Reconsideration of 2009 Endangerment Finding and Greenhouse Gas Vehicle Standards

Docket ID No. EPA-HQ-OAR-2025-0194

Comment from the Expert Working Group on Climate Change and Health in the United States

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Expert Working Group on Climate Change and Health in the United States

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Executive Summary

This Expert Working Group on Climate Change and Health in the United States comprises 114 scientists with experience researching various dimensions of the health effects of climate change. We are submitting this public comment in response to the proposed reconsideration of the Endangerment Finding and Greenhouse Gas Vehicle Standards. Our overall conclusion is that **EPA is incorrect in its assessment of uncertainties in the 2009 Endangerment Finding as a reason to reconsider the rule, given that the scientific evidence since that time reduces the uncertainty regarding health harms from climate change stemming from greenhouse gas emissions. Greenhouse gas emissions, by altering the climate and disrupting earth systems, pose a clear and indisputable danger to human health and well-being.**

Our comment summarizes the numerous pathways by which climate change endangers human health and well-being, including but not limited to extreme heat, extreme weather events, degraded air quality including through wildfire activity, increased infectious disease risk, and worsening allergen exposures. We emphasize scientific evidence generated since 2009, which has strengthened the case for some pathways and allows for the inclusion of additional pathways not considered in the original Endangerment Finding (e.g., mental health, occupational health, displacement, and violence). We describe populations at elevated risk from climate change and associated extreme events, including the very young, the very old, pregnant individuals, people with pre-existing medical conditions, poor people, and people affected by discrimination or disenfranchisement. We also describe advancements in scientific approaches to attribute extreme weather events to climate change as well as our improved understanding of the interactive effects of multiple climate hazards.

EPA justified the proposed rule change in part through a draft regulatory impact analysis that quantified some of the benefits and costs of the rule change. **In our comment, we discuss numerous deficiencies in EPA's analysis, including poorly described methods and unjustified assumptions.** EPA also excludes any costs associated with greenhouse gas emissions, which runs counter to extensive peer-reviewed literature and conclusions from expert reports. Uncertainty is both mischaracterized and inadequately incorporated into the draft regulatory impact analysis.

In summary, it is well established that U.S. transportation contributes significantly to global greenhouse gas emissions; that climate-sensitive health harms are quantifiable and costly; and that there are substantial health benefits of greenhouse gas emissions reductions including through improvements in air quality. The large body of peer-reviewed evidence supporting the Endangerment Finding since 2009 constitutes sufficient evidence of health harms from climate change stemming from greenhouse gas emissions. **As public health experts on the health effects of climate change, along with experts in greenhouse gas emission inventories and climate science, we <u>strongly oppose</u> this proposed rule change based on its harms to the health of the American people.**

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Introduction

We are responding to the U.S. Environmental Protection Agency's (EPA's) proposed rule, **"Reconsideration of the 2009 Endangerment Finding and Greenhouse Gas Vehicle Standards," Docket ID No. EPA-HQ-OAR-2025-0194.** Our response particularly focuses on the following proposal comment areas:

- **C-1:** "All aspects of this proposal, including legal and scientific developments that are being subject to public comment for the first time."
- **C-2:** "The scientific underpinnings of the Endangerment Finding are weaker than previously believed and contradicted by empirical data, peer-reviewed studies, and scientific developments since 2009."
- **C-3:** "The EPA is not proposing to reopen or substantively modify at this time any regulations necessary for criteria pollutant and air toxic measurement and standards, CAFE testing, and associated fuel economy labeling requirements. If there are any elements of our regulations, test procedures, or GHG emission models proposed for removal that should remain to support other programs outside of the EPA's GHG standards, we are seeking comment on what those elements are and why their preservation in the CFR is necessary."
- **C-13:** "We seek comment on the proposed bases for repeal presented in section V of this preamble, including on the economics of fleet turnover, the relative efficiency and emission reductions achieved by newer vehicles, and the potential costs to air quality of retaining standards that may slow fleet turnover as compared to the potential benefits of retaining GHG emission standards in response to global climate change concerns."
- **C-21:** "We request comment on the analysis provided within section VIII related to the benefits and costs of the proposed action and whether benefit cost analysis is an appropriate and lawful basis for repealing the Endangerment Finding and/or resulting vehicle standards."
- **C-23:** "Stakeholders state that NCA5 does not meet the requirements under Executive Order 14303 and deviated from OMB guidelines on quality, objectivity, utility, and integrity of information disseminated by Federal agencies. The Administrator takes these concerns seriously and seeks public comment on the validity of these concerns and how they should be taken into account when determining whether to finalize any of the alternatives proposed in this action."
- **C-27:** "We seek comment on any additional aspects of the Endangerment Finding that may have fallen short of the administrative law requirement that agency action be reasonable and reasonably explained. Conversely, we seek comment on why the approach taken in the Endangerment Finding remains reasonable given the legal and scientific developments discussed in this proposal, and the impact, if any, of the EPA's denial of rulemaking petitions in 2022 and 2010 on this alternative proposal."

In 2007, the U.S. Supreme Court ruled that greenhouse gases (GHGs) are air pollutants covered by the U.S. Clean Air Act. The ruling required EPA to "determine whether or not emissions of greenhouse gases from new motor vehicles cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare, or whether the science is too uncertain to make a reasoned decision." An affirmative finding requires EPA to regulate an air pollutant under the Act. Subsequently, in 2009, EPA issued an endangerment finding that deemed six well-mixed GHGs – carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride – to be air pollutants that endanger public health and welfare under Section 202(a)(1) of the Clean Air Act. This section then requires the EPA Administrator to set emissions standards for these GHGs from mobile and stationary sources. **Since 2009, the volume of relevant scientific evidence supporting the Endangerment Finding has grown dramatically.** Below, we detail new evidence since 2009 that supports preserving the Endangerment Finding and that suggests even more stringent enforcement is needed compared to past and current implementation of the finding.

As public health and clinical experts on the health effects of climate change and experts in GHG emission inventories and climate science, we <u>strongly oppose</u> this proposed rule change. GHG emissions inflict serious damage on the health and well-being of Americans, and their impacts will worsen unless they are controlled. These impacts are real and quantifiable. Robust and compelling evidence about the impacts of GHG emissions and climate change is summarized in this comment. Increasing GHG emissions cause increases in global average temperatures and ocean acidification. Global warming causes changes in our climate, including in temperature extremes, droughts and heavy precipitation events, and hurricane intensity, and leads to increased smog formation and wildfire extent and intensity. These climate impacts are adversely affecting livelihoods, impacting the economy, and increasing risks to health and well-being, especially to outdoor workers and the elderly, and imperiling pregnant individuals, children, and future generations of Americans.

We recognize that this proposed rule applies specifically to GHGs emitted from fossil fuel combustion in the transportation sector and not to criteria air pollutants as regulated under the Clean Air Act. However, fossil fuel combustion from transportation is both the largest source of GHG emissions in the United States and a significant contributor to ambient air pollution via emissions of criteria air pollutants. We document this important overlap in our discussion of comment areas **C-3** and **C-21**.

Below, we outline clear and extensive scientific evidence that GHG emissions from the transportation sector in the United States contribute to disrupting the Earth's climate, and that climate change impacts threaten human health through multiple pathways, both direct and indirect. Many of these impacts stem from increased frequency and intensity of extreme weather, including heat, floods, and droughts, as well as warming effects on air pollution formation, pollen, and changes in the dynamics of vector- and water-borne diseases (comment areas **C-1** and **C-2**). Many of these adverse health impacts were thoroughly documented by EPA at the time of the 2009 Endangerment Finding. Since then, numerous peer-reviewed original research studies, systematic reviews, and meta-analyses, as well as authoritative reports by the Intergovernmental Panel on Climate Change (IPCC), World Health Organization (WHO), and U.S. Global Change Research Program (USGCRP), which coordinates the U.S. National Climate Assessments (NCAs), and the National Academies of Sciences, Engineering, and Medicine have reinforced and extended the evidence of health harms resulting from climate change.[1–5] Moreover, since 2014, the field of climate attribution science has advanced such that it is now possible to link anthropogenic climate change, primarily driven by fossil fuel emissions, to the likelihood and intensity of weather extremes and changes in average temperatures, which ultimately lead to adverse human health conditions and deaths. **We argue below that the evidence since 2009 is now even stronger to warrant upholding the Endangerment Finding and Greenhouse Gas Vehicle Standards as necessary to protect current and future American generations.**

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1. U.S. Transportation Contributes Significantly to Global GHG Emissions

The U.S. transportation sector contributes significantly to global GHG emissions and to climate change. Total gross U.S. GHG emissions were 6343.2 million metric tons CO_2 equivalent (MMT CO_2-eq) in 2022.[6] Energy-related emissions account for the vast majority (82.0%) of this total. Across all sectors, transportation is the largest contributor at 1801.5 MMT CO_2-eq, or 28.4% of gross CO_2-eq GHG emissions. Mobile combustion on roads was the largest source of U.S. CO_2 emissions in 2022 among all Key Categories of emissions calculated by EPA.

CO_2-eq GHG emissions from transportation have remained relatively stable since 2000, with increased emissions from light-duty trucks offsetting decreases from passenger cars over this period. In 2022, passenger cars (20.4%), light-duty trucks (36.5%), and medium- and heavy-duty trucks (22.9%) collectively represented 79.8% of CO_2-eq GHG emissions from transportation. These vehicle types respectively represented 5.8%, 10.4%, and 6.5% of total U.S. gross CO_2-eq GHG emissions in 2022, and together they constituted 22.7%.

Globally, the U.S. ranks second behind China in terms of annual net GHG emissions. In 2022, the U.S. contributed 14% of total global CO_2 emissions from fossil fuel combustion, and U.S. transportation emissions were 4.8% of these global emissions.[7,8] **U.S. transportation sector CO_2 emissions are higher than the total fossil fuel CO_2 emissions (from all sectors) of all other countries aside from China and India** (Figure 1), and are roughly equivalent to emissions from all sectors in Russia.[7] **U.S. transportation therefore contributes significantly to global GHG emissions.**

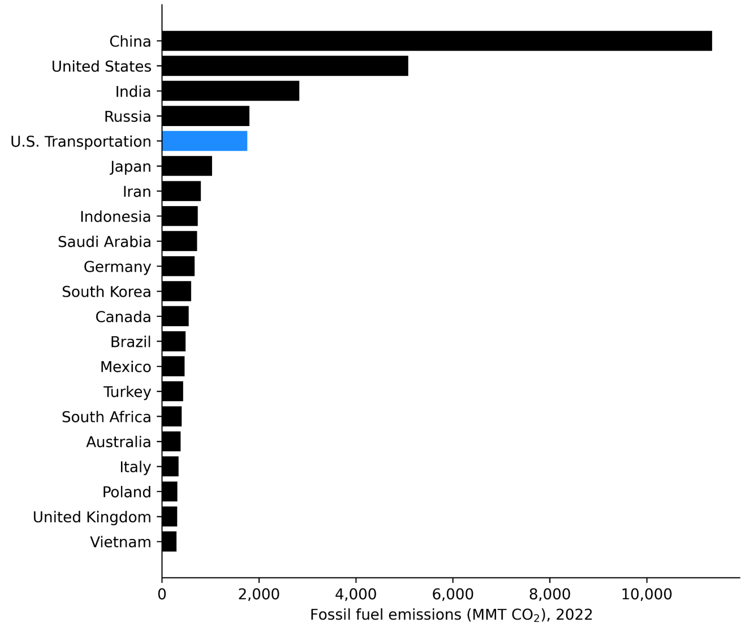

Figure 1. Total emissions from fossil fuels for the top 20 countries, with the U.S. transportation sector added for comparison. (Source: Friedlingstein et al. 2025;[7] Global Carbon Budget.[8] Drawn using data from Friedlingstein et al. (2025) with additional U.S. transportation sector data.)

The U.S. also has the largest historical responsibility for climate change of any country in the world and is responsible for almost a quarter (24.1%) of cumulative global CO_2 emissions from fossil fuels and industry since 1850 (Figure 2). Transportation emissions are a significant part of this total.

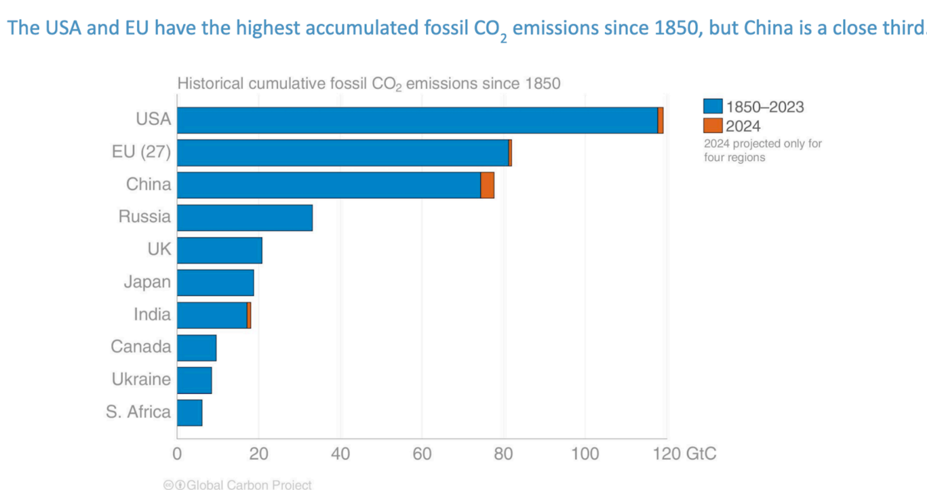

Figure 2. Historical cumulative fossil fuel CO_2 emissions since 1850. Calculated using territorial emissions. (Source: Global Carbon Project)

With the exception of 2020, the first full year of the COVID-19 pandemic, U.S. transportation emissions have shown little net change in recent years. Without policy intervention, emissions are projected to remain roughly constant in the coming decades.[9] If U.S. transportation emissions remained constant for the next 50 years, the sector would emit 90.5 $GtCO_2$-eq, or 7.5% of the total remaining global carbon budget if global warming is to be limited to 2°C (3.6°F) above preindustrial levels. (This calculation does not include temperature overshoot and relies on transient climate response, which assumes a linear relationship between cumulative emissions and temperature.) There are many cost-effective strategies to reduce transportation emissions, including more efficient and electric vehicles and mode shifts to active travel and public transit.

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2. EPA Regulation of Greenhouse Gases: Precedent for Regulating Pollutants as Groups and Pollutants with Global Impacts

EPA's reconsideration contends that GHGs should not be regulated as a group, even though the Clean Air Act authorizes the agency to do so and EPA frequently regulates groups of pollutants. EPA also contends that the effects of greenhouse gases are too indirect. However, EPA routinely assesses the risks posed by and regulates groups of pollutants that cause indirect harm. For example, EPA regulates a group of pollutants referred to as volatile organic compounds (VOCs) because of their role in the formation of tropospheric ozone, the main component of ground-level smog. A particular VOC itself might not be harmful when inhaled directly, but its secondary effect is when it interacts with other chemicals in the atmosphere in reactions that form ozone. Because these chemical reactions take time, the health impacts from ozone can take place far downwind from the sources of emissions. Likewise, GHG emissions – while not always individually harmful or harmful when inhaled directly – cause climate change that endangers human health and welfare, as detailed in Section 3.

EPA's reconsideration suggests that global air pollution issues are not in EPA's domain, despite the agency's recognized authority to regulate and long history of regulating other internationally transported pollution, such as nitrogen oxides (NO_x) and ozone. EPA has recognized – as does the Clean Air Act – that air pollution extends beyond national boundaries, so to argue that GHGs are beyond EPA's domain is nonsensical. For example, EPA has domestic rules in place to limit the emissions of persistent organic pollutants, pollutants that disseminate globally. As another example, since 1987, EPA and U.S. states have effectively reduced environmental releases of dioxins and furans from U.S. sources. EPA is also authorized to phase down production and consumption of hydrofluorocarbons in the United States consistent with amendments of the Montreal Protocol.[10]

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3. Climate Change Endangers Human Health

EPA contends in the docket that "uncertainties acknowledged in the Endangerment Finding are more significant than previously believed" (p. 36299) and that "the more pessimistic assumptions have not been borne out in empirical data and peer-reviewed studies through 2025" (p. 36299). However, the large body of scientific research that has been published since

Table 1. Increasing evidence over time of the health impacts of climate change

Health Pathways	Evidence in the 2009 Endangerment Finding	Additional Evidence Since 2009
Temperature Effects	✓	✓
Extreme Events		
Floods and Storms	✓	✓
Droughts	✓	✓
Wildfires	✓	✓
Climate-Sensitive Diseases	✓	✓
Aeroallergens	✓	✓
Air Quality		
Tropospheric Ozone	✓	✓
Particulate Matter	✓	✓
Interactive Effects of Multiple Climate Hazards	✓	✓
Mental Health		✓
Occupational Health		✓
Displacement		✓
Violence		✓
Impacts on Vulnerable Populations	✓	✓

2009 actually provides stronger and more widespread evidence of the significant health and welfare harms of climate change. Duffy et al.[11] previously reviewed this evidence and concluded: **"Since 2009, the amount, diversity, and sophistication of the evidence have increased markedly, clearly strengthening the case for endangerment."**

A large number of human health outcomes and diseases are influenced by climate change. Ongoing shifts in climate are already impacting human health. Table 1 shows numerous pathways by which climate change contributes to adverse health outcomes. Extensive scientific evidence on the relationship between exposure and health outcomes across these pathways is detailed below. Throughout the following sections, we summarize findings from the Technical Support Document (TSD) for the 2009 Endangerment Finding and highlight evidence gathered since then that is relevant to the original finding, which demonstrates higher certainty and scientific understanding of the health harms of climate change.

A. Health Impacts Discussed in the 2009 Endangerment Finding

The sections that follow match the structure of Section 7 (Human Health) and Section 8 (Air Quality) of the TSD for the 2009 Endangerment Finding. Each section provides a brief summary of the major claims made in 2009 TSD and details scientific evidence that has been published since then. As mentioned in the Introduction, much of the evidence of the health harms resulting from climate change that we describe below has also been catalogued in authoritative reports from the IPCC, WHO, USGCRP, and the U.S. National Academies.

i. Temperature Effects

According to EPA's TSD for the 2009 Endangerment Finding, "It is not clear whether reduced mortality from cold will be greater or less than increased heat-related mortality in the United States due to climate change (Gamble et al., 2008). Local factors, such as climate, topography, heat-island magnitude, demographic and health characteristics of the population, and policies that affect the social and economic structures of communities, including urban design, energy policy, water use and transportation planning are important in determining the underlying temperature-mortality relationship in a population (Confalonieri et al, 2007; Ebi et al., 2008)" (p. 83).

Deviations from moderate temperatures, whether higher (e.g. heat waves) or lower (e.g. polar vortex events), have long been shown to have substantial impacts on human health, including morbidity and mortality. The magnitude and pathways by which climate change impacts morbidity and mortality differ and are shaped by the cause of disease and death. Impacts are further modified by baseline regional climate and demographic factors such as age, income, and race/ethnicity.

For mortality, research has long noted that both extreme heat and extreme cold increase all-cause mortality. Hot days are more individually deadly than cold days, but most regions in the United States tend to have more cold days, and so research tends to find that extreme cold is responsible for more overall temperature-related deaths than extreme heat.[12–14] Heat-related deaths recorded by the U.S. Centers for Disease Control and Prevention have demonstrated an increasing trend since 2017, and extreme temperatures influence different causes of mortality in different ways.[15] Cardiovascular deaths increase with both heat and cold, but deaths from homicide, suicide, traffic accidents, and other accidental deaths decrease with cold and increase with heat (i.e. have a linear rather than U-shaped relationship with temperature).[16–19]

Mortality effects also differ substantially by age because older people are much more sensitive to extreme cold, while children are much more sensitive to extreme heat. Mortality among middle-aged people in the United States declines with cold and increases with heat.[13] Effects also differ substantially by region of the United States. Population acclimatization and access to heating and cooling options also mediate the effects of temperature extremes.[20] Typically colder regions in the United States are less sensitive to extreme cold temperatures, meaning they see substantially fewer deaths at a given cold temperature relative to more moderate regions. The majority of cold-related deaths in the United States therefore do not occur in the coldest regions. The inverse is true of extreme heat, although to a somewhat lesser degree: hot regions are less sensitive to individual hot days, but they experience many more of them.

Taken together, published evidence indicates that warming temperatures, by reducing cold days and increasing the number of days with extreme heat, will affect the extent and location of excess mortality in the United States. Warming temperatures will change who dies, where they die, and how they die. Temperature-related deaths among elderly people may decline, but temperature-related deaths among children and middle-aged people will likely increase. The best comprehensive estimates suggest that the net effect of climate change on all-cause, all-age mortality in the United States will be near zero: declines in cold-related deaths may slightly exceed increases in heat-related deaths, under most warming scenarios, but the net effect is not significantly different from zero in recent comprehensive analyses.[21–23]

The effect of temperatures on morbidity have also been well studied. Perhaps the best studied morbidity measures are hospitalizations and emergency department visits. The relationship between temperature and hospitalizations for all causes mirrors the temperature–mortality relationship, namely that both cold and heat increase overall hospitalizations.[13,24] For example, a study of the Veterans Administration's national electronic health record database from 2002-2019 found a statistically significant and clinically important increase in the incidence of heat related illnesses over time.[25]

Importantly, the sensitivity of hospitalizations to cold is driven nearly entirely by elderly populations who are particularly cold-sensitive, while middle-aged adults and children are less cold-sensitive and see somewhat larger hospitalization increases at hot temperatures. This pattern is even more stark for emergency department visits. Emergency department visits, which are more common among children and middle-aged adults, respond more linearly to temperature, meaning that any amount of warming will increase emergency department visits for all ages.[13,26,27] Among adults aged 18–64 years in the United States, heat exposure is also found to be associated with increased incidences of acute myocardial infarction and stroke.[28,29] Among adults aged >18 years with commercial health insurance, increasing summertime ambient temperatures were also associated with increased rates of emergency department visits for mental health outcomes.[30] Warming temperatures can be expected to increase emergency department visits for all ages.[13,26]

In summary, while climate change is expected to reduce cold-related illnesses and deaths in some regions, it will also increase heat-related illnesses, cognitive and behavioral problems, and deaths in other places, as well as reduce economic productivity, representing serious dangers to health and well-being for people in affected areas.

ii. Extreme Events

In 2016, the USGCRP reported that climate change will increase exposure risks and intensity of drought, wildfires, and flooding from extreme rain and hurricanes, all of which are associated with death, illness, injury, worsening underlying medical issues, and negatively impacted mental health.[5] Similarly, a 2021 systematic review of extreme weather and climate change found that "the coming decades will be characterized by increases in the frequency and intensity of many types of extreme weather and climate events, with the potential for significant impacts on populations and health care systems worldwide."[31] Extreme events related to climate change have and will continue to impact community lifelines, including critical infrastructure systems such as energy, water and sewer, transportation, and communications, and will threaten access to health care and emergency response systems. Several reports and peer-reviewed studies have identified climate change–related extreme weather impacts across the healthcare sector, from supply chain disruptions for necessary medical equipment to increased emergency department visits and patient deaths.[32–34]

a. Floods and Storms

According to EPA's TSD for the 2009 Endangerment Finding, "the IPCC projects a very likely increase in heavy precipitation event frequency over most areas" (p. 85). As projected, changing patterns of precipitation and increasing intensity of storm events has increased inland and coastal flooding in some areas of the United States.[5,35]

Flooding affects health in the long and short term. Direct health impacts from floods include death from drowning, hypothermia, and electrocution. Floods also increase the risk of injury and disease from water- and vector-borne diseases (described below) and exposure to toxic chemicals and molds. Flooding can also lead to indirect health harms, including by damaging homes, degrading water quality, and disrupting health care infrastructure. These indirect harms are detailed in the section below on interactive effects of climate hazards. From 2001 to 2020, 22,376 deaths were attributable to long-term exposure to floods in the United States, including deaths due to cardiovascular and respiratory diseases and external causes such as injuries and drowning.[36] **Recent reviews and meta-analyses have documented increases in mortality and morbidity outcomes following flooding and storm events**,[37,38] and studies report documented increases in health harms after specific flooding events in the United States, including increased emergency department visits for acute gastrointestinal illness in North Carolina after Hurricane Matthew in 2016 and Hurricane Florence in 2018.[39]

Regarding tropical cyclones, EPA stated in the 2009 TSD for the Endangerment Finding that "the IPCC (2007d) also projects likely increases in intense tropical cyclone activity as described in Section 6(b). Increases in tropical cyclone intensity are linked to increases in the risk of deaths, injuries, waterborne and foodborne diseases, as well as post-traumatic stress disorders (IPCC, 2007b)" (p. 85–86). **Recent findings indicate that the proportion of hurricanes that reach higher categories has increased globally over the last 40 years.**[35,40,41] In the United States, the speed at which hurricanes make landfall has decreased, leading to increases in rainfall and flooding associated with these storms. In 2024, Hurricane Helene led to the deaths of at least 227 people, and climate change has been estimated to have increased rainfall from the storm by 10%.[42]

b. Droughts

Regarding drought, EPA stated in the 2009 TSD for the Endangerment Finding that "areas affected by droughts are likely to increase according to the IPCC (2007d)" (p. 86). **Changes in precipitation patterns have resulted in increases in precipitation in the eastern United States and declines in the West.** Increased temperatures are also recognized for their role in extending droughts, and climate change is increasing the risk of droughts with unprecedented severity.[43–46] Worsening drought conditions influence health both directly from respiratory and other causes of mortality and indirectly through disruptions to food supplies.[47] Regional analyses in the United States have found higher respiratory mortality risks during periods of moderate and severe drought exposure in the Northeast, Northern Rockies and Plains, Ohio Valley, and Upper Midwest.[48] A study focused on the Upper Midwest found that severe drought exposure was associated with increased respiratory mortality, particularly among older adults and White individuals, and a study in the Northern Rockies and Plains found an increase in all-cause and cardiovascular mortality among older adults and women.[49,50]

c. Wildfires

According to EPA's TSD for the 2009 Endangerment Finding, "changes in the mean and variability of temperature and precipitation are projected to increase the size and severity of fire events, including in parts of the United States (Easterling et al., 2007)" (p. 86). Over the last 40 years, the area burned by wildfires each year in the United States has roughly quadrupled.[51] **Approximately half of the increase in the forest area burned by wildfires from 1984 to 2015 in the United States is attributable to climate change** (Figure 3).

Wildfires are associated with physical and mental health impacts, including premature death, both from fires themselves and from the air pollution they generate.[4,52] The 2018 Camp Fire in California directly led to the deaths of 85 people and the 2023 wildfire in Lahaina, Hawaii, led to 101 deaths.[53] Many more wildfire-related deaths occur as a result of wildfire smoke exposure. This and other health harms are detailed in the section below on wildfire smoke. Wildfires are projected to increase in number and severity in the future.[54–56] There are about 50 million U.S. homes in the wildland–urban interface, and this number has been increasing by 350,000 homes per year over the last two decades.[51]

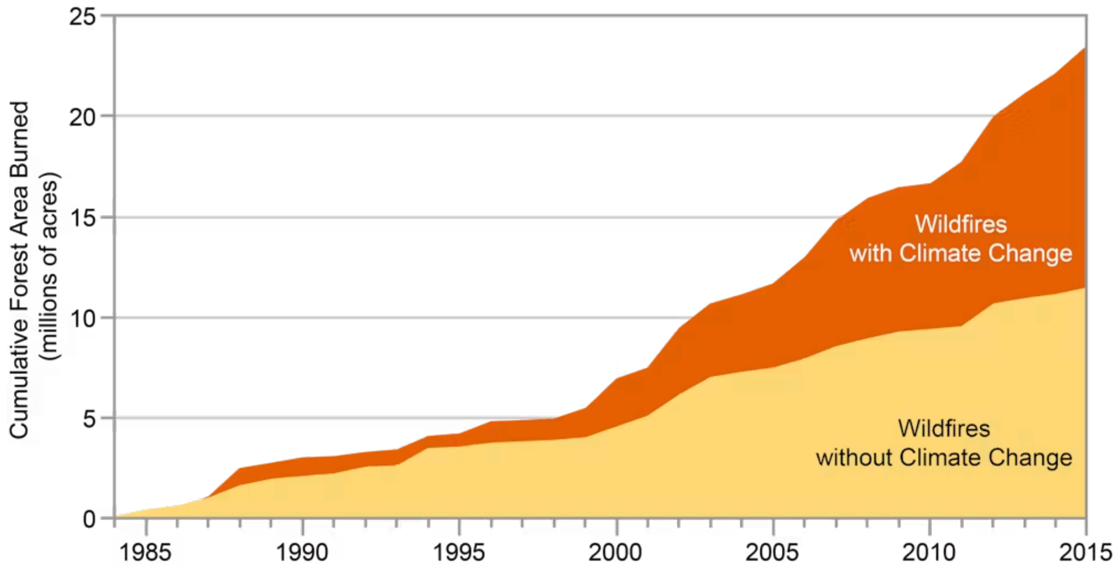

Figure 3. The cumulative forest area burned by wildfires has greatly increased between 1984 and 2015, with analyses estimating that the area burned by wildfire across the western United States over that period was twice what would have burned had climate change not occurred. (Source: Abatzoglou & Williams (2016),[52] as adapted by Reidmiller et al. (2018)[57])

The DOE Climate Working Group report that EPA relies on for this proposed rule change has been heavily criticized by scientists for failing to acknowledge heavily impacted areas where wildfires are increasing, including the western United States and boreal forests, and failing to acknowledge the body of scientific evidence on wildfire attribution to climate change.[58]

iii. Climate-Sensitive Diseases

The 2009 Endangerment Finding describes many food-, water-, air-, and vector-borne infectious diseases that are impacted by weather and climate. We highlight diseases for which there is strong evidence of climate-mediated impacts.

The TSD for the 2009 Endangerment Finding stated that coccidioidomycosis, also known as Valley fever, was “projected to increase in the southwestern United States” (p. 86). There is some evidence that the area of endemicity is expanding northward throughout the western United States, driven in part by higher temperatures and changing precipitation patterns.[59–61] In 2009, there were 12,926 reported Valley fever cases in the United States, which at the time was a record annual high since U.S. Centers for Disease Control and Prevention data became available in 1998.[62] Since then, 10 out of the last 14 years (through 2023) have had higher numbers of reported cases than this previous record high, with more cases reported in more states (Figure 4).

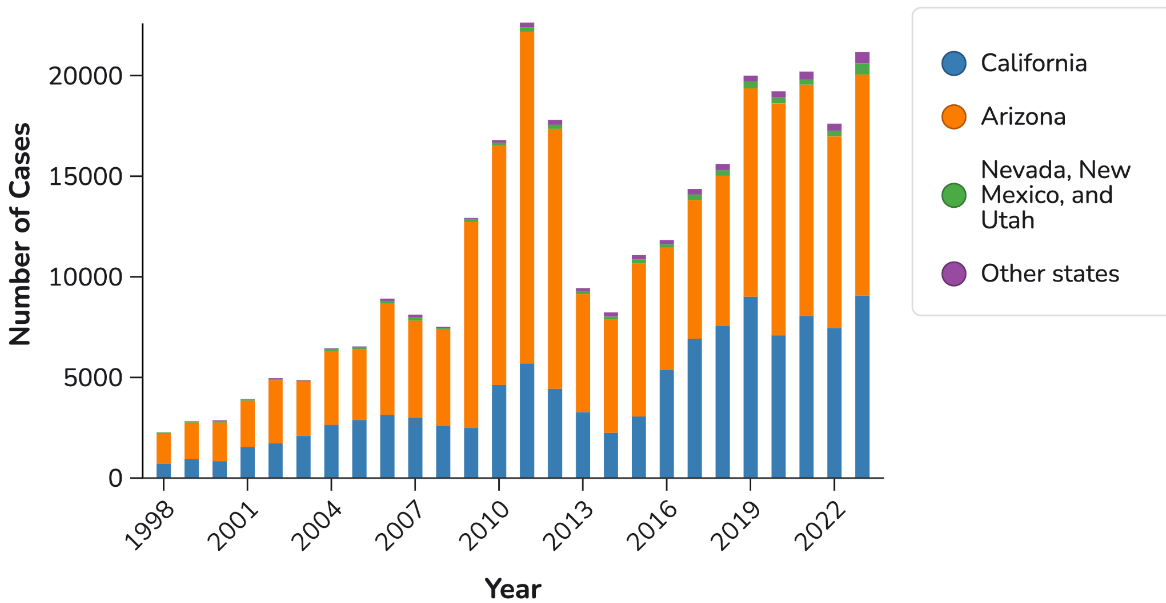

Figure 4. Reported Valley Fever cases, 1998–2023. (Source: CDC[62])

The TSD for the 2009 Endangerment Finding mentions that "foodborne diseases show some relationship with temperature" (p. 87), including an example of *Vibrio* infections from eating contaminated shellfish linked with higher temperatures. More recent evidence shows a stronger relationship between the number of *Vibrio* infections and climate change. A systematic review of *Vibrio* found that "infections with *Vibrio* [species] have been increasing in the U.S. and around the globe, a trend that has been attributed to the warming of the ocean waters and is predicted to be exacerbated by ongoing climate change" (Figure 5).[63] Warming temperatures increase the length of the infection season, and increases in flooding and heat waves also increase *Vibrio* exposure risk.

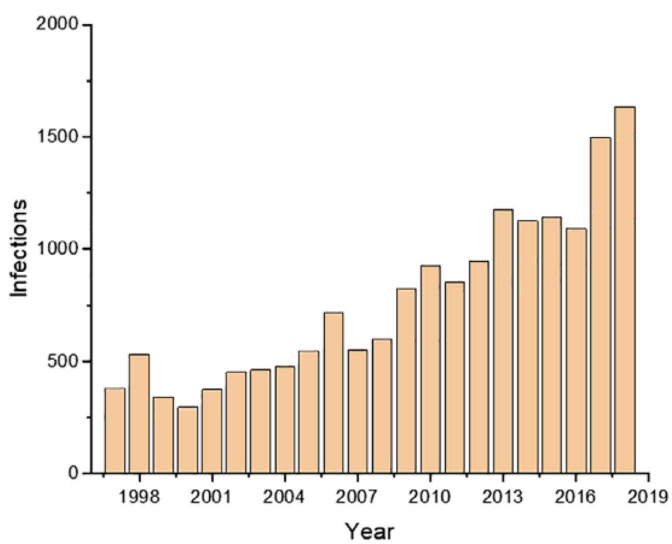

Figure 5. Annual *Vibrio* (not including toxigenic cholera) in the United States. (Source: Froelich and Danes (2020),[63] based on CDC data)

Waterborne diseases are also affected by climate change. **A systematic review of climate-attributable diarrhea burden found an "increasing risk of morbidity and mortality under future projections of diarrheal disease, incorporating climate conditions."**[64] In many U.S. cities, aging sewage treatment and stormwater management systems can be overwhelmed by extreme precipitation events, leading to drinking water contamination.[35,65] For example, using 2.5 inches of daily precipitation as a threshold for causing combined sewer overflow into Lake Michigan, the frequency of these contamination events is expected to rise by 50–120% by the end of the century due to climate change.[66] In rural regions of the United States that depend on well water, heavy precipitation has been found to be associated with *Salmonella* and *Campylobacter* infections, and extreme events can contaminate well water supplies.[67–70] Warmer surface water temperatures and enhanced mobilization of nutrients increase the likelihood of harmful algal blooms.[71] Cyanobacterial toxin exposure arising from harmful algal blooms can cause hepatic, renal, and neurological conditions.[72]

Regarding vector-borne disease, some regions of the United States will face different impacts of infectious disease due climate change, and some of these impacts are already evident. The latest IPCC assessment report stated with high confidence that **climate change has increased the geographical range of vector-borne diseases and/or the reproduction of disease vectors**.[3]

The TSD for the 2009 Endangerment Finding found that the suitable range for ticks capable of carrying Lyme disease would shift northward. More recent research has found increasing annual temperatures to be associated with increased incidence of Lyme disease in the U.S. Northeast.[73] Even as the role of climate change as a driver of geographic expansion and population increase of *Ixodes* ticks in the northern part of the eastern United States remains uncertain, some research has found that climate warming has expanded the suitability for *Ixodes* ticks and Lyme disease transmission in Canada.[74,75]

Regarding malaria, the TSD for the 2009 Endangerment Finding found that, "although large portions of the United States may be at potential risk for diseases such as malaria based on the distribution of competent disease vectors, locally acquired cases have been virtually eliminated, in part due to effective public health interventions, including vector and disease control activities (Ebi et al., 2008; Confalonieri et al, 2007)" (p. 87). However, **local malaria transmission returned to the United States in 2023 for the first time in 20 years, indicating vector presence and climate suitability**.[76]

Local transmission of dengue fever has recently occurred in Florida, Texas, Hawaii, and California.[77] Recent research has attributed 18% of the burden of dengue in 21 endemic countries to observed climate warming from 1995–2014 and projected further increases of 49–76% in dengue burden by mid-century, depending on the carbon emissions pathway.[78] The risk of other mosquito-borne illnesses including Zika virus, chikungunya virus, and West Nile Virus is expected to change as abundance, geographic ranges, and activity of their mosquito vectors change.

iv. Aeroallergens

In 2009, EPA stated in the TSD for the Endangerment Finding that “climate change, including changes in CO_2 concentrations, could impact the production, distribution, dispersion and allergenicity of aeroallergens and the growth and distribution of weeds, grasses, and trees that produce them (McMichael. et al., 2001; Confalonieri et al., 2007)” (p. 88). The docket states that “the Endangerment Finding identified uncertainties including, but not limited to: … increases in allergenic illnesses” (p. 36308). **There is now greater evidence and certainty that climate change influences allergenic illness.**

Pollen and mold exposure are associated with the development and exacerbation of allergic diseases, including allergic rhinitis and asthma, and may increase susceptibility to respiratory viral infections and chronic obstructive pulmonary disease (COPD) mortality.[79] A meta-analysis found that every exposure increase of 10 grass pollen grains per m^3 is linked to significant increases in asthma emergency department visits.[80] Similarly, a study in Michigan showed that high concentrations of grass and ragweed pollen were associated with an elevated risk of death from chronic respiratory causes.[81] Air pollution from wildfires, dust, and sandstorms can exacerbate the adverse health effects of pollen exposure. Pollutants can modify pollen structure as well as its protein and lipid content and the timing of pollen release, thereby increasing pollen allergenicity. Therefore, these interactions between air pollution and pollen heighten inflammation and elevate both the risk and severity of respiratory diseases.[82]

Since the 2009 Endangerment Finding, studies have found that increasing temperatures, CO_2, and ozone are driving higher pollen production, longer pollen seasons, and expanded geographical distribution of allergens.[83–88] For example, from 1995 to 2009, the ragweed pollen season lengthened by 13–27 days in parts of the United States.[89] Across the United States, by 2018 pollen seasons began an average of 20 days earlier than in 1990, and 50% of this change has been attributed to anthropogenic climate change.[83]

A greater body of evidence indicates that climate change may affect allergenic diseases due to climate-driven increases in rainfall and flooding, which further promote mold growth, extending and intensifying both pollen and mold seasons, as well as facilitating the spread of new allergenic species into previously unaffected regions.[84] Variations can occur within the same species, with weather and climate conditions impacting pollen production.[82] Increases in atmospheric fungal spore counts have been associated with increased asthma hospital admissions and emergency department visits, medication use, asthma symptoms, and peak flow variability.[90] Post-disaster studies further suggest that extreme weather events such as hurricanes can significantly increase mold and endotoxin exposures and mold reactivity, particularly among individuals with asthma.[91–93]

There is also growing evidence linking climate change to increased inflammation and susceptibility to respiratory viral infections due to heightened exposure to environmental allergens such as pollen and other environmental factors.[94] Drier, hotter conditions can promote airway inflammation.[95] Air pollution is also associated with greater allergic inflammation from pollen and a higher risk and severity of respiratory viral infections, including SARS-CoV-2, the virus that causes COVID-19.[96]

v. Air Quality

Climate change is projected to worsen air quality in many regions of the United States, posing harms to human health.[4] Air pollutants affected by climate change include coarse particulate matter (PM_{10} minus $PM_{2.5}$), fine particulate matter ($PM_{2.5}$), and ground-level ozone. These pollutants are likely to increase with increasing temperatures, heat waves, fires, and droughts.[97–99]

a. Tropospheric Ozone

In the TSD for the 2009 Endangerment Finding, EPA states that “according to the IPCC (Denman et al., 2007), climate change is expected to lead to increases in regional ozone pollution in the United States and other countries” (p. 89). Since then, a 2021 study with an EPA researcher as lead author found that under a high warming scenario, **climate change could lead to an additional 4,100 deaths attributable to ozone by 2095 across the contiguous United States**.[100] By 2050–2054, compared to 2010–2014, ozone-related deaths are estimated to increase by 2,516 per year in 183 U.S. cities under a medium emission scenario.[99] However, this increase would be reduced to 273 deaths per year under a scenario with strong climate and air pollution controls that are aligned with the Paris Agreement.[99]

Other recent studies provide further evidence that climate change exacerbates ozone pollution regionally. For example, Nolte et al.[101] found that ozone in the Central Great Plains and Midwest could increase 1–5 parts per billion (ppb) by 2050 and 10 ppb by 2095 under a high warming scenario. In some areas of the United States that currently meet ozone air quality standards, climate-induced increases in the frequency of high ozone days may push areas out of attainment with these standards.[102] This climate-induced rise in ozone pollution could put the health of millions of people at risk. This is especially concerning when considering the disparate impact of ozone exposure on vulnerable populations living in non-attainment areas, including older adults and children and individuals with existing chronic conditions such as obesity-related illness. There is evidence that current ozone standards may not be health-protective, let alone exceedances of current standards. For example, Stowell et al.[103] estimated that the current ozone standards of 70 ppb may not protect children’s health in the United States and that projected future ozone increases due to climate change may significantly impact the health of children and adolescents.

b. Particulate Matter

In the TSD for the 2009 Endangerment Finding, EPA states that “the overall directional impact of climate change on PM levels in the United States remains uncertain (CENR, 2008), as too few data yet exist on PM to draw firm conclusions about the direction or magnitude of climate impacts (CCSP, 2008b)” (p. 93).

Climate change increases $PM_{2.5}$ exposure in the United States through higher temperatures, which increase biogenic emissions from vegetation and soils, and increased emissions of primary $PM_{2.5}$ and secondary precursors during wildfires, heat waves, and droughts, as well as through increased humidity.[4] U.S. annual $PM_{2.5}$ concentrations are projected to increase by 2100 relative to present day (2015–2024) under a high warming scenario but could decrease under lower warming scenarios.[4] These projections do not account for the influence of climate change on wildfire smoke, which we detail in a section below. **Observed increases in wildfire smoke $PM_{2.5}$ have caused or contributed to the stagnation or reversal of $PM_{2.5}$ exposure reductions in more than half of U.S. states since 2016.**[104]

A recent study found that $PM_{2.5}$ episodes in the northeastern United States would last longer and occur more frequently under a high warming scenario.[105] Across the western United States, the co-occurrence of extreme $PM_{2.5}$ and ozone pollution events has increased in frequency, spatial extent, and duration between 2001 and 2020.[106] As a result, annual exposure to multiple harmful pollutants has increased by 25 million person-days per year. This trend is expected to continue under climate change, driven by the co-occurrence of extreme heat and wildfires. One study found that, under a high warming scenario, climate-induced changes in $PM_{2.5}$ concentrations could lead to an increase in the annual number of incident childhood asthma cases from 38,000 in 2030 to 200,000 by 2095.[107] This study also found that $PM_{2.5}$-attributable albuterol inhaler uses per year could rise from 29 million in 2030 to 160 million by 2095, which would cost billions of dollars per year by 2095.

1. Dust

Warmer and drier conditions, including droughts driven by climate change, are expected to increase dust concentrations (a component of particulate matter) over the United States, particularly in the Southwest. Achakulwisut et al.[108] found that increases in fine dust over the Southwest were significantly associated with soil dryness. For every unit decrease in the 2-month Standardized Precipitation-Evapotranspiration Index over the U.S. Southwest and northern Mexico, fine dust over the Southwest increased by 0.22–0.43 μg per m^3. This study projected that increases in airborne dust exposure by the end of the century could lead to 140 additional deaths per year in the U.S. Southwest under a low warming scenario and 750 additional deaths per year under a high warming scenario. Climate-driven changes in airborne dust exposure is a climate penalty that has important, if still poorly recognized, health consequences in the U.S. Southwest.

Additionally, lower lake levels, such as in the Great Salt Lake and the Salton Sea, can lead to more entrainment of dust that affects nearby communities. Climate change can amplify declining lake levels as a result of higher temperatures and persistent drought.[109] As lake levels lower, more dust from exposed lakebeds can move into the air and expose people. One study found that dust $PM_{2.5}$ exposures could increase from 24.0 μg per m^3 for “healthy” Great Salt Lake levels, defined by its elevation above sea level, to 26.5 μg per m^3 for very low lake levels.[110] Increases in lakebed dust exposures could have a range of negative health outcomes, including respiratory effects and oxidative stress.[111]

2. Wildfire Smoke

A recent study of fire smoke in the contiguous United States indicated that, between 2007 and 2018, fire smoke contributed more than 25% of the total daily $PM_{2.5}$ concentration at roughly 40% of regulatory air monitors in EPA's Air Quality System (AQS) for more than one month per year. People residing outside the vicinity of an AQS monitor (defined by a 5-kilometer radius) were subject to 36% more smoke-impacted days compared with those residing nearby monitor sites.[104]

Wildfire smoke-derived $PM_{2.5}$ has already imposed significant health harms on Americans. A 2018 paper by Fann et al.,[112] an EPA scientist, estimated that **$PM_{2.5}$ from wildland fires between 2008 and 2012 resulted in increased premature deaths and respiratory illnesses, primarily impacting northern California, Oregon, Idaho, Florida, Louisiana, and Georgia**. More recently, the 2023 wildfire season in Canada was estimated to be responsible for 5,400 deaths from short-term exposure in North America and 64,300 deaths from long-term exposure in North America and Europe.[113]

A recent study of wildfire $PM_{2.5}$ exposure due to anthropogenic climate change found that in the United States, "climate change contributed to approximately 15,000 wildfire particulate matter deaths over 15 years with interannual variability ranging from 130 to 5,100 deaths."[114] Another study estimated that wildfire smoke $PM_{2.5}$ contributed to approximately 11,415 nonaccidental deaths per year from 2007 to 2020 in the contiguous United States.[115]

Wildfire smoke is also associated with non-fatal health harms, including emergency department visits and hospitalizations for cardiovascular and respiratory diseases. A study in San Diego, California, found that people experiencing homelessness were increasingly likely to visit emergency departments after periods of increased $PM_{2.5}$ exposure from wildfire smoke.[116] In a separate study that included authors from EPA, short-term exposure to $PM_{2.5}$ on smoke days were implicated in elevated asthma-related hospitalizations among adults aged ≥65 in a study of 692 U.S. counties within 200 kilometers of 123 large wildfires between 2008 and 2010.[117] Wildfire smoke exposure among older adults has also been associated with increased cardiovascular and cerebrovascular emergency department visits during California's 2015 fire season in an analysis co-authored by an EPA scientist.[118] In Colorado, a study reported that acute exposure to fire smoke $PM_{2.5}$ can significantly increase the risk of asthma ED visits among children and adults.[119]

Wildfire smoke contains a complex mix of pollutants that can vary by location, with urban wildfires presenting risks of exposure to toxic chemicals from the burning of plastics, vehicles, and buildings, which differ from the pollutant mix in smoke from wildfires in wooded natural environments.[120–123] While particulate matter is most commonly studied, other components such as reactive organic compounds, which can be particles or gases, potentially play a role in increasing cancer risk from long-term exposure to smoke.[124]

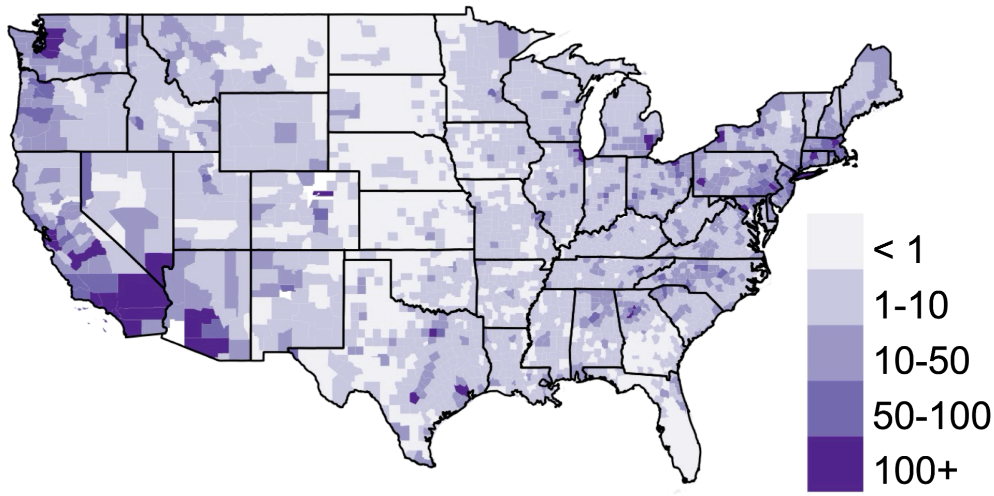

Figure 6. County-level projected increases in annual excess deaths due to smoke $PM_{2.5}$ in 2050; increases are calculated as the differences between the average deaths under SSP2-4.5 scenario over 2046-2055 and the 2011-2020 average. (Source: Figure 5c from Qiu et al. (2025)[129])

Recent studies have also linked wildfire encounters and wildfire smoke exposure with acute and chronic health outcomes. For example, a 2017 study of western U.S. states found that short-term exposure to wildfire-specific $PM_{2.5}$ was associated with risk of respiratory diseases in the elderly population during severe smoke days.[125] A study using the National Cancer Database showed that patients recovering from surgical resection of non–small cell lung cancer had worse overall survival if they lived near wildfire events during recovery.[126] Initial evidence suggests that wildfire smoke $PM_{2.5}$ may be more hazardous to human health than $PM_{2.5}$ emitted from other sources. An observational study conducted in Southern California found that wildfire-specific $PM_{2.5}$ increased the risk of respiratory hospitalization amongst children about ten times more than non-wildfire $PM_{2.5}$.[127] A study of the Medicare population showed that long-term exposure to wildfire smoke $PM_{2.5}$ was linked to a higher risk of heart failure compared with non-smoke $PM_{2.5}$, with greater susceptibility in women and socially vulnerable populations.[128]

Qiu et al.[129] quantified the future mortality burden in the United States due to wildfire smoke $PM_{2.5}$. Future wildfire smoke $PM_{2.5}$ could result in 67,880–71,420 excess deaths per year by 2050 across three climate warming scenarios, a 64–73% increase relative to the 41,380 annual average deaths due to smoke $PM_{2.5}$ from 2011–2020. Figure 6 shows the expected increase in deaths from wildfire smoke exposure in 2050 under an intermediate climate warming scenario. Cumulative excess deaths from wildfire smoke $PM_{2.5}$ could reach 1.9 million from 2026–2055. These estimates indicate that damages from climate-induced smoke could be substantial by mid-century in the United States.

vi. Interactive Effects of Multiple Climate Hazards

In the TSD for the 2009 Endangerment Finding, EPA stated that "there are few studies that address the interactive effects of multiple climate change impacts or of interactions between climate change health impacts and other kinds of local, regional, and global socioeconomic changes (Field et al., 2007). For example, climate change impacts on human health in urban areas will be compounded by aging infrastructure, maladapted urban form and building stock, urban heat islands, air pollution, population growth, and an aging population (Field et al., 2007)" (p. 82). **Recent evidence reinforces that compound climate-driven events are likely to harm human health.**

A study of hospitalizations in California from 2011–2019 found that compound wildfire smoke and extreme heat events were associated with combined impacts on morbidity.[130] Compound drought and heat wave events are linked to elevated mortality risk in individuals with COPD.[131] Several studies find that simultaneous exposure to ozone and other climate-sensitive risk factors like heat and wildfire smoke can lead to worse health outcomes than exposure to ozone alone.[132–134]

Several climate-related extreme events pose risks to electric power grids, including increased electricity demand during heat waves, emergency shutoffs due to wildfires, damage from wildfires, damage from storms and flooding, and drought conditions restricting hydroelectric power generation. Power outage events are associated with a wide range of adverse health outcomes, including higher rates of all-cause mortality and morbidity.[135–140] In particular, power grid failures can impact the health of those relying on electricity for medical care, including home oxygen therapy or medications that require refrigeration, and have been found to increase mortality and morbidity during heat waves.[136,141,142] Extreme heat driven by climate change could also drive up electricity use to satisfy cooling demand, which can increase $PM_{2.5}$ and ozone exposure and associated health harms.[143]

Damage to healthcare facilities, disruption of supply chains, stress among healthcare workers, and disruption of travel and access to healthcare can worsen pre-existing conditions.[144] For example, a U.S. Veterans Affairs medical center was forced to close for six months after Hurricane Sandy in 2012. Veterans who had been using the facility were found to have a 26% higher likelihood of uncontrolled blood pressure one year after the facility reopened, compared to veterans exposed to Hurricane Sandy whose healthcare facilities were not forced to close.[145] Sea level rise is contributing to more frequent coastal flooding, which can also interfere with healthcare access. For example, in Tybee Island, Georgia, tidal flooding now cuts residents off from the mainland – the site of the nearest hospital – around ten times per year.[146] In 2024, Hurricane Helene damaged a medical supply plant in western North Carolina that produces intravenous fluids, which caused hospitals outside the path of Hurricane Helene to postpone non-emergent and elective surgeries. This example illustrates how flooding in a single area not only affects those in the area, which included the deaths of 227 people due to Hurricane Helene,[42] but can also negatively affect health across the United States via supply chain disruptions.[147]

vii. Advances in Climate Attribution Science

While the regulatory docket describes potential uncertainties in “the extent to which human-induced climate change affects the intensity and frequency of extreme weather events” (p. 36308), **the ability to attribute extreme weather to anthropogenic climate change has vastly improved since 2009.** Advances in attribution science methods mean that scientists can now identify the influence of human-caused climate change on a range of extreme weather events, including heat waves, wildfires, floods, hurricanes, and droughts.[148–150] These methods allow scientists to compare the intensity or frequency of an extreme event to the intensity or frequency that we would expect in a world in which there was no human influence on the climate system.

A systematic review analyzed empirical data from 732 locations in 43 countries to estimate mortality burdens associated with the additional heat exposure that resulted from recent human-induced warming from 1991–2018. **In the United States, about 37% of warm-season heat-related deaths over this period were attributable to anthropogenic climate change**, similar to the average across all 43 countries.[151] The June 2021 heat wave over the U.S. Pacific Northwest and Canada, which led to temperature records being broken in some places by as much as 11°F, was determined to have been virtually impossible without anthropogenic climate change.[152,153] Washington State alone saw more than 440 excess deaths because of this event, which made it the deadliest weather event in the state.[154,155]

Other examples of attribution studies that link anthropogenic climate change to increased intensity of events include:

- **Flooding:** For recent catastrophic flooding in the Central Mississippi river valley that occurred April 2–6, 2025, World Weather Attribution found a 40% increase in the likelihood of the event and about a 9% increase in its intensity because of climate change.[156]
- **Hurricanes:** Hurricane Helene formed over record-high sea surface temperatures in 2024, and World Weather Attribution estimated that rainfall from the hurricane was 10% heavier due to climate change. Torrential rain and flash flooding occurred across Georgia, South Carolina, North Carolina, Tennessee, and Virginia during the storm. More than 227 people died from this event, making it the deadliest hurricane in the United States since Hurricane Katrina.[42]
- **Wildfires:** Numerous severe fire seasons in North America have been exacerbated by climate change because of declines in fuel moisture and increases in fire weather severity.[157–160] As a recent example, World Weather Attribution found that the 2023 Quebec fire season, which resulted in harmful smoke exposure across parts of the United States, was 50% more intense due to the impact of climate change.[161]

B. Impacts on Human Health and Well-Being Not Discussed in the 2009 Endangerment Finding

Several impacts to health and well-being were not discussed in the TSD for the 2009 Endangerment Finding. A review of the evidence in the Endangerment Finding found that evidence linking climate change to violence, ocean acidification, national security, and economic well-being had increased such that these impacts would warrant inclusion in the finding of endangerment.[11] Below, we summarize the growing body of scientific evidence indicating that climate change has health impacts related to mental health, displacement, and violence. We conclude the section by summarizing evidence showing that workers across various occupations are more vulnerable to climate related impacts and that certain groups in the United States are at greater risk from the health impacts of climate change due to their demographics and geography.

i. Mental Health

Systematic reviews and meta-analyses have consistently found negative impacts of extreme weather events on mental health, including increased rates of anxiety, depression, and post-traumatic stress disorder (PTSD).[162] Studies have also linked higher temperatures to an increased risk of psychiatric emergency department visits and hospitalizations, including for substance-use disorders, anxiety, stress-related disorders, mood disorders, and schizophrenia, as well as with attempted and completed suicides.[163,164] Encounters of wildfire events may also negatively affect mental health conditions such as anxiety disorders.[165]

Scientists have a better understanding of the multiple pathways by which climate change can impair mental health. These include not only increased temperatures and extreme weather events, such as wildfires, storms, and flooding, but also associations with poor air quality, indirect impacts such as involuntary displacement, and anxiety associated with awareness of the threat posed by climate change.[166,167] Substantial research has demonstrated that climate change anxiety is associated with exposure to the impacts of climate change and is negatively related to mental health and well-being, even when controlling for more general anxiety.[168,169] Global and U.S. surveys show high levels of climate distress in young people. The greater their exposure to dangerous weather events, the more likely respondents are to report climate distress.[170–172] Though climate distress is not a mental disorder, climate disruptions and the lack of effort to stop preventable disasters can contribute to anxiety and depression.[167]

ii. Displacement

Climate change is increasingly driving displacement in the United States, with profound implications for health and well-being. In Alaska, thawing permafrost, diminishing sea ice, and storm surges are accelerating coastal erosion.[173] Dozens of Alaska Native villages face imminent threats, and at least 12 villages have decided to relocate or explore relocation options.[174] Yet with no single agency tasked with overseeing relocation, villages like Kivalina and

Newtok have faced decades of delays, piecing together support from multiple funding streams that were never designed for community-scale climate migration.[175,176]

These predominantly Alaska Native communities are geographically remote, with year-round access only by small plane. Subsistence harvests of fish, berries, and marine mammals are central to nutrition and culture, while imported, store-bought food is prohibitively expensive. Relocation threatens food security, increases risk for chronic disease, and disrupts cultural continuity, an important determinant of Indigenous health.[177,178]

Similar challenges are occurring in coastal Louisiana, where residents of Isle de Jean Charles have already relocated after losing nearly all their land to sea-level rise and subsidence.[179] Families report stress, anxiety, and strained access to medical and social services.[177] Other U.S. coastal and island communities face the same trajectory.[180] In addition to mental health impacts, infectious disease risk due to inadequate water and sanitation, and threats to food security and nutrition, relocation undermines social determinants of health such as housing, livelihoods, and healthcare access.[180]

Beyond permanent relocation, shorter-term climate-related displacement affects Americans across the United States in areas struck by hurricanes, wildfires, and other extreme events and in areas with growing risk of extreme heat, water scarcity, flooding, and other long-term threats. According to the U.S. Census Bureau's Household Pulse Survey, more than 3 million Americans were displaced by disasters in 2023.[181] Of these, approximately one-third reported being displaced for more than one month. Displacement threatens health and well-being in many ways, including interruption of ongoing medical care for chronic conditions, inability to access appropriate care for acute conditions, weakened social cohesion, and worsened mental health conditions.[182] The financial implications of displacement and potential loss of a primary asset (i.e. a home), especially for older Americans, are profound and can influence health and well-being in numerous ways.

iii. Violence

Since violence and conflict are affected by political and economic conditions, adequate controls for confounding effects are necessary and underlying mechanisms are still being explored to identify effects from climate change.[18,183,184] Several recent major reports and meta-analyses suggest a link between temperature and violence, crime, or both. The IPCC found "crime, including violent crime, has been associated with higher temperatures in the USA (medium confidence)," particularly for violent crimes including aggravated assaults, rapes, and homicides.[35] A recent study of 44 U.S. cities found high temperatures to be associated with increased risk of violent crime, similar to some previous studies.[185] A recent meta-analysis found that higher temperatures were significantly associated with crime, violence, or both.[186] A systematic review found increased risk of suicide to be associated with increases in temperature.[187] In the United States, one study projected that an increase in warming of 2°C (3.6°F) above baseline average U.S. temperatures through the end of the century could lead to 563 more suicides per year.[188] **While there is still uncertainty regarding the relationship**

between violence and conflict and climate change, the existing evidence warrants consideration as another pathway by which climate change affects health, which was not included in the 2009 Endangerment Finding.

iv. Occupational Health

Workers, especially outdoor workers, are vulnerable to climate impacts, including from heat, smoke from climate-driven wildfires, and floods. In addition to the generally recognized direct impacts of high temperatures and elevated air pollution, including heat exhaustion and asthma exacerbation, these exposures also have indirect health impacts such as increased injury rates and missed work days.

Climate-driven heat exposure is associated with occupational injuries, illness, and death.[4] This is particularly relevant for workers in the construction, agriculture, transportation, warehousing, and waste management industries. A 2022 meta-analysis of occupational heat strain, which included 2,409 outdoor workers across 41 jobs in 21 countries, including the United States, found that occupational heat stress increased workers' core and skin temperatures, as well as heart rate and urine specific gravity, a measure of the concentration of dissolved chemicals and particles in urine.[189] A prior systematic review found that individuals working a single work shift under heat stress – defined as a wet-bulb globe temperature above 22.0 or 24.8°C (71.6 or 76.6°F), depending on work intensity – were about four times more likely to experience occupational heat strain than an individual working in thermoneutral conditions and that their core temperature increased by 0.7°C (1.3°F). Moreover, the study found that about 15% of individuals who typically or frequently worked under heat stress – defined as a minimum of 6 hours per day, 5 days per week, for 2 months of the year – experienced kidney disease or acute kidney injury.[190]

Increasingly severe wildfires pose increased occupational risks to firefighters who must fight fires over longer wildfire seasons. Wildland firefighters face a number of environmental and occupational exposures during wildfire suppression, which are linked to increased risk of PTSD, chronic stress, and other psychological symptoms.[191] These stress conditions can have long-term implications for mental and physical health and may be linked to wildfire smoke exposure.[191] $PM_{2.5}$ exposure from wildfire smoke also places firefighters at higher risk of lung cancer and cardiovascular disease.[192] One review finds that "health risks to firefighters from wildfire smoke will continue rising based on the ongoing climate change," noting the particulate risk from the increase of fires in the wildland–urban interface, where exposure to hazardous emissions from burning man-made materials is high.[193]

First responders, rescue and recovery workers, and clean-up crews may all be affected by exposure to toxic substances, mold, and other hazards during and after flooding and storm events. Workers helping clean up after Hurricane Katrina developed "Katrina cough," and landscaping workers experienced increased injuries after Hurricane Sandy. Flood waters from Hurricane Harvey led to chemical explosions at the Arkeme Chemical plant, which affected plant workers, first responders, and nearby residents.[194]

Farmers and agricultural workers are subject to several types of climate-driven health impacts. Drought during the growing season has been linked to increased occupational psychosocial stress among farmers, highlighting the broader mental health and occupational risks of climate-related drought exposure.[195] Agricultural workers in the United States are among a group of workers with the highest rate of occupational heat-related deaths, and the average number of days agricultural workers spend working in unsafe conditions is projected to double by mid-century in a high warming scenario.[196,197] Worker protections include providing cooling measures (such as shade, fans, or trees), cool drinking water, rest periods, acclimatization periods, and heat-related injury training, but only five states have heat protection standards according to the U.S. Occupational Safety and Health Administration, thresholds for protection vary, and the United States does not have a national heat standard, though one was proposed in 2024 but has not been finalized.[198–201]

v. Differential Impacts and Susceptibility

In the TSD for the 2009 Endangerment Finding, EPA finds that "climate change is very likely to accentuate the disparities already evident in the American health care systems, as many of the expected health effects are likely to fall disproportionately on the poor, the elderly, the disabled, and the uninsured (Ebi et al., 2008)" (p. 82). **Climate change threatens the health and well-being of all Americans, but some groups are especially vulnerable**, for a range of biological and social reasons. Groups at risk include the very young, the very old, pregnant individuals, people with pre-existing medical conditions, poor people, and people affected by discrimination or disenfranchisement.

a. Infants and Children

Children are especially vulnerable to several climate-related risks.[202–204] According to the American Academy of Pediatrics, "children's physical and mental health are threatened by climate change through its effects on temperature, precipitation, extreme weather (eg, heat waves, wildfires); ecological disruption; and community disruption."[205]

Extreme heat has long been recognized as a particular risk for children.[206,207] The risk begins with fetal development. Extreme heat is a risk factor for preterm birth, stillbirth, congenital anomalies, and gestational diabetes.[208–215] Several systematic reviews and meta-analyses suggest extreme temperatures experienced during pregnancy increase the risk of preterm birth and low-birth weight.[209,215–217] Lifelong consequences such as poor health and social outcomes may follow excessive exposure to heat in utero.[218]

Children are less able than adults to regulate body temperature during periods of extreme heat.[219] Infants are at high risk of heat-related mortality.[203,220] A particularly tragic example of such deaths occurs when children are left in cars on hot days.[221] Pediatric emergency visits rise during hot weather, not only for heat-related illness but also for certain infections[222,223] and for injuries.[224] Young people playing sports are at risk of heat-related illness, including heat stroke, which can be fatal.[225–228] Adapting by reducing sports activities in very hot weather – a trend that parents already report – deprives children of an opportunity for physical activity, a health behavior that improves physical and mental health and lowers chronic disease risk later in life.[229,230]. Beyond sports, extreme heat is linked to lower physical activity levels in preschool children during outdoor play time in childcare settings and elementary children during school recess.[230,231]

Young people's learning and cognitive performance decline in very hot weather, losses that can result in lifelong reductions in earnings.[202,232,233] Extreme heat is also associated with increases in violent behavior, including self-harm, which may affect children through their own behavior or as victims of abuse and neglect.[186,234–237]

Children are also disproportionately affected by air pollution because they have developing lungs and breathe faster than adults. Children are especially susceptible to wildfire smoke.[238,239] Wildfire smoke exposure in utero is associated with reduced birthweight, and exposure early in life is associated with immune and pulmonary toxicity, effects that can persist into adolescence.[240,241]

Young people report high levels of anxiety, depression, and other forms of mental distress in connection with climate change.[171,172,242–246] Children are also vulnerable to post-disaster mental health problems such as depression and post-traumatic stress, especially if certain risk factors operate, such as witnessing destruction, losing a home or loved one, or being displaced.[247–259]

b. Older Adults

Climate change disproportionately affects older adults.[260–262] **Older people are especially susceptible to extreme heat because of their reduced thermoregulatory capacity.**[263,264] Exposure to extreme heat in older people may accelerate aging[265] and is associated with elevated morbidity and mortality.[24,266,267]

Older people are also vulnerable to extreme events such as hurricanes and floods due to underlying medical conditions such as sensory and cognitive disabilities, dependence on assistive devices, social isolation, and limited mobility.[268,269] Accordingly, mortality among elders during and after an extreme event can exceed that in younger people. In the immediate aftermath of Hurricane Katrina in 2005, 49% of fatalities were among people aged ≥75 years, far in excess of their proportion of the population.[270] Following Hurricane Sandy in 2012, mortality among the elderly in affected areas increased nearly twice as much as in the general population,[271] and mortality among the elderly who lived in flooded areas remained elevated five years later.[272] Institutionalized elderly people face specific risks. A study of nursing home residents in Florida found that nearly half were exposed to power loss following Hurricane Irma in 2017, which was associated with an elevated risk of dying both one week and one month post-event.[273] Among disaster survivors, however, some studies show higher levels of psychological resilience in older adults than in younger people.[274–276]

c. Reproductive Health and Pregnancy

The USGCRP found in 2016 that pregnant and post-partum women are at high risk for distress and mental health consequences related to climate change.[5] In 2018, the WHO found that climate change–driven disruptions to nutrition were associated with risks and changes in patterns of maternal care, child care, and breastfeeding.[2] Since then, a systematic review analyzing over 32 million births in the United States found that **exposure to $PM_{2.5}$, ozone, and heat had a significant association to adverse birth outcomes**.[277] Another study of 29 million live births in the United States from 1989–2003 found that high ambient temperature during pregnancy was associated with lower fetal growth.[278] Multiple other systematic reviews and meta-analyses have also found associations between increases in heat exposure and increases in risk of stillbirth, pre-term birth, reduced birth weight, congenital anomalies, and gestational diabetes mellitus.[209,211,215,279,280]

There is also increasing concern about the impacts of climate change–related hazards on fertility. Evidence suggests that heat stress disrupts both male and female reproductive processes, raising the risk of infertility, miscarriage, and delayed conception with potential population-level consequences.[281] Rubin et al.[282] found that exposure to hazardous wildfire smoke was associated with decreased total motile sperm count among those undergoing intrauterine insemination. Gaskin et al.[283] showed that a 1°C (1.8°F) increase in the mean maximum temperature during the 90 days before ovarian reserve testing was associated with a lower antral follicle count (ovarian reserve). A 2025 study showed that deviations in temperatures from long-term trends resulted in an increase in the prevalence of female infertility, an association that was significant in the United States.[284] With an increase in global temperatures, female infertility is projected to increase in the future.[284]

d. People with Pre-Existing Medical Conditions

People with certain pre-existing medical conditions face a range of increased risks from climate change. People with cardiovascular disease,[285–290] respiratory disease,[291–295] renal disease,[296] and diabetes[297] are especially vulnerable to heat, including from increases in hospitalization and death during extreme heat events. People with cardiovascular disease and respiratory disease are also especially vulnerable to the effects of wildfire smoke, as reflected in increased rates of hospitalization and death.[298–301] People with allergies and asthma are vulnerable to a wide range of climate-related extreme events, including floods and wildfires, due to the aggravation of symptoms and increases in emergency department visits and hospitalizations.[302,303]

People with dementia are at increased risk from several climate-related exposures, including heat, air pollution, and extreme events, for reasons including inability to recognize a hazard and inability to take protective action.[304,305] Similarly, people with mental illness are at increased risk from several climate-related exposures. During extreme heat events, hospitalizations for mental illness increase and people with mental illness have dramatically increased mortality.[163,306–309]

Many chronic diseases bring increased risk during climate-related disasters. When electric power supply is interrupted, patients who require electricity for medical devices or medications are at risk. Ongoing care may be interrupted when daily routines are upended, health care facilities are overwhelmed with acute patients, supply chains are disrupted, infrastructure is damaged, and transportation is unavailable. For example, studies show worsening of diabetes control in patients affected by Hurricane Katrina.[310,311] When people have to relocate, as may occur during and after a hurricane, chronic care for kidney dialysis, cancer chemotherapy, and addiction treatment may be interrupted.[31,312–319] Additionally, certain medications used for chronic disease treatment can increase the risk of heat-related illness by a number of mechanisms that include impaired sweating, reduced thirst sensation, hypotension, and altered central thermoregulation.[320,321] Examples of such medications include antidepressants, antihypertensives, antipsychotics, and pain medications.

e. Poor People and People Affected by Discrimination or Disenfranchisement

Climate change amplifies pre-existing health disparities. **Nearly every adverse health outcome associated with climate change disproportionately affects low-income people, members of racial and ethnic minority communities, immigrants, and others who are marginalized**.[322–326] This has been documented with respect to exposures including heat,[327–331] flooding,[332–334] and extreme weather events,[335,336] and with regard to multiple health outcomes including children's health,[337] heat-related mortality,[338] nutrition,[339–341] and respiratory health.[342] Mechanisms are numerous but can reflect increased prevalence of pre-existing medical conditions (as discussed above), increased exposures given attributes of the built environment (e.g. urban heat islands and lack of tree canopy in poor neighborhoods), fewer resources for protection against exposures (e.g. air conditioning), and fewer financial resources available in situations of property damage or displacement.

f. Geographic Differences

Climate stressors have clear geographic differences across the United States, but the residents of most U.S. states are vulnerable to at least one type of stressor.[4] For example, the influence of increasing temperatures will have greater health effects in areas of the country where the effects of heat greatly exceed the effects of cold temperatures (as described above), and where the presence of residential air conditioning or other cooling sites is inadequate to meet the growing need. In areas of the U.S. Southeast and Southwest where extreme heat events are becoming increasingly more frequent, health risks are growing over time and can be clearly linked with climate change. Significant increases in heat waves have also been observed in recent decades in the Great Plains and Northern Rockies. Beyond interregional patterns of heat exposure based on baseline weather conditions, heterogeneity is expected within regions due to the presence of urban heat islands, coupled with the lack of availability of air conditioning within a larger percentage of lower-income households living in cities. Thus, there will be geographic and sociodemographic population groups who will disproportionately experience increasing health risks associated with increasing ambient temperatures.

While wildfire smoke events have been historically located in well-defined geographic areas (e.g. California), these events have become increasingly widespread with impacts seen across much of the country. Many states in the Midwest and South have experienced either stagnations in air quality improvements or reversals with increasing concentrations due to wildfires.[104] Even some of the geographic areas that had a more limited effect of wildfire smoke historically, such as in the Northeast, have experienced repeated wildfire smoke impacts in recent summers because of Canadian wildfires.[298,299] Air quality is also affected by dust storms, with major impacts earlier this year in states such as Arizona, New Mexico, and Texas. Drought conditions, which are associated with dust storms but can also influence infectious disease exposure, have increased rapidly in the West, Southwest, and Northwest, but with other regions like the Southeast and Midwest projected to have growing frequency of flash droughts in the coming decades.

Extreme storms also have well-defined geographic patterns, whether from hurricanes that primarily affect states in the Southeast and along the Atlantic Coast and Gulf of Mexico, or from tornados that are dominant in the Great Plains. Broadly, these trends reinforce that individuals living in all regions of the United States are vulnerable to the health risks associated with a changing climate.

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The following section pertains to:

- **C-3:** “The EPA is not proposing to reopen or substantively modify at this time any regulations necessary for criteria pollutant and air toxic measurement and standards, CAFE testing, and associated fuel economy labeling requirements. If there are any elements of our regulations, test procedures, or GHG emission models proposed for removal that should remain to support other programs outside of the EPA’s GHG standards, we are seeking comment on what those elements are and why their preservation in the CFR is necessary.”
- **C-13:** “We seek comment on the proposed bases for repeal presented in section V of this preamble, including on the economics of fleet turnover, the relative efficiency and emission reductions achieved by newer vehicles, and the potential costs to air quality of retaining standards that may slow fleet turnover as compared to the potential benefits of retaining GHG emission standards in response to global climate change concerns.”
- **C-21:** “We request comment on the analysis provided within section VIII related to the benefits and costs of the proposed action and whether benefit cost analysis is an appropriate and lawful basis for repealing the Endangerment Finding and/or resulting vehicle standards.”

4. Economic Effects of Climate Pollution and Co-Benefits of Pollution Controls

The costs and benefits considered in the Endangerment Finding reconsideration proposal and Draft Regulatory Impact Analysis (RIA) are narrow and fail to fully consider health co-benefits of GHG reductions and climate-related economic damages, including those to human health.

A. Deficiencies in the Draft Regulatory Impact Analysis

Chapter 6 of the Draft Regulatory Impact Analysis (RIA) presents results of the five main scenarios, which the authors state rely on the same models and tools as the 2024 RIAs, but with varying scenarios. However, neither this chapter nor Appendix A (which purportedly provides more detail on the methods used) provides sufficient insight into how or whether the models and tools that were used in the 2024 RIAs were rerun with the modified assumptions, including removal of IRA provisions and California's Advanced Clean Trucks (ACT) rule, changes in gasoline and diesel prices, and accounting for only 2.5 years of fuel savings. Some information about these modified assumptions are outlined in Chapters 2–5, but details on how these changes are incorporated into the modeling framework are not provided.

The summary results presented in Chapter 6 show only the net costs and savings of each scenario, but no details on each cost and saving category. In the second scenario (no IRA and ACT), for example, it is stated that changes in net societal costs are "largely driven by higher fuel consumption and associated fuel costs, which is greater than the reduction in vehicle technology costs" (p. 20), but no data are provided in the entire Draft RIA that reveal how much fuel consumption might change under this scenario. Appendix A disaggregates costs and savings somewhat, but fuel costs are grouped with repair, maintenance, insurance, and the vague "etc." cost categories, which makes it impossible to know the estimated fuel costs in these scenarios (and any other cost or savings category not reported independently, for that matter).

i. Energy System Impacts

The Draft RIA includes a "fuel price sensitivity assessment" that assumes gasoline and diesel prices will be \$1.00 and \$0.25 lower per gallon, respectively, than in the 2024 RIAs, which relied on fuel price data from the 2023 Annual Energy Outlook (AEO) Reference scenario. These lower fuel prices are applied in scenarios in which the effects of IRA vehicle tax credits and the ACT rule are removed. This assumption of lower fuel prices runs counter to projections from the 2025 AEO, which projects *higher* fuel prices in its Alternative Transportation scenario (which restricts IRA tax credit eligibility and excludes the ACT program and 2024 EPA vehicle rules and 2024 NHTSA CAFE standards) than in its Reference scenario (which includes the aforementioned programs and rules). The Alternative Transportation scenario appears to be the closest analog to the "no IRA and ACT" scenario, which suggests that is more appropriate to assume the fuel prices will increase relative to the updated Reference scenario, not decrease by an arbitrary amount as EPA currently assumes. It is true that gasoline and diesel prices are lower in the 2025 AEO Reference and Alternative Transportation scenarios than in the 2023

AEO Reference scenario, but the assumed $1.00 decrease in gasoline prices is larger than any difference between 2023 and 2025 AEO scenarios in any year. Part of the justification for assuming lower fuel prices than in the AEO seems to be EPA's stated claim that "it does not appear that AEO 2025 took into account the policies being implemented by President Trump that are intended to drive down the price of gasoline and diesel" (Draft RIA, p. 9). This is not sufficient basis for deviating from established methods for projecting fuel prices that have been used in previous RIAs, and there is no empirical evidence or alternative energy models to support this claim.

The Draft RIA correctly assumes that EV adoption will increase electricity demand, and make electricity more expensive, which is likely correct. It is assumed at baseline that there will be additional costs from data centers and industrialization. They include this effect of EV deployment as an impact but fail to apply the same logic to data centers and increased industrialization (p. 39). Further, EPA fails to evaluate the consumer effects of the higher gasoline prices that will result from higher gasoline demand under the proposed rollback.

The Draft RIA states (p. 39): "If the grid runs tight, system operators must either build costly new plants and lines, fire up expensive fossil "peaker" units, or curtail other demand—choices that divert capital and fuel away from alternative uses such as industrial expansion, data-center growth, or deeper decarbonization of existing loads. Consumers may face higher electricity rates or reliability risks, while public dollars earmarked for schools, or get pulled into emergency subsidies and grid upgrades. In short, every extra megawatt-hour (MWh) needed for EVs carries an opportunity cost." No supporting evidence is provided for these claims of higher electricity rates or reliability risks, and EPA has failed to consider counterfactual scenarios in which clean resources, especially wind and/or solar and storage have increased deployment proportionate to the increased load from additional EVs. EPA also fails to provide any evidence for why or how public education budgets would be affected. EPA assumes that EVs present an "opportunity cost" given that increased demands on the grid can risk reliability, but again no evidence is provided for this claim. In fact, the opposite could be true. EPA failed to evaluate scenarios where EVs were deployed with vehicle-to-grid technologies. This is a technology that enables bi-directional charging, among other things, meaning that EVs can act as distributed electricity storage and that can discharge during peak times, thus reducing the risk of blackouts and enhancing reliability.

No evidence or methods are provided on how the benefits of increased grid reliability were calculated, including how the value shown in Table RIA-5 was monetized.

Pages 41–42 of the Draft RIA state: "Substitution will also occur in fossil-fuel markets. Vehicle regulation shifts one component of fossil fuel demand, which unmistakably spills over onto supply and other elements of fossil-fuel demand. The other elements of demand include heating, cooking, industrial processes, agriculture, other forms of U.S. transportation such as air travel, and vehicle use outside the U.S.. This Appendix translates U.S.-vehicle emissions impacts into worldwide emissions using fossil-fuel supply and demand, described more fully in section C.5 of this Appendix. The ultimate conclusion is that half of the reduction of fossil-fuel use by U.S. vehicles–whether it be from powering ICE vehicles or generating electricity for EVs–is offset by increased fossil-fuel use elsewhere in the world economy." The assumption here seems to be that if EVs reduce oil and gas demand, that oil and gas will be burned somewhere else since it's cheaper. **Again, no evidence is provided to support the specific quantification that half of the reduction is offset.**

ii. Monetized Costs and Benefits

The air pollution disbenefits are poorly described and narrowly defined. For example, the Draft RIA (p. 37, 43) repeatedly states that EPA has modeled "PM emissions," whereas in all previous RIAs (including the 2024 RIA that this was modeled after) both primarily emitted and secondarily formed PM are included. In most prior analyses, secondarily formed PM (from emissions of precursors like NO_x, SO_2, and VOCs) have dominated the health impacts. It is not clear whether EPA omitted the impacts of secondary PM components and only modeled "PM emissions," which would be a systematic underestimate of health disbenefits, or if the authors of the Draft RIA do not recognize the difference between emissions and concentrations, which would betray a lack of understanding of the basic elements of the models being used. Because the Draft RIA, including Appendices A and B, does not provide any details on the methodology used to calculate air pollution health costs, it is not possible to determine which one of these issues is present. EPA must clarify which error has been made, and if it is an error that influences the underlying calculations, those calculations must be redone.

EPA reports health costs from "PM emissions" of $2.2–4.2 billion per year (Table RIA-1). No documentation is provided of where this range comes from, what underlying assumptions are made, what discount rate is applied, or anything else that would allow for this estimate to be critically examined. In Table RIA-5, there is a range of values from $2-4 billion that reflects differing discount rates (3% and 7%) and scenarios (EPA vs. Market), which one could assume is the same range as in Table RIA-1 but with fewer significant figures presented. However, PM-related benefits in the 2024 light- and medium-duty vehicle (LMDV) RIA are listed as being $5.3–10 billion with a 3% discount rate and $3.6–7.2 billion with a 7% discount rate (2022 dollars), with the uncertainty range in each case reflecting the choice of epidemiological study linking PM and mortality. It is therefore unclear if the authors have selected a single PM concentration–response function (and if so, which one?), if the only sources of uncertainty are assumed to be the discount rate and scenario, or anything else. The only hint as to what the authors assumed is their statement that there is a $10 billion $PM_{2.5}$ cost reduction in the 2024 LMDV rule (p. 42), but that was based on a single (3%) discount rate and a selected concentration-response function. EPA asserts that "much of the $10 billion reported in the 2024 LDMV rule was due to criteria air pollutant standards that are unchanged by this proposed action" (p. 42), but emission and air quality changes in the 2024 LMDV rule resulting from GHG and criteria air pollutant standards were modeled concurrently and therefore cannot be easily isolated. Relatedly, EPA argues that the range of $2-4 billion is less than the $10 billion in the 2024 RIA because of emissions offsets in vehicle markets and criteria pollutant standards unchanged by this proposed action. Given that no data were provided on emissions inputs for this model, the magnitude of emissions offsets in vehicle markets, or anything else related to the air pollution disbenefits, it is impossible to evaluate the veracity of this statement. **The lack of documentation and the discrepancies from the 2024 RIA raise concerns that errors or inappropriate assumptions have been made.** EPA needs to show their work and underlying assumptions, with analogous depth and breadth as in all prior RIAs, and then provide another comment period for this analysis to be evaluated by the public.

EPA claims that the primary set of scenarios modeled in the Draft RIA (summary costs and savings of which are also found in Tables 6 and 7 of the Federal Register document) uses “the same models and tools used to estimate the regulatory impacts presented in the 2024 RIAs” (p. 20), but all five of these scenarios *fully exclude* estimates of climate damages and PM-related health damages that were included in the 2024 RIAs. In both the 2024 LMDV and HD rules, climate benefits are the single largest category of costs or benefits, and PM health benefits are the third largest benefit category in the LMDV rule after climate benefits and avoided vehicle maintenance costs. The exclusion of climate damages does not reflect the current scientific understanding that there are real and quantifiable damages of greenhouse gas emissions, as discussed elsewhere in this document. As discussed in Section 5 below, the presence of some level of uncertainty in these estimates does not mean that there is insufficient evidence of health harms. Though it is difficult to isolate the $PM_{2.5}$ effects of GHG standards from the 2024 LMDV rule since emissions and air quality changes modeled the effects of GHG and criteria air pollutant changes concurrently, the contribution of GHG rules to changes in PM emissions (and associated damages) is decidedly not zero. **Excluding $PM_{2.5}$ damages entirely from the draft regulatory impact analysis therefore ignores an important category of potential damages from this new proposed rule.**

B. Climate-Sensitive Health Harms are Quantifiable and Economically Costly

The economic costs of climate change on human health across the United States are substantial and largely underestimated. These costs include medical treatments, lost wages and productivity due to illness and injury, and related reduced economic output, as well as costs for the health care sector to adapt to and mitigate climate impacts.[343] Direct health damages, such as death and illness/injury, and damages in sectors that impact health, including agriculture and water systems, make up a large portion of the overall economic costs of climate change.[344]

Between 2000 and 2009, the health-related costs associated with climate-sensitive events, including ozone pollution, heat waves, hurricanes, infectious disease outbreaks, river flooding, and wildfires, are estimated to have exceeded $14 billion (2011 dollars), mostly due to the value of lives lost prematurely.[345] Total health care costs were estimated to be $740 million from more than 760,000 encounters with the health care system. In 2012, the total health-related costs from 917 deaths, 20,568 hospitalizations, and 17,857 emergency department visits associated with similar climate-sensitive events across the United States, which also included allergens and harmful algal blooms, were estimated to be $10.0 billion (2018 dollars).[346] As these climate-sensitive events are projected to worsen, the United States can expect to see higher economic and health harms in the future.

Wildfires are increasingly contributing to economic losses and health damages, especially in the western United States. $PM_{2.5}$ from wildfire smoke is linked to increased premature deaths, hospital admissions, and emergency department visits from cardiovascular and respiratory diseases.[112,347] Economic costs associated with premature deaths and respiratory hospital admissions attributable to wildfire $PM_{2.5}$ from 2008 to 2012 in wildland fire–prone areas in northern California, Oregon, Idaho, Florida, Louisiana, and Georgia total between $11 and $20 billion (2010 dollars) per year for short-term exposures and between $76 and $130 billion (2010 dollars) per year for long-term exposures.[112] Smoke-related asthma events are projected to add an additional $1.5 billion per year to the health costs of wildfire smoke each season in the western United States.[348] A recent study found that climate change contributed to 15,000 premature deaths from wildfire $PM_{2.5}$ exposure between 2006 and 2020, which equates to $160 billion in cumulative economic burdens.[114] About 34% of these climate-attributable wildfire $PM_{2.5}$ deaths occurred in 2020, at a cost of $58 billion. Another recent study estimated that long-term exposure to carbonaceous $PM_{2.5}$ from fire smoke is responsible for approximately 7,455 non-accidental deaths annually in the contiguous United States, with associated annual monetized damage totaling $68.3 billion.[349] The mortality burden of wildfire $PM_{2.5}$ is expected to increase in the future, with one study projecting that climate-driven wildfire smoke could cause 30,040 additional excess deaths per year by 2050 relative to 2011–2020 under a high warming scenario, at a cost of $608 billion (not discounted, 2019 dollars).[129] Health costs including morbidity, mortality, and other costs such as medical expenses and lost work time related to wildfire smoke exposure from California wildfires in 2018 represented 31.5% of total statewide damages from wildfires that year. Nationwide, the country experienced $45.9 billion in economic damages related to these wildfires, indicating that economic and health costs can reach far beyond the immediate area in which wildfires occur.[350]

Suboptimal temperatures, including extreme heat and extreme cold, are another climate-sensitive hazard with notable health costs. Suboptimal temperatures can cause hyperthermia (overheating) and hypothermia, resulting in emergency department visits, emergency hospitalizations, and premature death.[351,352] For example, in the Minneapolis–St. Paul Twin Cities metropolitan area, exposures to both extremely low and high temperatures are estimated to cost $2.70 billion (2016 dollars) annually, and together, moderately and extremely low and high temperatures are estimated to cost $9.40 billion (2016 dollars).[352] Overall, the health-related economic burden of extreme heat in the U.S. is substantial and will grow substantially in the future. Costs from U.S. heat-related deaths linked to climate change are projected to increase to $200 billion in 2030 and $500 billion in 2050.[353,354]

Various other climate-sensitive exposures result in economic and health burdens across the United States. Harmful algal blooms (HABs), excessive growths of algae, can produce toxins and cause negative health impacts such as respiratory illness. Increased water temperatures and rainfall events driven by climate change can contribute to HABs. In places like coastal Florida, costs of HAB-associated emergency department visits for respiratory illness can equal $0.5–$4 million.[355] Climate-sensitive infectious diseases, such as West Nile virus, are also associated with costs related to various hospitalizations and medical treatment, with a 2012 West Nile outbreak linked to $1.1 billion in health-related costs.[346] From 2008 to 2017, large floods in the United States were associated with a 4.8% increase in emergency department visits and a 7.4% increase in hospitalizations among Medicare beneficiaries and over $260 million in costs to the Medicare system.[356]

In addition to the direct economic costs of climate-sensitive health harms, climate change also affects specific health conditions and demand for drugs used for standard-of-care treatment. Climate change may lead to an increase in drug demand particularly for asthma, stage 5 chronic kidney disease, and Alzheimer's disease treatment, all conditions expected to increase in prevalence.[357] Increasingly, U.S. residents are exposed to multiple climate hazards at once. Importantly, current estimates of health-related damages from climate change are conservative because of the challenge of accounting for how multiple climate-related stressors combine to create synergistic, or greater-than-additive, health risks. Beyond compound hazards, the costs associated with damaged healthcare infrastructure following extreme weather events, such as hospitals becoming inoperable during inland floods or coastal storms, are not typically included in current estimates. While labor productivity impacts are partially considered, they do not fully capture the costs associated with increased illness-related absenteeism, reduced cognitive function due to extreme heat, and the broader societal impacts of a less healthy workforce.[358]

C. EPA's 2022 Assessment of the Social Cost of GHGs

According to the U.S. federal government's Social Cost of Greenhouse Gases (SC-GHG) framework as established by an Interagency Working Group reconstituted in 2021 and Executive Order 13990, human health costs are a significant part of the economic damages from climate change. In 2023, EPA presented a set of SC-GHG estimates that incorporated numerous methodological updates addressing the near-term recommendations of the National Academies, which conducted a comprehensive review of prior government estimates.[359] Importantly, the 2023 report suggests current estimates are likely underestimates. Derived from three independent models and integrating state-of-the-science methodologies and data, this update was subject to public comment and substantive, external peer-review prior to use in regulatory analysis.[358,360–363] The 2023 report provided central estimates of $140, $230, and $380/metric ton for 2030 emissions using a near-term discount rate of 2.5%, 2.0%, and 1.5%, respectively. EPA's updates included extensive methodological and empirical updates to ensure the estimates were informed by and reflected areas of scientific uncertainty. Research following this adjustment has also found justification for higher social costs of carbon.[364–366]

While the most recent EPA SC-GHG incorporates costs related to heat- and cold-related mortality and partially includes morbidity- and mortality-related costs from extreme weather events, it does not yet fully account for health impacts from climate-sensitive air pollution, infectious diseases, malnutrition, allergies, wildfire smoke, or forced displacement and migration. Generally, while the social cost of carbon attempts to monetize some health-related costs of climate-sensitive hazards, several important exposure categories are not adequately captured, leading to an underestimation of the full public health burden of climate change. The exclusion of these costs is often due to a lack of complete data, difficulty in establishing methods for monetization, and the complexity of these impacts (e.g. compound hazards). Among these poorly captured effects, the psychological toll of climate change and overall burden of climate hazards on mental illness is a prime example. The mental health effects of climate change include stress, anxiety, and trauma from experiencing extreme weather events such as floods and wildfires. The mental health burden also encompasses eco-anxiety and the distress associated with surviving intense disaster episodes. Moreover, while some costing models include certain vector-borne diseases like malaria and dengue, they often fail to capture emerging or expanding diseases that currently afflict many U.S. states. The full health and economic costs associated with illnesses like Lyme disease and West Nile virus have been largely omitted.

According to a 2022 Office of Management and Budget (OMB) report and a 2024 White House report, climate change presents a significant and growing risk to federal budgets, particularly for programs like Medicare and Medicaid, due to rising health-related costs.[367,368] Extreme weather events and other climate impacts exacerbate health issues, increasing federal healthcare spending, with the 2022 OMB report estimating climate-related risks, including healthcare, could add $25–128 billion (2020 dollars) annually to federal spending by late-century. Moreover, the Economics chapter of NCA5 indicates that climate change will significantly increase health-related costs for households, governments, and businesses due to more frequent extreme weather, poorer air quality, and expanding ranges of infectious diseases.[4] These costs are expected to disproportionately affect marginalized and vulnerable communities.

As described above, there is substantial evidence linking climate change with health and well-being, with the ability to quantify and monetize the social cost of carbon. In the Draft RIA, EPA states (p. 42) that it “does not attempt to monetize the value, if any, of changes in GHG emissions that result from the proposed action.” This is inconsistent with both the evidence and models described above and with best practice in how to incorporate uncertainty into RIAs. According to OMB Circular A-4 (which is currently in force given that the 2023 update was rescinded via Executive Order), “When benefit and cost estimates are uncertain … you should report benefit and cost estimates (including benefits of risk reductions) that reflect the full probability distribution of potential consequences. Where possible, present probability distributions of benefits and costs and include the upper and lower bound estimates as complements to central tendency and other estimates. If fundamental scientific disagreement or lack of knowledge prevents construction of a scientifically defensible probability distribution, you should describe benefits or costs under plausible scenarios and characterize the evidence and assumptions underlying each alternative scenario.”[369] **Complete exclusion of the social cost of carbon, given the robust literature described above and its inclusion in previous RIAs, runs counter to this guidance and prevents EPA from evaluating a very important consequence of its proposed action.**

Stated another way, exclusion means that EPA has concluded either that there is a near-100% chance that the true value is zero, that the inclusion of the social cost of carbon would be de minimis and not affect policy decisions, or that there are no viable methods for quantification. The models described above, along with expert guidance from the National Academies, make it abundantly clear that quantification is viable and that there is a high probability of a non-zero value.[359] The results of the 2024 LMDV RIA, in which social cost of carbon was the largest single contributor to benefits, make it clear that this could not be assumed to be a de minimis contributor. The only rationale for the exclusion of social cost of carbon would therefore seem to be the Executive Order 14154, “Unleashing American Energy,” in which it is stated that EPA should consider “eliminating the ‘social cost of carbon’ calculation from any Federal permitting or regulatory decision,” and the associated OMB guidance. But EPA and OMB provide no evidence for why the methodologies developed and used across many analyses and years could not yield even a sensitivity value or a range of estimates to consider.

Of note, the decision to exclude any non-zero value for social cost of carbon not only violates Circular A-4, but it also violates risk assessment guidance provided to EPA and the federal government for many decades. Ever since the 1983 Risk Assessment in the Federal Government report (also known as the “Red Book”), it was clear that given large inherent uncertainties, human health risk assessment “requires judgments to be made when the available information is incomplete,” but that systematic structures are needed to ensure that these “judgments are consistent, explicit, and not unduly influenced by risk management considerations.”[370] Thus, best practice in risk assessment – and, by extension, regulatory impact analysis – involves separating out decisions in the assessment process from the ultimate policy decision. **The choice to assign a value of zero to the social cost of carbon, with no allowance for alternative values or consideration that there was any possibility that the value could not be zero, is in violation of how regulatory impact analyses should be done and contradicts a wide body of robust empirical evidence.**

In a subsequent National Academies report, the “Science and Decisions” committee discussed the concept of the “missing default,” where a value is assumed to be true with an implicit conclusion that the value is known without uncertainty. Stating that a value or model is extremely uncertain and then determining that it should be either excluded as a result or included with a single value is not best practice, especially when there are quantitative values available.[371] **EPA either needs to include the social cost of carbon, with associated characterization of uncertainty that reflects the empirical evidence (which the 2023 estimates provided), or provide specific insights regarding why previous scientific consensus reports were incorrect or what new evidence has emerged in the past few years that might lead to differing conclusions.**

D. Health Co-Benefits of Greenhouse Gas Emissions Reduction Strategies

i. Air Quality Benefits

This comment has detailed the adverse health impacts of GHG emissions through climate change pathways and indicated that reducing GHG emissions can reduce these health harms. Reducing GHG emissions also offers broad near-term benefits through other pathways. One of these is through the control of criteria air pollutants.

Reducing GHGs by reducing fossil fuel combustion reduces emissions of criteria air pollutants, improves air quality, and provides substantial health benefits. Therefore, **reducing GHG emissions enables and facilitates reductions of multiple air pollutants, supporting EPA's Clean Air Act implementation**. This is an important co-benefit of GHG emission reductions. This has been routinely understood by EPA and incorporated into previous GHG-related RIAs, including the Draft RIA for this rule (albeit with methodological challenges and exclusion of some $PM_{2.5}$-related health disbenefits as described above).

In 2023, the NCA found substantial reductions in GHG emissions would very likely improve air quality, which is associated with major health benefits. Specifically, each metric ton of CO_2 reduced is estimated to produce health benefits from $9 to $472 (in 2025 dollars), with a median of $110 per ton of CO_2, mainly from reductions in premature deaths from $PM_{2.5}$. These benefits offset or exceed the implementation costs of GHG reductions (Figure 7). This assessment was based on a large set of analyses by different research teams that focused on the entire United States or parts of the United States.[372–382]

Other reviews have found substantial health co-benefits for adults and children associated with climate policies, including the Regional Greenhouse Gas Initiative in the Northeast and Atlantic regions of the United States. Where evaluated, the economic benefits were also substantial.[383] In the context of global goals and across all sectors, the U.S. withdrawal from the Paris Agreement is estimated to cost 65,000 lives per year in the United States from $PM_{2.5}$ exposure.[384] The valuation of these major air quality-related health benefits offsets much or all of the cost of decarbonization in the United States, qualitatively similar to findings for much of the rest of the world.

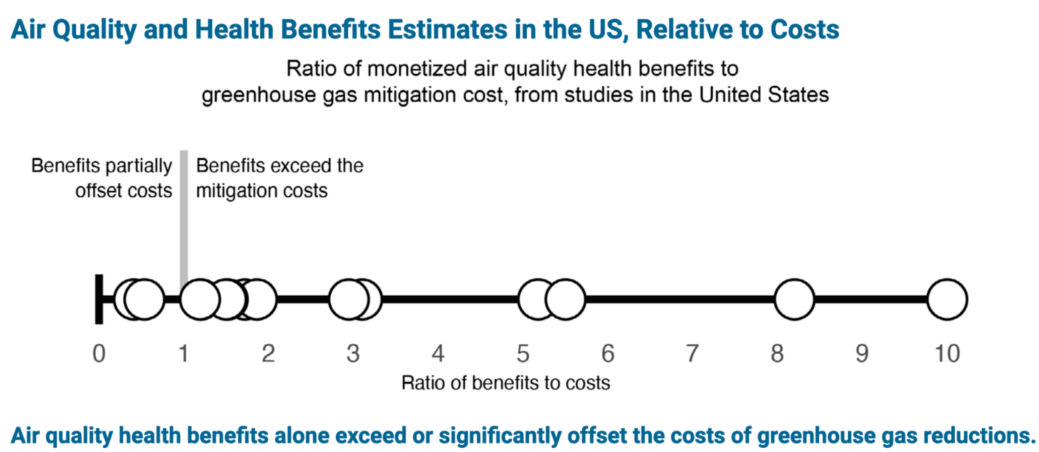

Figure 7. Controls on GHG emissions also reduce air pollutant emissions from the same sources (often fossil fuel combustion), improving air quality and saving lives. Each circle denotes the results from a study in the United States during 2013–2022. These studies find that the value of health benefits associated with improved air quality significantly offset or in most cases exceed the GHG emissions control costs, even without accounting for the additional benefits of slowing climate change. (Source: Figure 14.8 from Crimmins et al. (2023),[4] with credit to EPA, University of North Carolina at Chapel Hill, and Duke University)

Eliminating emissions of $PM_{2.5}$, sulfur dioxide, and nitrogen oxides from the electric power, transportation, building, and industrial sectors could prevent 53,200 premature deaths each year across the United States and provide $608 billion in benefits from avoided illness and death, according to estimates using EPA's Co-Benefits Risk Assessment screening tool.[382] Efforts to reduce methane, a GHG that contributes to the formation of ground-level ozone, can also prevent premature deaths and provide economic benefits. Within the RIAs and elsewhere in policy proposals for GHG emissions, air pollution co-benefits (or disbenefits for repeals) need to be acknowledged and incorporated.

ii. Transportation Mobility and Health Benefits

There are other health-related benefits from GHG policies that extend beyond air pollution that EPA has not acknowledged. In its reconsideration of the Endangerment Finding, EPA asserts that "the ability to own a vehicle is an important means to unlock economic freedom and participate in society as an employee, consumer, and community member" (p. 36313).

While transportation mobility and economic activity are important goals, EPA errs by equating these with conventional vehicle ownership. First, people can and do travel by many modes other than private vehicles, including public transportation, walking, biking, e-mobility, and shared ride services. Second, people can reduce travel demand by living in communities that place destinations – work, retail, recreation, worship, services – close to homes. Third, people who do drive personal vehicles can drive zero-emission vehicles. Each of these choices is associated with substantial health benefits.[385–400] And each of these choices can be promoted by climate policies that aim to reduce GHG emissions.

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The following section pertains to:

- **C-23:** "Stakeholders state that NCA5 does not meet the requirements under Executive Order 14303 and deviated from OMB guidelines on quality, objectivity, utility, and integrity of information disseminated by Federal agencies. The Administrator takes these concerns seriously and seeks public comment on the validity of these concerns and how they should be taken into account when determining whether to finalize any of the alternatives proposed in this action."

5. Scientific Uncertainty is Overstated by EPA

EPA's reconsideration mischaracterizes current scientific consensus on climate change in terms of observed impacts and future forecasts, specifically with regards to the Fifth National Climate Assessment. The robust process for the Fifth National Climate Assessment (NCA5), released on November 14, 2023, began years prior, with its expert authors and scientific information gathered through several distinct phases. The effort was coordinated by the USGCRP, a collaboration of 13 federal science agencies.

The first step took place in late 2020, when the USGCRP opened a call for public nominations for authors and technical experts for the assessment, with the nomination period closing on November 14, 2020. In the following months, a diverse team of more than 500 expert authors and 250 technical contributors was selected from across the country. This team, which was larger and more diverse than in previous assessments, drew from academia, government, the private sector, and Indigenous knowledge holders. Throughout 2021 and 2022, the author teams collected and integrated scientific information from thousands of peer-reviewed studies and technical reports. This included drawing on sources from government agencies, as well as stakeholder input gathered during workshops and public listening sessions. The authors also made special efforts to incorporate Indigenous knowledge.

The draft of NCA5 was subject to intensive expert and public review from late 2022 to mid-2023. A public comment period opened in the fall of 2022 and ran until January 31, 2023. During this time, a special committee convened by the National Academies of Sciences, Engineering, and Medicine (NASEM) conducted its own independent review, which ran from November 10, 2022, to March 20, 2023. The NASEM review assessed the draft's accuracy and credibility and provided recommendations for improvement. The authors were required to consider and document every public and NASEM comment, leading to a period of final revisions throughout the summer of 2023. After the final revisions, the completed NCA5 underwent a final interagency review by representatives of the USGCRP's member agencies. The final report was publicly released on November 14, 2023. USGCRP made the Global Change Information System available to provide transparent access to all scientific data and sources used in the report.

Furthermore, the findings of the National Climate Assessment and the Endangerment Finding are supported by major scientific organizations including the American Geophysical Union, American Meteorological Society, and the National Academies. Meanwhile, the recent DOE Climate Working Group report has been criticized by scientific societies, and a group of U.S. and international scientists have written a detailed rebuttal to many of the claims in the DOE report.[58] EPA's proposal to revoke the Endangerment Finding falsely presents sparse criticism as widespread scientific consensus.

To support EPA's claim that the NCA5 does not meet "requirements under Executive Order 14303 and deviated from OMB guidelines on quality, objectivity, utility, and integrity of information disseminated by Federal Agencies," EPA cites outside "watchdog" groups, which either do not disclose their funding sources or membership, or where records are available, primarily have funding from fossil fuel and conservative interests. This suggests EPA is favoring the fossil fuel industry and partisan interests with this proposed rule change. There are two groups criticizing the NCA5, Protect the Public's Trust and the CO2 Coalition.[401] Of note, Protect the Public's Trust does not disclose where or how it is funded and only lists one person associated with the organization.[402] Where funding information is available for the CO2 Coalition, it is funded primarily by organizations with fossil fuel interests.[403]

In Executive Order 14303, the administration states, “agencies have used Representative Concentration Pathway (RCP) scenario 8.5 to assess the potential effects of climate change in a “higher” warming scenario. RCP8.5 is a worst-case scenario based on highly unlikely assumptions like end-of-century coal use exceeding estimates of recoverable coal reserves. Scientists have warned that presenting RCP8.5 as a likely outcome is misleading.” RCP8.5 is one of many scenarios climate modelers use, with RCP8.5 representing high emissions estimates, which one might expect if no climate mitigation policy were implemented. At the same time that the administration argues that assumptions about coal use are too high, it is also promoting expansion of the use of coal under Executive Order 14261, “Reinvigorating America’s Beautiful Clean Coal Industry,” and has ordered coal plants in Michigan and Pennsylvania to remain operational despite planned closures.[404]

Furthermore, Executive Order 14303 requires “science conducted in a manner that is (i) reproducible; (ii) transparent; (iii) communicative of error and uncertainty; (iv) collaborative and interdisciplinary; (v) skeptical of its findings and assumptions; (vi) structured for falsifiability of hypotheses; (vii) subject to unbiased peer review; (viii) accepting of negative results as positive outcomes; and (ix) without conflicts of interest.” While the NCAs have followed procedures to ensure no conflicts of interest, unbiased peer review, transparency, and communication of uncertainty even before this Executive Order was issued, the new DOE report that EPA relies on to justify its proposed repeal of the Endangerment Finding fails to comply with these requirements.

Existence of uncertainty is a consistent component of government decision-making and environmental regulation. As stated in the National Academies report on Environmental Decisions in the Face of Uncertainty, “All EPA decisions involve uncertainty, but the type of uncertainty can vary widely from one decision to another. … Concerns about uncertainties have in some cases (such as in the agency’s work involving dioxin contamination) delayed rulemaking. Furthermore, some uncertainty analyses have not provided useful or necessary information for the decision at hand. Because of that, [the National Research Council] and other organizations have cautioned against excessively complex uncertainty analysis.”[405] In this reconsideration, EPA describes uncertainties in the 2009 Endangerment Finding as a reason to reconsider the rule. However, **in the light of the increased evidence supporting the Endangerment Finding since 2009 and the associated reduced uncertainty, this reconsideration appears capricious.** Just because uncertainty remains does not mean there is insufficient evidence of health harms of GHG emissions and resulting climate change impacts.

Conclusion

The scientific evidence that human-caused climate change endangers the health of the American population is abundantly clear, and underscores the need for regulation of greenhouse gas emissions to prevent further harms. **As of 2025, the evidence in support of the Endangerment Finding is, in fact, dramatically stronger than it was in 2009.** In light of our Expert Working Group's review of the scientific literature, we conclude that EPA's reconsideration of the Endangerment Finding would be contrary to the evidence and withdrawing the finding would be a violation of EPA's statutory mandate.

In its reconsideration, EPA describes uncertainties in the 2009 Endangerment Finding as a reason to reconsider the rule. The enormous body of peer-reviewed evidence supporting the Endangerment Finding since 2009 constitutes more than sufficient evidence of health harms from climate change stemming from GHG emissions. Furthermore, the RIA conducted by EPA to justify the rule from a benefit-cost perspective contains numerous flaws that invalidate its use in decision-making, including poorly described and minimally justified methods and assumptions as well as the complete exclusion of any impact of greenhouse gas emissions. **As public health experts on the health effects of climate change, along with experts in GHG emission inventories, climate science, and regulatory impact analysis, we <u>strongly oppose</u> this proposed rule change based on its harms to the health of the American people.**

References

We understand that some of the studies we have used for this public comment may be difficult to access. Therefore, we are making available full PDF files of all of the studies listed below in our reference section, which can be accessed here. Ignoring these studies in EPA's final rule making would constitute an unreasonable failure to consider significant and relevant scientific research.

1. National Academies of Sciences, Engineering, and Medicine. *Effects of Human-Caused Greenhouse Gas Emissions on U.S. Climate, Health, and Welfare*. (The National Academies Press, Washington, D.C., 2025).
2. World Health Organization. *COP24 Special Report: Health and Climate Change*. (World Health Organization, Geneva, 2018).
3. IPCC. *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. 33–115 https://doi.org/10.59327/IPCC/AR6-9789291691647 (2023) doi:10.59327/ipcc/ar6-9789291691647.
4. Crimmins, A. R. *et al. Fifth National Climate Assessment*. https://doi.org/10.7930/NCA5.2023 (2023) doi:10.7930/nca5.2023.
5. U.S Global Change Research Program. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. (U.S Global Change Research Program, Washington, D.C., 2016).
6. EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2023 (Inventory)*. https://library.edf.org/AssetLink/lho850vn3sgns65501wj6dleypl0o477.pdf?_gl=1*1gelixp*_gcl_au*ODg1NTM0NjQ0LjE3NDQ3NDk2NzQ.*_ga*Mjk5NDk4MDA1LjE3NDQ3NDk2NzQ.*_ga_2B3856Y9QW*czE3NDY3OTkzNTAkbzQkZzAkdDE3NDY3OTkzODQkajI2JGwwJGgw (2024).
7. Friedlingstein, P. *et al.* Global Carbon Budget 2024. *Earth Syst. Sci. Data* **17**, 965–1039 (2025).
8. Global Carbon Budget. Fossil fuel CO2 emissions increase again in 2024. (2024).
9. United States Department of Transportation. *DOT Report to Congress: Decarbonizing U.S. Transportation*. https://rosap.ntl.bts.gov/view/dot/75677 (2024) doi:10.21949/1530685.
10. US EPA, O. HFC Allowance Allocation and Reporting. https://www.epa.gov/climate-hfcs-reduction/hfc-allowance-allocation-and-reporting (2022).
11. Duffy, P. B. *et al.* Strengthened scientific support for the Endangerment Finding for atmospheric greenhouse gases. *Science* **363**, eaat5982 (2019).
12. Gasparrini, A. *et al.* Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *The Lancet* **386**, 369–375 (2015).
13. Gould, C. F. *et al.* Temperature extremes impact mortality and morbidity differently. *Sci. Adv.* **11**, eadr3070 (2025).
14. Alahmad, B., Tobias, A., Masselot, P. & Gasparrini, A. Are there more cold deaths than heat deaths? *Lancet Planet. Health* **9**, e170–e171 (2025).
15. Howard, J. T., Androne, N., Alcover, K. C. & Santos-Lozada, A. R. Trends of Heat-Related Deaths in the US, 1999-2023. *JAMA* **332**, 1203–1204 (2024).
16. Ranson, M. Crime, weather, and climate change. *J. Environ. Econ. Manag.* **67**, 274–302 (2014).
17. Benjamin Leard & Kevin Roth. Weather, Traffic Accidents, and Climate Change. (2015).
18. Burke, M. *et al.* Higher temperatures increase suicide rates in the United States and Mexico. *Nat. Clim. Change* **8**, 723–729 (2018).
19. Marshall Burke *et al.* Are We Adapting to Climate Change? *Work. Pap.* (2024).
20. Medina-Ramón, M. & Schwartz, J. Temperature, temperature extremes, and mortality: a study of acclimatisation and effect modification in 50 US cities. *Occup. Environ. Med.* **64**, 827–833 (2007).

21. Carleton, T. *et al.* Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits. *Q. J. Econ.* **137**, 2037–2105 (2022).
22. Heutel, G., Miller, N. H. & Molitor, D. Adaptation and the Mortality Effects of Temperature Across U.S. Climate Regions. *Rev. Econ. Stat.* 1–14 (2021) doi:10.1162/rest_a_00936.
23. Gasparrini, A. *et al.* Projections of temperature-related excess mortality under climate change scenarios. *Lancet Planet. Health* **1**, e360–e367 (2017).
24. Gronlund, C. J., Zanobetti, A., Schwartz, J. D., Wellenius, G. A. & O'Neill, M. S. Heat, Heat Waves, and Hospital Admissions among the Elderly in the United States, 1992–2006. *Environ. Health Perspect.* **122**, 1187–1192 (2014).
25. Osborne, T. F., Veigulis, Z. P., Vaidyanathan, A., Arreola, D. M. & Schramm, P. J. Trends in heat related illness: Nationwide observational cohort at the US department of veteran affairs. *J. Clim. Change Health* **12**, 100256 (2023).
26. Weinberger, K. R. *et al.* Projected Changes in Temperature-related Morbidity and Mortality in Southern New England. *Epidemiology* **29**, 473–481 (2018).
27. Sun, S. *et al.* Ambient heat and risks of emergency department visits among adults in the United States: time stratified case crossover study. *BMJ* **375**, e065653 (2021).
28. Chu, L. *et al.* Joint Exposure to Ozone and Temperature and Acute Myocardial Infarction Among Adults Aged 18 to 64 Years in the United States. *Circulation* **152**, 246–256 (2025).
29. Chu, L., Wang, R., Gross, C. P., Chen, K. & Ma, X. Ambient Temperature and Stroke Risk Among Adults Aged 18-64 Years. *J. Am. Coll. Cardiol.* **84**, 2327–2331 (2024).
30. Nori-Sarma, A. *et al.* Association Between Ambient Heat and Risk of Emergency Department Visits for Mental Health Among US Adults, 2010 to 2019. *JAMA Psychiatry* **79**, 341–349 (2022).
31. Ebi, K. L. *et al.* Extreme Weather and Climate Change: Population Health and Health System Implications. *Annu. Rev. Public Health* **42**, 293–315 (2021).
32. Salas, R. N. *et al.* Impact of extreme weather events on healthcare utilization and mortality in the United States. *Nat. Med.* **30**, 1118–1126 (2024).
33. Health Care Without Harm. *Safe Haven in the Storm: Protecting Lives and Margins with Climate-Smart Health Care*.
34. US Ways and Means Committee. *Health Care and the Climate Crisis: Preparing America's Health Care Infrastructure: Extreme Weather Events & Health Care Delivery*. https://democrats-waysandmeans.house.gov/health-care-and-climate-crisis-preparing-americas-health-care-infrastructure (2022).
35. Hicke, J. *et al.* Chapter 14: North America. in *Climate Change 2022: Impacts, Adaptation and Vulnerability* 1929–2042 (Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022). doi:10.1017/9781009325844.016.
36. Chu, L. *et al.* Floods and cause-specific mortality in the United States applying a triply robust approach. *Nat. Commun.* **16**, 2853 (2025).
37. Yang, Z. *et al.* Mortality and morbidity risks associated with floods: A systematic review and meta-analysis. *Environ. Res.* **263**, 120263 (2024).
38. Saulnier, D. D., Ribacke, K. B. & Schreeb, J. von. No Calm After the Storm: A Systematic Review of Human Health Following Flood and Storm Disasters. *Prehospital Disaster Med.* **32**, 568–579 (2017).
39. Quist, A. J. L. *et al.* Hurricane flooding and acute gastrointestinal illness in North Carolina. *Sci. Total Environ.* **809**, 151108 (2022).
40. Kossin, J. P. A global slowdown of tropical-cyclone translation speed. *Nature* **558**, 104–107 (2018).
41. Intergovernmental Panel On Climate Change (IPCC). Chapter 11: Weather and Climate Extreme Events in a Changing Climate. in *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2023). doi:10.1017/9781009157896.

42. World Weather Attribution. Climate change key driver of catastrophic impacts of Hurricane Helene that devastated both coastal and inland communities. https://www.worldweatherattribution.org/climate-change-key-driver-of-catastrophic-impacts-of-hurricane-helene-that-devastated-both-coastal-and-inland-communities/ (2024).
43. Nielsen-Gammon, J. W. *et al.* Unprecedented Drought Challenges for Texas Water Resources in a Changing Climate: What Do Researchers and Stakeholders Need to Know? *Earths Future* **8**, e2020EF001552 (2020).
44. Tripathy, K. P., Mukherjee, S., Mishra, A. K., Mann, M. E. & Williams, A. P. Climate change will accelerate the high-end risk of compound drought and heatwave events. *Proc. Natl. Acad. Sci.* **120**, e2219825120 (2023).
45. Overpeck, J. T. & Udall, B. Climate change and the aridification of North America. *Proc. Natl. Acad. Sci.* **117**, 11856–11858 (2020).
46. Martin, J. T. *et al.* Increased drought severity tracks warming in the United States' largest river basin. *Proc. Natl. Acad. Sci.* **117**, 11328–11336 (2020).
47. Salvador, C. *et al.* Public Health Implications of Drought in a Climate Change Context: A Critical Review. *Annu. Rev. Public Health* **44**, 213–232 (2023).
48. Gwon, Y. *et al.* The Association between Drought Exposure and Respiratory-Related Mortality in the United States from 2000 to 2018. *Int. J. Environ. Res. Public. Health* **20**, 6076 (2023).
49. Gwon, Y. *et al.* Impacts of drought on respiratory mortality in the upper midwest United States: a population subgroup assessment. *Environ. Res. Health* **3**, 025002 (2025).
50. Gwon, Y. *et al.* The effect of heterogeneous severe drought on all-cause and cardiovascular mortality in the Northern Rockies and Plains of the United States. *Sci. Total Environ.* **912**, 169033 (2024).
51. Burke, M. *et al.* The changing risk and burden of wildfire in the United States. *Proc. Natl. Acad. Sci.* **118**, e2011048118 (2021).
52. Abatzoglou, J. T. & Williams, A. P. Impact of anthropogenic climate change on wildfire across western US forests. *Proc. Natl. Acad. Sci.* **113**, 11770–11775 (2016).
53. National Fire Protection Association. Wildland Fires Statistics. https://www.nfpa.org/education-and-research/research/nfpa-research/fire-statistical-reports/wildland-fire-statistics.
54. Anderegg, W. R. L. *et al.* Future climate risks from stress, insects and fire across US forests. *Ecol. Lett.* **25**, 1510–1520 (2022).
55. Stavros, E. N., Abatzoglou, J. T., McKenzie, D. & Larkin, N. K. Regional projections of the likelihood of very large wildland fires under a changing climate in the contiguous Western United States. *Clim. Change* **126**, 455–468 (2014).
56. Barbero, R., Abatzoglou, J. T., Larkin, N. K., Kolden, C. A. & Stocks, B. Climate change presents increased potential for very large fires in the contiguous United States. *Int. J. Wildland Fire* **24**, 892 (2015).
57. Reidmiller, D. R. *et al.* Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. https://repository.library.noaa.gov (2017) doi:10.7930/NCA4.2018.
58. Dessler, A. & Kopp, R. E. Climate Experts' Review of the DOE Climate Working Group Report. Preprint at https://doi.org/10.22541/essoar.175745244.41950365/v1 (2025).
59. Gorris, M. E., Treseder, K. K., Zender, C. S. & Randerson, J. T. Expansion of Coccidioidomycosis Endemic Regions in the United States in Response to Climate Change. *GeoHealth* **3**, 308–327 (2019).
60. Howard, M. H., Sayes, C. M., Giesy, J. P. & Li, Y. Valley fever under a changing climate in the United States. *Environ. Int.* **193**, 109066 (2024).

61. Head, J. R. *et al.* Effects of precipitation, heat, and drought on incidence and expansion of coccidioidomycosis in western USA: a longitudinal surveillance study. *Lancet Planet. Health* **6**, e793–e803 (2022).
62. CDC. Reported Cases of Valley Fever. *Valley Fever (Coccidioidomycosis)* https://www.cdc.gov/valley-fever/php/statistics/index.html (2025).
63. Froelich, B. A. & Daines, D. A. In hot water: effects of climate change on Vibrio–human interactions. *Environ. Microbiol.* **22**, 4101–4111 (2020).
64. Miller, A. G. *et al.* Projections of climate change-attributable diarrhea burden: a systematic review. *Environ. Res. Lett.* **20**, 053008 (2025).
65. Olds, H. T. *et al.* High levels of sewage contamination released from urban areas after storm events: A quantitative survey with sewage specific bacterial indicators. *PLOS Med.* **15**, e1002614 (2018).
66. Patz, J. A., Vavrus, S. J., Uejio, C. K. & McLellan, S. L. Climate Change and Waterborne Disease Risk in the Great Lakes Region of the U.S. *Am. J. Prev. Med.* **35**, 451–458 (2008).
67. Lee, D., Chang, H. H., Sarnat, S. E. & Levy, K. Precipitation and Salmonellosis Incidence in Georgia, USA: Interactions between Extreme Rainfall Events and Antecedent Rainfall Conditions. *Environ. Health Perspect.* **127**, 097005 (2019).
68. Vereen, E. *et al.* Landscape and seasonal factors influence *Salmonella* and *Campylobacter* prevalence in a rural mixed use watershed. *Water Res.* **47**, 6075–6085 (2013).
69. Soneja, S. *et al.* Extreme precipitation events and increased risk of campylobacteriosis in Maryland, U.S.A. *Environ. Res.* **149**, 216–221 (2016).
70. Pieper, K. J. *et al.* Microbial Contamination of Drinking Water Supplied by Private Wells after Hurricane Harvey. *Environ. Sci. Technol.* **55**, 8382–8392 (2021).
71. Taranu, Z. E. *et al.* Acceleration of cyanobacterial dominance in north temperate-subarctic lakes during the Anthropocene. *Ecol. Lett.* **18**, 375–384 (2015).
72. Otten, T. G. & Paerl, H. W. Health Effects of Toxic Cyanobacteria in U.S. Drinking and Recreational Waters: Our Current Understanding and Proposed Direction. *Curr. Environ. Health Rep.* **2**, 75–84 (2015).
73. Couper, L. I., MacDonald, A. J. & Mordecai, E. A. Impact of prior and projected climate change on US Lyme disease incidence. *Glob. Change Biol.* **27**, 738–754 (2021).
74. Ogden, N. H. *et al.* Risk maps for range expansion of the Lyme disease vector, Ixodes scapularis, in Canada now and with climate change. *Int. J. Health Geogr.* **7**, 24 (2008).
75. Eisen, R. J. & Eisen, L. Evaluation of the association between climate warming and the spread and proliferation of *Ixodes scapularis* in northern states in the Eastern United States. *Ticks Tick-Borne Dis.* **15**, 102286 (2024).
76. Blackburn, D. *et al.* Outbreak of Locally Acquired Mosquito-Transmitted (Autochthonous) Malaria — Florida and Texas, May–July 2023. *MMWR Morb. Mortal. Wkly. Rep.* **72**, 973–978 (2023).
77. CDC. *Current Dengue Outbreak*. https://www.cdc.gov/dengue/outbreaks/2024/index.html (2025).
78. Childs, M. L., Lyberger, K., Harris, M. J., Burke, M. & Mordecai, E. A. Climate warming is expanding dengue burden in the Americas and Asia. *Proc. Natl. Acad. Sci.* **122**, e2512350122 (2025).
79. Sapkota, A. *et al.* Associations between alteration in plant phenology and hay fever prevalence among US adults: Implication for changing climate. *PLOS ONE* **14**, e0212010 (2019).
80. Erbas, B. *et al.* Outdoor pollen is a trigger of child and adolescent asthma emergency department presentations: A systematic review and meta-analysis. *Allergy* **73**, 1632–1641 (2018).
81. Larson, P. S., Steiner, A. L., O'Neill, M. S., Baptist, A. P. & Gronlund, C. J. Chronic and infectious respiratory mortality and short-term exposures to four types of pollen taxa in older adults in Michigan, 2006-2017. *BMC Public Health* **25**, 173 (2025).
82. WHO. Air Quality, Energy and Health Science and Policy Summaries. in *Second Global Conference on Air Pollution and Health* 1–140 (Cartagena, Colombia, 2025).

83. Anderegg, W. R. L. *et al.* Anthropogenic climate change is worsening North American pollen seasons. *Proc. Natl. Acad. Sci.* **118**, e2013284118 (2021).
84. Epstein, T. E. G. *et al.* Impact of climate change on aerobiology, rhinitis, and allergen immunotherapy: Work Group Report from the Aerobiology, Rhinitis, Rhinosinusitis & Ocular Allergy, and Immunotherapy, Allergen Standardization & Allergy Diagnostics Committees of the American Academy of Allergy, Asthma & Immunology. *J. Allergy Clin. Immunol.* **155**, 1767-1782.e2 (2025).
85. Agache, I. *et al.* EAACI guidelines on environmental science for allergy and asthma: The impact of short-term exposure to outdoor air pollutants on asthma-related outcomes and recommendations for mitigation measures. *Allergy* **79**, 1656–1686 (2024).
86. Paudel, B. *et al.* Increased duration of pollen and mold exposure are linked to climate change. *Sci. Rep.* **11**, 12816 (2021).
87. Lee, A. S. *et al.* Climate change and public health. *EMBO Rep.* **24**, e56821 (2023).
88. Zhang, Y. & Steiner, A. L. Projected climate-driven changes in pollen emission season length and magnitude over the continental United States. *Nat. Commun.* **13**, 1234 (2022).
89. Ziska, L. *et al.* Recent warming by latitude associated with increased length of ragweed pollen season in central North America. *Proc. Natl. Acad. Sci.* **108**, 4248–4251 (2011).
90. D'Amato, G. *et al.* The effects of climate change on respiratory allergy and asthma induced by pollen and mold allergens. *Allergy* **75**, 2219–2228 (2020).
91. Sampath, V., Aguilera, J., Prunicki, M. & Nadeau, K. C. Mechanisms of climate change and related air pollution on the immune system leading to allergic disease and asthma. *Semin. Immunol.* **67**, 101765 (2023).
92. Chew, G. L. *et al.* Mold and Endotoxin Levels in the Aftermath of Hurricane Katrina: A Pilot Project of Homes in New Orleans Undergoing Renovation. *Environ. Health Perspect.* **114**, 1883–1889 (2006).
93. Rao, C. Y. *et al.* Characterization of Airborne Molds, Endotoxins, and Glucans in Homes in New Orleans after Hurricanes Katrina and Rita. *Appl. Environ. Microbiol.* **73**, 1630–1634 (2007).
94. Wright, R. J. & Demain, J. G. Growing Impact of Climate Change on Respiratory Health and Related Allergic Disorders: Need for Health Systems to Prepare. *Immunol. Allergy Clin. North Am.* **44**, xi–xv (2024).
95. Edwards, D. A. *et al.* Global warming risks dehydrating and inflaming human airways. *Commun. Earth Environ.* **6**, 193 (2025).
96. Burbank, A. J. Climate Change and the Future of Allergies and Asthma. *Curr. Allergy Asthma Rep.* **25**, 20 (2025).
97. Mickley, L. J., Jacob, D. J., Field, B. D. & Rind, D. Effects of future climate change on regional air pollution episodes in the United States. *Geophys. Res. Lett.* **31**, (2004).
98. Wilkins, J. L., Pouliot, G., Foley, K., Appel, W. & Pierce, T. The impact of US wildland fires on ozone and particulate matter: a comparison of measurements and CMAQ model predictions from 2008 to 2012. *Int. J. Wildland Fire* **27**, (2018).
99. Domingo, N. G. G. *et al.* Ozone-related acute excess mortality projected to increase in the absence of climate and air quality controls consistent with the Paris Agreement. *One Earth* **7**, 325–335 (2024).
100. Fann, N. L., Nolte, C. G., Sarofim, M. C., Martinich, J. & Nassikas, N. J. Associations Between Simulated Future Changes in Climate, Air Quality, and Human Health. *JAMA Netw. Open* **4**, e2032064 (2021).
101. Nolte, C. G. *et al.* Regional temperature-ozone relationships across the U.S. under multiple climate and emissions scenarios. *J. Air Waste Manag. Assoc.* **71**, 1251–1264 (2021).
102. East, J. D., Monier, E., Saari, R. K. & Garcia-Menendez, F. Projecting Changes in the Frequency and Magnitude of Ozone Pollution Events Under Uncertain Climate Sensitivity. *Earths Future* **12**, e2023EF003941 (2024).

103. Stowell, J. D. *et al.* Warm season ambient ozone and children's health in the USA. *Int. J. Epidemiol.* **53**, dyae035 (2024).
104. Burke, M. *et al.* The contribution of wildfire to PM2.5 trends in the USA. *Nature* **622**, 761–766 (2023).
105. Fiore, A. M. *et al.* Characterizing Changes in Eastern U.S. Pollution Events in a Warming World. *J. Geophys. Res. Atmospheres* **127**, e2021JD035985 (2022).
106. Kalashnikov, D. A., Schnell, J. L., Abatzoglou, J. T., Swain, D. L. & Singh, D. Increasing co-occurrence of fine particulate matter and ground-level ozone extremes in the western United States. *Sci. Adv.* **8**, eabi9386 (2022).
107. Nassikas, N. J. *et al.* Modeling future asthma attributable to fine particulate matter (PM2.5) in a changing climate: a health impact assessment. *Air Qual. Atmosphere Health* **15**, 311–319 (2022).
108. Achakulwisut, P., Mickley, L. J. & Anenberg, S. C. Drought-sensitivity of fine dust in the US Southwest: Implications for air quality and public health under future climate change. *Environ. Res. Lett.* **13**, 054025 (2018).
109. Baxter, B. K. & Butler, J. K. Climate Change and Great Salt Lake. in *Great Salt Lake Biology: A Terminal Lake in a Time of Change* (eds Baxter, B. K. & Butler, J. K.) 23–52 (Springer International Publishing, Cham, 2020). doi:10.1007/978-3-030-40352-2_2.
110. Grineski, S. E. *et al.* Harmful dust from drying lakes: Preserving Great Salt Lake (USA) water levels decreases ambient dust and racial disparities in population exposure. *One Earth* **7**, 1056–1067 (2024).
111. Cowley, J. M. *et al.* Pro-inflammatory effects of inhaled Great Salt Lake dust particles. *Part. Fibre Toxicol.* **22**, 2 (2025).
112. Fann, N. *et al.* The health impacts and economic value of wildland fire episodes in the U.S.: 2008–2012. *Sci. Total Environ.* **610–611**, 802–809 (2018).
113. Zhang, Q. *et al.* Long-range PM2.5 pollution and health impacts from the 2023 Canadian wildfires. *Nature* 1–7 (2025) doi:10.1038/s41586-025-09482-1.
114. Law, B. E. *et al.* Anthropogenic climate change contributes to wildfire particulate matter and related mortality in the United States. *Commun. Earth Environ.* **6**, 336 (2025).
115. Ma, Y. *et al.* Long-term exposure to wildland fire smoke PM2.5 and mortality in the contiguous United States. *Proc. Natl. Acad. Sci.* **121**, e2403960121 (2024).
116. Schwarz, L. *et al.* Effects of fine particulate matter from wildfire and non-wildfire sources on emergency-department visits in people who were housed and unhoused in San Diego County (CA, USA) during 2012–20: a time-stratified case–crossover study. *Lancet Planet. Health* **8**, e906–e914 (2024).
117. DeFlorio-Barker, S., Crooks, J., Reyes, J. & Rappold, A. G. Cardiopulmonary Effects of Fine Particulate Matter Exposure among Older Adults, during Wildfire and Non-Wildfire Periods, in the United States 2008-2010. *Environ. Health Perspect.* **127**, 37006 (2019).
118. Wettstein, Z. S. *et al.* Cardiovascular and Cerebrovascular Emergency Department Visits Associated With Wildfire Smoke Exposure in California in 2015. *J. Am. Heart Assoc.* **7**, e007492 (2018).
119. Stowell, J. D. *et al.* Associations of wildfire smoke PM2.5 exposure with cardiorespiratory events in Colorado 2011–2014. *Environ. Int.* **133**, 105151 (2019).
120. Burki, T. Wildfires in southern California: concerns for lung health. *Lancet Respir. Med.* **13**, 202 (2025).
121. Casey, J. A. *et al.* The 2025 Los Angeles Wildfires and Outpatient Acute Healthcare Utilization. *medRxiv* 2025.03.13.25323617 (2025) doi:10.1101/2025.03.13.25323617.
122. Benmarhnia, T., Errett, N. A. & Casey, J. A. Beneath the smoke: Understanding the public health impacts of the Los Angeles urban wildfires. *Environ. Epidemiol.* **9**, e388 (2025).

123. Schollaert, C. *et al.* Air Quality Impacts of the January 2025 Los Angeles Wildfires: Insights from Public Data Sources. *Environ. Sci. Technol. Lett.* **12**, 911–917 (2025).
124. Pye, H. O. T. *et al.* Evolution of Reactive Organic Compounds and Their Potential Health Risk in Wildfire Smoke. *Environ. Sci. Technol.* **58**, 19785–19796 (2024).
125. Liu, J. C. *et al.* Wildfire-specific Fine Particulate Matter and Risk of Hospital Admissions in Urban and Rural Counties. *Epidemiology* **28**, 77–85 (2017).
126. Zhang, D., Xi, Y., Boffa, D. J., Liu, Y. & Nogueira, L. M. Association of Wildfire Exposure While Recovering From Lung Cancer Surgery With Overall Survival. *JAMA Oncol.* **9**, 1214–1220 (2023).
127. Aguilera, R., Corringham, T., Gershunov, A. & Benmarhnia, T. Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California. *Nat. Commun.* **12**, 1493 (2021).
128. Hao, H. *et al.* Long-Term Wildfire Smoke Exposure and Increased Risk of Heart Failure in Older Adults. *J. Am. Coll. Cardiol.* **85**, 2439–2451 (2025).
129. Qiu, M. *et al.* Wildfire smoke exposure and mortality burden in the US under climate change. *Nature* 1–3 (2025) doi:10.1038/s41586-025-09611-w.
130. Jones-Ngo, C. G. *et al.* Joint Effects of Wildfire Smoke and Extreme Heat on Hospitalizations in California, 2011–2020. *GeoHealth* **9**, e2024GH001237 (2025).
131. Rau, A. *et al.* Compound drought and heatwave extreme weather events: Mortality risk in individuals with chronic respiratory disease. *Environ. Epidemiol.* **9**, e389 (2025).
132. Anenberg, S. C., Haines, S., Wang, E., Nassikas, N. & Kinney, P. L. Synergistic health effects of air pollution, temperature, and pollen exposure: a systematic review of epidemiological evidence. *Environ. Health* **19**, 130 (2020).
133. Remigio, R. V. *et al.* Combined effects of air pollution and extreme heat events among ESKD patients within the Northeastern United States. *Sci. Total Environ.* **812**, 152481 (2022).
134. Fann, N. *et al.* The Role of Temperature in Modifying the Risk of Ozone-Attributable Mortality under Future Changes in Climate: A Proof-of-Concept Analysis. *Environ. Sci. Technol.* **56**, 1202–1210 (2022).
135. Dominianni, C., Lane, K., Johnson, S., Ito, K. & Matte, T. Health Impacts of Citywide and Localized Power Outages in New York City. *Environ. Health Perspect.* **126**, 067003 (2018).
136. Casey, J. A., Fukurai, M., Hernández, D., Balsari, S. & Kiang, M. V. Power Outages and Community Health: a Narrative Review. *Curr. Environ. Health Rep.* **7**, 371–383 (2020).
137. Richards, C. A. *et al.* Association of social vulnerability factors with power outage burden in Washington state: 2018–2021. *PLOS ONE* **19**, e0307742 (2024).
138. Xiao, J. *et al.* Increased risk of multiple pregnancy complications following large-scale power outages during Hurricane Sandy in New York State. *Sci. Total Environ.* **770**, 145359 (2021).
139. Zhang, W. *et al.* Power Outage: An Ignored Risk Factor for COPD Exacerbations. *Chest* **158**, 2346–2357 (2020).
140. Lin, S., Lu, Y., Justino, J., Dong, G. & Lauper, U. What Happened to Our Environment and Mental Health as a Result of Hurricane Sandy? *Disaster Med. Public Health Prep.* **10**, 314–319 (2016).
141. Stone, B. *et al.* Compound Climate and Infrastructure Events: How Electrical Grid Failure Alters Heat Wave Risk. *Environ. Sci. Technol.* **55**, 6957–6964 (2021).
142. Stone, B. *et al.* How Blackouts during Heat Waves Amplify Mortality and Morbidity Risk. *Environ. Sci. Technol.* **57**, 8245–8255 (2023).
143. Abel, D. W. *et al.* Air-quality-related health impacts from climate change and from adaptation of cooling demand for buildings in the eastern United States: An interdisciplinary modeling study. *PLOS Med.* **15**, e1002599 (2018).
144. Wu, Y. *et al.* Climate Change, Floods, and Human Health. *N. Engl. J. Med.* **391**, 1949–1958 (2024).

145. Baum, A., Barnett, M. L., Wisnivesky, J. & Schwartz, M. D. Association Between a Temporary Reduction in Access to Health Care and Long-term Changes in Hypertension Control Among Veterans After a Natural Disaster. *JAMA Netw. Open* **2**, e1915111 (2019).
146. Union of Concerned Scientists. Sea Level Rise and Tidal Flooding in Savannah and Tybee Island, Georgia. https://www.ucs.org/resources/sea-level-rise-and-tidal-flooding-savannah-and-tybee-island-georgia (2016).
147. Murphy, T. Helene damaged a factory that makes IV fluids. *AP News* (2024).
148. Philip, S. *et al.* A protocol for probabilistic extreme event attribution analyses. *Adv. Stat. Climatol. Meteorol. Oceanogr.* **6**, 177–203 (2020).
149. van Oldenborgh, G. J. *et al.* Pathways and pitfalls in extreme event attribution. *Clim. Change* **166**, 13 (2021).
150. Ebi, K. L. *et al.* Using Detection And Attribution To Quantify How Climate Change Is Affecting Health: Study explores detection and attribution to examine how climate change is affecting health. *Health Aff. (Millwood)* **39**, 2168–2174 (2020).
151. Vicedo-Cabrera, A. M. *et al.* The burden of heat-related mortality attributable to recent human-induced climate change. *Nat. Clim. Change* **11**, 492–500 (2021).
152. Philip, S. Y. *et al.* Rapid attribution analysis of the extraordinary heat wave on the Pacific coast of the US and Canada in June 2021. *Earth Syst. Dyn.* **13**, 1689–1713 (2022).
153. Di Liberto, T. Astounding heat obliterates all-time records across the Pacific Northwest and Western Canada in June 2021. *NOAA* https://www.climate.gov/news-features/event-tracker/astounding-heat-obliterates-all-time-records-across-pacific-northwest (2021).
154. Kearl, Z. & Vogel, J. Urban extreme heat, climate change, and saving lives: Lessons from Washington state. *Urban Clim.* **47**, 101392 (2023).
155. World Weather Attribution. Western North American extreme heat virtually impossible without human-caused climate change. https://www.worldweatherattribution.org/western-north-american-extreme-heat-virtually-impossible-without-human-caused-climate-change/.
156. World Weather Attribution. Effective emergency management prevented larger catastrophe after climate change fueled heavy rains in Central Mississippi river valley. https://www.worldweatherattribution.org/effective-emergency-management-prevented-larger-catastrophe-after-climate-change-fueled-heavy-rains-in-central-mississippi-river-valley/ (2025).
157. Kirchmeier-Young, M. C., Zwiers, F. W., Gillett, N. P. & Cannon, A. J. Attributing extreme fire risk in Western Canada to human emissions. *Clim. Change* **144**, 365–379 (2017).
158. Kirchmeier-Young, M. C., Gillett, N. P., Zwiers, F. W., Cannon, A. J. & Anslow, F. S. Attribution of the Influence of Human-Induced Climate Change on an Extreme Fire Season. *Earths Future* **7**, 2–10 (2019).
159. Barbero, R., Abatzoglou, J. T., Pimont, F., Ruffault, J. & Curt, T. Attributing Increases in Fire Weather to Anthropogenic Climate Change Over France. *Front. Earth Sci.* **8**, (2020).
160. Turco, M. *et al.* Anthropogenic climate change impacts exacerbate summer forest fires in California. *Proc. Natl. Acad. Sci.* **120**, e2213815120 (2023).
161. World Weather Attribution. Climate change more than doubled the likelihood of extreme fire weather conditions in Eastern Canada. https://www.worldweatherattribution.org/climate-change-more-than-doubled-the-likelihood-of-extreme-fire-weather-conditions-in-eastern-canada/ (2023).
162. Barbani, S. M. The indirect consequences of climate change and extreme environmental events on mental health: a literature review. *J. Public Health* (2025) doi:10.1007/s10389-025-02513-1.

163. Nori-Sarma, A. *et al.* Association Between Ambient Heat and Risk of Emergency Department Visits for Mental Health Among US Adults, 2010 to 2019. *JAMA Psychiatry* **79**, 341–349 (2022).
164. Thompson, R. *et al.* Ambient temperature and mental health: a systematic review and meta-analysis. *Lancet Planet. Health* **7**, e580–e589 (2023).
165. Zhu, Q. *et al.* Wildfires are associated with increased emergency department visits for anxiety disorders in the western United States. *Nat. Ment. Health* **2**, 379–387 (2024).
166. Clayton, S. & Brown, L. A. Climate change and mental health. *JAMA* **331**, 1761–1762 (2024).
167. Van Susteren, L. & Al-Delaimy, W. K. Psychological Impacts of Climate Change and Recommendations. in *Health of People, Health of Planet and Our Responsibility: Climate Change, Air Pollution and Health* (eds Al-Delaimy, W. K., Ramanathan, V. & Sánchez Sorondo, M.) 177–192 (Springer International Publishing, Cham, 2020). doi:10.1007/978-3-030-31125-4_14.
168. Cosh, S. M. *et al.* The relationship between climate change and mental health: a systematic review of the association between eco-anxiety, psychological distress, and symptoms of major affective disorders. *BMC Psychiatry* **24**, 833 (2024).
169. Kühner, C., Gemmecke, C., Hüffmeier, J. & Zacher, H. Climate change anxiety: A meta-analysis. *Glob. Environ. Change* **93**, 103015 (2025).
170. US Climate Emotions Map. https://www.us-climate-emotions-map.org/.
171. Hickman, C. *et al.* Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. *Lancet Planet. Health* **5**, e863–e873 (2021).
172. Lewandowski, R. E. *et al.* Climate emotions, thoughts, and plans among US adolescents and young adults: a cross-sectional descriptive survey and analysis by political party identification and self-reported exposure to severe weather events. *Lancet Planet. Health* **8**, e879–e893 (2024).
173. Nichelle Smith & Anoop Sattineni. Effect of Erosion in Alaskan Coastal Villages. in *52nd ASC Annual International Conference Proceedings* (Associated Schools of Construction, 2016).
174. United States Government Accountability Office. *ALASKA NATIVE VILLAGES: Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion*. https://www.gao.gov/products/gao-09-551 (2009).
175. Marlow, J. J. & Sancken, L. E. Reimagining Relocation in a Regulatory Void: The Inadequacy of Existing us Federal and State Regulatory Responses to Kivalina's Climate Displacement in the Alaskan Arctic. *Clim. Law* **7**, 290–321 (2017).
176. Ashley Rawlings. Erosion-Induced Community Displacement in Newtok, Alaska and the Need to Modify FEMA and NEPA to Establish a Relocation Framework for a Warming World. *Seattle J. Environ. Law* **5**, (2015).
177. Newell, S. L., Dion, M. L. & Doubleday, N. C. Cultural continuity and Inuit health in Arctic Canada. *J. Epidemiol. Community Health* **74**, 64–70 (2020).
178. Robin Bronen. *Climate-Induced Displacement of Alaska Native Communities*. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/united-states/west-coast-amp-hawaix27i/alaska/Bronen.--2013.--CC-Displacement-of-Native-Communities.pdf (2013).
179. Crepelle, A. The United States first climate relocation: recognition, relocation, and indigenous rights at the Isle de Jean Charles. *Belmont Rev.* **6**, (2018).
180. Dannenberg, A. L., Frumkin, H., Hess, J. J. & Ebi, K. L. Managed retreat as a strategy for climate change adaptation in small communities: public health implications. *Clim. Change* **153**, 1–14 (2019).
181. Aung, T. W. & Sehgal, A. R. Prevalence, Correlates, and Impacts of Displacement Because of Natural Disasters in the United States From 2022 to 2023. *Am. J. Public Health* **115**, 55–65 (2025).
182. Kintziger, K. W. & Scales, S. E. Escaping Disaster: Understanding the Drivers and Disparities in Disaster Displacement in the United States. *Am. J. Public Health* **115**, 52–54 (2025).
183. Burke, M., Hsiang, S. M. & Miguel, E. Climate and Conflict. *Annu. Rev. Econ.* **7**, 577–617 (2015).

184. Levy, B. S., Sidel, V. W. & Patz, J. A. Climate Change and Collective Violence. *Annu. Rev. Public Health* **38**, 241–257 (2017).
185. Heo, S., Choi, H. M., D. Berman, J. & Bell, M. L. Temperature, violent crime, climate change, and vulnerability factors in 44 United States cities. *Environ. Int.* **195**, 109246 (2025).
186. Choi, H. M. *et al.* Temperature, Crime, and Violence: A Systematic Review and Meta-Analysis. *Environ. Health Perspect.* **132**, 106001 (2024).
187. Heo, S., Lee, W. & Bell, M. L. Suicide and Associations with Air Pollution and Ambient Temperature: A Systematic Review and Meta-Analysis. *Int. J. Environ. Res. Public. Health* **18**, 7699 (2021).
188. Belova, A. *et al.* Projecting the Suicide Burden of Climate Change in the United States. *GeoHealth* **6**, e2021GH000580 (2022).
189. Ioannou, L. *et al.* Occupational heat strain in outdoor workers: A comprehensive review and meta-analysis. *Temperature* **9**, 67–102 (2022).
190. Flouris, A. D. *et al.* Workers' health and productivity under occupational heat strain: a systematic review and meta-analysis. *Lancet Planet. Health* **2**, e521–e531 (2018).
191. Bonita, I., Halabicky, O. M. & Liu, J. Exposure to Wildfires Exposures and Mental Health Problems among Firefighters: A Systematic Review. *Atmosphere* **15**, 78 (2024).
192. Navarro, K. M. *et al.* Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality. *Environ. Res.* **173**, 462–468 (2019).
193. Hwang, J. *et al.* Face-to-face with scorching wildfire: potential toxicant exposure and the health risks of smoke for wildland firefighters at the wildland-urban interface. *Lancet Reg. Health - Am.* **21**, 100482 (2023).
194. Levy, B. S. & Roelofs, C. Impacts of Climate Change on Workers' Health and Safety. in *Oxford Research Encyclopedia of Global Public Health* (Oxford University Press, 2019). doi:10.1093/acrefore/9780190632366.013.39.
195. Berman, J. D. *et al.* The association between drought conditions and increased occupational psychosocial stress among U.S. farmers: An occupational cohort study. *Sci. Total Environ.* **798**, 149245 (2021).
196. Tigchelaar, M., Battisti, D. S. & Spector, J. T. Work adaptations insufficient to address growing heat risk for U.S. agricultural workers. *Environ. Res. Lett.* **15**, 094035 (2020).
197. Gubernot, D. M., Anderson, G. B. & Hunting, K. L. Characterizing Occupational Heat-Related Mortality in the United States, 2000–2010: An Analysis Using the Census of Fatal Occupational Injuries Database. *Am. J. Ind. Med.* **58**, 203–211 (2015).
198. Bethel, J. W., Spector, J. T. & Krenz, J. Hydration and Cooling Practices Among Farmworkers in Oregon and Washington. *J. Agromedicine* **22**, 222–228 (2017).
199. Marquez, D. *et al.* The Effect of Participatory Heat Education on Agricultural Worker Knowledge. *J. Agromedicine* **28**, 187–198 (2023).
200. Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings. *Federal Register* https://www.federalregister.gov/documents/2024/08/30/2024-14824/heat-injury-and-illness-prevention-in-outdoor-and-indoor-work-settings (2024).
201. Occupational Safety and Health Administration. Heat - Standards. https://www.osha.gov/heat-exposure/standards.
202. EPA. *Climate Change and Children's Health and Well-Being in the United States Report*. https://www.epa.gov/cira/climate-change-and-childrens-health-and-well-being-united-states-report (2023).
203. Uibel, D., Sharma, R., Piontkowski, D., Sheffield, P. E. & Clougherty, J. E. Association of ambient extreme heat with pediatric morbidity: a scoping review. *Int. J. Biometeorol.* **66**, 1683–1698 (2022).
204. Weeda, L. J. Z., Bradshaw, C. J. A., Judge, M. A., Saraswati, C. M. & Le Souëf, P. N. How climate change degrades child health: A systematic review and meta-analysis. *Sci. Total Environ.* **920**, 170944 (2024).

205. Ahdoot, S. *et al.* Climate Change and Children's Health: Building a Healthy Future for Every Child. *Pediatrics* **153**, e2023065504 (2024).
206. Xu, Z. *et al.* Impact of ambient temperature on children's health: A systematic review. *Environ. Res.* **117**, 120–131 (2012).
207. Xu, Z. *et al.* The impact of heat waves on children's health: a systematic review. *Int. J. Biometeorol.* **58**, 239–247 (2014).
208. Ilango, S. D. *et al.* Extreme heat episodes and risk of preterm birth in California, 2005–2013. *Environ. Int.* **137**, 105541 (2020).
209. Chersich, M. F. *et al.* Associations between high temperatures in pregnancy and risk of preterm birth, low birth weight, and stillbirths: systematic review and meta-analysis. *BMJ* m3811 (2020) doi:10.1136/bmj.m3811.
210. Huang, M. *et al.* Acute associations between heatwaves and preterm and early-term birth in 50 US metropolitan areas: a matched case-control study. *Environ. Health* **20**, 47 (2021).
211. Dalugoda, Y., Kuppa, J., Phung, H., Rutherford, S. & Phung, D. Effect of Elevated Ambient Temperature on Maternal, Foetal, and Neonatal Outcomes: A Scoping Review. *Int. J. Environ. Res. Public. Health* **19**, 1771 (2022).
212. Shanmugam, R., Sirala Jagadeesh, N., srinivasan, bhuvana, S, K. & Venugopal, V. A Comprehensive Review on Hot Ambient Temperature and Its Impacts on Adverse Pregnancy Outcomes. *J. Mother Child Med. Wieku Rozw.* **27**, (2023).
213. Darrow, L. A. *et al.* Preterm and Early-Term Delivery After Heat Waves in 50 US Metropolitan Areas. *JAMA Netw. Open* **7**, e2412055 (2024).
214. Fitch, A. *et al.* Heat Waves and Early Birth: Exploring Vulnerability by Individual‐ and Area‐Level Factors. *GeoHealth* **9**, e2025GH001348 (2025).
215. Lakhoo, D. P. *et al.* A systematic review and meta-analysis of heat exposure impacts on maternal, fetal and neonatal health. *Nat. Med.* **31**, 684–694 (2025).
216. Ruan, T. *et al.* Association between low ambient temperature during pregnancy and adverse birth outcomes: A systematic review and meta-analysis. *Chin. Med. J. (Engl.)* **136**, 2307–2315 (2023).
217. Khosravipour, M. & Golbabaei, F. Short-term ambient temperature variations and incidence of preterm birth: A systematic review and meta-analysis. *Int. J. Hyg. Environ. Health* **256**, 114319 (2024).
218. Brink, N. *et al.* Impacts of heat exposure in utero on long-term health and social outcomes: a systematic review. *BMC Pregnancy Childbirth* **24**, 344 (2024).
219. Smith, C. J. Pediatric Thermoregulation: Considerations in the Face of Global Climate Change. *Nutrients* **11**, 2010 (2019).
220. Schinasi, L. H. *et al.* High Ambient Temperature and Infant Mortality in Philadelphia, Pennsylvania: A Case–Crossover Study. *Am. J. Public Health* **110**, 189–195 (2020).
221. Dowd, M. D. Vehicular Hyperthermia—A Highly Preventable and Potentially Fatal Problem. *Pediatr. Ann.* **47**, (2018).
222. Xu, Z. *et al.* Extreme temperatures and paediatric emergency department admissions. *J. Epidemiol. Community Health* **68**, 304–311 (2014).
223. Bernstein, A. S. *et al.* Warm Season and Emergency Department Visits to U.S. Children's Hospitals. *Environ. Health Perspect.* **130**, 017001 (2022).
224. Girma, B., Liu, B., Schinasi, L. H., Clougherty, J. E. & Sheffield, P. E. High ambient temperatures associations with children and young adult injury emergency department visits in NYC. *Environ. Res. Health* **1**, 035004 (2023).
225. Kerr, Z. Y. *et al.* Exertional Heat-Stroke Preparedness in High School Football by Region and State Mandate Presence. *J. Athl. Train.* **54**, 921–928 (2019).
226. Poore, S., Grundstein, A., Cooper, E. & Shannon, J. Regional differences in exertional heat illness rates among Georgia USA high school football players. *Int. J. Biometeorol.* **64**, 643–650 (2020).

227. Dee, S. G. *et al.* Increasing Health Risks During Outdoor Sports Due To Climate Change in Texas: Projections Versus Attitudes. *GeoHealth* **6**, e2022GH000595 (2022).
228. Yeargin, S. W. *et al.* Exertional heat illness risk factors and physiological responses of youth football players. *J. Sport Health Sci.* **10**, 91–98 (2021).
229. Travis E. Dorsch & Jordan A. Blazo. *2024 Parenting Survey Final Report*. https://www.aspeninstitute.org/wp-content/uploads/2025/06/National-Youth-Sports-Parent-Survey-FINAL.pdf (2024).
230. Lanza, K. *et al.* Heat-Resilient Schoolyards: Relations Between Temperature, Shade, and Physical Activity of Children During Recess. *J. Phys. Act. Health* **20**, 134–141 (2023).
231. Koepp, A. E., Lanza, K., Byrd-Williams, C., Bryan, A. E. & Gershoff, E. T. Ambient Temperature Increases and Preschoolers' Outdoor Physical Activity. *JAMA Pediatr.* **177**, 539–540 (2023).
232. Cedeño Laurent, J. G. *et al.* Reduced cognitive function during a heat wave among residents of non-air-conditioned buildings: An observational study of young adults in the summer of 2016. *PLOS Med.* **15**, e1002605 (2018).
233. Park, R. J., Goodman, J., Hurwitz, M. & Smith, J. Heat and Learning. *Am. Econ. J. Econ. Policy* **12**, 306–339 (2020).
234. Younan, D. *et al.* Long-Term Ambient Temperature and Externalizing Behaviors in Adolescents. *Am. J. Epidemiol.* **187**, 1931–1941 (2018).
235. Evans, M., Gazze, L. & Schaller, J. *Temperature and Maltreatment of Young Children*. w31522 http://www.nber.org/papers/w31522.pdf (2023) doi:10.3386/w31522.
236. Datzberger, S., Howard-Merrill, L., Parkes, J. & Iorfa, S. K. How do extreme weather events contribute to violence against children? *Child Abuse Negl.* **158**, 107093 (2024).
237. Sokol, R., Gerlein‐Safdi, C., Degli Esposti, M. & Wallace, M. Extreme Weather Events Interact With Local Contexts to Alter the Frequency of Firearm Violence and Child Maltreatment in Wayne County, Michigan. *GeoHealth* **9**, e2025GH001406 (2025).
238. Hauptman, M., Balmes, J. R. & Miller, M. D. The hazards of wildfire smoke exposure for children. *Curr. Probl. Pediatr. Adolesc. Health Care* **50**, 100756 (2020).
239. Holm, S. M., Miller, M. D. & Balmes, J. R. Health effects of wildfire smoke in children and public health tools: a narrative review. *J. Expo. Sci. Environ. Epidemiol.* **31**, 1–20 (2021).
240. Fernández, A. C. G. *et al.* Retrospective analysis of wildfire smoke exposure and birth weight outcomes in the San Francisco Bay Area of California. *Environ. Res. Health* **1**, 025009 (2023).
241. Black, C. *et al.* Early Life Wildfire Smoke Exposure Is Associated with Immune Dysregulation and Lung Function Decrements in Adolescence. *Am. J. Respir. Cell Mol. Biol.* **56**, 657–666 (2017).
242. Perera, F. & Nadeau, K. Climate Change, Fossil-Fuel Pollution, and Children's Health. *N. Engl. J. Med.* **386**, 2303–2314 (2022).
243. Crandon, T. J., Scott, J. G., Charlson, F. J. & Thomas, H. J. A social–ecological perspective on climate anxiety in children and adolescents. *Nat. Clim. Change* **12**, 123–131 (2022).
244. Vergunst, F. & Berry, H. L. Climate Change and Children's Mental Health: A Developmental Perspective. *Clin. Psychol. Sci.* **10**, 767–785 (2022).
245. Coffey, Y., Bhullar, N., Durkin, J., Islam, M. S. & Usher, K. Understanding Eco-anxiety: A Systematic Scoping Review of Current Literature and Identified Knowledge Gaps. *J. Clim. Change Health* **3**, 100047 (2021).
246. Burke, S. E. L., Sanson, A. V. & Van Hoorn, J. The Psychological Effects of Climate Change on Children. *Curr. Psychiatry Rep.* **20**, 35 (2018).
247. Tang, B., Liu, X., Liu, Y., Xue, C. & Zhang, L. A meta-analysis of risk factors for depression in adults and children after natural disasters. *BMC Public Health* **14**, 623 (2014).
248. Pfefferbaum, B., Jacobs, A. K., Van Horn, R. L. & Houston, J. B. Effects of Displacement in Children Exposed to Disasters. *Curr. Psychiatry Rep.* **18**, 71 (2016).

249. Lai, B. S., Lewis, R., Livings, M. S., La Greca, A. M. & Esnard, A. Posttraumatic Stress Symptom Trajectories Among Children After Disaster Exposure: A Review. *J. Trauma. Stress* **30**, 571–582 (2017).
250. Lai, B. S. *et al.* Trajectories of Posttraumatic Stress in Youths After Natural Disasters. *JAMA Netw. Open* **4**, e2036682 (2021).
251. SAMHSA Disaster Technical Assistance Center Supplemental Research Bulletin. *Behavioral Health Conditions in Children and Youth Exposed to Natural Disasters*. https://www.samhsa.gov/sites/default/files/srb-childrenyouth-8-22-18.pdf (2018).
252. Rubens, S. L., Felix, E. D. & Hambrick, E. P. A Meta‐Analysis of the Impact of Natural Disasters on Internalizing and Externalizing Problems in Youth. *J. Trauma. Stress* **31**, 332–341 (2018).
253. Betty S. Lai & Annette La Greca. *Understanding the Impacts of Natural Disasters on Children*. https://www.srcd.org/sites/default/files/resources/2020%20Child%20Evidence%20Brief%20EDITED.pdf (2020).
254. Felix, E., Rubens, S. & Hambrick, E. The Relationship Between Physical and Mental Health Outcomes in Children Exposed to Disasters. *Curr. Psychiatry Rep.* **22**, 33 (2020).
255. Danese, A., Smith, P., Chitsabesan, P. & Dubicka, B. Child and adolescent mental health amidst emergencies and disasters. *Br. J. Psychiatry* **216**, 159–162 (2020).
256. Powell, T., Wegmann, K. M. & Backode, E. Coping and Post-Traumatic Stress in Children and Adolescents after an Acute Onset Disaster: A Systematic Review. *Int. J. Environ. Res. Public. Health* **18**, 4865 (2021).
257. Barkin, J. L. *et al.* Effects of extreme weather events on child mood and behavior. *Dev. Med. Child Neurol.* **63**, 785–790 (2021).
258. La Greca, A. M., Burdette, E. T. & Brodar, K. E. Climate change and extreme weather disasters: evacuation stress is associated with youths' somatic complaints. *Front. Psychol.* **14**, 1196419 (2023).
259. Hoffmann, J. A. *et al.* Supporting Children's Mental Health Needs in Disasters. *Pediatrics* **155**, e2024068076 (2025).
260. Gamble, J. L. *et al.* Climate Change and Older Americans: State of the Science. *Environ. Health Perspect.* **121**, 15–22 (2013).
261. McDermott-Levy, R., Kolanowski, A. M., Fick, D. M. & Mann, M. E. Addressing the Health Risks of Climate Change in Older Adults. *J. Gerontol. Nurs.* **45**, 21–29 (2019).
262. Figueiredo, T. *et al.* The interplay between climate change and ageing: A systematic review of health indicators. *PLOS ONE* **19**, e0297116 (2024).
263. Meade, R. D. *et al.* Physiological factors characterizing heat-vulnerable older adults: A narrative review. *Environ. Int.* **144**, 105909 (2020).
264. Millyard, A., Layden, J. D., Pyne, D. B., Edwards, A. M. & Bloxham, S. R. Impairments to Thermoregulation in the Elderly During Heat Exposure Events. *Gerontol. Geriatr. Med.* **6**, 2333721420932432 (2020).
265. Choi, E. Y. & Ailshire, J. A. Ambient outdoor heat and accelerated epigenetic aging among older adults in the US. *Sci. Adv.* **11**, eadr0616 (2025).
266. Macey, S. M. & Schneider, D. F. Deaths from Excessive Heat and Excessive Cold Among the Elderly. *The Gerontologist* **33**, 497–500 (1993).
267. Gronlund, C. J., Zanobetti, A., Wellenius, G. A., Schwartz, J. D. & O'Neill, M. S. Vulnerability to renal, heat and respiratory hospitalizations during extreme heat among U.S. elderly. *Clim. Change* **136**, 631–645 (2016).
268. Fernandez, L. S., Byard, D., Lin, C.-C., Benson, S. & Barbera, J. A. Frail Elderly as Disaster Victims: Emergency Management Strategies. *Prehospital Disaster Med.* **17**, 67–74 (2002).
269. Tuohy, R. & Stephens, C. Exploring older adults' personal and social vulnerability in a disaster. *Int. J. Emerg. Manag.* **8**, 60 (2011).

270. Brunkard, J., Namulanda, G. & Ratard, R. Hurricane Katrina Deaths, Louisiana, 2005. *Disaster Med. Public Health Prep.* **2**, 215–223 (2008).
271. Kim, S. *et al.* Hurricane Sandy (New Jersey): Mortality Rates in the Following Month and Quarter. *Am. J. Public Health* **107**, 1304–1307 (2017).
272. Keenan, O. J. *et al.* Long-term impacts of hurricanes on mortality among Medicare beneficiaries: evidence from Hurricane Sandy. *Front. Public Health* **13**, 1523941 (2025).
273. Skarha, J. *et al.* Association of Power Outage With Mortality and Hospitalizations Among Florida Nursing Home Residents After Hurricane Irma. *JAMA Health Forum* **2**, e213900 (2021).
274. Adams, V., Kaufman, S. R., Van Hattum, T. & Moody, S. Aging Disaster: Mortality, Vulnerability, and Long-Term Recovery among Katrina Survivors. *Med. Anthropol.* **30**, 247–270 (2011).
275. Hrostowski, S. & Rehner, T. Five Years Later: Resiliency Among Older Adult Survivors of Hurricane Katrina. *J. Gerontol. Soc. Work* **55**, 337–351 (2012).
276. Strough, J., Parker, A. M., Ayer, L., Parks, V. & Finucane, M. L. Aging and Emotional Well-Being After Disasters: Vulnerability and Resilience. *The Gerontologist* **64**, gnad099 (2024).
277. Bekkar, B., Pacheco, S., Basu, R. & DeNicola, N. Association of Air Pollution and Heat Exposure With Preterm Birth, Low Birth Weight, and Stillbirth in the US: A Systematic Review. *JAMA Netw. Open* **3**, e208243 (2020).
278. Sun, S. *et al.* Ambient Temperature and Markers of Fetal Growth: A Retrospective Observational Study of 29 Million U.S. Singleton Births. *Environ. Health Perspect.* **127**, 067005 (2019).
279. Bonell, A. *et al.* An expert review of environmental heat exposure and stillbirth in the face of climate change: Clinical implications and priority issues. *BJOG Int. J. Obstet. Gynaecol.* **131**, 623–631 (2024).
280. Sexton, J. *et al.* Systematic review of ambient temperature exposure during pregnancy and stillbirth: Methods and evidence. *Environ. Res.* **197**, 111037 (2021).
281. Molla, A. Extreme heat and human fertility: Amplified challenges in the era of climate change. *J. Therm. Biol.* **130**, 104158 (2025).
282. Rubin, E. S. *et al.* Poor air quality from wildfire smoke is associated with decrease in total motile sperm count at time of intrauterine insemination. *Fertil. Steril.* **121**, 881–883 (2024).
283. Gaskins, A. J. *et al.* Impact of ambient temperature on ovarian reserve. *Fertil. Steril.* **116**, 1052–1060 (2021).
284. Qian, J. *et al.* Ambient temperature and female infertility prevalence: an ecological study based on the 2019 global burden of disease study. *Reprod. Biol. Endocrinol.* **23**, 27 (2025).
285. Chang, A. Y., Tan, A. X., Nadeau, K. C. & Odden, M. C. Aging Hearts in a Hotter, More Turbulent World: The Impacts of Climate Change on the Cardiovascular Health of Older Adults. *Curr. Cardiol. Rep.* **24**, 749–760 (2022).
286. Liu, J. *et al.* Heat exposure and cardiovascular health outcomes: a systematic review and meta-analysis. *Lancet Planet. Health* **6**, e484–e495 (2022).
287. Desai, Y., Khraishah, H. & Alahmad, B. Heat and the Heart. *Yale J. Biol. Med.* **96**, 197–203 (2023).
288. Singh, N. *et al.* Heat and Cardiovascular Mortality: An Epidemiological Perspective. *Circ. Res.* **134**, 1098–1112 (2024).
289. Ndlovu, N. & Chungag, B. N. Impact of heat stress on cardiovascular health outcomes of older adults: A mini review. *Aging Health Res.* **4**, 100189 (2024).
290. Achebak, H. *et al.* Ambient temperature and risk of cardiovascular and respiratory adverse health outcomes: a nationwide cross-sectional study from Spain. *Eur. J. Prev. Cardiol.* **31**, 1080–1089 (2024).
291. Witt, C. *et al.* The Effects of Climate Change on Patients With Chronic Lung Disease. *Dtsch. Ärztebl. Int.* (2015) doi:10.3238/arztebl.2015.0878.
292. O'Lenick, C. R. *et al.* Impact of Heat on Respiratory Hospitalizations among Older Adults in 120 Large U.S. Urban Areas. *Ann. Am. Thorac. Soc.* **22**, 367–377 (2025).

293. Halpin, D. M. G. *et al.* Climate Change and Chronic Obstructive Pulmonary Disease: A GOLD Science Committee Review. *Am. J. Respir. Crit. Care Med.* **211**, 700–708 (2025).
294. Tran, H. M. *et al.* Extreme temperature increases the risk of COPD morbimortality: A systematic review and meta-analysis. *Sci. Total Environ.* **958**, 178087 (2025).
295. Zhu, Z., Ji, B., Tian, J. & Yin, P. Heat exposure and respiratory diseases health outcomes: An umbrella review. *Sci. Total Environ.* **970**, 179052 (2025).
296. Remigio, R. V. *et al.* Association of Extreme Heat Events With Hospital Admission or Mortality Among Patients With End-Stage Renal Disease. *JAMA Netw. Open* **2**, e198904 (2019).
297. Zilbermint, M. Diabetes and climate change. *J. Community Hosp. Intern. Med. Perspect.* **10**, 409–412 (2020).
298. Chen, H., Samet, J. M., Bromberg, P. A. & Tong, H. Cardiovascular health impacts of wildfire smoke exposure. *Part. Fibre Toxicol.* **18**, 2 (2021).
299. Patwary, M. M. *et al.* Wildfire exposure and health outcomes: An umbrella review of systematic reviews and meta-analyses. Preprint at https://doi.org/10.32942/X2N62B (2024).
300. Gould, C. F. *et al.* Health Effects of Wildfire Smoke Exposure. *Annu. Rev. Med.* **75**, 277–292 (2024).
301. Williams, V. A. *et al.* Impact of Wildfires on Cardiovascular Health. *Circ. Res.* **134**, 1061–1082 (2024).
302. Balmes, J. R., Hicks, A., Johnson, M. M. & Nadeau, K. C. The Effect of Wildfires on Asthma and Allergies. *J. Allergy Clin. Immunol. Pract.* **13**, 280–287 (2025).
303. Chou, C. K., Winker, R., Rebuli, M. E., Moran, T. & Rager, J. E. Respiratory Health Impacts from Natural Disasters and Other Extreme Weather Events: The Role of Environmental Stressors on Asthma and Allergies. *Curr. Allergy Asthma Rep.* **25**, 25 (2025).
304. Zuelsdorff, M. & Limaye, V. S. A Framework for Assessing the Effects of Climate Change on Dementia Risk and Burden. *The Gerontologist* **64**, gnad082 (2024).
305. Peterson, L. J., Hackett, S. E., Dobbs, D. & Haley, W. E. Dementia Caregivers' Perspectives on Disaster Preparedness: Barriers, Resources, and Recommendations. *The Gerontologist* **64**, gnad076 (2024).
306. Wang, X., Lavigne, E., Ouellette-kuntz, H. & Chen, B. E. Acute impacts of extreme temperature exposure on emergency room admissions related to mental and behavior disorders in Toronto, Canada. *J. Affect. Disord.* **155**, 154–161 (2014).
307. Thompson, R., Hornigold, R., Page, L. & Waite, T. Associations between high ambient temperatures and heat waves with mental health outcomes: a systematic review. *Public Health* **161**, 171–191 (2018).
308. Mullins, J. T. & White, C. Temperature and mental health: Evidence from the spectrum of mental health outcomes. *J. Health Econ.* **68**, 102240 (2019).
309. Lee, M. J., McLean, K. E., Kuo, M., Richardson, G. R. A. & Henderson, S. B. Chronic Diseases Associated With Mortality in British Columbia, Canada During the 2021 Western North America Extreme Heat Event. *GeoHealth* **7**, e2022GH000729 (2023).
310. Cefalu, W. T., Smith, S. R., Blonde, L. & Fonseca, V. The Hurricane Katrina Aftermath and Its Impact on Diabetes Care. *Diabetes Care* **29**, 158–160 (2006).
311. Fonseca, V. A. *et al.* Impact of a Natural Disaster on Diabetes. *Diabetes Care* **32**, 1632–1638 (2009).
312. Mokdad, A. H. *et al.* When chronic conditions become acute: prevention and control of chronic diseases and adverse health outcomes during natural disasters. *Prev. Chronic. Dis.* **2 Spec no**, A04 (2005).
313. Ford, E. S. *et al.* Chronic disease in health emergencies: in the eye of the hurricane. *Prev. Chronic. Dis.* **3**, A46 (2006).

314. Arrieta, M. I., Foreman, R. D., Crook, E. D. & Icenogle, M. L. Insuring Continuity of Care for Chronic Disease Patients After a Disaster: Key Preparedness Elements. *Am. J. Med. Sci.* **336**, 128–133 (2008).
315. Kleinpeter, M. A. Disaster preparedness of dialysis patients for Hurricanes Gustav and Ike 2008. *Adv. Perit. Dial. Conf. Perit. Dial.* **25**, 62–67 (2009).
316. Runkle, J. D., Zhang, H., Karmaus, W., Martin, A. B. & Svendsen, E. R. Prediction of Unmet Primary Care Needs for the Medically Vulnerable Post-Disaster: An Interrupted Time-Series Analysis of Health System Responses. *Int. J. Environ. Res. Public. Health* **9**, 3384–3397 (2012).
317. Ochi, S., Hodgson, S., Landeg, O., Mayner, L. & Murray, V. Disaster-driven evacuation and medication loss: a systematic literature review. *PLoS Curr.* **6**, ecurrents.dis.fa417630b566a0c7dfdbf945910edd96 (2014).
318. Sato, H. & Tomio, J. Emergency and disaster preparedness for chronically ill patients: a review of recommendations. *Open Access Emerg. Med.* 69 (2014) doi:10.2147/OAEM.S48532.
319. Blum, M. F. *et al.* Hurricanes and Mortality among Patients Receiving Dialysis. *J. Am. Soc. Nephrol. JASN* **33**, 1757–1766 (2022).
320. Westaway, K. *et al.* Medicines can affect thermoregulation and accentuate the risk of dehydration and heat-related illness during hot weather. *J. Clin. Pharm. Ther.* **40**, 363–367 (2015).
321. Layton, J. B. *et al.* Heatwaves, medications, and heat-related hospitalization in older Medicare beneficiaries with chronic conditions. *PLOS ONE* **15**, e0243665 (2020).
322. Ebi, K. L. & Hess, J. J. Health Risks Due To Climate Change: Inequity In Causes And Consequences: Study examines health risks due to climate change. *Health Aff. (Millwood)* **39**, 2056–2062 (2020).
323. Berberian, A. G., Gonzalez, D. J. X. & Cushing, L. J. Racial Disparities in Climate Change-Related Health Effects in the United States. *Curr. Environ. Health Rep.* **9**, 451–464 (2022).
324. Morello-Frosch, R. & Obasogie, O. K. The Climate Gap and the Color Line — Racial Health Inequities and Climate Change. *N. Engl. J. Med.* **388**, 943–949 (2023).
325. Song, X. *et al.* A systematic review of the inequality of health burdens related to climate change. *Front. Environ. Sci. Eng.* **18**, 63 (2024).
326. Brubacher, L. J. *et al.* Climate change, biodiversity loss, and Indigenous Peoples' health and wellbeing: A systematic umbrella review. *PLOS Glob. Public Health* **4**, e0002995 (2024).
327. Benz, S. A. & Burney, J. A. Widespread Race and Class Disparities in Surface Urban Heat Extremes Across the United States. *Earths Future* **9**, e2021EF002016 (2021).
328. Hsu, A., Sheriff, G., Chakraborty, T. & Manya, D. Disproportionate exposure to urban heat island intensity across major US cities. *Nat. Commun.* **12**, 2721 (2021).
329. Manware, M., Dubrow, R., Carrión, D., Ma, Y. & Chen, K. Residential and Race/Ethnicity Disparities in Heat Vulnerability in the United States. *GeoHealth* **6**, e2022GH000695 (2022).
330. Lanza, K. *et al.* Heat vulnerability of Latino and Black residents in a low-income community and their recommended adaptation strategies: A qualitative study. *Urban Clim.* **51**, 101656 (2023).
331. Slesinski, S. C., Matthies-Wiesler, F., Breitner-Busch, S., Gussmann, G. & Schneider, A. Social inequalities in exposure to heat stress and related adaptive capacity: a systematic review. *Environ. Res. Lett.* **20**, 033005 (2025).
332. Sanders, B. F. *et al.* Large and inequitable flood risks in Los Angeles, California. *Nat. Sustain.* **6**, 47–57 (2022).
333. Wing, O. E. J. *et al.* Inequitable patterns of US flood risk in the Anthropocene. *Nat. Clim. Change* **12**, 156–162 (2022).
334. Lindersson, S. *et al.* The wider the gap between rich and poor the higher the flood mortality. *Nat. Sustain.* **6**, 995–1005 (2023).
335. Smiley, K. T. *et al.* Social inequalities in climate change-attributed impacts of Hurricane Harvey. *Nat. Commun.* **13**, 3418 (2022).

336. Young, R. & Hsiang, S. Mortality caused by tropical cyclones in the United States. *Nature* **635**, 121–128 (2024).
337. Arpin, E. *et al.* Climate Change and Child Health Inequality: A Review of Reviews. *Int. J. Environ. Res. Public. Health* **18**, 10896 (2021).
338. Khatana, S. A. M., Werner, R. M. & Groeneveld, P. W. Association of Extreme Heat With All-Cause Mortality in the Contiguous US, 2008-2017. *JAMA Netw. Open* **5**, e2212957 (2022).
339. Lake, I. R. *et al.* Climate Change and Food Security: Health Impacts in Developed Countries. *Environ. Health Perspect.* **120**, 1520–1526 (2012).
340. Mirzabaev, A. *et al.* Severe climate change risks to food security and nutrition. *Clim. Risk Manag.* **39**, 100473 (2023).
341. Ek, C., Hébert, J. R., Friedman, D. B. & Porter, D. E. Climate Change, Racism, and Food Insecurity: Cyclical Impacts of Stressors Exacerbate Health Disparities. *J. Racial Ethn. Health Disparities* (2024) doi:10.1007/s40615-024-02202-x.
342. Smirnova, N., Shaver, A. C., Mehta, A. J., Philipsborn, R. & Scovronick, N. Climate Change, Air Quality, and Pulmonary Health Disparities. *Clin. Chest Med.* **44**, 489–499 (2023).
343. Ebi, K. L., Hess, J. J. & Watkiss, P. Health Risks and Costs of Climate Variability and Change. in *Injury Prevention and Environmental Health* (eds Mock, C. N., Nugent, R., Kobusingye, O. & Smith, K. R.) (The International Bank for Reconstruction and Development / The World Bank, Washington (DC), 2017).
344. Hutton, G. The economics of health and climate change: key evidence for decision making. *Glob. Health* **7**, 18 (2011).
345. Knowlton, K., Rotkin-Ellman, M., Geballe, L., Max, W. & Solomon, G. M. Six Climate Change–Related Events In The United States Accounted For About $14 Billion In Lost Lives And Health Costs. *Health Aff. (Millwood)* **30**, 2167–2176 (2011).
346. Limaye, V. S., Max, W., Constible, J. & Knowlton, K. Estimating the Health‐Related Costs of 10 Climate‐Sensitive U.S. Events During 2012. *GeoHealth* **3**, 245–265 (2019).
347. Clarke, H. *et al.* Health costs of wildfire smoke to rise under climate change. *Npj Clim. Atmospheric Sci.* **6**, 102 (2023).
348. Stowell, J. D. *et al.* Asthma exacerbation due to climate change-induced wildfire smoke in the Western US. *Environ. Res. Lett.* **17**, 014023 (2022).
349. Jin, Z. *et al.* Fire Smoke Elevated the Carbonaceous PM2.5 Concentration and Mortality Burden in the Contiguous U.S. and Southern Canada. *Environ. Sci. Technol.* **59**, 12196–12210 (2025).
350. Wang, D. *et al.* Economic footprint of California wildfires in 2018. *Nat. Sustain.* **4**, 252–260 (2020).
351. Lay, C. R. *et al.* Emergency Department Visits and Ambient Temperature: Evaluating the Connection and Projecting Future Outcomes. *GeoHealth* **2**, 182–194 (2018).
352. Liu, Y., Saha, S., Hoppe, B. O. & Convertino, M. Degrees and dollars – Health costs associated with suboptimal ambient temperature exposure. *Sci. Total Environ.* **678**, 702–711 (2019).
353. Atlantic Council of the United States. *Extreme Heat: The Economic and Social Consequences for the United States*. (Atlantic Council, Washington, DC, 2021).
354. Atlantic Council of the United States. Extreme Heat: The Economic & Social Consequences for the United States Methodology. (2021).
355. Hoagland, P. *et al.* The Costs of Respiratory Illnesses Arising from Florida Gulf Coast Karenia brevis Blooms. *Environ. Health Perspect.* **117**, 1239–1243 (2009).
356. Wettstein, Z. S. *et al.* Emergency Care, Hospitalization Rates, and Floods. *JAMA Netw. Open* **8**, e250371 (2025).
357. Mahshid Abir *et al. Impact of Climate Change on Health and Drug Demand*. https://aspe.hhs.gov/reports/climate-change-drug-demand (2024).
358. Cromar, K. R. *et al.* Global Health Impacts for Economic Models of Climate Change: A Systematic Review and Meta-Analysis. *Ann. Am. Thorac. Soc.* **19**, 1203–1212 (2022).

359. U.S. Environmental Protection Agency. *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*. https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf (2023).
360. Rennert, K. *et al.* Comprehensive evidence implies a higher social cost of CO2. *Nature* **610**, 687–692 (2022).
361. Cromar, K., Howard, P., Vásquez, V. N. & Anthoff, D. Health Impacts of Climate Change as Contained in Economic Models Estimating the Social Cost of Carbon Dioxide. *GeoHealth* **5**, e2021GH000405 (2021).
362. Carleton, T. A. *et al.* Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits. Working Paper at https://doi.org/10.3386/w27599 (2020).
363. The Climate Impact Lab. Documentation for Data-driven Spatial Climate Impact Model (DSCIM) Version092023-EPA. (2023).
364. Kopits, E. *et al.* Economic Damages from Climate Change to U.S. Populations: Integrating Evidence from Recent Studies. Working Paper at (2025).
365. Barrage, L. & Nordhaus, W. Policies, projections, and the social cost of carbon: Results from the DICE-2023 model. *Proc. Natl. Acad. Sci.* **121**, e2312030121 (2024).
366. Moore, F. C. *et al.* Synthesis of evidence yields high social cost of carbon due to structural model variation and uncertainties. *Proc. Natl. Acad. Sci.* **121**, e2410733121 (2024).
367. Office of Management and Budget. *Climate Risk Exposure: An Assessment of the Federal Government's Financial Risks to Climate Change*. https://bidenwhitehouse.archives.gov/wp-content/uploads/2022/04/OMB_Climate_Risk_Exposure_2022.pdf (2022).
368. Office of Management and Budget. *Addressing the Impacts of Climate Change - Federal Budgetary Risks, Adaptation Planning, and the Climate Benefits of Federal Investments*. https://climateprogramportal.org/resource/opb-white-paper-addressing-the-impacts-of-climate-change-federal-budgetary-risks-adaptation-planning-and-the-climate-benefits-of-federal-investments/ (2025).
369. Office of Management and Budget. Circular No. A-4. (2023).
370. *Risk Assessment in the Federal Government: Managing the Process*. 366 (National Academies Press, Washington, D.C., 1983). doi:10.17226/366.
371. National Research Council. *Science and Decisions: Advancing Risk Assessment*. 12209 (National Academies Press, Washington, D.C., 2009). doi:10.17226/12209.
372. Shindell, D. T., Lee, Y. & Faluvegi, G. Climate and health impacts of US emissions reductions consistent with 2 °C. *Nat. Clim. Change* **6**, 503–507 (2016).
373. Buonocore, J. J., Lambert, K. F., Burtraw, D., Sekar, S. & Driscoll, C. T. An Analysis of Costs and Health Co-Benefits for a U.S. Power Plant Carbon Standard. *PLOS ONE* **11**, e0156308 (2016).
374. Garcia-Menendez, F., Saari, R. K., Monier, E. & Selin, N. E. U.S. Air Quality and Health Benefits from Avoided Climate Change under Greenhouse Gas Mitigation. *Environ. Sci. Technol.* **49**, 7580–7588 (2015).
375. Saari, R. K., Selin, N. E., Rausch, S. & Thompson, T. M. A self-consistent method to assess air quality co-benefits from U.S. climate policies. *J. Air Waste Manag. Assoc.* **65**, 74–89 (2015).
376. Thompson, T. M., Rausch, S., Saari, R. K. & Selin, N. E. A systems approach to evaluating the air quality co-benefits of US carbon policies. *Nat. Clim. Change* **4**, 917–923 (2014).
377. Zhao, B. *et al.* Air Quality and Health Cobenefits of Different Deep Decarbonization Pathways in California. *Environ. Sci. Technol.* **53**, 7163–7171 (2019).
378. Zapata, C. B., Yang, C., Yeh, S., Ogden, J. & Kleeman, M. J. Low-carbon energy generates public health savings in California. *Atmospheric Chem. Phys.* **18**, 4817–4830 (2018).
379. Dimanchev, E. G. *et al.* Health co-benefits of sub-national renewable energy policy in the US. *Environ. Res. Lett.* **14**, 085012 (2019).

380. Shindell, D., Faluvegi, G., Nagamoto, E., Parsons, L. & Zhang, Y. Reductions in premature deaths from heat and particulate matter air pollution in South Asia, China, and the United States under decarbonization. *Proc. Natl. Acad. Sci.* **121**, e2312832120 (2024).
381. Lelieveld, J. *et al.* Air pollution deaths attributable to fossil fuels: observational and modelling study. *BMJ* **383**, e077784 (2023).
382. Mailloux, N. A., Abel, D. W., Holloway, T. & Patz, J. A. Nationwide and Regional PM2.5-Related Air Quality Health Benefits From the Removal of Energy-Related Emissions in the United States. *GeoHealth* **6**, e2022GH000603 (2022).
383. Perera, F. & Lau, K. A review of studies assessing the benefits of clean air and climate mitigation policies for child and adult health. *J. Clim. Change Health* **21**, 100369 (2025).
384. Rosanka, S. & Carlton, A. M. The legacy of the U.S. Clean Air Act at a crossroads. *Npj Clean Air* **1**, 1–4 (2025).
385. Sugiyama, T. *et al.* Car use and cardiovascular disease risk: Systematic review and implications for transport research. *J. Transp. Health* **19**, 100930 (2020).
386. Ding, D. *et al.* The co-benefits of active travel interventions beyond physical activity: a systematic review. *Lancet Planet. Health* **8**, e790–e803 (2024).
387. Celis-Morales, C. A. *et al.* Association between active commuting and incident cardiovascular disease, cancer, and mortality: prospective cohort study. *BMJ* j1456 (2017) doi:10.1136/bmj.j1456.
388. Bandara, T. N. *et al.* Longitudinal effects of the built environment on transportation and recreational walking and differences by age and sex: A systematic review. *Soc. Sci. Med.* **368**, 117811 (2025).
389. Wali, B. *et al.* Pathways from Built Environment to Health Care Costs: Linking Objectively Measured Built Environment with Physical Activity and Health Care Expenditures. *Environ. Behav.* **54**, 747–782 (2022).
390. Raifman, M., Lambert, K. F., Levy, J. I. & Kinney, P. L. Mortality Implications of Increased Active Mobility for a Proposed Regional Transportation Emission Cap-and-Invest Program. *J. Urban Health* **98**, 315–327 (2021).
391. Glazener, A. *et al.* Fourteen pathways between urban transportation and health: A conceptual model and literature review. *J. Transp. Health* **21**, 101070 (2021).
392. Choma, E. F. *et al.* Health benefits of decreases in on-road transportation emissions in the United States from 2008 to 2017. *Proc. Natl. Acad. Sci.* **118**, e2107402118 (2021).
393. Visa, M. A. *et al.* Neighborhood-scale air quality, public health, and equity implications of multi-modal vehicle electrification. *Environ. Res. Infrastruct. Sustain.* **3**, 035007 (2023).
394. Bretones, A. *et al.* Public Health-Led Insights on Electric Micro-mobility Adoption and Use: a Scoping Review. *J. Urban Health* **100**, 612–626 (2023).
395. Pennington, A. F., Cornwell, C. R., Sircar, K. D. & Mirabelli, M. C. Electric vehicles and health: A scoping review. *Environ. Res.* **251**, 118697 (2024).
396. Pan, S. *et al.* Impacts of the large-scale use of passenger electric vehicles on public health in 30 US. metropolitan areas. *Renew. Sustain. Energy Rev.* **173**, 113100 (2023).
397. Peters, D. R., Schnell, J. L., Kinney, P. L., Naik, V. & Horton, D. E. Public Health and Climate Benefits and Trade-Offs of U.S. Vehicle Electrification. *GeoHealth* **4**, e2020GH000275 (2020).
398. Hall, C. E., Brooks, S. K., Mills, F., Greenberg, N. & Weston, D. Experiences of working from home: umbrella review. *J. Occup. Health* **66**, uiad013 (2024).
399. Denzer, M. & Grunau, P. The impacts of working from home on individual health and well-being. *Eur. J. Health Econ.* **25**, 743–762 (2024).
400. Xia, T., Zhang, Y., Crabb, S. & Shah, P. Cobenefits of Replacing Car Trips with Alternative Transportation: A Review of Evidence and Methodological Issues. *J. Environ. Public Health* **2013**, 1–14 (2013).
401. Re: Request for Correction under EO 14303 and the Information Quality Act Concerning the 5 th National Climate Assessment Published by the U.S. Global Change Research Program.

402. D'Angelo, C. A 'Nonprofit' Watchdog, Led By A Former Trump Official, Is Largely A Phantom. *Huffington Post* (2023).
403. Waldman, S. Physicist leading Trump's 'adversarial' climate review also led group touting carbon emissions. *E&E News* (2019).
404. Brown, C. & Stevens, H. Coal and Gas Plants Were Closing. Then Trump Ordered Them to Keep Running. *The New York Times* (2025).
405. *Environmental Decisions in the Face of Uncertainty*. 12568 (National Academies Press, Washington, D.C., 2013). doi:10.17226/12568.