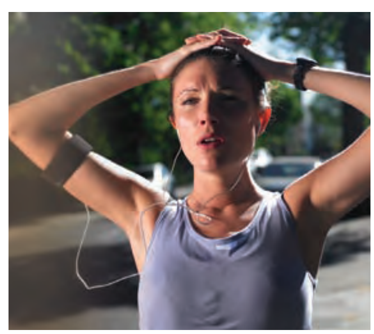
CLIMATE CHANGE
AND YOUR HEALTH

Rising Temperatures, Worsening Ozone Pollution







Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

The Union of Concerned Scientists is a nonprofit partnership of scientists and citizens combining rigorous scientific analysis, innovative policy development, and effective citizen advocacy to achieve practical environmental solutions. Established in 1969, we seek to ensure that all people have clean air, energy, and transportation, as well as food that is produced in a safe and sustainable manner. We strive for a future that is free from the threats of global warming and nuclear war, and a planet that supports a rich diversity of life. Sound science guides our efforts to secure changes in government policy, corporate practices, and consumer choices that will protect and improve the health of our environment globally, nationally, and in communities throughout the United States. In short, UCS seeks a great change in humanity's stewardship of the earth.





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CLIMATE CHANGE AND YOUR HEALTH

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Organization affiliations are for identification purposes only. The opinions expressed in this report are the sole responsibility of the authors.

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Executive Summary

The quality of life for America's children and their families is adversely affected when ozone pollution increases. Children who miss school because they are experiencing or recovering from an asthma attack may not only fall behind in their studies but also get less exercise and lose time with friends (because they cannot play outside when ozone levels are high). And for every child who goes to the doctor or stays home from school, there is probably a worried parent who is stressed and missing work.

MILLIONS OF AMERICANS SUFFER from the harmful effects of ground-level ozone pollution, which exacerbates lung diseases such as asthma and can cause breathing difficulties even in healthy individuals. The result is more time spent in hospital emergency rooms, as well as additional sick days and even premature deaths. These health impacts not only involve suffering; they are also costly, constituting a significant drag on the U.S. economy. While power plants and cars are among the main sources of ozone-forming pollutants (the chemical precursors to ozone), ozone's formation is dependent on temperature, among other conditions. As a result, climate change has the potential to increase ozone pollution—and its health and economic burdens—across large parts of the country both now and in the future.

This report from the Union of Concerned Scientists combines projections of future climate-induced temperature increases with findings on the relationship between ozone concentrations and temperature to illustrate a potential "climate penalty on ozone."[1] This penalty demonstrates how higher temperatures could increase ozone pollution above current levels, assuming that emissions of ozone-precursor pollutants remain constant.

We analyzed this climate penalty's health consequences expected in 2020 and 2050, including increases in respiratory symptoms, hospital visits for the young and old, lost school days, and premature mortality, for most of the continental United States. We also projected the economic costs of these health impacts in 2020.

Key findings include:[2]

- Just nine years from now, in 2020, we estimate that the continental United States could pay an average of $5.4 billion (2008$) in health impact costs associated with the climate penalty on ozone.
- Higher ground-level ozone concentrations due to rising temperatures in 2020 could lead to an average of 2.8 million more occurrences of acute respiratory symptoms such as asthma attacks, shortness of breath, coughing, wheezing, and chest tightness. In 2050, that could rise to an average of 11.8 million additional occurrences.

- The climate penalty on ozone could lead to an average of 944,000 more missed school days in 2020. In 2050, that could rise to an average of 4.1 million additional missed school days.
- Higher ozone concentrations due to rising temperatures could lead to an average of 3,700 more seniors and 1,400 more infants hospitalized for respiratory-related problems in 2020. In 2050, that could rise to 24,000 more seniors and 5,700 more infants hospitalized.
- Many states and counties that are already struggling to control ozone pollution will have to work even harder to maintain healthy air quality in a warming climate.
- California and states in the Midwest and the Mid-Atlantic could be hit especially hard by the climate penalty on ozone. California may experience the greatest health impacts, with an estimated average of $729 million in 2020 alone.

The findings of this report illustrate yet another reason why we must take action to address climate change without delay—and why our inaction to date will lead directly to real costs within this decade. To make our air cleaner, the U.S. Environmental Protection Agency (EPA) must strengthen its current standards for ozone and ozone-forming pollutants that come from power plants, industry, and vehicles. But in the face of a rapidly warming world, these efforts alone will not be sufficient—we also need new strategies to reduce the pollution that causes climate change.

Climate change has the potential to increase ozone pollution—and its health and economic burdens—across large parts of the country both now and in the future.

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Introduction

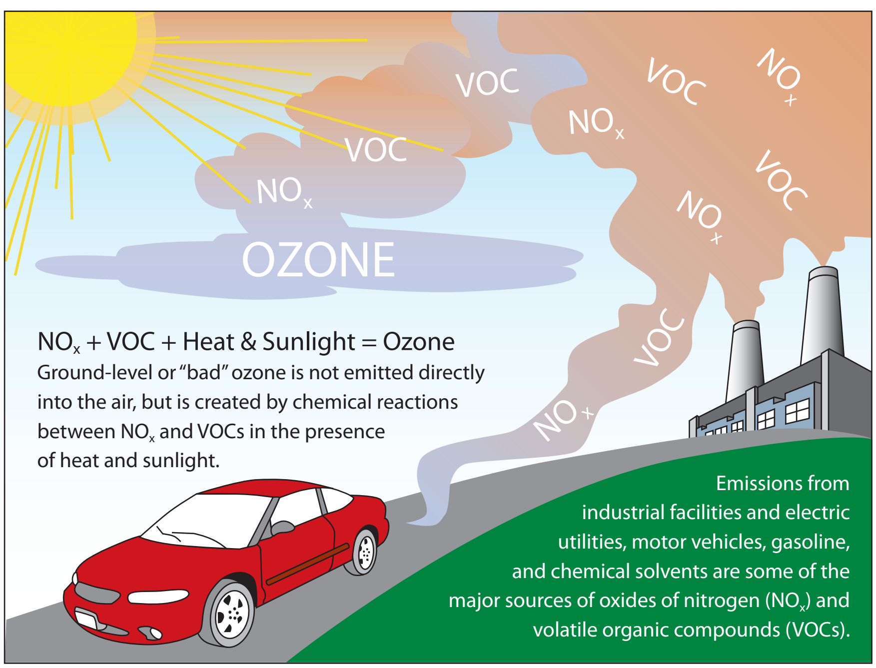
MILLIONS OF AMERICANS SUFFER from the harmful effects of ground-level ozone pollution—be they children too sick to go to school, high school football players not allowed to practice outdoors in the summer, 65-year-olds with lung disease unable to take a walk in the park, or farmers at risk when they harvest their fields. Not only does ozone pollution cause a number of serious breathing problems, and therefore a great deal of suffering, it also is damaging in monetary terms. Whether tallying up the dollars lost to sick days or the high costs of emergency room visits, ozone pollution is expensive.

And now health professionals have an additional ozone pollution concern: climate change. Temperatures in the United States have already risen more than two degrees Fahrenheit (°F) (1.1 degrees Celsius) over the past century, largely because of an excess of heat-trapping gases, especially carbon dioxide, in the atmosphere. Temperatures are likely to keep rising, certainly throughout the next few decades and likely much longer (Karl, Melillo, and Peterson 2009).

Here's the connection: warmer temperatures affect ground-level ozone. Ground-level ozone is formed when a complex set of chemical reactions is triggered by heat and sunlight[3] (Figure 1). That's why we hear warnings of "bad air days" due to ozone pollution most often during the summer and on cloud-free days. Hotter temperatures in a changing climate mean that ozone concentrations are likely to rise over most of the United States (Jacob and Winner 2009 and references therein), possibly offsetting some of the gains we have made in driving down the pollutants that form ozone (Wu et al. 2008).

This report explores how such a phenomenon may occur in many regions of the United States. We model the potential health consequences and costs in 2020 that would be associated with a climate-induced increase in ozone pollution. We also model the health impacts that could occur in 2050.[4] Our results show that as we continue to work to reduce ozone pollution and its health effects in the future, we cannot ignore the consequences of ever-increasing temperatures.

FIGURE 1. Illustration of Ground-Level Ozone Formation



Source: Adapted from EPA 2010.

"Bad" ozone can be distinguished from "good" ozone, which is present at high altitudes in the atmosphere and beneficial because it protects the earth from excessive ultraviolet radiation. But bad, or ground-level, ozone—the primary component of smog—is harmful to health. Human activities such as driving cars and generating electricity are major sources of the ingredients that form smog.[5]

Ozone Pollution and Climate Change—An Unhealthful Mix

When weather forecasters warn about poor air quality or "bad air days" and report an associated color to indicate healthy or unhealthy air (Figure 2), they are usually referring to the level of smog—a hazardous mixture of air pollutants that affect the health and quality of life of children and adults alike.

The Role of Ozone Precursor Pollutants

Ground-level ozone—the primary component of smog—is formed when oxides of nitrogen (NO_x) and volatile organic compounds (VOCs), which are "precursor emissions," chemically react in the presence of heat and sunlight. Some of the major human-made sources of these precursor emissions are power plants, vehicles, and industrial processes.

Reductions in NO_x and VOCs—the primary ingredients in ozone formation—decrease ozone pollution. Thanks in large part to the Clean Air Act, the U.S. Environmental Protection Agency (EPA) reports that a 48 percent decrease nationally in estimated NO_x emissions and a 57 percent decrease in VOC emissions occurred between 1980 and 2009. Average ozone levels have also declined steadily, dropping 30 percent in this same time period (EPA 2011a). The EPA estimates that emissions of NO_x will continue to decline and

FIGURE 2. **Air Quality Index Warning System**

Air Quality Index	Health Impacts
Good (0–50)	No health impacts are expected when air quality is in this range.
Moderate (51–100)	Unusually sensitive people should consider limiting prolonged outdoor exertion.
Unhealthy for Sensitive Groups (101–150)	The following groups should limit prolonged outdoor exertion: • People with lung disease, such as asthma • Children and older adults • People who are active outdoors
Unhealthy (151–200)	The following groups should avoid prolonged outdoor exertion: • People with lung disease, such as asthma • Children and older adults • People who are active outdoors Everyone else should limit prolonged outdoor exertion.
Very Unhealthy (201–300)	The following groups should avoid all outdoor exertion: • People with lung disease, such as asthma • Children and older adults • People who are active outdoors Everyone else should limit outdoor exertion.

Source: Adapted from EPA 2011.

The Air Quality Index (AQI) is a simple color-coded warning system that alerts the public when air pollutants reach unhealthy levels in a local area. Yellow, for example, means "moderate" air quality conditions and red means "unhealthy" conditions. An AQI value of 100 usually corresponds to the current ozone standard established by the EPA—so as the standard changes, the ozone concentration corresponding to an AQI of 100 will change. Air quality may be reported in a newspaper's weather section or on radio or television, particularly when conditions are problematic. (See the EPA's AIRNow website [*www.airnow.gov*] for daily ozone forecasts and real-time ozone conditions.)

322 state counties across the country (out of the 675 counties monitored) do not meet the current standard for safe levels of ozone, including counties with many of the nation's largest cities. Nearly half of Americans live in areas with "unhealthful" levels of ozone pollution.

could decrease by 26 percent between 2010 and 2020, depending on implementation of reduction standards. Reductions in VOC emissions are expected to essentially level off, declining only 3 percent between 2010 and 2020 (EPA 2011b).

The Importance of Ozone Standards

Further declines in these emissions depend on the EPA's pollution standards becoming stronger in the future and on the continued success of emissions reduction efforts—by the EPA, the states, and others.[6] National averages, however, mask significant local and regional "hot spots" of ozone pollution, especially in urban areas. Cities such as Los Angeles, Baltimore, Washington, DC, Chicago, Boston, Dallas, and Philadelphia are among those that have been designated "out of compliance" with (that is, in non-attainment of) the EPA's current ozone standards.

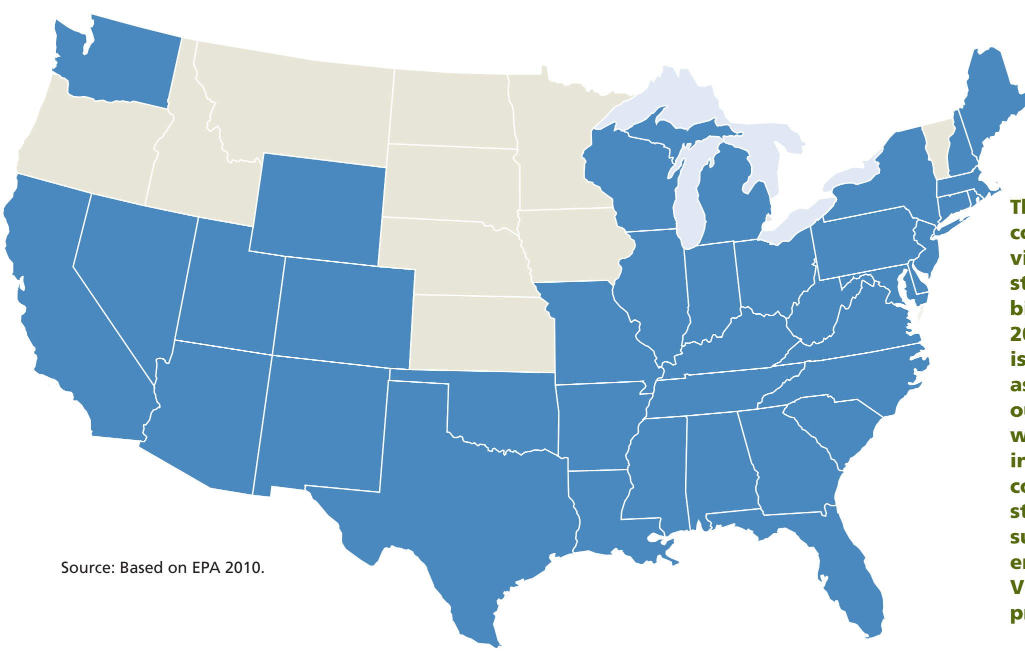
The EPA sets standards for permissible levels of ground-level ozone pollution in terms of its concentration in outdoor air, reported in the units of parts per billion (ppb). The current EPA ozone standard, set in 2008, mandates that summertime ozone concentrations must not show a trend of exceeding 75 ppb (averaged over 8 hours) over a three-year period.[7]

However, the unanimous recommendation of an independent scientific advisory panel convened in 2008 to advise the EPA concluded that the ozone standard should be strengthened to a range of 60 to 70 ppb (Henderson 2008) to protect the health of children, older adults, outdoor workers, and people with asthma and other lung diseases.[8] The current World Health Organization recommendation, for example, is even stronger—at 50 ppb.[9]

The EPA is currently revising its standard in response to court challenges that the agency take into account the latest scientific information on the health impacts of ozone; it is expected that a new rule will be proposed in July 2011.[10]

Meanwhile, 322 counties (out of the 675 counties monitored) in many states across the country do not meet the current standard for safe levels of ozone, as represented in Figure 3. Because these counties include many of the nation's largest cities, nearly half of Americans (48.2 percent) live in areas with "unhealthful" levels of ozone pollution (ALA 2011).[11]

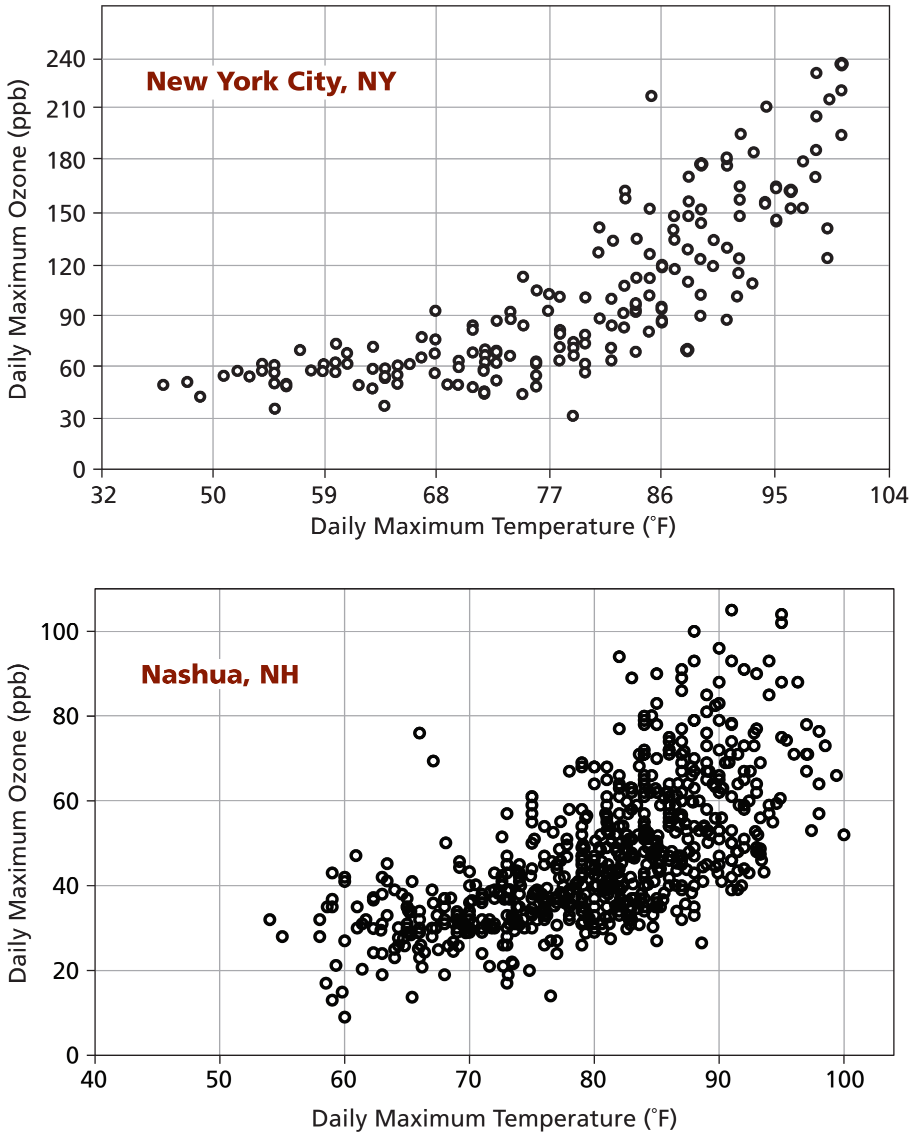
FIGURE 3. **States with Counties that Violate the Current EPA Ozone Standard**



Source: Based on EPA 2010.

The shaded states contain counties that violate the current ozone standard of 75 parts per billion set by the EPA in 2008—a standard that is already recognized as too weak to protect our health. In a warmer world, more counties in additional states could fail to meet the standard, unless they substantially reduce emissions of NO_x and VOCs (the chemical precursors to ozone).

FIGURE 4. **Ozone Pollution Worsens as Daily Temperatures Increase**



These two graphs show a strong positive correlation between temperature (horizontal axis) and ozone levels (vertical axis) in New York City and Nashua, NH. Based on observed data from New York City for May to October ("smog season," averaging period not specified) for the years 1988 to 1990, and observed data (using a one-hour average) from Nashua, NH, for the years 2005 to 2010, both scatter plots show that the higher the temperature, the higher the ozone level, regardless of a city's size. Climate change is projected to bring higher average temperatures over this century, which could increase the occurrence of elevated ozone concentrations.

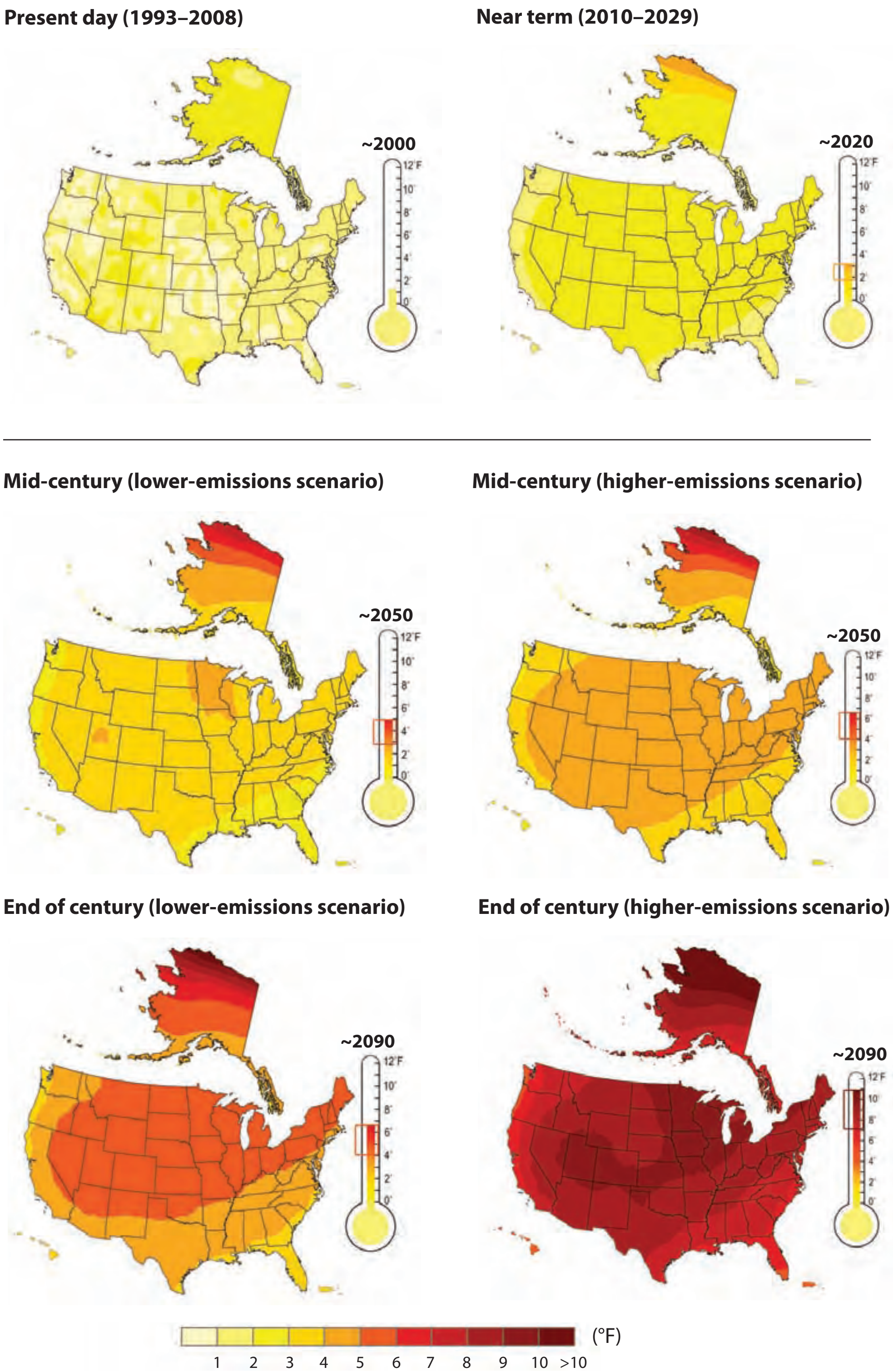
Sources: NAST 2001 (NYC); New Hampshire Department of Environmental Services 2011.

Higher Temperatures Could Make Ozone Pollution Worse

The strong positive relationship between high temperatures and ozone formation is well established (Jacob and Winner 2009). This relationship has been shown both in large cities such as New York City and in smaller cities such as Nashua, NH (Figure 4). In addition to enabling the basic chemical reactions that create ground-level ozone, high temperatures often create stagnant air conditions that cause ozone pollution to settle over an area and remain for a longer time, which in turn increases the potential for human exposure to harmful ozone concentrations (Leibensperger et al. 2008).

Ozone pollution tends to be most severe in urban areas, where vehicular and industrial emissions cluster and where the temperatures are often higher than in surrounding suburbs. However, unhealthful ozone levels can also be found in suburban and rural areas downwind of cities (Logan 1989). Also, precursor emissions from power plants are often carried hundreds of miles over large areas of the country. For example, some pollution from power plants in the Midwest may be transported by prevailing winds to the eastern United States. In addition to harming health, ozone pollution in rural areas negatively affects agriculture and vegetation, such as by decreasing soybean yields (Fishman et al. 2010).

FIGURE 5. **Present-Day and Projected Temperature Increases for the United States***



*All present-day and projected temperature changes are in °F and in reference to a 1961–1979 baseline.

Source: Adapted from Karl, Melillo, and Peterson 2009.

Projected temperature increases for the United States are based on a combination of global climate models. In less than 10 years, largely because of the energy choices the world has already made, much of the country is likely to see temperature increases of an additional 1 to 2°F by 2020—on average about half the increase we have experienced in the last century. However, the emissions choices made today can still make a difference in how much warming we expect to see in future decades, as demonstrated by the difference between the lower- and higher-emissions scenarios at mid-century (2040–2049) and the end of the century (2080–2099).[12]

While recent research shows that current ozone standards need to be stronger to protect health, higher temperatures in a warmer world will make the job of maintaining healthy air ever more difficult.

Given the strong dependence of ozone formation on temperature, a changing climate can make ozone pollution worse. As temperatures increase in a warmer world, days that are conducive to ozone formation are likely to be more frequent (see the technical appendix online). Temperatures in the United States have already increased more than 2°F over the past century because of human-caused emissions of carbon dioxide and other heat-trapping gases. The amount of warming we will see later this century depends heavily on the amount of heat-trapping gases we emit today. If the world's emissions rise at the current pace, parts of the United States are projected to warm another 7 to 11°F (3.9 to 6.1°C) by the end of the century (Karl, Melillo, and Peterson 2009). Even if emissions of all heat-trapping gases were to stop immediately, warming would still be "locked in" for years afterward because carbon dioxide resides in the atmosphere a very long time. As such, temperatures will remain elevated for at least the next decade and possibly longer (Armour and Roe 2011; Gillett et al. 2011; Solomon et al. 2009).

What this means is that climate change is likely to complicate the challenge of reducing ozone pollution. Although emissions of ozone-forming pollutants are currently declining, temperature increases associated with climate change are likely to work against this trend. As a result, even to maintain today's ozone levels may require a greater reduction in precursor emissions. Also, there could be a positive-feedback effect; because increasing temperatures would correspond to greater electricity demand for air conditioning during hot summer months, emissions of ozone-forming pollutants from fossil-fuel power plants would probably increase further. States and counties trying to control ozone pollution and its accompanying health problems thus face a challenging situation: while recent research shows that current ozone standards need to be stronger to protect health, higher temperatures in a warmer world will make the job of maintaining healthy air ever more difficult.

Poor air quality puts large numbers of people at risk for respiratory ailments such as asthma, chronic bronchitis, and emphysema. Today, one in four children in Harlem suffers from asthma (Nicholas et al. 2005). On days with poor air quality, which could increase in a warmer world, both children and adults are more likely to have difficulty breathing, and people with asthma may require a visit to the emergency room.

A Closer Look at Our Methods and Assumptions

Four key steps are involved in this report's analyses of a) the effect that a warmer world could have on ozone pollution and b) the associated health and economic impacts across much of the United States (more detail on all of these steps can be found in the technical appendix online):

1. Deriving a Climate Penalty Factor for the United States

We surveyed the published studies to pick a "climate penalty factor," reviewing both measured data and model projections pertinent to the relationship between temperature and ozone (Bloomer et al. 2009; Jacob and Winner 2008 [and references therein]; Steiner et al. 2006; Taha 2001). Selection of the climate penalty factor was weighted toward a study based on more than two decades of observed data from nearly half of the continental United States (Bloomer et al. 2009). The terms "climate penalty factor" and "climate change penalty," specifically mentioned in some of these published studies, were used to describe the increase in ground-level ozone associated with a given increase in temperature and also the additional reductions in precursor emissions needed to meet a desired ozone level due to the effects of climate change (Bloomer et al. 2009; Wu et al. 2008).

A key simplifying assumption was the choice of a single climate penalty factor—of 1.2 ppb/°F—to apply equally across most of the nation. The current state of research shows that there is regional variation in climate penalty factors—for example, some studies of the Los Angeles Basin show that its urban areas could experience penalty factors greater than 4 ppb/°F (Taha 2001). More research is needed to develop robust regional climate penalty factors that would yield more accurate national numbers. For certain areas, other associated climate consequences (such as changes in vegetation emissions and ventilation processes) could offset the climate penalty (EPA 2009; Wu et al. 2008). Currently, studies are inconclusive as to whether ozone will increase with climate change in the Southeast and coastal Northwest in particular. Therefore we have excluded eight states from our analysis (Florida, Georgia, South Carolina, Alabama, Mississippi, Louisiana, Oregon, and Washington).

A bad air day in Los Angeles, CA.

We also did not factor into our analysis the fact that some areas of the country (such as California, the Midwest, and the Northeast) could see higher average climate penalty factors, which would mean even greater effects on the health impacts in these places than we report. Finally, we did our modeling using average increases in ozone levels, but in some regions climate change is expected to increase the number of ozone-caused "bad air days" as well as to increase the number of peak pollution episodes more drastically than the average levels (Wu et al. 2008; Bell et al. 2004). This could even further increase the associated health effects beyond what the climate penalty indicates.

2. Estimating Temperature Changes in 2020 and 2050

We used future projections of temperature for two different climate scenarios—a lower-emissions and a higher-emissions scenario, based on information adapted from the U.S. Global Change Research Program (Karl, Melillo, and Peterson 2009)—to determine the most likely range for U.S. average temperature increases in the years 2020 and 2050. The projections for temperature change in the USGCRP report are specified in relation to a 1961 to 1979 baseline, and we scaled them to show changes in temperature relative to the present (Figure 5).[17]

The increases in U.S. average temperatures expected in the two decades centered around 2020 are roughly 1 to 2°F higher than what they are today. The higher-emissions scenario leads to a likely increase of 3 to 5.5°F for the two decades centered around 2050, while a lower-emissions scenario leads to an increase of 2 to 4°F over the same period.

3. Determining the Climate Penalty on Ozone

To derive the climate penalty on ozone (projected future increases in ozone concentrations), we simply multiplied the likely temperature projections from the USGCRP report by the climate penalty factor to determine what levels of increased ground-level ozone could be estimated to occur in the years 2020 and 2050 (Table 1). These calculated values ranged from increases in ground-level ozone of 1 to 2 ppb in 2020 to 2 to 7 ppb in 2050. These values reflected the range in temperatures associated with different future climate scenarios, but they did not account for the ranges of climate penalties found in published studies.

4. Running the BenMAP Model

We analyzed the human health impacts of these increases in ground-level ozone due to the climate penalty for the years 2020 and 2050, utilizing the EPA's BenMAP model; we used the upper and lower ends of the indicated ranges. The model applies information from published epidemiological studies and population projections to estimate the health effects at national, regional, state, and county levels. For our analysis, we focused on national and state data for five categories of impacts: premature mortality, respiratory-related hospital admissions for infants and seniors, asthma-related emergency room visits, occurrences of acute respiratory symptoms (minor restricted-activities days), and lost school days. The model cannot accurately project cost estimates in 2050 because it does not include an income adjustment factor that far out into the future. Also note that BenMAP is not able to directly model air quality; we used monitored air quality data for 2007 that is embedded in the model, and we imposed the climate penalty on top of those measurements.

A major simplifying assumption we made in our analysis was to hold emissions of ozone precursors (such as NO_x and VOCs) constant at 2007 levels and only vary the climate-induced ozone penalty. This followed the convention in the published studies and allowed us to isolate the impact of the climate penalty from other factors affecting ozone pollution. EPA data show that, in fact, U.S. emissions of NO_x and anthropogenic VOCs have been declining over time, driven by provisions of the Clean Air Act, among other factors.[20] These trends are expected to continue, but their relative magnitude depends on the success of EPA regulations.

More details on the BenMAP model and how we used it can be found in the technical appendix online.

This report focuses on national and state data for five categories of health impacts: premature mortality, respiratory-related hospital admissions for infants and seniors, asthma-related emergency room visits, occurrences of acute respiratory symptoms, and lost school days.

While we must limit our heat-trapping emissions in order to lower mid-century temperature increases, temperatures will likely continue to rise for the next decade or two. Therefore, the best near-term option for protecting health is to significantly lower the pollutants that form ground-level ozone.

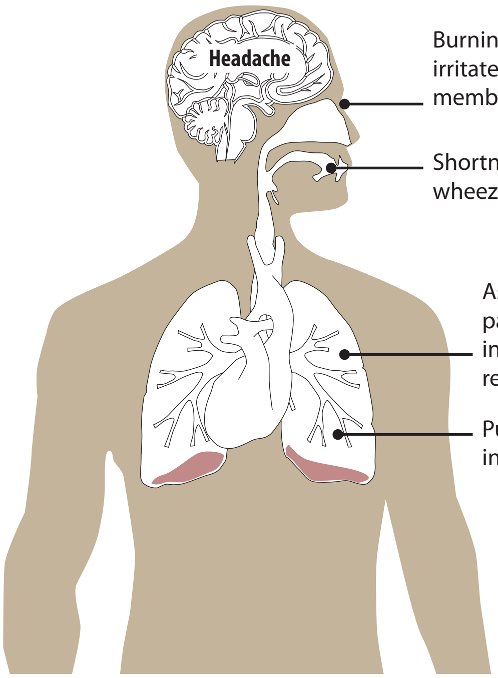
Ozone Is Bad for Your Health

Ground-level ozone, the primary component of smog, irritates the lungs' mucous membranes and other tissues, thereby compromising a person's ability to breathe (Figure 6). Exposure to an increase in ozone concentrations[18] on the order of 10 ppb—beyond an already elevated background level—is associated with increased hospital admissions for pneumonia, asthma, allergic rhinitis, and other respiratory diseases, as well as with premature death. By exacerbating respiratory problems, higher ozone pollution levels send more people to the doctor's office and hospital emergency room and lead to more lost work and school days (Ito, De Leon, and Lippman 2005).

Bearing the Brunt of Ozone Pollution

Ozone is one of the most widespread and dangerous air pollutants. Nearly 37 million children aged 18 and under and more than 17.4 million adults aged 65 and over live in counties with unhealthful ozone levels (ALA 2011). While ozone is bad for nearly everyone, some groups are more susceptible than others.

FIGURE 6. How Ozone Affects the Human Body



People who do not suffer from lung conditions often fail to appreciate what they feel like, how dangerous they are, and why the quality of life for the sufferer can be compromised. This is what breathing ozone can feel like if you have a lung condition: you may find it difficult to breathe deeply and vigorously; you may be short of breath and be in pain when taking a deep breath; you may cough, wheeze, and have a chronically sore or scratchy throat; and your asthma attacks may become more frequent. Inside your body, repeated ozone exposures may inflame and damage your lung lining and make the lungs more susceptible to infection.

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Infants and children are particularly vulnerable to air pollution because their lungs are still growing and developing (Committee on Environmental Health 2004). When children's small airways are irritated or swollen, it's simply harder and more painful for them to breathe (Thurston et al.1997). They also have rapid breathing rates, which increases their exposure to inhaled ozone. Parents with young athletes need to be especially aware of bad air days. According to one study, children playing three or more team sports in communities with high daytime ozone concentrations were approximately three times more likely to develop asthma than children playing no sports (McConnell et al. 2002).

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Adults aged 65 years or older are at excess risk of ozone-related hospitalization or death (Delfino, Murphy-Moulton, and Becklake 1998). As the large demographic bulge of the "baby boomers"—estimated at 79 million Americans—moves into this age category over the next two to three decades, air-pollution-related health effects can be expected to substantially increase (Haaga 2002).


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Given their limited access to health-care resources, **low-income and some minority groups** tend to suffer greater impacts when exposed to ozone pollution. Socioeconomic status is an important determinant of differences in asthma prevalence and severity among ethnic minorities in the United States (Forno and Celedon 2009).[19] The large majority of children in this country without any health insurance coverage live in families that fall below the poverty line. Further, very young children, poor children, and children from Spanish-speaking families appear to be at particularly high risk for inadequate asthma therapy—e.g., the use of inhalers (Halterman et al. 2000).


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Outdoor workers such as lifeguards, police officers, construction workers, and farmers are likewise susceptible. One study found that farmers who spend most of the day outside when ozone levels are high suffer reduced lung function that persists for a couple of days (Brauer and Brook 1997). Another study found that healthy and active outdoor workers—lifeguards, in this case—had greater obstruction in their airways when ozone levels were high (Thaller 2008).


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Healthy people also exhibit a small but significant decrease in lung function following a prolonged exposure to ozone levels as low as 60 ppb during mild exercise (Kim et al. 2010).

The Health Conditions Affected by Ozone Pollution

Many Americans who live with chronic respiratory and other diseases are affected by ozone pollution, sometimes fatally. For example:

Asthma. Ozone pollution does not cause asthma, but it exacerbates the condition's effects by causing the patient's lung tissues and airways to become red, swollen, and constricted (Cody et al. 1992). At present some 3.2 million children and more than 9.5 million adults with asthma live in parts of the United States with very high ozone levels in 2011 (ALA 2011). The prevalence of asthma has been increasing since the early 1980s across all age and racial groups and both genders (Pleis et al. 2009). Asthma is the third-ranking cause of hospitalization among children under 15 (DeFrances, Cullen, and Kozak 2007). Asthmatic children using inhalers are vulnerable even to very low levels of ozone—exposure to levels of 50 ppb (33 percent less than the current "safe" level) has been associated with increased shortness of breath and the need for rescue medication (Gent, Triche, and Holford 2003). Expenditures for health and lost productivity related to asthma are estimated to top $20 billion every year (NIH 2009).

Chronic lung disease. Conditions such as chronic obstructive pulmonary disease (COPD)—a long-lasting obstruction of the airways—can be exacerbated by even small increases in elevated ozone levels (e.g., an increment of 10 ppb), with a corresponding effect on public health and health care costs (ALA 2007). COPD includes emphysema, which reduces the ability of the lungs to expel air. A person with emphysema may feel shortness of breath during exertion and, as the disease progresses, even while at rest. COPD also includes chronic bronchitis, which is an inflammation of the bronchial tubes that bring air into the lungs; the condition makes breathing difficult and causes chest congestion and a bad cough. These respiratory diseases are prevalent in the United States. Nearly 4.8 million people with chronic bronchitis and nearly 2.3 million with emphysema live in counties with unhealthful ozone levels (ALA 2011).

Premature death. Because of its serious effects on human health, ozone is also associated with premature deaths, particularly among vulnerable populations and even more particularly among those with respiratory and heart problems. As with chronic lung disease exacerbations, even a small increase in the previous week's average ozone level has substantial effects on death rates. One study, which used data from 95 large U.S. urban communities to estimate a national average of mortality associated with short-term exposure to elevated ozone levels, showed that a small (10 ppb) increase in ozone pollution was associated with a 0.52 percent increase in deaths per day. This study found that an estimated 3,700 deaths annually could be attributed to this small increase in daily ozone levels (Bell et al. 2004).

Analyzing the Impact of Climate Change on Ozone Pollution

OZONE POLLUTION IS PROJECTED to get worse with future warming. But how *much* worse might it be in a world of increasing temperatures? And what would be the implications for the health of our families and our pocketbooks? This report seeks to address these questions by drawing on well-established scientific literature as well as by conducting a new modeling analysis of health impacts and related costs.

Our Approach

This report takes a multidisciplinary approach in evaluating the potentially serious consequences of climate change for ozone pollution and human health in 2020 and 2050. We first surveyed published studies on the relationship between climate (with a specific focus on temperature) and ground-level ozone. From this effort, we chose a single published number that represented the change in ozone pollution per degree rise in temperature (measured in ppb/°F)—a number generally referred to as the "climate penalty factor" (Bloomer 2009). This value, which was consistent both with observational and model studies for a range of nationally averaged estimates (see the technical appendix online), represented changes in ozone pollution from climate alone; ozone precursor emissions were held constant at 2007 levels.

We then used published projections of temperature for two different climate scenarios (a lower-emissions and a higher-emissions scenario) to determine a likely range for increases in temperature in the United States for the years 2020 and 2050. We combined the climate penalty factor with the temperature projections to determine a range for the potential changes in ozone concentration levels—a range called the "climate penalty on ozone"—for the two climate scenarios in both 2020 and 2050.[13]

Finally, we put those increases in ozone concentration into a health model (the Environmental Benefits Mapping model, or BenMAP[14]) that estimates changes in health impacts that arise from changes in ozone pollution. The model can estimate these impacts in terms of incidence (such as the occurrences of acute respiratory symptoms or the number of hospital admissions), as well as in terms of associated costs. (See the box "A Closer Look at Our Methods and Assumptions" for more detailed information.)

Table 1 summarizes how we arrived at the projected increases in ozone pollution that were then used in our modeling analysis.

TABLE 1. Projected Increase in Ozone Concentration Caused by Climate-Induced Temperature Change in 2020 and 2050

Emissions Scenario	Projected Increase in Temperature (°F)	Climate Penalty Factor (ppb/°F)	Projected Increase in Ozone (ppb)
2020 Emissions Scenario[15]	1–2	1.2	1–2 in 2020
2050 Higher-Emissions Scenario[16]	3–5.5	1.2	4–7 in 2050
2050 Lower-Emissions Scenario	2–4	1.2	2–5 in 2050

By multiplying the projected temperature-increase range by the climate penalty factor, we get the range for the projected increases in ozone in 2020 and 2050. For 2050, the temperature increase is highly dependent on whether global warming emissions continue to be released at their current rate or are reduced.

Health and Economic Impacts of the Climate Penalty on Ozone Pollution

We present the overall health impacts of the climate penalty on ozone for 40 states and the District of Columbia (hereafter referred to as "the US-40") for 2020 and 2050. We also present these health impacts in terms of economic costs for the US-40 for 2020. In addition, we present the 10 worst-affected states in 2020 in terms of health and economic impacts. In each case, our results represent an additional impact above what would have occurred without the climate penalty on ozone.

Our results are derived from a 1 ppb and a 2 ppb ozone increase in 2020 and a 2 ppb and a 7 ppb ozone increase in 2050 (Table 1). We note that we are already feeling the impacts of a climate penalty on ozone pollution because of past climate change. Moreover, our results are not cumulative—they represent impacts in the specific year 2020 or 2050. Climate penalties will likely cause increasing ozone pollution, and associated illnesses and costs, in the intervening years.

We modeled the US-40, and not all 50 states, for two reasons. First, the BenMAP model does not include Alaska and Hawaii. Second, for the eight states of Florida, Georgia, South Carolina, Alabama, Mississippi, Louisiana, Oregon, and Washington, the climate penalty may be absent, inconclusive, or a benefit rather than a penalty (see the box "A Closer Look at Our Methods and Assumptions").

The US-40 Climate Penalty and Health

When it comes to our quality of life, the health of our children, and the productivity of our economy, even small amounts of ozone can add up to real consequences. The results presented in this report show that the climate penalty on ozone increases all five health types of impacts examined—occurrences of acute respiratory symptoms, asthma-related emergency room visits, hospital admissions for seniors and infants, lost school days, and premature deaths—both for 2020 and 2050.[21] Millions of people will be affected by these impacts (Tables 2 and 3).

The increases in health impacts in 2050 are substantially larger than 2020 for two reasons: 1) the climate penalty grows with increasing temperatures, and 2) an expanding and aging population puts more people at risk for adverse health effects.

TABLE 2. Health Impacts from the Climate Penalty on Ozone in the US-40 in 2020*

	Lower Case (1 ppb)			Higher Case (2 ppb)		
Category of Health Impact	**Low**	**Central**	**High**	**Low**	**Central**	**High**
Occurrences of Acute Respiratory Symptoms	719,220	1,414,770	2,109,440	1,437,480	2,825,850	4,210,690
Emergency Room Visits, Asthma-Related[22]	1	600	1,100	1	1,200	2,190
Seniors Admitted to Hospital, Respiratory-Related	180	1,840	4,560	350	3,680	9,080
Infants Admitted to Hospital, Respiratory-Related	370	710	1,050	740	1,420	2,090
Lost School Days	211,030	471,530	668,590	422,060	943,560	1,337,160
Premature Deaths	100	260	470	200	510	930

* Numbers are rounded to the nearest 10, except where less than 10. The low and high values represent the 5th and 95th percentiles of the distribution curve. The central value represents the point in the distribution curve with the most likely occurrence. The EPA reports data from the BenMAP model in terms of this most likely or central value, and often includes the 5th and 95th percentiles.

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Parents, coaches, and athletes should all be made aware of a recent study that found that children in communities with high ozone levels who were involved in three or more outdoor sports at the varsity level were three times more likely to develop asthma compared with children playing no sports (McConnell et al 2002).

If temperatures continue on their current upward trajectory, in 2020—just nine years from now—Americans could contend with an average of 2.8 million more occurrences of acute respiratory symptoms such as serious breathing problems, shortness of breath, coughing, wheezing, and chest tightness, possibly leading to restricted activity for the people affected. In 2050 under the higher-emissions scenario, instances of acute respiratory symptoms escalate to an average of 11.8 million.

Seniors and infants are particularly susceptible to being hospitalized for respiratory distress when they are exposed to high levels of ozone, which can also put increased stress on their caregivers and families. In 2020, an average of 3,700 seniors may be hospitalized under the higher ozone scenario; in 2050, this number is likely to climb to an average of 24,000 hospitalizations for seniors. The number of infants likely to be hospitalized averages 1,400 in 2020 and 5,700 in 2050.

In 2020, American children are most likely to miss an average of 944,000 school days linked to increased ozone pollution from the climate penalty. In the year 2050, that number may be as high as 5.8 million additional school days lost.

The US-40 Climate Penalty and Costs

Climate change has already begun to exact economic costs, and they are likely to get bigger both in the near and longer terms. This report highlights one such potential cost of our inaction to reduce global warming emissions. Impacts such as increased occurrences of acute respiratory symptoms and premature deaths not only impose a physical burden, but also take an economic toll. In 2020 alone, a climate penalty on ozone pollution could cost the U.S. public an average of $2.7 billion (1 ppb) to $5.4 billion (2 ppb), as shown in Table 4.[23] For comparison, U.S. federal funding for public health emergency preparedness for events such as natural

TABLE 3. Health Impacts from the Climate Penalty on Ozone in the US-40 in 2050*

	Lower Case (2 ppb)			Higher Case (7 ppb)		
Category of Health Impact	**Low**	**Central**	**High**	**Low**	**Central**	**High**
Occurrences of Acute Respiratory Symptoms	1,729,580	3,400,090	5,066,330	6,033,100	11,822,430	17,560,240
Emergency Room Visits, Asthma-Related	1	1,480	2,710	2	5,190	9,430
Seniors Admitted to Hospital, Respiratory-Related	660	6,850	16,910	2,300	23,940	58,280
Infants Admitted to Hospital, Respiratory-Related	870	1,660	2,440	3,010	5,680	8,290
Lost School Days	528,390	1,181,260	1,674,030	1,849,190	4,145,280	5,858,590
Premature Deaths	290	750	1,360	1,000	2,610	4,740

* Numbers are rounded to the nearest 10, except where less than 10. The low and high values represent the 5th and 95th percentiles of the distribution curve. The central value represents the point in the distribution curve with the most likely occurrence. The EPA reports data from the BenMAP model in terms of this most likely or central value, and often includes the 5th and 95th percentiles.

disasters, pandemics, and acts of bioterrorism was about $1.2 billion in 2010 (Levi et al. 2010).

These potential health costs are estimated here only for the single year of 2020. We cannot present costs for 2050 because the model did not include projections for income growth past 2024. However, it is clear that without action to check climate change, the climate penalty could accumulate year after year and worsen over time. In addition, the larger projected population would mean more people affected; with rising income levels and health care costs, these impacts would likely be more expensive.[24]

Seniors and infants are particularly susceptible to being hospitalized for respiratory distress when they are exposed to high levels of ozone, which can also put increased stress on their caregivers and families.

Although we do not present the economic costs of the five health categories broken out individually here, most of the cost projections are driven by increased premature mortality (see the technical appendix online). However, all of the health effects described in our analysis place a burden on the U.S. economy and health care system. These costs include, for example, the medical expenses of a hospital stay caused by respiratory illness and the loss of income for a sick patient unable to work. As another example, the value of lost school days is derived from the income lost by a parent who has to stay home with his or her sick child. Furthermore, ours is not a comprehensive accounting of all the costs associated with the health impacts of ozone pollution. For example, we did not address the costs associated with pain and suffering.

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The 10 Hardest-Hit States

The health impacts of the climate penalty on ozone will be felt across large areas of the country, but some states and regions are likely to be worse off than others. The greatest consequences are expected for the Midwest, the Mid-Atlantic, and California—all locations with large numbers of residents living in urban areas. Other areas that could face serious impacts include those with the highest number of vulnerable populations such as children and seniors, and those areas with high NO_x and VOC emissions from vehicles and power plants. Given the limited categories of health and cost addressed above, our results most likely underestimate the consequences for those regions of the country (such as portions of California) that are projected to see a higher climate penalty on ozone than the national

TABLE 4. Health Costs from the Climate Penalty on Ozone in the US-40 in 2020*

	Low	Central	High
Total Costs for a 1 ppb Increase in Ozone Concentration	$443,592,290	$2,712,237,590	$6,864,137,670
Total Costs for a 2 ppb Increase in Ozone Concentration	$886,805,720	$5,423,277,380	$13,724,094,610

* Expressed in 2008$. Numbers are rounded to the nearest 10.

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All the health effects described in this report place a burden on the U.S. economy and health care system. These costs include, for example, the medical expenses of a hospital stay caused by respiratory illness and the loss of income for a sick patient unable to work, or the income lost by a parent who stays home with a sick child.

average. By contrast, some limited areas of the country, such as pockets of the Southeast and Northwest, could see no climate penalty or even a small decrease in ozone concentrations, although the scientific literature on this is inconclusive.

In Table 5, states are ranked according to their estimated number of increased occurrences of acute respiratory symptoms associated with the climate penalty. The results correspond to the higher ozone level in 2020. Health impacts are likely to be greatest in areas with larger exposed populations, so states with large populations or large urban areas are projected to be the most affected.

As shown in Table 6, the 10 states with the highest projected additional health costs from all health impact categories are usually those states with the largest projected populations. Thus California faces the largest costs. However, this trend does not always hold true. Pennsylvania, for example, has fewer projected residents than are projected for Illinois, yet the state is expected to experience higher costs, probably because of demographic factors such as a large number of seniors. Such additional costs come on top of an already substantial burden. California, for example, is already struggling with poor air quality in many counties and the challenges of being out of compliance with the existing air pollution standards (Kleeman et al. 2010).

TABLE 5. State Rankings: Occurrences of Acute Respiratory Symptoms Associated with a Climate Penalty of 2 ppb in 2020*

Rank	State	Population	Low	Central	High
1	California	42,206,743	225,210	442,720	659,680
2	Texas	28,634,896	147,140	289,250	431,000
3	New York	19,576,920	108,150	212,600	316,790
4	Illinois	13,236,720	73,110	143,720	214,160
5	Pennsylvania	12,787,354	67,660	133,010	198,190
6	Ohio	11,644,058	62,530	122,920	183,150
7	Michigan	10,695,993	56,470	111,020	165,420
8	North Carolina	10,709,289	52,350	102,920	153,360
9	New Jersey	9,461,635	51,030	100,320	149,480
10	Virginia	8,917,395	47,250	92,890	138,420

* Occurrences are rounded to the nearest 10. Population projections are courtesy of U.S. Census 2010 and are not rounded.

The results for the other 30 states and the District of Columbia can be found in the technical appendix online.

TABLE 6. State Rankings: Health Care Costs Associated with a Climate Penalty of 2 ppb in 2020*

Rank	State	Population	Low	Central	High
1	California	42,206,743	$122,327,850	$729,189,390	$1,833,793,410
2	Texas	28,634,896	$79,533,660	$466,321,840	$1,168,692,990
3	New York	19,576,920	$64,435,580	$391,568,950	$989,410,430
4	Pennsylvania	12,787,354	$51,854,220	$331,680,220	$849,044,420
5	Illinois	13,236,720	$43,131,710	$272,348,970	$688,944,830
6	Ohio	11,644,058	$44,397,880	$270,632,840	$688,928,900
7	Michigan	10,695,993	$37,111,390	$230,322,580	$584,559,100
8	North Carolina	10,709,289	$33,827,120	$208,603,060	$528,660,190
9	New Jersey	9,461,635	$32,958,790	$203,089,680	$515,592,450
10	Virginia	8,917,395	$29,436,950	$177,950,320	$449,390,850

* Costs are rounded to the nearest 10. Population projections are courtesy of U.S. Census 2010 and are not rounded.

The results for the other 30 states and the District of Columbia can be found in the technical appendix online.

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Lifeguards at Galveston, TX, beaches provided evidence of the impact of short-term exposure to ozone pollution: researchers found that many lifeguards had greater obstruction in their airways when ozone levels were high. Thanks to this research, Galveston beachgoers are now warned, by an "environmental alert" flag, of air and weather conditions that could pose a health threat (Thaller 2008).

Where Do We Go from Here?

Many states are already struggling with meeting ozone standards, as evidenced by the fact that over 48 percent of Americans currently live in areas with unhealthful ozone levels (ALA 2011: Figure 2). In a warming world, even greater numbers of states could face the health and economic consequences of failing to meet these minimally protective ozone standards. At the very least, the climate-change-induced increase in ozone pollution imposes an additional challenge for the states that currently have areas with unsafe ozone levels: they must work harder to reduce ozone-forming pollutants simply to maintain their current—and often unhealthful—ozone levels.

As states come to grips with this challenge they will need tailored information about how their regional air quality will be affected by future climate change. Further research efforts could include better determination of a) climate penalties for individual regions of the United States and b) future trends in local precursor emissions.

We do not have much time to deal with this challenge. It is already too late to prevent the increase in temperatures driven by climate change over the next decade—and perhaps over the next several decades—given the long residence time of carbon dioxide in the atmosphere. Consequently, the climate penalty for 2020 will also be very difficult to avoid, and the harm

The good news is that both ozone pollution and climate change are fundamentally caused in large part by the same activities: human beings burning fossil fuels to generate electricity and run their vehicles. We can address both ozone pollution and climate change by investing in more fuel-efficient cars, reducing miles driven, and using more renewable energy sources—such as wind, solar, and geothermal—to generate electricity.

to our health and economy associated with this penalty will undermine some of the gains made in reducing ozone-precursor emissions. The EPA's most recent report detailing the benefits and costs of the Clean Air Act shows that it is projected to avoid an estimated 7,100 premature deaths associated with ozone pollution in 2020 (EPA 2011b). But a warmer climate may erode the current ozone-reduction benefits of the Clean Air Act between 3 percent (1 ppb) and 7 percent (2 ppb) in 2020.[25] Although we did not model it, we believe that the best option in the near term is to significantly lower the precursor pollutants that form ground-level ozone so that the health impacts do not escalate further.

In the 2050 time frame, we can do better: we have the choice to significantly lower our heat-trapping emissions from current levels and also make deep cuts in emissions of precursor pollutants. By reducing both kinds of emissions, we can significantly lower the 2050 health impacts due to ozone pollution.

In addition to bad air quality, climate change poses other threats to the health and well-being of Americans. This report addresses just one public health threat associated with climate change, but there are numerous others, including heat waves, elevated allergen levels, more occurrences of waterborne diseases, changing disease vectors, and degraded water quality.

The good news is that both ozone pollution and climate change are fundamentally caused in large part by the same activities: human beings burning fossil fuels to generate electricity and run their vehicles. Therefore we can address both ozone pollution and climate change by implementing practical policies and programs and changing individual behaviors. For example, we can reduce both ozone-precursor and carbon emissions from power plants, refineries, and vehicles by:

- Investing in more fuel-efficient cars and reducing miles driven
- Developing fuels that are less carbon-intensive
- Providing good public transit and other commuting and travel alternatives
- Increasing energy efficiency at industrial and commercial facilities
- Developing and retrofitting homes and buildings to be more efficient
- Using more renewable energy resources—such as wind, solar, and geothermal—to generate electricity
- Ensuring that ozone- and carbon-reduction standards are strong enough to be truly protective of public health
- Working collaboratively with global partners to reduce carbon emissions from other countries.

The United States has the knowledge and the technology to reduce unhealthful pollution while also potentially saving billions of dollars. The choices we make today about the way we live, the energy we use, and the pollution we release will make a difference for the health and well-being of ourselves, our children, and our descendants long into the future. The benefits of cleaning up pollution sources will be a win for climate, a win for air quality, a win for public health, and a win for the economy.

Endnotes

1 Bloomer et al. 2009 examined 21 years of ozone and temperature measurements compiled by the U.S. Environmental Protection Agency's Clean Air Status and Trends Network (CASTNET) from rural areas in the eastern United States. The data showed a correlation between increased temperatures and increased levels of ozone.

2 Key findings are reported using the "central" numbers, from the 2 ppb ozone-increase case in 2020 and the 7 ppb ozone-increase case in 2050, presented in Tables 2, 3, and 4. Health effects modeled included number of acute respiratory symptoms (illnesses), emergency room visits, hospital admissions for infants and seniors, lost school days, and premature death.

3 See *www.epa.gov/air/ozonepollution/basic.html*, accessed on May 11, 2011.

4 The online technical appendix to this report provides a more detailed description of the chemical reactions that form ozone. See *www.ucsusa.org/climateandozonepollution*.

5 This report uses the EPA BenMAP model to calculate these impacts. Background on that model can be found at *www.epa.gov/air/benmap*; for details on our methodology, see this report's technical appendix online.

6 A variety of regulations, including the acid rain program of the Clean Air Act, the Transport Rule, the Mercury and Air Toxics Rule, and light- and heavy-duty vehicle regulations have the beneficial effect of lowering ozone precursors while also tackling other pollution impacts.

7 To assess whether states are meeting the standard, the EPA examines the data collected over a year—data that are reported as averages over each eight-hour period—and then determines the fourth-highest such reading of ozone levels for that year. The agency then averages the readings over three consecutive years. To meet the 2008 EPA ozone standard, that final average cannot exceed 75 ppb.

8 The rule proposed in the Federal Register can be found at *www.epa.gov/air/ozonepollution/fr/20100119.pdf*, accessed on May 11, 2011.

9 The WHO standard for ozone is 100 µg/m^3 (eight-hour mean), which translates to approximately 50 ppb (eight-hour mean). See *whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf*, accessed on May 11, 2011.

10 The rule proposed in the Federal Register can be found at *www.epa.gov/air/ozonepollution/fr/20100119.pdf*, accessed on May 11, 2011.

11 "Unhealthful" ozone concentrations range from 76 ppb to 374 ppb (see the American Lung Association air quality chart regarding ozone: online at *www.stateoftheair.org/2011/ key-findings/methodology.html*, accessed on May 11, 2011). The weighted averages were derived by counting the number of days in each unhealthful range (orange, red, purple, and maroon) in each year (2007 to 2009).

12 See Karl, Melillo, and Peterson 2009 for more information on the future temperature projections.

13 The terms climate penalty and climate penalty factor are not original to this document. The terms have previously appeared in Wu et al. 2008 and Bloomer et al. 2009.

14 More information on the BenMAP model can be found at *www.epa.gov/air/benmap*.

15 The near-term (2020) emissions scenario represents the average of the higher- and lower-emissions scenarios. The two scenarios are not appreciably different enough in terms of temperature increases by 2020 to warrant individual analysis of each. The higher scenario is the A2 scenario and the lower scenario is the B1. See IPCC 2000 for more detailed information on the emissions scenarios.

16 The higher scenario is the A2 scenario and the lower scenario is the B1. See IPCC 2000 for more detailed information on the emissions scenarios.

17 The present day is defined as the period 1993 to 2008 in Karl, Melillo, and Peterson 2009.

18 Elevated refers to ozone levels deemed unsafe for exposure (i.e., concentrations above a particular threshold). The EPA has a recommended maximum level of 75 ppb averaged over an eight-hour period.

19 However, ethnic disparities in asthma may also be due to differences among ethnic groups in genetic makeup and gene-environment interaction.

20 See for NO_x: *www.epa.gov/airtrends/nitrogen.html,* accessed on May 11, 2011.

Excerpt: Using a nationwide network of monitoring sites, EPA has developed ambient air quality trends for nitrogen dioxide (NO_2). Trends from 1980–2009 and from 1990–2009 are shown here. Under the Clean Air Act, EPA sets and reviews national air quality standards for NO_2. Air quality monitors measure concentrations of NO_2 throughout the country. EPA, state, tribal, and local agencies use that data to ensure that NO_2 in the air is at levels that protect public health and the environment. Nationally, average NO_2 concentrations have decreased substantially over the years.

See for VOCs: *cfpub.epa.gov/eroe/indexcfm?fuseaction=detail.viewInd&lv=list.listbyalpha&r=219697&subtop=341,* accessed on May 11, 2011.

Excerpt: According to NEI [National Emissions Inventory] data, national total estimated VOC emissions from anthropogenic sources, excluding wildfires and prescribed burns, decreased by 35 percent between 1990 and 2005 (from 23,048,000 to 15,047,000 tons) (Exhibit 2-11, panel A). Trends in estimated anthropogenic VOC emissions in all 10 EPA regions were consistent with the overall decline seen nationally from 1990 to 2005 (Exhibit 2-12). Changes in VOC emissions ranged from a 7-percent reduction (Region 10) to a 54-percent reduction (Region 9).

21 The individual must be treated in a hospital as an inpatient and stay there at least one night. Treatment as an outpatient is not considered hospitalization.

22 The very low 5th-percentile estimates for asthma-related emergency room visits are the result of the weak statistical power of the study used; nevertheless, these estimates still represent actual health impacts.

23 These figures are driven in large part (over 85 percent) by the valuation of premature mortality. The EPA uses a standard metric from the economics literature—the value of a statistical life, or VSL—to calculate these numbers. While VSL is imperfect and has its critics, it is the metric conventionally used in these kinds of economic valuation studies. It is essential to note that this metric should not be misinterpreted as the value of an individual person's life. See the technical appendix online for a fuller explanation.

24 As income rises, the economic value that people attach to health risks increases. Also, the cost of lost work days increases.

25 The number 7,100 and the range of 3 to 7 percent come from EPA 2011b. That report estimates that premature deaths in 2020 could be 710, or 10 percent of 7,100, while the number of deaths avoided would be 93 to 97 percent of 7,100.

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CLIMATE CHANGE AND YOUR HEALTH

Millions of Americans already suffer from the harmful effects of ground-level ozone pollution, which causes a number of serious and costly breathing problems. Now health professionals have an additional air pollution concern: climate change. Because warmer temperatures affect ground-level ozone, climate change will likely cause ozone concentrations to rise over most of the United States.

Climate Change and Your Health: Rising Temperatures, Worsening Ozone Pollution shows how higher temperatures could increase ozone pollution above current levels (assuming that emissions of ozone-precursor pollutants remain constant), and analyzes the resulting expected health consequences of these ozone increases in 2020 and 2050, as well as the economic costs of these health impacts in 2020.

The United States has the knowledge and the technology to reduce unhealthful pollution while also potentially saving billions of dollars. The choices we make today will make a difference for the health and well-being of ourselves, our children, and our descendants long into the future.

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