Air Pollution Sources and Effects

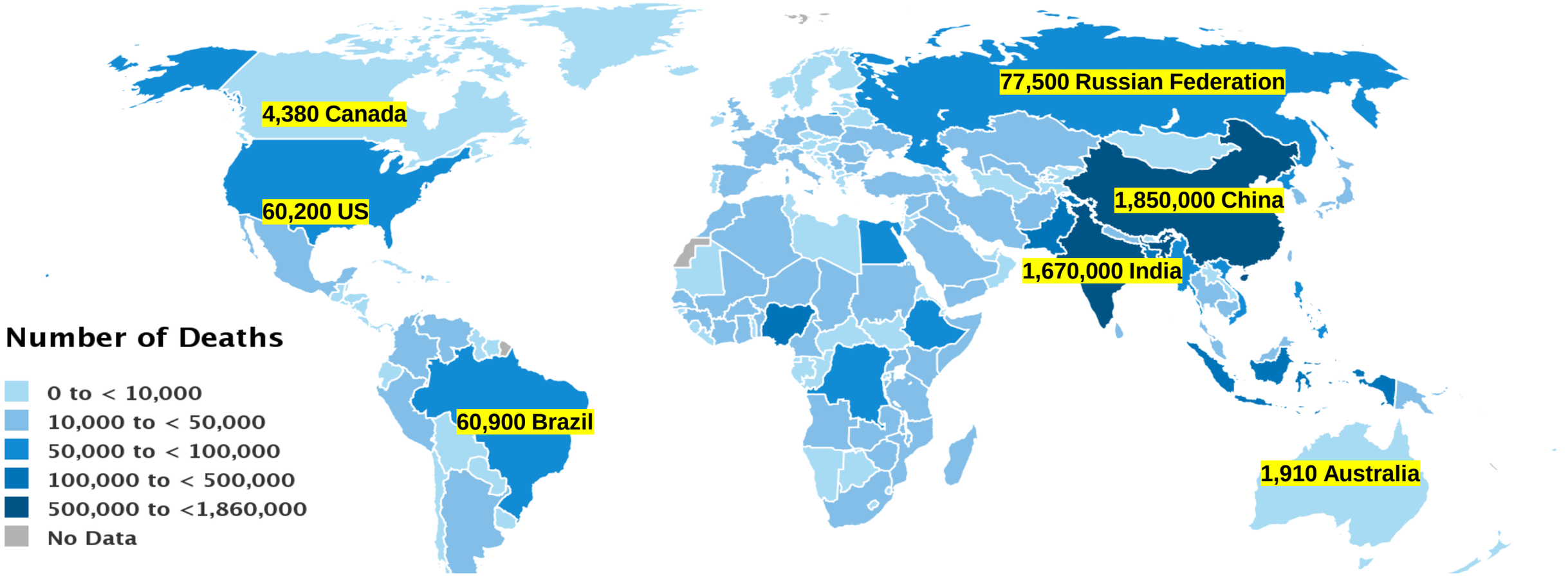
Air Pollution

- **Air pollution**- the introduction of chemicals, particulate matter, or microorganisms into the atmosphere (**Troposphere**-***ground-level pollution***) at concentrations high enough to harm plants, animals (including humans), and materials such as buildings, or to alter ecosystems.

- **Air pollution can occur *naturally* such as volcanos, vegetation (tree leaves), wildfires or *Human activities* such as automobiles, airplanes, industrial, agriculture, waste.**

- **Air pollution is a global system** with inputs of different sources of pollution and outputs, which are components of the atmosphere (clouds, particles), biosphere, vegetation, & soil that remove air pollutants.

Air Quality in the World



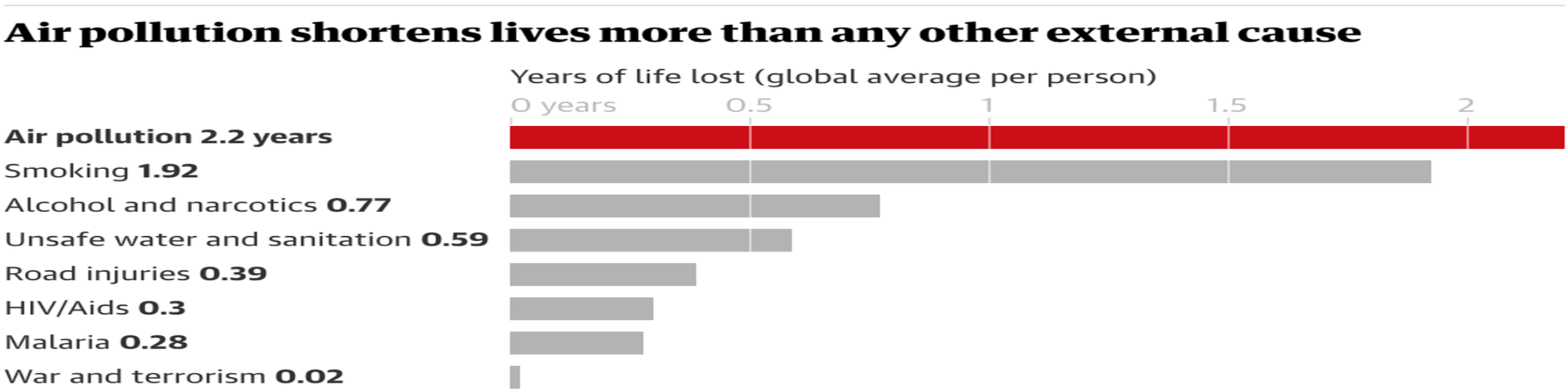
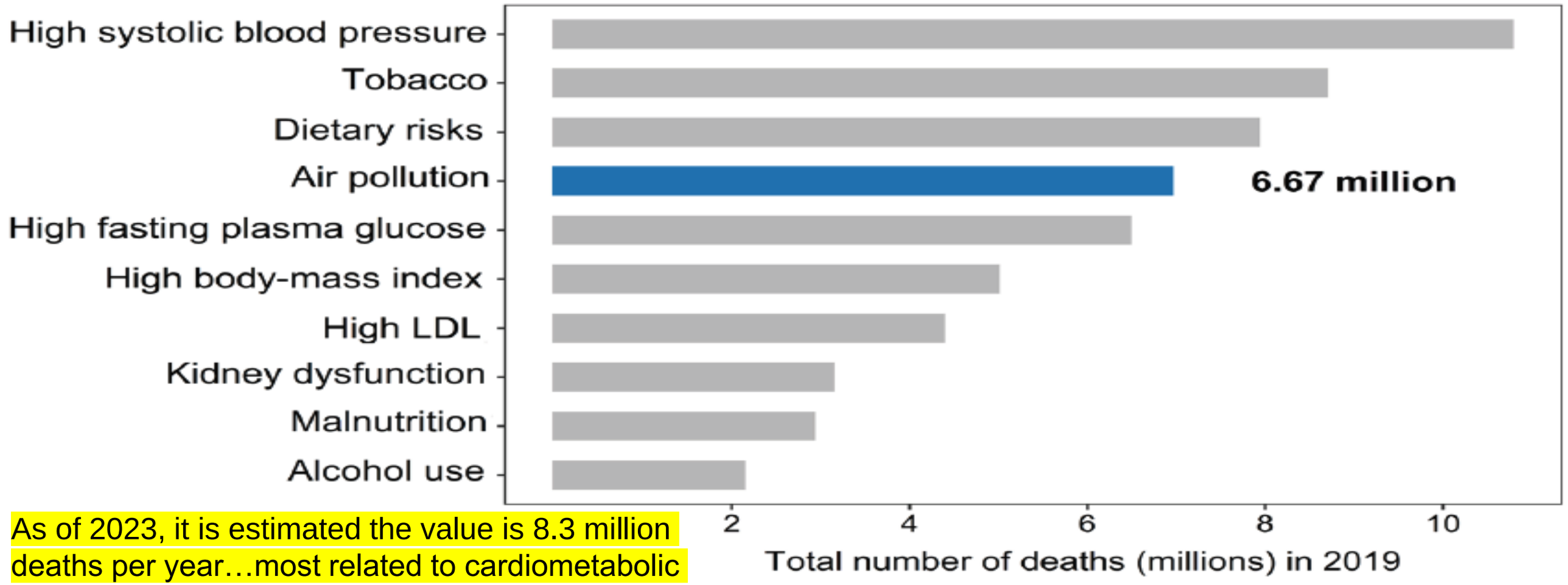
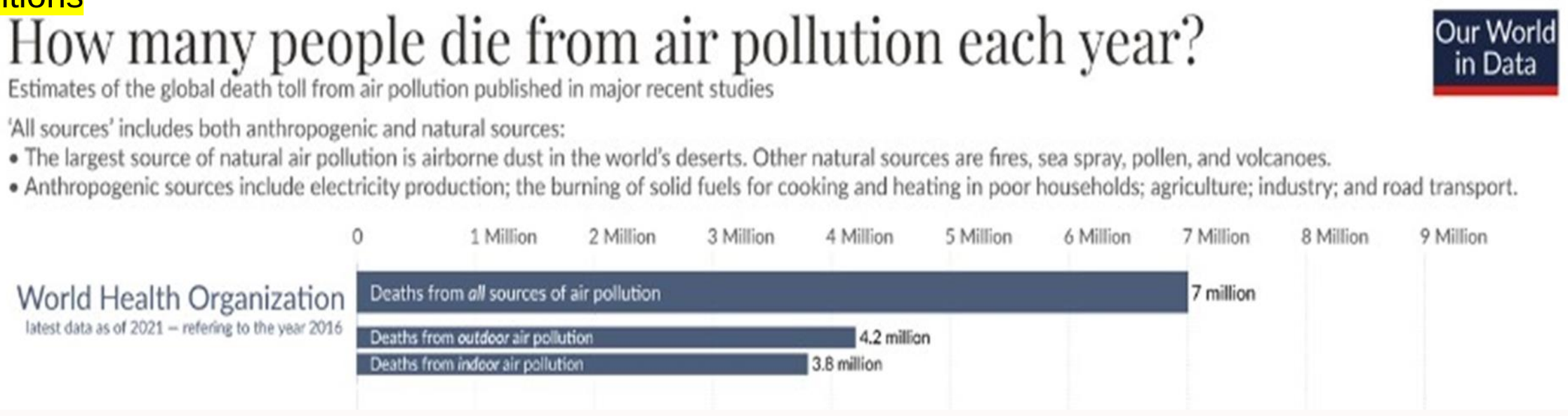


FIGURE 1 Global ranking of risk factors by total number of deaths from all causes in 2019.



As of 2023, it is estimated the value is 8.3 million deaths per year…most related to cardiometabolic conditions



Air pollution is shortening life expectancies

New research link…smoke + ozone pollution video

Major Air Pollutants (6 major)

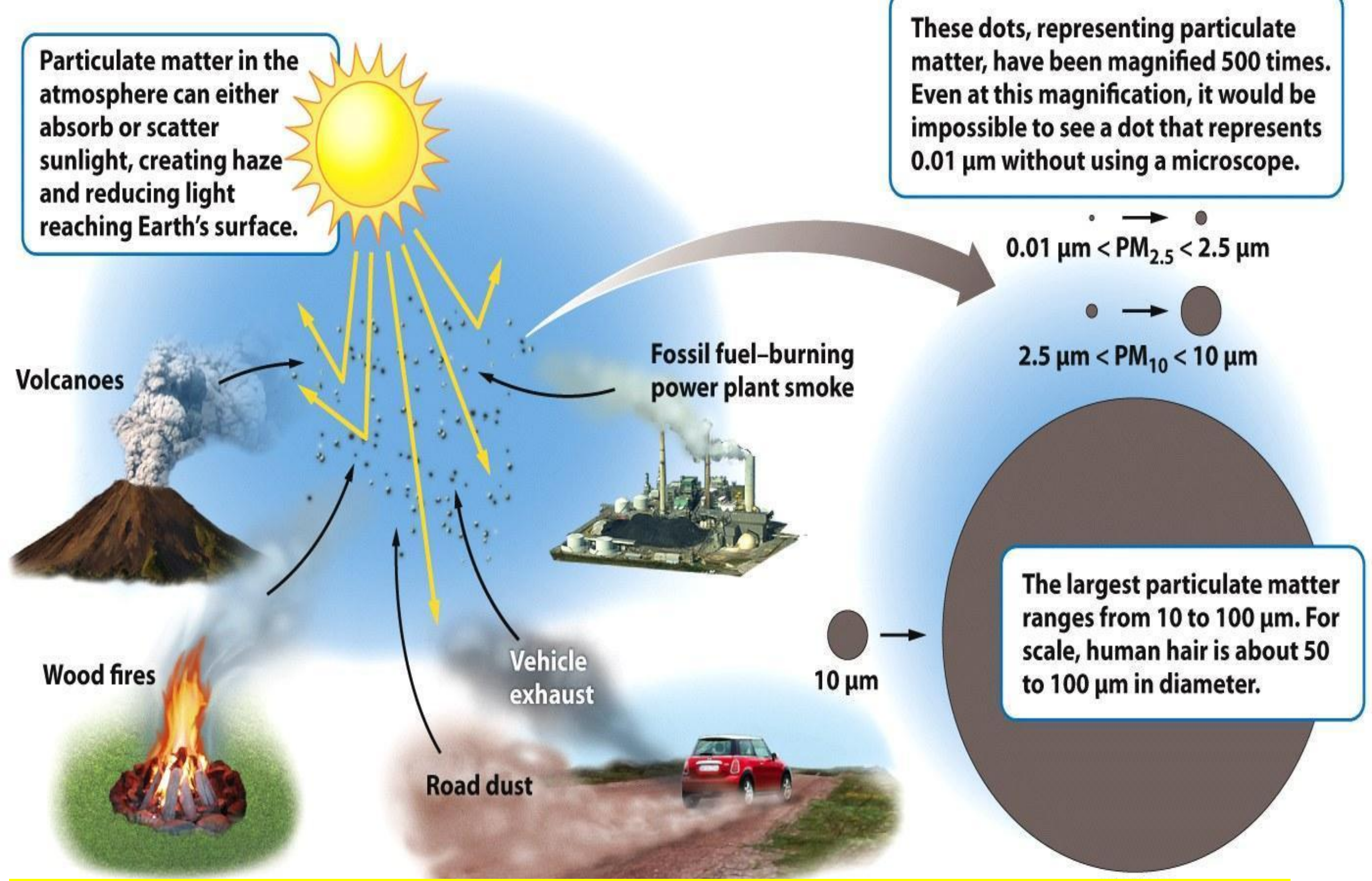
According to legislators, environmental scientists & other methods of monitoring air pollution controls…these are **the 6 major pollutants** that significantly threaten human well beings, ecosystems, and/or infrastructures.

Under the Clean Air Act, these are called *criteria air pollutants*.
The EPA must specify allowable concentrations.

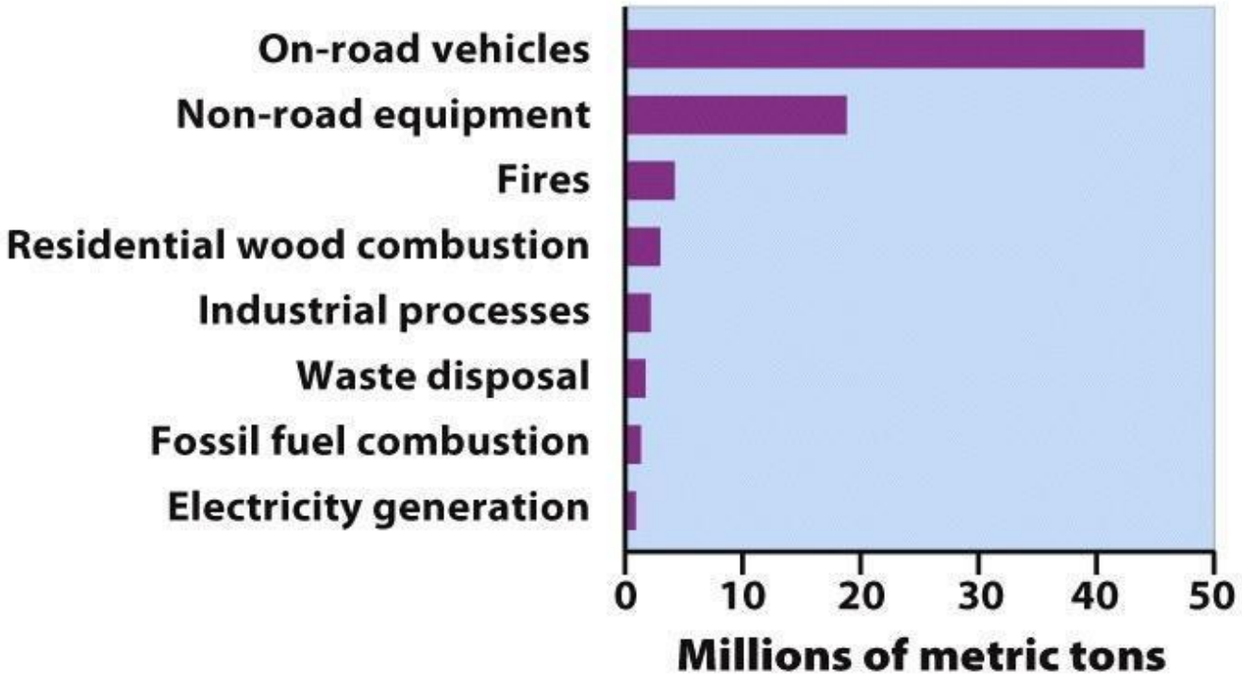
1. Sulfur Dioxide (combustion of fuels such as coal & oil)

2. Nitrogen Oxides (Motor vehicles & stationary fossil fuel combustion, lightning, forest fires, decomposition)

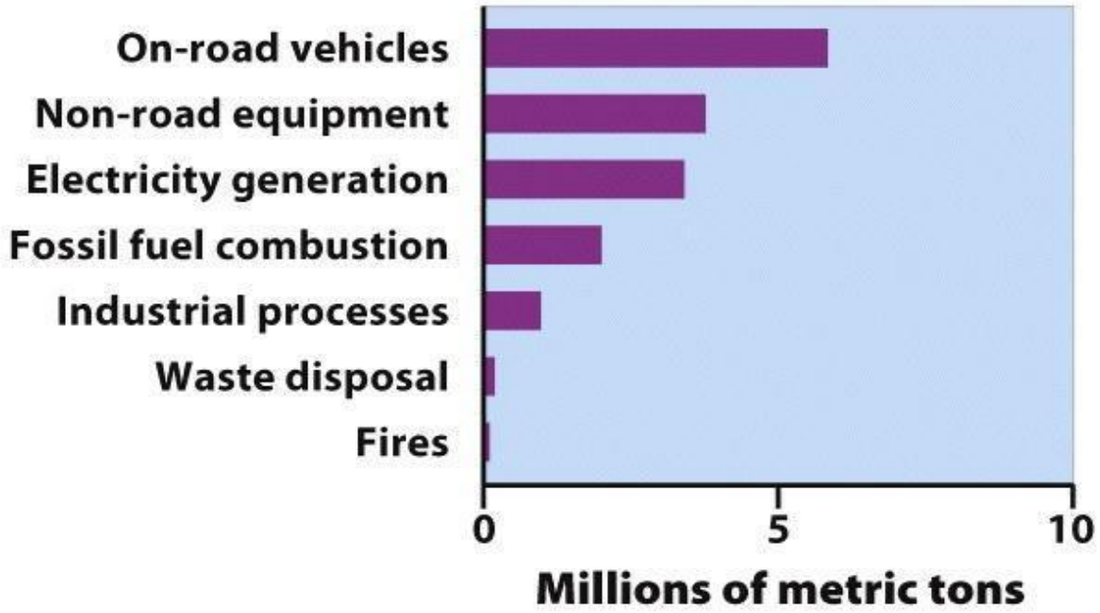
3. Carbon Oxides (emission in vehicle exhaust, respiration)



4. Particulate Matter (combustion of wood, animal manure, biofuels, coal, oil, & gasoline) Natural or anthropogenic....ranges in particle size & absorb or scatter light.

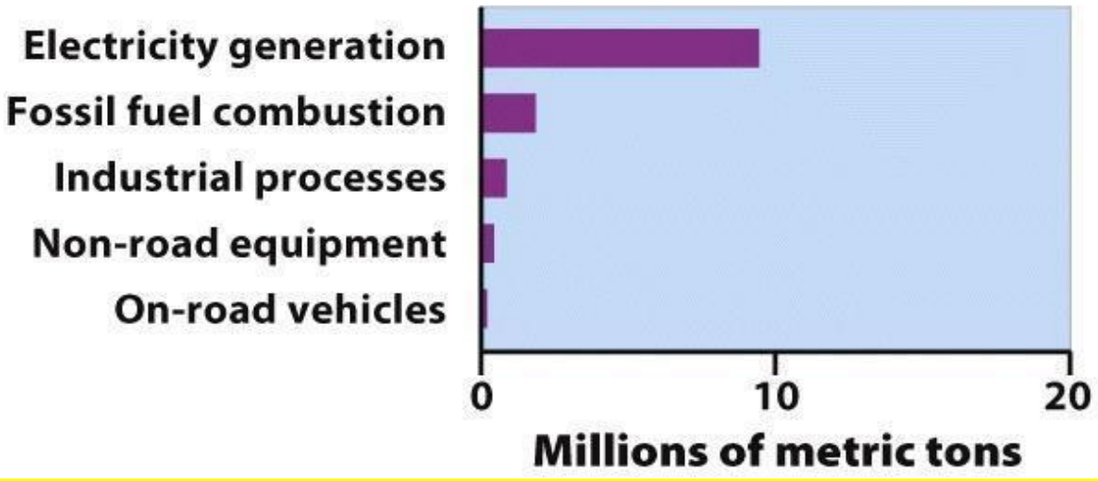


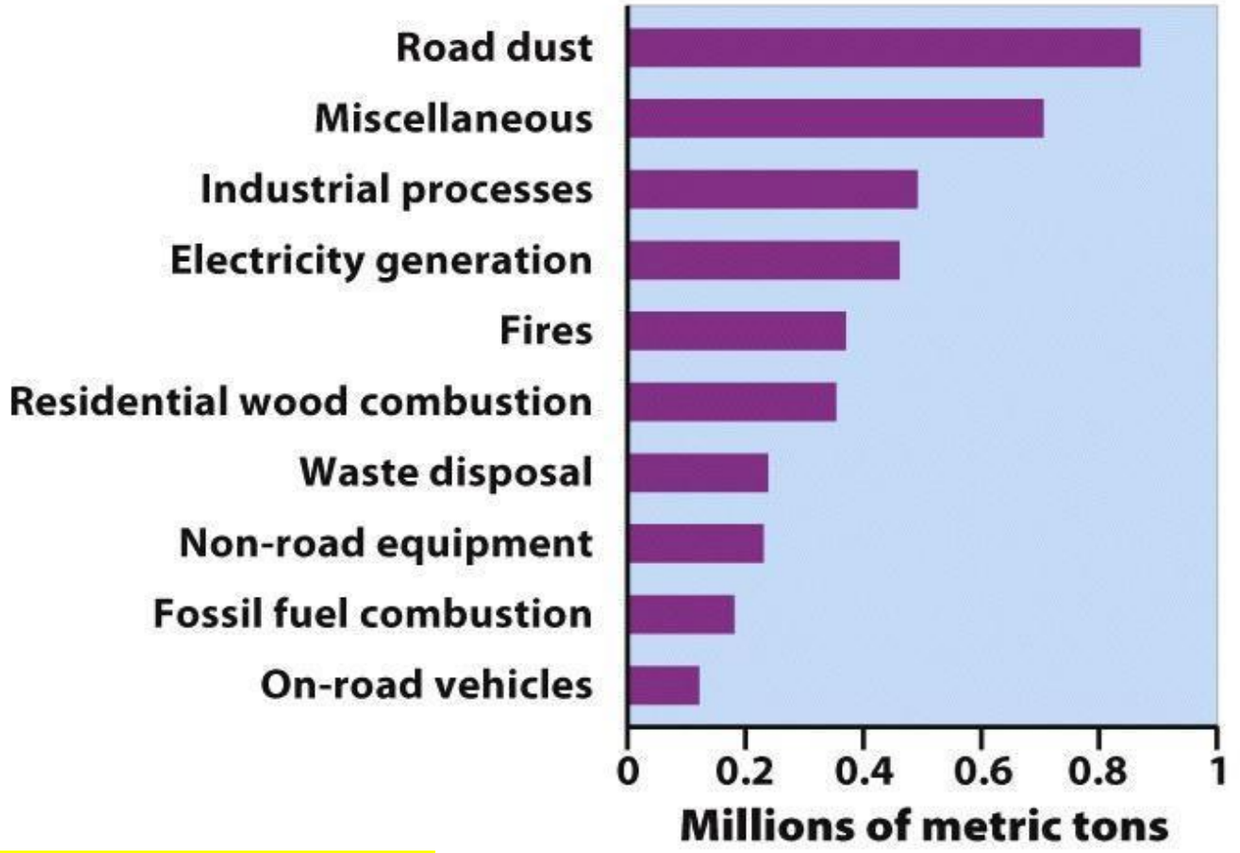
(a) Carbon monoxide



(b) Nitrogen oxides

Smaller PM# are considered especially dangerous to human health because they bypass many of our body's defenses





atter ($PM_{2.5}$)

"Transportation," are the largest source of *CO & NOx*. *SO2* is the generation of **electricity primarily coal**. *Particular Matter* are **road dust, industrial processes, electricity & natural/man-made fires**

U.S. Greenhouse Gas Emissions in 2021*

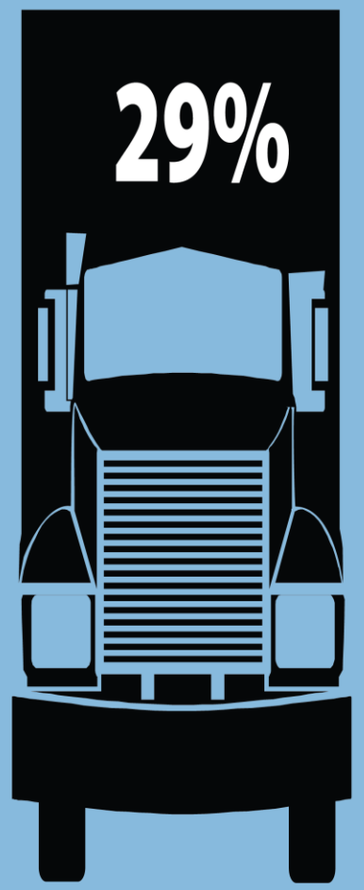
3%
Fluorinated Gases

6%
Nitrous Oxide (N_2O)

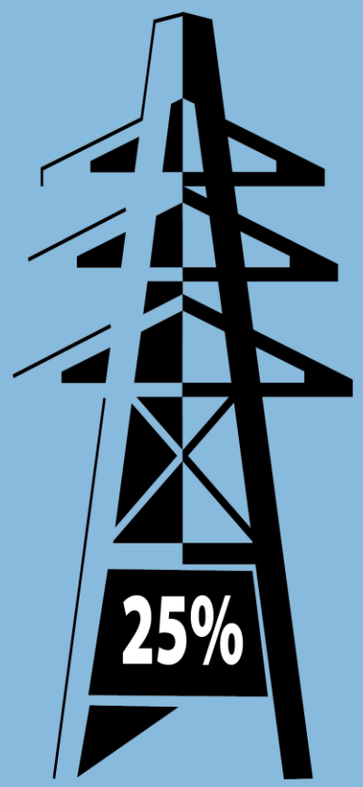
11%
Methane (CH_4)

79%
Carbon Dioxide (CO_2)

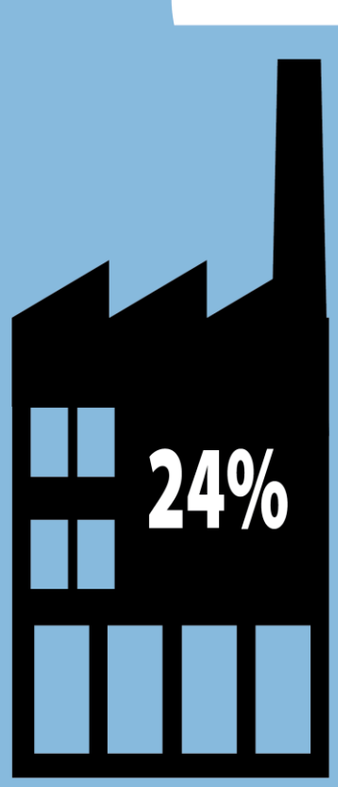
Total U.S. Greenhouse Gas Emissions by Economic Sector in 2021*



Transportation



Electric Power Industry



Industry

Agriculture

Commercial

Residential

Major Air Pollutants Con't

5. Ozone (sun acting on SO_2 & NOx. Emitted from smokestacks or automobiles....*secondary pollutant (undergone transformation)* ....VOC + NOx + sunlight)

- **Volatiles Organic Compounds (VOCs)** (organic compound that become vapors at typical atmospheric temperatures. Hydrocarbons, such as gasoline, lighter fluid, oil-based paints, dry-cleaning fluids, aerosol cans & perfumes

6. Lead (paint & gasoline...phased out, deposited on ground & water)

Mercury (coal & oil...phased out, bioaccumulation in fish & marine life...not as damaging as Pb due to atmospheric)

Primary vs. Secondary Pollutants

1. **Primary pollutants-** polluting compounds that come directly out of the *smoke-stack, exhaust pip, or natural* emission source.

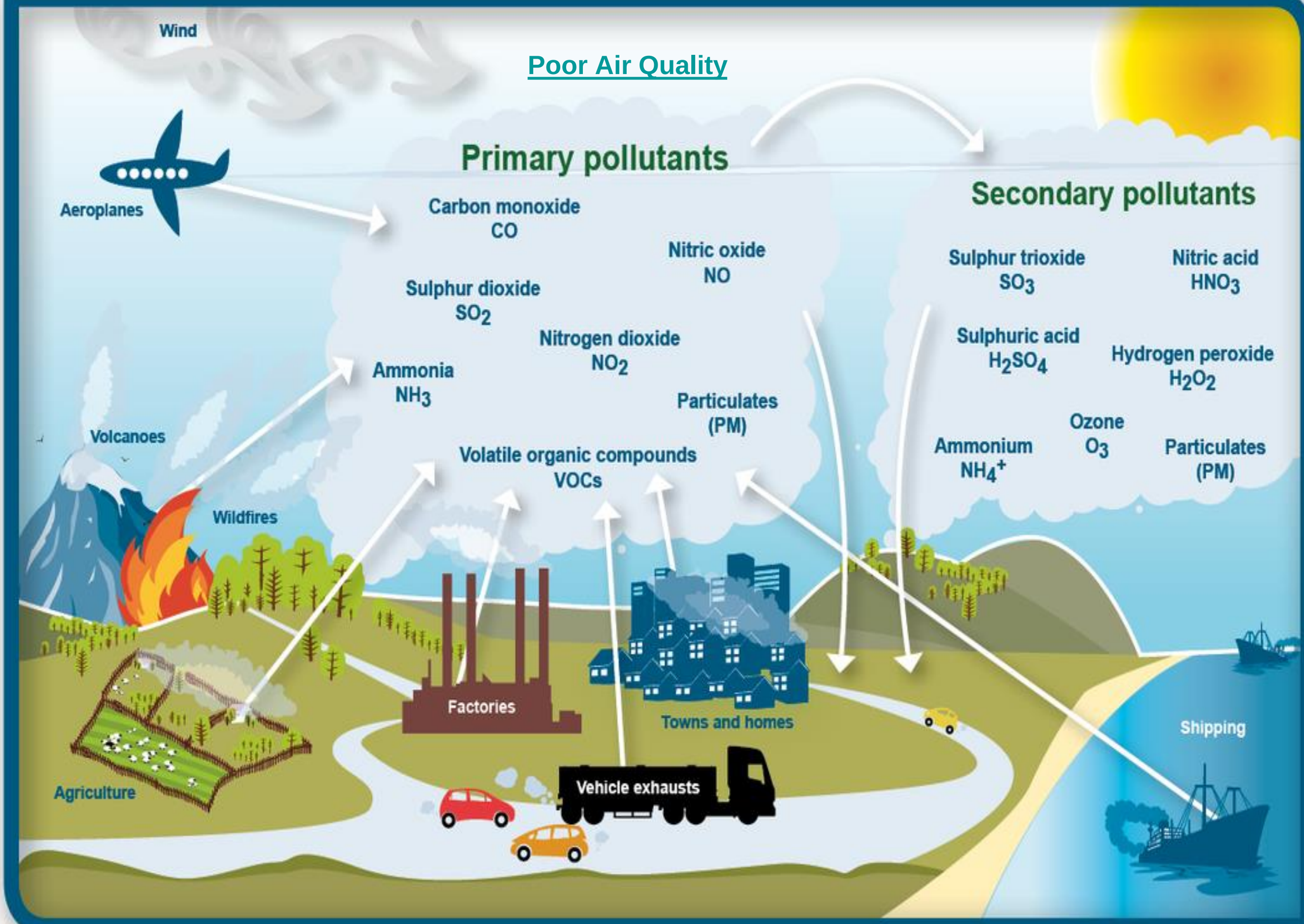
   - *Ex. CO, CO_2, SO_2, NOx, and most suspended particulate matter.* ***(major sources)***

2. **Secondary pollutants-** **pollutants that have undergone transformation** in the presence of sunlight, water, oxygen, or other compounds.

   - *ex. Nitric acid & sulfuric acid (acid deposition – lowers pH), Photochemical oxidants & Ozone* (damage to respiratory system, lowers immunity, can lead to heart disease and degrade plant tissue, rubber and plastics)

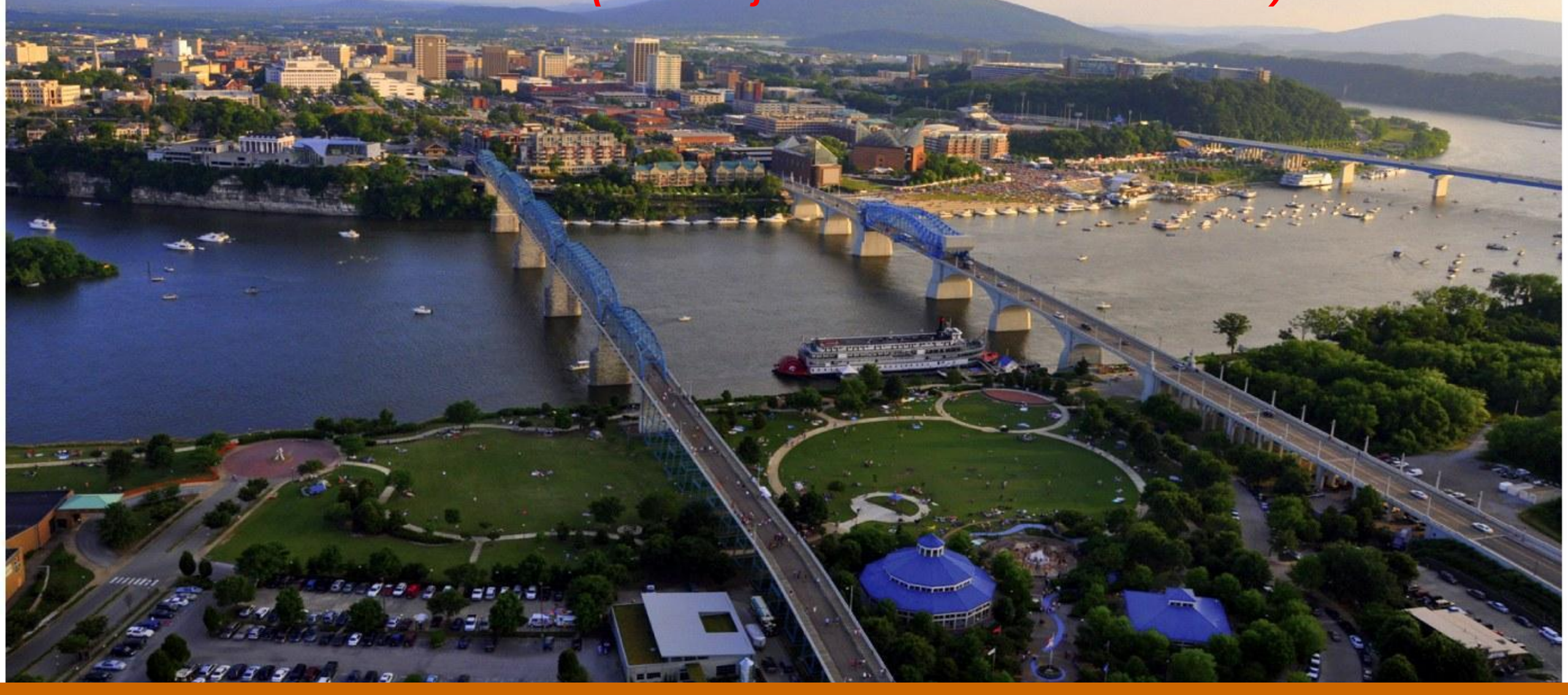
Occurs more rapidly in the day (due to the sun's radiation energy) and wet conditions (due to the water component).

Poor Air Quality

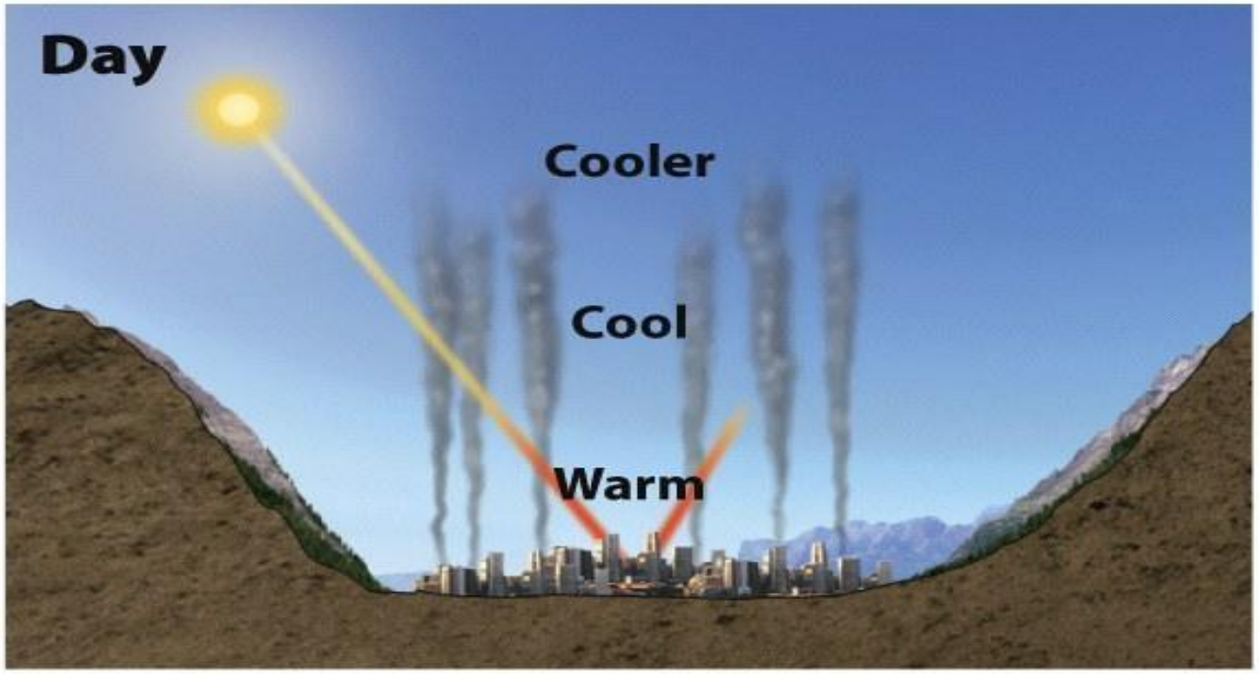


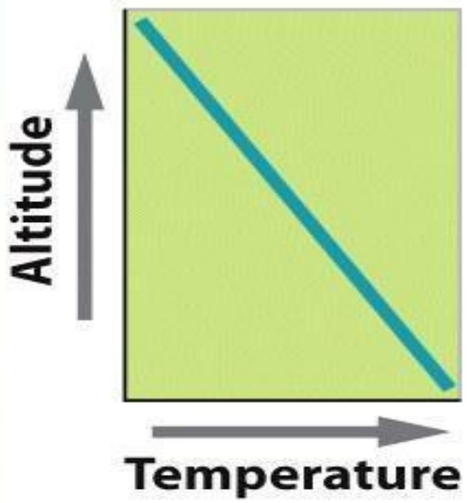
Chattanooga, Tennessee…considered to be one of the highly polluted cities in the U.S in the 1960s (based on location trapping the pollution…btwn mountains "bowled").

By 1969, high rates of respiratory disease led ppl to take action & created a *new* ***Air Pollution Control Ordinance (with conjunction w/Clean Air Act 1970).***



Within 3 yrs., the city had cleaned up the air quality and created new economically & environmentally sustainable businesses such as the largest fleet of electric public busing service in the U.S.

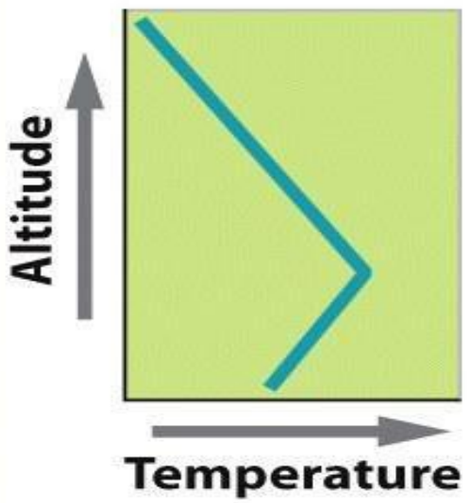




A. Under normal conditions, temps decrease while altitude increases.

(a) Normal conditions

Cool air stays close to the surface, the warm inversion layer traps emissions that then accumulate beneath it.



B. Mid-altitude, relatively warm inversion layer traps & accumulates emissions

(b) Thermal inversion

when a relatively warm layer of air at mid-altitude covers a layer of cold, dense air below.

Figure 15.8
Environmental Science

Acid Deposition

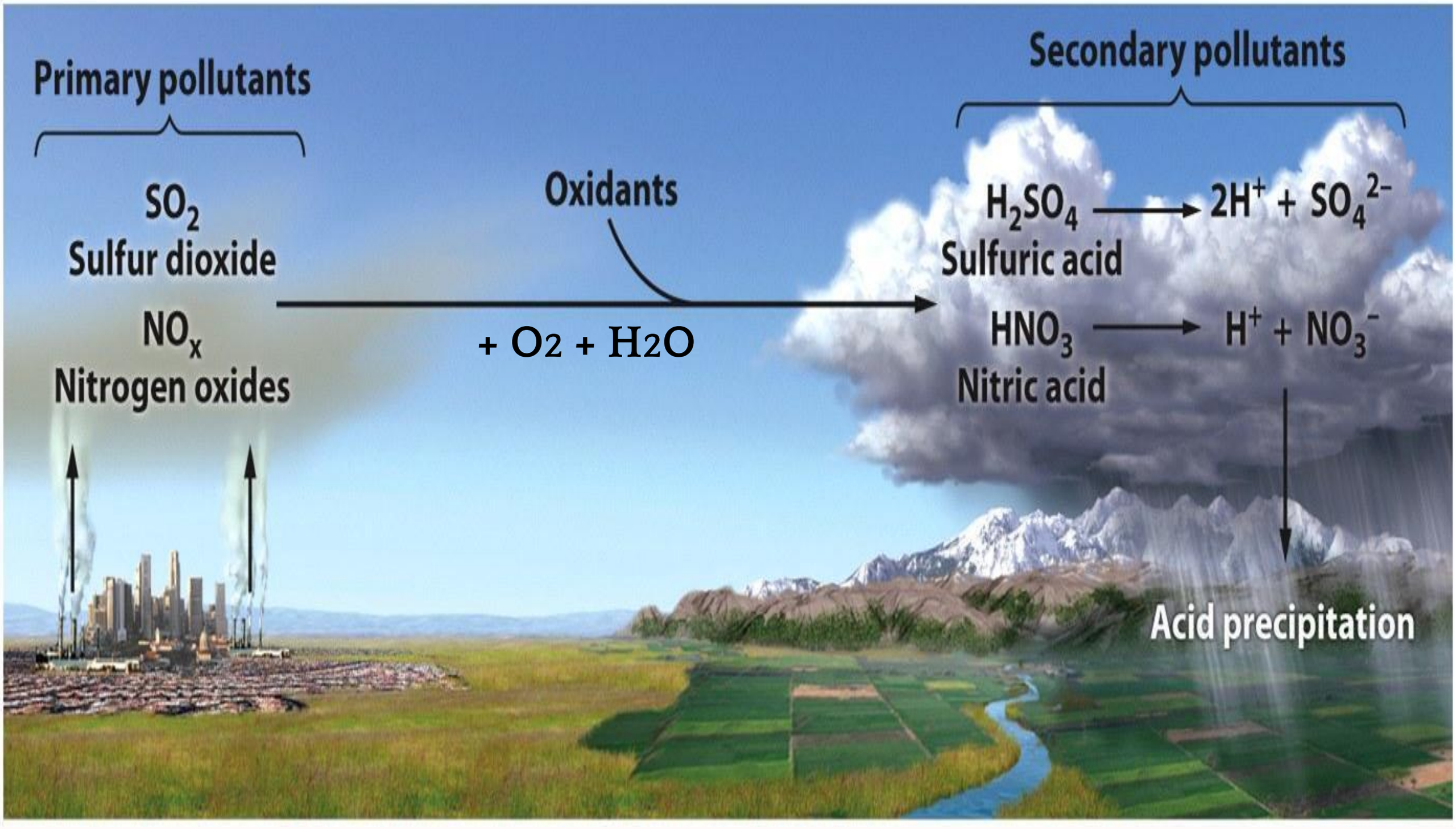
- **Acid deposition-** occurs when nitrogen oxides and sulfur oxides are released into the atmosphere and combine with atmospheric oxygen and water. These form the ***secondary pollutants*** *nitric acid and sulfuric acid.*

$NO_x + SO_x + O_2 + H_2O \longrightarrow$ nitric & sulfuric acids

(primary pollutants) (secondary pollutants)

- These secondary pollutants further **break down into nitrate and sulfate** (inorganic pollutants) which causes the hydrogen ions (H+) that generate the acidity in acid deposition.

Acid Deposition – secondary pollutant

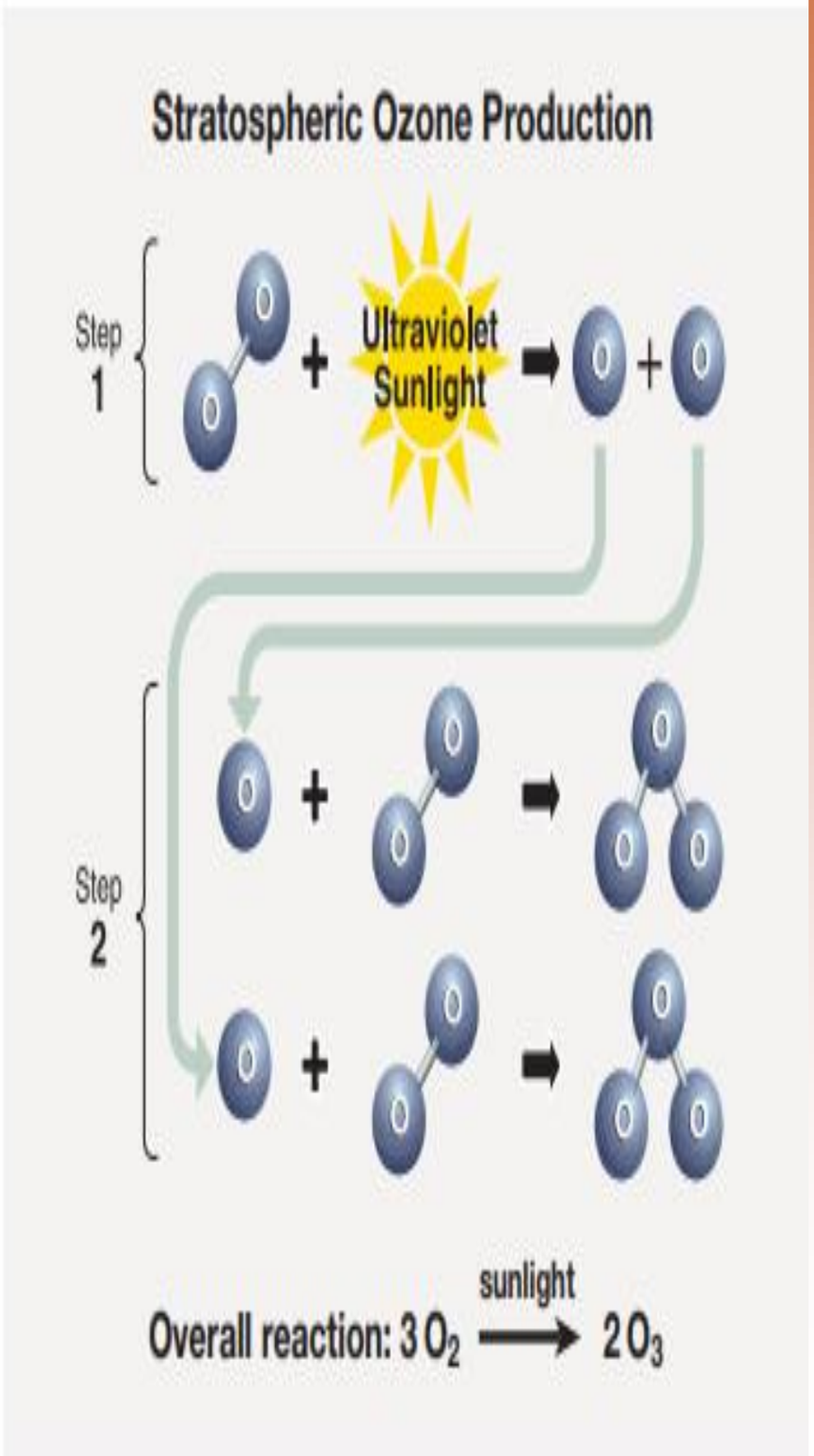


hydrogen ions (H+) that generate the acidity in acid deposition.

Effects of Acid Deposition

- **Lowering the pH** of lake water *(not in GREAT LAKES, why?)*
  - pH of an acid deposition is less than 6 on pH scale (5.6 and below)
- **Decreasing species diversity** of aquatic organisms *(different species survive in different aquatic zones and pH levels, any changes causes decrease in reproduction & food)*
- **Mobilizing metals** that are found in soils and releasing these into surface waters *(metals bound to organic & inorganic compounds in soils & sediments are released into surface water)*
- **Damaging** statues, monuments, and buildings ***(infrastructure)***
- Humans are not directly affected by the precipitation (skin is a robust barrier), affected more by the NO_x & SO_2 in air

OZONE – *secondary pollutant*

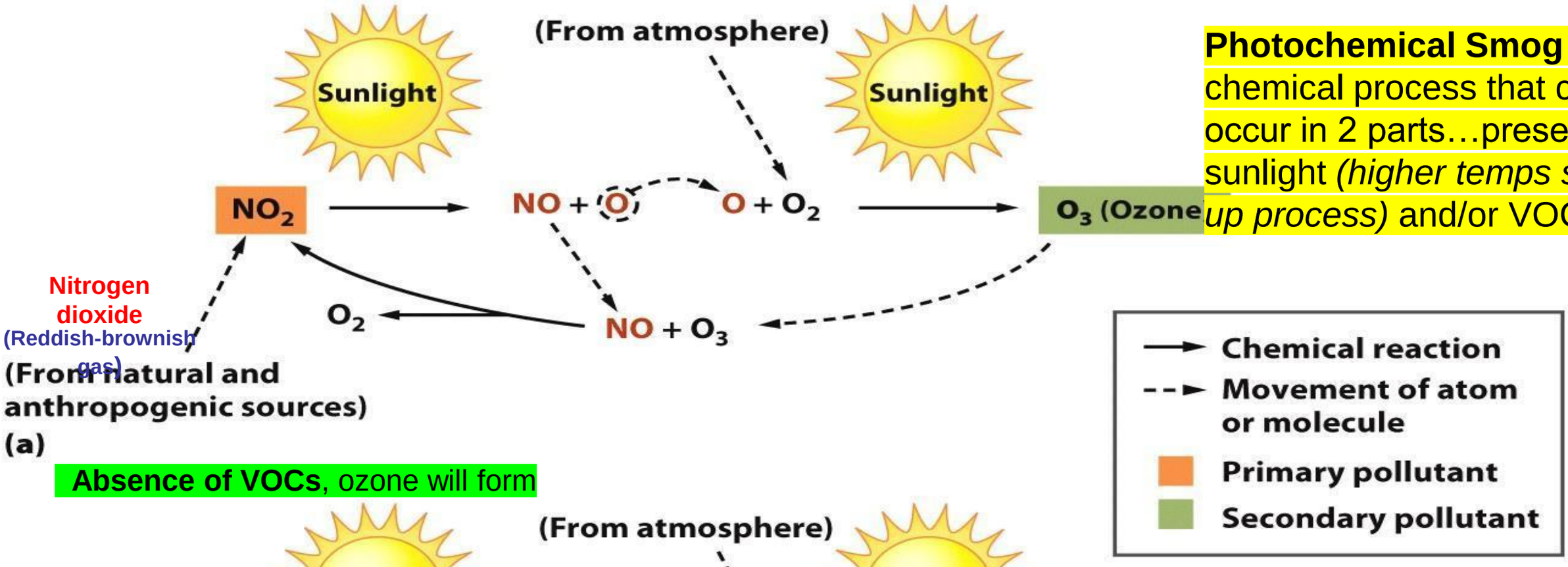


- ***Tropospheric and Stratospheric ozone*** *are chemically identical… at* ground level it is a respiratory irritant (troposphere), but in the stratosphere (no humans are exposed) it is a protection from UV radiation!!

- Ozone forms naturally from UV radiation (sun) breaking down molecular oxygen (O_2)

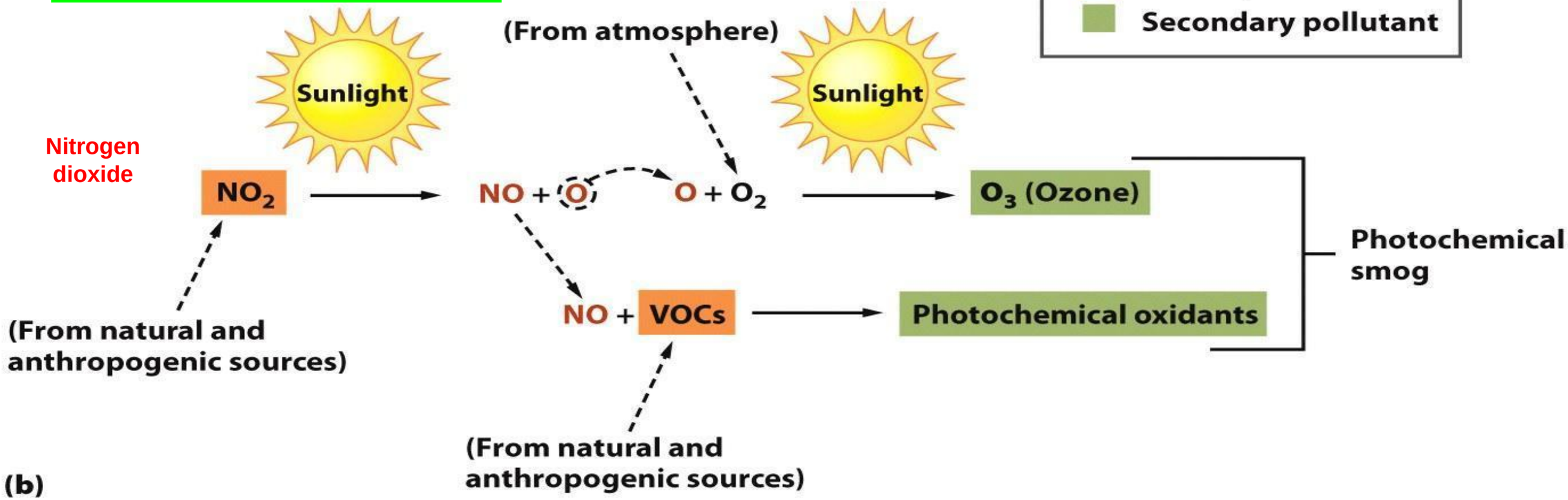
.Tropospheric Ozone & Photochemical Smog

Photochemical Smog is a chemical process that can occur in 2 parts…presence of sunlight *(higher temps speed up process)* and/or VOCs



(a)

Absence of VOCs, ozone will form



(b)

Presence of VOCs, ozone will form during daylight hours. **VOCs (benzene...plastics, nylon, paint, lubricates, aerosol cans, pesticides…etc) will combine with NOx to form photochemical oxidants**, which reduce the amount of ozone that will break down later and contribute to **prolong periods of photochemical smog**.

Anthropogenic Contributions to Ozone

- **Certain chemicals can break down ozone**, particularly **chlorine.**
- The *major source of chlorine* (Cl acts as a catalyst) *in the stratosphere* is a compound known as **chlorofluorocarbons (CFCs)**
  - Chlorofluorocarbons (**CFCs)** drift slowly upward to the stratosphere, where they are broken up by ultraviolet radiation, releasing chlorine atoms, which are able to **destroy ozone** molecules. ...
  - When sunlight returns in the spring, the chlorine begins to **destroy ozone**.
- CFCs are used in ***refrigeration and air conditioning***, as propellants in ***aerosol cans*** and as "blowing agents" to inject air into foam products like ***Styrofoam.***

Depletion of the Ozone Layer

- In addition to **CFC's** (chlorine), compounds such as **NOx**, **Bromines** (method to control pests-termites), **CCl_4** (cleaning solvent) can also contribute to the destruction of stratospheric ozone

- Global Ozone concentrations had decreased by more than 10%.

- Depletion was greatest at the poles (Arctic vs. Antarctic – *"ozone hole") during August – November*

- Decreased stratospheric ozone has increased the amount of UV-B radiation that reaches the surface of Earth ***(radiation has increased 6% since 1979....cancer/other aliments on rise that suppress immune system)***

Hydrochlorofluorocarbons (HCFCs) vs. chlorofluorocarbons (CFCs)

- **HCFCs are one class of chemicals being used to replace the CFCs** but **much more expensive to manufacture than** CFCs

- HCFCs have less ozone depletion potential, in addition to less global-warming potential. HFCs do not contain chlorine and do not contribute to destruction of stratospheric ozone.

- **Because they contain hydrogen, HCFCs break down more easily in the atmosphere (Shorter atmospheric lifetimes) than do CFCs, but more reactive in the atmosphere (absorb more thermal radiation, acting like a greenhouse gas).**

- **The Ozone-Depleting Substances Phaseout: 2020-2030; The 2020 HCFC Allocation and Other Updates (Production of CFC's ceased in 1995). No more production or import of HCFC's by 2030.**

- On December 19th, 2019, the EPA signed a final rule titled *Protection of Stratospheric Ozone: Adjustments to the Allowance System for Controlling HCFC Production and Import, 2020-2029.* This final rule implements the next step in the phaseout of hydrochlorofluorocarbons (HCFCs)…certain strands under the Clean Air Act and the *Montreal Protocol on Substances that Deplete the Ozone Layer.* This rule also revises elements of the ozone-depleting substance phase-out program and complementary provisions.

- **Alternative refrigerants**…Ammonia and Hydrocarbons – evaporate are room temp, short-lived, but more reactive so plumbing must be corrosive-resistant and leak proof.

Indoor Air Pollutants

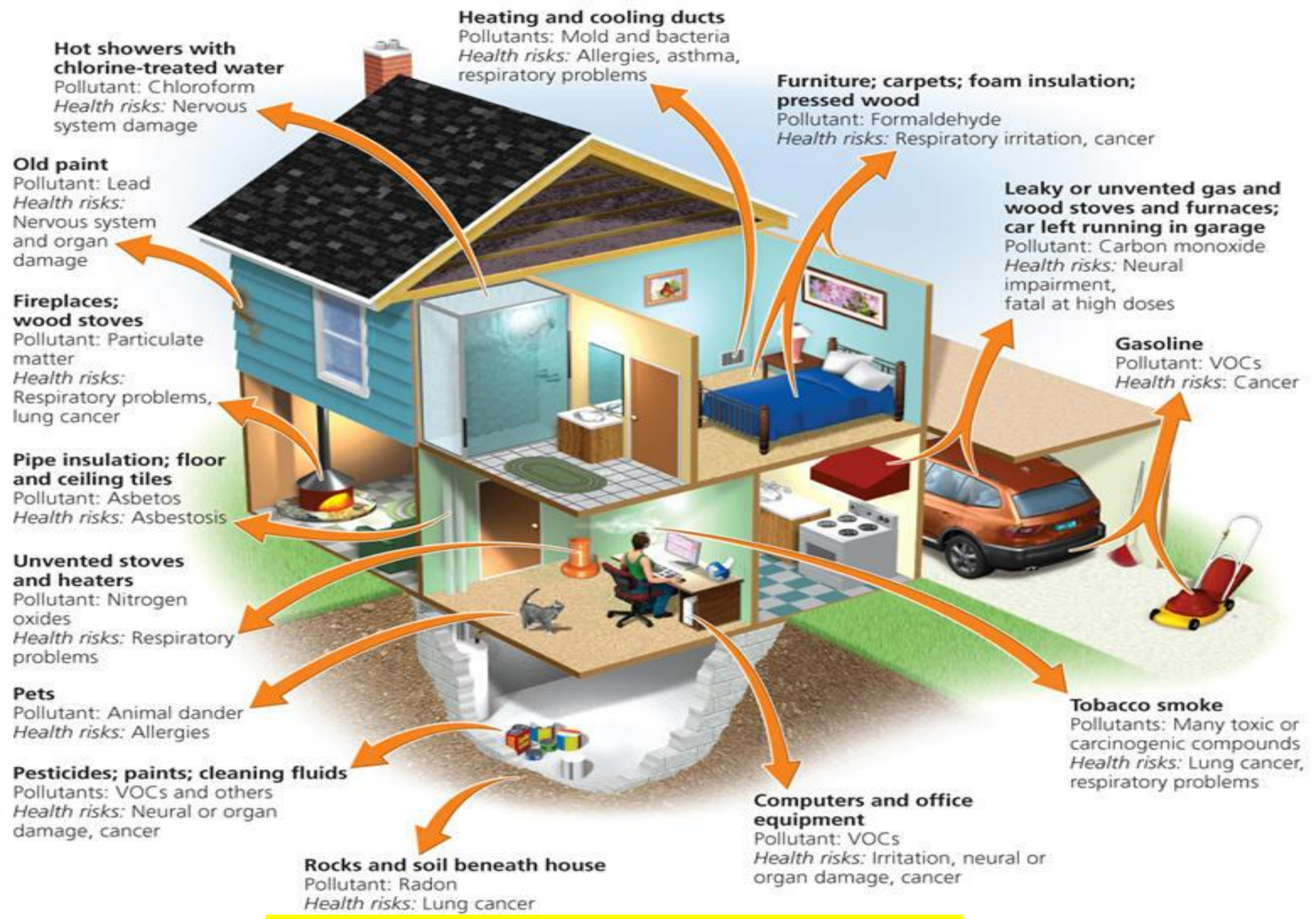
- **Wood, animal manure or coal (particular matter** - anything smaller than 2.5 is extremely dangerous to humans because it can bypass our defend system**)** used for cooking and heating usually in *developing countries* (poor to no ventilation in the "home")
  - Working Toward Sustainability: BioLite Stoves **(pg. 430)**

- **Asbestos** – old, damaged, disrupted insulation materials (was commonly used as insulation in the past)

- **Carbon Monoxide *indoors/outdoors–** exhaust systems malfunctions...interferes with oxygen, binding with hemoglobin

- **Radon** – seeps into home through cracks in foundation or soil, drinking water from underlying rock, soil or groundwater.

- **VOCs in home products** – used in building material, detergents, fabrics, furniture, & other home products such as glue & *paint (most toxic chemical is formaldehyde, found in carpet glue, pressed wood for cabinets...etc)*



Sources of Indoor Air Pollutant

Ways to Prevent Air Pollution

1. **Reduce use of coal & oil** to decrease air pollution emissions *(emissions are very difficult to control once dispersed into atmosphere)*

2. Removing sulfur dioxide from coal by ***fluidized combustion*** *(granulated coal is burned in close proximity to calcium carbonate, reduces SO_2 emissions)*

3. **Catalytic converters** on cars *(reduces the NOx & CO emission due to the removal of Lead from gasoline)*

4. **Baghouse filters** *(particles are remove by a series of filter bags that physically filters out particles).*

5. Electrostatic precipitators – air pollution device, where particles are given a negative charge, causing them to be attracted to positively charge plate, where they held until collected, removed and disposed of

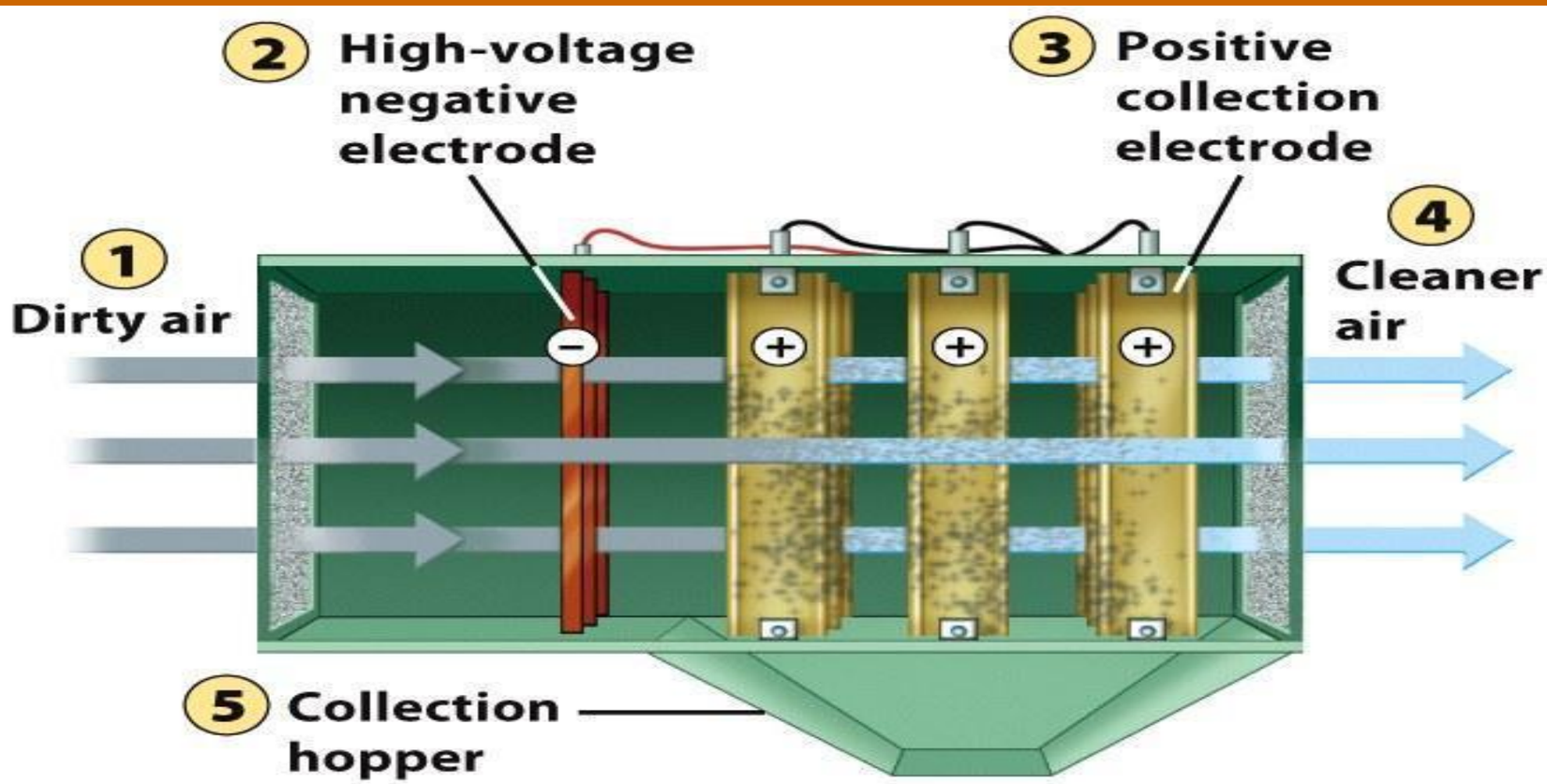


Figure 15.12
Environmental Science

6. Scrubbers

on smokestacks

– particles are "scrubbed" from the exhaust stream by water droplets.

Water-particle "sludge" is collected and processed for disposal.

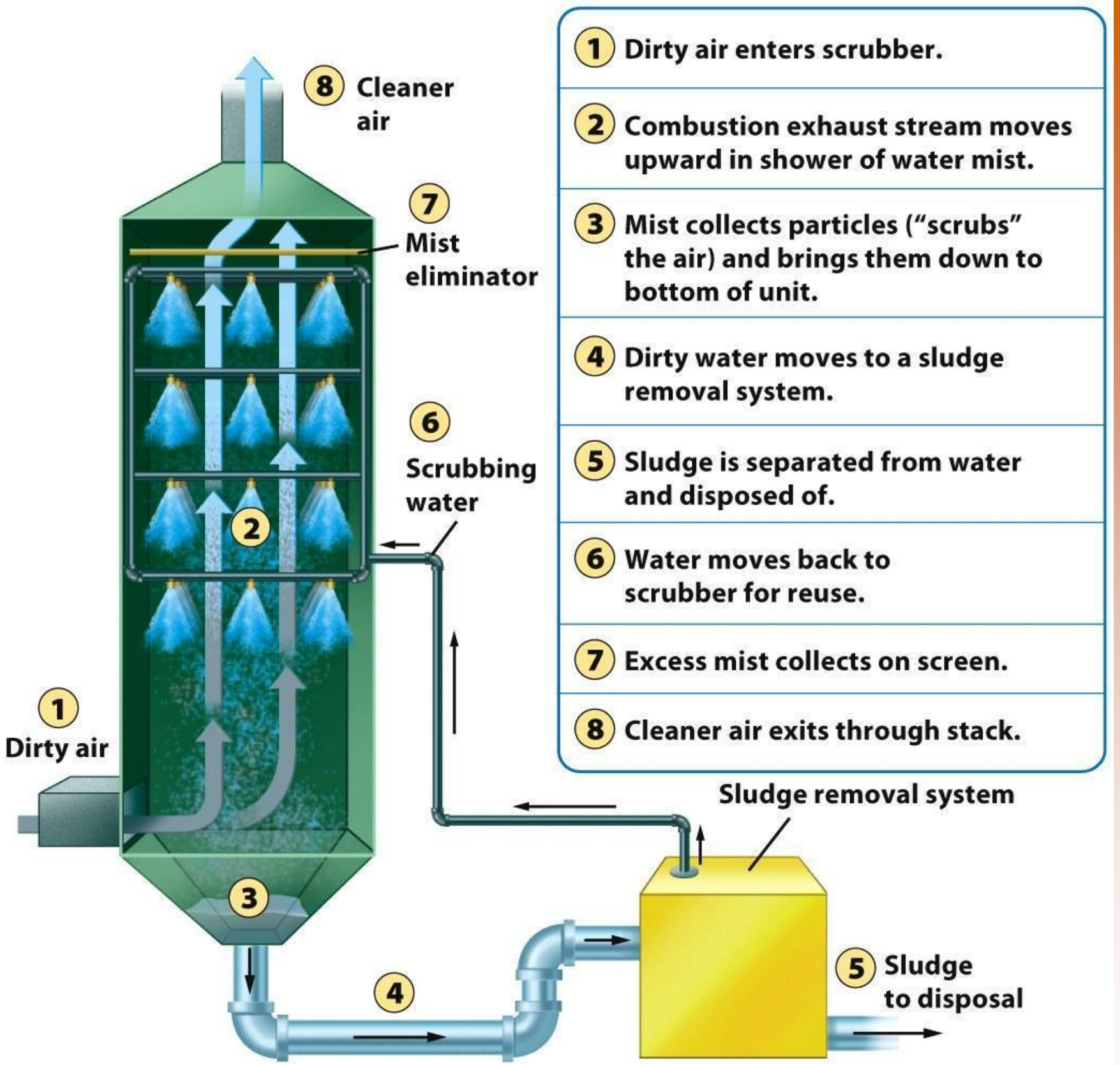
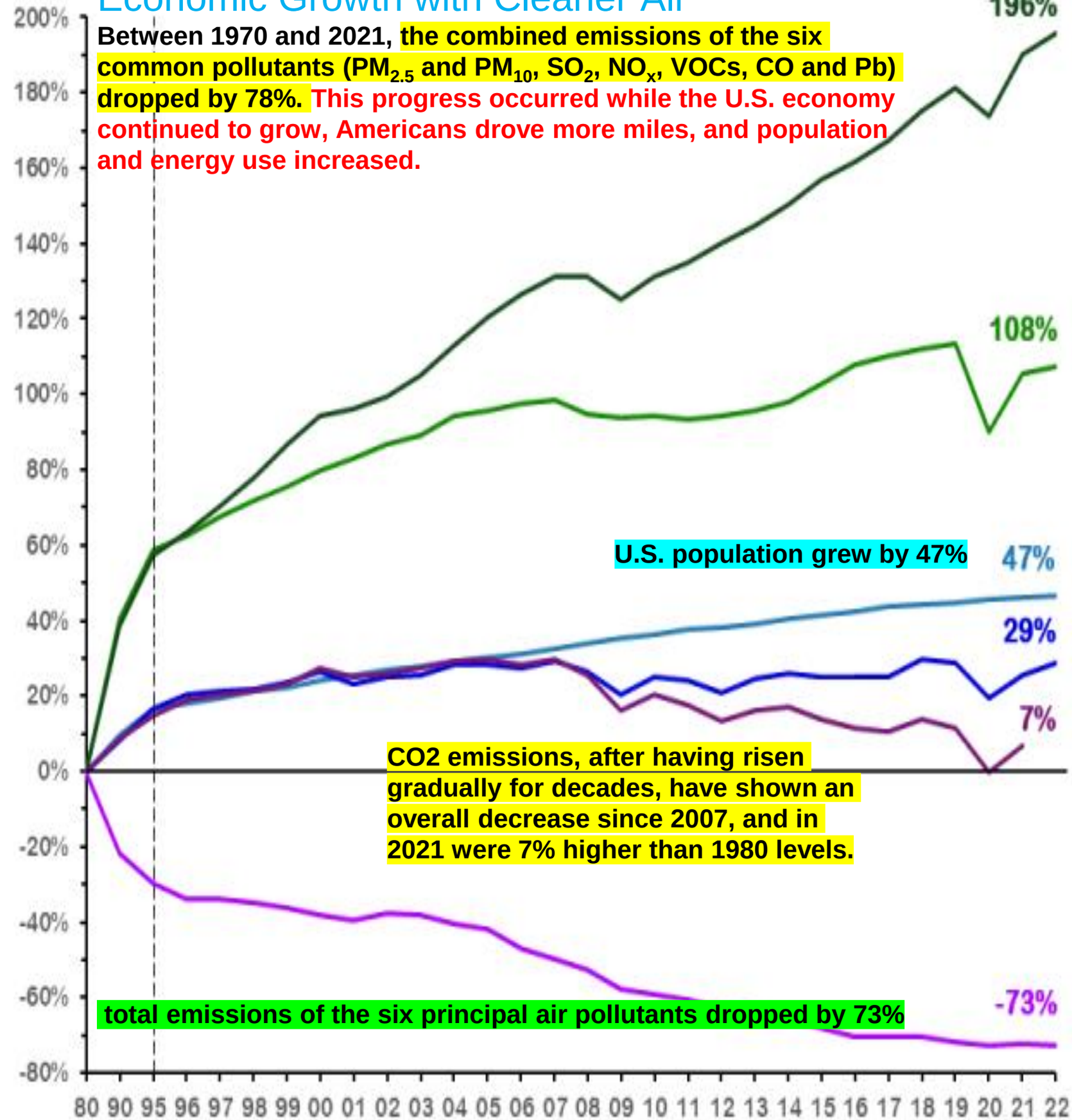


Figure 15.13
Environmental Science

Comparison of Growth Areas and Emissions, 1980-2022

Economic Growth with Cleaner Air

Between 1970 and 2021, the combined emissions of the six common pollutants ($PM_{2.5}$ and PM_{10}, SO_2, NO_x, VOCs, CO and Pb) dropped by 78%. This progress occurred while the U.S. economy continued to grow, Americans drove more miles, and population and energy use increased.




Gross Domestic Product


Vehicles Miles Traveled


Population

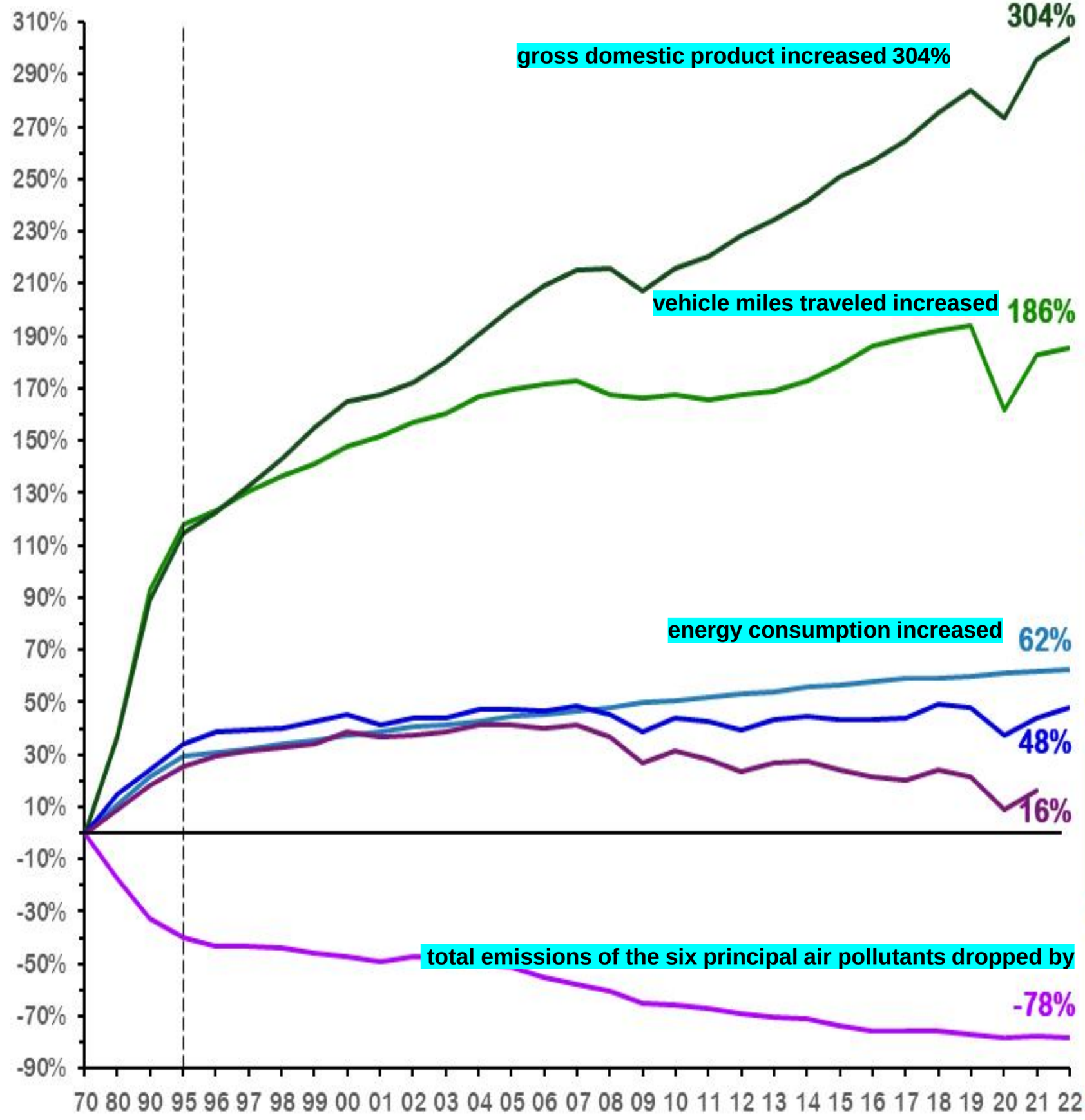

Energy Consumption


CO_2 Emissions


Aggregate Emissions (Six Common Pollutants)

Comparison of Growth Areas and Emissions, 1970-2022

The graph below shows that between 1970 and 2022…



Gross Domestic Product

Vehicles Miles Traveled

Population

Energy Consumption

CO_2 Emissions

Aggregate Emissions
(Six Common Pollutants)

Air Quality Trends Show Clean Air Progress

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

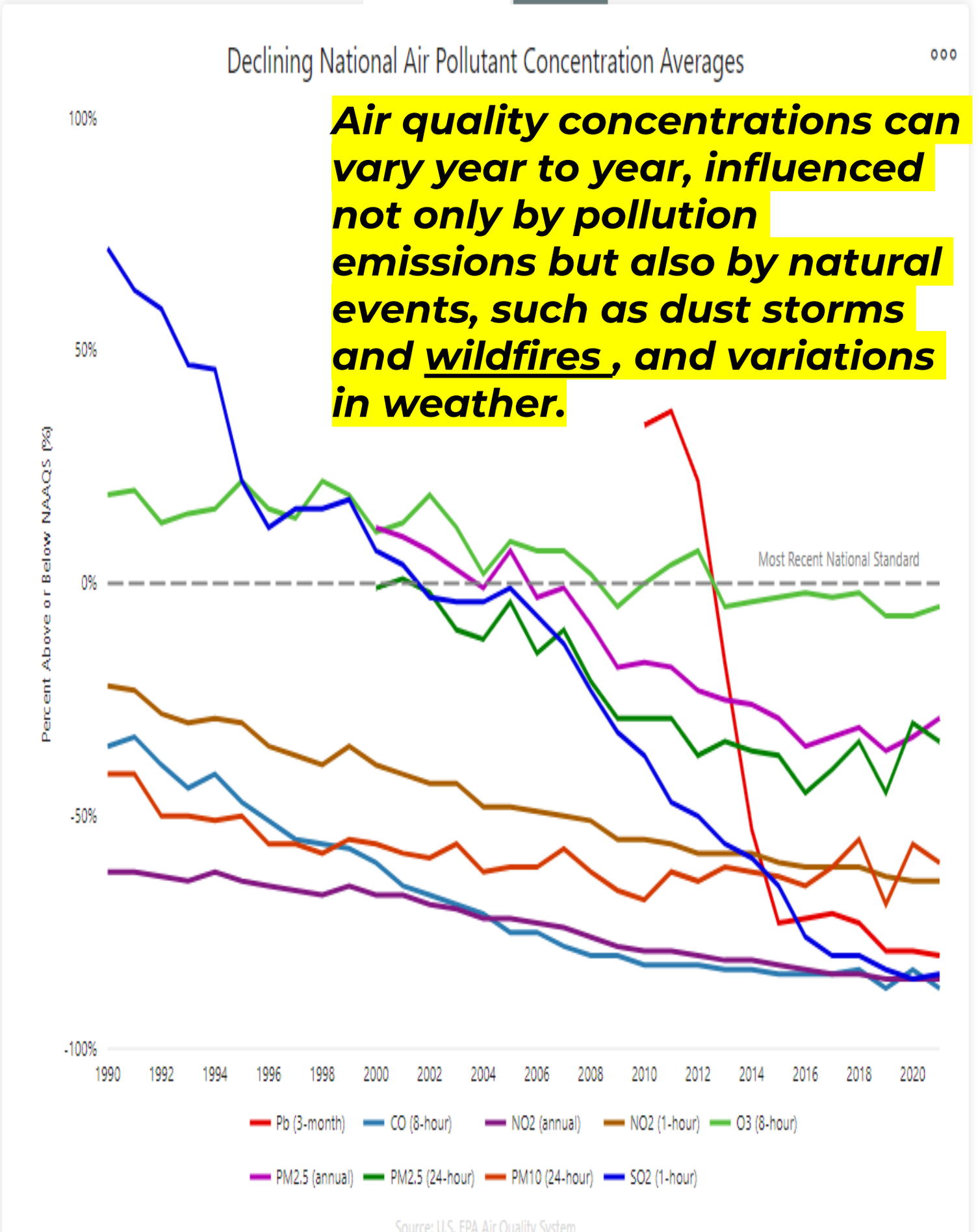
- Carbon Monoxide (CO) 8-Hour, ↓ 79%
- Lead (Pb) 3-Month Average, ↓ 85% (from 2010)
- Nitrogen Dioxide (NO_2) Annual, ↓ 61%
- Nitrogen Dioxide (NO_2) 1-Hour, ↓ 54%
- Ozone (O_3) 8-Hour, ↓ 21%
- Particulate Matter 10 microns (PM_{10}) 24-Hour, ↓ 32%
- Particulate Matter 2.5 microns ($PM_{2.5}$) Annual, ↓ 37% (from 2000)
- Particulate Matter 2.5 microns ($PM_{2.5}$) 24-Hour, ↓ 33% (from 2000)
- Sulfur Dioxide (SO_2) 1-Hour, ↓ 91%
- 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.*

Tip Click pollutant names in the chart legend to hide or include trend lines, and hover over any line to display percentages above or below the most recent standard. Click the Emission Totals tab to view emission trends.

Concentration Averages | Emission Totals



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_2) Annual, ↓ 60%
- Nitrogen Dioxide (NO_2) 1-Hour, ↓ 54%
- Ozone (O_3) 8-Hour, ↓ 22%
- Particulate Matter 10 microns (PM_{10}) 24-Hour, ↓ 34%
- Particulate Matter 2.5 microns ($PM_{2.5}$) Annual, ↓ 42% (from 2000)
- Particulate Matter 2.5 microns ($PM_{2.5}$) 24-Hour, ↓ 42% (from 2000)
- Sulfur Dioxide (SO_2) 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.

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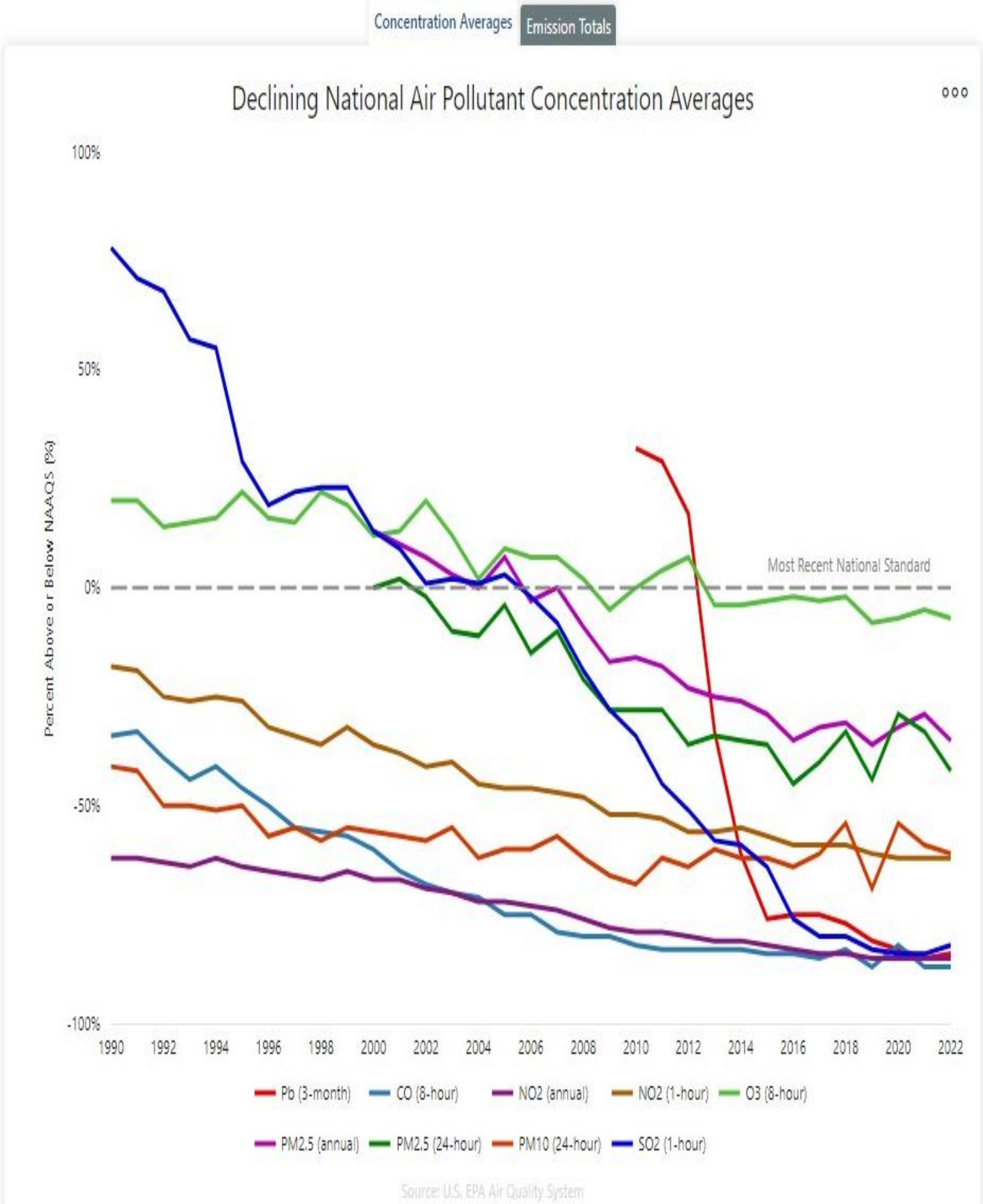

Innovative Pollution Control

- Montreal Protocol is an agreement that allowed for a reduction, and eventual elimination, of CFC production and use
- Limit amt. of gasoline spills at stations, restrict the evaporation of dry-cleaning fluid, use of lighter fluid, wood-burning stoves & fireplaces
- Reduce number of bakeries within certain area (emissions from bread rising contains VOCs)
- Permitting automobiles to be driven every other day (based on license plate numbers - even vs. odd)
- Expand public transportation, carpool lanes, tolls on roads to reduce drivers or independent drivers
- Sell the right to pollute for major corporations (financial penalty if quantities are not equated)…demand factories to install “scrubbers” *(dirty air particles are cleaned with water vapors)* on smokestacks and filters.

Lowering coal burning temperatures to reduce NOx emissions from coal burning plants