

# State of New Hampshire Air Quality - 2017: Air Pollution Trends, Effects and Regulation



March 2018



# State of New Hampshire

## Air Quality - 2017:

### Air Pollution Trends, Effects and Regulation

March 2018

Prepared by the  
New Hampshire Department of Environmental Services  
29 Hazen Drive, P.O. Box 95  
Concord, New Hampshire 03302-0095  
(603) 271-1370  
[www.des.nh.gov](http://www.des.nh.gov)

Robert R. Scott, Commissioner  
Clark Freise, Assistant Commissioner  
Craig Wright, Air Resources Division Director



Principal Author and Chief Research Scientist  
Jeffrey T. Underhill, Ph.D., Air Resources Division, NHDES

#### Contributing Authors and Editors

Jessica Dunbar	David Healy	Sherry Godlewski
Julie Sophis	Charles Martone	Chris Skoglund

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**STATE OF NEW HAMPSHIRE  
OFFICE OF THE GOVERNOR**



**CHRISTOPHER T. SUNUNU**  
Governor

Dear NH Citizens,

It is my pleasure to share with you this report from the New Hampshire Department of Environmental Services (NHDES) detailing the progress we have made together in ensuring that NH's air quality meets federal standards established in the 1990 Clean Air Act. My hope is that this report will inform you about the complex challenges we face and help you to better understand the potential impacts to our health and economy. Understanding that in New Hampshire a strong economy and a clean environment go hand-in-hand, our citizens, businesses, legislature, and government agencies have combined common sense regulation, innovation, and cost-effective strategies to address the threats of poor air quality that could hinder our quality of life, tourism, and manufacturing/industry base.

In the 1990's, because air pollution reduction technology was not widely applied either locally or nationally, the Northeast suffered from poor air quality. Faced with major increases in the number of vehicles traveling our roads, air pollution traveling from large uncontrolled power facilities to our south and west, and our own significant in-state sources of air pollution, our air quality regularly failed to meet federal health-based air quality standards. As a result, we faced significant health care costs, such as increased asthma, heart disease, and premature deaths while also triggering numerous federal requirements that had the potential to impact our economic growth. With our state motto "Live Free or Die" always in mind, we have addressed federal requirements in a cooperative way, such as being the first state to implement a simple electronic motor vehicle emissions test in place of the more costly and time-consuming tailpipe test. We are finding a common-sense cost-effective way to improve our air quality. We also found innovative ways to reduce mercury, lead, and other toxic compounds in our air. We eliminated MtBE while maintaining cleaner-burning gasoline, and required innovative controls on high emitting power generation facilities.

We have worked diligently in cooperation with our upwind neighbors to ensure that they take the necessary steps to prevent transported pollution from negating all of the good work we have done locally. We have enacted reasonable incentives for low pollution renewable power and cost-effective market-based solutions to address greenhouse gases from the energy sector. And while much progress has been made, we occasionally still experience poor to moderate air quality. Ozone and wood smoke continue to provide challenges for us and new threats, such as Perfluorinated compounds (PFCs) have to be investigated and addressed.

I thank NHDES staff, particularly the primary author Dr. Jeff Underhill, for their diligence and dedication working to produce this report and improve our environment. I also appreciate the ongoing dialogue between NHDES, my office and other state agencies, our legislature, and business community to continue our progress.

All in all, I am proud of the progress we have made together, and know we will face new challenges with the same Yankee ingenuity and common sense that make our state such a great place to live and work!

Sincerely,

  
Christopher T. Sununu  
Governor

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## REPORT HIGHLIGHTS

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- During 2016 and 2017, the air in almost every location in New Hampshire is far cleaner today than it was 25 years ago. Maximum measured concentrations of carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead in New Hampshire have decreased by over 90%. Ozone has decreased by about 85%, and particles have decreased by about 70%. Toxic air pollutant emissions, and hence their concentrations in the air, have similarly decreased.
- The air is cleaner today because of a wide range of efforts at many levels. Energy efficiency measures have reduced electrical and fuel demand, which offsets the need for new power plants and refineries. Science and industry have found ways to produce cleaner fuels and consumer products that are just as effective as the original products, if not more so. New cars are much cleaner and more fuel efficient than those of even a few years ago.
- Although the air is getting cleaner, scientists are discovering that some air pollution standards, which were set years ago, are not as protective as originally intended. Because of an improved scientific review process required under the Clean Air Act (CAA), the Environmental Protection Agency (EPA) is required to review and revise, if necessary, the air pollution standards based on the latest advances in science. As a result, revisions have been made to the ambient air standards for ozone, airborne particles, sulfur dioxide, nitrogen dioxide, and lead, resulting in greater health protection.
- Despite the improvement in air quality, air pollution in New Hampshire is estimated to have cost residents and businesses of New Hampshire over \$3 billion per year from 2013 to 2015 in health care costs and lost productivity.
- New Hampshire experiences a few days during most years when concentrations of a pollutant may be high enough to be considered unhealthy for sensitive individuals in some communities, but this does not occur often enough to be considered in violation of the health standard, as most standards are evaluated over a three-year period.
  - Ozone exceedances occur nearly every spring and summer in the southern portion of the state and at elevations above 3000 feet.
  - Exceedances of the PM<sub>2.5</sub> standard can occur during cold weather in populated valleys where burning wood for heating is common. The City of Keene experienced periodic exceedances up until 2013 but did not exceed during 2014 and 2015, partly due to the elimination of large numbers of older wood stoves under NHDES sponsored change out programs.
  - There have been no measured exceedances of other pollutants since 2012.

- New Hampshire meets the National Ambient Air Quality Standards (NAAQS) for all criteria pollutants (carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO<sub>2</sub>), small particles (PM<sub>2.5</sub> and PM<sub>10</sub>), ozone (O<sub>3</sub>), and sulfur dioxide (SO<sub>2</sub>)) in all portions of the state.
  - In the past, New Hampshire has violated the ozone, carbon monoxide and SO<sub>2</sub> standards.
  - State Implementation Plans (SIPs) outline state plans to comply with health standards for areas in violation.
  - Maintenance plans are in place for areas previously designated as nonattainment in New Hampshire to ensure unhealthy conditions do not reoccur.
  - Air pollution is controlled by means of a comprehensive set of state and federal rules, regulations and legislation designed to protect our air resources as cost-effectively as possible.
  
- Deposition (settling of pollutants from the air that can impact soils or water) of acids, nitrogen and mercury has decreased over the past 10 to 20 years.
  - Acid deposition, also known as acid rain, has decreased in response to decreasing emissions of SO<sub>2</sub> and nitrogen oxides. New Hampshire water bodies are now slowly recovering from damage due to decades of acid rain. The same is true of nitrogen deposition, which can cause nitrification, or over fertilizing and algae blooms in water bodies. Further improvement is needed before full recovery can be achieved in New Hampshire.
  - Large reductions in air emissions of mercury, particularly from coal-fired power plants, directly translate to declining deposition in New Hampshire. Unfortunately, mercury is slow to be removed from the environment and after about 50 years of significant emissions and deposition, it will take some time before New Hampshire water bodies recover and fish consumption advisories can be lifted.
  
- Transport of air pollutants in the wind from upwind states and beyond remains a significant contributor to many of our state's worst air quality episodes. Periods of high ozone and small particle concentrations, as well as atmospheric deposition (of acids, nitrogen and mercury) are heavily driven by transport. Effective federal regulation and oversight is needed to address air pollution contribution between states.
  - SO<sub>2</sub>, CO, wood smoke and lead are pollutants that can be more effectively addressed on a local basis.

## **1 INTRODUCTION**

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Over the past 45 years, significant progress has been made in reducing emissions of air pollutants and improving air quality across the country, including New Hampshire. Much of this progress is due to programs under the Clean Air Act (CAA) of 1970 and its Amendments of 1977 and 1990. Improvements in technology, atmospheric science, and the understanding of pollution health effects have led to a cleaner environment and healthier citizens while maintaining economic growth. With the health and environmental improvements that it has yielded, the CAA has benefited society in many ways.

The air in almost every location in New Hampshire is far cleaner today than it was 25 years ago. Maximum measured carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead concentrations in New Hampshire have decreased by over 90%. Ozone has decreased by about 85%, and particles have decreased by about 70%. Toxic air pollutant emissions, and hence their concentrations in the air, have similarly decreased.

The air is cleaner today because of a wide range of efforts at both the federal and state levels. Power plant regulations, including market-based programs, have reduced air pollution levels across the eastern United States. Energy efficiency measures have reduced electrical and fuel demand, which offsets the need for new power plants and refineries. Science and industry have found ways to produce cleaner fuels and consumer products that are just as effective as the original products, if not more so. Renewable portfolio standards have encouraged development of new non-emitting sources of energy (e.g., solar, wind, etc.). New cars are much cleaner and more fuel efficient than those of a decade ago and will continue to improve due to federal fuel economy and emissions standards. For economic and environmental reasons, individuals are reducing fuel consumption through choices such as driving less and using electricity more efficiently in a variety of ways in their homes.

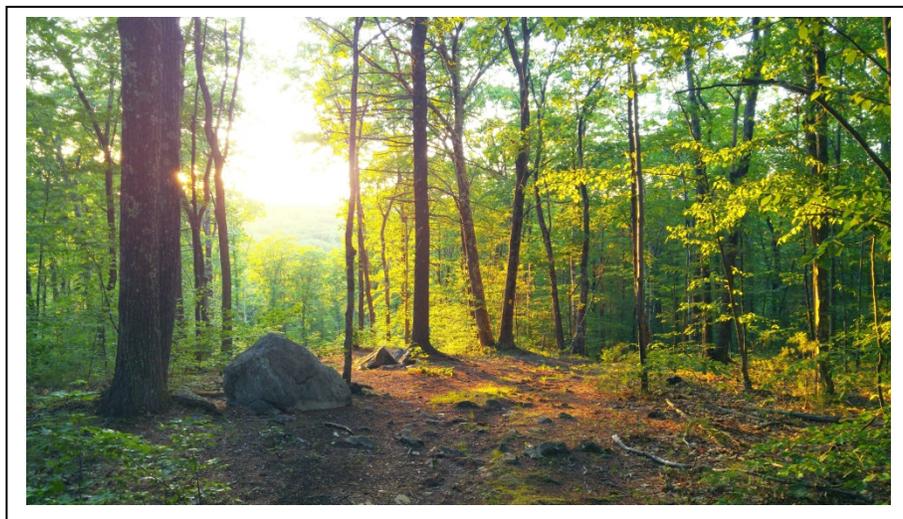
Although the air is getting cleaner, scientists are discovering that some air pollution standards, which were set years ago, are not as protective as originally intended. Because of an improved scientific review process under the CAA, the Environmental Protection Agency (EPA) is required to review and revise, if necessary, the air pollution standards based on the latest advances in science. As a result, recent revisions have been made to the ambient air standards for ozone, airborne particles, sulfur dioxide, nitrogen dioxide, and lead, resulting in greater health protection. In each case, EPA documented that the benefits of revising the standard exceed the anticipated costs of meeting the new goal.

New Hampshire is still challenged to fully meet lower ozone, fine particle, and sulfur dioxide standards as it was in the past when pollution concentrations were generally much higher. “Poor air” days are not common in New Hampshire, but they still occur a few days per year for these pollutants. Most poor air quality days occur along the southern portion of the state where the population is the highest and upwind pollution is most likely to cross into the state,

though New Hampshire does see poor air quality at higher elevations, including Mt. Washington, that are impacted by air pollution transport from upwind pollution sources.

Improving air quality in New Hampshire can be complicated because of the significant impacts of pollution that originates outside the state, sometimes thousands of miles away. Just as weather forecasters look to where the wind is coming from, air pollution forecasters look to see how air pollution travels over an entire region. The same wind that brings the weather often brings air pollution along with it. This movement of air pollution is called “transport” and it is not a simple process. Pollutants in the air undergo complex chemical reactions, and pollution is added to or removed from the air as it moves along. These transported pollutants can add to locally emitted pollution and lead to poor air days in the state, thus it is important to consider both local and transported air pollution when seeking ways to improve air quality.

Pollution in the air, or deposition on the water or the land, affects both human health and the economy. Sources of emissions bear the costs of pollution controls and normally pass those costs along to consumers. In addition, there are economic costs associated with the health effects of pollution. When air is



cleaner, fewer visits to doctors and hospitals lead to reduced health care costs and fewer employee sick days lead to increased productivity. Further, a cleaner and healthier environment can translate into an improved tourist experience, which can boost the local economy. Reducing air pollution can create economic costs for industry and consumers, and it is important to manage those costs wisely. However, there is also the potential for a great economic return on the investment in cleaner air, and that too needs to be considered.

Despite the progress that has been made, portions of New Hampshire still face air pollution challenges. As the state’s population grows and pollution is transported in from other regions, there is an ongoing challenge to maintain our current levels of clean air. This report provides an update on the overall air quality status of New Hampshire in 2017, an overview of how air quality has changed over past decades, and a discussion of why some air pollutants are of greater concern than others for New Hampshire.

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## 2 AIR POLLUTANTS OF CONCERN

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Many pollutants contribute to degradation of air quality, but a relatively small number stand out for their potential widespread impacts to public health and the environment. The pollutants of greatest concern include the “criteria pollutants” (Section 2.1), airborne toxics such as mercury (Section 2.2), and pollutants that cause regional haze (Section 2.3).

Another category of air pollutants are greenhouse gases, which impact the climate by trapping heat at the earth’s surface (see Section 8). This report focuses on air pollutants with a direct impact on human health via inhalation and therefore does not cover climate change-causing pollutants in detail. However, the following reports by The Sustainability Institute at the University of New Hampshire provide an overview of greenhouses gases and climate change in New Hampshire: *Climate Change in Southern New Hampshire: Past, Present, and Future*<sup>1</sup> and *Climate Change in Northern New Hampshire: Past, Present, and Future*.<sup>2</sup>

### 2.1 Criteria Pollutants

The Environmental Protection Agency (EPA) has set National Ambient Air Quality Standards (or NAAQS, see Section 3.1) for six of the most common air pollutants.<sup>3</sup> The NAAQS are designed to protect citizens’ health and welfare from the effects of these six air pollutants, with an adequate margin of safety. These “criteria” pollutants have been a primary focus of regulatory action since the early days of air quality legislation. The criteria pollutants, each described in more detail later in this section, are:

1. Carbon Monoxide
2. Lead
3. Nitrogen Dioxide
4. Ozone
5. Particulate Matter
6. Sulfur Dioxide

#### 2.1.1 Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless gas emitted from combustion processes. The majority of CO emissions, particularly in urban areas, come from mobile sources. Mobile sources include cars, trucks, buses, and off-road equipment such as marine engines and construction equipment. Incomplete combustion of fuel emits CO directly from vehicle tailpipes, especially when vehicles are starting or warming up. Vehicles whose engines and exhaust systems are not “tuned” or maintained properly can emit more CO than well-maintained vehicles. CO emissions from the mobile sector have been largely controlled, and thereby

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<sup>1</sup> <https://sustainableunh.unh.edu/sites/sustainableunh.unh.edu/files/images/southernnhclimateassessment2014.pdf>

<sup>2</sup> <https://sustainableunh.unh.edu/sites/sustainableunh.unh.edu/files/images/northernnhclimateassessment2014.pdf>

<sup>3</sup> Section 108(a) of the Clean Air Act requires the establishment of national ambient air quality standards. The CAA was last amended in 1990.

reduced, through advancements in technology and vehicle inspection and maintenance programs.

Carbon monoxide can cause harmful health effects by reducing oxygen delivery to the body's tissues and organs, such as the heart and brain. CO can increase the severity of lung ailments and cause dizziness, fatigue, and nausea. At extremely high levels, CO can cause death.

### **2.1.2 Lead**

Lead is a metal found naturally in the environment, but with great consequence to human health, it was added to products such as gasoline and paint. After the detrimental effects of lead poisoning were realized, lead was banned from these products in the 1970s and 1980s.

Historically, the major sources of lead emissions into the air have been fuels used in on-road motor vehicles and industrial sources. However, lead emissions from the transportation sector have declined dramatically in recent decades because of the federal ban on leaded gasoline for on-road motor vehicles. Today, remaining sources of airborne lead include ore and metals processing, burning of aviation fuels, car battery plants and incinerators.

Once inhaled or ingested, lead distributes throughout the body in the blood and can result in a variety of adverse health effects depending on the level of exposure. In adults, these include damage to the nervous system, kidney function, immune system, reproductive and developmental systems, brain, and cardiovascular system. For infants and children, exposures to low levels of lead early in life have been linked to harmful effects on IQ (intelligence quotient), learning, memory and behavior. There is no known safe level of lead in the body.

Lead is persistent in the environment and accumulates in soils and sediments through deposition from the air, mining, erosion and direct discharge of waste streams into water bodies. Ecosystems near sources of lead demonstrate a wide range of adverse effects including losses in biodiversity, changes in community composition, decreased growth and reproductive rates in plants and animals, and neurological effects in vertebrates.

### **2.1.3 Nitrogen Dioxide**

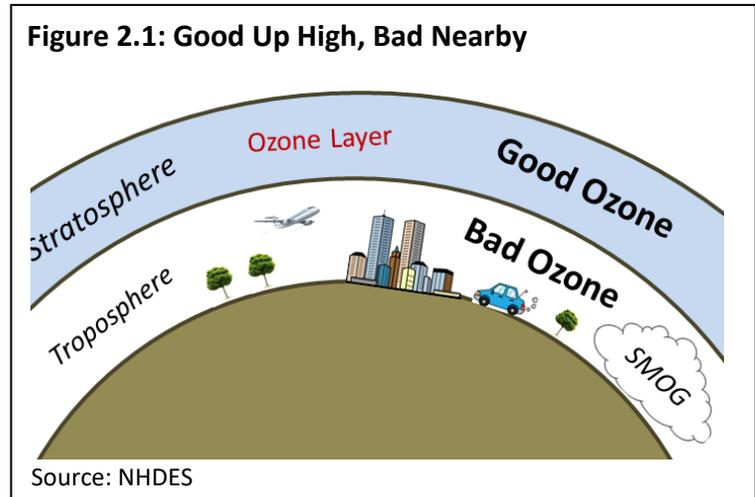
Nitrogen dioxide (NO<sub>2</sub>) is one of a group of highly reactive gases known as nitrogen oxides (NO<sub>x</sub>). NO<sub>x</sub> compounds, including NO<sub>2</sub>, are usually produced by high heat (such as during combustion processes) when exposed to the mix of oxygen and nitrogen found in the ambient air. Other members of this pollutant group include nitrous acid and nitric acid. NO<sub>2</sub> is the component of NO<sub>x</sub> with the greatest direct health concern. Since ambient air concentrations of NO<sub>2</sub> are measured and recorded, it is used as the general indicator for the larger NO<sub>x</sub> group.

Common sources of NO<sub>x</sub> emissions include cars, trucks, and buses; off-road equipment; power plants; and agricultural sources. Atmospheric NO<sub>2</sub> forms quickly in the presence of these NO<sub>x</sub> emissions sources. NO<sub>2</sub> is associated with a number of adverse effects on the human respiratory

system, affecting the health of sensitive populations such as children, the elderly, and people with asthma. When moisture is present,  $\text{NO}_2$  and other  $\text{NO}_x$  compounds can react with ammonia and other chemicals to form fine particles. These particles can penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease.  $\text{NO}_2$  also contributes to multiple health and environmental concerns through the formation of ground-level ozone (Section 2.1.4), fine particle pollution (Section 2.1.5), and atmospheric deposition (including acid rain) (Section 6).

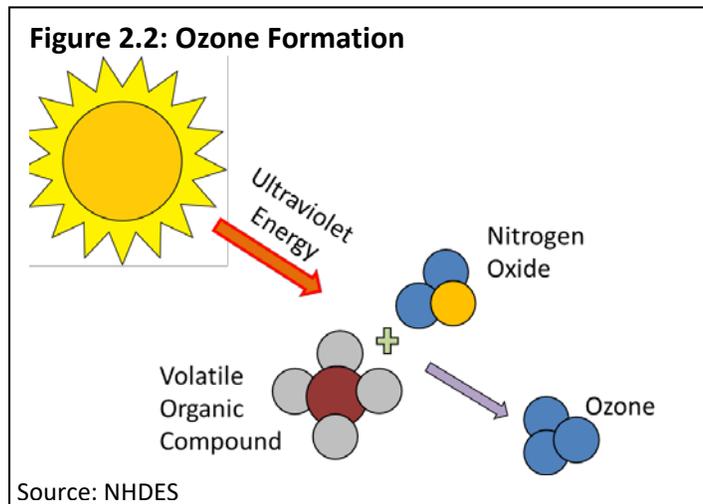
### 2.1.4 Ozone

Ozone ( $\text{O}_3$ ) is found in two regions of the Earth's atmosphere – at ground-level in the troposphere and at higher levels in the stratosphere. Both types of ozone have the same chemical composition. While upper atmospheric ozone protects the earth from the sun's harmful rays, ground-level ozone is the main component of smog (Figure 2.1).



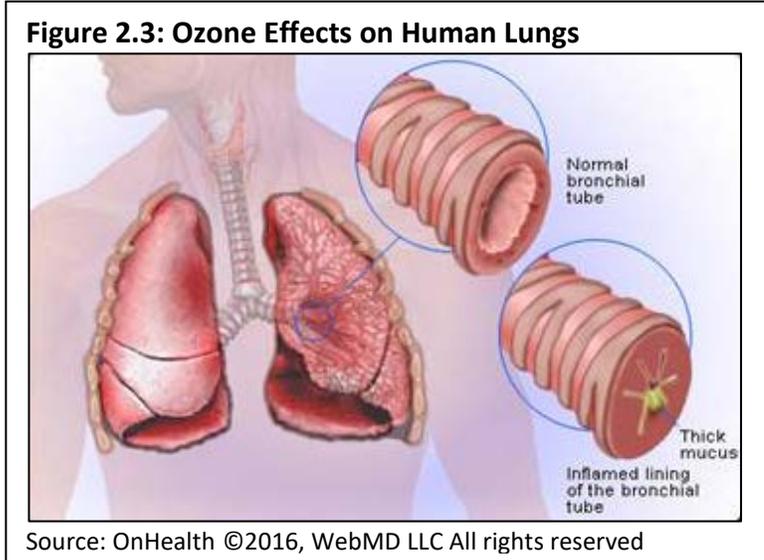
Ground-level ozone is not emitted directly into the air but is created by chemical reactions between nitrogen oxides ( $\text{NO}_x$ ) and volatile organic compounds (VOCs) in the presence of heat and sunlight (Figure 2.2). Because its formation requires heat and strong ultraviolet (uv) sunlight, ozone usually reaches its highest concentrations during the warmer months. Scientists and air quality regulators commonly refer to this as the “ozone season.” In New Hampshire, the ozone season is March through September<sup>4</sup>, though high ozone levels have occasionally been observed outside this period in recent years.

Emissions from electric power generation, industrial plants, motor vehicles, and vapors from gasoline and chemical solvents are the major anthropogenic sources of  $\text{NO}_x$  and VOCs. These ozone precursors are the subject of numerous air pollution control requirements (further described in Section 9).



<sup>4</sup> In New Hampshire and other states, the ozone season was extended from April to include the month of March. This change was made as part of the 2015 ozone NAAQS implementation rule.

Even relatively low concentrations of ozone can produce adverse health effects. Exposure to ozone can reduce lung function; aggravate chronic lung diseases such as asthma, emphysema, and bronchitis; and promote other respiratory problems (Figure 2.3). Persons at highest risk include children, older adults, those with lung disease, and those who are active outdoors. Breathing elevated concentrations of ozone may contribute to premature death in people with heart and lung disease.



Ozone also affects sensitive ecosystems, including forests, parks, wildlife refuges, and wilderness areas. In particular, ozone harms sensitive vegetation, including trees and crops, during the growing season (Figure 2.4). Ozone is absorbed by leaves and pine needles and impedes growth. Weakened plants can die from insects, fungus and freezing. Ozone damage also reduces crop yields.

### 2.1.5 Particulate Matter

Particulate matter, also called particle pollution, is the term for a mixture of solid particles and liquid droplets (aerosols) found in the air. These particles include dust, dirt, soot and smoke. Some are large enough to be seen with the naked eye, and some are so small that they can only be detected using an electron microscope. Fine particulate matter is of greatest concern to human health because it is small enough to lodge deeply in the lungs (see  $PM_{2.5}$  in Figure 2.5).

**Figure 2.4: Ozone Effects on Forests**



Source: Cornell University- New York State Integrated Pest Management Program, NH Bugs and Woodlot Association of Alberta

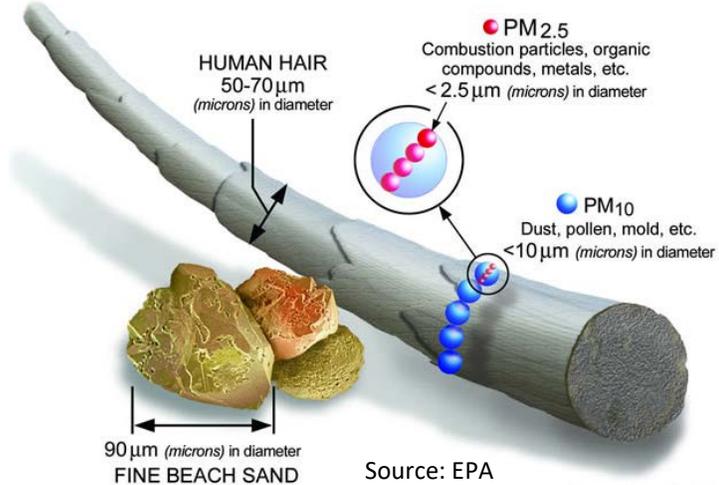
Particle pollution includes:

- **Coarse particles** – diameters 10 micrometers and smaller ( $PM_{10}$ )
- **Inhalable coarse particles** – diameters larger than 2.5 micrometers but smaller than 10 micrometers ( $PM_{10-2.5}$ )
- **Fine particles** – diameters 2.5 micrometers and smaller ( $PM_{2.5}$ )

Fine particulate matter can be emitted directly from a combustion source, or it can form by condensation when exhaust gases cool. It can also form through secondary chemical reactions when gases and other air pollutants combine and react downwind from the point of emission. Secondary chemical formation often occurs when nitrogen oxides or sulfur dioxide react in the presence of ammonia gases. Sources of ammonia include industrial emissions, agriculture, and natural sources. Other major sources of  $PM_{2.5}$  in New Hampshire include wood burning for residential heating in the winter and summer wildfires in upwind areas. Sources of coarse particles include dust caused by traffic on dry pavement or unpaved roads, some agricultural activities, construction and demolition operations, industrial processes, and biomass burning.

People most at risk from particle pollution exposure include those with heart or lung disease, such as asthma, and older adults and children. Research indicates that pregnant women, newborns, and people with certain health conditions, such as obesity or diabetes, also may be more susceptible to PM-related effects. These effects include decreased lung function, an irregular heartbeat, and increased respiratory symptoms. Fine particulate matter also leads to haze (Section 2.3), which obscures the view in scenic areas.

**Figure 2.5: Size of Particle Pollution**



### 2.1.6 Sulfur Dioxide

Sulfur dioxide ( $SO_2$ ) is one of a group of highly reactive gases known as sulfur oxides ( $SO_x$ ). The NAAQS for  $SO_2$  is intended to protect against exposure to the entire group of gaseous sulfur oxides.  $SO_2$  is the most common component of  $SO_x$  and thus serves as the indicator for the larger group.

The largest sources of  $SO_2$  emissions are combustion of fossil fuels at power plants, refineries, and other industrial facilities. Most commonly, these fossil fuels include coal and oil products, such as residual and distillate oils, diesel, and gasoline. Smaller sources of  $SO_2$  emissions include

various industrial processes; the burning of sulfur-containing fuels in locomotives, large ships, and off-road equipment; and the use of heating oil for commercial and residential purposes. In New Hampshire, and throughout the Northeast, oil is commonly used for residential heating during cold weather. Since oil naturally contains a small amount of sulfur, residential heating can produce a low, yet widespread, level of background SO<sub>2</sub> throughout the region during colder months.

The Acid Rain Program (Section 9.1.2), introduced under the 1990 amendments of the Clean Air Act, initiated significant reductions of SO<sub>2</sub> (and NO<sub>x</sub>) from the electric generation industry and several additional federal and state programs have since built on this progress in areas throughout the eastern United States. Most Northeast states are currently in the process of introducing rules and legislation to lower the sulfur content in heating fuels over the next few years (New Hampshire implemented these regulations in statute in 2016, effective July 1, 2018). This will not only lower SO<sub>2</sub> concentrations in the air, but will improve visibility and reduce furnace cleaning and maintenance costs for the consumer.

SO<sub>x</sub> can react with other compounds in the atmosphere to form fine particle pollution, which is harmful to the human respiratory system and can aggravate existing heart disease (see Section 2.1.5 above). Specifically, SO<sub>2</sub> may convert into compounds that include ammonium sulfate and sulfuric acid. Ammonium sulfate is a particle pollutant and the largest contributor to haze in New Hampshire. Sulfur oxides are also linked with nitrogen oxides in their contribution to acid deposition.

**Key Point:** The criteria pollutants are carbon monoxide, lead, ground-level ozone, nitrogen oxides, particulate matter, and sulfur oxides. These pollutants come from a variety of sources. For each, EPA sets National Ambient Air Quality Standards, with the goal of protecting the health of people and the environment.

## 2.2 Toxic Air Pollutants

Toxic air pollutants, also known as hazardous air pollutants, are those pollutants known or suspected to cause cancer or other serious health effects, such as birth defects, or to cause adverse environmental effects. Toxic air pollutants are a significant concern at the federal and state level. Under the Clean Air Act (CAA) Amendments of 1990, EPA listed and promulgated regulations for the control of 187 hazardous air pollutants.<sup>5</sup> EPA limits emissions of these pollutants through rigorous performance standards for companies that emit any of these hazardous air pollutants in significant quantities.

Examples of toxic air pollutants include benzene, which is found in gasoline; perchloroethylene, which is emitted from some dry cleaning facilities; and methylene chloride, which is used as a solvent and paint stripper by a number of industries. Others include dioxin, asbestos, toluene, and several metals, such as cadmium, chromium, lead, and mercury.

<sup>5</sup> <http://www.epa.gov/ttn/atw/eparules.html>

Toxic air pollutants are emitted from many types of sources. Although business and industry are significant contributors, other sources include gasoline stations, dry cleaners, research laboratories, motor vehicles and natural sources, such as radon gas, volcanic eruptions and forest fires. Emissions from industrial sources are the result of the production or use of hazardous chemicals in manufacturing processes, including industrial venting of process emissions, combustion by-products and waste disposal. The use of many consumer products, such as household cleaners, pesticides and paints also releases toxic pollutants into the air.

The human health effects of toxic air pollutants are as varied as the pollutants that cause them. With sufficient exposure, chronic health effects can result. Toxics can impact the nervous system, the immune system, and the respiratory system, and can have developmental effects. Observed cancers have been linked to many toxic air pollutants, resulting in their classification as known carcinogens. Short-term exposure, sometimes as short as a few minutes, can cause eye and skin irritation, coughing, vomiting, and dizziness. In addition, many air toxics are emitted in the form of particles or as organic vapors, contributing to the harmful health and environmental impacts of particulate matter (Section 2.1.5) and ground-level ozone (Section 2.1.4).

Toxic air pollutants can also deposit from the air onto soil or lakes and streams. Here, they affect ecological systems by moving up the food chain and eventually impact human health through the consumption of contaminated food, particularly fish. For example, people who regularly consume fish from the Great Lakes have been found to have higher concentrations of certain toxic chemicals, such as polychlorinated biphenyls (PCBs), in their bodies than people who do not. Fish-eating birds, mammals and reptiles have experienced a variety of adverse effects associated with toxic pollution.

Some toxic air pollutants remain in the environment for relatively short periods of time. These pollutants, which include formaldehyde, toluene and benzene, generally impact human health and the environment close to emission sources. Other toxic air pollutants, such as lead, mercury and dioxin, break down slowly, if at all, and cycle through the environment many times. Many of these “persistent” pollutants are appearing in unexpected locations far away from obvious sources.

### **2.2.1 Mercury**

Mercury is perhaps the toxic air pollutant of greatest consequence because of its widespread nature, its high potential for causing adverse health effects, and its current concentration in our environment. This naturally occurring element is found in air, water and soil. It exists in several forms: elemental or metallic, inorganic and organic. Mercury has traditionally been mined from the earth’s crust and used in products like thermometers, switches, and some light bulbs.

Mercury is found in many rock types, including coal. When coal is burned, mercury is released into the environment. Coal-burning power plants are collectively the largest anthropogenic source of mercury emissions to the air in the United States, accounting for over 40 percent of

all domestic human-caused mercury emissions.<sup>6</sup> EPA has estimated that about one quarter of mercury emissions from U.S. coal-burning power plants are deposited within the contiguous U.S., and the remainder enters the global cycle. EPA currently estimates that less than half of all mercury deposition within the U.S. comes from domestic sources.

Coal-fired power plants are the largest source of mercury emissions, not only nationally, but in New Hampshire. Other active sources in New Hampshire include municipal waste combustors, wastewater sludge incinerators and a variety of smaller oil-burning sources.

While breathing air contaminated with mercury is one possible exposure route, a greater concern is the deposition of airborne mercury onto water and land (Section 6.4), where it can enter food chains and eventually accumulate in body tissues. The most common way humans are exposed to mercury is by eating fish or shellfish contaminated with mercury.<sup>7</sup>

### **2.3 Haze-Causing Pollutants**

In 1999, EPA announced a major effort to improve air quality in national parks and wilderness areas with the establishment of the Regional Haze Rule. The Regional Haze Rule calls for state and federal agencies to work together to improve visibility in 156 Class I areas. In New Hampshire, this includes the Great Gulf Wilderness and the Presidential Dry River Wilderness, both of which surround Mt. Washington (Figure 2.6).



**Figure 2.6:**  
**Haze near Mt. Washington**  
Regional haze can obscure vistas of important landmarks, as in this split-image view of the Presidential Range and adjacent valley from Conway, New Hampshire, on clear and hazy days.

Source:  
[http://hazecam.net/mtwash\\_gallery.aspx](http://hazecam.net/mtwash_gallery.aspx)

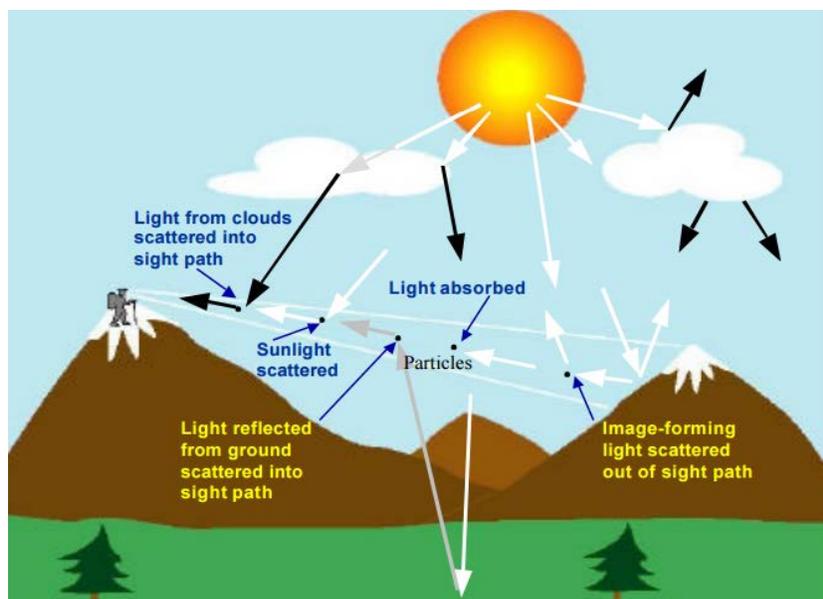
Haze is an atmospheric phenomenon that obscures the clarity, color, texture, and form of what is seen. It is caused primarily by particles and gases released from human-made sources but

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<sup>6</sup> Source: 2014 National Emissions Inventory, <https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data>

<sup>7</sup> For advice about consuming fish and shellfish, visit <http://www.epa.gov/mercury/advisories.htm> and <https://www.epa.gov/choose-fish-and-shellfish-wisely>.

can also be produced by natural phenomena, including forest fires, dust storms, and sea spray. Pollutants impair visibility by scattering and absorbing light, thereby reducing the amount of visual information about distant objects that reaches an observer (Figure 2.7).



**Figure 2.7:**  
**What Causes Haze?**

Haze is caused when sunlight is absorbed, scattered, or interfered with by pollution particles. Large particles are efficient at absorbing light, thus darkening a distant image. Small particles can absorb and scatter light, obscuring an image or creating a whitish appearance. Gases cause light to scatter, adding or subtracting colors to a view of an image.

Source: Adapted from Malm  
<http://vista.cira.colostate.edu/Improve/visibility-basics/>

Some haze-causing pollutants are emitted directly to the atmosphere by emission sources such as electric power plants, factories, motor vehicles, construction activities, and agricultural burning. Others form when gases interact to form new particles that are carried downwind. Because haze-causing emissions generally span broad geographic areas and can be transported hundreds or thousands of miles, regional haze occurs in every part of the nation.

The pollutants that commonly cause hazy conditions in the eastern U.S. are fine particles composed mainly of sulfate, nitrate, organic carbon<sup>8</sup>, elemental carbon (soot), and crustal material (e.g., soil dust, sea salt, etc.). Of these, only elemental carbon impairs visibility by absorbing visible light; the others scatter light. Sulfate, nitrate and organic carbon are secondary pollutants that form in the atmosphere primarily from SO<sub>2</sub>, NO<sub>x</sub>, and VOCs, respectively. By contrast, soot and crustal material and some organic carbon particles are released directly to the atmosphere.

In 2016, ammonium sulfate (an aged product of SO<sub>2</sub> and ammonia emissions) is the dominant contributor to regional haze pollution throughout the Northeast and Mid-Atlantic states. On the haziest 20 percent of days, it accounts for one half to two thirds of total fine particle mass and

<sup>8</sup> The term “organic carbon” encompasses a large number of hydrogen and carbon containing molecules. Light scattering secondary organic aerosols result from the oxidation of hydrocarbons that are emitted from many different sources, ranging from automobiles to solvents, to natural vegetation. Organic carbon can be emitted as a primary particle from sources such as wood burning, meat cooking, automobiles, and paved road dust.

is responsible for about three quarters of total light extinction (loss in light intensity) at Class I sites in the Northeast region (note: Class I sites are a set of 156 national parks and wilderness areas that are protected under EPA's Regional Haze Program, discussed further below and in Section 9.4.3). Organic carbon consistently accounts for the next largest fraction; its contribution typically ranges from 20% to 30% of total mass on the haziest days.

The relative contributions of ammonium nitrate, elemental carbon, and fine soil are smaller than those of sulfate and organic carbon – usually less than 10% of total mass, depending on location. In some settings, especially large metropolitan areas, nitrate plays a considerably larger role, underscoring the contribution of local NO<sub>x</sub> sources to fine particle pollution in urban areas.

**Key Point:** Haze is caused by particle pollution and obscures views in scenic areas. The Regional Haze Rule is a multi-state effort to reduce haze in 156 protected Class I national parks and wilderness areas throughout the United States. In the Northeast, sulfate particles, followed by organic carbon particles, are the largest contributors to haze formation.

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### 3 STANDARDS AND ATTAINMENT

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The Environmental Protection Agency (EPA) has set standards for the six criteria pollutants (Section 3.1). When air quality levels in an area violate one of these standards, EPA may designate that area as being in “nonattainment” of the standard (Section 3.2). In contrast, where air pollution is below the threshold of the standard, the area is considered in “attainment.”

Under the Clean Air Act (CAA), nonattainment areas are subject to regulations which ensure that air quality levels will eventually meet the standard. The CAA requires each state to submit and periodically revise a State Implementation Plan (SIP). A SIP describes the regulations and other strategies the state will use to bring nonattainment areas into attainment, keep former nonattainment areas from returning to nonattainment, and maintain good air quality in areas that are already in attainment. The SIP process is described further in Section 3.3; Section 3.4 describes New Hampshire’s current and past nonattainment areas.

#### 3.1 National Ambient Air Quality Standards (NAAQS)

The Clean Air Act (CAA) requires ambient outdoor standards for specific air pollutants. According to the CAA, such standards should be based upon extensive research and review by experts in the field and be protective of human and environmental health with an adequate margin of safety.

EPA has set National Ambient Air Quality Standards for the six criteria air pollutants (Section 2.1): carbon monoxide (CO), lead, nitrogen dioxide (NO<sub>2</sub>), ozone, particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), and sulfur dioxide (SO<sub>2</sub>).<sup>9</sup> EPA sets the NAAQS based on recommendations from the Clean Air Scientific Advisory Committee (a panel of appointed experts) and its own advisory staff. The CAA requires EPA to review the standards every five years and update them as needed. Each NAAQS is set for a



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<sup>9</sup> Section 108(a) of the Clean Air Act requires the establishment of national ambient air quality standards. The CAA was last amended in 1990.

specific time period of continuous exposure; for instance, the limit may apply to average exposure over a one-hour, eight-hour, 24-hour, or annual period.

**Key Point:** Air pollution standards are normally expressed in concentration units of parts per million (ppm), parts per billion (ppb), or micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). These units reflect the average amount of the pollutant present in a certain volume of ambient air over a defined period of time (as set by the standard).

There are two types of NAAQS: primary and secondary. Primary standards set limits to protect public health for the most vulnerable populations, such as children, older adults, and people with pre-existing heart or lung disease. Secondary standards set limits to protect public welfare, including protection against damage to animals, crops, vegetation, buildings, and visibility in scenic places.

Table 3.1 lists the current primary and secondary NAAQS for each criteria pollutant. The table also describes the form of the “design value” for each standard; this is a value used to determine whether a violation of the standard has occurred (Section 3.2).

**Key Point: Parts per billion (ppb)?  
What does that mean?**

75ppb is like putting 75 drops of pollution into this Olympic-sized swimming pool.

It’s not much, but the pollution can still have a significant impact.



**How the National Ambient Air Quality Standards (NAAQS) are set:**

Under the Clean Air Act, the NAAQS are to be reviewed every five years to ensure adequacy of health protection. A review begins with an independent scientific advisory panel that reviews the most recent health science relative to the specific pollutant under review. The Clean Air Scientific Advisory Committee (CASAC) consists of scientists, doctors, researchers and industry specialists and they provide independent advice to the EPA Administrator on the technical bases for EPA's NAAQS. Exposure limit recommendations (often a range) contain an adequate margin of safety. An EPA science panel then reviews the recommendation and forms an EPA internal recommendation for the Administrator to consider. In the final step, the EPA Administrator seeks agreement with the Office of Management and Budget (OMB) which resides within the Executive Office of the President of the United States. After promulgation of the standard, EPA issues a rule to implement the new/revised standard along with steps required to demonstrate compliance. Costs of meeting a health standard are not considered during scientific review for determining safe exposure to a pollutant, however costs are considered when determining how to comply.

**Table 3.1: National Ambient Air Quality Standards (2016)<sup>10,11</sup>**

Pollutant [final rule cite]		Primary/ Secondary	Averaging Time	Level	Form ("Design Value")
<a href="#">Carbon Monoxide</a> [76 FR 54294, Aug 31, 2011]	primary	8-hr	9 ppm	Not to be exceeded more than once per year	
		1-hr	35 ppm		
<a href="#">Lead</a> [73 FR 66964, Nov 12, 2008]	primary and secondary	Rolling 3 month	0.15 µg/m <sup>3 a</sup>	Not to be exceeded	
<a href="#">Nitrogen Dioxide</a> [75 FR 6474, Feb 9, 2010] [61 FR 52852, Oct 8, 1996]	primary	1-hr	100 ppb	98 <sup>th</sup> percentile, averaged over 3 years	
	primary and secondary	Annual	53 ppb <sup>b</sup>	Annual Mean	
<a href="#">Ozone (2015)</a> [80 FR 65292, Oct 26, 2015]	primary and secondary	8-hr	0.070 ppm <sup>c</sup>	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years	
<a href="#">Particle Pollution</a> Dec 14, 2012	PM <sub>2.5</sub>	primary	Annual	12 µg/m <sup>3</sup>	annual mean, averaged over 3 years
		secondary	Annual	15 µg/m <sup>3</sup>	annual mean, averaged over 3 years
		primary and secondary	24-hr	35 µg/m <sup>3</sup>	98 <sup>th</sup> percentile, averaged over 3 years
	PM <sub>10</sub>	primary and secondary	24-hr	150 µg/m <sup>3</sup>	Not to be exceeded more than once per year on average over 3 years
<a href="#">Sulfur Dioxide</a> [75 FR 35520, Jun 22, 2010] [38 FR 25678, Sept 14, 1973]	primary	1-hr	75 ppb <sup>d</sup>	99 <sup>th</sup> percentile of 1-hr daily maximum concentrations, averaged over 3 years	
	secondary	3-hr	0.5 ppm	Not to be exceeded more than once per year	

<sup>a</sup> Final rule signed October 15, 2008. The 1978 lead standard (1.5 µg/m<sup>3</sup> as a quarterly average) remains in effect until one year after an area is designated for the 2008 standard, except that in areas designated nonattainment for the 1978, the 1978 standard remains in effect until implementation plans to attain or maintain the 2008 standard are approved.

<sup>b</sup> The official level of the annual NO<sub>2</sub> standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard.

<sup>c</sup> Final rule signed October 1, 2015, and effective December 28, 2015. The previous (2008) O<sub>3</sub> standards additionally remain in effect in some areas. Revocation of the previous (2008) O<sub>3</sub> standards and transitioning to the current (2015) standards will be addressed in the implementation rule for the current standards.

<sup>d</sup> Final rule signed June 2, 2010. The 1971 annual and 24-hour SO<sub>2</sub> standards were revoked in that same rulemaking. However, these standards remain in effect until one year after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.

**Key Point:** EPA sets National Ambient Air Quality Standards (NAAQS) for the six criteria pollutants. NAAQS may be primary or secondary. Primary standards set limits to protect people’s health; secondary standards set limits to protect public welfare, including prevention of damage to buildings and the environment.

<sup>10</sup> For an updated summary of the NAAQS, see EPA’s [NAAQS Table](https://www.epa.gov/criteria-air-pollutants/naqs-table), (<https://www.epa.gov/criteria-air-pollutants/naqs-table>).

<sup>11</sup> For more information on EPA’s process for reviewing the NAAQS, see [NAAQS Review Process](https://www.epa.gov/criteria-air-pollutants/process-reviewing-national-ambient-air-quality-standards), (<https://www.epa.gov/criteria-air-pollutants/process-reviewing-national-ambient-air-quality-standards>).

### 3.2 Nonattainment of the Standard: Exceedance versus Violation

When EPA establishes a new NAAQS or revises an existing NAAQS (Section 3.1), it sets in motion a series of actions to ensure air quality throughout the country meets those standards. As an initial step, EPA must designate areas as meeting the standard (“attainment”) or not meeting the standard (“nonattainment”). EPA bases these designations on violations of the standard.

When an air quality monitor measures a value over the NAAQS threshold, it may be an exceedance of the NAAQS, but not necessarily a violation of the NAAQS. Exceedances are based on a short-term measurement. Violations indicate whether an area is subject to designation as nonattainment and are based on a calculated “design value” from measurements over a longer period of time, normally three years.

**Key Point:**

An **exceedance** occurs when a measured concentration exceeds the threshold of the National Ambient Air Quality Standard (NAAQS).

A **violation** occurs when the calculated design value exceeds the NAAQS.

The **design value** is a calculated ambient air concentration that covers a specific duration, normally 3 years.

To identify a violation of the standard, EPA uses the calculated design value as measured over its designated duration. The form of the design value differs for each pollutant, but it normally does not represent a single maximum. Instead, the design value is based on a statistical pattern within identified health exposure limits. The use of design values, as opposed to single maximum values, helps to prevent basing an area’s nonattainment status on a single incident, which may not reflect typical conditions over the long term.

To understand the difference between an exceedance and a violation, it may be helpful to consider an example, such as the primary standard for NO<sub>2</sub> (Table 3.2, also shown in Table 3.1):

**Table 3.2: Example NAAQS, Nitrogen Dioxide**

Pollutant	Primary/ Secondary	Averaging Time	Level	Form (“Design Value”)
Nitrogen Dioxide	primary	1-hour	100 ppb	98 <sup>th</sup> percentile, averaged over 3 years

The primary standard for NO<sub>2</sub> is 100 parts per billion (ppb) for a 1-hour period. An exceedance occurs if a measurement during any single one-hour period exceeds 100 ppb. However, the design value for this standard is the average 98<sup>th</sup> percentile over three years. A violation of the NO<sub>2</sub> standard occurs only when the 98<sup>th</sup> percentile of 1-hour concentrations, averaged over three years, exceeds 100 ppb. Only then would the area violate the NAAQS and be subject to nonattainment for NO<sub>2</sub>. In summary, exceedances may occur; however, they do not indicate a violation unless the design value surpasses the NAAQS.

The NAAQS standards and the form of their design values are provided in Table 3.1. Tables 3.3 and 3.4 summarize all exceedances of NAAQS thresholds in New Hampshire since 2009 for all criteria pollutants. Tables 3.5 and 3.6 summarize recent design values from monitored data in New Hampshire. Note that monitoring data for 2017 was not finalized at the time of this publication.

**Table 3.3: State-Wide Summary of NAAQS Exceedances, 2009-2016**

Pollutant	Period	NAAQS	Number of Days with Exceedances								Most Recent
			2009	2010	2011	2012	2013	2014	2015	2016	
CO	1-Hour	35 ppm	0	0	0	0	0	0	0	0	1978
	8-Hour	9 ppm	0	0	0	0	0	0	0	0	1996
Lead	Quarter	0.15 µg/m <sup>3</sup>	0	0	0	0	0	0	0	0	None
NO <sub>2</sub>	1-Hour	100 ppb	// <sup>d</sup>	0	0	0	0	0	0	0	None
Ozone	8-Hour	70-75ppb <sup>b</sup>	2	8	2	3	3	1	7 <sup>b</sup>	6 <sup>b</sup>	2016
PM <sub>10</sub>	24-Hour	150 µg/m <sup>3</sup>	0	0	0	0	0	0	0	0	1989
PM <sub>2.5</sub>	24-Hour	35 µg/m <sup>3</sup>	1	2	4	1	3	0	0	0	2013
	Annual	12 µg/m <sup>3c</sup>	0	0	0	0	0	0	0	0	None
SO <sub>2</sub>	1-Hour	75ppb	// <sup>d</sup>	96	62	1	0	0	0	0	2012
	3-Hour <sup>a</sup>	500ppb	0	0	0	0	0	0	0	0	1980

<sup>a</sup> Denotes secondary NAAQS, otherwise primary.

<sup>b</sup> The ozone NAAQS was revised from 75ppb to 70 ppb in 2015.

<sup>c</sup> The PM<sub>2.5</sub> annual NAAQS was revised from 13 to 12 µg/m<sup>3</sup> in 2012

<sup>d</sup> The 1-Hour NO<sub>2</sub> and SO<sub>2</sub> NAAQS were promulgated for the first time in 2010.

**Table 3.4: Community Summary of NAAQS Exceedance Days, 2009-2016**

Parameter/Primary Standard/Location	Number of Days with Exceedances								Most Recent
	2009	2010	2011	2012	2013	2014	2015	2016	
<b>Ozone (8-Hour)</b>									
Concord	0	1	0	0	0	0	1 <sup>a</sup>	0	2015
Laconia	0	1	0	0	0	0	0 <sup>a</sup>	0	2010
Londonderry	--	--	1	2	0	0	1 <sup>a</sup>	1 <sup>a</sup>	2016
Manchester	0	1	0	--	--	--	--	--	2010
Mt. Washington Summit	0	2	0	0	2	0	6 <sup>a</sup>	2 <sup>a</sup>	2016
Nashua	0	2	1	2	0	0	1 <sup>a</sup>	1 <sup>a</sup>	2016
Pack Monadnock Summit	0	4	0	2	0	1	2 <sup>a</sup>	3 <sup>a</sup>	2016
Portsmouth	1	2	1	1	1	0	1 <sup>a</sup>	0	2015
Rye	2	1	2	1	0	0	1 <sup>a</sup>	1 <sup>a</sup>	2016
<b>PM<sub>2.5</sub> (24-Hour)</b>									
Keene	1	1	4	1	3	0	0	0	2013
Pembroke	0	1	0	0	0	0	0	0	2010
Portsmouth	0	1	0	0	0	0	0	0	2010
<b>SO<sub>2</sub> (1-Hour)</b>									
Concord	// <sup>b</sup>	--	5	0	0	0	0	0	2011
Manchester	// <sup>b</sup>	1	1	--	--	--	--	--	2011
Pembroke	// <sup>b</sup>	95	57	1	0	0	0	0	2012

<sup>a</sup> Denotes exceedance count based on the 2015 ozone NAAQS. Other ozone counts are relative to the 2008 ozone NAAQS.

<sup>b</sup> The 1-Hour SO<sub>2</sub> NAAQS was promulgated for the first time in 2010.

-- Denotes no data or insufficient data collected at that site.

Site comments: Includes all monitoring stations in operation since 2008. Manchester closed in 2012; Londonderry opened January 1, 2011; Concord station began SO<sub>2</sub> monitoring in 2011.

Source: NHDES, 2017

**Table 3.5: 2013-15 Monitoring Design Values in New Hampshire**

	Carbon Monoxide		Lead <sup>a</sup>	Nitrogen Dioxide	Ozone	Particulate Matter <sup>b</sup>			Sulfur Dioxide	
	1-Hr	8-Hr	3-Month	1-Hr	8-Hr	Daily PM <sub>2.5</sub>	Annual PM <sub>2.5</sub>	Daily PM <sub>10</sub>	1-Hr	3-Hr
<b>NAAQS: Units</b>	<b>35 ppm</b>	<b>9 ppm</b>	<b>0.15 µg/m<sup>3</sup></b>	<b>100 ppb</b>	<b>70 ppb</b>	<b>35 µg/m<sup>3</sup></b>	<b>12 µg/m<sup>3</sup></b>	<b>150 µg/m<sup>3</sup></b>	<b>75 ppb</b>	<b>0.5 ppm*</b>
Concord	--	--	--	--	62	--	--	--	8	0.007
Keene	--	--	--	--	60	26	8.8	--	--	--
Laconia	--	--	--	--	58	11	5.0	--	--	--
Lebanon	--	--	--	--	59	16	6.3	--	--	--
Londonderry	0.5	0.4	0.0040	--	65	18	8.2	--	6	0.006
Mt. Washington Base	--	--	--	--	57	--	--	--	--	--
Mt. Washington Summit	--	--	--	--	69	--	--	--	--	--
Nashua	--	--	--	--	64	--	--	--	--	--
Pack Monadnock Summit	0.5	0.3	--	--	67	14	6.3	--	5	0.003
Pembroke	--	--	--	--	--	--	--	--	20	0.014
Portsmouth	--	--	--	--	66	18	6.8	51	29	0.017
Rye	--	--	--	--	68	--	--	--	--	--

\* - Second maximum values (Design Values for 3-hour SO<sub>2</sub>) are not to be exceeded more than once per year.

**Table 3.6: 2014-16 Monitoring Design Values in New Hampshire**

	Carbon Monoxide		Lead <sup>a</sup>	Nitrogen Dioxide	Ozone	Particulate Matter <sup>b</sup>			Sulfur Dioxide	
	1-Hr	8-Hr	3-Month	1-Hr	8-Hr	Daily PM <sub>2.5</sub>	Annual PM <sub>2.5</sub>	Daily PM <sub>10</sub>	1-Hr	3-Hr
<b>NAAQS: Units</b>	<b>35 ppm</b>	<b>9 ppm</b>	<b>0.15 µg/m<sup>3</sup></b>	<b>100 ppb</b>	<b>70 ppb</b>	<b>35 µg/m<sup>3</sup></b>	<b>12 µg/m<sup>3</sup></b>	<b>150 µg/m<sup>3</sup></b>	<b>75 ppb</b>	<b>0.5 ppm</b>
Concord	--	--	--	--	61	--	--	--	7	0.005
Keene	--	--	--	--	61	23	8.0	--	--	--
Laconia	--	--	--	--	58	10	4.5	--	--	--
Lebanon	--	--	--	--	57	15	5.9	--	--	--
Londonderry	0.5	0.4	0.0047	--	65	15	6.6	--	5	0.003
Mt. Washington Base	--	--	--	--	57	--	--	--	--	--
Mt. Washington Summit	--	--	--	--	67	--	--	--	--	--
Nashua	--	--	--	--	63	--	--	--	--	--
Pack Monadnock Summit	0.3	0.3	--	--	68	13	5.8	--	3	0.001
Pembroke	--	--	--	--	--	--	--	--	20	0.012
Portsmouth	--	--	--	--	65	15	6.0	28	23	0.010
Rye	--	--	--	--	67	--	--	--	--	--

-- Denotes no data or insufficient data collected at that site.

<sup>a</sup> EPA rules require lead design values be rounded to the second decimal place for comparison to the standard. However, to be more descriptive of very small values monitored in New Hampshire, lead design values in this table are rounded to the fourth decimal place.

<sup>b</sup> EPA rules define PM<sub>10</sub> design values as the average number of exceedances per year over three years. However, to show New Hampshire's monitored values relative to the standard, PM<sub>10</sub> values in this table are the maximum 24-hour averages over three years.

Source: NHDES, 2017

### 3.3 State Implementation Plans

The CAA requires each state to develop a plan to attain and maintain the NAAQS for the criteria pollutants in all areas of the state designated as nonattainment. These plans, known as state implementation plans (SIPs), must be developed and adopted through a process that allows public input, and the final plans must be approved by EPA.<sup>12</sup>

SIPs have two main components:

1. Demonstration that the state has the basic air quality management program components in place to implement the requirements needed to attain or maintain a new or revised NAAQS; and
2. Identification of the emission control requirements the state will rely upon to attain and/or maintain the primary and secondary NAAQS.

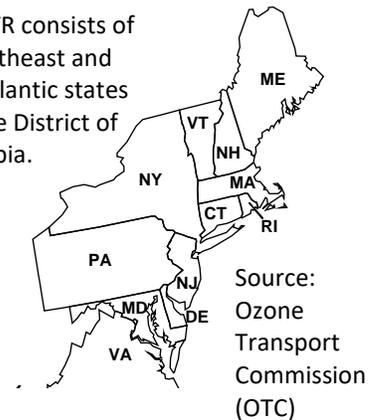
Whenever a NAAQS is revised, states must also update their respective SIPs to demonstrate a plan to attain the revised standard (or maintain it if air quality levels already meet it) and to fulfill other statutory obligations. The CAA requires a specific type of SIP revision for any area designated as nonattainment (i.e. an area that violates the NAAQS); this plan requires states to describe how they will meet the NAAQS and achieve attainment status by the statutory attainment date as specified under the CAA. The SIP process also includes a “good neighbor” component which requires states to consider how emissions from their state affect nonattainment areas in other states.

In addition to addressing the six criteria pollutants, SIPs are required under the visibility protection section of the CAA to provide for the control of air pollutants that impair visibility at 156 national parks and wilderness areas currently protected as Class I federal areas (see Section 2.3 above and Section 9.4.3 below).

In the 1990 CAA Amendments, the U.S. Congress recognized that the more densely populated northeast states share the same air shed, where emissions in one location can affect the air quality in other locations. In order to address air quality over the entire region, the CAA created an area called the Ozone Transport Region (OTR, Figure 3.1), extending from Maine to Northern Virginia. States in the OTR must implement additional control measures beyond the usual SIP requirements to deal with the pervasive nature of ozone in the Northeast. The additional measures apply everywhere within the region regardless of an area’s attainment status.

**Figure 3.1: States in the Ozone Transport Region (OTR)**

The OTR consists of 12 Northeast and Mid-Atlantic states and the District of Columbia.



<sup>12</sup> For more information on the NAAQS review process, please visit [EPA's State Implementation Plan Status and Information, https://www.epa.gov/criteria-air-pollutants/naaqs-implementation-process](https://www.epa.gov/criteria-air-pollutants/naaqs-implementation-process)

**Key Point:** The Clean Air Act provisions required for nonattainment areas, such as vehicle emission inspection and maintenance programs, are not retracted when the area comes into attainment of the federal standard. To prevent emission increases that could cause a backsliding into nonattainment, they are continued in order to maintain air quality improvements.

### 3.4 New Hampshire Attainment Designations

While most areas of New Hampshire have attained, and continue to meet, the NAAQS (Section 3.1), this has not always been the case. At various times, EPA has designated certain areas of the state as nonattainment areas (Section 3.2). New Hampshire has always met the NAAQS for three of the criteria pollutants: lead, particulate matter, and NO<sub>2</sub>. Portions of the state were previously designated as nonattainment areas for CO and ozone, but the state currently meets the NAAQS for those pollutants as well. In 2016, only one area of the state is designated nonattainment for any pollutant (SO<sub>2</sub>, see Section 3.4.1 and Figure 3.2). Table 3.7 summarizes the history of attainment and nonattainment area designations in New Hampshire.

**Table 3.7: Historical Summary of New Hampshire’s Air Quality Area Designations**

Pollutant	Area Designations	
	Former Status	Current Status
<b>Carbon Monoxide (CO)</b>	Nonattainment for Manchester and Nashua; attainment for all other areas <sup>a</sup>	Attainment for all areas
<b>Lead (Pb)</b>	Attainment for all areas	Unclassifiable/Attainment for all areas
<b>Nitrogen Dioxide (NO<sub>2</sub>)</b>	Attainment for all areas	Unclassifiable/Attainment for all areas
<b>Ozone (O<sub>3</sub>)</b>	<p><u>1-hour NAAQS</u>: Nonattainment for Cheshire, Hillsborough, Merrimack, Rockingham, and Strafford Counties; attainment for all other areas<sup>b</sup></p> <p><u>8-hour NAAQS</u>: Nonattainment for portions of Hillsborough, Merrimack, and Rockingham Counties; attainment for all other areas<sup>c</sup></p>	Attainment for all areas
<b>Particulate Matter (PM)</b>	Attainment for all areas	Attainment for all areas
<b>Sulfur Dioxide (SO<sub>2</sub>)</b>	Attainment for all areas	Nonattainment for portions of Hillsborough, Merrimack, and Rockingham Counties; unclassifiable for all other areas <sup>d</sup>

<sup>a</sup> In 1980, EPA designated the City of Manchester and the City of Nashua as nonattainment areas by for CO (45 FR 24869 and 48 FR 29479, respectively). Following passage of the Clean Air Act Amendments of 1990, both cities were designated as “nonattainment” and “not classified” for CO (56 FR 56694), although ambient monitoring showed that air quality was meeting the NAAQS by then. In 2000, EPA re-designated Manchester and Nashua to attainment of the CO standard, effective on January 29, 2001 (65 FR 71078).

<sup>b</sup> New Hampshire’s area designations for the 1-hour primary ozone NAAQS (now revoked) are codified at [40 CFR 81.330](#).

<sup>c</sup> [69 FR 23857](#) ). Improved air quality made it possible for this area to be re-designated to attainment on December 27, 2012 ([78 FR 6741](#)).

<sup>d</sup> New Hampshire’s SO<sub>2</sub> nonattainment area was established in EPA’s initial round of air quality designations on July 25, 2013, for the 2010 SO<sub>2</sub> primary NAAQS ([78 FR 47191](#)).

Source: NHDES and EPA

### 3.4.1 Sulfur Dioxide Designation

Currently, the only nonattainment area in New Hampshire is for the 1-hour SO<sub>2</sub> NAAQS. Air quality monitoring has identified a portion of central New Hampshire that violates the 1-hour standard of 75 parts per billion (Figure 3.2). This designation is likely to be revised to attainment in the next year to reflect more recent monitoring and modeling in the area, newly implemented pollution controls, and the state’s 1-hour SO<sub>2</sub> state implementation plan.

### 3.4.2 Carbon Monoxide Designation

New Hampshire currently meets the CO NAAQS in all parts of the state. Portions of the state previously designated as nonattainment have improved and have since been reclassified to attainment. Ongoing maintenance requirements are in place to prevent these areas from slipping back to nonattainment. These “maintenance areas” include Manchester and Nashua.

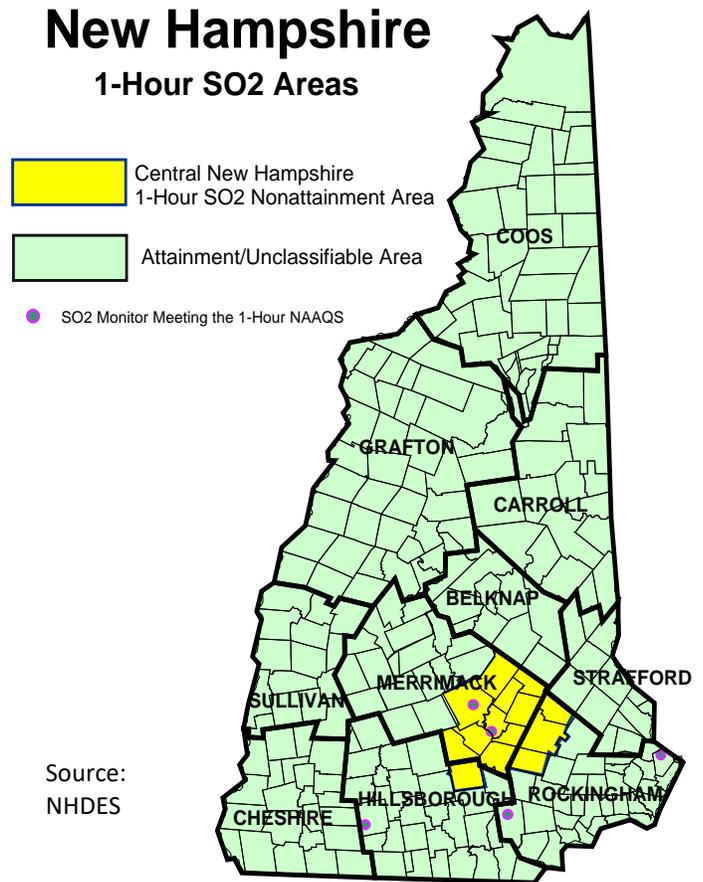
### 3.4.3 Ozone Designation

Nonattainment designations may fall into specific categories depending on the degree of severity. Areas with higher degrees of severity must develop more stringent plans and implement increasingly significant emission reductions. For ozone, nonattainment designation classifications include: marginal, moderate, serious, severe and severe-17. Marginal areas have 3 years from the time they are designated as nonattainment to come into attainment. Similarly, moderate areas have 6 years; serious areas have 9 years; severe areas have 12 years; and severe-17 areas have 17 years.

Portions of New Hampshire were previously designated as marginal, moderate and serious nonattainment for the 1990 1-hour ozone NAAQS (Figure 3.3). New Hampshire has since met the 1990 1-hour NAAQS, which has since been revoked. In 1997, EPA established a new ozone NAAQS based on an eight-hour averaging time (with a level of 85 ppb). Portions of New Hampshire were

**Figure 3.2: SO<sub>2</sub> Nonattainment Area**

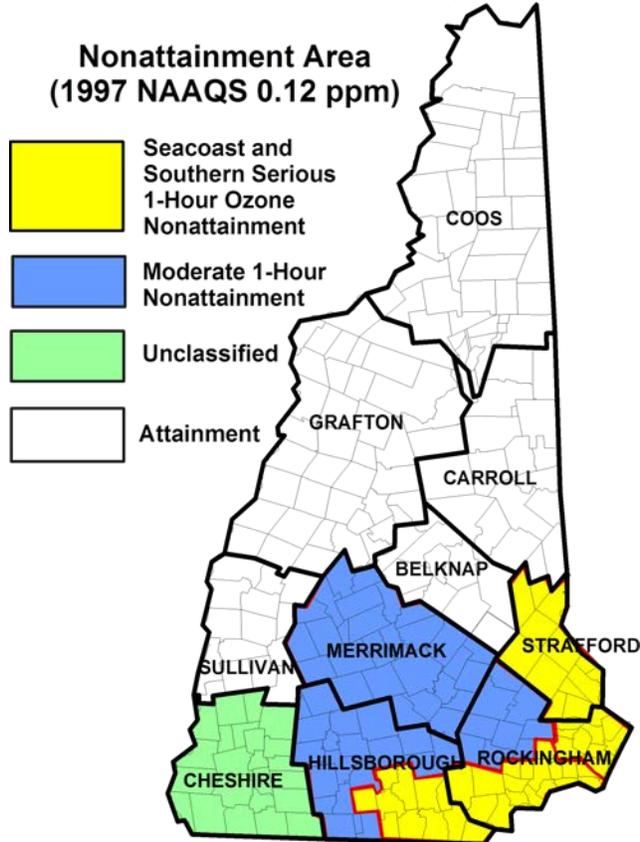
New Hampshire’s nonattainment area for the 2010 SO<sub>2</sub> primary NAAQS includes portions of three counties in the southern part of the state.



designated as moderate nonattainment under this NAAQS (Figure 3.4). Ozone levels in the state have since improved, and the area has been re-designated to attainment.

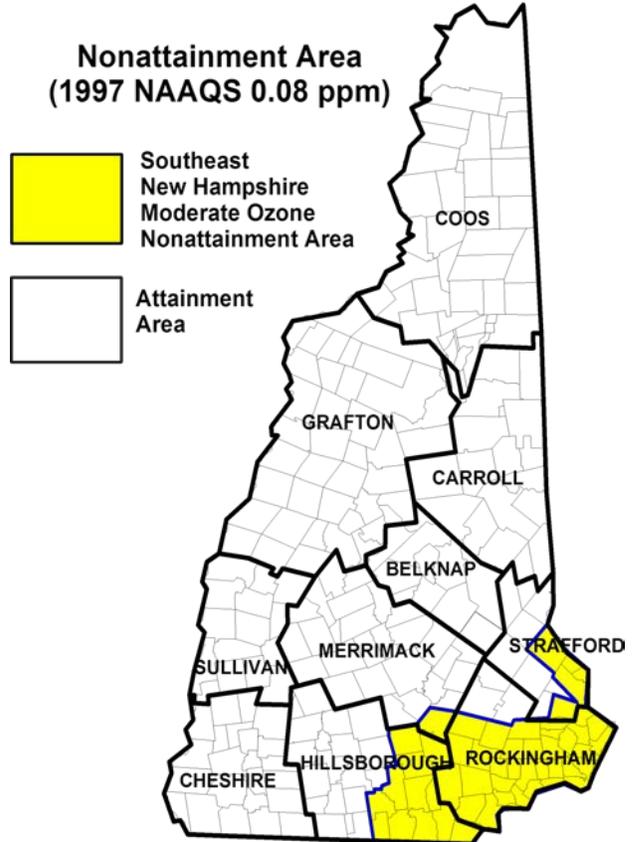
In 2008, EPA revised the 8-hour ozone NAAQS to 75 ppb and New Hampshire was designated as attainment statewide. In October 2015, EPA again revised the 8-hour ozone NAAQS, lowering it to a level of 70 ppb. EPA has not yet made designations for the 70 ppb standard, but based on the most recent available monitoring data it appears that all of New Hampshire will be in attainment. Existing maintenance requirements will remain in place for areas previously designated as nonattainment. These measures will help prevent these areas from slipping back to nonattainment levels; air quality regulators refer to such maintenance measures as “anti-backsliding” requirements.

**Figure 3.3: Previous (1990) 1-Hour Ozone Nonattainment Area in New Hampshire**



Source: NHDES

**Figure 3.4: Previous (1997) 8-Hour Ozone Nonattainment Area in New Hampshire**



Source: NHDES

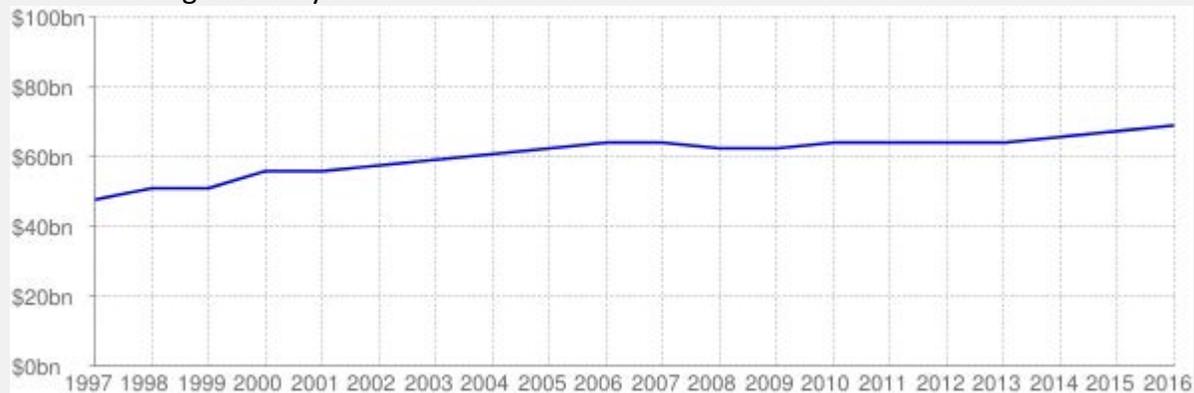
### 3.4.4 Designations of Other Criteria Pollutants

New Hampshire is designated as either attainment or unclassifiable/attainment statewide for NO<sub>2</sub>, lead, PM<sub>2.5</sub> and PM<sub>10</sub>. The term unclassifiable is sometimes applied in recognition that ambient air monitoring has not taken place in all areas.

**Key Point:** It is possible for an area to exceed a National Ambient Air Quality Standard and not violate it. An exceedance occurs when a single day's air quality exceeds the threshold of the standard.

**Key Point:** Currently, New Hampshire has only one nonattainment area for one criteria pollutant: sulfur dioxide. In the past, parts of New Hampshire have been in nonattainment for carbon monoxide and ozone, but air quality has improved, and these areas no longer violate these standards.

**Key Point:** New Hampshire has achieved steady economic growth since the Clean Air Act was implemented (Real GDP [2009 Chained Dollars]). Only a minor decline is noted during the national Great Recession during the late 2000's. The goal of achieving cleaner air is consistent with a thriving economy.



<http://www.deptofnumbers.com/gdp/new-hampshire/>

**Key Point:** A 2011 EPA peer-reviewed study found that clean air programs established by the 1990 CAA amendments were expected to yield direct national benefits to the American people vastly exceeding compliance costs. The study found benefits estimated in 2020 exceed costs by a factor of more than 30-to-1 with an uncertainty range of 3-to-1 to 90-to-1. In addition to direct benefits vastly exceeding direct costs, economy-wide modeling conducted for the study found that the economic welfare of American households is better with post-1990 clean air programs than without them. **Economic welfare and economic growth rates are improved because cleaner air means fewer air-pollution-related illnesses, which in turn means less money spent on medical treatments and lower absenteeism among American workers. The study projects that the beneficial economic effects of these two improvements alone more than offset the economic impacts from expenditures for pollution control.** <https://www.epa.gov/clean-air-act-overview/benefits-and-costs-clean-air-act-1990-2020-report-documents-and-graphics>

Another, earlier peer-reviewed EPA study examined the national benefits and costs of Clean Air Act programs from 1970 to 1990, and also found that the public health protection and environmental benefits exceeded the costs by a large margin.

<https://www.epa.gov/sites/production/files/2015-06/documents/contsetc.pdf>

## 4 STATE OF AIR QUALITY IN NEW HAMPSHIRE

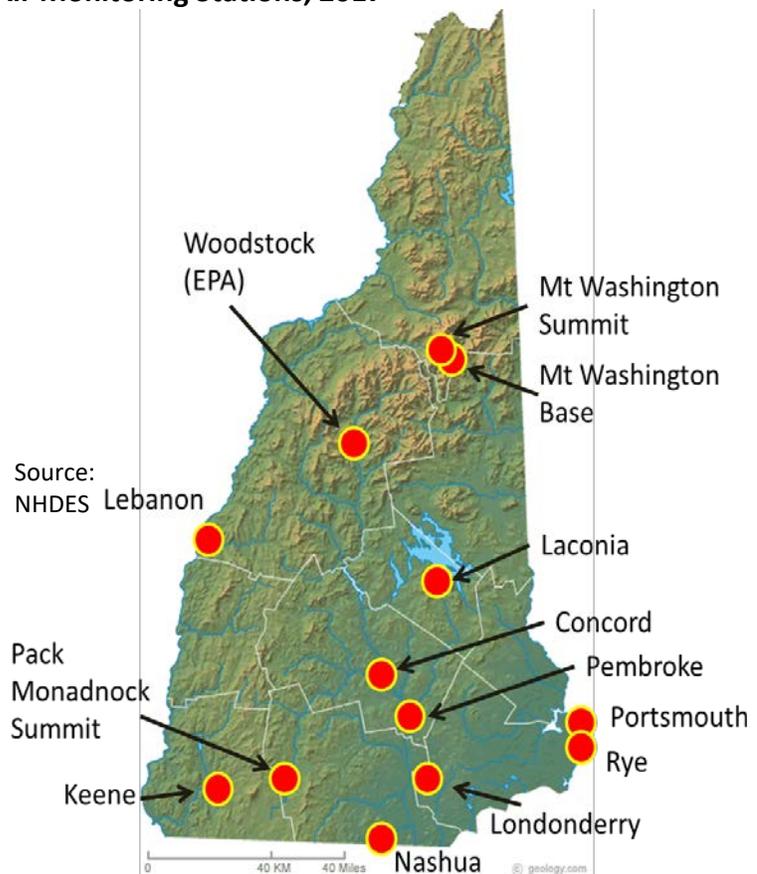
Over several decades of monitoring air quality, the New Hampshire Department of Environmental Services (NHDES) has learned a great deal about air pollution patterns in New Hampshire. Sections 4.1 and 4.2 below provide information about where New Hampshire has collected air quality data and how the Environmental Protection Agency (EPA) and NHDES use the Air Quality Index. Subsequent sections discuss how air pollution levels in the state vary by season (Section 4.3) and location (Section 4.4), and how pollutant concentrations have changed over time (Section 4.5). Finally, Section 4.6 describes New Hampshire temperature and precipitation trends and how they relate to air quality trends and Section 4.7 discusses health effects and related costs.

### 4.1 Air Quality Monitoring in New Hampshire

Air pollution monitoring in New Hampshire officially began in 1970. Since then, New Hampshire's monitoring network has evolved, with some stations moved or removed and others added<sup>13</sup>. The pollutants monitored and the type of equipment used to measure them has also changed over time. Figure 4.1 shows the locations of monitoring stations operating in New Hampshire in 2017.

**Key Point:** NHDES operates a network of air quality monitors throughout the state to measure levels of ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter, and a number of other pollutants in the outdoor air.

**Figure 4.1: New Hampshire Air Monitoring Stations, 2017**



<sup>13</sup> New Hampshire's monitoring program: <http://des.nh.gov/organization/divisions/air/tsb/ams/aqmdp/index.htm>

NHDES reports air pollution concentrations measured at these monitoring stations in real time on its website.<sup>14</sup> The data is also reported to EPA, which in turn displays it on its nationwide AirNow website<sup>15</sup>.

## 4.2 Air Quality Index

Monitored data may be reported in different units, such as parts per billion or micrograms per cubic meter, depending on the pollutant. At times, one pollutant will be higher than another relative to their NAAQS threshold. To provide a simplified overall picture of air quality at any given time, EPA has developed a multi-pollutant classification system called the Air Quality Index (AQI). When displaying air quality data on their respective websites, EPA and NHDES color code air quality levels based on the AQI, which assists the public in understanding the health-related impacts associated with measured air quality levels.

The AQI scale starts at zero for perfectly clean air and increases to 100 to indicate that one or more air pollutants have reached the health-based air quality standard. The scale continues above 100 to indicate the degree to which air pollution exceeds the standards. Lower AQI scores represent better air quality. Table 4.1 describes each of the AQI categories. The color coding shown in this table is the same as that used on the EPA and NHDES websites.

**Table 4.1: Air Quality Index Levels of Health Concern**

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
<b>Good</b>	<b>0 – 50</b>	<b>Air quality is considered satisfactory and air pollution poses little or no risk.</b>
<b>Moderate</b>	<b>51 - 100</b>	<b>Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.</b>
<b>Unhealthy for Sensitive Groups</b>	<b>101 - 150</b>	<b>Members of sensitive groups may experience health effects. The general public is not likely to be affected.</b>
<b>Unhealthy</b>	<b>151 - 200</b>	<b>Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.</b>
<b>Very Unhealthy</b>	<b>201 - 300</b>	<b>Health warnings of emergency conditions. The entire population is more likely to be affected.</b>
<b>Hazardous</b>	<b>301 - 500</b>	<b>Health alert: everyone may experience more serious health effects</b>

<sup>14</sup> View real time air quality data for New Hampshire at [www.airquality.nh.gov](http://www.airquality.nh.gov).

<sup>15</sup> Nationwide air quality information is available on AirNow: [www.airnow.gov](http://www.airnow.gov).

When the AQI level is “good,” it is expected that the general population will experience no symptoms due to air quality. When air pollution increases into the “moderate” level, some extremely sensitive individuals may start to experience health symptoms. Sensitive individuals, such as children, the elderly, and people with respiratory disease, may begin to experience symptoms when AQI levels reach “unhealthy for sensitive groups (USG),” and the general population could experience symptoms when “unhealthy” levels are reached. Although the AQI in other parts of the country and the world can reach the “Very Unhealthy” and “Hazardous” levels due to general air pollution, it is very unlikely that the AQI in New Hampshire would reach these levels. If these levels were to occur in New Hampshire, they would most likely be due to a very discrete and localized event, such as a forest fire, and not due to generalized air pollution.

NHDES keeps track of air pollution emissions and trends on a daily basis, and issues daily forecasts of air quality on its website<sup>16</sup>. These forecasts use the AQI scale to more effectively convey the appropriate health message to the public. When air quality is expected to reach unhealthy levels (USG or above), NHDES declares an “Air Quality Action Day,” urging people to take precautions to protect their health and to take steps to reduce air pollution.

**Key Point:** The Air Quality Index provides a simple, color-coded, multi-pollutant scale for describing air quality levels. Lower values represent cleaner air. When air quality is expected to reach levels of Unhealthy for Sensitive Groups or higher, NHDES alerts the public by calling an Air Quality Action Day. Real-time air quality data and forecasts for New Hampshire can be viewed at: <https://www2.des.state.nh.us/airdata/>

### **4.3 Seasonality of Criteria Pollutants**

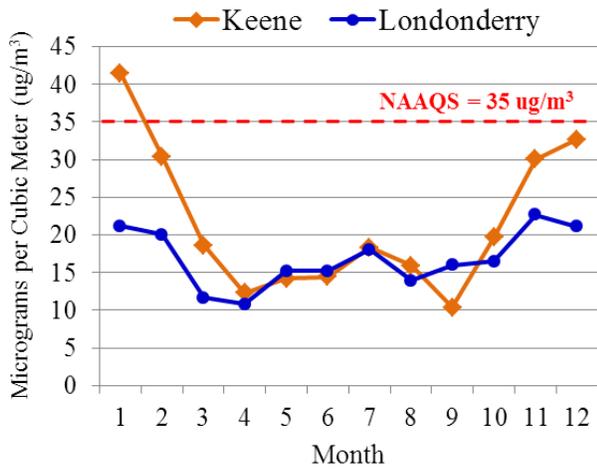
Weather is a major factor affecting air pollution in New Hampshire. Air pollutant emissions and dispersion are influenced by heating and electrical demands along with seasonal changes in wind flows, temperatures and the sun’s energy. As a result, air pollution concentrations change seasonally, meaning that each of the criteria pollutants have certain times of year when their concentrations are generally at their highest. This phenomenon is described further in the paragraphs below.

During the cold winter months, heating homes and businesses with oil, coal and wood can cause increased levels of fine particulate matter (PM<sub>2.5</sub>, Figure 4.2 and PM<sub>10</sub>, Figure 4.3), carbon monoxide (CO, Figure 4.4), nitrogen dioxide (NO<sub>2</sub>, Figure 4.5) and sulfur dioxide (SO<sub>2</sub>, Figure 4.6). Winter winds usually come from a westerly or northwesterly direction, bringing in a relatively clean air mass from more rural northern areas. This generally indicates that wintertime increases in PM<sub>2.5</sub> and other pollutants are mostly due to local emissions, rather than general regional pollution.

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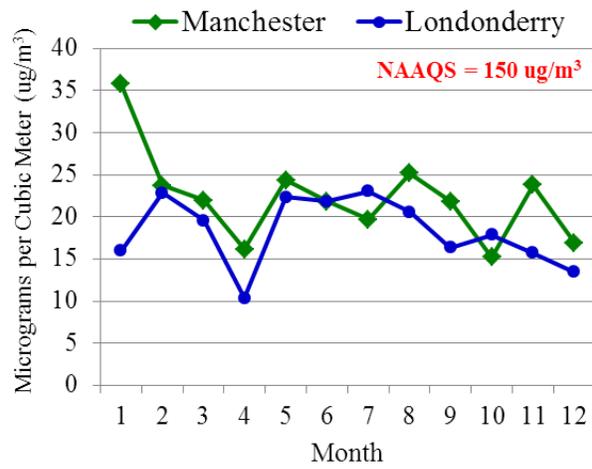
<sup>16</sup> NHDES posts daily air pollution forecasts at [http://www2.des.state.nh.us/airdata/air\\_quality\\_forecast.asp](http://www2.des.state.nh.us/airdata/air_quality_forecast.asp).

**Figure 4.2: Average Monthly Maximum 24-Hour PM<sub>2.5</sub>, Londonderry/Keene**



Based on 2011, 2012 and 2013 data.  
Source: NHDES

**Figure 4.3: Average Monthly Maximum 24-Hour PM<sub>10</sub>, Manchester/Londonderry**



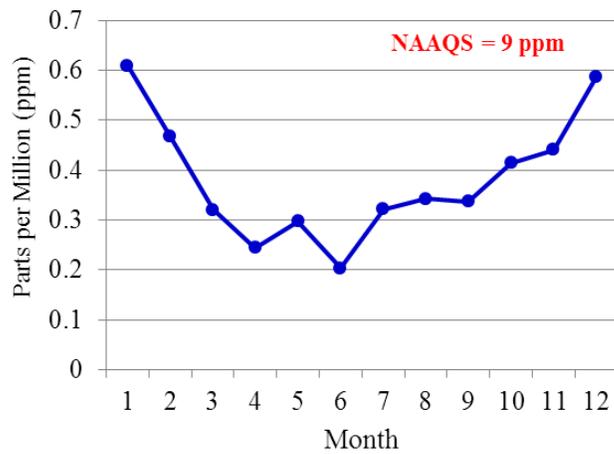
Based on 2011 and 2012 data for Londonderry and 2007, 2009 and 2010 data for Manchester.

**PM<sub>2.5</sub>** – Figure 4.2 shows the difference in monthly patterns of average maximum PM<sub>2.5</sub> levels between Londonderry and Keene. In Londonderry, PM<sub>2.5</sub> is fairly constant year round, being similarly affected by regional transport in summer and heating in winter. In Keene, PM<sub>2.5</sub> reaches much higher concentrations in winter. This occurs because Keene has a dense population of homes that heat with wood. In addition, Keene is situated in a valley where the air can become stagnant and pollution can build up, particularly at night. The localized effect of residential woodstoves in the Keene valley leads to distinctly high concentrations of PM<sub>2.5</sub> in the winter compared to the summer (this is discussed further in Section 5).

**PM<sub>10</sub>** – PM<sub>10</sub> is also a component of wood smoke, but dust from construction and agricultural activity is an even larger component. These and other emissions sources can produce PM<sub>10</sub> year round (Figure 4.3). Because PM<sub>10</sub> particles are larger and heavier, they tend to fall to the ground more quickly than smaller particles. For this reason, PM<sub>10</sub> concentrations tend to be highest close to the emissions source.

**CO** – CO results from incomplete combustion of fuels, whether from gasoline burned in cars or fuels burned for heat. In winter, cold temperatures can make combustion less efficient. When this is combined with stagnant weather patterns, local CO concentrations can increase much like PM<sub>2.5</sub>. In urban and residential locations, such as Londonderry, home heating can add a significant amount of CO emissions. As a result, wintertime increases in measured CO concentrations are evident (Figure 4.4).

**Figure 4.4: Average Monthly Maximum 8-Hour CO, Londonderry**



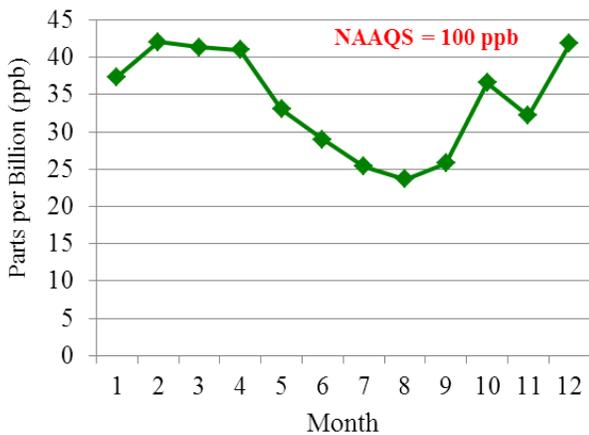
Based on 2011, 2012 and 2013 data.

Source: NHDES

**NO<sub>2</sub>** – NO<sub>2</sub> concentrations also tend to be higher in winter (Figure 4.5). Although NO<sub>x</sub> is emitted from residential heating, this is not entirely the reason for higher wintertime NO<sub>2</sub> concentrations. In the heat and sunlight of summer, NO<sub>2</sub> is consumed in chemical reactions and, along with other pollutants, is converted to ozone (see the discussion on ozone formation in Section 2.1.4). NO<sub>2</sub> is not consumed as readily in colder weather and can therefore be more prevalent in winter.

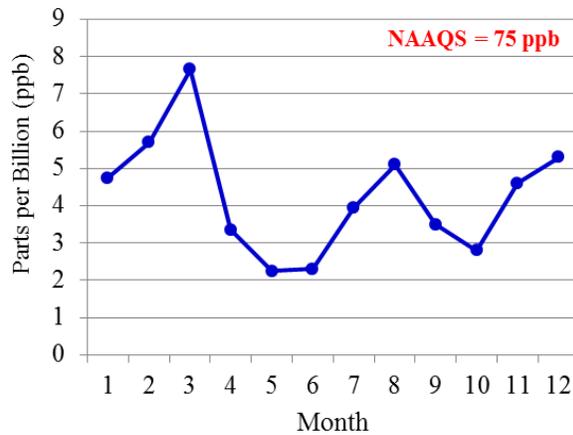
**SO<sub>2</sub>** – Although background SO<sub>2</sub> is highest in the winter, large local sources can cause high SO<sub>2</sub> concentrations any time of year (Figure 4.6). In the Northeast, background SO<sub>2</sub> is mostly caused by residential heating (with oil and coal) during cold weather. Summertime peaks in SO<sub>2</sub> usually vary by location and are driven by emissions of nearby (oil and coal) power plants. Emissions from these power plants are greatest during the summer in response to increased electrical demand for uses such as air conditioning. Starting in 2018, the sulfur content of fuel oils will be reduced, which should further reduce state-wide SO<sub>2</sub> emissions.

**Figure 4.5: Average Monthly Maximum 1-Hour NO<sub>2</sub>, Manchester**



Based on 2006, 2007 and 2008 data.  
Source: NHDES

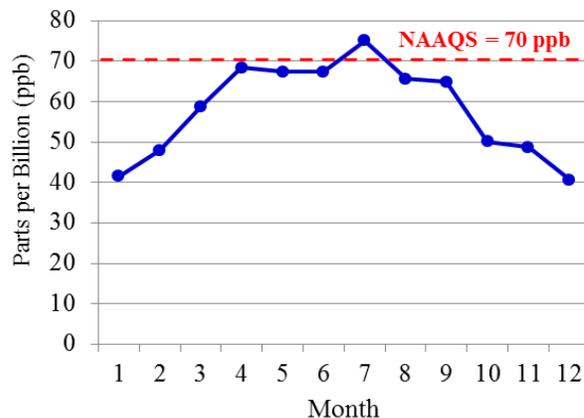
**Figure 4.6: Average Monthly Maximum 1-Hour SO<sub>2</sub>, Londonderry**



Based on 2012 and 2013 data.  
Source: NHDES

**O<sub>3</sub>** – As described earlier, winter winds often come from the west or northwest, usually bringing a relatively clean regional air mass. In the summer, however, winds often come from the south and southwest, passing over regions with high emissions from power plants, major highways and populated metropolitan areas such as Washington D.C., New York City and Boston. As the wind moves air pollution from these upwind locations toward New Hampshire, chemical reactions create ozone, secondary PM<sub>2.5</sub> (see Section 2.1.5 for a discussion of “secondary” PM<sub>2.5</sub>) and atmospheric deposition (Section 6). The hot, sunny weather and prevailing southwesterly wind patterns combine to transport air pollution from upwind areas and cause peak ozone concentrations in New Hampshire during the summer (Figure 4.7). Particulate matter levels can also climb during the summer (Figures 4.2 and 4.3), brought in on the same winds that carry ozone.

**Figure 4.7: Average Monthly Maximum 8-Hour Ozone, Londonderry**

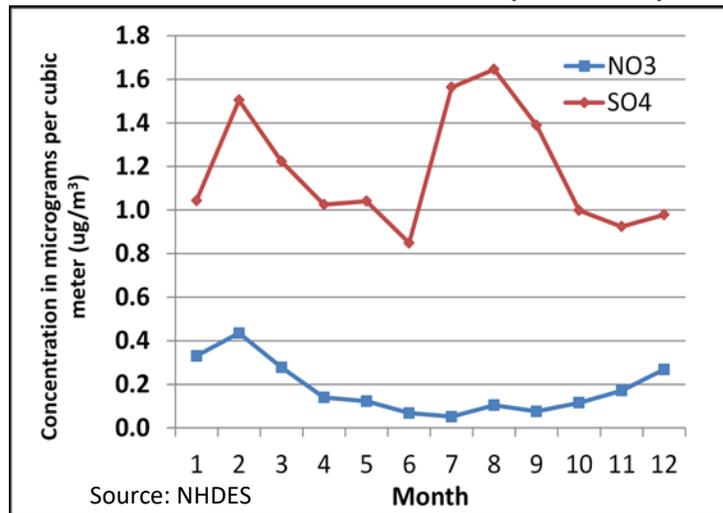


Based on 2011, 2012 and 2013 data.  
Source: NHDES

Some of the highest ozone concentrations in the state have been measured in spring and summer on the summit of Mount Washington (6,289 feet above sea level). Air pollution at high elevations can be an indicator of air pollution traveling to New Hampshire from distant places (Section 7.2). When ozone and its precursors rise to higher levels of the atmosphere, there are no buildings or other obstacles to interrupt their travel. Further, ozone breaks down more slowly at higher altitudes than at the surface, and stronger sunlight is available to increase the rate of its formation. Under these conditions, ozone and its precursors can travel long distances to reach the mountain summits of New Hampshire.

**Sulfates (SO<sub>4</sub>) and Nitrates (NO<sub>3</sub>)** – SO<sub>2</sub> and NO<sub>x</sub> emissions can combine with ammonia leading to the formation of ammonium sulfate and ammonium nitrate particles, a component of PM<sub>2.5</sub>. These pollutants are of special interest in pristine areas because they can also impair visibility (Section 2.3) and deposit to the ground and waterways, affecting the health of the ecosystem. In New Hampshire, sulfates, nitrates and other visibility impairing air pollutants are monitored and recorded near the Great Gulf Class I area, adjacent to Mt. Washington. Much like SO<sub>2</sub>, sulfate concentrations are highest during the summer and, like NO<sub>2</sub>, nitrate concentrations are greatest during winter (Figure 4.8).

**Figure 4.8: Average Monthly Patterns for Nitrates and Sulfates at the Great Gulf Class I Area (2011-2015)**



**Lead** – Recent data for lead is not available for New Hampshire locations. However, because lead is an inert air pollutant and because it is associated with very specific activities such as aviation gasoline usage, it does not display any particular seasonal pattern.

**Key Point:** Air quality varies significantly by season. Some pollutants are highest in winter; for instance, fine particle pollution increases in winter primarily because of the burning of heating fuels. Other pollutants, like ozone, are highest in summer, when electric power is in greatest demand and the heat of summer promotes chemical reactions among pollutants.

#### 4.4 Air Quality Ratings by County, 2014-2016

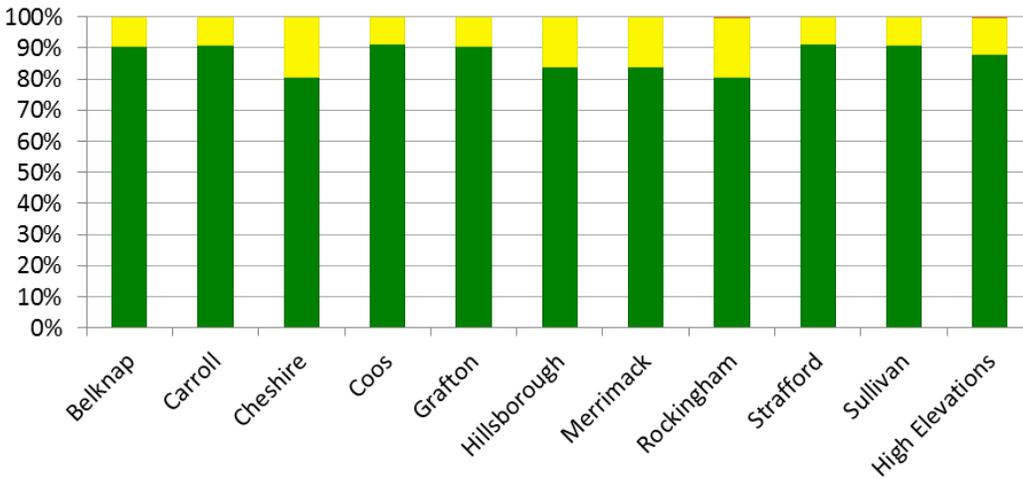
As mentioned in Section 4.2, the AQI was developed to be an easy-to-understand multi-pollutant indicator of air quality. This section discusses recent air pollution patterns for New Hampshire counties using the AQI ratings of good, moderate and unhealthy for sensitive populations (USG).

Throughout New Hampshire, the AQI is most often good or moderate and only reaches USG on isolated occasions. Although the AQI is a multi-pollutant indicator, it is primarily driven in New Hampshire by two air pollutants, ozone and fine particulate matter (PM<sub>2.5</sub>). The AQI for SO<sub>2</sub> can be impacted on a very local basis in the vicinity of power plants or other large, discrete sources of SO<sub>2</sub> emissions. However, recent monitoring data has demonstrated that SO<sub>2</sub> rarely exceeds the good range in New Hampshire.

From 2012 to 2014, all monitoring stations in New Hampshire recorded good air quality during at least 75% of the days. Air quality in the USG range was recorded on no more than two days, with the remainder of the days in the moderate range (Figure 4.9). During this time, the AQI was in the good range for nearly 90% of days in Belknap, Carroll, Coos, Grafton and Sullivan Counties. In the last three years, no days have reached USG in these five counties.

Hillsborough, Merrimack and Rockingham Counties had between 77% and 82% good days and a total of four USG days. Strafford County and high elevation areas (areas above 3,000 feet in Carroll, Coos and Grafton Counties) saw between 85% and 90% good air quality days. The high elevation areas experienced a total of four spring and summer season USG days due to long range ozone transport (high elevation ozone transport is discussed above in Section 4.3 and later in Section 7.2). Cheshire County experienced 78% good air quality days and had three wintertime USG days (with the remainder being moderate).

**Figure 4.9: Annual Air Quality Ratings by County, 2014-2016 (Percent of Days)**



Source: NHDES

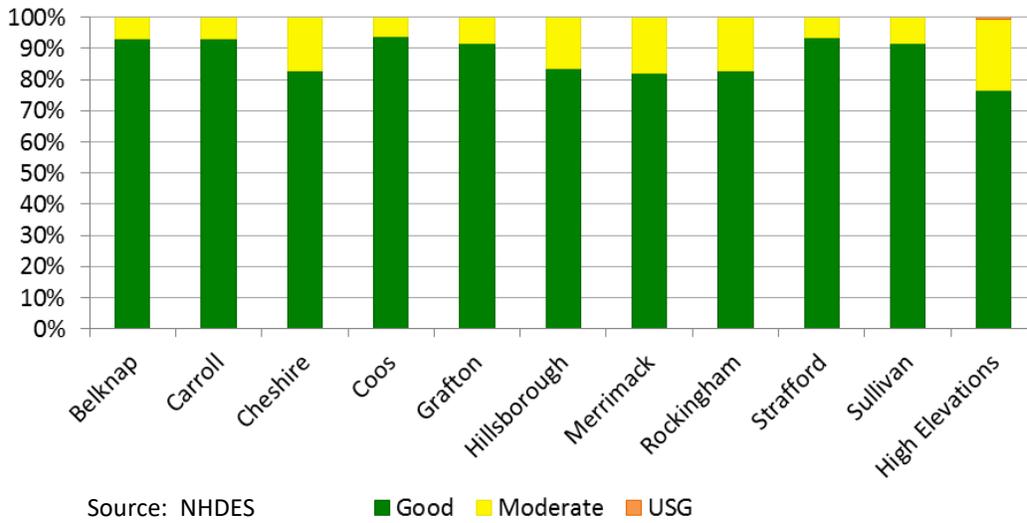
■ Good ■ Moderate ■ USG

Figures 4.10 through 4.13 illustrate seasonal air quality trends for each county in New Hampshire. Considerable variation in air pollution patterns occur because heating and wind patterns play a large role in New Hampshire’s air quality (Section 4.3).

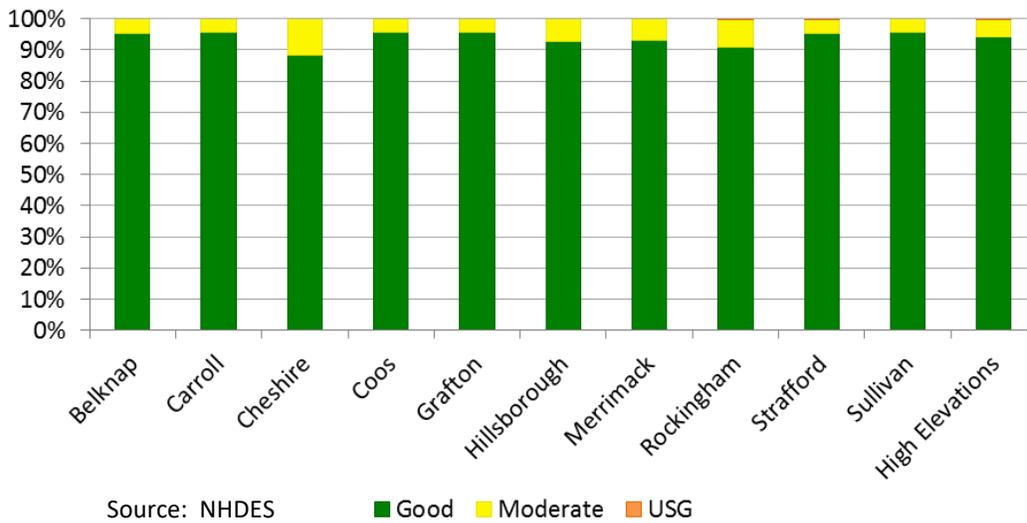
**Spring and Fall**

Air quality during spring and fall is very consistent throughout the state and presents some of the best air quality of the year (Figures 4.10 and 4.11). During these seasons, at least 80% of days with good air quality can normally be expected, and USG air quality days are uncommon. In spring and fall, residential heating is not at its full capacity and there is less need for extra energy generation for air conditioning. In addition, spring and fall wind patterns are usually more conducive to cleaner air in New Hampshire than those that occur during summer.

**Figure 4.10: Spring Air Quality Ratings by County, 2014-2016 (Percent of Days)**



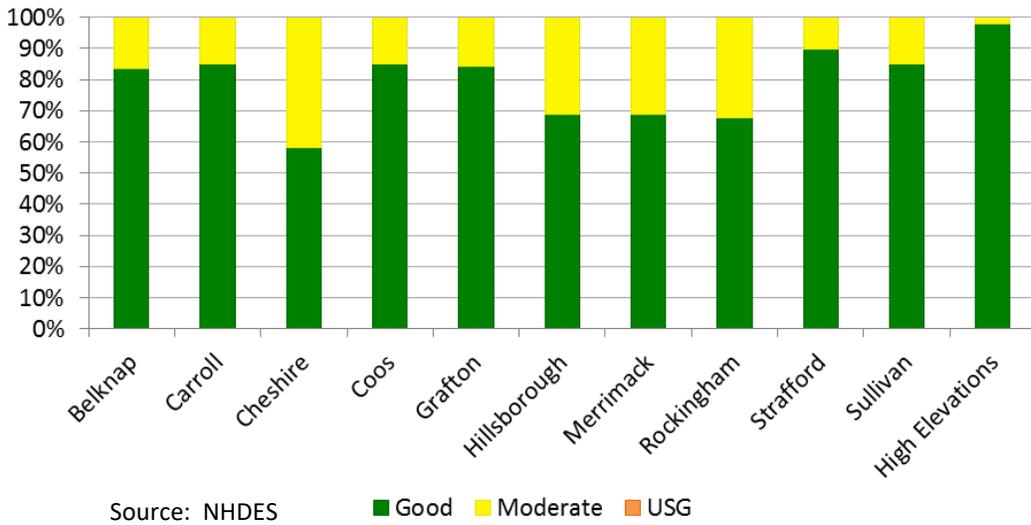
**Figure 4.11: Fall Air Quality Ratings by County, 2014-2016 (Percent of Days)**



Winter

As shown in Figure 4.12, winter had more days with moderate air quality than summer over the last three years in New Hampshire. During the winter, residential wood heating in Keene drives the AQI for Cheshire County to a point where about one out of every two days experiences moderate air pollution or higher. Hillsborough, Merrimack and Rockingham counties experience about one in three winter days with air quality of moderate or higher. Other counties with representative monitors experience good air quality on at least 85% of winter days. However, it is not possible to place a monitor everywhere and there may be additional areas that, similar to Keene, experience a higher percentage of poor air quality due to localized wood smoke issues. Note that residential heating can cause localized impacts that are not reflected in the county-wide ratings.

**Figure 4.12: Winter Air Quality Ratings by County, 2014-2016 (Percent of Days)**



Summer

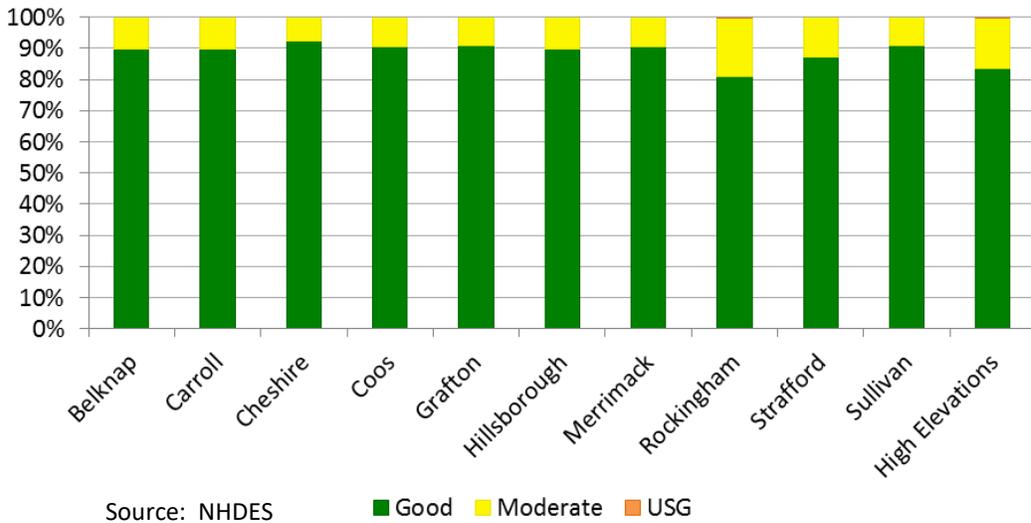
The summer AQI is dominated by ozone transported into the state. The southern counties see the most moderate AQI days (Figure 4.13).

During the summer, the areas most likely to experience moderate air quality or higher are the southern and southeastern counties of New Hampshire: Hillsborough, Merrimack, Rockingham and Strafford. These counties are more populated than northern parts of the state, and therefore have higher levels of localized emissions from motor vehicles and other residential and commercial activities. More significantly, however, these counties are the most directly downwind of air pollution transported from areas to the south and southwest of the state. These counties can experience moderate or higher air quality as often as every one in four days. They are also likely to experience at least one USG day during the summer. The remaining counties in New Hampshire have about 90% of days in the good range.

Monitors located at the summit of Mt. Washington and Pack Monadnock Mountains (High Elevations) demonstrate a special transport case which is discussed further in Section 7.2. High

elevation areas, above 3,000 feet in elevation, experience their worst air quality during the summer or late spring with about three out of every 10 days being moderate or higher. High elevation areas typically experience at least one day with USG air quality during the spring and summer season. The pollution at high elevations can come from hundreds or even thousands of miles away. At high altitudes, ozone and its precursor pollutants are able to travel unimpeded and build up over long distances, reaching the mountain summits at high concentrations (see Section 4.3).

**Figure 4.13: Summer Air Quality Ratings by County, 2014-2016 (Percent of Days)**



**Key Point:** New Hampshire air quality reaches the air quality index of unhealthy for sensitive groups only a few days per year. The highest AQI tends to occur most often in the southern counties because these areas are the most populated and closest to out-of-state emission sources.

#### 4.5 Air Pollution Trends

Air pollution trends in New Hampshire show that air quality has improved significantly over recent decades. In the past, measured CO, ozone and SO<sub>2</sub> concentrations were substantially higher in the state than they are now. Investments made to improve air quality have paid off in the form of a cleaner environment and healthier citizens, with fewer people seeking health care treatment for air quality related concerns. Quality of life in New Hampshire has improved in that lakes and rivers are cleaner and the view of scenic vistas is clearer.

EPA and state air agencies compile an emissions inventory for criteria air pollutants every three years. An emissions inventory is an estimate and accounting of the mass (e.g. tons) of pollutants emitted over a given time period (usually one year). The following sections present emissions inventory estimates for the criteria pollutants from 2002, when higher quality emissions data became available, to 2014, the most recently available triennial inventory. Air toxics emissions trends are shown beginning with the year 1988, when the national air toxics inventory began.

Emission sources of air pollutants are often categorized as on-road mobile, non-road mobile, area, or point sources:

- **On-Road Mobile** – vehicles driven on the road – e.g., cars, trucks, buses, motorcycles.
- **Non-Road Mobile** – vehicles or mobile equipment typically operated off of public roadways – e.g., lawn mowers and other lawn/garden equipment; recreational vehicles such as snowmobiles; agricultural equipment; construction equipment; boats.
- **Area** – small-scale but widespread sources – e.g., wood stoves or other residential heaters; cleaning products; paint; dry cleaners; gas stations; agricultural activities such as tilling; landfills; dust from unpaved roads.
- **Point** – large stationary sources – e.g., power plants, municipal waste incinerators.

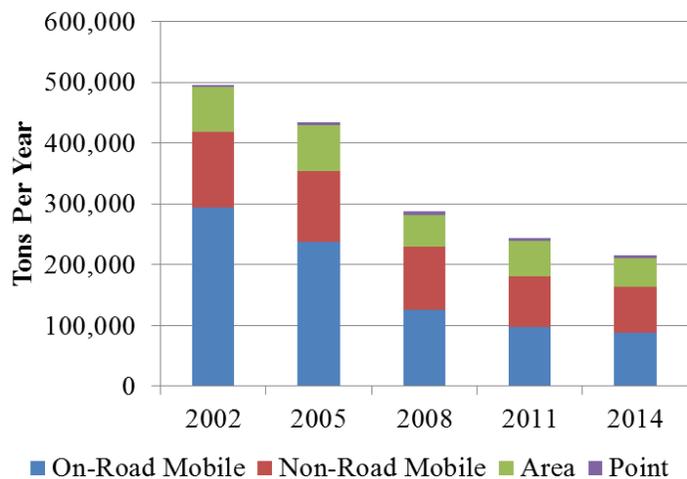
The following sections also discuss statewide trends in airborne concentrations of these pollutants based on air pollution monitoring, which officially began in New Hampshire in 1970. Pollutant concentrations describe the amount of a pollutant measured in a parcel of air. As described earlier in Section 3.1, pollutant concentrations are typically expressed in units of mass per volume of air, such as parts per million (ppm) or micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). This differs from pollutant emissions, which describe the amount (i.e. mass) of a pollutant released from a source before it is able to disperse or react with other chemicals in the atmosphere. Emissions are usually expressed in units of mass per period of time, such as pounds per hour or tons per year. For chemically inert pollutants, there is generally a direct relationship between the raw amount emitted (i.e. emissions) and the amount measured in the ambient air (i.e. concentration) or deposited to the ground or water surfaces.

#### 4.5.1 Carbon Monoxide (CO)

**Emissions** – Mobile sources account for more than half of the state’s CO emissions. However, modern passenger cars are capable of emitting 90 percent less CO over their lifetimes than their uncontrolled counterparts of the 1960s. Much of this is due to the catalytic converter, first installed in new cars in 1975. With improvements in fuel economy, changes in gasoline composition, and more comprehensive vehicle inspections (Section 9.2), CO emissions from mobile sources in New Hampshire continue to decline (Figure 4.14) despite large increases in the number of vehicles on the road and the number of miles they travel.

**Monitored Concentrations** – From the 1970s through the early 1990s, the highest concentrations of CO could be found where cars and trucks traveled in largest numbers (Manchester and Nashua).

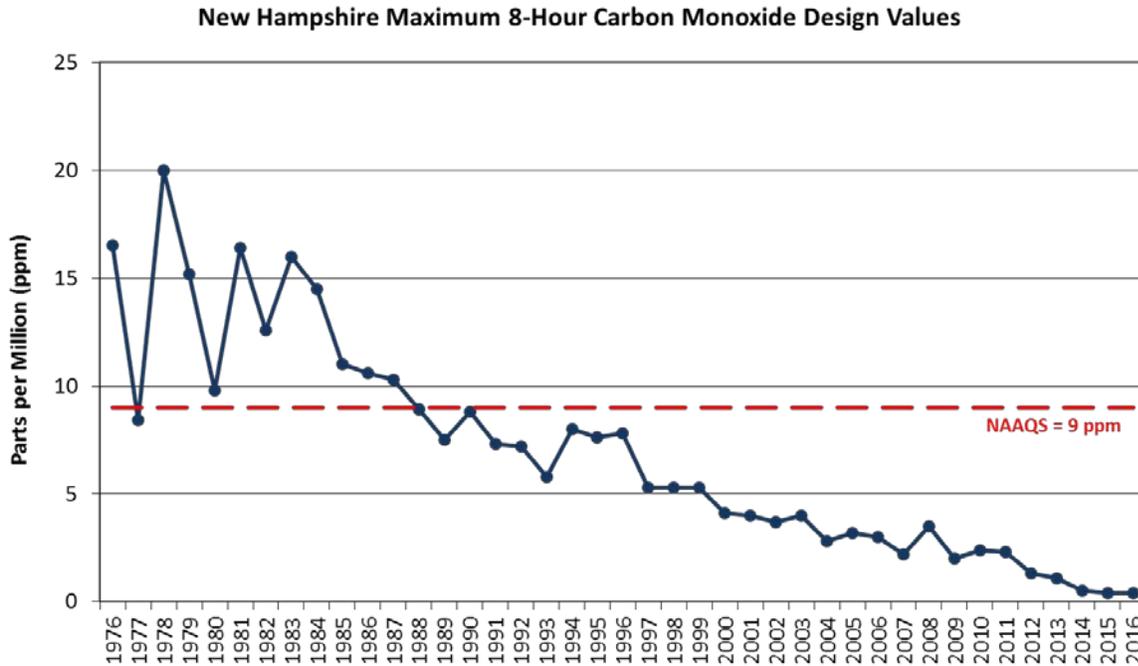
**Figure 4.14: CO Emission Trends, New Hampshire, Tons per Year**



Source: NHDES

Conditions throughout the state have improved significantly over the past 15 years. Today, all CO monitors in the region are recording CO concentrations well below the NAAQS (Figure 4.15).

**Figure 4.15: CO 8-Hour Trends, New Hampshire, 1976-2016**



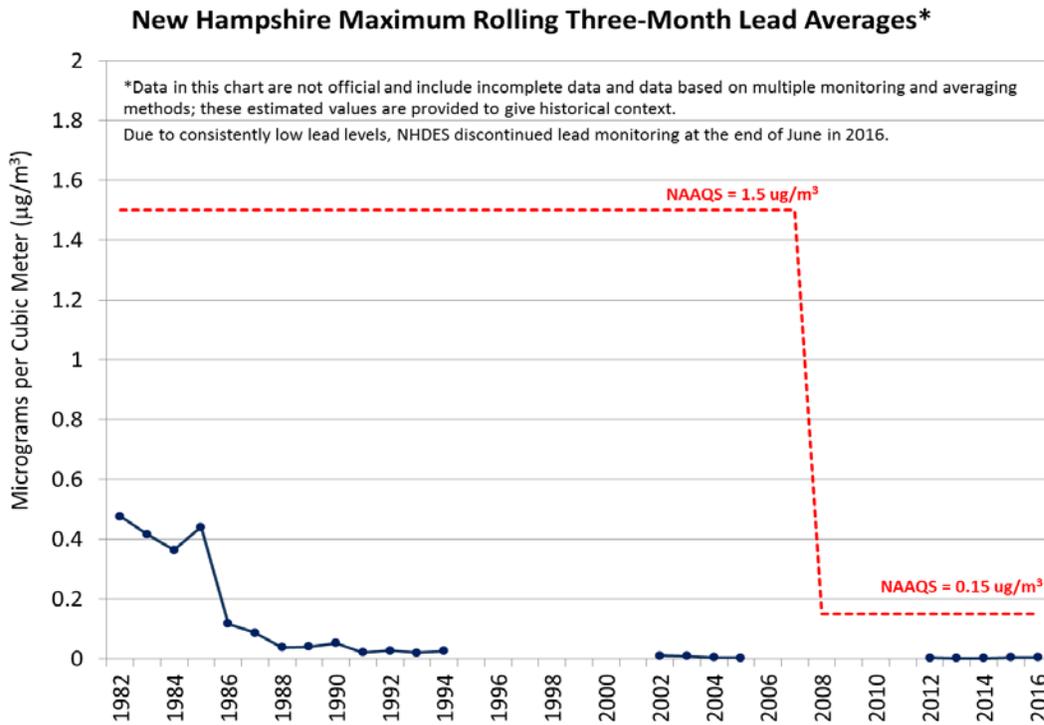
Source: NHDES

#### 4.5.2 Lead (Pb)

**Emissions** – Emissions of lead dropped nationwide when lead was removed from gasoline decades ago. Increased controls on incinerators and bans on burning construction or demolition materials that contain leaded paint have led to further decreases in lead emissions. However, coal burning, incinerator sources, and piston-powered aircraft (which still require a leaded fuel) continue to emit some lead into the air.

**Monitored Concentrations** – With lead removed from or largely controlled for major emission sources, atmospheric lead concentrations in New Hampshire are very low (Figure 4.16).

**Figure 4.16: Pb Trends, New Hampshire, 1982-2016**



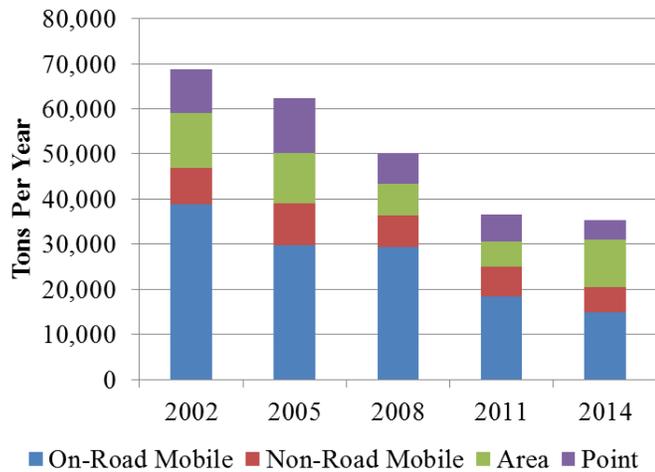
Source: NHDES

### 4.5.3 Nitrogen Dioxide (NO<sub>2</sub>)

**Emissions** – Recent decades have seen large decreases in nitrogen oxide (NO<sub>x</sub>) emissions (Figure 4.17). Cap and trade programs (Section 9.1), installation of emissions controls and more efficient operational practices have led to significant reductions in NO<sub>x</sub> from point sources. Mobile source NO<sub>x</sub> emissions have decreased significantly as well, but remain the largest source of NO<sub>x</sub> in New Hampshire.

Continued reductions in NO<sub>x</sub> emissions are important because NO<sub>x</sub> is chemically involved in the formation of pollutants such as ozone (Section 2.1.4) and fine particulate matter (Section 2.1.5), and it contributes to several air-quality-related phenomena including acid rain (Section 6.2), regional haze (Section 2.3), and nitrogen deposition (Section 6.3).

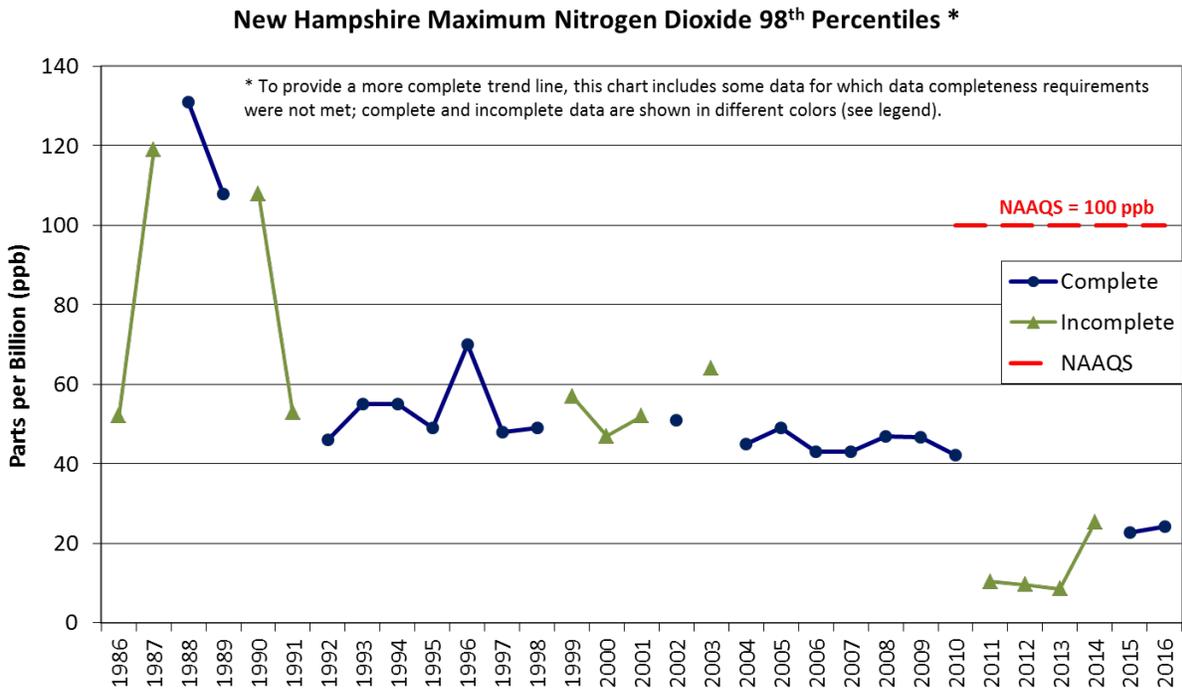
**Figure 4.17: NO<sub>x</sub> Emission Trends, New Hampshire, Tons per Year**



Source: NHDES

**Monitored Concentrations** – As emissions of NO<sub>x</sub> have decreased, so have concentrations of NO<sub>x</sub> in the atmosphere. Since NO<sub>2</sub> is the primary component of NO<sub>x</sub>, NO<sub>2</sub> concentrations have also dropped. Today in New Hampshire, NO<sub>2</sub> concentrations are well below the NAAQS (Figure 4.18).

**Figure 4.18: NO<sub>2</sub> 1-Hour Trends, New Hampshire, 1986-2016**



Source: NHDES

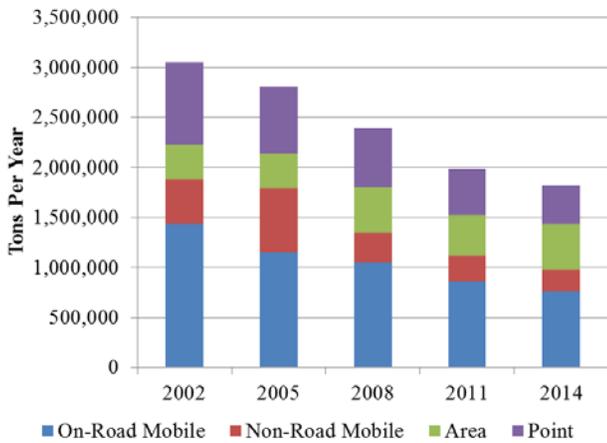
#### 4.5.4 Ozone (O<sub>3</sub>)

**Emissions** – Ozone is not directly emitted into the atmosphere, but is formed from the reaction of precursor pollutants, NO<sub>x</sub> and VOCs. These precursors often originate from regions to the south and southwest of New Hampshire and enter the state by long-range pollution transport (Section 7).

Because of transport, greater regional emissions of NO<sub>x</sub> and VOCs are most indicative of trends influencing ozone levels in New Hampshire. The geographic area of greatest focus is the Ozone Transport Region (OTR, see Figure 3.1 and Section 3.3). New Hampshire and the rest of the OTR have a successful track record for reducing NO<sub>x</sub> and VOC emissions, resulting in steady ozone decreases over the last decade (Figures 4.19, 4.20, and 4.21).

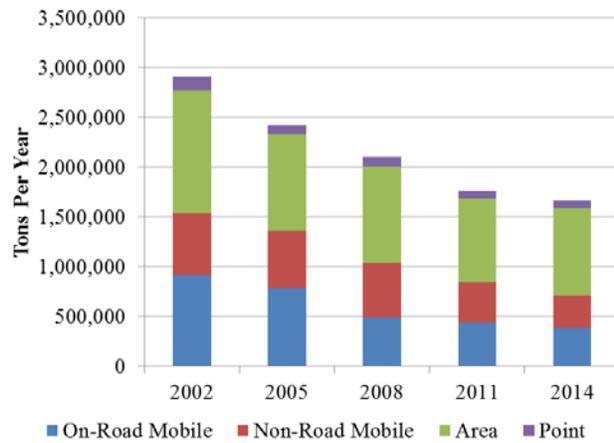
These trends are largely due to air pollution control measures designed to reduce ozone by targeting emissions of its precursor pollutants with consideration for the regional nature of ozone and ozone precursor transport. Examples include the Acid Rain Program, NO<sub>x</sub> budget programs, the Cross-State Air Pollution Rule, and Transportation Conformity (Section 9).

**Figure 4.19: NO<sub>x</sub> Emission Trends, Ozone Transport Region, Tons per Year**



Source: NHDES

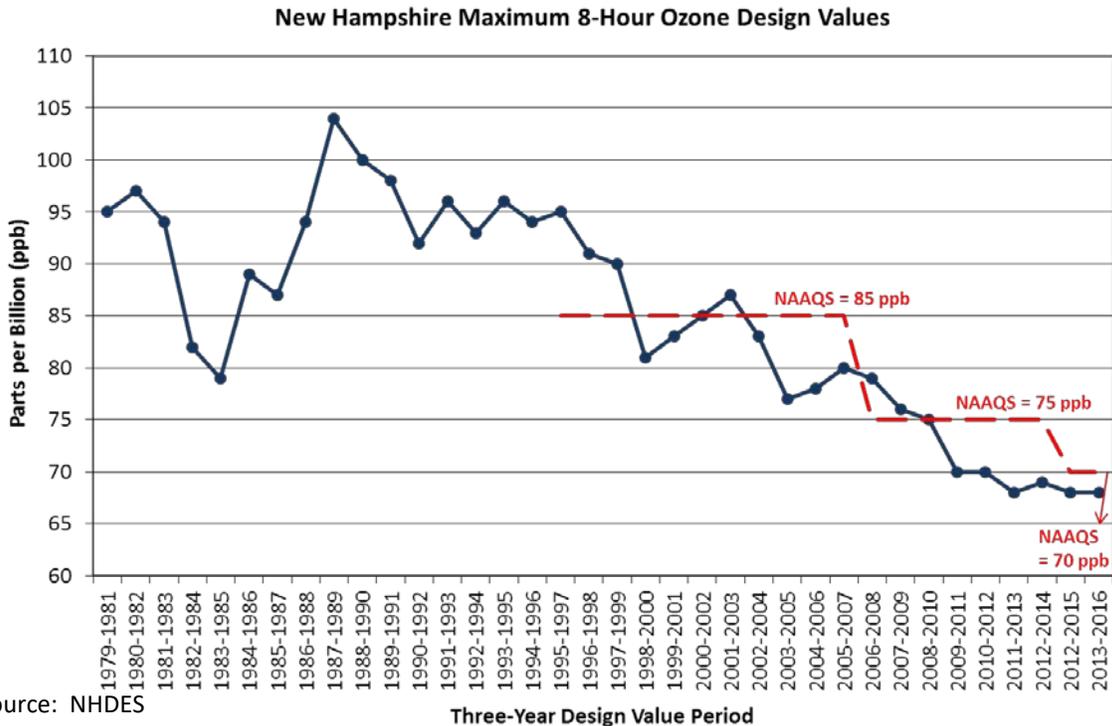
**Figure 4.20: Man-made VOC Emission Trends, Ozone Transport Region, Tons per Year**



Source: NHDES

**Monitored Concentrations** – With the lowering of NO<sub>x</sub> and VOC emissions, the concentration of ozone in New Hampshire has been steadily decreasing since the 1970s and is currently below the NAAQS (Figure 4.21) noting, however, the ozone NAAQS was lowered from 85 to 75 ppb in 2008 and then was further lowered from 75 ppb to 70 ppb in October 2015. Figure 4.21 also demonstrates how monitored ozone concentrations in parts of New Hampshire have hovered around the level of the new 70 ppb standard in recent years.

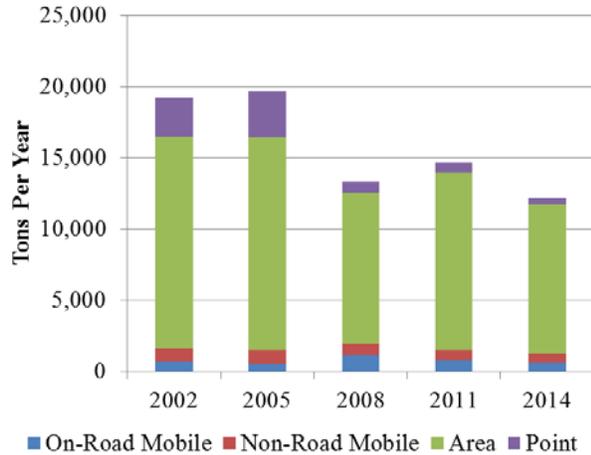
**Figure 4.21: Ozone 8-Hour Trends, New Hampshire, 1979-2016**



#### 4.5.5 Fine Particles (PM<sub>2.5</sub>)

**Emissions** – PM<sub>2.5</sub> emissions appear to decrease through 2008, and then increase in 2011 (Figure 4.22), but the 2011 inventory uses a different methodology to quantify PM<sub>2.5</sub> emissions than was used in prior years. Therefore, the true change in PM<sub>2.5</sub> emissions between 2008 and 2011 is uncertain. Nevertheless, emissions likely have been and will continue to gradually decrease as combustion techniques become more efficient. For instance, directly emitted PM<sub>2.5</sub> can be controlled from point sources with after-combustion technology.

**Figure 4.22: PM<sub>2.5</sub> Emission Trends, New Hampshire, Tons per Year**

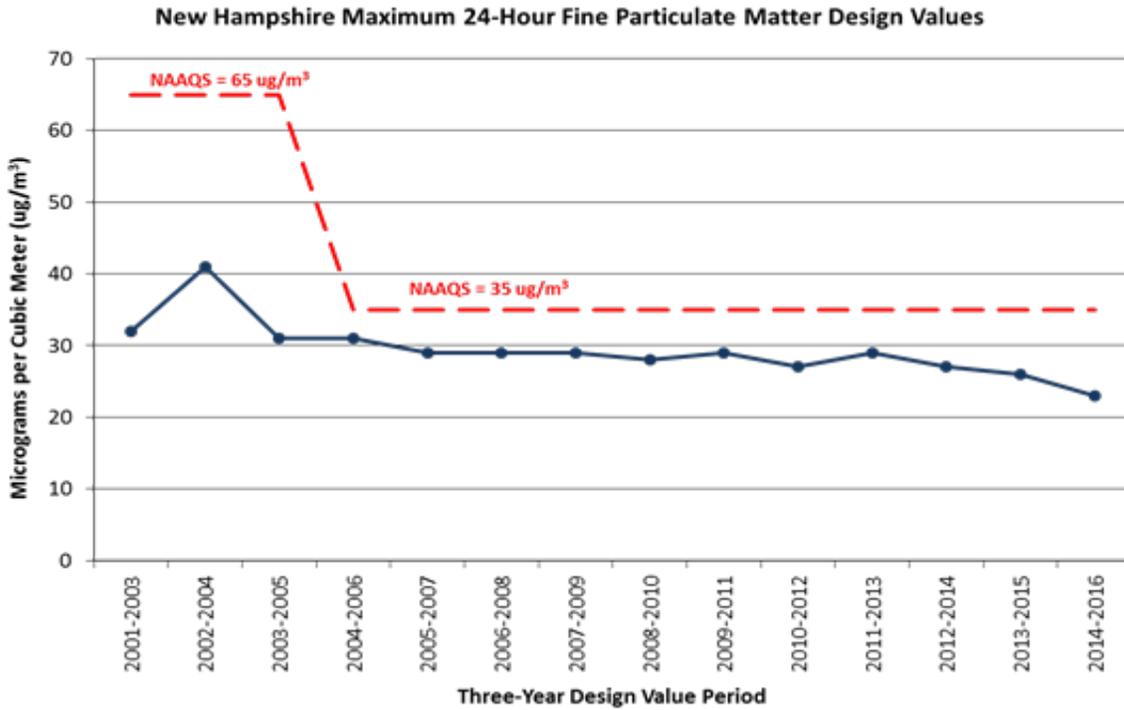


Source: NHDES

Controlling PM<sub>2.5</sub> emissions from residential wood heating, which is considered an area source for emissions inventory purposes, remains a challenge (Section 5), however new EPA-certified woodstoves are significantly cleaner than older woodstoves. As more of the older wood-burning units are replaced with newer models, PM<sub>2.5</sub> emissions from wood heating are expected to decline over time.

**Monitored Concentrations** – The concentration of PM<sub>2.5</sub> in the atmosphere results from directly emitted PM<sub>2.5</sub> and secondarily formed particles (e.g. SO<sub>2</sub> and NO<sub>x</sub> are precursors to PM<sub>2.5</sub>). Since these pollutants have experienced a slow decrease in emissions, airborne PM<sub>2.5</sub> concentrations have also decreased and remain below the NAAQS (Figure 4.23).

Figure 4.23: PM<sub>2.5</sub> 24-Hour Trends, New Hampshire, 2001-2016



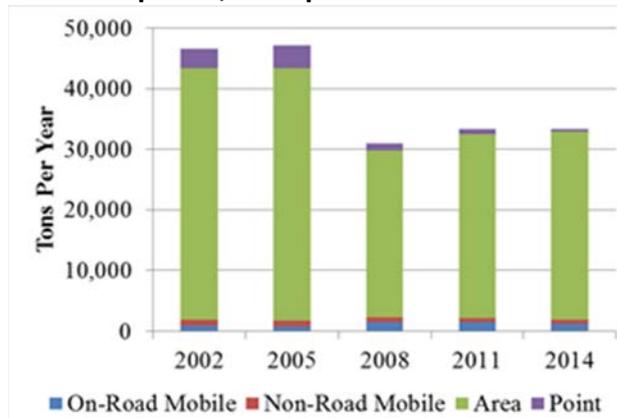
Source: NHDES 2017

#### 4.5.6 Coarse Particles (PM<sub>10</sub>)

**Emissions** – As with PM<sub>2.5</sub>, PM<sub>10</sub> emissions estimates have been influenced by a change in emissions inventory methodology in 2011. Emission controls and improved combustion practices have reduced PM<sub>10</sub> emissions from point sources (Figure 4.24). Area sources, which are varied and often difficult to regulate, have been somewhat variable over the years.

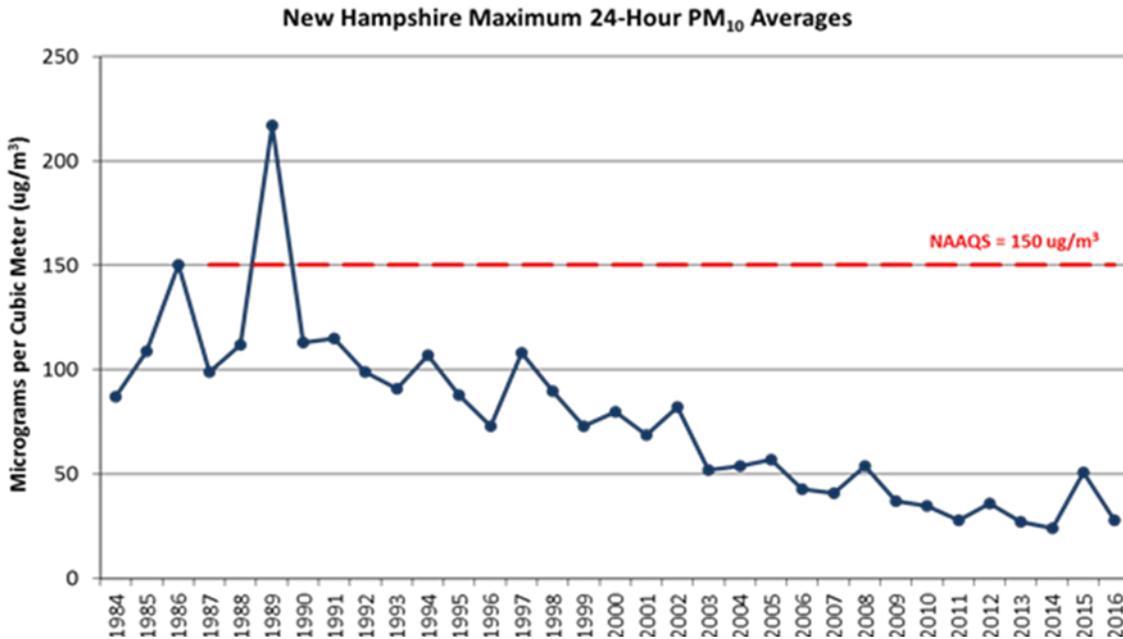
**Monitored Concentrations** – The overall trend in the concentration of PM<sub>10</sub> in the atmosphere continues downward and remains well below the NAAQS (Figure 4.25).

Figure 4.24: PM<sub>10</sub> Emission Trends, New Hampshire, Tons per Year



Source: NHDES

Figure 4.25: PM<sub>10</sub> 24-Hour Trends, New Hampshire, 1984-2016



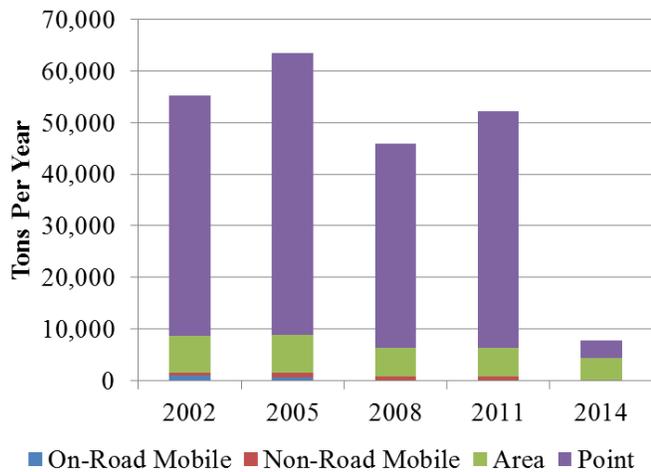
Source: NHDES

#### 4.5.7 Sulfur Dioxide (SO<sub>2</sub>)

**Emissions** – SO<sub>2</sub> emissions have decreased significantly over recent years (Figure 4.26). Point source regulations such as the Acid Rain Program, Cross-State Air Pollution Rule, and Regional Haze Rule have contributed to this trend (Section 9.1). SO<sub>2</sub> emission reductions not only benefit local areas, they help reduce secondary PM<sub>2.5</sub> formation, regional haze, and acid deposition over large regions.

Complying with New Hampshire Clean mercury reduction requirements (Section 9.1.7), the Merrimack Station power plant in Bow recently installed a scrubber to reduce mercury emissions, which has the added benefit of reducing SO<sub>2</sub> emissions by over 90%. Because the scrubber was installed in late 2011, a

Figure 4.26: SO<sub>2</sub> Emission Trends, New Hampshire, Tons per Year

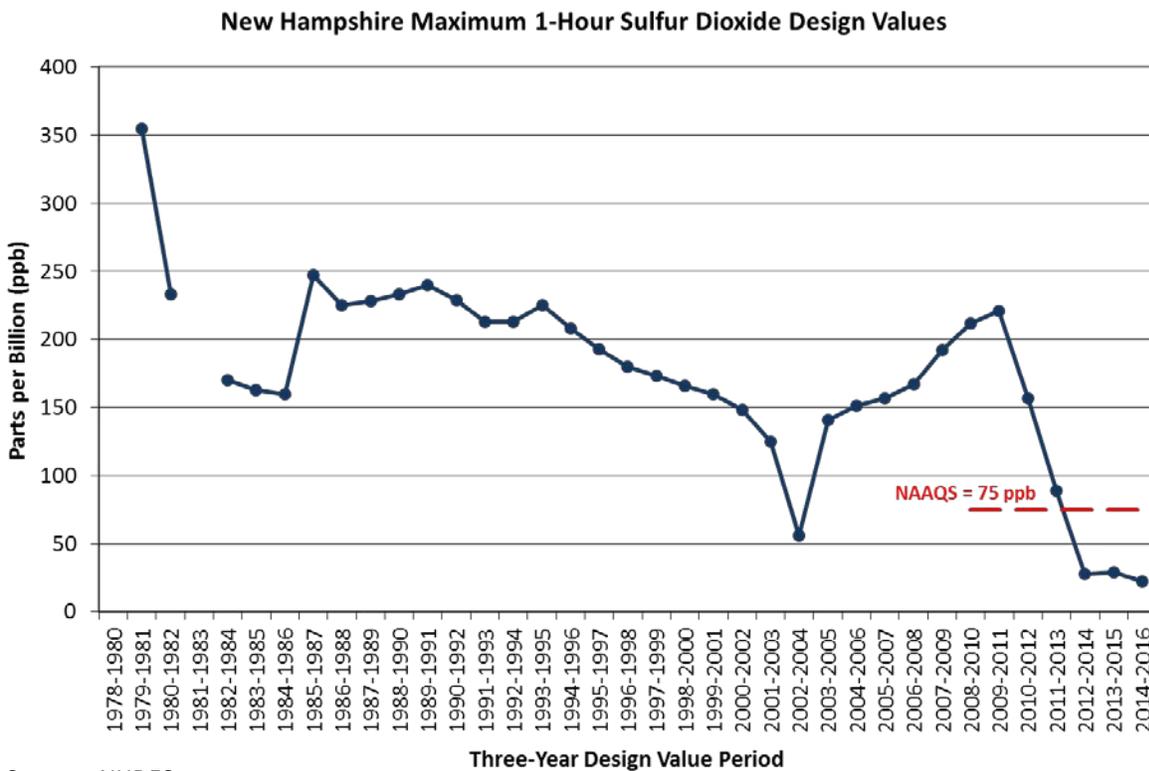


Source: NHDES

sharp downward trend can be seen in Figure 4.26. Substantial reductions in SO<sub>2</sub> emissions have been achieved since the scrubber became fully operational in 2012, and this trend is clearly evident for the 2014 triennial emissions inventory period.

**Monitored Concentrations** – SO<sub>2</sub> concentrations in New Hampshire have experienced very significant decreases since 1978, a reduction of over 90% (Figure 4.27). High SO<sub>2</sub> concentrations in the early 1980s were caused by paper mills in the northern counties, which are no longer in operation. Since the early 1980s, emissions from the Merrimack Station power plant have dominated the statewide trend. The 2003-2011 period of increasing concentrations corresponds to a relocation of the nearest monitoring station to the Merrimack power plant. The dramatic SO<sub>2</sub> drop in 2012 is the result of the initiation of scrubber controls at Merrimack Station, leading to the lowest statewide SO<sub>2</sub> levels in New Hampshire’s air monitoring history.

**Figure 4.27: SO<sub>2</sub> 1-Hour Trends, New Hampshire, 1978-2016**



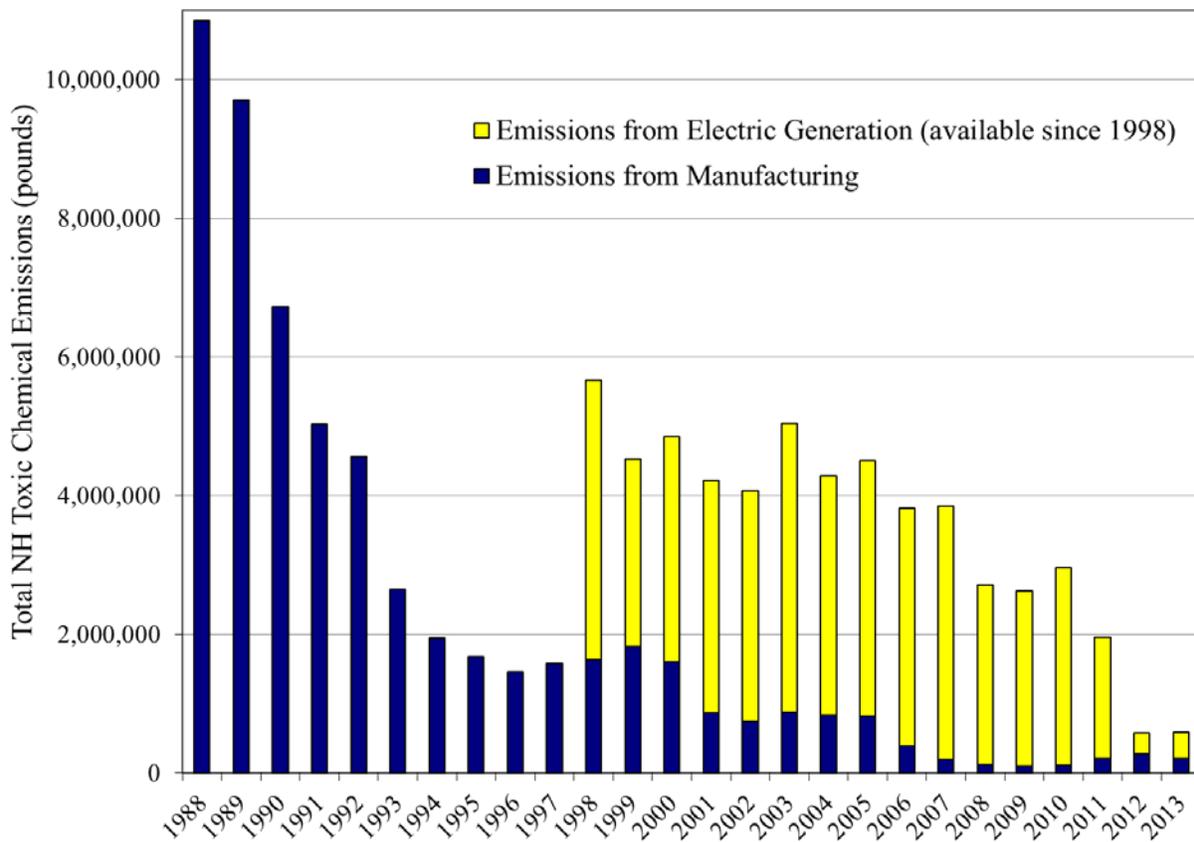
**4.5.8 Air Toxics**

**Emissions** – EPA’s Toxics Release Inventory (TRI) is the most comprehensive compendium of air toxics emissions from sources throughout the United States, including New Hampshire (Figure 4.28). Air toxics may come from a variety of sources, including cars and trucks, power plants, and even household cleaners. The TRI tracks two of the primary stationary sources of air toxics emissions: the manufacturing and electric generation sectors. A combination of emissions controls

and pollution prevention practices have been utilized at New Hampshire manufacturing sources through the early 2000s and beyond, leading to a steady decrease in emissions.

This downward trend steepened in more recent years as the economy took a downturn, resulting in less manufacturing activity and lower electricity demand. Most recently, manufacturing related emissions have rebounded slightly as the economy has recovered. However, emissions from electric generation dropped dramatically in 2012 due to the installation of the scrubber at the Merrimack Station power plant in Bow; this control technology effectively reduced the emissions of many air pollutants, including air toxics, from this major source in New Hampshire.

**Figure 4.28: Toxic Chemical Emissions from Electric Generation and Manufacturing in New Hampshire, Based on Data from EPA’s Toxic Release Inventory (TRI), 1988-2013**

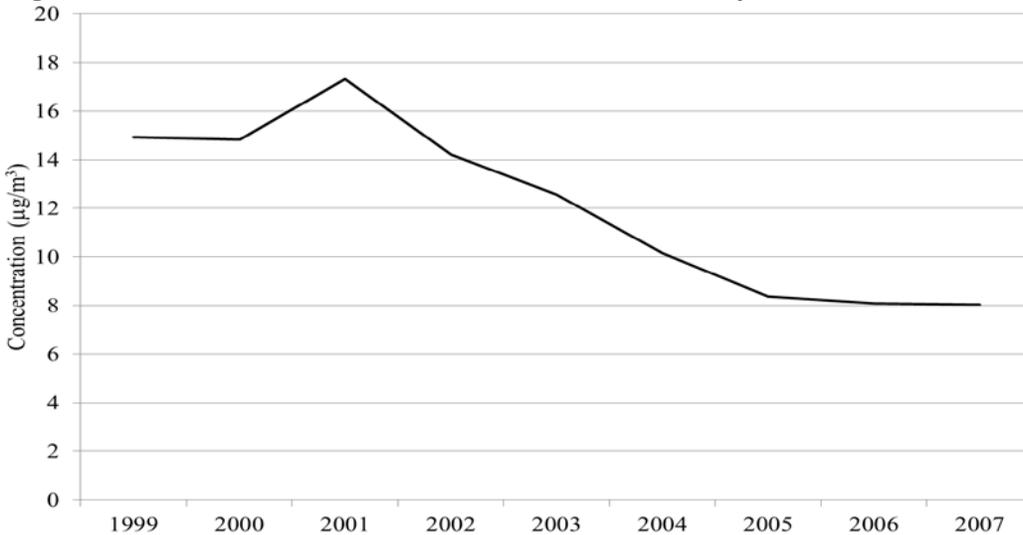


Note: Toxics Release Inventory (TRI) is a national summary of toxics emissions from various sources.

Data Source: USEPA, 2013

**Monitored Concentrations** – Ambient air monitoring of common toxic air pollutants in New Hampshire was made possible by an EPA grant. This funding enabled NHDES to monitor air concentrations of toxics from 1999 through 2007 at three locations: Claremont, Manchester, and Portsmouth (Figure 4.29). Consistent with emissions inventories, airborne concentrations of toxics at these monitoring sites decreased over this period.

**Figure 4.29: Trends for Common Air Toxics in New Hampshire, 1999-2007**



*Note: Annual values depicted here represent the average total air toxics concentration among all sampling days at all three monitoring locations (Claremont, Manchester, Portsmouth) for the most commonly detected toxic compounds: carbon tetrachloride, chloroform, chloromethane, benzene, dichloromethane, ethylbenzene, methyl ethyl ketone (MEK), methyl tert-butyl ether (MBTE), m&p-xylenes, o-xylene, styrene, toluene, and 1,1,1-trichloroethane.*

Source: NHDES

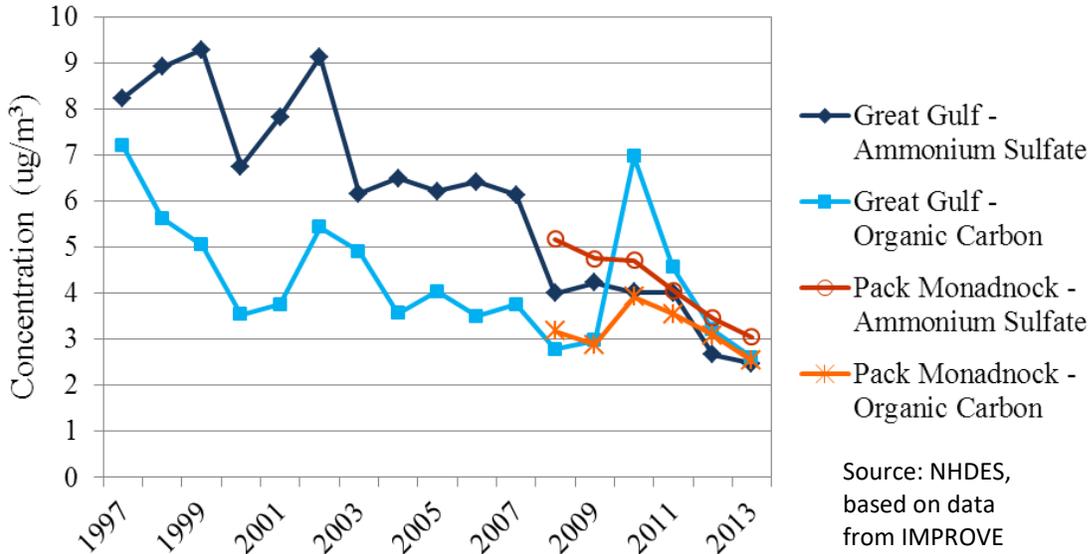
#### 4.5.9 Haze and Haze-Causing Pollutants

Haze occurs when airborne particles reduce visibility by scattering or absorbing light (Section 2.3). Haze can occur anywhere, but it is of special concern in ecologically sensitive and scenic areas, such as the Class I national parks and wilderness areas protected by the federal Regional Haze Rule (Section 9.4.3). The Interagency Monitoring of Protected Visual Environments (IMPROVE) program monitors visibility and visibility-reducing pollutants in several scenic areas throughout the country, including two in New Hampshire: Great Gulf Wilderness and the summit of Pack Monadnock in Miller State Park<sup>17</sup>.

**Haze-Causing Pollutants** – The most significant haze-causing pollutants in the Northeast are sulfates (e.g. ammonium sulfate) and organic carbon. These pollutants may originate far away from the areas where they ultimately degrade visibility. Figure 4.30 shows average concentrations of these two pollutants at New Hampshire IMPROVE sites on the haziest days of the year. Ammonium sulfate and organic carbon have been trending downward at these locations. Although organic carbon concentrations rose significantly in 2010, this may have been influenced by lower than usual data capture that year (thereby artificially increasing the average); concentrations in the years following have returned to levels consistent with the long-term trend.

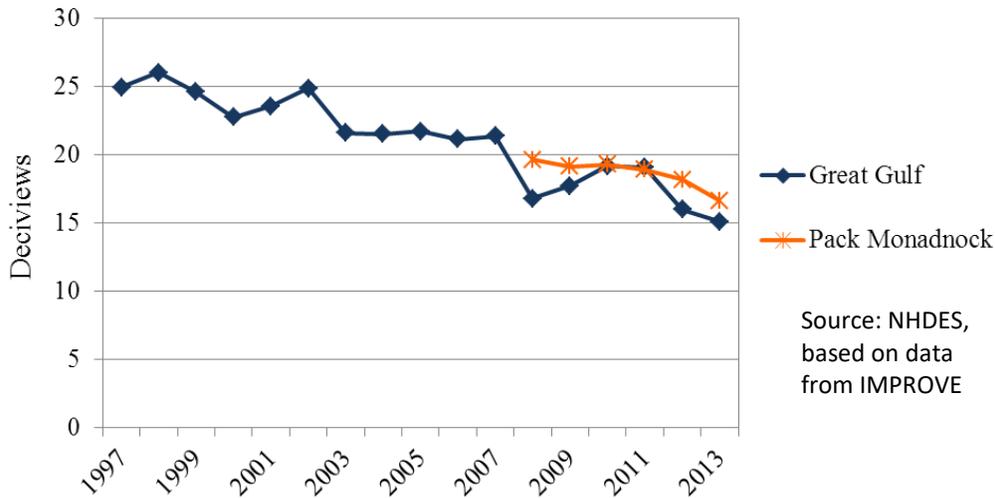
<sup>17</sup> IMPROVE monitoring began at a new site in Londonderry, NH, in 2011, but it is not included in this discussion of trends due to lack of long-term monitoring data.

**Figure 4.30: Ammonium Sulfate and Organic Carbon Trends on 20% Hazyest Days at Great Gulf Wilderness and Pack Monadnock IMPROVE Monitoring Sites, 1997-2013**



**Visibility** – The IMPROVE program directly measures visibility, which is quantified in units of deciviews. Larger deciview values equate to lower visibility (and therefore hazier conditions) and are generally expressed on a logarithmic scale. Shown in Figure 4.31, visibility has been steadily improving at Great Gulf Wilderness and on Pack Monadnock. The Regional Haze Rule provides location-specific visibility goals to be reached by the year 2064. For Great Gulf Wilderness, the 2064 goal for the 20% hazyest days is about 12 deciviews. The visibility measured in 2013 at Great Gulf is only a few deciviews above this goal, meaning that, should this trend continue, the visibility goal set forth in the Regional Haze Rule will be met well ahead of the 2064 target year.

**Figure 4.31: Visibility Trends at Great Gulf Wilderness and Pack Monadnock IMPROVE Monitoring Sites, 1997-2013**



**Key Point:** For the majority of monitored air pollutants, emissions and airborne concentrations in New Hampshire have been decreasing in recent decades.

## **4.6 Weather and Air Quality Trends**

As described in the above section, air quality in New Hampshire has improved over time for nearly every major pollutant. Much of this is due to reductions in emissions of these pollutants or their precursors. However, a discussion of air pollution trends is not complete without considering trends in weather patterns. As mentioned in Section 4.3, the weather significantly affects air pollution in New Hampshire.

Any given year can be warmer or colder and wetter or drier than others. Hotter weather often brings an increase in electrical demand, while very cold weather can create greater heating demands; these and other activities contribute to seasonal variations in air pollution emissions. Precipitation patterns are also an important consideration. Precipitation can act to clean the air in two ways, by: (1) lowering electrical demand for fans and air conditioning by keeping the temperature cooler; and (2) directly washing pollution out of the air.

To better understand air pollution trends, it is helpful to understand how the weather changes from year to year. Temperature, precipitation and dew point temperature trends at the National Weather Service station in Concord, New Hampshire, have been reliably collected since 1921 (Figures 4.32 and 4.33). The data show year-to-year variations as expected, but there are also small long-term temperature and precipitation increases. A rising dew point represents higher water vapor content in the air, which can lead to increased precipitation. Warmer air can hold more water vapor, allowing dew point temperatures to increase.

Annual average temperatures in Concord, NH have increased 1.0 degrees Fahrenheit (°F) over the approximately 90 years of available data. Annual average maximum and minimum temperatures have also increased by about 1.1°F and 0.4°F respectively. Annual maximum and minimum temperatures have also seen small increases. Long-term precipitation records show that annual precipitation in Concord has increased by approximately 1.9 inches since 1920.

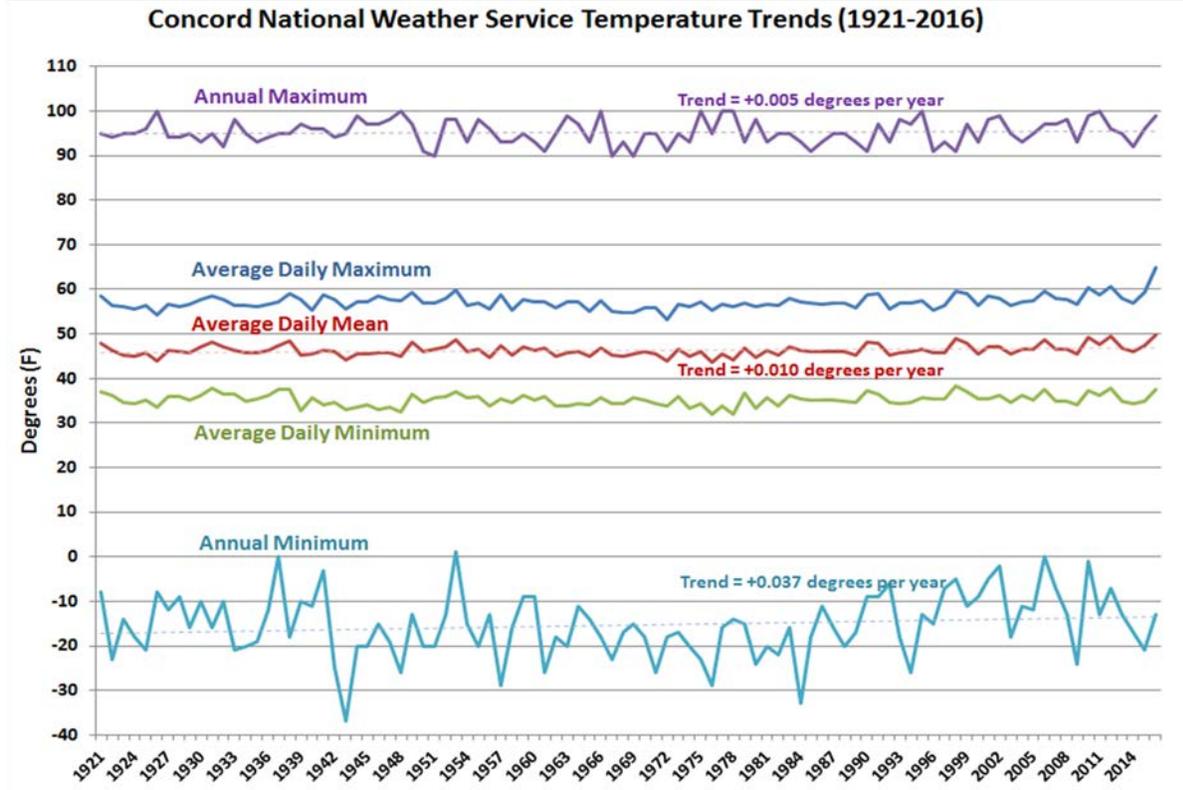
New Hampshire has seen air pollution improvements despite the trend of increasing temperatures. Further, the national population has nearly tripled since the early 1920's, and energy demand and vehicle miles traveled have increased dramatically. Again, improvements in pollution controls have outpaced societal growth. The increase in precipitation has contributed slightly to these decreases in air pollution, but much of the progress is due to the success of air pollution controls and reductions in emissions.

Since temperature affects energy demands and the rate of secondary pollution formation, some air pollutants such as ozone and PM<sub>2.5</sub> tend to have higher concentrations during summers with higher temperatures. When temperatures are high in local and upwind regions, and the wind flow patterns are favorable for transport, air pollution tends to be highest. Considering temperature

departures from climatological averages (Figure 4.34), the summers with higher than normal temperatures (illustrated with yellow, orange and red colors) also had the most ozone exceedance days in the Northeast portion of the country (2007, 2010, 2011, 2012). Colder summers (depicted by green, blue and purple colors) had the fewest ozone exceedance days (2009, 2013, 2014, 2015). Of these years, New Hampshire experienced increased ozone exceedance counts in 2007, 2010 and 2012 and lower counts in 2009, 2011 and 2014 (Figure 4.35). The ozone standard was lowered in 2008 and again in 2015 which caused increased ozone exceedance counts for each year despite having relatively low ozone concentrations compared to previous years

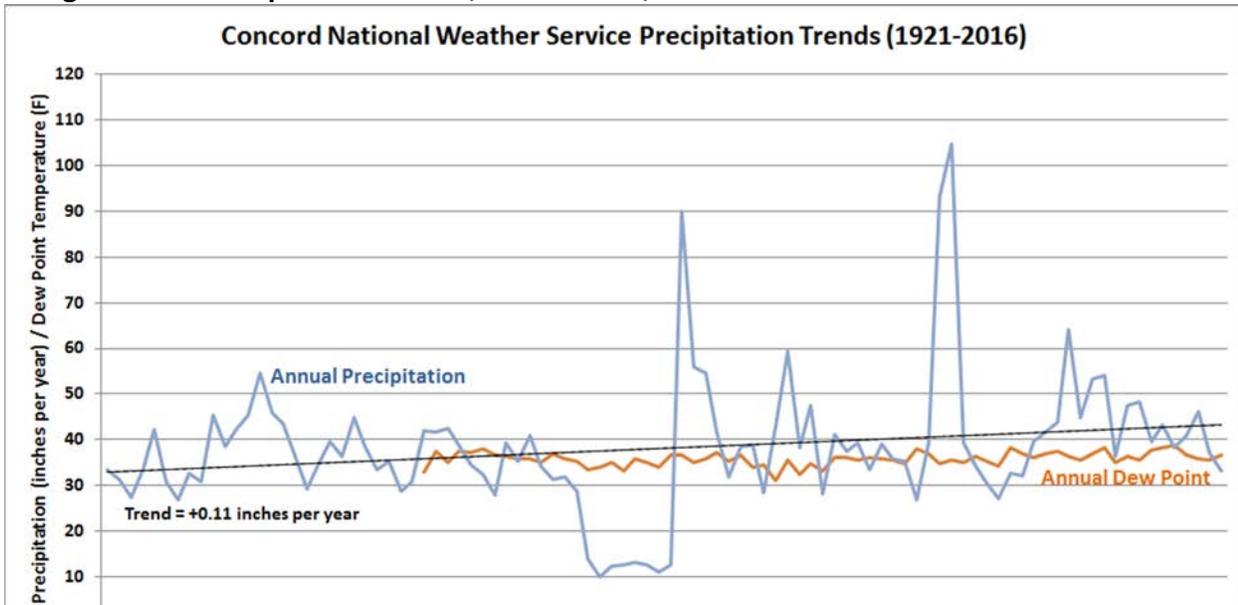
**Key Point:** Air quality in New Hampshire continues to improve despite gradual warming of temperatures and only small increases in precipitation.

Figure 4.32: Temperature Trends, Concord NH, 1921-2016



Source: NOAA/NHDES

Figure 4.33: Precipitation Trends, Concord NH, 1921-2016



Source: NOAA/NHDES

Figure 4.34: 2007-2016 Average Summer Temperature Departure from Normal (°F)

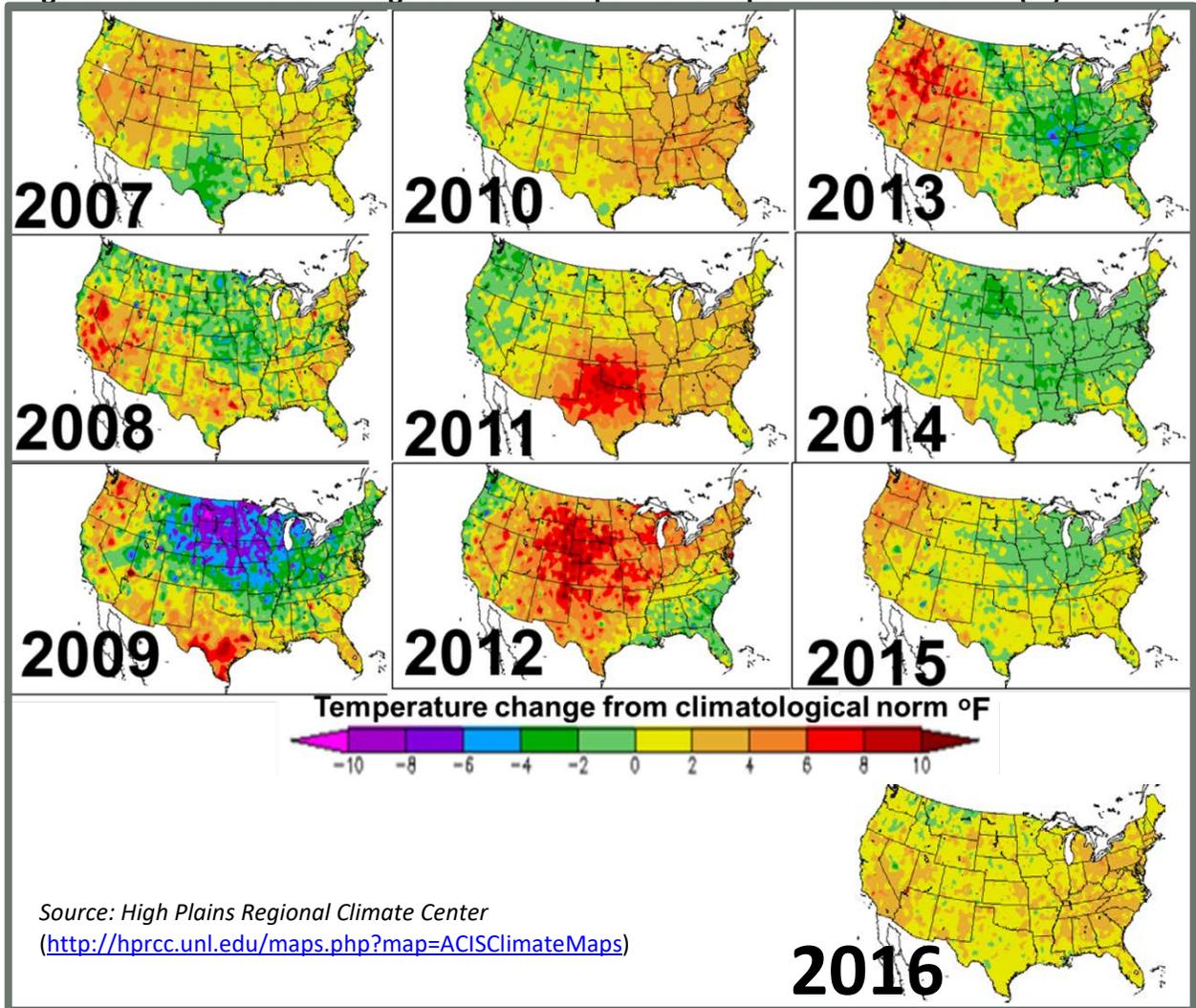
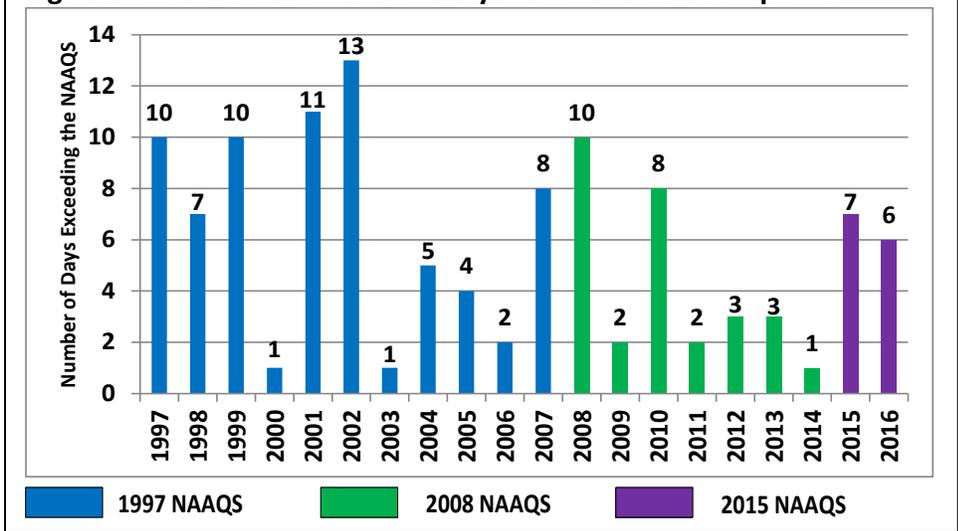


Figure 4.35: Ozone Exceedance Day Counts in New Hampshire



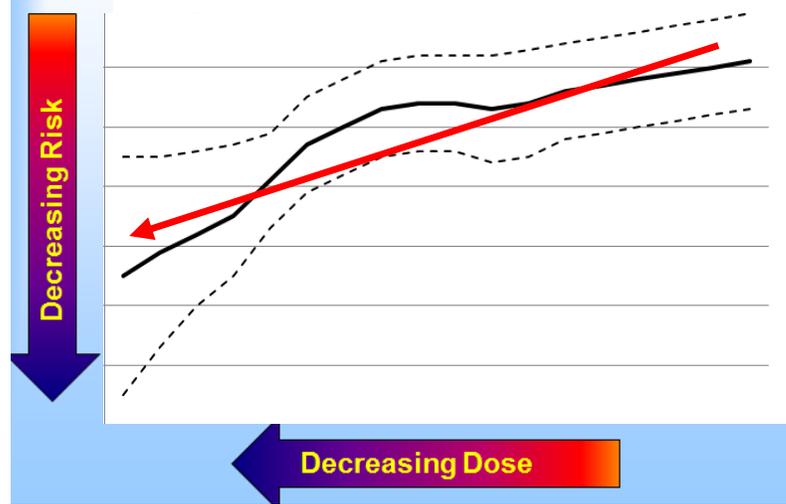
Source: NHDES

### 4.7 Air Pollution and Health Effects

The connection between air pollution exposure and health impacts is often not obvious. Unless air pollution concentrations are high enough to cause an immediate reaction, the connection between health effects and air pollution exposure is often unrecognized. For example, exposure to air pollution can trigger or exacerbate existing ailments that may be considered unrelated, such as asthma or tightness in the chest when breathing. Repeated exposure to air pollution over time can be the cause of these ailments, yet the connection to air pollution may not be made. Typically, such ailments are treated symptomatically without identifying the actual cause or causes. While air pollution is rarely listed as a cause of death, it may be the underlying cause of a fatal complication to an already compromised individual. Statistically, air pollution in the United States is estimated to cause thousands of premature deaths and millions of other health complications every year. As noted in Section 4.5, air quality has improved significantly in recent decades. This has translated into saved lives and reduced health care costs, and continued improvements are anticipated.

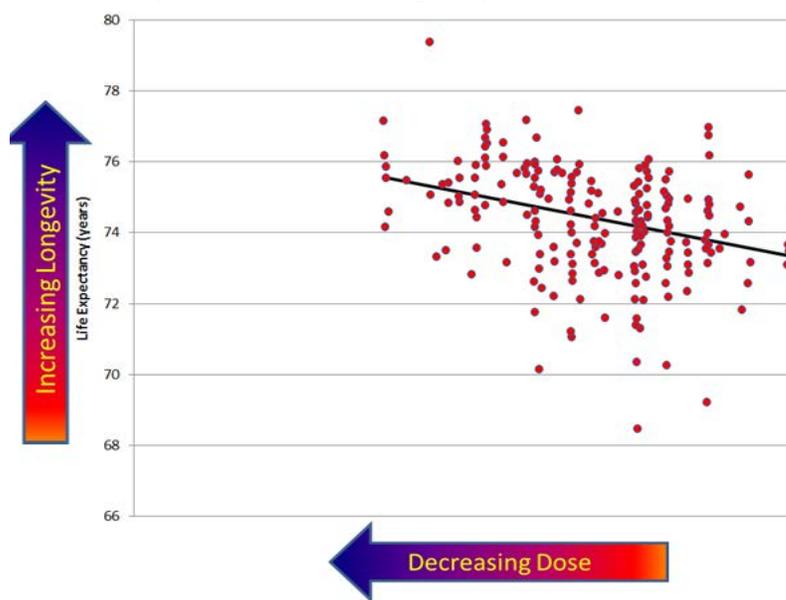
Studies connecting air pollution exposure to health impacts are routinely reviewed prior to setting air pollution health standards. Figure 4.36 shows an example of typical dose to impact relationship. This figure shows the connection between exposure to PM<sub>2.5</sub> and risk of a person developing an adverse health effect. The solid line in the center represents a mean value trend and the dotted lines on the upper and lower sides represent

**Figure 4.36: Health Statistical Relationship between PM<sub>2.5</sub> Exposure and Negative Health Symptoms**



Source: NHDES, 2003

**Figure 4.37: Health Study Statistical Relationship between PM<sub>2.5</sub> Exposure and Life Longevity**



Source: Adapted From Pope, 2009

confidence intervals. As is typical of such studies, there are variables and uncertainties involved, but nonetheless, a clear trend appears showing that with decreasing dose, risk of adverse health impacts also decreases.

Additional studies have connected decreasing exposure of PM<sub>2.5</sub> with increasing life expectancy. In particular, a study by Pope, et. al.<sup>18</sup>, examined this connection in a variety of cities throughout the United States, as represented by the various data points in the plot (Figure 4.37).

#### **4.7.1 Air Pollution and Health Costs**

Reducing air pollution by installing pollution controls or by using different fuels is often represented to the public as a cost, but the price of not reducing air pollution tends to be a hidden cost and a very expensive one at that. Health impacts, whether just feeling under the weather on a high pollution day or chronic asthma that has developed from repeated events of high air pollution, involve costs that add up. In fact, people die in this country every year due to air pollution exacerbating other health conditions or triggering heart attacks. Air pollution also costs businesses when employees miss work or come to work sick, and increases the cost of health insurance coverage that pays medical bills for air pollution triggered doctor's visits.

Public health and economic well-being are influenced by many factors. Human health, for example, is influenced by genetics, environment and social choices. These factors do not act individually, but collectively, resulting in compounded and often synergistic effects. Putting a price tag on any one of these factors is a complex process. Fortunately, recent research and scientific studies provide sufficient evidence to calculate the health-related costs associated with certain air pollutants.

The following points illustrate the potential health-related and economic costs associated with air pollution. Table 4.2 contains estimated average cost per incident of common health endpoints recently used by EPA for air pollution exposure.

Potential impacts of air pollution on health-related costs:

- Increased mortality.
- Increased emergency room asthma visits.
- Increased asthma attacks.
- Increased acute and chronic bronchitis.
- Increased hospital admissions.
- Increased upper and lower respiratory symptoms.
- Increased cardiovascular symptoms and illnesses.
- Increased health claims and health risks for all New Hampshire residents.
- Possible decrease in resistance to disease, viruses and bacterial infection.

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<sup>18</sup> Pope, et. al., *Fine-Particulate Air Pollution and Life Expectancy in the United States*, New England Journal of Medicine, January 22, 2009.

Potential impacts of air pollution on business costs, including tourism:

- Increased employee work days lost.
- Decreased worker wellness/decreased worker productivity.
- Higher insurance costs due to higher claims.
- Increased environmental requirements may lead to higher cost for fuels and electricity.
- Added environmental regulatory burden for businesses located in nonattainment areas (i.e. areas designated as not meeting air quality standards, see Section 3).
- Lost ability to attract new businesses and jobs due to environmental regulatory burden in nonattainment areas.
- Reduced crop yields and loss of agricultural business.
- Lost tourism and associated business loss.

**Table 4.2: Median Economic Valuation per Health-Related Endpoints (2011 Dollars)**

Health Endpoint Category	EPA (2011\$)*
Premature deaths (Mortality)	\$9,350,000
Acute Myocardial Infarction (ages 45-54)	\$120,000
Acute Myocardial Infarction (ages 55-64)	\$210,000
Hospital Admission – Cardiovascular (18-64)	\$44,000
Hospital Admission – Cardiovascular (65-99)	\$42,000
Hospital Admission – respiratory	\$37,000
Hospital Admission – Chronic Lung Disease	\$22,000
Hospital Admission – Asthma	\$16,000
Acute Bronchitis	\$485
Emergency Room – Asthma	\$440
Respiratory Symptoms – Upper	\$33
Respiratory Symptoms – Lower	\$21
Asthma Exacerbation	\$58
Lost Work Days	\$150
School Loss Days	\$98
Minor Restricted Activity Days	\$66

Source: EPA, 2015 Ozone Regulatory Impact Assessment (RIA)

\* - Considerable variability in valuation exists. Valuations presented here are interpolated median 2011 valuations. Greater detail regarding these valuations is available in the referenced document.

**Key Point:** If given the choice, most people would not pay 3 extra cents per gallon of cleaner burning gasoline because they do not perceive a benefit to the added cost, health or otherwise, even though the cumulative public benefit is significant.

#### 4.7.2 Air Pollution Health Impact Valuation in New Hampshire

The Ozone Transport Commission (OTC) conducted a modeling exercise with recent ozone and PM<sub>2.5</sub> monitoring data to estimate health impact valuations from air pollution in New Hampshire. BenMap<sup>19</sup> is a commonly used computational model created to perform health cost assessment and has been used by EPA for its recent air pollution standard evaluations. OTC used the most recent available version of the model with EPA updated valuations for this analysis.

OTC worked with NHDES to design a BenMap study that separates out any natural or background-level air pollution from concentrations measured over a recent three-year period (2013-2015). Based on recent analyses by EPA<sup>20</sup> and Columbia University<sup>21</sup>, a background ozone concentration of 40ppb for an 8-hour period was used. For PM<sub>2.5</sub>, an annual value of 4 µg/m<sup>3</sup> was selected by NHDES to estimate a background concentration in the state. BenMap was then run producing health valuation estimates for daily ozone and PM<sub>2.5</sub> concentration differences between monitored concentrations and the background ozone and PM<sub>2.5</sub> concentration estimates. The results of this analysis for New Hampshire are summarized in Table 4.3. The average annual health impact valuations in New Hampshire from United States ozone and PM<sub>2.5</sub> pollution for the period of 2013 through 2015 is approximately \$3.8 billion (ozone and PM<sub>2.5</sub> combined). Impacts can vary considerably depending on weather variations and the actual amount of air pollution measured in the state. For the three-year period, 2014 had the highest health impact valuation (\$3.87 billion/year) and 2015 had the low valuation (\$3.79 billion/year). Approximately 97 percent of the health impact for each year is from PM<sub>2.5</sub> exposure and roughly 19% is from New Hampshire manmade PM<sub>2.5</sub> emission sources.

**Table 4.3: Estimated Annual Average New Hampshire Health Incidents and Valuations for Manmade Air Pollution (2013-15 Model Estimated Incidents)**

Health Effect Endpoint	PM <sub>2.5</sub>	Ozone
Mortality, All Causes (all ages)	1,296	16
Hospital Admissions (respiratory and cardiac)	221	28
Emergency Room Visits (respiratory and cardiac)	226	23
Acute Respiratory Symptoms (bronchitis and asthma)	518,676	62,611
Lost Work Days	67,175	N/A
Lost School Days	N/A	17,680
<b>Estimated Total Valuation (2010\$)</b>	<b>\$3,699,000,000</b>	<b>\$132,000,000</b>

<sup>19</sup> Environmental Benefits Mapping and Analysis Program, BenMAP-CE is an open-source computer program that calculates the number and economic value of air pollution-related deaths and illnesses. The software incorporates a database that includes many of the concentration-response relationships, population files, and health and economic data needed to quantify these impacts. <https://www.epa.gov/benmap>

<sup>20</sup> EPA, "Implementation of the 2015 Primary Ozone NAAQS: Issues Associated with Background Ozone, White Paper for Discussion", 2016

<sup>21</sup> Fiore, A.M., et al, "Estimating North American background ozone in U.S. surface air with two independent global models: Variability, uncertainties, and recommendations", Atmospheric Environment, 96, 2014

This analysis was repeated for New Hampshire to consider the potential benefits of meeting the current ozone and PM<sub>2.5</sub> NAAQS thresholds (70ppb and 12 µg/m<sup>3</sup>, respectively) over the three-year period (2013-2015). The results of this analysis for New Hampshire are summarized in Table 4.4. The average annual health impact valuations in New Hampshire from United States air pollution emissions for the period of 2013 through 2015 is approximately \$4.5 million (ozone and PM<sub>2.5</sub> combined).

**Table 4.4: Annual Average New Hampshire Health Valuation Improvements Due to More Protective Ozone and PM<sub>2.5</sub> Standards (2013-15 Monitoring)**

Health Effect Endpoint	PM <sub>2.5</sub> (meeting 12ug/m3)	Ozone (meeting 70ppb)
<b>Modeled Incidents</b>		
Mortality, All Causes (all ages)	0.7	0.6
Hospital Admissions (respiratory and cardiac)	0.1	1.1
Emergency Room Visits (respiratory and cardiac)	0.1	0.7
Acute Respiratory Symptoms (bronchitis and asthma)	212	2,064
Lost Work Days	30.5	
Lost School Days		540
<b>Estimated Annual Total Valuation (2010\$)</b>	<b>\$2,000,000</b>	<b>\$2,500,000</b>

Extrapolating the New Hampshire BenMap modeling results from Table 4.3 (impacts from manmade ozone and PM<sub>2.5</sub>) to a county level can be done utilizing photochemical contribution modeling conducted by EPA and OTC (described in Section 7.7). This photochemical modeling estimated how much of the ozone and PM<sub>2.5</sub> measured in locations throughout New Hampshire was coming from within the state and how much was coming from areas located upwind. When this data is applied to the OTC/NHDES BenMap results and recent census data, county-level estimates for health-related costs can be estimated (Table 4.5). Even though ozone and PM<sub>2.5</sub> is also created by natural sources within and upwind of New Hampshire, this portion is excluded from the transported percentages.

Because of the relatively high populations in Hillsborough and Rockingham Counties and the relatively higher ozone and PM<sub>2.5</sub> concentrations measured there, these counties account for 60% of the total state health impact valuation. Conversely, Coos County has a relatively low population and cleaner air which establishes it as the county with the lowest health impact valuation (about 2% of the state total).

**Table 4.5: Health-Related Costs by County from Ozone and PM<sub>2.5</sub> Pollution in New Hampshire**

County/Monitor Location	County Population (2014 census estimate)	Annual Ozone (ppb) <sup>a</sup>	Estimated Ozone from Transport (%) <sup>b,d</sup>	Annual PM <sub>2.5</sub> (µg/m <sup>3</sup> ) <sup>a</sup>	Estimated PM <sub>2.5</sub> Transport (Annual %) <sup>b</sup>	N.H. Estimated Total Annual Health Impact Valuations (Millions 2010\$)	
						Ozone	PM <sub>2.5</sub>
Belknap	60,305	31.0 <sup>c</sup>	92%	5.5	80%	\$5.5	\$120.5
Carroll	47,399	25.3 <sup>c</sup>	93%	5.5 <sup>c</sup>	80%	\$4.3	\$94.7
Cheshire	76,115	24.0	99%	8.8	62%	\$7.2	\$243.4
Coos	31,653	25.3 <sup>c</sup>	96%	6.2 <sup>c</sup>	80%	\$2.8	\$71.3
Grafton	89,658	25.3	97%	6.2	98%	\$8.3	\$202.0
Hillsborough	405,184	31.0 <sup>c</sup>	97%	8.4	80%	\$40.7	\$1,236.9
Merrimack	147,171	31.0	92%	6.2	80%	\$14.3	\$331.6
Rockingham	300,621	28.9	91%	8.4	82%	\$32.1	\$917.7
Strafford	125,604	28.9 <sup>c</sup>	92%	8.4 <sup>c</sup>	82%	\$13.0	\$383.4
Sullivan	43,103	25.3 <sup>c</sup>	98%	6.2	85%	\$4.1	\$97.1
Mt Washington / Miller State Park	--	37.0	97%	5.4 <sup>c</sup>	98%		
<b>State Totals</b>	<b>1,326,813</b>	--	--	--	--	<b>\$132</b>	<b>\$3,699</b>

<sup>a</sup> Based on 2013-2015 monitoring data.

<sup>b</sup> Manmade portion of the annual ozone averages attributed to transport from outside of New Hampshire. Apportionment based on location specific factors derived from photochemical modeling (discussed in Section 7).

Excludes natural emission sources located in, and upwind of, New Hampshire.

<sup>c</sup> Nearest representative monitor was used since annual ozone monitoring was not conducted in this county.

<sup>d</sup> Ozone percentage estimates are based on high ozone periods.

The data support heavy transport impact to New Hampshire where manmade emissions in upwind states are primarily responsible for producing high concentrations of ozone in New Hampshire. Counties located along the western and southern borders of the state have the lowest ozone contributions from in-state pollution sources, while those counties located further east have more ozone impacts from in-state emission sources. As mentioned in earlier sections, prevailing winds in New Hampshire during the ozone season are from southwest to northeast, meaning that western and southern counties have only small portions of the state located upwind. Therefore the western and southern counties are influenced less by in-state emission sources and have higher transport percentages (97-99%). Counties located further east and north are downwind of more New Hampshire-based air pollution sources and thus experience slightly lower transport percentages (91-93%). The high elevation monitoring locations in New Hampshire are located at altitudes that experience efficient air pollution transport and are relatively isolated from local emission sources.

Transport of PM<sub>2.5</sub> into New Hampshire from upwind states follows a similar pattern to that found for ozone, but overall transport rates of PM<sub>2.5</sub> are lower. This lower percentage is driven by local residential heating emissions during colder months (Section 5). These emissions can accumulate in populated areas during periods of calm winds causing PM<sub>2.5</sub> concentrations to rise towards unhealthy levels for sensitive populations. Communities like Keene, contribute substantially to their own PM<sub>2.5</sub> concentrations, especially on a 24-hour basis during winter. On

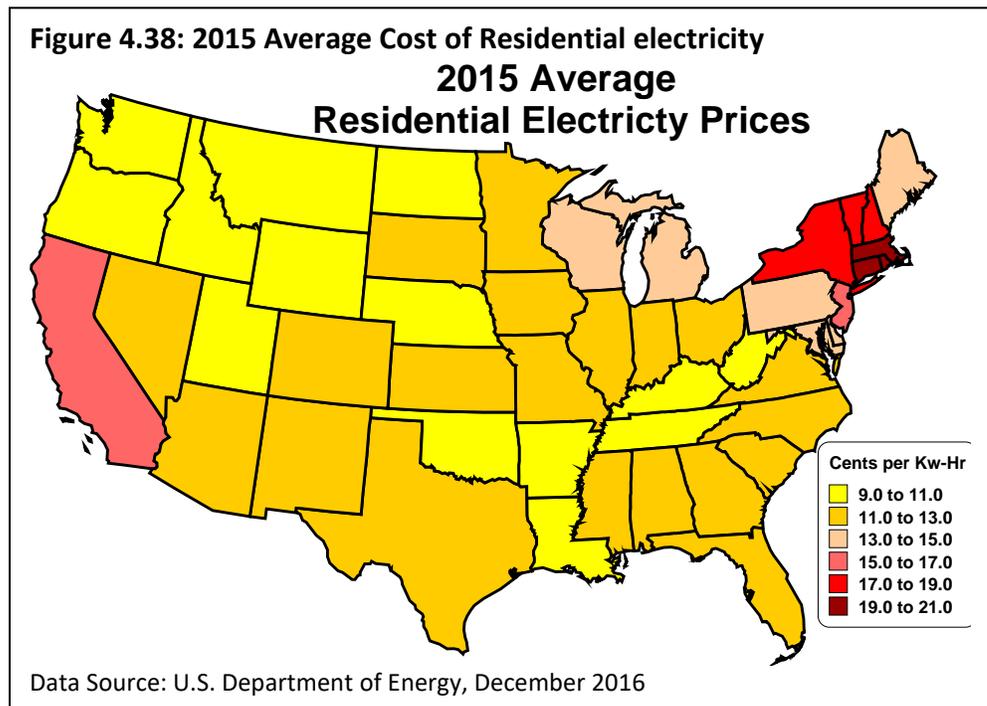
an annual basis, these periods of high locally produced emissions decreases the transport percentage of PM<sub>2.5</sub> from upwind areas. As a result, even though Keene is located in the southwestern portion of the state, it has the lowest PM<sub>2.5</sub> transport rate identified thus far in New Hampshire. High elevation monitors do not have local residential heating emissions and therefore experience very high rates of PM<sub>2.5</sub> transport.

#### 4.7.3 Other Air Pollution Economic Impacts

Beyond increased employee work days lost and higher health insurance claims that could raise insurance premiums, there are added costs of doing business in areas that have unhealthy air quality. Higher operating costs result for certain businesses due to increased federal requirements and air pollution controls required for operation in nonattainment areas. National and regional pollution levels can make a big difference in what local businesses must face in terms of emission controls and permit restrictions. If the air blowing into the state is already dirty, there is less room for local sources to release air emissions before the local air becomes unhealthy. In fact, there are areas of the country where there is almost no room at all for local emissions because the incoming air is already unhealthy. This places a serious barrier on new businesses trying to locate in states located downwind of large pollution sources.

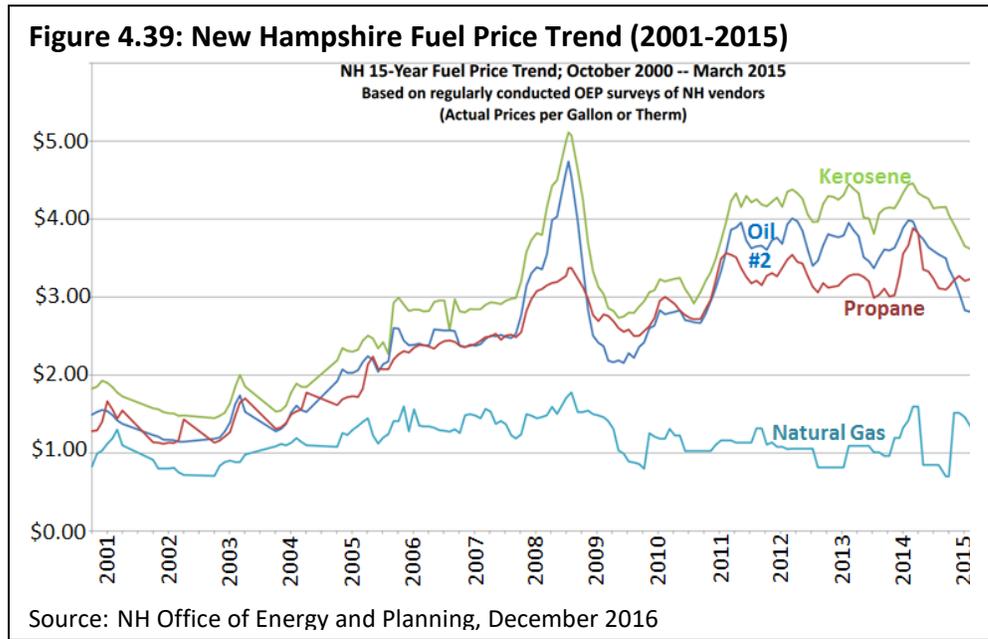
New Hampshire is a “downwind state,” meaning it is located downwind of high pollution emitting regions, and has a history of receiving air pollution transport. As a result, some businesses in New Hampshire have had to work through strict environmental permitting rules and regulations and have to buy air pollution credits as a condition for obtaining an air operating permit.

This situation has greatly improved in more recent years because all of New Hampshire, except for a very small area in central New Hampshire, is now in attainment with the National Ambient Air Quality Standards (see Section 3.4). The Northeast United States already suffers from some of the highest energy costs in the



**Key Point:** Most fuels need to be shipped to New England which crimps supply and adds to costs.

country, which drives up the cost of electricity generation in the region (Figure 4.38). To stabilize the costs of electricity in New Hampshire, generation from burning natural gas has significantly replaced the use of other fossil-based fuels. Natural gas costs have remained fairly stable while prices of other fuels (and in some cases cost of use) have generally increased since 2000 (Figure 4.39).



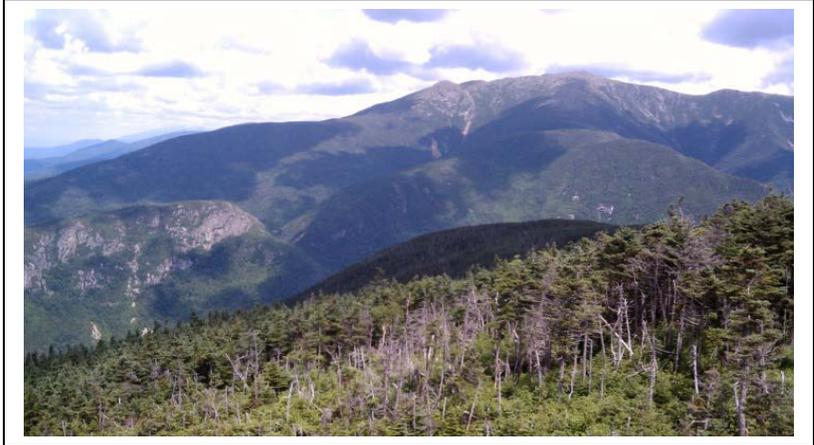
Agricultural businesses in locations with high air pollution levels have seen stunted growth and reduced crop yield as a result of ozone pollution and acid rain. Ozone has been shown to suppress the immunity of crops and other foliage and can lead to fatal freeze and insect damage. Loggers supplying the region’s paper mills have noted a decline in forest health and growth rate of timber supplies in the Northeast from earlier harvests. Acid rain (see Section 6) further extends the problem by leaching nutrients from soils, thus slowing forest growth, and in some cases, killing vegetation. Air pollution and acid deposition have improved in the Northeast since 1990, but accumulated damage can take decades for environmental recovery. If crop growth and forest health decline due to transport of air pollution, so too does revenue from related industries, such as farming, the maple sugar industry, and the

**Key Point: Air Pollution in the White Mountains** - How does one account for the loss of not being able to see the other side of a lake or a nearby mountain because of haze? What would the costs be associated with suffering from an ozone-induced burning sensation in the lungs from hiking in the mountains? Hikers don’t expect reduced visibility and unhealthy air quality while hiking in the remote backcountry, but air pollution transport can affect all areas of the northeastern United States and southeastern Canada, including New Hampshire’s White Mountains. For example, the summit of Mt. Washington can record ozone concentrations comparable to the more populated areas in south central New Hampshire and the Boston Metropolitan area.

timber industry (NHDES Clean Power Strategy, 2001).

Tourism is the second largest industry in New Hampshire, bringing in more than \$5 billion annually to the economy from over 37 million tourist visits according to a Plymouth State College report for 2014<sup>22</sup>.

According to the N.H. Division of Travel and Tourism Development, over 65,000 people are employed in the tourism industry, which includes hotels, restaurants, attractions, museums, art galleries, theaters, parks and sports facilities.



Visitors that support the tourism industry often come to New Hampshire for the “clean air” and beautiful mountains and lakes. Visitors would be less satisfied with their stay in New Hampshire if they encounter unhealthy air in the state’s supposedly pristine areas. People would be less likely to return to New Hampshire for vacation or business purposes and they might stay for shorter periods of time. The end result would be lost revenue and a decline in New Hampshire’s tourism industry. For these reasons, there is great economic benefit associated with the state, regional, and federal programs that have improved and protected air quality in New Hampshire.

**Key Point:** Failing to have a healthy environment not only reduces quality of life but ultimately reduces business opportunities, which in turn reduces jobs, lowers income and jeopardizes the economic outlook of affected communities.

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<sup>22</sup> Plymouth State College report (March 2015): <https://www.plymouth.edu/institute-for-new-hampshire-studies/nh-tourism-data/return-on-investment/>

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## 5 WOOD SMOKE IN NEW HAMPSHIRE

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Pollution from wood smoke affects New Hampshire residents during the winter months, and this phenomenon has garnered increased attention in recent years. The major pollutant associated with wood smoke is fine particulate matter (PM<sub>2.5</sub>), but it also contains carbon monoxide, nitrogen oxides and small levels of various toxins and carcinogens. To help quantify the effects of wood smoke, New Hampshire monitors for PM<sub>2.5</sub> in several locations throughout the state. Although PM<sub>2.5</sub> can come from many sources, much of the PM<sub>2.5</sub> measured in New Hampshire during the winter comes from wood smoke (Section 4.3).

Winter-time PM<sub>2.5</sub> monitoring has shown that wood smoke concentrations in New Hampshire fall in the good or moderate range on most days (refer to Section 4.2 for a discussion of the Air Quality Index). However, PM<sub>2.5</sub> monitoring data from Keene have revealed a few periods over the past several years when PM<sub>2.5</sub> concentrations rose to levels at which sensitive people may experience difficulty breathing, aggravated asthma, or heart conditions (i.e. an AQI of unhealthy for sensitive groups or USG). The odor of wood smoke on air pollution monitoring filters from Keene was evidence that wood burning may be driving the high PM<sub>2.5</sub> concentrations in that area. In response, NHDES acted proactively to lower pollution concentrations by facilitating a wood stove change-out program, in which residents were given financial incentive to replace their older, more polluting wood stoves with newer, cleaner, EPA-certified models (see Section 5.3 below for a discussion of EPA-certified woodstoves). The wood stove change-out program was accompanied by outreach and educational programs to help residents burn wood more cleanly. In addition, NHDES further studied the wood smoke pollution issue by enacting several special ambient air monitoring programs.

### 5.1 Continuous PM<sub>2.5</sub> Monitoring

Until relatively recently, the primary method for measuring PM<sub>2.5</sub> was to collect samples on filters and then weigh the filters in a laboratory to determine the mass of PM<sub>2.5</sub> collected during the sampling period (typically 24 hours). This method results in an average concentration over the 24-hour period that the sample was collected. With this method, samples were not collected every day, but rather only once out of every six days. However, newer monitoring technology became available several years ago, providing PM<sub>2.5</sub> monitoring data at an hourly resolution. These optical-based monitors allow PM<sub>2.5</sub> concentrations to be tracked on a near real-time basis. In contrast to a single average value for a day, the enhanced resolution of hourly data reveals how PM<sub>2.5</sub> concentrations rise and fall over the course of the day. Further, the near real-time data allows air quality forecasters to issue more timely air quality advisories when PM<sub>2.5</sub> concentrations rise higher than expected.

**Key Point:** Improving upon less frequent 24-hour sampling methods, NHDES has added continuous, hourly sampling of fine particulate matter at five air monitoring locations. A sixth location will be added in 2017.

Currently, NHDES monitors hourly PM<sub>2.5</sub> at five sites using Beta Attenuation Monitor (BAM) technology. These sites and the date when the BAM was first installed at each site are as follows:

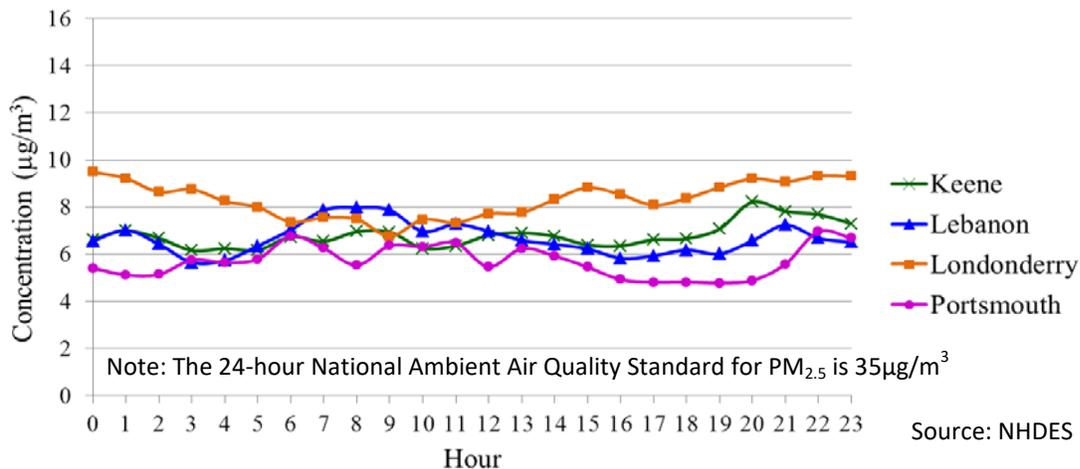
- Keene (October 2008).
- Lebanon (December 2008).
- Portsmouth (February 2010).
- Londonderry (January 2011).
- Pack Monadnock Summit (May 2011).
- Laconia (ETA 2017).

## 5.2 Diurnal Patterns in PM<sub>2.5</sub> Concentrations

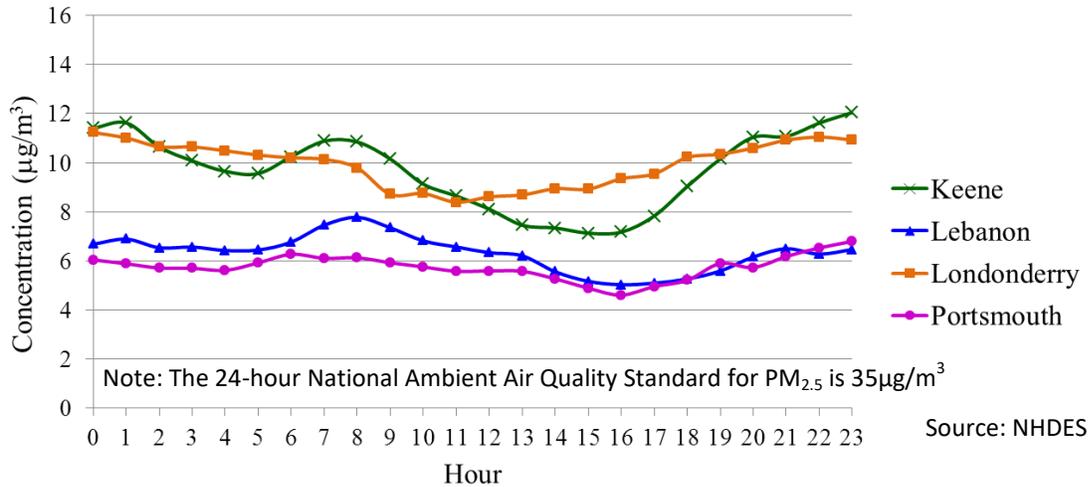
Based on continuous hourly BAM data, Figures 5.1 and 5.2 show average concentrations over the course of a summer and winter day, respectively. The typical diurnal (daily) pattern in PM<sub>2.5</sub> concentrations differs markedly from summer to winter.

Most of the year, including the summer, the predominant air flow brings in pollution from other areas, creating fairly uniform PM<sub>2.5</sub> concentrations throughout the day and similar average levels at each monitoring location (Figure 5.1). In contrast, winter PM<sub>2.5</sub> levels tend to be highest at night (Figure 5.2). Concentrations rise in the evening, remain elevated overnight, dip toward morning, and rebound briefly around 8 a.m. before settling to minimum daytime levels. The evening rise and morning peak coincide with the hours when residents commonly stoke their woodstoves before leaving for work or after arriving home. This wintertime diurnal pattern is most evident in Keene and Lebanon.

**Figure 5.1: Summer Seasonal Hourly Average PM<sub>2.5</sub> in Keene, Lebanon, and Manchester, June – August 2014**



**Figure 5.2: Winter Seasonal Hourly Average PM<sub>2.5</sub> in New Hampshire, December 2013 – February 2014**



In winter (Figure 5.2), Keene and Londonderry exhibit comparatively higher concentrations than other locations, with greater increases at night during the winter.

PM<sub>2.5</sub> data presented in Figures 5.1 and 5.2 include average values among all days in the season, but data for individual days show that Londonderry rarely climbs higher than the mid-20s in µg/m<sup>3</sup>; in contrast, Keene generally experiences several days per season with a 24-hour average in the high-20s or low to mid-30s µg/m<sup>3</sup>. NHDES has also measured a higher frequency of one-hour PM<sub>2.5</sub> concentrations well above the USG threshold in Keene than at any other site.

Although PM<sub>2.5</sub> in Londonderry and Keene often measures in the moderate range during the winter, Keene PM<sub>2.5</sub> has demonstrated the greatest potential to reach USG levels over a 24-hour period. Keene lies in a valley, where air pollution can be more readily trapped near the ground on cold, calm nights. It can accumulate there until the heat of daybreak initiates vertical mixing. This phenomenon is called a thermal inversion (Figure 5.3).

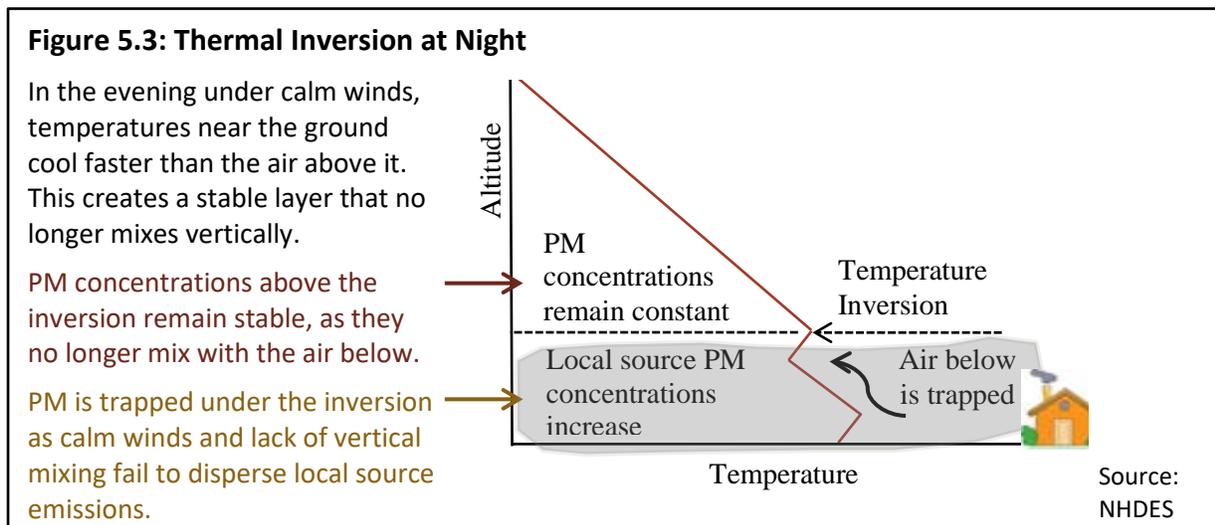
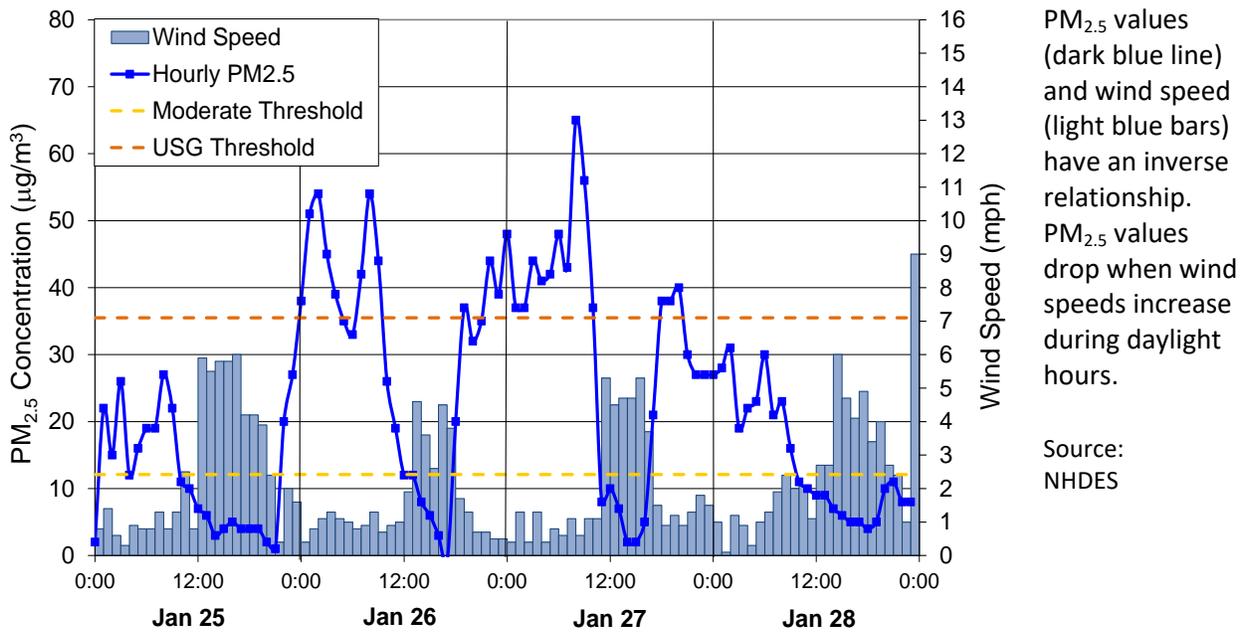


Figure 5.4 shows detailed hourly PM<sub>2.5</sub> concentration and wind speed data from Keene over a four-day period when PM<sub>2.5</sub> concentrations were particularly high at night. As wind speeds diminished late each day, Keene’s PM<sub>2.5</sub> concentrations rose quickly. As winds resumed during the day, PM<sub>2.5</sub> concentrations decreased. Because of this relationship between wind speed and PM<sub>2.5</sub> stagnation, air quality forecasters closely monitor wind speeds and the potential for overnight thermal inversions during the winter months. Another consideration for air quality forecasters during the winter is long-range transport. Daytime winds can transport PM<sub>2.5</sub> into the region from distant pollution sources. When these conditions are followed by a nighttime stagnation event that traps local wood smoke pollution, then there is even more potential for PM<sub>2.5</sub> levels to reach the USG range in valley locations such as Keene. Despite the contribution from long-range transport, however, NHDES analysis of recent air quality events in Keene suggests that the primary contributor is wood smoke from local residential wood burning.

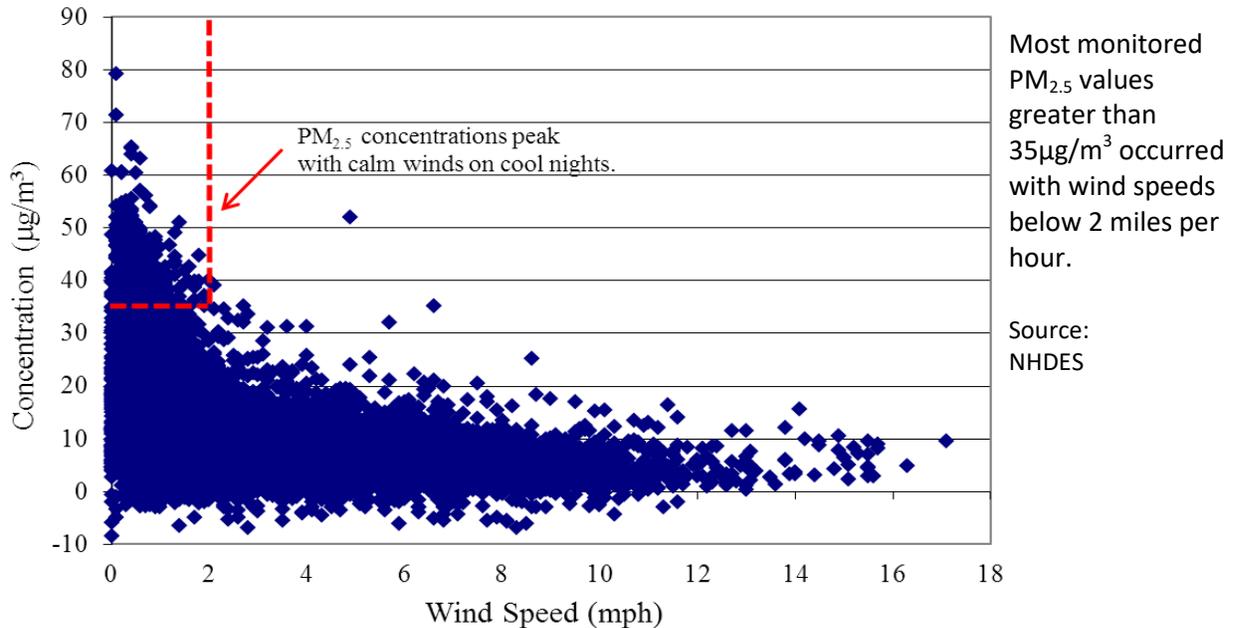
**Figure 5.4: PM<sub>2.5</sub> Concentration Patterns as a Function of Wind Speed, Keene, New Hampshire, January 25- 28, 2009**



Wintertime PM<sub>2.5</sub> concentrations above the USG threshold are most likely when winds are very calm. Figure 5.5 shows the correlation between low wind speeds and high PM<sub>2.5</sub> in Keene on cold winter nights; PM<sub>2.5</sub> values of USG and above tend to occur only when wind speeds fall below two miles per hour.

**Key Point:** The National Ambient Air Quality Standard (NAAQS) for 24-hour PM<sub>2.5</sub> (and PM<sub>10</sub>) considers concentrations measured from midnight to the following midnight instead of concentrations measured during any consecutive 24-hour period. Because lungs don’t know the time of day, NHDES forecasts PM<sub>2.5</sub> based on any 24-hour consecutive period to be more protective of public health. The NAAQS was set based on data collected on filters exposed for 24-hours (midnight to midnight) and has not yet been updated after the emergence of hourly PM<sub>2.5</sub> monitoring technology that can measure variable 24-hour periods.

**Figure 5.5: PM<sub>2.5</sub> Concentration as a Function of Wind Speed on Cold Nights ≤ 45°F Keene, New Hampshire, 2012-2014**



Because historical filter-based PM<sub>2.5</sub> samples provide only 24-hour average concentrations and are collected only once out of every few days, there is less robust historical data available for analysis. Therefore, it is difficult to determine whether localized wood smoke events are more frequent today than years ago, but recent patterns indicate a slow decline in PM<sub>2.5</sub> since 2001 (Section 4.5.5). To keep improving wintertime air quality in communities like Keene, NHDES continues to: monitor wood smoke pollution, provide education and outreach regarding its health effects, and promote ways to reduce wood smoke emissions.

**Key Point:** Air monitoring data reveals that calm winds, cold temperatures and the presence of temperature inversions can lead to high PM<sub>2.5</sub> concentrations on winter nights in some places in New Hampshire; among the state’s PM<sub>2.5</sub> monitoring locations, this occurs most frequently in Keene, where woodstove use is prevalent, and valley topography aids in trapping air pollution near the ground.

**Key Point:** Wood can be burned cleanly when clean burning practices are used. This involves using operating instructions and fuel wood specified by the manufacturer (of the stove, furnace or boiler). Using modern equipment (EPA certified if available) greatly reduces pollution emissions as well as the amount of wood needed for combustion. Larger industrial, institutional and electric generating facilities now use wood as a renewable fuel source and do so more cleanly by adding post-combustion particle emission controls.

### 5.3 Residential Heating

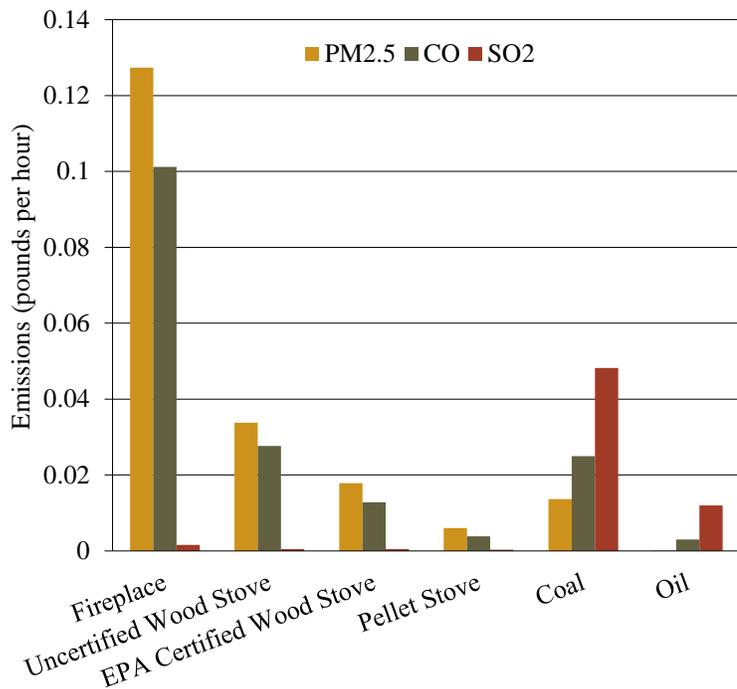
Many of New Hampshire’s residents heat their homes with wood using a variety of devices that can burn chopped wood or pellets. Pellet fuels consist of sawdust-like woody material compressed into a small pellet shape. Devices used to burn wood typically consist of standard fireplaces, which do not effectively provide indoor heat, and wood stoves, pellet stoves, and outdoor wood boilers (OWB), which do provide effective indoor heat. Pollution emission rates vary widely among the different types of units and the types of wood they combust. Further, emissions from wood burning devices are distinctly different from home furnaces that use other fuels (Figure 5.6).

Wood burning is often considered environmentally friendly, but it is not always neighborhood friendly.

Smoke from one chimney can disperse and impact the air quality around neighboring homes. The Environmental Protection Agency (EPA) has established a certification program for wood stoves. Certified wood stoves are considerably cleaner than older, conventional wood stoves. New Hampshire does not generally regulate residential wood burning devices, but the state does have requirements regarding the sale, installation, and use of OWBs, and is taking partial delegation regarding the sale of woodstoves complaint with new source performance standards. EPA, state and local ordinances focused on wood burning devices are intended to prevent PM<sub>2.5</sub> air pollution stagnation events, especially in valley locations which are particularly susceptible to these types of events.

PM<sub>2.5</sub> events can occur any time of year in proximity to an emissions source while it is in operation. Such events can be minimized or even eliminated by using cleaner wood burning devices or choosing to use a cleaner burning fuel. Applying best management practices, such as burning only dry, seasoned hard wood, can further reduce pollution from wood burning. To reduce wood smoke pollution and prevent possible nuisance situations, NHDES recommends that residents: always use heating devices in accordance with the manufacturer’s specifications; understand and follow local permitting and zoning provisions; and use clean burning practices.

**Figure 5.6: Emissions Rates per Residential Unit**



**Notes:**

1. CO emissions posted have been divided by 10.
2. Low sulfur oil and biofuels reduces PM<sub>2.5</sub> emissions and virtually eliminates SO<sub>2</sub> emissions.

Source: NHDES, based on EPA emission factors.

Neighborhood friendly devices include EPA-certified stoves or pellet stoves as opposed to older stove models and outdoor wood boilers. EPA's Burn Wise<sup>23</sup> initiative provides information regarding wood-burning heating options and clean burning practices to help homeowners reduce emissions from residential wood burning.

**Key Point:** Wood-burning heating devices can be a significant source of wintertime PM<sub>2.5</sub> in New Hampshire. New EPA-certified wood stoves are many times cleaner than older models.

## **5.4 A Specific Focus on Keene**

As discussed in Section 5.1, NHDES began using new technology that allows for the measurement of continuous hourly PM<sub>2.5</sub>. This type of monitoring began in Keene in 2008 and drew attention to the significant variation in wintertime particle concentrations between day and night. Daytime PM<sub>2.5</sub> concentrations can be in the good range and then rise quickly into the unhealthy for sensitive groups (USG) range overnight. Previous filter-based PM<sub>2.5</sub> monitoring technique effectively averages the day and night concentrations into a single 24-hour average. However, continuous monitoring data revealed, for the first time, the extent and potential health risks associated with particle buildup on some winter nights in Keene. In response, NHDES initiated efforts to improve air quality in Keene. These initiatives included a wood stove change-out program and several special monitoring studies to better understand and address the issue. The following sections provide an overview of these efforts.

### **5.4.1 Wood Stove Change-out Program**

NHDES conducted a woodstove change-out program from October 2009 through June 2010 with the goal of replacing 100 conventional woodstoves in Keene with newer cleaner models. As mentioned in Section 5.3, conventional wood stoves produce more air pollution than EPA-certified models. In addition, they can also produce more pollution than other home heating options, such as pellet stoves.

Participants in the change-out program received a rebate to replace an older stove with an EPA-certified woodstove, a pellet stove, a gas stove, or other updated and more efficient system. The program required removal of the old stove and professional installation of the new unit. Through the change-out, NHDES administered the exchange of 86 old wood stoves, replaced by 63 EPA-certified wood stoves, 15 pellet stoves, and eight gas stoves.

### **5.4.2 Wood Burning Surveys**

To better understand wood-burning habits in New Hampshire, NHDES and Keene State College performed a series of surveys of Keene residents. Keene State College students conducted the first survey in December 2009 at the Keene transfer station. After the wood stove change-out, NHDES completed a second survey in mid-June 2010. A Keene State College student and an

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<sup>23</sup> For more information about Burn Wise, visit: <http://www.epa.gov/burnwise/appliances.html>.

NHDES intern conducted a third survey over the summer and fall of 2010 involving phone calls to 529 respondents.

Survey results suggest that about 20% of Keene residents heat with wood, with 6% relying on it as their primary source of heat and 14% using it as a secondary source. The majority of wood-burning units were wood stoves, though fireplaces were common as a secondary source, and a very small number of respondents used pellet stoves or outdoor wood boilers. About 60% of respondents using wood stoves reported having a stove that was definitely, or most likely, EPA certified. Most people who heat with wood in the Keene area said they burn seasoned hardwood and no other materials.

### **5.4.3 Mobile Air Monitoring**

The focus on wood burning in Keene prompted questions about the existence of other communities in New Hampshire, previously unmonitored, which may experience similar levels of wood smoke stagnation. To address this question, NHDES drove a specially fitted vehicle through many parts of the state to monitor overnight PM<sub>2.5</sub> concentrations. Section 5.5 provides an extensive overview of this study and its results.

### **5.4.4 Indicator Species of Wood Burning**

NHDES performed a special monitoring study during the winter of 2012-2013 to further study the role that residential wood burning plays in Keene's wintertime PM<sub>2.5</sub> concentrations. NHDES enhanced its Keene monitoring station to collect data for a set of "indicator species." The presence, or absence, of indicator species can be evidence of the type of emissions source that produced them. In this manner, the monitoring of indicator species helps to assign how much of the measured PM<sub>2.5</sub> pollution is coming from each potential source type. Indicator species selected for this study, and the potential source types they represent, included the following:

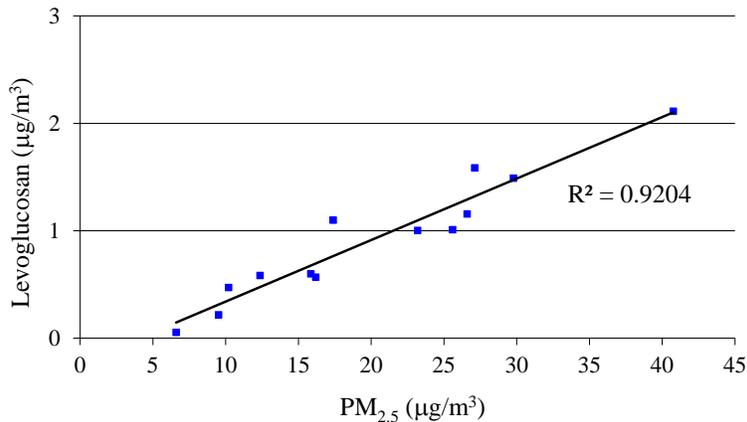
- **Levoglucosan** – wood burning.
- **Carbon Monoxide** – emitted in large quantities during wood and coal combustion, emitted to lesser degrees for other fuel burning.
- **Sulfur Dioxide** – coal and oil combustion.
- **Black Carbon** – related strongly to wood burning and, to a lesser degree, to soot from other sources.
- **Tracer Metals**
  - Arsenic – coal
  - Cadmium – automotive
  - Chromium – coal and industry
  - Copper – oil and industry
  - Lead – coal, oil, and industry
  - Manganese – oil
  - Nickel – coal
  - Vanadium – oil.

Levoglucosan was specifically selected because it is an organic compound uniquely formed during the burning of wood cellulose. If it is measured in the air, wood was burned. Carbon monoxide and black carbon are also good indicators of wood burning, but there are other sources in the area that can create these pollutants. SO<sub>2</sub> and the trace metals were selected to help identify contributions from local coal, oil, industry and automotive emission sources.

The study found a very strong relationship between levoglucosan and PM<sub>2.5</sub> concentrations (Figure 5.7). Carbon monoxide and PM<sub>2.5</sub> also have a strong correlation (Figure 5.8), but the correlation between levoglucosan and PM<sub>2.5</sub> is greater. These results suggest that wood burning devices are a significant contributor to PM<sub>2.5</sub> in Keene during winter nights. The slightly weaker correlation for carbon monoxide is likely due to the variety of other source types that emit the pollutant in the area.

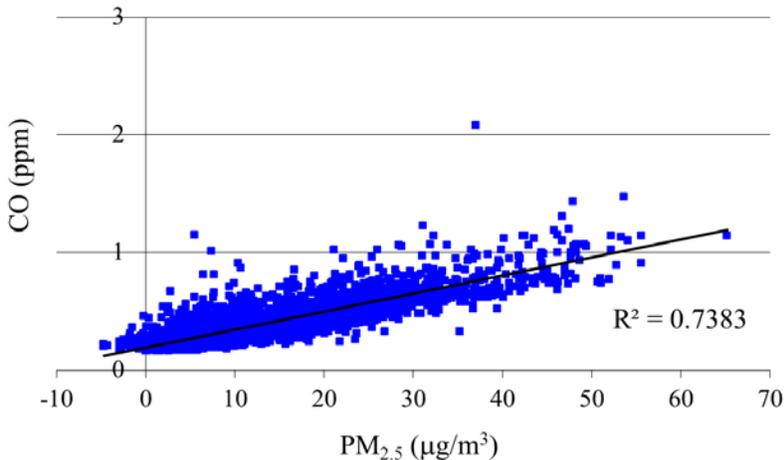
The indicator species for oil burning, mobile sources and industry were present in the majority of the collected samples, but generally did not correlate well with PM<sub>2.5</sub> concentrations. This suggests that these source types are not significant contributors to high overnight PM<sub>2.5</sub> concentrations measured in Keene.

**Figure 5.7: Levoglucosan vs PM<sub>2.5</sub> Correlation, Keene, New Hampshire**



Source:  
NHDES

**Figure 5.8: CO vs PM<sub>2.5</sub> Correlation, Keene, New Hampshire**



Source:  
NHDES

This study revealed that PM<sub>2.5</sub> levels in Keene correlate very well with two indicator species of wood burning: levoglucosan and carbon monoxide. As mentioned earlier, tracer species for coal, oil, industry, and automobiles were present in varying amounts, but generally showed weak correlations with PM<sub>2.5</sub> concentrations; these sources play only a minor role in Keene's PM<sub>2.5</sub> levels. Regional transport can contribute to unhealthy air in the city; however, local residential wood burning is the dominant source during high wintertime PM<sub>2.5</sub> events in Keene.

**Key Point:** In response to high PM<sub>2.5</sub> levels monitored on some winter nights in Keene, NHDES has conducted several outreach initiatives and special studies to address the issue.

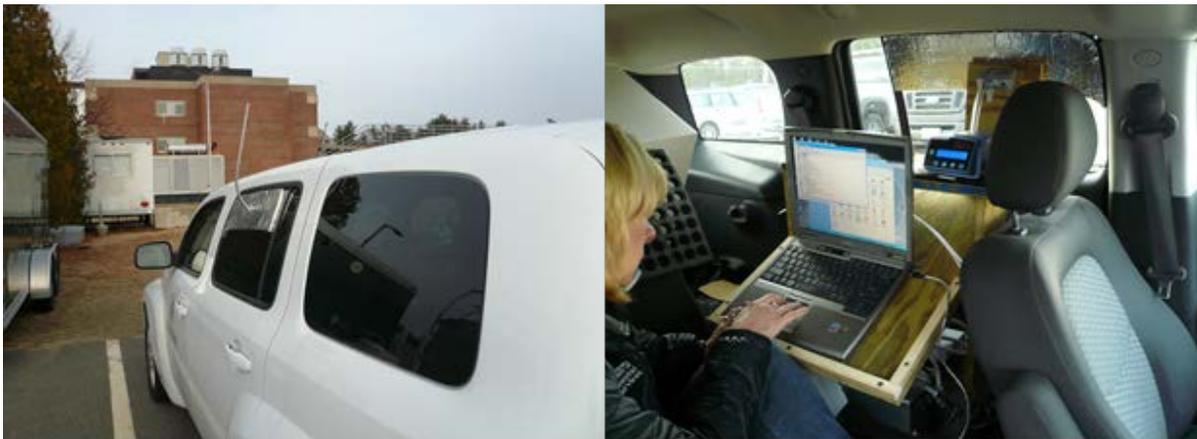
## 5.5 Mobile Air Monitoring for PM<sub>2.5</sub>

### 5.5.1 Study Overview

With Keene identified as a community affected by overnight PM<sub>2.5</sub> events from wood burning, questions arose about whether other communities in the state have similar issues. Performing continuous PM<sub>2.5</sub> monitoring in hundreds of communities throughout the state was simply not practical, however it was possible to identify communities of interest with a screening test designed to take a simple snapshot of wood smoke concentrations.

With a grant from the Environmental Protection Agency (EPA), NHDES obtained the necessary equipment to outfit a vehicle with portable sensors. Periodically, from 2010 to 2012, this vehicle was driven throughout the state during overnight hours when thermal inversions were predicted to occur. A portable Personal DataRAM 1500 (pDR) particulate matter monitor was used for this study; this type of unit is small enough to be mounted inside a moving vehicle (Figure 5.9). While the data collected provide valuable insight into localized air quality, the samples are one-time, short-term snapshots of air quality and do not guarantee that the data are representative of longer-term patterns in those areas.

**Figure 5.9: NHDES Vehicle Fitted with the pDR 1500 for Mobile Monitoring**



The left image displays the probe on the vehicle; the right image shows the Personal DataRAM 1500 (pDR) particulate monitor.

Source: NHDES

NHDES mobile air monitoring took place during five nights when Keene's PM<sub>2.5</sub> concentrations were expected to be high. With the pDR 1500 mobile monitor sampling air from a probe on the top of the vehicle, drivers followed planned routes, focusing on a different section of the state each night. They worked in two shifts to capture evening-to-midnight and early morning peaks, completing all sampling by approximately 8-9am when wood smoke stagnation tends to break-up. They were given the flexibility to divert from the planned route as needed to investigate the sight or smell of smoke or a sudden increase in concentration.

NHDES selected target communities to include on each route, making sure to pass through places with apparent potential for high PM<sub>2.5</sub> events based on characteristics similar to Keene: topography conducive to thermal inversions, moderately high population density, and relatively high rates of residential wood burning. Listed below are the target communities assigned to the five sampling loops.

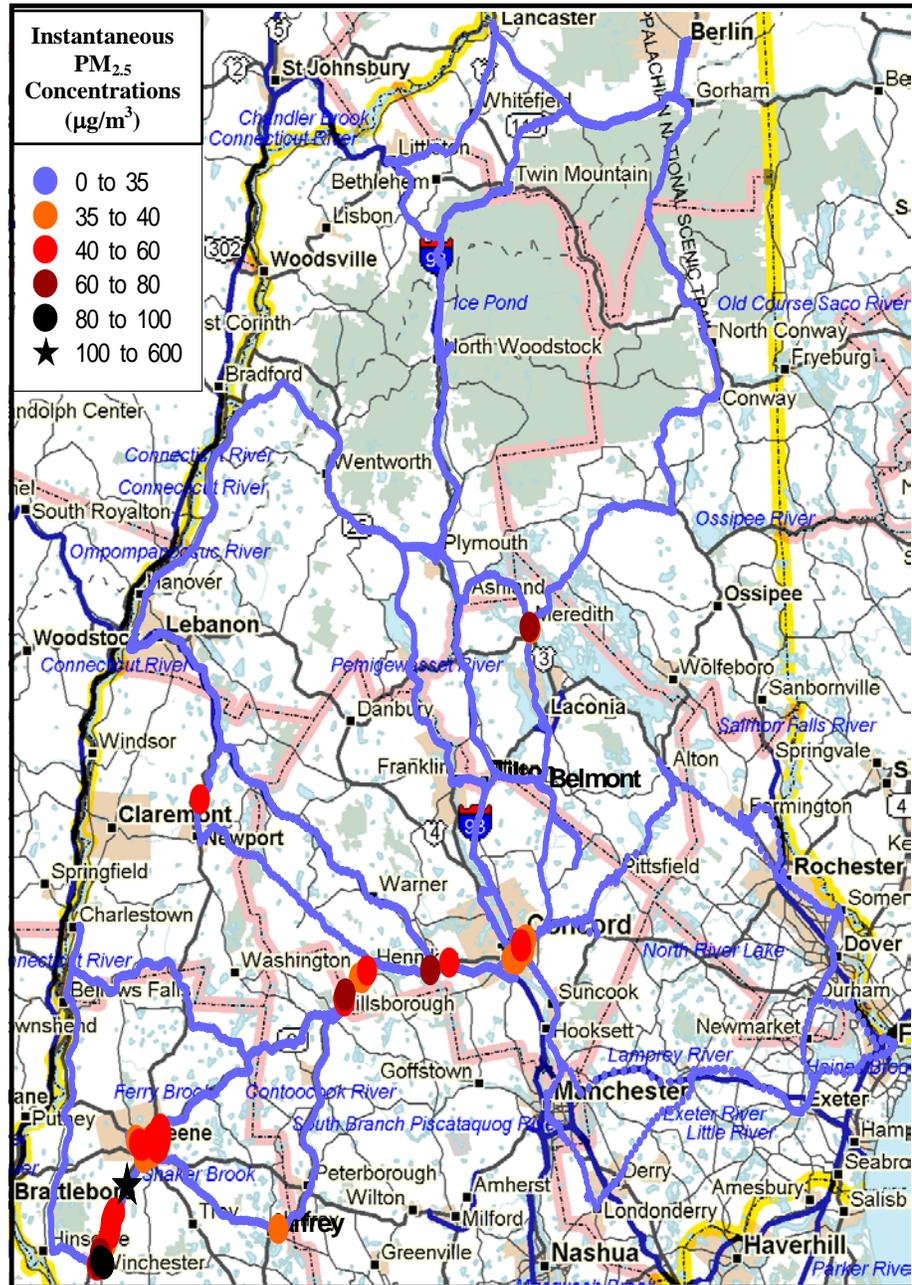
- **Central Loop (Event 1)** - Concord, Franklin, Bristol, Plymouth, Orford, Lebanon, Hanover, Newport, Bradford, Henniker.
- **Southwestern Loop (Event 2)** - Concord, Hillsboro, Marlow, Acworth, Charlestown, Walpole, Chesterfield, Hinsdale, Winchester, Keene, Jaffrey, Peterborough, Antrim.
- **Northern Loops**
  - **Run 1 (Event 3)** - North Woodstock - Lincoln, Gorham, Berlin, Conway, Meredith, Laconia, Belmont, Tilton.
  - **Run 2 (Event 4)** - North Woodstock - Lincoln, Gorham, Berlin, Lancaster, Littleton, Franconia, Meredith, Laconia, Belmont, Tilton.
- **Southeastern Loop (Event 5)** – Concord, Alton, Farmington, Rochester, Somersworth, Dover, Durham, Portsmouth, Exeter, Raymond, Londonderry, Manchester, and Pembroke.

### 5.5.2 Mobile PM<sub>2.5</sub> Sampling Results

Figure 5.10 provides a composite look at the mobile PM<sub>2.5</sub> data measured throughout the state during the 2010-12 mobile monitoring study. The color scheme highlights concentrations of USG and above. The map filters out very brief spikes in concentration and displays values over 35 µg/m<sup>3</sup> only when those values were sustained for at least one and a half minutes while the vehicle was in motion. This helps distinguish larger communities and neighborhoods at risk of PM<sub>2.5</sub> events from localized sources, such as smoke from a single chimney or exhaust from a vehicle driving by the mobile monitor.

The mobile monitor recorded continuously high PM<sub>2.5</sub> levels primarily along two stretches. Communities between Winchester and Keene show the highest concentrations. Concentrations

**Figure 5.10: Filtered Composite Map of Mobile Monitoring PM<sub>2.5</sub> Values, 2010-2012 Study**



Note: Data values are instantaneous and do not represent the 24-hour form of the PM<sub>2.5</sub> NAAQS. Data values were collected on different days and times and are not necessarily comparable. Some high concentrations marked in this figure may be localized to a single source and brief in duration.

Source: NHDES

measured along the route from Concord to Hillsborough were also significant. Table 5.1 lists these and other towns of greatest interest based on PM<sub>2.5</sub> concentrations measured during the mobile monitoring study:

**Table 5.1: Potential Communities of Interest for Wood Smoke:**

Primary	Secondary	Others to Watch
Keene	Concord	Acworth
Henniker	Hopkinton	Antrim
Hillsborough	Jaffrey	Belmont
Newport	Lancaster	Berlin
West Swanzey	Lincoln / North Woodstock	Charlestown
Winchester	Meredith	Conway
	Laconia	Farmington
	Plymouth	Langdon
		Marlow
		Pittsfield
		Raymond
		Westmoreland

*Note: Not every town in New Hampshire has been sampled. The list above reflects only towns measured during this study.*

### 5.5.3 Mobile Monitoring Summary and Conclusions

Based on the New Hampshire 2010-2012 mobile monitoring study, Keene appears to incur higher wintertime PM<sub>2.5</sub> concentrations and more frequent episodes than other large communities in New Hampshire. Data from this study suggest other communities in the state may periodically reach high PM<sub>2.5</sub> levels under stagnant conditions, particularly populated cities and valleys of the southwestern part of the state. However, considerably more continuous stationary data, rather than instantaneous snapshot measurements, are needed to clarify the degree of 24-hour risk associated with PM<sub>2.5</sub> exposure in these places. The study gives no indication of a current health risk in these communities based on the 24-hour National Ambient Air Quality Standard (NAAQS). In fact, Keene does not currently violate the PM<sub>2.5</sub> NAAQS (Section 3.2).

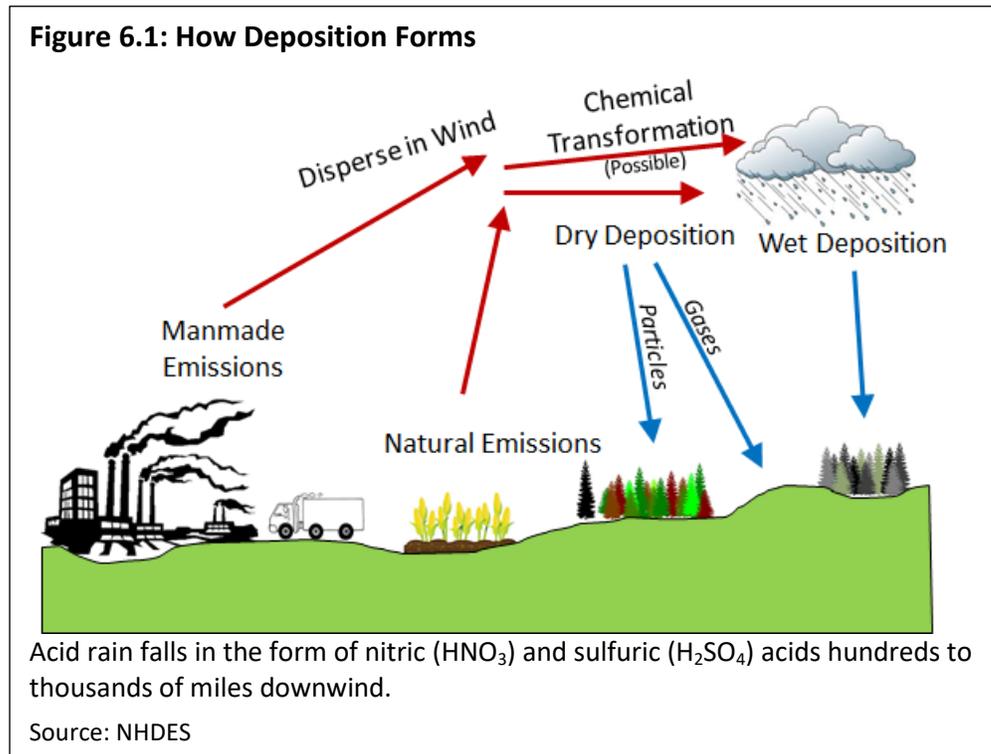
There appear to be numerous localized PM<sub>2.5</sub> concentration spikes throughout the state associated with single sources. Such areas could represent isolated areas of elevated PM<sub>2.5</sub> concentrations if the local pattern of the smoke were persistent and if it repeatedly affected nearby residences or businesses. While epidemiological studies have increasingly implicated short-term PM<sub>2.5</sub> spikes in adverse cardiac and respiratory outcomes, a firm declaration of health risks cannot be made with regard to isolated concentration spikes recorded in this study.

**Key Point:** Based on results of a multi-year NHDES mobile monitoring study, Keene appears to be unique in the frequency and high level of PM<sub>2.5</sub> experienced on some winter nights, but a few other communities may also experience some degree of high PM<sub>2.5</sub> concentrations at times. Determining the extent of risk in these locations will require additional study.

## 6 ATMOSPHERIC DEPOSITION

Virtually all air pollutants deposit onto ground and water surfaces to some extent, either through wet or dry deposition. Wet deposition occurs when pollutants are washed out of the atmosphere by rain, snow, or fog. Dry deposition occurs when pollution is directly deposited onto the surface by gravity (Figure 6.1). How much pollution falls to the surface depends on how much of the pollutant is in the air and how efficient it is at depositing.

Perhaps the best known type of deposition is acid rain. However, the more accurate term for this process is acid deposition since acids can deposit in rain, snow, fog and in a dry form. Decades of acid deposition have acidified many of the state's lakes and streams to varying degrees. Despite efforts to reduce the pollution that



causes acidification, it will take many more years before the state's water resources return to pre-industrial acid levels. The most significant contributors to acid deposition are sulfur dioxide ( $\text{SO}_2$ ) and nitrogen oxides ( $\text{NO}_x$ ), which can form sulfuric and nitric acids in the air. Deposition of other compounds also occurs and sometimes becomes problematic. For example, deposition of perfluorodated compounds such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) have been recently noted as a significant contributor to localized groundwater contamination.

Not all atmospheric deposition consists of acidic compounds. Efforts have been ongoing to reduce deposition of other pollutants as well, including two of concern in New Hampshire: nitrogen and mercury.

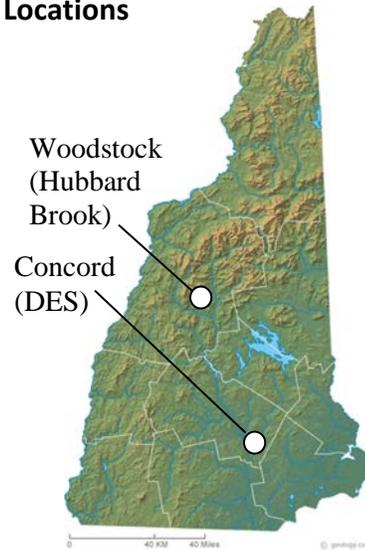
Excess deposition of nitrogen-containing compounds to lakes, coastal waters, and estuaries can cause algal blooms, which lead to low levels of dissolved oxygen in the water and can kill fish and shellfish. Deposited mercury can enter the food chain and ultimately work its way up to human consumers. Ingested mercury can affect brain and neurological development, especially in developing fetuses. Fish consumption advisories are currently in place for fish caught anywhere in New Hampshire. Similar advisories exist for other northeastern states. In 1977, the U.S. State Agricultural Experiment Stations developed the National Atmospheric Deposition Program (NADP) to measure atmospheric deposition of acids and other pollutants and to study their effects on the environment. Measurement locations were placed throughout the country to provide broad geographic coverage and to track long-term trends of acid deposition (Section 6.2) as well as several key chemical species, including total nitrogen (Section 6.3). Another deposition network called the Mercury Deposition Network (MDN) was developed in 1996 to track mercury deposition. The MDN currently has over 100 sites in the United States and Canada (Section 6.4).

### 6.1 Seasonality of Deposition

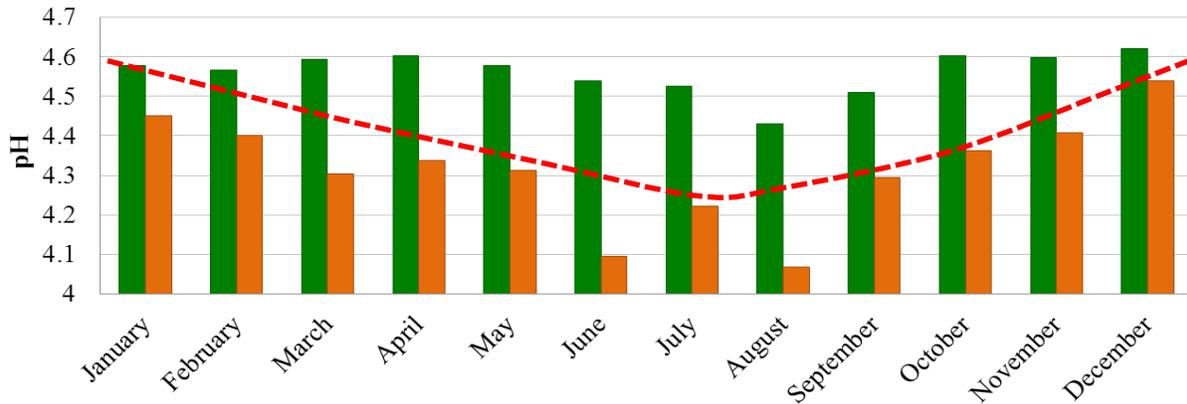
Acidity of precipitation has been monitored at two locations in New Hampshire since the early 1970s. The NADP network includes a location at Hubbard Brook Experimental Forest in Woodstock, New Hampshire. NHDES has also unofficially collected and tested precipitation at its office complex on Hazen Drive in Concord, New Hampshire (Figure 6.2).

The acidity of deposition varies depending on the route of the air mass and how many pollution sources lie along its path. In New Hampshire, the warmer summer months tend to have wind flow patterns that bring more polluted air from the south and from the industrial Midwest. As a result, acidity of deposition increases (pH decreases) during the summer months. In winter, winds arrive in New Hampshire from a more northwesterly direction, where fewer pollution sources are found. During cold weather, the acidity of precipitation decreases and the pH increases (Figure 6.3).

**Figure 6.2: New Hampshire Precipitation Acidity Monitoring Locations**



**Figure 6.3: Average pH per Month, 1978-2013**



Source: NADP and NHDES      ■ Hubbard Brook   ■ NHDES

Deposition of sulfates is similar in that the highest deposition rates occur in the summer when the winds come to New Hampshire by way of more polluted regions upwind (Figure 6.4). Summer weather also increases electrical demand which increases the coal burning needed to generate electricity. Coal is a major source of sulfur emissions, which can react into sulfates and sulfuric acid.

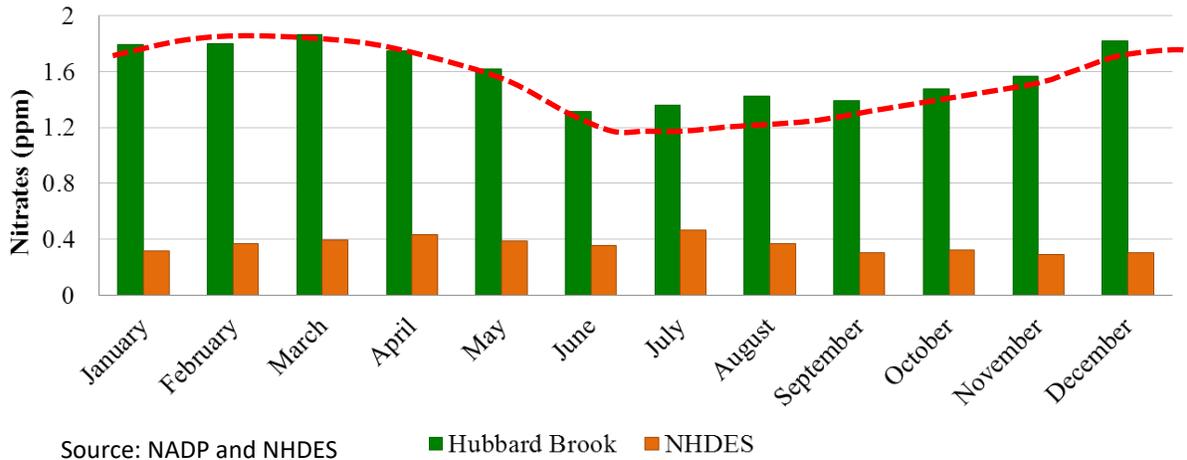
**Figure 6.4: Average Sulfates per Month, 1978-2013**



Source: NADP and NHDES      ■ Hubbard Brook   ■ NHDES

Figure 6.5 shows nitrogen deposition patterns by month. Monthly deposition patterns at the NHDES station in Concord appear fairly consistent throughout the year, but the Hubbard Brook location shows a clear trend of higher nitrogen deposition in the colder months and lower deposition in the summer. This pattern in nitrogen deposition is consistent with nitrogen dioxide (NO<sub>2</sub>) concentrations measured in the air; in New Hampshire, monitored NO<sub>2</sub> dips in the summer and rises in the winter. In addition, atmospheric chemistry favors the creation of sulfates when sulfur is available and the creation of nitrates when sulfur concentrations drop. Thus during the summer when sulfur is plentiful, sulfates are preferentially created instead of nitrates. Conversely, nitrates are preferentially created during the winter months.

Figure 6.5: Average Nitrates per Month, 1986-2012



## 6.2 Acid Rain and Acid Deposition

In addition to their contribution to ozone and small particle sulfate and nitrate formation, the air pollutants SO<sub>2</sub> and NO<sub>x</sub> can react in the air to form sulfuric (H<sub>2</sub>SO<sub>4</sub>) and nitric (HNO<sub>3</sub>) acid, respectively. These acidic compounds return to the earth through acid deposition. Acid rain, or wet acid deposition, is the most familiar form of acid deposition.

Acid deposition increases the acidity of New Hampshire’s streams, ponds, and lakes, adversely affecting fish populations. According to studies conducted by Hubbard Brook Research Station in Thornton, New Hampshire, acid deposition over the past 60 years has caused the acidity of the state’s streams and lakes to reach critical levels (Driscoll et al., 2001). Under these conditions, native species of fish and plants can no longer thrive. Acid deposition strips nutrients from the soil which slows the growth of crops and trees and has threatened native species of white pine. Acid deposition and the associated nutrient losses also affect overall forest productivity. Trees deprived of critical nutrients can become susceptible to insect infestation, drought, frost, and ozone damage. In addition, sulfates and nitrates that build up on soils and other surfaces can leach into water bodies, substantially slowing the recovery of water ecosystems. The acids also leach aluminum from soils and rocks; natural processes can then carry the aluminum into nearby water bodies where it can be toxic to fish.

### 6.2.1 Acid Deposition Trends

Since the Acid Deposition provisions were added to the Clean Air Act in 1990, the acidity of atmospheric deposition is now about 10 times less acidic than it was in 1985, but more needs to be done. Figure 6.6 shows that precipitation at the NHDES station in the southern part of the state is generally more acidic than at Hubbard Brook in the northern part of the state. (pH neutral is 7.0)

Figure 6.6: Annual Average pH Trends, 1978-2013

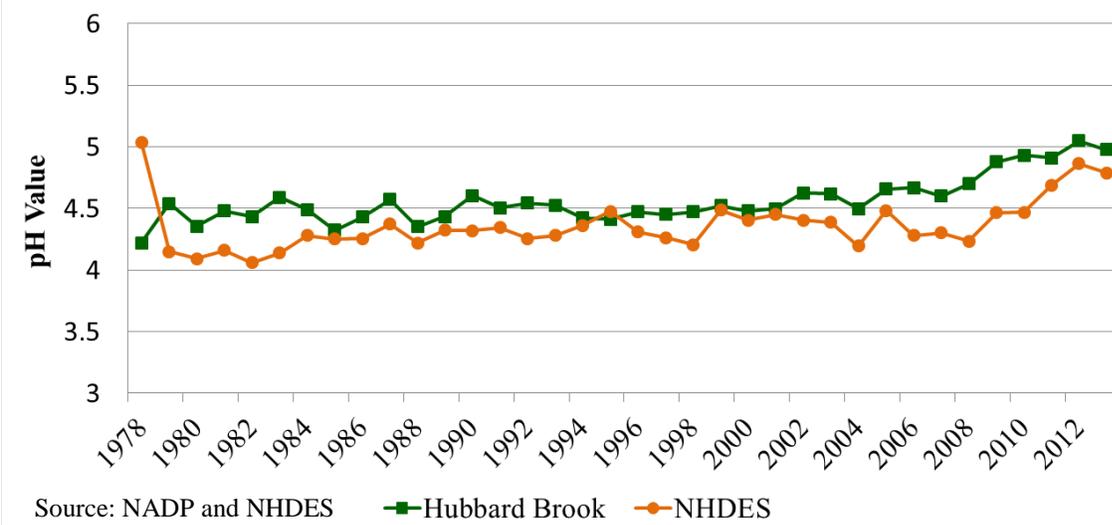
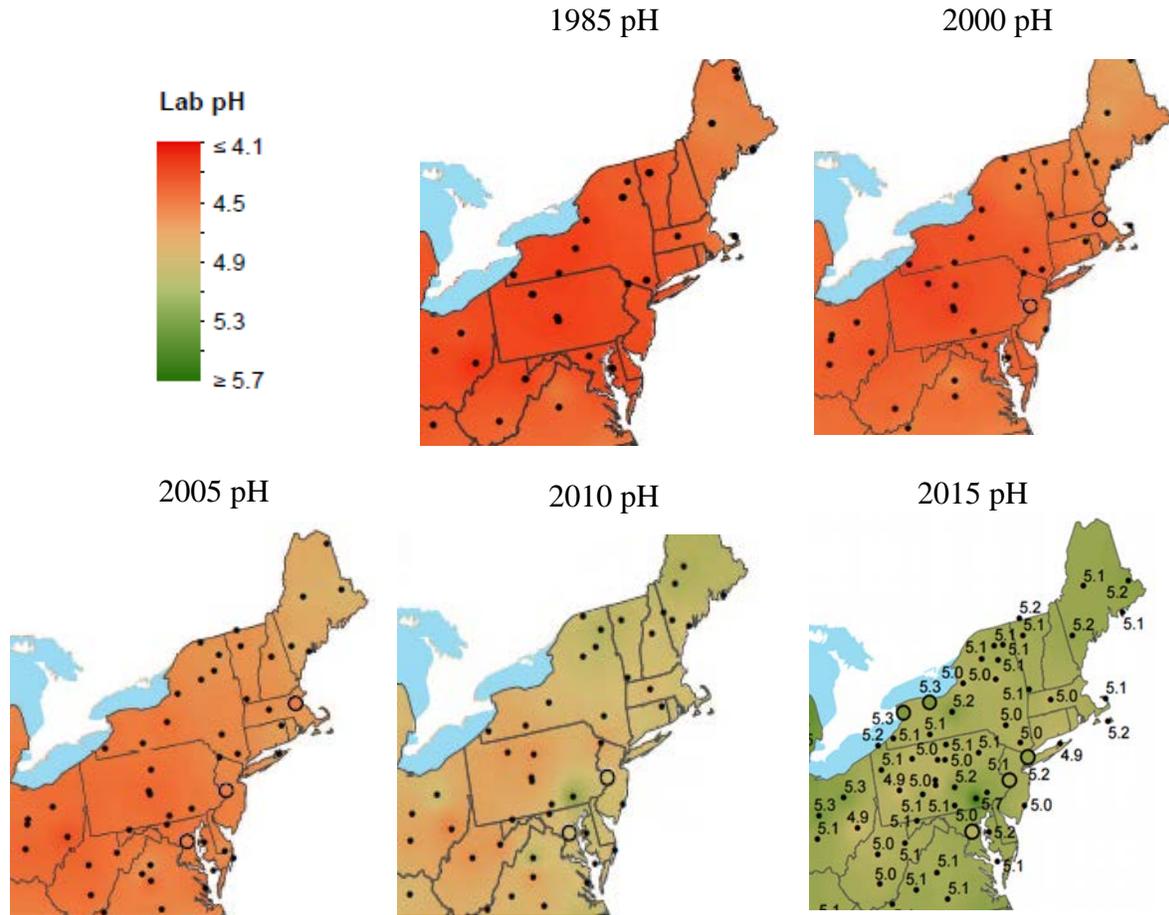


Figure 6.7 provides a geographic interpretation of NADP pH measurements throughout the Northeast in 2013 and going back in time. The maps show higher pH values throughout the Northeast in 2013 and 2010 compared to earlier years (higher pH means less acidity). This positive trend, if maintained, will lead to a slow recovery of New Hampshire lakes and streams from years of acid deposition.

**Figure 6.7: Acidity of Precipitation in the Northeast, 1985-2015**



Source: Data collected through the National Atmospheric Deposition Program (NADP): <http://nadp.sws.uiuc.edu/NADP/>

### 6.2.2 Acidity of Water bodies in New Hampshire

New Hampshire lakes are extremely vulnerable to acid deposition because their buffering capacity has been depleted due to decades of acid deposition. A water body’s buffering capacity, measured as acid neutralizing capacity (ANC), is its ability to neutralize acid inputs without becoming more acidic. This capacity is determined primarily by the amount of calcium carbonate or other carbonates (e.g., limestone) in the system. New Hampshire’s granite bedrock contributes few of these carbonate minerals to surface waters which makes the state’s water bodies more susceptible to acidification.

**An ANC value less than or equal to zero or a pH less than five denotes acidification**, and the lower the pH, the more acidic the water body. Table 6.1 lists New Hampshire’s acidified lakes and remote ponds based on the most recently sampled ANC and pH levels. This table shows that all geographic areas of New Hampshire have or have had acidified water bodies, proving just how vulnerable the state’s water bodies are to the effects of acid deposition.

**An ANC of 10 or less or a pH of six or less is considered highly sensitive to acid inputs.** Based on data collected since 2000, about 80% of the state's lakes and 90% of the remote, mostly high-elevation, ponds are highly sensitive or worse. Table 6.2 lists acidity data for New Hampshire's largest lakes (over 400 acres) based on the most recent samples. While none of these water bodies currently meet the criteria for an acidified water body, many show signs of acid sensitivity, with either a pH less than or equal to six or an ANC under less than or equal to 10.

There are significant differences in the acidity status of lakes and ponds between summer (June-August) and winter (December-February). In the summer, the pH of water bodies may be artificially elevated (i.e., less acidic) due to photosynthesis. As a result, winter pH data is a better indicator of the pH to which aquatic organisms are exposed during the year. Since 2000, samples reveal that about 30% of the state's lakes and ponds have pH values of six or less in the summer. But in the winter, however, almost 60% of these water bodies have pH values of six or less. For remote ponds, this percentage is over 80%; the majority of these remote pond data are from summer samples.

The effects of acid deposition can be especially harmful in the spring when the winter snow pack melts. The ecosystem is shocked with a large volume of water carrying several months' accumulation of deposited acids and toxic metals such as mercury. Further, this toxic shock occurs during the critical first phases of the annual reproductive cycles of plants, animals, and fish. Acidified lakes are unlikely to support a naturally reproducing population of fish.

After the spring snowmelt, the New Hampshire Fish and Game Department stocks a number of remote ponds with brook trout. Many of these ponds would probably not support a naturally reproducing brook trout population due to exposure of the developing embryos to the springtime acid shock. In fact, some ponds are no longer stocked because of poor fish survival or poor returns.

Water body samples in Tables 6.1 and 6.2 were collected in summer, winter and spring. Through various monitoring programs, NHDES staff and volunteers have taken acidity samples in over 700 water bodies since the 1980s, but not every water body can be sampled every year, or even every decade. Consequently, the most recent data in the tables may be very current or may have been taken several years ago.

**Key Point:** Acid deposition, commonly occurring as acid rain, increases acidity in water bodies and causes harm to aquatic ecosystems. Precipitation in New Hampshire has been less acidic in recent years, but several of the state's water bodies remain highly sensitive to acid inputs.

**Table 6.1: Acidified Water Bodies\***

LAKE	TOWN	COUNTY	Date	PH	ANC
ASHUELOT POND	WASHINGTON	SULLIVAN	8/20/2014	4.94	-0.7
AUSTIN CATE WETLAND	STRAFFORD	STRAFFORD	6/13/2002	4.66	<.8
BAKER POND	CHESTERFIELD	CHESHIRE	3/9/1994	4.9	0.2
BARRETT POND	WASHINGTON	SULLIVAN	1/11/2000	4.9	0.2
BEAR HILL POND	ALLENSTOWN	MERRIMACK	2/20/1997	4.6	<0.6
BRACKETT POND	WENTWORTH	GRAFTON	6/21/2005	4.59	-1.1
CONE POND	THORNTON	GRAFTON	2/14/1996	4.5	<0.9
CONSTANCE LAKE	PIERMONT	GRAFTON	5/31/1994	4.8	-0.5
CORSER POND	ERROL	COOS	6/21/2005	4.98	0.5
CUMMINGS MEADOW	JAFFREY	CHESHIRE	2/2/2010	4.64	0.2
DARRAH POND	LITCHFIELD		8/20/2004	4.91	-0.9
DERBY POND	ORANGE	GRAFTON	6/21/2006	5.16	-0.1
DIVOL POND	RINDGE	CHESHIRE	2/5/1991	4.6	<1
ECHO LAKE	CONWAY	CARROLL	2/17/2004	5.1	0
FOUR MILE POND	DIX'S GRANT	COOS	6/26/2000	5.1	-0.2
HUNTS POND	HANCOCK	HILLSBOROUGH	1/30/2007	4.54	-1.1
KIAH POND	SANDWICH	CARROLL	1/29/1996	4.9	<0.3
KILBURN POND	WINCHESTER	CHESHIRE	2/5/1992	4.5	<1.2
KINSMAN POND	LINCOLN	GRAFTON	9/8/1994	4.5	<1.9
LONG POND	DUNBARTON	MERRIMACK	1/31/2005	4.99	-0.1
LOVEWELL POND	NASHUA	HILLSBOROUGH	2/24/1993	4.2	<2.3
MEETINGHOUSE POND	MARLBOROUGH		8/23/2005	5.2	-0.6
NANCY POND	LIVERMORE	GRAFTON	8/1/1995	4.7	<0.8
NORTH POND	WASHINGTON	SULLIVAN	1/5/2005	4.92	-0.1
NORTHWOOD LAKE	NORTHWOOD		8/18/2014	4.9	5.1
PIPER POND	WILMOT	MERRIMACK	3/8/2007	4.74	-0.1
PISGAH RESERVOIR	WINCHESTER	CHESHIRE	7/20/1982	4.4	0
POWWOW POND	KINGSTON		8/15/2014	4.36	19.6
PURGATORY POND	DUNBARTON	MERRIMACK	1/4/2005	4.99	0.3
ROCKWOOD POND	FITZWILLIAM		7/28/2014	4.51	0.8
ROCKY POND	WENTWORTH	GRAFTON	6/21/2005	4.68	-0.5
ROBBINS POND	RINDGE	CHESHIRE	2/10/1999	4.9	<0.2
ROUND POND	GILFORD	BELKNAP	2/6/1996	4.8	<0.1
ROUND POND	NOTTINGHAM	ROCKINGHAM	1/14/1993	4.2	<3.7
SIGNAL POND	ERROL	COOS	6/11/2014	4.64	1
SIP POND	FITZWILLIAM	CHESHIRE	2/11/2008	4.3	-0.9
SPRUCE POND	DEERFIELD	ROCKINGHAM	2/22/2000	4.9	<0.1
SPORTSMAN POND	FITZWILLIAM	CHESHIRE	3/3/1982	4.8	<0.1
STONE POND	MARLBOROUGH		8/10/2014	4.41	2.5
THREE TRIO POND	ODELL	COOS	6/21/2005	4.86	0.2
WASON POND	CHESTER		1/29/1998	4.8	1.2
WHITCOMB POND	ODELL	COOS	6/21/2005	4.96	0.7
WILD GOOSE POND	PITTSFIELD		8/1/2014	4.88	2.9
WILLEY POND, BIG	STRAFFORD	STRAFFORD	2/9/2000	4.5	<1.4
WILLEY POND, LITTLE	STRAFFORD	STRAFFORD	2/9/2000	4.6	<0.8
WINKLEY POND	BARRINGTON		2/16/2006	5.09	0

An ANC value less than or equal to zero or a pH less than five denotes acidification

An ANC of 10 or less or a pH of six or less is considered highly sensitive to acid inputs

\* Samples represent conditions only at the location where they are taken;  
pH and ANC values may vary among different locations within the same water body.

Source: NHDES

**Table 6.2: pH and ANC for Waterbodies\* Larger than 400 Acres**

LAKE	TOWN	COUNTY	DATE	pH	ANC
AYERS ISLAND DAM POND	BRISTOL	GRAFTON	8/1/1996	6.3	4.4
BALCH POND	WAKEFIELD	CARROLL	3/10/2003	6.2	10.3
BARNSTEAD PARADE DAM POND	BARNSTEAD	BELKNAP	1/22/2004	6.01	3.1
BOW LAKE	STRAFFORD	STRAFFORD	1/29/2009	5.48	2.8
BROAD BAY	FREEDOM	CARROLL	10/1/2014	6.07	7.7
CONNECTICUT LAKE, FIRST	PITTSBURG	COOS	6/19/2007	6.36	5.7
CONNECTICUT LAKE, SECOND	PITTSBURG	COOS	8/4/2009	5.52	6
CONWAY LAKE	CONWAY	CARROLL	2/21/2006	6.16	3.1
CRYSTAL LAKE	GILMANTON	BELKNAP	9/4/2014	6.03	4.7
DAN HOLE POND	TUFTONBORO	CARROLL	8/14/2014	6.49	4.3
FRANCIS, LAKE	CLARKSVILLE	COOS	7/29/2014	6.71	9.6
GOOSE POND	CANAAN	GRAFTON	9/28/2014	6.19	8.3
GREAT EAST LAKE	WAKEFIELD	CARROLL	1/27/1993	6.8	7.1
HIGHLAND LAKE	STODDARD	CHESHIRE	9/7/2014	5.78	2.2
ISLAND POND	DERRY	ROCKINGHAM	8/18/2014	6.47	15.1
JACKMAN RESERVOIR	HILLSBOROUGH	HILLSBORO	8/21/2014	5.81	2.6
LOVELL LAKE	WAKEFIELD	CARROLL	9/4/2014	7.17	13.3
MASCOMA LAKE	ENFIELD	GRAFTON	8/19/2014	6.13	13
MASSABESIC LAKE	MANCHESTER	HILLSBORO	3/15/2001	6.1	4.8
MASSASECUM LAKE	BRADFORD	MERRIMACK	7/25/2014	6.03	3.5
MERRYMEETING LAKE	NEW DURHAM	STRAFFORD	2/13/2006	6.31	6.5
MONOMONAC, LAKE	RINDGE	CHESHIRE	5/22/2015	5.97	3.3
MOORE RESERVOIR	LITTLETON	GRAFTON	2/14/1994	6.7	13
NEWFOUND LAKE	BRISTOL	GRAFTON	2/25/1993	6.3	3.3
NORTHWOOD LAKE	NORTHWOOD	ROCKINGHAM	8/18/2014	6.45	5.1
NUBANUSIT LAKE	HANCOCK	HILLSBORO	9/10/2014	5.88	1.3
OPECHEE BAY	LACONIA	BELKNAP	1/27/2000	6.6	7.3
OSSIPEE LAKE	OSSIPEE	CARROLL	9/30/2014	6.09	6
PAUGUS BAY	LACONIA	BELKNAP	1/31/2001	6.4	7.3
PAWTUCKAWAY LAKE	NOTTINGHAM	ROCKINGHAM	5/19/2015	5.93	5.8
PINE RIVER POND	WAKEFIELD	CARROLL	6/6/2011	6.3	6
PLEASANT LAKE	DEERFIELD	ROCKINGHAM	9/23/2014	6.05	2.9
PLEASANT LAKE	NEW LONDON	MERRIMACK	10/2/2014 (pH); 9/24/2014 (ANC)	7.01	5.6
POWDER MILL POND	BENNINGTON	HILLSBORO	2/3/1998	6	3.7
PROVINCE LAKE	EFFINGHAM	CARROLL	9/26/2013	6.74	6.7
SILVER LAKE	MADISON	CARROLL	8/26/2003	6.01	3.7
SPOFFORD LAKE	CHESTERFIELD	CHESHIRE	8/12/2014	6.47	9.3
SQUAM LAKE	HOLDERNESS	GRAFTON	2/27/1989	6.2	5.7
SQUAM LAKE, LITTLE	ASHLAND	GRAFTON	2/1/2010	6.21	4.9
SUNAPEE LAKE	NEW LONDON	MERRIMACK	9/15/2014	6.01	5.5
SUNAPEE LAKE, LITTLE	NEW LONDON	MERRIMACK	8/12/2014	5.93	4.9
SWAINS LAKE	BARRINGTON	STRAFFORD	2/28/2001	5.7	3.3
UMBAGOG, LAKE	ERROL	COOS	3/8/2006	6.18	4.6
WAUKEWAN, LAKE	NEW HAMPTON	BELKNAP	8/28/2014	6.35	8.6
WEBSTER LAKE	FRANKLIN	MERRIMACK	9/24/2014 (pH); 8/19/2014 (ANC)	6.63	7.3
WENTWORTH, LAKE	WOLFEBORO	CARROLL	2/13/2007	6.21	4.4
WINNIPESAUKEE, LAKE	MOULTONBOROUGH	CARROLL	8/18/2014 (pH); 2/11/2009 (ANC)	6.69	6.2
WINNISQUAM, LAKE	LACONIA	BELKNAP	8/22/2014	6.64	7.7

An ANC of 10 or less or a pH of six or less is considered highly sensitive to acid inputs

Source: NHDES

\* Samples represent conditions only at the location where they are taken; pH and ANC values may vary within the same waterbody.

### 6.3 Nitrogen Deposition

Similar to acidic compounds, nitrogen compounds in the air may deposit onto the ground or water surfaces through various deposition processes. Concentrations of total nitrogen and other substances dissolved in precipitation are generally quite low. However, they can accumulate over time, either right where they deposit or downstream of that location. A small amount of deposited nitrogen can act as a natural fertilizer, but large amounts can lead to algae blooms, which can kill fish. Ponds and small lakes covered with a film of green may be the result of excess nitrogen. There are a number of water bodies in New Hampshire that are sensitive to nitrogen deposition including Great Bay near the state’s seacoast (Section 6.3.2).

#### 6.3.1 Trends in Nitrogen Deposition

In New Hampshire, nitrogen deposition has been officially tracked since 1978 at the Hubbard Brook Experimental Forest in the town of Woodstock. In 1986, NHDES began unofficial deposition measurements at its office location in Concord. As shown in Figure 6.8, both locations demonstrate downward trends of nitrogen deposition, decreasing by about 50 percent over the last 25 years. It might seem counter intuitive that nitrogen deposition is greater in the remote northern portion of the state as compared to the Concord region, but the mountains in the North wring extra precipitation from weather systems carrying transported nitrogen emissions. This pattern can be seen in Figure 6.9.

**Figure 6.8: Annual Average Nitrates, 1978-2012**

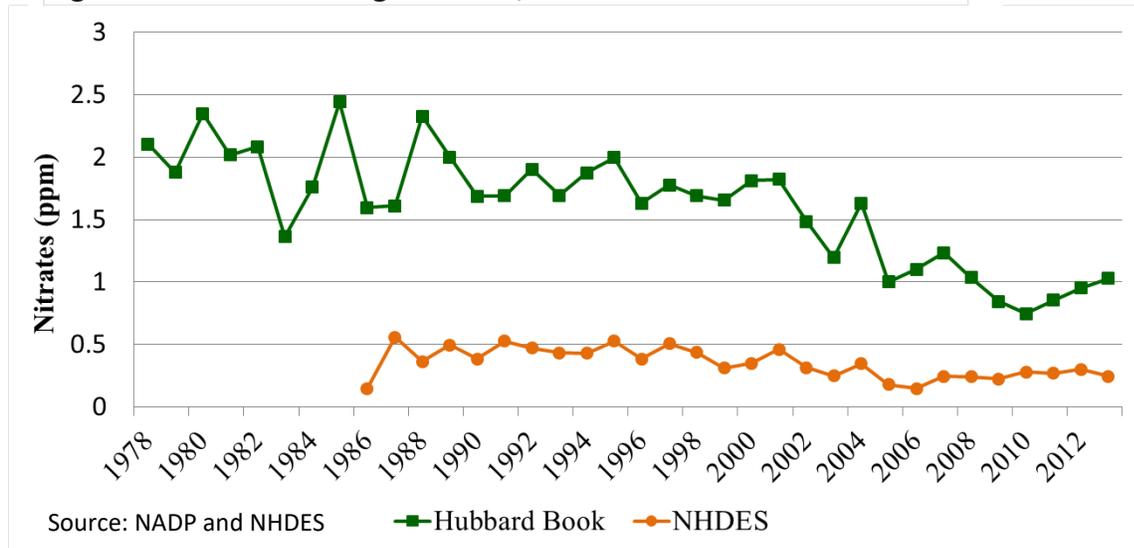
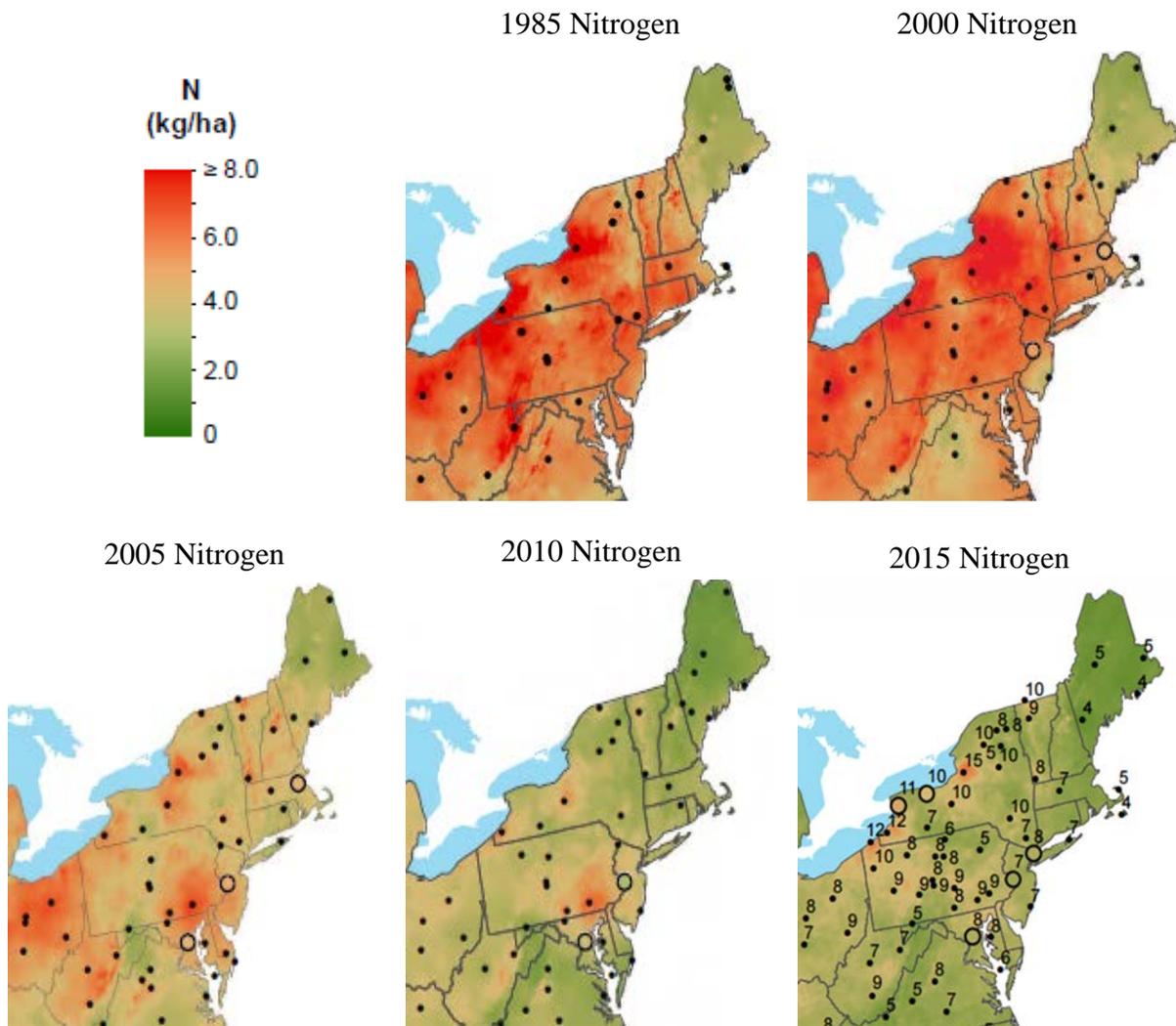


Figure 6.9 below shows the geographic distribution of nitrogen deposition rates in the Northeast United States during select years since 1985. Notably, nitrogen deposition has decreased significantly since 1985 due to air pollution control programs. Nitrogen deposition rates in the Northeast tend to be highest in mountainous areas and areas close to locations with high nitrogen emissions. Hubbard Brook, in the White Mountain region of the state, sees considerably higher nitrogen deposition than the southern part of the state.

**Figure 6.9: Total Nitrogen Deposition by Precipitation in the Northeast, 1985-2015**

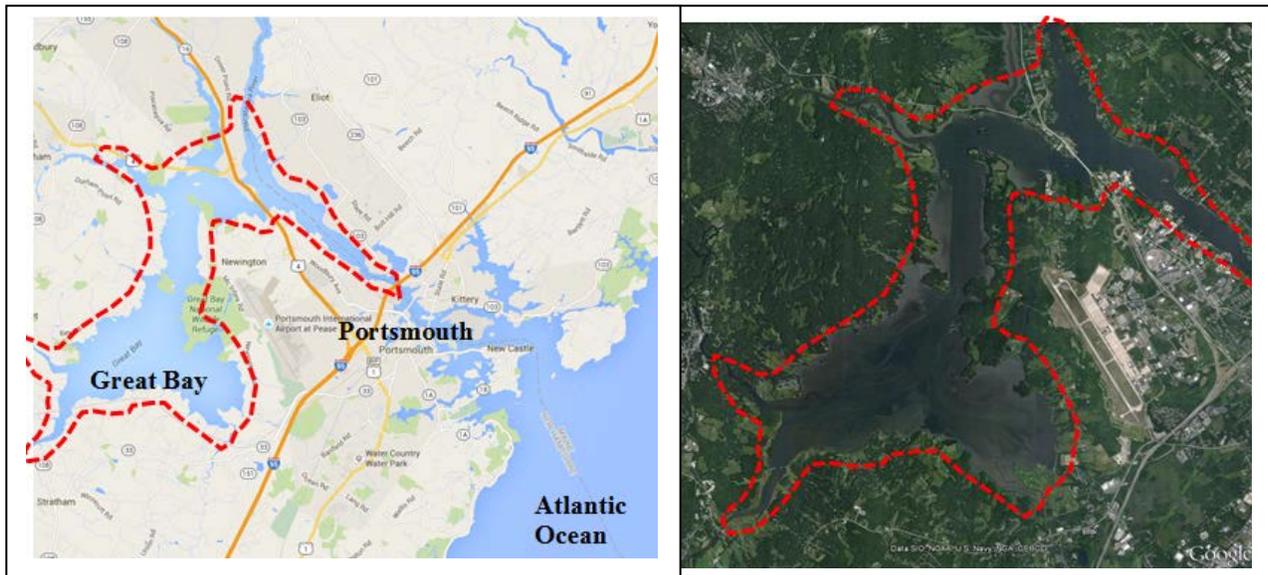


Source: Data collected through the National Atmospheric Deposition Program (NADP): [\(http://nadp.sws.uiuc.edu/NADP/\)](http://nadp.sws.uiuc.edu/NADP/)

### 6.3.2 Great Bay Deposition Study

One area in New Hampshire with significant sensitivity to nitrogen deposition is Great Bay. Great Bay is located near the New Hampshire Atlantic coastline and is essentially a tidal-affected river estuary (Figure 6.10). In 2013, NHDES performed a study of nitrogen inputs to Great Bay. For this study, NHDES did not directly measure nitrogen deposition, but used measurements taken by others, such as the University of New Hampshire, as inputs to a modeling analysis.

**Figure 6.10: Google Earth Images of the Great Bay Estuary**



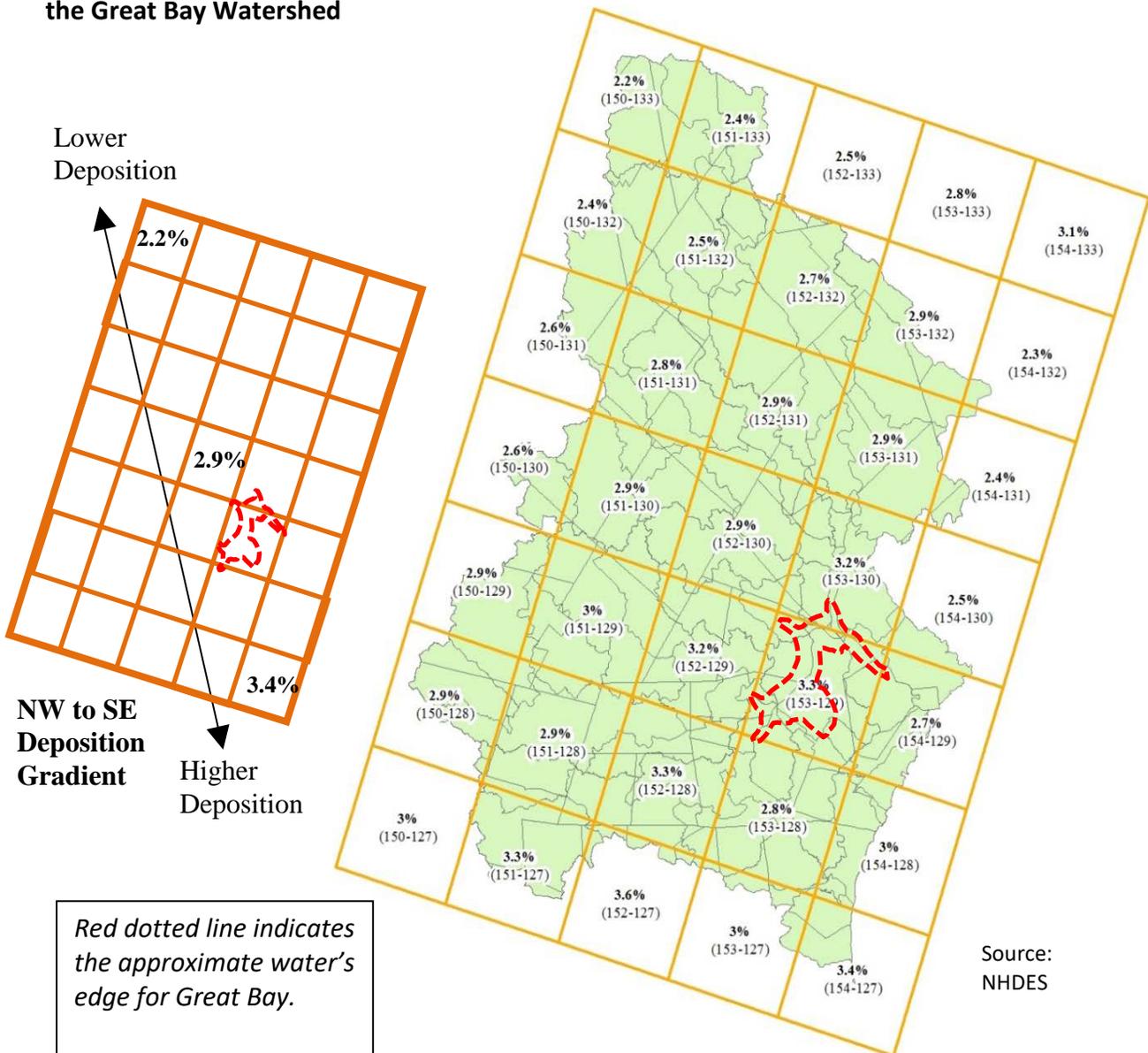
*Red dotted line indicates the approximate waters-edge for Great Bay.*

NHDES ran a regional dispersion model for the eastern United States to generate estimated deposition rates and atmospheric concentrations of key nitrogen species to Great Bay. The intent of this study was to estimate sources of atmospheric deposition of nitrogen to the Great Bay watershed, the area from which waters naturally drain into the bay. The two major goals of the analysis were to estimate: (1) how much of the nitrogen deposition to the Great Bay watershed comes from sources inside versus outside the state, and (2) how much of the nitrogen comes from specific source categories (on- and off-road mobile sources, power generation, and “area” sources such as residential heating).

The modeling study revealed a gradient of nitrogen deposition across the Great Bay watershed area, from a low in the northwest to a high in the southeast. Figure 6.11 illustrates this deposition gradient by showing the percent of total deposition (wet plus dry) estimated for each model grid cell representing the watershed. For example, the model estimated that 2.2% of total deposition in the watershed occurs in the northwestern-most (i.e. the upper left) grid cell.

The regional model is also capable of isolating the influence of geographic regions and emissions sectors. Table 6.3 shows the estimated percent contribution from various geographic regions and emissions categories to total nitrogen deposition in the Great Bay watershed.

**Figure 6.11: Percent Total Deposition Occurring in Each of the Modeled Grid Cells Representing the Great Bay Watershed**



Red dotted line indicates the approximate water's edge for Great Bay.

Green shaded areas represent the full Great Bay watershed, including feed waters.

Source: NHDES

**Table 6.3: Total Deposition, Wet and Dry, Percent of Total**

	Sources Located in:		
	All Locations	New Hampshire	All Other Areas
<b>All Emissions Sources</b>	<b>100%</b>	<b>37%</b>	<b>63%</b>
<b>On-Road – Mobile (highway)</b>	32%	10%	22%
<b>Non-Road – Mobile</b>	22%	9%	13%
<b>Area*</b>	20%	9%	11%
<b>Point - Power Generation</b>	26%	9%	17%

\*Area source emissions are categories that are too widespread or numerous to estimate individually. Examples include residential heating, consumer solvent use, and dry cleaning. Emissions for area source categories are therefore estimated using aggregate data such as statewide fuel use, population, etc.

As shown in Table 6.3, NHDES modeling indicated that approximately 63% of total nitrogen deposition in Great Bay comes from sources outside New Hampshire (“non-NH” sources). Contributions from non-NH sectors were 11-22%, with on-road mobile sources having the highest contribution. All in-state source sectors had fairly equal contributions of 9-10%. The five highest contributing sectors, in order from greatest to least impact, were:

- 1) Non-NH on-road (22 percent).
- 2) Non-NH point (17 percent).
- 3) Non-NH non-road (13 percent).
- 4) Non-NH area (11 percent).
- 5) NH on-road (10 percent).

The study also included a projection into the future for national, regional and local NO<sub>x</sub> emissions. Based on this projection, the downward trend in NO<sub>x</sub> emissions is expected to continue, at least in the near term. NO<sub>x</sub> emission reductions will largely come from the point and mobile sectors as a result of the Federal Clean Air Interstate Rule/Cross-State Air Pollution Rule, motor vehicle emissions control programs, and federal rules for non-road engines and fuels (Section 9). Continued emission reductions are expected as older on- and off-road vehicles are phased out and replaced by newer, cleaner vehicles. Since atmospheric deposition of nitrogen is directly correlated to atmospheric NO<sub>x</sub> emissions, a corresponding downward trend in nitrogen deposition can be expected as well.

**Key Point:** The amount of nitrogen in precipitation in New Hampshire is relatively low, and regional nitrogen deposition has been declining, but even small amounts of nitrogen deposition can accumulate and overwhelm natural systems. A study of Great Bay on the Seacoast suggests that the majority of nitrogen inputs to this area come from outside New Hampshire.

## **6.4 Mercury Deposition**

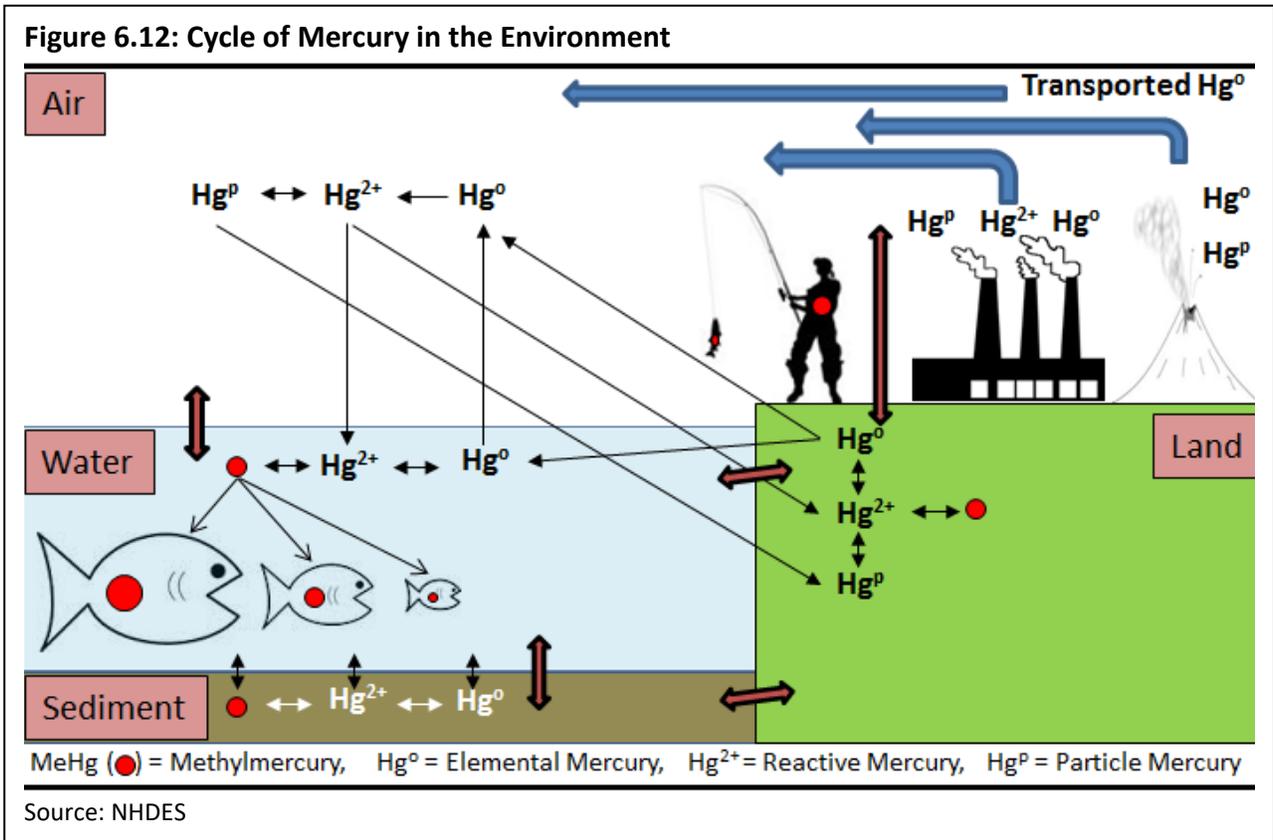
For thousands of years, civilizations have found mercury to be useful in many ways. Worldwide industrial use of mercury in mining and manufacturing processes, as well as emissions from power generation, has greatly increased mercury concentrations in the environment. Unfortunately, appreciation of mercury's adverse health effects on humans is only recent. Currently, health concerns in the United States center on human consumption of fish contaminated with methyl mercury (Me-Hg); Me-Hg refers to a group of organic mercury compounds.

Neurotoxicity is the most important health concern associated with mercury exposure. Me-Hg easily reaches the bloodstream and is distributed to all tissues, and it can cross the normally protective blood-brain barrier and enter the brain. It can also readily move through the placenta to developing fetuses and their developing brains, and is therefore a particular concern to pregnant women and women of childbearing age. Low-level exposure is linked to learning disabilities in children and interference with reproduction in fish-eating animals. EPA lists Me-Hg and mercuric chloride as possible human carcinogens.



Mercury reaches surface waters primarily through wet and dry atmospheric deposition. Estimates suggest wet deposition accounts for 50-90% of the mercury load to most of the nation's inland water bodies and estuaries. Wet deposition rates are variable, and tend to be greatest in summer. Dry deposition rates may be higher than wet deposition rates on forest canopies.

Mercury persists in the environment for long periods by cycling back and forth between the air and soil, all the while changing chemical forms (Figure 6.12). Atmospheric lifetimes of inorganic elemental mercury are estimated to be up to two years, while organic Me-Hg may stay in the soils for decades. Mercury is never removed from the environment; it is just moved to other locations and eventually buried under soils and sediments.



### 6.4.1 Bioaccumulation of Mercury

Mercury is in a class of chemicals called persistent bioaccumulative toxins. Mercury accumulates in biological tissue through complex reactions, many of which are still unknown. It is understood that some types of bacteria incorporate inorganic mercury into their bodies through chemical conversion to several organic Me-Hg compounds. Me-Hg is more toxic and difficult to remove from bacterial systems than inorganic mercury.

Any higher-level organisms that consume these bacteria also consume the Me-Hg they contain, and each predator that consumes a lower predator that has consumed Me-Hg will add more Me-Hg to their system with each meal. This process of accumulation towards the higher end of the food chain is called bioaccumulation. Estimates suggest that Me-Hg can bioaccumulate more than a million fold in the aquatic food chain. Thus even trace levels of mercury in the environment can magnify into a health issue.

Humans can bioaccumulate Me-Hg as well, if fish containing Me-Hg is consumed in sufficient quantities and with sufficient regularity. If fewer Me-Hg contaminated foods are consumed, concentrations in humans will decrease, but only very slowly because brain and organ tissue cannot release Me-Hg efficiently. For health protection purposes, people must take caution when Me-Hg is introduced into the diet, which usually occurs via fish consumption. For this

reason, fish consumption advisories<sup>24</sup> for mercury exist in almost every state in the country, warning people to limit consumption of certain species of fish. These fish advisories also make suggestions about which species of fish are low in mercury and will support a healthy diet. A few states also have wildlife consumption advisories for mercury. Methyl mercury also poses health risks to other animals that consume prey contaminated with Me-Hg.

#### **6.4.2 Trends in Mercury Deposition**

Figure 6.13 shows a geographic interpretation of NADP mercury measurements throughout the Northeast in 2015 and going back in time. Unlike pH and nitrogen, mercury deposition in the Northeast does not yet show a clear trend of improvement. Instead, mercury deposition seems to fluctuate from year to year.

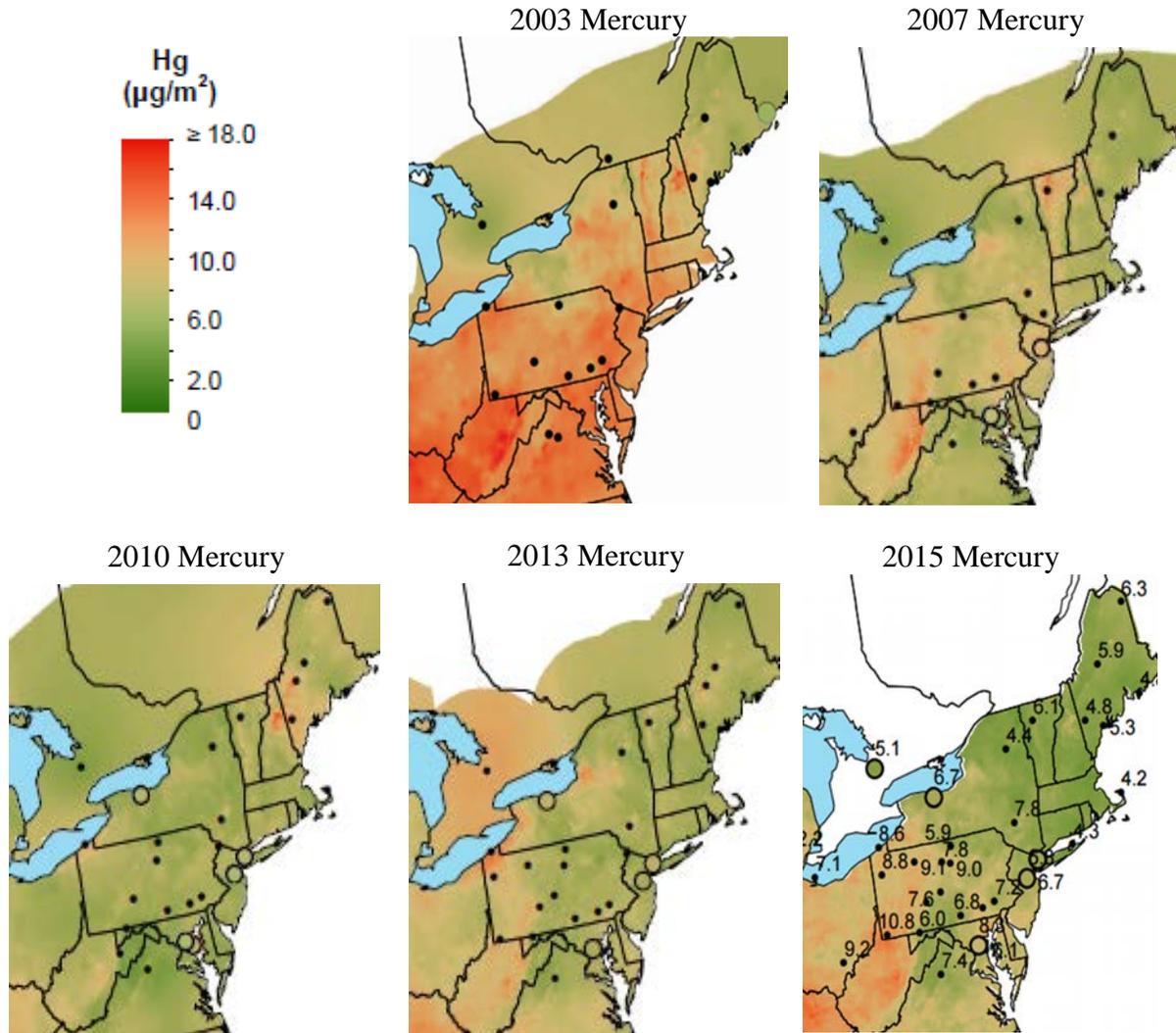
Mercury emissions and deposition should begin to decrease in the next few years as new federal regulations targeting toxic emissions across the United States begin to produce results. Unfortunately, worldwide emissions of mercury are increasing, and some of those emissions can make their way into the United States. This could slow improvements in our region.

**Key Point:** Mercury is a neurotoxin and is especially dangerous to developing fetuses. Organic forms of mercury, called methyl mercury, are often found in fish and can accumulate at higher levels of the food chain. Fish consumption advisories help people avoid eating fish high in mercury.

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<sup>24</sup> NHDES fish consumption guidelines are located at: [http://des.nh.gov/organization/divisions/air/pehb/ehs/ehp/documents/fish\\_advisory.pdf](http://des.nh.gov/organization/divisions/air/pehb/ehs/ehp/documents/fish_advisory.pdf), and EPA fish advisories and related resources are located at: <http://www2.epa.gov/fish-tech>.

Figure 6.13: Mercury Deposition by Precipitation in the Northeast, 2003-2015



Source: Data collected through the National Atmospheric Deposition Program (NADP): <http://nadp.sws.uiuc.edu/NADP/>

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## 7 AIR POLLUTION TRANSPORT

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### 7.1 Introduction to Air Pollution Transport

Since a significant amount of the pollution experienced in New Hampshire comes from upwind areas, understanding where it comes from and how it gets here is necessary in order to develop strategies for improving our air quality. When air pollution blows from one location to another, especially when it crosses state or international boundaries, it is known as air pollution transport. Air pollution transport can be very complicated since pollutants are transported differently depending on a number of characteristics and factors. Adding to the complexity, many air pollutants undergo chemical reactions in the atmosphere, changing their composition and concentrations along the transport route. Air pollution is normally categorized into four categories based on how far a pollutant can travel before it impacts a downwind location (see Table 7.1). Researchers in government, industry and academia continue to study air pollution chemistry and transport mechanisms in order to better understand this phenomenon.

**Table 7.1: Air Pollution Transport Characteristics**

Category	Range	Pollutants Transported
Local	Less than 20-30 miles	Particles, sulfur dioxide, oxides of nitrogen, volatile organic gases (may contain toxic materials), carbon monoxide, mercury (some forms), ozone (in some cases)
Regional	20-30 miles up to 1,000 miles	Ozone, small particles (may contain toxic materials), mercury (some forms)
National	1,000 to 3,000 miles	Dioxin, very small particles (may contain toxic materials), Ozone (under certain conditions), mercury (some forms)
Global	Greater than 3,000 miles	CFC's (chlorofluorocarbons), mercury (some forms), carbon dioxide

Air pollution generally decreases in concentration as it dilutes while moving away from its source, this is referred to as dispersion. However, when there are hundreds to millions of sources of similar pollutants such as cars and trucks, there is a cumulative effect where the concentrations can actually increase downwind.

When the Clean Air Act was first created, it was generally thought that air pollution was primarily a local phenomenon. If an area had an air pollution issue, then local emissions in that area were controlled to address it. There were some exceptions of course, but it was widely believed that all six criteria pollutants

**Key Point: Modeling Air Quality -** Researchers use information on air pollution chemistry and transport mechanisms to perform atmospheric modeling. Atmospheric dispersion models simulate air pollution events and project future conditions in order to determine emission reduction strategies needed to achieve air quality standards. Modern atmospheric models are typically run on powerful computers.

(Section 2.1) were of local, rather than transported, concerns. This line of thinking began to change in the 1990s when widespread areas in the East were unable to successfully meet their ozone attainment deadlines. It was believed that ozone was moving from one area to another. Studies and modeling analyses were undertaken to better understand the ozone transport phenomenon.

One major collaborative effort to seek an interstate transport solution was the Ozone Transport Assessment Group (OTAG). OTAG was created in 1995 as a temporary ad hoc group to perform modeling and scientific analyses to address the problem of air pollution transport in eastern ozone nonattainment areas. OTAG consisted of representatives from 37 states (mostly east of the Mississippi River), several federal agencies, university researchers, and industries. OTAG and other transport research studies have developed the following general conclusions:

*Some pollutants such as acids, small particles, and ozone (and its precursors NOx and volatile organic gases) move with the wind and can survive in the atmosphere for several days, or even several weeks. In order to identify sources responsible for air pollution, knowledge of potential sources and how air masses move is necessary.*

Three major transport pathways (patterns) and numerous sub-pathways have been discovered and tracked by researchers involved with the North American Research Strategy for Tropospheric Ozone - Northeast (NARSTO/NE) analyses. These analyses involved observations taken by aircraft, tethered balloon, and mountain-top air pollution monitors. The major pathways include:

1. Low-Level Flows (Near Surface)
2. Mid-Level (Channeled)
3. High-Level (Synoptic)

**Low-Level (also called Near-Surface Flow):** Most emissions are released near the ground in the lowest 600 feet of the atmosphere and move horizontally with surface-level winds. These winds swirl around objects such as buildings and trees. There are also vertical motions to these winds that can lift ground-level pollution to higher levels and bring aloft pollution down from higher levels.

Low-level flows are responsible for short to medium-range air pollution transport from cities or industrial complexes to nearby downwind areas (Figure 7.1). In locations near large water bodies, the low-level flow can be altered or even

**Figure 7.1: Near Surface Air-Sea Wind Flows – Short Range Transport**

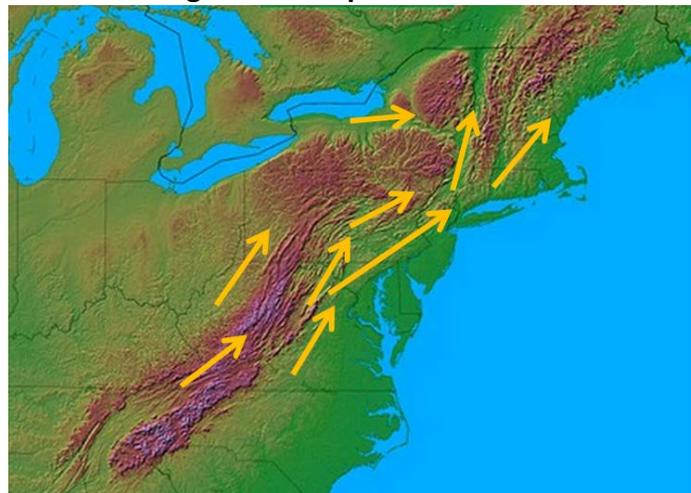


Source: NHDES, 2015

dominated by the maritime air sheds. It is not uncommon for beach-goers to experience a cool sea breeze when temperatures may be hotter just a few miles inland. Sea breezes are caused by the warm air inland rising and the cool air from over the water rushing in to fill the vacuum created by the rising air. Such breezes also can occur near large lakes and bays. When air pollution is nearby, these breezes can affect where the pollution is transported. Often, air pollution from emission sources near the water will be transported very efficiently to downwind locations where the sea breeze makes landfall.

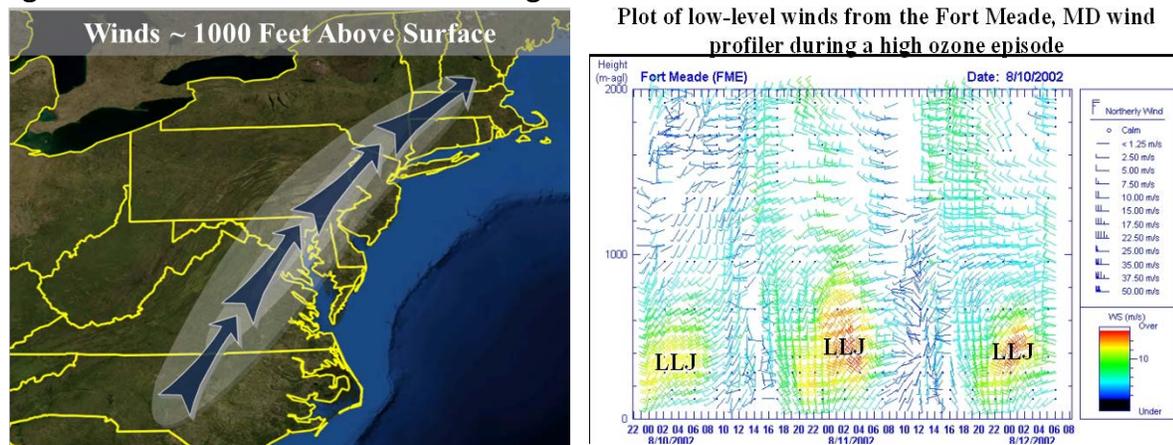
**Mid-Level (also called Channeled Flow):** Mid-elevation winds (about 600 to 2,500 feet above the ground) usually follow terrain features such as mountain ridges and can move pollution fairly quickly across a region of several hundred miles (Figure 7.2). Power plants, which can have exhaust stacks that are hundreds of feet tall, can release pollutants directly into this layer. Because air at this altitude tends to swirl with the winds, pollution in this layer mixes up and down. Mid-level transport can enhance local (surface-level) transport as well as contribute to regional-range transport. Researchers have recently discovered a mid- to low-level sub-pathway called the “low-level jet” (Figure 7.3). The low level jet wind phenomenon forms at night and can move pollution at high speeds northeastward along the eastern front range of the Appalachian Mountains.

**Figure 7.2: Channeled Air Flow in the Northeast – Regional Transport**



Source: NHDES, 2015

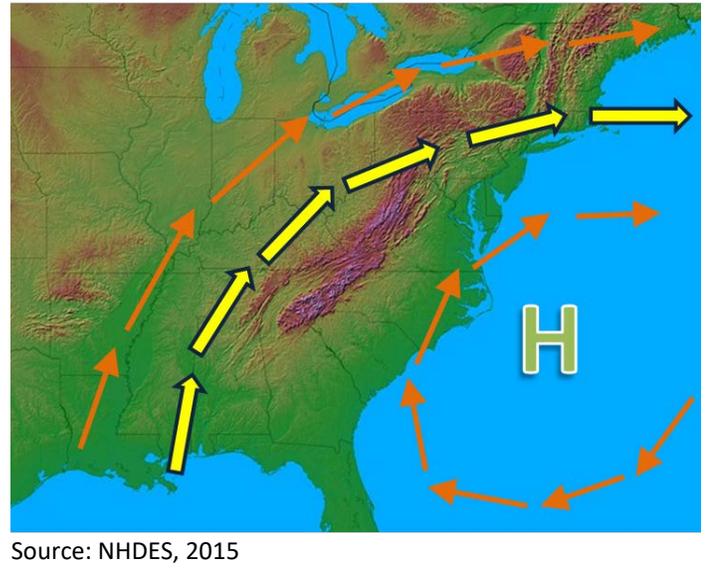
**Figure 7.3: Nocturnal Low-Level Jet – Regional Transport**



The nocturnal low-level jet is a fast-moving narrow channel of air that develops overnight at about 1,000 feet above the ground. Wind speeds can reach 40 miles per hour in a region of relatively calm winds. This phenomenon is typically observed at night between the Appalachian Mountains and the Atlantic Ocean. Source: MDE, 2010

**High-Level (also called Synoptic Flow):** Higher-elevation winds (from around 2,500 to 7,000 feet above the ground) follow large-scale weather features such as high- and low-pressure systems and cold and warm fronts. Pollution in this layer moves horizontally and mixes upward and downward to and from mid-levels during the heating of the day, often in great quantities. These systems can move pollutants at speeds of up to 100 miles per hour at these higher elevations (see Figure 7.4). High-level transport is largely responsible for regional, national, and global air pollution transport. The summit of Mt. Washington resides in this layer and can experience long range ozone transport (Table 4.5).

**Figure 7.4: Synoptic Air Flow – Long-Range Transport Pattern**

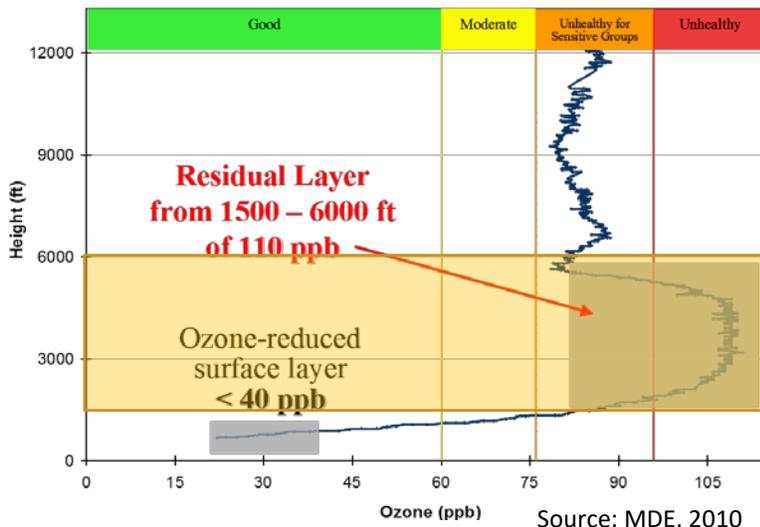


Source: NHDES, 2015

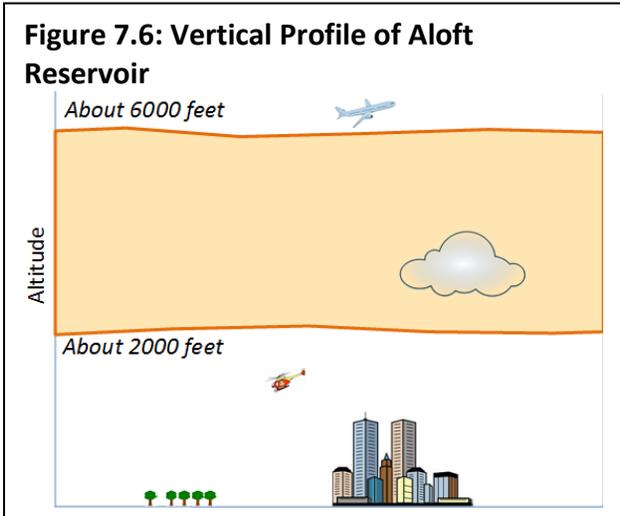
## 7.2 The “Aloft Ozone Reservoir”

Mid to high-level transport arrives in the Northeast and New Hampshire at altitudes high enough that pollution eludes detection by the ground-based monitoring networks. Several studies have been aimed at high-level transport to better understand its nature as well as when and how it mixes pollution downward to the ground. Figure 7.5 shows one such atmospheric sounding over Beltsville, Maryland. At 7AM in 2005, ozone was measured in the good range on the ground while just 2,000 feet straight up it was measured to be unhealthy (see Section 4.2 for a discussion of the Air Quality Index and “Good” and “Unhealthy” terminology).

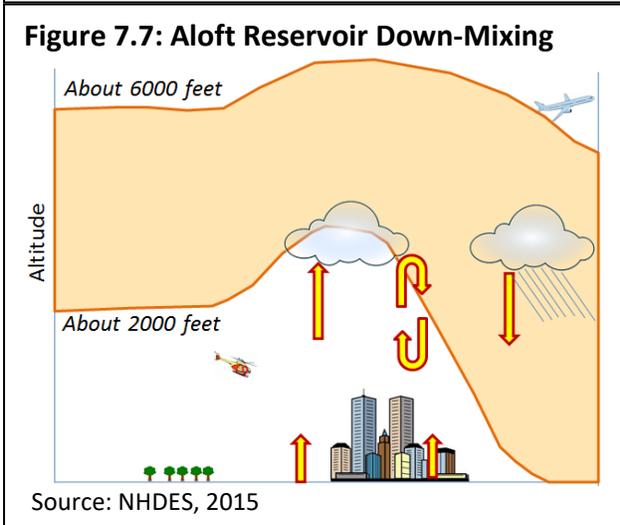
**Figure 7.5: Measured Ozone by Altitude over Beltsville, MD – August 2, 2005 at 7AM**



Source: MDE, 2010

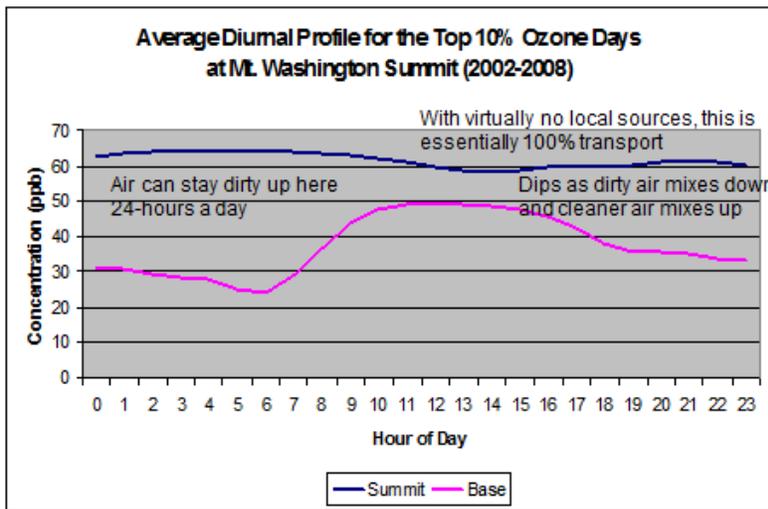


Balloon and airplane studies have verified the existence of an aloft reservoir containing high concentrations of ozone and its precursors (Figure 7.6). It doesn't exist everyday over every location, but when it is present it can have considerable impact when and where it eventually down-mixes to the ground (Figure 7.7). Down-mixing can happen when day-time heating from the sun causes ground-level air to rise. Aloft air then mixes downward to fill the void of the uprising air. Nearby thunderstorms can also cause down-mixing of the aloft reservoir.



The same thing occurs in New Hampshire, however usually to a lesser degree. Figure 7.8 shows average ozone concentrations on high ozone days as measured at the base and summit of Mt. Washington, about 4,000 feet different in elevation. Because Mt. Washington is so remote from pollution sources, the ozone measured there is nearly 100% from mid to high-level transport. Ozone measured at the base of the mountain increases in the late morning when air begins to mix up and down, bringing polluted air down from higher elevations.

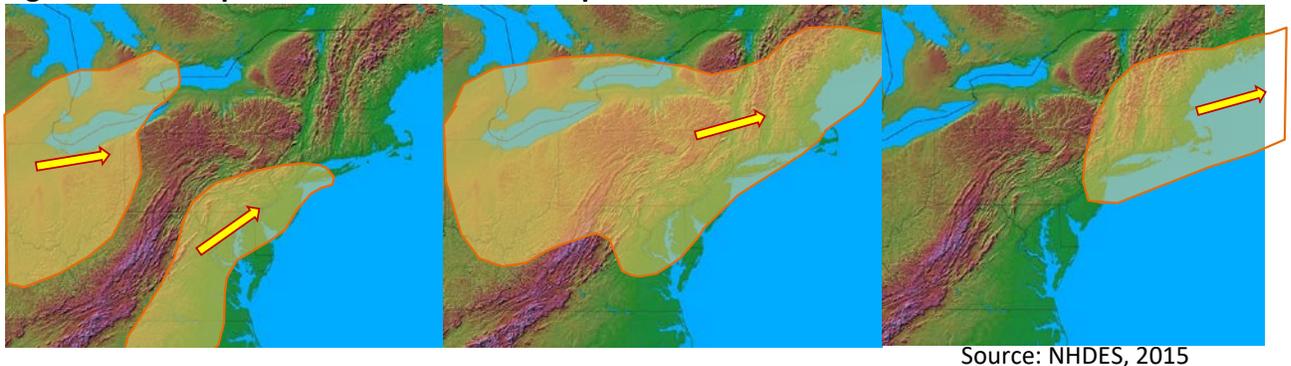
**Figure 7.8: Mt Washington New Hampshire Average Diurnal Ozone on High Ozone Days**



Source: NHDES, 2010

This aloft reservoir builds in upwind areas (Figure 7.9), and some of it may originate from as far away as Asia. During a severe event, this reservoir might build in different areas and then combine over the Northeast states before exiting out over the Atlantic Ocean and far eastern Canada. The aloft reservoir is most likely to affect ground-level concentrations in mountainous areas over 2,000 feet where the aloft layer meets the ground without any downward mixing. However, convective weather patterns can bring it down to lower elevations at almost any point along the way.

**Figure 7.9: Example of Aloft Reservoir Transport Movement**



### 7.3 Air Pollution Modeling of Transport

As discussed in sections above, transport of certain air pollutants may exceed 600 miles as they travel with the wind through the different transport pathways. Air pollutants that survive long enough in the air to transport across state and international boundaries are generally the same pollutants that have been difficult to remedy. These include ozone, small particles ( $PM_{2.5}$ ), regional haze and atmospheric deposition of acids, nitrogen and mercury.

In order to mitigate impacts from air pollution, scientists need to understand where pollution comes from, where it goes and how it gets there. Researchers use atmospheric models as part of these efforts. For short-range air pollution impacts, a source-oriented dispersion model is normally applied. These models use estimates of emissions and source specific parameters in order to model how pollution from a single source, or a small group of sources, disperses. Weather data from a nearby meteorological station is normally used with the model to predict estimates of downwind impacts, normally within 50 kilometers (31 miles) of a source. Some models include chemistry modules to produce estimates of secondary air pollution (note: secondary air pollution is not directly emitted but forms in a reaction after precursor pollutants are released). The AERMOD model is commonly used for single source dispersion studies. It is a Gaussian dispersion model developed by the American Meteorological Society and the Environmental Protection Agency Regulatory Model Improvement Committee.

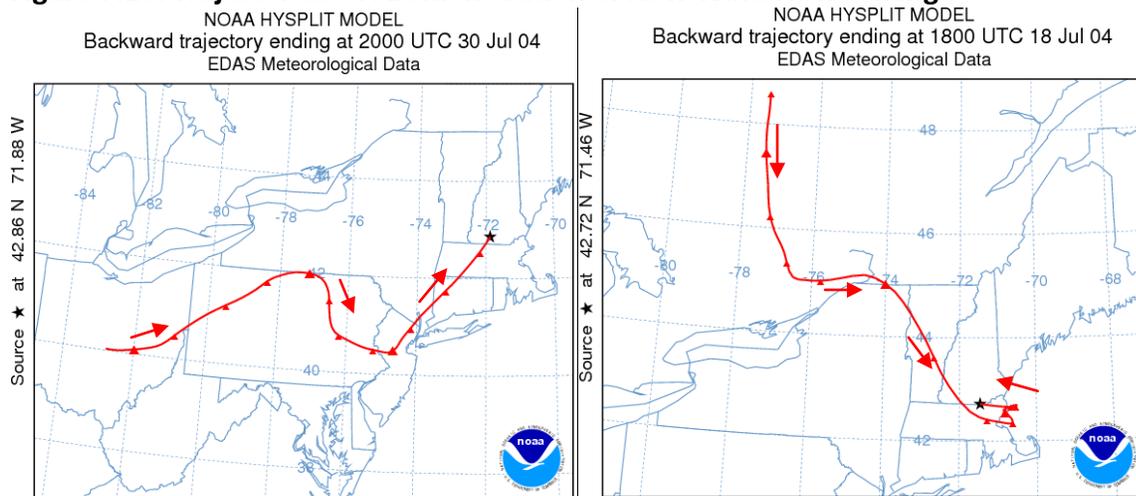
Other models are used to address long-range transport and cumulative impacts from many sources. Most long-range models use a grid-based domain (analogous to a Rubik's Cube shape) in order to represent real-



world characteristics. Each grid block contains pollution emission inputs and meteorological inputs corresponding to that grid cell's geographical location. The model uses applicable chemical and meteorological algorithms to estimate pollutant concentrations and fluxes within that grid cell before passing them along to neighboring cells with the modeled winds. Such models are routinely applied to large areas, such as the entire lower-48 states, or in the case of studies to address ozone in New Hampshire and other northeast states, the entire eastern half of the United States. This modeling domain consists of millions of pollution sources ranging from cars and trucks to ships and trains, to large industries and power plants. CMAQ (Community Multi-scale Air Quality model) and CAMx (Comprehensive Air Quality Model with Extensions) are the most commonly applied grid models.

Trajectory models (Figure 7.10) can be useful for gaining a basic idea of where longer lived pollution (Ozone and PM<sub>2.5</sub>) might have originated. These models simply look at weather patterns during periods of time at specific locations. With this information, an estimated path of air pollution travel can be simulated. It should be noted, there are multiple sources of meteorological data that can be used in trajectory models and they can produce differing results. Therefore trajectories are used only as a general estimate of the transport pathway and not to identify specific culpable pollution sources.

**Figure 7.10: Trajectories – A Demonstration of How Wind Flows Change**



Source: NOAA HYSPLIT/NHDES, 2015

When trajectory model runs are conducted with different starting altitudes, the three basic transport patterns can appear. Figure 7.11 shows a composite of trajectory model runs for different hours on different dates. The red lines indicate trajectories beginning at low elevation and show a low-level transport pattern along the east coast. While most red lines approach the destination of coastal Connecticut after passing over metropolitan New York City, many of them have differing starting points. But the commonality of each one passing over the emission-rich environment of a large city just prior to the destination is an important consideration. Some red (low-level) and blue (mid-level) trajectories channel through the Appalachian Mountains, but the clock-wise pattern of most of the blue and green (high-level) trajectory lines

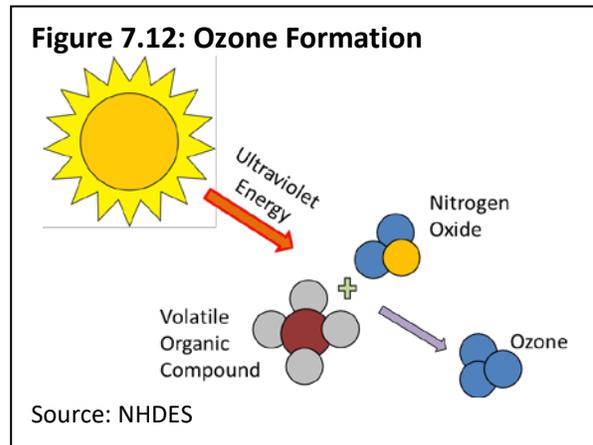
is particularly noticeable. This is a classic long-range transport pattern caused by a large high pressure system sitting over North Carolina. This type of airflow can bring air pollution from Midwest industrial areas to the Northeast. Since daytime heating and topography cause air pollution to mix up and down in the lower atmosphere, all transport mechanisms need to be considered.

**Figure 7.11: Wind Flow Patterns on Four High Ozone Days in 2012**



#### 7.4 Emissions of Ozone and Small Particle Precursors

There are two components that are generally needed for ozone or regional PM<sub>2.5</sub> air pollution events to occur: a weather pattern conducive for air pollution accumulation and emissions of precursor species (nitrogen oxide (NO<sub>x</sub>) and volatile organic compounds for ozone (Figure 7.12), NO<sub>x</sub>, sulfur dioxide (SO<sub>2</sub>), ammonia, and/or organic compounds for PM<sub>2.5</sub>). New Hampshire emission estimates for 2011 show that about half of the NO<sub>x</sub> emissions come from the OnRoad (cars and trucks) sector while the remainder comes from a variety of sources including EGUs (power plants, also referred to as electric generating units), construction equipment, industry, and local business and residential sources. For SO<sub>2</sub>, EGUs were the dominant source category in New Hampshire with most of the remainder from residential home heating with oil (Area sector, see Table 7.2 below). Since 2011, New Hampshire's power plants have reduced their SO<sub>2</sub> emissions by about 90%. Ammonia is commonly emitted by agriculture and livestock activities and organic compounds are emitted by fuel evaporation, solvents, cars and trucks, industry, and vegetation.



**Table 7.2: General Emission Source Sectors**

Category	Description
Area	Small business and residential emissions
Oil and Gas (Area and Point)	Emissions from oil and gas well drilling along with support equipment and ongoing pipeline pressurization
OnRoad	Typical highway traffic (cars and trucks)
NonRoad	Mobile sources that are not typically used on highways (construction equipment, airport, rail and port support vehicles)
MAR*	Marine, airport and rail – ships, boats, aircraft, locomotive engines
Point (EGU)	Power plants – electric generating units
Point (Non-EGU)	Boilers and non-utility energy and heat for business sector

\* - MAR emissions are mostly considered within the NonRoad sector, but some are considered Area and Point

Increasingly, downwind states are finding that they must rely on upwind states to control air pollution emissions to address transport. However, a common counter-argument used by upwind sources is that individual sources cause only small amounts of impact beyond their local areas. Science, however, is finding that even small contributions become cumulative and can have negative health implications at both local and regional levels in downwind areas.

**Key Point:** Power plants are often the first sources of pollution that people think of, but cars and trucks actually produce most of the ozone producing emissions in the eastern states. Individually, a car may be relatively clean, but when there are millions of them each driving 5 to 100 miles every day, the emissions really add up. Add to that the emissions associated with fueling those vehicles, a nearly perfect recipe is created for ozone or “photochemical smog.”

Throughout the Northeast and the Midwest, similar NO<sub>x</sub> and SO<sub>2</sub> emission patterns are seen (Figures 7.13 and 7.14). Even though pollution emissions from cars and trucks (OnRoad) have been reduced, they still cumulatively emit about half of all NO<sub>x</sub> in the region due to their sheer number and the number of miles they’re driven. Some states still have significant NO<sub>x</sub> emissions from their power plants (EGUs) and as a result their mobile source emissions are below 50% of the NO<sub>x</sub> emission total.

Since there is relatively little sulfur in gasoline and diesel fuels, mobile sources (OnRoad) are not a significant source of SO<sub>2</sub> emissions. Virtually all SO<sub>2</sub> emissions in the region are from power plants (EGUs) and industry (Non-EGU Pt) except for the Northeast states that use residential heating oil (Area). Since 2011, a number of power plants throughout the eastern United States have installed SO<sub>2</sub> scrubber systems that can reduce emissions by 90% or more. Some of these systems have a co-benefit of also reducing certain toxic air pollutants including mercury.

Figure 7.13: Estimated Annual NOx Emissions by State by Sector - 2014

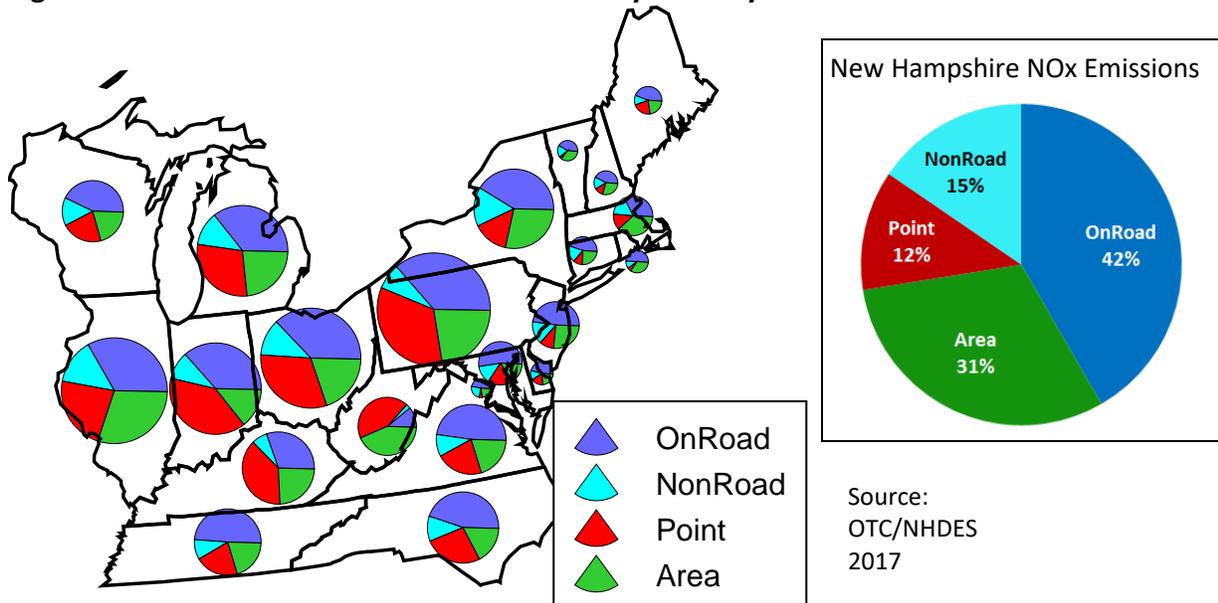
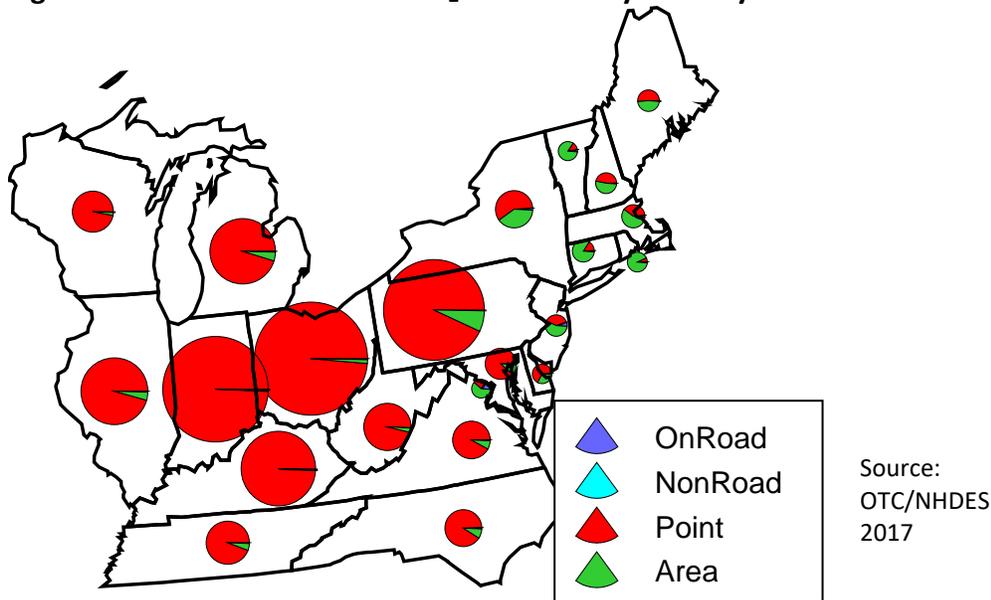


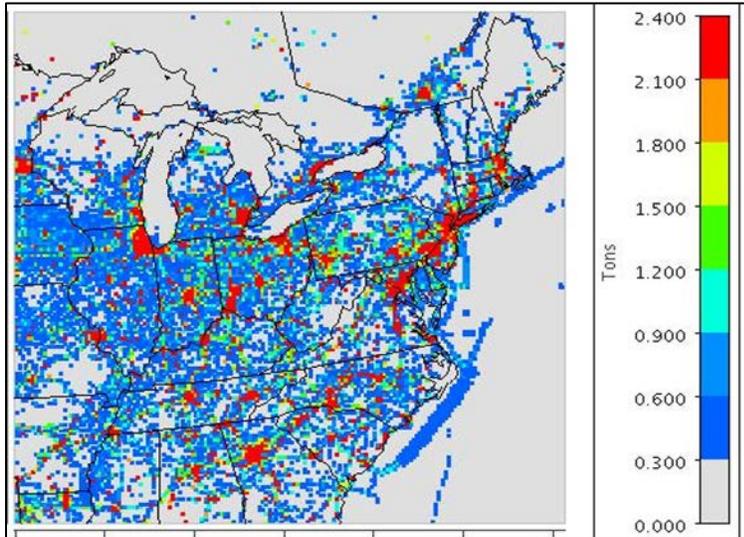
Figure 7.14: Estimated Annual SO<sub>2</sub> Emissions by State by Sector - 2014



With so many air pollution sources and constantly changing weather patterns, it is difficult to determine culpability for air pollution transport. When New Hampshire receives air pollution from outside of the state, it is not obvious which specific source or source sector – power plants, industries, mobile sources, and area sources – or even what state is responsible for it. Individual sources may argue that they do not contribute to air pollution transport in a meaningful way, and that emissions reductions at their facility would be inconsequential and therefore not warranted. Historical successes, however, have demonstrated that when widespread emission reductions are made over large numbers of pollution sources, meaningful pollution reduction benefits occur.

Figures 7.15 and 7.16 show emission inputs for two pollutants (nitrogen oxides – NO<sub>x</sub>, and volatile organic compounds – VOCs) for a grid-based photochemical model used for modeling ozone and PM<sub>2.5</sub> in the Northeast states. These diagrams demonstrate just how widespread air pollution sources are in the eastern United States and Canada. Running grid-based models helps to understand how these air pollution sources affect people living in other areas, but it is a complex task. As the science continues to improve, these models are proving to be valuable for understanding and addressing transport of pollutants such as ozone, PM<sub>2.5</sub> and regional haze.

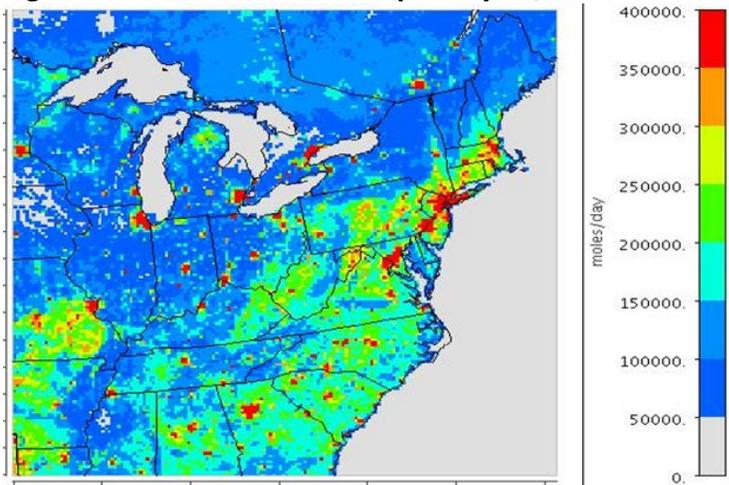
**Figure 7.15: NO<sub>x</sub> Emission Map – July 22, 2011**



The maps on the left use a scale where warmer colors represent higher emissions than locations shown in cooler colors. Areas in red have the highest emissions and then decrease in emissions through orange, yellow, green and blues. Areas in grey indicate low emissions or a lack of data for the location. In general, cities, industrial areas and major highways have the highest NO<sub>x</sub> emissions.

Source: NYSDEC, 2015

**Figure 7.16: VOC Emission Map – July 22, 2011**



VOC emissions also tend to be highest in cities, but biogenic emissions, those coming from trees and other vegetation, produce large amounts of certain VOCs. Some trees emit higher amounts of VOCs than other, thus forests rich in such trees show widespread green colors. Areas with lower emitting vegetation and non-forested areas generally have the lowest VOC emissions.

Source: NYSDEC, 2015

## 7.5 Weather Patterns and Transport

Air pollution transport science is much more than just tracking how the winds blow smoke stack pollution from one place to another. Air pollutants also react chemically with each other in the air and with naturally occurring gases and particles. Weather patterns change from year to year leading to accumulation of more pollution in some years and less in other years. Warm humid

weather leads to increased electrical demand and higher pollution emissions. When air pollution emissions are paired with certain weather patterns, an air pollution event of high concentrations can occur. Often these weather conditions in New England include heat and light winds coming from the southwest. Conversely, cooler and rainy weather decreases electrical demand and is often paired with less pollution-conducive weather. These conditions are usually associated with lower region-wide air pollution concentrations. Each year brings differing weather patterns. Thus some are hotter, others are cooler, some are dryer and some are wetter than average. Weather variability also causes some years to be more susceptible to air pollution events.

Figure 7.17 demonstrates recent year to year variability in ozone concentrations across the eastern United States. 2011, 2012, 2015 and 2016 had hotter weather with more stagnation, and thus ozone levels within the region were relatively high. Years 2013 and 2014 were cooler and rainier with fewer periods of stagnation, and therefore ozone levels for these years were relatively lower overall. Regardless of the year to year weather variability, ozone concentrations are often higher in areas downwind of large urban or industrial areas (generally to the northeast of the higher air pollution emitting region).

Similar to the New Hampshire emission trends reported in Section 4.5.3, emissions of NO<sub>x</sub> (an ozone precursor pollutant) across the Northeastern United States decreased by about 60% since 1997 and about 10% since 2011 (Figure 7.18) driving an overall trend towards lower ozone concentrations, but weather patterns and wind flows are a large component for the magnitude and frequency of ozone events in the Northeast.

Certain weather patterns can still cause pollution to pool and concentrate leading to air pollution events. Two important factors that affect ozone production efficiency include the chemical mixture of the atmosphere and the strength of the sunlight reaching the ground. When the weather is cloudy, there is less ultraviolet sunlight (UV) available to drive the chemical reaction to produce ozone

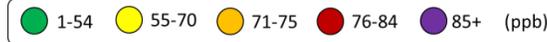


**Key Point:** Solar energy from the sun, usually in the form of ultraviolet radiation (UV) can speed up chemical reactions. Ozone production requires UV energy to pull an oxygen atom off of a donor molecule and to make it available in a high enough state of energy ( $O^*$ ) to bind with an oxygen atom ( $O_2$ ) to form ozone ( $O_3$ ). At night, when this energy is not available, ozone is not created and can only be destroyed. If it avoids destruction, it can live on for hours and be transported large distances. While ozone may not be created during the night, emissions of its precursor pollutants (NO<sub>x</sub> and VOCs) are still produced, creating buildup in concentrations overnight which can lead to an ozone “bloom” the next day when UV radiation becomes strong enough to drive the chemical reaction. One other note, UV radiation is often stronger at higher altitudes, meaning ozone formation at higher elevations can become very efficient if there are enough precursor pollutants available. This is a key element driving longer range ozone transport.

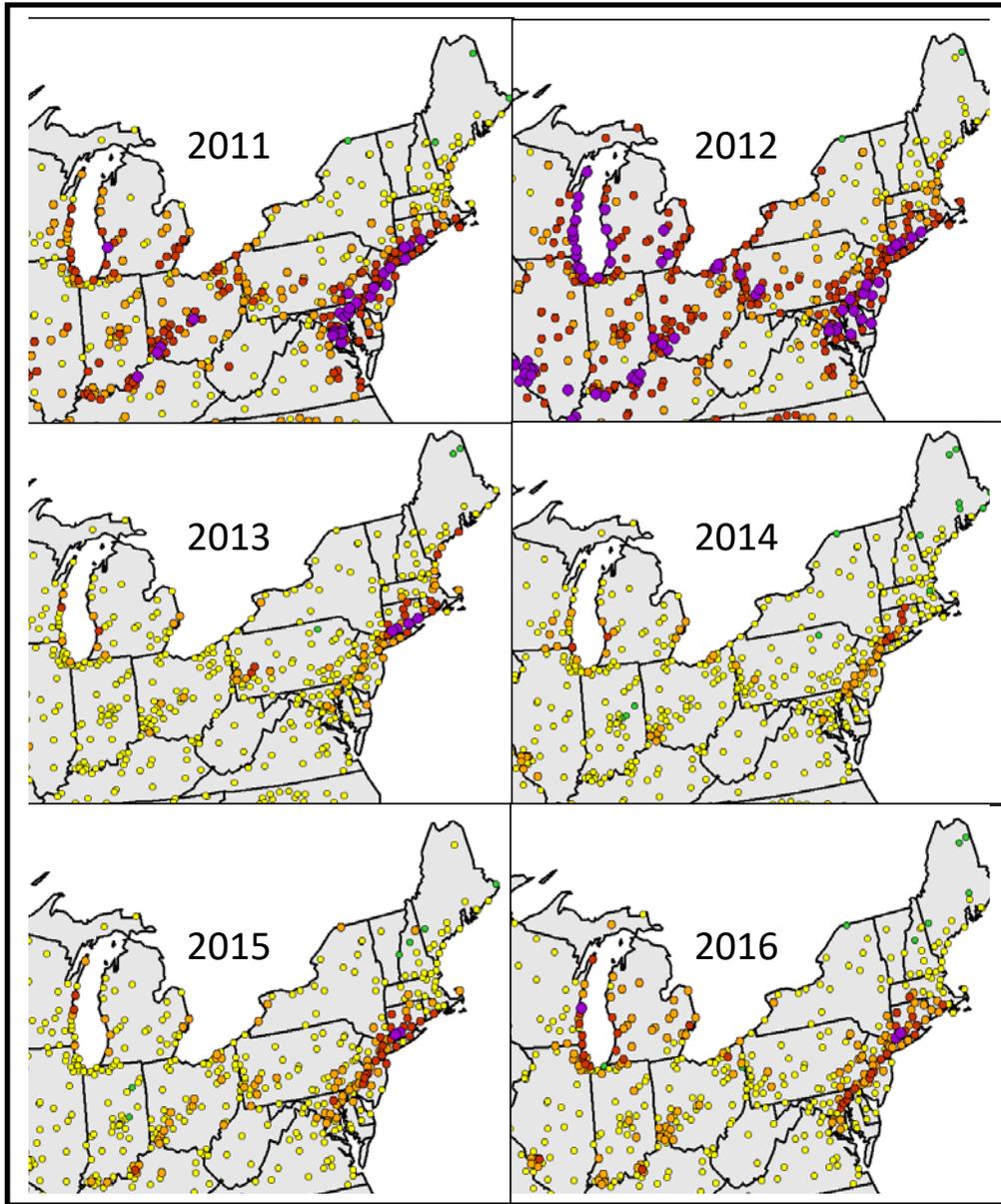
and as a result, there is less locally created ozone. Ozone occurring in cloudy areas is often transported there from other locations where more UV is (or was) available.

**Figure 7.17: 4<sup>th</sup> Maximum Daily 8-hour Ozone Concentrations by Monitor (2011-2016)**

*The 4<sup>th</sup> maximum is the annual NAAQS indicator.*



*Dots indicate concentrations at monitor locations.*



Source:  
USEPA &  
NHDES,  
2015

As described in other sections of this report, NO<sub>x</sub> is emitted by many sources, ranging from power plants to cars and trucks. Almost anything that burns a fuel produces NO<sub>x</sub>, making it a very widespread pollutant. NO<sub>x</sub> is not only involved in creating ozone, but it also plays a role in creating PM<sub>2.5</sub>, acid rain, regional haze, and nitrogen deposition into sensitive water bodies. Generally, reducing NO<sub>x</sub> emissions is beneficial for human health and the environment because

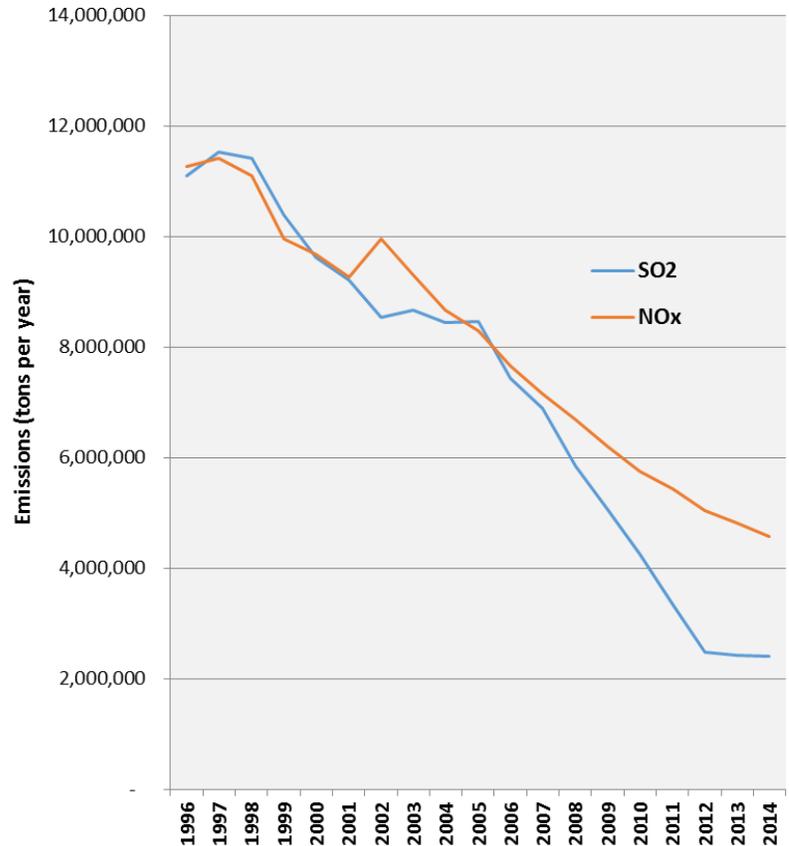
doing so addresses a number of air pollution concerns. But this can have implications in terms of atmospheric chemistry. Because of certain chemical processes, reducing emissions of one pollutant can occasionally increase concentrations of another. For example, in areas where NO<sub>x</sub> concentrations are very high, reducing NO<sub>x</sub> emissions can actually interrupt localized ozone-destroying chemistry. As a result, local ozone increases. Conversely, increased NO<sub>x</sub> emissions can sometimes “scavenge” ozone in chemical reactions, leading to localized ozone decreases. This ozone reducing effect is often seen near the center of large urban areas or near large power plants where NO<sub>x</sub> concentrations are high. Atmospheric scientists commonly refer to this as “NO<sub>x</sub> dis-benefit” or “titration.” However, as the distance increases from high NO<sub>x</sub> emitting areas, the ozone destruction properties of NO<sub>x</sub> convert to ozone producing properties.

When weather conditions align just right, significant air pollution events can result in the Northeast. Figure 7.19 shows the evolution of one such large ozone event that reached the

southeastern portion of New Hampshire on July 20-21, 2011. The primary event began back on July 14, 2011 when ozone and ozone precursor started to accumulate in the Midwest under favorable weather patterns (see red dotted line). On July 15, there was a significant accumulation of precursors (NO<sub>x</sub> and VOCs) combined with strong sunshine. The region started to show a widespread area where ozone exceeded moderate levels (>55ppb) and several locations near urban and industrial areas exceeded the level of the 2015 NAAQS (70ppb). On July 16 the area began to build to the north and east with even higher ozone concentrations. A second area of high ozone (encircled in green) that started to build on July 15 along the urban East Coast corridor, deepened and moved to the Northeast. On July 17’ the primary ozone event (red) continued to accumulate pollution and moved north into the Michigan area and

**Figure 7.18: Estimated Emissions of NO<sub>x</sub> and SO<sub>2</sub> for the Northeastern United States**

**Northeast NO<sub>x</sub> and SO<sub>2</sub> Emission Trends (1996-2014)**



Data Source: EPA (<https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data>)

eastward into western New York and northern Pennsylvania. The East Coast ozone plume (green) missed New Hampshire to the south and moved out over the ocean.

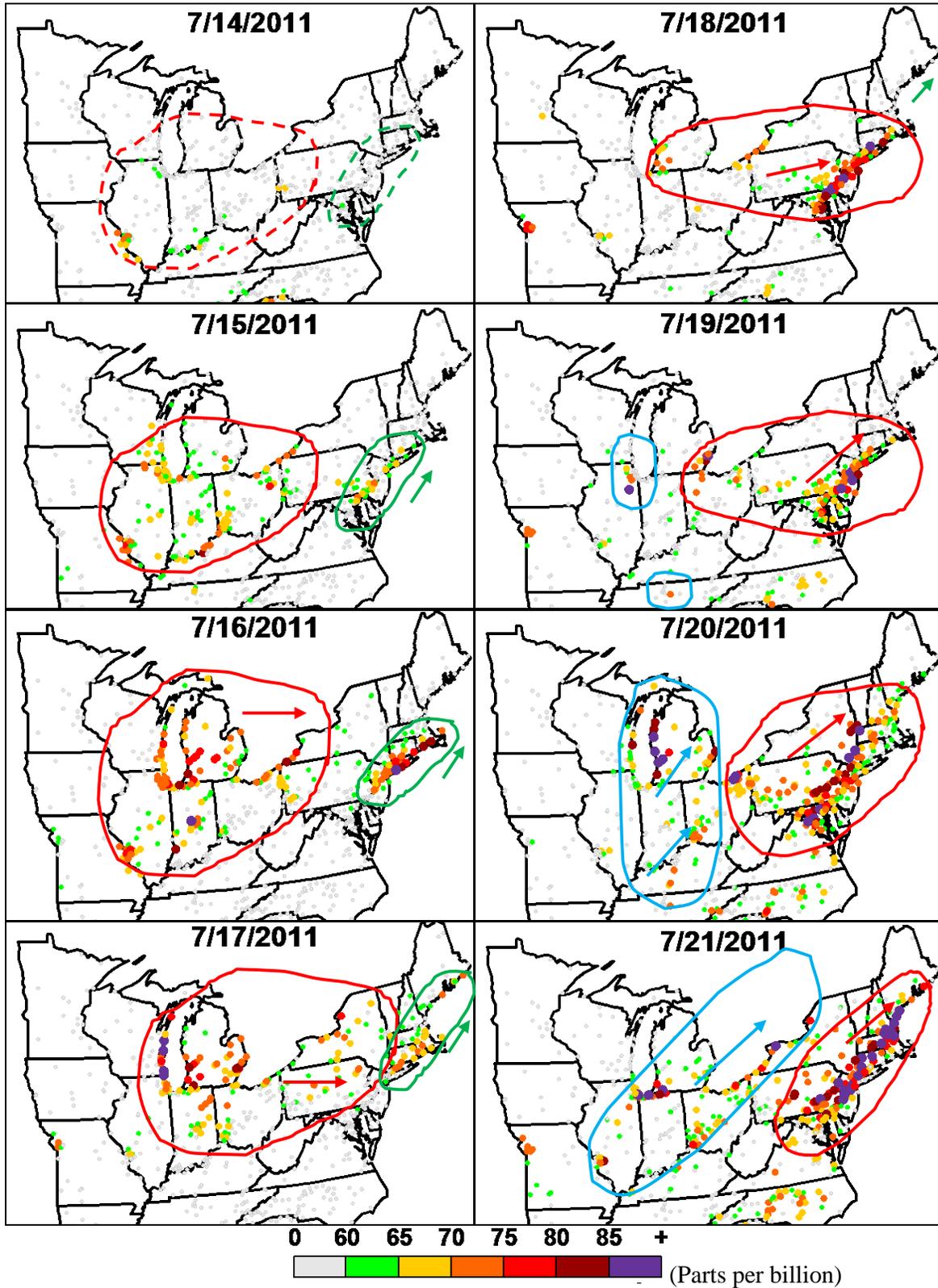
On July 18 and 19, the primary ozone plume reached the urbanized East Coast and urban emissions began to combine Midwestern emissions with East Coast city emissions. In addition, another area in the Midwest (encircled in blue) began to show some ozone accumulation. On July 20 to 21, the primary ozone plume continued to deepen and spread northeastward. High ozone concentrations began to reach New Hampshire on July 20 and became higher and more widespread on July 21. Maximum 8-hour ozone concentrations in New Hampshire on July 21 reached 90ppb in Nashua. By July 22, this event was swept out to sea by a cold front and ozone concentrations in New Hampshire returned to the good range.

## **7.6 Where Does New Hampshire's Air Pollution Originate?**

It can be very challenging to determine the exact origin of air pollution in New Hampshire. Many air pollutants are localized: in other words, nearby emissions lead to locally high pollution concentrations. Carbon monoxide, lead, nitrogen dioxide, sulfur dioxide and many types of particulate matter and air toxins are considered local air pollutants. When local concentrations of one of these pollutants are high, then emissions reductions from nearby sources are usually sufficient to address the issue. However when concentrations of ozone or fine particulate matter (PM<sub>2.5</sub>), or deposition of acid, nitrogen, or mercury are high, the cause might be local, distant, or both. Atmospheric chemistry and dispersion make it even more difficult to determine the origin of air pollution, and the longer an air pollutant stays in the air, the more chemistry and dispersion act on it. Dispersion normally lowers pollution concentrations, however atmospheric chemistry can create other types of air pollution in downwind areas. Ozone and PM<sub>2.5</sub> are two such pollutants that can increase downwind of emission source areas.

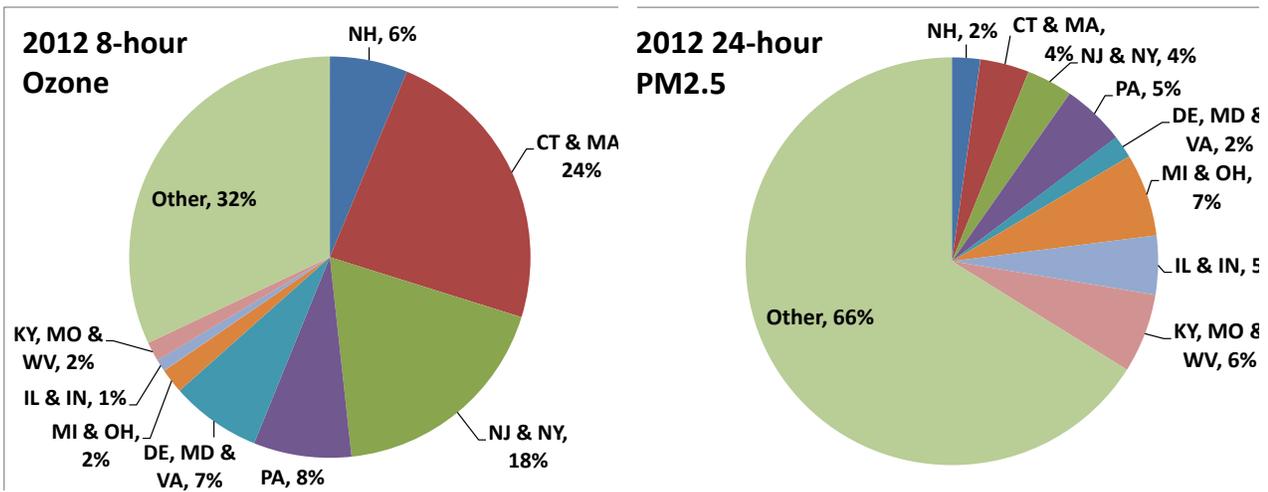
Fortunately, there have been several regional modeling analyses designed specifically to consider ozone and PM<sub>2.5</sub> air pollution transport between states. One such analysis was conducted by EPA in 2009 for the Cross State Air Pollution Rule. At that time, EPA modeled interstate air pollution transport projections for the year 2012. Then in 2015, EPA updated its interstate ozone transport modeling to reflect a projected year of 2017. The findings of this EPA modeling, and other modeling analyses that have been conducted, are all fairly similar; over 90% of ozone on high ozone days in New Hampshire originates outside the state (range 91 to nearly 100%) and about 80% of PM<sub>2.5</sub> on most high PM<sub>2.5</sub> days originates outside the state (range 62 to 98%) (Figure 7.20 and Table 4.5). A similar range was reported for New Hampshire in the 2004 NHDES report; *Air Pollution Transport and How it Affects New Hampshire*, which used a slightly different methodology. It should be noted that there are wood smoke stagnation events that occur in some New Hampshire communities, especially Keene, that have strong local emission source causality (see Section 5.4).

Figure 7.19: Development of High Ozone Events in the Northeast - July 14-21, 2011



Source: USEPA/NHDES, 2015

**Figure 7.20: Average Contribution of States to New Hampshire Air Quality Based on EPA CAMx Modeling (Percent -%)**

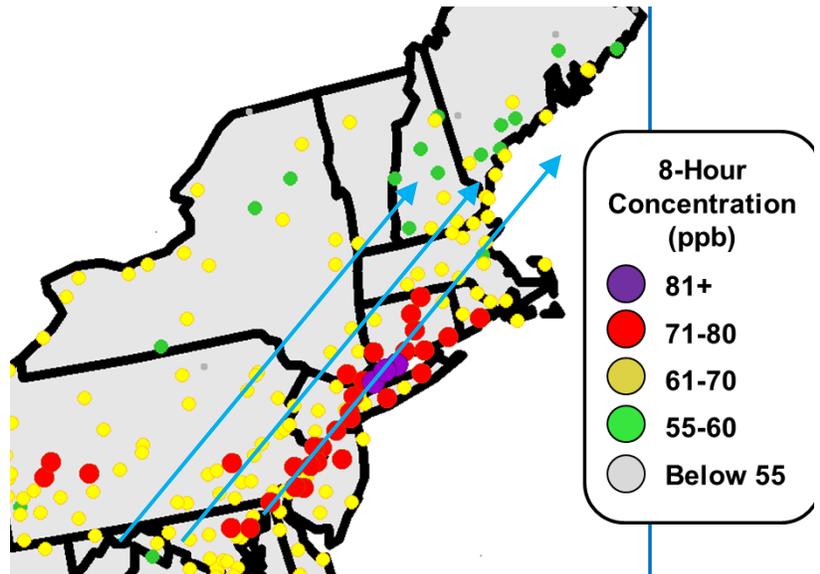


Source: USEPA/NHDES, 2015

Just as air pollution levels vary across the state, there is variation in the amount of air pollution that transports from outside the state versus how much New Hampshire contributes to itself. The highest out-of-state transport contribution is typically found in locations near the upwind borders of the state (south and west). In these cases, there are few New Hampshire pollution

sources that are physically located between the upwind state border and the monitoring location. Parts of New Hampshire that are located on the eastern border of the state generally see higher New Hampshire air pollution contributions. Rockingham and Strafford counties have the highest New Hampshire emission contributions which are on average about 5 to 10 percent of total ozone and PM<sub>2.5</sub> pollution. Mountain-top monitoring, Mt. Washington in Coos

**Figure 7.21: Ozone Air Pollution Patterns and Prevailing Winds**



Source: NHDES, 2015

County and Pack Monadnock Mountain in Hillsborough County are dominated by out of state sourced air pollution and experience some of the highest ozone concentrations in the state.

Figure 7.21 is an illustration of how ozone concentrations in New Hampshire are affected by pollution transport from outside the state.

Table 4.5 (page 68) presents the results of EPA ozone and PM<sub>2.5</sub> transport contribution modeling for a portion of the New Hampshire monitoring network. These results support the notion that New Hampshire is indeed a downwind state in regard to ozone and PM<sub>2.5</sub> air pollution transport. Southern and western New Hampshire contributes to eastern parts of the state on average about 2% to 3% of the total PM<sub>2.5</sub> and between 4% and 7% of total ozone. These numbers do not accurately reflect all the nuances discussed in earlier sections, such as localized wood smoke stagnation and mountaintop ozone events, but they appear reasonable for most locations on most days of the year. Upwind states provide about 20% to 35% of New Hampshire measured PM<sub>2.5</sub> and very long-range (and international) transport and forest fires account for the rest (and majority) of local PM<sub>2.5</sub>.

Nearby upwind states and cumulative impacts from states located further away produce much larger ozone contributions to all of New Hampshire. On average, very long-range and international transport each account for 30% to 40% of ozone transport into New Hampshire.

Despite the low self-contribution percentage, New Hampshire is still considered a significant contributor to its own air pollution levels and New Hampshire-based air pollution programs are needed and required. New

Hampshire also lies upwind of, and contributes air pollution to, Maine, maritime Canada, and a small portion of Northeast Massachusetts. Therefore, New Hampshire's pollution emissions are important to those areas just as upwind state pollution is to New Hampshire. In some cases, local emissions in New Hampshire do cause locally unhealthy air quality. Examples can include wood burning and other exhaust or chemical releases/leaks with poor dispersion design.

Achieving all emission clean air goals and attaining ambient air quality standards in New Hampshire requires looking at sources of air pollution, both locally and outside state borders. These emission sources and their impact on New Hampshire's air quality must be carefully and scientifically analyzed.

**Key Point:** Emissions from cars, trucks and buses (called mobile sources) contribute about 50% of the nation's NO<sub>x</sub> emissions. Individually, new light duty vehicles are very clean compared to vehicles from 20 years ago. However, there are over 250 million vehicles on the road in the United States and Canada, and each vehicle currently averages about 16,500 miles per year. Thus, these relatively "clean" vehicles, when taken en masse, contribute a sizable share of air pollution in the Northeast and in upwind states, particularly along the heavily traveled I-95 corridor. Diesel vehicles contribute more because they are more polluting and many diesel trucks average over 100,000 miles per year. Overall, vehicle miles driven per year and vehicle population have been steadily increasing, counteracting much of the improvements made in vehicle emissions.

## **7.7 A Transport Success Story**

As mentioned in Section 7.1, attempting to control ozone on a local-only basis in the 1990s was not very successful. While local emissions were reduced and ozone concentrations decreased, more ozone from other areas continued to transport downwind preventing those areas from meeting clean air requirements. In 1998, EPA issued the NO<sub>x</sub> SIP call (Section 9.1.3), which was the first super-regional program ever designed to reduce ozone transport in the eastern United States. Further reducing ozone transport within the Ozone Transport Region (OTR) (a 13 state region spanning from northern Virginia to Maine – Figure 3.1) was a regional initiative called the OTC-MOU<sup>25</sup>, adopted on September 27, 1994. These efforts successfully reduced ozone in the Northeast by about 60% and in New Hampshire by 33% since the early 1980s. Not only did ground-level ozone decline, but measurements in the aloft reservoir (Section 7.2) also showed significantly lower ozone. Figure 7.26 shows the long term trend in measured ozone concentrations averaged over all monitors in the OTR. A strong downward trend in ozone concentrations is evident, due in large part to these regional and super-regional initiatives.

## **7.8 Dealing with Air Pollution Transport**

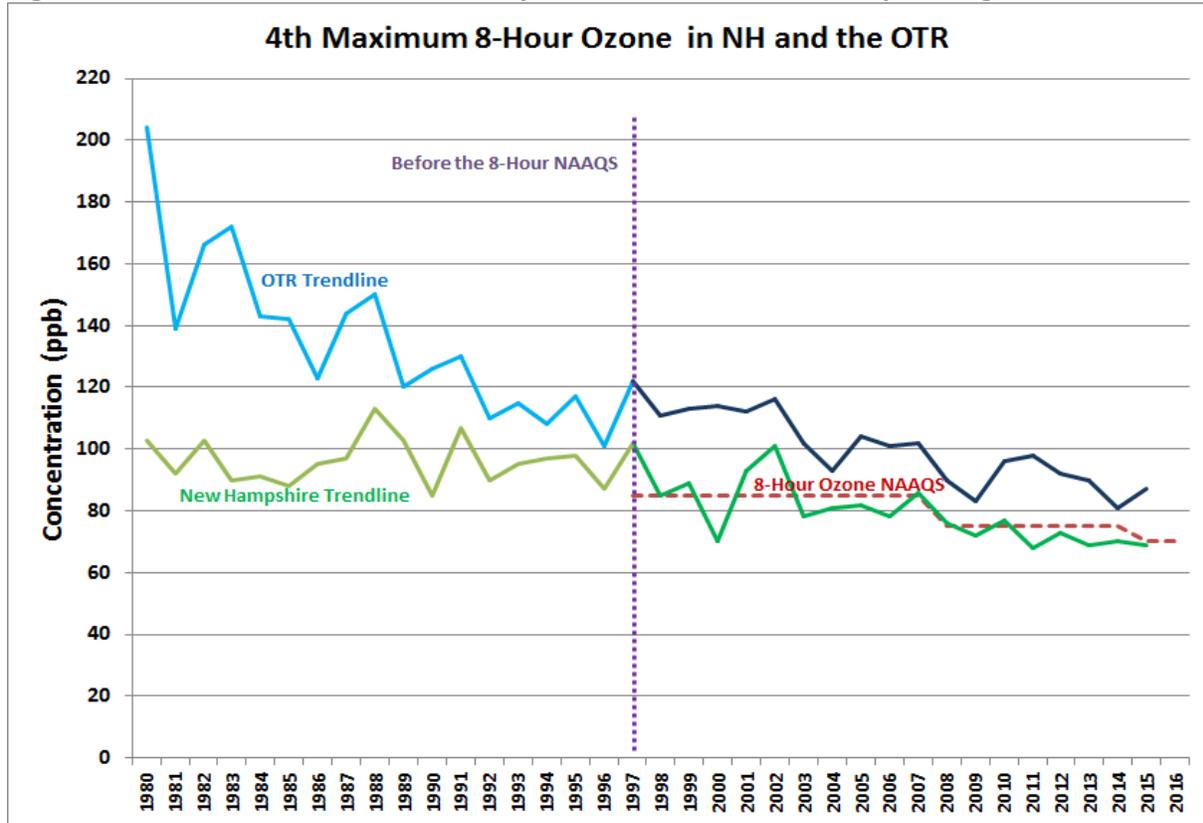
Allocation of responsibility for transported air pollution must be done with a high degree of certainty in order to develop a sound and workable solution. While reducing pollution emissions from all sources everywhere would certainly work, it would be expensive and not necessarily efficient. Instead, a combination of approaches is normally applied that includes a degree of widespread (national or super-regional) emission reductions along with additional emission reductions applied to local, nearby, and regionally upwind emission sources. For greatest cost effectiveness, large pollution sources or areas with high emission density of pertinent air pollutants are usually targeted as first candidates since they probably affect multiple locations. Modeling may be performed to identify how far upwind to look for contributing emissions, especially if more cost effective ways to reduce pollution emissions can be identified. While the cost of air pollution control can be high, the financial and health benefits have historically been greater by a factor of 3 to 1 or more.

**Key Point:** Regional and national emissions controls are effective for highly transportable pollutants and they promote the sharing of air pollution control costs in an equitable and impartial manner.

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<sup>25</sup> Ozone Transport Commission Memorandum of Understanding, 1994:  
[http://www.otcair.org/upload/Documents/Formal%20Actions/MOU%2094\\_2.pdf](http://www.otcair.org/upload/Documents/Formal%20Actions/MOU%2094_2.pdf)

**Figure 7.22: Ozone Trends in New Hampshire and the Ozone Transport Region**



Source: USEPA and NHDES, 2015

*The Ozone Transport Region includes Connecticut, Delaware, District of Columbia, Maryland, Massachusetts, Maine, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and northern Virginia.*

In some locations, the most cost effective pollution reductions have long-since been implemented and air pollution levels are still too high. These locations must work to either justify even higher cost pollution controls or look upwind for help. In order to achieve additional upwind pollution reductions, states may work together collaboratively to find a remedy or may request help from EPA by either requesting a regional or national air pollution remedy rule or by Clean Air Act petition to reduce emissions at specific sources. When emission sources and resulting pollution impacts lie in different states, or even countries, the situation can become controversial.

**Key Point:** When “upwind” locations have air pollution monitoring data that meet clean air requirements, there can be resistance to adding additional air pollution control regulations and costs to address transport for the benefit of “downwind” locations.

Since the 1990s, New Hampshire and other Northeast states have worked collaboratively together to implement a number of emission reduction programs within their boundaries in order to attain National Ambient Air Quality Standards (NAAQS) and provide healthy air quality. Aggressive national or near-national actions have also been implemented by EPA, aimed at all major sectors of air pollution – power plants, industry, cars, trucks, distributed generators and various small engines such as those in boats, lawnmowers, and snowmobiles. These widespread measures have lowered air pollution concentrations nationwide.

While onroad cars and trucks account for about half of the air pollution emissions leading to ozone (photochemical smog) in the eastern United States, all states, except for California, are prohibited by the Clean Air Act from establishing their own vehicle emission standards. States may, however, opt to follow federal standards or adopt California standards, which must be at least as stringent, and have historically been more stringent, than federal standards. All Northeast states except for New Hampshire have adopted California’s Low Emission Vehicle standard and several have also adopted their Zero Emission Vehicle standard that will increase the use of non-emitting vehicles such as electric vehicles in those states. EPA recently passed a new “Tier 3” standard that will apply to model year 2017 and newer vehicles (Section 9.2.5), and that will also reduce emissions from older vehicles by requiring a reduction in the sulfur content of gasoline. Additionally, EPA has adopted standards for diesel vehicles (Section 9.2.2) that, when fully phased-in will provide significant emission reductions from heavy-duty diesel vehicles, locomotives, and many other pollution sources. Unfortunately for states needing air pollution reductions now to meet clean air regulations, EPA’s regulatory programs for heavy-duty vehicles will not realize their full benefits for many years due to the durability of these types of engines and a slower fleet turnover rate.

**Key Point:** Addressing one pollutant at a time may result in industry having to relocate, upgrade or replace equipment that was recently installed to control one air pollutant, so that new equipment to control other pollutants can be installed. In many cases, the industry would have chosen a different type of pollution control technology capable of controlling more than one pollutant if it had known that reductions of another pollutant were soon to be required. From the industry’s perspective, the “one pollutant at a time” procedure lacks regulatory certainty and is ultimately more expensive than controlling multiple pollutants simultaneously.

**Key Point:** Energy efficiency measures not only reduce the amount and cost of fuels needed, but also reduce emissions of air pollution. When enough energy efficiency measures are implemented region-wide, fewer power plants are needed.

Given the limitations on further controlling mobile sources beyond federal actions, much of the focus of current emission reduction regulations is on large industry, especially power plants. Industry prefers that any regulation involving them be applied in a way that allows a single action to address multiple concerns. In other words, if an emission source has to control mercury and NO<sub>x</sub> and SO<sub>2</sub>, planning a single remedy is much more cost effective than applying

remedies one at a time in isolation to each other. A multi-pollutant approach provides a more comprehensive, cost effective way to plan for long-term facility layout and equipment requirements.

**Key Point:** With over 1.4 million vehicles on the road in New Hampshire and steady growth in total miles driven, strong federal emission reduction requirements for motor vehicles are essential for meeting clean air goals.

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## 8 CLIMATE AND AIR POLLUTION

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It is difficult to develop air pollution mitigation plans without considering the prospect of climate change. The weather and climate are major factors driving our energy needs and the need for producing this energy is connected to air pollution patterns. Further, many of the same activities that produce our air pollution contribute to climate change and therefore the issues are best managed and remediated with an understanding of how they are caused and connected. Chapter 8 reviews greenhouse gas emissions and how they contribute to climate change. It also presents measured evidence of change in New Hampshire.

**Key Point: Climate vs. Weather**

When we look outside and talk about how the conditions have gone from sunny to rainy or damp to humid, we are talking about **weather**. The weather refers to immediate environmental conditions and can vary from hour to hour, day to day or even from year to year.

**Climate** considers average conditions over an extended period of years. The normal climate is determined by a 30-year average of conditions and climate change represents a sustained pattern of change from the normal climate.

**Key Point: International Academies: Joint statement**

"Climate change is real. There will always be uncertainty in understanding a system as complex as the world's climate. However there is now strong evidence that significant global warming is occurring. The evidence comes from direct measurements of rising surface air temperatures and subsurface ocean temperatures and from phenomena such as increases in average global sea levels, retreating glaciers, and changes to many physical and biological systems. It is likely that most of the warming in recent decades can be attributed to human activities (IPCC 2001)." (2005, 11 international science academies)<sup>26</sup>

**Key Point:** Observations of climate change are growing as each year passes. Continued unabated, climate change will lead to significant loss of infrastructure and habitat, as well as increasing conflict from competition for resources.

### Overview

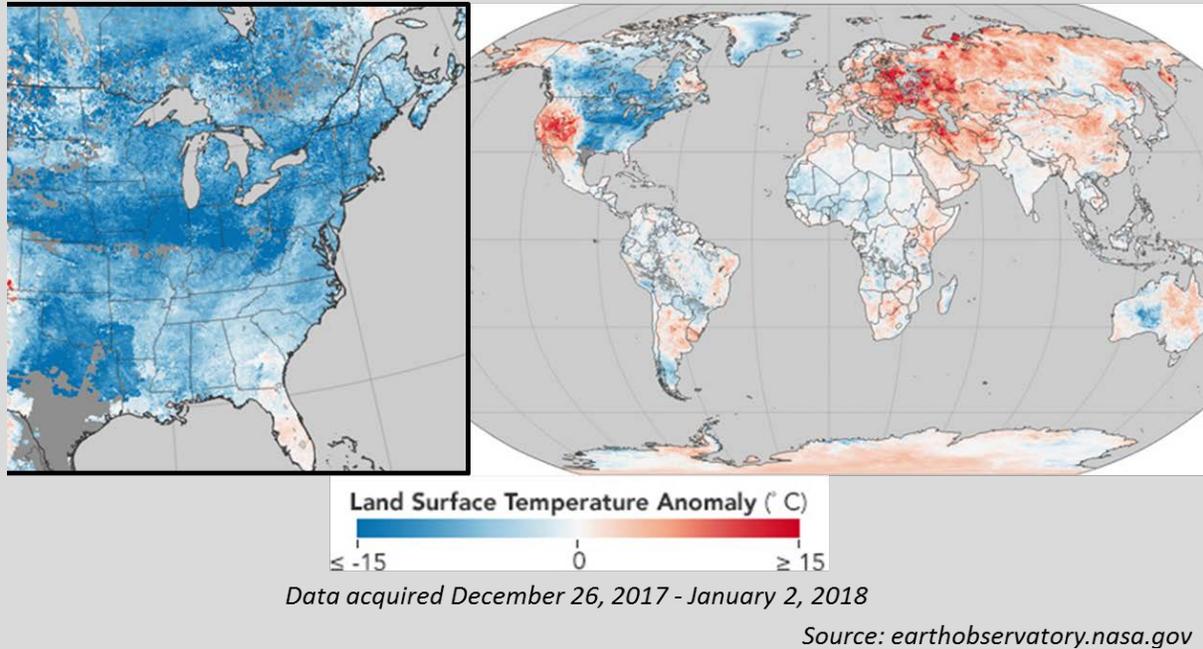
Human activity along with natural emissions has led to the build-up of greenhouse gases (GHGs) into the atmosphere, primarily carbon dioxide (CO<sub>2</sub>), a process which has caused a significant increase in the Earth's air and ocean temperatures. The rise in the concentration of GHGs has resulted in the Earth's average annual temperature rising by over 1.8 degrees Fahrenheit (°F) from the time temperature records began in 1880 through 2016. The same temperature record shows that 16 of the 17 warmest years on record have occurred since 2001. The year 2016 continued the trend by setting a new global average annual temperature record, the third such record in three years. This connection between rising GHGs and the

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<sup>26</sup> Joint science academies' statement: Global response to climate change (2005)  
<http://nationalacademies.org/onpi/06072005.pdf> .

Earth's temperature is supported by the overwhelming majority of the world's climate scientists.

**Key Point:** Global average temperatures are tracked because the variability of weather causes some locations to be cool while others are warmer than usual. It also causes some areas to be wetter than normal while others are dryer. Despite portions of the planet being cooler than normal, the Earth can still set record warm average temperatures. For example, the eastern U.S suffered record cold in late 2017 and early 2018, possibly giving a false impression that it was cold everywhere.



The increase in the average global air and ocean temperatures has been directly linked to observed local and regional changes in: the type and intensity of precipitation; the length of seasons; the relative height of sea level; and the frequency and intensity of extreme weather events. These changes have led to health, environmental and economic impacts as invasive species and diseases have become more prevalent, landscapes have been altered, and extreme storms have devastated communities.<sup>27,28</sup> New Hampshire residents, businesses and communities are already experiencing the effects of a changing climate as our environment changes including: more intense rainstorms that wash out roads and culverts, damage homes, businesses, and wastewater and drinking water facilities; and gradual warming, which supports

<sup>27</sup> Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz, (2014). Ch. 16: Northeast. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn. <http://nca2014.globalchange.gov/report/regions/northeast>.

<sup>28</sup> IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. [https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR\\_AR5\\_FINAL\\_full\\_wcover.pdf](https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf)

larger pest populations (*e.g.*, ticks, mosquitoes) that infect people and wildlife with disease and which negatively affects our cold weather industries and maple syrup producers.

As the GHGs that cause the Earth to warm continue to increase in the atmosphere, further changes to our climate and environment are expected, including impacts to the state's and region's air quality as well as a further increase in the frequency and severity of extreme weather.

In April of 2007 (*Massachusetts v. EPA*, 549 U.S. 497 [2007]), the United States Supreme Court found that greenhouse gases are air pollutants covered by the Clean Air Act. The Court held that the EPA Administrator must determine whether or not emissions of greenhouse gases from new motor vehicles cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision. The EPA Administrator is required to follow the language of section 202(a) of the Clean Air Act. On April 17, 2009, the EPA Administrator signed a proposed "endangerment and cause or contribute" finding for greenhouse gases under Section 202(a) of the Clean Air Act. EPA reviewed, considered, and incorporated public comments prior to issuing final Findings in December 2009.

Fortunately, the solutions to manmade causes and their impacts to global warming and climate change are increasingly available as technologies mature, knowledge is developed, and experience and expertise expands. In terms of managing the GHG emissions that cause climate change, energy efficiency and renewable energy technologies, which replace the need for fossil fuels, are increasingly cost competitive with traditional energy resources. To avoid the most severe impacts of climate change, these technologies needed to be adopted economy wide in order to decarbonize the economy; a process which is expected to result in positive public health and economic outcomes for New Hampshire.

In parallel there is an ongoing effort to begin to adapt to the changes we are seeing in our climate. Understanding our vulnerabilities to flooding, power outages, extended periods of summer heat and other climate change impacts helps us begin to address our vulnerabilities. Taking actions to reduce our vulnerabilities and decreasing our dependence on fossil fuels will make New Hampshire and our communities more resilient to our changing climatic conditions.

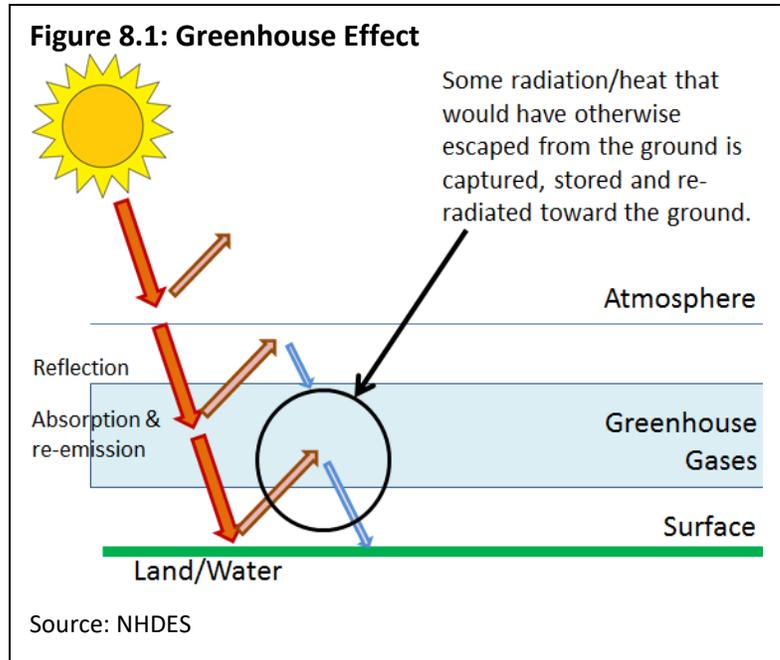
## **8.1 Natural Warming**

### The Greenhouse Effect

We depend on the Earth's atmosphere to provide not only the oxygen we breathe, but also to maintain the Earth's capacity to support life. The atmosphere is able to do this through a natural process referred to as the "greenhouse effect." Without our atmosphere, the Earth would experience daytime temperatures that exceed the boiling point of water and overnight temperatures that fall well below zero degrees Fahrenheit. For reference, the moon does not

have an atmosphere and experiences temperatures ranging from 250 degrees Fahrenheit during the day to minus 240 degrees Fahrenheit at night.

As can be seen in Figure 8.1, a portion of the sun's energy that reaches the Earth is reflected back into space by the atmosphere. This is essential to keeping the Earth from overheating. The solar radiation that does reach the surface warms the ground and bodies of water. Some of this heat is then reradiated upward as infrared radiation, with a portion escaping into space. The greenhouse effect



occurs when GHGs in the atmosphere absorb the infrared energy rising from the Earth's surface and re-radiates it back downward to the surface. At night, when the sunlight is no longer warming the surface, residual daytime heat continues to radiate upward, providing nighttime cooling at the ground. The greenhouse effect continues to trap a portion of that heat at the Earth's surface, thus preventing the Earth's nighttime temperature from dropping precipitously. This balance between incoming and outgoing radiation has kept Earth's overall average temperature at about 59 degrees Fahrenheit.

While the greenhouse effect is essential to life on Earth, too strong an effect traps much of the sun's energy leading to an accumulation of heat. Even small changes in GHG concentrations can increase or decrease how much heat the Earth retains. The changes in the atmospheric concentration of GHGs are important, because as their concentrations change, it changes the radiative and thermal patterns around the globe. Even very small changes can change how air moves. As every meteorologist knows, when the sun shines, warm air rises upward from the ground where other air moves to fill the vacuum. This along with the rotation of the planet creates weather and causes it to change. When the average weather patterns change over a period of decades, then the climate is determined to have changed.

**Key Point:** Natural atmospheric concentrations of greenhouse gases are about 200 parts per million of air, or 0.02%. If such a tiny amount of greenhouse gas can effectively regulate the earth temperature to habitable levels, imagine what doubling of the concentration can do.

## 8.2 Greenhouse Gases (GHGs)

The greenhouse effect is driven by a class of atmospheric gases that occur both naturally and as a result of human activities. While chemically different, each gas shares the capacity, in their

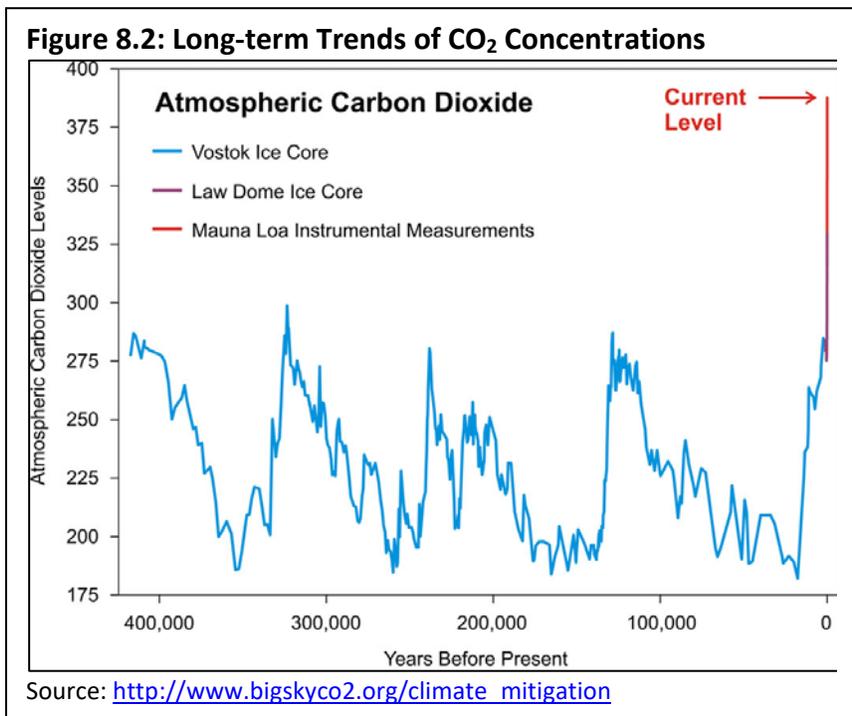
current amounts, to trap infrared radiation in the Earth's atmosphere and maintain the air and ocean temperatures at the levels sufficient to sustain life.

The most common naturally occurring GHGs include: CO<sub>2</sub>; methane (CH<sub>4</sub>); nitrous oxide (N<sub>2</sub>O); ozone (O<sub>3</sub>); and water vapor (H<sub>2</sub>O). The first three of these are generated by biological processes and are relatively long-lived (decades to centuries). While critical to life on Earth, they actually make up a tiny fraction of the total atmosphere. CO<sub>2</sub>, the most important, is actually measured in parts per million (ppm) molecules of gas in the atmosphere. One part per million is equivalent to one drop of water diluted into about 13 gallons of liquid (roughly the fuel tank of a compact car). Methane and N<sub>2</sub>O make up a much smaller portion and are measured in parts per billion (ppb). While these concentrations may seem too small to have any meaningful effect, remember that the criteria pollutants discussed in earlier chapters can cause significant human health impacts and death at similar concentrations.

Water vapor is unusual in that it is very abundant and has a large contribution to warming, but it has a very short atmospheric lifetime (a few days). Massive amounts of water vapor are constantly entering the atmosphere as a result of evaporation, but is relatively short lived as it is constantly cycling with weather events and falls back to Earth as rain or snow fairly quickly (hours to days or until it reaches saturation levels).

### 8.2.1 Rising Greenhouse Gases Concentrations

CO<sub>2</sub> comprises a much larger portion of the atmosphere than the other two gases. Its concentration in the atmosphere is now higher than it has been for hundreds of thousands of years, as shown using analyses of Antarctic ice core data (Figure 8.2). The rise and fall of CO<sub>2</sub> over the past several hundred thousand years is associated with the cycle of ice ages. When CO<sub>2</sub> was very low (~180 ppm), massive ice sheets covered significant portions of the northern hemisphere.

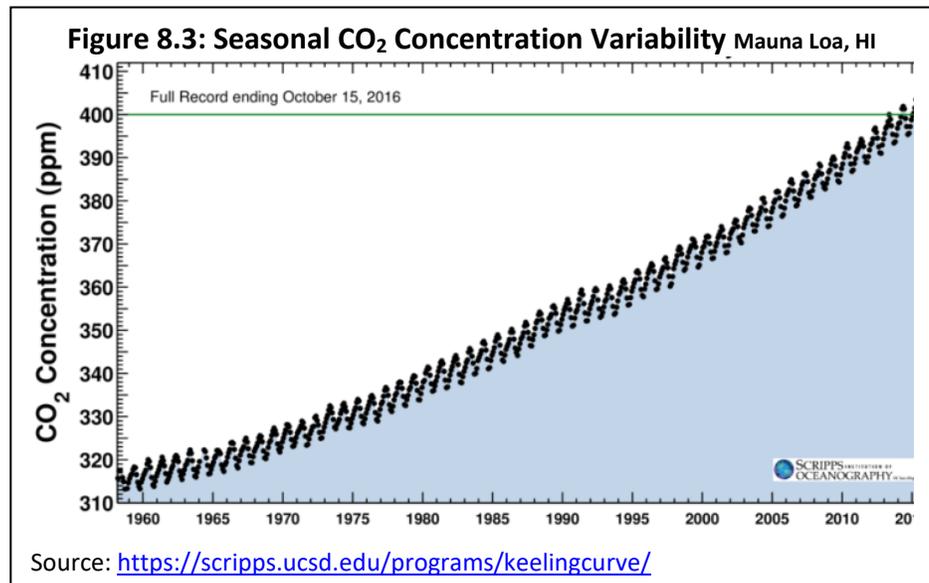


While CO<sub>2</sub> concentrations rose and fell due to natural processes over the past several hundred thousand years, the concentration held steady at around 280 ppm for centuries prior to 1750. In 2016, the average concentration of CO<sub>2</sub> in the atmosphere rose to and remained above 400 ppm throughout the entire year for the first time in several million years. The CO<sub>2</sub> concentration is now projected to remain above that level indefinitely.<sup>29,30</sup> Half of the overall rise from 280 to 400 ppm has occurred since 1980.

## 8.2.2 Acceleration of Greenhouse Gas Emissions

The cause of the rapid increase in CO<sub>2</sub> (Figure 8.2) is linked to a variety of human activities.<sup>31</sup> The first to occur, beginning millennia ago, include deforestation and land clearing for agriculture, a process which can decrease the amount of vegetation available to absorb CO<sub>2</sub> from the atmosphere and which can release carbon that has been locked away in soils.

Beginning with the industrial revolution of the mid-1800s, fossil fuels (*e.g.*, coal and oil) became more widely adopted and gradually replaced the then traditional forms of energy such as biomass, wind and water in Europe and North America. As the new CO<sub>2</sub>-emitting technologies became adopted on a wide-



spread basis, CO<sub>2</sub> began accumulating in the atmosphere at a faster pace than natural forces could remove it. While Figure 8.2 shows this as a rapid accumulation in the atmosphere, this is largely a result of the timescale of the figure. As shown in Figure 8.3, the accumulation has occurred gradually, with a cyclical variation occurring each year.

CO<sub>2</sub> is relatively well mixed in the atmosphere around the planet, but there are some small variations. CO<sub>2</sub> concentrations are normally slightly higher in the northern hemisphere where

<sup>29</sup> Met Office (2015). *2016 Global Mean Temperature Forecast*, <http://www.metoffice.gov.uk/news/releases/archive/2015/global-temperature>, (Accessed June 1, 2016).

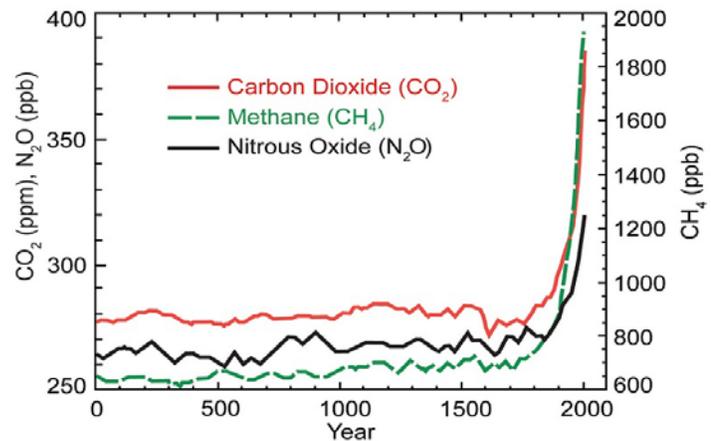
<sup>30</sup> <https://www.theguardian.com/environment/2016/oct/18/2016-locked-into-being-hottest-year-on-record-nasa-says>

<sup>31</sup> IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp, [http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR\\_AR5\\_FINAL\\_full\\_wcover.pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf), (Accessed June 24, 2016).

there is more land area and human population. More of the southern hemisphere is covered by ocean. Due to this imbalance between the North and the South, there is also a seasonal fluctuation where CO<sub>2</sub> concentrations are highest during winter when there is less plant growth to absorb the gas. During northern summers, vegetative growth is sufficiently large enough that it is capable of reducing the atmospheric CO<sub>2</sub> concentration by several ppm (Figure 8.3).

Carbon dioxide, as noted above, is not the only gas that enables the greenhouse effect. Methane and N<sub>2</sub>O have also seen their concentrations rise since 1750 (Figure 8.4). Methane occurs naturally from biological activities in wetlands and animals, but increasing human activities have dramatically increased levels throughout the production and transport of coal, natural gas and oil. Methane emissions also result from

**Figure 8.4: Long-term GHG Concentration Trends**



Source: <https://www3.epa.gov/climatechange/images/science/GHGConc2000-large.jpg>

**Key Points:**

- Carbon dioxide, methane, nitrous oxide, water vapor and man-made F-gases are the major greenhouse gases
- Emissions of carbon dioxide and other greenhouse gases rapidly accelerated during the industrial revolution (which started in 1760) and has risen to concentrations not experienced for over 100,000 years.

livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills. N<sub>2</sub>O also occurs naturally, but agricultural activities, such as fertilizer use, are the primary source of N<sub>2</sub>O emissions. The combustion of fossil fuels, solid waste and biomass also generates N<sub>2</sub>O. Ozone, which is present in very small amounts globally, has always occurred naturally (e.g., lightning during thunderstorms), but has increased dramatically as its precursor air pollutants (i.e., nitrogen oxides and volatile organic compounds) have increased significantly.

**Key Point:** Common sources of CO<sub>2</sub> include combustion of fossil fuels, industrial processes, and deforestation (burning). Respiration is only a small contributor. Plants are one of nature’s best tools for removing CO<sub>2</sub> from the air in their respiration process. Carbon is stored in their leaves and woody components until decomposed or burned. CO<sub>2</sub> is also absorbed and stored into water (oceans), but becomes less efficient with increasing temperatures.

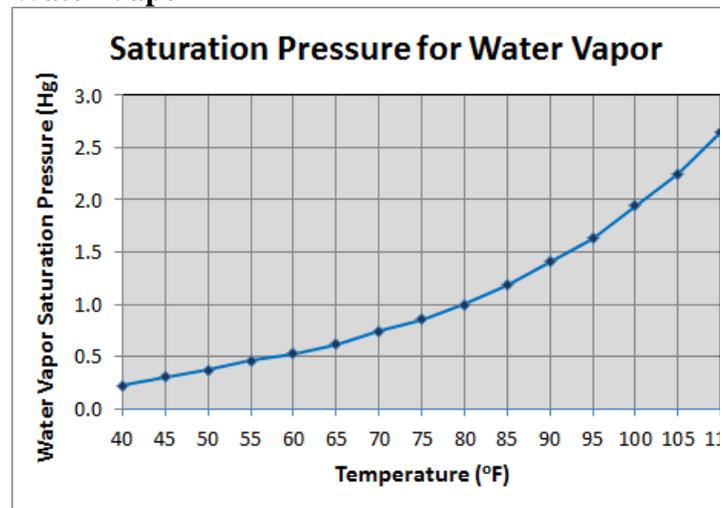
Water vapor is influenced by different processes. Rather than being influenced directly by human activity, water vapor is influenced by air and water temperature. Warm air can hold more water vapor than cooler air and when temperatures rise near water bodies, evaporation

of water increases leading to higher water vapor concentrations (Figure 8.5). This also means that water vapor is subject to a positive feedback loop, meaning that as the concentration of GHGs grow, the greenhouse effect increases and global temperatures rise. As the air and water temperatures rise, more water vapor can enter the atmosphere and cause further warming. Fortunately, water vapor only remains in the atmosphere until it falls out as rain or snow, so the increased greenhouse effect due to this feedback loop does not grow exponentially.

Water vapor is not alone in being affected by feedback loops. Methane is influenced by a complicated positive feedback process involving the thawing of permafrost in cold portions of the planet. Permafrost

describes soils underneath the ground surface that have been frozen for long periods of time. When enough warming occurs, this permafrost thaws and biological materials in the previously frozen soil begin to decay, releasing methane. This newly released methane further enhances the greenhouse effect, which continues the cycle, leading to further thawing of permafrost. Unlike water vapor, methane does remain in the atmosphere for more than a decade, so this feedback loop has the potential to spur significant warming.

**Figure 8.5: Relationship of Air Temperature and Water Vapor**



Source: NHDES

**Key Point:** As the GHGs have risen in the atmosphere, so too has the strength of the greenhouse effect, a process which has resulted in warming temperatures worldwide. In its Fifth Assessment Report in 2014, the Intergovernmental Panel on Climate Change stated that the causes and impacts of climate change have passed key thresholds and that the scientific community was “now 95 percent certain that humans are the main cause of current global warming.”<sup>32</sup> In a more recent review of more than 24,000 peer-reviewed papers on global warming published in 2013 and 2014, only five reject the reality of rising temperatures or the fact that human emissions are the cause, i.e., more than 99.9 percent of all climate scientists agreed.<sup>33</sup>

<sup>32</sup> IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp, [http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR\\_AR5\\_FINAL\\_full\\_wcover.pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf), (Accessed June 24, 2016).

<sup>33</sup> Powell, J. (2016). *Climate Scientists Virtually Unanimous Anthropogenic Global Warming Is True*, *The Bulletin of Science Technology Society*, March 28, 2016, <http://bst.sagepub.com/content/early/2016/04/25/0270467616634958.full.pdf+html>, (Accessed May 15, 2016).

In addition to the changes in GHGs that occur naturally, there are a number of synthetic GHGs that occur exclusively due to human activities. Among the most important are the fluorinated gases (F-gases), which are used for industrial processes, refrigeration, and in a variety of consumer products. These gases include chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>). Chlorofluorocarbons are the same type of gases that were causing the stratospheric ozone hole over the Antarctic and Arctic regions.

### **8.2.3 Greenhouse Gas Impact on Warming**

The GHGs differ not only in the amount emitted into the atmosphere, but also in terms of their potential to trap heat near the Earth's surface, and therefore, contribute to global warming and climate change. The term used to refer to how potent a GHG is for warming is "global warming potential" (GWP). GWP is a relative measure of how much heat a GHG traps in the atmosphere, whereby GHGs can be compared to the heat trapping capability of a similar mass of CO<sub>2</sub>. GWPs of GHGs are calculated based on how long they remain in the atmosphere, on average, and how strongly they absorb energy and they are expressed as a factor of carbon dioxide (whose GWP is the lowest and standardized to 1).

The top GHGs and their GWP are summarized in Table 8.1. While other types of GHGs have greater GWPs than CO<sub>2</sub>, the sheer volume of CO<sub>2</sub> that has accumulated in the atmosphere (*i.e.*, ppm vs. ppb and ppt) far outweighs the impact that other GHGs currently have on warming. For this reason, the amounts of any GHG are usually expressed as CO<sub>2</sub>-equivalents (CO<sub>2</sub>e) to communicate the relative warming value of that amount of gas as well as to allow the warming potential of different gases to be summed. For instance, 10 metric tons of CO<sub>2</sub> are expressed as 10 MTCO<sub>2</sub>e, while 10 metric tons of methane is expressed as 280 MTCO<sub>2</sub>e. The emissions of the CO<sub>2</sub> and methane can now be expressed as 290 MTCO<sub>2</sub>e.

#### A Rapidly Warming World

The rise in the concentration of CO<sub>2</sub> and other GHGs has resulted in the Earth's average annual temperature rising by over 1.8 degrees Fahrenheit (Figure 8.6) from the time temperature records began in 1880 through 2015, which exceeded 2014 for the warmest year on record. The National Aeronautics and Space Administration (NASA) and the National Oceanographic and Atmospheric Administration (NOAA) released global temperature data that showed 16 of the 17 warmest years on record have occurred since 2001.<sup>34</sup> 2016 again set a new global average annual temperature record,<sup>35,36</sup> the third such record in three years.

**Key Point:** Global average surface temperatures have increased more than 1.8°F since 1880. Average temperatures measured by the NWS in Concord, NH have increased by about 1.0°F since 1921.

<sup>34</sup> NASA (2016). *NASA, NOAA Analyses Reveal Record-Shattering Global Warm Temperatures in 2015*, <http://www.giss.nasa.gov/research/news/20160120/>, (Accessed June 1, 2016).

<sup>35</sup> Met Office (2015). *2016 Global Mean Temperature Forecast*, <http://www.metoffice.gov.uk/news/releases/archive/2015/global-temperature>, (Accessed June 1, 2016).

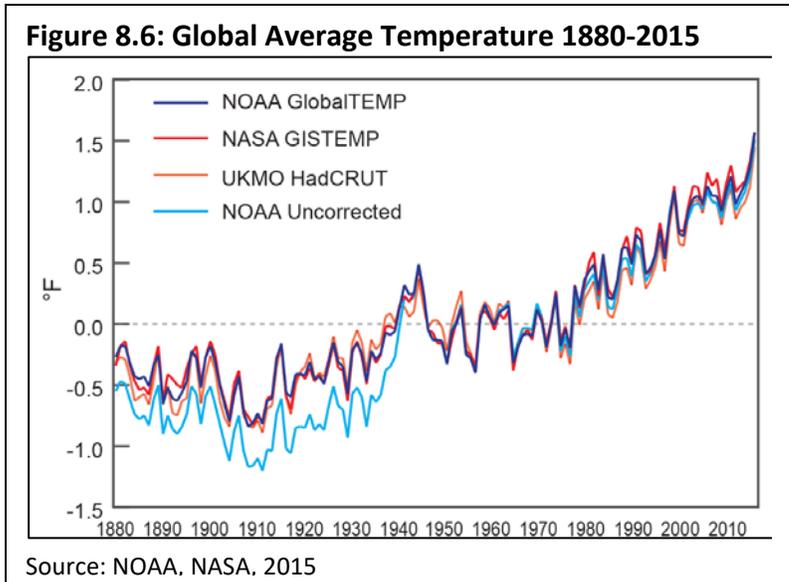
<sup>36</sup> <https://www.theguardian.com/environment/2016/oct/18/2016-locked-into-being-hottest-year-on-record-nasa-says>

**Table 8.1: Top GHGs and their Concentrations, Lifetimes, and Warming Potentials (2016)**

Compound	Pre-1750 Atmospheric Concentration	2016 Average Atmospheric Concentration	Global Warming Potential	Atmospheric Lifetime (years)	Increased radiative forcing (W/m <sup>2</sup> )
<i>Concentrations in parts per million (ppm)</i>					
Carbon Dioxide (CO <sub>2</sub> )	280	400	1	100-300	1.94
<i>Concentrations in parts per billion (ppb)</i>					
Methane (CH <sub>4</sub> )	722	1834	28	12.4	0.5
Nitrous Oxide (N <sub>2</sub> O)	270	328	265	121	0.2
Ozone (O <sub>3</sub> )	237	337	NA	hours-days	0.4
<i>Concentrations in parts per trillion (ppt)</i>					
Halon Gases					
Carbon tetrachloride (CCl <sub>4</sub> )	zero	82	1,730	26	0.014
CFC-11 Trichlorofluoromethane (CCl <sub>3</sub> F)	zero	232	4,660	45	0.06
CFC-113(CCl <sub>2</sub> CClF <sub>2</sub> )	zero	72	5,820	85	0.022
CFC-12 (CCl <sub>2</sub> F <sub>2</sub> )	zero	516	10,200	100	0.166
HCFC-22(CHClF <sub>2</sub> )	zero	233	1,760	11.9	0.049
HFC-134a(CH <sub>2</sub> FCF <sub>3</sub> )	zero	84	1,300	13.4	0.0134
Sulfur Hexafluoride (SF <sub>6</sub> )	zero	8.6	23,500	3200	0.0049
Halons Total (including unlisted)	zero	NA	NA	NA	0.36

**8.2.4 Quantifying Manmade Greenhouse Gas Emissions**

In order to better understand human contribution to climate change, it is helpful to develop estimates of greenhouse gas emission inventories. This can then be used to compare who emits what, and how much. Once a reasonable inventory is compiled, the science can be better analyzed and a plan for remediation can be considered. It should be noted that human activity can cause increases in certain “natural” emissions due to positive feedback responses where warming caused from manmade emissions trigger increases in natural emissions (Discussed in Section 8.2.2) Such increases in natural emissions are not included in the emission estimates.

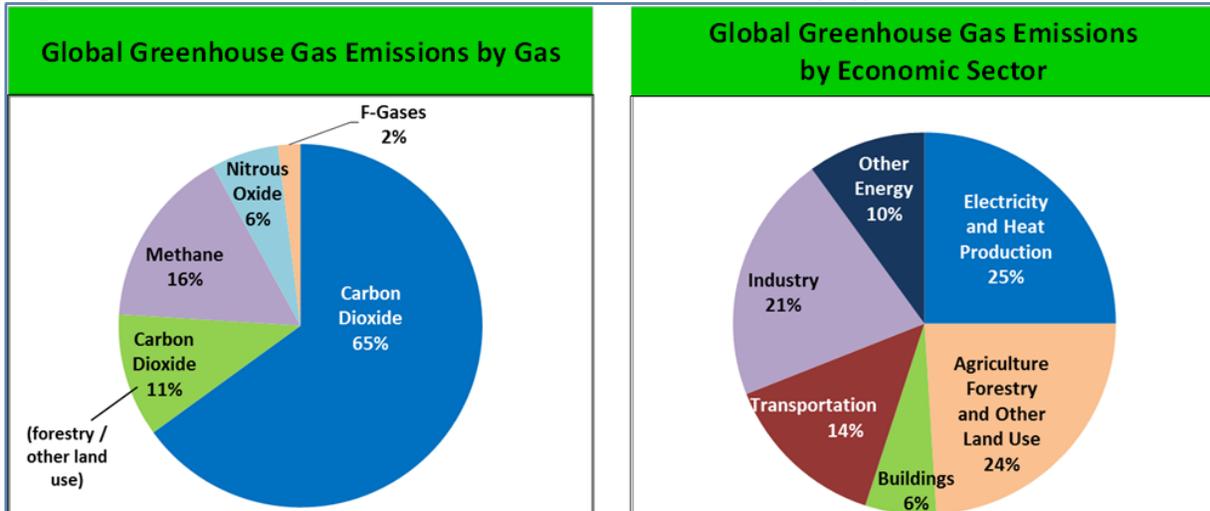


Of the GHG gases described in this section, CO<sub>2</sub> receives the most attention because it has the largest overall impact on the changes in the greenhouse effect. Figures 8.7 and 8.8 show the

global and New Hampshire GHG emissions for the year 2014, including the total and relative GHG emissions by type and by emission source sector. The emissions inventoried at the global and state scale only account for the GHG emissions associated with human activities.

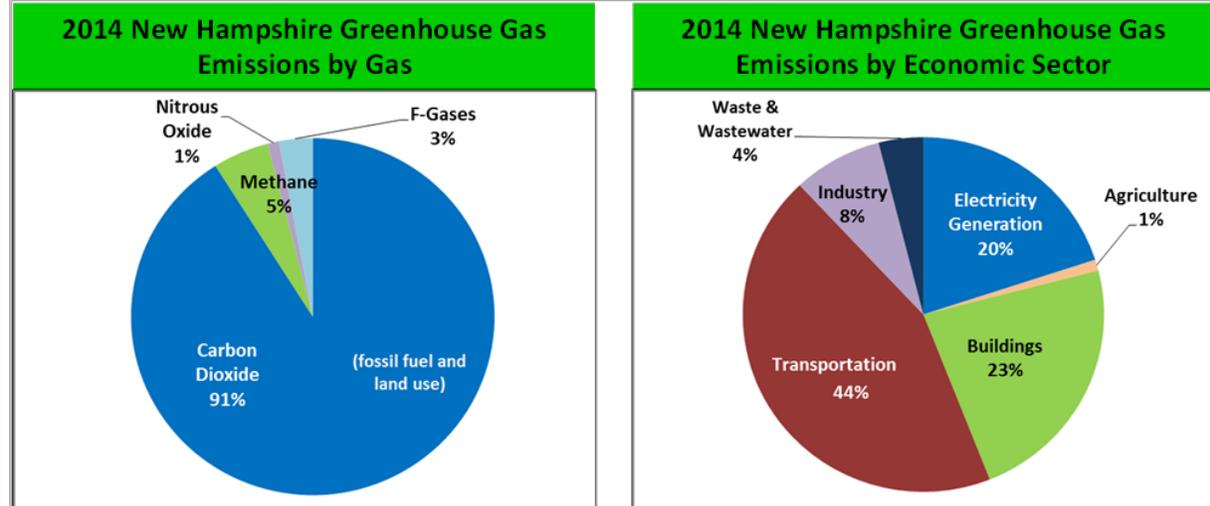
In both sets of figures, the left-hand pie charts illustrate the relative importance of CO<sub>2</sub> as it represents more than 75% (includes both the blue and green slices) of global emissions and more than 90% (just the blue wedge) of New Hampshire’s GHG emissions. The vast majority of the CO<sub>2</sub> is a result of fossil-fuel combustion, with only a small amount resulting from the waste and wastewater activities. The right hand pie charts illustrate the relative contribution of each emission source sector. As a developed economy with a very small agricultural base remaining, New Hampshire’s emissions are very different from the global profile.

**Figure 8.7: World-wide Man-made Greenhouse Gas Emissions by Type and Sector**



Source: [https://www.epa.gov/sites/production/files/2016-05/global\\_emissions\\_gas\\_2015.png](https://www.epa.gov/sites/production/files/2016-05/global_emissions_gas_2015.png) and [https://www.epa.gov/sites/production/files/2016-05/global\\_emissions\\_sector\\_2015.png](https://www.epa.gov/sites/production/files/2016-05/global_emissions_sector_2015.png)

**Figure 8.8: New Hampshire Greenhouse Gas Emissions by Type and Sector**



Source: NHDES

### 8.3 Observations of Change in New Hampshire

The increase in the average global temperature has been directly linked to observed New Hampshire and regional changes in the frequency and intensity of precipitation, the length of seasons, ocean temperature and sea-level, as well as a significant rise in extreme weather events. These changes have led to health, environmental and economic impacts as invasive species and diseases have expanded, landscapes have been altered, and extreme storms have devastated communities.<sup>37,38,39</sup>

Environmental changes potentially related to climate change are being observed in New Hampshire. Some notable New Hampshire centric observations include:

#### Primary Impacts

- Increases in annual & seasonal average temperature.
- Increases in the total amount and intensity of precipitation.
- Increases in extreme weather of all types.

#### Secondary Impacts:

- Sea-level rise along the Seacoast.
- Earlier ice-in and ice-out dates on New Hampshire lakes and ponds.
- Changes in garden hardiness zone maps.
- Increases in summer drought.
- Changes in maple syrup production and moose populations.

#### Temperature Patterns

Figure 8.9 and Figure 4.32 (in Section 4.6) indicate average temperatures in Concord, New Hampshire have risen about 1.0°F in the 96 years since 1921. These changes didn't always appear as a steady trend. Instead, there are a lot of year to year fluctuation, but over longer durations, a sustained pattern is evident. In some cases, changes appear more as surges between stable periods.

#### New Hampshire Ice Storm



<sup>37</sup> Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz, (2014). *Ch. 16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn. <http://nca2014.globalchange.gov/report/regions/northeast>.

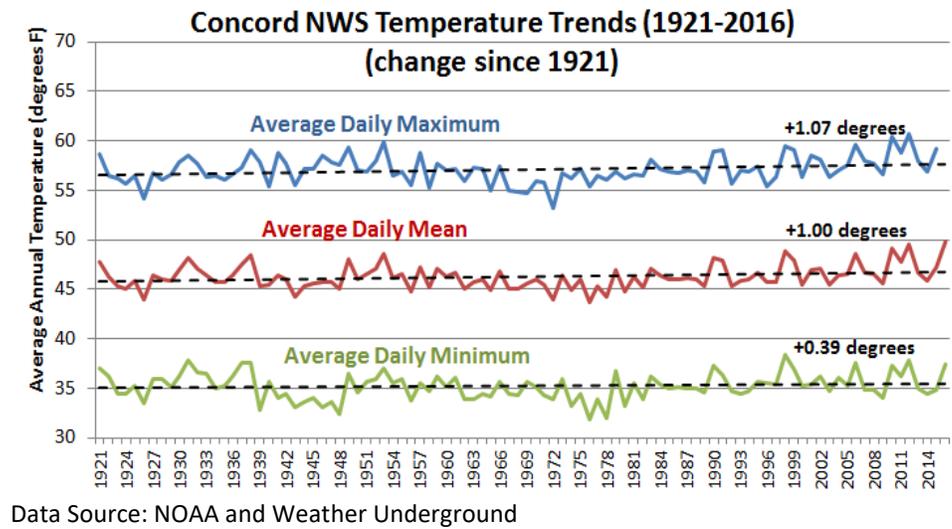
<sup>38</sup> IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. [https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR\\_AR5\\_FINAL\\_full\\_wcover.pdf](https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf)

<sup>39</sup> Hayhoe K, CP Wake, J Bradbury, T Huntington, L Luo, MD Swartz, J Sheffield, B Anderson, A DeGaetano, D Wolfe, E Wood (2007) Past and future changes in climate and hydrological indicators in the U.S. Northeast. *Climate Dynamics* 28, 381–407. doi: 10.1007/s00382-006-0187-8.

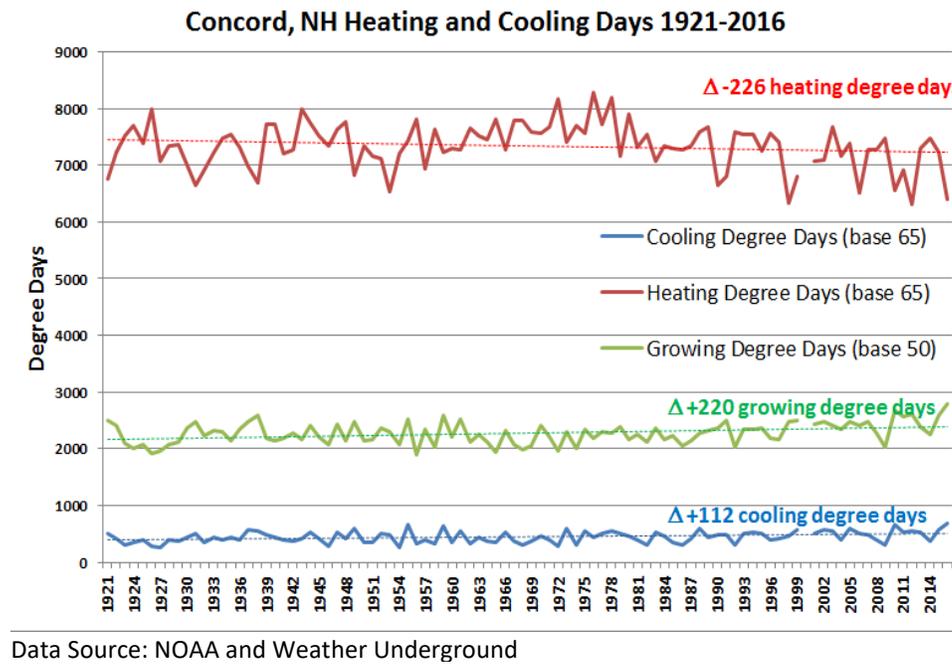
As part of its weather tracking, the National Weather Service (NWS) generated a new, more robust measure of a day's temperature patterns. Cooling Degree Days and Heating Degree Days statistics represent the amount of cooling and heating needed to maintain comfortable indoor temperatures during hot and cold weather over the course of the year (Figure 8.10).

A third metric, Growing Degree Days, represents a measure of heat accumulation used to predict plant and pest development rates such as the date that a crop reaches maturity. Plants need a certain threshold of growing degree days in order to emerge and flower and areas with higher growing degree days are capable of growing certain species that cannot thrive where lower growing degree days are found. Conversely, some plants need a certain amount of dormant time and require lower growing degree day locations.

**Figure 8.9 Concord Annual Average Temperature Trends**



**Figure 8.10: Annual Heating and Cooling Degree Days, Concord, NH**



During the 96-year (1921-2016) period, the amount of cooling needed to maintain comfortable indoor summer-time temperatures increased about 25% and the amount of heating required to maintain comfortable cold weather season indoor temperatures decreased by about 2%. The growing degree day metric also grew by about 9% (Figure 8.10).

In an assessment of state-wide temperature data for a 52-year period, from 1960 to 2012, researchers for Climate Solutions NE found that, while temperature fluctuations occur every year, clear general trends have emerged, including:<sup>40,41,42</sup>

1. Daily maximum, minimum and average temperatures throughout most of New Hampshire have generally demonstrated increasing trends.
2. The number of days where the temperature reaches 90 degrees and higher is also mostly up (Table 8.2).
3. The number of days where the minimum temperature drops below 32 degrees is down (Table 8.2).
4. The number of days where the ground is covered by snow has decreased (Table 8.3).
5. The agricultural growing season has grown longer (Table 8.4).

**Table 8.2: New Hampshire Hot and Cold Day Changes (1960-2012)**

Location	Days > 90°F		Maximum Temperature (°F) Hottest Day of Year	
	1960-2012 average	Change (days/52 years)	1960-2012 average	Change (°F/52 years)
Berlin	2.5	-2.1	92.1	-2.3
Durham	8.3	+4.1	95.0	0.0
Hanover	6.0	+0.5	94.4	0.0
Keene	7.5	0.0	94.9	0.0
Nashua	7.7	+3.5	95.1	0.0
Pinkham Notch	0.2	0.0	87.4	+1.2
Location	Days < 32°F		Minimum Temperature (°F) Coldest Day of Year	
	1960-2012 average	Change (days/52 years)	1960-2012 average	Change (°F/52 years)
Berlin	168.1	-16.5	-20.2	+10.1
Durham	150.5	-26.0	-14.5	+9.6
Hanover	151.1	-19.8	-18.9	+6.7
Keene	157.9	+2.8	-16.8	+11.4
Nashua	153.8	-26.0	-12.0	+13.3
Pinkham Notch	180.3	-18.3	-18.0	+7.0

Source: Climate Solutions NE and US Global Historical Climatology Network

<sup>40</sup> Wake, CP, E Burakowski, P Wilkinson, K Hayhoe, A Stoner, C Keeley, and J LaBranche (2014) Climate Change in Northern New Hampshire: Past, Present, and Future. Climate Solutions New England Report, Sustainability Institute at the University of New Hampshire. <https://sustainableunh.unh.edu/sites/sustainableunh.unh.edu/files/images/northernnhclimateassessment2014.pdf>

<sup>41</sup> Wake, C.P., E. Burakowski, P. Wilkinson, K. Hayhoe, A. Stoner, C. Keeley, and J. LaBranche (2014) Climate Change in Southern New Hampshire: Past, Present, and Future. Climate Solutions New England Report, Sustainability Institute at the University of New Hampshire. <https://sustainableunh.unh.edu/sites/sustainableunh.unh.edu/files/images/southernnhclimateassessment2014.pdf>

<sup>42</sup> Hayhoe K, CP Wake, J Bradbury, T Huntington, L Luo, MD Swartz, J Sheffield, B Anderson, A DeGaetano, D Wolfe, E Wood (2007) Past and future changes in climate and hydrological indicators in the U.S. Northeast. Climate Dynamics 28, 381–407. doi: 10.1007/s00382-006-0187-8.

**Table 8.3: New Hampshire Snow Covered Day Changes (1960-2012)**  
(Greater than one inch of snow on the ground)

Location	1970-2012 mean (days)	Change (days/52 years)
Hanover	119	-25.0
Newport	106	-30.7
Durham	79	-35.4
Marlow	108	-32.8
Weare	98	-39.0
Greenland	94	-28.1
Keene	97	-25.0
Milford	84	-7.1

Sorted from north to south  
↓

Source: Climate Solutions NE and US Global Historical Climatology Network

**Table 8.4: New Hampshire Growing Season Changes (1960-2012)**

Location	Growing Season	
	1960-2012 mean (days)	Change (days/52 years)
Berlin	168.2	+19.8
Durham	170.4	+52.0
Hanover	175.9	+30.7
Keene	164.4	+14.6
Nashua	177.2	+52.0
Pinkham Notch	159.4	+20.8

Source: Climate Solutions NE and US Global Historical Climatology Network

Annual precipitation is also trending upward, as are the number of large precipitation events (Table 8.5). National Weather Service data collected at Concord, New Hampshire demonstrate that 1-inch (or more) precipitation events have increased in frequency from about 5.7 times per year in the early 1920's to about 8.8 per year in the mid-2010s. During the same period, 3-inch (or more) events have increased from about one every 4 years to one every 3 years.

**Table 8.5: New Hampshire Large Precipitation Event Trends (1960-2012)**

Location	1 inch in 24 hours		Wettest Day of the year	
	1960-2012 mean (events/year)	Change (events/52 years)	1960-2012 mean (inches)	Change (inches/52 years)
Berlin	7.8	+5.2	2.5	+0.5
Durham	10.5	0.0	3.1	+0.5
Errol	6.0	+1.6	1.9	+0.5
Hanover	7.6	+2.1	2.2	+0.5
Keene	9.2	+6.2	2.4	+0.5
Lakeport	9.0	+5.2	2.5	+0.5
Marlow	9.6	+4.2	2.4	+0.5
Milford	11.8	0.0	2.8	+0.5
Mt. Sunapee	11.3	+4.2	2.7	+1.0
Nashua	11.8	+5.2	2.7	+0.5
Newport	8.3	+4.7	2.4	+0.5
Pinkham Notch	15.1	+6.2	3.6	+1.0

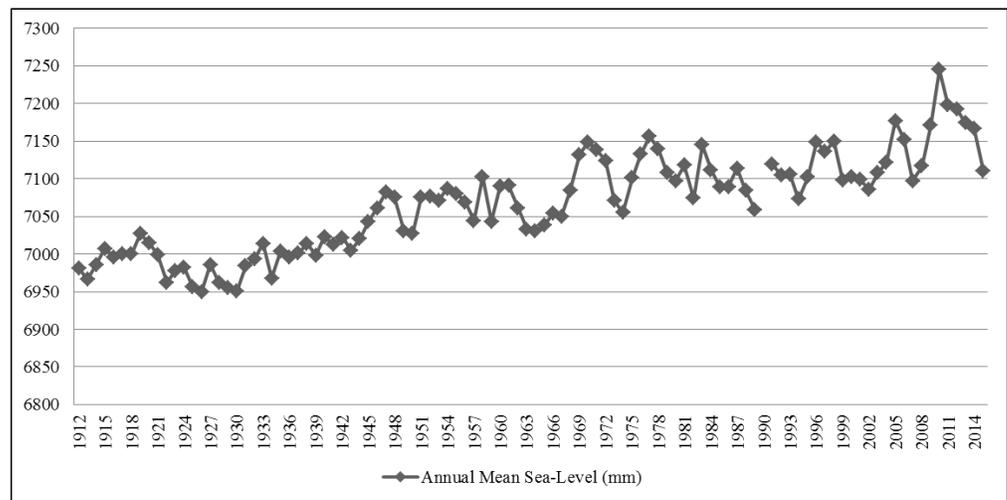
Source: Climate Solutions NE and US Global Historical Climatology Network

Sea-Level Rise

The sea-level along the coastline of New Hampshire is constantly changing with the tides, winds and currents making it difficult to observe how average sea levels might be changing. In 1926, a tidal gauge was placed at Portsmouth Harbor for the purpose of tracking normal tides, but the data collected allows a longer-term evaluation of how sea-level has changed since 1926. For the period 1926 to 2001, sea-level rose nearly half a foot (5.3 inches), at a rate of about 0.693 inches per decade. The gauge was relocated in 2001. A similar tidal gauge was placed just up the coast from Portsmouth, in Portland, Maine, that offers a long-term look at average seas surface levels up through the most recent available year of 2015 (Figure 8.11). The annual values represent the annual mean of the monthly mean sea-level data. The data show some four to six year cycling (short-term increases and decreases) and a long-term increasing trend.

Increases in relative sea-level contribute to heightened flooding of coastal infrastructure, increased coastal erosion, saltwater contamination of freshwater ecosystems, and loss of salt marshes. Low-lying shorelines such as sandy beaches and marshes are likely to be the most vulnerable to rising seas.

**Figure 8.11: Relative Annual Sea-Level (mm) – Portland, Maine (1912-2015)**



Source: NHDES with data obtained from <http://www.psmi.org/data/obtaining/stations/183.php>

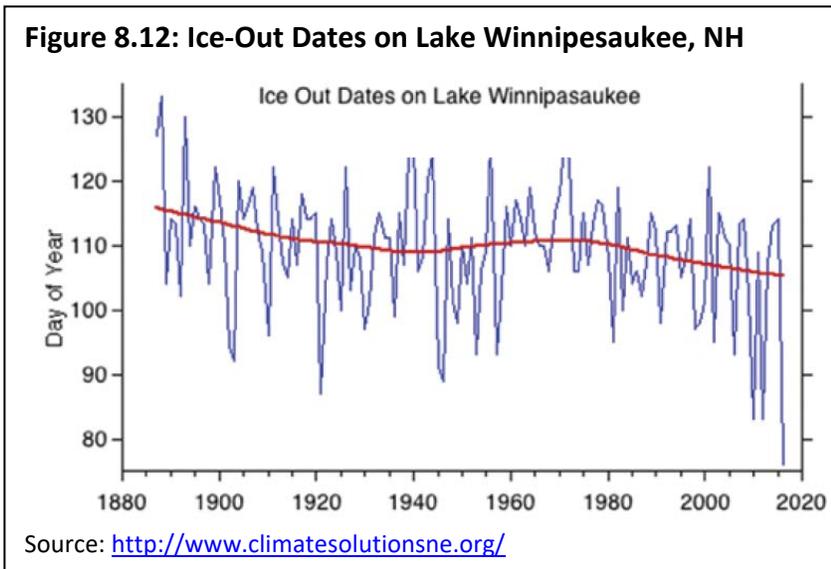
Sea-level rise is a complex phenomenon that does not occur equally around the world. Several factors contribute to this variability including tides, winds, currents temperatures and thermal expansion, salinity differences and density changes, and subsiding and uplifting coastlines. For more information about sea-level rise and other coastal hazards along the NH coast, consult the New Hampshire Coastal Risks and Hazards Commission’s Science and Technical Advisory Panel Report “Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire.”<sup>43</sup>

<sup>43</sup> STAP (2014). *Sea-level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire*, Science and Technical Advisory Panel, NH Coastal Risks and Hazards Commission, 44 pp. [http://nhcrhc.stormsmart.org/files/2013/11/CRHC\\_SAP\\_FinalDraft\\_09-24-14.pdf](http://nhcrhc.stormsmart.org/files/2013/11/CRHC_SAP_FinalDraft_09-24-14.pdf) (Accessed October 15, 2016).

### Ice-out Dates on Lake Winnepesaukee

#### Ice-out on Lake

Winnepesaukee has been tracked in New Hampshire since the late 1800s and is considered a measure of how cold the New Hampshire winter was that year. Ice-out is called when ice in the lake has melted and cleared enough that the tour ship MS Mount Washington can make all of its ports of call on the lake. Figure 8.12 plots these data by year and provides a (red) best fit line to help



determine if any trends exist. The blue line presents the actual ice-out data on a year-by-year basis, showing typical yearly variability, some years colder than others resulting in later ice-out dates. The long-term trend appearing is that lake ice-out dates in the 2010s are occurring 7 to 10 days sooner on average than 130 years earlier<sup>44</sup>.

### Changes in Plant Hardiness Zone Maps

Temperature patterns in United States are also tracked by farmers and backyard gardeners interested in planting their properties. Generations of agricultural experience found that some regions are better suited for certain plants based on their growing seasons and how cold it gets in the winter. Science has since

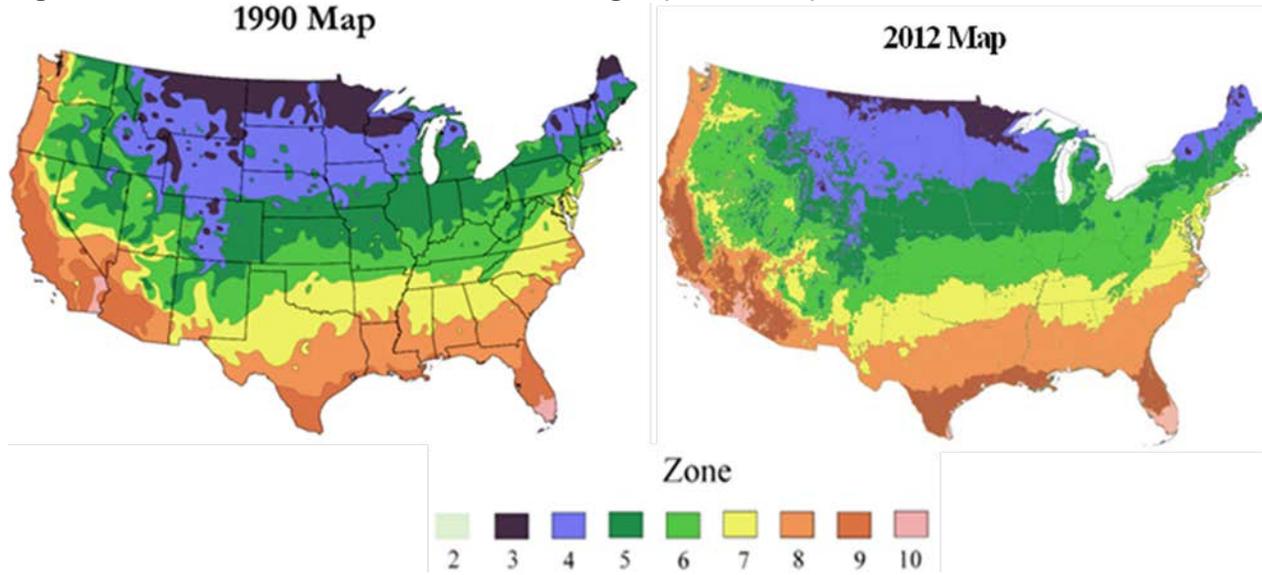


developed a mechanism for rating plants based on their weather tolerances and needs in order to thrive. Hardiness zones maps were developed to help the farmer and gardener match plants as either being suitable or not recommended based on their location.

Figure 8.13 presents United States Department of Agriculture (USDA) plant hardiness maps for 1990 and 2012, demonstrating changes affecting local growers. In the 1990 USDA map, New Hampshire was rated as zone 3 in the north to zone 5 in the south, with zone 4 covering most of the central part of the state. In the 2012 map, northern New Hampshire shifted to zone 4, southern New Hampshire shifted to zone 6, and most of the rest of the state is in zone 5. This is a shift of nearly one full plant hardiness zone over a 22-year period.

<sup>44</sup> Hodgkins, G. A. (2010) Historical Ice-Out Dates for 29 Lakes in New England, 1807–2008. United States Geological Survey Open File Report 2010–1214. 38 p. <http://pubs.usgs.gov/of/2010/1214/pdf/ofr2010-1214.pdf>

**Figure 8.13: USDA Plant Hardiness Zone Changes (1990-2012)**



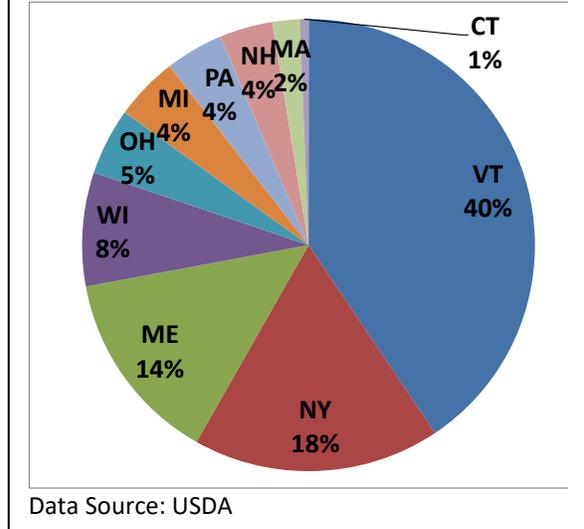
Source: USDA <http://planthardiness.ars.usda.gov/PHZMWeb>

Maple Syrup Production

According to the Department of Agriculture, New Hampshire produces about 4% (or about 124,000 gallons) of the nation’s maple syrup (Figure 8.14). Maple syrup production is considered a New England and a New Hampshire tradition and this region accounts for over 60% of the nation’s product. Most of the remaining maple syrup production in the United States takes place in states lining the eastern Canadian border (New York, Pennsylvania, Ohio, Michigan and Wisconsin).

Over thousands of years, tree species adapted to and thrived in the climate conditions where they were located, particularly temperature and moisture. The Sugar Maple, most heavily used for maple syrup production, thrives in regions where summer temperatures don’t frequently reach 100°F or where the winter temperatures regularly drop below 0°F. After a winter dormant period, Maple trees produce their sap when spring arrives.

**Figure 8.14: 2013 State Contribution of Maple Syrup Production**

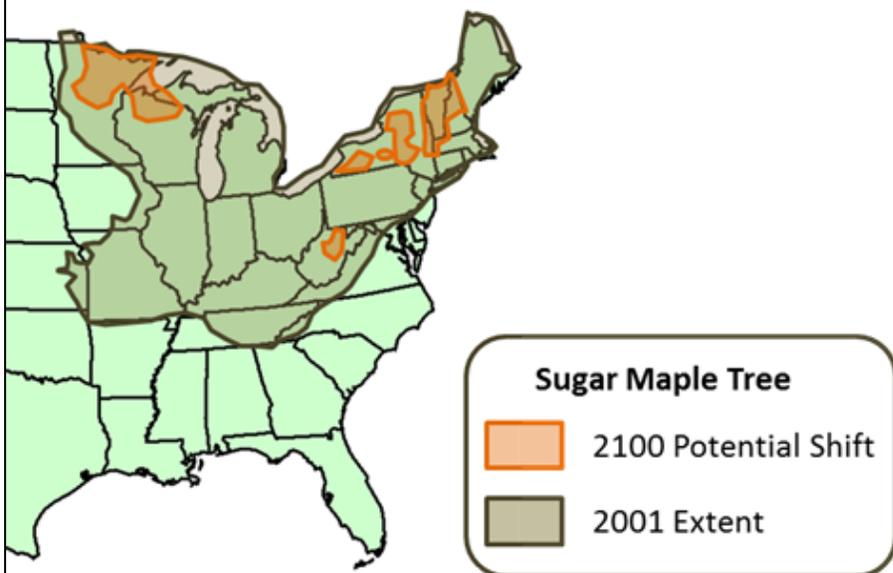


Good weather for spring sap production features nighttime temperatures in the 20s (°F) and sunny days with temperatures in the 40s (°F). This alternate freezing and thawing temperature

cycle causes the pressure changes inside the tree that makes the sap flow. If the nighttime temperatures are too cold, it takes longer for the sap to warm up and “run” in the daytime. If the temperatures are very cold, the sap may not run at all.

Since the maple trees best suited for syrup production are located in a limited geographic portion of the country, they are somewhat vulnerable to seasonal and climatic changes if they occur too quickly. As seen in the USDA Hardiness Zone data (Figure 8.13), zones best suited for certain vegetation have already experienced some northward shifting, which is also true for sugar maples. Projections for the sugar maples in New England include seasonal shifting of best sap flow season from February through April to January through early March in order to get the right day-night temperature variation. In future years, syrup production in New Hampshire is expected to dwindle as the sap flowing cycle is further disrupted and a shorter sap flow season develops. In the longer range, should temperatures become too warm and/or if there are associated factors such as increased insects, drought, etc. occur, the sugar maple may no longer thrive in much of our region (Figure 8.15).

**Figure 8.15: Maple Tree Migration**



Source: Adapted from U.S. Forest Service, December 2002

**Key Point:** Sugar is produced in the maple tree leaves during photosynthesis and then is transported into the tree’s wood and stored during the winter in the form of carbohydrates. These sugars are then converted to sucrose and dissolved into the tree’s sap that moves within the tree trunk and roots due to pressure changes created by the cycling of freezing and warm temperatures. During warm periods when temperatures rise above freezing, enough pressure develops in the tree that the sap can easily flow out of the tree through a wound or tap hole. As soon as temperatures no longer fluctuate between freezing at night and thawing during the day, sap stops flowing. This causes sugaring season to shift earlier during warmer winters and springs.

Changes in Moose Populations

Moose are one of the more popular forms of wildlife in New Hampshire. It can be quite breathtaking for people to see these large animals roaming the forests. Unfortunately, the New Hampshire moose are being attacked by a very small parasite, the Winter Tick. Warm winters are ideal for Winter Tick propagation and when they have a favorable winter researchers have found that there is a corresponding jump in the number of ticks found on the moose. Tens of thousands of Winter Ticks have been counted on New Hampshire Moose after a warm winter. While a strong adult moose might be able to survive an attack, a 70% mortality rate of juvenile moose is driving the overall population down in the state. Since the early 2000s the estimated number of moose in New Hampshire has declined from about 7,500 to about 4,000<sup>45</sup>.

Changes in Bird Populations

Changes in climate can be a factor that affects nesting behavior and residency of birds by changing availability of food, water and shelter, as well as the populations of predators. New Hampshire bird populations can also be affected by changes in out of state breeding grounds. Changes in wintering grounds are at least one contributing factor affecting bird populations<sup>46</sup>.

**TABLE 8.6: Recent Population Trends of Some Common Birds in New Hampshire<sup>47</sup>**

Decreasing	Increasing
Baltimore Oriole	American Crow
Barn Swallow	American Goldfinch
Brown Thrasher	Bald Eagle
Cedar Waxwing	Common Raven
Cliff Swallow	Downy Woodpecker
Eastern Kingbird	Eastern Bluebird
Eastern Meadowlark	House Finch
Field Sparrow	Mallard Duck
Killdeer	Osprey
Northern Mockingbird	Pileated Woodpecker
Purple Finch	Pine Warbler
Rose-breasted Grosbeak	Red-bellied Woodpecker
Ruffed Grouse	Ruby-throated Hummingbird
Scarlet Tanager	Tufted Titmouse
White-throated Sparrow	Turkey Vulture
Wood Thrush	Wild Turkey
Yellow Warbler	Yellow-bellied Sapsucker



<sup>45</sup> New Hampshire Fish and Game, 2017

<sup>46</sup> National Audubon Society, 2016 <http://www.audubon.org/news/audubon-scientists-uncover-one-third-wintering-bird-populations-declined-1966>

<sup>47</sup> New Hampshire Fish and Game, 2017 <http://www.wildlife.state.nh.us/nongame/birds-trends.html>

## 8.4 Addressing Climate Change

Since our climate is already experiencing measurable change and we are committed to some degree of additional change due to already emitted greenhouse gases, responding to climate change involves a two-pronged approach:

- Reducing manmade emissions of and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere (“mitigation”).
- Adapting to the climate change already in the pipeline (“adaptation”).

### 8.4.1 Reducing Greenhouse Gas Emissions

In order to avoid more significant economic impacts locally and even more severe impacts on vulnerable nations around the globe, the scientific community has determined that the average global temperature increase must be held at or below 2°C (3.6°F), as exceeding this would put the world at serious risk of catastrophic climate change.<sup>48</sup> Limiting the rise to 1.5°C (2.7°F) or less, as identified in the 2015 *Paris Agreement*, would provide a greater degree of safety.<sup>49,50</sup>

In order to stabilize the climate at or below the 2°C (3.6°F) increase, GHG emissions must drop rapidly and permanently. The consensus view of climate scientists is that global GHG emissions must fall 40-70% below 2010 levels by 2050 and to nearly zero by the end of the century.<sup>51</sup> To meet this target, North American emissions must fall 80% below 1990 by 2050. Analysis suggests that in absence of additional reduction measures beyond those already in place, long-term average temperature increase will reach between 3.6°C and 5.3°C (6.5°F and 9.5°F) (compared with pre-industrial levels), with most of the increase occurring this century.<sup>52, 53</sup>

Fortunately, solutions exist to address these challenges and they are becoming increasingly more cost effective and diverse. Two ways to address the use of energy are energy efficiency

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<sup>48</sup> DDPP (2014). *Executive Summary, Pathways to Deep Decarbonization*, Deep Decarbonization Pathways Project, [http://unsdsn.org/wp-content/uploads/2014/09/DDPP\\_ExecutiveSummary\\_digit.pdf](http://unsdsn.org/wp-content/uploads/2014/09/DDPP_ExecutiveSummary_digit.pdf), (Accessed June 1, 2016).

<sup>49</sup> IPCC (2013). *Climate Change 2013: The Physical Science Basis – Summary for Policymakers*. Contribution of Working Group I to the Intergovernmental Panel on Climate Change Fifth Assessment Report, Stockholm, Sweden. <http://www.climatechange2013.org>, (Accessed June 1, 2016).

<sup>50</sup> Kartha, S. (2013). *The Three Salient Global Mitigation Pathways Assessed in Light of the IPCC Carbon Budgets*, Stockholm Environment Institute, <https://www.sei-international.org/mediamanager/documents/Publications/Climate/SEI-DB-2013-Climate-risk-emission-reduction-pathways.pdf>, (Accessed June 1, 2016).

<sup>51</sup> IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. [https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR\\_AR5\\_FINAL\\_full\\_wcover.pdf](https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf)

<sup>52</sup> IEA (2013). *Redrawing the Energy - Climate Map, World Energy Outlook Special Report*, <http://www.worldenergyoutlook.org/weo2013/>, (Accessed May 4, 2015).

<sup>53</sup> IPCC, 2014: Summary for Policymakers. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. [http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc\\_wg3\\_ar5\\_summary-for-policymakers.pdf](http://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf), (Accessed May 4, 2015).

and renewable energy. Efficiency entails using the same amount of energy to do more work, whereas renewable energy is energy that comes from resources that are continually replenished such as sunlight, wind, flowing water, tides, waves and geothermal heat.

Going forward, advances in battery technology will enable more intermittent-renewable sources, like wind and solar, to be integrated into our energy system by allowing excess energy to be stored when it is being produced and the stored energy to be released when winds weaken or the sun sets. Further changes are expected as electric vehicle technology advances, which will enable the displacement of traditional internal combustion engines. The final mix of technologies are uncertain, but when the secondary benefits of greener policies — like lower fuel costs, fewer premature deaths from air pollution and reduced medical bills — are taken into account, the changes might wind up saving money and lives.

#### **8.4.2 New Hampshire Climate Action Plan**

To address greenhouse gas emissions and the current and projected impacts of climate change, the *Climate Change Policy Task Force* (CCPTF) was formed in December 2007 by the Governor by executive order. The CCPTF was charged with developing a set of climate change action goals as well as a set of recommendations outlining the regulatory, voluntary and policy actions that can be taken to achieve those goals. In March 2009, following over a year of effort supported by business, community and nonprofit representatives, as well as by hundreds of New Hampshire residents, the Task Force issued the *New Hampshire Climate Action Plan*.<sup>54</sup> The Plan contains 67 recommendations, which the Task Force selected to achieve the reductions necessary to achieve its goals. These were distilled into five essential goals:

- Maximize energy efficiency in buildings and transportation.
- Increase renewable and low-emitting heat and electric power sources.
- Protect our natural resources to maintain the amount of carbon sequestered.
- Develop an integrated education, outreach and workforce training program.
- Adapt to existing and potential climate change impacts.

A clear message that the CCPTF formulated from the Plan development process is that the solutions to climate change present a significant set of opportunities. The reduction in carbon emissions can avoid the “export” of dollars that formerly left the state economy to pay for energy inputs, and this can be accomplished through efficiency and conservation. These savings can then be reinvested to create growth in non-energy sectors of the economy. The development of renewable energy sources not only keeps dollars in the economy but creates jobs by doing so. Over the long-term, investments in climate change mitigation, when combined on a global scale, can reduce expenditures by avoiding the most severe impacts of climate change.

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<sup>54</sup> CCPTF (2009). NH Climate Action Plan, Climate Change Policy Task Force, 82 pp.  
[http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action\\_plan/nh\\_climate\\_action\\_plan.htm](http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/nh_climate_action_plan.htm)

### **8.4.3 NEG/ECP Regional Climate Initiative**

New Hampshire participates in the New England Governors' and Eastern Canadian Premiers' (NEG/ECP) Conference, which seeks to coordinate the actions of the 11 jurisdictions in northeastern North America. The NEG/ECP first developed a *Regional Climate Change Action Plan* in 2001<sup>55</sup> with regional targets set for 2010, 2020 and 2050. In 2015, the NEG/ECP established a new interim target for 2030 and launched the NEG/ECP's *Regional Climate Change Initiative*, with the adoption of *Resolution 39-1*<sup>56</sup>, with a goal to develop a new *Regional Climate Change Action Plan* to be submitted in 2017.

#### Building Resilience

New Hampshire State Agencies are working together to build climate change resilience in our state government. There are limited resources available and many of the state's programs and assets serve dual uses (transportation culverts support wildlife passage) so the need to work together is imperative. Regionally there are two workgroups assisting municipalities in their efforts to build resiliency into their planning and zoning efforts. The New Hampshire Coastal Adaptation Workgroup works with communities and municipal decision makers in our coastal watershed. The Upper Valley Adaptation Workgroup is focusing its efforts in the Upper Connecticut River Valley; partnering with communities on the Vermont side of the river as well. NHDES staff co-chair these two workgroups ensuring communication between state agencies and our municipal decision makers. Collaboration is essential as we jointly work to make our communities and our state more resilient to the changing climate.

## **8.5 Effects of Climate Change on Air Pollution**

When ambient temperatures change, concentrations of other air pollutants change along with it. When the weather is cold, there is a need for heating. Home furnaces burn natural gas, oil, coal, and wood, all of which produce their own mix of air pollutants. Normally cold weather is accompanied by winds that effectively disperse and dilute the pollutant emissions; however there are cases where calm winds and thermal inversions can trap pollution emissions (Section 5).

Warm weather brings with it cooling needs which increase the demand for electricity. Electric power plants that burn natural gas, oil or coal, increase their production and air pollution emissions. Heat waves lead to high electricity demand days and back-up generating units often come online. Because these typically run less often than larger power plants, they often don't have the same state-of-the-art air pollution controls, and thus produce higher air pollution emissions. Emissions of all criteria air pollutants increase on hot days. Ozone, which is not

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<sup>55</sup> NEG/ECP (2016). *Energy and the Environment*, New England Governors and Eastern Canadian Premiers, <http://www.cap-cpma.ca/key-initiatives/energy-and-the-environment/>

<sup>56</sup> NEG/ECP (2015). *Resolution 39-1: Resolution Concerning Climate Change*, 39<sup>th</sup> Annual Conference of the New England Governors and Eastern Canadian Premiers, St. John's, NL, August 30-31, 2015, <http://www.coneg.org/Data/Sites/1/media/39-1-climate-change.pdf>.

directly emitted from sources, is created with a mixture of NO<sub>x</sub> and volatile organic compounds (VOCs) in the presence of sunlight and heat. When temperatures increase, the chemical reaction occurs faster, producing more ozone.

A changing climate due to an increased Greenhouse Effect produces not just a warmer planet (on average), but greater variability in weather patterns and extremes. Some locations on the earth have experienced more frequent and extreme heat waves than seen in past decades while other locations might be cooler than usual. Droughts and floods have been occurring at greater frequency, once again, occurring in some locations and not others. The non-uniformity of climate change is the result of a complex interaction between the Sun's energy and the oceans, land masses and frozen surfaces. Under stable conditions, this interaction leads to prevailing winds that generally blow from west to east in the northeastern United States, and ocean currents that generally flow northward along the eastern U.S. coastline. These wind and current conditions have stabilized our climate to temperate levels with some moderate degrees of variability. Changes in ocean temperatures and the amount of Earth's frozen surface alter the energy interaction, leading to more variability in wind patterns and ocean currents. Even subtle changes can cause more extreme weather events in the short term and noticeable new patterns over the long-term.

Small changes in temperatures and wind flow patterns can cause changes in air pollution emissions and transport patterns of air pollution emissions in upwind states.

**Key Points:**

**Changes observed in New Hampshire from 1960 to 2012** (source: Climate Solutions NE)

- Average annual precipitation has increased 6 inches (15%)
- Average maximum temperatures have warmed by about 2°F (more in winter)
- Average minimum temperatures have warmed by 3°F (annual) and 6°F (winter)
- Number of hot days (maximum >90°F) per year has increased from 5–6 days
- Number of cold days (minimum < 32°F) per year has decreased by 15 (9%)
- Number of precipitation events that drop >4 inches in 48 hours has increased 3–10 fold in the southern half of the state.
- Growing season has lengthened by 14 days
- Snow covered days have decreased by 20 days

**Key Point:** Changes in climate affect the way we use energy. More air conditioning is used during hotter than normal weather and more indoor heating is used during colder than normal weather. When this occurs, energy consumption increases. When that energy involves burning natural gas, oil, coal or wood, or involves using electricity generated by burning these fuels, more air pollution is created. Further, subtle changes in ground and water surface temperatures have produced variations to prevailing wind patterns, the same ones involved in air pollution transport.

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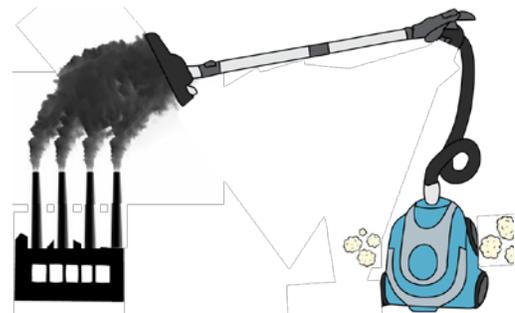
## 9 AIR POLLUTION CONTROL IN NEW HAMPSHIRE

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Air quality in New Hampshire has improved significantly over recent years and decades (see Section 4.5 for more information about emissions and pollution trends). In fact, certain areas in New Hampshire previously designated nonattainment for a pollutant standard have come into attainment (see Section 3.4 for more information about New Hampshire's former nonattainment areas). Except for a small portion of central New Hampshire designated nonattainment for the 1-hour sulfur dioxide (SO<sub>2</sub>) standard, New Hampshire is currently designated statewide attainment or unclassifiable/attainment for all criteria pollutants.

Air pollution controls, coupled with an appropriate compliance assurance and enforcement program, are needed to ensure that all of New Hampshire and areas affected by New Hampshire air pollution emissions maintain this progress and do not violate health, welfare or visibility standards. Differing emissions reduction approaches are used in order to address the physical nature and the economics of different pollution source types. For example, power plant emissions controls are not the same as those for motor vehicles, and requiring low volatility paint solvents won't help reduce emissions from home furnaces. Depending on the type of source and pollutant, emission reduction strategies may be voluntary, market-based, or regulatory driven. When pollution controls are needed, research and fact-finding is done to better understand the available technologies, costs of control, and needed flexibility in the application of regulations or legislation.

Emissions limits come in many different forms to produce comprehensive protection while allowing maximum flexibility and choice. Typical pollution reduction requirements include application of add-on controls, switching to cleaner fuels, operational limitations and/or complying with emissions caps established under market-based emission trading programs.



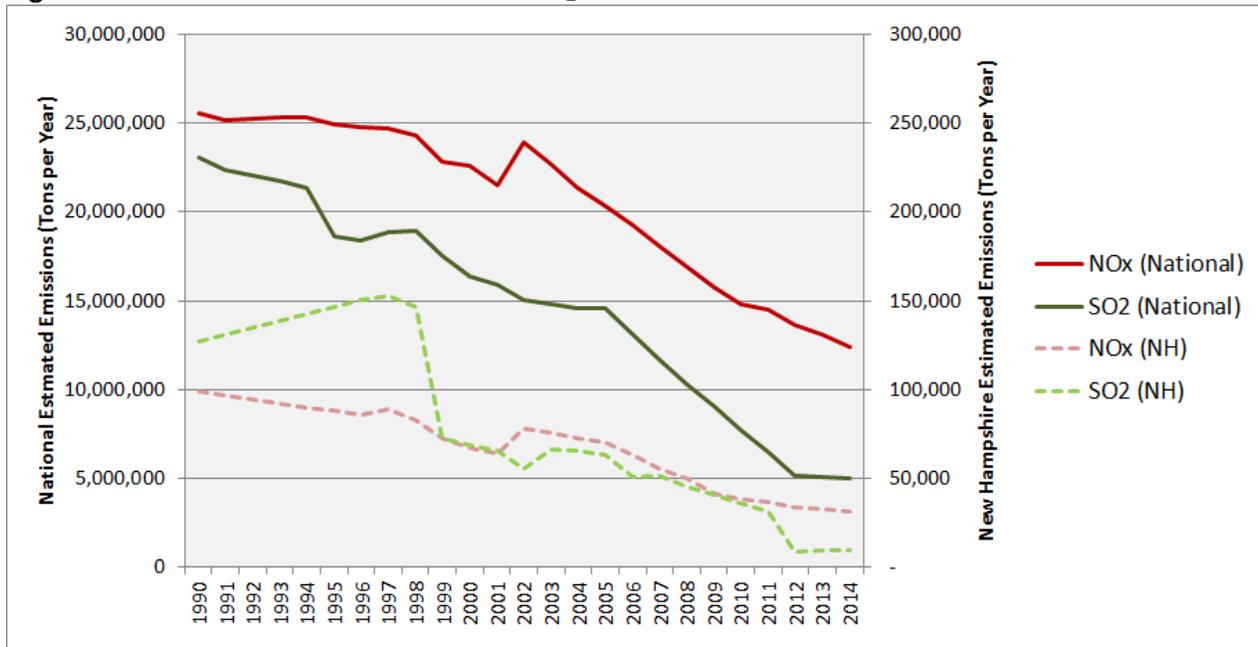
Air pollution reduction requirements are implemented through a variety of federal and state air quality regulations and pollution control programs. As described in the following subsections and summarized in Table 9.1, some of these regulations and control programs are directed at **stationary sources**, including power plants and factories (Section 9.1); others pertain to **mobile sources**, such as cars and trucks (Section 9.2); some to **non-road sources** such as boats, trains, airplanes and construction vehicles (Section 9.3); and some cover **other source categories** (Section 9.4). Emission reductions of NO<sub>x</sub> and SO<sub>2</sub> from these programs since 1996 are presented in Figure 9.1.

**Table 9.1: Air Pollution Requirement Quick Reference Guide**

<b>Sector</b>	<b>Requirement</b>	<b>Pollutant(s)<sup>57</sup></b>	<b>Report Section</b>
<b>Stationary Point Smoke Stacks</b>  (Power Plants & Industrial Sources)	1. New Source Review (NSR)		9.1.1
	a. Prevention of Significant Deterioration (PSD) Permit	Criteria	
	b. Nonattainment NSR Permit	Criteria	
	c. Minor Source Permit	Criteria	
	2. Acid Rain Program	N, S	9.1.2
	3. EPA NOx Budget Trading Program	N	9.1.3
	4. Clean Air Interstate Rule (CAIR)	N, S	9.1.4
	5. Cross-State Air Pollution Rule (CSAPR)	N, S	9.1.5
	6. New Hampshire NOx Budget Program	N	9.1.6
	7. New Hampshire Clean Power Act	CO <sub>2</sub> , M, N, S	9.1.7
8. New Hampshire Air Toxics Control Program	T	9.1.8	
9. New Hampshire Open Market Programs	N, V	9.1.9	
10. Regulations Limiting Emissions		9.1.10	
a. New Source Performance Standards (NSPS)	Varies		
b. Maximum Achievable Control Technology (MACT)			
i. Mercury and Air Toxic Standards (MATS)	M, T		
ii. Best Available Control Technology (BACT)	Criteria		
iii. Lowest Available Emission Rate (LAER)	Criteria		
iv. Reasonable Available Control Measures (RACM)	Criteria		
v. Reasonably Available Control Technology (RACT)	Criteria		
vi. BART	N, P, S		
<b>Mobile Sources</b>  (On-Road Vehicles)	1. Transportation Conformity	CO, N, P, V	9.2.1
	2. Diesel Emissions Reduction Act	CO, N, P	9.2.2
	3. Granite State Clean Cities	F	9.2.3
	4. Enhanced Inspection and Maintenance	CO, N, V	9.2.4
	5. Emissions and Fuel Standards		9.2.5
	a. Corporate Average Fuel Economy Standards (CAFÉ)	F	
b. Greenhouse Gas Standards	CO <sub>2</sub>		
c. Tier 3 Standards	N, S		
d. Heavy Duty Vehicle Standards	N,P,S		
6. Alternative Fuel Vehicles	Varies	9.2.6	
<b>Non-Road</b>	1. Non-road Mobile and Portable Sources	C, N, P, T, V	9.3
<b>Other Sources</b>	1. General Conformity	Criteria	9.4.1
	2. OTC Model Rules	V	9.4.2
	3. Regional Haze Rule	N, P, S, V	9.4.3
	4. BART	N, P, S	9.1.10
	5. Other products may be regulated during manufacture for sales	Varies	

<sup>57</sup> F=Reduced fuel consumption M=mercury, N=NOx, P=PM (PM<sub>2.5</sub> and/or PM<sub>10</sub>), S=SO<sub>2</sub>, T=air toxics, V=VOC

**Figure 9.1: Emission Trends of NO<sub>x</sub> and SO<sub>2</sub> from 1990 to 2014**



Source: USEPA and NHDES, 2016

## 9.1 Stationary Sources – Regulatory Programs and Controls

Several federal and state regulations focus on reducing air pollution from large stationary sources, such as power plants, factories, and large institutional facilities. The following subsections highlight several of these programs and rules applicable to large stationary sources. Multiple regulatory approaches may apply to address differing environmental needs.

- **Permitting Programs** – Under a permitting program, such as New Source Review (Section 9.1.1), major stationary sources must apply for a permit before building a new facility or making a major modification to an existing facility.
- **Emissions Trading Programs** – Emissions trading programs provide companies with the economic incentive to reduce emissions and the flexibility to do so in a cost effective way. This occurs through the trading of emissions allowances or credits; in this context, “trading” is any type of transfer from one source to another and usually takes place as a buy/sell arrangement. There are two general types of emissions trading programs: cap-and-trade allowance programs and project-based credit programs.
  - **Cap-and-Trade** – A cap-and-trade program sets a cap, or upper limit, on emissions of a particular pollutant from a group of sources. The cap is generally lower than the sources’ baseline<sup>58</sup> emissions.

<sup>58</sup> Baseline emissions are an estimate of current or recent emissions. Calculation of this value may differ by program and change over time; it is determined by the regulatory agency during the design of the program.

Under cap-and-trade, allowances<sup>59</sup> are allocated to sources in fixed amounts. An allowance represents authorization to emit a specific quantity of a pollutant (e.g., one ton). Sources without a sufficient number of allowances to cover their emissions must purchase more from other sources. Conversely, some emission sources that reduce their emissions more than required have more allowances than needed and may sell those they do not use or save them for future use.

The overall number of allowances under the cap is restricted to ensure that total emissions from all participating sources do not exceed the desired level. While not every source makes actual air pollution reductions, the end results of cap and trade are (1) timely overall air pollution emission reductions, (2) reduced overall costs of compliance, and (3) potential emission reductions beyond required levels.

Examples of cap and trade programs include:

- The Federal Acid Rain Program (Section 9.1.2).
  - EPA's Nitrogen Oxides (NOx) Budget Trading Program (Section 9.1.3).
  - The New Hampshire Nitrogen Oxides Budget Program (Section 9.1.6).
  - The New Hampshire Clean Power Act (Section 9.1.7).
- **Project Based** – In a project-based program, also referred to as a credit program, sources earn credit for projects that reduce emissions by more than what is required by regulation. Credits may also become available when a facility shuts down. Other facilities may purchase these emission reduction credits and use them toward compliance with a conventional regulatory requirement (e.g., New Source Review project emission offsets– Section 9.1.1, compliance with RACT requirements – Section 9.1.10, etc.)

Credit programs are designed specifically to impart flexibility to existing programs. Emission reductions are not mandatory and are based on volunteer participation. Examples of project-based programs include New Hampshire's open market trading programs (Section 9.1.9).

The main difference between cap and trade allowances and project-based credits is that the regulatory agency provides a fixed number of cap and trade allowances up front, while sources earn project-based credits through voluntary action. Both programs may result in emission reductions, but only cap and trade, which involves an explicit requirement of emission reductions, is intended for use as a strategy in state implementation plans (SIPs) to achieve attainment of the standards.

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<sup>59</sup> For information about cap and trade allowances, please see [EPA Allowance Markets](http://www.epa.gov/airmarkets/participants/allowance/index.html), (<http://www.epa.gov/airmarkets/participants/allowance/index.html>).

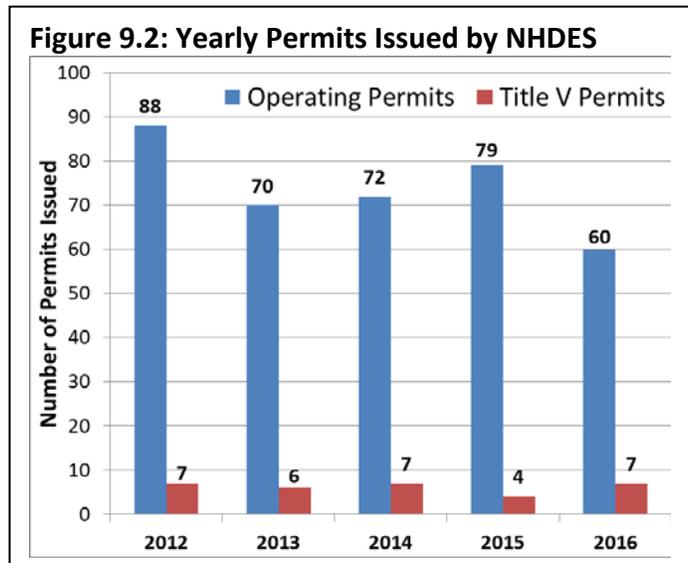
- Regulations Limiting Emissions** – EPA has established numerous control technology-based regulations which limit emissions of various pollutants from many types of sources. These regulations generally set limits on emission levels<sup>60</sup> that cannot be exceeded; these limits are typically based on employing certain types of air pollution control technologies. Section 9.1.10 provides an overview of several of these regulations.

### 9.1.1 New Source Review – Federal Program

The New Source Review (NSR) program<sup>61</sup> is a pre-construction permitting program established by the 1977 Clean Air Act (CAA) Amendments. NSR applies to each of the six criteria pollutants and can apply to certain hazardous pollutants. NSR requires a permit for (1) construction of new major power plants and industrial facilities with emissions above specified pollutant thresholds; and (2) major modifications to existing large facilities that will result in a “significant” (as defined in regulations) increase in air pollution. NSR ensures air quality is not significantly degraded by the addition of new or modified stationary sources (e.g., factories, industrial boilers, and power plants). Permits issued by year by NHDES are shown in Figure 9.2.

NSR consists of three types of permitting requirements:

- Prevention of Significant Deterioration Permits** – Prevention of Significant Deterioration (PSD) permits are required for new major sources or major sources making a major modification when that source is located in an attainment area. PSD permits require:
  - (1) Installation of Best Available Control Technology (BACT; Section 9.1.10)
  - (2) An air quality analysis and assessment of additional impacts
  - (3) Opportunity for public involvement



The PSD air quality analysis must show that the new or modified source will not cause or contribute to a violation of the NAAQS or deteriorate air quality beyond an allowable amount called the PSD increment.

<sup>60</sup> If EPA determines that technological or economic limitations on the application of measurement methodology would make a numerical emissions standard infeasible, a design, equipment, work practice, operational standard, or combination thereof, may be prescribed instead.

<sup>61</sup> <https://www.epa.gov/nsr>

Further air quality impact analyses may be required to evaluate and address additional impacts, such as visibility and pollutant deposition in nearby Class I protected areas, such as national parks/forests (see Section 2.3 for more information about Class I areas).

The PSD program does not prevent sources from increasing emissions, so long as the above requirements are met. The PSD program was designed to achieve balance between economic development and maintaining clean air where air quality meets the standards.

- **Nonattainment-NSR Permits** – Nonattainment-NSR permits are required for new major sources or major sources making a major modification when that source is located in a nonattainment area. All nonattainment NSR programs require:
  - (1) Installation of Lowest Achievable Emission Rate (LAER; Section 9.1.10) control technology.
  - (2) Emission offsets.
  - (3) Opportunity for public involvement.

Emission offsets are emission reductions from nearby sources that are greater than the potential increase in emissions from a proposed source or modification. These emission reductions must (1) offset the emissions increase from the new source or modification and (2) provide a net air quality benefit. Using emission offsets, a nonattainment area can move toward attainment while allowing for economic growth.

- **Minor Source Permits** – Most sources that have the potential to emit pollutants in amounts at which the PSD or Nonattainment-NSR requirements would apply have no need or intention to actually emit pollutants at those levels. Most of these smaller sources request permit limitations which limit their emissions to below the thresholds at which PSD or Nonattainment-NSR requirements would apply. These sources, commonly known as ‘synthetic minor’ sources, have voluntarily accepted the minor source permits in lieu of completing NSR review.

Through PSD permits, NSR assures that new emissions do not significantly worsen air quality in attainment areas. Through Nonattainment NSR permits, NSR assures that new emissions do not slow progress toward cleaner air in nonattainment areas. NSR also assures that any major new or modified source is at least as clean as other similar existing sources. In addition to ensuring that new sources meet stringent standards, this requirement also drives advances in air pollution control technologies.

### **9.1.2 Acid Rain Program – Federal Program**

Title IV of the 1990 CAA Amendments enacted the Acid Rain Program<sup>62</sup> to reduce emissions of two significant contributors to acid rain: SO<sub>2</sub> and NO<sub>x</sub>. It required a two-phase tightening of restrictions placed on fossil fuel-fired power plants with the goals of reducing annual SO<sub>2</sub> emissions by 10 million tons below 1980 levels and NO<sub>x</sub> emissions by 2 million tons below 1980 levels. These requirements applied to all new utility units as well as existing utility units serving generators with an output capacity greater than 25 megawatts.

Phase I for SO<sub>2</sub> began in 1995 at the largest, higher emitting electric utility plants, mostly coal-fired plants. Phase II, which began in the year 2000, tightened emission limits on the Phase I plants and added restrictions for smaller, cleaner plants fired by coal, oil, or gas.

Phase I for NO<sub>x</sub> began in 1996 and applied to specific types of coal-fired boilers: dry-bottom wall-fired boilers and tangentially-fired boilers. Phase II in 2000 tightened the emission limits on these boilers and added limits for a second group of boilers, including cyclone boilers, wet bottom boilers, boilers applying cell-burner technology, and others.

The Acid Rain Program uses the cap and trade system for SO<sub>2</sub> emission reductions only; facilities may not purchase allowances to cover NO<sub>x</sub> reductions. The program allocates SO<sub>2</sub> allowances based on historic fuel consumption and a specific emission rate. Phase II sets a permanent cap of 8.95 million on total SO<sub>2</sub> allowances for utilities.

The only affected power plant in New Hampshire under Phase I was Public Service of New Hampshire's (PSNH – now known as Eversource) Merrimack Station in Bow. Additional New Hampshire facilities affected under Phase II include the PSNH Newington Station's dual fuel (i.e., oil or natural gas-fired) unit in Newington and the three coal units at the PSNH Schiller Station in Portsmouth (one of these has since converted to biomass).

The highly successful Acid Rain Program has reduced emissions by far more than expected at a fraction of anticipated costs and has inspired the development of other trading programs. It represents a dramatic departure from traditional command and control regulatory methods that establish specific, inflexible emissions limitations. Instead, the Acid Rain Program introduces an allowance trading system harnessing free market incentives to reduce pollution.

### **9.1.3 EPA's NO<sub>x</sub> Budget Trading Program – Federal Program**

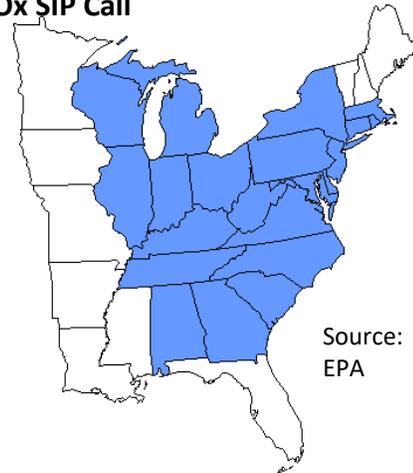
EPA's NO<sub>x</sub> Budget Trading Program is similar to New Hampshire's NO<sub>x</sub> Budget Program in that it is a cap and trade program addressing the regional nature of ozone pollution through widespread reduction of NO<sub>x</sub>, one of ozone's precursors. EPA's program is a product of the 1998 NO<sub>x</sub> SIP Call and affects stationary sources over a larger area of the eastern United States than the OTC programs.

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<sup>62</sup> <https://www.epa.gov/airmarkets/acid-rain-program>

On September 24, 1998, EPA finalized a rule, known as the NO<sub>x</sub> SIP Call, requiring 22 states and the District of Columbia (Figure 9.3) to submit SIPs addressing the regional transport of ground-level ozone. Designed to improve air quality throughout the eastern United States, the program called for an approximately 28 percent reduction in NO<sub>x</sub> emissions. The rule required emission reduction measures to be in place by May 1, 2003.

**Figure 9.3: States Included in the EPA NO<sub>x</sub> SIP Call**



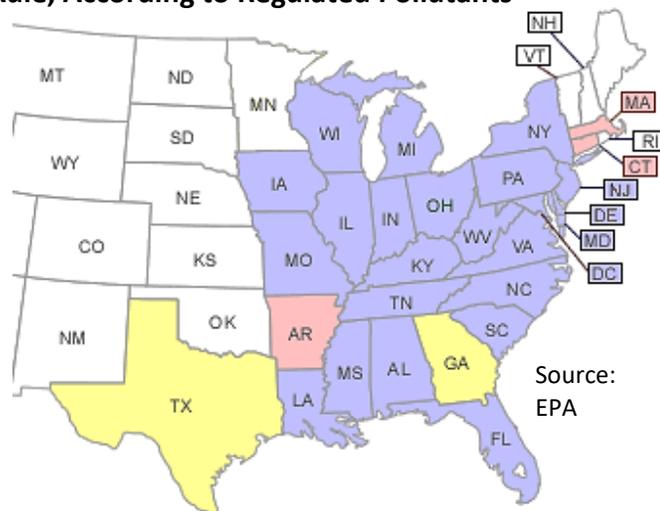
Source: EPA

The final rule includes a model NO<sub>x</sub> Budget Trading Program that allows states to achieve most of the required emission reductions based on the economics of the free market, a proven, cost-effective way of reducing total emissions. It does not mandate which sources have to reduce emissions, allowing states flexibility to reduce emissions from sources of their choice.

#### 9.1.4 Clean Air Interstate Rule (CAIR) – Federal Program

On March 10, 2005, EPA issued the Clean Air Interstate Rule (CAIR)<sup>63</sup> to help lower ozone and fine particle (PM<sub>2.5</sub>) levels in the eastern United States. This rule provided states with another tool for addressing transport of pollution over a region. CAIR covered 27 eastern states and the District of Columbia (Figure 9.4), using a cap-and-trade system to reduce power plant emissions of SO<sub>2</sub> and NO<sub>x</sub> by 70%; SO<sub>2</sub> and NO<sub>x</sub> are PM<sub>2.5</sub> precursors, and NO<sub>x</sub> is an ozone precursor.

**Figure 9.4: States Included in the Clean Air Interstate Rule, According to Regulated Pollutants**



Source: EPA

Under CAIR, states must fulfill one of two compliance options: (1) meet the state’s emissions budget by requiring power plants to participate in an EPA-administered interstate cap and trade system that caps emissions in two stages, or (2) meet the state’s emissions budget through measures of the state’s choosing.

CAIR established two phases of emissions caps for each state in the program. The first phase began in 2009 for NO<sub>x</sub> and 2010 for SO<sub>2</sub>;

- Controlled for fine particles (annual SO<sub>2</sub> & NO<sub>x</sub>) and ozone (ozone season NO<sub>x</sub>) – 22 states & District of Columbia
- Controlled for fine particles only (annual SO<sub>2</sub> & NO<sub>x</sub>) – 3 states
- Controlled for ozone only (ozone season NO<sub>x</sub>) – 2 states
- Not covered by the Clean Air Interstate Rule

<sup>63</sup> <https://archive.epa.gov/airmarkets/programs/cair/web/html/index.html>

NOx emissions were to be reduced by 53%(about 1.7 million tons), and SO<sub>2</sub> emissions by 45%(about 4.3 million tons), from 2003 levels. By 2015, CAIR's second phase sought to reduce NOx emissions by 61%(about 2 million tons) and SO<sub>2</sub> emissions by 57%(about 5.4 million tons) from 2003 levels. At full implementation, including additional reductions beyond 2015, CAIR was expected to reduce power plant SO<sub>2</sub> emissions in affected states to just 2.5 million tons, 73%below 2003 emissions levels.

There have been a series of legal challenges and regulatory actions regarding CAIR. As of 2014, the CAIR emission caps are still in place, but the rule is being replaced by the Cross-State Air Pollution Rule (Section 9.1.5).

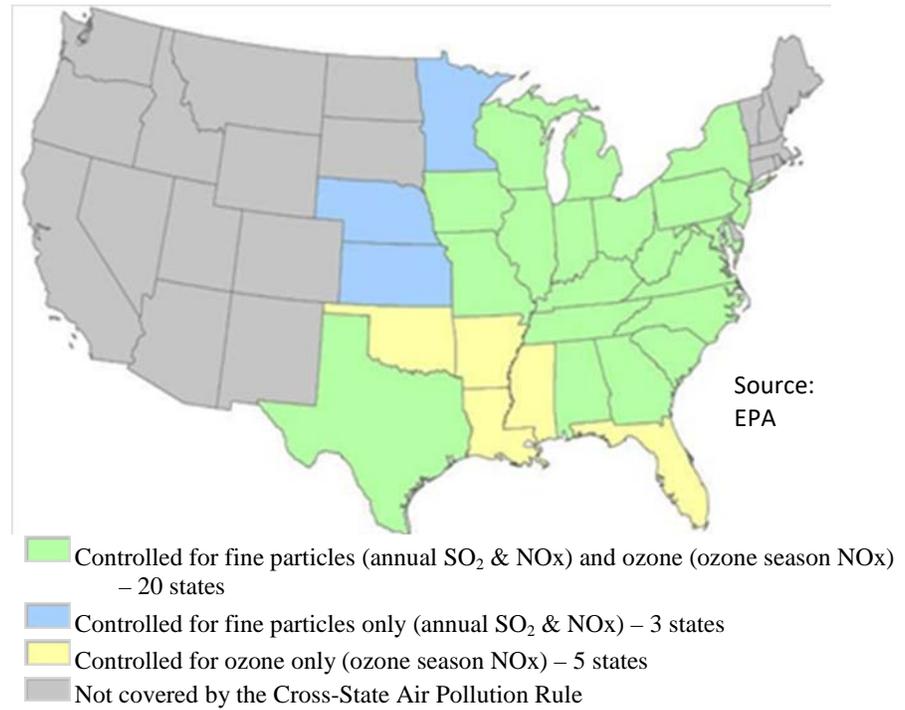
### 9.1.5 Cross-State Air Pollution Rule (CSAPR) – Federal Program

On July 6, 2011, EPA finalized the Cross-State Air Pollution Rule (CSAPR)<sup>64</sup>, a cap-and-trade program intended to assist states in attaining the ozone and fine particle NAAQS and meeting regional haze and interstate transport requirements for ozone and PM<sub>2.5</sub>. This rule requires 28 states (Figure 9.5) to reduce annual SO<sub>2</sub> emissions, annual NOx emissions, and/or ozone season NOx emissions. Combined with other state and EPA actions, the Cross-State Air Pollution Rule is expected to reduce power plant SO<sub>2</sub> emissions by 73%and NOx emissions by 54%from 2005 levels in the CSAPR region.

CSAPR replaces CAIR. In December 2008, the courts had temporarily allowed the requirements of CAIR to remain in place, but directed EPA to issue a new rule concerning the transport of air pollution across state boundaries. This action responds to the court's concerns and is EPA's alternative to CAIR.

The courts were not initially supportive of CSAPR, but EPA challenges were successful. On October 23, 2014, after years of

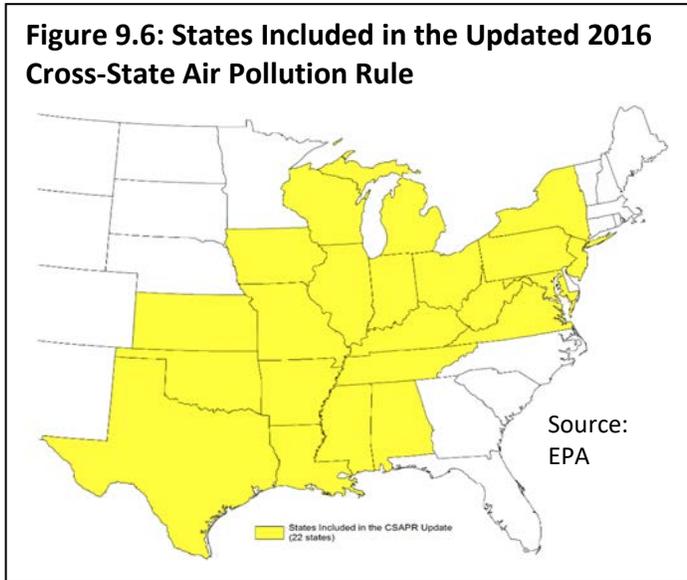
**Figure 9.5: States Included in the 2011 Cross-State Air Pollution Rule**



<sup>64</sup> <https://www.epa.gov/csapr>

legal proceedings, the D.C. Circuit Court granted an EPA request to lift a hold on CSAPR with the concession of a three-year delay in compliance deadlines. Accordingly, CSAPR Phase 1 implementation was scheduled for 2015; Phase 2 is set to begin in 2017.

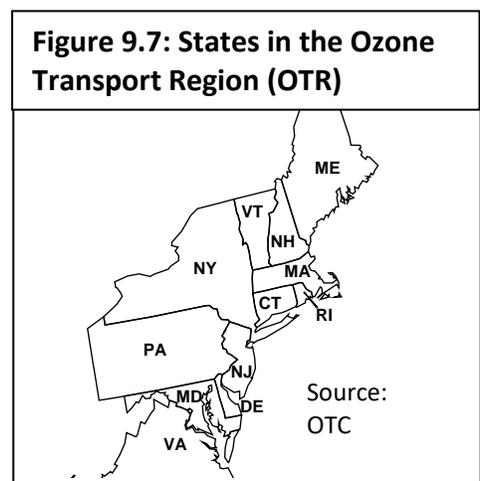
On November 16, 2015, EPA proposed an update to CSAPR (finalized on September 7, 2016) that reduces NO<sub>x</sub> emissions by 80,000 tons in 22 states between 2015 and 2017 (Figure 9.6). New emission caps are proposed for these states to capitalize on emission reductions that can take place quickly and cost effectively, such as operation and optimization of existing pollution controls already in place. States are to meet these new requirements in 2017 and the updated rule is expected to prevent over 60 premature deaths, 67,000 asthma attacks and 240 hospital and emergency room visits per year.



#### 9.1.6 New Hampshire's NO<sub>x</sub> Budget Program – State/Regional Program

In 1999, New Hampshire rule Env-A 3200 implemented a NO<sub>x</sub> Budget Program<sup>65</sup> to reduce summertime NO<sub>x</sub> emissions from power plants using a cap and trade system. The program focuses on summertime emissions because in hot weather NO<sub>x</sub> readily reacts to create ozone, a major summertime pollutant. New Hampshire was one of several states to adopt a NO<sub>x</sub> Budget Program as a result of the Ozone Transport Commission (OTC) Memorandum of Understanding (MOU).

The Ozone Transport Region (OTR) consists of 12 Northeast and Mid-Atlantic states (Figure 9.7). On September 27, 1994, these states signed the OTC MOU, an agreement to lower NO<sub>x</sub> emissions throughout the region. A regional approach is especially important because NO<sub>x</sub> contributes to several air quality issues, such as acid rain, haze, and ozone formation, that can impact areas far downwind of emission sources. Similar to the Acid Rain Program, the OTC NO<sub>x</sub> Budget Programs have been highly successful in reducing summertime NO<sub>x</sub> emissions.<sup>66</sup>



<sup>65</sup> <http://des.nh.gov/organization/divisions/air/tsb/tps/aetp/categories/overview.htm>

<sup>66</sup> For more information, see the [NHDES NH's NO<sub>x</sub> Budget Trading Program Overview Sheet](http://des.nh.gov/organization/divisions/air/tsb/tps/aetp/documents/ctfs.pdf), (<http://des.nh.gov/organization/divisions/air/tsb/tps/aetp/documents/ctfs.pdf>).

### 9.1.7 New Hampshire Clean Power Act – State Program

New Hampshire rule Env-A 2900 implements New Hampshire’s Clean Power Act (RSA Chapter 125-O)<sup>67</sup>, calling for annual emission reductions of four important pollutants: carbon dioxide (CO<sub>2</sub>), NO<sub>x</sub>, SO<sub>2</sub> and mercury. The act, which became law on July 1, 2002, required emission reductions starting in 2007 from three PSNH (now known as Eversource) power plants: Merrimack Station in Bow, Schiller Station in Portsmouth, and Newington Station in Newington.

The New Hampshire Clean Power Act required and successfully achieved the following emissions reductions:

- **CO<sub>2</sub>** – Emissions were to be reduced to 1990 levels by the end of 2006. This aligned the target for carbon reductions with those of the New England Governors and Eastern Canadian Premiers Climate Change Action Plan, adopted in August 2001.
- **SO<sub>2</sub> and NO<sub>x</sub>** – Emissions were to be reduced 87% and 70%, respectively, from 1999 levels by the end of 2006.
- **Mercury** – A scrubber system capable of reducing mercury emissions by at least 80% from baseline levels was to become operational by June of 2013.

The Clean Power Act uses cap-and-trade systems to accomplish emission reductions for each pollutant except mercury. Voluntary expenditures by PSNH for energy efficiency, renewable energy, and conservation programs can be converted into allowances to help comply with emission caps. If PSNH reduces its direct emissions below a three-year moving average, it can get credit for those reductions the following year. If PSNH acquires allowances from other states directly upwind from New Hampshire, it will get a premium on these over allowances acquired from more remote states.

Table 9.2 reflects actual emissions from the three affected power plants. Emissions of SO<sub>2</sub>, NO<sub>x</sub> and mercury are all down substantially over a 12-year period that encompasses the New Hampshire Clean Power Act. Emissions trading accounted for some of the facilities’ compliance with the Act.

**Table 9.2: New Hampshire Clean Power Act Emission Reductions Achieved (Eversource)**

	1993	2007	2015
<b>SO<sub>2</sub></b>	53,076 tons	42,501 tons	1,784 tons
<b>NO<sub>x</sub></b>	35,141 tons	4,549 tons	1,753 tons
<b>Mercury</b>	NA	238 lbs	23 lbs

The Clean Power Act is based on NHDES’ 2001 Clean Power Strategy, a comprehensive plan for reducing power plant emissions in New Hampshire. PSNH, the Governor’s Office, and several state environmental organizations, key legislators, and environmental and energy officials negotiated agreement on a comprehensive emissions reduction program. Introduced as an

<sup>67</sup> [http://des.nh.gov/organization/divisions/air/tsb/tps/aetp/clean\\_power\\_act.htm](http://des.nh.gov/organization/divisions/air/tsb/tps/aetp/clean_power_act.htm)

amendment to House Bill (HB) 284, the Clean Power Act passed in January 2002 and became effective July 1 of the same year.

The Clean Power Act was amended per HB 1673 in 2006 to incorporate provisions for mercury reductions; this involved installation of scrubber control equipment at Merrimack Station. In 2008, House Bill 1434 further amended the Clean Power Act to incorporate the Regional Greenhouse Gas Initiative (RGGI)<sup>68</sup> for greater CO<sub>2</sub> reductions.

### **9.1.8 New Hampshire Air Toxics Control Program**

At the state level, New Hampshire began regulating toxic air pollutants even before the 1990 CAA Amendments. The New Hampshire Air Toxics Control Program<sup>69</sup>, enacted in 1987 and revised in 1996, protects public health by reducing human exposure to toxic air pollutants. The program is codified in NH RSA Chapter 125-I, Air Toxics Control Act, and in NH Code of Administrative Rules Chapter Env-A 1400, Regulated Toxic Air Pollutants.

The New Hampshire Air Toxics Program covers a list of approximately 650 regulated toxic air pollutants that includes and expands on EPA's list of hazardous air pollutants.<sup>70</sup> New Hampshire sets Ambient Air Limits (AALs) for these toxic air pollutants<sup>71</sup>, reviews the limits each year, and updates them as needed based on the latest scientific information. According to data from EPA, toxic air emissions from the manufacturing sector in New Hampshire have decreased by over 85 percent since enactment of New Hampshire's Air Toxics Control Program in 1987.

**Key Point:** Toxic air pollutants are pollutants known or suspected to cause cancer or other serious health effects and adverse environmental effects. New Hampshire's Air Toxics Program regulates approximately 650 air toxics. Mercury is an air toxic of particular concern. The most common route of mercury exposure is consumption of fish.

### **9.1.9 New Hampshire Open Market Programs – State Programs**

In addition to mandatory cap and trade programs for power plants, New Hampshire has two voluntary open market programs that were established effective on January 21, 1997, to follow the project-based approach: mass-based Discrete Emissions Reduction (DER) Trading (under Env-A 3100) and rate-based Emission Reduction Credits (ERC) Trading (under Env-A 3000). These programs apply to emissions of ground-level ozone precursor pollutants: volatile organic compounds (VOCs) and NOx.

Subject to some restrictions, any source may voluntarily reduce its emissions and register for either type of open market credit:

<sup>68</sup> For more information on RGGI, please visit the [Regional Greenhouse Gas Initiative Webpage](http://rggi.org/), (<http://rggi.org/>).

<sup>69</sup> <http://des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-1.pdf>

<sup>70</sup> <http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1400.pdf>

<sup>71</sup> <http://www.des.nh.gov/organization/commissioner/legal/rules/documents/env-a1400.pdf>

- **Discrete Emissions Reductions** – DERs represent a discrete quantity of emissions reductions (1 DER = 1 ton). A source earns DER credits by controlling emissions more than required, such that the DER credits represent the quantity of emissions removed by the extra controls.
- **Emissions Reduction Credits** – ERCs represent a rate of emissions reductions over time (1 ERC = 1 ton/year). ERCs may be used year after year at the same rate. A source earns ERCs following the shutdown of a facility, such that the ERC credits represent the rate of emissions that facility would have produced if it had continued to operate.

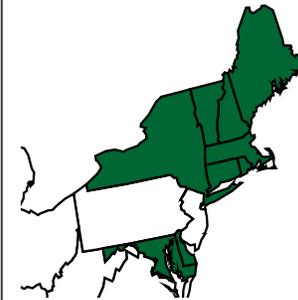
The primary users of DER and ERC credits are sources subject to Reasonably Available Control Technology (Section 9.1.10) or NSR compliance (Section 9.1.1). DER and ERC trading systems are intended to give these sources more flexibility and the opportunity to reduce costs of compliance. Although not intended as attainment strategies, these trading systems do provide environmental and economic benefits. For example, users of DER credits must acquire extra credits before using them, such that 10 percent of the total credits purchased do not count toward compliance requirements, but are applied as an added environmental benefit.

Under the ERC system, the owner of a source obtaining credits from the shutdown of one facility may use them at another facility under the same ownership. If this is not an option, credits from the shutdown become public ERCs in a state-controlled account, and the state selects recipients of these credits based on criteria that prioritize economic benefit, such as job retention at an existing company or generation of jobs from the opening of a new source.

**Key Point: Regional Greenhouse Gas Initiative (RGGI)**

NHDES and the State of New Hampshire are participating in the Regional Greenhouse Gas Initiative (RGGI) with other Northeast and Mid-Atlantic States. RGGI is a regional plan to implement a flexible, market-based program to reduce carbon dioxide (CO<sub>2</sub>) emissions – a major cause of global warming – from power plants in the Northeast and Mid-Atlantic states. New Hampshire and nine other states have adopted laws and/or regulations to establish a framework for implementing RGGI in their respective states. RGGI has proven beneficial in reducing emissions of nitrogen oxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), PM<sub>2.5</sub>, mercury and other air pollutants as a co-benefit of reducing reliance on more polluting fuels.

2017 RGGI Member States



### 9.1.10 Regulations Limiting Emissions – Federal Standards and Control Requirements

Stationary sources must comply with emission standards and control technology requirements that limit the emission of air pollutants. These regulations typically break down to specific requirements for different stationary source categories, such as landfills, asphalt plants, power

plants, etc. The following standards and control requirements, summarized in Table 9.3, apply to stationary sources:

**Table 9.3: Applicability of Emissions-Limiting Regulations for Stationary Sources**

Regulation	Pollutants Controlled	Areas Where Standards Apply	Sources Covered
<b>NSPS</b>	mostly criteria pollutants	any area	variety of stationary sources, including smaller sources
<b>MACT</b>	hazardous air pollutants	any area	mostly major stationary sources; MATS applies to plants with capacity $\geq 25$ megawatts
<b>BACT</b>	criteria and some hazardous air pollutants	any area	stationary sources subject to NSR PSD permits
<b>LAER</b>	criteria pollutants	nonattainment areas	stationary sources subject to Nonattainment NSR permits
<b>RACM</b>	criteria pollutants	nonattainment areas	variety of sources; RACT applies to stationary sources in nonattainment areas or OTR
<b>BART</b>	visibility-impairing pollutants	any area	26 stationary source categories; sources built between 1962-1977 with potential to emit $\geq 250$ tons/year

- **New Source Performance Standards (NSPS)** – New Source Performance Standards (NSPS) are federal emission standards for certain stationary source categories that cause or significantly contribute to air pollution. Whereas most other standards focus on large sources (also referred to as “major sources”), NSPS covers many smaller sources as well. These standards concern a variety of air pollutants, primarily criteria pollutants (Section 2.1), and apply to sources constructed, reconstructed, or modified since the standards were proposed on December 23, 1971. They are intended to promote use of the best air pollution control technologies, taking into account the cost of that technology, energy requirements, and other non-air quality, health, and environmental impacts. Today, approximately 90 NSPS and associated test methods are in place.
- **Maximum Achievable Control Technology (MACT)** – Maximum Achievable Control Technology (MACT) requires existing and new stationary sources to meet emission limits on hazardous air pollutants based on the performance of existing sources with control technologies that achieve the greatest emission reductions in their particular source category. For existing sources, MACT limits are based on the average emissions limitations currently achieved by the best performing 12% of similar sources. For new sources, MACT limits must equal the level of emissions control currently achieved.
  - **Mercury and Air Toxics Standards (MATS)** – The Mercury and Air Toxics Standards (MATS) is a MACT standard (see above) which applies only to coal and

oil-fired power plants with a capacity of 25 megawatts or greater. New power plants must meet the emissions limitations upon startup, whereas existing power plants must meet the emissions limitations by April 16, 2015 (or, for certain facilities that were granted an extension, by April 16, 2016).

- **Best Available Control Technology (BACT)** – Best Available Control Technology (BACT) regulations restrict emissions by requiring use of the best available controls after taking into consideration factors such as technical feasibility, cost of control, energy consumption and regional environmental impact. BACT is determined on a case-by-case basis and is considered the EPA standard for all emission sources that fall under NSR’s PSD permitting guidelines (Section 9.1.1). By definition, BACT must always be at least as stringent as any NSPS or MACT standard established for that source category.
- **Lowest Achievable Emission Rate (LAER)** – Lowest Achievable Emission Rate (LAER) is defined as the most stringent emissions limitation contained in any SIP or the most stringent emissions limitation achieved in practice for a particular source category. It limits the source to the lowest achievable emissions possible based on commercially available technology, and, in some instances, based on non-commercial experimental or demonstration technologies. LAER is required for sources subject to NSR Nonattainment permits (Section 9.1.1). It is more stringent than BACT because it does not consider factors other than emission reduction potential. Also, by definition, LAER must be at least as stringent as any NSPS established for that source category.
- **Reasonably Available Control Measures (RACM)** – Reasonably Available Control Measures (RACM) are Clean Air Act requirements that provide for the implementation of all reasonably available control measures “as expeditiously as practicable” to achieve attainment of the NAAQS in nonattainment areas.<sup>72</sup> For any nonattainment area, a state satisfies RACM regulations by including in its SIP all economically and technologically feasible control measures that will provide sufficient progress toward attainment. The SIP must show that RACM will be implemented as expeditiously as practicable and that no additional reasonably available measures will achieve attainment sooner or further enhance progress toward attainment. Although often applied to stationary sources, RACM may apply to other types of sources as well.
  - **Reasonably Available Control Technology (RACT)** – Reasonably Available Control Technology (RACT) is a type of RACM (see above) applicable to stationary sources located in nonattainment areas or the Ozone Transport Region (OTR). EPA has defined RACT as “the lowest emission limitation a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility.”<sup>73</sup> RACT requires applicable stationary sources of air pollution to adopt controls that are reasonably available;

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<sup>72</sup> CAA Section 172(c)(1)

<sup>73</sup> 44 FR 53761 (Sept. 17, 1979)

thus, they may not be the most stringent controls adopted by other similar sources. RACT is less stringent than BACT or LAER.

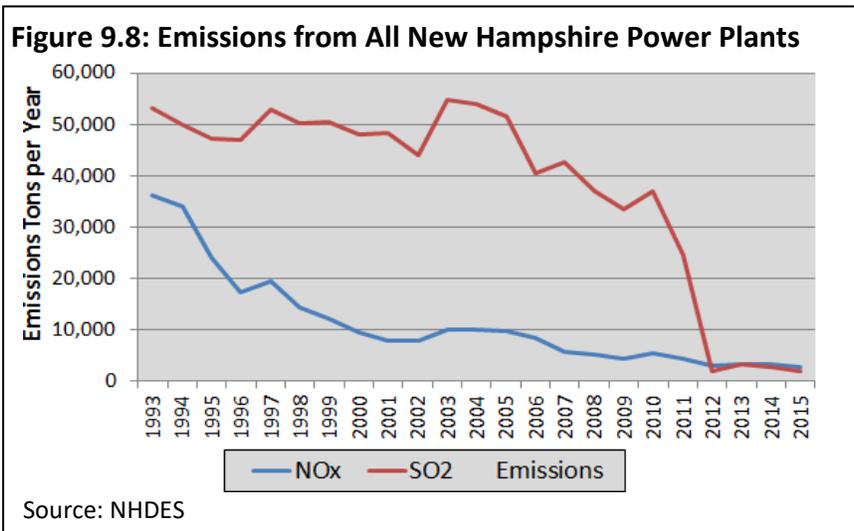
State implementation plans must provide for compliance for all RACT-subject sources located in nonattainment areas. In addition, section 184(b)(1)(B) of the CAA expanded RACT to include certain sources of NOx and VOCs, not only in nonattainment areas, but in any area within the OTR. Under this section of the CAA, New Hampshire, as a member of the OTR, must implement RACT for all significant sources of NOx and VOCs, including VOC source categories covered by the Control Technique Guideline (CTG) documents. CTGs describe EPA-recommended strategies for controlling VOC emissions from specific sources and activities. For instance, EPA has published CTGs for source categories such as industrial coating processes, bulk gasoline facilities, and solvent use.

- Best Available Retrofit Technology (BART)** – Best Available Retrofit Technology (BART) is required under the EPA Regional Haze Rule to facilitate visibility improvements in Class I areas by reducing visibility-impairing emissions from certain large facilities. A Class I area is a national park, wilderness area, or monument that receives special air quality protection; there are two Class I areas in New Hampshire (Section 2.3).

BART requires an assessment that takes into consideration the costs of compliance, the energy and non-air quality environmental impacts of compliance, any existing pollution control technology currently in use at the source, the remaining useful life of the source, and the degree of visibility improvement which may be reasonably expected to result from the use of such technology.

BART requirements are specified for 26 industrial source categories. They apply to older facilities that began operation or received a permit between August 7, 1962 and August 7, 1977. BART-applicable facilities must have the potential to emit more than 250 tons per year of one or more pollutants that contribute to reduced visibility in at least one Class I area.

New Hampshire and federal emission reduction programs have achieved approximately 78 percent reduction of total power plant NOx emissions and 96% of total SO<sub>2</sub> emissions since 1993 (Figure 9.8).



## **9.2 Mobile Sources – Regulatory Programs**

### **9.2.1 Transportation Conformity – Federal Program**

To fulfill CAA requirements, EPA established transportation conformity in 1993 for transportation projects within nonattainment and maintenance areas. Transportation conformity is a review process for proposed transportation projects and plans to demonstrate the projects or plans conform to SIP requirements for meeting the NAAQS. A conforming project or plan are those whose total emissions from a project or within an air quality region for a regional plan, are at or below acceptable levels for a project, or within a federally approved mobile source emissions budget for plans. Transportation projects within a nonattainment or maintenance area receiving federal funding, requiring federal approval, or being of regional significance must undergo this process to ensure they will not adversely impact air quality. Potentially relevant projects may include widening of roads, building of a new major center, or any other change that will likely increase traffic flow in an area.

Transportation conformity addresses the pollutants emitted or contributed to by vehicles; namely, CO, ozone, NO<sub>x</sub>, VOCs, and particulates. In New Hampshire, transportation conformity requirements apply to the carbon monoxide (CO) maintenance areas of Manchester and Nashua (Section 3.4.2).<sup>74</sup>

### **9.2.2 Diesel Emissions Reduction Act Program – Federal Program**

From 2008 through federal fiscal year 2014, New Hampshire has received funding totaling approximately \$929,500 under the federal Diesel Emissions Reduction Act Program (DERA). These funds have been used to promote projects that reduce emissions from pre-2007 diesel vehicles. Such projects have included idle reduction technology, vehicle replacements and transition to cleaner burning fuels. Projects completed to date have the potential to reduce CO by 15 tons per year, NO<sub>x</sub> emissions by 85 tons per year, and PM<sub>2.5</sub> by two tons per year.

### **9.2.3 Granite State Clean Cities – State/National Program**

Begun in 2002, Granite State Clean Cities Coalition (GSCCC) is New Hampshire's implementation of the national Clean Cities Program, a voluntary program coordinated by the U.S. Department of Energy. GSCCC works with local vehicle fleet managers to reduce petroleum use in the transportation sector and reduce air pollution emissions. The coalition is one of NHDES' outreach initiatives in partnership with over 120 public and private stakeholders. Each year, GSCCC lowers greenhouse gas (GHG) emissions by thousands of tons. Just in 2014, the program reduced petroleum use within the coalition by 1.7 million gallons, lowering GHG emissions by about 14,700 tons.

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<sup>74</sup> The SO<sub>2</sub> nonattainment area is not included because SO<sub>2</sub> is not a major pollutant emitted from the transportation sector. EPA also specifically excluded the 8-hour ozone maintenance area from Transportation Conformity requirements.

GSCCC also manages Granite State Clean Cars, a consumer-based program that encourages car buyers to purchase highly fuel-efficient vehicles. The Clean Cars program is a partnership between NHDES, the NH Auto Dealers Association, and 19 dealerships.

#### **9.2.4 Enhanced Inspection and Maintenance – State Program**

New Hampshire’s inspection and maintenance (I/M) program is a major part of the state’s strategy to reduce vehicle emissions. It was established in response to federal requirements under the CAA for: (1) states or portions of states that exceed the ozone NAAQS; and (2) all states in the Ozone Transport Region (OTR).

In 1998 the NH General Court passed legislation (HB 1513) mandating a statewide Enhanced Inspection and Maintenance (Enhanced I/M) program. In its initial form the inspection included a visual inspection to confirm the presence and functionality of certain emission control components, but did not include tailpipe testing as specified under the CAA. Instead, New Hampshire took advantage of the presence of “on-board diagnostics” (OBD) required in all 1996 and newer light duty vehicles to implement an inspection program that was environmentally superior to tailpipe testing due to its ability to detect and fail vehicles before they became “gross emitters.” In June 2004, NHDES and the NH Division of Motor Vehicles implemented the New Hampshire On Board Diagnostics and Safety Testing Program (NHOST)<sup>75</sup> that combines a safety inspection with the OBD test. Per legislative requirements, New Hampshire’s I/M program applies to all passenger vehicles less than 20 model years old; currently, this includes 1996 and newer vehicles.

OBD technology is a federally required component on all 1996 and newer light-duty vehicles. The system detects malfunctions of engine or emissions components that could result in increased emissions at least one and one half times the emissions standard to which the vehicle was initially certified. When the system detects a malfunction it illuminates the “check engine” light on the vehicle dashboard to notify the motorist that an emissions related problem needs attention. By identifying malfunctions at such an early stage, emissions are significantly reduced and subsequent damage to other vehicle components can often be avoided, saving consumers money.

In 2014, 1.2 million vehicles model year 1996 and newer underwent Enhanced I/M inspections. Computer modeling (base on the year 2015) estimates that Enhanced I/M can eliminate over five tons of NO<sub>x</sub>, over 30 tons of CO, and almost two tons of VOCs per day in New Hampshire.

#### **9.2.5 Emissions and Fuel Economy Standards – Federal Standards**

Several types of national standards address emissions from mobile sources:

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<sup>75</sup> To learn more about the NHOST Program, take a look at the [New Hampshire OBD & Safety Testing Program Website](http://www.nhostservices.com/news.html), (<http://www.nhostservices.com/news.html>)

- **Corporate Average Fuel Economy Standards** – Corporate Average Fuel Economy (CAFE) standards set rules regarding the average fuel economy of vehicles. CAFE standards originate with the Energy Policy and Conservation Act of 1975, which made the Department of Transportation’s National Highway Traffic Safety Administration (NHTSA) responsible for regulating CAFE standards. The most recent update in 2012 requires vehicle manufacturers to achieve a combined average fuel economy for passenger cars, light-duty trucks, and medium-duty passenger vehicles of least 35.5 mpg by 2017 and of 54.5 mpg by 2025.
- **Greenhouse Gas Standards** – In 2010, EPA partnered with NHTSA to establish a new national program to reduce mobile source GHG emissions. This program coordinated EPA GHG emission standards with NHTSA CAFE fuel economy standards (higher fuel economy directly results in lower GHG emissions). Initially, these applied to light-duty vehicles of model years 2012-2016. Rules were added for medium- and heavy-duty vehicles in 2011, and in 2012, the program expanded to light-duty vehicles of model years 2017 through 2025. Also, beginning with model year 2012, federal and California vehicle standards for fuel economy and GHG emissions are harmonized through model year 2025.
- **Tier 3 Vehicle Emission and Fuel Standard Program** – Tier 3 refers to a set of fuel and vehicle standards adopted by EPA in 2014. Starting in 2017, Tier 3 will restrict the sulfur content of gasoline and reduce tailpipe emissions of multiple pollutants. The cleaner gasoline will also immediately reduce air pollution from existing cars and trucks. Tier 3 follows the 1991 EPA release of similar, but less stringent, Tier 2 standards that were phased in between 2004 and 2007. Tier 2, Tier 3, and CAFE standards will result in significant air quality benefits in New Hampshire and across the nation.<sup>76</sup>
- **Heavy-duty Engine and Vehicle Standards** – In 2000, EPA announced a new regulatory program for heavy-duty diesel vehicles that would regulate the vehicle and its fuel as a single system. Those rules, known as the 2007 heavy duty diesel rules, established a requirement for ultra-low sulfur fuel and significant reductions in NOx and PM from heavy-duty diesel vehicles phased in from model years 2007 to 2010<sup>77</sup>. Before EPA began regulating sulfur in diesel, diesel fuel contained as much as 5,000 parts per million (ppm) of sulfur. Under this new rule all highway diesel fuel contained no more than 15 ppm by 2010 (known as ultra-low sulfur diesel, or ULSD), and in 2014 ULSD requirements also applied to non-road fuel.

In 2011, the Environmental Protection Agency (EPA) and the Department of Transportation’s National Highway Traffic Safety Administration (NHTSA) adopted

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<sup>76</sup> For more information about reduction in vehicle fuel emissions, please visit the [NHDES Vehicle Emission and Fuel Economy Webpage](http://des.nh.gov/organization/divisions/air/tsb/tps/msp/standards.htm), (<http://des.nh.gov/organization/divisions/air/tsb/tps/msp/standards.htm>).

<sup>77</sup> See <https://nepis.epa.gov/Exe/ZyPDF.cgi/P1001CXZ.PDF?Dockey=P1001CXZ.PDF>, EPA420-F-00-057 December 2000

the first ever program to reduce GHG emissions and improve the fuel economy of heavy-duty trucks and buses for model year 2014-18 vehicles, followed by a Phase 2 proposal in 2015 to apply through 2027 model years <sup>78</sup>.

### **9.2.6 Alternative Fuel Vehicles**

Alternative fuel vehicles (AFVs) are vehicles that run on a fuel other than gasoline or diesel. Many of these vehicles are able to reduce emissions of criteria pollutants compared to gasoline- or diesel-fueled vehicles; most alternative fuels also reduce GHG emissions. These vehicles play an important role in reducing emissions and reliance on foreign petroleum sources. AFVs may use electricity, natural gas, propane, hydrogen, biodiesel or ethanol:

- **Electric Vehicles** – The lowest emission vehicles are plug-in electric vehicles (EVs) propelled entirely by an electric motor. Plug-in hybrid electric vehicles (PHEVs) have both an electric motor and a gasoline-powered internal combustion engine that can recharge the battery pack while the vehicle is moving. These vehicles have lower emissions than conventional vehicles, even when accounting for emissions from electricity generation, which is primarily from natural gas in New England. In 2012, there were only 244 EVs registered in New Hampshire. In 2013, that number almost doubled to 433, and as of 2015 it had grown to about 835. During the same time, car dealers, hotels, schools and towns began to install publicly-available EV recharging stations. There are currently 50 EV charging station locations in New Hampshire.
- **Natural Gas and Propane Vehicles** - Over the past five years, several municipal and private fleets have added compressed natural gas (CNG) vehicles to their inventory. The most notable are the City of Nashua and the University of New Hampshire, with over 40 CNG vehicles each. Both fleets received some federal funding through NHDES to help offset the higher cost of the vehicles.

There are currently 3 CNG fueling stations statewide, including one private and two state-of-the-art public fueling stations installed in Pembroke and Nashua in the past few years. Lack of access to the natural gas pipeline continues to somewhat limit the deployment of natural gas vehicles and fleets.

- **Hydrogen (Fuel Cell) Vehicles** – Fuel cell vehicles (FCV) use a fuel cell to generate electricity by the reaction of hydrogen and oxygen in the fuel cell to drive the electric motor. The oxygen is typically from compressed air, and the hydrogen is from compressed hydrogen or, often, from natural gas. When fueled by compressed hydrogen an FCV is a zero emission vehicle. Deriving the hydrogen from other sources such as natural gas does add emissions. Currently, no fuel cell vehicles are registered in the state, and the nearest fueling station is in Massachusetts.

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<sup>78</sup> See EPA's Heavy-Duty Regulations and Standards at <https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-onroad-vehicles-and-engines>

- **Biodiesel Vehicles** – Biodiesel is a renewable derived from living matter, such as plant oils (e.g. soy, canola) or animal fat. It is typically blended with conventional diesel; blends containing at least 20% biodiesel are considered alternative fuels. New Hampshire is home to New England’s largest biodiesel production plant, White Mountain Biodiesel, which produces over 4 million gallons of the fuel annually, primarily from used restaurant grease. Many municipal and several private fleets use biodiesel in blends varying from 5-50 percent.
- **Flex-fuel Vehicles** – A flex-fuel vehicle can operate on blends of gasoline and ethanol containing up to 85% ethanol (E85). While most gasoline today contains 10% ethanol, and could contain up to 15 % based on federal rules, only flex-fuel vehicles are able to adjust to and burn blends higher than that. Flex-fuel vehicles are plentiful in New Hampshire, but at this time there are no E85 fueling stations in the state.

### **9.3 Nonroad Mobile and Portable Sources**

Regulated nonroad mobile sources represent a highly diverse group of engine types and equipment, ranging from small portable engines and equipment such as lawn mowers and generators to locomotive and marine engines and recreational vehicles. Many nonroad mobile sources operate through the use of diesel engines. Others known as spark-ignition engines operate with gasoline, liquefied petroleum gas, or natural gas. Diesel and spark ignition engines both produce air pollutants, with diesel engines producing substantially more NO<sub>x</sub> and particulates, and spark-ignition engines producing more VOCs. These pollutants can cause serious health and environmental issues and have been linked to many respiratory health problems, such as asthma, heart disease and cancer.

Until the mid-1990s, there were very few regulations controlling nonroad mobile emissions. As part of the 1990 CAA Amendments, EPA studied the contribution of nonroad sources to ozone and other pollutants, concluding that nonroad engines contributed significantly to air quality issues related to pollutants such as NO<sub>x</sub>, VOCs and PM. Between 1994 and 2004, EPA issued fourteen regulations designed to control nonroad engine pollutants.

The manufacture or importation of all types of nonroad engines and equipment is prohibited under the CAA unless the engines are certified by EPA as meeting emission standards and display the appropriate EPA emissions label. Manufacturers must ensure that each new engine, vehicle, or piece of equipment meets the latest emission standards. The certification process is complicated by the increase in the number of foreign manufacturers of nonroad engines and equipment.

EPA is developing an engine and vehicle compliance information system, known as Verify, that gathers emission and fuel economy compliance data for all types light-duty and heavy-duty vehicles and nonroad engines. Under this system, engine and vehicle manufacturers report this information to the Verify system. The Verify modules for nonroad compressions ignition and nonroad spark ignition engines were completed in the summer of 2010.

## **9.4 Other Sources – Regulatory Programs and Controls**

### **9.4.1 General Conformity – Federal Program**

While transportation conformity focuses on transportation projects, general conformity focuses on other types of projects. Any project that is federally funded or requires federal approval and has the potential to exceed a certain minimum<sup>79</sup> level of emissions is subject to general conformity review. Required by the Clean Air Act, general conformity ensures that projects conform to SIP requirements for all NAAQS. General conformity has been in place since 1993, and revisions to the rule in 2010 better streamline its implementation process. The program complements the National Environmental Protection Act, which also requires an environmental review of large projects.

Projects potentially subject to general conformity are first reviewed to determine whether the requirements of general conformity apply. An example of a New Hampshire project that triggered general conformity review is the construction of a new air traffic control tower at the Manchester-Boston Regional Airport in the 1990s. Current projects, such as the Northern Pass transmission line and Kinder-Morgan pipeline, will also need to be reviewed to determine if general conformity applies.

Like transportation conformity, general conformity requirements only apply to areas out of attainment with the NAAQS or those designated as maintenance areas. Currently, this includes the CO maintenance areas of Manchester and Nashua (Section 3.4.2) and a small SO<sub>2</sub> nonattainment area in central New Hampshire (Section 3.4.1). EPA recently announced a stricter ozone standard effective in late 2015; if the new standard leads to parts of New Hampshire being reclassified as nonattainment for ozone, more New Hampshire projects may fall under general conformity requirements.

### **9.4.2 OTC Model Rules – Regional Program**

In 2014, New Hampshire revised its VOC Limits for Consumer Products rule (Env-A 4100). This rule is aimed at reducing emissions of VOCs by establishing limits on the VOC content of various consumer products, such as paints and cleaners. VOC emission limits are currently in effect for about three quarters of the nearly 100 products covered by the rule, and the remainder will take effect on January 1, 2017.

This rule was based on the Ozone Transport Commission (OTC) 2012 Model Rule; OTC has developed several “model rules” to establish regional consistency in methods for controlling specific categories of ozone precursor emissions. Not all OTC states have yet adopted the 2012 Model Rule, but others are expected to adopt it within the next two years.

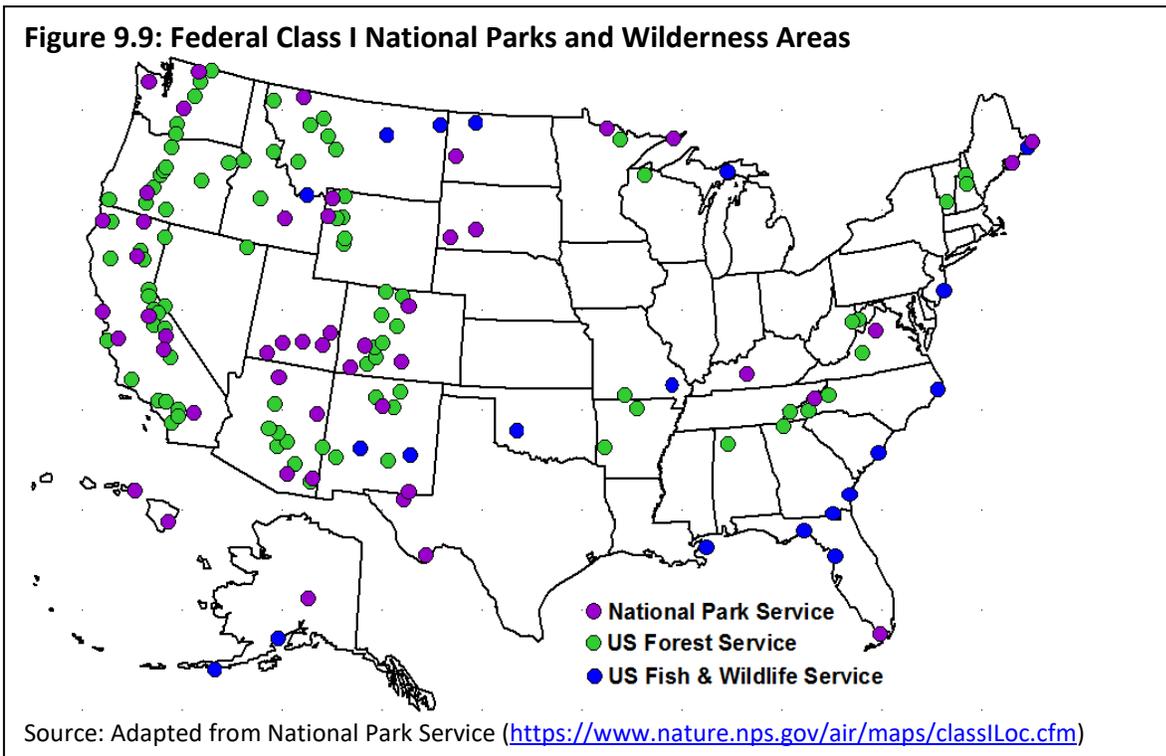
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<sup>79</sup> The term for this minimum threshold is “de minimis.” General conformity de minimis thresholds differ by pollutant and area and are listed here: <https://www.epa.gov/general-conformity/de-minimis-emission-levels>.

Also based on the OTC model rule, New Hampshire re-adopted Env-A 4200 in 2014. This rule reduces emissions of VOCs by limiting the VOC content of Architectural and Industrial Maintenance (AIM) coatings.

### 9.4.3 Regional Haze Rule – Federal Program

The 1999 Regional Haze Rule seeks to improve visibility in national parks and wilderness areas by reducing haze-producing pollutants (see Section 2.3 for more information about haze). The rule covers 156 national parks and wilderness areas designated as Class I areas for visibility protection, including two in New Hampshire: Great Gulf Wilderness and the Presidential Dry River Wilderness (Figure 9.9).

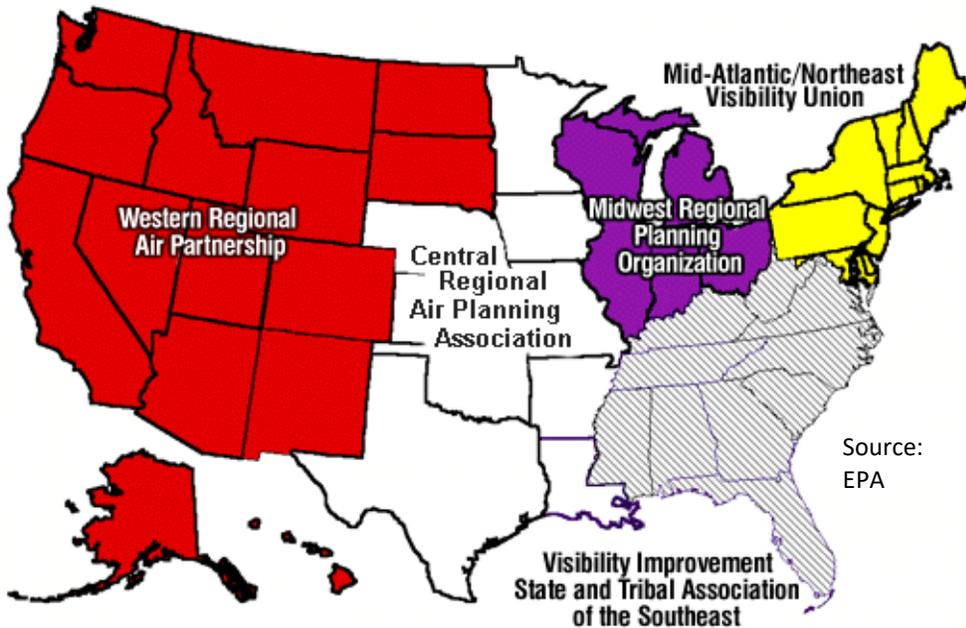


To fulfill the Regional Haze Rule, states are required to submit SIP revisions every 10 years describing emission reductions that will progressively improve visibility over the next decade. New Hampshire submitted its first regional haze SIP in 2011.

Regional haze SIPs may address emission reductions from any source category. For stationary sources, the rule requires BART regulations for older power plants built between 1962 and 1977, with the option to substitute participation in CSAPR for BART (see Sections 9.1.5 and 9.1.10 for more information about CSAPR and BART, respectively). New Hampshire elected to rely on BART for the state's major stationary sources. This included added controls on the PSNH (now known as Eversource) Merrimack Power Plant in Bow that have dramatically reduced SO<sub>2</sub> emissions (Section 4.5.7).

EPA encourages states and tribes to work together toward a coordinated approach to reduce haze and has established regional planning organizations for this purpose (Figure 9.10). New Hampshire is a member of the Mid-Atlantic/Northeast Visibility Union (MANEVU).

**Figure 9.10: Regional Planning Organizations**



*Note: Three regional planning organizations now operate under different names. These include the Lake Michigan Air Directors Consortium (LADCO) for the Midwest Regional Planning Organization, Southeastern States Air Resource Managers (SESARM) for Visibility Improvement State and Tribal Association of the Southeast, and Central States Air Resource Agencies (CennSARA) for Central Regional Air Planning Association.*

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## 10 CONCLUSION

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In 2016 and 2017 New Hampshire was fortunate to enjoy a majority of good air quality days. Only six days in 2016 (and five during 2017) saw some portion of the state exceed federal health standards for ozone (noting that to “exceed” the standard does not necessarily mean to “violate” the standard) and there were no instances where the other major air pollutants exceeded their respective health standards. This good news can be credited to nearly 30 years of research, regulation, and air pollution control implementation in the United States. Air pollution concentrations in New Hampshire are down by 70 to over 90 percent from levels measured in the late 1970’s and early 1980’s.

New Hampshire air quality improvements have out-paced improvements seen in other portions of the country due to several factors:

1. New Hampshire lies in the downwind (northeastern) portion of the Ozone Transport Region (OTR), an area defined in the Clean Air Act as requiring strict air pollution regulation to lower the very high ozone levels found there. Because of this Clean Air Act classification, the OTR got a head start on reducing air pollution emissions and the OTR states learned how to effectively work together towards that goal.
2. Most states in the region are members of the Regional Greenhouse Gas Initiative (RGGI) which among other things has encouraged lower emitting electrical generation and more efficient electrical use. Both actions, when taken regionally, have benefited New Hampshire’s air quality.
3. The federal acid rain program targeted emissions of large facilities in the coal burning regions of the Midwest and Northeast. Again, New Hampshire lies downwind of this region.
4. Upwind states cleaning up their own air to meet requirements benefit downwind states like New Hampshire.

Thanks to declining air pollution emissions in New Hampshire and in upwind states, New Hampshire met air pollution requirements in 2017 in all portions of the state for all six criteria pollutants. While the Central New Hampshire SO<sub>2</sub> nonattainment area is still in effect and an attainment plan SIP was recently submitted, the source emissions in the area have already been addressed and the region is now measuring “clean data” (air quality meeting the health standard). This area is expected to be redesignated to attainment soon.

Even though all areas of the state are currently meeting the health standards, some areas of the state still experience occasional Air Quality Action Days, or days when air quality forecasters predict that one or more air pollutants may exceed the level of the health standard. Because the federal standards consider duration of exposure to air pollution, individual days exceeding the standard do not necessarily result in violation of the standards. When Air Quality Action Days occur during spring or summer, they are usually the result of a regional air pollution event

being transported into New Hampshire with the winds from upwind states. Air Quality Action Days in New Hampshire during the late fall and throughout the winter usually result from stagnation of local pollution emissions in valley communities.

Ozone and small particle air pollution in New Hampshire during 2011 was analyzed with a model that estimates health and economic impacts. Meeting federal health standards as required under the federal Clean Air Act is important for the protection of public health. It reduces physician and hospital visits, improves work and school attendance and productivity, and reduces air pollution related mortality. Ensuring current health standards are met every day in New Hampshire is expected to provide almost \$2 million in health valuation benefits beyond simply just meeting the standards (remember that compliance with a standard may still allow some days with unhealthy air pollution levels). Should the air quality in New Hampshire continue to get even cleaner, there will be additional health benefits and valuations. Modeling indicates estimated that over \$3 billion in annual health impact



valuations could be saved if concentrations of the two air pollutants were reduced to natural background levels throughout the state. Achieving natural background levels of air pollution may be an idealistic goal, but it is illustrative to how people continue to benefit from increasingly cleaner air down to very low air pollution concentrations.

The air quality outlook in New Hampshire over the next 10 years looks promising. We anticipate that air pollution trends will continue to improve in most cases throughout the state. Continued reductions of acid, nitrogen and mercury deposition should result in cleaner lakes and streams in the state and ultimately the removal of fish consumption advisories. Year to year weather variability, transport patterns, and the economic variability in fuel costs and consumption will likely cause some temporary increases, but long-term regulation and commitments promise continued improvement. Ultra-long-range transport from other countries along with the likelihood of increasing global temperatures presents concerns and creates uncertainty over the long-term, especially at higher elevations in the state, most indications are that New Hampshire will continue to benefit from increasingly cleaner and healthier air over the next decade.

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## COMMONLY USED ACRONYMS

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AAL	Ambient Air Limits, a health based air limit
acf	actual cubic foot
AIM	Architectural and Industrial Maintenance
AQI	Air Quality Index
ARD	Air Resources Division
ASTM	American Society of Testing and Materials
BACT	Best Available Control Technology
BAM	Beta Attenuating Monitor
BART	Best Available Retrofit Technology
BEV	Battery Electric Vehicle
Btu	British thermal units
°C	Degrees in Celsius (temperature)
CAA	Clean Air Act
CAFÉ	Corporate Average Fuel Economy
CAIR	Clean Air Interstate Rule
CAS	Chemical Abstracts Service
CASAC	Clean Air Science Advisory Committee
CCPTF	Climate Change Policy Task Force
CEMS	Continuous Emissions Monitoring System
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CH <sup>4</sup>	Methane (a natural gas)
CNG	Compressed Natural Gas
CO	Carbon monoxide – a criteria pollutant
CO <sub>2</sub>	Carbon Dioxide – a greenhouse gas
CPMS	Continuous Parameter Monitoring System
CSAPR	Cross State Air Pollution Rule
CTG	Control Technology Guidelines
DER	Discrete Emissions Reductions
DERA	Diesel Emissions Reduction Act
DSCFM	dry standard cubic feet per minute
EERS	Energy Efficiency Resource Standard
Env-A	New Hampshire Code of Administrative Rules - Air Resources Division
EPA	U.S. Environmental Protection Agency
ERC	Emission Reduction Credit
ETP	External temperature, temperature outside of the monitoring station
EV	Electric Vehicle
°F	Degrees in Fahrenheit (temperature)
FCV or FCEV	Fuel Cell Electric Vehicle
ft	foot or feet (also f <sup>2</sup> – square feet, and f <sup>3</sup> – cubic feet)
gal	gallon
GHGs	Greenhouse Gases
GSCCC	Granite State Clean Cities Coalition

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GWP	Global Warming Potential
H <sub>2</sub> SO <sub>4</sub>	Sulfuric Acid
H <sub>2</sub> O	Water or water vapor
HAPS	Hazardous Air Pollutants, substances that are defined as hazardous
HCl	Hydrogen chloride
HEV	Hybrid Electric Vehicle
HFCs	Hydrofluorocarbons
Hg	Mercury
HNO <sub>3</sub>	Nitric acid
hp	horsepower
hr	hour
°K	Degrees in Kelvin (temperature)
LAER	Lowest Achievable Emission Rate
LLJ	Low Level Jet
LNG	Liquid Natural Gas
LPG	Liquefied Petroleum Gas
LPG	Liquid Propane Gas
m	Meter (also m <sup>2</sup> – square meter, and m <sup>3</sup> – cubic meter)
MACT	Maximum Achievable Control Technology
MATS	Mercury and Air Toxics Standards
MDE	Maryland Department of the Environment
MDN	Mercury Deposition Network
Me-Hg	Methyl mercury
MM	million
mmBTU	One million British Thermal Units – a measure of energy
MW	megawatt
NAAQS	National Ambient Air Quality Standard
NADP	National Acid Deposition Network
NASA	National Aeronautics and Space Administration
NCORE	National Core, an air monitoring network
NEG/ECP	New England Governors' and Eastern Canadian Premiers' Conference
NEPA	National Environmental Protection Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHDES	New Hampshire Department of Environmental Services
NHOST	New Hampshire OBD and Safety Testing
NOAA	National Oceanographic and Atmospheric Administration
NO <sub>2</sub>	Nitrogen Dioxide – a criteria pollutant
N <sub>2</sub> O	Nitrous Oxide (a greenhouse gas)
NOx	Nitrogen oxides of multiple oxidation levels – usually used as a measure of emissions
NOy	Total Reactive Nitrogen
NSPS	New Source Performance Standard
NSR	New Source Review
NYDEC	New York Department of Environmental Conservation
O <sub>3</sub>	Ozone, a chemically reactive air pollutant – a criteria pollutant
OBD	On Board Diagnostics
OTAG	Ozone Transport Assessment Group
OTC	Ozone Transport Commission

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OTR	Ozone Transport Region
OWB	Outdoor Wood Boiler – or hydronic heater
PACIS	Powdered Activated Carbon Injection System
PAMS	Photochemical Assessment Monitoring Station
Pb	Lead – a criteria pollutant
PCB	Polychlorinated Biphenyl
pDR	Personal DataRAM 1500 – portable particle monitor
PFCs	Perfluorinated chemicals
pH	A measure of acidity based on a logarithmic measure of free hydrogen atoms
PHEV	Plug-in Hybrid Electric Vehicles
PM	Particulate Matter
PM <sub>10</sub>	Particulate Matter smaller than 10 microns in diameter – a criteria pollutant
PM <sub>2.5</sub>	Particulate Matter smaller than 2.5 microns in diameter – a criteria pollutant
ppb	parts per billion, a measure of concentration (by volume for air pollutants)
ppm	parts per million, a measure of concentration (by volume for air pollutants)
ppmvd	parts per million dry volume
PSD	Prevention of Significant Deterioration
psig	pounds per square inch gauge
PSNH	Public Service of New Hampshire – An electric service provider now called Eversource
PV	Photo Voltaic
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RACM	Reasonably Available Control Measures
RACT	Reasonably Available Control Technology
REF	Renewable Energy Fund
RGGI	Regional Greenhouse Gas Initiative
RPS	Renewable Portfolio Standard
RSA	Revised Statutes Annotated
RTAP	Regulated Toxic Air Pollutant
s	second
scf	standard cubic foot
SDA	Spray Dryer Absorber
SIP	State Implementation Plan
SO <sub>2</sub>	Sulfur Dioxide – a criteria pollutant
SOx	Sulfur oxides of multiple oxidation levels – usually used as a measure of emissions
tpy	tons per consecutive 12-month period
TSP	Total Suspended Particulate
TSU	Temporary Stationary Unit – a functional trailer for temporary air pollution monitoring
µg/m <sup>3</sup>	Micrograms per cubic meter – a measure of concentration
USDA	United States Department of Agriculture
USG	Unhealthy for sensitive groups
UV	Ultraviolet (radiation), a type of light from the sun
VOCs	Volatile Organic Compounds