

# PROTECTING EARTH'S AIR



# Protecting Earth's Air Lecture

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THE OHIO STATE UNIVERSITY

# Protecting Earth's Air Objectives

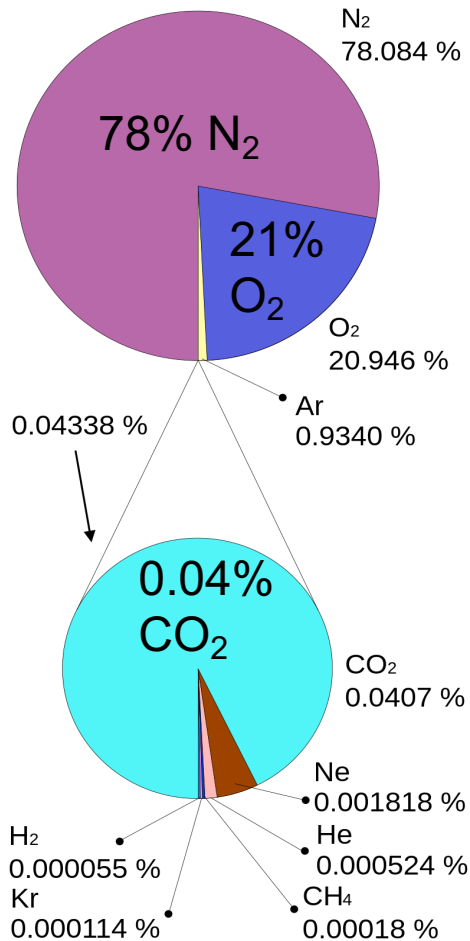
1. Define Earth's atmosphere, air pollution, and identify common air pollutants.
2. Differentiate between primary and secondary air pollution, natural and anthropogenic air pollution.
3. Examine the environmental, health, social, and economic impacts associated with air pollution.
4. Identify legislation, policies, and technological strategies for preventing and mitigating air pollution.

**Objective 1: Define Earth's atmosphere, air pollution, and identify common air pollutants.**

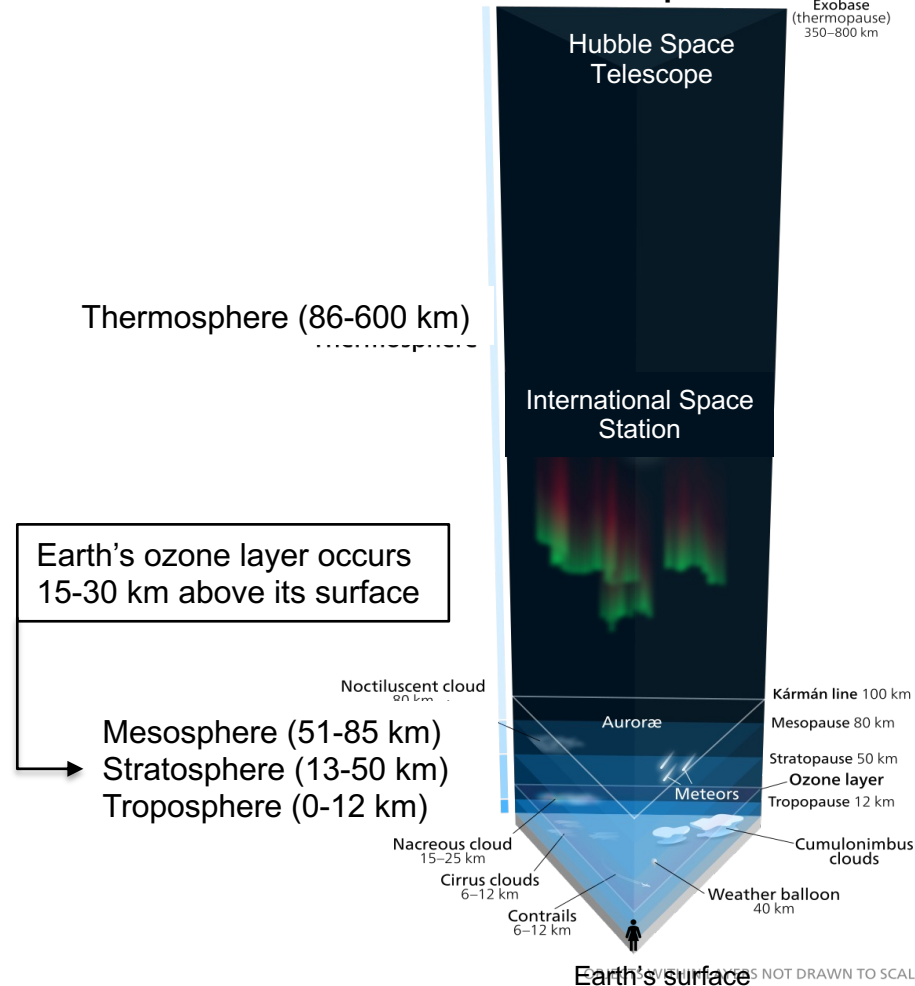


99% of Earth's atmosphere is nitrogen (78% N<sub>2</sub>) and oxygen (21% O<sub>2</sub>)

Carbon dioxide (CO<sub>2</sub>) only makes up 0.04% of Earth's atmosphere



## Outer space



**Air Pollution = gases, liquids, or particles added to the atmosphere that harm living organisms or ecosystems, affects climate, or impacts structures**

Air-quality problems span the globe and can have serious consequences to human health.

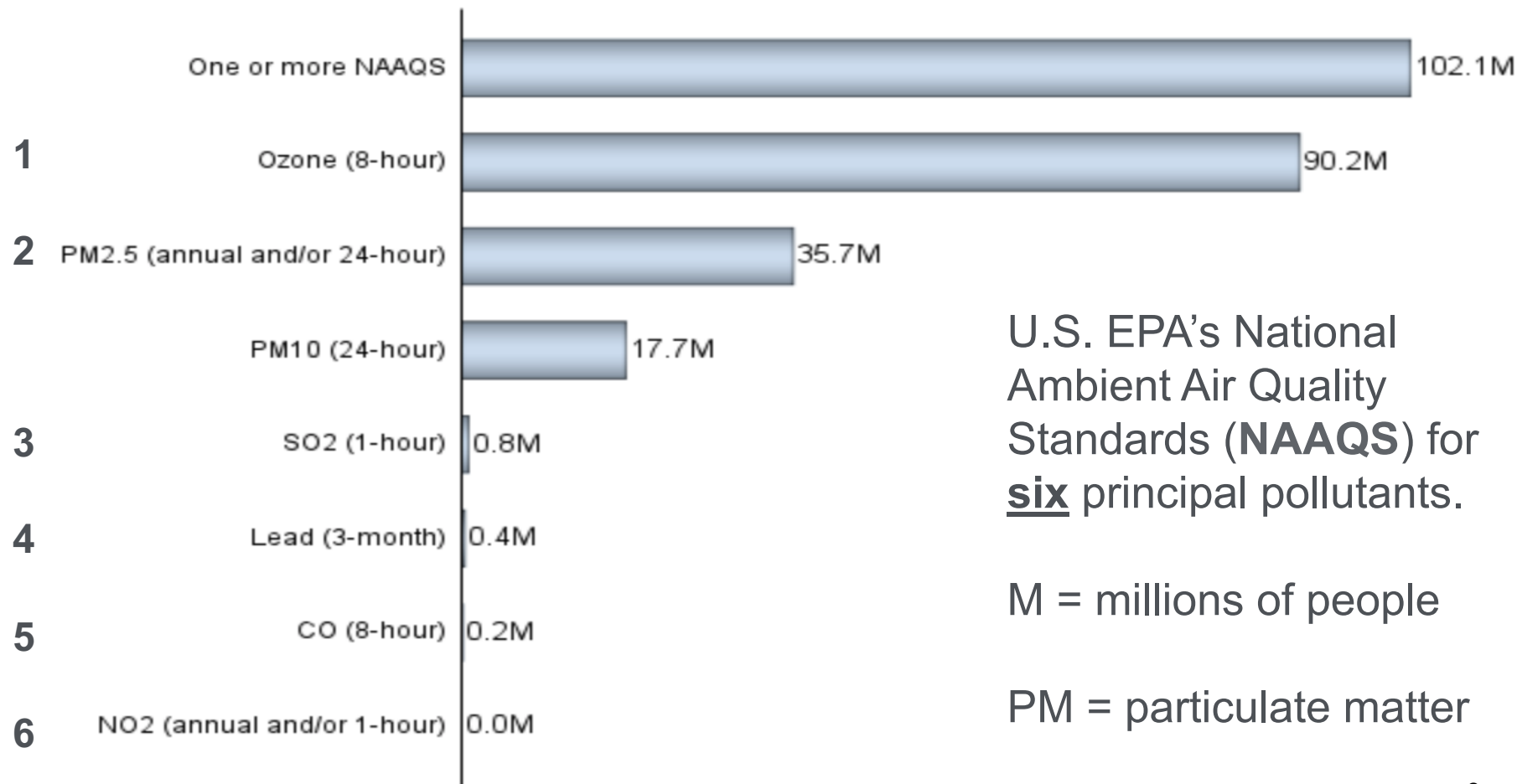
The World Health Organization reports that over 90% of the global population breathes polluted air. They also report that over 7 million individuals die each year from causes related to air pollution.

Pollutants can travel thousands of kilometers from their source and it's this reality that makes air pollution a challenging problem to solve.





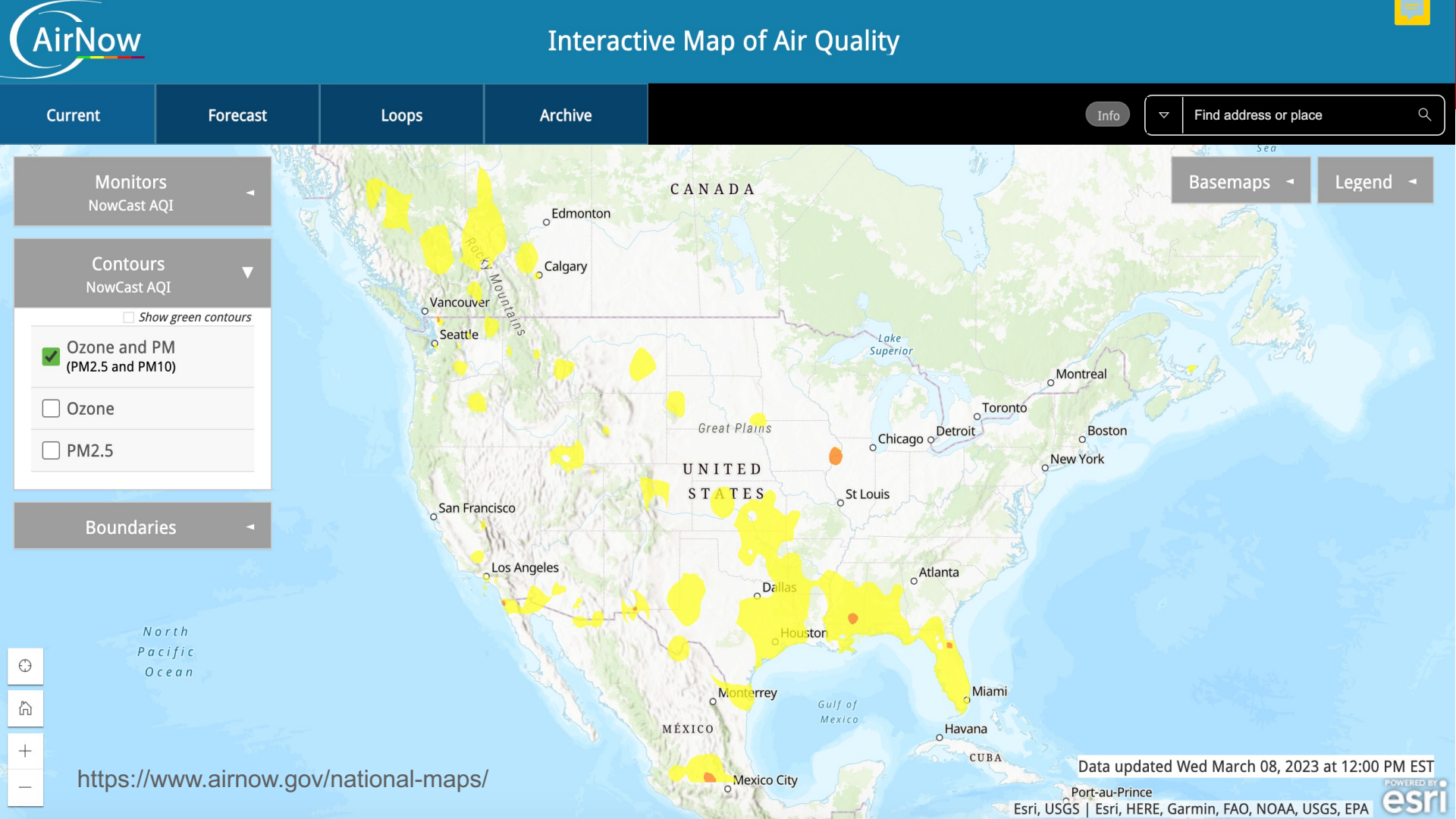
## Number of People Living in Counties with Air Quality Concentrations Above the Level of the NAAQS in 2021



U.S. EPA's National Ambient Air Quality Standards (**NAAQS**) for six principal pollutants.

M = millions of people

PM = particulate matter



Current

Forecast

Loops

Archive

Info

Find address or place

Monitors

NowCast AQI

Contours

NowCast AQI

Show green contours

☒ Ozone and PM  
(PM2.5 and PM10)

☐ Ozone

☐ PM2.5

Boundaries

Basemaps

Legend



# OUR NATION'S AIR

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## TRENDS THROUGH 2022

Link: <https://gispub.epa.gov/air/trendsreport/2023/#home>

# U.S. EPA Air Quality Trends Improving


[Intro](#)[Growth](#)[NAAQS](#)[Visibility](#)[Toxics](#)[Spotlight](#)[Summary](#)

## Air Quality Trends Show Clean Air Progress

Nationally, concentrations of air pollutants have dropped significantly since 1990:

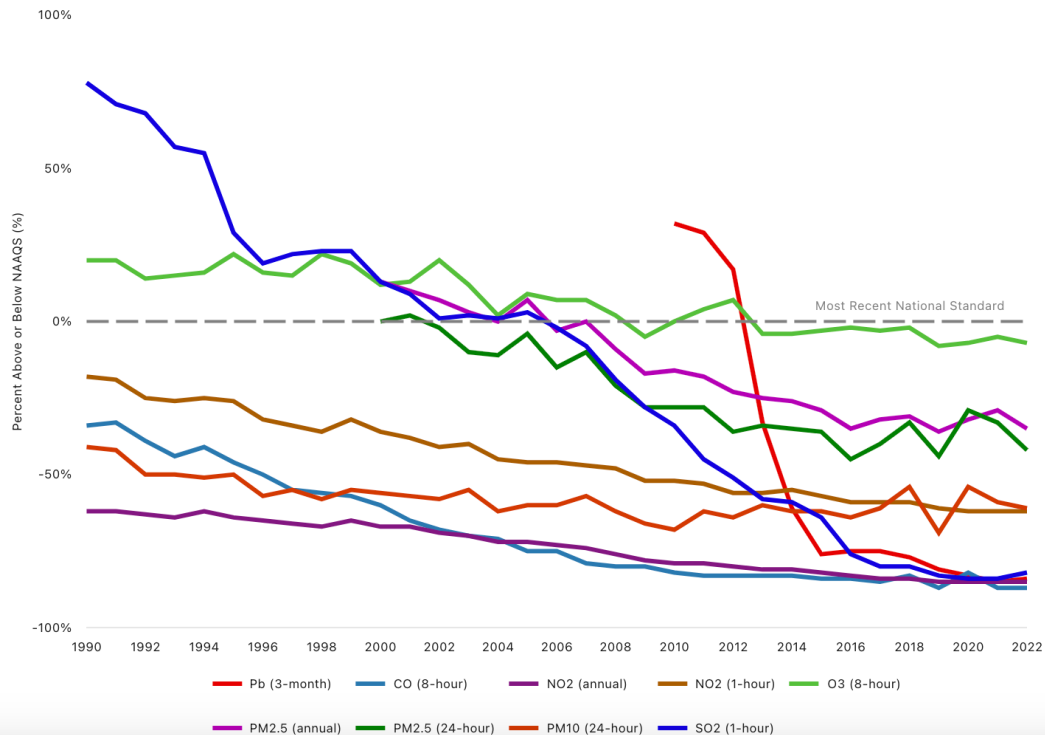
- Carbon Monoxide (CO) 8-Hour, ↓ 81%
- Lead (Pb) 3-Month Average, ↓ 88% (from 2010)
- Nitrogen Dioxide (NO<sub>2</sub>) Annual, ↓ 60%
- Nitrogen Dioxide (NO<sub>2</sub>) 1-Hour, ↓ 54%
- Ozone (O<sub>3</sub>) 8-Hour, ↓ 22%
- Particulate Matter 10 microns (PM<sub>10</sub>) 24-Hour, ↓ 34%
- Particulate Matter 2.5 microns (PM<sub>2.5</sub>) Annual, ↓ 42% (from 2000)
- Particulate Matter 2.5 microns (PM<sub>2.5</sub>) 24-Hour, ↓ 42% (from 2000)
- Sulfur Dioxide (SO<sub>2</sub>) 1-Hour, ↓ 90%
- Numerous air toxics have declined with percentages varying by pollutant

Despite increases in air concentrations of pollutants associated with fires, carbon monoxide and particle pollution, national average air quality concentrations remain below the current, national standards.

 Air quality concentrations can vary year to year, influenced not only by pollution emissions but also by natural events, such as dust storms and [wildfires](#), and variations in weather.

[Concentration Averages](#)[Emission Totals](#)

### Declining National Air Pollutant Concentration Averages



Source: EPA

# Carbon Monoxide (CO)

**Carbon monoxide (CO)** = clear odorless gas that is emitted when carbon compounds are burned (i.e., coal, oil, natural gas).

## Sources

- The greatest sources of outdoor CO are cars, trucks, vehicles, and machinery that burn fossil fuels (e.g., gasoline, diesel).
- Indoors CO comes from unvented kerosene and gas space heaters, leaking chimneys, gas furnaces, and gas stoves.

## Public Health

- CO reduces the amount of oxygen that can be carried in the blood and critical to organs like the heart and brain.
- At high levels (e.g., indoors or in enclosed areas), CO can cause dizziness, confusion, unconsciousness and even death.
- High levels of CO not likely to occur outdoors. However, outdoor CO pollution is a concern for people with heart disease.

## Environmental Health

- CO contribute to the formation of CO<sub>2</sub> and ozone, greenhouse gases that warm the planet.



# Lead (Pb)

**Lead (Pb)** = heavy metal, soft and malleable with gray color. There is no safe exposure level for lead. Any amount of contact, breathing, swallowing lead or lead dust is unsafe.

## Sources

- Leaded gasoline was major source of Pb in atmosphere up until 1980s when USA removed lead from gasoline. The level of lead in air today has decreased by 98% because of use of unleaded gasoline.
- Today Pb in air comes from lead and ore smelters, utilities, lead-acid battery manufacturers, waste incinerators.

## Public Health

- Lead damages brain and nervous system, kidney function, immune system, reproductive and developmental systems.
- In infants and children, Pb causes learning disabilities, lower IQ, behavioral issues, long term negative impact on intelligence.
- Lead is extremely difficult to remove from body once it has been ingested or inhaled.

## Environmental Health

- Lead is toxic to all wildlife. Pb poisoning and death in birds is well documented, from ingestion of lead ammunition. Solution is to replace lead with copper ammunition and tungsten fishing weights.

# Nitrogen Oxides (NO<sub>x</sub>, NO, NO<sub>2</sub>)

**Nitrogen oxides (NO<sub>x</sub>)** = reddish/brown gas, composed of NO and/or NO<sub>2</sub> that has an irritating, strong odor. It's emitted when gasoline, diesel or coal is used in motor vehicles or power plants. NO<sub>x</sub> gases are highly reactive and produce secondary pollutants in atmosphere.

## Sources

- The two largest sources of NO<sub>x</sub> is from motor vehicles (burning gasoline or diesel), and coal-fired power plants that burn coal to produce electricity.

## Public Health

- Harms respiratory system and makes breathing difficult. Long-term exposure can contribute to asthma and increase respiratory infections.
- NO<sub>x</sub> combines with volatile organic compounds (VOCs) in the atmosphere in the presence of sunlight to form smog.

## Environmental Health

- NO<sub>x</sub> combines with water in the atmosphere to form nitric acid (HNO<sub>3</sub>), which leads to acid rain that is harmful to aquatic organisms (particularly eggs, larvae, juveniles).
- Decreases soil health and degrades water.
- Toxic to animals and plants.

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

**Ozone (O<sub>3</sub>)** = good or bad depending on where it's located in atmosphere. High in the stratosphere O<sub>3</sub> is good because it blocks cancer-causing ultraviolet light. O<sub>3</sub> in troposphere is bad because people and organisms are exposed to it.

## Sources

- O<sub>3</sub> forms in the troposphere when sunlight, NO<sub>x</sub> and VOCs react with each another. Forms on hot sunny days in cities due to pollution (NO<sub>x</sub> and VOC) from cars, power plants, industry, manufacturing.

## Public Health

- O<sub>3</sub> can make symptoms worse for people with asthma, bronchitis or emphysema. Can lead to difficulty breathing
- Watch AQI and when ozone levels are high (summer afternoon) stay indoors and use air conditioner

## Environmental Health

- O<sub>3</sub> harms and/or kills plants by oxidizing (burning) tissue.
- Ozone damage to crops is a problem for agriculture.
- USDA estimates loss of billions of dollars in crop revenue (soybean, corn) each year due ground-level ozone pollution.

# Particulate Matter (PM, PM<sub>2.5</sub>, PM<sub>10</sub>)

**Particulate Matter (PM)** = complex mixture of solid particles and liquid droplets. Divided by size: PM<sub>10</sub> or PM<sub>2.5</sub>

## Sources

- Hundreds of different sources of particulate matter,
- Some PM emitted directly from sources like construction sites, unpaved roads, fields, fires, smokestacks.
- Most PM forms in the atmosphere because of chemical reactions between sulfur dioxide, nitrogen oxides, and pollutants emitted from power plants, industry, and automobiles.

## Public Health

- Premature death in people with heart and lung disease
- Heart attacks, irregular heartbeat
- Asthma, difficulty breathing,
- Produce haze and reduce visibility.

## Environmental Health

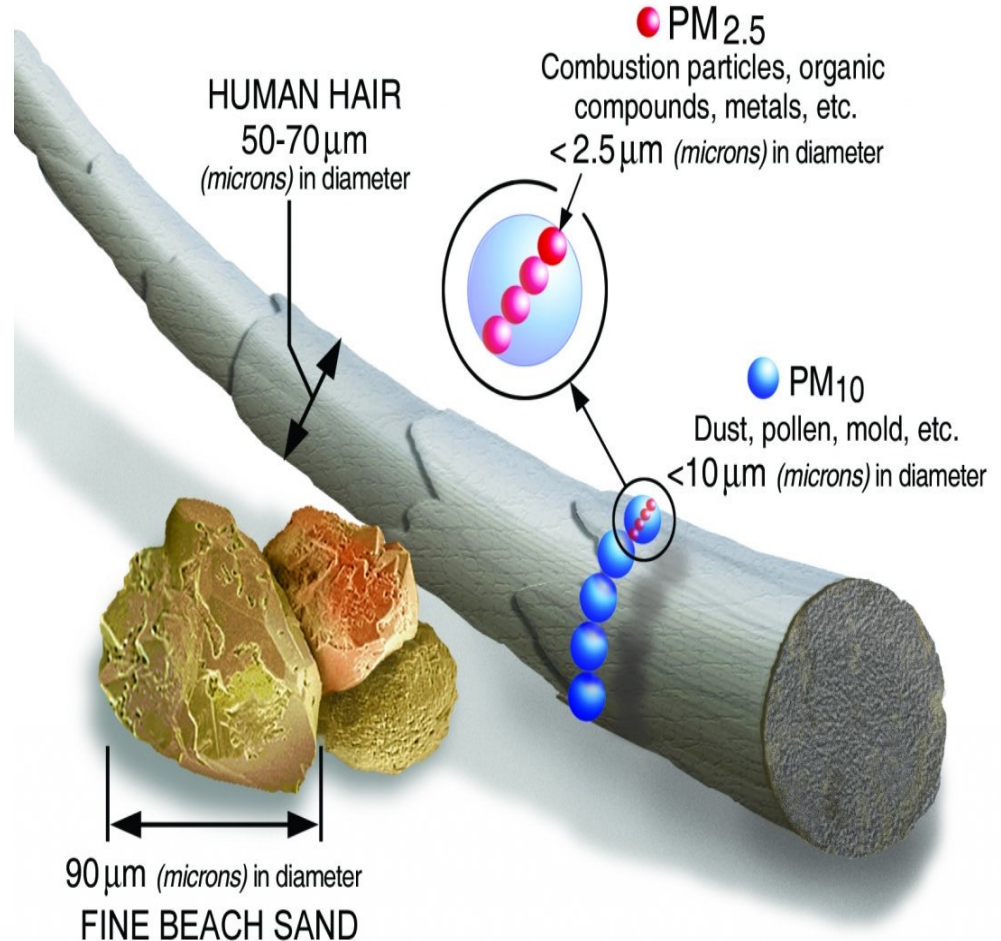
- Wind can carry PM long distances and deposit pollutants into soil and water.
- Acidic lakes, rivers, streams. Change nutrient balance in coastal waters and rivers.
- Depletion of soil nutrients, damage crops and forests.
- Kill eggs and juveniles of aquatic organisms.
- Damage statues and monuments.

**Particulate Matter (PM)** - particle pollution, very small liquid or solid pollutant that enter the air

Components can be dust, soil, smoke, ash, asbestos, mold, etc. Particulate matter includes two types:

**PM<sub>10</sub>** - inhalable particles, with diameters that are 10 micrometers to 2.5 micrometers (size of pollen or mold spore).

**PM<sub>2.5</sub>** - fine, inhalable particles, with diameters that are 2.5 micrometers and smaller (size of single bacterium).



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

**Sulfur dioxide (SO<sub>2</sub>)** = colorless gas that has an irritating, strong odor like rotten eggs, or burnt matches. It's emitted when coal and oil are burned or from smelting of mineral ores.

## Sources

- The largest source of SO<sub>2</sub> is from coal that is burned in coal-fired power plants to produce electricity.
- SO<sub>2</sub> is also released in industrial plants, ships, and heavy equipment that use fuel which is high in sulfur content.

## Public Health

- Harms respiratory system and makes breathing difficult particularly for people with asthma. Can lead to wheezing, shortness of breath, asthma attack and hospitalization.
- Reacts with other compounds in the atmosphere to form small particles of haze, which leads to reduced visibility.

## Environmental Health

- SO<sub>2</sub> combines with water vapor in the atmosphere to form sulfuric acid, which leads to acid rain that is harmful to aquatic organisms (particularly eggs, larvae, juveniles) and decreases soils health.
- SO<sub>2</sub> damages plant foliage, soil health and decreases growth of natural vegetation and crops.

# Volatile Organic Compounds (VOCs)

## Volatile Organic Compounds (VOCs)

= human made gases that readily evaporate and are emitted by certain organic liquids and solids. Many have a strong odor.

### Sources

- There are thousands of products and processes that release harmful VOCs.
- Household products like cleaning agents, paints, varnishes, carpet, glue, furnishings, upholstery, wax, pesticides, herbicides.
- Industrial solvents, building materials, furnishings, fuels (gasoline, kerosine).

- Manufacturing and industrial processes (chlorination water treatment, production of petroleum products, semiconductor fabrication).

### Public Health

- Short term exposure can lead to nausea, vomiting, headaches, breathing difficulty, irritation of eyes, nose, throat
- Long term exposure can lead to asthma, cancer, damage to liver, kidney, central nervous system, birth defects

### Environmental Health

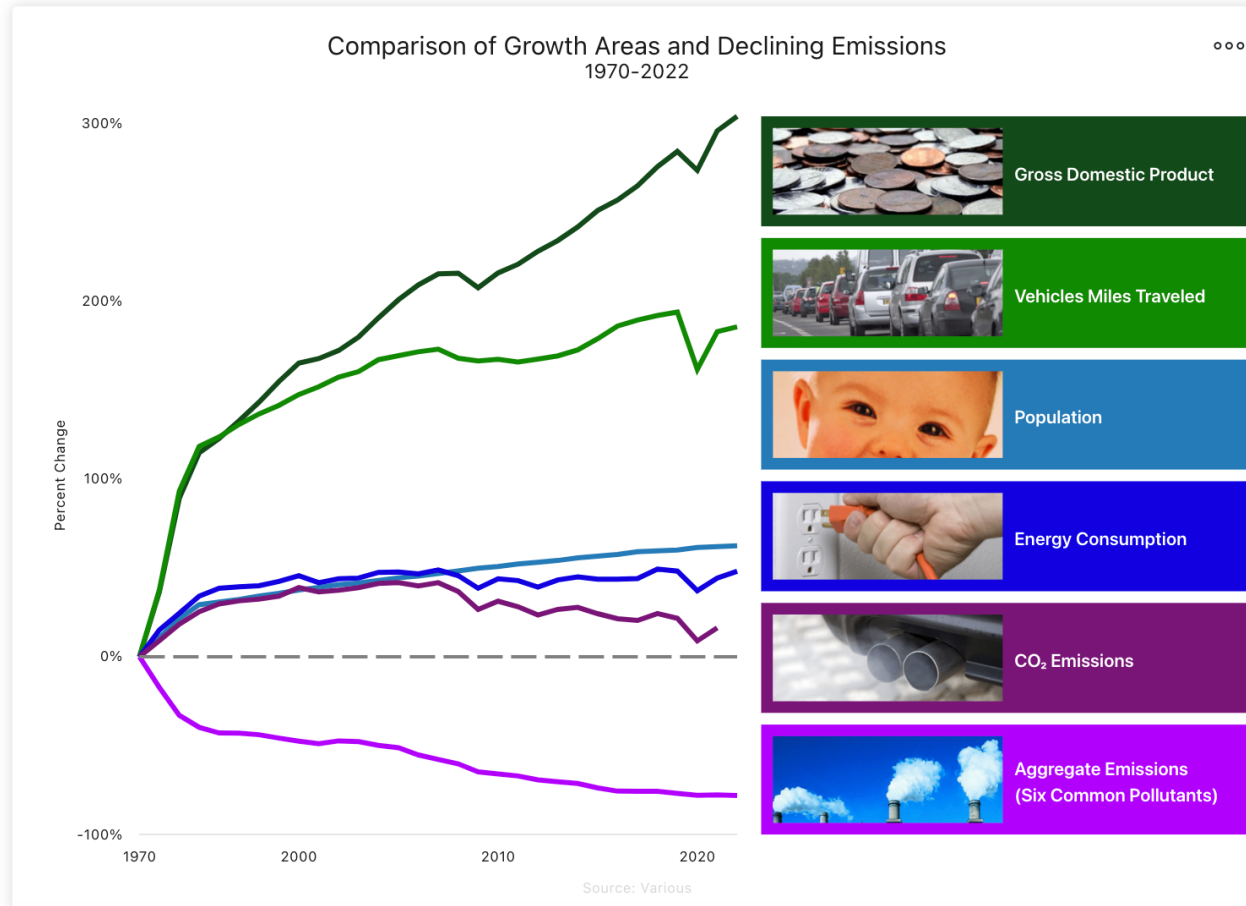
- VOCs react with NO<sub>x</sub> gases in the atmosphere to form ground-level ozone and smog.



# Economic Strength with Cleaner Air

Between 1970 and 2022, the combined emissions of the six common pollutants (PM<sub>2.5</sub> and PM<sub>10</sub>, SO<sub>2</sub>, NO<sub>x</sub>, VOCs, CO and Pb) dropped by 78 percent. This progress occurred while U.S. economic indicators remain strong.

**Tip** Click any of the legend items on the right side of the chart to hide or include trend lines. The y-axis may change based on the selections.



# Hazardous Air Pollutants (HAPs)

## **Hazardous Air Pollutants (HAPs)**

= pollutants that are known or suspected of causing serious health effects like cancer, reproductive disorders, birth defects, nervous system disorders, immune system dysfunction, endocrine disorders and organ damage. These pollutants also adversely impact wildlife, plants, waters and soils.

**U.S. EPA has a list of 188 hazardous air pollutants (HAPs)** that it regulates and monitors. Link to HAPs:

<https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications>

- EPA's List of 188 HAPs includes compounds like arsenic compounds, asbestos, benzene, chloroform, cyanide compounds, formaldehyde, methanol, mercury compounds, phenol, radionuclides, toluene, and vinyl chloride.
- These pollutants are emitted by thousands of different sources including factories, refineries, power plants, manufacturing, fuels, building materials, cleaning solvents, cars, trucks, equipment, etc.

**Objective 2: Differentiate**

**between primary and secondary air**

**pollution, natural and**

**anthropogenic air pollution.**

Winds always moves from H to L

Cold air sinks

Warm air rises

Cold air sinks

H High Pressure

L Low Pressure

90° N



60° N

Westerlies

30° N

Trade Winds

0° Equator

Trade Winds

30° S

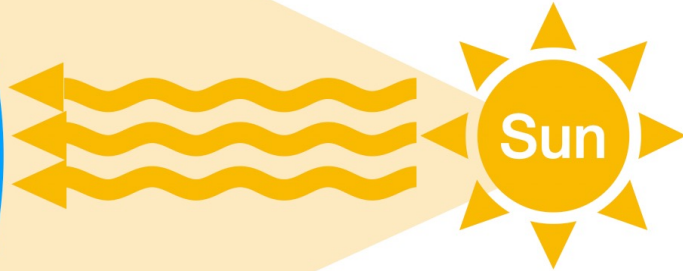
Westerlies

60° S

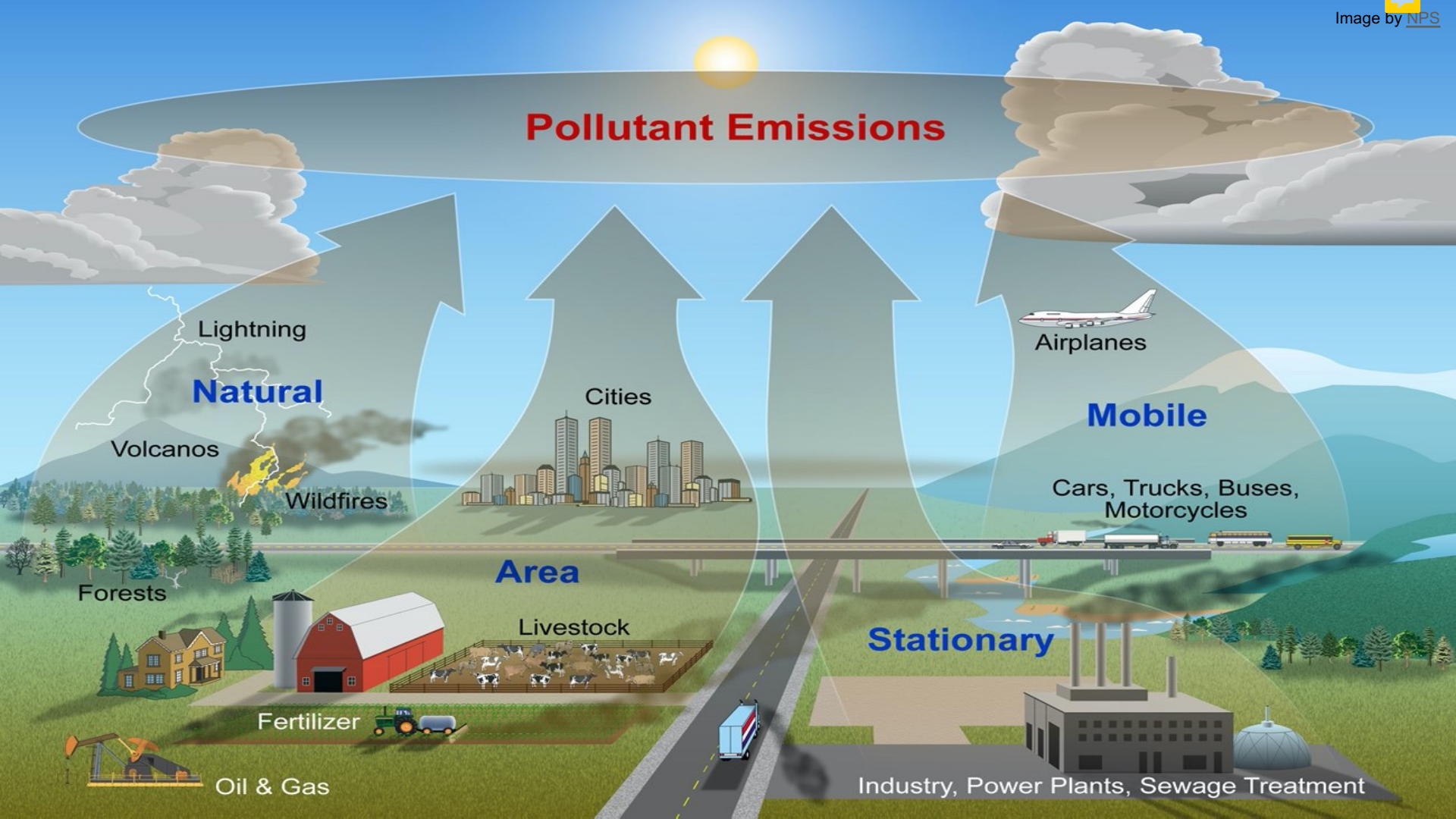
90° S



Sun's radiation is focused on the equator throughout the year. As Earth spins on its axis, the Sun's energy warms Earth's surface land and water at the equator.



Coriolis Effect - as Earth spins on its axis it causes winds and ocean currents to curve rather than move in a straight line. Wind curves to left in Southern Hemisphere, and to right in Northern Hemisphere.





**Natural Air Pollutants = pollutants that come from natural sources like wildfires, volcanic eruptions, ocean spray, or sandstorms**

Natural releases harmful substances into our atmosphere such as ash and gases from volcanic eruptions, smoke and PM from wildfires, and gases like methane from decomposing organic matter.

Wildfires smoke = CO, PM, NO<sub>2</sub>, O<sub>3</sub>

Volcano = hydrogen fluoride (HF), PM, SO<sub>2</sub>



**Anthropogenic Air Pollutants = air pollutants produced from human activities** (agriculture, manufacturing, transportation, electricity generation, etc.)

These include **common pollutants** like carbon monoxide, ammonia, nitrogen oxide, lead, ozone, particular matter (PM<sub>2.5</sub> and PM<sub>10</sub>), sulfur dioxide, and volatile organic compounds (VOCs).

The U.S. EPA also monitors almost 188 different **Hazardous Air Pollutants (HAPs)** like asbestos, benzene, chromium, mercury, paint stripper, and solvents like toluene.





# U.S. Emissions of Common Pollutants by Source

## Understanding Emission Sources Helps Control Air Pollution

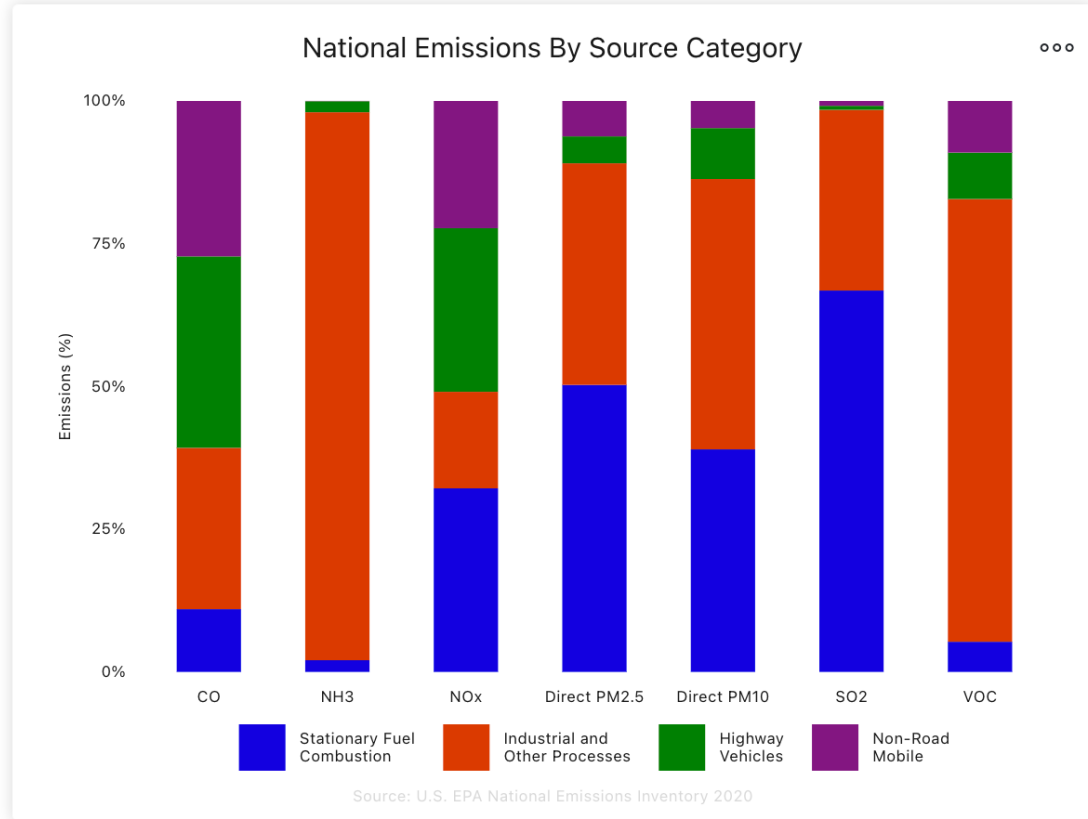
Generally, emissions of air pollution come from

- stationary fuel combustion sources (such as electric utilities and industrial boilers),
- industrial and other processes (such as metal smelters, petroleum refineries, cement kilns and dry cleaners),
- highway vehicles, and
- non-road mobile sources (such as recreational and construction equipment, marine vessels, aircraft and locomotives).

As the chart shows, pollutants are emitted by a variety of sources. For example, electric utilities, part of the stationary fuel combustion category, release SO<sub>2</sub>, NO<sub>x</sub> and particles.

EMISSION INVENTORIES

**Tip** Click the ellipsis in the upper righthand corner and check "Show Totals" to view the chart based on totals instead of percentages. Click source categories in the chart legend to hide or include, and hover over any bar to display totals by source category.



# Sources of Outdoor Air Pollution

- ✓ Vehicle exhausts
- ✓ Industry emissions
- ✓ Coal-fired power plants
- ✓ Natural-gas power plants
- ✓ Indoor burning of solid fuels (charcoal, wood, animal waste)
- ✓ Natural sources (sandstorms, volcanic eruptions, wildfires)
- ✓ Agriculture
- ✓ Metal Ore Smelters
- ✓ Oil Refineries
- ✓ Mining Operations
- ✓ Construction Sites



# Sources of Indoor Air Pollution

- ✓ Fuel-burning appliances (gas stoves, gas dryers)
- ✓ Tobacco products
- ✓ Household cleaners
- ✓ Central heating and cooling systems
- ✓ Excess moisture/mold
- ✓ Newly installed materials, flooring, cabinets, carpet, upholstery, etc.
- ✓ Insulation
- ✓ Fireplaces and chimneys
- ✓ Paints, glues and solvents

## Potential Solutions

control/remove sources, use ventilation in kitchens and bathrooms, use air purifiers, open windows, don't smoke, install radon reduction system, use dehumidifier, vent attics and crawl space, don't use harsh cleaners, install carbon monoxide detectors



**Primary Air Pollutant** = a solid, liquid or gas released directly into the air from a mobile or stationary source, and it is immediately toxic to humans

Examples: carbon monoxide, asbestos, toluene, lead

**Secondary Air Pollutant** = pollutant that is not directly emitted, but is produced in the atmosphere when other pollutants react with each other to produce a new air pollutant, which is toxic to humans

Examples: ground-level ozone, smog, haze, acid rain



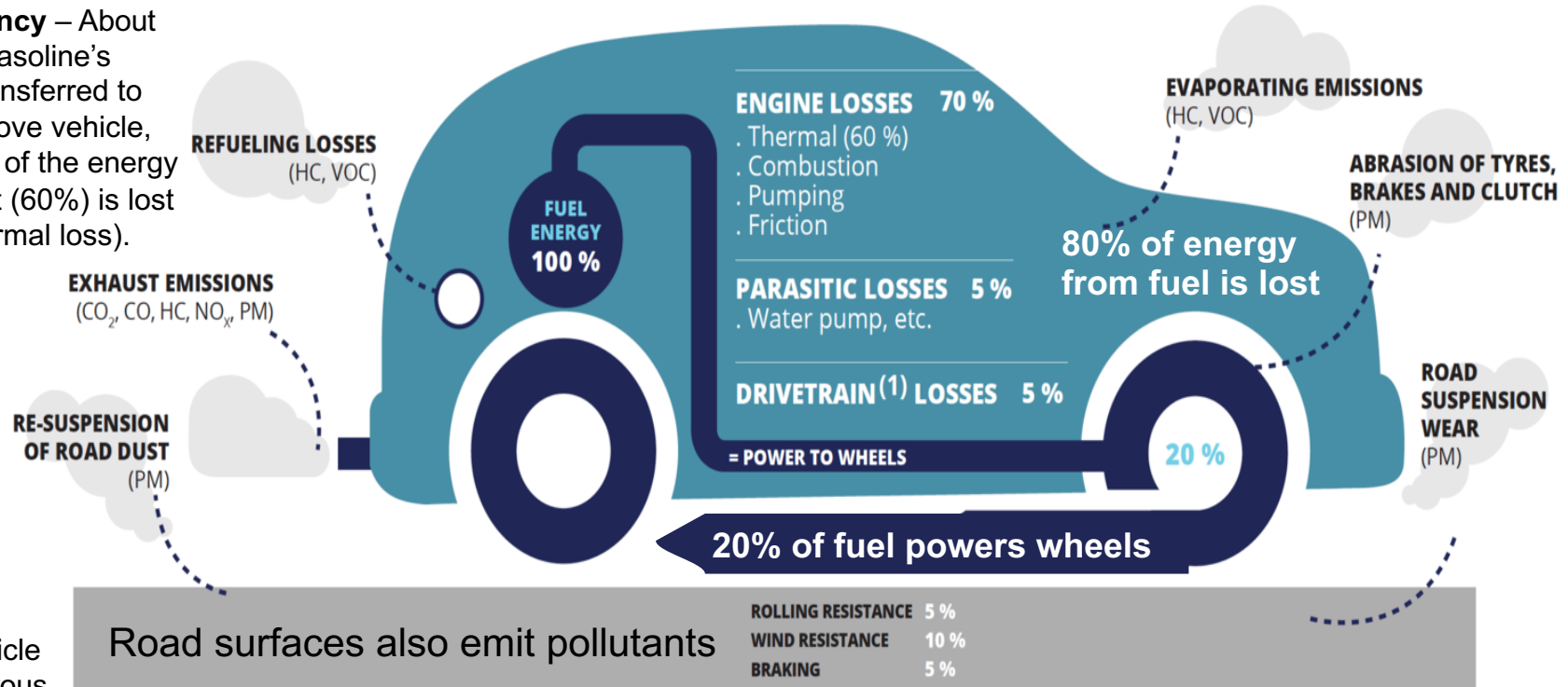
Image by Lars Kuczynski, [Unsplash](#).





# Vehicle Emissions and Fuel Efficiency

**Fuel Efficiency** – About 20-30% of gasoline's energy is transferred to wheels to move vehicle, and 70-80% of the energy is lost. Most (60%) is lost as heat (thermal loss).



A single vehicle emits numerous pollutants from several sources and processes.

Hydrocarbons (**HC**) are organic compounds that are composed of hydrogen and carbon. Examples of HC includes gasoline, diesel fuel, oil, lubricants, greases. Volatile organic compounds (**VOCs**), Particulate Matter (**PM**), Carbon Dioxide (**CO<sub>2</sub>**), Carbon Monoxide (**CO**), Nitrogen Oxides (**NO<sub>x</sub>**).

## Counties Designated "Nonattainment"

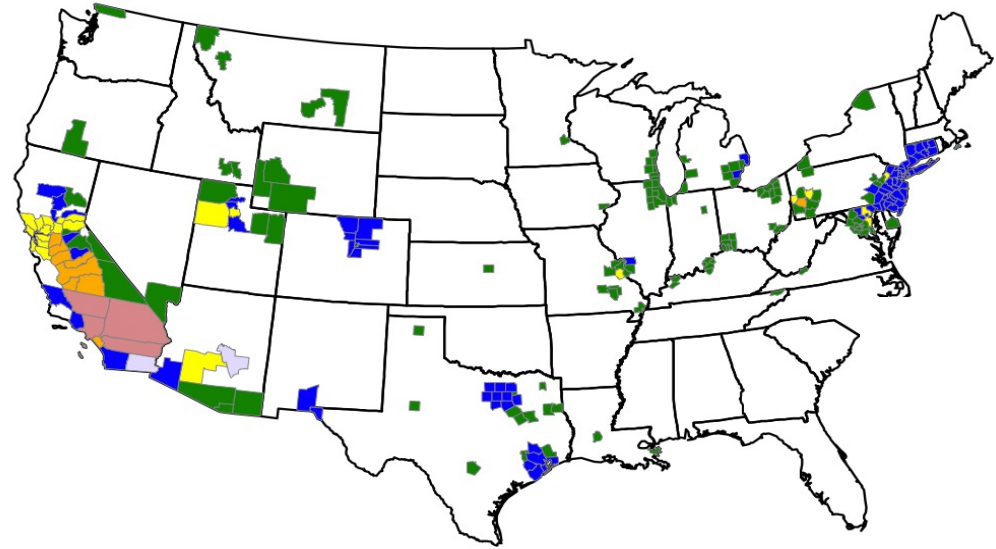
for Clean Air Act's National Ambient Air Quality Standards (NAAQS) \*



**Nonattainment** = a county that has not attained the standard for one to six criteria pollutants.

**EPA Criteria Pollutants = six of the most common air pollutants that the United States' EPA has set air quality standards.**

1. Carbon Monoxide (CO)
2. Lead (Pb)
3. Nitrogen Oxides (NO<sub>x</sub>)
4. Ground-Level Ozone (O<sub>3</sub>)
5. Particulate Matter (PM<sub>2.5</sub>, PM<sub>10</sub>)
6. Sulfur Dioxide (SO<sub>2</sub>)



### Legend \*\*

- County Designated Nonattainment for 6 NAAQS Pollutants
- County Designated Nonattainment for 5 NAAQS Pollutants
- County Designated Nonattainment for 4 NAAQS Pollutants
- County Designated Nonattainment for 3 NAAQS Pollutants
- County Designated Nonattainment for 2 NAAQS Pollutants
- County Designated Nonattainment for 1 NAAQS Pollutant



PR





**Objective 3: Examine the  
environmental, health, social, and  
economic impacts associated with  
air pollution.**

# Environmental Impacts of Air Pollution

## Smog



## Healthy



## Acid Rain



Image by Tomschyhaha, Wikimedia Commons. CC BY SA 4.0.

Image by Lovecz, Wikimedia Commons.

## Soil Health

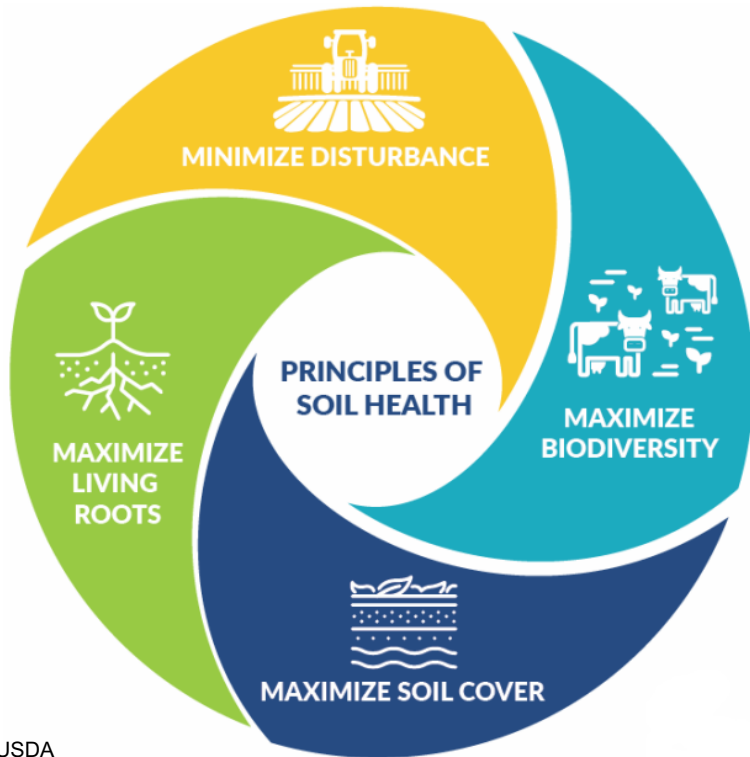


Image by USDA

## Crop Damage

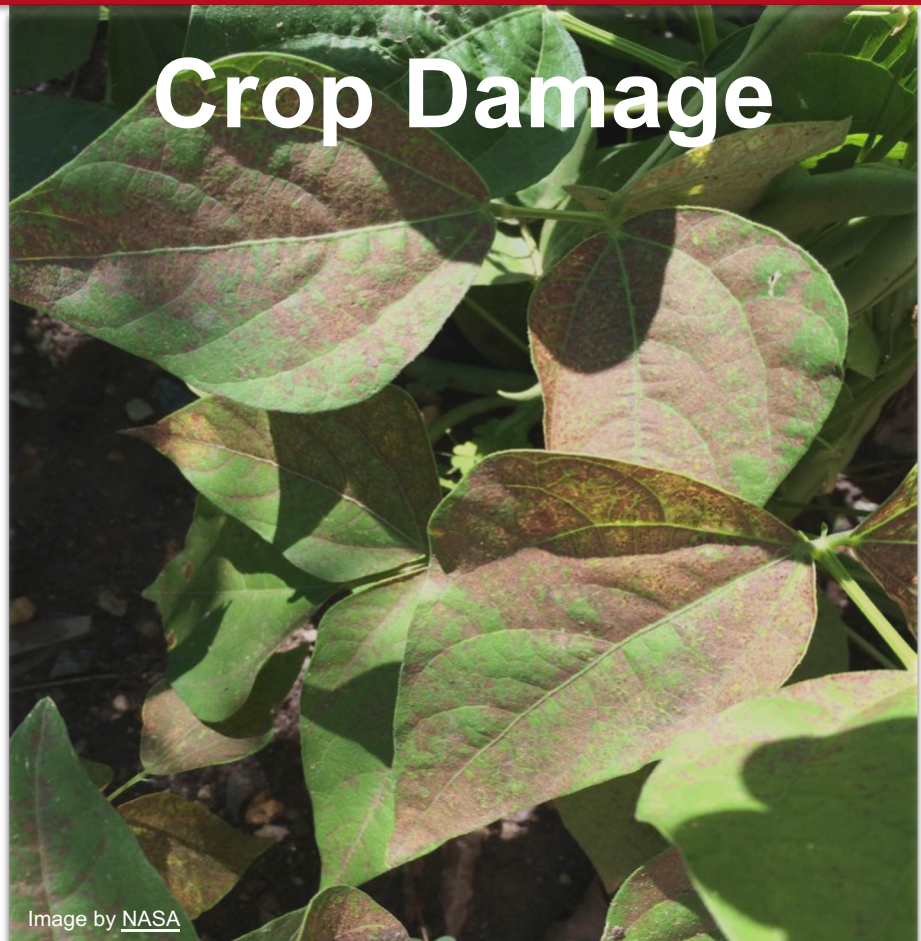


Image by NASA



## Wildlife Health

A pollutant that harms humans likely harms wildlife as well



## Water Quality

USGS water  
quality  
monitoring  
station,  
New Mexico



# Health Impacts of Air Pollution

## Short Term (Acute) Effects

- Often temporary
- Bad odors
- Illnesses like bronchitis and pneumonia
- Asthma attacks
- Skin, eye, nose, throat irritations
- Headaches
- Dizziness
- Nausea
- Coughing and difficulty breathing
- Increased risk of long-term effects
- Can trigger heart attacks, strokes and irregular heart beats





# Health Impacts of Air Pollution

## Long Term (Chronic) Effects

- Can impact health for weeks, years, or lifetime
- Certain cancers such as lung cancer
- Cardiovascular disease, heart attacks and stroke
- Respiratory diseases like emphysema and chronic obstructive pulmonary disease (COPD)
- Damage to vital organs (lungs, heart, brain)

Chronic effects are more likely to impact and cause harm to;

1. Children (less developed immune system)
2. Older adults (less effective immune system)
3. Those living in urban areas (greater exposure)



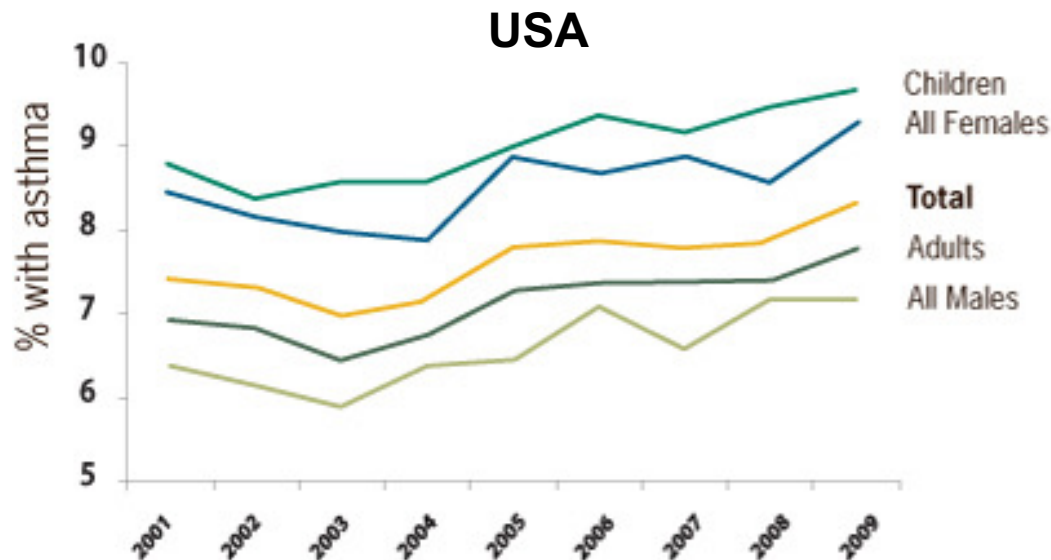


# Health Impacts of Air Pollution

**Asthma = chronic, respiratory illness that restricts airways and makes it difficult to breathe**

Asthma and other conditions such as heart and lung disease can be further impaired by exposure to air pollution.

Urban communities are most at risk for developing asthma because pollutants are most concentrated in cities.



1 in 12

About 1 in 12 people (about 25 million) have asthma, and the numbers are increasing every year.



56 Billion

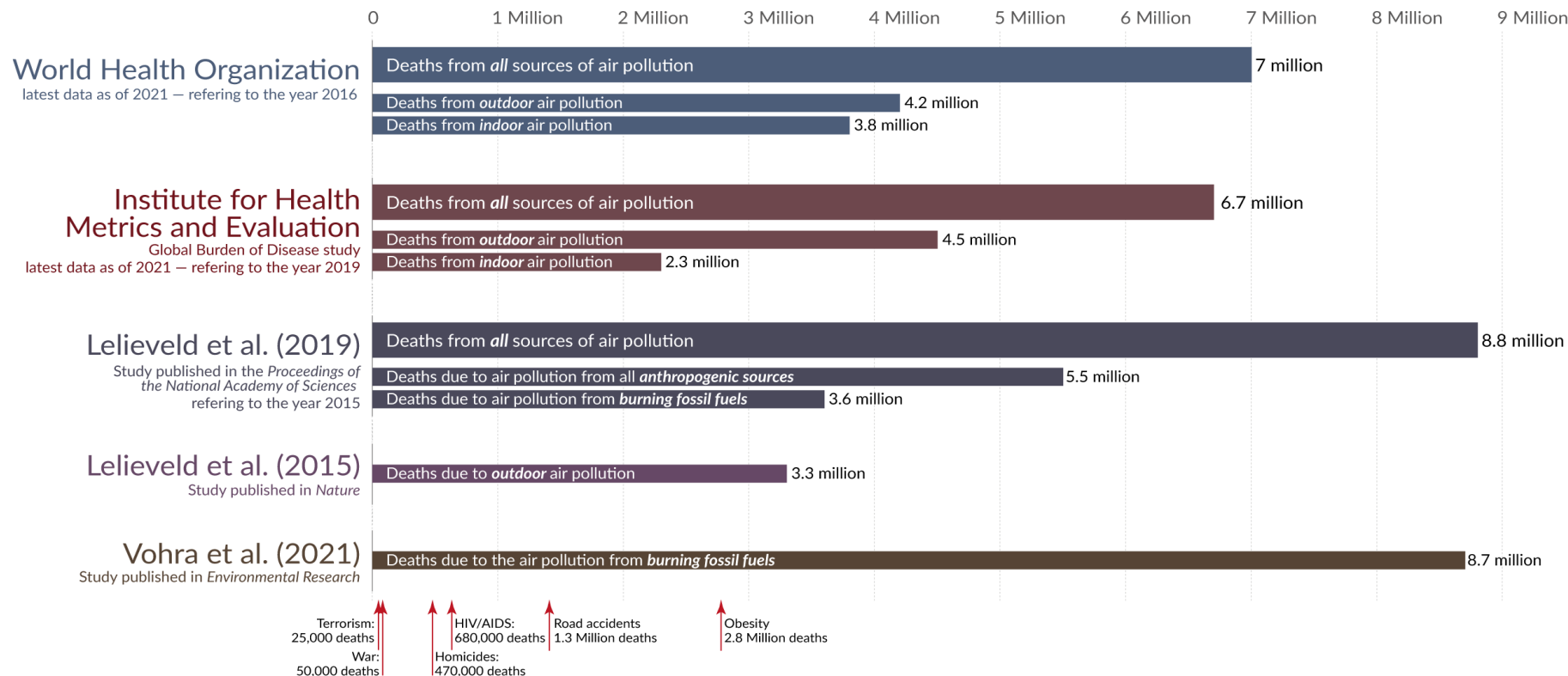
Asthma cost the US about \$56 billion in medical costs, lost school and work days, and early deaths in 2007.

# How many people die from air pollution each year?

Estimates of the global death toll from air pollution published in major recent studies

'All sources' includes both anthropogenic and natural sources:

- The largest source of natural air pollution is airborne dust in the world's deserts. Other natural sources are fires, sea spray, pollen, and volcanoes.
- Anthropogenic sources include electricity production; the burning of solid fuels for cooking and heating in poor households; agriculture; industry; and road transport.



Data on annual death tolls from other causes is the latest data from the World Health Organization, UCDP, and Global Terrorism Database as of November 2021.

OurWorldinData.org – Research and data to make progress against the world's largest problems.

Licensed under CC-BY by the author Max Roser

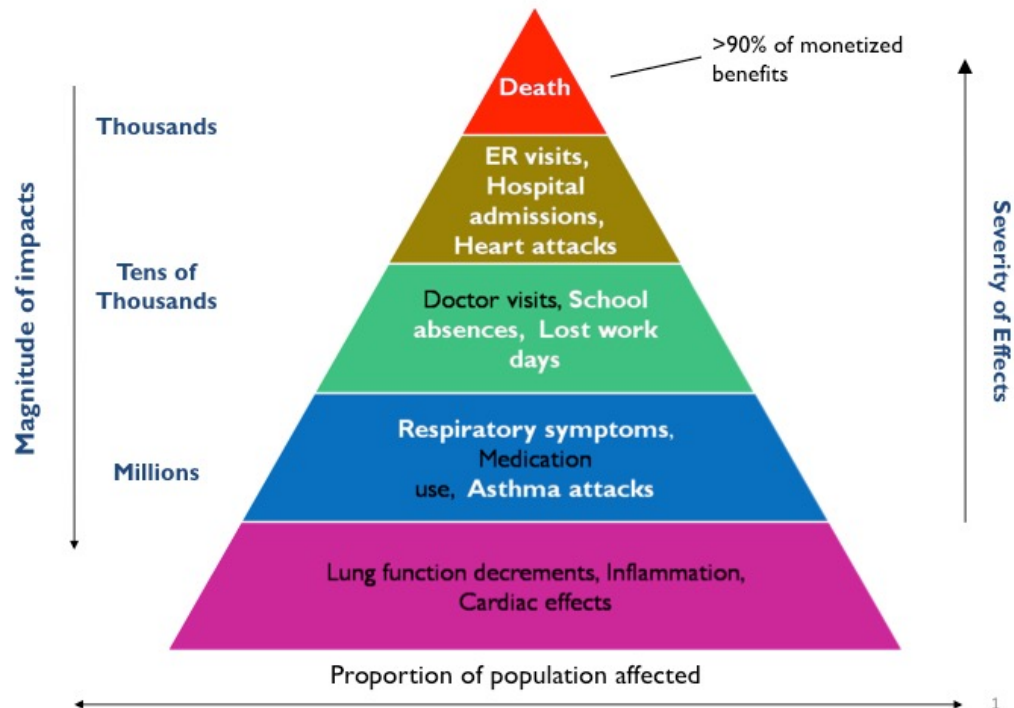
# Societal & Economic Impacts of Air Pollution

## Economic Costs of Air pollution

- Healthcare and medical bills
- Sick days from missed work
- Cost of regulations
- Lost revenue from crop damage
- Cost of cleaning polluted waters

Low-income and minority areas are at a greatest risk. These areas often experience poorest air quality as pollution sources are often located in these areas.

## A “Pyramid of Effects” from Air Pollution



# Societal & Economic Impacts of Air Pollution

## 2019 Deaths Attributed to Outdoor Air Pollution

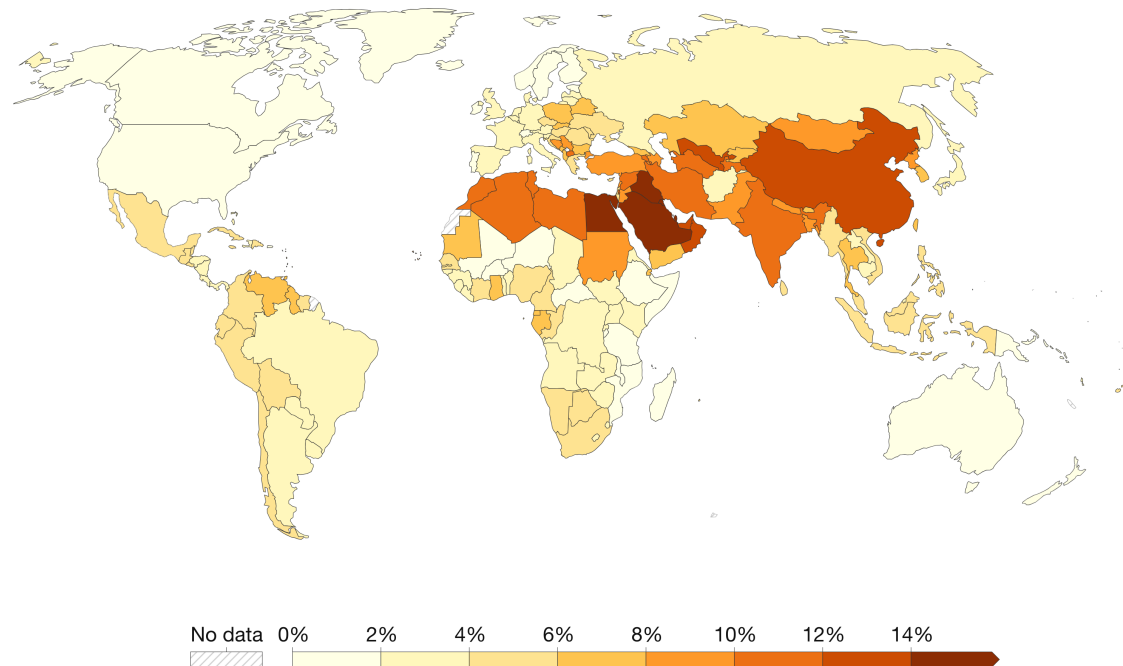
The World Health Organization (WHO) estimates that ambient (outdoor) air pollution caused 4.2 million premature deaths worldwide in 2019.

WHO estimates that about 90% of these premature deaths occurred in low-income and middle-income countries.

### Share of deaths attributed to outdoor air pollution, 2019

Share of deaths, from any cause, where ambient particulate matter air pollution is a risk factor.

Our World  
in Data



Data source: IHME, Global Burden of Disease (2019)

[OurWorldInData.org/outdoor-air-pollution](https://OurWorldInData.org/outdoor-air-pollution) | CC BY

# Societal & Economic Impacts of Air Pollution

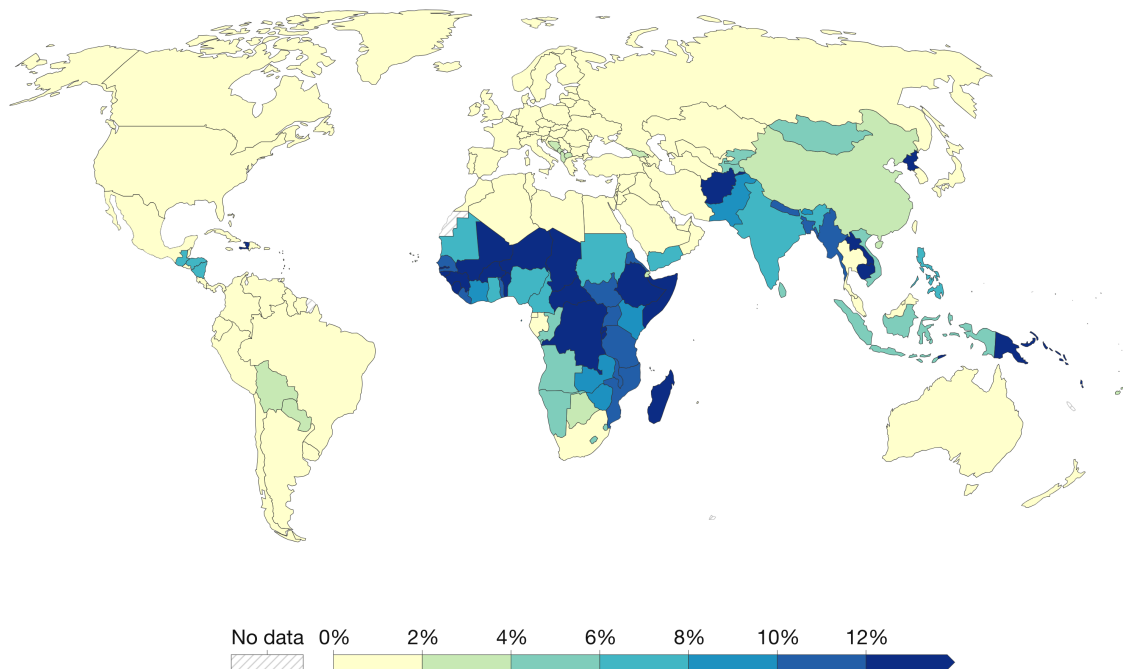
## 2019 Deaths Attributed to Indoor Air Pollution

- The World Health Organization (WHO) estimates that 2.4 billion people cook using open fires or stoves fueled by kerosene, biomass and coal, which generate harmful indoor air pollution.
- WHO estimates that indoor (household) air pollution caused 3.2 million deaths in 2019.

### Share of deaths from indoor air pollution, 2019

Share of deaths, from any cause, which are attributed to indoor air pollution – from burning solid fuels – as a risk factor.

Our World  
in Data



Data source: IHME, Global Burden of Disease (2019)

[OurWorldInData.org/indoor-air-pollution](https://OurWorldInData.org/indoor-air-pollution) | CC BY





# Power Plants and Neighboring Communities Mapping Tool



## Filters

### Fuel Type

All

Biomass

Coal

Gas

Oil

Other Fossil

### State

No states selected

### Demographic Index

0+

### Low-Income

0+

### People of Color

0+

### Less than High School E...

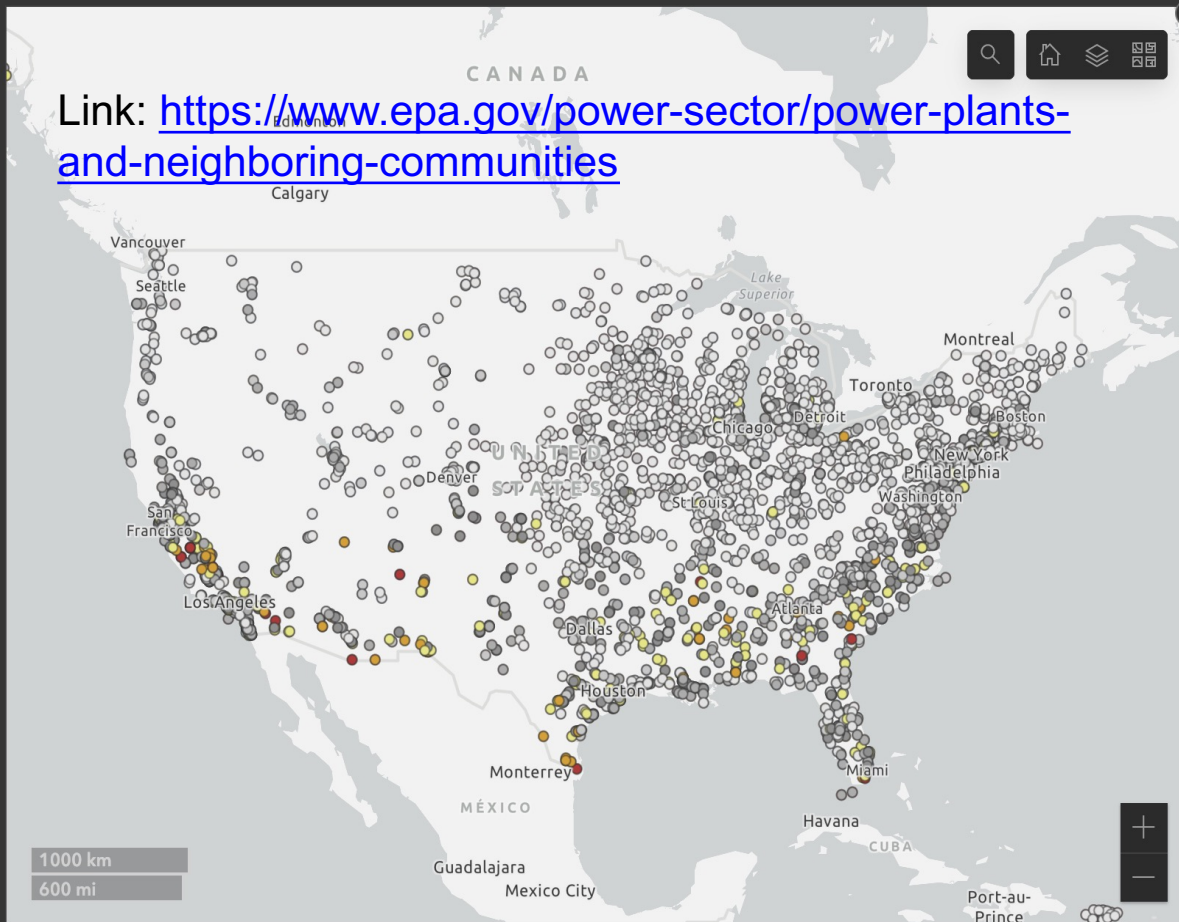
0+

### Linguistically Isolated

0+

### Population Less than 5

Link: <https://www.epa.gov/power-sector/power-plants-and-neighboring-communities>



## Legend

### Combustion Power Plants

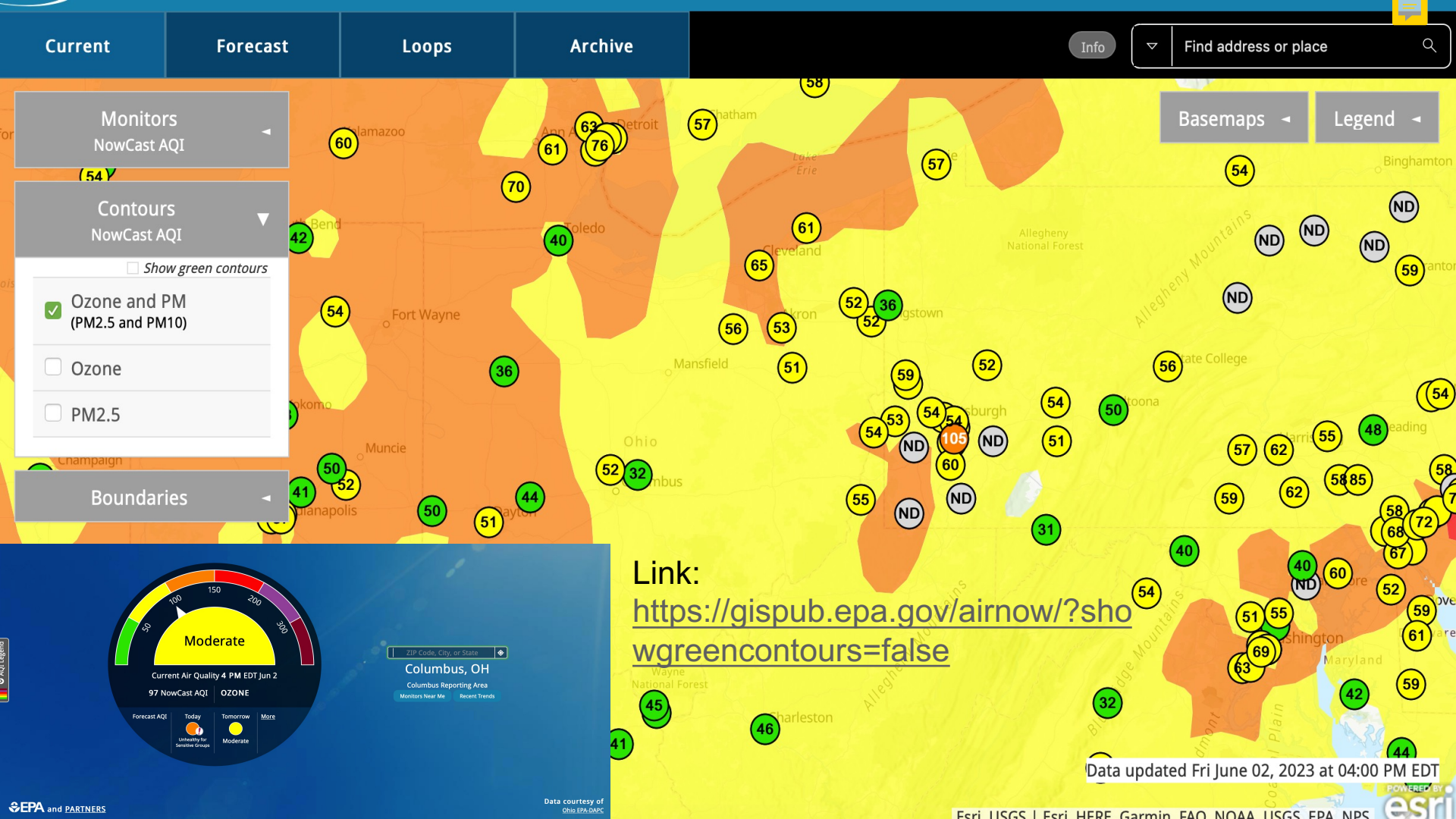
#### Demographic Index (National Percentile)

- 95 - 100
- 90 - 94
- 80 - 89
- 70 - 79
- 60 - 69
- 50 - 59
- 0 - 49

### Fuel Types

### Number of Power Plants

3,477



Current

Forecast

Loops

Archive

Info

Find address or place

Monitors

NowCast AQI

Contours

NowCast AQI

☐ Show green contours

☒ Ozone and PM  
(PM2.5 and PM10)

☐ Ozone

☐ PM2.5

Boundaries

Basemaps

Legend

Link:

<https://gispub.epa.gov/airnow/?showgreencontours=false>

Data updated Fri June 02, 2023 at 04:00 PM EDT

**Objective 4: Identify legislation, policies, and technological strategies for preventing and mitigating air pollution.**

# The U.S. Clean Air Act (1970)

**U.S. Clean Air Act (CAA)** – a federal law that regulates air emissions from stationary and mobile sources. It authorizes the Environmental Protection Agency (EPA) to establish standards (NAAQS, NESHAP) to protect public health and welfare and regulate emissions of hazardous air pollutants.

CAA was originally enacted in 1963 and amended in 1967, 1970, 1977, 1990. We typically refer to 1970 as year the CAA was enacted.

Requires the use of technology to minimize pollution from stationary and mobile sources.

Established **National Ambient Air Quality Standards (NAAQS)** - establishes limits for carbon monoxide (CO), ground-level ozone (O<sub>3</sub>), particulate matter (PM<sub>10</sub>, PM<sub>2.5</sub>), lead (Pb), sulfur dioxide (SO<sub>2</sub>), and nitrogen dioxide (NO<sub>2</sub>) allowed in outdoor air.

Established **National Emissions Standards for Hazardous Air Pollutants (NESHAP)** – establishes limits for 188 hazardous air pollutants (HAPs) allowed in outdoor air.

EPA assists all 50 states in adopting State Implementation Plans to meet emission national standards.

# NAAQS

## National Ambient Air Quality Standards (NAAQS)

Standards were set for the 6 common pollutants known as **Criteria Pollutants** in outdoor air.

**Primary Standard** protects humans, including sensitive groups such as asthmatics, children, and the elderly.

**Secondary standard** protects against decreased visibility and damage to animals, crops, vegetation, and buildings.

Pollutant		Standard	Averaging Time	Level	Form
Carbon Monoxide (CO)		Primary	8 hours	9 ppm	Not to be exceeded more than once per year
			1 hour	35 ppm	
Lead (Pb)		Primary and Secondary	Rolling 3 month average	0.15 µg/m3	Not to be exceeded
Nitrogen Dioxide (NO2)		Primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Primary and Secondary	1 year	53 ppb	Annual Mean
Ozone (O3)		Primary and Secondary	8 hours	0.070 ppm	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	PM2.5	Primary	1 year	12.0 µg/m3	annual mean, averaged over 3 years
		Secondary	1 year	15.0 µg/m3	annual mean, averaged over 3 years
		Primary and Secondary	24 hours	35 µg/m3	98th percentile, averaged over 3 years
	PM10	Primary and Secondary	24 hours	150 µg/m3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO2)		Primary	1 hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		Secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year



# U.S. Air Quality Improving for all 6 Criteria Pollutants


[Intro](#)[Growth](#)[NAAQS](#)[Visibility](#)[Toxics](#)[Spotlight](#)[Summary](#)

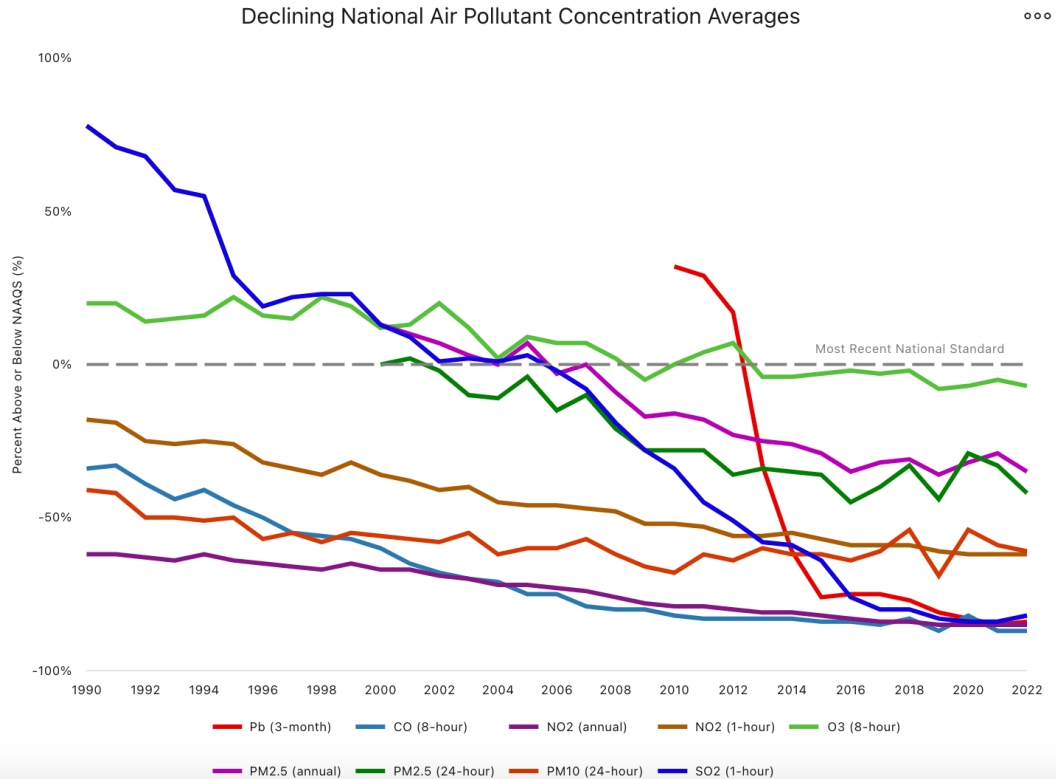
## Air Quality Trends Show Clean Air Progress

Nationally, concentrations of air pollutants have dropped significantly since 1990:

- Carbon Monoxide (CO) 8-Hour, ↓ 81%
- Lead (Pb) 3-Month Average, ↓ 88% (from 2010)
- Nitrogen Dioxide (NO<sub>2</sub>) Annual, ↓ 60%
- Nitrogen Dioxide (NO<sub>2</sub>) 1-Hour, ↓ 54%
- Ozone (O<sub>3</sub>) 8-Hour, ↓ 22%
- Particulate Matter 10 microns (PM<sub>10</sub>) 24-Hour, ↓ 34%
- Particulate Matter 2.5 microns (PM<sub>2.5</sub>) Annual, ↓ 42% (from 2000)
- Particulate Matter 2.5 microns (PM<sub>2.5</sub>) 24-Hour, ↓ 42% (from 2000)
- Sulfur Dioxide (SO<sub>2</sub>) 1-Hour, ↓ 90%
- Numerous air toxics have declined with percentages varying by pollutant

Despite increases in air concentrations of pollutants associated with fires, carbon monoxide and particle pollution, national average air quality concentrations remain below the current, national standards.

 Air quality concentrations can vary year to year, influenced not only by pollution emissions but also by natural events, such as dust storms and [wildfires](#), and variations in weather.

[Concentration Averages](#)[Emission Totals](#)

# National Emissions Standards for Hazardous Air Pollutants (NESHAP)

**NESHAP** established standards for **Hazardous Air Pollutants (HAPs)** – pollutants that are known or suspected of causing serious health effects like cancer, reproductive disorders, birth defects, nervous system disorders, immune system dysfunction, endocrine disorders and organ damage. These pollutants also adversely impact wildlife, plants, waters and soils.

**U.S. EPA has a list of 188 hazardous air pollutants (HAPs)** that it regulates and monitors. Link to HAPs:  
<https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications>

- EPA's List of 188 HAPs includes compounds like arsenic compounds, asbestos, benzene, chloroform, cyanide compounds, formaldehyde, methanol, mercury compounds, phenol, radionuclides, toluene, and vinyl chloride.
- These pollutants are emitted by thousands of different sources including factories, refineries, power plants, manufacturing, fuels, building materials, cleaning solvents, cars, trucks, equipment, etc.

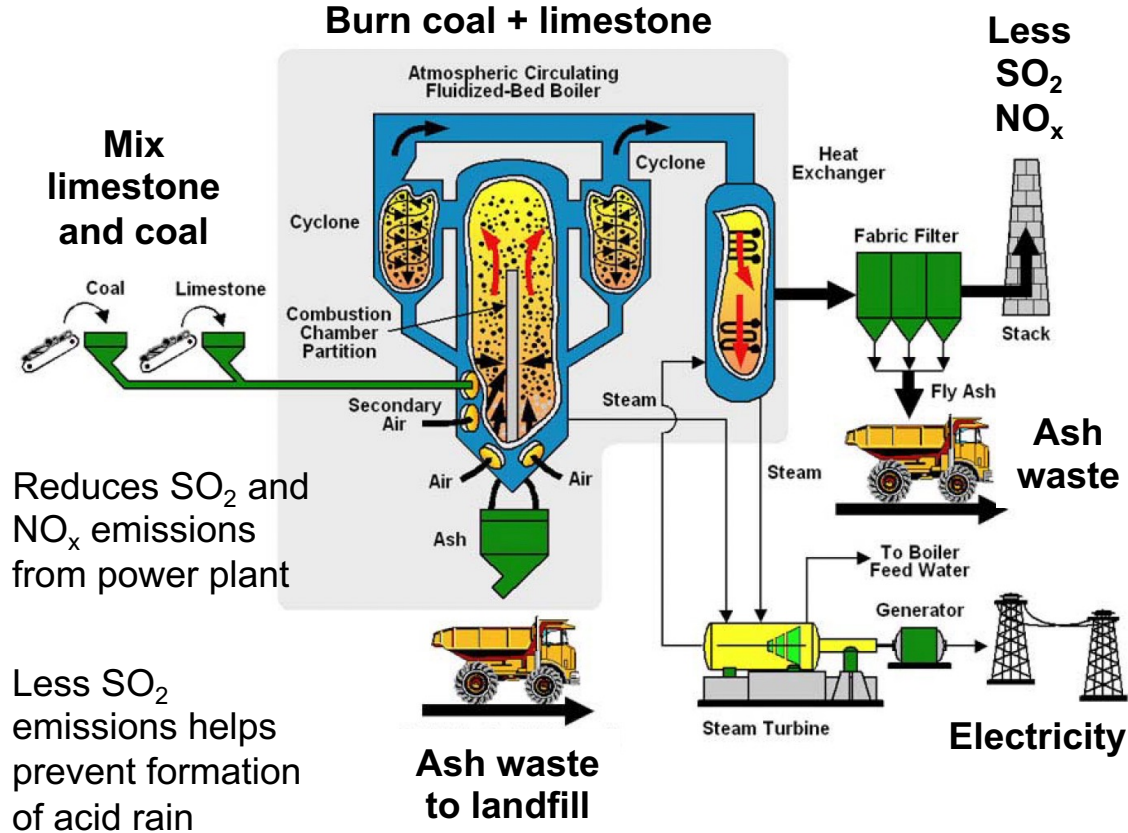
# How can we reduce air pollution?



Technology	Policy
Filters	Clean Air Act
Electrostatic precipitators	Cap-and-trade
Catalytic converters	Funding for research and development
Scrubbers	Green taxes
Ventilation systems	Penalties and fines
Sensors	Compliance monitoring and inspections
Fluidized bed combustion	Tax exemption programs

# Fluidized Bed Combustion used by Coal-Fired Power Plant

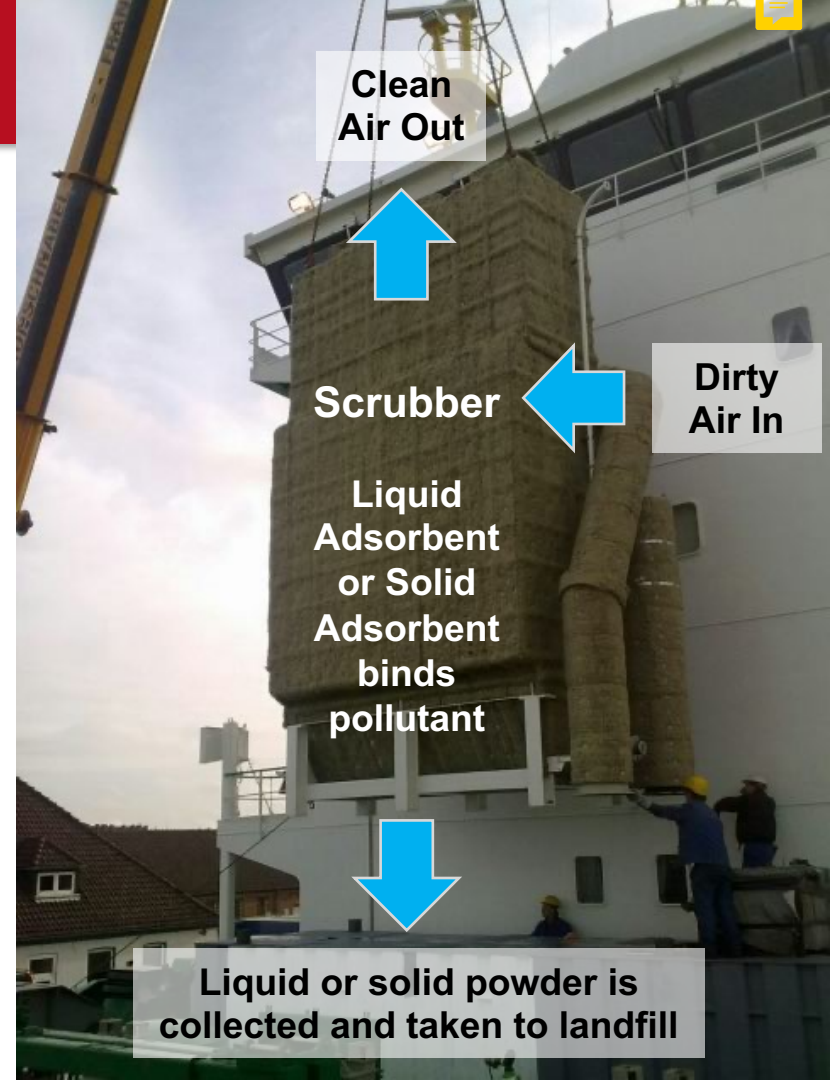
**Fluidized Bed Combustion** -used by **coal-fired power plants**. The plant mixes coal with limestone ( $\text{CaCO}_3$ ) prior to burning it, the limestone binds to the sulfur and nitrogen in the coal and neutralize coal's acidic components when its burned. The sulfur and nitrogen ash waste settles out of the exhaust air, is collected, and disposed of in landfill.



# Scrubber

**Scrubber** - system that removes particulate matter or toxic gases from industrial exhaust (e.g., power plant). Liquid (e.g., water, chemical solution) or solid adsorbents (e.g., soda ash) are sprayed into the polluted air, they bind to the pollutants and cause it to precipitate or settle out, thus removing it from exhaust gases.

The resulting liquid solution or solid powder now contains the pollutant and must be collected and disposed of safely (e.g., hazardous waste landfill).






# Catalytic Converter

**Catalytic converter** - device on the exhaust system of internal combustion engine that converts toxic emission gases ( $\text{CO}$ ,  $\text{NO}_x$ ) into less-toxic gases ( $\text{CO}_2$ ,  $\text{N}_2$ ,  $\text{O}_2$ ).

Used on gasoline and diesel vehicles. Can also be used for coal-fired power plants. When gasoline, diesel, or coal is burned for energy it emits toxic gases like carbon monoxide and nitrogen oxides.

Consists of a metal catalyst (platinum, rhodium, or palladium). When the high-temperature exhaust gases,  $\text{CO}$  and  $\text{NO}_x$ , pass over the metal catalyst, the pollutants are chemically converted into oxygen, nitrogen, and carbon dioxide.

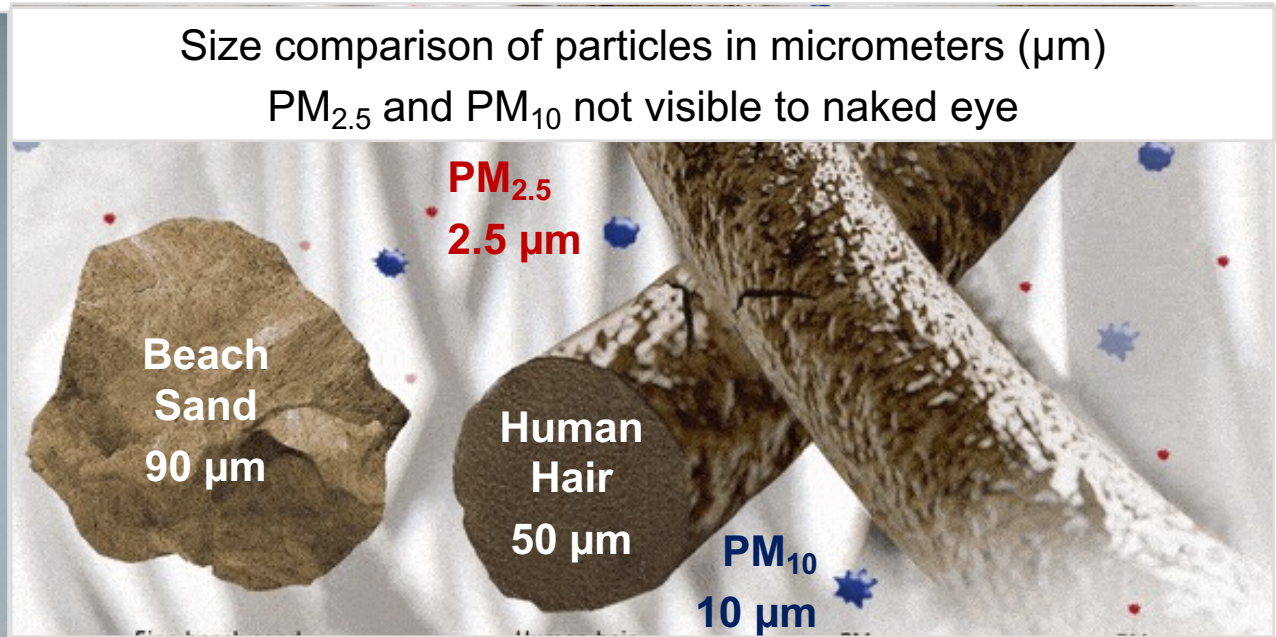
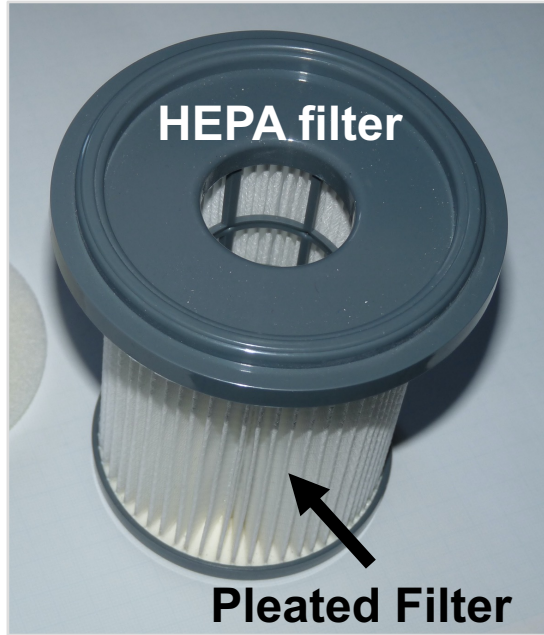


Catalytic converter on the underside of an old truck



Honeycomb core inside of catalytic converter containing platinum, rhodium, palladium

# HEPA Filter (High Efficiency Particulate Air Filter)



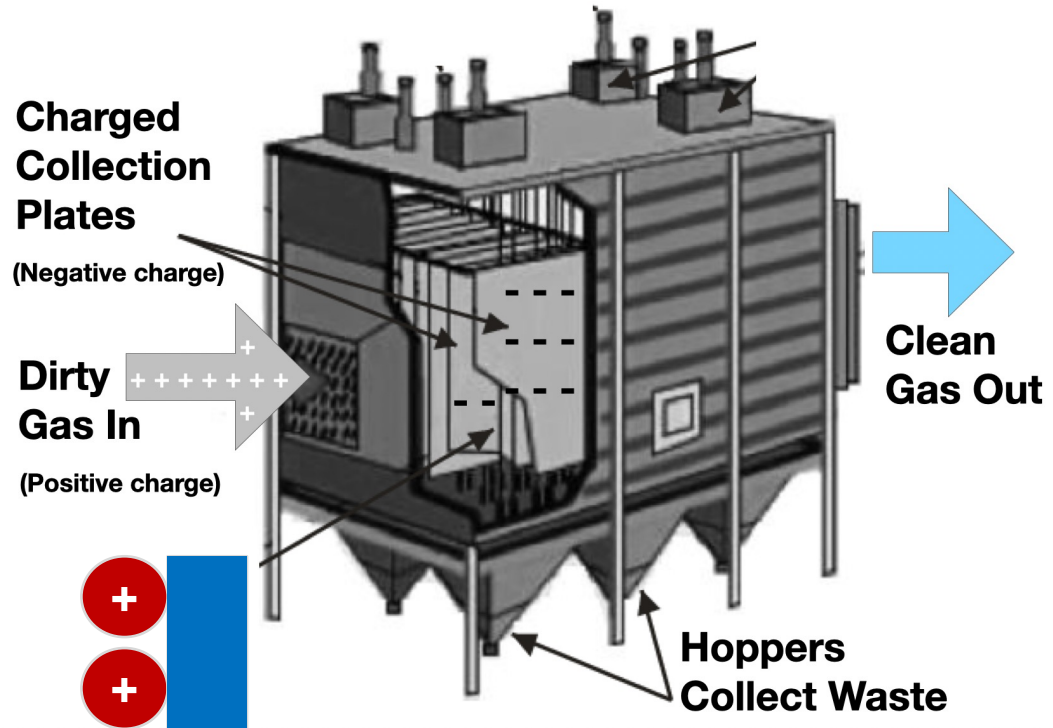
**HEPA Filtration** – a pleated mechanical air filter that can remove 99.97% of dust, pollen, mold, bacteria and airborne particles with a size of  $0.3 \mu\text{m}$ ). Particles that are larger or smaller than  $0.3 \mu\text{m}$  are trapped with even higher efficiency than 99.97%.

# Electrostatic Precipitator

## Electrostatic Precipitator

= device used in industry that removes particles, dust, and smoke pollution from gas exhaust using an electrostatic energy to charge particles positive or negative. The charged pollution particles are attracted to metal plates carrying the opposite charge (e.g., positive dust particle collects on negative metal plate). Particles are washed off the plates, collected as solid waste, and disposed of safely in a landfill.

Electrostatic precipitators can remove 99% of pollution



# Policies to Reduce Air Pollution

- **Clean Air Act** – See previous CAA slides.
- **Funding for Research and Development** See previous slides on technology.
- **Compliance Monitoring and Inspections** Is the responsibility of Environmental Protection Agency (EPA)
  - **Penalties and Fines** – EPA levies against companies who don't meet air quality standards.
- **Green Taxes** – economic approach to limit pollution when a financial charge is levied against activities that are harmful to the environment. Some examples include severance tax for natural resources, carbon tax for fossil fuel use, licensing fees, waste disposal, duties on imported goods).
- **Cap and Trade** – economic approach to control pollution in which a government sells a limited number of permits (caps) to companies that allow the emission of a certain quantity of a specific pollutant . Most notable example is carbon dioxide emission trading of the 2015 Paris Climate Agreement, which is designed to limit climate change.
- **Tax Exemption Programs** – economic approach to limit pollution by allowing a polluter to install a technology that reduces pollution and in return a government reduces the amount of taxes the company owes.