Human Health

- Significant increases in illness and death related to extreme heat and heat waves are projected, along with small decreases in cold-related impacts.
- Health impacts due to reduced air quality are projected to be an increasing problem, especially in urban areas.
- Physical and mental health impacts due to extreme weather events are projected to increase.
- Infectious diseases borne by food, water, and insects are projected to increase.

- Allergies and asthma are on the rise, with climate change expected to play an increasing role in the future.
- Certain groups, including children, the elderly, and the poor, are most vulnerable to the range of health effects.

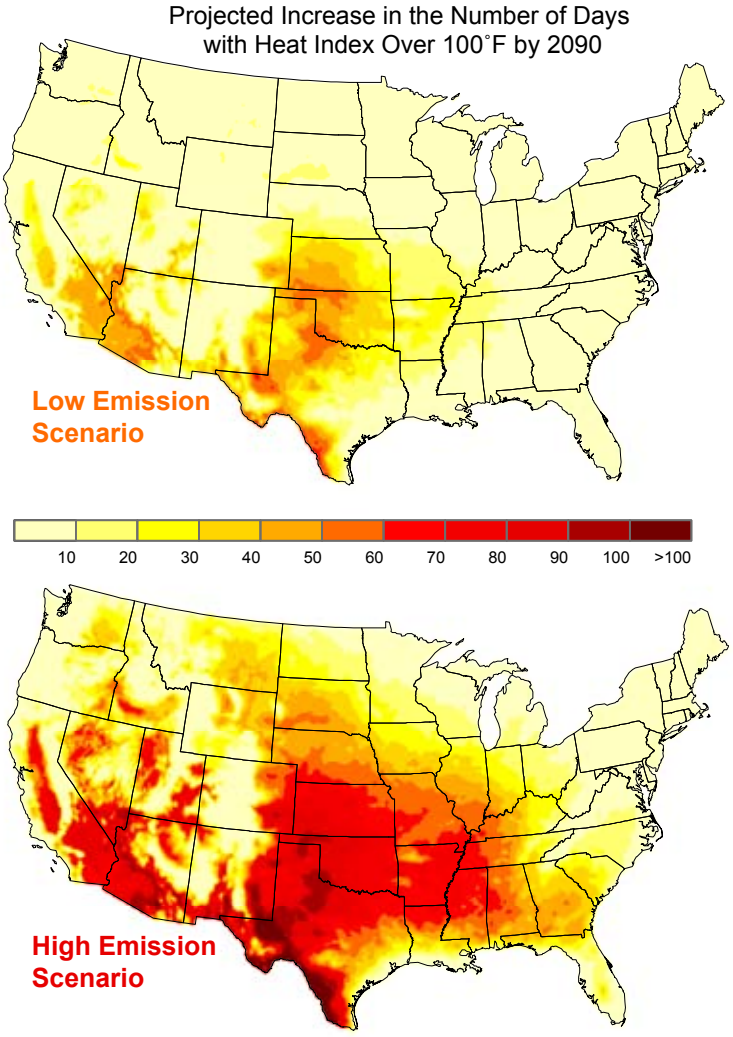
Key Sources CCSP 3.2 Climate Projections | CCSP 3.3 Extremes | CCSP 4.3 Impacts | CCSP 4.5 Energy | CCSP 4.6 Health | IPCC WG-1 | IPCC WG-2 | ACIA Arctic Impacts

Global warming poses unique challenges to human health. Unlike health threats caused by a particular toxin or disease pathogen, climate change affects multiple pathways that lead to harmful exposures. There are direct health impacts from heat waves and severe storms, ailments caused less directly as warming exacerbates air pollution and airborne allergens, and many climate-sensitive infectious diseases.

Increased risks associated with diseases originating outside the United States must also be considered because we live in an increasingly globalized world. Many poor nations are expected to suffer even greater health consequences from climate change. With global trade and transport, however, disease flare-ups in any part of the world can potentially reach the United States. In addition, weather and climate extremes such as severe storms and drought, can undermine public health infrastructure, further stress environmental resources, destabilize economies, and potentially create security risks both internally and internationally.

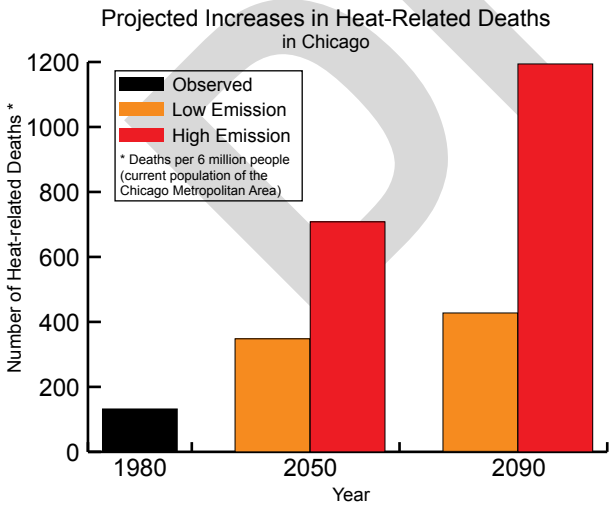
Significant increases in illness and death related to extreme heat and heat waves are projected, along with small decreases in cold-related impacts.

Temperatures are rising and the probability of severe heat waves is increasing. Analyses suggest that currently rare extreme heat waves will become much more commonplace in the future. At the same time, the U.S. population is aging, and older people are more vulnerable to hot weather and heat waves. The percentage of the U.S. population over age 65 is projected to be 13 percent by 2010 and 20 percent by 2030 (over 50 million people)[1], growing dramatically as the Baby Boomers join the ranks of the elderly[2]. Diabetics are also at greater risk of heat-related death and the prevalence of obesity and diabetes is increasing.



Heat is already the leading cause of weather-related deaths in the United States, responsible for more than 3,400 deaths between 1999 and 2003. As human-induced warming is projected to raise average temperatures by about 6 to 11ºF in this century, heat waves are expected to increase in frequency, severity and duration in portions of the U.S. where they already occur. For example, the number of heat wave days in Los Angeles is projected to double if emissions are not reduced.

A recent analysis of 21 U.S. cities found that the average number of deaths due to heat waves would more than double by 2050, even though it accounted for changes made to adjust to the increased heat such as limiting outdoor activities, increasing fluid intake, and purchasing and using air conditioners. The greatest increases in deaths are projected to occur in mid-latitude major cities including New York, Chicago, and Philadelphia. Over 10,000 additional heat wave deaths due to global warming are projected for just those three cities by 2050, with over 23,000 additional deaths projected for the 21 cities studied[3]. Higher emissions scenarios result in higher death tolls while lower emissions would result in far fewer deaths.

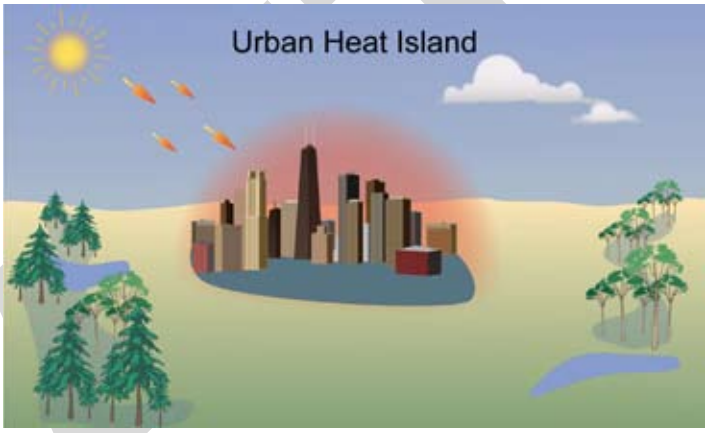


The full effect of global warming on heat-related illness and death involves a number of factors: actual changes in temperature (averages, high and lows); human population characteristics such as age, wealth, and fitness; and policies that affect urban design, transportation, and energy and water use. For example, projected increases in residential and industrial development will increase the urban heat-island effect in the absence of improved urban design and technologies to reduce heat loads.

Adaptation Strategies

Some U.S. cities have implemented systems for reducing the risk of death during heat waves, notably Philadelphia, the first to adopt such a system in the mid 1990s. The city focuses its efforts on the elderly, homeless, and poor. During a heat wave, the health department issues a heat alert and contacts news organizations with tips on how vulnerable people can protect themselves. The health department and thousands of block captains use a buddy system to check on elderly residents in their homes, electric utilities are barred from shutting off services for non-payment, and public cooling places extend their hours. The city operates a "Heatline" where nurses are standing by to assist callers experiencing health problems; if callers are deemed at-risk, mobile units are dispatched to the residence. The city has also implemented a "Cool Homes Program" for elderly low-income residents, which provides measures such as roof coatings and roof insulation that save energy and lower indoor temperatures. Philadelphia's system is estimated to have saved 117 lives over its first three years of operation[4].

The elderly are especially vulnerable to extreme heat.



Large amounts of concrete and asphalt in cities absorb and hold heat. Tall buildings prevent heat from dissipating and reduce air flow. At the same time, there is generally little vegetation to provide shade and evaporative cooling. As a result, parts of cities can be up to 10°F warmer than the surrounding suburban areas, compounding the temperature increases resulting from human-induced warming.

Reduced extreme cold

In a warmer world, extreme cold would be reduced and that could reduce the number of deaths caused by low temperatures. Research suggests that this effect would be relatively minor, however, probably because virtually all Americans have heat in their homes (as opposed to air conditioning, which is not universal). Current information on U.S. deaths due to extreme cold as well as extreme heat comes from recent research that analyzed daily mortality and weather data for 6,513,330 deaths in 50 U.S. cities between 1989 and 2000. The researchers found that, on average, cold snaps increased death rates by 1.6 percent, while heat waves triggered a 5.7 percent increase in death rates. Relatively milder winters attributable to global warming will not make up for the more severe health effects of summertime extremes[5].

It has been speculated that because death rates are higher in winter than in summer, warming might decrease deaths overall, but this ignores the fact that the principal causes of winter deaths are influenza and pneumonia, and it is unclear how these highly seasonal diseases are affected by temperature[6].

Health impacts due to reduced air quality are projected to be an increasing problem, especially in urban areas.

Poor air quality, especially in cities, is a serious concern across the United States. Half of all Americans live in counties where air pollution exceeds national health standards. Higher temperatures and related changes in climate increase pollutants such as ozone and very small particles (less than 2.5 micrometers in diameter) that cause heart and lung-related illnesses and deaths. It has been firmly established that breathing ozone results in short-term decreases in lung function and damages the cells lining the lungs. It also increases the incidence of asthma-related hospital visits and premature deaths. Vulnerability to ozone effects is greater for those who spend time outdoors, especially with physical exertion, because this results in a higher cumulative dose to their lungs. As a result, children, outdoor workers, and athletes are at higher risk for these ailments[7].

Ground-level ozone concentrations are affected by many factors including weather conditions, emissions of gases from vehicles and industries that lead to ozone formation, especially nitrogen oxides and volatile organic compounds (VOCs), natural emissions of VOCs from plants, and pollution blown in from other places[8]. A warmer climate is projected to increase the natural emissions of VOCs, accelerate ozone formation, and increase the frequency and duration of stagnant air masses that allow pollution to accumulate, which will exacerbate health symptoms.

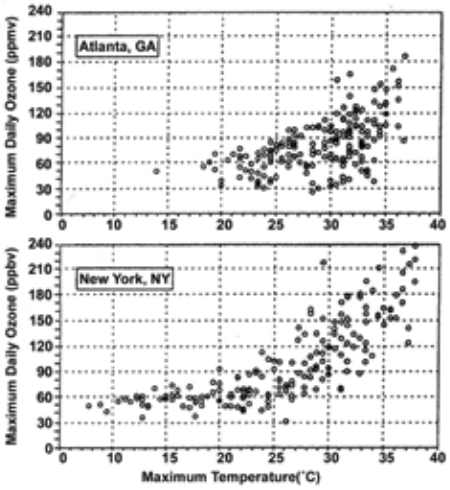
Increased temperatures and water vapor due to human-induced carbon dioxide emissions have been found to increase ozone more in areas with already elevated concentrations, meaning that global warming tends to exacerbate ozone pollution most in already polluted areas. The graphs illustrate the observed association between ground-level ozone concentration and temperature in Atlanta and New York City (May to October 1988-1990)[9].

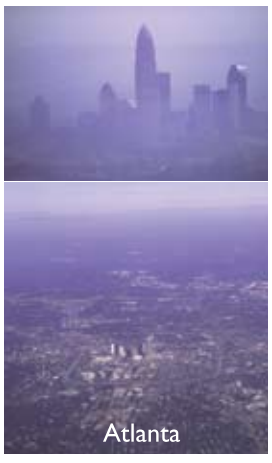
By the middle of this century, Red Ozone Alert Days (when the air is unhealthy for everyone) in the 50 largest cities in the Eastern U.S. are projected to increase by 68 percent due to warming alone[10]. The projected increases in stagnant air masses are projected to exacerbate this further[11].

The maps on the facing page show projected changes across the continental U.S., averaged over the summer months (June through August) under high and low emissions scenarios[13]. By themselves, higher temperatures and other projected climate changes would increase ozone levels under both scenarios. However, the maps indicate that future projections of ozone depend heavily on emissions[14], with the high emissions scenario increasing ozone by large amounts, while the low emissions scenario results in an overall decrease in ground-level ozone by the end of the century.

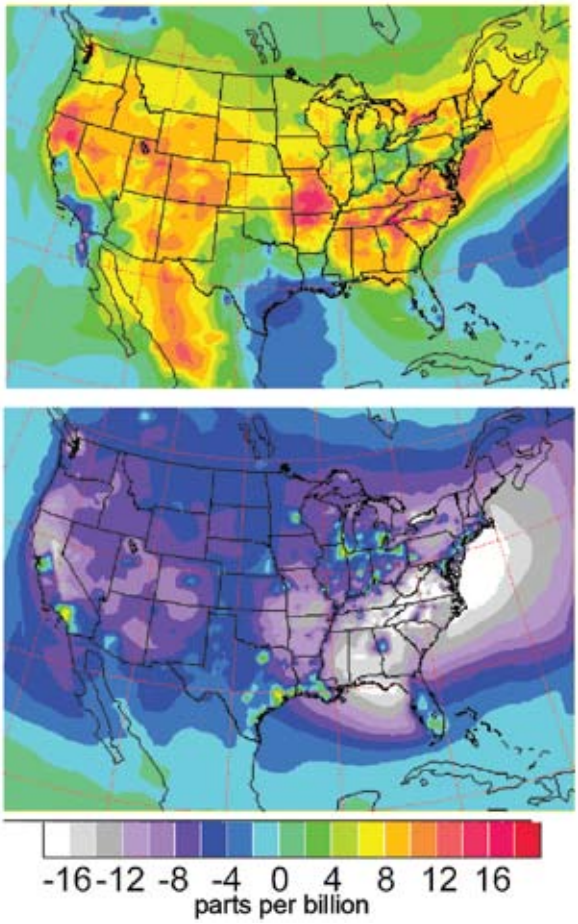
Very small particles (such as soot) arise from burning fossil fuels, principally coal and diesel fuel. These particles cause respiratory symptoms including coughing and difficulty breathing, decreased lung function, aggravated asthma, and development of chronic bronchitis, as well as heart ailments including heart attack and arrhythmia. The most susceptible people include children, older adults, and those with existing heart and lung disease and diabetes[15].

Maximum Daily Ozone Concentrations and
Maximum Daily Temperature in Atlanta and New York





Theses graphs illustrate the observed association between ground-level ozone concentrations and temperature in Atlanta and New York City (May to October 1988-1990). The projected higher temperatures across the U.S. in the 21st century are likely to increase the occurrence of high ozone concentrations, especially since extremely hot days frequently have stagnant air circulation patterns, although this will also depend on emissions of ozone precursors and meteorological factors. Ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function.



Projected changes in summer ground-level ozone for the 2090s relative to 1996-2000 under high emissions (top) and low emissions (bottom) scenarios[13].

Adaptation Strategies

Like many other areas in the country, the Air Quality Alert program in Rhode Island encourages residents to reduce air pollutant emissions by limiting car travel and the use of small engines, lawn mowers, and charcoal lighter fluids. To help cut down on the use of cars, all regular bus routes are free on Air Quality Alert days. Television weather reports include alerts when ground-level ozone is high, warning especially susceptible people to limit their time outdoors.

Pennsylvania offers the following suggestions for high ozone days:

- Refuel vehicles after dark. Avoid spilling gasoline and stop fueling when the pump shuts off automatically.
- Conserve energy. Don't overcool homes. Turn off lights and appliances that are not in use. Wash clothes and dishes only in full loads.
- Limit daytime driving. Consider carpooling or taking public transportation. Properly maintain vehicles, which also helps to save fuel.
- Limit outdoor activities such as mowing the lawn or sports to the evening hours.
- Avoid burning leaves, trash and other materials.

Spotlight on Air Quality in California:

California currently experiences the worst air quality in the nation. More than 90 percent of the population lives in areas that violate air quality standards for ground-level ozone or small particles. These pollutants contribute to 8,800 deaths and $71 billion in health care costs every year in California. Higher temperatures are projected to increase the frequency, intensity and duration of conditions conducive to air pollution formation, potentially increasing by 75 to 85 percent the number of days conducive to air pollution formation in Los Angeles and the San Joaquin Valley. Air quality could be further compromised by wildfires, which are increasing as a result of warming. Recent analysis suggests that if heat-trapping emissions are not significantly curtailed, large wildfires could become up to 55 percent more frequent toward the end of this century[12].

Physical and mental health impacts due to extreme weather events are projected to increase.

Injury, illness, and death are projected to increase as the number and intensity of extreme weather events rises. Human health impacts in the United States are generally projected to be less severe than in poorer countries where the public health infrastructure is less developed. This assumes that medical and emergency relief systems in the U.S. will function well and that timely and effective adaptation measures will be developed and deployed. Of course, we have already seen serious failures of these systems in the aftermath of Hurricanes Katrina and Rita, so we must conclude that coping with future impacts will require significant improvements.

Extreme storms

Over 2,000 Americans were killed in the 2005 hurricane season, more than double the average number of lives lost to hurricanes in the U.S. over the previous 65 years. But the human health impacts of extreme storms go beyond direct injury and death to indirect effects such as carbon monoxide poisoning from portable electric generators in use following hurricanes, an increase in stomach and intestinal illness among evacuees, and mental health impacts such as depression and post-traumatic stress disorder. Failure to fully account for both direct and indirect health impacts may result in inadequate preparation for and response to future extreme weather events[16].

Floods

Heavy downpours have increased in recent decades and are projected to increase further as the world continues to warm. In the U.S., the amount of precipitation falling in the heaviest 1 percent of rain events increased by 20 percent in the past century, while total precipitation increased by 7 percent. Over the last century, there was a 50 percent increase in the frequency of days with precipitation over four inches in the upper Midwest[17]. Other regions, notably the South, have also seen strong increases in heavy downpours, with most of these coming in the warm season and almost all of the increase coming in the last few decades. Heavy rains can lead to flooding which can cause health impacts from direct injuries to increased incidence of water-borne diseases due to bacteria such as cryptosporidium and giardia.

Wildfires

Wildfires in the U.S. are already increasing due to warming. In the West, there has been a nearly fourfold increase in large wildfires in recent decades, with greater fire frequency, longer fire durations, and longer wildfire seasons[18]. This increase is strongly associated with increased spring and summer temperatures and earlier spring snowmelt, which have caused drying of soils and vegetation[19]. In addition to direct injuries and deaths due to burns, wildfires can cause eye and respiratory illnesses due to fire-related air pollution.

Infectious diseases borne by food, water, and insects are projected to increase.

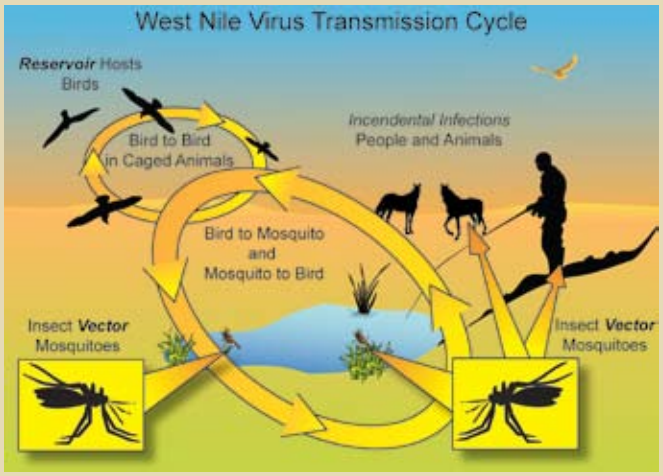
A variety of diseases carried by food, water, or animals like insects, birds, and rodents are projected to increase in a warmer world. A number of important disease-causing agents (pathogens) commonly transmitted by food, water, or animals, are susceptible to changes in replication, survival, persistence, habitat range, and transmission as a result of changing climatic conditions such as increasing temperature, precipitation, and extreme weather events.

- Cases of food poisoning due to *salmonella* and other bacteria increase with rising temperatures.
- Cases of water-borne *cryptosporidium* and *giardia* increase due to heavy downpours. These parasites can be transmitted in drinking water as well as through recreational water use[20].
- Climate change affects the abundance and distribution of the mosquitoes, ticks, and rodents that carry West Nile virus, Equine encephalitis, Lyme disease, and Hantavirus.
- Heavy rain and flooding can contaminate certain food crops with feces from nearby livestock or wild animals, increasing the incidence of food-borne disease associated with fresh produce.
- *Vibrio* accounts for 20 percent of the illnesses and 95 percent of the deaths associated with eating infected shellfish. There is a close association between temperature, *vibrio*, and clinical illness. The U.S. infection rate increased 41 percent from 1996 to 2006. Evidence suggests that rising temperatures will lead to an increased disease burden associated with *vibrio* in shellfish.

Spotlight on West Nile Virus

The first outbreak of West Nile virus in the U.S. occurred in the summer of 1999. The strain of West Nile virus that entered New York City that record hot July differed from other strains of the virus in that it required particularly high temperatures for efficient transmission. Within five years, the disease had spread across the continental United States, transmitted by mosquitoes that acquire the virus from infected birds. During the epidemic summers of 2002-2004 in the U.S., epicenters of West Nile virus were linked to above-average temperatures. Since 1999, West Nile had caused over 24,000 reported cases and over 1,000 Americans have died from it[21]

A more infectious and virulent strain of West Nile Virus has now evolved in the United States. The very hot summer of 2002 likely prompted the spread of this more dangerous, mutated strain. Recent analyses indicate that this strain responds strongly to higher temperatures, suggesting that greater risks from disease will result from future warming[21a].



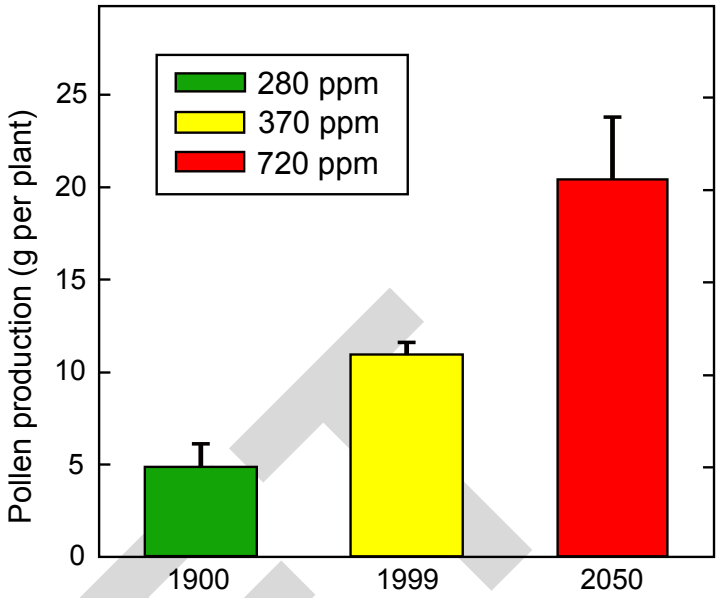
While West Nile virus causes mild flu-like symptoms in most people, about one in 150 infected people develop serious illness, including the brain inflammation diseases encephalitis and meningitis. Projected increases in heat waves portend increased risks from West Nile virus in the future. This disease also provides a good example of how globalization interacts with climate change to increase disease risks. West Nile Virus entered the U.S., probably as a result of international travel, and then responded to the hotter and drier conditions to present a new health threat.

Allergies and asthma are on the rise, with climate change expected to play an increasing role in the future.

There are over 700 plant species known to induce human illness[22]. Rising carbon dioxide levels have already been observed to increase the growth and toxicity of some that are very troublesome. For example, ragweed gets a disproportionately large boost from carbon dioxide compared to many beneficial plants. From a human health perspective, this mean a longer and more intense allergy season, and does not bode well for many asthma sufferers, because 70 percent of them also suffer from allergies and find their asthma exacerbated by allergies.

The observed increase in carbon dioxide levels has roughly doubled the amount of pollen that ragweed produces, and another doubling is projected to occur in this century if carbon dioxide levels continue to rise unrestrained. Pine trees are also projected to double their pollen production by the middle of this century.

Pollen Counts Rise with Increasing Carbon Dioxide



Pollen production from ragweed grown in chambers at carbon dioxide levels of a century ago (about 280 parts per million [ppm]). was about 5 grams per plant; at today's approximate carbon dioxide level, it was about 10 grams; and at a level projected to occur during this century if emissions are not reduced, it was about 20 grams[23].


Pollen on car

Poison Ivy

Poison ivy growth and toxicity is also greatly increased by carbon dioxide, with plants growing larger and more poisonous. These increases are much greater than those of most beneficial plants. For example, poison ivy vines grow twice as much per year in air with doubled pre-industrial carbon dioxide levels as in unaltered air, which is nearly five times the increase reported for tree species in other analyses[24]. Recent and projected increases carbon dioxide have also been shown to stimulate the growth of stinging net and leafy spurge, two weeds that cause rashes when they come into contact with human skin[25,26] .

Certain groups, including children, the elderly, and the poor, are most vulnerable to the range of health effects.

Infants and children, pregnant women, the elderly, people with chronic medical conditions, outdoor workers, and people living in poverty are especially at risk from increasing heat stress, air pollution, extreme weather events, and diseases carried by food, water and insects.

Children's small body mass to surface area ratio and other factors make them more vulnerable to heat-related illness and death. Their increased breathing rates relative to body size, time spent outdoors, and developing respiratory tracts heighten their sensitivity to air pollution impacts. In addition, children's immature immune systems increase their risk of serious consequences from water- and food-borne diseases, while developmental factors make them more vulnerable to complications from severe infections such as *E coli*.

Pregnant women have increased susceptibility to a variety of climate-sensitive infectious diseases including malaria and food-borne infections[27]. The greatest health burdens generally fall on the poor, who are more likely to have inadequate housing and to lack access to health care and air conditioning.

Some elderly people are frail and have limited mobility. The elderly are also generally more sensitive to extreme heat for several reasons. They have a reduced ability to regulate their own body temperature or sense when they are too hot. They are at greater risk of heart failure that is exacerbated when greater cardiac output is required for cooling during heat waves. They may also be on medications, such as diuretics for high blood pressure, increasing the risk of dehydration. People 65 years of age and older comprised 72 percent of the heat-related deaths due to the 1995 Chicago heat wave[28]. Older people are also more likely to have preexisting medical conditions that may put them at greater risk of harm from climate-related events or conditions.

The multiple health risks associated with diabetes will increase the vulnerability of the U.S. population to human-induced warming. The number of Americans with diabetes has grown to about 24 million people, or roughly 8 percent of the U.S. population. Almost 25 percent of the population 60 years and older had diabetes in 2007[29]. Fluid imbalance and dehydration create higher risks for diabetics during heat waves. People with diabetes related heart disease are at especially increased risk of dying in heat waves.

Adaptation Strategies

People who are more fit are better able to cope with heat stress. Thus, taking steps to reduce obesity is a strategy for adapting to a warmer world. High obesity rates in the United States are one cause of the current rise in diabetes. A factor in rising obesity rates is a sedentary lifestyle and automobile dependence; 60 percent of Americans do not meet minimum daily exercise requirements. Making cities more walk-able and bike-able would thus have multiple benefits: personal fitness and weight loss; reduced local air pollution and associated respiratory illness; and reduced greenhouse gas emissions.