Trouble In The Air

Millions of Americans breathed polluted air in 2020
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Errata: The original version of this report contained an error regarding EPA’s characterization of the impacts of a "Moderate" level of air pollution and an error regarding the number of air quality monitoring locations for a small subset of geographies in Appendix A. The errors have been corrected in this version and language concerning monitoring locations has been edited for clarity.
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Table of contents

Executive summary ................................................................. 1
Introduction .............................................................................. 5
Air pollution threatens public health ......................................... 6
  Air pollution is harmful even at levels the EPA considers safe .......... 8
Fossil fuel combustion is a major source of air pollution .......... 11
  Ozone .............................................................................. 11
  Particulate matter ............................................................ 12
  Air toxics .......................................................................... 13
Global warming will make air pollution worse ....................... 14
Air pollution was widespread in the United States in 2020 .......... 18
  Exposure to either ozone or particulate matter ....................... 19
  Exposure to ozone pollution ............................................... 21
  Exposure to particulate pollution .......................................... 23
  Wildfires caused very unhealthy levels of air pollution ........... 25
  Progress on air pollution is stalling ....................................... 28
Conclusion and recommendations ........................................... 29
Methodology ............................................................................ 31
Appendix A: Days with elevated ozone, particulates and total pollution, by geographic area, 2020 .......... 35
Appendix B: Sources of pollutants that contribute to ozone and particulate pollution, by state, 2017 .... 55
Notes .................................................................................... 59
Executive summary

Despite much progress in reducing levels of air pollution in the U.S., millions of Americans are exposed to unhealthy levels of pollution every year.\(^1\) Ozone and small particulate matter less than 2.5 microns in diameter (PM\(_{2.5}\)), among other pollutants, are widespread in the U.S. and have serious health effects.

Currently, the U.S. Environmental Protection Agency (EPA) considers safe and acceptable levels of air pollution that many American public health groups and international agencies consider unhealthy. This report examines EPA air quality data from 2020 and shows how often Americans living in large urban areas, small urban areas and rural counties were exposed to air pollution that could damage their health.\(^2\)

Fossil fuel combustion is the primary human-caused source of air pollution – and the main driver of global warming, which threatens to make air quality even worse in the years to come.

Policymakers must move quickly to reduce air pollution, including by electrifying every sector of the economy and transitioning to clean, renewable sources of electricity.

### TABLE ES-1. TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED MORE THAN 100 DAYS OF ELEVATED OZONE AND/OR PM\(_{2.5}\) IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days with ozone and/or PM(_{2.5}) AQI over 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles-Long Beach-Anaheim, CA</td>
<td>209</td>
<td>13,109,903</td>
</tr>
<tr>
<td>Phoenix-Mesa-Chandler, AZ</td>
<td>149</td>
<td>5,059,909</td>
</tr>
<tr>
<td>Riverside-San Bernardino-Ontario, CA</td>
<td>203</td>
<td>4,678,371</td>
</tr>
<tr>
<td>San Diego-Chula Vista-Carlsbad, CA</td>
<td>232</td>
<td>3,332,427</td>
</tr>
<tr>
<td>Denver-Aurora-Lakewood, CO</td>
<td>129</td>
<td>2,991,231</td>
</tr>
<tr>
<td>San Antonio-New Braunfels, TX</td>
<td>101</td>
<td>2,590,732</td>
</tr>
<tr>
<td>Sacramento-Roseville-Folsom, CA</td>
<td>122</td>
<td>2,374,749</td>
</tr>
<tr>
<td>Austin-Round Rock-Georgetown, TX</td>
<td>103</td>
<td>2,295,303</td>
</tr>
<tr>
<td>Cincinnati, OH-KY-IN</td>
<td>103</td>
<td>2,232,907</td>
</tr>
<tr>
<td>Indianapolis-Carmel-Anderson, IN</td>
<td>112</td>
<td>2,091,019</td>
</tr>
</tbody>
</table>
Millions of Americans across the country experienced elevated levels of air pollution in 2020

- More than one in six Americans – 58.4 million – living in 53 large and small urban areas and rural counties experienced over 100 days of air pollution at levels above what the EPA considers “good” during 2020.³
- 179.2 million additional Americans – or more than half the country – living in 257 large and small urban areas and rural counties experienced between 31 and 100 days of elevated air pollution.⁴
- The 237.6 million people that experienced more than a month of elevated air pollution represents over 70% of the U.S. population.⁵
Ozone pollution

- 13.6 million Americans living in 11 large and small urban areas and rural counties experienced over 100 days of ozone pollution at levels above what the EPA considers “good” in 2020.

- An additional 57.3 million Americans living in 90 large and small urban areas and rural counties experienced between 31 and 100 days of elevated ozone pollution.

Particulate pollution

- 30.7 million Americans living in 26 large and small urban areas and rural counties experienced over 100 days of particulate pollution at levels above what the EPA considers “good.”

- An additional 175.4 million Americans living in 194 large and small urban areas and rural counties experienced between 31 and 100 days of elevated particulate pollution.

### TABLE ES-2. TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED MORE THAN 100 DAYS OF ELEVATED OZONE IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days with ozone AQI over 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phoenix-Mesa-Chandler, AZ</td>
<td>103</td>
<td>5,059,909</td>
</tr>
<tr>
<td>Riverside-San Bernardino-Ontario, CA</td>
<td>162</td>
<td>4,678,371</td>
</tr>
<tr>
<td>Fresno, CA</td>
<td>110</td>
<td>1,000,918</td>
</tr>
<tr>
<td>Bakersfield, CA</td>
<td>142</td>
<td>901,362</td>
</tr>
<tr>
<td>Colorado Springs, CO</td>
<td>104</td>
<td>753,839</td>
</tr>
<tr>
<td>Visalia, CA</td>
<td>158</td>
<td>468,680</td>
</tr>
<tr>
<td>Boulder, CO</td>
<td>106</td>
<td>327,171</td>
</tr>
<tr>
<td>Madera, CA</td>
<td>132</td>
<td>157,761</td>
</tr>
<tr>
<td>Hanford-Corcoran, CA</td>
<td>125</td>
<td>152,692</td>
</tr>
<tr>
<td>Carlsbad-Artesia, NM</td>
<td>110</td>
<td>58,418</td>
</tr>
</tbody>
</table>

### TABLE ES-3. TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED MORE THAN 100 DAYS OF ELEVATED PM$_{2.5}$ IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days with PM$_{2.5}$ AQI over 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles-Long Beach-Anaheim, CA</td>
<td>178</td>
<td>13,109,903</td>
</tr>
<tr>
<td>Riverside-San Bernardino-Ontario, CA</td>
<td>118</td>
<td>4,678,371</td>
</tr>
<tr>
<td>San Diego-Chula Vista-Carlsbad, CA</td>
<td>225</td>
<td>3,332,427</td>
</tr>
<tr>
<td>Indianapolis-Carmel-Anderson, IN</td>
<td>101</td>
<td>2,091,019</td>
</tr>
<tr>
<td>Fresno, CA</td>
<td>171</td>
<td>1,000,918</td>
</tr>
<tr>
<td>Bakersfield, CA</td>
<td>119</td>
<td>901,362</td>
</tr>
<tr>
<td>Dayton-Kettering, OH</td>
<td>102</td>
<td>809,248</td>
</tr>
<tr>
<td>Stockton, CA</td>
<td>153</td>
<td>767,967</td>
</tr>
<tr>
<td>Jackson, MS</td>
<td>116</td>
<td>589,082</td>
</tr>
<tr>
<td>Spokane-Spokane Valley, WA</td>
<td>102</td>
<td>574,585</td>
</tr>
</tbody>
</table>
Air pollution harms our health, even at low levels.

- Exposure to ozone and particulate pollution has been linked to premature death; damage to the respiratory and cardiovascular systems; worsened mental health and neural functioning; problems with fertility, conception, pregnancy and birth; increased risk of many types of cancer; and harm to children. (See section “Air pollution threatens public health.”)

- Air pollution, including ozone and particulate pollution, can weaken the immune system and help airborne pathogens spread. Air pollution has been linked to increased risk of infection from, and worse health outcomes due to, many infectious diseases, including influenza, pneumonia, the common cold, HIV-AIDS, Ebola and COVID-19. (See section “Air pollution threatens public health.”)

- Levels of air pollution that meet current federal air quality standards can be harmful, especially with prolonged exposure. The World Health Organization, the American Thoracic Society, the American Lung Association and other groups recommend lower thresholds for what are considered acceptable pollution levels than those set by the U.S. Environmental Protection Agency. In fact, according to a 2021 literature review by an Australian government-funded air pollution research organization, “… current evidence suggests there is no ‘safe’ level of air pollution,” including both PM$_{2.5}$ and ozone. (See section “Air pollution is harmful at levels the EPA considers safe.”)

Global warming and air pollution are intimately connected.

- Extracting, transporting and burning fossil fuels produces not just the greenhouse gases that drive global warming, but also many of the air pollutants that damage our health.

- Air pollutants that damage our health can also worsen global warming, and the increasing temperatures and changing weather patterns associated with global warming are likely to make air pollution, and its health effects, worse.
  - Higher temperatures have resulted in increased ozone levels in multiple years in the last decade.
  - Changes in weather patterns due to the changing climate are likely to increase concentrations of air pollution and to trap that air pollution near the ground, increasing exposure to unhealthy levels of pollution.

- Global warming will likely continue to increase the frequency of wildfires and droughts in the U.S. and make wildfires more severe while extending the fire season. That means more smoke and dust polluting the air. Global warming will also increase the rate at which the earth and plants emit pollutants naturally, which could make air pollution even worse. (See section “Global warming will make air pollution worse.”)

To protect Americans against health-threatening air pollution, policy makers need to take swift action to curb emissions, including:

- Electrifying buildings and equipment that currently burn fossil fuels directly. This includes switching fossil fuel-powered building systems and industry to electric alternatives and reducing emissions from transportation by accelerating the switch to electric cars and trucks.

- Further transforming the way we move by improving access to and the quality of public transportation systems and infrastructure for walking, biking and other non-driving forms of transportation.

- Increasing the use of renewable energy like wind, solar and geothermal and incentivizing improved energy efficiency.

- Protecting and building upon the Clean Air Act by strengthening air quality standards to levels fully protective of public health and by ensuring strong and consistent enforcement.
Introduction

The year 2020 shut the world down. As COVID-19 spread, cars, trucks, planes, trains and ships stopped moving. People across the U.S. isolated and distanced themselves from one another, and many noticed that their skies were clearer.

Just a few months later, however, the skies over much of America were as polluted as ever as the nation endured one of the worst fire seasons on record. Millions of acres of land were burned and lives from California to Washington to Colorado were upended. The skies in the American West turned red and orange, a horrifying reflection of the conflagrations. The effects of the fires didn’t stay contained to the West Coast and the Rockies, however: Americans across the country noticed their summer skies darkened and smelled the smoke from far-off wildfires.

There are many lessons that can be learned from 2020, including about air pollution. We had the lesson burned into us that the greenhouse gases we produce today will have repercussions for the air our children and grandchildren breathe – just as the carbon pollution pumped into the atmosphere over the last century helped fuel 2020’s devastating wildfires. But we also learned the hopeful lesson that if we reduce pollution today, we can enjoy noticeably cleaner skies almost overnight.

These lessons share the same takeaway: Cutting air pollution now – including by transitioning away from burning fossil fuels in our homes, businesses and vehicles – can help us and future generations enjoy healthier lives.

America has the tools and the technology to make our air cleaner and reduce our global warming emissions. It’s time to put them into practice.
Air pollution threatens public health

Americans breathe air polluted with a variety of contaminants, including particulate matter (PM), ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, volatile organic compounds (VOCs), and many other toxic or hazardous substances. This pollution, which comes from burning fossil fuels, agricultural activity, wildfires, and other sources, creates significant risks to public health. Each year, millions of Americans suffer from adverse health impacts linked to air pollution, and tens of thousands have their lives cut short.

Two pollutants of special concern are particulate matter and ozone. Fine particulate pollution smaller than 2.5 micrometers (PM$_{2.5}$) poses especially high health risks because it can be deposited deep in the lungs.$^{11}$ Ozone that forms near the ground is the main ingredient in smog and can damage human health in a variety of ways.

Air pollution – including, but not limited to, PM$_{2.5}$ and ozone pollution – damages many aspects of health and wellbeing, from lung function to mental health.

**Premature death.** Air pollution is the “greatest environmental health risk factor in the United States,” according to a recent study published in *Environmental Science & Technology Letters*, and is associated with 100,000-200,000 excess deaths each year.$^{12}$ Globally, particulate matter and ozone pollution are responsible for millions of deaths each year. A recent study in the journal *Environmental Research* modeled premature deaths due to PM$_{2.5}$ from fossil fuel combustion and found that such pollution was responsible for as many as 10.2 million excess deaths worldwide in 2012, and as many as 8.7 million in 2018.$^{13}$ A separate study in *Environmental Health Perspectives* estimated the global premature death toll of long-term ozone exposure to be as high as 1.23 million in 2010 just among adults over 30 years old.$^{14}$ Small changes in pollution levels affect death rates. A 2019 study published in the *New England Journal of Medicine* found that when the concentration of fine particulate matter (PM$_{2.5}$) increased by 10 micrograms per cubic meter (μg/m$^3$), daily mortality in the U.S. increased by 1.58%, the equivalent of an additional 122 deaths every day.$^{15}$ In addition, studies on pollution reduction in the United States showed that every 10 μg/m$^3$ improvement in a city’s annual average air quality reduced relative risk of death by 27%, and that mortality benefits of air pollution reduction extend down to extremely low concentrations of pollutants, indicating that any amount of air pollution can cause damage.$^{16}$ Similarly, a study of the health effects of air pollution found that in the U.S., “exposure to PM$_{2.5}$ increased all-cause mortality rates at concentrations below the present national limits.”$^{17}$

**Damage to respiratory and cardiovascular systems.** In weeks with elevated ozone or particulate matter pollution, hospital emergency rooms see more patients for breathing problems.$^{18}$ A 2019 study published in *JAMA: The Journal of the American Medical Association* found that higher levels of pollutants including ozone and particulate matter in the air are associated with increased risk of emphysema.$^{19}$ Air pollution, especially traffic-related air pollution, not only worsens asthma but may also cause more people to actually become asthmatic.$^{20}$ Air pollution can cause chronic obstructive pulmonary disease (COPD) and increase the likelihood of dying from COPD, as well as increase the risk of chronic bronchitis.$^{21}$
Research also shows strong associations between air pollution and cardiovascular diseases. Air pollution may cause arteries to calcify, may reduce levels of "good cholesterol," may increase the risk of hypertensive disorders in pregnant women, and may increase risk of stroke. Particulate pollution in particular is associated with increased risk of ischemic heart disease mortality, cerebrovascular mortality, stroke and myocardial infarction.

Worsened mental health and neural functioning. Recent studies have found that air pollution can affect mental health and cognition in many ways and at all ages. Two 2019 studies published in *PLOS Biology* found that poor air quality, including higher levels of particulate matter and ozone, was associated with increased risk of bipolar disorder. Long-term exposure to particulate pollution has also been associated with increased risk of Alzheimer’s disease and other forms of dementia. Air pollution has been linked to accelerated cognitive decline in older adults; to worse performance on tests of memory, cognition and IQ in young children; to increased risk for attention disorders, anxiety and depression in children; to lower academic performance in students; and to brain inflammation and tissue damage in children. Recent studies show an association between air pollution and feelings of nervousness, powerlessness and restlessness, as well as common mental disorders, physical symptoms of mental distress, and even psychotic experiences. And more and more evidence indicates that air pollution can increase the risk of depression and rates of outpatient psychiatric hospitalizations.

Decreased fertility and harm to pregnancies. Exposure to air pollution has been associated with decreased male and female fertility, lower rates of conception and worse pregnancy outcomes. A 2018 literature review found that higher levels of air pollution, particularly particulate matter, are associated with lower female fertility. And in 2020, a meta-analysis revealed that air pollution significantly impacted male fertility in a variety of ways. A separate meta-analysis, published in *Environmental Health*, found that increased air pollution levels, particularly levels of particulate pollution, are associated with lower rates of pregnancy, both clinically aided and not.

Beyond effects on fertility, air pollution can also affect pregnancies and births. Maternal exposure to either PM\(_{2.5}\) or ozone is associated with pre-term birth and low birth weight – which can increase the risk of death or adverse health outcomes – as well as stillbirth, especially among vulnerable populations. PM\(_{2.5}\), including at levels far lower than the EPA standard, was estimated by one study estimated to be responsible for up to 42,800 preterm births in the U.S. and Canada in 2010, or 10% of all preterm births in those countries in that year.

Particulate matter exposure has also been associated with reduced female fertility, reduced pregnancy rates and higher rates of miscarriage. Increased cancer risk. Exposure to air pollution can cause lung cancer and other cancers. The International Agency for Research on Cancer (IARC), part of the World Health Organization, has found that outdoor air pollution generally, and particulate matter specifically, are carcinogenic to humans. The IARC determined that “exposures to outdoor air pollution or particulate matter in polluted outdoor air are associated with increases in genetic damage that have been shown to be predictive of cancer in humans.” In 2010, 223,000 lung cancer deaths globally were attributed to exposure to PM\(_{2.5}\). A meta-analysis of studies of lung cancer and air pollution found that an increase in annual average PM\(_{2.5}\) concentration of 10 \(\mu g/m^3\) can increase the risk of lung cancer incidence and mortality by as much as 14%. Some studies have also shown that exposure to air pollution can reduce the likelihood of surviving lung cancer. Additionally, there is mounting evidence that air pollution – including that from fuel combustion indoors, traffic, and general outdoor air pollution – can increase the risk of oral, cervical, esophageal and bladder cancer, and may also be linked to brain, meningeal, kidney, liver, and colorectal cancer incidence and mortality. There is even suggestion that traffic-related air pollution may be connected to childhood leukemia and to adult breast cancer. A different meta-analysis suggests that an increase of 10 \(\mu g/m^3\) of PM\(_{2.5}\) may increase risk of cancer mortality by almost 20%.
Air pollution threatens public health

Increase risk of infectious diseases. By weakening immune systems and helping pathogens spread, air pollution can increase the risk of contracting infectious diseases and the risk of dying from them. Common air pollutants, including PM2.5 and ozone, have been associated with an increased risk of infection from, and of worse outcomes due to: influenza and influenza-like illnesses, diseases caused by the respiratory syncytial virus, pneumonia, diseases caused by rhinovirus, and other severe acute respiratory infections. Additional evidence suggests that exposure to air pollutants weakens the immune system, which can increase the risk of infection by viruses such as HIV, Nipah, Ebola, severe acute respiratory syndrome coronaviruses (SARS-CoV), and metapneumoviruses. In particular, many recent studies have shown that increased levels of air pollution, including particulate matter and ozone, increase the risk of infection by SARS-CoV-2, the virus that causes COVID-19, and increase the likelihood of death after infection. A study published in August 2021 in Scientific Advances found that the particulate pollution in the western U.S. that resulted from wildfires significantly increased the COVID-19 infection rate and the rate of severe disease and death due to COVID-19.

Children at risk

Children are particularly vulnerable to air pollution because their bodies are developing, and also because they tend to spend more time outside. Children are also exposed to higher levels of air pollution because they walk or are pushed in strollers closer to the height of vehicle exhaust pipes. In addition to the health effects detailed elsewhere, children are particularly vulnerable to impaired lung development and impaired long-term lung functioning from particulate pollution. Even prenatal exposure to air pollution can impair lung function and lung development in childhood.

Air pollution is harmful even at levels the EPA considers safe

In order to communicate the potential health risks of air pollution to the public, the EPA uses the Air Quality Index (AQI), which classifies levels of different pollutants into the color-coded risk categories of “Good,” “Moderate,” “Unhealthy for Sensitive Groups,” “Unhealthy,” “Very Unhealthy,” and “Hazardous.” (See Table 1 for details and colors.)

Air quality classified as “Good,” for example, poses “little or no risk” according to the EPA. “Moderate” pollution is described by the EPA as “acceptable,” though the agency notes “there may be a risk for some people, particularly those who are unusually sensitive to air pollution.” Higher levels of pollution threaten much more of the population and can damage health after much shorter exposure times.

The AQI is linked to the National Ambient Air Quality Standards (NAAQS), which are periodically reviewed and adjusted based on the latest research on the links between pollution and public health. For example, currently the EPA has concluded that ozone levels above 70 parts per billion (ppb) for eight hours or more are unhealthy for sensitive people, and when ozone exceeds that level, the EPA warns that children, older adults, people with lung disease, people who are active outdoors, people with certain genetic variants and people who lack certain nutrients in their diets should consider limiting their exposure. The EPA has concluded that sensitive people are at risk when levels of PM2.5 average 35.5 micrograms per cubic meter of air (µg/m³) over 24 hours.

However, research suggests that even “moderate” air quality can, in fact, pose broad threats to public health, and a variety of medical and public health organizations have recommended tighter air quality standards that are more protective of public health.

The World Health Organization (WHO), for example, recommends lower ozone and particulate pollution standards than are currently in place in the United States. The WHO published air quality guidelines in 2006 that recommended an ozone pollution standard equal to
51 ppb over eight hours. By comparison, 15 years later, the current U.S. ozone standard is 70 ppb. The WHO recommends that fine particulates be limited to 15 µg/m³ over 24 hours, which is more protective than the current U.S. standard of 35 µg/m³, though they have also noted that “there is little evidence to suggest a threshold below which no adverse health effects would be anticipated.” The American Thoracic Society, the American Lung Association and other health and advocacy groups support lowering the EPA standards to be more in line with the WHO recommendations, and some groups have petitioned to have the EPA standards reconsidered.

The EPA is currently revisiting the particulate standards because “available scientific evidence and technical information suggests that the current standards may not be adequate to protect public health and welfare.”

### TABLE 1. U.S. EPA AIR QUALITY INDEX VALUES AND COLORS

<table>
<thead>
<tr>
<th>Air quality category</th>
<th>Air quality index values</th>
<th>Color</th>
<th>Ozone readings (ppb)</th>
<th>24-Hour pm&lt;sub&gt;2.5&lt;/sub&gt; Readings (µg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>0-50</td>
<td>Green</td>
<td>0-54</td>
<td>0-12</td>
</tr>
<tr>
<td>Moderate</td>
<td>51-100</td>
<td>Yellow</td>
<td>55-70</td>
<td>12.1-35.4</td>
</tr>
<tr>
<td>Unhealthy for Sensitive Groups</td>
<td>101-150</td>
<td>Orange</td>
<td>71-85</td>
<td>35.5-55.4</td>
</tr>
<tr>
<td>Unhealthy</td>
<td>151-200</td>
<td>Red</td>
<td>86-105</td>
<td>55.5-150.4</td>
</tr>
<tr>
<td>Very Unhealthy</td>
<td>201-300</td>
<td>Purple</td>
<td>106-200</td>
<td>150.5-250.4</td>
</tr>
<tr>
<td>Hazardous</td>
<td>301-500</td>
<td>Maroon</td>
<td>201+</td>
<td>250.5+</td>
</tr>
</tbody>
</table>

A particulate monitor in Brockton, Massachusetts. Credit: Massachusetts Department of Environmental Protection via Flickr, CC BY 2.0.
A growing body of evidence supports the conclusion that even very low levels of pollution can affect health. In fact, there may not be a minimum threshold at which air pollution should be considered safe.

- In response to new data about deaths linked to particulate pollution, a 2019 editorial in the *New England Journal of Medicine* noted that “Even high-income countries, such as the United States, with relatively good air quality could still see public health benefits from further reduction of ambient PM concentrations (i.e., below the current [pollution standards]).”62

- In a 2017 study, researchers examined more than 22 million deaths in the Medicare population from 2000 to 2012 and found that a 10 ppb rise in warm-season ozone pollution increased the daily mortality rate by 0.5%, regardless of how low pollution levels had been initially.63 The authors concluded that there is “no evidence of a threshold” below which ozone or particulate pollution is safe.

- Even when concentrations of ozone are at levels the EPA considers “good” or “moderate,” a 2006 study found that an increase in ozone pollution results in more premature deaths.64

- In 2006, the WHO concluded that there is no documented safe level of exposure to particulate pollution.65

- A 2019 analysis of the effect of particulate pollution on all-cause mortality in 652 cities around the world concluded that there is no threshold below which particulate pollution is safe.66

- A 2021 literature review by an Australian air quality research organization to provide air pollution standards recommendations to the Australian government found that “…current evidence suggests there is no ‘safe’ level of air pollution,” including both PM2.5 and ozone.67

These results indicate that the current EPA standards may be insufficiently protective of health. The many serious health impacts of ozone and particulate pollution exposure detailed in the previous section, and the growing evidence that there are no safe levels of pollution, mean that federal and state leaders need to do more to improve air quality.
Fossil fuel combustion is a major source of air pollution

Air pollution comes from both human and natural sources. Gasoline, diesel, methane gas, coal and other fossil fuels burned for transportation, electricity generation, industrial processes, heating and other purposes are major sources of the nitrogen oxide (NOx) and volatile organic compound (VOC) emissions that contribute to the formation of ground-level ozone and also can turn into particulate pollution. Fossil fuel combustion, fires and dust are major direct sources of particulate pollution and some of those sources also produce precursor chemicals that combine into particulates.

Ozone

Ozone, the main component of smog, is formed by chemical reactions between NOx and VOCs in the presence of sunlight, and its formation is accelerated by higher temperatures. The production and consumption of fossil fuels are major sources of NOx and VOC emissions. Burning fossil fuels for transportation is responsible for the majority of NOx emissions in the United States. (See Figure 1.)

- Transportation, which includes on-road vehicles, ships, trains, farm and construction equipment, and other vehicles, accounted for 59% of U.S. NOx emissions in 2017. Cars, SUVs and other light-duty vehicles were responsible for 18% of total NOx emissions from human activities, while on-road diesel vehicles were responsible for 13%.

- In 2017, electricity generation by utilities at coal-fired power plants produced 9% of total human-related NOx emissions. Overall, electricity generation by utilities accounted for 11% of emissions.

- Industrial activities accounted for 14% of NOx emissions from human activities.

Wildfires and transportation were the two biggest sources of VOC emissions in the United States in 2017 (excluding VOCs released by plants). (See Figure 2.)

Figure 1. Anthropogenic sources of nitrogen oxide (NOx) pollution in 2017, United States (rounded)
Fossil fuel combustion is a major source of air pollution

- Wildfires and planned burns produced more than one-third of VOCs from human activities and fires in 2017.72
- Transportation was responsible for 18% of anthropogenic VOC emissions.
- Oil and gas production accounted for 15% of anthropogenic VOC emissions. In areas with oil and gas production, these emissions can have a significant influence on air quality. For example, along Colorado’s Front Range, emissions from oil and gas operations account for 30%-40% of locally produced ozone.73
- Solvents such as those used in consumer products, pesticides, graphic arts, architectural applications and other activities created 17% of anthropogenic VOCs.
- Trees and other plants are also a major source of VOCs, which they naturally emit for a variety of reasons including as defense mechanisms, to attract pollinators and to communicate with other plants.74 VOC emissions from plants can contribute to ground-level ozone when they react with pollution from human sources.75 Additionally, VOC emissions from plants are likely to increase as global warming drives temperatures up.76

**Particulate matter**

Particulate matter consists of solid or liquid particles that can be emitted directly from a source (such as from a diesel engine) or that can form in the air from chemicals such as VOCs, sulfur dioxide, ammonia and NO₃.77 Because of its size, PM₂.₅ poses elevated health risks as it can be absorbed deep into the lungs.78 The impact of PM₂.₅ is further increased by the fact that it is so lightweight that it remains in the air for a long time and can travel hundreds of miles from its source.79

Primary particulate matter is created by a variety of sources, including fossil fuel combustion; dust from roads, agriculture and construction; wildfires; and wood burned for heating.80 On average across the U.S., the majority of the particulate pollution in the atmosphere is secondary particulate pollution, which forms through chemical reactions of other pollutants in the air.81 Secondary PM₂.₅ can be created from sources including sulfur dioxide emitted by burning coal and other fossil fuels for electricity generation and industrial power; nitrogen oxides from fossil fuel combustion; and ammonia from fertilizer and manure.82

Mobile sources (including cars, trucks and other on-road and off-road vehicles) accounted for 20% of both primary and secondary PM₂.₅ in one 2004 study.83 Mobile sources may have disproportionately larger impacts on health compared to other sources, however, because mobile sources generally emit pollution in closer proximity to people. A 2019 study estimated that transportation emissions were associated with more than a quarter of U.S. deaths caused by fine particulate matter created by human activity.84

In addition to combustion emissions, cars, trucks and other on- and off-road vehicles play a role in producing other forms of particulate pollution. In 2017, dust from paved and unpaved roads accounted for 14% of primary fine particulate emissions.85 Vehicle braking also produces particulate pollution potentially containing heavy metals such as zinc and copper that may create health risks.86
Electricity generation is another contributor to PM$_{2.5}$ pollution. Power plants produce large amounts of sulfur dioxide, which can turn into PM$_{2.5}$. According to a 2019 study, sulfur dioxide from coal-fired power plants accounts for 11% of the total health damage from PM$_{2.5}$.88

Agriculture is another major source of particulate pollution. Dust from crop and livestock operations accounted for 14% of primary PM$_{2.5}$. Agriculture is also responsible for 80% of national emissions of ammonia, which can react in the atmosphere to form secondary particulate matter. Agricultural ammonia emissions, which come from sources including animal waste and fertilizer, are responsible for a significant percentage of human mortality attributed to PM$_{2.5}$.89 90 91

Air toxics

Fossil fuel combustion also releases toxic air contaminants such as benzene, formaldehyde and 1,3-butadiene that contribute to ozone and particulate pollution, and that are also hazardous on their own. These pollutants can cause cancer, and some, such as formaldehyde, increase the risk of asthma. Exposure to air toxics creates additional health threats above and beyond the threats highlighted in this report related to particulate matter and ozone.
Global warming will make air pollution worse

Pollution from cars, trucks, power plants, factories and fossil fuel infrastructure is the biggest immediate threat to air quality. But changes resulting from global warming threaten to make air quality even worse. Not only do some of the pollutants that damage our health also contribute to climate change, but the predicted changes in climate and the frequency and severity of natural disasters resulting from global warming are likely to fill the air we breathe with more pollutants. According to the U.S. Global Change Research Program’s Fourth National Climate Assessment, “climate change will worsen existing air pollution levels” without additional efforts to improve air quality. The report continues, “[t]his worsened air pollution would increase the incidence of adverse respiratory and cardiovascular health effects, including premature death.”

The vicious cycle of air pollution and global warming is already impacting our daily lives.

- Higher temperatures have already resulted in increased ozone, despite lower emissions of the chemicals that create ozone. In the central U.S. in the summer of 2012, for example, higher temperatures caused higher levels of ozone than in the years before and after. Yearly fluctuations in temperature occur naturally, but global warming drives up average temperature and the likelihood of extreme heat events. Recent years continue to be among the hottest in recorded history, and the American Lung Association warns that increasing temperatures – driven by global warming – will make ozone formation more likely and will make ozone removal more difficult.

- Hotter, drier conditions increase the frequency and severity of wildfires, which create particulate pollution and the precursors to ozone and can spike air pollution to very dangerous levels. By one estimate, global warming nearly doubled the total acreage that burned in western states from 1984 to 2015, compared to a scenario in which the climate had not changed. (See Figure 3.) By 2018, summer wildfires in California burned areas eight times larger each year than they did in 1972. In addition to creating the conditions for much larger fires, climate change has also extended the fire season in the western U.S. by at least 84 days, stretching out the period during which Americans may be exposed to the air pollution they create. Wildfires also burn for longer, causing more prolonged and widespread exposure to pollutants. The typical large wildfire now burns for more than seven weeks, compared to less than a week in the 1970s.

In the years to come, climate change will make air pollution even worse. In particular, the changing climate is likely to expose more people to ozone pollution more frequently, and to make the consequences of that exposure worse:

- Rising temperatures will result in more ozone formation. According to an analysis by researchers at Harvard and the National Center for Atmospheric
Research, people in the Northeast, Midwest and Southwest will experience an additional three to nine days of ozone pollution of above 75 parts per billion (ppb) annually by 2050 compared to 2000 because of higher temperatures predicted as a result of global warming. Ozone concentrations at that level are in the range the EPA considers “unhealthy for sensitive groups.”

- With higher temperatures throughout the year, unhealthy levels of ozone may become more common in the spring and fall, in addition to the summer ozone problems that are common today.

- Climate change is likely to increase the frequency and severity of events like wildfires that create ozone precursors and create conditions – including increased temperature – that increase the rate of ozone formation. It could also influence weather patterns that affect how ozone is transported.

- The U.S. Global Change Research Program has concluded that global warming will make it more difficult to control ozone pollution, and that maintaining current pollution levels in a warmer world will require reduced emissions of the chemicals that form ozone.

- Higher temperatures may also exacerbate the health effects of exposure to any given amount of ozone, as higher temperatures are associated with an increased risk of ozone-related premature death.

The effects of climate change on air pollution are not limited to ozone. A study in the journal *Air Quality, Atmosphere & Health* found that global warming will likely increase PM$_{2.5}$ pollution levels, from both anthropogenic sources and natural ones, and that global warming-induced PM$_{2.5}$ pollution increases could cause almost 200,000 more premature deaths globally each year. The increase in PM$_{2.5}$ pollution could come partly from increased emission of aerosols from plants, which emit more precursors to ozone and particulates with higher temperatures. It could also come partly from faster reactions of particulate precursors in the atmosphere.
such that those precursors become particulate pollution more quickly. A third possible cause for the increase in particulate pollution is an increase in the frequency and severity of droughts, which means less of the precipitation that removes particulates from the atmosphere.

Additionally, global warming is likely to change wind, precipitation and fire patterns in ways that could increase exposure to air pollution:

- Climate-driven changes may increase the number of days with stagnant air, trapping and concentrating pollution near the ground. Decreased air circulation may already be worsening air quality by trapping pollution precursors and pollution near the ground. Multiple days of stagnant air can lead to especially high levels of air pollution, including both ozone and PM$_{2.5}$, which can have severe health consequences.

- Climate change will increase the frequency and severity of wildfires, as a result of hotter temperatures and more droughts. According to the Fourth National Climate Assessment, resulting wildfires will “diminish air quality, increase incidences of respiratory illness from exposure to wildfire smoke, impair visibility, and disrupt outdoor recreational activities.”

- Global warming is projected to cause severe droughts in the southwestern U.S., increasing dust pollution. A 2019 study found that droughts could increase dust levels in the region, increasing deaths and hospitalizations attributable to fine dust by 230% and 360%, respectively. Reduced rainfall caused by global warming may also increase air pollution levels because rainfall removes particulate matter from the atmosphere.

- Higher temperatures change the metabolism of plants, which can increase evaporative emissions of volatile organic compounds, precursors to ozone and particulate matter.

Smoke and ash blanket San Francisco in September 2020. Credit: Christopher Michel via Flickr, CC BY 2.0.
Increased ozone pollution is also likely to accelerate climate change. For instance, the Environmental Protection Agency (EPA) has found that there is strong evidence to suggest that surface level ozone damages plant life in many ways, and that among its effects is decreasing the amount of carbon that plants sequester. The EPA also notes that tropospheric ozone (including the surface ozone that affects health) is a driver of global warming. This is distinct from stratospheric ozone in the upper atmosphere, which protects us from ultraviolet radiation.

The impact of PM$_{2.5}$ pollution on global warming is less clear. Some forms of PM$_{2.5}$, such as black carbon, absorb sunlight, which has a small warming effect. Other forms of PM$_{2.5}$ can actually cool the atmosphere, such as aerosols in the upper atmosphere that reflect incoming sunlight. According to the Intergovernmental Panel on Climate Change, the net effect of particulates given potential future scenarios is very likely to cause increased warming over the next few decades. Additionally, future changes in particulate pollution and other short-lived climate forcers like ozone and methane are likely to continue to cause some warming, with the magnitude of that effect heavily influenced by the strength of our climate and pollution mitigation efforts. This is partly because fire smoke is likely to become a larger portion of the PM$_{2.5}$ pollution concentration, and the forms of particulate matter in smoke drive warming in addition to causing health damage.

In many cases, the activities that cause air pollution also contribute to global warming. Efforts to reduce our reliance on fossil fuels, which contribute to global warming, have the potential to help reduce ozone and particulate pollution as well.
Air pollution was widespread in the United States in 2020

About this analysis

Hundreds of air quality monitors in both urban and rural areas across the nation report air pollution levels hourly. Based on this information and computer modeling, the U.S. Environmental Protection Agency (EPA) communicates present and forecasted air quality conditions using its Air Quality Index (AQI).

This report estimates the number of days of elevated air quality experienced in 2020 by people across the country based on the number of days when air quality monitors reported an AQI of 51 or higher. This includes days that the EPA coded air quality as “moderate,” “unhealthy for sensitive groups,” “unhealthy,” “very unhealthy,” or “hazardous.” Air pollution data were grouped locally, by metropolitan and micropolitan areas and rural counties. In areas that contain more than one monitoring location, days in which half or more of the monitoring locations in the area reported an air quality problem were included in the tally of days with degraded air quality.

Grouping air quality data across large geographies can mask local variations in air quality conditions with implications for public health. Because air quality varies over short distances based on weather conditions and sources of pollution, among other factors, the air people actually breathe could be of a different quality than the aggregate data for the area suggests. The EPA’s AirNow website can be used to find the locations of monitors and to locate the closest monitor to you. In addition, gaps in monitoring could result in air quality data failing to reflect actual conditions on the ground.

This report presents the number of days with elevated ground-level ozone pollution and with elevated particulate pollution, which pose different types of threats to health. It also presents the number of days in each area when ozone and/or particulate pollution were elevated, a measure of how often residents have to breathe polluted air. Air quality monitors report pollution levels at different time intervals, and not all of them report year-round. This analysis therefore likely presents an undercount of the number of days of elevated pollution experienced around the country.
Exposure to either ozone or particulate matter

Both ozone and particulate pollution are dangerous for human health. In 2020, more than 58.4 million people living in 53 large and small urban areas and rural counties experienced more than 100 days of either elevated ozone pollution, elevated PM$_{2.5}$ pollution or both. (See Table 2.) These Americans live all over the country, from Georgia to Ohio, and Pennsylvania to Texas and Washington.

Less frequent bad air conditions are even more widespread. In 2020, more than 179.2 million people – more than half the country’s residents – living in 257 large and small urban areas and rural counties experienced between 31 and 100 days of elevated ozone and/or PM$_{2.5}$ pollution. (See Table 3.)

Overall, 237.6 million people experienced more than a month of elevated air pollution in 2020, representing over 70% of the U.S. population.$^{131}$

### TABLE 2. TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED MORE THAN 100 DAYS OF ELEVATED OZONE AND/OR PM$_{2.5}$ IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days with ozone and/or PM$_{2.5}$ AQI over 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles-Long Beach-Anaheim, CA</td>
<td>209</td>
<td>13,109,903</td>
</tr>
<tr>
<td>Phoenix-Mesa-Chandler, AZ</td>
<td>149</td>
<td>5,059,909</td>
</tr>
<tr>
<td>Riverside-San Bernardino-Ontario, CA</td>
<td>203</td>
<td>4,678,371</td>
</tr>
<tr>
<td>San Diego-Chula Vista-Carlsbad, CA</td>
<td>232</td>
<td>3,332,427</td>
</tr>
<tr>
<td>Denver-Aurora-Lakewood, CO</td>
<td>129</td>
<td>2,991,231</td>
</tr>
<tr>
<td>San Antonio-New Braunfels, TX</td>
<td>101</td>
<td>2,590,732</td>
</tr>
<tr>
<td>Sacramento-Roseville-Folsom, CA</td>
<td>122</td>
<td>2,374,749</td>
</tr>
<tr>
<td>Austin-Round Rock-Georgetown, TX</td>
<td>103</td>
<td>2,295,303</td>
</tr>
<tr>
<td>Cincinnati, OH-KY-IN</td>
<td>103</td>
<td>2,232,907</td>
</tr>
<tr>
<td>Indianapolis-Carmel-Anderson, IN</td>
<td>112</td>
<td>2,091,019</td>
</tr>
</tbody>
</table>

### TABLE 3. TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED 31-100 DAYS OF ELEVATED OZONE AND/OR PM$_{2.5}$ IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days with ozone and/or PM$_{2.5}$ AQI over 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York-Newark-Jersey City, NY-NJ-PA</td>
<td>47</td>
<td>19,124,359</td>
</tr>
<tr>
<td>Chicago-Naperville-Elgin, IL-IN-WI</td>
<td>84</td>
<td>9,406,638</td>
</tr>
<tr>
<td>Dallas-Fort Worth-Arlington, TX</td>
<td>72</td>
<td>7,694,138</td>
</tr>
<tr>
<td>Houston-The Woodlands-Sugar Land, TX</td>
<td>96</td>
<td>7,154,478</td>
</tr>
<tr>
<td>Miami-Fort Lauderdale-Pompano Beach, FL</td>
<td>38</td>
<td>6,173,008</td>
</tr>
<tr>
<td>Philadelphia-Camden-Wilmington, PA-NJ-DE-MD</td>
<td>49</td>
<td>6,107,906</td>
</tr>
<tr>
<td>Atlanta-Sandy Springs-Alpharetta, GA</td>
<td>67</td>
<td>6,087,762</td>
</tr>
<tr>
<td>San Francisco-Oakland-Berkeley, CA</td>
<td>70</td>
<td>4,696,902</td>
</tr>
<tr>
<td>Detroit-Warren-Dearborn, MI</td>
<td>95</td>
<td>4,304,136</td>
</tr>
<tr>
<td>Seattle-Tacoma-Bellevue, WA</td>
<td>47</td>
<td>4,018,598</td>
</tr>
</tbody>
</table>
Air pollution was widespread in the United States in 2020.

Figure 4. Number of days when half or more monitoring locations reported elevated ozone and/or PM$_{2.5}$ AQI over 50 in 2020.
Exposure to ozone pollution
In 2020, almost 13.6 million people living in 11 large and small urban areas and rural counties were exposed to more than 100 days – well over three full months – of elevated ozone pollution. (See Table 4.) These Americans live in Western states: California, New Mexico, Arizona and Colorado.

Ozone is harmful even with less frequent exposure, however. In 2020, almost 57.3 million people living in 90 large and small urban areas and rural counties from every region of the country were exposed to between 31 and 100 days of elevated ozone pollution. (See Table 5.) This still represents a significant reduction in exposure relative to 2018, when up to 170 million Americans experienced between 31 and 100 days of elevated ozone.132

The drop in ozone exposure between 2018 and 2020 also appeared in the EPA’s analysis of long-term ozone trends, in which the agency found a 34% decrease in the number of days of elevated ozone levels in 35 major cities around the country between 2018 and 2020.133

### TABLE 4. TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED MORE THAN 100 DAYS OF ELEVATED OZONE IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days with ozone AQI over 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phoenix-Mesa-Chandler, AZ</td>
<td>103</td>
<td>5,059,909</td>
</tr>
<tr>
<td>Riverside-San Bernardino-Ontario, CA</td>
<td>162</td>
<td>4,678,371</td>
</tr>
<tr>
<td>Fresno, CA</td>
<td>110</td>
<td>1,000,918</td>
</tr>
<tr>
<td>Bakersfield, CA</td>
<td>142</td>
<td>901,362</td>
</tr>
<tr>
<td>Colorado Springs, CO</td>
<td>104</td>
<td>753,839</td>
</tr>
<tr>
<td>Visalia, CA</td>
<td>158</td>
<td>468,680</td>
</tr>
<tr>
<td>Boulder, CO</td>
<td>106</td>
<td>327,171</td>
</tr>
<tr>
<td>Madera, CA</td>
<td>132</td>
<td>157,761</td>
</tr>
<tr>
<td>Hanford-Corcoran, CA</td>
<td>125</td>
<td>152,692</td>
</tr>
<tr>
<td>Carlsbad-Artesia, NM</td>
<td>110</td>
<td>58,418</td>
</tr>
</tbody>
</table>

### TABLE 5. TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED 31-100 DAYS OF ELEVATED OZONE IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days with ozone AQI over 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles-Long Beach-Anaheim, CA</td>
<td>100</td>
<td>13,109,903</td>
</tr>
<tr>
<td>Detroit-Warren-Dearborn, MI</td>
<td>32</td>
<td>4,304,136</td>
</tr>
<tr>
<td>San Diego-Chula Vista-Carlsbad, CA</td>
<td>42</td>
<td>3,332,427</td>
</tr>
<tr>
<td>Denver-Aurora-Lakewood, CO</td>
<td>98</td>
<td>2,991,231</td>
</tr>
<tr>
<td>San Antonio-New Braunfels, TX</td>
<td>47</td>
<td>2,590,732</td>
</tr>
<tr>
<td>Sacramento-Roseville-Folsom, CA</td>
<td>61</td>
<td>2,374,749</td>
</tr>
<tr>
<td>Las Vegas-Henderson-Paradise, NV</td>
<td>81</td>
<td>2,315,963</td>
</tr>
<tr>
<td>Cincinnati, OH-KY-IN</td>
<td>34</td>
<td>2,232,907</td>
</tr>
<tr>
<td>Milwaukee-Waukesha, WI</td>
<td>33</td>
<td>1,577,676</td>
</tr>
<tr>
<td>Oklahoma City, OK</td>
<td>37</td>
<td>1,425,375</td>
</tr>
</tbody>
</table>
Air pollution was widespread in the United States in 2020.

Figure 5. Number of days when half or more monitoring locations reported elevated ozone AQI over 50 in 2020.
Exposure to particulate pollution
In 2020, almost 30.7 million people living in 26 large and small urban areas and rural counties were exposed to more than 100 days of elevated PM$_{2.5}$ pollution. (See Table 6.) These Americans were in states from California to Oregon and from Washington to Texas.

Particulate pollution can cause health damage even with less frequent exposure, however. In 2020, almost 175.4 million people living in 194 large and small urban areas and rural counties experienced between 31 and 100 days of elevated PM$_{2.5}$ pollution. (See Table 7.) Particulate pollution affects every part of the country.

All told, more than 206 million Americans experienced more than a month of elevated particulate pollution in 2020, more than 62% of the U.S. population.\textsuperscript{134}

\begin{table}[h]
\centering
\caption{TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED MORE THAN 100 DAYS OF ELEVATED PM$_{2.5}$ IN 2020}
\begin{tabular}{|l|c|c|}
\hline
Location & Number of days with PM$_{2.5}$ AQI over 50 & Population \\
\hline
Los Angeles-Long Beach-Anaheim, CA & 178 & 13,109,903 \\
Riverside-San Bernardino-Ontario, CA & 118 & 4,678,371 \\
San Diego-Chula Vista-Carlsbad, CA & 225 & 3,332,427 \\
Indianapolis-Carmel-Anderson, IN & 101 & 2,091,019 \\
Fresno, CA & 171 & 1,000,918 \\
Bakersfield, CA & 119 & 901,362 \\
Dayton-Kettering, OH & 102 & 809,248 \\
Stockton, CA & 153 & 767,967 \\
Jackson, MS & 116 & 589,082 \\
Spokane-Spokane Valley, WA & 102 & 574,585 \\
\hline
\end{tabular}
\end{table}

\begin{table}[h]
\centering
\caption{TEN MOST POPULOUS LOCATIONS THAT EXPERIENCED 31-100 DAYS OF ELEVATED PM$_{2.5}$ IN 2020}
\begin{tabular}{|l|c|c|}
\hline
Location & Number of days with PM$_{2.5}$ AQI over 50 & Population \\
\hline
New York-Newark-Jersey City, NY-NJ-PA & 36 & 19,124,359 \\
Chicago-Naperville-Elgin, IL-IN-WI & 64 & 9,406,638 \\
Dallas-Fort Worth-Arlington, TX & 50 & 7,694,138 \\
Houston-The Woodlands-Sugar Land, TX & 81 & 7,154,478 \\
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD & 32 & 6,107,906 \\
Atlanta-Sandy Springs-Alpharetta, GA & 66 & 6,087,762 \\
Phoenix-Mesa-Chandler, AZ & 62 & 5,059,909 \\
San Francisco-Oakland-Berkeley, CA & 70 & 4,696,902 \\
Detroit-Warren-Dearborn, MI & 83 & 4,304,136 \\
Seattle-Tacoma-Bellevue, WA & 41 & 4,018,598 \\
\hline
\end{tabular}
\end{table}
Air pollution was widespread in the United States in 2020.

Figure 6. Number of days when half or more monitors reported PM$_{2.5}$ AQI over 50 in 2020.
Wildfires caused very unhealthy levels of air pollution

Although by some metrics Americans’ exposure to air pollution was better in 2020 than in years past, looking only at the number of days with air quality past a certain threshold masks the severity of the air pollution to which many Americans were exposed over the course of the year.

In 2020, many Americans were exposed to incredibly high levels of air pollution. Some of the pollution is due to the sources that cause bad air quality across the country: traffic, industry, dust, etc. But many of the worst air days were caused by the record-setting wildfire season in the western U.S. Because of the wildfires, most of the locations with the worst air quality measurements in 2020, and most of those with the largest number days with bad air quality, were in the western U.S., especially in California, Washington, Oregon, New Mexico and Colorado.

For instance, Mono County, California, on the California/Nevada border in the central part of the state, east of Yosemite, experienced the single worst PM$_{2.5}$ AQI measurement in 2020, according to EPA data. (See Table 8 and Figure 7.) Mono County saw the concentrations of pollutants in its air spike in September and October of 2020, reaching an AQI over 700 as the fires in California – including the nearby Creek Fire, which burned almost 380,000 acres – were exacerbated by an intense heat wave.135 (See Figure 7.) Mono County’s AQI reading of 714 is literally off the charts: it is what the EPA describes as “Beyond the AQI,” and corresponds to a 24-hour PM$_{2.5}$ concentration of about 900 µg/m$^3$ which, according to one comparison tool, is like smoking approximately 41 cigarettes in a day.136

Similarly, the Portland-Vancouver-Hillsboro region in Oregon and Washington saw particulate matter concentrations in the air skyrocket in September when a series of fires exploded in the region.137 (See Figure 8.) The area had never seen air quality as bad as it got during that stretch, according to a county official.138 Exposure to wildfire smoke is particularly concerning because recent evidence indicates that the particulate matter in wildfire smoke may be many times more dangerous than ambient particulates.139

Particulate pollution concentrations reached extremely unhealthy levels all along the West Coast, from Washington to California. (See Table 8.) Even short exposures to this level of pollution can cause health damage.
Air pollution was widespread in the United States in 2020.

Figure 8. PM$_{2.5}$ AQI for the Portland-Vancouver-Hillsboro region, Oregon-Washington in 2020

Table 8. Highest AQI Reading for the Top 10 Unique Places by Single Monitor

<table>
<thead>
<tr>
<th>Location</th>
<th>Monitor address</th>
<th>Date of reading</th>
<th>PM$_{2.5}$ AQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mono County, CA</td>
<td>330 Matty Avenue, Lee Vining, California, 93541</td>
<td>9/17/20</td>
<td>714</td>
</tr>
<tr>
<td>Prineville, OR</td>
<td>251 S.E. Court St., Prineville, Oregon, 97754</td>
<td>9/12/20</td>
<td>561</td>
</tr>
<tr>
<td>Eugene, OR</td>
<td>47674 School St., Oakridge, Oregon, 97463</td>
<td>9/12/20</td>
<td>550</td>
</tr>
<tr>
<td>Medford, OR</td>
<td>711 Welch St., Medford, Oregon, 97501</td>
<td>9/12/20</td>
<td>517</td>
</tr>
<tr>
<td>Portland-Vancouver-Hillsboro, OR-WA</td>
<td>2722 N.E. 84th Ave., Vancouver, Washington, 98662</td>
<td>9/13/20</td>
<td>509</td>
</tr>
<tr>
<td>Klamath Falls, OR</td>
<td>4856 Clinton St., Klamath Falls, Oregon, 97603</td>
<td>9/12/20</td>
<td>472</td>
</tr>
<tr>
<td>Plumas County, CA</td>
<td>420 Gulling Street, Portola, California, 96122</td>
<td>9/12/20</td>
<td>469</td>
</tr>
<tr>
<td>Yakima, WA</td>
<td>141 Ward Rd., Toppenish, Washington, 98948</td>
<td>9/14/20</td>
<td>465</td>
</tr>
<tr>
<td>Ukiah, CA</td>
<td>125 E. Commercial St., Willits, California, 95490</td>
<td>9/9/20</td>
<td>456</td>
</tr>
<tr>
<td>Spokane-Spokane Valley, WA</td>
<td>261 E 1st St., Colville, Washington, 99114</td>
<td>9/13/20</td>
<td>432</td>
</tr>
</tbody>
</table>
Air pollution also affects rural areas

Though much of the data in this section is presented with the context of population to show how many people experience bad air quality, this masks the fact that air pollution is very much a threat to rural areas with fewer people in them. Though some sources of pollution, like road traffic, are less present in rural areas, industrial pollution, smoke and agricultural pollution can still be prevalent, and weather patterns can bring pollution in from other places. In 2020, many rural areas experienced many days of elevated air pollution (see Table 9). With a changing climate and increasingly long and severe fire seasons, being in the countryside no longer means the air is necessarily cleaner.

Unfortunately, in many areas of the country, especially in rural areas, there are few or no air quality monitors, which makes understanding the full extent of the pollution problem in the U.S. difficult.

### TABLE 9. TEN LEAST POPULOUS LOCATIONS THAT EXPERIENCED MORE THAN 100 DAYS OF OZONE AND/OR PM$_{2.5}$ AQI ABOVE 50 IN 2020

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of days in 2020 with ozone and/or PM$_{2.5}$ AQI above 50</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harney County, OR</td>
<td>111</td>
<td>7,373</td>
</tr>
<tr>
<td>Mono County, CA</td>
<td>139</td>
<td>14,534</td>
</tr>
<tr>
<td>Mariposa County, CA</td>
<td>116</td>
<td>17,160</td>
</tr>
<tr>
<td>Plumas County, CA</td>
<td>118</td>
<td>18,967</td>
</tr>
<tr>
<td>Lincoln County, MT</td>
<td>148</td>
<td>20,343</td>
</tr>
<tr>
<td>Okanogan County, WA</td>
<td>109</td>
<td>42,620</td>
</tr>
<tr>
<td>Calaveras County, CA</td>
<td>102</td>
<td>46,308</td>
</tr>
<tr>
<td>Nogales, AZ</td>
<td>117</td>
<td>46,808</td>
</tr>
<tr>
<td>Carlsbad-Artesia, NM</td>
<td>110</td>
<td>58,418</td>
</tr>
<tr>
<td>Red Bluff, CA</td>
<td>117</td>
<td>64,494</td>
</tr>
</tbody>
</table>
Progress on air pollution is stalling
Though air quality in the U.S. has improved over the decades, in recent years that progress has slowed. The U.S. Environmental Protection Agency calculates that the average level of ozone pollution dropped by 20% from 2000 to 2020 and that fine particulate pollution levels and 1-hour NO₂ levels dropped by 30% and 39% respectively over the same period.¹⁴⁰

However, the agency’s analysis of elevated ozone and particulate pollution in 35 major cities shows that the progress that had been made in reducing air pollution around the country in past decades has seemingly stalled out since about 2013.¹⁴¹ The EPA’s analysis shows mixed results in pollution reduction for the studied cities, with some continuing to reduce the number of days residents are exposed to elevated pollution levels and others, especially in the western U.S., dealing with more and more polluted air.¹⁴²

As explained previously, fossil fuel combustion is the main sources of both air pollution and the greenhouse gases that drive global warming. Transitioning away from fossil fuels can therefore both reduce air pollution and help mitigate the worst effects of climate change. Since the changing climate, as previously discussed, is likely to worsen air pollution without other interventions, cutting fossil fuel use and thereby limiting the extent of global warming would have the indirect effect of reducing the negative effects of global warming on air quality.
Conclusion and recommendations

As more research is conducted on air pollution and its effects on human health and well-being, we are learning that the scale and magnitude of those effects is much larger than we knew even a few years ago. We are learning that air pollution can cause and/or worsen everything from heart disease to cancer, depression to COVID-19, and that exposure to particulate and ozone pollution at any level increases the risk of death from all causes.

We are also learning more and more about the scale of the air pollution problem and its interconnections with many aspects of our society and environment. It is clear that fossil fuel combustion is one of the main sources of air pollution. And it is increasingly clear that global warming will both exacerbate the air pollution problem and be accelerated by many forms of air pollution.

The single biggest tool to improving air quality and reducing climate pollution to protect Americans’ health and avoid the worst impacts of climate change is to rapidly shift away from fossil fuels throughout the economy. In addition, policymakers should strengthen standards for air quality to levels that are more protective of public health. Opportunities to achieve significant and lasting reductions in air pollution include:

Electrifying buildings, equipment and transportation. Using fossil fuels in our homes, businesses, industry and transportation necessitates emitting air pollution – including greenhouse gases – at every step of the process, from pumping the fuel out of the ground to piping it around the country and then to burning it where we live and work. Policymakers should be working to support and accelerate:

- **Switching to electricity for building and industry systems.** Heating, cooling and hot water systems can be replaced by heat pump systems, which are much more efficient than fossil fuel-powered systems and previous generations of electric equipment. Many industrial processes that require less heat – such as paper production and recycling, plastic recycling, and aluminum casting – can already be electrified and increasing the efficiency of industrial processes can also cut emissions. With further research and development, new electrification technologies could replace equipment even in harder-to-decarbonize fields such as steel and cement production.

- **Electrifying transportation.** Highway vehicles are a major source of air pollution. Pollution from vehicles is also especially harmful, as vehicle emissions often occur in densely populated urban areas and directly into the air people breathe. Specifically, policymakers should:
  - Hasten the transition to electric cars, SUVs and light-duty trucks. Fourteen states – California, Colorado, Connecticut, Maine, Maryland, Massachusetts, Minnesota, New Jersey, New York, Oregon, Rhode Island, Vermont, Virginia and Washington – already have electric vehicle sales requirements. Elected officials in other states should seek to adopt such requirements and set goals to have all new passenger vehicles be electric vehicles by 2035 at the latest. In addition, states should also support the development of infrastructure needed to recharge those vehicles.
○ Establish strong federal fuel economy and global warming pollution standards for light-duty vehicles. On August 5, 2021, President Biden signed an executive order setting a goal that 50% of new light-duty vehicles sold in 2030 be zero-emission vehicles. To accomplish this goal, federal agencies will need to set more ambitious limits on tailpipe pollution for the next decade to push the auto industry to develop more electric vehicles.

○ Replace diesel buses with electric buses. Transit agencies and school districts should replace buses powered by fossil fuels with electric buses over their next replacement cycle. Both New York City and the state of California have committed to replacing all transit buses with electric buses by 2040.

○ Reduce pollution from all forms of transportation, including medium- and heavy-duty vehicles, airplanes, railroads and marine vessels by establishing incentives and mandates for zero- and reduced-emissions technologies. Already, 15 states and the District of Columbia have committed to having 30% of new medium- and heavy-duty trucks be zero-emission vehicles by 2030, and 100% by 2050. Separately, California is developing tougher standards to cut NOx pollution from heavy-duty diesel trucks. Other states should adopt California's standard once it is finalized.

Increasing the use of clean, renewable energy. Renewable energy sources such as wind and solar power can reduce air pollution and climate pollution by cutting the need for production, transportation and burning of fossil fuels. Policymakers should commit to obtaining 100% of electricity from clean and renewable sources. This will be easier to accomplish with improved energy efficiency and reduced energy use. Already, eight states and many cities and counties have adopted commitments to obtain all of their energy from clean sources in the coming decades.

Protecting and building upon progress achieved under the Clean Air Act. The Clean Air Act has reduced air pollution and improved public health across the nation since its enactment five decades ago. With the challenge that climate change presents to air quality, the nation will need to take further action to maintain current air quality levels, much less improve air quality. To protect public health, political leaders and regulators should:

• Strengthen ozone and particulate matter standards. Ozone and particulate matter standards should be brought in line with the best available scientific understanding of what is necessary to minimize adverse effects on human health. Groups including the World Health Organization, the American Lung Association and the American Thoracic Society all recommend standards tighter than the EPA's. The EPA should make a careful review of the latest research on the dangers of air pollution and should tighten pollution standards to be maximally protective of public health.

• Ensure strong enforcement of the Clean Air Act, including by requiring enforcement agencies to:

  ○ Issue timely, health-based air quality permits that are maximally protective of public health.

  ○ Take timely, aggressive enforcement action to hold polluters accountable.

  ○ Expand and improve air quality monitoring.

Reform the way we move by enabling people to drive less and walk, bike and use transit more. Such a change would cut air pollution and global warming pollution and give more people access to the health benefits of increased physical activity. Street and community designs that make walking and biking both safe and pleasant can help encourage people to drive less. Frequent, reliable transit service can attract more riders. Providing people with more options for getting out of their cars will require policymakers to increase funding for walking, biking and transit (which could be done by shifting funds away from new road construction) and supporting development patterns that allow people to travel easily without a car.
Methodology

This report estimates the number of days of degraded air quality experienced in 2020 by people living across the U.S. based on the number of days when air quality monitors for PM$_{2.5}$ or ozone reported an AQI of 51 or higher. Particulate matter and ozone are among the air pollutants that the World Health Organization reports as having the "strongest evidence for public health concern."154 (See “Air pollution threatens public health.”) The report also presents the number of days with elevated ozone and/or particulate pollution, a measure of how often residents have to breathe polluted air, and presents some of the highest single-monitor AQI measurements from 2020.

Data from air pollution monitors were grouped regionally by metropolitan and micropolitan areas and rural counties. In areas that contain more than one monitoring location, days in which half or more of the monitoring locations in the area reported an air quality problem were included in the tally of days with degraded air quality.

Air pollution data for 2020 are from U.S. Environmental Protection Agency, Air Data: Pre-Generated Data Files, accessed at https://aqs.epa.gov/aqsweb/airdata/download_files.html, 30 June 2021. This analysis uses the daily summary data for ozone and the daily summary data for PM$_{2.5}$ measured with FRM/FEM mass methods, which includes a daily EPA-calculated Air Quality Index (AQI) score for each monitoring station and for each pollutant. Only the PM$_{2.5}$ data calculated as 24-hour averages or 24-hour block averages in the “Sample Duration” column were used.

The geographic units included in this analysis were core-based statistical areas (CBSA) – metropolitan and micropolitan areas identified by the federal Office of Management and Budget – and counties that are not part of a CBSA but that include one or more air quality monitoring locations. Each CBSA or county may have more than one monitoring location, and each location may have multiple monitors.

Due to a discrepancy in the names of 38 geographic areas between the U.S. Environmental Protection Agency’s air quality data CBSA names and those in the U.S. Census Bureau’s population data, CBSAs with the same primary city were assumed to be the same in the EPA and Census datasets, and the Census names and population data were used.

The method for each pollutant was as follows:

1. Count the number of monitoring locations with eight-hour ozone AQIs and 24-hour PM$_{2.5}$ AQIs above 50 for each CBSA and county.

2. Divide that by the total number of monitoring locations within each CBSA/county that reported an AQI for that pollutant on that day.

3. Tally the number of days on which half or more reporting locations in each CBSA or county reported an AQI above 50 for each pollutant.

4. Tally the number of days with elevated AQI for either pollutant by counting each day in which a CBSA or county had elevated AQI for either pollutant, classifying a day with elevated AQI for both ozone and PM$_{2.5}$ as a single day with elevated pollution levels.

The populations for 13 geographic areas were not included in these two sources, and alternate sources — some with 2018 or 2019 data — were used:

- The estimated 2020 population presented in this report for the Bishop, California, CBSA is that of Inyo County, California, from U.S. Census Bureau, QuickFacts, Inyo County, California, accessed 20 September 2021 at https://www.census.gov/quickfacts/fact/table/inyocountycalifornia/POP010220.

- The estimated 2020 population presented in this report for the Macon, Georgia, CBSA is that of Macon-Bibb County, Georgia, obtained from U.S. Census Bureau, QuickFacts, Macon-Bibb County, Georgia, accessed 20 September 2021 at https://www.census.gov/quickfacts/fact/table/maconbibbcountygeorgia/POP010220.

- The estimated 2020 population presented in this report for the Rockland, Maine, CBSA is that of Knox County, Maine, obtained from U.S. Census Bureau, QuickFacts, Knox County, Maine, accessed 20 September 2021 at https://www.census.gov/quickfacts/fact/table/knoxcountymaine/POP010220.


- The estimated 2020 population for Adjuntas, Puerto Rico, was obtained from U.S. Census Bureau, QuickFacts, Adjuntas Municipio, Puerto Rico, accessed 29 July 2021 at https://www.census.gov/quickfacts/fact/table/adjuntasmunicipiopuertorico/POP010220.


- The estimated 2020 population for Mayagüez, Puerto Rico, is that of Mayagüez and Hormigueros municipios, Puerto Rico, obtained from U.S. Census Bureau, QuickFacts, Mayagüez Municipio, Puerto Rico and Hormigueros Municipio, Puerto Rico, accessed 20 September 2021 at https://www.census.gov/quickfacts/fact/table/mayaguezmunicipiopuertorico,hormiguerosmunicipiopuertorico/POP010220.


Methodology
The estimated 2019 population presented in this report for the San Juan-Carolina-Caguas, Puerto Rico, CBSA was obtained from Data USA, San Juan-Carolina-Caguas, PR Metropolitan Statistical Area (MSA), accessed 29 July 2021 at https://datausa.io/profile/geo/san-juan-carolina-caguas-pr#about.

The estimated 2019 population presented in this report for the Marshall, Texas, CBSA is that of Harrison County, Texas, obtained from Census Reporter, Harrison County, Texas, accessed 12 August 2021 at https://censusreporter.org/profiles/05000US48203-harrison-county-tx/.

Because the Longview, Texas CBSA includes Harrison County, the population of Harrison County was subtracted from the population of Longview, Texas.


Finally, the EPA air quality data was summarized to provide counts for each CBSA and county of the number of ozone monitoring locations, the number of PM$_{2.5}$ monitoring locations, the number of days on which an ozone AQI was reported, and the number of days on which a PM$_{2.5}$ AQI was reported.

The data assessed may miss certain threats that air pollution poses to public health. For example, averaging pollution data over eight hours for ozone and 24 hours for particulate pollution, as is the case for the AQI data used in this report, may mask short-term spikes in pollution that can damage health. Additionally, this analysis would be affected if different monitors in the same area are targeted towards different forms of the same pollutant (i.e. background vs. high pollution). Some results not counted as indicating degraded air quality in this analysis also likely pose a threat to health. (See “Air pollution is harmful at some levels the EPA considers safe.”) Attributing elevated air quality to full counties or CBSAs may mask variations on a smaller geographic level. Additionally, this analysis is affected both by the number of monitors in a given location (which determines the threshold at which we classify a day with elevated air pollution) and the frequency of reporting. Finally, this assessment does not include analysis of other pollutants, which can also be harmful to human health and the environment.
Sources of air pollution

For purposes of categorization in Appendix B and Figures 1 and 2, pollutant sources were aggregated based on the EPA’s “Tier 1” source categorization as follows:

<table>
<thead>
<tr>
<th>Tier 1 category</th>
<th>New categorization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical &amp; Allied Product Mfg</td>
<td>Industrial and other processes</td>
</tr>
<tr>
<td>Fuel Comb. Elec. Util.</td>
<td>Electricity generation</td>
</tr>
<tr>
<td>Fuel Comb. Industrial</td>
<td>Industrial and other processes</td>
</tr>
<tr>
<td>Fuel Comb. Other</td>
<td>Residential, commercial and institutional</td>
</tr>
<tr>
<td>Highway Vehicles</td>
<td>Transportation</td>
</tr>
<tr>
<td>Metals Processing</td>
<td>Industrial and other processes</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Miscellaneous</td>
</tr>
<tr>
<td>Off-Highway</td>
<td>Transportation</td>
</tr>
<tr>
<td>Other Industrial Processes</td>
<td>Industrial and other processes</td>
</tr>
<tr>
<td>Petroleum &amp; Related Industries</td>
<td>Petroleum &amp; related industries</td>
</tr>
<tr>
<td>Solvent Utilization</td>
<td>Miscellaneous</td>
</tr>
<tr>
<td>Storage &amp; Transport</td>
<td>Miscellaneous</td>
</tr>
<tr>
<td>Waste Disposal &amp; Recycling</td>
<td>Miscellaneous</td>
</tr>
</tbody>
</table>

For VOCs, additional categorizations were applied as follows:

- Sources with an original Tier 1 source category of “solvent utilization” were categorized with the same name.
- Sources with original Tier 3 source categories of “prescribed burning” or “forest wildfires” were categorized as “wildfires and prescribed burning.”
Appendix A: Days with elevated ozone, particulates and total pollution, by geographic area, 2020

This count includes air pollution at or above the level the EPA labels “moderate,” and indicated in yellow or worse in its Air Quality Index. N/A indicates the location does not have a monitor for the type of pollution in question.

Air pollution data are listed by state. Results for urban areas are listed first, in alphabetical order, followed by results for rural counties that are not part of a metropolitan or micropolitan area. Many rural counties do not have any air pollution monitors and therefore do not appear here. Metropolitan and micropolitan areas that extend into more than one state are listed multiple times, once for each state.

Included with the counts of days of elevated pollution are counts of monitoring locations for that pollutant and the number of days on which an AQI for that pollutant was reported.

TABLE A1. DAYS WITH ELEVATED OZONE, PARTICULATES AND TOTAL POLLUTION, BY GEOGRAPHIC AREA, 2020

<table>
<thead>
<tr>
<th>State or territory</th>
<th>Urban area or county</th>
<th>Ozone</th>
<th>Particulate</th>
<th>Number of days with elevated ozone</th>
<th>Number of days with reported ozone AQI</th>
<th>Number of monitoring locations</th>
<th>Number of days with elevated particulate</th>
<th>Number of days with reported particulate AQI</th>
<th>Number of monitoring locations</th>
<th>Number of days with elevated ozone and/or particulate</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Birmingham-Hoover, AL</td>
<td>16</td>
<td>365</td>
<td>7</td>
<td>86</td>
<td>362</td>
<td>5</td>
<td>94</td>
<td>1,091,921</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Columbus, GA-AL</td>
<td>3</td>
<td>246</td>
<td>2</td>
<td>62</td>
<td>358</td>
<td>4</td>
<td>63</td>
<td>322,658</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Daphne-Fairhope-Foley, AL</td>
<td>7</td>
<td>234</td>
<td>1</td>
<td>12</td>
<td>113</td>
<td>1</td>
<td>19</td>
<td>229,287</td>
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<td></td>
<td>Decatur, AL</td>
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<td>234</td>
<td>1</td>
<td>30</td>
<td>218</td>
<td>1</td>
<td>39</td>
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<td></td>
<td>Fort Payne, AL</td>
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<td>366</td>
<td>1</td>
<td>8</td>
<td>109</td>
<td>1</td>
<td>14</td>
<td>71,658</td>
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<td>Gadsden, AL</td>
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<td>239</td>
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<td>15</td>
<td>115</td>
<td>1</td>
<td>18</td>
<td>102,371</td>
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<td></td>
<td>Huntsville, AL</td>
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<td>246</td>
<td>2</td>
<td>13</td>
<td>122</td>
<td>1</td>
<td>24</td>
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<td>Mobile, AL</td>
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<td>1</td>
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<td>14</td>
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<td></td>
<td>Tuscaloosa, AL</td>
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<td></td>
<td>Clay County, AL</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td></td>
</tr>
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<td></td>
<td>Sumter County, AL</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td></td>
</tr>
<tr>
<td>State or territory</td>
<td>Urban area or county</td>
<td>Number of days with elevated ozone</td>
<td>Number of days with reported ozone AQI</td>
<td>Number of ozone monitoring locations</td>
<td>Number of days with elevated particulate</td>
<td>Number of days with reported particulate AQI</td>
<td>Number of particulate monitoring locations</td>
<td>Number of days with elevated ozone and/or particulate</td>
<td>Population</td>
<td></td>
<td></td>
</tr>
<tr>
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</tr>
<tr>
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<td>Anchorage, AK</td>
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<td>N/A</td>
<td>N/A</td>
<td>35</td>
<td>366</td>
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<td>35</td>
<td>397,308</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>Fairbanks, AK</td>
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<td>362</td>
<td>3</td>
<td>89</td>
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<tr>
<td></td>
<td>Juneau, AK</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>18</td>
<td>343</td>
<td>1</td>
<td>18</td>
<td>31,849</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arizona</td>
<td>Flagstaff, AZ</td>
<td>48</td>
<td>366</td>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>48</td>
<td>142,481</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nogales, AZ</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>117</td>
<td>360</td>
<td>1</td>
<td>117</td>
<td>46,808</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Payson, AZ</td>
<td>100</td>
<td>366</td>
<td>1</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>100</td>
<td>54,303</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phoenix-Mesa-Chandler, AZ</td>
<td>103</td>
<td>366</td>
<td>29</td>
<td>62</td>
<td>366</td>
<td>13</td>
<td>149</td>
<td>5,059,909</td>
<td></td>
<td></td>
</tr>
<tr>
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Appendix B: Sources of pollutants that contribute to ozone and particulate pollution, by state, 2017

Data are from the EPA’s 2017 National Emissions Inventory. “Transportation” includes on- and off-road vehicles. “Industrial and other processes” includes fuel combustion for industrial purposes, chemical and related product manufacturing, metals processing, and other industrial processes.

### TABLE B1. SHARE OF NITROGEN OXIDES FROM VARIOUS EMISSION SOURCES, 2017

Percentages represent share of total emissions minus biogenic emissions. Selected emission sources are the top four national emission sources for nitrogen oxides. The category of “Other, from human activity” includes residential, commercial, institutional and miscellaneous sources, but excludes vegetation.

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TABLE B2. SHARE OF VOLATILE ORGANIC COMPOUNDS FROM VARIOUS EMISSION SOURCES, 2017

Percentages represent share of total emissions minus vegetation emissions. Selected emission sources are the top four national emission sources for volatile organic compounds. The category of “Other, from human activity” includes residential, commercial and institutional sources; industrial and other processes; electricity generation; and miscellaneous sources excluding vegetation emissions.

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<th>Transportation</th>
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<th>Solvent utilization</th>
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1 U.S. Environmental Protection Agency, A Look Back: Ozone and PM in 2020, accessed 3 August 2021 at https://epa.maps.arcgis.com/apps/Cascade/index.html?appid=9f72f0d74be4d398e794d1231f24ef0.

2 Throughout this report, “large and small urban areas” refers to metropolitan areas (population above 50,000) and micropolitan areas (which have a population of 10,000 to 50,000 people). See: U.S. Census Bureau, Metropolitan and Micropolitan: About, archived at https://web.archive.org/web/20210824025452/https://www.census.gov/programs-surveys/metro-micro/about.html.


4 Ibid.

5 Ibid.


34 See note 29.


36 Ibid., p. 443-444.


39 Ibid.

40 Ibid.


42 See note 17.


48 Ibid.

49 Ibid.


51 Xiaodan Zhou et al., “Excess of COVID-19 cases and deaths due to fine particulate matter exposure during the 2020 wildfires in the United States,” Scientific Advances, 7(33), 13 August 2021, DOI:10.1126/sciadv.abc8789, archived at http://web.archive.org/web/20210816033811/https://advances.sciencemag.org/content/7/33/eabc8789.


54 Ibid.


56 Ibid.


64 Michelle L. Bell, Roger D. Peng and Francesca Dominici, “The Exposure-Response Curve for Ozone and Risk of Mortality and the Adequacy of Current Ozone Regulations,” Environmental Health Perspectives, 114(4): 532-6, April 2006, DOI:10.1289/ehp.8816, p. 535.

66 See note 11.

67 See note 6.


70 Ibid.

71 Ibid. 60% of VOC emissions were biogenic in 2017.

72 Ibid.


78 See note 11, p. 713.


80 Ibid., Table 3-2.


103 See note 94.

104 See note 95, p. 4023.


109 See note 94, p. 517.


123 Ibid., p. ES-18.


128 Ibid.

129 See note 126.

130 U.S. Environmental Protection Agency, AirNow, accessible at https://gispub.epa.gov/airnow/.

131 See note 3.


134 See note 3.


138 Ibid.


141 U.S. Environmental Protection Agency, A Look Back: Ozone and PM in 2020, accessed 3 August 2021 at https://epa.maps.arcgis.com/apps/Cascade/index.html?appid=9f72f0d7f4be4d398e794f123f124e0. Note: the EPA uses a higher threshold to classify elevated pollution levels than used in the analysis for this report. See methodology.

142 Ibid.


156 See Methodology.