

9. Human Health

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Key Messages:

- 1. Climate change threatens human health and well-being in many ways, including impacts from increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes, ticks, and fleas. Some of these health impacts are already underway in the United States.**
- 2. Climate change will, absent other changes, amplify some of the existing health threats the nation now faces. Certain people and communities are especially vulnerable, including children, the elderly, the sick, the poor, and some communities of color.**
- 3. Public health actions, especially preparedness and prevention, can do much to protect people from some of the impacts of climate change. Early action provides the largest health benefits. As threats increase, our ability to adapt to future changes may be limited.**
- 4. Responding to climate change provides opportunities to improve human health and well-being across many sectors, including energy, agriculture, and transportation. Many of these strategies offer a variety of benefits, protecting people while combating climate change and providing other societal benefits.**

1 Climate change, together with other natural and human-made health stressors, influences human
2 health and disease in numerous ways. Some existing health threats will intensify and new health
3 threats will emerge. Not everyone is equally at risk. Important considerations include age,
4 economic resources, and location. Preventive and adaptive actions, such as setting up extreme
5 weather early warning systems and improving water infrastructure, can reduce the severity of
6 these impacts, but there are limits to the effectiveness of such actions in the face of some
7 projected climate change threats.

8 Climate change presents a global public health problem, with serious health impacts predicted to
9 manifest in varying ways in different parts of the world. Public health in the U.S. can be affected
10 by disruptions of physical, biological, and ecological systems, including disturbances originating
11 in the U.S. and elsewhere. Health effects of these disruptions include increased respiratory and
12 cardiovascular disease, injuries and premature deaths related to extreme weather events, changes
13 in the prevalence and geographical distribution of food- and waterborne illnesses and other
14 infectious diseases, and threats to mental health.

15 Key weather and climate drivers of health impacts include: increasingly frequent, intense, and
16 longer-lasting extreme heat, which worsens drought, wildfire, and air pollution risks;
17 increasingly frequent extreme precipitation, intense storms, and changes in precipitation patterns
18 that lead to drought and ecosystem changes (Ch. 2: Our Changing Climate); and rising sea levels
19 that intensify coastal flooding and storm surge (Ch. 25: Coasts). Key drivers of vulnerability
20 include the attributes of certain groups (age, socioeconomic status, race, current level of health)
21 (See Ch. 12: Indigenous Peoples for examples of health impacts on vulnerable populations) and
22 of place (floodplains, coastal zones, urban areas), as well as the resilience of critical public health
23 infrastructure.

24 ***Wide-ranging Health Impacts***

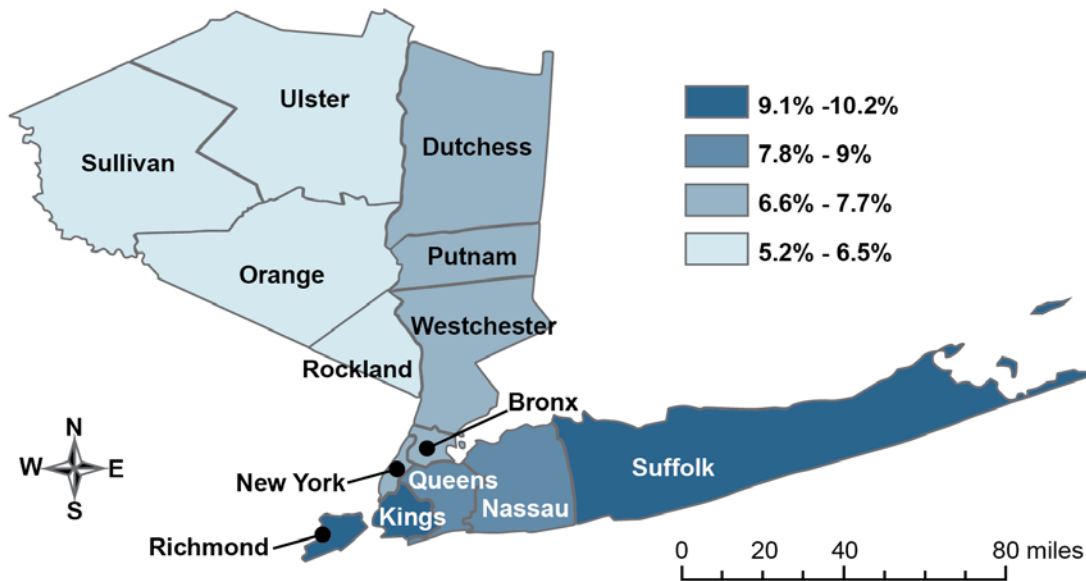
25 **Climate change threatens human health and well-being in many ways, including impacts**
26 **from increased extreme weather events, wildfire, decreased air quality, threats to mental**
27 **health, and illnesses transmitted by food, water, and disease-carriers such as mosquitoes,**
28 **ticks, and fleas. Some of these health impacts are already underway in the United States.**

29 **Air Pollution**

30 Climate change is projected to harm human health by increasing ground-level ozone and
31 particulate matter air pollution in some locations. Ground-level ozone (a key component of
32 smog) is associated with many health problems, such as diminished lung function, increased
33 hospital admissions and emergency room visits for asthma, and increases in premature deaths.^{1,2}
34 Factors that affect ozone formation include heat, concentrations of precursor chemicals, and
35 methane emissions, while particulate matter concentrations are affected by wildfire emissions
36 and air stagnation episodes, among other factors.^{3,4} By increasing these different factors, climate
37 change is projected to lead to increased concentration of ozone and particulate matter in some
38 regions.^{5,6,7,8} Increases in global temperatures could cause associated increases in premature
39 deaths related to worsened ozone and particle pollution. Estimates have ranged from 1,000 to
40 4,300 additional premature deaths nationally per year by 2050 from combined ozone and particle
41 health effects.^{9,10} There is less certainty in the responses of airborne particles to climate change
42 than there is about the response of ozone. Health-related costs of the current effects of ozone air

1 pollution exceeding national standards have been estimated at \$6.5 billion (in 2008 U.S. dollars)
 2 nationwide, based on a U.S. assessment of health impacts from ozone levels during 2000 to
 3 2002.^{11,12}

Projected Climate Change Worsens Asthma



4
 5 **Figure 9.1:** Projected Climate Change Worsens Asthma

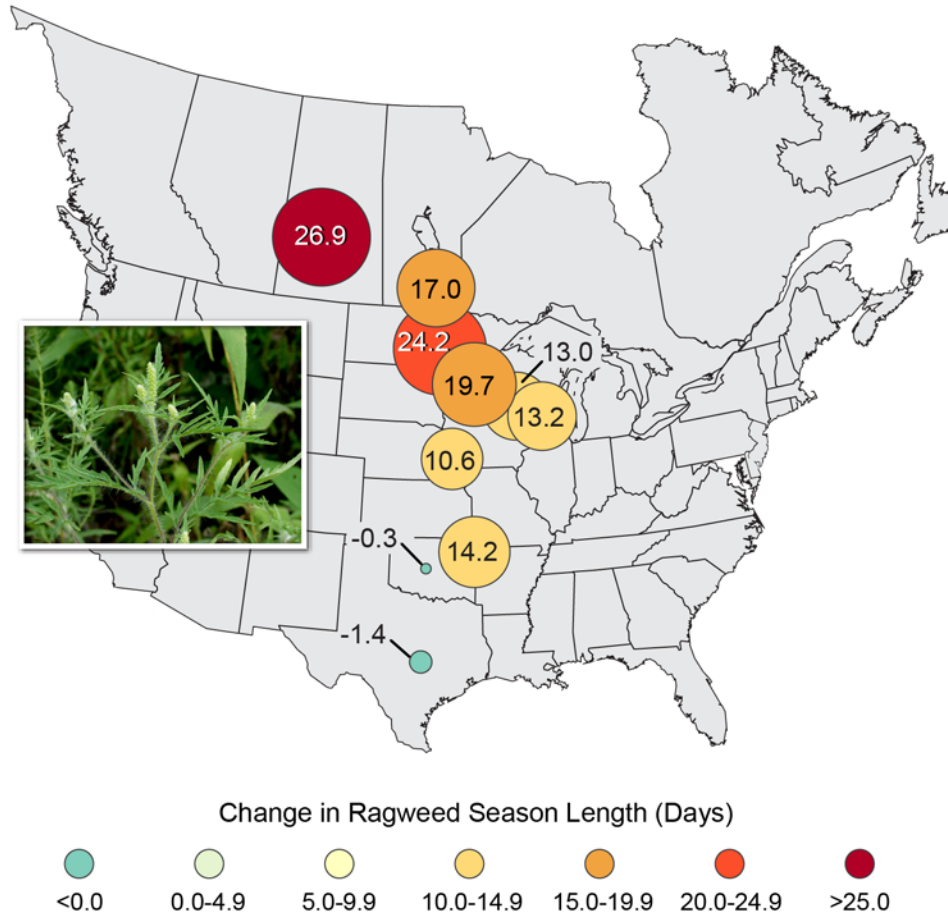
6 **Caption:** Projected climate change will increase temperatures, which will affect ground-
 7 level ozone concentrations. The figure shows projected percentage increases in
 8 emergency room visits for ozone-related asthma among children in the New York City
 9 region by the 2020s, associated with the effects of climate change. Projections for
 10 changing severity of asthma symptoms and increased need for disease management, with
 11 locally increasing ground-level ozone concentrations, are relative to mid 1990s baseline
 12 conditions and assume climate change associated with increasing emissions (A2
 13 scenario). Asthma accounts for one-quarter of all emergency room visits in the U.S. –
 14 1.75 million each year. Costs for this chronic disease increased from an estimated \$53
 15 billion in 2002 to about \$56 billion in 2007. In 2010, an estimated 25.7 million
 16 Americans had asthma, which has become a problem in every state. The condition is
 17 distinctly prevalent in California’s Central Valley, where one out of every six children
 18 has asthma symptoms. (Figure source: Sheffield et al. 2011b).¹³

19 **Allergens**

20 Climate change, as well as increased CO₂ by itself, can contribute to increased production of
 21 plant-based allergens.^{13,14,15,16,17,18} Higher pollen concentrations and longer pollen seasons
 22 increase allergic sensitizations and asthma episodes,^{19,20,21} and diminish productive work and
 23 school days.^{18,21,22} Simultaneous exposure to toxic air pollutants can worsen allergic
 24 responses.^{23,24,25} Extreme rainfall and rising temperatures can also foster indoor air quality

1 problems, including the growth of indoor fungi and molds, with increases in respiratory and
2 asthma-related conditions.²⁶

Ragweed Pollen Season Lengthens



3
4 **Figure 9.2:** Ragweed Pollen Season Lengthens

5 **Caption:** Ragweed pollen season length has increased in central North America between
6 1995 and 2011 by as much as 11 to 27 days in parts of the U.S. and Canada, in response
7 to rising temperatures. Increases in the length of this allergenic pollen season are
8 correlated with increases in the number of days before the first frost. As shown in the
9 figure, the largest increases have been observed in northern cities. In 2012, a warm winter
10 leading to early pollen production among trees and plants, followed by hot, dry, low-
11 humidity conditions through the spring and summer contributed to wide circulation of
12 aeroallergens and a severe allergy season, according to reports from physicians. (Data
13 from Ziska et al. 2012;¹⁸ Photo credit: Lewis Ziska, USDA).

14

1 Wildfires

2 Climate change has already contributed to increasing wildfire frequency (Ch. 7: Forests).^{16,27}
3 Long periods of record high temperatures are associated with droughts that contribute to dry
4 conditions and drive wildfires in some areas.²⁸ Nationally, 3,445 people in the U.S. died as a
5 result of wildfires in 2010.²⁹ Wildfire smoke contains particulate matter, carbon monoxide,
6 nitrogen oxides, and various volatile organic compounds (which are ozone precursors)³⁰ and can
7 significantly reduce air quality, both locally and in areas downwind of fires.^{31,32} Smoke exposure
8 increases respiratory and cardiovascular hospitalizations, emergency department visits and
9 medication dispensations for asthma, bronchitis, chest pain, chronic obstructive pulmonary
10 disease (commonly known by its acronym, COPD), respiratory infections, and medical visits for
11 lung illnesses.^{31,33,34} It has been associated with hundreds of thousands of deaths annually, in an
12 assessment of the global health risks from landscape fire smoke.^{31,33,35,36} Future climate change is
13 projected to increase wildfire risks and associated emissions, with harmful impacts on
14 health.^{16,37,38,39}

Wildfire Smoke has Widespread Health Effects



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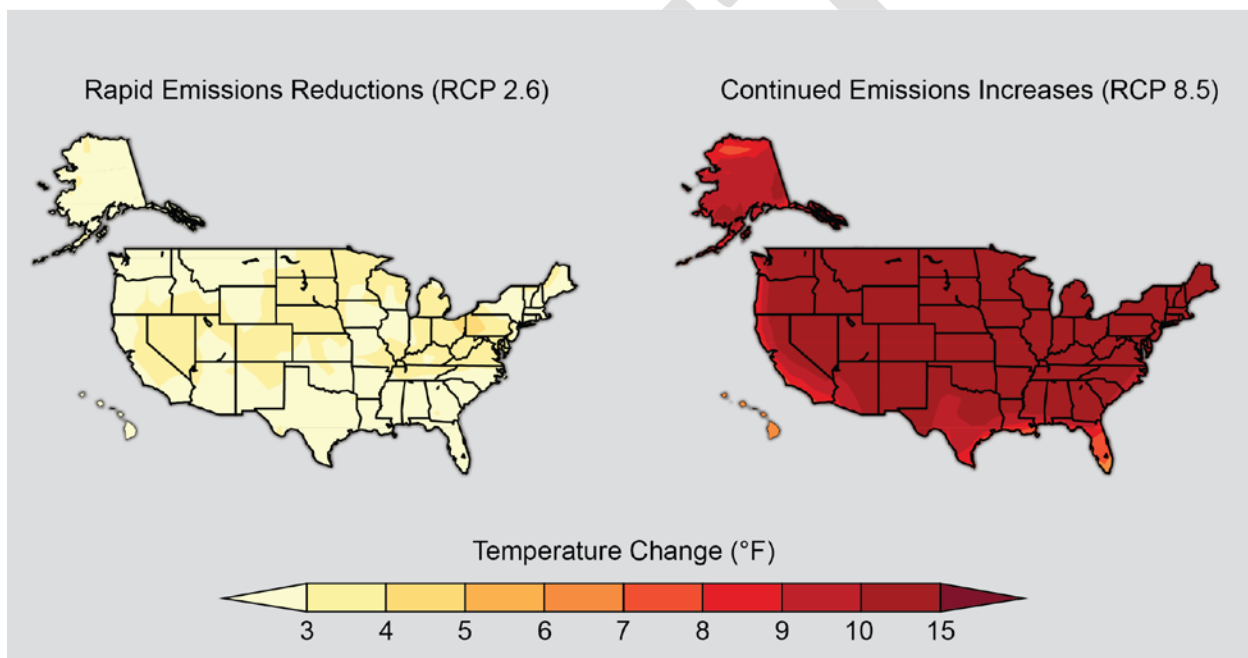
2 **Figure 9.3:** Wildfire Smoke has Widespread Health Effects

3 **Caption:** Wildfires, which are increasing in part due to climate change, have health
 4 impacts that can extend thousands of miles. Shown here, forest fires in Quebec, Canada
 5 during July 2002 (red circles) resulted in up to a 30-fold increase in airborne fine particle
 6 concentrations in Baltimore, Maryland, a city nearly a thousand miles downwind. These
 7 fine particles, which are extremely harmful to human health, not only affect outdoor air
 8 quality, but also penetrate indoors, increasing the long-distance effects of fires on health.
 9 U.S. wildfires in 2012, at almost 9.2 million acres burned, were exceeded only by U.S.
 10 wildfires in 2006 when over 9.5 million acres were burned or destroyed.⁴⁰ Global deaths
 11 from landscape fire smoke have been estimated at 260,000 to 600,000 annually.³⁶ (Figure
 12 source: MODIS satellite, Land Rapid Response Team, NASA/GSFC).

1 Temperature Extremes

2 Extreme heat events have long threatened public health in the United States.^{41,42,43} Many cities,
 3 including St. Louis, Philadelphia, Chicago, and Cincinnati, have suffered dramatic increases in
 4 death rates during heat waves. Deaths result from heat stroke and related conditions,^{42,43,44} but
 5 also from cardiovascular disease, respiratory disease, and cerebrovascular disease.^{45,46} Heat
 6 waves are also associated with increased hospital admissions for cardiovascular, kidney, and
 7 respiratory disorders.^{46,47,48} Extreme summer heat is increasing in the U.S. (Ch. 2: Our Changing
 8 Climate; Key Message 7),⁴⁹ and climate projections indicate that extreme heat events will be
 9 more frequent and intense in coming decades (Ch. 2: Our Changing Climate; Key Message
 10 7).^{2,50,51,52}

Projected Temperature Change of Hottest Days



11 **Figure 9.4:** Projected Temperature Change of Hottest Days

12 **Caption:** The maps show projected increases in the average temperature on the hottest
 13 days by late this century (2081-2100) relative to 1986-2005 under a scenario that assumes
 14 a rapid reduction in heat-trapping gases (RCP 2.6) and a scenario that assumes continued
 15 increases in these gases (RCP 8.5). The hottest days are those so hot they occur only once
 16 in 20 years; across most of the continental U.S., those days will be about 10°F to 15°F
 17 hotter in the future than they have been. (Figure source: NOAA NCDC / CICS-NC).
 18

19 Some of the risks of heat-related sickness and death have diminished in recent decades, possibly
 20 due to better forecasting, heat-health early warning systems, and/or increased access to air
 21 conditioning for the U.S. population.⁵³ However, extreme heat events remain a cause of
 22 preventable death among older people nationwide. Urban heat islands, combined with an aging

1 population and increased urbanization, are projected to increase the vulnerability of urban
2 populations to heat-related health impacts in the future (Ch. 11: Urban).^{54,55,56}

3 Milder winters resulting from a warming climate can reduce illness, injuries, and deaths
4 associated with cold and snow. Vulnerability to winter weather depends on many non-climate
5 factors, including housing, age, and baseline health.⁵⁷ While deaths and injuries related to
6 extreme cold events are projected to decline due to climate change,⁵⁸ these reductions are not
7 expected to compensate for the increase in heat-related deaths.^{58,59}

8 **Precipitation Extremes: Heavy Rainfall, Flooding, and Droughts**

9 The frequency of heavy precipitation events has already increased for the nation as a whole, and
10 is projected to increase in all U.S. regions (Ch. 2: Our Changing Climate).^{52,60} Increases in both
11 extreme precipitation and total precipitation have contributed to increases in severe flooding
12 events in certain regions (See Ch. 2: Our Changing Climate, Figure 2.21). Floods are the second
13 deadliest of all weather-related hazards in the U.S., accounting for approximately 98 deaths per
14 year,⁶¹ most due to drowning.⁶² Flash floods (See Ch. 3: Water, Flood box) and flooding
15 associated with tropical storms result in the highest number of deaths.⁶¹

16 In addition to the immediate health hazards associated with extreme precipitation events when
17 flooding occurs, other hazards can often appear once a storm event has passed. Waterborne
18 disease outbreaks typically result in the weeks following inundation,⁶³ and water intrusion into
19 buildings can result in mold contamination that manifests later, leading to indoor air quality
20 problems. Buildings damaged during hurricanes are especially susceptible to water intrusion.
21 Those living in damp indoor environments experience increased prevalence of asthma and other
22 upper respiratory tract symptoms, such as coughing and wheezing⁶⁴ as well as lower respiratory
23 tract infections such as pneumonia, Respiratory Syncytial Virus (RSV), and RSV pneumonia
24 (see Figure 9.7).⁶⁵

25 At the opposite end of precipitation extremes, drought also poses risks to public health and
26 safety.⁶⁶ Drought conditions may increase the environmental exposure to a broad set of health
27 hazards including wildfires, dust storms, extreme heat events, flash flooding, degraded water
28 quality, and reduced water quantity. Dust storms associated with drought conditions contribute to
29 degraded air quality due to particulates and have been associated with increased incidence of
30 Coccidioidomycosis (Valley fever), a fungal pathogen, in Arizona and California.⁶⁷

31

1 **Disease Carried by Vectors**

2 Climate is one of the factors that influence the distribution of diseases borne by vectors (such as
3 fleas, ticks, and mosquitoes, which spread pathogens that cause illness).^{68,69,70,71,72,73,74,75} The
4 geographic and seasonal distribution of vector populations, and the diseases they can carry,
5 depend not only on climate, but also on land use, socioeconomic and cultural factors, pest
6 control, access to health care, and human responses to disease risk, among other
7 factors.^{69,70,76,77,78} Daily, seasonal, or year-to-year climate variability can sometimes result in
8 vector/pathogen adaptation and shifts or expansions in their geographic ranges.^{70,71,78} Such shifts
9 can alter disease incidence depending on vector-host interaction, host immunity, and pathogen
10 evolution.⁶⁸

11 North Americans are currently at risk from numerous vector-borne diseases, including
12 Lyme,^{72,79,80} dengue fever,⁸¹ West Nile virus,⁸² Rocky Mountain spotted fever,⁸³ plague, and
13 tularemia.⁸⁴ Vector-borne pathogens not currently found in the U.S., such as chikungunya,
14 Chagas disease, and Rift Valley fever viruses, are also threats. Climate change effects on the
15 geographical distribution and incidence of vector-borne diseases in other countries where these
16 diseases are already found can also affect North Americans, especially as a result of increasing
17 trade with, and travel to, tropical and subtropical areas.^{71,78} Whether climate change in the U.S.
18 will increase the chances of acquiring diseases such as dengue fever in the U.S. is uncertain, due
19 to vector-control efforts and lifestyle factors, such as time spent indoors, that reduce human-
20 insect contact.

21 Infectious disease transmission is sensitive to local, small-scale differences in weather, human
22 modification of the landscape, and human behavior that affects vector-human contact, among
23 other factors. There is a need for finer-scale, long-term studies to help quantify the relationships
24 among weather variables, vector range, and vector-borne pathogen occurrence, the consequences
25 of shifting distributions of vectors and pathogens, and the impacts on human behavior. Enhanced
26 vector surveillance and human disease tracking are needed to address these concerns.

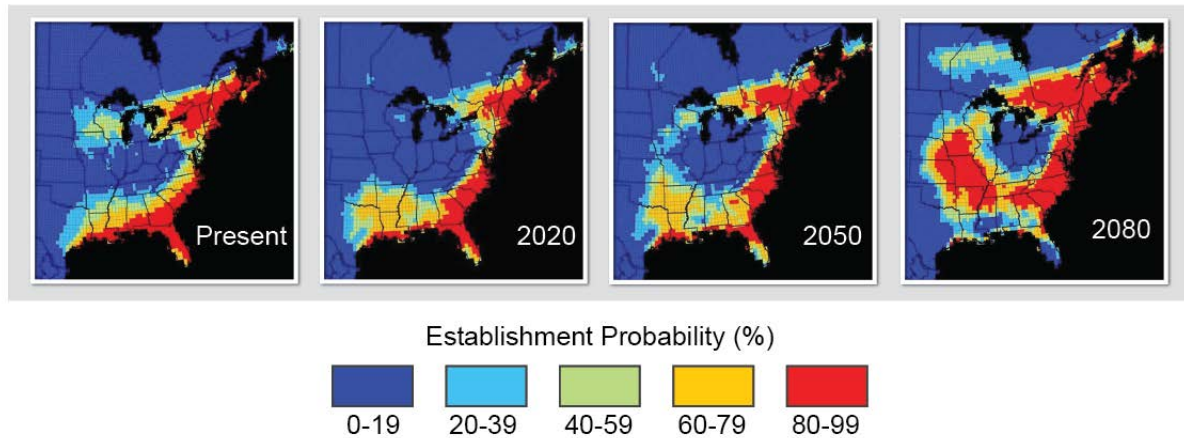
27 **Box: Transmission Cycle of Lyme Disease**

28 The development and survival of blacklegged ticks, their animal hosts, and the Lyme disease
29 bacterium, *B. burgdorferi*, are strongly influenced by climatic factors, especially temperature,
30 precipitation, and humidity. Potential impacts of climate change on the transmission of Lyme
31 disease include: 1) changes in the geographic distribution of the disease due to the increase in
32 favorable habitat for ticks to survive off their hosts;⁸⁵ 2) a lengthened transmission season due to
33 earlier onset of higher temperatures in the spring and later onset of cold and frost; 3) higher tick
34 densities leading to greater risk in areas where the disease is currently observed due to milder
35 winters and potentially larger rodent host populations; and 4) changes in human behaviors,
36 including increased time outdoors, which may increase the risk of exposure to infected ticks.

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Projected Changes in Tick Habitat



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3 **Figure 9.5:** Projected Changes in Tick Habitat

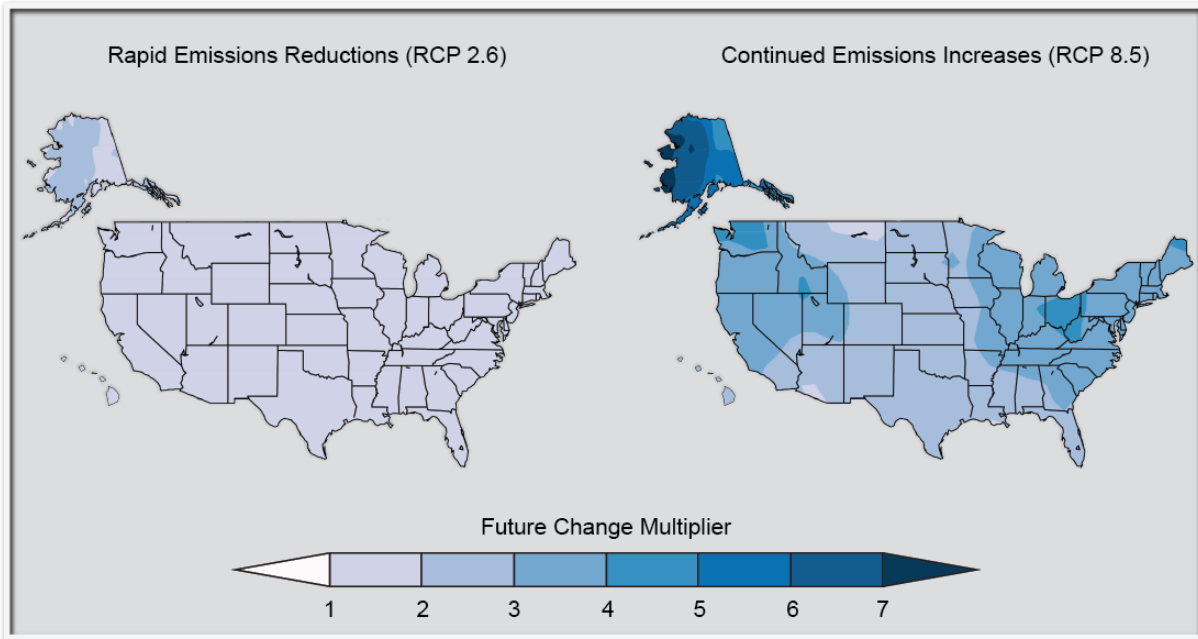
4 **Caption:** The maps show the current and projected probability of establishment of tick
 5 populations (*Ixodes scapularis*) that transmit Lyme disease. Projections are shown for
 6 2020, 2050, and 2080. The projected expansion of tick habitat includes much of the
 7 eastern half of the country by 2080. For some areas around the Gulf Coast, the
 8 probability of tick population establishment is projected to decrease by 2080. (Figure
 9 source: adapted from Brownstein et al. 2005).⁸⁶

10 **Food- and Waterborne Diarrheal Disease**

11 Diarrheal disease is a major public health issue in developing countries and a persistent concern
 12 in the United States. Exposure to a variety of pathogens in water and food causes diarrheal
 13 disease. Air and water temperatures, precipitation patterns, extreme rainfall events, and seasonal
 14 variations are all known to affect disease transmission.^{87,88,89} In the U.S., older adults are most
 15 vulnerable to serious outcomes, and those exposed to inadequately or untreated groundwater will
 16 be among those most affected.

17 In general, diarrheal diseases including Salmonellosis and Campylobacteriosis are more common
 18 when temperatures are higher,^{90,91} though patterns differ by place and pathogen. Diarrheal
 19 diseases have also been found to occur more frequently in conjunction with both unusually high
 20 and low precipitation.⁹² Sporadic increases in streamflow rates, often preceded by rapid
 21 snowmelt⁹³ and changes in water treatment,⁹⁴ have also been shown to precede outbreaks. Risks
 22 of waterborne illness and beach closures resulting from changes in the magnitude of recent
 23 precipitation (within the past 24 hours) and lake temperature are expected to increase in the
 24 Great Lakes region due to projected climate change.^{95,96}

Projected Change in Heavy Precipitation Events



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Figure 9.6: Projected Change in Heavy Precipitation Events

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Caption: Maps show the increase in frequency of extreme daily precipitation events (a daily amount that now occurs just once in 20 years) by the later part of this century (2081-2100) compared to the latter part of the last century (1981-2000). Such extreme events are projected to occur more frequently everywhere in the U.S. Under a rapid emissions reduction scenario (RCP 2.6), these events would occur nearly twice as often. For a scenario assuming continued increases in emissions (RCP 8.5), these events would occur up to five times as often. (Figure source: NOAA NCDC / CICS-NC).

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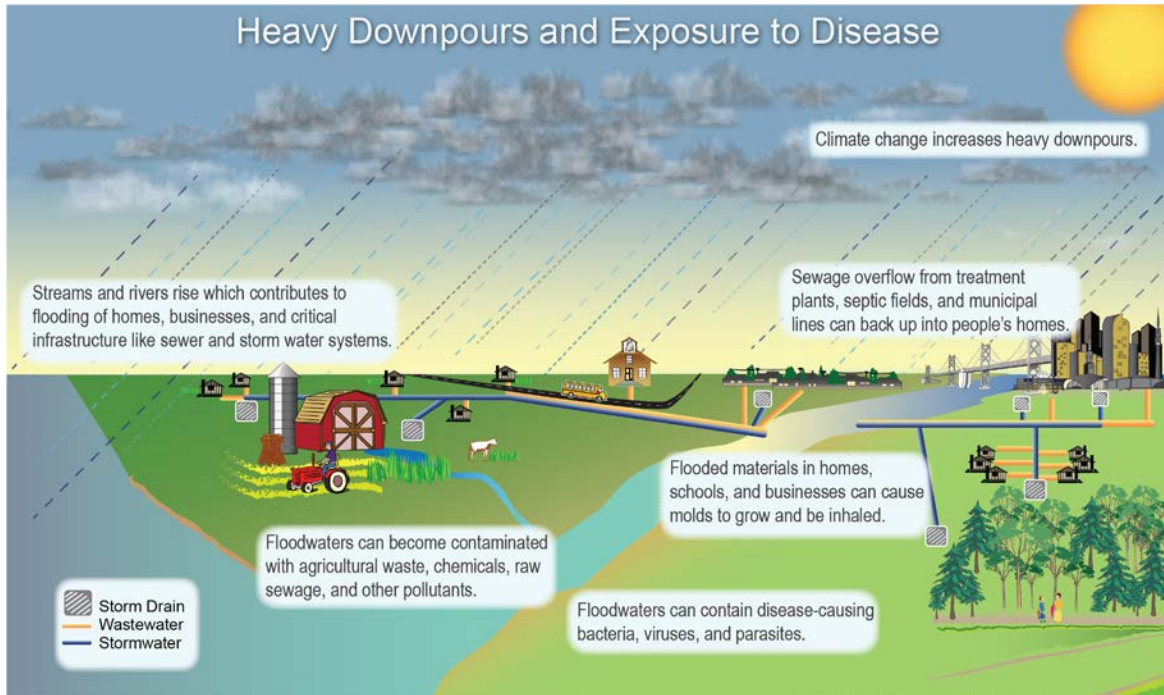
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Figure 9.7: Heavy Downpours and Exposure to Disease

Caption: Heavy downpours, which are increasing in the U.S., have contributed to increases in heavy flood events (Ch. 2: Our Changing Climate, Key Message 6). The figure above illustrates how people can become exposed to waterborne diseases, which typically arise in the weeks following inundation.⁶³ Human exposures to waterborne diseases can occur via drinking water, as well as recreational waters.^{97,98,99,100} (Figure source: NOAA NCDC / CICS-NC).

Harmful Bloom of Algae



1

2 **Figure 9.8:** Harmful Bloom of Algae

3 **Caption:** Remote sensing color image of harmful algal bloom in Lake Erie on October 9,
 4 2011. The bright green areas have high concentrations of algae, which can be harmful to
 5 human health. The frequency and range of harmful blooms of algae are increasing.^{99,100}
 6 Because algal blooms are closely related to climate factors, projected changes in climate
 7 are likely affecting the observed changes in algal blooms. Other factors related to
 8 increases in harmful algal blooms include shifts in ocean conditions such as excess
 9 nutrient inputs.^{98,100} (Figure source: NASA Earth Observatory).

10 Food Security

11 Globally, climate change is expected to threaten both food production and certain aspects of food
 12 quality. Many crop yields are predicted to decline due to the combined effects of changes in
 13 rainfall, severe weather events, and increasing competition from weeds and pests on crop plants
 14 (Ch. 6: Agriculture; Key Message 6).^{101,102} Livestock and fish production¹⁰³ is also projected to
 15 decline. Prices are expected to rise in response to declining food production and associated
 16 trends such as increasingly expensive petroleum (used for agricultural inputs such as pesticides
 17 and fertilizers).¹⁰⁴

18 While the U.S. will be less affected than some other countries,^{105,106} the nation will not be
 19 immune. Health can be affected in several ways. First, Americans with particular dietary
 20 patterns, such as Alaskan natives, will confront shortages of key foods (Ch. 12: Indigenous
 21 Peoples; Key Message 1).¹⁰⁷ Second, food insecurity increases with rising food prices.¹⁰⁸ In such
 22 situations, people cope by turning to nutrient-poor but calorie-rich foods, and/or they endure
 23 hunger, with consequences ranging from micronutrient malnutrition to obesity.¹⁰⁹ Third, the
 24 nutritional value of some foods is projected to decline. Elevated atmospheric CO₂ is associated
 25 with decreased nitrogen concentration, and therefore decreased protein, in many crops, such as
 26 barley, sorghum, and soy.¹¹⁰ The nutrient content of crops is also projected to decline, with

1 reduced levels of nutrients such as calcium, iron, zinc, vitamins, and sugars.¹¹¹ Fourth, farmers
2 are expected to need to use more herbicides and pesticides because of increased growth of
3 pests¹¹² and weeds¹¹³ as well as decreased effectiveness¹¹⁴ and duration¹¹⁵ of some of these
4 chemicals (Ch. 6: Agriculture). Farmers, farmworkers, and consumers will thus sustain increased
5 exposure to these substances and their residues, which can be toxic. These climate change
6 impacts on the nutritional value of food exist within a larger context in which other factors, such
7 as agricultural practices, food distribution systems, and consumer food choices, also play a role.

8 **Mental Health and Stress-related Disorders**

9 Mental illness is one of the major causes of suffering in the U.S., and extreme weather events can
10 affect mental health in several ways.^{116,117,118,119} First, following disasters, mental health
11 problems increase, both among people with no history of mental illness, and those at risk, a
12 phenomenon known as “common reactions to abnormal events.” These reactions may be short-
13 lived or, in some cases, long-lasting.¹²⁰ For example, research demonstrated high levels of
14 anxiety and post-traumatic stress disorder among people affected by Hurricane Katrina,¹²¹ and
15 similar observations have followed floods,¹²² heat waves,¹²³ and wildfires¹²⁴ – events
16 increasingly fueled by climate change (See Ch. 2: Our Changing Climate). Indirect health
17 consequences are also a concern, such as adverse birth outcomes including pre-term birth, low
18 birth weight, and maternal complications.¹²⁵

19 Second, some patients with mental illness are especially susceptible to heat.¹²⁶ Suicide varies
20 seasonally¹²⁷ and rises with hot weather,¹²⁸ suggesting potential climate change impacts on
21 depression and other mental illnesses. Dementia is a risk factor for hospitalization and death
22 during heat waves.^{123,129} Patients with severe mental illness such as schizophrenia are at risk
23 during hot weather related both to their illness¹³⁰ and because their medications may interfere
24 with temperature regulation or even directly cause hypothermia.¹³¹ Additional potential mental
25 health impacts, less well understood, include the distress associated with environmental
26 degradation¹³² and displacement,¹³³ and the anxiety and despair that knowledge of climate
27 change might elicit in some people (Ch. 12: Indigenous Peoples; Key Message 5).¹¹⁸

Elements of Vulnerability to Climate Change

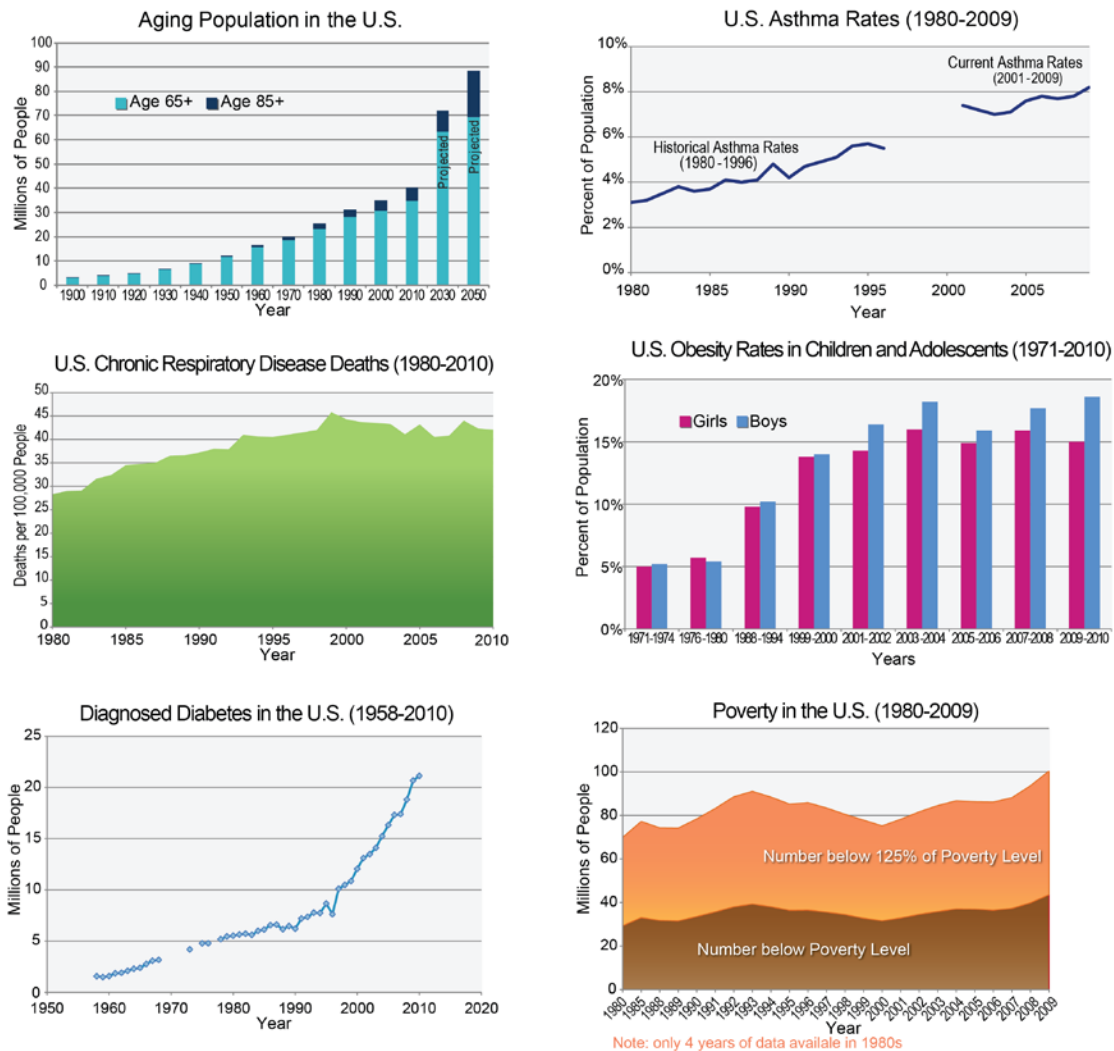


Figure 9.9: Elements of Vulnerability to Climate Change

Caption: A variety of factors can increase the vulnerability of a specific demographic group to health effects due to climate change. For example, older adults are more vulnerable to heat stress because their bodies are less able to regulate their temperature. Overall population growth is projected to continue to at least 2050, with older adults comprising an increasing proportion of the population. Similarly, there are an increasing number of people who are obese and have diabetes, heart disease, or asthma, which makes them more vulnerable to a range of climate-related health impacts. Their numbers are also rising. The poor are less able to afford the kinds of measures that can protect them from and treat them for various health impacts. (Data from CDC; Health E-Stat; U.S. Census Bureau 2010, 2012; and Akinbami et al. 2011).¹³⁴

1 ***Most Vulnerable at Most Risk***

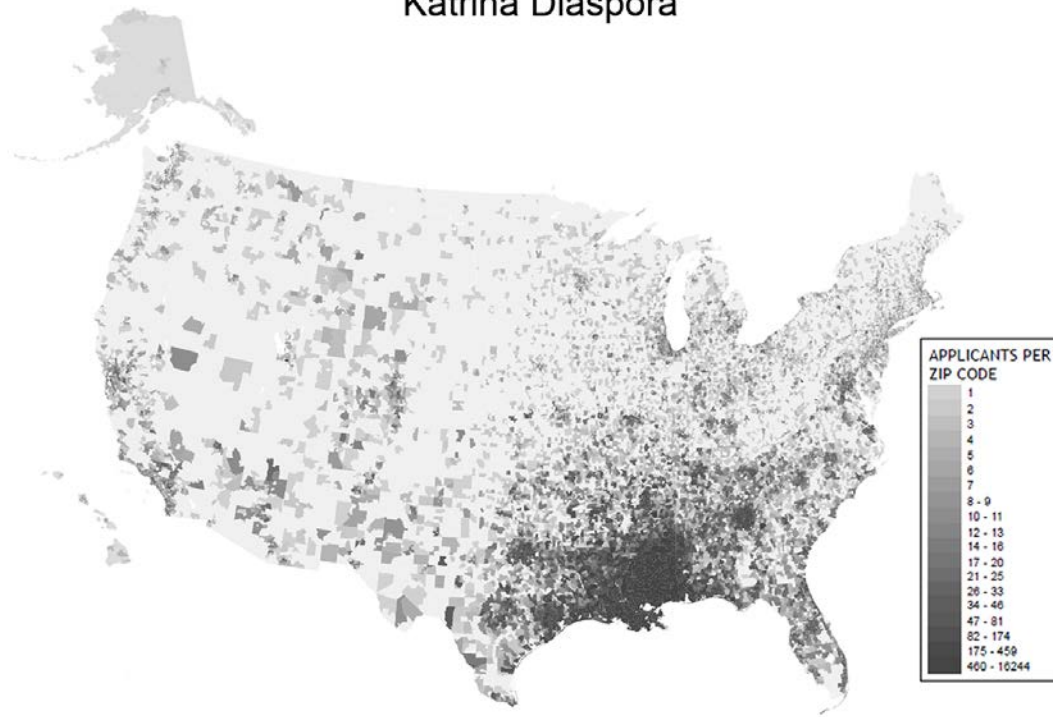
2 **Climate change will, absent other changes, amplify some of the existing health threats the**
3 **nation now faces. Certain people and communities are especially vulnerable, including**
4 **children, the elderly, the sick, the poor, and some communities of color.**

5 Climate change will increase the risk of climate-related illness and death for a number of
6 vulnerable groups in the U.S., as when Hurricane Katrina devastated New Orleans in 2005.
7 Children, primarily because of physiological and developmental factors, will disproportionately
8 suffer from the effects of heat waves,⁴⁵ air pollution, infectious illness, and trauma resulting from
9 extreme weather events.^{13,15,17,21,135,136,137,138} The country's older population also could be harmed
10 more as the climate changes. Older people are at much higher risk of dying during extreme heat
11 events.^{43,45,136,139} Pre-existing health conditions also make older adults susceptible to cardiac and
12 respiratory impacts of air pollution²⁵ and to more severe consequences from infectious
13 diseases;¹⁴⁰ limited mobility among older adults can also increase flood-related health risks.¹⁴¹
14 Limited resources and an already high burden of chronic health conditions, including heart
15 disease, obesity, and diabetes, will place the poor at higher risk of health impacts from climate
16 change than higher income groups.^{25,45} Potential increases in food cost and limited availability of
17 some foods will exacerbate current dietary inequalities and have significant health ramifications
18 for the poorer segments of our population (Ch. 12: Indigenous Peoples; Key Message 1).^{106,142}

19 **Box: Societal System Failures During Extreme Events**

20 We have already seen multiple system failures during an extreme weather event in the U.S., as
21 when Hurricane Katrina struck New Orleans.¹⁴³ Infrastructure and evacuation failures
22 and collapse of critical response services during a storm is one example of multiple system
23 failures. Another example is a loss of electrical power during a heat wave or wildfires, which can
24 reduce food and water safety.¹⁴⁴ Air conditioning has helped reduce illness and death due to
25 extreme heat,¹⁴⁵ but if power is lost, everyone is vulnerable. By their nature, such events can
26 exceed our capacity to respond.⁷⁶ In succession, these events severely deplete our resources
27 needed to respond, from the individual to the national scale, but disproportionately affect the
28 most vulnerable populations.¹⁴⁶

Katrina Diaspora



1

2 **Figure 9.10:** Katrina Diaspora

3 **Caption:** This map illustrates the national scope of the dispersion of displaced people
 4 from Hurricane Katrina. It shows the location by zip code of the 800,000 displaced
 5 Louisiana residents who requested federal emergency assistance. The evacuees ended up
 6 dispersed across the entire nation, illustrating the wide-ranging impacts that can flow
 7 from extreme weather events, such as those that are projected to increase in frequency
 8 and/or intensity as climate continues to change (Ch. 2: Our Changing Climate; Key
 9 Message 8). (Figure source: Kent 2006).¹⁴⁷

10 -- end box --

11 Climate change will disproportionately affect low-income communities and some communities
 12 of color (Ch. 12: Indigenous Peoples; Key Message 2),^{136,146,148,149,150,151,152,153,154,155} raising
 13 environmental justice concerns. Existing health disparities^{151,156,157} and other inequities^{158,159,160}
 14 increase vulnerability. Climate change related issues that have an equity component include heat
 15 waves, air quality, extreme weather and climate events. For example, Hurricane Katrina
 16 demonstrated how vulnerable certain groups of people were to extreme weather events, because
 17 many low-income and of-color New Orleans residents had difficulty evacuating and recovering
 18 from the storm.^{152,153,154,159,161,162,163}

1 Box: Multiple Climate Stressors and Health

2 Climate change impacts add to the *cumulative* stresses currently faced by vulnerable populations
3 including children, the elderly, the poor, some communities of color, and people with chronic
4 illnesses. These populations, and others living in certain places such as cities, floodplains, and
5 coastlines, are more vulnerable not only to extreme events, but also to ongoing, persistent
6 climate-related threats. These threats include poor air quality, heat, drought, flooding, and mental
7 health stress. Over time, the accumulation of these stresses will be increasingly harmful to these
8 populations.

9 – end box –

10 Prevention Provides Protection

11 **Public health actions, especially preparedness and prevention, can do much to protect**
12 **people from some of the impacts of climate change. Early action provides the largest health**
13 **benefits. As threats increase, our ability to adapt to future changes may be limited.**

14 Prevention is a central tenet of public health. Many conditions that are difficult and costly to treat
15 when a patient gets to the doctor could be prevented before they occur at a fraction of the cost.
16 Similarly, many of the larger health impacts associated with climate change can be prevented
17 through early action at significantly lower cost than dealing with them after they occur.^{151,164}
18 Early preventive interventions, such as early warnings for extreme weather, can be particularly
19 cost-effective.^{165,166,167} As with many illnesses,¹⁶⁸ once impacts are apparent, even the best
20 adaptive efforts can be overwhelmed, and damage control becomes the priority.⁶⁰

21 Box: Large-Scale Environmental Change Favors Disease Emergence

22 Climate change is causing large-scale changes in the environment, increasing the likelihood of
23 the emergence or reemergence of unfamiliar disease threats.¹⁶⁹ Factors include shifting ranges of
24 disease-carrying pests, lack of immunity and preparedness, inadequate disease monitoring, and
25 increasing global travel. Diseases including Lyme disease and dengue fever pose increasing
26 health threats to the U.S. population; the number of U.S. patients hospitalized with dengue fever
27 more than tripled from 2000 to 2007.¹⁷⁰ Although most cases of dengue fever during that time
28 period were acquired outside the contiguous United States, the introduction of infected people
29 into areas where the dengue virus vector is established increases the risk of locally acquired
30 cases. The public health system is not currently prepared to monitor or respond to these growing
31 disease risks. The introduction of new diseases into non-immune populations has been and
32 continues to be a major challenge in public health. There are concerns that climate change may
33 provide opportunities for pathogens to expand or shift their geographic ranges.^{171,172}

34 -- end box --

35 Activities that reduce carbon pollution often also provide co-benefits in the form of preventive
36 health measures. For example, reliance on cleaner energy sources for electricity production¹⁷³
37 and more efficient and active transport, like biking or walking,¹⁷⁴ can have immediate public
38 health benefits, through improved air quality and lowered rates of obesity, diabetes, and heart
39 disease.¹⁷⁵ Reducing carbon pollution also reduces long-term adverse climate-health impacts,
40 thus producing cost savings in the near- and longer-term.¹⁷⁵ Preventing exposures to other

1 climate-sensitive impacts already apparent can similarly result in cost savings. For instance, heat
2 wave early warning systems protect vulnerable groups very effectively, and are much less
3 expensive than treating and coping with heat illnesses. Systems that monitor for early outbreaks
4 of disease are also typically much less expensive than treating communities once outbreaks take
5 hold.^{11,47,176}

6 Effective communication is a fundamental part of prevention. The public must understand risk in
7 order to endorse proactive risk management. The public is familiar with the health risks of
8 smoking, but not so for climate change. When asked about climate change impacts, Americans
9 don't mention health impacts,¹⁷⁷ and when asked about health impacts specifically, most believe
10 it will affect people in a different time or place.¹⁷⁸ But diverse groups of Americans find
11 information on health impacts to be helpful once received, particularly information about the
12 health benefits of mitigation (reducing carbon emissions) and adaptation.¹⁷⁹

13 Determining which types of prevention to invest in (such as monitoring, early warning systems,
14 and land-use changes that reduce the impact of heat and floods) depends on several factors,
15 including health problems common to that particular area, vulnerable populations, the preventive
16 health systems already in place, and the expected impacts of climate change.¹⁸⁰ Local capacity to
17 adapt is very important; unfortunately the most vulnerable populations also frequently have
18 limited resources for managing climate-health risks.

19 Overall, the capacity of the American public health and health care delivery systems is
20 decreasing, the number of hospital emergency departments is dropping,¹⁸¹ and funding for public
21 health programming is increasingly limited. The cost of dealing with current health problems is
22 diverting resources from preventing them in the first place. This makes the U.S. population more
23 vulnerable, especially because shortages of health care and public health professionals are
24 projected by 2020.^{182,183} Without careful consideration of how to prevent future impacts, similar
25 patterns could emerge regarding the health impacts from climate change. However, efforts to
26 quantify and map vulnerability factors at the community level are underway.^{149,163,184}

27 There are public health programs in some locations that address climate-sensitive health issues,
28 and integrating such programs into the mainstream public health toolkit as adaptation needs
29 increase would improve public health resilience to climate change.^{76,185,186,187} Given that these
30 programs have demonstrated efficacy against current threats that are expected to worsen with
31 climate change, it is prudent to invest in creating the strongest climate-health preparedness
32 programs possible.¹⁵¹ One survey suggested that climate change preparedness activities and
33 climate-health research are significantly underfunded,¹⁸⁰ highlighting the positive opportunities
34 to address this shortfall before needs become more widespread. *America's Climate Choices:
35 Adapting to the Impacts of Climate Choices* (Table 3.5) provides examples of health adaptation
36 options.¹⁸⁶

37

1 *Responses Have Multiple Benefits*

2 **Responding to climate change provides opportunities to improve human health and well-**
3 **being across many sectors, including energy, agriculture, and transportation. Many of**
4 **these strategies offer a variety of benefits, protecting people while combating climate**
5 **change and providing other societal benefits.**

6 Policies and other strategies intended to reduce carbon pollution and mitigate climate change can
7 often have independent influences on human health. For example, reducing CO₂ emissions
8 through renewable electrical power generation can reduce air pollutants like particles and sulfur
9 dioxide. Efforts to improve the resiliency of communities and human infrastructure to climate
10 change impacts can also improve human health. There is a growing recognition that the
11 magnitude of health “co-benefits,” like reducing both pollution and cardiovascular disease, could
12 be significant, both from a public health and an economic standpoint.^{175,188,189} Some climate
13 change resilience efforts will benefit health, but potential co-harms should be considered when
14 implementing these strategies. For example, although there are numerous benefits to urban
15 greening, such as reducing the urban heat island effect while simultaneously promoting an active
16 healthy lifestyle,^{157,190,191} the urban planting of allergenic pollen producing species, such as
17 maple, birch and oak²¹ could increase human pollen exposure and allergic illness. Increased
18 pollen exposure has been linked to increased emergency department visits related to asthma and
19 wheezing¹⁹² in addition to respiratory allergic illnesses such as allergic rhinitis or hay fever.¹⁹³
20 The selective use of low to moderately pollen producing species can decrease pollen exposure.¹⁹⁴

21 Much of the focus of health co-benefits has been on reducing health-harming air
22 pollution.^{5,173,174,195,196} One study projects that replacing 50% of short motor vehicle trips with
23 bicycle use and the other 50% with other forms of transportation like walking or public transit
24 would avoid nearly 1,300 deaths in 11 Midwestern metropolitan areas and create up to \$8 billion
25 dollars in health benefits annually for the upper Midwest region.¹⁸⁸ Such multiple-benefit actions
26 can reduce heat-trapping gas emissions that lead to climate change, improve air quality by
27 reducing vehicle pollutant emissions, and improve fitness and health through increased physical
28 activity.^{96,197,198,199,200}

29 Innovative urban design could create increased access to active transport.⁹⁶ The compact
30 geographical area found in cities presents opportunities to reduce energy use and emissions of
31 heat-trapping gases and other air pollutants through active transit, improved building
32 construction, provision of services, and infrastructure creation, such as bike paths and
33 sidewalks.^{197,201} Urban planning strategies designed to reduce the urban heat island effect, such
34 as green/cool roofs, increased green space, parkland and urban canopy, could reduce indoor
35 temperatures, improve indoor air quality, and could produce additional societal co-benefits by
36 promoting social interaction and prioritizing vulnerable urban populations.^{191,197}

37 Food consumption and production provide another example of co-benefits. Diets higher in fruits
38 and vegetables, and lower in red meat, can reduce the risk of cardiovascular disease and of some
39 cancers.^{199,202,203} Livestock production is a major contributor to methane emissions, although this
40 can be somewhat reduced by recovery methods such as the use of biogas digesters. Methane is a
41 potent greenhouse gas; production from livestock accounts for about 30% of the U.S.
42 total.^{199,203,204} Although not the focus of this assessment, a large-scale change in dietary practices,

1 in addition to improving population health, could also have an effect on the amount of methane
2 emitted to the atmosphere.²⁰⁵

3 In addition to producing health co-benefits²⁰⁶ climate change prevention and preparedness
4 measures could also yield positive equity impacts. For example, several studies have found that
5 communities of color and poor communities experience disproportionately high exposures to air
6 pollution.^{207,208} Climate change mitigation policies that improve local air quality thus have the
7 potential to strongly benefit health in these communities.

8 An area where adaptation policy could produce more equitable health outcomes is with respect to
9 extreme weather events. As discussed earlier, Hurricane Katrina demonstrated that communities
10 of color, poor communities, and certain other vulnerable populations (like new immigrant
11 communities) are at a higher risk to the adverse effects of extreme weather events.^{150,153} These
12 vulnerable populations could benefit from urban planning policies that ensure that new buildings,
13 including homes, are constructed to resist extreme weather events.¹⁹⁷

Traceable Accounts

Chapter 9: Human Health

Key Message Process: The key messages were developed during technical discussions and expert deliberation at a two-day meeting of the eight chapter Lead Authors, plus Susan Hassol and Daniel Glick, held in Boulder, Colorado May 8-9, 2012; through multiple technical discussions via six teleconferences from January through June, 2012, and an author team call to finalize the Traceable Account draft language on Oct 12, 2012; and through other various communications on points of detail and issues of expert judgment in the interim. The author team also engaged in targeted consultations during multiple exchanges with Contributing Authors, who provided additional expertise on subsets of the key message. These discussions were held after a review of the technical inputs and associated literature pertaining to Human Health, including a literature review,²⁰⁹ workshop reports for the Northwest and Southeast U.S. and additional technical inputs on a variety of topics.

<p>Key message #1/4</p>	<p>Climate change threatens human health and well-being in many ways, including impacts from increased extreme weather events, wildfire, decreased air quality, threats to mental health, and illnesses transmitted by food, water, and diseases-carriers such as mosquitoes, ticks, and fleas. Some of these health impacts are already underway in the United States.</p>
<p>Description of evidence base</p>	<p>The key message and supporting text summarizes extensive evidence documented in several foundational technical inputs prepared for this chapter, including a literature review²⁰⁹ and workshop reports for the Northwest and Southeast U.S. Nearly 60 additional technical inputs related to human health were received and reviewed as part of the Federal Register Notice solicitation for public input.</p> <p>Air Pollution: The effects of decreased ozone air quality on human health have been well documented concerning projected increases in ozone,^{5,6,8,10,38,210} even with uncertainties in projections owing to the complex formation chemistry of ozone and climate change, precursor chemical inventories, wildfire emission, stagnation episodes, and methane emissions.³ Ozone exposure leads to a number of health impacts.^{1,2}</p> <p>Allergens: The effects of increased temperatures and atmospheric CO2 concentration have been documented with studies showing that reduced health will result from increased exposure to aeroallergens.^{14,15,16,17,19,21,22,23,25,102} Additional studies have shown extreme rainfall and higher temperatures lead to increased air quality issues such as fungi and mold health concerns.²⁶</p> <p>Wildfire: The effects of wildfire on human health have been well documented with the increase in wildfire frequency^{16,27,38,39} leading to decreased air quality^{30,31,32} and negative health impacts.^{31,33,35}</p> <p>Temperature Extremes: The effects of temperature extremes on human health have been well documented for increased heat waves,^{49,51,52} which cause more deaths,^{45,46} hospital admissions⁴⁸ and population vulnerability.^{54,55}</p> <p>Extreme Weather Events: The effects of weather extremes on human health have been well documented, particularly for increased heavy precipitation, which leads to more deaths,^{61,62} waterborne diseases,⁶³ and illness.⁶⁴</p> <p>Vector-borne Diseases:</p>

	<p>The effects of climate change on vector-borne diseases have been documented in a number of publications. Studies have explored the effects climate change will have on location and adaptation of vectors,^{70,71,73} which can alter their effect on human health,⁶⁸ and have documented how a number of vector-borne diseases affecting the United States.^{72,79,81,82,83} There are some ambiguities on the relative role and contribution of climate change among the range of factors that affect disease transmission dynamics.^{68,69,70,71,72,73} However, observational studies are already underway and confidence is high based on scientific literature that climate change has contributed to the expanded range of certain disease vectors, including <i>Ixodes</i> ticks which are vectors for Lyme disease in the United States.^{75,80,85}</p> <p>Food- and Waterborne Disease: There has been extensive research concerning the effects of climate change on water- and food-borne disease transmission.^{89,90,92,93,94} The current evidence base strongly supports waterborne diarrheal disease being both seasonal and sensitive to climate variability. There are also multiple studies associating extreme precipitation events with waterborne disease outbreaks.⁸⁷ This evidence of responsiveness of waterborne disease to weather and climate, combined with evidence strongly suggesting that temperatures will increase and extreme precipitation events will increase in frequency and severity (Ch. 2: Our Changing Climate), provides a strong argument for climate change impacts on waterborne disease by analogy. There are multiple studies associating extreme precipitation events with waterborne disease outbreaks, and strong climatological evidence for increasing frequency and intensity of extreme precipitation events in the future. The scientific literature modeling projected impacts of climate change on waterborne disease is somewhat limited, however. Combined, we therefore have overall medium confidence in the impact of climate change on waterborne and food-borne disease.</p> <p>Harmful Algal Blooms: There are extensive studies showing that, due to climate change, reduced health will result from increased spread and frequency of harmful algae blooms,^{98,99,100} which have multiple exposure routes.⁹⁷</p> <p>Food Security: Climate change is expected to have global impacts on both food production and certain aspects of food quality. The impact of temperature extremes, changes in precipitation and elevated atmospheric CO₂, and increasing competition from weeds and pests on crop plants are areas of active research (Ch. 6: Agriculture; Key Message 6).^{18,101} The U.S. as a whole will be less affected than some other countries. However, the most vulnerable, including those dependent on subsistence lifestyles, especially as Alaskan natives and low-income populations, will not be immune.</p> <p>Threats to Mental Health: The effects of climate change on mental health have been extensively studied.^{116,118,119} Studies have shown the impacts of mental health problems after disasters,¹²⁰ with extreme events like Hurricane Katrina,¹²¹ floods,¹²² heat waves,¹²³ and wildfires¹²⁴ having led to mental health problems. Further work has shown that people with mental illnesses are increasingly vulnerable under heat waves, which are linked to suicide,^{127,128} increased hospitalization and death for dementia patients,^{123,129} and increased risk for schizophrenia patients,^{130,131} and for a number of other mental illnesses.^{118,119,132,133}</p>
<p>New information and remaining uncertainties</p>	<p>Important new evidence on heat-health effects^{42,43} confirmed many of the findings from a prior literature review. Uncertainties in the magnitude of projections of future climate-related morbidity and mortality can result from differences in climate model projections of the frequency and intensity of extreme weather events such as heat</p>

	<p>waves and other climate parameters such as precipitation.</p> <p>Efforts to improve the information base should address the coordinated monitoring of climate and improved surveillance of health effects.</p>
Assessment of confidence based on evidence	<p>Overall: Very High confidence. There is considerable consensus and a high quality of evidence in the published peer-reviewed literature that a wide range of health effects will be exacerbated by climate change in the United States. There is less agreement on the magnitude of these effects, because of the exposures in question; and the multi-factorial nature of climate-health vulnerability, with regional and local differences in underlying health susceptibilities and adaptive capacity. Other uncertainties include how much effort and resources will be put into improving the adaptive capacity of public health systems to prepare in advance for the health effects of climate change, prevent harm to individual and community health, and limit associated health burdens and societal costs.</p> <p>Increased Ozone Exposure: Very High confidence.</p> <p>Allergens: High confidence.</p> <p>Wildfires: Very High confidence.</p> <p>Thermal Extremes: Very High confidence.</p> <p>Extreme Weather Events: Very High confidence.</p> <p>Vector-borne Infectious Diseases: High confidence.</p> <p>Food- and Waterborne disease: Medium confidence.</p> <p>Harmful Algal Blooms: Medium confidence.</p> <p>Food Security: Medium confidence for food quality; High confidence for food security.</p> <p>Threats to Mental Health: Very high confidence for post-disaster impacts; Medium confidence for climate-induced stress.</p>

1

CONFIDENCE LEVEL			
Very High	High	Medium	Low
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

2

- 1 **Chapter 9: Human Health**
- 2 **Key Message Process:** See process for Key Message #1

<p>Key message #2/4</p>	<p>Climate change will, absent other changes, amplify some of the existing health threats the nation now faces. Certain people and communities are especially vulnerable, including children, the elderly, the sick, the poor, and some communities of color.</p>
<p>Description of evidence base</p>	<p>The key message and supporting text summarizes extensive evidence documented in several foundational technical inputs prepared for this chapter, including a literature review²⁰⁹ and workshop reports for the Northwest and Southeast regions.²¹¹ Nearly 60 additional technical inputs related to human health were received and reviewed as part of the Federal Register Notice solicitation for public input.</p> <p>Current epidemiological evidence on climate-sensitive health outcomes in the U.S. indicate that health impacts will differ substantially by location, pathway of exposure, underlying susceptibility and adaptive capacity. These disparities in health impacts will largely result from differences in the distribution of individual attributes in a population that confer vulnerability (age, socioeconomic status, race), attributes of place that reduce or amplify exposure (floodplain, coastal zone, urban heat island), as well as the resilience of critical public health infrastructure.</p> <p>Amplification of existing health threats: The effects of extreme heat and heat waves; worsening air pollution and asthma; extreme rainfall and flooding and displacement; and injuries associated with extreme weather events, fueled by climate change, are already substantial public health issues. Trends projected under a changing climate are projected to exacerbate these health effects in the future.⁶⁰</p> <p>Children: The effects of climate change increase vulnerability of children to extreme heat, and increased health damage (morbidity, mortality) resulting from heat waves has been well documented.^{15,21,49,51,137} Extreme heat also causes more pediatric deaths,^{45,46} and more emergency room visits and hospital admissions.^{47,48} Adverse effects from increased heavy precipitation can lead to more pediatric deaths, waterborne diseases,⁶³ and illness.¹³⁸</p> <p>The elderly: Heat stress is especially damaging to the health of older people;^{43,47,58,129,139,209} as are climate-sensitive increases in air pollution.⁸³</p> <p>The sick: People and communities lacking the resources to adapt, to enhance mobility and escape health-sensitive situations, are at relatively high risk.¹⁶³</p> <p>The poor: People and communities lacking the resources to adapt, or to move and escape health-sensitive situations, are at relatively high risk.¹⁶³</p> <p>Some communities of color: There are racial disparities in climate-sensitive exposures to extreme heat in urban areas, and in access to means of adaptation for example air conditioning use.^{146,149,155,212} There are also racial disparities in withstanding, and recovering from, extreme weather events.^{153,161}</p> <p>Climate change will disproportionately impact low-income communities and some communities of color, raising environmental justice concerns.^{136,159,163,213,146,149,152,153,155,212,214} Existing health disparities^{151,156,157} and other inequities^{159,160} increase vulnerability. For example, Hurricane Katrina demonstrated how vulnerable these populations were to extreme weather events because many low-income and of-color New Orleans residents had difficulty</p>

	evacuating and recovering from the storm. ^{153,161} Other climate change related issues that have an equity component include heat waves and air quality. ^{136,146,152,163,212,214}
New information and remaining uncertainties	Important new evidence ⁴³ confirmed findings from a prior literature review. ¹³⁶ The potential for specific climate-vulnerable communities to experience highly harmful health effects is not entirely clear in specific regions and on specific time frames, due to uncertainties in rates of adaptation, and uncertainties about the outcome of public health interventions, currently being implemented, that aim to address underlying health disparities and determinants of health. ²⁰⁶ The public health community has not routinely conducted evaluations of the overall success of adaptation interventions or of particular elements of those interventions.
Assessment of confidence based on evidence	Given the evidence base and remaining uncertainties, confidence that climate change will amplify existing health threats: Very high. Among those especially vulnerable are: Children: Very high. The elderly: Very high. The sick: Very high. The poor: Very high. Some communities of color: High.

1

CONFIDENCE LEVEL			
Very High	High	Medium	Low
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

2

1 **Chapter 9: Human Health**

2 **Key Message Process:** See process for Key Message #1

Key message #3/4	Public health actions, especially preparedness and prevention, can do much to protect people from some of the impacts of climate change. Early action provides the largest health benefits. As threats increase, our ability to adapt to future changes may be limited.
Description of evidence base	<p>The key message and supporting text summarizes extensive evidence documented in several foundational technical inputs prepared for this chapter, including a literature review²⁰⁹ and workshop reports for the Northwest and Southeast U.S. Nearly 60 additional technical inputs related to human health were received and reviewed as part of the Federal Register Notice solicitation for public input.</p> <p>A number of studies have demonstrated prevention activities that reduce carbon pollution, like using alternative energy sources¹⁷³ and using active transportation like biking or walking,^{174,188} can lead to significant public health benefits, which can save costs in the near and long term.¹⁷⁵ Health impacts associated with climate change can be prevented through early action at significantly lower cost than dealing with them after they occur. For example, heat wave early warning systems are cheaper than treating heat related illnesses.¹⁶⁴ Existing adaptation programs have improved public health resilience.^{8,151} However, studies have shown that factors such as uncertainty about what type of prevention to invest in,¹⁸⁰ underfunding of climate-health research and preparedness activities,¹⁸⁵ and the declining public health care system^{181,215} will inhibit our prevention potential.</p> <p>Considering U.S. public health in general, the cost-effectiveness of many prevention activities is well established.¹⁸² Some preventive actions are cost saving, while others are deemed cost-effective based on a pre-determined threshold. Overall a larger proportion of effective prevention efforts are cost-saving compared with clinical interventions that address disease once symptoms are manifest.¹⁶⁵ However, there is less information on the cost-effectiveness of specific prevention interventions relevant to climate sensitive health threats (for example, heat early warning systems). Overall, we have high confidence that public health actions can do much to protect people from some of the impacts of climate change, and that early action provides the largest health benefits.</p> <p>The inverse relationship between the magnitude of an impact and a community’s ability to adapt is well established and understood. Two extreme events, Hurricane Katrina and the European heat wave of 2003, illustrate this relationship well.¹⁶⁶ Extreme events interact with social vulnerability to produce extreme impacts, and the increasing frequency of extreme events associated with climate change is prompting concern for impacts that may overwhelm adaptive capacity.^{60,172} This is equally true of the public health sector, specifically, leading to very high confidence that as threats increase, our ability to adapt to future changes may be limited.</p>
New information and remaining uncertainties	<p>A key issue (uncertainty) is the extent to which the nation, states, communities and individuals will be able to adapt to climate change, because this depends on the levels of local exposure to climate-health threats, underlying susceptibilities, and the capacities to adapt that are available at each scale. Currently the capacity of the American public health and health care delivery systems are decreasing, making the U.S. population even more vulnerable.^{54,182}</p> <p>Steps for improving the information base on adaptation include undertaking a more comprehensive evaluation of existing climate-health preparedness programs and</p>

	their effectiveness in various jurisdictions (cities, counties, states, nationally).
Assessment of confidence based on evidence	<p>Overall, given the evidence base and remaining uncertainties: High.</p> <p>High: Public health actions, especially preparedness and prevention, can do much to protect people from some of the impacts of climate change. Prevention provides the most protection; but we do not as yet have a lot of post-implementation information with which to evaluate preparedness plans.</p> <p>High: Early action provides the largest health benefits. There is evidence that heat-health early warning systems have saved lives and money in U.S. cities like Philadelphia, PA.¹⁶⁴</p> <p>Very high: Our ability to adapt to future changes may be limited.</p>

1

CONFIDENCE LEVEL			
Very High	High	Medium	Low
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

2

1 **Chapter 9: Human Health**

2 **Key Message Process:** See process for Key Message #1

Key message #4/4	Responding to climate change provides opportunities to improve human health and well-being across many sectors, including energy, agriculture, and transportation. Many of these strategies offer a variety of benefits, protecting people while combating climate change and providing other societal benefits.
Description of evidence base	<p>The key message and supporting text summarizes extensive evidence documented in several foundational technical inputs prepared for this chapter, including a literature review²⁰⁹ and workshop reports for the Northwest and Southeast U.S. regions.²¹¹ Nearly 60 additional technical inputs related to human health were received and reviewed as part of the Federal Register Notice solicitation for public input.</p> <p>A number of studies have explored the opportunities available to improve health and well-being as a result of adapting to climate change,¹⁷⁵ with many recent publications illustrating the benefit of reduced air pollution.^{5,173,174,195} Additionally, some studies have looked at the co-benefits to climate change and health of applying innovative urban design practices which reduce energy consumption and pollution while increasing public health,^{96,188,197,198} decrease vulnerability of communities to extreme events^{150,197} and reduce the disparity between different societal groups.^{206,207,216}</p>
New information and remaining uncertainties	More studies are needed to fully evaluate both the intended and unintended health consequences of efforts to improve the resiliency of communities and human infrastructure to climate change impacts. There is a growing recognition that the magnitude of these health co-benefits or co-harms could be significant, both from a public health and an economic standpoint. ²¹⁷
Assessment of confidence based on evidence	Given the evidence base and remaining uncertainties, confidence is very high

3

CONFIDENCE LEVEL			
Very High	High	Medium	Low
Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts

4

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