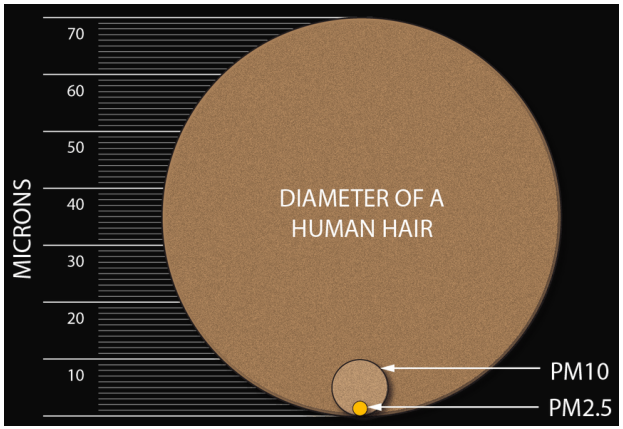
The Air We Breathe

Why we should care about ‘fine particulates,’ even in the US

By Mike Feldman | February 18, 2021



What is PM2.5?

Fine particulate air pollution, or PM2.5 for short, is the general term for inhalable particles that are 2.5 micrometers or smaller (over 30 times thinner than a human hair). It can be emitted from natural or humanmade sources, including cars, power plants, and wildfires, and can be composed of hundreds of different chemicals.[1]

Due to its small size, inhaling PM2.5 can allow it to enter the lungs and bloodstream, which can cause significant damage over time. Decades of research has linked PM2.5 exposure with premature death in people with heart or lung disease, poor health indicators such as aggravated asthma, decreased lung function, and nonfatal heart attacks, and many other adverse outcomes.[2] [3] [4]

Photo: Michigan Public Radio
PM2.5 diagram: Undark Magazine

1 US Environmental Protection Agency (EPA)
2 Ibid.
3 Apte et al (2015), ‘Addressing Global Mortality from Ambient PM2.5’, *Environmental Science & Technology*
4 Lepeule et al (2012), ‘Chronic Exposure to Fine Particles and Mortality: An Extended Follow-up of the Harvard Six Cities Study from 1974 to 2009’, *Environmental Health Perspectives*

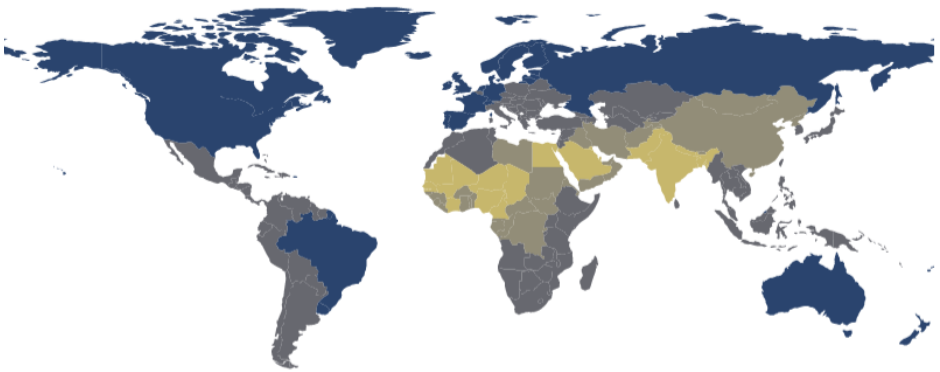
PM2.5 is a global killer

Exposure to PM2.5 is highest in Asia, Africa and the Middle East and is generally higher in countries with lower socioeconomic development. In 2019, the five countries with the highest annual average PM2.5 concentrations were India, Nepal, Niger, Qatar, and Nigeria, while the five lowest were Finland, Sweden, Iceland, Nauru, and Estonia. (The United States was 19th-lowest.)

The predominant sources of PM2.5 can vary by region, season, climate, and country. In North Africa and the Middle East, wind-carried mineral dust from the Saharan and Arabian deserts can linger in the air. In heavily urbanized areas such as northern India and eastern China, exhaust from vehicles and soot and sulfates from power plants and factories can pollute the landscape.

PM2.5 air pollution is highest in North Africa, the Middle East & SE Asia

Average annual PM2.5 concentration (2019)[2]



Concentration (micrograms per cubic meter, or µg/m3)

- 0 - 12: Considered 'good' air quality by EPA over 24-hour period
- 12 - 35: Moderate air quality
- 35 - 55: Unhealthy for sensitive groups
- 55 - 150: Unhealthy

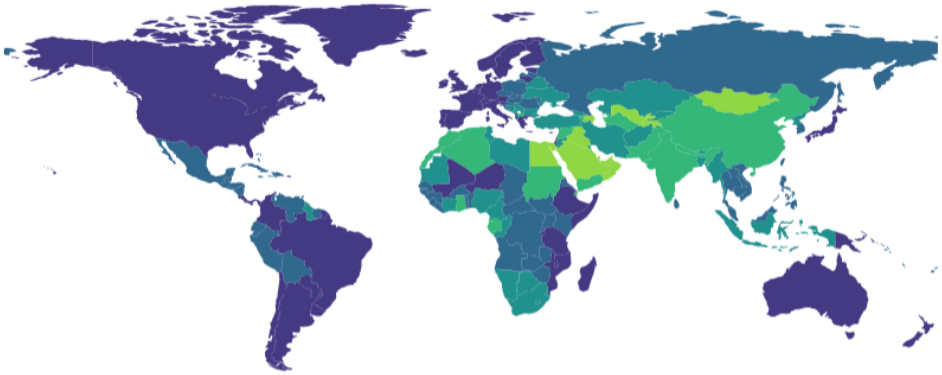
Note: The EPA's annual standard for PM2.5 is 12 µg/m3. (It does not differentiate at higher levels.)

The countries with the highest rates of death attributable to PM2.5 are, as one may expect, generally in the regions with the highest PM2.5 concentrations. The five countries with the highest rates in 2019 were Uzbekistan, Egypt, Qatar, Oman, and Iraq, with deaths ranging from 122 to 176 per 100,000 population. For comparison, as of February 2021, the COVID-19 death rate in the United States is 150 per 100,000 (the 5th-highest in the world).[1]

According to the *State of Global Air 2020* report, 7 percent of all worldwide deaths could be attributed to PM2.5 in 2019, representing almost 4 million deaths (about 3 times more than the number who died from traffic collisions). China and India accounted for almost 60 percent of these PM2.5-attributable deaths, as they experienced 1.42 million and 980,000 in 2019, respectively.

...as are deaths attributable to PM2.5

Deaths/100k attributable to PM2.5 (2019)[3]



PM2.5 Deaths/100k population

- 0 - 25
- 25 - 50
- 50 - 75
- 75 - 100
- 100+

Data sources: State of Global Air 2020, Global Burden of Disease Study 2019
Note: No data available for Antarctica

1 Johns Hopkins University
2 Average annual concentrations are weighted by population, meaning greater weight is given to the pollutant concentrations where most people live
3 Deaths are calculated based on a standard distribution of population across age categories, which allows direct comparison of death rates across countries with different age distributions

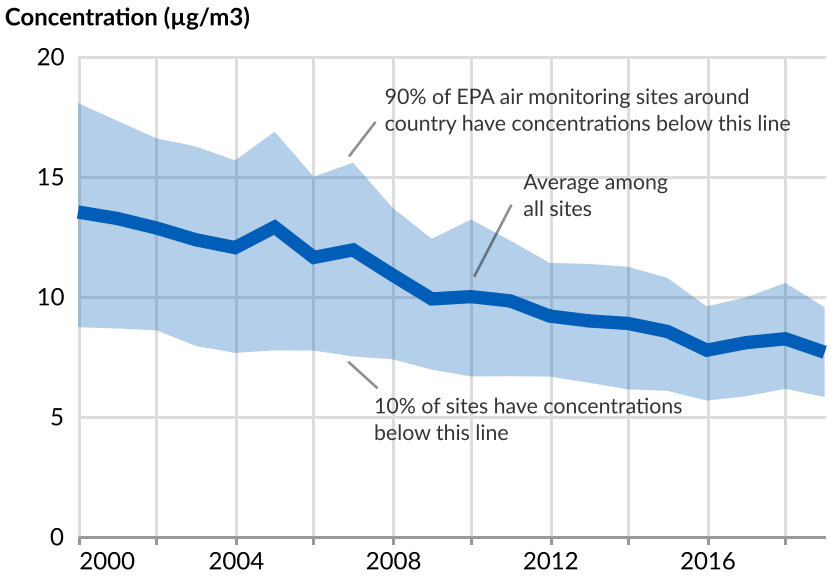
But PM2.5 trends in the US are encouraging

Compared to the rest of world, the United States is faring well with respect to PM2.5. Out of 205 eligible countries, in 2019 the US had the 19th-lowest PM2.5 concentrations and the 18th-lowest PM2.5-attributable death rate, both ahead of countries such as Japan, Germany, and the United Kingdom.

Further, as pictured below, average PM2.5 levels have declined steadily since 2000. A contributor to this trend were actions taken by the EPA in 1997, 2006, and 2012 to set stricter air quality standards for PM2.5, as they have done periodically since the Clean Air Act of 1970 gave them this power.

US PM2.5 levels have declined substantially

90th %ile, 10th %ile & annual avg of US PM2.5 levels ('00-'19)[1]



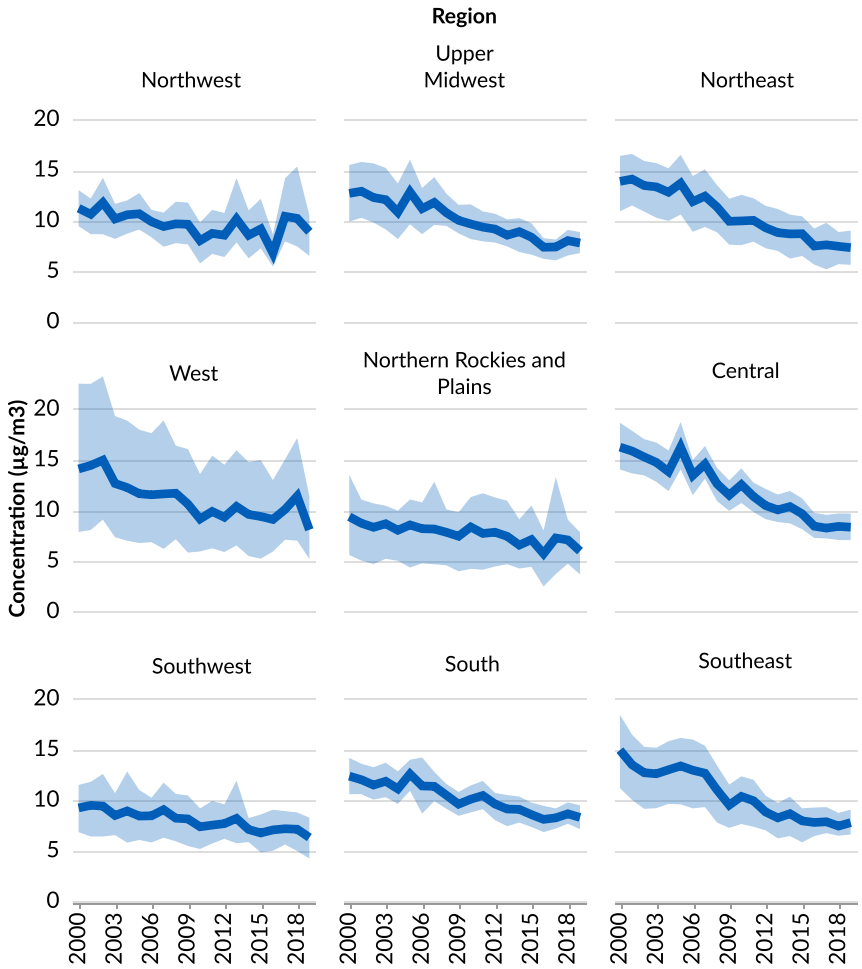
Data source: Environmental Protection Agency (EPA)

1 Data is seasonally weighted and is based on data from 406 monitoring sites around the country
2 Region definitions (per NOAA):
Central: IL, IN, KY, MO, OH, TN, WV;
Northeast: CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT;
Northern Rockies & Plains: MT, NE, ND, SD, WY;
Northwest: ID, OR, WA;
South: AR, KS, LA, MS, OK, TX;
Southeast: AL, FL, GA, NC, SC, VA;
Southwest: AZ, CO, NM, UT;
Upper Midwest: IA, MI, MN, WI;
West: CA, NV

This trend has been relatively consistent across the US, as all regions have experienced declining PM2.5 levels over the past 20 years. While regional differences in air pollution still persist (more on that later), PM2.5 concentrations have shown significant convergence across the country.

...and levels are declining across regions

90th %ile, 10th %ile & annual avg of regional PM2.5 levels ('00-'19)[1] [2]

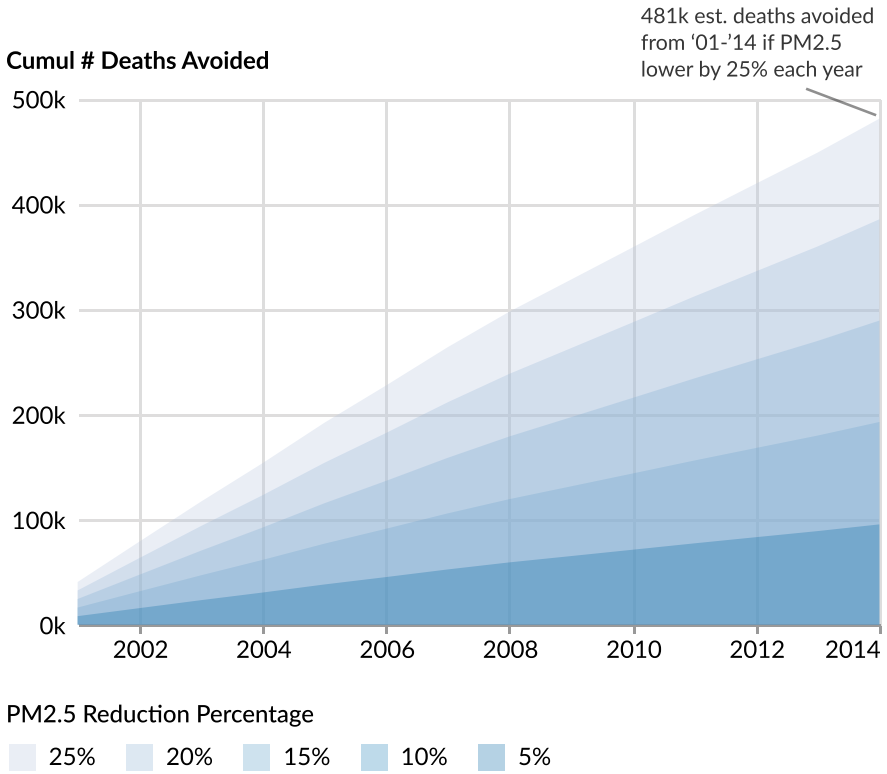


The US can still do better

The Centers for Disease Control and Prevention (CDC) estimates that if PM2.5 levels had been 25 percent lower across the US each year between 2001 and 2014, nearly 500,000 deaths could have been avoided. For context, in 2019 EPA staff scientists recommended tightening the EPA's PM2.5 air quality standards from 12 to 9 micrograms per cubic meter, which would have been a 25 percent reduction. (The EPA under the Trump administration ultimately rejected this change).

Reducing PM2.5 could have avoided almost 500k deaths

Estimated total deaths avoided from lowering PM2.5 concentration levels by [X]% ('01-'14)

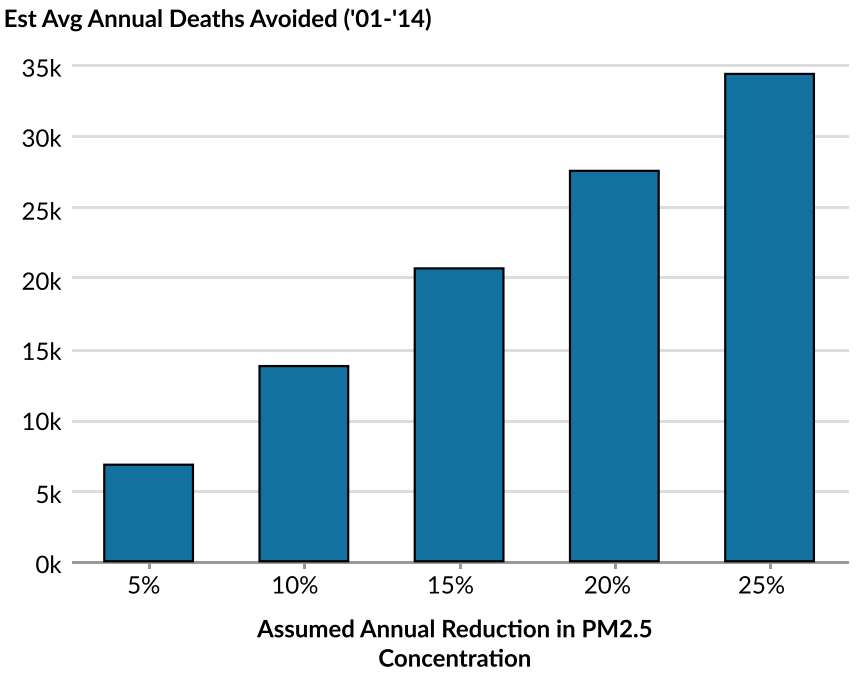


This means PM2.5 is responsible for at least tens of thousands of premature deaths per year. For comparison, the 10th-leading cause of death in the US in 2019 was suicide, at approximately 47,000 deaths.

Note that in the CDC's analysis, benefits still accrue even for small reductions in PM2.5 levels. This is because research has not identified a 'safe' level of PM2.5; even levels below the current EPA standards have been associated with increased risk of mortality.[1] [2]

...which means tens of thousands of deaths every year

Estimated avg annual deaths avoided from lowering PM2.5 levels ('01-'14)



Data source: Centers for Disease Control and Prevention (CDC)

1 Shi et al (2016), "Low-Concentration PM2.5 and Mortality: Estimating Acute and Chronic Effects in a Population-Based Study", *Environmental Health Perspectives*
2 Di et al (2017), "Air Pollution and Mortality in the Medicare Population", *The New England Journal of Medicine*

Some regions suffer more pollution than others

The burden of PM2.5 is not felt evenly across the US. The regions most acutely affected include:

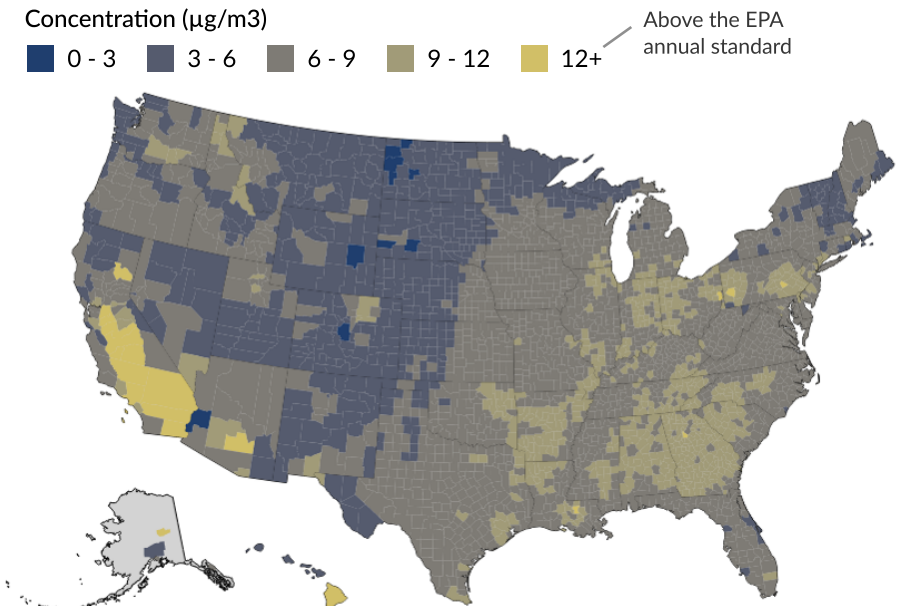
1. *Southern California*: Of the 10 counties with the highest PM2.5 concentrations, 8 are in California (led by Kern County in the San Joaquin Valley). All had annual average concentrations of at least 14 micrograms per cubic meter in 2016, 2 micrograms above the EPA standard. Major ongoing contributors to this pollution include cow manure from feedlots, vehicle exhaust, oil fields, debris from almond farming, and wood stoves and barbecue pits. In recent years, wildfires have made an overwhelming contribution.[1]

2. *Rust Belt (Pennsylvania, Ohio, Indiana, Illinois, southern Michigan, southeastern Wisconsin):* A disproportionate reliance on manufacturing and industrial sectors and coal-fired power means Rust Belt states maintain PM2.5 levels higher than their neighbors.[2]

3. *Southeastern US (Georgia, Alabama, Mississippi):* Prescribed fires drive much of this region's PM2.5 emissions, as 70 percent of all prescribed fire in the US from 1998 to 2018 was completed in the Southeast.[3]

Air pollution is unequally distributed, and is particularly bad in Southern California

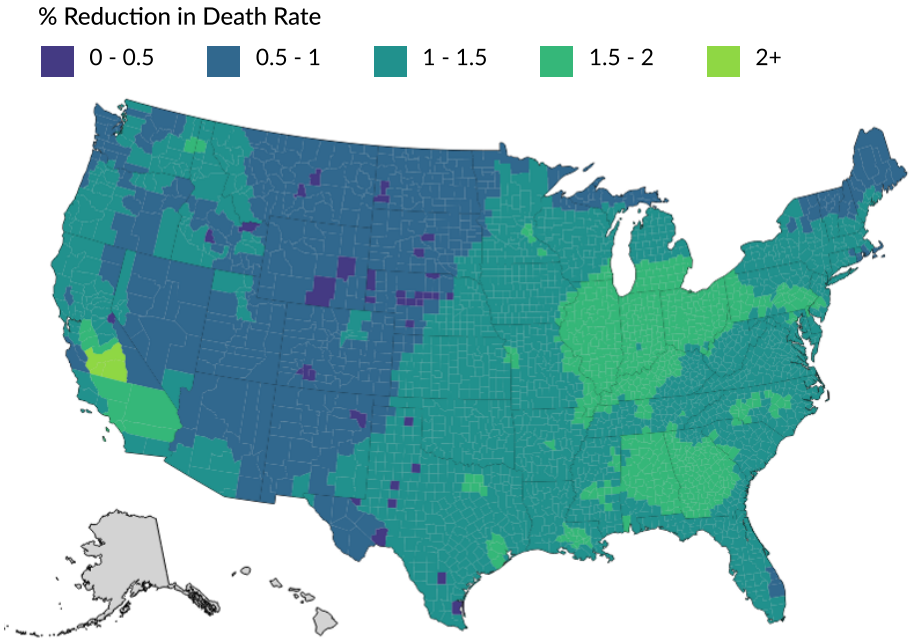
Average ambient concentrations of PM2.5 by county (2016)



Data source: CDC
Note: Only limited data available for Alaska

Southern California and the Rust Belt would benefit most from reduction in PM2.5 levels

Estimated % change in death rate due to 25% reduction in PM2.5 concentration (2014)[4]



1 Borrell, "In California's Fertile Valley, Industry Hangs Heavy in the Air", *Undark Magazine*, December 3, 2018
2 Davenport, "Eastern States Press Midwest to Improve Air", *The New York Times*, December 9, 2013
3 Kolden (2019), "We're Not Doing Enough Prescribed Fire in the Western United States to Mitigate Wildfire Risk", *Fire*
4 Measures change compared to baseline death rate

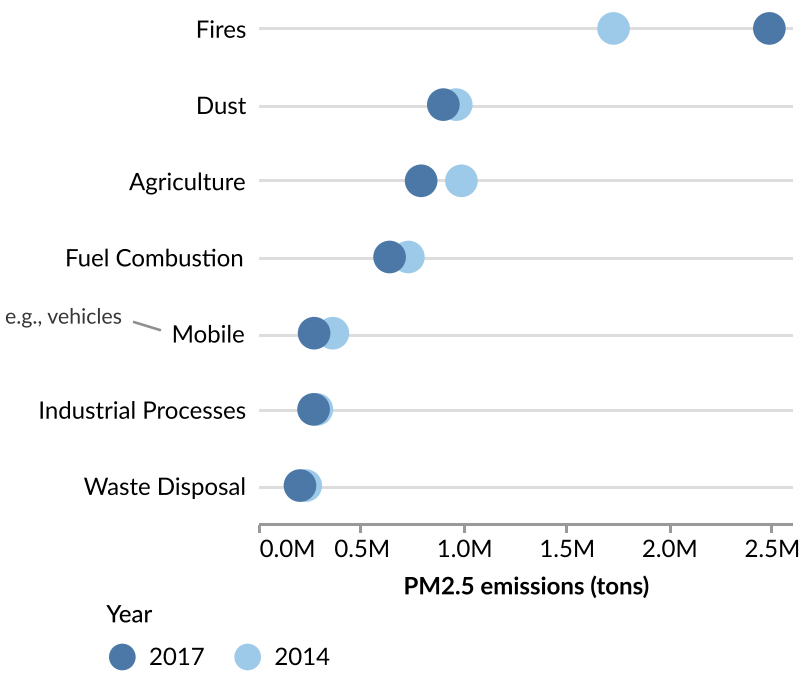
Top sources include fires, farms, wood-burning stoves

Fires, both wild and prescribed, are typically among the top sources of PM2.5 emissions nationally, but a record wildfire season in 2017 made wildfires the clear number one.

Emissions from fuel combustion (fuel burning for energy use), vehicle exhaust, and industrial processes are also all significant sources of PM2.5.

Fires were largest source of PM2.5 emissions in 2014 & 2017

PM2.5 emissions in US by source (2014 & 2017)[2]

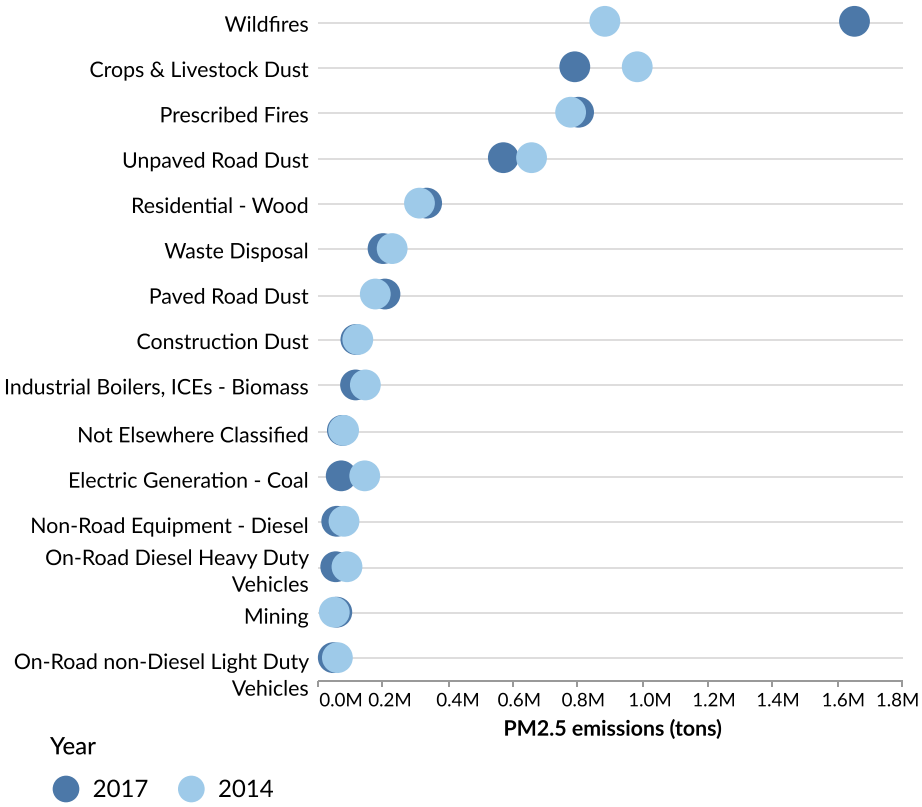


Perhaps more surprising is the combination of agriculture, road dust, and wood-burning stoves, which were the second, fourth, and fifth-highest sources of PM2.5 emissions, respectively, in 2017.

Dust emitted from agriculture can include windblown soil erosion and particles from livestock manure; road dust are bits of dirt kicked up by vehicles, and can be particularly significant in rural areas; and wood-burning stoves are used by millions of Americans as their primary heating source.[1]

Crop & livestock dust, road dust, residential wood burning are all major PM2.5 sources

PM2.5 emissions in US by source: **detailed** (2014 & 2017)[3]



Data source: EPA, National Emissions Inventory

1 Per EPA
2 Only sources with emissions >150k tons in 2014 & 2017 included
3 Only includes 2017 top 15 detailed sources of emissions

Reducing PM2.5 is controversial in the US

Despite the copious evidence on the adverse effects of PM2.5, regulation of PM2.5 is controversial in the United States.

Over its four years, the Trump administration weakened national auto emissions standards, attempted to repeal power plant emission restrictions, rejected tightening the national PM2.5 air quality standards, proposed changing which studies can be used to inform those standards, and proposed a new methodology for calculating the health risks of PM2.5 that would predict fewer deaths caused by air pollution. This came after the Obama administration enacted national auto and power plant emission standards and implemented stricter standards on PM2.5.[1]

Because PM2.5 is not a hot-button topic of political discourse in the United States, these actions can be easy to miss. But even though the topic may be arcane, and though United States has made progress over the decades in reducing PM2.5, thousands of lives every year still hang in the balance.

1 Popovich, "America's Skies Have Gotten Clearer, but Millions Still Breathe Unhealthy Air", *The New York Times*, June 19, 2019