementation of Complete Streets. Walkability can also be improved by L4, eliminating parking minimums, and L5, protecting urban tree canopy.

Indicator 33.1: Walkability of urban and suburban communities.

Top line: Cities in North Carolina vary in their walkability. Data from Walk Scores™ offers a snapshot of walkability in metro areas at a given time. Comparing the most recent scores archived data from 2014 shows that North Carolina's larger cities are slightly more walkable in 2025.

About walkability: A walkable community is one in which residents can access essential and nonessential destinations on foot safely. Walkability is correlated with community quality of life and the overall life satisfaction of residents.[800] In an early 2020 survey of local leaders across North Carolina, 57% said improving walkability was a priority for their community, but many said local match requirements and lack of local administrative capacity made it hard for them to access state and federal grant funds.[801] There are also challenges to those funding streams. In 2013, the state Strategic Transportation Investments Act prohibited the use of state transportation funds for projects that are primarily focused on bicycle and pedestrian improvements.[802]

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fatalities by race/ethnicity, American Journal of Preventive Medicine, August 2022, 63(2): 160, https://doi.org/10.1016/j.amepre.2022.03.012.

[799] League of American Bicyclists, State Ranking and Report Cards, 2024 and 2017.

[800] Jeremy Mattson et al., Transportation, community quality of life, and life satisfaction in metro and non-metro areas of the United States, Wellbeing, Space and Society, 2021, 2, https://doi.org/10.1016/j.wss.2021.100056.

[801] Suzanne Leland, The Implementation of Active Transportation Policies at the Local Level: Findings From a North Carolina Survey, Public Works Management & Policy, May 2022, 27 (3): 315, https://doi.org/10.1177/1087724X221088835, at 323, 326, 329.

[802] Session Law 2013-183, House Bill 817

This indicator uses a score between 0-100 derived by analyzing walking routes to nearby amenities from walkscore.com. For cities and neighborhoods, Walk Scores are calculated for a grid of latitudinal and longitudinal points approximately 500 feet apart, each point on the grid is weighted by population density. Score are assigned based on the distance to amenities in 13 categories (e.g., grocery stores, coffee shops, restaurants, bars, movie theaters, schools, parks, libraries, bookstores, fitness centers, drug stores, hardware stores, clothing/music stores).[803] Amenities within a quarter mile, or a five minute walk, are awarded maximum points. The further away amenities are, the fewer points awarded; amenities outside of a 30 minute walk are given no points. Walk Score also uses other measures including population density and road metrics (including block length and intersection density). This indicator has its limitations, however. There is no mention of pedestrian facilities such as sidewalks, crosswalks, or grade separated crossings (overpasses like bridges or underpasses). As mentioned in the previous indicator (32.2) on pedestrian safety, pedestrian features, along with other road design features like lighting, speed limit, number of vehicle lanes, and land use mix can be risk factors for pedestrian safety.[804] A measure of walkability without safety considerations is incomplete, but for our purposes we will compare the most recent Walk Score, as of February 2025 (Walk Scores are updated in real time or close to)[805] to archived data from March 2014; scores improved in 11 of the 12 metro areas. We consider this a positive trend. Cities in North Carolina range in scores between 18 and 47.[806]

[803] Lucas Carr, et al., Walk Score™ As a Global Estimate of Neighborhood Walkability, American Journal of Preventative Medicine, Nov 2010, 39 (5): 460, doi.org/10.1016/j.amepre.2010.07.007.
[804] *Idem*; Vikash Gayah et al., Quantification of systemic risk factors for pedestrian safety on North Carolina, NCDOT Project 2022-11, October 2022, available here.
[805] Chris Woods, blog post: Download of the Week: Q&A with Walk Score CEO Josh Herst, Multifamily Executive, July 2011.
[806] Walk Score, webpage: Cities in North Carolina, visited February 2025.

Table 33.1: "Walk Scores" by metro area have improved

	March 2014	Feb 2025
	Walk Score	Walk Score Change
Charlotte	24	+2
Raleigh	29	+2
Greensboro	28	+1
Winston-Salem	22	+0
Durham	28	+2
Fayetteville	18	+3
Wilmington	32	+3
Asheville	35	+2
Concord	17	+1
Burlington	31	+2
Gastonia	22	+1
Hickory	27	+1

Source: walkscore.com, as of February 2025. Wayback Machine used for data from 2014. • Created with Datawrapper

Goal 34: Land use patterns offer compact options

Trend: Negative

Development and land use patterns have major impacts on most North Carolinians' daily lives, determining commuting time and costs, housing availability and prices, access to essentials and amenities, and opportunities to build and maintain community. Over the last two decades, even as

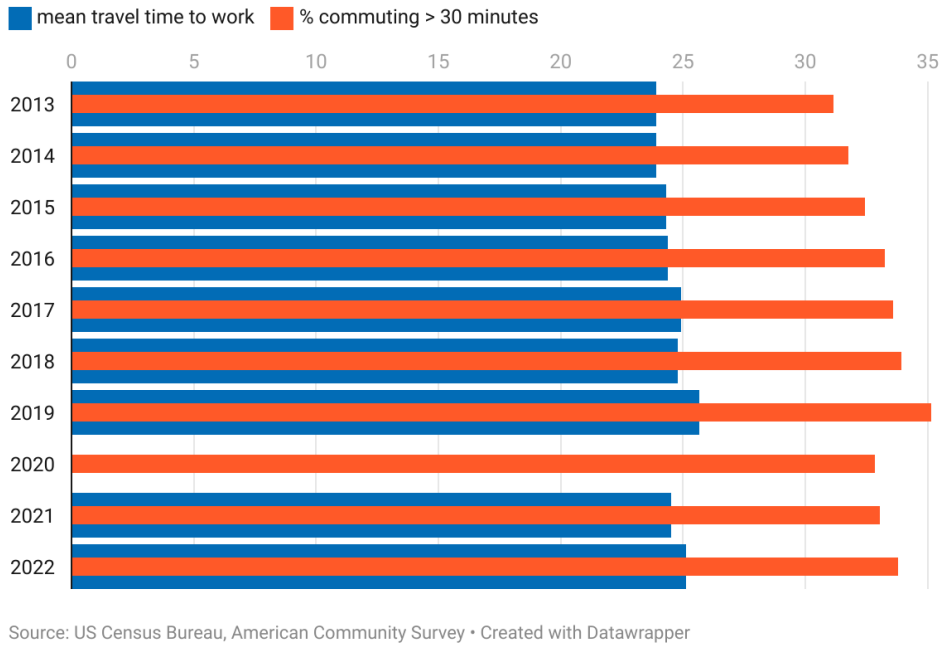
some rural counties have lost residents, North Carolina's population has grown by 29%.[807] For this goal, we track two indicators: Are residents able to get to or from work in under 30 minutes, or are growth patterns increasingly trapping residents in their cars (indicator 34.1)? As North Carolina's towns and counties receive new residents, where are those residents landing (indicator 34.2)? The trend for commuting distances is negative; the trend for macro growth patterns – sprawling exurbs – is negative as well.

Solutions: North Carolina should, K4, manage its transportation investments to avoid inducing sprawl; L1, support scalable affordable housing solutions; L2, reform single family zoning to promote density; L3, promote transit-accessible development; and L4, eliminate mandatory minimum parking for development.

Indicator 34.1: Percentage of residents with commutes shorter than 30 minutes.

Top line: Long distance commuting chews up time and is a risk factor for multiple health hazards. Yet, over the last decade, both the mean travel time for solo commuters and the percentage of solo commuters who must travel more than 30 minutes to get to work have continued to climb. This largely reflects where we build new housing, and it is an unhealthy trend.

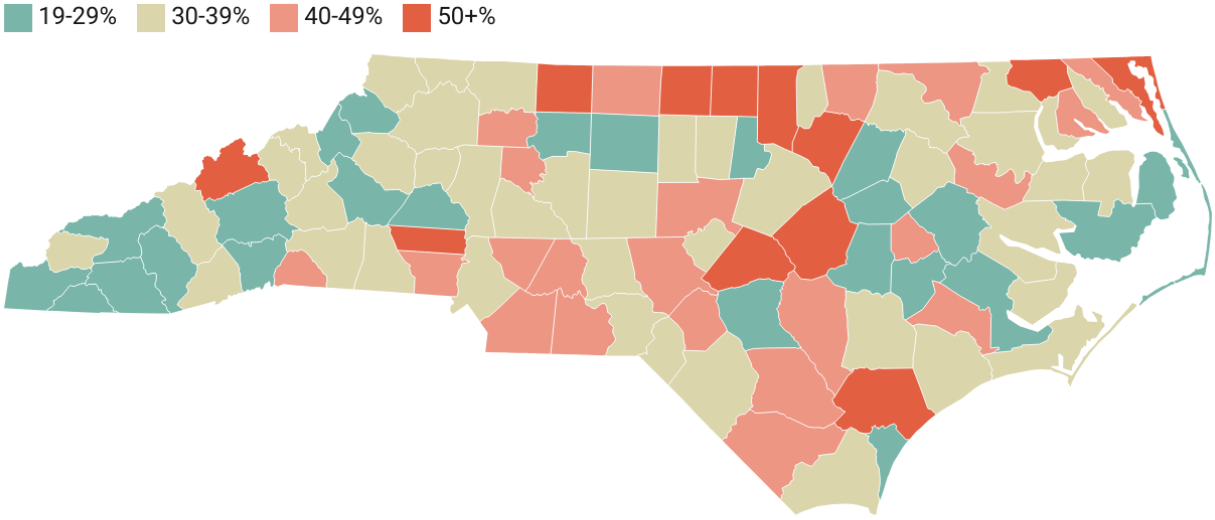
Figure 34.1: Percentage of solo commuters in NC who commute more than 30 minutes; mean travel time to work for all solo commuters



[807] U.S. Census Bureau, Resident Population in North Carolina [NCPOP], retrieved from FRED, Federal Reserve Bank of St. Louis, September 4, 2024.

About commute times: Sprawling land use patterns impose direct costs in time and money on residents as they commute to and from work, shuttle kids to school and activities, and run errands.[808] Longer commutes are associated with health risk factors, including higher blood pressure and habits of inactivity.[809] Each hour a person spends in a car daily correlates with a 6% greater probability they are obese.[810] This indicator tracks, of those North Carolinians who commute alone, the percentage that have to drive more than 30 minutes each way.

Map 34.1: Percentage of solo commuters who commute more than 30 minutes to work by county, 2018-2022



Source: County Rankings and Roadmaps, University of Wisconsin Population Health Institute, 2024. • Created with Datawrapper

Rates of long commutes vary widely across North Carolina's 100 counties, ranging from 19% in Buncombe County to 63% in Gates County. Over half the residents in 12 counties have long commutes: these are all counties with bedroom communities that serve near-ish metro regions: Virginia Beach; Wilmington; the Triangle; the Triad; Charlotte; Asheville.[811] Overall, over the last ten years, the percentage of solo commuters who travel more than 30 minutes to get to work has risen from 31.1% to

[808] Shima Hamidi and Reid Ewing, Is sprawl affordable for Americans?: Exploring the association of transportation affordability and urban sprawl, Transportation Research Record, 2015, 2500 (1): 75, https://doi.org/10.3141/2500-09 (finding that increased transportation costs more than offset reduced house prices, yielding higher total household costs for residents of sprawling suburbs).

[809] Christine Hoehner et al., Commuting distance, cardiorespiratory fitness, and metabolic risk, American Journal of Preventive Medicine, June 2012, 42 (6): 571, DOI: 10.1016/j.amepre.2012.02.020.

[810] Lawrence Frank et al., Obesity relationships with community design, physical activity, and time spent in cars, American Journal of Preventive Medicine, August 2004, 27 (2): 87, DOI: 10.1016/j.amepre.2004.04.011.

[811] County Health Rankings and Roadmaps, Long Commute – Driving Alone: North Carolina, 2024, based on US Census Bureau, American Community Survey 5-year data, visited August 30, 2024.

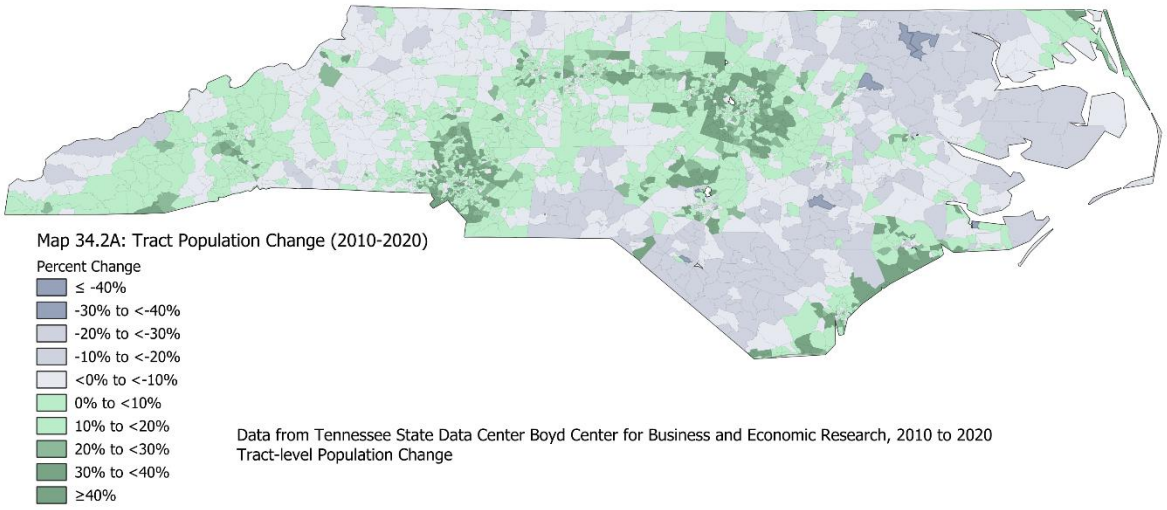
33.8%.[812] That's not a large percentage change, but represents 98,000 additional workers with commutes extending past the 30 minute milestone. A much larger number of workers have also seen their commutes lengthen on either side of the 30 minute mark. That's reflected in the increase of just over a minute in the mean travel time, a collective loss of 60,000 hours each workday for the state's 3.6 million solo commuters.[813] We count this as a harmful trend.

Indicator 34.2: Patterns of residential migration

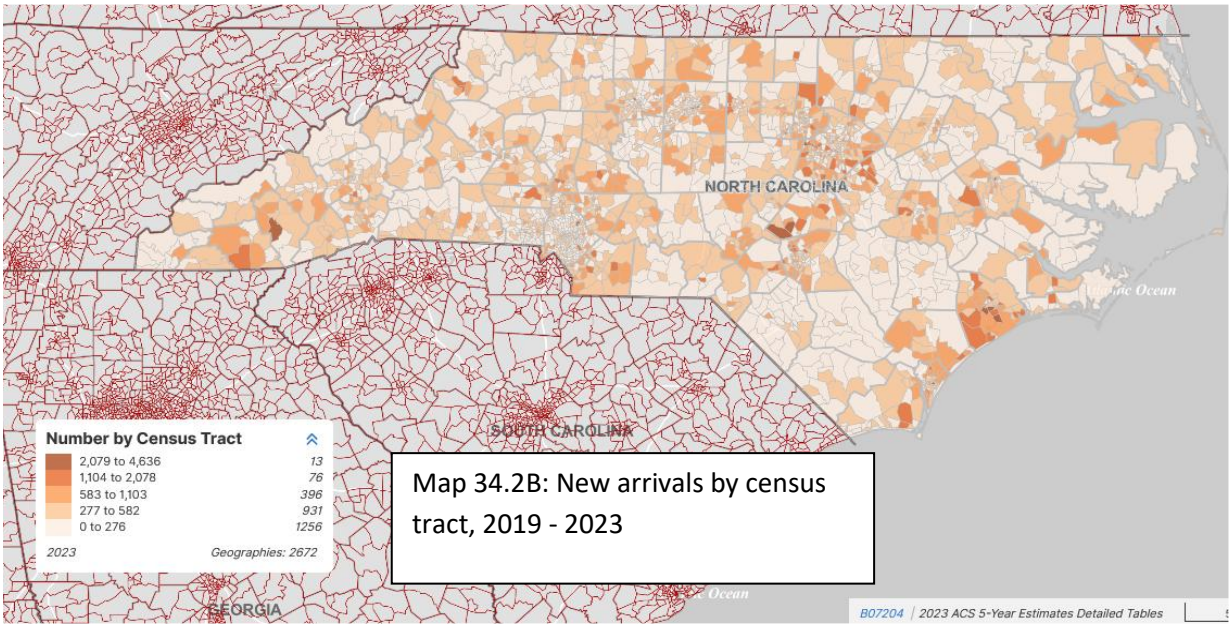
Top line: From 2010 through 2020, much of North Carolina's net growth landed in sprawling developments on the urban fringe; that pattern has continued into the current decade. It drives a slew of other trends, most in bad directions, and we therefore view this trend as negative too.

About patterns of migration: North Carolina continues to grow rapidly. The way we accommodate that growth, forcing much of it to greenspace on the urban fringe, may be the single most important indicator in this report. As we noted in 2019, North Carolina's growth patterns are among the most sprawling in the nation.[814] Growth on the urban fringe is chewing up farmland (indicator 9.2) and open space (indicator 6.1), increasing impervious surface (indicator 7.3) and degrading water quality (indicator 4.2), forcing residents to drive longer distances to get to work and amenities (indicator 34.1), increasing local governments' cost of service (indicator 37.1), and driving up carbon emissions from the transportation sector (indicator 29.1). Our current growth patterns provide a path to the middle class for some homeowners – no small thing – but make massively inefficient use of the existing building stock. Moreover, development acts as a one-way ratchet: once farms and forests are cleared and paved, they are lost for the foreseeable future. Our current growth patterns benefit a subset of the development and finance industries but are unsustainable and cost us all in ways large and small. We rate this a bad trend.

[812] US Census Bureau, American Community Survey, B08303, Travel time to work, 2013 - 2022.
[813] US Census Bureau, American Community Survey, DP03, Mean travel time to work, 2013 – 2022.
[814] Reid Ewing and Shima Hamidi, Costs of Sprawl, 2017 (North Carolina had three of the nation's ten most sprawling cities in 2000 – Fayetteville, Winston-Salem, and Hickory – and four in 2010 – adding Charlotte to the other three).



In 2019, we assessed growth patterns using a complicated sorting of census tracts.[815] For this update, we're taking a simpler approach, looking at two maps that capture spatial trends. Figure 34.2A, produced by the Tennessee State Data Center using data from the 2010 and 2020 decennial censuses, shows net change in all census tracts in North Carolina from 2010 to 2020.[816]



Map 34.2B: New arrivals by census tract, 2019 - 2023

[815] *2019 State of the Environment*, Indicator 45.1, at 117.

[816] Tennessee State Data Center, interactive map: 2010 to 2020 Tract Change, last visited February 2, 2025. See also, Lisa Carlson, blog post: Looking at population change across NC's census tracts, Carolina Demography, February 20, 2023.

Figure 34.2B examines the years since the 2020 census: the map shows households that reported to the 2019-2023 (5-year) American Community Survey that they had moved from another city or town within the last year.[817] It shows gross growth, not net, so even rural census tracts that suffered net loss can show arrivals. But overall, it extends the pattern of flows from the last decade: the largest absolute number of new arrivals are settling in census tracts on the urban fringe. That pattern is even easier to see when one zeroes in on metro areas.

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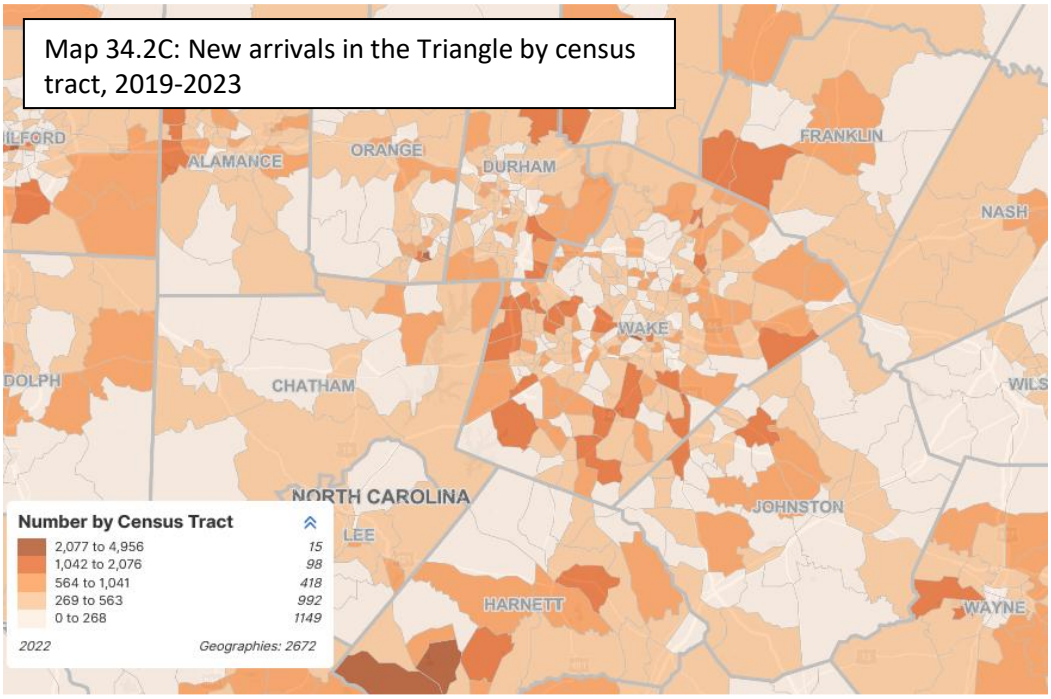
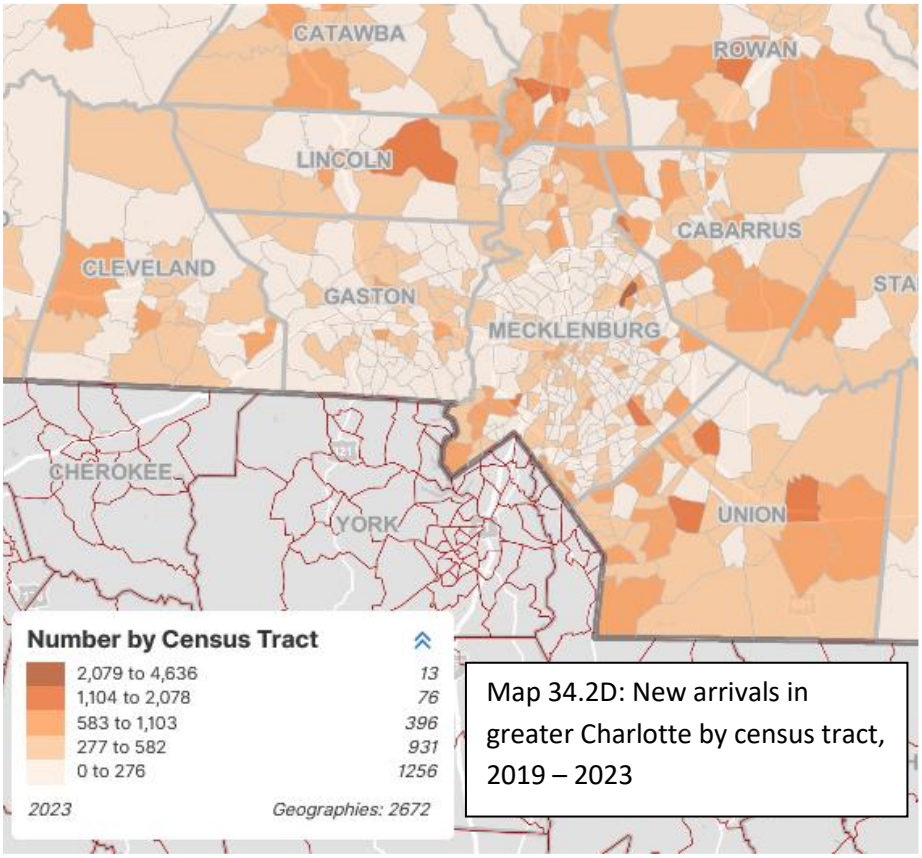


Researchers generally classify growth patterns as sprawling based on a mix of factors, such as density, land use mix, centeredness, street connectivity, and local accessibility.[818] More centralized growth

[817] US Census Bureau, American Community Survey, 5 year estimates, 2019- 2023, table B07204, Geographical Mobility in the Past Year for Current Residence - State, County, and Place Level in the United States.

[818] Changyeon Lee, Metropolitan sprawl measurement and its impacts on commuting trips and road emissions, Transportation Research Part D: Transport and Environment, May 2020, 82, https://doi.org/10.1016/j.trd.2020.102329. On some distinguishing features of sprawl along the coast, see, Thomas Crawford, Where does the coast sprawl the most? Trajectories of residential development and sprawl in coastal North Carolina, 1971–2000, Landscape and Urban Planning, December 2007, 83 (4): 294, https://doi.org/10.1016/j.landurbplan.2007.05.004.

patterns are associated with less air pollution;[819] greater financial well-being for residents at all income levels;[820] and lower per capita municipal costs for fire protection, streets, parks, and sewer and water service.[821]

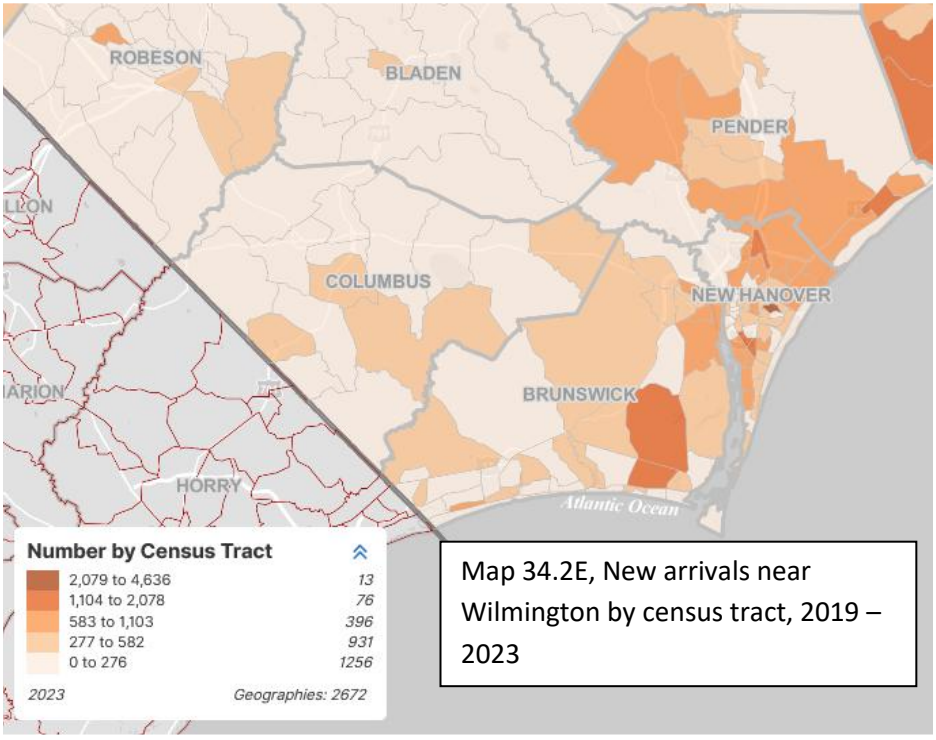


Map 34.2D: New arrivals in greater Charlotte by census tract, 2019 – 2023

The relationship of land use patterns to economic mobility is nuanced. In general, compact patterns have been found good for economic mobility at the regional level; at a finer grain, sprawl patterns tend to be positive for people moving to the urban edge and bad for people in existing neighborhoods.[822] The net impacts look particularly grim in North Carolina and the South generally. For example, a study of growth in Charlotte found that development along the I-485 loop pulled activity away from inner-ring neighborhoods and undermined the success of infill projects.[823] Road investments in particular can drive sprawl; in the Triangle, for example, construction of the Triangle Expressway spurred rapid development along its route, significantly increasing total vehicle miles traveled.[824]

[819] Lara Clark et al., Air Quality and Urban Form in U.S. Urban Areas: Evidence from Regulatory Monitors, Env. Sci. & Techn., July 2011, 45 (16): 7028, https://doi.org/10.1021/es2006786.
[820] Wen Hao Lee et al., How do sprawl and inequality affect well-being in American cities?, Cities, September 2018, 79: 70, https://doi.org/10.1016/j.cities.2018.02.023.
[821] Jeremy Mattson, Relationships between Density and per Capita Municipal Spending in the United States, Urban Science, September 2021, 5 (3): 69, https://doi.org/10.3390/urbansci5030069.
[822] Russell Smith and Zachary Blizard, A census tract level analysis of urban sprawl's effects on economic mobility in the United States, Cities, August 2021, https://doi.org/10.1016/j.cities.2021.103232.
[823] Melissa Anne Currie and Janni Sorensen, Repackaged "urban renewal": Issues of spatial equity and environmental justice in new construction, suburban neighborhoods, and urban islands of infill, Journal of Urban Affairs, June 2018, 41 (4), https://doi.org/10.1080/07352166.2018.1474081.
[824] Sonu Mathew et al., Spatial and Temporal Effects of a Toll Road on Land Use Developments and Travel Demand, International Conference on Transportation and Development, June 2021, doi/10.1061/9780784483541.022.

While this report focuses on current conditions and trends rather than detailed policy solutions, in the case of growth patterns, we note that there are better alternatives to the current pattern. Proponents of sprawl argue that it is essential to lower housing prices and improve affordability (indicators 27.1 and 27.2) and, indirectly, the adequacy of household incomes (indicator 26.3); that increasing metropolitan density is likely to come at the expense of urban tree cover (indicator 35.1); and that sprawl's emissions problems can be reduced by electrifying the transportation system (indicator 29.4). A pro-rural, pro-urban answer is that housing affordability and tree cover can be addressed with smart metropolitan policies. Even as metropolitan housing prices are high, we have a significant capacity of underused spaces that could be unlocked by state and local policy.[825] Urban density does not require chopping down all the trees and can be accomplished without triggering gentrification. More fundamentally, we cannot afford the current pattern of growth. We lack the revenue to maintain existing transportation infrastructure (indicator 30.1); continuing to prioritize new capacity on the urban fringe guarantees we will not provide adequate maintenance in rural areas, or safe non-driving options in urban centers.



Map 34.2E, New arrivals near Wilmington by census tract, 2019 – 2023

Recent developments: The question of climate-driven growth patterns in North Carolina merits special mention. Following Hurricanes Matthew and Florence, some coastal North Carolinians who lost homes or jobs in the storms migrated inland. Climate-driven weather disasters can disrupt census data collection, making it hard both for government to track migration as it happens and provide support to residents who are relocating.[826] Out-migration after Matthew and Florence was significant for specific

[825] The 2023 5-year American Community Survey estimates that North Carolina has upwards of 600,000 vacant properties; less than a third of those are seasonal or second homes. US Census Bureau, American Community Survey (5-year), 2023, B25002, Vacancy Status. In addition, many urban single-family homes have room on their lots to add accessory dwelling units.

[826] Zoya Teirstein, Can the US Census keep up with climate-driven displacement?, Grist, September 3, 2024.

communities in the coastal plain.[827] Yet, movement out of flood-prone counties over the last ten years has been more than offset by movement in, both at the national level and in North Carolina.[828]

Recent books have outlined a future of large-scale domestic migration as the sea rises and stronger storms and floods threaten the coastal plain (among other forms of natural disasters).[829] In recent years, news stories have periodically presented Asheville and other places in North Carolina as possible 'climate havens.'[830] But the devastation wrought in western NC by Hurricane Helene has quieted those predictions, at least for time, driving home the lesson that no place is truly insulated from the harms of an increasingly unstable climate.[831]

Goal 35: Landscapes support quality of life

Trend: Positive

Living with access to green space benefits mental and physical health, educational performance, and economic productivity. For this goal, we track trends in the density of the tree canopy in North Carolina's largest cities, and the proximity of public parks for residents across the state, rural as well as urban. Both indicators show positive trends, adding up to good news for this goal.

Solutions: North Carolina should A1, Fund the NC Land & Water Fund; A2, Fund the Parks & Recreation Trust Fund; A3, Fund the Agricultural Development & Farmland Preservation Trust Fund; B4, encourage local farmland protection plans; D1, protect North Carolinians from disproportionate burdens; G7, expand funding for the Community Conservation Assistance Program; and L5, encourage and protect urban tree canopy.

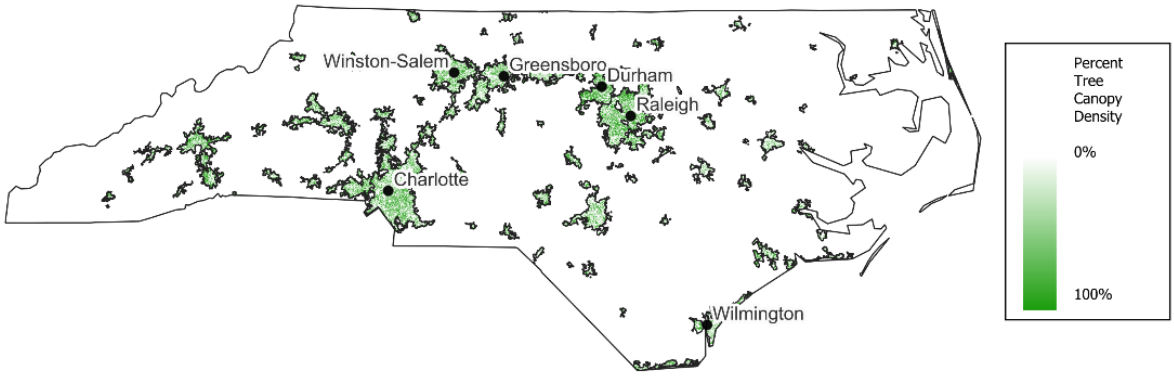
Indicator 35.1: Percentage tree canopy in urban communities

Top line: Tree canopy in urban areas helps reduce stormwater runoff and buffer against high temperatures. Although the data is complicated by a definitional change in the 2020 census, tree canopy

[827] See, for example, Jake Bittle, Higher Ground: America's oldest Black town is trapped between rebuilding and retreating, Grist, September 20, 2022; Stephen Marson and Mac Legerton, Disaster diaspora and the consequences of economic displacement and climate disruption, including Hurricanes Matthew (October 8, 2016) and Florence (September 14, 2018) in Robeson County, North Carolina, Natural Hazards, January 2021, 107: 2247, https://doi.org/10.1007/s11069-021-04529-8; Christopher Flavelle, Climate Change Is Bankrupting America's Small Towns, September 2, 2021 (discussing Fair Bluff, Princeville, and Seven Springs).
[828] Mira Rojanasakul and Nadja Popovich, Where Americans Have Been Moving Into Disaster-Prone Areas, New York Times, September 30, 2024.
[829] Jake Bittle, The Great Displacement: Climate Change and the Next American Migration, February 2023; Abrahm Lustgarten, On the Move, March 2024.
[830] See, for example, Iris Seaton, Asheville ranks on list of cities most likely to see impact of 'climate migration', Asheville Citizen-Times, June 5, 2023.
[831] Manuela Andreoni, 'Climate Havens' Don't Exist, New York Times, October 1, 2024.

levels in North Carolina's largest cities changed very little between 2011 and 2021, even as these cities grew. That's a positive trend.

Map 35.1: 2021 Tree Canopy Density in urban areas



About tree canopy: Tree canopy in urban areas has multiple benefits. A 2013 study of tree cover in residential yards in Raleigh found that tree cover intercepted between 9% and 21% of rainfall, reducing surface stormwater runoff.[832] Tree canopy also significantly reduces the 'heat island effect', the tendency of urbanized areas to experience significantly higher temperature extremes than the surrounding landscapes. For example, a GIS comparison of tree cover layers and street-level heat in Charlotte in 2018-2019 revealed that the urban heat island effect was strongest in parts of the city with the least tree cover.[833] Higher local temperatures translate to health harms; a recent study of 1,275 census tracts across North Carolina found that excess deaths during hot weather (so-called 'heat mortality') were strongly correlated with lack of tree cover and high levels of impervious surface.[834] Impacts are not limited to health; after controlling for other factors, a 2018 study of 318 public schools in Chicago found that students performed better academically at campuses with tree cover (grasses and shrubs had no effect).[835]

Nationwide and in North Carolina, urban tree cover has a strong correlation with racial and income demographics. For example, a study of Richmond, Virginia found that sites with higher temperatures on the 10 hottest days of the year consistently had higher concentrations of small particulate (PM2.5)

[832] Elina Inkiläinen et al., The role of the residential urban forest in regulating throughfall: A case study in Raleigh, North Carolina, USA, Landscape and Urban Planning, November 2013, 119: 91, https://doi.org/10.1016/j.landurbplan.2013.07.002.
[833] Veronica Westendorff, Role of trees in mitigation urban heat island in Charlotte, North Carolina, USA, WIT Transactions on Ecology and the Environment, July 2020, 245: 73, http://dx.doi.org/10.2495/EID200081.
[834] Hayon Michelle Choi et al, The effect modification of greenspace and impervious surface on the heat-mortality association: Differences by the dissimilarity index, Science of the Total Environment, January 2024, 908, https://doi.org/10.1016/j.scitotenv.2023.168074.
[835] Ming Kuo et al, Might School Performance Grow on Trees? Examining the Link Between "Greenness" and Academic Achievement in Urban, High-Poverty Schools, Frontiers in Psychology, September 2018, 9, https://doi.org/10.3389/fpsyg.2018.01669.

pollution and were concentrated in economically vulnerable neighborhoods.[836] That helps explain the association with increased mortality, since concentrated PM2.5 exposures can be a trigger for heart attacks and strokes. A 2022 study focused on four of the state's five most urbanized counties – Cumberland, Forsyth, Mecklenburg, and Wake – found that neighborhood tree cover was strongly correlated with demographics. Tree cover at schools was not, but generally, schools enjoyed less tree cover than surrounding neighborhoods.[837]

To track changes in urban tree canopy, we use the tree canopy density layer from the from the United States Geological Survey's National Land Cover Database, clipped to and averaged within the Urban Areas defined by the 2020 decennial census. Importantly for our calculation, the US Census Bureau changed what was counted as an 'urban area' in the 2020 census in a way that substantially narrowed the area of North Carolina's cities, cutting out the least-dense, leafiest suburbs.[838] When we used the 2020 urban area designations and compared tree canopy in 2011 to tree canopy in 2021, we found very little change across the decade. Our overall takeaway is that tree canopy had been essentially stable in most large North Carolina cities – decreasing 2.2% in Raleigh, increasing 2.7% in Hickory – even as all these cities gained population. We count that as a positive trend.

[836] Andre Eanes et al., Assessing Inequitable Urban Heat Islands and Air Pollution Disparities with Low-Cost Sensors in Richmond, Virginia, Sustainability, December 2020, 12 (23), https://doi.org/10.3390/su122310089.
[837] Zhenzhen Zhang et al., Equally green? Understanding the distribution of urban green infrastructure across student demographics in four public school districts in North Carolina, USA, Urban Forestry & Urban Greening, January 2022, 67, https://doi.org/10.1016/j.ufug.2021.127434.
[838] Specifically, before 2020, the US Census Bureau defined 'urban areas' as those containing at least 2,500 people; from 2020 on, the agency raised the threshold to 2,000 housing units or 5,000 people, significantly narrowing the spatial extent of 'urban areas' in some cities. US Census Bureau, 2020 Census Urban Areas FAQs, December 2022.

Table 35.1: Percentage of tree canopy in NC urban communities

	Baselined, published SOE2019		*Calculated by NCCN 2025*		
Urban area	Area - 2010 Census Areas (sq. mi.)	Avg Canopy Density - 2011 NLCD and 2010 Census Areas	Area - 2020 Census (sq mi)	Avg Canopy Density - 2021 NLCD and 2020 Census Areas	Avg Canopy Density - 2011 NLCD and 2020 Census Areas
Durham	183	61.1%	185	52.0%	52.0%
Gastonia	139	54.0%	126	41.6%	41.2%
Raleigh	523	52.4%	560	42.8%	45.0%
Winston-Salem	325	48.1%	313	38.1%	38.1%
Asheville	267	48.0%	250	44.2%	44.3%
Charlotte	777	47.8%	652	36.7%	37.1%
Concord	181	47.4%	201	35.3%	35.8%
Burlington	91	46.0%	93	32.5%	32.6%
Hickory	265	45.6%	223	37.6%	34.9%
Greensboro	189	45.0%	171	33.6%	33.2%

Table: Analysis by NCCN • Source: Tree Canopy Data from National Land Cover Database, Urban Areas from Census Bureau 2020 TIGER Files. • Created with Datawrapper

Recent developments: In January 2024, Governor Cooper issued Executive Order 305, establishing (among other provisions) a goal of planting 1 million trees in urban areas by 2040.[839] Depending on how state, municipal, and private partners organize efforts to achieve this goal, it could deliver significant health and equity benefits to neighborhoods that currently experience the strongest heat island effects.

Indicator 35.2: Percentage of residents within ½ mile of a public park

Top line: The share of NC residents that live within ½ mile of a public park or elementary school has grown significantly in the last decade. We consider this a positive trend.

Access to open space: Access to open space is correlated with overall physical, mental and social health.[840] Some research suggests that parks access is more important for certain kinds of physical

[839] Executive Order 305 (EO 305), An Order to Protect and Restore North Carolina's Critical Natural and Working Lands, February 12, 2024.
[840] Lincoln Larson and Aaron Hipp, Nature-based Pathways to Health Promotion: The Value of Parks and Greenspace, NC Medical Journal, March 2022, 83 (2): 99, https://doi.org/10.18043/ncm.83.2.99.

health – cardiovascular health, birth outcomes, and mortality – in urban areas than in rural.[841] Yet, in North Carolina, evidence suggests parks access benefits mental health in rural as well as urban areas.[842] Access to parks and nature also benefit children; a 2021 study of several hundred middle school students in South Carolina found that time spent in nature was correlated with positive youth development.[843]

Across the country, access to parks is distributed unevenly. One of the most cited analysis, a 2016 review of 49 empirical studies, found that across the country, "[l]ow socioeconomic and ethnic minority people have access to fewer acres of [urban] parks, fewer acres of parks per person, and to parks with lower quality, maintenance, and safety than more privileged people."[844] More recently, a study of 122,988 urban parks across the US found that neighborhoods within 10 minute walk of parks tend to be whiter. Parks in whiter neighborhoods are generally cooler in summer and have more tree cover than parks in Black or Hispanic neighborhoods.[845]

This indicator tracks the percentage of North Carolinians who live within ½ mile of a public park or elementary school (to serve as accessible open space); the Centers for Disease Control releases estimates for five-year intervals.[846] In 2010, 13% of North Carolinians lived within a half mile of a park or public elementary school; 10 years later, that proportion had tripled, to 39% of residents, and access improved dramatically across the decade for all racial groups. We suspect this is a direct consequence of sustained funding of the North Carolina Parks & Recreation Trust Fund. The data treats ethnicity in a way that makes it hard to assess disparities, but it appears those have narrowed as well. This is a very positive trend.

As a side note, many North Carolinians found parks a crucial resource and outlet during the COVID-19 pandemic. A recent survey of state and local parks managers found that state parks experienced more

[841] Matthew Browning, Where greenspace matters most: A systematic review of urbanicity, greenspace, and physical health, Landscape and Urban Planning, January 2022, 217, https://doi.org/10.1016/j.landurbplan.2021.104233.
[842] Sophia Ryan et al., Spatial Analysis of Greenspace and Mental Health in North Carolina, Family and Community Health, July/September 2023, 46 (3): 181, https://doi.org/10.1097/fch.0000000000000363.
[843] Edmond Bowers et al., Nature as an Ecological Asset for Positive Youth Development: Empirical Evidence from Rural Communities. Frontiers in Psychology, June 2021, 12, https://doi.org/10.3389/fpsyg.2021.688574.
[844] Alessandro Rigolon, A complex landscape of inequity in access to urban parks: A literature review, Landscape and Urban Planning, September 2016, 153: 160, https://doi.org/10.1016/j.landurbplan.2016.05.017; see also, Ming Wen et al., Spatial disparities in the distribution of parks and green spaces in the USA, Annals of Behavioral Medicine, January 2013, 45 (Suppl. 1): S18, https://doi.org/10.1007/s12160-012-9426-x.
[845] Richelle Winkler et al., Unequal access to social, environmental and health amenities in US urban parks, Nature Cities, November 2024, 1: 861, https://doi.org/10.1038/s44284-024-00153-2.
[846] CDC, database: National Environmental Public Health Tracking Network, Measure: National percentage of population that resides within half a mile of a park, visited March 14, 2025.

frequent social and environmental impacts than local parks during the COVID-19 pandemic, but there were no notable differences in the impacts at rural versus urban parks.[847]

Goal 36: Development is resilient

Trend: Negative

As discussed under goal 1, climate change is already bringing disruptions to North Carolina, including stronger storms, more intense flooding, and more intense droughts and wildfires. 'Resilience' can mean many things; in this report, we use the term to mean strategies that decrease the vulnerability of human health and property to a rapidly changing global and regional climate. That's consistent with the way the term is used in North Carolina's Climate Risk Assessment and Resilience Plan, a multi-hazard analysis of the state's risks and vulnerabilities.[848]

In our 2019 report, we tried to track resilience based on losses from extreme events – flooding, wind/rain, and wildfire. For this update, we retain an improved form of wind/rain losses (indicator 35.2) but replace the others with two new indicators: the number of severe repetitive loss properties in the state (indicator 35.1); and the projected total value of properties vulnerable to flooding over the next three decades (indicator 35.3). Each of the new indicators tracks potential loss rather than actual losses, which are too volatile to guide policy. For this update, the number of severe repetitive loss properties and the expected payouts for wind/raid damage are both headed in the wrong direction. North Carolina is developing a powerful tool to project future vulnerability, but it is still under construction, so the third indicator is effectively a placeholder in this update.

Several other indicators in this report also tie to flood resilience, including the percentage of housing stock in floodplains (indicator 28.2), and the vulnerability of the transportation system (indicator 31.3), water and wastewater infrastructure (indicator 37.2), and energy infrastructure (indicator 40.1). The state's natural systems are among our strongest shields against loss; wetlands (indicator 6.3) absorb and slow floodwaters; natural and living shorelines (indicator 3.2) protect against storm surge; and avoiding high concentrations of impervious surface (indicators 7.2 and 7.3) also helps prevent flooding.

We note that this update omits an indicator of wildfire risk. North Carolina experienced a dramatic wildfire season in 2016, following several years of dry conditions in the mountains. While no lives were lost to wildfire that season in North Carolina, fires around Gatlinburg claimed 14 lives, injured 191 other people, and inflicted upwards of $2 billion in damages.[849] At the time, wildfire experts noted that North

[847] Justin Beall et al., Environmental and social impacts of shifting park-use patterns during the COVID-19 pandemic: Insights from state and local park managers, Journal of Outdoor Recreation and Tourism, December 2024, 48, https://doi.org/10.1016/j.jort.2024.100833.
[848] NC DEQ, NC Climate Risk Assessment and Resilience Plan [*NC Resilience Plan*], June 2020.
[849] Kelly Ann Krueger, Remembering the Gatlinburg Wildfires five years later, WVLT8, November 28, 2021; Brianna Paciorka, 2016 Gatlinburg fire: then and now photos, Knoxville News, November 25, 2021.

Carolina led the nation in the absolute number of acres in the 'wildland-urban interface' (WUI), areas where the density of houses and trees creates the greatest risk that a wildfire will destroy homes and threaten lives.[850] We reflected that concern in our 2019 report. Climate change is anticipated to increase the frequency of periods of dry conditions, setting the stage for more destructive wildfires.[851] We suspect that current land use patterns – low density and rural sprawl – are increasing North Carolina's vulnerability to wildfire.[852] Moreover, timber downed by Helene in North Carolina's mountain counties is likely to present an increasing wildfire risk over the next five years.[853] Yet, from 2013 to 2022, North Carolina experienced no discernable trend in numbers of wildfires or acres burned.[854] In the absence of a trend in losses or a consensus on how to model vulnerability over time, we're setting aside this indicator for this update.

Solutions: To improve resilience against extreme weather and climate change, North Carolina can A1, invest in floodplain restoration; A5, enact state wetlands protections; A6, invest in peat, salt marsh, and forest conservation; G6, strengthen stormwater management; M1, build out the NC Flood Resilience Blueprint; M2, fund buyout of repetitive-loss properties; M3, keep new development out of the floodplain; M4, keep new state-funded facilities safe from floods by staying out of or above the 500-year floodplain; M5, establish a well-funded dam removal program; M6, direct counties to adopt proactive wildfire management plans; M7, address landslide hazards; M8, enact a path for resolving heirs properties, which can prevent survivors from accessing disaster assistance; and M9, invest in Fortified roofs across the Coastal Plain.

Indicator 36.1: Number of severe repetitive loss properties

Top line: Despite increases in federal and state support for flood mitigation, the number of 'severe repetitive loss' properties in North Carolina has grown by more than 50% over the last decade. That's partly a reflection of better recognition of vulnerability that's been there all along, but it's also a reflection of increasing flood risk as a result of climate change, and of development that puts new structures in the path of floods. It's a negative trend.

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[850] Volker C. Radeloff et al, Rapid Growth of the US wildland-urban interface raises wildfire risk, PNAS March 27, 2018, 115:13, 3314-3319, https://doi.org/10.1073/pnas.1718850115. USDA defines the WUI as places where housing density is greater than 1 house per 40 acres and more than 50% of the area is in wildland vegetation (intermix), or that have less than 50% vegetation but are within 1.5 miles of a densely vegetated area over 5 square kilometers in size. USDA, Urban wildland interface communities within the vicinity of federal lands that are at high risk from wildfire, 66 Fed. Reg. 751–777, 2001.

[851] NC DPS, State of North Carolina 2023 Hazard Mitigation Plan [*2023 SHMP*], December 2022, at 3-76 to 3-88; NCICS, North Carolina Climate Science Report, September 2020, at 188 -191.

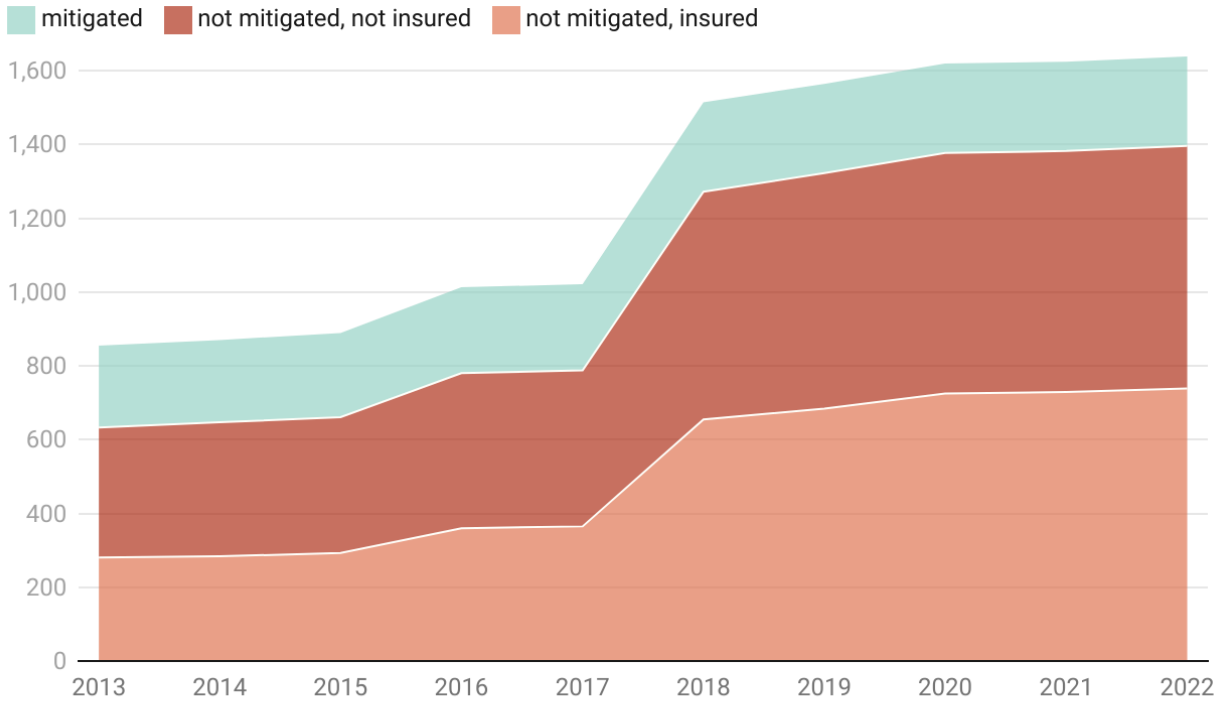
[852] Lisa Sorg, In the hot seat: Development, climate leads to increased risk of wildfires near NC cities and suburbs, NC Newsline, May 24, 2023.

[853] Martha Quillin, Downed trees from Hurricane Helene are now a fire risk for NC mountains, foresters say, News & Observer, November 6, 2024; Southern Group of State Foresters, blog post: Spring 2025 Wildfire Risk Outlook: What to Expect in the Southeast, February 27, 2025 (noting elevated risk of wildfire in 2025).

[854] NCDA, NC Forest Service, Annual Legislative Report on Wildfires, October 2022, at 4.

About severe repetitive loss properties: the National Flood Insurance Program (NFIP) provides federally subsidized flood insurance for owners and renters. Property owners in the floodplain who have received federal disaster funds following a flood are required to have flood insurance, or forfeit eligibility for disaster assistance after future floods.[855] Yet, only 4% of homeowners nationally have flood insurance.[856] The Federal Emergency Management Agency (FEMA) defines properties that have received an NFIP payout of at least $5,000 four times or more, or that have twice received a payout greater than the value of the property, as 'severe repetitive loss' (SRL) properties.[857] State and federal agencies prioritize SRL properties for voluntary buyouts or, in some cases, for subsidized elevation that raises the building above the likely height of floodwaters.

Figure 36.1: Number of severe repetitive loss properties in North Carolina



Source: NRDC, Losing Ground dashboard, using NFIP data. • Created with Datawrapper

Unfortunately, over the last decade, the number of unmitigated SRL properties in North Carolina has swelled from roughly 633 to 1,396. The percentage of these that are insured by the NFIP has increased from 44% to 53% – that's good – but the absolute number of uninsured homeowners on SLR properties has almost doubled. Most disconcertingly, new properties have been added to the SRL list 19 times

[855] FEMA, NFIP, Federal Disaster Assistance: Meeting the Flood Insurance Requirement, July 2024.
[856] Andrew Moore, blog: Many Americans Lack Flood Insurance Despite Rising Risks – Here's Why, NCSU, College of Natural Resources News, November 1, 2022 [Flood Risk]
[857] FEMA, NFIP, A Policyholder's Guide to Severe Repetitive Loss, July 2023.

faster than we've removed them through elevations or buyouts.[858] That is a terrible trend. Moreover, the SLR properties are just the most exposed. In North Carolina, over 13,000 properties have flooded at least twice, and nearly 6,000 of those are uninsured.[859]

A related challenge for flood resilience is that FEMA's floodplain maps are out of date. An estimated 14% of the SRL properties in North Carolina are outside the FEMA-mapped 100-year floodplain.[860] That's likely the result of a combination of factors: increased impervious surface is causing flooding downstream beyond the traditional floodplain; in addition, more frequent intense storms means that the 100 year flood, or the flood with an annual probability of 1%, now involves a lot more water and covers a much larger floodplain. Multiple non-governmental analyses predict a much wider risk of current and future flooding than FEMA maps suggest.[861]

Buyouts of vulnerable properties are a key strategy for flood hazard reduction, but can take painfully long both for property owners and for administering agencies.[862] A 2020 study of buyouts in eight North Carolina jurisdictions found that program design could significantly shape the local economic impact of buyouts through the spatial distribution of properties, whether property owners stay in the town or move away, and how acquired properties are subsequently managed.[863] After storms, a number of property owners agree to buyouts because their properties have been damaged and they can't afford to repair them to local occupancy standards. Such buyouts may be the best option for the community (and the owners) but are likely to feel less than 'voluntary'.[864] Management of acquired properties has been a particular challenge for local governments, with properties often left vacant, and only a small percentage converted to publicly accessible recreational parks or trails. A 2023 study of 418 parcels in Greenville and Pitt Counties found that the local governments leased many properties to remaining neighboring landowners because the governments lacked funds to maintain them directly.[865]

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[858] NRDC, dashboard: Losing Ground, January 9, 2024, using data from FEMA's National Flood Insurance Program [*Losing Ground*]

[859] NRDC, dashboard: Flooded again, September 17, 2024, using data from FEMA's National Flood Insurance Program.

[860] *Losing Ground.*

[861] Moore, blog: Flood Risk (NCSU analysis finds 1.01 million square miles at risk compared to FEMA's 221,000 square miles of mapped 100-year floodplain); First Street Foundation, the First National Flood Risk Assessment: Defining America's Growing Risk, 2020 (estimating that the number of properties with substantial flood risk is 1.7 times the number suggested by FEMA floodplain maps).

[862] Anuradha Mukherji et al, Buyout programme experiences and perspectives of local public officials in eastern North Carolina, Environmental Hazards, January 2024, https://doi.org/10.1080/17477891.2023.2299371.

[863] Todd BenDor, et al., Floodplain Buyouts and Municipal Finance, Natural Hazards Review, April 2020, 21(3), https://doi.org/10.1061/(ASCE)NH.1527-6996.0000380.

[864] Julia Cardwell, Community Perceptions of a Floodplain Buyout Program in Charlotte, North Carolina, Natural Hazards, September 2022, 115: 2141, https://doi.org/10.1007/s11069-022-05631-1.

[865] Kayode Adenjii, master's thesis: Impact of Buyout Programs on Land Use Patterns in the Special Flood Hazard Area of Pitt County, North Carolina, July 2023.

Flood insurance is a crucial tool to protect residents and businesses from being wiped out by storms and floods.[866] Yet, studies have found that the average NFIP policy is only maintained for a few years.[867] Uptake of policies increases after a hurricane or flood, in part because once a property floods, eligibility for future FEMA disaster assistance is contingent on maintaining coverage. But premiums are still out of reach of low-income families, leaving low-income communities more vulnerable to future storms.[868]

Recent developments: From October 2021 to April 2023, FEMA transitioned all NFIP policies to Risk Rating 2.0, a new approach to setting NFIP premiums intended to better reflect properties' actual risk of flooding.[869] As of 2021, the NFIP covered over 139,000 properties in North Carolina. FEMA expected the premium to decrease for 26% of those properties; stay the same or increase by less than $10 per month for 65%; increase by $10 to $20 per month for 6%; and increase by more than that for just 3%, less than 4,000 policies.[870] Risk Rating 2.0 imposes a surcharge on severe repetitive loss properties, and requires, at their next renewal, that these properties be transferred to a special 'facility' that the NFIP services directly.[871] FEMA's goal is to ensure that these properties are proactively offered mitigation opportunities – buyouts or elevations – to reduce future losses.

The shift to Risk Rating 2.0 has created a challenge for a related NFIP program, the Community Rating System (CRS), which offers premium discounts to policyholders whose jurisdictions adopt various CRS-recommended policies to reduce flood hazards.[872] As of April 2024, 101 North Carolina towns and cities participated in the CRS.[873] Researchers have found communities that participate in CRS have more residents buying flood insurance – that's good for community resilience following a disaster – and the most comprehensive analyses suggest that CRS communities also have lower flood damage claims.[874] Yet the core concept of Risk Rating 2.0 (actuarially sound premiums based on property-specific risk) is somewhat at odds with the method of the CRS (premium reductions for community compliance). In mid-2024 FEMA sought public comment on what, if anything, to do about this mismatch, looking to possible action in 2025.[875]

[866] Xuesong You and Carolyn Kousky, Improving Household and Community Disaster Recovery: Evidence on the Role of Insurance, EDF EDP 23-1, March 2023.
[867] Julia Cardwell, Trends in Flood Insurance Behavior Following Hurricanes in North Carolina, The North Carolina Geographer, June 2021.
[868] *Idem*, at 10 – 11.
[869] FEMA, webpage: NFIP's Pricing Approach, updated November 28, 2023; FEMA, NFIP, Flood Insurance Manual [*Flood Insurance Manual*], October 2022
[870] FEMA, factsheet: North Carolina – Risk Rating 2.0, March 2021.
[871] *Flood Insurance Manual*, at 3.II.B.3 and Appendix F.
[872] FEMA, webpage: Community Rating System, updated august 12, 2024.
[873] FEMA, data file: April 2024 CRS Eligible Communities, downloaded September 17, 2024.
[874] Jesse Gourevitch and Nicholas Pinter, Federal incentives for community-level climate adaptation: an evaluation of FEMA's Community Rating System, Environmental Research Letters, March 2023, 18: 034037, DOI 10.1088/1748-9326/acbaae; Yanjun Liao et al, Community Responses to Flooding in risk Mitigation Actions: Evidence from the Community Rating System, RFF Working Paper 24-08, June 2024.
[875] Regulations.gov, Non-rulemaking Docket FEMA-2024-0022, visited September 17, 2024.

Unrelated to changes in the NFIP, in 2023 several environmental and community groups petitioned the NC Real Estate Commission to put flood history on the real estate disclosure form.[876] The final updated form, which took effect in July 2024, asks whether a property is in a designated flood hazard zone, has experienced damage from flooding, or has ever received post-flood disaster assistance from the federal government.[877] The latter is important because, as noted above, a property that has received assistance must maintain flood insurance or lose eligibility for future assistance.[878] As with other topics on the form, sellers can decline to say yes or no and instead make no representation.

At the very end of 2024, the NC General Assembly enacted a provision, appended to the third Helene disaster recovery bill, that prohibits local governments from downzoning properties without the agreement of every affected landowner.[879] The provision is both sweeping in impact and loose in wording, and has the potential to undermine local efforts to keep new development or denser redevelopment out of floodplains and out of harm's way.[880]

Indicator 36.2: Expected cost of wind & water insurance claims

Top line: According to filings from the NC Rate Bureau, the actuarially sound cost of insuring against wind and water damage continues to rise (faster than inflation). That's a sign that, on average, our developed landscapes are at greater risk of harm, a bad trend.

About wind & water insurance claims: In January 2024, the NC Rate Bureau, representing companies providing home insurance to North Carolinians, asked NC Commissioner of Insurance Mike Causey to approve a major rate hike: a 42% average increase in insurance premiums, with some areas along the coast proposed to experience a 99% increase.[881] Following an immediate public outcry, Commissioner Causey denied the request, sending it to a negotiation process.[882] In January 2025, Commissioner Causey announced an agreement with the NC Rate Bureau to allow a 7.5% statewide base rate increase in June 2025 and again in June 2026, with a maximum increase of 35% along the coast.[883]

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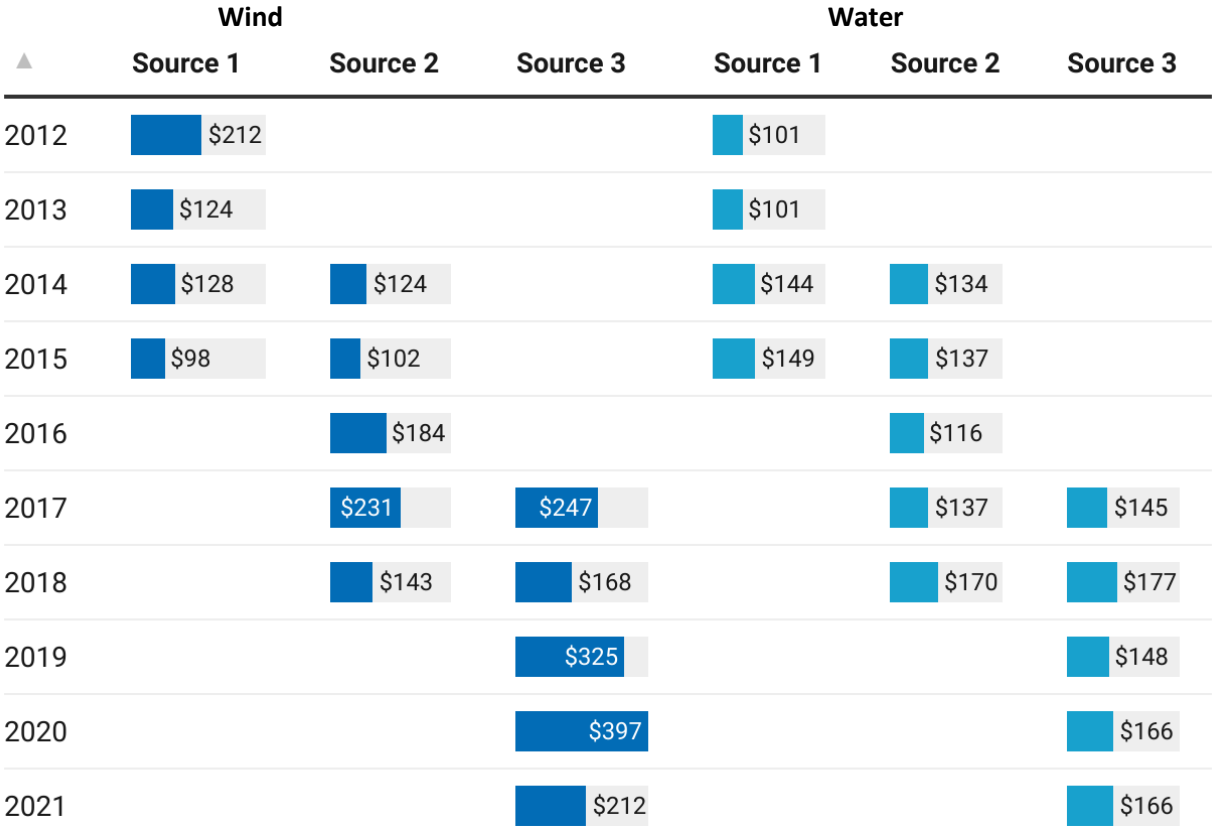
[876] Catherine Kozak, Flood history questions added to real estate disclosure form, Coastal Review, July 19, 2024.
[877] NC Real Estate Commission, form: Residential Property and Owners' Association Disclosure Statement, revised May 2024.
[878] FEMA, webpage: Individuals and Households Program, March 22, 2024.
[879] SL2024-57 (S382), Disaster Relief-3/Budget/Various Law Changes, Subpart III-K.
[880] See, Adam Lovelady, blog post: Limits on 'Down-Zoning', Coates Canons, December 20, 2024.
[881] Bilyana Garland, North Carolina homeowners brace for potential 42% insurance rate hike in 2024, ABC News 12, January 17, 2024; Letter, Joanna Biliouris, NC Rate Bureau, to Commissioner Mike Causey, NC Dept. of Insurance, January 3, 2024, with supporting materials [NC Rate Bureau 2024].
[882] Chantal Allam, NC insurance commissioner has rejected a requested 42.2% rate hike, News & Observer, July 10, 2024; NC Department of Insurance, press release: Insurance Commissioner Mike Causey rejects insurance companies' average 42.2% rate hike request, February 6, 2024.
[883] NC Department of Insurance, press release: Commissioner Causey negotiates settlement on Rate Bureau's homeowners' insurance request, January 17, 2025; the detailed rate changes are here.

While outrage over proposed rate increases was widely felt, the industry faces a genuine problem. Partly as a result of climate change, many properties are at significantly greater risk than has been reflected in their premiums.[884] In California (fire), Florida (storms), and Louisiana (storms), the industry has responded by declining to renew or issue new policies, leaving residents uninsured, or forcing the state – which is to say, taxpayers of the state – to pick up the tab.[885] North Carolina has experienced few carrier withdrawals to date, and North Carolina policies have remained a net money-maker for the industry.[886] But modelers have predicted that, across the Southeast, damaging winds will reach further inland by the mid-century, increasing the risk to buildings in the Coastal Plain and bringing wind risk to inland counties that have always thought of themselves as safe from hurricanes.[887] While most of the modelers' concern about wind damages is focused on hurricanes reaching further inland, National Weather Service data and recent scientific studies have tracked increases in tornados in North Carolina and other eastern states, even as frequencies decline in the traditional 'tornado alley' states of Texas and Oklahoma.[888]

[884] First Street Foundation, The 9th National Risk Assessment: the Insurance Issue, September 20, 2023.
[885] Christopher Flavelle, Jill Cowan, and Ivan Penn, Climate Shocks Are Making Parts of America Uninsurable. It Just Got Worse, NY Times, June 2, 2023; David Sherfinski, Climate change-driven insurance crisis threatens new US states, Context, May 2, 2024.
[886] Adam Wagner, As it evaluates Risk, Nationwide won't renew 10,000 insurance policies in Eastern NC, News & Observer, October 5, 2023; Chantal Allam, More NC residents are losing home insurance as underwriters tighten guidelines, News & Observer, July 10, 2024; Christopher Flavelle and Mira Rojanasakul, The Home Insurance Crunch: See What's Happening in Your State, New York Times, May 13, 2024.
[887] First Street Foundation, The 7th National Risk Assessment: Worsening Winds, February 27, 2023; Evelyn Shu et al, Assessing Property Exposure to Cyclonic Winds under Climate Change, Climate, November 2023, 11 (11): 217, https://doi.org/10.3390/cli11110217.
[888] Kiley Bense, As Tornado Alley Shifts East, Bracing for Impact in Unexpected Places, Inside Climate News, September 4, 2024.

Figure 36.2: Pure premiums in five-year groups, wind and water damage (in nominal dollars)



2011-2015: NC Rate Bureau, 2017. 2014- 2018: NC Rate Bureau, 2020. 2017- 2021: NC Rate Bureau, 2024.

Source: NC Rate Bureau fillings, 2024, 2020, 2017. • Created with Datawrapper

Our indicator for this risk is a complex calculation from the NC Rate Bureau made on the basis of the most recent five years of claims. Home insurance typically excludes losses from flooding; those are covered either by the federally subsidized National Flood Insurance Program (NFIP), discussed under the previous indicator, or – more rarely – through separate policies for sale on the private market. But damage from wind and rain falling on or into the house is typically covered by home insurance. Rather than track the raw losses, which are highly volatile, we track the NC Rate Bureau's calculation of the 'pure premium' needed to cover wind and water losses.[889] The NC Rate Bureau uses a model to smooth

[889] 2017-2021: Letter, Joanna Biliouris, NC Rate Bureau, to Commissioner Mike Causey, NC Dept. of Insurance, January 3, 2024, with supporting materials, at E-451 (Exhibit 2, Page 3, Calculation of Average Annual Pure Premium Trends, Based on NCRB Industry Loss Experience); 2014-2018: Letter, Joanna Biliouris, NC Rate Bureau, to Commissioner Mike Causey, NC Dept. of Insurance, November 9, 2020, with supporting materials, at D-15 (NC Homeowners Insurance, Frequency, Severity, and Pure Premium Rate of Changes, Owners Forms); 2011-2015: Letter, Raymond Evans, NC Rate Bureau, to Commissioner Mike Causey, NC Dept. of Insurance, November 17, 2017, with supporting materials, at E-293, (Exhibit 1(I), NC Homeowners Insurance, Losses by Cause, Owners, Pure Premium.

out highly volatile hurricane damage, and then combines that with other wind and water claims for an estimate of what premium will be needed to cover expected claims plus the cost of investigating and paying them out.

As the chart suggests, the estimated pure premiums are not consistent from one five-year look-back to another. But across the last three analyses, wind and water losses trended upwards, reflected in a rising pure premium. We count that as a bad trend.

One source of hope is that we do know how to anchor roofs to hold on in stronger winds. Research has shown that houses that retain their roofs suffer structural damage much less often. A network of contractors are trained and certified to install so-called 'fortified' roofs, and the North Carolina Insurance Underwriting Association (NCIUA) offers grants for homeowners on the Outer Banks and North Carolina's barrier islands to reduce the cost of installation to owners – and some owners can receive reductions in their monthly premiums as well.[890] Given projections for future wind fields, fortifying roofs may be a cost-effective hazard mitigation strategy for homeowners on the mainland as well.

Indicator 36.3: Anticipated vulnerability to floods over the next 30 years

Top line: This is the most important of our three resilience indicators, but we don't assign a trend to it this year because the tool that will allow us to measure North Carolina's projected vulnerability to floods – the NC Flood Resilience Blueprint Tool – is still under construction. This is an area of policy that has seen substantial attention, funding, and action over the last five years, and we expect that to continue.

About anticipated vulnerability to floods: The two previous indicators under this goal address the number of properties that are flooded over and over, and the cost of damage from wind and rain. The indicator is focused on flooding more broadly: the state's overall projected vulnerability to flooding. This is the most important resilience indicator, but the model that may allow us to assess this trend is still being built: the NC Flood Resilience Blueprint Tool.

Attention to current and future flood risk exploded following Hurricanes Matthew (2016) and Florence (2018); floods caused by those storms reached far beyond the mapped 100-year and 500-year floodplains.[891] As the atmosphere warms and holds more water, intense rainfall events and subsequent flooding become more likely. Official state reports, including the State Hazard Mitigation Plan that the NC Division of Emergency Management must update and submit to the Federal Emergency Management Agency (FEMA) every five years, anticipate larger and more frequent floods.[892] For a sense

[890] NC Department of Insurance, webpage: Fortified Homes & Mitigation Credit, visited September 18, 2024; Catherine Kozak, Coastal property owners yet to embrace roof-girding grants, Coastal Review, April 15, 2024.
[891] Danica Schaffer-Smith et al., Repeated Hurricanes Reveal Risks and Opportunities for Social-Ecological Resilience to Flooding and Water Quality Problems, Environmental Science & Technology, June 2020, 54(12), https://doi.org/10.1021/acs.est.9b07815.
[892] *NC Resilience Plan*; *2023 SHMP*, at 3-5 to 3-20.

of the potential change, a 2020 study estimates that, under a high but plausible global emissions scenario, the 100 year flood in the Neuse will become worse than the current 500 year flood.[893]

State and federal agencies already have a handful of models and tools that offer a sense of current flood risk. The Flood Inundation Mapping and Alert Network (FIMAN), housed in the NC Division of Emergency Management, shows current and projected water levels at nearly 600 gauges across the state.[894] Some of the gauges include scenarios that show the spatial extent of landscape inundation at various flood stages. Under indicator 31.3, resilience of the transportation system, we mention NCDOT's flood warning system, which feeds into the public-facing DriveNC tool, showing roads that are closed during a weather disaster.[895] The National Hurricane Center hosts a storm surge risk map that provides a sense of current potential depth of inundation for various storm strengths.[896]

At build out, the NC Flood Resilience Blueprint will tie together some of these resources and a number of new tools to provide a standardized approach for assessing current and future risks and evaluating proposed flood mitigation strategies in all 17 river basins.[897] Most historic and current floodplain modeling in North Carolina – approved by FEMA and used by local governments in the form of floodplain maps – is linear, one-dimensional (1D) modeling.[898] Yet, FEMA itself notes that 1D modeling can perform poorly in highly urbanized areas and along rivers with wide, shallow floodplains (as in much of the Coastal Plain), where 'breakout flow' leaves the main waterway.[899] The Blueprint tool is expected to incorporate 2D modeling in parts of the state, allowing projections of risk to account for water flow across the landscape, a key aspect of being able to assess risks of local rain-driven as well as river-driven flooding.[900] Eventually, the Blueprint tool may be able to incorporate probabilistic modeling, which has been used in such local contexts as the Charlotte metro area to capture risks that even 2D modeling cannot.[901]

Sea level rise, also discussed under indicator 1.3 (ongoing rate of rise), presents a particular challenge for flood resilience. The combination of ongoing geological subsidence and climate-driven sea level rise means that by 2100, surge from a storm like Hurricane Irene (2011) is projected to inundate 27% more

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[893] Indira Pokhrel, Forecasting of Future Flooding and Risk Assessment under CMIP6 Climate Projection in Neuse River, North Carolina, Forecasting, August 2020, 2 (3), https://doi.org/10.3390/forecast2030018.
[894] NC Emergency Management, interactive map: Flood Inundation Mapping and Alert Network (FIMAN), visited September 20, 2024.
[895] NCDOT, webpage: Flood Warning System, updated May 7, 2024; NCDOT, interactive map, DriveNC.gov, visited September 20, 2024.
[896] National Hurricane Center, interactive map: Storm Surge Risk Maps, visited September 20, 2024.
[897] NC DEQ, Division of Mitigation Services, Statewide Flood Resiliency Blueprint Implementation Report, July 1, 2024.
[898] FEMA, Guidance for Flood Risk Analysis and Mapping, November 2021.
[899] *Idem*, at 36 – 37.
[900] NC DEQ, RFP # 16-1025799571, DEQ Flood Resiliency Blueprint Phase III, June 21, 2024, at 18, 54.
[901] Timothy Stephens and Brian Bledsoe, Probabilistic mapping of flood hazards: Depicting uncertainty in streamflow, land use, and geomorphic adjustment, Anthropocene, March 2020, 29: 100231, https://doi.org/10.1016/j.ancene.2019.100231.

land than Irene did, and a storm like Matthew (2016), 40% more.[902] That risk is not distributed equitably; a recent study found low-income communities and communities of color far more likely to experience impacts of tidal flooding and inundation than more affluent, predominantly white communities.[903] Another study suggests that by 2050, sea level rise will threaten between 380 and 580 units of affordable housing in the state.[904] As of 2023, researchers found that while most coastal counties recognized sea level rise as a threat, very few had conducted comprehensive analyses of vulnerability.[905]

Another challenge for resilience in North Carolina is compound flooding, or flooding caused by a combination of river flooding (fluvial), intense rain (pluvial), and storm surge.[906] In general, local governments and the state are currently poorly equipped to predict risks from rain driven flooding and compound flooding. Perhaps as a result, residents at risk from pluvial flooding are unlikely to have been required or prodded to buy flood insurance, leaving them especially vulnerable when they are flooded. For example, First Street Foundation estimates that 78% of the properties flooded by Hurricane Debby (2024) – a storm with strongly pluvial rather than fluvial impacts – were outside of the mapped 100-year floodplain.[907]

Further inland, a key aspect of flood resilience is dam safety. As rain events become more intense, the upper end of plausible rainfall – the 'probable maximum precipitation' (PMP) – may approach the design limits of existing dams.[908] North Carolina's dam safety program regulates roughly 2500 dams; 1500 of these are classified as 'high hazard' dams, meaning that a failure of the dam would likely result in loss of human life or more than $200,000 in downstream property damage.[909] In June 2024, the National Academy of Sciences announced that the traditional method of estimating PMP is flawed (it assumed

[902] Jeremy Johnston et al., Projecting the effects of land subsidence and sea level rise on storm surge flooding in Coastal North Carolina, Nature Scientific Reports, November 2021, 11: 23679, https://doi.org/10.1038/s41598-021-01096-7

[903] Leah Handwerger et al., Present and future sea level rise at the intersection of race and poverty in the Carolinas: a geospatial analysis, The Journal of Climate Change and Health, August 2021, 3: 100028, https://doi.org/10.1016/j.joclim.2021.100028; *see also*, Oliver Wing et al., Inequitable patterns of US flood risk in the Anthropocene, Nature Climate Change, January 2022, 12:156, https://doi.org/10.1038/s41558-021-01265-6.

[904] Maya Buchanan et al., Sea level rise and coastal flooding threaten affordable housing, Environmental Research Letters, December 2020, 15: 124020, DOI 10.1088/1748-9326/abb266

[905] Andrew Grandage et al., Treading Water: Planning for Sea Level Rise in the Southeastern United States, Research & Theory, May 2023, 29 (1), https://doi.org/10.1177/1087724X231178868; Andra Garner et al., Evaluating Knowledge Gaps in Sea-Level Rise Assessments from the United States, Earth's Future, January 2023, 11 (2), https://doi.org/10.1029/2022EF003187.

[906] Scott Curtis, et al., Perceptions of risk to compound coastal water events: A case study in eastern North Carolina, USA, Progress in Disaster Science, December 2022, https://doi.org/10.1016/j.pdisas.2022.100266; Anuradha Mukherji et al., Mitigating compound coastal water hazards in Eastern North Carolina, Journal of Environmental Planning and Management, March 2023, 67: 1852, https://doi.org/10.1080/09640568.2023.2183112.

[907] First Street Foundation, Review of Hurricane Debby: First Steet Recreation Finds Majority of Damaged Homes Outside of FEMA Flood Zones, August 12, 2024.

[908] See, for example, Xiajing Lin et al., Risk of hydrological failure under the compound effects of instant flow and precipitation peaks under climate change: A case study of Mountain Island Dam, North Carolina, Journal of Cleaner Production, February 2021, 284, https://doi.org/10.1016/j.jclepro.2020.125305.

[909] NC DEQ, webpage: Dam Safety Program Overview, visited September 20, 2024; *2023 SHMP*, at 3-89, 3-90.

there is an absolute maximum for precipitation when in fact there may not be), and proposed a new approach that can shift with the climate.[910] NC DEQ began updating North Carolina's model in August 2023 with an expected completion date of June 2025.[911]

One priority for advocates has been to ensure that 'natural infrastructure' or 'nature based solutions' are a part of flood resilience strategies. Nature based solutions (NBS), also sometimes called green infrastructure, rely on natural processes to manage floodwaters and limit harm.[912] On the local scale, these can include raingardens and swales for stormwater (as an alternative to concrete detention basins); on the watershed scale, NBS can include floodplain restoration or 'water banking' programs, in which farmers are paid to have their lands occasionally flooded (an alternative to channelizing rivers or building levees).[913] In general, NBS or green infrastructure can cost more or less than 'gray' engineered approaches, but usually provides significantly more economic and social co-benefits.[914] Because flood mitigation strategies have often relied on engineered solutions, supporters of NBS face the challenge of broadening existing policies and convincing institutions to try out the new, better options. In the last few years, researchers have estimated that green infrastructure could reduce annual maximum flood flows in some communities in North Carolina by 30% to 40%, and have begun identifying specific locations and projects.[915] Longer term, North Carolina will need to develop a nuanced practice of hybrid solutions, a patchwork of green and gray strategies.[916]

Recent developments: The Cooper administration advanced climate adaptation through a series of executive orders, starting with Executive Order 80, which was primarily focused on emissions reductions but called for cabinet agencies to "integrate climate … adaptation practices into the programs and operations."[917] In July 2022, Cooper issued Executive Order 266, directing the state Department of Administration to update a floodplain policy for state construction that had not been revised since

[910] National Academy of Sciences, Modernizing Probable Maximum Precipitation Estimation, June 28, 2024; NOAA, blog post: National Academies unveils strategy to modernize probably maximum precipitation estimates, June 28, 2024.
[911] NC DEQ, 2023 Climate Strategy Report, October 1, 2023, at 19.
[912] USEPA, webpage: Green Infrastructure, updated September 18, 2024; NRDC, webpage: Green Infrastructure: how to Manage Water in a Sustainable Way, July 25, 2022.
[913] NC Coastal Federation, Action Plan for Nature-Based Stormwater Strategies, March 2021; NC Policy Collaboratory, Collaboratory Flood Resiliency Study, June 2021 [*Collaboratory Flood Study*], especially at 28 (Barbara Doll on natural infrastructure and riverine flooding), and 36 (Jonas Monast on wetlands).
[914] FEMA, Building Community Resilience with Nature-Based Solutions: A Guide for Local Communities, June 2021; FEMA, Building Community Resilience with Nature-Based Solutions: Strategies for Success, March 2023.
[915] Jack Kurki-Fox et al., The flood reduction and water quality impacts of watershed-scale natural infrastructure implementation in North Carolina, USA, Ecological Engineers, August 2022, 188, https://doi.org/10.1016/j.ecoleng.2022.106696; Meredith Hovis et al., Natural Infrastructure Practices as Potential Flood Storage and Reduction for Farms and Rural Communities in the North Carolina Coastal Plain, Sustainability, August 2021, 13: 9309, https://doi.org/10.3390/su13169309; Madalyn Baldwin et al., Geospatial Analysis and Land Suitability for "FloodWise" Practices: Nature-Based Solutions for Flood Mitigation in Eastern, Rural North Carolina, September 2022, 11 (9): 1504, https://doi.org/10.3390/land11091504.
[916] See, for example, Conservation International, Practical Guide to Implementing Green-Gray Infrastructure, 2020.
[917] EO 80, §2.

1993.[918] The updated policy was finalized in January 2024 and took effect in February 2025; with narrow exceptions, it prevents construction of new state-owned facilities in the 100 year and 500 year floodplains, increases elevation requirements for structures built along the coast, and stipulates that future state construction projects must consider nature-based infrastructure to minimize or mitigate harmful impacts.[919] The policy does not apply to construction that is funded but not owned by the state, and does not apply to local government or private projects. (Federal agencies are subject to FEMA's Federal Flood Risk Management Standard, adopted by final rule in July 2024 with an effective date in September 2024.)[920]

Other efforts have focused on land and natural resources conservation. The Natural & Working Lands Action Plan, released in tandem with the NC Climate Risk and Resilience Plan in June 2020, listed a slew of strategies, including wetlands and forest restoration, integration of resilience into local comprehensive land use plans, and conservation of salt marshes and peatlands.[921] In January 2024, Governor Roy Cooper reiterated his administration's commitment to conservation strategies with Executive Order 305 on Natural and Working Lands. Among other provisions, EO 305 establishes three new goals for the state to achieve by 2040, measured against a 2020 baseline: to permanently conserve 1 million new acres of natural lands, with a special focus on wetlands; to restore or reforest 1 million new acres of forests and wetlands; and to plant 1 million trees in urban areas of the state.[922] NC DEQ released a progress report in October of 2024 which discusses progress on the recommendations made in the 2020 NWL Action Plan publication and sets out pathways to meeting EO 305's goals.[923]

Passage of the federal Inflation Reduction Act (IRA) in August 2022 provided a federal framework and funding streams to support investments in adaptation on natural and working lands.[924] It has taken some time for federal agencies to disburse substantial IRA funding, but NC DEQ included resilience investments in North Carolina's Priority Climate Action Plan (PCAP), submitted to EPA in March 2024.[925] Excellent news arrived in July 2024 when EPA awarded a $421 million Carbon Pollution Reduction Grant (CPRG) to North Carolina, South Carolina, Virginia, and Maryland.[926] The funds will support peatlands

[918] Executive Order 266 (EO 266), Updating the North Carolina Uniform Floodplain Management Policy for State Construction, July 25, 2022.
[919] NCDOA, Uniform Floodplain Management Policy for State Property, January 2024.
[920] FEMA, webpage: Federal Flood Risk Management Standard, updated September 18, 2024.
[921] NC DEQ, North Carolina Natural and Working Lands Action Plan, June 2020.
[922] EO 305, §1.
[923] NC DEQ, North Carolina Natural and Working Lands Action Plan: 2024 Progress Report, October 2024.
[924] Public Law 117-169 (H.R. 5376), Inflation Reduction Act of 2022, August 16, 2022; The White House, Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action, January 2023.
[925] NC DEQ, NC Priority Climate Action Plan, March 1, 2024. A subsequent Comprehensive Climate Action Plan (CCAP) is theoretically due for submittal to USEPA in December 2025.
[926] Governor's Office, press release: Governor Cooper and NCDENCR Announce Historic $421 Million Award to Bipartisan Multi-State Coalition Supporting Conservation and Restoration, July 22, 2024; factsheet: Atlantic Conservation Coalition Climate Pollution Reduction Grant Overview, no date.

protection and restoration, salt marsh restoration, living shorelines, farmland preservation, and reforestation.

The NC General Assembly has played a crucial role both in directing resilience policy and funding state action. In 2019 the NCGA directed the UNC Collaboratory to draw on expertise from across the university system to address flood resiliency; the Collaboratory's final report was published July 2021.[927] In the FY21-22 state budget, the NCGA appropriated funds for a variety of purposes, including $38 million to the Department of Agriculture for 'stream rehabilitation', nearly $1.5 million to the NC DEQ Division of Coastal Management for the Resilient Coastal Communities Program, and $15 million for Land and Water Fund projects to reduce flood risk.[928] The legislation also included $20 million to NC DEQ for the creation of the NC Flood Resilience Blueprint, $3.5 million to NC DEQ to test nature-based strategies to address chronic flooding in the Stoney Creek watershed in Wayne County, and $32 million to the Department of Public Safety for resilience-related earmarks for specific local governments.[929] The legislature sent a separate $96 million to NC DEQ, with a caveat that the agency couldn't spend the funds until it prepared a draft Blueprint report, to be submitted to the legislature by the end of 2023.[930] The resulting report is the roadmap for fully building out the NC Flood Resilience Blueprint tool and program.[931] In the meantime, NC DEQ is developing action plans for the Neuse and five other river basins to spend out the $96 million.[932]

SYSTEMS

The last large category of goals and indicators is a counterpart to the static built environment of buildings and transportation facilities: the infrastructure that manages flows of water, energy, and waste. We find that water infrastructure presents a mixed picture – water and wastewater utilities have grown stronger over the last several years, but affordability of water service is mixed. Our energy infrastructure has made progress, but affordability remains a question mark. Waste management trends are also mixed, with progress in waste reduction and cleaning up underground storage tanks, and lost ground on composting, recycling, and cleaning up contaminated sites generally. Overall, trends for our systems and key services are mixed.

[927] *Collaboratory Flood Study*.
[928] SL 2021-180 (S105), Current Operations Appropriations Act of 2021, §5.9(a).
[929] *Idem*.
[930] SL 2021-180, §40.7.(c).
[931] NC DEQ, Draft North Carolina Flood Resiliency Blueprint, March 2024.
[932] NC DEQ, Division of Mitigation Services, Statewide Flood Resiliency Blueprint Implementation Report, July 1, 2024, at 11.

Goal 37: Water systems are sustainable and resilient and have adequate capacity

Trend: Positive

Over three-quarters of North Carolinians get our drinking water from publicly owned drinking water utilities.[933] The state's universe of 540 publicly owned drinking water utilities is highly skewed: the top five utilities serve 25% of the state's population, while, at the other extreme, 409 systems with under 10,000 customers each serve just 10% of the population. In general, the large systems are in good shape – their service areas are densely populated, so capital costs are spread over many households, and their staffing benefits from economies of scale. In contrast, many small utilities are hanging on by a thread, and many are simply not financially viable without periodic injections of state or federal funding. Further, many utilities have underestimated their vulnerability to sea level rise and increased flooding. Large systems usually have reserves and the ability to raise rates to meet these challenges; small systems often don't.

Data for the percentage of residents served by centralized wastewater utilities is scarce. Boilerplate in the Governor's annual proclamation of 'SepticSmart week' – part of a national education campaign – claims that 'nearly 50 percent of North Carolina residents rely on septic systems'.[934] But in fact data on septic use in North Carolina (and most of the country) hasn't been systematically collected since the 1990 federal census. Following a multi-year period of discussion and vetting, the US Census Bureau agreed in late 2023 to add a question on whether residences are served by sewer or septic to the American Community Survey.[935] Small wastewater systems face many of the same challenges as small drinking water systems.

This goal covers both the fiscal viability of North Carolina's public water utilities – drinking and wastewater – and their flood vulnerability. Capacity to meet demand is one of the factors the state uses to judge which utilities are 'distressed', so that is addressed by the indicator 36.1 as well. Since 2020, the state has significantly boosted investments in water systems to promote stability and resilience, and those investments appear to have paid off, with water systems edging back from the brink of nonviability. Long term safety from flooding is less clear – and a number of utilities were badly damaged

[933] Numbers derived from US EPA, Safe Drinking Water Information System search, retrieved April 24, 2024. According to EPA's data, 8.3 million North Carolinians receive water from systems owned by local governments; 93,000 from federal systems (mostly military bases), and 885,000 from privately-owned systems. Given a 2024 estimated state population of 10.88 million, at least 1.6 million North Carolinians (15% of the population) must be self-supplied from private groundwater wells. The US Geological Survey estimates that as of 2010, 22.7% of the population relied on private wells for water at home. T.D. Johnson, et al., Estimating domestic well locations and populations served in the contiguous U.S. for years 2000 and 2010, Science of the Total Environment, 2019, 687, 1261, https://doi.org/10.1016/j.scitotenv.2019.06.036, and related geonarrative.

[934] See, for example, Governor Roy Cooper, Proclamation: Septicsmart Week 2023, September 2023.

[935] Memo: David Waddington to Donna Daily, American Community Survey, November 17, 2023.

by Helene – but the positive trends in financial stability suggest that North Carolina is moving towards rather than away from the goal of having healthy drinking and wastewater utilities.

Solutions: To improve the health of water systems, North Carolina should, A5, enact state wetland protections (which filter out pollution and lower costs for downstream water treatment); D1, protect North Carolinians from disproportionate burdens; E1, fund lead pipe replacement; F3 and G4, curb the discharge of forever chemicals to air and water; G3, update surface water quality standards; G5, build out One Water strategies for impaired reservoirs; G9, address the fate of non-viable water utilities; L6, authorize 'assured supply' ordinances; and M4, keep state-funded facilities safe from floods.

Indicator 37.1: Number of water utilities that are 'distressed'

Top line: In 2019, we offered an incomplete but sobering snapshot of water utility financial health, based on a voluntary survey of utilities by the UNC Environmental Finance Center. Since then, the state legislature and DEQ have set up the Viable Utility program to identify and support failing water utilities. Data for 2019 through 2023 suggest that fewer utilities are meeting the threshold to be designated distressed. This is a trend in the right direction.

About water utility health: Many of North Carolina's smaller utilities are probably not viable in the long term without recurring infusions of outside funding. One critical measure of the sustainability of a water utility is whether it raises enough revenue to cover its operating costs and pay off long-term debt from capital expenses. Of the 341 public systems in North Carolina that answered a survey question on this in 2017, 21% did not raise enough revenue to cover operations and debt; that includes 10% that did not raise enough revenue even to cover their operating costs.[936] All of these systems had fewer than 10,000 connections.

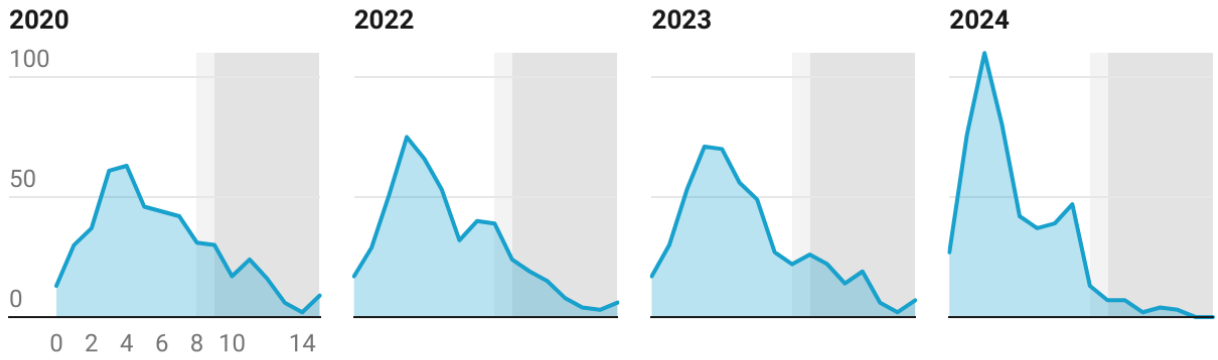
Small systems can face challenges for a variety of reasons. Some build water infrastructure to serve industrial customers who then close or leave; some serve rural communities where the population is shrinking. Past state funding strategies have often covered capital costs for expansions without asking whether the utility's ratepayers could afford to maintain the expanded system. Until recently, both state and local leaders have been hesitant to discuss regionalization or system merger as a solution. A series of hurricanes in 2016, 2018, and 2019 damaged infrastructure across many small systems, bringing the question of their long-term viability to a head.

Recent developments: In 2020, the NC General Assembly enacted S.L.2020-79 (H1087), Water/ Wastewater Public Enterprise Reform.[937] That act established the Viable Utility program, staffed by DEQ's Division of Water Infrastructure (DWI) and overseen by the State Water Infrastructure Authority (SWIA). Under the program, SWIA designates utilities as 'distressed' based on a variety of factors, and

[936] UNC Environmental Finance Center, 2018 North Carolina Water & Wastewater Rates Report, January 2018, at 25. A map showing the location of all the systems is at 28.
[937] S.L.2020-79 (H1087), Water/ Wastewater Public Enterprise Reform, codified in part at NCGS 159G-34.5.

then directs state funding to help distressed systems find a path to stability. That can mean adding infrastructure, or merging with or connecting to other nearby systems.[938] Systems are listed as distressed if their fiscal affairs have been taken over by the Local Government Commission (LGC); if they fail to submit annual audits to the LGC for two years; or if they score poorly on a slate of 20 factors.[939] SWIA and DWI have not created an official channel to come off the Viable Utility list ("de-designation"), therefore analyzing absolute numbers of distressed utilities would not provide an accurate trend. Instead, this indicator tracks the distribution of assessment scores for each local government unit (LGU) as measured against those 20 factors, which include measures of financial difficulty, inability to meet demand, and poor management.[940]

Figure 37.1: Annual assessment scores by State Water Infrastructure Authority for Local Government Units



Assessments use data from the previous year. A score of 8 or more is considered distressed for single systems (dw OR ww), and 9 or more is distressed for dual systems (dw and ww).

Source: State Water Infrastructure Authority. 2020 Agenda Item G, 2022 Agenda Item J , 2023 Agenda Item L, 2024 Agenda Item L -- Reassessment and Designation of Local Government Unit Systems as Distressed. • Created with Datawrapper

Figure 37.1 shows that across the last four assessments, fewer systems meet the threshold for being designated distressed (a score of 8 for single systems or 9 for dual systems, shown as the shaded band on each graph), as compared to the original 2020 assessment. This is a positive trend.

[938] In FY22-23, the Viable Utility Reserve (VUR) awarded $333.6 million for construction, roughly $10.3 million for asset inventory and assessment, and none for merger or regionalization. DEQ/DWI, Annual Report of the Water Infrastructure Fund, November 1, 2023, at 2-6.
[939] State Water Infrastructure Authority July 18-19, 2023 Meeting Agenda Item L – 2023 Reassessment and Designation of Systems as Distressed.
[940] DEQ/ DWI, Distressed Unit Assessment Criteria, visited April 23, 2024.

Indicator 37.2: Number of water systems with critical infrastructure in the 500-year floodplain

Top line: in 2019, we did not assign a trend to this indicator for lack of a data source. This year, we have only a partial snapshot of system vulnerability, so again we assign no trend – but we expect it will become possible to identify a trend based on statewide data within the next five years.

About flood risk for water utilities: Hurricanes Matthew (2016), Florence (2018), and Dorian (2019) put a spotlight on the vulnerability of critical water infrastructure in North Carolina, knocking out dozens of drinking water and wastewater plants both within and beyond the 100-year floodplain.[941] In 2021, the UNC Environmental Finance Center (EFC) evaluated the flood risks facing North Carolina's water and wastewater utilities.[942] The study found that wastewater systems were generally more vulnerable than drinking water systems; smart actions by staff could keep initial damage from becoming worse; but funding to recover from flooding was limited and slow. Because of these dynamics, utilities benefited greatly from having a positive fund balance at the start of a disaster. The study also noted that most utilities needed more concrete guidance from state and federal agencies on how to plan for resilience.[943]

The EFC study examined utilities' key infrastructure in the Lumber, Cape Fear, and Neuse river basins, and offered the preliminary assessments of vulnerability shown in table 37.2. It's worth noting that the EFC analysis assessed only whether infrastructure was located in the floodplain. The study did not attempt to determine whether sites in the floodplain had been elevated or hardened to protect them from flooding, so the actual vulnerability may be less than suggested by the chart. The study also covered three river basins with some of North Carolina's lowest-lying, widest floodplains. Still, having a third of wastewater plants and a quarter of wastewater pumps at risk guarantees major spills of wastewater during a large flood. The sharp *drop* in numbers from the 100-year floodplain to the 500-year floodplain indicates how many utilities have located their critical facilities adjacent to rivers that flood.

Of note, in 2024 the EFC debuted a new climate resiliency dashboard for water and wastewater utilities.[944] The dashboard allows users to both to benchmark a single utility against state and national measures, and to rate the risk and vulnerability of each utility's service area. The dashboard includes a model to predict a utility's expected annual losses from natural hazards. The dashboard does not offer a perspective of change over time, and it is not set up to assess aggregate risk for all utilities in the state, but it will be a useful tool for individual utility managers and concerned customers.

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[941] For details from Hurricane Florence, see Jim Gregson, NC DEQ Division of Water Resources, Hurricane Florence Impact on Water and Wastewater Facilities, presentation to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources, November 13, 2018.
[942] UNC School of Government, Environmental Finance Center, Flood Resilience and NC Water and Wastewater Utilities, June 2021.
[943] *Idem*, at 3.
[944] UNC School of Government, Environmental Finance Center, web dashboard: Climate Resiliency Dashboard for Water & Wastewater Utilities, visited August 20, 2024.

Table 37.2: Percentage of water infrastructure locations at risk in three river basins

Type of Infrastructure	% in 100-year Floodplain	% in 500-year Floodplain	Total % at risk in 500-year flood
Water treatment plants	7%	1%	9%
Sewer treatment plants	30%	4%	34%
Water distribution pumps	12%	4%	15%
Sewer distribution pumps	23%	3%	26%
Sewer pipes	14%	8%	23%
Sewer pipes length	25%	17%	32%

Source: EFC, Flood Resilience. • Created with Datawrapper

Recent developments: North Carolina's Drinking Water State Revolving Fund (DWSRF) and Clean Water State Revolving Fund (CWSRF, for wastewater) are crucial funding mechanisms for water infrastructure. Both offer competitive grants and low-interest loans to utilities. The DEQ Division of Water Infrastructure (DWI) and State Water Infrastructure Authority (SWIA) award funds based on an annual intended use plan (IUP) that sets out scoring criteria. Projects can receive a modest number of points for elevating or hardening water infrastructure to protect it from floods. Advocates have urged DWI and SWIA to treat flood resilience not merely as positive factor but as a threshold condition before a project can receive state funds; the agency has not yet taken that step.

The 2020 American Rescue Plan Act (ARPA) and the 2021 Infrastructure, Investment, and Jobs Act (IIJA) provided a massive influx of federal funds to be distributed through the SRF programs; projects receiving most these funds were scored through competitive mechanisms.[945] In addition to that, in the 2023 state budget, the NC General Assembly earmarked roughly $2 billion in state surplus funds to a list of specific water infrastructure projects, 95% of them in state House and Senate districts represented by Republican legislators.[946] None of these earmarked projects are specifically required or encouraged to be flood resilient under the terms of their authorization.

[945] NC DEQ, Annual Report to the NCGA on the Water Infrastructure Fund, November 1, 2023, at 1-3 (ARPA), 3-16 (IIJA/BIL).
[946] SL 2023-134 (H259), 2023 Appropriations Act, §12.2.(e); NC DEQ, webpage: 2023 Appropriations Act Directed Projects, visited August 20, 2024; Dawn Baumgartner Vaughan and David Raynor, $30 billion budget pays for

In July 2022, Governor Roy Cooper issued Executive Order 266, directing the NC Department of Administration to update North Carolina's 1993 policy governing state construction projects in floodplains.[947] The updated Uniform Floodplain Management Policy (UFMP) for State Facilities, discussed also under indicator 35.2, flood vulnerability, was finalized in January 2024 and took effect in February 2025. The UFMP prioritizes keeping most new state-owned facilities out of the 500-year floodplain.[948] It does not apply to state-funded construction, but the lines it draws would make good policy sense for state-funded and local-owned construction as well.

In September 2024, Hurricane Helene ravaged water systems across western North Carolina. Floods and landslides associated with the storm damaged 88 wastewater systems and 75 drinking water systems.[949] In the immediate aftermath of the storm, the state and federal responses emphasized restoration of service. Through feats of engineering, Asheville and some other local towns were able to lift 'boil water' advisories by mid-November.[950] Disaster legislation enacted by the NC General Assembly allowed local governments and water systems to convert infrastructure funds to water system repair, and authorized NC DEQ to offer emergency loans to local governments, subsequently adding $100 million to float the loans.[951] In hopes that many of these expenditures would be reimbursed with federal disaster funds, the loans were not made forgivable. As of March 2025, over 20 systems have applied for loans, which must be repaid when federal reimbursements are received or by June 2030.[952]

Goal 38: North Carolinians have access to affordable water

Trend: Mixed

Clean drinking water and effective sanitation are essential for public safety and quality of life, but they are not free. Access to affordable drinking water and wastewater is a key element of environmental justice. For this goal, we track a single indicator: the affordability of public water and sewer service as measured against household income, and find a cautionary result.

Solutions: To keep water service affordable, North Carolina should, G10, implement a state-level program similar to LIHWAP to help local governments establish subsidies for low- and moderate- income households; and G11, establish a septic repair fund for low-income households.

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projects, programs all over NC. See what your area is getting, News & Observer, October 13, 2023; '95%', Grady O'Brien, NCCN analysis, September 29, 2023.

[947] Executive Order No. 266 (EO 266), Updating the North Carolina Uniform Floodplain Management Policy for State Construction, July 25, 2022.

[948] NC DOA, Uniform Floodplain Management Policy for State Property, January 2024, especially Article 3.C.1.

[949] *Helene DNA 2.0*, at 50-51.

[950] Lucas Thomae, NC municipal water systems score wins after Helene. But work far from over, Carolina Public Press, November 21, 2024.

[951] S.L.2024-51 (H149), Disaster Recovery Act of 2024, §10.1; S.L. 2024-53 (S743), §4C.4, 4C.5, 4C.6, 4C.7.

[952] NC DEQ, DWI, presentation: Overview of the Division of Water Infrastructure, presentation to the NC House Agriculture, Environment, and Natural Resources Committee, March 5, 2025, slide 4.

Indicator 38.1: Affordability of public water and sewer service

Top line: For this indicator, we focus on the rates paid by those connected to publicly owned drinking water and wastewater utilities. The available data isn't entirely clear but suggest that the costs of water and sewer service have increased not just in absolute terms but relative to household income, which make it likely that affordability has suffered. We assign this a yellow flag as a caution.

About water affordability: Access to safe and affordable water is essential to the health and wellbeing of communities, however affordability can be challenging to assess since it can look different in different contexts. The commonly used metric Percent Median Household Income (% MHI) is the proportion of the Median Household Income that is spent on water and wastewater bills at an average consumption threshold within a community. This metric is far from perfect, as use of % MHI can mask the experiences of low-income residents, whose incomes are not represented by the median household income (MHI) of the utility's service area.[953] Even if water or wastewater costs seem a small portion of a community's MHI, they can have a much larger impact on low-income households.

The 2019 State of the Environment Report shared a baseline statistic from the Center for Environmental Finance at UNC's School of Government's 2018 NC Water and Wastewater Rates Report: 57% of utilities in North Carolina charged more than 2.5% of median household income for 5,000 gallons/month of combined water and sewer service.[954] The threshold of 2.5% of MHI is no longer standard for assessing affordability, and subsequent reports from EFC have moved away from its use. One alternative metric asks how many households in a community face water rates greater than 4.6% of household income; that threshold was derived by US EPA in 1997 as an estimate of one day's labor per month at minimum wage.[955]

EFC's 2024 analysis shifted to look at the water rates at the median of the water utilities. EFC found that the median rate for water increased from 1.07% in 2018 to 1.17% in 2024, for wastewater the median % MHI increased from 1.36% and 1.46%.[956] This indicates that, on average, system water rates went up faster than household income. That's not inherently a bad thing; many water systems have chronically underfunded maintenance of their infrastructure and needed to increase rates to keep up with depreciation.[957] But it does suggest affordability hasn't improved for low income households, which would mirror national trends.[958] EFC provides data sets for each utility, but because utilities are inconsistent in how they report populations receiving service, we're unable to assess the percentage of

[953] *Ibid*; see also, Shadi Eskaf, Percent MHI as an Indicator of Affordability of Residential Rates: Using the U.S. Census Bureau's Median Household Income Data, The Environmental Finance Blog, January 9, 2013.
[954] UNC EFC, 2018 North Carolina Water & Wastewater Rates Report, January 2018, at 23.
[955] Lauren Patterson, et al., Affordability of household water services across the United States [*Patterson et al.*], PLoS Water, May 2023 *2*(5), e0000123. https://doi.org/10.1371/journal.pwat.0000123.
[956] UNC EFC, 2024 North Carolina Water & Wastewater Rates Report, 2024, at 13.
[957] *Idem*, at 11.
[958] Diego Cardoso and Casey Wichman, Water Affordability in the United States, Water Resources Research, November 2022, 58 (12), https://doi.org/10.1029/2022WR032206.

households that face water rates greater than 4.6% of household income. For that reason, we assign this indicator a yellow caution flag rather than a positive or negative trend.

A key factor that shapes water rates is utility size: larger water utilities tend to have lower base charges than smaller utilities because they can spread fixed costs across a larger customer base.[959] A study of water and wastewater affordability found that in communities with fewer than 10,000 residents, water and wastewater bills were significantly more expensive.[960] Those communities also had more households facing rates greater than 4.6% of household income, making unaffordability a more pervasive problem.[961]

Some communities cannot get access to public water and sewer services at all: there are persistent disparities in public water services in North Carolina rooted in racist exclusion of neighborhoods and perpetuated by policies which focus on extending service only when the project is likely to have a positive financial return for the local government (via water bills and property tax revenue).[962] This has real implications for disparities in property values, quality of life, and health outcomes given that unlike public water utilities, private wells are not regulated under the Safe Drinking Water Act (SDWA), leaving testing and treating responsibilities on the well user. Studies have found significant disparities in private well testing and treatment in North Carolina by race, ethnicity, and income: high-income white households are 10 times more likely to report previous well testing, and 4.2 times more likely to be using a treatment system than low-income, Black, or Indigenous households or households made up of other people of color.[963] Another study found that 99% of emergency room visits for acute gastrointestinal illness were associated with contamination of private wells, generally from septic systems.[964]

ENERGY

Energy powers our homes, businesses, and vehicles. When it is expensive, unreliable, or inaccessible, lives are disrupted. Electricity is a secondary energy source, created by converting primary sources of

[959] *Idem*, at 6.
[960] *Patterson et al.*
[961] *Ibid.*
[962] Julia Marie Naman and Jacqueline MacDonald Gibson, Disparities in Water and Sewer Services in North Carolina: An Analysis of the Decision-Making Process, Am J Public Health, 2015, 105:10, 10.2105/AJPH.2015.302731; Hannah Leker and Jacqueline MacDonald Gibson, Relationship between race and community water and sewer service in North Carolina, USA, PLoS ONE, 2018, 13:3, https://doi.org/10.1371/journal.pone.0193225.
[963] Andrew George et al., Drinking Water Disparities in North Carolina Communities Served by Private Wells, Environmental Justice, June 2023, https://doi.org/10.1089/env.2022.0100
[964] Nicolas DeFelice et al., Reducing emergency department visits for acute gastrointestinal illnesses in North Carolina (USA) by extending community water service, Environmental Health Perspectives, 2016, 24:10, 1583, https://doi.org/10.1289/EHP160.

energy like fossil fuels, wind and solar energy to then distribute via the energy grid, a complex network of power lines, transformers, substations, and other infrastructure.

To track energy-related trends in North Carolina, we focus on four goals. The first three are affordability (goal 39); reliability of the electric grid (goal 40); and environmental impact (goal 41). Because a deep transition to clean energy will advance all three, we include a separate goal for the transition (goal 42). This section is trending positively overall, in large part due to positive trends in reliability and emissions from energy extraction. However, if North Carolina continues to rely on volatile and risky energy sources like natural gas, ratepayers will pay more and experience outages.

These four goals also have a close relationship to overall GHG emissions (goal 2), outdoor air quality (goals 12 and 14), the transition to an electrified transportation system (goal 32) and safe retirement of legacy fossil fuel infrastructure (indicator 45.3).

Goal 39: Energy rates are affordable, and costs fairly distributed

Trend: Neutral

Solutions: Diversifying options by J1, expanding renewable energy generation and storage, will save ratepayers money. As will J3, declining to invest in new gas generating capacity; J7, investing federal energy monies equitably; J9, modernizing North Carolina's building code to be more energy efficient; and J10, establishing a state-funded energy assistance program for low-income households.

Indicator 39.1: Percentage of households that spend more than 6% of their budget on energy

Top line: Expensive energy – electricity or home heating – can sink a family's budget. In theory, a family shouldn't spend more than 6% of their household budget on energy. This indicator measures how much more than 6% of their income a family at 200% of the federal poverty level has to spend on energy annually. Reflecting the volatility of gas prices, that number has swung between $900 and $1400 over the last decade, but without an overall trend. We assess the trend as neutral but note the added pain that price volatility inflicts on households with limited income.

About energy affordability: The portion of income that a family spends on energy offers a pragmatic measure of energy affordability. For this indicator, we rely on the Home Energy Affordability Gap, a well-regarded analysis issued annually by the consulting firm of Fish, Sheehan, and Colton (FSC).[965] FSC uses a

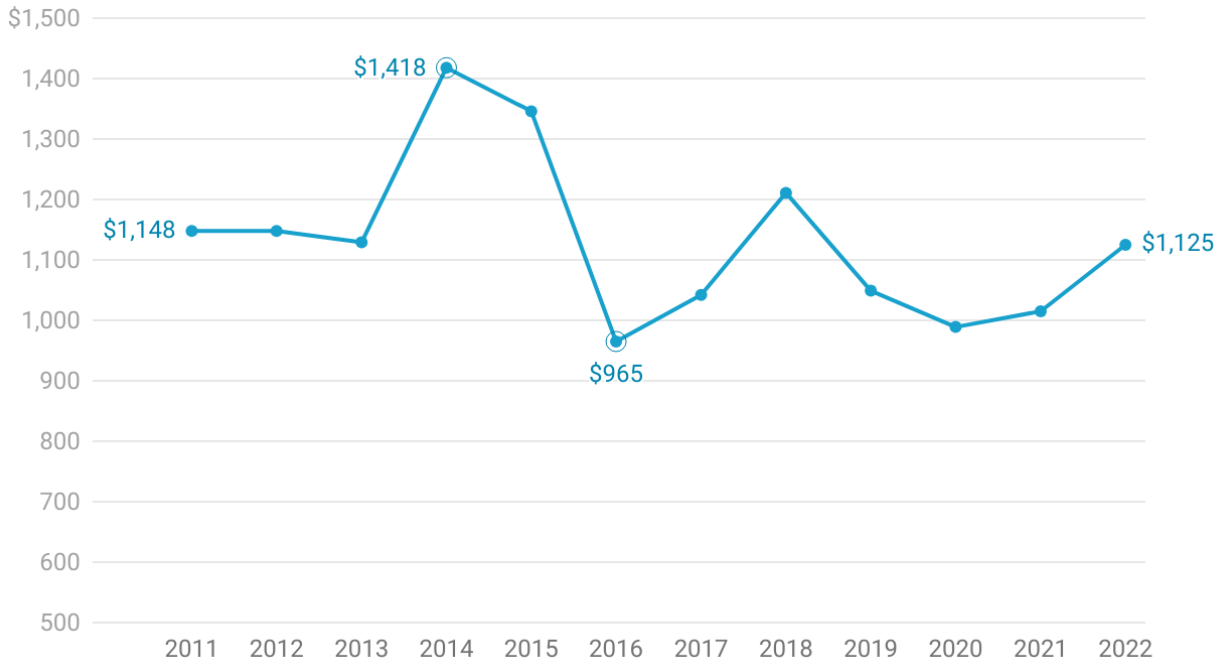
[965] Fisher, Sheehan, and Colton, website: Home Energy Affordability Gap. Another tool that may be useful in the construction of state and local policies to improve energy affordability is the US Department of Energy's Low Income Energy Affordability Data (LEAD) tool, available here. However, the authors of the tool recommend against using it to understand changes over time. NREL, Low-Income Energy Affordability Data (LEAD) Tool Methodology, July 2019, at 20.

model to estimate the percentage of households with energy costs greater than 6% of the household budget in all counties in the United States. That threshold reflects the recommendation of the US Department of Housing that housing not exceed 30% of a household's income, combined with the empirical estimate that energy costs usually account for about 20% of total housing costs.[966]

On average, in 2022, a North Carolina family at or just below 200% of the federal poverty level spent 6% of their income on energy; roughly 31% of households in the state fall at that level or below.[967] Families with incomes below 200% of the federal poverty level typically spent more than 6% of their income on energy; that is, their energy expenses were not 'affordable'. For example, households at the federal poverty level spent, on average, 16% of their income on energy.[968] The FSC indicator, dubbed the 'affordability gap', estimates the total amount by which all household energy bills in the state exceed 6% of household income. That's a great indicator for state programs that track the scale of the cumulative shortfall. But, in a growing state, the indicator has an inherent bias: as population grows, the absolute number of households that face unaffordable power bills should grow too, and the total gap should gradually increase, whether or not conditions are getting better for an average family. So, for this indicator, we use another number calculated annually by FSC: the gap between actual costs and affordable costs for a family with income at 200% of the federal poverty rate. That's what the chart below shows.[969]

[966] See, DEFG, Energy Affordability and Energy Service Choices. October 2014, at 2-3.
[967] Fisher, Sheehan, and Colton, Home Energy Affordability Gap 2017: North Carolina factsheet, April 2018.
[968] *Ibid*.
[969] Fisher, Sheehan, and Colton, website: Home Energy Affordability Gap, 2017, 2018.

Figure 39.1: Average affordability gap for North Carolina household at 200% of federal poverty level, by year



y-axis begins at $500. Affordability gap refers to the gap between "affordable" home energy bills (6% of gross household income) and "actual" home energy bills.

Source: Fisher, Sheerhan, and Colton, Home Energy Affordability Gap, 2012 - 2022 • Created with Datawrapper

Year to year changes in the affordability gap for an average household reflect a number of variables, but the biggest contributor to the volatility in the gap over the last ten years has been fossil fuel prices. Natural gas prices spiked in 2017 and 2022; propane and fuel oil prices spiked in 2014, 2017, 2018, and 2022. In comparison, the estimated cost to heat and cool homes with electricity has changed much less. Analysis of NC residential electricity rates between 2017 and 2024 showed that a significant portion of rising customer costs come from fuel costs.[970] Overall, the affordability gap for an average household at 200% of the federal poverty line shows volatility but no trend, so we count this as neutral.

Recent developments: Duke Energy has consistently projected load growth in its service areas, mostly connected to data centers and energy-consuming technology, and to meet that growth, the utility has proposed to add gas plants.[971] In North Carolina, reliance on cost-volatile gas is to blame for higher energy bills.[972] Increasing the proportion of energy that comes from gas will cost ratepayers money in

[970] Environmental Defense Fund, press release: New analysis shows reliance on gas is primary driver of rise in Duke Energy power bills, April 18, 2024, citing EQ Research, issue brief: The Role of Fuel Costs in Duke Energy's North Carolina's Retail Rates from 2017 through March 2024, April 2024.
[971] Duke Energy, factsheet: Carolinas Resource Plan, Jan 2024.
[972] *Idem,* [EDF EQ Issue Brief]

the long run. Other states have implemented cost sharing mechanisms to mitigate volatility risk to ratepayers.[973]

Energy rates in North Carolina have climbed over the last few years. Duke Energy Carolinas and Duke Energy Progress filed rate cases with the NC Utilities Commission (NCUC) in 2023. Advocates intervened in the case in opposition to Duke Energy's proposed 'return on equity' and to challenge Duke Energy's proposals for performance-based regulation and expensive grid upgrades.[974] Ultimately the NCUC approved the rate hikes, rejecting many of the intervenors' central arguments and authorizing a high return for Duke Energy shareholders at the expense of rate payers. The NCUC also approved an affordability settlement with provisions for assistance for low-income ratepayers.

Several federal and state programs support energy efficiency improvements that lower energy bills. The Low-Income Home Energy Assistance Program (LIHEAP) and the Weatherization Assistance Program (WAP) are cornerstone of energy burden programs. Established in the 1980s to address rising energy costs, they work in concert. LIHEAP addresses acute needs, covering bills for eligible families and residents; WAP lowers energy costs over time by installing energy conservation and efficiency measures. The Home Energy Rebate Programs were established more recently by the Inflation Reduction Act (IRA). Their purpose is to help American households save on energy bills, upgrade dated energy equipment and improve energy efficiency, reduce indoor and outdoor air pollution, and provide workforce training.

Other programs offer loans to homeowners and businessowners to increase energy efficiency or install clean and resilient systems (like solar and battery storage. FreddieMac offers Energy Efficient Mortgages (EEM) to purchase or refinance a home that is already energy efficient, or to finance energy efficient improvements to an existing home.[975] The Commercial Property Assessed Capital Expenditure Act (C-PACE) is a North Carolina program that provides long-term financing options to businesses from private vendors to pay for clean energy, water conservation, renewable, and resilient improvements in new and existing development.[976]

Goal 40: Energy infrastructure is reliable

Trend: Positive

For assessing the reliability of North Carolina's energy infrastructure, we track a single indicator: the average duration of power outages. That is improving, giving this a positive direction.

[973] RMI, report: Strategies for Encouraging Good Fuel-Cost Management, July 2023.
[974] SELC, press release: Commission approves Duke Energy Carolinas rate increase and low-income affordability programs, December 2023.
[975] Energystar, website: Energy Efficient Mortgages.
[976] Briana Kraemer, Private Funding bill for commercial property improvements sent to Gov Cooper, The Carolina Journal, June 2024.

Solutions: North Carolina can improve grid reliability, especially during extreme weather by J1, expanding renewable energy generation and storage. Reliance on gas contributes to outages, so J3, declining to invest in new gas generating capacity; and J4, minimizing new natural gas pipelines will improve reliability as well. North Carolina should also J5, pursue grid modernization to support distributed generation and electrification.

Indicator 40.1: Average duration of power outages

Top line: Even in good years, North Carolina's electric grid demonstrates poor reliability compared to other states. In years when the state is pummeled by a hurricane, reliability scrapes the bottom of the barrel. The last few years have shown some improvement over the few before that, and the NC Utilities Commission has approved investments to improve grid reliability. We count this as a positive trend but note that continued progress depends on decisions of the NC Utilities Commission (NCUC). Expanded reliance on gas will likely lower reliability in the future (as it has in the recent past), while expanded distributed generation – especially solar and battery power – could significantly improve reliability if done competently.

About power outages and grid reliability: Responsibility for the reliability of the electric grid is split between a mix of federal, state, and private actors. The Federal Energy Regulatory Commission (FERC) oversees the 'bulk power system', consisting of power plants and transmission lines; FERC oversees the compliance of power utilities with reliability standards set by the North Americans Electric Reliability Corporation (NERC).[977] At the state level, the NCUC approves utility proposals for new generation sources and oversees setting of rates and tariffs, including utility plans for grid investments to improve reliability.

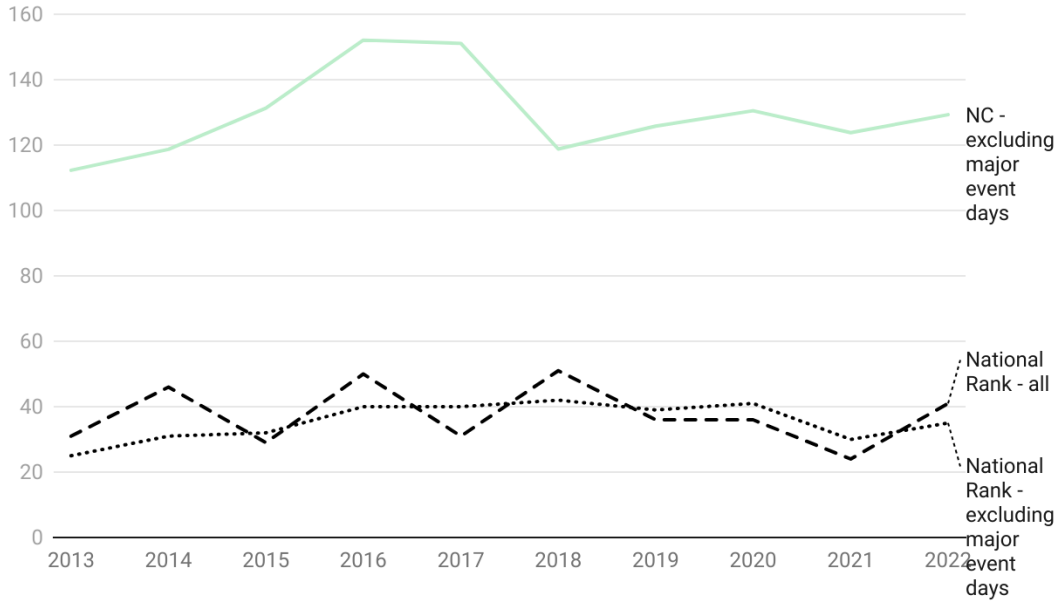
The US Energy Information Administration tracks reliability on the electric grid, calculating both by utility and by state the total number of minutes that an average customer lost power (for more than five minutes at a time) in a given year.[978] In our 2019 report, we cited North Carolina's ranking among the 50 states (and the District of Columbia) as published in US News & World Report's annual state ranking.[979] But since the data came from the EIA series, for this update we're drawing directly from the source.

Our metric is the 'system average interruption duration index' (SAIDI), a measure of the total minutes of 'non-momentary' power outages that an average electric utility customer in the state experiences in a year.[980] EIA considers any power outage lasting more than five minutes non-momentary. The SAIDI metric comes in two flavors: including 'major event days' and excluding them. The determination of which days are 'major event days' is arcane and not all utilities follow the standard method, but in general, they are days when a major weather disaster takes down chunks of the grid. SAIDI excluding

[977] Federal Energy Regulatory Commission, webpage: Reliability Explainer, August 16, 2023.
[978] See, US Energy Information Administration, Electric Power Annual 2022, October 2023, Table 11.2: Reliability metrics using IEEE of U.S. distribution system by state.
[979] US News & World Report, Energy Rankings: Measuring States' Energy Infrastructure, May 2018.
[980] EIA provides a helpful SAIDI explainer video.

major days gives a better sense of how well utilities are managing the grid on a regular basis; SAIDI including them gives a better read on how consumers are experiencing grid reliability (since an outage is an outage whether it reflects clumsy grid management or a hurricane). Longer term, while utilities cannot control the weather, they can choose to build a grid that is more or less susceptible to outages. For example, a utility can incorporate distributed generation from solar power and batteries to help its grid bounce back faster after a major storm. That would show up as a reduction over time in SAIDI with major days. Because EIA calculates SAIDI for all 50 states and the District of Columbia, it is possible to rank the states by the reliance of their electric grids in any given year.

Figure 40.1: Duration of power outages in North Carolina, minutes per year



A Major Event Day is any day that exceeds a daily System Average Interruption Duration Index (SAIDI, the minutes of non-momentary electric interruptions, per year, the average customer experienced) threshold called Tmed. Tmed is a duration statistic calculated from daily SAIDI values from the past five years.

Source: US Energy Information Administration, Electric Power Annual 2022, October 2023, Table 11.2: Reliability metrics using IEEE of US Distribution System by State • Created with Datawrapper

North Carolina's SAIDI data for the last decade, both absolute and relative to other states, shows the impact of major storms. For example, when major event days are included, North Carolina ranked 50th in 2016 (Hurricane Matthew) and 51st, dead last, in 2018 (Hurricane Florence).[981] But even in years without major disasters, North Carolina's rankings compared to other states are poor. We rank this indicator as showing very modest improvements in grid reliability.

Recent developments: Several outages in the last two years have illustrated the challenges – and choices – facing grid managers. On December 3, 2022, someone attacked two substations in Moore County,

[981] US Energy Information Administration, Electric Power Annual 2022, October 2023, Table 11.2: Reliability metrics using IEEE of U.S. distribution system by state.

cutting power to more than 45,000 residents and causing the death of one person.[982] That outage was part of a national rise in physical and cyber-attacks on the grid that has fed dramatic headlines.[983]

Yet, direct attacks on the grid remain exceptionally rare; a recent analysis found that, since 2000, 111 out of 120 major U.S. power outages (92.5%) were caused by extreme weather, and extreme-weather outages have become much more frequent as a result of climate change.[984] Winter Storm Elliott, which occurred December 21–26, 2022, cut power to 15% of Duke Energy's customers (roughly 500,000 residents).[985] FERC noted that the failure of the grid in Winter Storm Elliot was largely a failure of gas infrastructure.[986] That infrastructure performed much better during the milder January 2024 winter storm event, during which no customers were forced off the grid.[987]

It's been suggested that environmental justice communities have experienced a disproportionate share of outages from specific storms.[988] We've not seen a geographically comprehensive analysis of this.

Goal 41: Risk to the environment from energy extraction and use are minimized

Trend: Positive

North Carolina does not have significant fossil fuel energy extraction within state boundaries, and our renewable energy sources are relatively benign. Energy impacts on the environment in North Carolina largely reflect generation and consumption of electricity. One exception is harvesting of biomass for export in the form of wood pellets to be burned overseas, which results in net carbon emissions and visits significant harms on communities around pellet processing plants.[989]

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[982] John Nagy and Jonathan Bym, Moore County Warrants Shed Light on 2022 Power Grid Attacks, The Pilot, December 15, 2023; Madison Carter and Michael Prats, Unsealed warrant provides closer look at NC power grid attack investigation, WSOC-TV, February 2, 2024.
[983] Catherine Morehouse, Tensions at home and abroad pose growing threat to US grid, E&E News, April 8, 2024; Catherine Morehouse, Extremists keep trying to trigger mass blackouts – and that's not even the scariest part, Politico, September 10, 2023.
[984] Climate Central, web report: Weather-related Power Outages Rising, April 4, 2024; Karri Peifer and Andrew Freedman, Most of Virginia's major power outages are due to extreme weather, Axios, June 10, 2024.
[985] FERC, Inquiry into Bulk-Power System Operations During December 2022 Winter Storm Elliot, October 2023, at 13, footnote 40.
[986] *Idem*, at 20, 21. *See also*, FERC & NERC, presentation: FERC-NERC-Regional entity Joint Inquiry Into Winter Storm Elliot, September 21, 2023.
[987] FERC, presentation transcript: System performance review of the January 2024 arctic storms, April 25, 2024.
[988] See, for example, Vote Solar, blog post: Weathering the Storm: A look at grid reliability in North Carolina's Environmental Justice Communities, April 24, 2024 (analyzing the distribution of outages from the April 11, 2024 storm).
[989] Emma Shumway, Wood Pellet Production in the U.S. South and Exportation for 'Renewable' Energy in Europe; the New Green Sacrifice Zone, Columbia Journal of Environmental Law, June 2023, 48 (2), https://doi.org/10.52214/cjel.v48i2.11735.

This goal relies on two indicators: greenhouse gas emissions from energy generation (indicator 41.1), which are falling; and the energy efficiency of the state economy, which is gradually improving (indicator 41.2). Overall, we see a marginally positive trend towards this goal this year.

Solutions: To reduce our greenhouse gas emissions from energy generation, North Carolina should pursue energy recommendations J1 through J9.

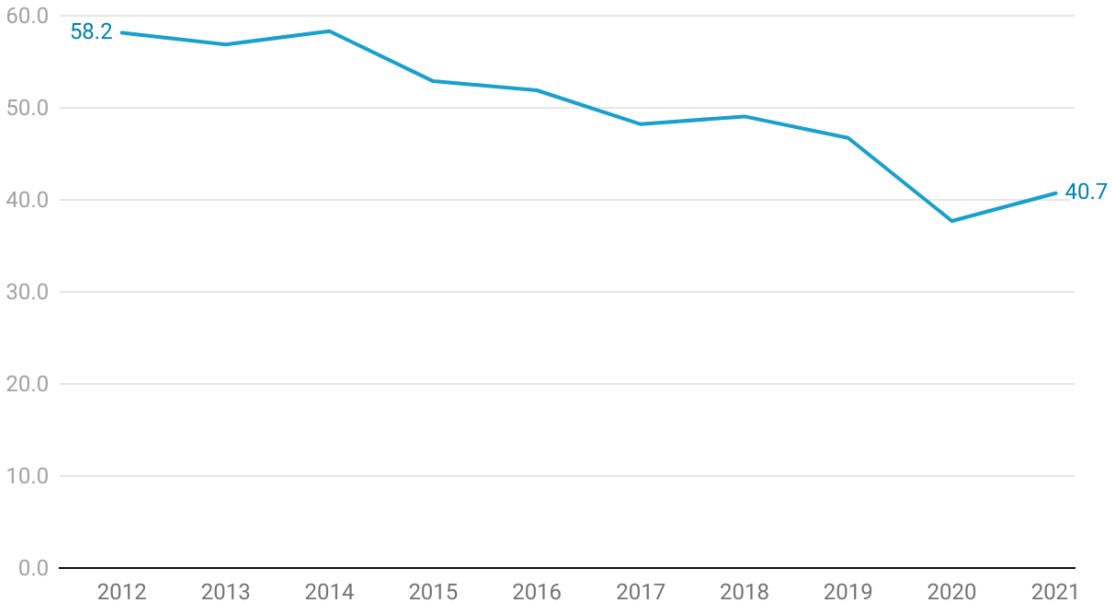
Indicator 41.1: GHG emissions from energy consumption

Top line: Greenhouse gas (GHG) emissions from the electricity sector have dropped rapidly in North Carolina over the last fifteen years, largely thanks to the retirement of coal-fired power plants. If the NC Utilities Commission approves Duke Energy's plans to build multiple additional gas plants across the Carolinas, reductions in the sector will be delayed or reversed – but for this update, the trend is positive.

About GHG emissions from the electricity sector: As with other greenhouse gas emissions indicators, for this indicator we rely on data from US EPA's greenhouse gas emissions inventory because it allows for consistent comparisons with emissions from other states and counties – but for the electric generating sector, the state and federal statistics are identical. The baseline year against which GHG reductions are measured in EO 80 and SL2021-165 (H951) is 2005. According to the EPA and the official state inventory, GHG emissions from North Carolina's electricity sector have dropped by 46.9% since 2005.[990] This is primarily due to the retirement of old coal-fired power plants, whose energy production resulted in more emissions per unit of energy than the natural gas and renewables facilities that have replaced them. In addition, overall electricity consumption has remained essentially flat in North Carolina since around 2000.[991]

[990] US EPA, website: Greenhouse Gas Inventory Data Explorer, visited May 23, 2024; NC DEQ, Greenhouse Gas Emissions Inventory (1990-2050), January 2024.
[991] US Energy Information Administration (EIA), State Energy Data System, North Carolina: State Profile and Energy Estimates, Table CT8, Electric power sector consumption estimates, 1960-2022, visited August 31, 2024.

Figure 41.1: Annual emissions from NC's electric generation sector, million metric tons (MMT) of CO2 equivalents (CO2e)



Source: US EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks by State, 1990-2021. • Created with Datawrapper

Of the main energy generation types in North Carolina, emissions are growing only from the methane gas sector, as investor-owned utilities replace energy produced from coal with energy produced from gas. Historically, industrial use accounted for the majority of natural gas consumption in North Carolina, but combustion of gas for generation of electricity overtook industrial uses in 2012. Using the most recently reported figures, industry in 2022 accounted for just 20% of the state's gas use, with the residential sector (home heating) at 10% and commercial uses at 8%.[992]

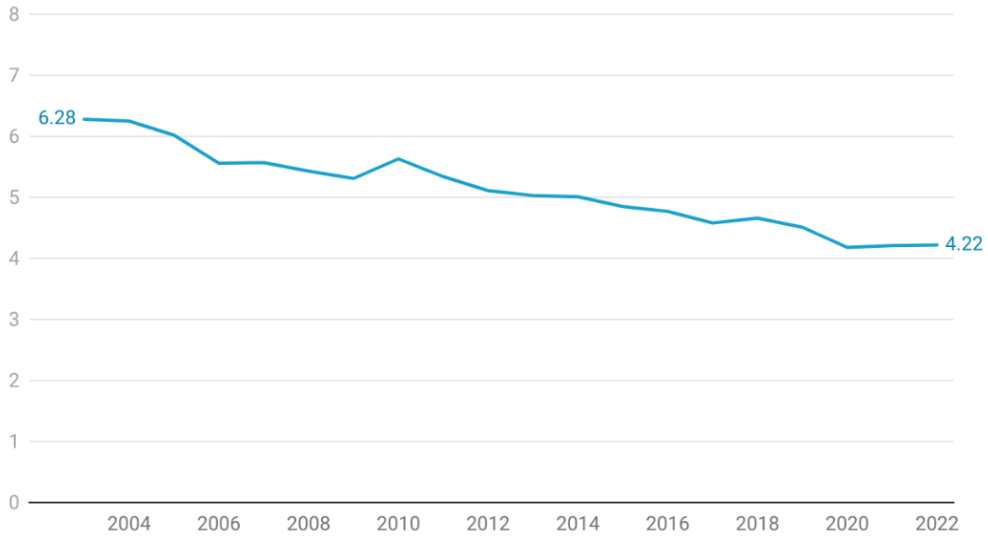
Indicator 41.2: Energy efficiency of the economy

Top line: For the last two decades, North Carolina's economy has continued to become more efficient in its use of energy. In 2022, we expended an estimated 4,220 British thermal units (BTUs) of energy for each dollar of the state' gross domestic product, down from 7,320 BTUs/ dollar in 2000. North Carolina's state economy is the 30th most efficient in the country – not even in the top half – but the trend is in the right direction.[993]

[992] US EIA, webpage: North Carolina state profile and energy estimates, updated February 15, 2024.
[993] US EIA, State Energy Data System, Table C10. Total Energy Consumption Estimates, Real Gross Domestic Product (GDP), Energy Consumption Estimates per Real Dollar of GDP, Ranked by State, 1960-2022, June 2024.

About energy efficiency: A key measure of the energy efficiency of the state's economy is the amount of energy used per unit of economic activity. The federal Energy Information Administration (EIA) calculates this using Gross State Product adjusted for inflation; the data has a two-year time lag.[994] This indicator is agnostic about the source of the power, and assumes that it is better if a given level of energy use can generate more economic activity – or, conversely, if the same level of activity can be sustained with less energy consumption. Data since 2000 shows an overall drop in the energy intensity of North Carolina's economy, a positive trend.

Figure 41.2: Total Energy consumption per dollar of real GDP, Thousand BTU per chained (2017) dollar in North Carolina



Source: EIA, State Energy Data System (SED)S, 1960-2022. • Created with Datawrapper

Goal 42: North Carolina transitions to a diverse mix of renewable energy sources

Trend: Mixed

This goal relies on two indicators: the percentage of electricity used in North Carolina that comes from renewable sources (indicator 42.1), and the trend in grid modernization (indicator 42.2). Overall, we find mixed trends for this goal.

Solutions: North Carolina can transition to renewable energy sources by, J1, expanding renewable generation and storage; J3, declining to invest in new gas capacity; J4, minimizing new gas pipelines; J5,

[994] US EIA, State Energy Data System (SEDS): 1996 – 2021 (complete). Ranked by state; Total energy consumption, real GDP, and energy intensity.

modernizing the grid to support distributed generation; and J7, spending out IRA dollars to promote clean energy in underserved communities.

Indicator 42.1: Percentage of energy from clean sources

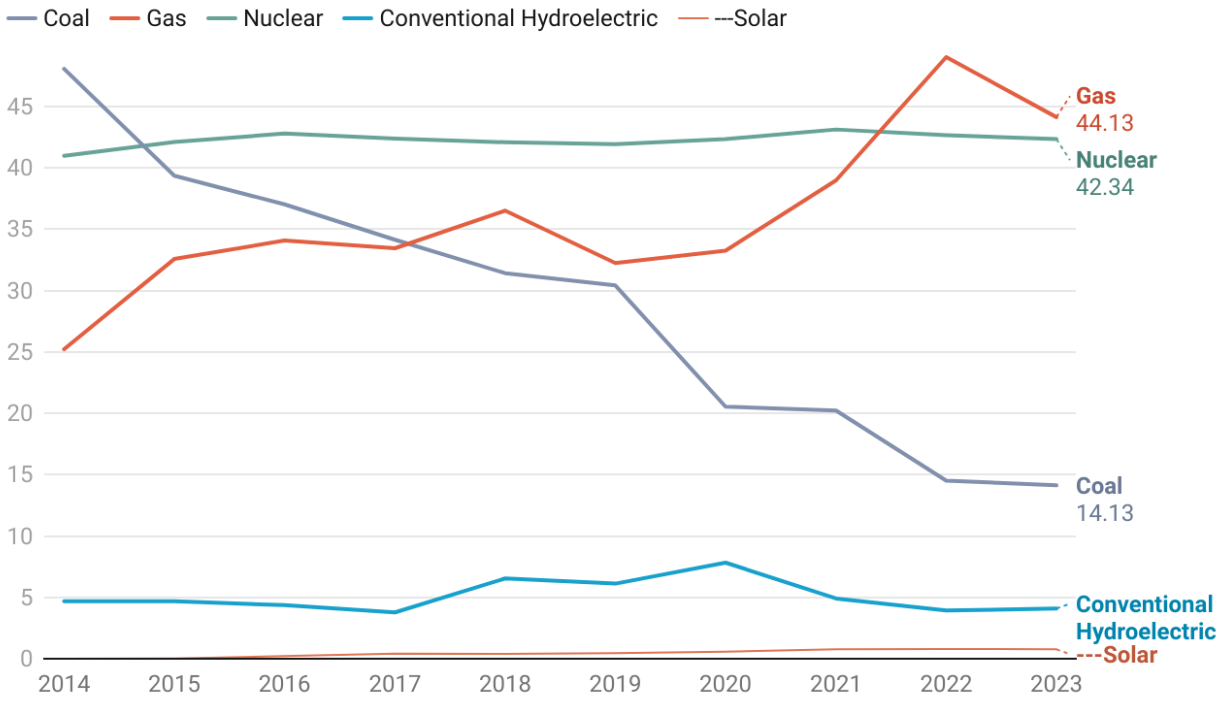
Top line: Solar energy has grown rapidly in North Carolina over the last decade, but not as quickly in the last few years, as the NC General Assembly and the NC Utilities Commission have not continued to push the regulated electric utilities to transition as quickly as they could. Solar is growing, but not quickly enough to achieve long term carbon reduction goals; we mark this trend as inadequate.

About energy from clean sources: Reaching state, national, and global carbon reduction targets will require a massive transition in the sources of the electric power North Carolinians consume. The state's energy mix has already evolved over the last decade, as coal fired power plants have closed and methane gas plants come online. Meanwhile nuclear plants have provided a steady 42% of the state's electricity, and hydropower has ranged between 4% and 7% of generation. Utility-scale solar has grown from 6,000 MWHr of generation in 2014 to 763,000 MWHr in 2023. That's rapid growth, but still less than 1% of the electric generation in the state.[995] Because the current speed of the transition to solar is far slower than we need – and because speeding it up would save ratepayers money as well as helping to curb greenhouse gas emissions – we assess the current trend as inadequate.

One recurring question about the expansion of solar is whether it presents a threat to North Carolina agriculture. The short answer: it does not. Conversion of farmland for sprawl development, addressed in indicator 9.2, loss of farmland, and indicator 34.2, patterns of residential growth, is a far greater threat to farmland and the rural landscape. A 2022 report by the NC Sustainable Energy Association (NCSEA) calculated that solar photovoltaic systems occupy only 0.12% of North Carolina's total land area, and only 0.28% of its agricultural land.[996] Moreover, unlike farmland converted to development, farmland with solar panels can still be used for some agricultural activities, such as grazing livestock.

[995] US EIA, webpage: North Carolina State Energy Profile, updated February 15,2024; queried with Electricity Data Browser, visited August 19, 2024.
[996] NCSEA, North Carolina Solar Land Use and Agriculture, 2022 Update.

Figure 42.1: Annual North Carolina electric generation by source, hundred-thousand megawatt-hours



Source: EIA, State Energy Data System (SED)S, 2014-2023 • Created with Datawrapper

Recent developments: As mentioned in previous energy sections of this report, Duke Energy, like many other utilities across the US Southeast, claims that demand for electricity will surge. The 2023 Carbon Plan included significant investments in solar and wind energy projects, and intervenors challenging the Plan ultimately agreed to a settlement with Duke Energy August 2024, seeing the compromise as progress towards solar energy and battery storage, however incremental.[997] However, Duke Energy has proposed, and the NC Utilities Commission has approved, the construction of new gas plants to meet demand. Gas-fired power plants are prone to failure during grid peaks, which occur in late afternoons in the summer and early mornings in the winter. FERC has estimated that 20% of power loss during Winter Storm Elliot in 2022 was a direct result of gas fuel issues.[998]

Enbridge Gas (formerly Dominion Energy) has plans to build a gas pipeline - called the T15 Reliability project - that will connect to new and existing natural gas infrastructure, resulting in hundreds of thousands of tons of new greenhouse gas emissions from North Carolina each year.[999]

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[997] Elizabeth Ouzts, Duke Energy's plans for more gas gain traction with former critics, Canary Media, September 2024.
[998] FERC, report: Winter Storm Elliott Report: Inquiry into Bulk-Power System Operations During December 2022, November 2023. Figure 7, page 18.
[999] Lisa Sorg, On the Frontlines of North Carolina's Natural Gas Buildout, The Assembly, September 8, 2024.

A smooth and complete transition to clean energy will require significant investment on every level. President Joe Biden signed Executive Order 14008, Tackling the Climate Crisis at Home and Abroad, committing 40% of overall investments in Federal climate, clean energy, affordable and sustainable housing reach communities under resourced and overburdened by pollution. The Justice40 initiative helped guide funding from the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA). For every dollar the government contributed to clean energy infrastructure through the IRA, the private sector paid $5.47, leading to nearly a quarter-trillion dollars in new funds in the clean economy between October 2022 and early 2024.[1000]

Indicator 42.2: Progress towards a modernized grid

Top line: The index we relied on to evaluate grid modernization in 2019 is being updated. In the meantime, recent and ongoing actions before the NC Utilities Commission make North Carolina one of the most active states in the nation on grid modernization, moving generally in the right direction. We count this as a positive trend.

About grid modernization: transitioning to a sustainable mix of energy sources – including heavy reliance on electricity to power motor vehicles – will require significant revisions to the electric grid. 'Grid modernization' can mean a variety of things; for purposes of this report, we use the term to include improvements to the electric transmission and distribution system to support a cleaner mix of energy sources, greater efficiency, greater reliability, and lower overall costs.

In our 2019 report, we relied on the Grid Modernization Index (GMI), an annual ranking of state grids issued by the Gridwise Alliance from 2012-2018. The index considered 65 indicators grouped into three categories: state policies; customer engagement (responsiveness to and data sharing with customers); and grid operations (effectiveness and reliability).[1001] The first two years of the index did not share individual state rankings for most states. From 2014 to 2018, North Carolina was ranked 24th, 11th, 15th, and 23rd. Evaluations were performed by a team of industry professionals and analysts; the index tended to yield better scores for states that are a part of a regional transmission organization, which most of North Carolina is not. Of the three categories, North Carolina scored relatively better on policies and operations, and not as well on customer engagement.

In 2022, Gridwise Alliance announced it would revamp its analytical framework to reflect the increasing complexity of the grid. An early report identifies key drivers of that complexity, including electrification of vehicles and buildings; the rapid expansion of distributed generations sources (like wind and solar); and the need for grid resilience in the face of increasingly frequent climate-driven disasters. Gridwise Alliance plans to reorganize its original three categories into four pillars: state policies; customer adoption & options; grid optimization; and system design & coordination.[1002] Unfortunately, the next

[1000] Rhodium Group, report: Clean Investment Monitor: G4 2023 Update, February 2024.
[1001] Gridwise Alliance, Grid Modernization Index 2018, December 2018.
[1002] Gridwise Alliance, Grid Modernization Index: Readiness Framework, April 2022.

iteration of the assessment using this new framework is still under development, so not available for this update.

Another resource for tracking grid modernization is the NC Clean Energy Technology Center's (NC CETC) *50 States of Grid Modernization*, issued quarterly and with an annual review.[1003] *50 States* is not a ranking; rather, it catalogs all grid-related legislative and regulatory actions across the states in close-to-real-time. CETC groups actions into six categories: studies and investigations; utility business model and rate reform; incentives; planning & market access; policies; and deployment. In 2023, NC CETC identified North Carolina as the 13th most active state on grid modernization, with 23 distinct actions spread across all six categories, with an outsize share in deployment.[1004] North Carolina was unusual for the proportion of actions in the regulatory sphere and a relatively quiet legislative environment. *50 States* does not indicate whether the specific changes in North Carolina are more or less substantive compared to those in other states. The state's main investor-owned utility, Duke Energy, has moved slower to plan and build out capacity for electrification than it could. Still, the NC Utilities Commission is moving North Carolina's grid in the right direction, and we count the activity as reflecting a positive trend.

Goal 43: North Carolina minimizes production of solid waste

Trend: Mixed

A first step to better materials management is to reduce how much we throw away. We measure progress towards this goal with two indicators: the total volume of municipal solid waste (indicator 43.1), and the number of local programs to divert organic waste into compost and out of the solid waste stream (indicator 43.2). Solid waste generation has plateaued since the 2018-2019 fiscal year, which we consider a positive trend. But the very limited data on diversion of organic wastes suggests minimal change, so we evaluate that indicator as showing inadequate progress towards the goal of waste reduction this year, for a mixed trend on solid waste overall.

Solutions: To reduce the volume of solid waste generated each year, North Carolina should H1, enact producer responsibility policies; H2, promote diversion of food waste to compost; and H3, reduce plastic pollution.

Indicator 43.1: Tons of municipal solid waste generated annually in-state

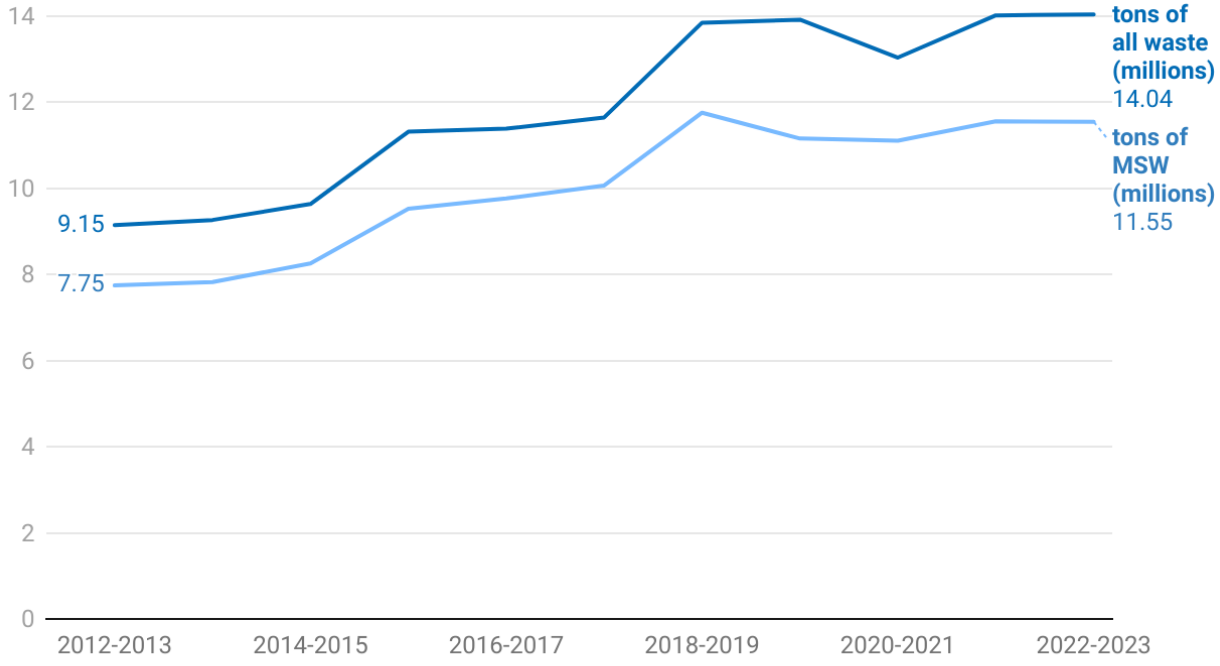
Top line: After years of growing much faster than the state's population, North Carolina's generation of both total and municipal solid waste paused in FY2018-2019 and has been virtually flat since then. It's

[1003] NC Clean Energy Technology Center, 50 States of Modernization: 2023 Annual Review and Q4 2023 Quarterly Report, January 2024.
[1004] *Idem*, at 11.

unclear whether this is a function of the COVID-19 pandemic, or whether it will last, but it is a very positive trend.

About solid waste: North Carolina recognizes several different kinds of waste, with different rules governing the disposal of each: municipal solid waste, construction & demolition waste, land clearing & inert debris, hazardous materials, and coal combustion residuals, among others. For purposes of this indicator, we track municipal solid waste (MSW), which most directly reflects what ordinary North Carolinians are consuming and throwing away. We rely on the data kept by NC DEQ Division of Waste Management and reported annually.[1005]

Figure 43.1: Tons of total waste, municipal solid waste (MSW) generated in North Carolina



Source: NCDEQ, DWM, Annual Reports • Created with Datawrapper

Generation of municipal solid waste continues to rise gradually, although the rise is smaller than population growth. From 2013 through 2019, municipal solid waste generation skyrocketed, with per capita generation rising from 0.94 tons per resident per year to 1.33 tons. Since then, however, municipal solid waste generation has remained nearly flat at around 11.5 million tons and a slight decline in per capita generation to 1.26 tons.[1006] State regulators estimate that in-state MSW landfills

[1005] NC DEQ, Division of Waste Management, Public and Private Municipal Solid Waste, FY12-13 through FY16-17, November 2018; NC DEQ, Division of Waste Management, Public and Private Municipal Solid Waste, FY 2017-2018, December 2018.

[1006] NC DEQ, DWM, MSW Landfill Report, Public and Private Municipal Solid Waste, FY 2022-2023 (municipal solid waste); NC DEQ, Division of Waste Management, FY22-23 NC Solid Waste and Materials Management Annual Report, April 15, 2024, at 68 (all waste).

have a total remaining capacity of roughly 379 million tons, which should last about 28 years at current disposal rates – though different regions of the state have different practical capacities, and some landfills are expected to reach capacity in the next decade.[1007] In coming years, greater diversion of food wastes and other compostable materials, and improved design of consumer goods by manufacturers to facilitate recycling, could stretch this capacity much further.

Indicator 43.2: Number of local governments with food waste diversion programs

Top line: Diversion of food waste from landfills to composting offers a way to reduce greenhouse gas emissions (methane) from the waste stream and save money for local governments. Yet, over the last five years, the state appears to have made no progress towards increasing composting rather than burial of food waste; this stall is a negative trend.

About food waste diversion and compost: A largely untapped opportunity for waste reduction and costs savings is diversion of compostable wastes. Sent to MSW landfills, food and other organic wastes rot and release methane, a potent greenhouse gas. Sent to composting facilities, these wastes release carbon dioxide rather than methane and yield organic and inorganic nutrients that can be used to fertilize new crops. In 2017, North Carolina benefited from 47 composting and 16 mulching operations, diverting a total of 18,469 tons of food waste and 34,263 tons of yard waste.[1008] By 2022, this increased to 58 composting operations, but the state estimated the same level of food waste diversion.[1009] Diverted foods wastes are still vastly smaller in weight and volume than yard waste (which includes winter storm and hurricane debris). The state's most thorough analysis of the potential for food waste diversion dates from 2016; the report found that in-state compost facilities had enough existing capacity to meet a US EPA goal of reducing North Carolina's landfill disposal of food waste by 50%.[1010] The report also estimated that composting operations create 3.7 jobs per 10,000 tons of diverted materials. Yet only two counties offered food scrap collection programs, and none offered curbside collection. We count recent trends in food diversion as showing no progress.

Goal 44: North Carolina maximizes reuse and recycling of waste

Trend: Negative

Solutions: North Carolina should H1, enact producer responsibility policies so that companies that create or package products are responsible for their disposal; and H3, promote biodegradable alternatives to plastics and reduce single-use plastics.

[1007] NC DEQ, DWM, FY22-23 NC Solid Waste and Materials Management Annual Report, April 15, 2024, at 68.
[1008] NC DEQ, Division of Waste Management, Annual Report to the NC General Assembly, December 2017, at 67.
[1009] NC DEQ, DWM, FY22-23 NC Solid Waste and Materials Management Annual Report, April 15, 2024, at 69.
[1010] NC DEQ, Division of Environmental Assistance and Customer Service, NC Organics Recycling Study: Materials Managed 2011-2015 & Food Recovered 2015, June 2016.

Indicator 44.1: Volume of paper, metal, and glass recycling

Top line: Recycling of paper, glass, and metal can cut carbon emissions and conserve resources. Metal recycling has grown over the past decade, but glass and paper recycling streams have declined significantly, so we mark this as trending in the wrong direction.[1011]

About recycling: As noted above, material that is sent to a landfill is a loss in two senses. First, the landfilled waste requires long term management to ensure that it does not contaminate surrounding properties. Second, for us to maintain our habits of consumption, another unit of the same material must be extracted and processed somewhere in the world, with all the environmental impacts that implies. Well-designed recycling protects our quality of life while minimizing our footprint on both ends of the product life-cycle. An estimated 2.25 million North Carolinians have access to recycling through one of the 303 curbside collection programs run by local governments.[1012]

In 2019, we tracked recycling of all materials. In the last five years, however, the entire plastics supply chain has come under increasing scrutiny as a major driver of greenhouse gas emissions.[1013] Studies are divided on whether plastics recycling by itself cuts or increases emissions, but it is clear it does little to offset the impact of the plastics stream as a whole.[1014] Moreover, some forms of plastics 'recycling' release a slew of toxic air pollutants, only some of which are regulated or even monitored.[1015] 'Biodegradable' plastics can't always be recycled, and have been shown to break down into microplastics and nanoplastics.[1016] Simply burying plastics in a landfill isn't great either; unfiltered landfill leachate is becoming a significant source of microplastics pollution to the environment.[1017] For all these reasons, plastics reduction has emerged as a far more important goal than plastics recycling. In this update, we track the percentage of glass, metal, and paper that are recycled, but not plastics (though we include plastics in the chart below, for comparison).

[1011] NC DEQ, Division of Waste Management, FY22-23 NC Solid Waste and Materials Management Annual Report, April 15, 2024, at 76 (2019-2023); NC DEQ, Division of Waste Management, FY18-19 NC Solid Waste and Materials Management Annual Report, January 2020, at 80 (2014-2019).

[1012] NC DEQ, Division of Waste Management, FY22-23 NC Solid Waste and Materials Management Annual Report, April 15, 2024, at 84.

[1013] Nihan Karali, Nina Khanna, Nihar Shah, Climate Impact of Primary Plastic Production, April 2024 (production of primary plastics emitted roughly 5.3% of total greenhouse gas emissions in 2019, and is growing); Center for International Environmental Law, Plastic & Climate: the Hidden Costs of a Plastic Planet, May 2019;

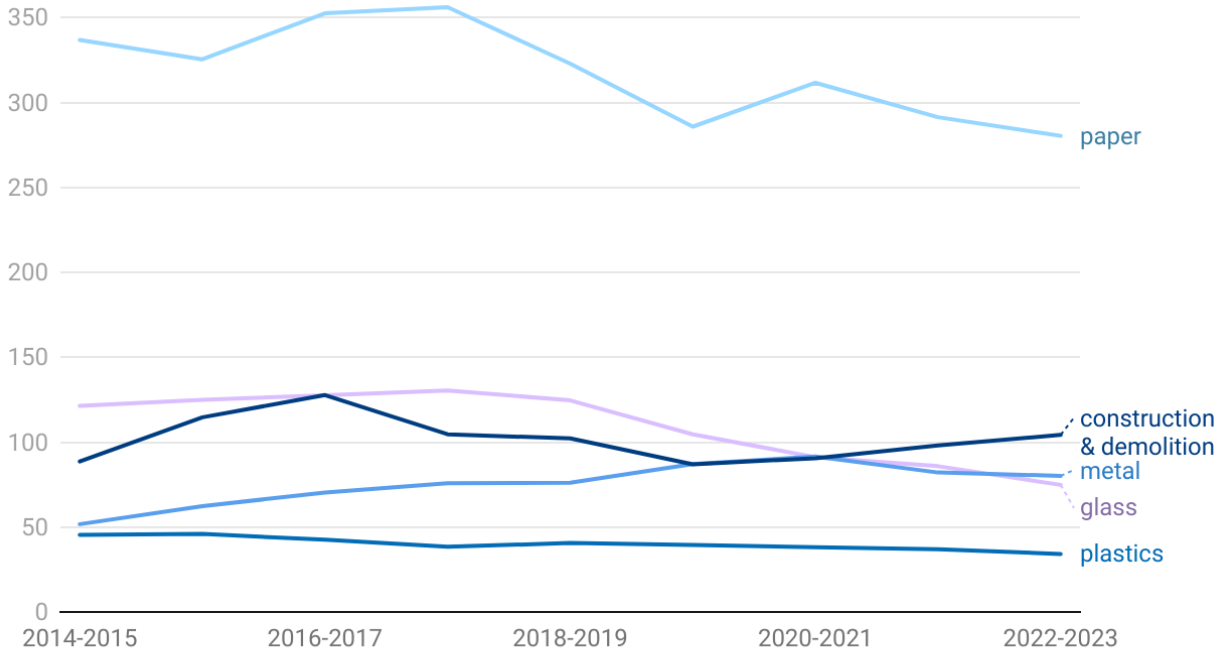
[1014] OECD, Global Plastics Outlook [*Global Plastics Outlook*], April 2022, at 36, 42. The United States leads the world in per capita consumption of plastics, at 220 kg/ year, and only 4.5% of it is recycled. OECD, Global Plastics Outlook datasets: plastic waste by region and end-of-life fate, available here.

[1015] NRDC, issue brief: Recycling Lies: "Chemical Recycling" of Plastic is Just Greenwashing Incineration, February 2022; *Global Plastics Outlook*, at 109, 110.

[1016] Huiyan Tong et al., Micro- and nanoplastics released from biodegradable and conventional plastics during degradation: Formation, aging factors, and toxicity, Science of the Total Environment, August 2022, 833, https://doi.org/10.1016/j.scitotenv.2022.155275.

[1017] Mosarrat Samiha Kabir et al., Microplastics in landfill leachate: Sources, detection, occurrence, and removal, Environmental Science and Ecotechnology, October 2023, 16, https://doi.org/10.1016/j.ese.2023.100256.

Figure 44.1: Annual volume of recycling, selected components, in thousands of tons



Source: NCDEQ, DWM, Annual Reports. • Created with Datawrapper

Overall, paper and glass recycling peaked around 2018, when China announced it would stop accepting waste imports; since then, volumes of paper recycling in North Carolina have fallen by 21% and volumes of glass recycling by 42%.[1018] Metal recycling increased by 60% over the last decade and now outweighs the glass recycling stream. Construction and demolition (C&D) recycling – a commercial rather than a household waste stream – accounts for just a fraction of the C&D waste stream, the great majority of which is disposed in C&D landfills. C&D recycling dropped during the pandemic but – unlike paper and glass – has returned to pre-pandemic levels. Overall, despite the bright spot offered by metal recycling, the trend in recycling volumes is negative.

In 2019, our indicator was based on the recovery ratio, or the tonnage of recycling divided by the tonnage of solid waste.[1019] We haven't seen recovery ratio calculated for specific components of the waste stream, so for this update, we've moved to absolute volumes of paper, glass, and metal. But the concept of the recovery ratio is still worth understanding. A recovery ratio of 1 implies that for every unit of material we throw away, we reuse another – but we are very far below this. As of 2019, the recovery ratio was stalled in the range of 0.15 to 0.17; it has since dropped to 0.11. That's in part a

[1018] NC DEQ, Division of Waste Management, FY22-23 NC Solid Waste and Materials Management Annual Report, April 15, 2024, at 76 (2019-2023); NC DEQ, Division of Waste Management, FY18-19 NC Solid Waste and Materials Management Annual Report, January 2020, at 80 (2014-2019).

[1019] NC DEQ, Division of Waste Management, Annual Report to the NC General Assembly, December 2017, Tables 4 & 5, at 75.

reflection of manufacturers using lighter packaging, so the same volume of overall recycling weighs less, leading to a lower ratio – but it also signals that recycling continues to address only a small share of our collective waste stream.

Goal 45: North Carolina minimizes hazardous waste generation and remediates past contamination

Trend: Mixed

In addition to municipal waste and construction & demolition waste, North Carolina's economy generates hazardous waste that has to be managed with special care and at greater expense. Inevitably some hazardous wastes spill, contaminating soil and water. For this goal, we examine three indicators: how much hazardous waste the state is producing (indicator 45.1), the rate at which we are cleaning up past contamination compared to the discovery of new contaminated sites (indicator 45.2); and the rate at which we are cleaning up leaking underground petroleum storage tanks compared to the discovery of new leaking tanks (indicator 45.3). The first earns a yellow caution; the second is trending poorly, and the third is trending well, yielding a mixed result for the goal as a whole. We do not include an indicator for the ongoing cleanup, negotiated in a legal settlement and confirmed by legislation in 2014, of Duke Energy's massive coal ash pits, as that continues under tight regulatory oversight.[1020]

Solutions: Avoiding creation of hazardous waste in the first place is the ultimate form of pollution prevention and can be advanced through consumer pressure for clean supply chains and, E5, strategic state and private investments in green chemistry. North Carolina should also H4, continue to address past contamination; and H5, plan for the indefinite management of closed landfills.

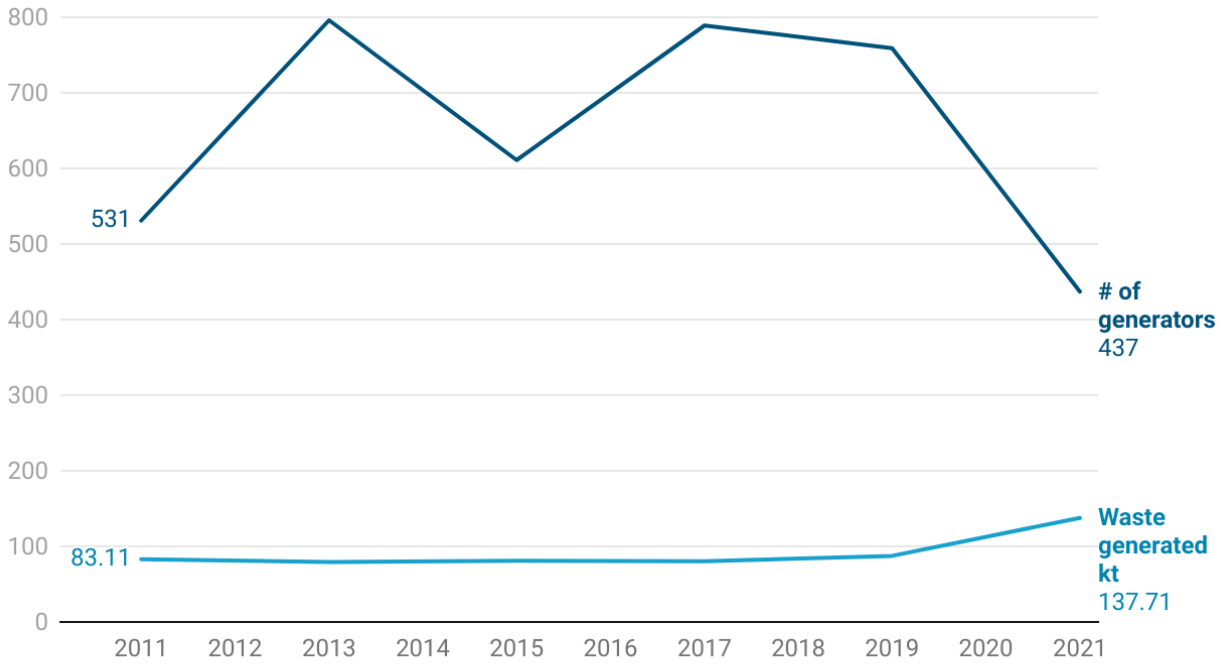
Indicator 45.1: Volume of hazardous waste generated annually

Top line: For most of the last decade, hazardous waste generation in North Carolina has remained flat, even as large numbers of small generators move above and below the minimum reporting thresholds. A spike in hazardous waste generation in 2021 – the most recent year of data – comes from just two facilities and may not last even at those sites. On the other hand, hazardous waste generation isn't declining, so we assign this indicator a yellow caution flag.

About hazardous waste: Generation of hazardous waste is an inevitable part of economic activity in a modern, technologically advanced society. However, even when hazardous wastes are conscientiously managed, accidents happen, threatening public health, property, and natural ecosystems, and imposing costs on future North Carolinians. Reducing the volume of hazardous waste generated annually will reduce these harms.

[1020] NC DEQ, DWM, FY22-23 NC Solid Waste and Materials Management Annual Report, at 63, 65.

Figure 45.1: Hazardous waste generated annually, in thousands of tons, and number of generators



Source: US EPA, Biennial Hazardous Waste Reports. • Created with Datawrapper

This indicator tracks the pounds of hazardous waste generated by businesses in North Carolina. The federal Resource Conservation and Recovery Act (RCRA) requires major generators to report their volumes of hazardous waste to EPA every other (odd) year, and the data is published late in the following (even) year, with a one year lag, so the most recent data is from 2021. Not all waste is equally problematic; this indicator does not distinguish between wastes that are extremely toxic in low quantities and more generally hazardous materials, but it does give a sense of the direction of our waste generation.

Hazardous waste generation in North Carolina has remained relatively flat for the last decade, jumping up dramatically in 2021.[1021] However, virtually all the increase is accounted for by just two facilities: Nucor Steel in Cofield, consistently the largest generator in the state; and American Zinc (formerly Horsehead Metals) in Mooresboro.[1022] We decline to count this as a trend pending more data, but it clearly isn't a decline, so it earns a yellow warning flag.

What's more notable is the wide fluctuation in the number of generators reporting each biennium. That's a signal that many companies are hovering right around the minimum reporting threshold. State staff note, "these generators are subject to reduced reporting and regulatory requirements because they are often small businesses for whom periodic reporting could be overly burdensome…. However,

[1021] US EPA, web query: Biennial Hazardous Waste Report, Trends Analysis, visited September 2, 2024.
[1022] US EPA, web query: Biennial Hazardous Waste Report, Detailed Search, visited September 2, 2024.

these facilities collectively generate a significant amount of hazardous waste that must be managed properly and in compliance with applicable rules," and staff spends substantial time providing technical assistance to them.[1023] A quick skim of the sites listed in EPA's Biennial Report makes clear that 'small' generators are distributed widely across the state.

Indicator 45.2: Number of known contaminated sites vs number of remediated sites

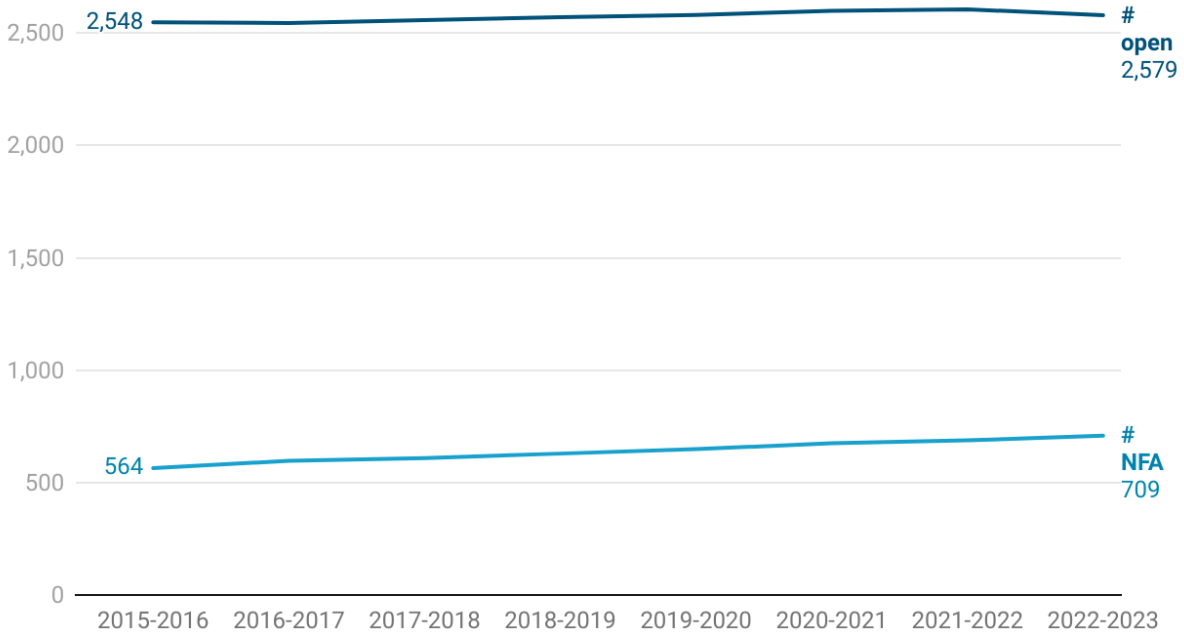
Top line: North Carolina is discovering contaminated sites that need remediation faster than we are cleaning them up. That's a negative trend.

About contaminated sites: North Carolina's Inactive Hazardous Wastes Sites Program, housed in NC DEQ's Division of Waste Management, identifies and cleans up contaminated sites.[1024] Every year new sites are added to the inactive sites list, while at others, remediation activities conclude and the sites are assigned a 'no further action' (NFA) status. NFA determinations have clauses that allow cleanups to be reopened if additional contaminants are later discovered on the site, or if additional remediation is found to be necessary to prevent a significant risk to human health or the environment.[1025]

The indicator we track is the relative flow of sites into and out of the program: are we gaining or losing ground? Less than half the sites on the list have a financially viable 'responsible party' who could be forced to pay for the cleanup; the state foots the bill for the rest, prioritizing sites that threaten to contaminate nearby public or private drinking water wells, or to release air toxics into inhabited buildings.[1026] As a result of enduring funding deficits, the state is gradually falling behind on cleanups; every year, more sites are added to the list than finish remediation and are released from the program.[1027] A decade ago, the official list had 2,548 open sites; now, with 145 sites fully remediated, the list stands at 2,579 open sites. This trend is running in the wrong direction.

[1023] NC DEQ, Division of Waste Management, FY22-23 Annual Report, April 15, 2024, at 29.
[1024] NCGS 130A-310 et seq.; NC DEQ, Division of Waste Management, FY22-23 Annual Report, April 15, 2024, at 37.
[1025] NCGS 130A-310.73(c).
[1026] NC DEQ, Division of Waste Management, FY22-23 Annual Report, April 15, 2024, at 40.
[1027] NC DEQ, DWM, NC Solid Waste and Materials Management Annual Reports, available here.

Figure 45.2: Open and no further action (NFA) contaminated sites



Source: NCDEQ, DWM, Annual reports, FY15-16 through FY22-23 • Created with Datawrapper

Much ongoing remediation is conducted by responsible parties. Legislative changes in 2013 introduced risk-based remediation to the program; now, on a site by site basis, levels of contamination can be left in the ground that are not expected to pose greater than 1 in a million risk of cancer from any one chemical, or 1 in 10,000 for any combination of chemicals.[1028] As of July 2023, 49 responsible parties had used risk-based remediation at 49 sites covering 285 acres.[1029] Because risk-based remediation contains but does not remove contamination, 'DEQ requires annual certification by landowners that engineered barriers are being maintained, site-specific land-use restrictions are being adhered to, and deed instruments remain in effect through the property's sale or subdivision.'[1030] Thus, in contrast to fully remediated sites, risk-remediated site will always require some level state oversight and spending.

North Carolina also has a 'brownfields' program, launched in 1998, that offers liability protections to landowners who are not responsible for contamination but purchase contaminated properties and clean them up to make them suitable for redevelopment.[1031] By the end of 2023, the Brownfields program had finalized 760 agreements with partners to remediate contaminated sites. Contamination at many brownfields sites is contained rather than fully removed, so these sites also need indefinite monitoring

[1028] NCGS 130A-310.66 - 310.77; NC DEQ, DWM, webpage: Risk-Based Remediation, visited September 2, 2024.
[1029] NC DEQ, DWM, Risk-Based Remediation Fund Annual Report, October 1, 2023.
[1030] *Idem*, at 4.
[1031] NC DEQ, DWM, webpage: Brownfields Redevelopment Section, visited September 4, 2024.

and oversight, and staff has noted the increase in 'post-agreement work' as a component of the program.[1032]

North Carolina's rules provide that sites that appear fully remediated can nonetheless be pulled back into a cleanup program if new contamination is discovered at a site. Traditionally, reopening a site has been a rare occurrence, with just a handful in the last decade. However, EPA's announcement of very low health values for PFOS and PFOA, coupled with the fact that these compounds were not listed as hazardous wastes, means that some sites that have been released from state remediation programs may turn out to need additional measures to address PFAS contamination. Provisions for considering PFAS were added to DEQ's risk-based remediation guidance in July 2024.[1033]

Recent developments: Over the last five years, experts have considered the potential for climate change to complicate the management of contaminated sites.[1034] Sea level rise and floods may mobilize contamination at existing known or unknown contaminated sites; North Carolina had a taste of that in 2023 when coastal erosion uncovered petroleum-contaminated soils in Buxton on Hatteras.[1035] Sea level rise and flooding may also cause spills that create new contaminated sites.[1036] Finally, climate impacts may threaten the infrastructure we already use to manage waste; US EPA has published analyses and decision support tools to help state and local governments identify and prepare for this risk.[1037]

Indicator 45.3: Relative trends in storage tank closure and remediation

Top line: Thanks to expanded state appropriations and additional funding from EPA, North Carolina has made substantial progress in recent years in closing sites contaminated by leaking underground storage tanks (USTs). That's a positive trend, but there are a couple of caveats. First, some of the progress has been made by essentially abandoning 'low risk' non-commercial sites without remediation. These sites aren't clean; they're just not counted as open anymore. Second, looking to the future, the transition to electric vehicles is likely to result in a massive temporary surge in gas station closures – and demands for effective regulatory oversight – that could result in much greater long-term costs if not met with adequate resources in the near term.

[1032] NC DEQ, DWM, FY22-23 Annual Report, at 14.
[1033] NC DEQ, DWM, factsheet: What's New to the DEQ Risk Calculator, July 2024.
[1034] K. Hill et al., Rising Coastal Groundwater as a Result of Sea-Level Rise Will Influence Contaminated Coastal Sites and Underground Infrastructure, Earth's Future, September 2023, 11 (9), https://doi.org/10.1029/2023EF003825 (North Carolina has 13 Superfund sites at risk from sea level rise, putting it among the top four states for federally managed contaminated land that may be exposed).
[1035] Catherine Kozak, Navy base's wretched reminders not just petroleum in soils, Coastal Review Online, November 2, 2023; Pipe, liquids removed from contaminated Buxton Beach site, Coastal Review Online, May 21, 2024.
[1036] Jennifer Allen, Researchers say get ready for more floods, contamination, Coastal Review Online, September 1, 2022.
[1037] US EPA, Vulnerability of Waste Infrastructure to Climate Induced Impacts in Coastal Communities, July 2019; US EPA, blog post: Effects of Coastal Sea Level Rise on US Hazardous Waste, May 18, 2023.

About storage tank closure and remediation: Underground storage tanks (USTs) and aboveground storage tanks (ASTs) are widely used for petroleum products. As tanks age, they leak, and if those leaks are not caught early, they can cause soil and groundwater contamination that is expensive to clean up. Federally mandated improvements in tank design, such as the introduction of double-walled tanks and sensors that can be retrofitted to single-walled tanks, have helped but not eliminated the risk.[1038] North Carolina has over 13,000 commercial USTs in operation, and an unknown number of non-commercial USTs (such as for home heating oil) and ASTs.[1039]

In the late 1980s, the NCGA established two state UST cleanup programs, one for commercial and the other for non-commercial properties. The non-commercial fund was paid for by an excise tax of gasoline and by motor-fuel and kerosene inspection taxes – but by the early 2000s, it was perpetually running out of funds to meet reimbursement requests from landowners. In 2015, the NCGA ended state reimbursement of non-commercial USTs reported after October 1, 2015, and deleted requirements for private owners to clean up low-risk non-commercial spills.[1040] The Commercial UST Fund continues, funded by a combination of the motor fuels tax and modest annual fees for tank owners ($420 per tank). The program prioritizes medium and high-risk sites for state funds, but since 2021 has had sufficient funding to direct responsible parties to address lower-risk sites to prevent them from becoming worse.[1041] As of June 30, 2023, DEQ knew of 34,467 commercial and non-commercial UST releases since the beginning of the program, with 5,395 still needing remediation, or 'open'; and 7,735 AST releases, with 2,370 still open.[1042]

[1038] See, NC DEQ, DWM, factsheet: FAQ about Secondary Containment Operation and Maintenance Requirements for UST Systems and Components Installed or Replaced After November 1, 2007, November 2023; NC DEQ, DWM, factsheet: Siting and Secondary Containment Requirements for Underground Storage Tank Systems Installed prior to 11/1/2007 and near Wells and Surface Waters, October 2015.

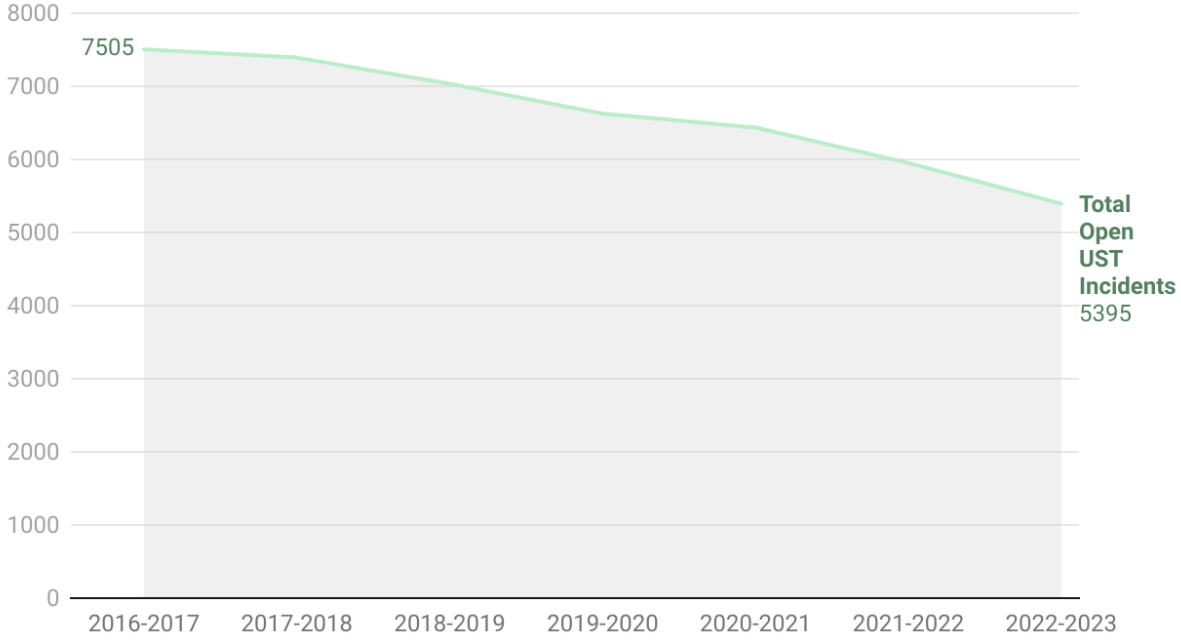
[1039] NC DEQ, DWM, Registered Tanks Database, available here, downloaded September 4, 2024. Another 2200+ commercial tanks are listed as 'temporarily closed'. Very few ASTs are required to register with the state, so we don't really know how many there are. NC DEQ, DWM, webpage: Aboveground Storage Tanks, visited September 4, 2024.

[1040] S.L. 2015-241 (H97), Appropriations Act of 2015, §14.16B. SL 2017-57 (S257), Appropriations Act of 2017, §13.19 directed the NC Environmental Management Commission to revise rules to carry out SL 2015-241; those rules are at 15A NCAC 02L .0400 et seq.

[1041] NC DEQ, DWM, Leaking Underground Storage Tank Cleanup Fund Annual Report, November 1, 2023, at 9. For statistics for each year, see, NC DEQ, DWM, Leaking Underground Storage Tank Cleanup Annual Reports, as follows: 2017 (at 6, 11), 2018 (at 6, 11) , 2019, (at 6, 7), 2020 (at 6, 7), 2021 (at 6, 7), 2022 (at 6, 7), and 2023 (at 6, 7).

[1042] *Idem*, at 6.

Figure 45.3: Number of 'open' Underground Storage Tank (UST) incidents



Source: NCDEQ, DWM, UST Program Annual Reports. • Created with Datawrapper

Over the last decade, the number of releases remaining 'open' has trended consistently downward, which we count as positive.[1043] In the most recent year, DEQ received reports of 386 new commercial and non-commercial incidents and closed 942. The agency received reports of 285 ASTs and roadside spills, and closed 245. The substantial drop in open sites in recent years is the result of an overlay of non-recurring funding from EPA matched with state funds, used to target a longstanding backlog of unresolved but low-risk sites.[1044] The state estimates that cleaning up all currently known UST contaminated sites would require $315.5 million beyond funding that has already been obligated.[1045]

The accelerating transition to electric vehicles seems likely to explode this progress. The tipping point may occur far sooner than the overall percentage of EVs in the fleet would suggest, starting with gas stations whose business is only marginally profitable.[1046] As facilities close, the number of reports of UST contamination will likely spike and the agency will have to oversee a surge of tank removals just as revenue from the current funding mechanism – the motor fuels tax and the annual registration fee – dries up. If funds and staffing are inadequate, contamination will spread and responsible parties vanish, increasing future costs to neighbors and the state. USTs are located disproportionately in low-income

[1043] *Idem*, at 6, 8.
[1044] *Idem*, at 13.
[1045] *Ibid.*
[1046] See, for example, Matthew Metz, blog post: Electric Vehicles and the Future of Gas Stations, NEIWPCC, July 2021.

communities and communities of color, so a failure to meet the moment will burden environmental justice communities most of all.[1047]

Goal 46: Risks from the waste cycle are distributed equitably

Trend: Positive

This goal, fair distribution of the health and environmental risks created by our waste management, has a single indicator – proximity to transfer, storage, and disposal facilities – and a positive trend.

Solutions: North Carolina should, D1, protect all North Carolinians from disproportionate burdens; G8, improve land application of municipal waste sludge; H4, develop a plan for remediating past contamination; and H5, prevent future contamination from closed disposal facilities.

Indicator 46.1: Proximity to transfer, storage, and disposal waste facilities

Top line: Proximity to waste facilities has been connected to a variety of adverse health outcomes. Studies show waste facilities are often located in low income neighborhoods and historically African American neighborhoods. Analysis of census tract level data from the EPA's EJScreen supports that association; the correlation seems to be slightly weaker in 2024 than in 2018, suggesting marginal reductions in the inequitable distribution of exposure risks. We consider this a positive trend.

About proximity to TSD facilities: To be clear, proximity to a treatment, storage and disposal facility (TSDF) does not guarantee exposure. However, it does increase risk, and that shows up in the empirical data as worse health outcomes. A recent analysis of health outcomes around 624 landfills in the Southeast (including North Carolina) found strong associations of diabetes, high blood pressure, and asthma with living within half a mile of a landfill, and particularly strong correlations for residents near pre-1990 landfills and more recent high-volume landfills.[1048]

The problem of inequitable distribution of exposure to TSDF facilities is not new; a 2003 analysis found that facilities in North Carolina were disproportionately located in low-income areas. At the census-tract level, most were in 'overwhelmingly white' census tracts – but when the analysis was confined to a 1 mile radius of the TSDF facilities, most were in 'overwhelmingly African American' neighborhoods.[1049] Two decades later, we have not had the resources to dedicate to a 'concentric circle' analysis – we're considering the census tract levels – but looking for a broad trends: is census tract-level proximity to TSD

[1047] Andrew Murray, dissertation: Groundwater Vulnerability in the United States: Identifying Inequitable Contaminants and Water Sources, 2023.
[1048] Benjamin Antwi, master's thesis: Are Chronic Disease Indicators Associated with Living Close to Treatment, Waste, & Disposal Sites (Landfills) in Southeastern United States?, May 2024.
[1049] Douglas Patrick Rodgers, master's thesis: Environmental Equity in North Carolina: An Empirical Study, November 2003.

sites becoming more or less correlated with the presence of low income or minority residents? For this analysis we calculated a simple correlation between the EJ Screen demographic index (created to compare racial and socioeconomic make up of a census tracts) and an index calculated to represent proximity to hazardous waste facilities, including both TSDF and large quantity generators (LQG) of hazardous waste.[1050] For data from 2018, the two indices are positively correlated (0.19); data from 2024 shows that they are still positively correlated but less so (0.11) – so the indicator shows an encouraging trend. This analysis is not a precise statistical test, and the change in correlation may be attributable to the sensitivity of the test. It's also possible that as North Carolina's population grows, lower-income people and people of color are being displaced to other parts of the state – so while the TSF facilities are stationary, communities are changing around them. Although the strength of the correlation has weakened slightly according to our test, communities of color and low-income communities continue to experience the cumulative impacts of greater exposures.

A natural disaster can generate 5x to 15x times the volume of waste that a community would generate in an ordinary year; much of that debris is disposed of in construction & demolition (C&D) landfills and municipal solid waste (MSW) landfills. A 2022 study of 613 counties across the South found that the receiving landfills are disproportionately located in low-income areas and communities with higher percentages of minority residents, so natural disasters ratchet up the potential exposure for these residents.[1051]

Recent developments: In September 2024, community advocates announced that they had reached a settlement with GFL, the company that runs the Sampson County landfill, the largest in the state, to address the ongoing release of PFAS, other pollutants, and odor from the landfill into the community.[1052]

Epilogue: Disparities, environmental justice, and a healthy future for all North Carolinians

This report focuses on the overall trend lines for goals and indicators across the state. Yet our data also shows that different groups of North Carolinians experience many of these indicators, and sometimes experience these trends, very differently. There are substantial disparities in the distribution of environmental benefits and burdens across North Carolina. We see, for instance, inequitable access to green space, jobs, and healthy food; we also see disparities in exposure to toxic chemicals, in vulnerability to storms and floods, and in the impacts of swings in water or electric rates.

Where disparities occur along racial or ethnic lines, they often reflect the current impact of historic decisions, of explicitly discriminatory laws and patterns of public investment. Allowing these disparities

[1050] EPA, EJScreen Index, December 2024 (archived on WaybackMachine).
[1051] Laura McKinney and Ryan Thompson, Landfills and disasters: a geospatial analysis of environmental injustice across the Southern United States, Environmental Sociology, January 2022, 8 (2): 173, https://doi.org/10.1080/23251042.2021.2004497.
[1052] Liz McLaughlin, NC landfill owner to pay for decades of pollution, WRAL, September 3, 2024.

to persist can violate state and federal anti-discrimination laws. Health outcome and exposure disparities based on income don't face the same legal scrutiny, but are pervasive and troubling.

Some of the sharpest disparities are between urban and rural populations. In North Carolina, the urban/rural disparities tend to overlap with percentage of the population with disabilities, and with age – proportionately, rural North Carolina has more young people and seniors, and fewer working age adults. Maps of median household income and poverty rates by county are nearly opposite one another, with wealth concentrated in the Triangle, greater Charlotte, and retirement destinations on the coast and in the mountains, and poverty disproportionately concentrated in rural counties.[1053] State spending and state programs are a crucial engine for sustaining economic opportunity and environmental quality in these rural counties.

Ultimately, the disparities noted in this report are real and remain an obstacle to too many North Carolinians living their best lives. Narrowing or eliminating those disparities is an appropriate goal for public policy; so is improving conditions for vulnerable North Carolinians, and for all North Carolinians collectively. We believe that all Americans should have opportunity for healthy lives, and that state spending and regulatory programs shouldn't undercut that for any group of residents on the basis of race, ethnicity, wealth, geography, or ability/disability. That commitment to fairness and opportunity belongs at the heart of state action.

To that end, we have attached a Solutions Document to this report, listing policies that, if adopted and implemented, will improve public and environmental health and give all North Carolinians a shot at a better quality of life. These solutions are not all equally plausible in the near term. Some will take many more years to accomplish than others, and some may eventually happen in very different forms. Yet we believe that most will ultimately happen. We are hopeful that they will secure a brighter future for the state as a whole, and in the process narrow the many of the disparities identified in this report. North Carolina's current and future residents deserve no less.

[1053] U.S. Census Bureau, American Community Survey, 2019-2023, Tables S1901 (income) and S1701 (poverty).