Union of Concerned Scientists

FACT SHEET

# Heat Waves and Climate Change

## *The Effects of Worsening Heat on People, Communities, and Infrastructure*

Heat waves are a familiar phenomenon to many of us in the United States. But as climate change makes these heat waves more routine, and more severe, they are likely to become increasingly disruptive and dangerous to our daily lives. When temperatures rise to extreme levels, calls to emergency medical services increase, schools without air conditioning cancel classes, energy use increases to keep indoor spaces cool and electricity grids are strained to meet that demand, and heat-related illness—or even death—threatens the elderly, the very young, those who work outdoors, and those unable to afford or access cooling.

During the spring and summer of 2012, much of the contiguous United States—particularly the eastern half—experienced a catastrophic, prolonged heat wave (Figure 1; Cattiaux and Yiou 2013). The extreme heat directly caused 123 deaths and contributed to an additional—though unquantified—number of fatalities by, for example, exacerbating pre-existing health conditions (NCEI 2018; Berko et al. 2014). Extreme temperatures and the associated drought resulted in $33 billion in losses to individuals, businesses, and public assets (NCEI 2018). Corn production dropped by more than 10 percent compared to the previous year, sending global crop prices soaring to record levels (USDA 2013; Plume and Zabarenko 2012) and causing losses the US beef industry with high feed prices (Stewart 2012). The heat and drought set the stage for expansive, destructive wildfires with more than 9 million acres burning across the country (NCEI 2013).

*In Phoenix on July 5, 2018, temperatures surpassed 112°F. Days with extreme heat are a more frequent occurrence in the United States today and are on the rise. Source: Ross D. Franklin/AP.*

*During a 2016 heat wave in Arizona, first responders check the vital signs of a man exposed to heat-stress conditions. Such conditions can exacerbate existing medical conditions and induce heat-related illnesses such as heat stroke and heat exhaustion. Soaring temperatures in Tucson led to several deaths and calls from public health officials for residents to exercise extreme caution. Source: A.E. Araiza/Arizona Daily Star.*

With record-breaking heat waves becoming increasingly common (Habeeb, Vargo, and Stone 2015) and changes in temperature extremes already palpable, we find ourselves questioning with each heat wave whether this is the new normal. The number of dangerously hot summer days has increased over large and small Midwestern cities like Cincinnati, Ohio, and Peoria, Illinois, since the 1940s and 1950s (Martin Perera et al. 2012). Climate change has made the extreme heat waves we are already experiencing more likely to happen and is projected to make heat waves even hotter and more frequent in the future (Vose et al. 2017; Diffenbaugh and Scherer 2013; Knutson, Zeng, and Wittenberg 2013).

This fact sheet summarizes the current and potential impacts of extreme heat on people. See the companion fact sheet for an exploration of the latest science on how extreme heat has changed, is likely to keep changing as global temperatures rise, and how those changes could be curtailed if we take action to reduce heat-trapping emissions at *www.ucsusa.org/extremeheat*.

## Extreme Heat Basics

"Heat wave," "excessive heat event," "heat advisory," "hot spell"—extreme heat has many different names. For the purposes of this fact sheet, extreme heat refers to temperatures that are either exceptionally high relative to typical local conditions or reach levels that may be harmful to human health or infrastructure.

Temperature typically follows a daily cycle. Temperatures increase after sunrise, peak during the afternoon hours,

[ ***Exposure to extreme heat is among the top causes of weather-related deaths in the United States.*** ]

continue to decline after sunset, and typically reach the daily low point during the night. When extreme daytime temperatures persist over a prolonged period (usually at least two days), it is often referred to as a heat wave (NWS n.d. a).

The impacts of temperature extremes on human health and wellbeing are generally considered in concert with humidity to measure heat stress conditions: those in which the human body has difficulty cooling itself (CDC 2017a). When exposed to high temperatures, the human body sweats to release heat. When exposed to high humidity as well, that sweat does not evaporate as quickly and the body's ability to cool itself is compromised. Heat stress can result and, if not addressed, can lead to heat-related illnesses like heat exhaustion and heat stroke.

To warn people of anticipated or ongoing heat stress conditions, the National Weather Service combines heat and relative humidity to produce its heat index, or the "feels like" temperature (NWS n.d. b), used to issue heat advisories and warnings across the country. Heat advisories can therefore cite heat index values much higher than the air temperature in humid locations, such as coastal North Carolina, and several degrees cooler than the air temperature in arid locations such as Arizona.

## Heat and Health

Heat is among the deadliest extreme weather hazards in the United States (NWS 2018; CDC 2017b). When exposure to heat is high enough to raise the body's core temperature, heat stress illness—which encompasses heat cramps, heat exhaustion, and heat stroke—can occur (CDC 2017b; Choudhary and Vaidyanathan 2014). With heat cramps, an individual experiences muscle pain or spasms. Heat exhaustion can cause dizziness, a weak pulse, nausea, and fainting. The most severe heat-related illness, heat stroke, occurs when a person's temperature increases above 103 degrees Fahrenheit and is associated with a fast pulse as well as many of the previously mentioned symptoms (CDC 2017b). In addition to causing increased heat-related death, increased daily air temperatures or periods of extended high temperatures have been shown to


*A water-spray fan provides relief from the heat for this young child in Waco, Texas, during a July 2018 heat wave. Children are disproportionately vulnerable to the effects of extreme heat, in part because they require care to stay properly hydrated. Source: Paul Moseley/Star-Telegram via AP.*

increase cardiovascular mortality (Medina-Ramón et al. 2006; Curriero et al. 2002), respiratory mortality (Mastrangelo et al. 2007), and heart attacks (Braga, Zanobetti, and Schwartz 2002). During heat waves, increases are also seen in calls to emergency medical services (Dolney and Sheridan 2006) and hospital admissions (Zhang, Chen, and Begley 2015; Medina-Ramón et al. 2006).

The timing of a heat wave is an important determinant in the health risks the event presents to communities. The risk of death is nearly twice as high for the first heat wave of a season than others, likely in part because people's bodies acclimate to heat as the warm season progresses (Anderson and Bell 2011). Cooler night-time temperatures typically provide relief from a hot day, but when these remain high, health risks rise, especially for those without access to air conditioning or who choose not to turn it on due to high energy costs (Anderson and Bell 2011). Heat-related deaths can occur quickly—typically the same day or the day after extreme temperature spikes—which signals the need for a quick response to extreme heat conditions by public health officials and either the people exposed or their caregivers (Anderson and Bell 2009). During heat waves, the public is often advised by public health officials to check in with isolated or otherwise vulnerable neighbors to help ensure they do not succumb to heat illness (CDC 2017c).

## Impacts of Extreme Heat on Daily Life

### GOING TO SCHOOL

Children under the age of 14 are more vulnerable to extreme heat than are healthy adults, in part because they are less likely to seek proper hydration and help when they most need it (Xiao et al. 2017). Extreme heat affects not just children's bodies, but the indoor climate of the schools in which they spend hours each day. In a 2013 survey of public schools, 30 percent were rated as having air conditioning systems that were in just fair or poor condition (Alexander and Lewis 2014). While nearly all schools in southern states are equipped with air conditioning, many schools elsewhere in the nation are either only partially air conditioned or are completely without it (Barnum 2017). For example, in the city of Baltimore, a number of schools do not have air conditioning; when the heat index is forecast to surpass 90°F in Baltimore, these schools are forced to close (BCPS 2016; Snyder 2016). And in Detroit, only about one-third of schools are fully equipped with air conditioning (Barnum 2017). In May 2018, public schools across the city were forced to close early over multiple days as a result of insufficient power and cooling amidst a heat wave (Detroit Free Press 2018).

The effect of hot conditions on kids diminishes their ability to learn and lowers their performance on tests (Goodman et al. 2018; Zivin, Hsiang, and Neidell 2017). Low-income and minority students are disproportionately affected (Goodman et al. 2018; Zivin, Hsiang, and Neidell 2017), and research suggests that this is in part because they are more likely to attend schools and live in homes without air conditioning (Goodman et al. 2018). Given the financial resources available to most school districts, efforts to expand air conditioning of schools may be prohibitively expensive.

### WORKING OUTDOORS

Millions of people living in the United States work primarily outdoors—construction workers, police officers, farm workers, military personnel, roofers, postal workers, landscapers, and others—and are at risk of heat stress when temperatures soar. Farm and construction workers are at particular risk, with more than 33 percent of occupational heat-related deaths

> ***Not all U.S. residents are equally at risk. A variety of factors increase vulnerability to extreme heat.***

*Work proceeds on this Kansas highway in July 2016, as temperatures rise to 102°F. Outdoor workers—particularly those in the construction and agricultural sectors—are disproportionately exposed to heat-stress conditions and suffer higher rates of health impacts when heat waves hit. Source: Charlie Riedel/AP.*

occurring in the construction sector and about 20 percent occurring in the agriculture/forestry/fishing/hunting sector (Gubernot, Anderson, and Hunting 2015). Among all US workers, the highest occupational heat-related fatality rates were found among men, among Latinos, and among employees at very small companies that may lack resources to enact rigorous heat-safety procedures or whose employees may carry out work alone (Gubernot, Anderson, and Hunting 2015; Yorio and Wachter 2013).

Some business models can also make occupational heat-related injury and illness more likely by creating incentives for workers to push themselves beyond safe limits. For example, on US farms, field workers are often paid by the amount they harvest, incentivizing them to skip breaks and work in ways that increase their risk of heat-related illness or death (Gubernot, Anderson, and Hunting 2015).

It is difficult to estimate the effects of heat stress on worker health because incidents are often underreported. For example, people, especially those who are foreign-born, may fear punitive action, such as being reported to the US Citizenship and Immigration Services (Gubernot, Anderson, and Hunting 2014), upon reporting a workplace injury or illness.

### CITY LIVING

Urban residents face unique heat-related risks in a changing climate. In addition to experiencing the effects of global temperature increases, cities experience temperature increases locally due to the urban heat-island effect, so called because the temperature gradient in the city resembles an island of heat surrounded by a sea of cooler temperatures (UCAR 2011). Cities are hotter primarily because they contain an abundance of heatretaining materials and surfaces, such as asphalt, pavement, and cement. The extra heat absorbed during the day is then re-radiated at night, keeping temperatures in urban areas warmer than their surroundings. During heat waves, this dynamic can be particularly harmful (Rosenzweig et al. 2005), as night-time temperatures stay high and prevent urban residents' access to relief from high daytime temperatures (Stone, Hess, and Frumkin 2010).

Vulnerability to heat in urban areas is not equally distributed, with lower-income residents among those at greater risk (Box 1; Harlan et al. 2013; Harlan et al. 2006).

#### RURAL RESIDENTS

Hot temperatures also have serious consequences for the health and quality of life of rural residents. The hospitalization rate for heat-related illnesses is higher among residents in rural and small urban areas than in large urban communities—the distance to healthcare facilities is likely a contributing factor (Schmeltz et al. 2015).

Heat stress also has major implications for rural residents' livelihoods. Heat stress can have negative effects on crop production, as it can adversely affect several processes, including flowering and photosynthesis (Lobell et al. 2013). Heat stress is also costly to livestock farmers. The dairy industry is particularly vulnerable to heat conditions, with milk production decreasing in the face of heat stress (West 2003). The sector is already incurring major heat-related losses, and these are expected to continue to increase as temperatures rise (Key, Sneeringer, and Marquardt 2014). Heat stress already costs the average American dairy an estimated $39,000 annually. By 2030, it is estimated that, as a result of a warmer climate, the average dairy will lose an additional $2,000 and $5,000 every year (using 2010 prices), costs that will be passed on to consumers (Key, Sneeringer, and Marquardt 2014).

BOX 1.

## Who is Most Vulnerable to Heat Stress?

Increases in the number of US residents and moves to locations with more extreme heat are projected to result in many more of us being exposed to heat stress conditions (Jones et al. 2015). Not all US residents are equally at risk, however, and a variety of factors increase residents' vulnerability to extreme heat. Non-white and low-income US residents are at greater risk of illness and injury from heat for several reasons, including lower access to healthcare, lack of access to or inability to afford air conditioning, and simply living in hotter urban areas (Hayden et al. 2017; Schmeltz, Petkova, and Gamble 2016; Schmeltz et al., 2015; Fiscella et al. 2000).

Age is another key risk factor. Very young children (particularly those younger than one year of age) are especially at risk of heat-related death. Extreme heat can increase the number of cases of renal disease, fever, and imbalance of electrolytes in children, as well as worsen kids' allergies (Xu et al. 2012). People aged 65 and older—and especially 75 and up—are also vulnerable, as extreme heat is associated with increases in cardiovascular and respiratory-related deaths in this group (Åström, Bertil, and Joacim 2011; Anderson and Bell 2009). Although the increased use of air conditioning by elderly US residents has reduced their heat-related deaths (Barnett 2007), the percentage of elderly individuals in the United States is increasing, which means more vulnerable individuals will be exposed to extreme heat. People with medical conditions, both physical (such as respiratory or cardiovascular disease) and psychiatric, have an increased risk of heat-related death (Bouchama et al. 2007). Being confined to bed or home, or dependent on the care of another person, also significantly increases the risk of heat-related death (Bouchama et al. 2007).

Other people who might not appear, at first glance, to be at particular risk often are. New evidence suggests that some middle-aged individuals (aged 40 to 64) may be at an elevated risk to extreme heat—possibly because members of that demographic do not perceive themselves as vulnerable and may not take appropriate measures to protect themselves (Schmeltz et al. 2015). And less attention is often paid to typically healthy individuals not in the age groups mentioned above who have an outsized exposure to extreme heat—such as athletes. For example, between 1980 and 2014, 61 US football players across all levels of the sport suffered fatal heat strokes (Grundstein, Hosokawa, and Casa 2018).

## OUR INFRASTRUCTURE AND ENERGY SYSTEM

### RISKS TO TRANSPORTATION

Many types of infrastructure are affected by extreme heat, including our roads, rails, and air travel. A 2017 heat wave in Phoenix, for example, led to 50 flight cancellations when temperatures increased to 119°F—above the operable limit of several types of aircraft (Wang 2017). Rising maximum daily temperatures will constrain the allowable weight of aircrafts at takeoff, creating new costs for the airline industry and its customers, as well as disrupting passenger travel and air shipments more frequently (Coffel, Horton, and de Sherbinin 2017).

High temperatures increase the risk of pavement deterioration, depending on the paving materials and the traffic load of a given road (Daniel et al. 2014; Rowan et al. 2013). The type of pavement used is typically based on historical climate conditions; the increasing occurrence of frequent and prolonged extreme heat outside of historical norms will present challenges to our roadway system (Holsinger 2017). For example, following a wet winter that increased soil moisture conditions in Sacramento, California, high temperatures in June 2017 caused concrete to expand and sidewalks and roads to buckle across the city (NBC 2017). Extreme heat is also problematic for our rail systems, as railroad tracks exposed to high temperatures are at risk of warping or buckling (Magill 2014). When temperatures reach 90°F, trains may need to reduce speeds to prevent accidents (Rowan et al. 2013). When temperatures approach 110°F, the risk of buckling increases significantly, creating dangerous conditions that are costly to repair (Rowan et al. 2013).

### ENERGY DEMAND FOR COOLING

As heat waves worsen, our energy system will need to adapt to help communities and businesses cope with rising temperatures (Box 2). Access to air conditioning will be vital in many places, even life-saving for the elderly, young children, and those with pre-existing health conditions. However, increased cooling needs for both air conditioning and refrigeration will place significant stress on the power system during periods of extreme heat. And if that power comes from

BOX 2.

## Climate-Smart Energy Solutions

Because our current electricity system is dominated by fossil fuels, it generates significant water and air pollution, as well as high levels of greenhouse gas emissions. Ramping up low-carbon electricity sources like wind and solar power and increasing energy efficiency can help reduce the pollution and water usage associated with electricity generation, while simultaneously reducing emissions responsible for climate change (Hibbard et al. 2014; Rogers et al. 2013). Renewable energy and electricity storage technologies can also add flexibility to the electricity grid. Together with microgrids, renewables can support increased grid resilience and reliability in the face of extreme weather. Electricity storage also has the potential to replace fossil-fired "peaking" power plants, which are called upon in times of high demand for electricity such as during extreme heat events (UCS 2018). These peakers are typically inefficient, are costly to run, and harm local air quality in surrounding communities (Krieger, Casey, and Shonkoff 2016). Increasing the efficiency of air conditioners and refrigerators themselves is critical, as is phasing out climate-warming hydrofluorocarbons used in them. Time-of-use electricity rates can help moderate demand during peak periods and limit the need for polluting peaker plants while allowing consumers to shift demand to times when there is cleaner electricity on the grid (McNamara, Jacobs, and Wisland 2017; Cappers et al. 2016).

A modernized and low-carbon electricity system, combined with local adaptation measures, can help reduce the impacts of extreme heat on residents and businesses. Our cities, homes, and offices need to be designed in ways that reduce the need for cooling. Making buildings more energy efficient can help reduce energy use and energy bills, including during peak demand periods. This includes design features in buildings that encourage greater air flow, using light or reflective materials on roofs, planting more trees to create shade, and reducing pavement that contributes to the heat island effect in urban areas. Community cooling centers can also provide respite to many people, reducing the need for and costs to cool individual homes. And improved policies can both cut heat-trapping emissions and help communities adapt to rising heat. Such policies can advance renewable energy, energy storage, and energy efficiency, as well as make these solutions more affordable and more widely available, especially in marginalized communities.

*During an extended heat wave in St. Louis, Missouri, in 2011, public health workers and volunteers went door to door to check on the wellbeing of disabled and elderly residents. Source: United Way of Greater St. Louis.*

fossil-fired power plants, there will also be an increase in soot, smog, and other forms of air pollution with the associated public health consequences (Abel et al. 2018). Conventional power plants, including nuclear and coal-fired power plants, also require large quantities of water for cooling, which poses a further challenge during droughts (DOE 2015; Rogers et al. 2013). Other impacts of climate change also threaten electricity infrastructure, including wildfires that can destroy poles and towers carrying transmission lines (Davis and Clemmer 2014; Cleetus and Mulik 2014). And high temperatures reduce transmission capacity (Bartos et al. 2016). Together, all of these factors stemming from increasing extreme heat across the country can increase the price of electricity.

## What Can We Do? Preventing the Worst Consequences of Extreme Heat

Many consequences of climate change will be difficult to forestall or avoid; extreme heat is among the most straightforward. Actions we take now can help reduce the scale of the problem, bolster how prepared we are to cope with heat and help us to avoid the most severe consequences of climate change. By stabilizing global carbon emissions in the next few decades so that carbon dioxide in our atmosphere remains below 550 parts per million by 2100, the frequency of heat waves the United States is likely to see around mid-century would be reduced by approximately 50 percent, compared to a scenario in which carbon emissions continue to increase rapidly through to 2100 (Vose et al. 2017; Sun et al. 2015). And if the global community pursues aggressive emissions reductions in line with the Paris Agreement goal of keeping warming below 3.6°F, the hottest daily temperatures that occur each year in many parts of the country are likely to increase by just 3.6°F, as compared with conditions at the end of the twentieth century, instead of by 10°F.

Together with actions that would reduce carbon emissions and minimize future warming, individuals and communities need policies and infrastructure that take better account of more frequent, intense, and long-lasting extreme heat conditions. For example, while existing air-conditioning installations have helped protect the health of many vulnerable US residents, in the coming decades increased reliance on air conditioning to cope with extreme heat is likely to contribute to increased global warming emissions, worsening air quality, and an increase in air pollution–related illness and mortality unless we more aggressively invest in clean energy technology, energy conservation, and energy efficiency measures (Abel et al. 2018).

In addition to infrastructure-focused measures, existing policies need to be leveraged and new policies enacted to better help people—particularly outdoor workers, children, low-income and minority groups, elderly people, and athletes—cope with extreme heat. Policies that ensure the safety of all outdoor workers, documented or otherwise, and that expand access to and awareness of public cooling facilities are just two examples.

Heat waves have always been an aspect of summer weather in the United States. But as climate change makes heat waves more intense and more frequent, we need to be cognizant of the dangers. New and strengthened policies to protect public health and infrastructure will help us navigate a hotter near-term future more safely, while our work to reduce emissions today will have profound impacts for decades to come, helping the country to avoid the most dangerous heat increases over our long-term future.

ACKNOWLEDGEMENTS
The fact sheet team would like to express thanks to the following individuals for their invaluable review: Dr. Meredith Jennings, National Academies of Sciences, Engineering, and Medicine Gulf Research Program; Dr. Kim Knowlton, Natural Resources Defense Council; and Dr. Benjamin Sanderson, CERFACS/CNRS Laboratoire Climat, Environnement, couplage et incertitudes.

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