AIR POLLUTION

HEALTH, ENVIRONMENTAL, AND CLIMATE IMPACTS

Air pollution can affect our health in many ways. Numerous scientific studies have linked air pollution to a variety of health problems including: (1) aggravation of respiratory and cardiovascular disease; (2) decreased lung function; (3) increased frequency and severity of respiratory symptoms such as difficulty breathing and coughing; (4) increased susceptibility to respiratory infections; (5) effects on the nervous system, including the brain, such as IQ loss and impacts on learning, memory, and behavior; (6) cancer; and (7) premature death. Some sensitive individuals appear to be at greater risk for air pollution-related health effects, for example, those with pre-existing heart and lung diseases (e.g., heart failure/ischemic heart disease, asthma, emphysema, and chronic bronchitis), diabetics, older adults, and children. In 2008, approximately 127 million people lived in counties that exceeded national air quality standards.

Air pollution also damages our environment. Ozone can damage vegetation, adversely impacting the growth of plants and trees. These impacts can reduce the ability of plants to uptake CO_2 from the atmosphere and indirectly affect entire ecosystems. Visibility is reduced by particles in the air that scatter and absorb light. Typical visual range in the eastern U.S. is 15 to 30 miles, approximately one-third of what it would be without man-made air pollution. In the West, the typical visual range is about 60 to 90 miles, or about one-half of the visual range under natural conditions.

Pollution in the form of acids and acid-forming compounds (such as sulfur dioxide [SO_2] and oxides of nitrogen [NO_x]) can deposit from the atmosphere to the Earth's surface. This acid deposition can be either dry or wet. Wet deposition is more commonly known as acid rain. Acid rain can occur anywhere and, in some areas, rain can be 100 times more acidic than natural precipitation. Acid deposition can be a very serious regional problem, particularly in areas downwind from high SO_2- and NO_x-emitting sources (e.g., coal burning power plants, smelters, and factories). Acid deposition can have many harmful ecological effects in both land and water systems. While acid deposition can damage tree foliage directly, it more commonly stresses trees by changing the chemical and physical characteristics of the soil. In lakes, acid deposition can kill fish and other aquatic life.

Air pollution can also impact the Earth's climate. Different types of pollutants affect the climate in different ways, depending on their specific properties and the amount of time they stay in the atmosphere. Any pollutant that affects the Earth's energy balance is known as a "climate forcer." Some climate forcers absorb energy and lead to climate warming, while others reflect the sun's rays and prevent that energy from reaching the Earth's surface, leading to climate cooling. Climate forcers can either be gases or aerosols (solid or liquid droplets suspended in the air) and include many traditional air pollutants, such as ozone and different types of particle pollution.

Greenhouse gas (GHG): A gas that traps heat in the atmosphere. The principal greenhouse gases affected by human activities are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone, and fluorinated gases (hydrofluorocarbons [HFCs], perfluorocarbons [PFCs], and sulfur hexafluoride [SF_6]).

Climate forcing pollutant: Any pollutant that affects the Earth's energy balance, including GHGs and aerosols. These pollutants are also called "radiative forcers." Some climate forcers absorb energy and warm the atmosphere (positive radiative forcing), while others cool it by reflecting sunlight back into space (negative radiative forcing).

Under normal conditions, most of the solar radiation reaching the Earth's surface is radiated back toward space. However, atmospheric greenhouse gases—like CO_2, CH_4, and ozone—can trap this energy and prevent the heat from escaping, somewhat like the glass panels of a greenhouse. Greenhouse gases (GHGs) are necessary to life as we know it because they keep the planet's surface warmer than it would otherwise be. However, as the concentrations of these gases continue to increase in the atmosphere, largely due to the burning of fossil fuels like coal and oil, the Earth's

Health, Environmental, and Climate Effects of Air Pollution		
Pollutant	**Health Effects**	**Environmental and Climate Effects**
Ozone (O_3)	Decreases lung function and causes respiratory symptoms, such as coughing and shortness of breath; aggravates asthma and other lung diseases leading to increased medication use, hospital admissions, emergency department (ED) visits, and premature mortality.	Damages vegetation by visibly injuring leaves, reducing photosynthesis, impairing reproduction and growth, and decreasing crop yields. Ozone damage to plants may alter ecosystem structure, reduce biodiversity, and decrease plant uptake of CO_2. Ozone is also a greenhouse gas that contributes to the warming of the atmosphere.
Particulate Matter (PM)	Short-term exposures can aggravate heart or lung diseases leading to symptoms, increased medication use, hospital admissions, ED visits, and premature mortality; long-term exposures can lead to the development of heart or lung disease and premature mortality.	Impairs visibility, adversely affects ecosystem processes, and damages and/or soils structures and property. Variable climate impacts depending on particle type. Most particles are reflective and lead to net cooling, while some (especially black carbon) absorb energy and lead to warming. Other impacts include changing the timing and location of traditional rainfall patterns.
Lead (Pb)	Damages the developing nervous system, resulting in IQ loss and impacts on learning, memory, and behavior in children. Cardiovascular and renal effects in adults and early effects related to anemia.	Harms plants and wildlife, accumulates in soils, and adversely impacts both terrestrial and aquatic systems.
Oxides of Sulfur (SO_x)	Aggravate asthma, leading to wheezing, chest tightness and shortness of breath, increased medication use, hospital admissions, and ED visits; very high levels can cause respiratory symptoms in people without lung disease.	Contributes to the acidification of soil and surface water and mercury methylation in wetland areas. Causes injury to vegetation and local species losses in aquatic and terrrestrial systems. Contributes to particle formation with associated environmental effects. Sulfate particles contribute to the cooling of the atmosphere.
Oxides of Nitrogen (NO_x)	Aggravate lung diseases leading to respiratory symptoms, hospital admissions, and ED visits; increase susceptibility to respiratory infection.	Contributes to the acidification and nutrient enrichment (eutrophication, nitrogen saturation) of soil and surface water. Leads to biodiversity losses. Impacts levels of ozone, particles, and methane with associated environmental and climate effects.
Carbon Monoxide (CO)	Reduces the amount of oxygen reaching the body's organs and tissues; aggravates heart disease, resulting in chest pain and other symptoms leading to hospital admissions and ED visits.	Contributes to the formation of CO_2 and ozone, greenhouse gases that warm the atmosphere.
Ammonia (NH_3)	Contributes to particle formation with associated health effects.	Contributes to eutrophication of surface water and nitrate contamination of ground water. Contributes to the formation of nitrate and sulfate particles with associated environmental and climate effects.
Volatile Organic Compounds (VOCs)	Some are toxic air pollutants that cause cancer and other serious health problems. Contribute to ozone formation with associated health effects.	Contributes to ozone formation with associated environmental and climate effects. Contributes to the formation of CO_2 and ozone, greenhouse gases that warm the atmosphere.
Mercury (Hg)	Causes liver, kidney, and brain damage and neurological and developmental damage.	Deposits into rivers, lakes, and oceans where it accumulates in fish, resulting in exposure to humans and wildlife.
Other Toxic Air Pollutants	Cause cancer; immune system damage; and neurological, reproductive, developmental, respiratory, and other health problems. Some toxic air pollutants contribute to ozone and particle pollution with associated health effects.	Harmful to wildlife and livestock. Some toxic air pollutants accumulate in the food chain. Some toxic air pollutants contribute to ozone and particle pollution with associated environmental and climate effects.

temperature is climbing above past levels. Such changes in temperature, along with changes in precipitation and other weather conditions due to climate change, may lead to even higher air pollution levels.

In addition to GHGs, other pollutants contribute to climate change. Black carbon (BC), a component of particle pollution, directly absorbs incoming and reflected solar radiation and reduces reflection of sunlight off of snow and ice. In these ways, BC contributes to increased absorption of energy at the Earth's surface and warming of the atmosphere. Recent studies suggest that BC may be having a significant impact on the Earth's climate. Other types of particles—particularly sulfates, nitrates, and some types of directly emitted organic carbon—are largely reflective and therefore have a net cooling impact on the atmosphere. Particles can also have important indirect effects on climate through impacts on clouds and precipitation.

The longer a pollutant stays in the atmosphere, the longer the effect associated with that pollutant will persist. Some climate forcing pollutants stay in the atmosphere for decades or centuries after they are emitted, meaning today's emissions will affect the climate far into the future. These pollutants, like CO_2, tend to accumulate in the atmosphere so their net warming impact continues over time. Other climate forcers, such as ozone and BC, remain in the atmosphere for shorter periods of time so reducing emissions of these pollutants may have beneficial impacts on climate in the near term. These short-lived climate forcers originate from a variety of sources, including the burning of fossil fuels and biomass, wildfires, and industrial processes. Short-lived climate forcing pollutants and their chemical precursors can be transported long distances and may produce particularly harmful warming effects in sensitive regions such as the Arctic.

SOURCES OF AIR POLLUTION

Air pollution consists of gas and particle contaminants that are present in the atmosphere. Gaseous pollutants include SO_2, NO_x, ozone, carbon monoxide (CO), volatile organic compounds (VOCs), certain toxic air pollutants, and some gaseous forms of metals. Particle pollution ($PM_{2.5}$ and PM_{10}) includes a mixture of compounds. The majority of these compounds can be grouped into five categories: sulfate, nitrate, elemental (black) carbon, organic carbon, and crustal material.

Some pollutants are released directly into the atmosphere. These include gases, such as SO_2, and some particles, such as crustal material and elemental carbon. Other pollutants are formed in the air. Ground-level ozone forms when emissions of NO_x and VOCs react in the presence of sunlight. Similarly, some particles are formed from other directly emitted pollutants. For example, particle sulfates result from SO_2 and ammonia (NH_3) gases reacting in the

EMISSIONS INCLUDED IN THIS REPORT

- PM emissions include directly emitted particles only. This report does not include gaseous emissions that condense in cooler air (i.e., condensibles) that form particles or emissions from fires and resuspended dust. Note that the emissions do not include secondarily formed pollutants resulting from other directly emitted pollutants.
- SO_2, NO_x, VOCs, CO, and lead emissions originate from human activity sources only.
- NH_3 emissions primarily result from animal livestock operations and are estimated using population data (e.g., cattle, pigs, poultry) and management practices.
- 2008 emissions from industry were derived from the 2005 emissions inventory, except for SO_2 and NO_x emissions, which were derived from measured data from electric utilities.
- Highway vehicle emissions were based on emissions measurements from vehicle testing programs.
- Emissions data were compiled using the best methods and measurements available at the time.

atmosphere. Weather plays an important role in the formation of secondarily formed air pollutants, as discussed later in the Ozone and Particle Pollution sections.

EPA tracks direct emissions of air pollutants and emissions that contribute to the formation of key pollutants, also known as precursor emissions. Emissions data are compiled from many different organizations, including industry and state, tribal, and local agencies. Some emissions data are based on actual measurements while others are estimates.

Generally, emissions come from large stationary fuel combustion sources (such as electric utilities and industrial boilers), industrial and other processes (such as metal smelters, petroleum refineries, cement kilns, manufacturing facilities, and solvent utilization), and mobile sources including highway vehicles and non-road sources (such as recreational and construction equipment, marine vessels, aircraft, and locomotives). Sources emit different combinations of pollutants. For example, electric utilities release SO_2 , NO_x , and particles.

Figure 2 shows the distribution of national total emissions estimates by source category for specific pollutants in 2008. Electric utilities contribute about 70 percent of national SO_2 emissions. Agricultural operations (other processes) contribute over 80 percent of national NH_3 emissions. Almost 50 percent of the national VOC emissions originate from solvent use (other processes) and highway vehicles. Highway vehicles and non-road mobile sources together contribute approximately 80 percent of national CO emissions. Pollutant levels differ across regions of the country and within local areas, depending on the size and type of sources present.

Fossil fuel combustion is the primary source contributing to CO_2 emissions (not shown in Figure 2). In 2007 (the most recent year for which data are available), fossil fuel combustion contributed almost 94 percent of total CO_2 emissions (source: http://epa.gov/climatechange/emissions/usinventoryreport.html). Major sources of fossil fuel combustion include electricity generation, transportation (including personal and heavy-duty vehicles), industrial processes, residential, and commercial. Electricity generation contributed approximately 42 percent of CO_2 emissions from fossil fuel combustion while transportation contributed approximately 33 percent.

Primary sources of CH_4 emissions (not shown) include livestock, landfills, and natural gas systems (including wells, processing facilities, and distribution pipelines). In 2007, these sources contributed about 64 percent of total U.S. CH_4 emissions. Other contributing sources include coal mining (10 percent) and manure management (8 percent).

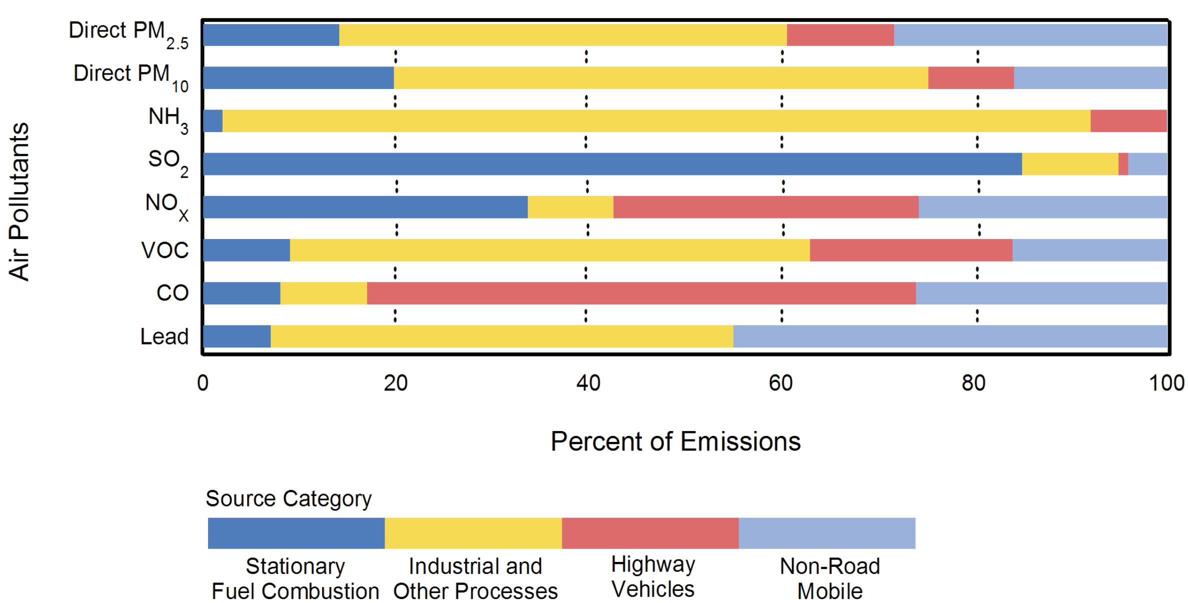

Figure 2. Distribution of national total emissions estimates by source category for specific pollutants, 2008.

TRACKING POLLUTANT EMISSIONS

Since 1990, national annual air pollutant emissions have declined, with the greatest percentage drop in lead emissions. NH_3 shows the smallest percentage drop (six percent), while direct $PM_{2.5}$ emissions have declined by over one-half, PM_{10} , NO_x , and VOC emissions have declined by over one-third, and SO_2 and CO emissions have declined by almost one-half, as shown in Table 1.

Table 1. Change in annual national emissions per source category (1990 vs. 2008) (thousand tons).

Source Category	$PM_{2.5}$	PM_{10}	NH_3	SO_2	NO_x	VOC	CO	Lead
Stationary Fuel Combustion	-773	-813	+43	-10,490	-5,323	+445	-228	-0.42
Industrial and Other Processes	-343	-217	-446	-731	-144	-3,150	-442	-2.80
Highway Vehicles	-213	-216	+153	-439	-4,386	-5,970	-71,389	-0.42
Non-Road Mobile	-17	-24	-28	+85	+474	-76	-3,411	-0.27
Total Change	-1,346	-1,270	-278	-11,575	-9,379	-8,751	-75,470	-3.91
Percent Change (1990 vs. 2008)	-58%	-39%	-6%	-50%	-36%	-35%	-53%	-79%

The combined emissions of the six common pollutants and their precursors ($PM_{2.5}$ and PM_{10} , SO_2 , NO_x , VOCs, CO, and lead) dropped 41 percent on average since 1990, as shown in Figure 3. This progress has occurred while the U.S. economy continued to grow, Americans drove more miles, and population and energy use increased. These emissions reductions were achieved through regulations and voluntary partnerships between federal, state, local, and tribal governments; academia; industrial groups; and environmental organizations. There was a notable reduction in vehicle miles traveled and energy consumed from 2007 to 2008. Factors likely contributing to this reduction include the nationwide spike in gasoline prices during 2008 and the economic recession that began in 2008. Figure 3 also shows total CO_2 emissions increasing by about 20 percent from 1990 to 2007 (http://epa.gov/climatechange/emissions/usinventoryreport.html).

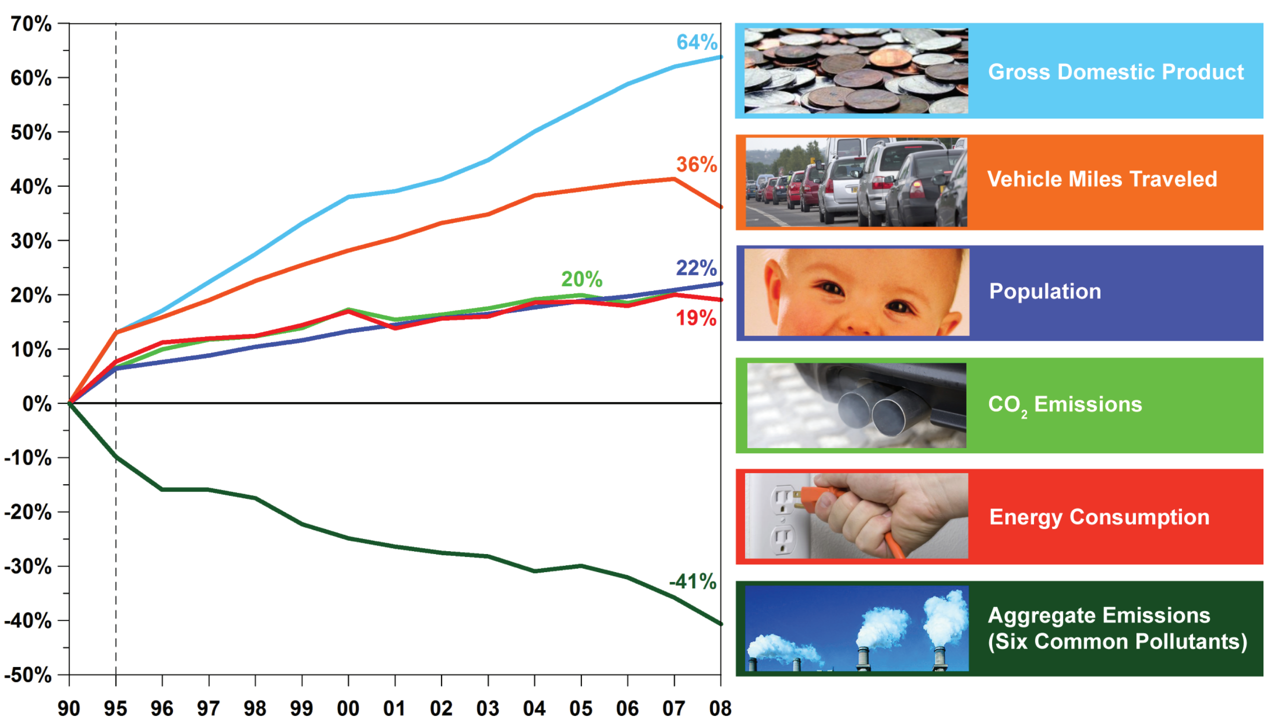

Figure 3. Comparison of growth measures and emissions, 1990-2008.

Note: CO_2 emissions estimates are from 1990 to 2007.