



Confronting Climate Change in the U.S. Midwest



MINNESOTA

From its fertile croplands and boreal forests to its 10,000 lakes and many riverside communities, Minnesota has been strongly shaped by its climate. However, that climate is changing due to global warming, and unless we make deep and swift cuts in our heat-trapping emissions, the changes ahead could be dramatic. This report presents new projections showing some of the potential impacts of global warming on Minnesota, including severe summer heat, more dangerous storms and floods, and new threats to agricultural production.

GLOBAL WARMING AND THE MIDWEST

Global warming is caused by an increase of pollutants in the atmosphere, including carbon dioxide produced by human activities such as the burning of fossil fuels and the clearing of forests. The carbon dioxide acts like a blanket that traps heat in our

atmosphere and warms our climate; oceans, forests, and land can absorb some of this carbon, but not as fast as we are creating it. As a result, heat-trapping emissions are building up in our atmosphere to levels that could produce severe effects including extreme heat, prolonged droughts, intense storms, corrosive ocean acidification, and dangerous sea-level rise. Because these emissions linger in the atmosphere for 100 years or more, we must act quickly to avert the worst effects of global warming.

The climate of the Midwest has already changed measurably over the last half century (De Gaetano 2002; Kunkel et al. 1999). Average annual temperatures have risen, accompanied by a number of major heat waves in the last few years. There have been fewer cold snaps, and ice and snow are melting sooner in the spring and arriving later in the fall. Heavy rains are occurring about twice as frequently as they did a century ago, increasing the risk of flooding.



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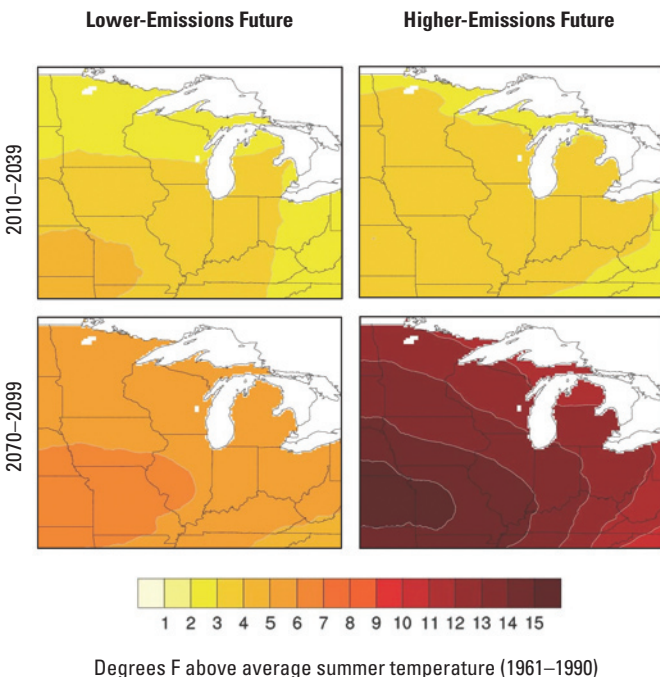
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Scorching Summers Become Standard

If our heat-trapping emissions continue to increase at the current rates, every summer in Minnesota toward the end of the century is projected to be as hot as or hotter than 1988—the state’s hottest summer on record. Under the higher-emissions scenario (right), average summer temperatures are projected to increase over the next several decades by more than 3°F and, toward the end of the century, by an extraordinary 12°F. Under the lower-emissions scenario (left), that increase would be halved.

New Climate Projections for Minnesota

New research summarized here projects significant consequences for Minnesota as soon as the next few decades, increasing in severity into the middle and end of this century. This report considers these consequences in terms of three time frames: 2010–2039 (“the next few decades”), 2040–2069 (“mid-century”), and 2070–2099 (“toward the end of the century”). We compare these periods with the climate in Minnesota during 1961–1990 (“the historical baseline”).

Toward the end of the century, if current pollution trends continue, projected effects in the state include:

Far more scorching summers

- Every summer in Minnesota would be hotter than the most severe summer during the historical baseline.
- Minneapolis-St. Paul would experience almost 70 days per summer with highs over 90 degrees Fahrenheit (°F) and almost a month of days per summer over 100°F.
- Minneapolis-St. Paul would face at least two heat waves per summer like the one that killed hundreds in Chicago in 1995, and at least one heat wave every other summer like the even deadlier European heat wave of 2003.
- Air quality would deteriorate, as hotter weather causes more severe smog problems (assuming similar levels of tailpipe and smokestack emissions). This would have serious consequences for public health, including a greater incidence of asthma attacks and other respiratory conditions.

Dangerous storms and flooding

- More precipitation would fall as rain rather than snow, with days on which snow falls decreasing by one-third.
- Heavy rains would become more common throughout the year, leading to a greater incidence of flash flooding.
- Winters and springs, when the flood risk is already high, would become around 30 percent wetter.

New threats to agriculture

- Crops and livestock would face substantially more heat stress, decreasing crop yields and livestock productivity.
- Warmer winters and a growing season up to six weeks longer would enable pests like the corn rootworm and European corn borer to expand their range.
- Crop production would be inhibited by changing rain patterns such as wetter springs (which delay planting and increase flood risk) and 15 percent less rain during the increasingly hot summers.

Effective and Affordable Solutions

The most dangerous effects of climate change are likely to occur if the global average temperature rises more than two degrees Celsius above where it stood in 1850. Science

shows we still have a chance of keeping temperatures below this level if we cut heat-trapping emissions deeply and quickly—and limit atmospheric levels of carbon dioxide to 450 parts per million (see www.ucsusa.org/mwclimate for more details).

Minnesota can do its part by implementing its own carbon-reducing state policies and investing in clean energy technologies that can both reduce consumer energy costs and build new growth industries in the state. Minnesota can also play a lead role in calling for strong federal legislation that would provide climate-friendly choices for Minnesota consumers and businesses and help for resource managers and local governments that must prepare for the effects of climate change that cannot be avoided.

A recent analysis by the Union of Concerned Scientists (UCS), *Climate 2030: A National Blueprint for a Clean Energy Economy* (Cleetus, Clemmer, and Friedman 2009) demonstrates that the United States can cut heat-trapping emissions deeply and swiftly enough to avoid the most dangerous consequences of climate change. A comprehensive climate and energy approach—combining a cap on emissions with policies that encourage renewable electricity, energy efficiency, and cleaner transportation choices—can reduce emissions 26 percent below 2005 levels by 2020 and 56 percent below 2005 levels by 2030 while saving consumers and businesses money.

Our Analysis

Our analysis considers two different possible futures: one with a lower level of global warming pollution and one with a higher level (see www.ucsusa.org/mwclimate). These futures represent the best and worst cases of the emissions scenarios described by the international scientific community in 2000 and which have been focal points for scientific analysis ever since. However, they by no means encompass the full range of emissions futures that could plausibly unfold.

Climate protection policies, if implemented quickly, could reduce emissions significantly below the lower-emissions scenario considered here. On the other hand, up until 2008, global emissions have been higher than the higher-emissions scenario being considered.

HOW WILL EMISSIONS CHOICES AFFECT MINNESOTA'S FUTURE?

Dangerously Hot Summers

Our new research projects dramatically hotter summers for Minnesota. This is true under both the lower- and higher-emissions scenarios, but the prevalence of extreme heat is much greater under the higher-emissions scenario. The conditions that constitute “extreme” were measured in three ways: comparing future summers with the hottest summer during the historical baseline, counting the expected number of days above 90°F and 100°F degrees per summer, and projecting the likelihood of extreme heat waves similar to those that hit Chicago in 1995 and much of Europe in 2003. By all three measures, summers in Minnesota will become dangerously hot.

Comparisons with the historical baseline

As soon as the next few decades, more than half of Minnesota’s summers could be hotter than the hottest summer the state experienced during the historical baseline (1988). Under the higher-emissions scenario every Minnesota summer at mid-century is projected to be hotter than 1988. Even under the lower-emissions scenario at least 80 percent of summers at mid-century would be hotter

than 1988 and all summers would be hotter toward the end of the century (though not as hot as under the higher-emissions scenario).

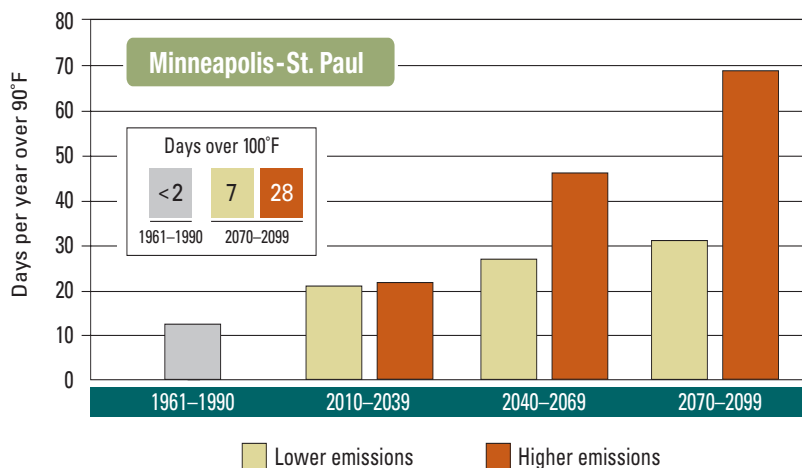
These findings are particularly troubling because the summer of 1988 brought record-breaking heat to Minnesota and much of the nation. The average temperature in Minnesota that summer was more than 4°F higher than normal. Nationwide, the unusual heat combined with widespread drought to cause an astonishing \$40 billion in losses to agriculture and related industries, making the 1988 heat wave and drought the United States’ second costliest weather-related disaster in modern times (after Hurricane Katrina) (NCDC 2009). By mid-century, however, summers like these will likely be considered *cooler* than average.

More days over 90°F and 100°F

Because heat waves are especially

lethal in cities, where urban landscapes absorb more heat during the day and are less effective at releasing it at night (the “heat island” effect), our analysis focused on the extreme heat projected for the state’s largest urban area, Minneapolis-St. Paul, and the number of days each year likely to exceed 90°F and 100°F. During the historical baseline Minneapolis-St. Paul averaged only 12 days per summer with highs over 90°F. That number rises substantially in the next few decades, and toward the end of the century under the higher-emissions scenario, the Twin Cities are projected to experience almost 70 days over 90°F—nearly the entire summer. Under the lower-emissions scenario that number would be cut by about half.

As for the more dangerous days over 100°F, Minneapolis-St. Paul averaged only about one such day each summer during the historical baseline. But toward the end of the



Extreme Heat Becomes More Frequent

Under the higher-emissions scenario, the Twin Cities could experience nearly an entire summer of days above 90°F toward the end of the century. Under the lower-emissions scenario, the number of such days would be halved. Dangerously hot days over 100°F (shown in the inset box) are also projected to increase dramatically, with almost a month of such days expected under the higher-emissions scenario.

century under the higher-emissions scenario, the Twin Cities are projected to face 28 such days—four full weeks. That number would be reduced to seven under the lower-emissions scenario. Other Minnesota cities such as Bloomington, Duluth, and Rochester will face conditions similar to Minneapolis-St. Paul.

More deadly heat waves

The severe heat projected for Minneapolis-St. Paul poses serious health risks for residents. Heat waves already kill more people in the United States each year than hurricanes, tornadoes, floods, and lightning combined (CDC 2006), and the average annual death toll of nearly 700 may well be an underestimate, since there are no uniform reporting requirements and many such deaths are probably misclassified (Luber

2008). Studies show that deaths from many causes, including cardiovascular and respiratory diseases, increase during heat waves.

The health costs associated with heat waves are not limited to deaths; many other people become sick enough to be hospitalized. In 2005, medical costs related to extreme heat and cold totaled \$1.5 billion nationwide, or more than \$16,000 per patient. The Chicago heat wave of 1995 increased admissions to Cook County hospitals 11 percent (more than 1,000 patients) during the peak week (Semenza et al. 1999). Many heat-related deaths and illnesses can be prevented by improving warning systems, access to air conditioning, and year-round medical staffing.

Our research projects how likely Minneapolis-St. Paul would be to experience heat waves as severe as

those that affected Chicago in 1995 or Europe in 2003 (see the text box below). Our findings are disturbing; under the higher-emissions scenario, for example:

- By **mid-century** Minneapolis-St. Paul would experience a heat wave as hot as the 1995 Chicago heat wave almost every summer and a heat wave like the 2003 European heat wave at least every fifth summer
- Toward the **end of the century** Minneapolis-St. Paul would experience at least two heat waves as hot as the 1995 Chicago heat wave every summer and a heat wave like the 2003 European heat wave every other year

A heat wave similar to the 2003 European heat wave would cause more than 140 deaths in Minneapolis-St. Paul

Minnesota Could Face Heat Waves of Historic Proportions

In July 1995, Chicago experienced its worst weather-related disaster ever. Temperatures reached or exceeded 90°F for seven days in a row and exceeded 100°F on two of those days (Kaiser et al. 2007). Conditions were made worse by high humidity levels, unusually warm night-time temperatures, and pollution that built up in the stagnant air. Thousands of Chicagoans developed serious heat-related conditions, overwhelming the city's emergency responders and forcing 23 hospitals to close their emergency room doors to new patients. Like the city's hospitals, the county morgue was completely overwhelmed (Klinenberg 2002).

The heat wave was ultimately responsible for between 450 and 700 deaths in Chicago (Klinenberg 2002; CDC 1995). Hundreds of additional heat-related deaths occurred in other

If our heat-trapping emissions continue unabated, heat waves of historic proportions are projected to become routine in Minnesota.

parts of the Midwest and along the East Coast (NOAA 1996).

Yet Chicago's experience pales in comparison to the European heat wave of 2003—the worst of the past 150 years in terms of both duration and intensity. For almost three months daily high temperatures were hotter than normal, with half of those days more than 10°F above normal. Daily low temperatures were

also abnormally hot. The death toll was initially estimated around 30,000 (UNEP 2004), but more recent analyses have identified 70,000 heat-related deaths that summer in 16 countries (Robine et al. 2008). Hardest hit was France, where fatalities exceeded 2,000 per day during the heat wave's peak (Pirard et al. 2005).

If our heat-trapping emissions continue unabated, heat waves like these are projected to become routine in Minnesota: under the higher-emissions scenario, Minneapolis-St. Paul would experience a heat wave comparable to the 2003 European heat wave at least every fifth year by mid-century. Toward the end of the century Minneapolis-St. Paul would suffer such a heat wave every other year under the higher-emissions scenario but only once every 15 years under the lower-emissions scenario.



Warming Climate Leads to Poor Air Quality

The fact that air pollution worsens as temperatures rise should concern residents of Indianapolis—poor air quality puts large numbers of people at risk from respiratory illnesses such as asthma, chronic bronchitis, and emphysema. Higher temperatures are also expected to increase the dangers of allergy-related diseases (Ziska et al. 2008).

(36 per every 100,000 residents), compared with 30 heat-related deaths per summer during the baseline period. This estimate assumes the demographics, vulnerability, and infrastructure of the Twin Cities do not change from today. Increased use of air conditioning would likely reduce the death toll, but the general aging of the population would likely increase the death toll since the elderly are most vulnerable to heat. The number of Minnesota residents older than 65 is projected to be twice as large in 2030 as in 2000, rising to more than 19 percent of the state's population (U.S. Census Bureau 2004).

Changes in air quality could also play a role: for example, if air quality deteriorates because warmer temperatures exacerbate smog and soot pollution, and we continue to burn more fossil fuels in our power plants and vehicles, heat-related mortality would likely rise. Conversely, cleaner air created by a shift away from fossil fuels would likely reduce heat-related mortality.

More dangerous air pollution

In areas where there are local sources of fossil fuel emissions, ground-level

ozone—a dangerous air pollutant and the main component of smog—increases at temperatures over 90°F (Luber 2008). Since our projections show that, under the higher-emissions scenario, Minnesota will experience such temperatures virtually the entire summer toward the end of the century, the state can expect far more days of unhealthy ozone levels than would occur without global warming.

High concentrations of ground-level ozone (not to be confused with ozone in the stratosphere, which provides an important natural shield against solar radiation) diminish lung function, cause a burning sensation in the lungs, and aggravate asthma and other respiratory conditions. Ozone may also contribute to premature death, especially in people with heart and lung disease (EPA 2008). Studies show that when ozone levels go up, so do hospitalizations for asthma and other lung conditions, and it appears that heat and ozone together increase mortality (Luber 2008). Ozone also damages plant life; the Environmental Protection Agency (EPA) warns that a climate change-induced increase in ozone could damage ecosystems and

agriculture as well as human health (EPA 2008).

Another air contaminant is small particulate pollution (or soot). Small particulates increase the severity of asthma attacks in children, increase the number of heart attacks and hospitalizations related to cardiovascular disease and asthma, and cause early deaths from heart and lung disease (ALA 2009). The leading source of small particulate air pollution is coal-fired power plants, and as demand for electricity increases in response to rising temperatures, power plants generate more emissions. Therefore, climate change threatens to exacerbate Minnesota's particulate air pollution.

In Minnesota today, more than 8 percent of the population (more than 80,000 children and more than 200,000 adults) suffers from asthma (ALA 2009). Heart disease is responsible for nearly 400 of every 100,000 deaths among people 35 and older in Minnesota (CDC 2009). The combination of increasing heat, ozone, and small particulate pollution can be especially dangerous for these populations.

Changes in Storm, Flood, and Drought Patterns

Flooding in Minnesota

Minnesotans have suffered through significant flooding in recent years along many of the state's rivers and streams, but most dramatically along the Red River of the North and its tributaries. In 1997, western Minnesota and eastern North Dakota experienced their worst natural disaster in memory when the Red River rose to record levels and breached the defenses of many communities, particularly East Grand Forks, MN, and Grand Forks, ND. More than 60,000 people were forced to evacuate the two cities (NOAA 2009b)—the largest displacement of an American urban area by flooding prior to Hurricane Katrina (NPR 2007). The flood killed 11 people (Lott et al. 2009) and caused more than \$5 billion in damage to the region's homes, businesses, and farms (USGS 2009). The Red River valley was also flooded in 2001, 2006, and 2009, and although the 1997 flood was characterized at the time as a

100-year flood, the 2009 flood nearly equaled it.

Other parts of the state are vulnerable to flooding as well. A series of thunderstorms in August 2007 dropped a tremendous amount of rain on Minnesota, especially in the southeastern portion of the state where 8 to 20 inches of rain fell in three days. Many southeastern counties received at least six inches of rain over a 24-hour period—traditionally considered a 100-year event. The subsequent flash flooding triggered mudslides, closed roads, affected hundreds of homes and businesses, and caused seven deaths (State Climatology Office 2007).

As heavy rainfalls become more common, the threat of flooding will rise, as will the value of property at risk and the costs of emergency response systems and flood control measures such as levees and dams.

More frequent downpours and flooding

Heavy downpours are already twice as frequent in the Midwest as they were a century ago (Kunkel et al.

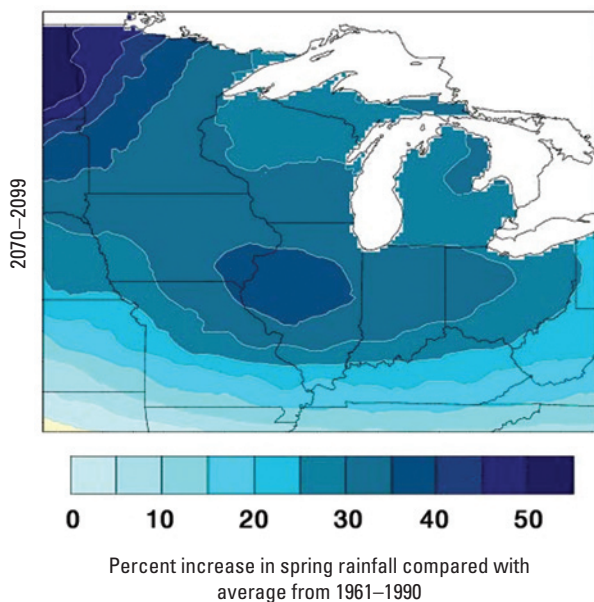
1999). While scientists cannot attribute any single storm to climate change, more heavy precipitation can be attributed to climate change that has already occurred over the past 50 years (Trenberth et al. 2007).

Our analysis indicates that the warming ahead will make Minnesota substantially more vulnerable to the kind of natural disasters it has suffered since 1997. Two findings stand out from the research:

- **Precipitation is more likely to come in the form of heavy rains.** Under either emissions scenario, Minneapolis-St. Paul is projected to experience a more than 66 percent increase in heavy rainfalls (defined as more than two inches of rain in one day) over the next few decades. Toward the end of the century, heavy rainfalls are projected to be almost twice as frequent under either emissions scenario. The maximum amount of precipitation falling within a one-, five-, or seven-day period is also projected to rise under both scenarios.
- **Winters, springs, and falls will be wetter but summers will be drier.** Winters and springs are projected to see up to 50 percent more precipitation toward the end of the century under the higher-emissions scenario, and autumns are projected to see more precipitation as well. Meanwhile, summers could see 15 percent less rain. As described above, more of the rain that does fall will be in the form of downpours.

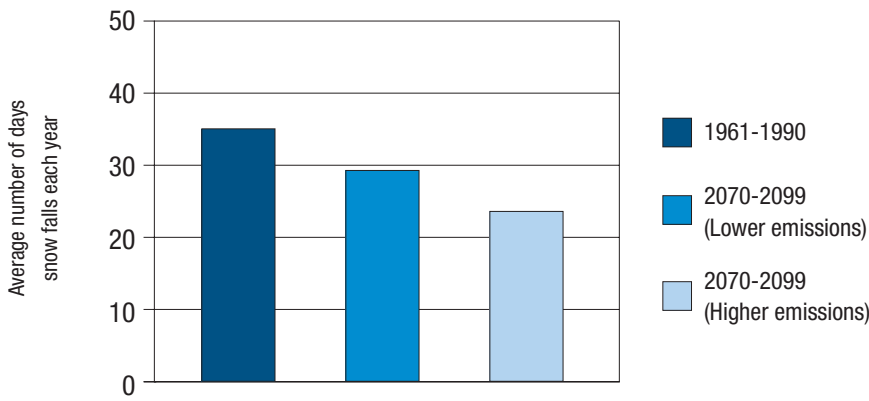
These projections show a substantially increased risk of flooding in Minnesota as the century progresses, especially if emissions are high. While there is likely to be some increase in local summertime flooding due

Higher-Emissions Future



Spring Rains Increase

Heavy downpours are now twice as frequent in the Midwest as they were a century ago. Under the higher-emissions scenario, Minnesota's spring rainfall is projected to increase almost 15 percent over the next several decades and 30 to 50 percent toward the end of the century. This may lead to more flooding, delays in the planting of spring crops, and declining water quality in rivers, streams, and storage reservoirs.



Fewer Days of Snow Falling

The traditional Minnesota winter may become shorter as the state's climate warms, and higher winter and spring temperatures will likely bring more precipitation in the form of rain rather than snow. If our heat-trapping emissions continue to increase at current rates, toward the end of the century Minnesota is expected to have one-third fewer days every year when snow falls compared with the historical baseline (1961–1990).

to more frequent downpours, the greatest flooding risk is in the winter and spring, when rainfalls combine with melting snow and still-frozen soils to increase runoff. The highest change in spring rainfall is projected for the northwestern part of the state, which is already vulnerable to flooding. Analyses of various rivers in the Midwest (which used a level of emissions somewhat lower than our higher-emissions scenario) projected more than triple the number of high-flow days toward the end of the century (Cherkauer and Sinha 2009; Wuebbles et al. 2008).

More frequent short-term droughts

Paradoxically, Minnesota could face not only the risk of greater flooding but also the risk of greater drought, although climate projections are less consistent in this regard. The more temperatures rise, the more water evaporates from the soil and plants, requiring more rainfall just to maintain the same soil moisture levels.

However, the Midwest is projected to receive less rain in the summer (when temperatures are hottest), not more. As a result, the likelihood of drought in the region will increase, as overall water levels in rivers, streams, and wetlands are likely to decline. Short-term droughts are projected to increase, but long-duration droughts (lasting more than two years) are likely to decline.



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Lower water levels in the Great Lakes

Water levels in the Great Lakes are projected to decline both in the summer (due to increased evaporation caused by higher temperatures) and winter (due to a decrease in lake ice) (Angel and Kunkel 2009; Hayhoe et al. 2009). The greatest declines are expected for Lake Huron and Lake Michigan. Increasing air temperatures and evaporation coupled with decreasing precipitation and ice cover have already lowered water levels over the past decade (1997–2007), with Lake Superior setting a new record low in September 2007. At the end of 2008, Lake Superior was nine inches below average (NOAA 2009).

The falling water level in Lake Superior and the other Great Lakes threatens the port of Duluth-Superior, which plays a crucial role in Minnesota's—and the region's—economy. In 2007, the port received more than 1,200 ships and 48 million tons of cargo, primarily coal, iron ore, and grain (Duluth Seaway Port Authority 2009)—enough to support 2,000 jobs (not including employment in the industries producing the cargo) (Duluth Seaway Port Authority 2009). Three-fourths of U.S. iron ore is shipped through Duluth to

Declining Lake Levels Endanger the State's Economy

Under the higher-emissions scenario, water levels in the Great Lakes are projected to fall between one and two feet toward the end of the century. Such a decline represents a threat to the livelihood of 2,000 workers at the port of Duluth-Superior, which received more than 1,200 ships and 48 million tons of cargo in 2007.



Changes Mean Uncertainty for Agriculture

Minnesota's farmers would benefit from the longer growing seasons expected to accompany global warming, but projected increases in spring rains could interfere with planting and cause more flooding. Farmers therefore face greater risk and expense if climate change continues unabated.

steel mills in other states or abroad (Jorgensen 2008).

Because freighters that carry iron ore and other bulk materials are designed and loaded to barely clear the shallowest points along their routes, low water levels force these ships to carry less cargo or change their routes. Every lost inch of water depth can force a freighter to carry between 50 and 270 tons less cargo (Lydersen 2008).

Under the lower-emissions scenario, water levels in the Great Lakes are projected to fall less than one foot toward the end of the century; under the higher-emissions scenario, levels are projected to fall between one and two feet. A decline of this magnitude can have significant economic, aesthetic, recreational, and environmental impacts, such as significantly lengthening the distance to the lake-shore, affecting beach and coastal ecosystems, exposing toxic contaminants, and impairing recreational boating and commercial shipping.

New Threats to Minnesota's Agriculture

Minnesota is an important part of the nation's agricultural heartland. Forty-three percent of the state's acreage is devoted to cropland (USDA 2009a); the state ranks fourth in the nation in

corn production, third in soybeans, first in sugar beets, and tenth in wheat (USDA 2009c). Minnesota also has one of the nation's most productive livestock industries, including turkeys, chickens, pigs, and dairy cows. In 2002, around 15 percent of Minnesota's jobs were farm-related, employing more than 500,000 people (USDA 2005), and in 2007, agricultural commodities brought more than \$12 billion to the state (USDA 2009a).

The heat and precipitation changes projected for Minnesota have potentially profound implications for agricultural production. Toward the end of the century, growing seasons are likely to lengthen by three weeks under the lower-emissions scenario and six to seven weeks under the higher-emissions scenario. Also, rising CO₂ levels have a fertilizing effect on crops. These changes by themselves would increase crop production, but they will be accompanied by many other changes that threaten production, such as heat stress, increased drought and flood risks, and an expansion of crop pests' range.

More heat stress for crops

The extreme summer heat projected for Minnesota, particularly under higher-emissions scenarios, puts the

region's crops at significant risk. Corn and wheat crops, for example, can fail at 95°F, with the risk increasing the longer the heat lasts. When such hot spells coincide with droughts, as they often do, crop losses can be severe.

The United States lost \$40 billion from a 1988 heat wave—mostly due to crop losses. Crop yields in Minnesota dropped precipitously that year, with corn and wheat falling nearly two-thirds and soybeans below three-quarters of their average annual yields for the period 1978–1997 (USDA 2009b). Over the next few

decades (under both emissions scenarios) more than half of Minnesota summers are projected to be hotter than 1988, and by mid-century under the higher-emissions scenario, almost all Minnesota summers are projected to be hotter than 1988.

Our analysis projects the frequency with which Minnesota and the Midwest would face three- and seven-day periods of crop-damaging temperatures of 95°F or higher. During the historical baseline such periods of intense heat were extremely rare in the Midwest, with three-day periods occurring about once every 10 years and seven-day periods occurring on average only once every 30 years in the more southern states.

Under the higher-emissions scenario, however, a three-day period with temperatures reaching 95°F or higher is projected to occur every other summer in Minnesota by mid-century, and one is projected to occur in three of every four years toward the end of the century. A more destructive seven-day period would occur at least once every five summers by mid-century and every other summer toward the end of the century. Under the lower-emissions scenario, the frequency of such periods

would be significantly less toward the end of the century, with a week-long period of extreme heat remaining rare in the state.

Recent analysis of the impact that projected temperature and precipitation changes will have on the value of U.S. farmland found that rain-fed (non-irrigated) farmland in the eastern and central United States could decrease in value as much as 25 percent by mid-century, and as much as 69 percent toward the end of the century (Schlenker et al. 2006). Almost all of the loss is due to the increasing number of days above 93°F, a temperature at which most crops start to suffer.

Wider spread of pests

The warmer winters ahead mean that crop pests and pathogens normally kept in check by cold temperatures are projected to expand their ranges northward. A recent study warned that the expanded ranges of corn pests have caused substantial economic impact in the form of higher seed and insecticide costs and lower yields (Diffenbaugh et al. 2008). Already, corn pests cost U.S. corn producers more than \$1 billion annually; the corn earworm alone is responsible for destroying about 2 percent of the nation's corn crop every year, and it has shown resistance to a wide range of insecticides (Diffenbaugh et al. 2008).

Minnesota's valuable corn crop would be at risk if two types of corn rootworm and the European corn borer do indeed move north. During the historical baseline, conditions conducive to these pests occurred rarely. Under the higher-emissions scenario, however, conditions conducive to these species will occur virtually every year in Minnesota toward the end of the century.

Potentially damaging changes in precipitation

Crops under stress from extreme heat need more rain, but Minnesota is projected to receive less rain in the summer growing season as the climate warms. Dry conditions will be a particular problem for Minnesota's crops because only about 3 percent have access to irrigation (USDA 2009a). In addition, the projected increase in spring rains could interfere with planting and pose a greater risk of floods like those of 1993, which reduced the state's crop yield 44 percent below the average of the three preceding years (Pielke et al. 2002). Changes in precipitation are therefore likely to limit farmers' ability to take advantage of the longer growing seasons expected to accompany future climate change.

There are many uncertainties about the timing and extent of the effects that climate change will have on Minnesota's agriculture. Much depends on how quickly and successfully farmers can adapt to changing weather patterns by altering their

traditional crop choices, planting times, and other practices. However, as the number of summer days characterized by extreme heat increases over the course of this century, yields of virtually every crop will decrease—and the losses will only get worse as the climate continues to change.

CLIMATE SOLUTIONS FOR MINNESOTA

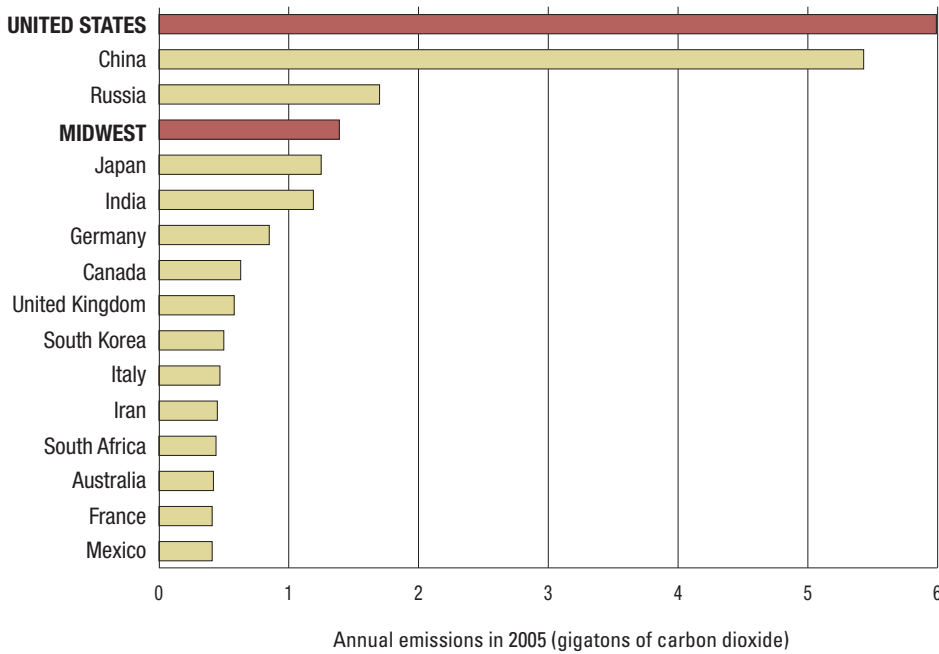
Since 1990, Minnesota's economy, population, and global warming emissions have grown nearly twice as fast as the Midwest as a whole. Transportation and electricity generation are the largest contributors to the state's global warming emissions, each accounting for roughly one-third of the total (EIA 2008a). Sixty-two percent of the electricity generated in Minnesota comes from coal-fired power plants (compared with the national average of 50 percent) (EIA 2007), and the state even imports a substantial additional amount of coal-fired electricity from North Dakota. Agriculture also



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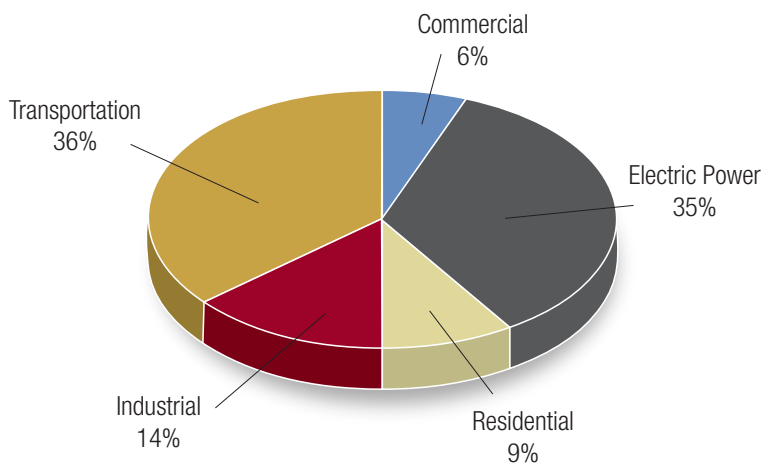
More Disastrous Spring Floods Could Be on the Way

While Minnesotans will likely see some increase in localized summer flooding due to heavier downpours, the greatest flood risk will be in the winter and spring, when heavy rains can combine with melting snow and still-frozen soils to increase runoff. This would result in catastrophic flooding like that experienced in spring 2009 along Minnesota's Red River.



The Midwest Burns More Fossil Fuels Than Entire Nations

The total combined emissions from eight states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) would make the Midwest the world's fourth largest polluter if it were a nation. The region's emissions are more than double those of the United Kingdom, which has about the same population (EIA 2008b).



Vehicles and Power Plants Are Minnesota's Biggest Polluters

Transportation and electricity generation—primarily from coal-fired power plants—are the largest sources of heat-trapping emissions in Minnesota (EIA 2008a). This chart reflects CO₂ associated with power plants located within the state and has not been adjusted to reflect power imported to or exported from Minnesota.

produces global warming emissions—close to 13 percent of Minnesota's total (WRI 2007), which is nearly double the national average of 7 percent (USDA 2008).

If Minnesota and the world are to avoid the worst consequences of climate change, the state must aggressively reduce its emissions by:

- increasing energy efficiency and conservation in industries and homes;
- boosting the use of renewable energy resources such as wind power, advanced biofuels, and geothermal energy;
- improving vehicle fuel efficiency and reducing the number of miles Minnesotans drive; and
- improving agricultural practices to reduce the release of heat-trapping emissions from soil tilling and fertilization application.

These actions will also provide benefits such as lower energy costs (within a few years or less), new local jobs, cleaner air and water, and improved habitats. A recent analysis by the Union of Concerned Scientists shows that businesses and industries in the region could collectively save \$8.2 billion in 2030 by instituting these kinds of changes (Cleetus, Clemmer, and Friedman 2009).

With its excellent wind capacity and first-rate research universities, Minnesota has the resources to reduce heat-trapping emissions from its agriculture and manufacturing sectors. The state has already made strides toward implementing a number of the strategies listed above, and deserves credit for its progress on the following initiatives:

- The Next Generation Energy Act of 2007 set goals for statewide emissions reductions of 15 percent

by 2015, 30 percent by 2025, and 80 percent by 2050.

- Minnesota was one of the first states to adopt a renewable electricity standard, which is now one of the country's strongest: the state's largest utility, Xcel Energy, must produce 30 percent of its electricity from renewable resources (such as wind, solar, and bioenergy) by 2020, and all other state utilities must meet a standard of 25 percent by 2025. In 2006, 6.8 percent of Minnesota's electricity came from renewable resources—the highest percentage in the Midwest (EIA 2009).
- Minnesota is one of only four midwestern states that require electric and natural gas utilities to reduce energy demand through energy efficiency programs (in Minnesota's case, a reduction of 1.5 percent annually). Energy efficiency measures save consumers money, reduce global warming emissions, and create local jobs for people who perform tasks such as energy audits, weatherizing homes, and manufacturing efficient windows.

Pathways to Real Progress

Minnesota has made significant progress, but more can be done to take advantage of clean energy opportunities and reduce global warming emissions, including:

Complete the state's global warming plan

While Minnesota has adopted goals for reducing global warming emissions, the Pawlenty administration has failed to prepare a comprehensive plan for meeting these goals (as required by law).



© Great River Energy

Green Building Design Saves Money and Energy

The headquarters of Minnesota electricity wholesaler Great River Energy combines energy efficiency with on-site renewable energy to reduce fossil fuel use by 75 percent, cut CO₂ emissions by 60 percent, and save nearly 50 percent on energy costs compared with conventional buildings.

Promote combined heat and power

The Minnesota stakeholder planning process found that emissions could be significantly cut through greater use of combined heat and power (CHP), which is the practice of using waste heat from industrial processes to generate electricity. Minnesota should encourage greater use of CHP through measures such as tax incentives, attractive financing arrangements, and utility rate structures favorable to CHP.

Stop investing in polluting coal plants

Minnesota should adopt a moratorium on both the construction of new coal plants and the import of power from proposed coal plants outside state borders—unless and until such plants reduce their emissions using carbon capture and storage (CCS) technology (provided this proves commercially feasible). New financial commitments to coal plants without CCS will lock the state into high CO₂ emissions for decades to come, increase financial risks for ratepayers, and inhibit necessary investments in clean energy technologies.

Building More Resilient Communities

Because climate change is already upon us and some amount of additional warming is inevitable, Minnesota must adapt to higher temperatures and more heavy rains while working to reduce its emissions. Any delay in emissions reductions will make it more difficult and costly to adapt; conversely, aggressive steps to reduce emissions *now* will provide the time ecosystems and societies need to become more resilient. For each adaptation measure considered, Minnesota's decision makers must carefully assess the potential barriers, costs, and unintended social and environmental consequences.

A State-Federal Partnership

Although Minnesota can achieve much with its own policies and resources, the scale of emissions reductions required suggests that individual states will need strong support from the federal government. The United States should therefore enact a comprehensive set of climate and energy policies including standards for renewable electricity, energy efficiency, and transportation that set

a tight limit on heat-trapping emissions nationwide. The goal should be to reduce emissions at least 35 percent below current levels by 2020 and at least 80 percent by 2050.

A national renewable electricity standard and strong fuel economy standards for cars and trucks can boost local economies while substantially reducing emissions nationwide. For example, our analysis found that a renewable electricity standard of 20 percent by 2020 would create 3,100 jobs in Minnesota and lower residents' electricity and natural gas bills a total of \$118 million by 2020 (UCS 2007). A separate UCS analysis showed that if every car and light truck on U.S. roads averaged 35 miles per gallon (mpg) by 2018 (compared with the fleetwide average of 26 mpg today), drivers would save enough in fuel costs to create 4,600 new jobs in Minnesota by 2020 (UCS 2007b). The Obama administration is currently pursuing new standards that would achieve an average of 35.5 mpg by 2016.

Another complementary federal strategy known as a "cap-and-trade" program would set a price on emissions and require polluters to obtain government-issued permits in order to continue emitting. By auctioning these permits the government could generate revenue for investment in:

- Energy efficiency and renewable energy solutions



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Wind Energy Represents Hope for Minnesota

Minnesota obtains more than 7 percent of its electricity from wind—more than any other state. Nationwide, the wind power industry employs 85,000 people (AWEA 2009) while generating clean energy that reduces the heat-trapping emissions from coal-fired power plants (the United States' primary contributor to global warming).

- Assistance for consumers, workers, and communities facing the most difficult transition to a clean energy economy (coal miners and mining towns, for example)
- Conservation of precious natural resources
- Assistance for communities that must adapt to unavoidable consequences of climate change

Setting a price on heat-trapping emissions will also stimulate investment in cleaner and more efficient energy technologies by making them more cost-competitive. One possibility is power plants equipped with CCS technology (if and when this becomes feasible).

Finally, federal resources devoted to climate monitoring and assessments can provide essential infor-

mation for states and communities that need to devise and implement adaptation plans. Minnesota's U.S. senators and representatives must therefore support strong federal climate and clean energy policies that will help the state reduce emissions, transition to a clean energy economy, and prepare for the climate change that will occur in the interim.

CONCLUSION

Climate change represents an enormous challenge to Minnesota's way of life and its residents' livelihoods, but we can meet this challenge if we act swiftly. The emissions choices we make today—in Minnesota and throughout the nation—will shape the climate that our children and grandchildren inherit. The time to act is now.

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world.

For more information on the Midwest's changing climate, along with a list of references for this report, visit:

www.ucsusa.org/mwclimate

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