Union of Concerned Scientists

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Confronting Climate Change in the U.S. Midwest

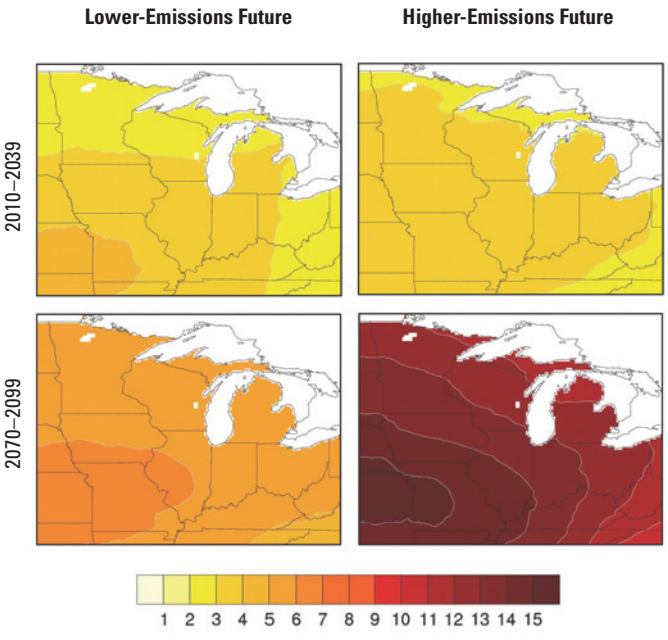
INDIANA

From its fertile croplands and many riverside communities to its economy, infrastructure, and lifestyle, Indiana 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 the Hoosier state, 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. 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.



Degrees F above average summer temperature (1961–1990)

Scorching Summers Become Standard

If our heat-trapping emissions continue to increase at the current rates, every summer in Indiana toward the end of the century is projected to be as hot as or hotter than 1983—Indiana's hottest summer of the last half century. 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 13°F. Under the lower-emissions scenario (left), that increase would be halved.

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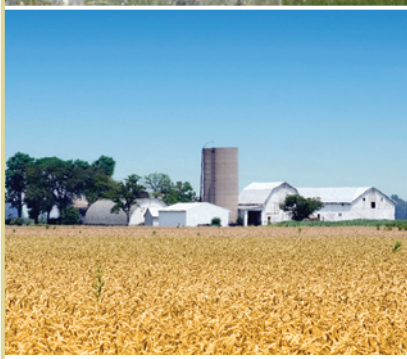

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New Climate Projections for Indiana

New research summarized here projects significant consequences for Indiana 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 Indiana 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 Indiana would be hotter than the most severe summer during the historical baseline.
- Indianapolis would experience more than 80 days per summer with highs over 90 degrees Fahrenheit (°F) and almost a month of days per summer over 100°F.
- Indianapolis would face at least two heat waves per summer like the one that killed hundreds in Chicago in 1995, and 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

- 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 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 corn earworm 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 almost 10 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).

Indiana 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. Indiana can also play a lead role in calling for strong federal legislation that would provide climate-friendly choices for Indiana 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 used for scientific analysis ever since. However, they by no means encompass the full range of 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 INDIANA'S FUTURE?

Dangerously Hot Summers

Our new analysis projects dramatically hotter summers for Indiana. 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" heat 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 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 Indiana will become dangerously hot.

Comparisons with the historical baseline

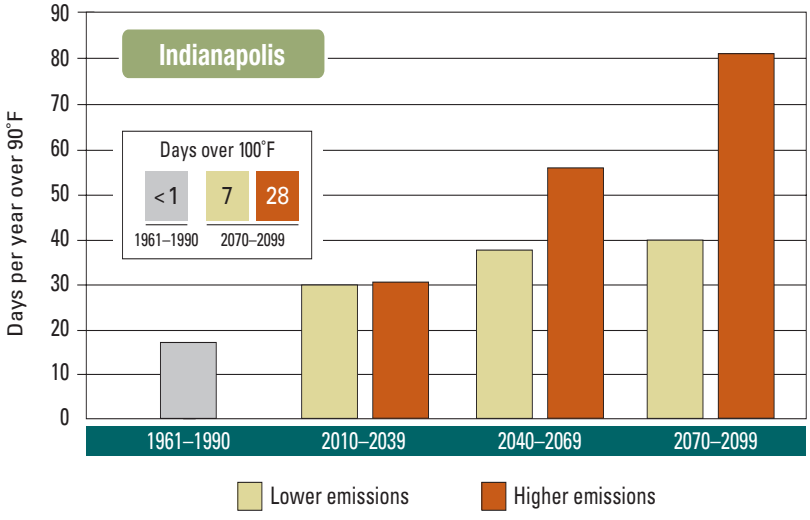
As soon as the next few decades, almost three-quarters of Indiana's summers could be hotter than the hottest summer the state experienced during the historical baseline (1983). Under the higher-emissions scenario every Indiana summer at mid-century is projected to be hotter than 1983. Even under the lower-emissions scenario 90 percent of summers at mid-century would be hotter than 1983, 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 historical baseline includes the scorching summers of 1983 and 1988, which brought record-breaking heat to Indiana and much of the nation. The average temperature in Indiana in both summers was more than 3°F higher than normal, and in Indianapolis alone almost 100 people died of heat-related conditions in 1988. 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 city, Indianapolis, and the number of days each year likely to exceed 90°F and 100°F. During the historical baseline Indianapolis averaged only 17 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 city is projected to experience more than 80 days above 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, Indianapolis averaged only about one such day each summer during the historical baseline. But toward the end of the century under the higher-emissions scenario, the city is projected to face 28 such days—four full weeks. That number would be reduced to seven under the lower-emissions scenario. Compounding matters is the likelihood that Indiana's summers will continue to be humid—probably even more humid. Other Indiana cities



Extreme Heat Becomes More Frequent

Under the higher-emissions scenario, Indianapolis 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.

such as Evansville, Fort Wayne, Gary, and South Bend will face conditions similar to Indianapolis.

More deadly heat waves

The severe heat projected for Indiana 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 deaths are probably misclassified (Luber 2008). Studies show that deaths from many causes, including cardiovascular and respiratory disease, 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 Indianapolis 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 Indianapolis would experience a heat wave as hot as the 1995 Chicago heat wave virtually every summer and a heat wave like the 2003 European heat wave at least every fifth summer
- Toward the end of the century Indianapolis 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 280 deaths in Indianapolis (36 per every 100,000 residents), compared with 25 heat-related deaths per summer during the baseline period. This assumes the demographics, vulnerability, and infrastructure of Indianapolis do not change from today. Increased use of air conditioning in the city would likely reduce the death toll, but the general

Indiana 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 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 Indiana: under the higher-emissions scenario, Indianapolis would experience a heat wave comparable to the 2003 European heat wave every fifth year by mid-century. Toward the end of the century Indianapolis would suffer such a heat wave every other year under the higher-emissions scenario and once a decade under the lower-emissions scenario.

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

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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).

aging of the population would likely increase the death toll since the elderly are most vulnerable to heat. The number of Indiana residents older than 65 is projected to be more than 1.5 times higher in 2030 than 2000, rising to more than 18 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, Indiana will experience such temperatures virtually the entire summer toward the end of the century, the state can also expect far more days of unhealthy ozone levels than would occur without global warming. This is particularly bad news for the 12 counties (which include those around Indianapolis) that already experience ozone levels higher than the Environmental Protection Agency's (EPA's) health-based ozone standard (IDEM 2008).

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 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 of particular concern in Indiana is small particulate pollution (or soot); 17 counties have already been identified as failing to meet federal air quality standards for this pollutant (EPA 2008) and Indianapolis ranks among the nation's 20 most soot-polluted cities (ALA 2009). 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 Indiana's particulate air pollution.

In Indiana today, more than 8 percent of the population (more than 100,000 children and more than 300,000 adults) suffers from asthma (ALA 2009). Cardiovascular diseases including stroke are the leading cause of death—killing more than 19,000 in 2002 (AHA 2008). The combination of increasing heat, ozone, and small particulate pollution can be especially dangerous for these populations.

Changes in Storm, Flood, and Drought Patterns

In 2008 Indiana experienced a year of devastating storms and flooding. Floods affected virtually every part of the state between January and September, leading to three federal disaster declarations. The worst storms brought tornadoes and historic rainfalls (between 2 and 10 inches in just two days) to southern and central Indiana in early June. The resulting flooding, including flash floods, forced thousands to evacuate and caused more than $1 billion in damage to 25,000 homes, hundreds of businesses, and infrastructure including roads, railroads, dams, and utilities (NOAA 2008). Fifty counties were declared federal disaster areas (Thomas 2008). The year was one of the costliest for natural disasters in Indiana's history, with the state receiving more than $560 million in federal disaster assistance (Thomas 2008).

As heavy rainfalls become more common, the threat of flooding will rise, as will the value of the 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 Indiana substantially more vulnerable to the kind of natural disasters it suffered in 2008. Two findings stand out from the research:

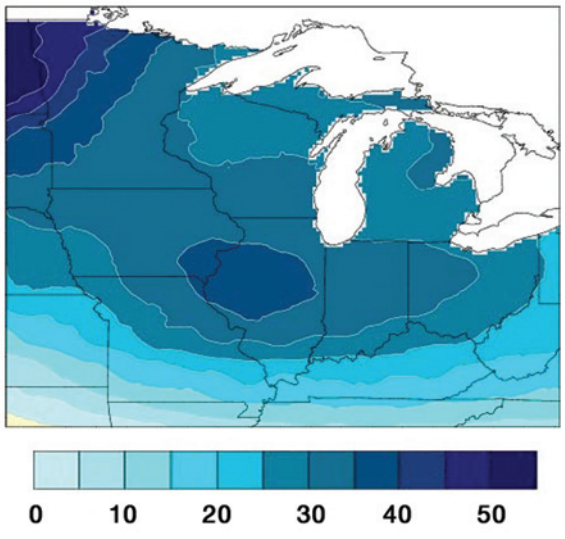
- **Precipitation is more likely to come in the form of heavy rains.** Under the higher-emissions scenario Indianapolis is projected to experience a more than 35 percent increase in heavy rainfalls (defined as more than two inches of rain in one day) over the next few decades. Toward the end of the century, heavy rainfalls are projected to be 64 percent more frequent under the higher-emissions scenario and 50 percent more frequent under the lower-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 almost one-third 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 will see 9 percent less rain. As described above, more of the rain that does fall will be in the form of downpours.

These projections support earlier studies showing a substantially increased risk of flooding in Indiana as the century progresses, especially if emissions are high. While there is likely to be some increase in local summertime flooding due to more frequent downpours, the greatest flooding risk will occur in the winter and spring, when rainfalls combine with melting snow and still-frozen soils to increase runoff. In fact, 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, Indiana could face not only the risk of greater flooding but also the risk of greater drought,

Higher-Emissions Future



Percent increase in spring rainfall compared with average from 1961–1990

Spring Rains Increase

Heavy downpours are now twice as frequent in the Midwest as they were a century ago. Under the higher-emissions scenario, Indiana's spring rainfall is projected to increase almost 15 percent over the next several decades and more than 30 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.

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. In Indiana, short-term droughts are projected to increase, but long-duration droughts (lasting more than two years) are likely to decline.

Lower water levels in the Great Lakes

Water levels in the Great Lakes are projected to decline both in 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. Under the lower-emissions scenario, water levels 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 lakeshore, affecting beach and coastal ecosystems, exposing toxic contaminants, and impairing recreational boating and commercial shipping.

More threats to water quality

Heavy rains increase runoff that not only washes pollutants into waterways but—in cities such as Indianapolis—also causes raw sewage to spill from sewers into rivers. This has been a long-standing problem in Indianapolis, where an average of 60 overflows discharges about 8 billion gallons of untreated sewage into the White River and its tributaries every year (EPA 2006).

Following legal action by the EPA, the city has agreed to spend nearly $2 billion over the next 20 years implementing measures designed to reduce the average number of overflows to four in a typical year (EPA 2006). However, the heavier downpours ahead mean the typical overflow from years past are likely to be exceeded, so raw sewage will continue to spill regularly into the White River unless the city spends even more to prevent this from happening.

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Storm Runoff Threatens Public Health

Heavy rains often cause raw sewage to spill from city sewers into rivers. Projected increases in rainfall due to climate change would worsen this problem in Marion County, where about 8 billion gallons of untreated sewage already spill into the White River and its tributaries every year.

New Threats to Indiana's Agriculture

Indiana is an important part of the nation's agricultural heartland. Fifty-six percent of the state's acreage is devoted to cropland (USDA 2009a); its production of corn ranks fifth in the nation and its production of soybeans ranks fourth (IDA 2006). Indiana also produces substantial quantities of other crops including wheat and fruit, and it can boast one of the nation's most productive livestock industries. In 2002, nearly 15 percent of Indiana's jobs were farm-related (USDA 2005) and, in 2007, agricultural commodities brought nearly $8 billion to the state (USDA 2009a).

The heat and precipitation changes projected for Indiana 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 by six to seven weeks under the higher-emissions scenario. Also, rising CO_2 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 Indiana, particularly under the higher-emissions scenario, puts the region's crops at significant risk. Corn 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.

Changes Mean Uncertainty for Agriculture

Indiana'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.

The United States lost $40 billion from a 1988 heat wave—mostly due to crop losses. Crop yields in Indiana dropped precipitously that year, with corn and soybeans falling below three-quarters of their average annual yields for the period 1978–1997 (USDA 2009b). Over the next few decades (under both emissions scenarios) most Indiana summers are projected to be hotter than 1988, and by mid-century under the higher-emissions scenario, all Indiana summers are projected to be hotter than 1988.

Our analysis projects the frequency with which Indiana 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 Indiana within the next few decades, and one is projected to occur every summer toward the end of the century. A more destructive seven-day period would occur in at least half of Indiana's summers by mid-century and in at least three of every four summers 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 occurring in about half of Indiana's summers.

The possibility of crop-damaging heat waves becoming commonplace in Indiana within a few decades represents a significant threat to the state's economy, which took in $2.7 billion from corn alone in 2007 (USDA 2009a). Crops such as wheat and tomatoes that fail at lower temperatures than corn are even more vulnerable.

A detailed study of the expected effects of climate change on crop yields in five Midwest states shows that corn yields in Indiana may decline as much as 50 percent by the middle of this century under a variety of scenarios and assumptions (Southworth et al. 2000). For soybeans, a crop that benefits more than corn from CO_2 fertilization, results were mixed, with some scenarios showing small yield gains and others showing decreases. For wheat, the study's two Indiana locations had differing results, with yields declining as much as 15 percent in southwestern Indiana but increasing by small amounts in east-central Indiana.

Hotter projected temperatures led to lower yields in all cases; corn yields, for example, begin to decline at 92°F and fall sharply at 100°F. Widely varying climate conditions during the growing season also decreased average yields in all of the study's models, so as temperatures continue to rise and weather becomes more extreme and variable, yields of all major crops will likely decline.

More heat stress for livestock

Extreme heat is also projected to cause heat stress for much of Indiana's livestock. Dairy cattle are particularly vulnerable to high temperatures, and milk production can decline when temperatures exceed 75°F to 80°F depending on humidity. During the historical baseline, average summer temperatures and humidity in Indiana did not exceed levels known to cause stress in livestock. Under the higher-emissions scenario, however, dairy cattle and other livestock will endure near-permanent heat stress during the average Indiana summer toward the end of the century unless they are kept cool using costly measures such as air-conditioned barns.

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 expanding ranges of corn pests could have a 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).

Indiana's valuable corn crop would be at risk if the corn earworm does indeed move north. During the historical baseline, conditions conducive to the corn earworm occurred about once every five years in parts of southern Indiana and about once every 15 years in northern Indiana. Under the higher-emissions scenario, however, conditions conducive to the corn earworm will occur in three of every four years toward the end of the century in southern Indiana and in about half of all years in northern Indiana.

Potentially damaging changes in precipitation

Crops under stress from extreme heat need more rain, but Indiana is projected to receive less rain in the summer growing season as the climate warms. Dry conditions will be a particular problem for Indiana'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 June 2008, which affected about 9 percent of the state's farmland and were called a "disaster" for Indiana agriculture (NOAA 2008). Changes in precipitation are therefore likely to limit farmers' ability to take advantage of the longer growing seasons expected to accompany future climate change.

CLIMATE SOLUTIONS FOR INDIANA

Indiana is the seventh largest producer of global warming emissions among all the states (EIA 2008a). Its per capita emissions are 88 percent higher than the national average (U.S. Census Bureau 2009; EIA 2008a), mainly because 94 percent of Indiana's electricity is generated by coal-fired power plants (compared with the national average of 50 percent) (EIA 2007). Agriculture also produces global warming emissions—close to 7 percent of the U.S. total in 2005 (USDA 2008).

If Indiana 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 Hoosiers drive; and
- improving agricultural practices to reduce the release of heat-trapping emissions from soil tilling and fertilizer application.

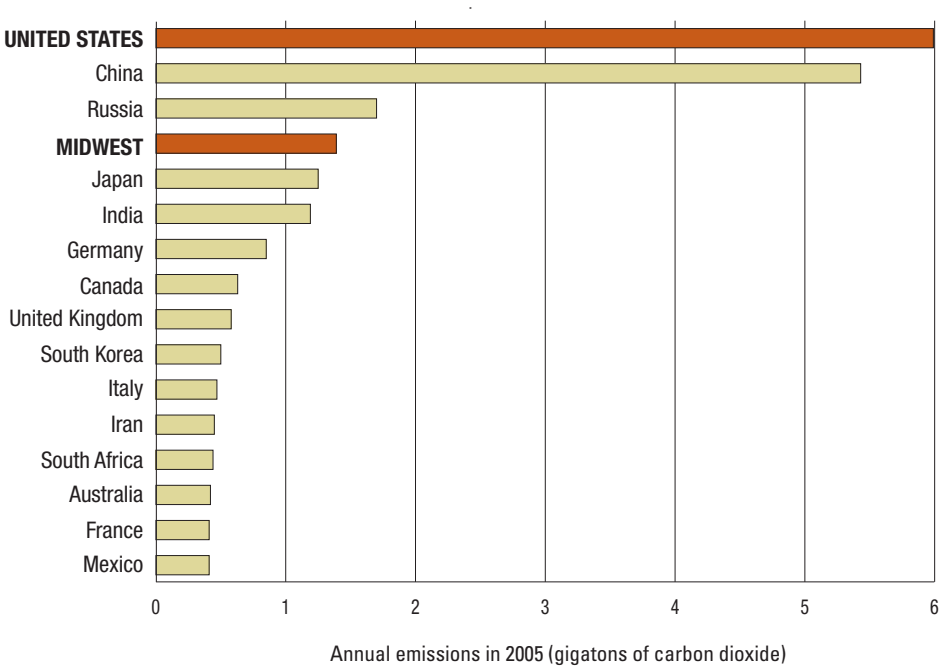
These actions will also provide benefits such as lower energy costs (after just a few years), new local jobs, and cleaner air and water. A recent analysis by the Union of Concerned Scientists shows that businesses and industries in the region could collectively save $3.8 billion in 2020 and $11.9 billion in 2030 by instituting these kinds of changes (Cleetus, Clemmer, and Friedman 2009).

While Indiana has made strides toward implementing a number of the strategies listed above, it generally lags well behind other Midwest states. The state does deserve credit for its progress on the following initiatives:

- Zero-interest loans for renewable energy and energy efficiency projects
- Energy efficiency requirements for all new state buildings
- Property tax exemptions for renewable energy systems
- Rebates for geothermal heat pumps

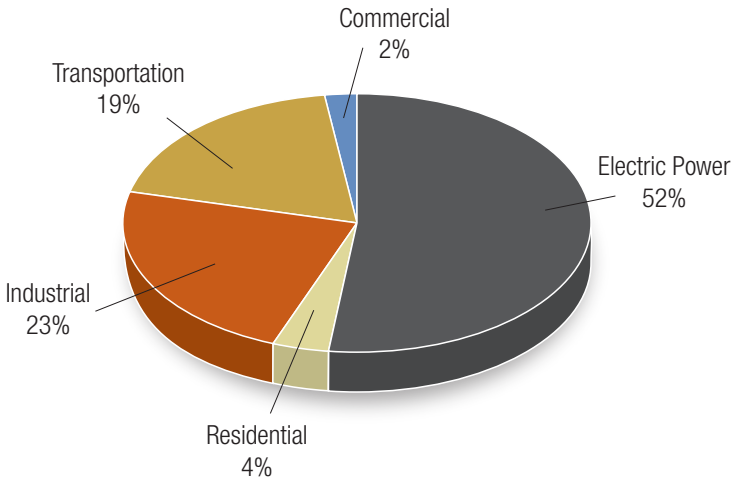
Livestock Face Increasing Heat Stress

Milk production can decline when temperatures exceed 75°F to 80°F. If heat-trapping emissions continue to rise at their current pace, Indiana's dairy cattle will experience near-permanent heat stress during the average summer toward the end of the century, potentially causing declines in milk yields.



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).



Power Plants Are Indiana's Biggest Polluters

Electricity generation—primarily from coal-fired power plants—is the largest source of heat-trapping emissions in Indiana, followed by industry and transportation (EIA 2008a).

Pathways to Real Progress

The emissions reductions achieved by Indiana's clean energy and climate strategies to date pale in comparison to what is actually possible. The state should immediately pursue the cost-effective strategies summarized below.

Energy efficiency programs

Indiana could duplicate the progress achieved in Illinois, Michigan, Minnesota, and Ohio by requiring its utilities to help customers implement energy efficiency projects. This strategy saves consumers money, reduces global warming emissions, and creates local jobs for people who perform energy audits, weatherize homes, and manufacture efficient windows. The Midwest Energy Efficiency Alliance estimates that "energy efficiency programs could save Indiana families and businesses $500 million in direct natural gas bill savings and $802 million in direct electricity savings over the next five years. As a result of downward pressure on natural gas prices, consumers in Indiana could see an additional $565 million in savings by 2011" (MEEA 2009).

Renewable electricity standards

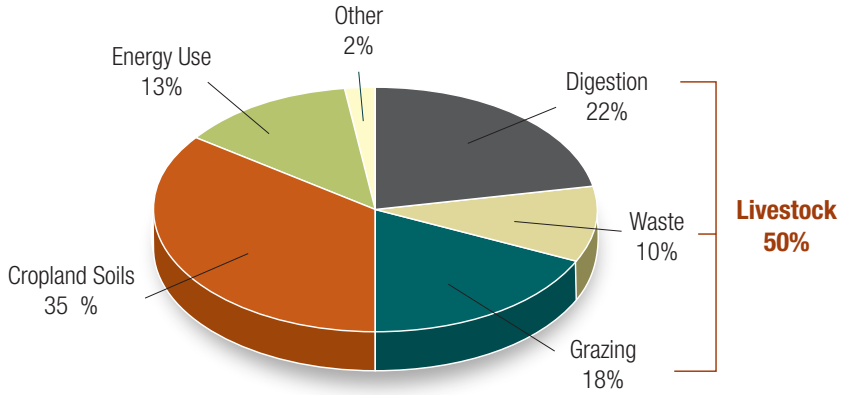
Indiana is the only Midwest state out of eight not to have a renewable electricity standard, which requires electric utilities to gradually increase the amount of renewable energy resources (such as wind, solar, and bioenergy) in their power supplies. These policies—also called renewable portfolio standards—have emerged as an effective tool for reducing market barriers to new technologies and for promoting a cleaner, sustainable power supply.

However, with its excellent resources and strong agricultural and manufacturing sectors, Indiana is particularly well-positioned to benefit

from renewable energy. It already ranks as the fastest-growing state for wind energy installations thanks to several projects brought online since the start of 2008—due in part to renewable electricity standards adopted in other states (AWEA 2009). By the end of 2009, construction should be completed on Fowler Ridge—one of the largest wind farms in the United States. A standard of Indiana's own would keep this momentum going, and the policy is popular among Hoosier voters: 81 percent support a standard that would require utilities to generate at least 15 percent of their electricity from renewable resources by 2021 (Yang 2009).

Better building codes

Modern building codes require a minimum level of energy efficiency in the design and construction of new buildings. Indiana adopted an updated code for its commercial sector in 2009, but its residential codes are years behind other states such as Illinois, Ohio, and Wisconsin, which all have residential codes meeting the requirements of the federal Energy Conservation and Production Act. By updating its standards, Indiana would also become eligible to compete for $3.1 billion in federal stimulus funds available for state energy programs.



Emissions percentages are CO_2-equivalent units

Agriculture Contributes to Warmer Temperatures

Agriculture generates 7 percent of total U.S. heat-trapping emissions, including three potent global warming gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Half of these emissions come from livestock production, one-third from the cultivation and fertilization of cropland (which decreases its ability to absorb carbon), and the rest from energy used for power generation, transportation, and construction (USDA 2008).

Increased public transit and passenger rail

Given the fact that nearly one-fifth of Indiana's heat-trapping emissions come from the automobile sector, the state should invest in low-carbon transportation options including public transit and passenger rail—yet Indiana currently spends almost 30 times as much on its highways as on public transit, so its cities' transit systems lag behind those of comparable Midwest cities. Federal stimulus funds are available to help Indiana upgrade its passenger rail network.

© Indianapolis Airport Authority

Green Building Design Saves Money and Energy

The new Indianapolis airport terminal is highly energy efficient. Its windows feature a ceramic coating that allows natural light to enter while lowering heating and cooling costs, and its location in the middle of the airfield reduces planes' taxiing and fuel use.

Building More Resilient Communities

Because climate change is already upon us and some amount of additional warming is inevitable, Indiana 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, Indiana's decision makers must carefully assess the potential barriers, costs, and unintended social and environmental consequences.

A State-Federal Partnership

Although Indiana can achieve much with its own policies and resources, the scale of emissions reductions required suggests that individual

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Hybrid Vehicles Are a Win-Win for Indiana

A number of Indiana cities have added hybrid buses (which offer lower emissions and higher fuel economy) to their transit fleets. Further additions would benefit the state economy, since at least three Indiana-based companies manufacture hybrid drivetrains or components.

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 5,300 jobs in Indiana and lower residents' electricity and natural gas bills a total of $130 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 6,000 new jobs in Indiana by 2020 (UCS 2007b).

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
- 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 carbon capture and storage technology (if and when this proves commercially feasible).

Finally, federal resources devoted to climate monitoring and assessments can provide essential information for states and communities that need to devise and implement adaptation plans. Indiana'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 Indiana'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 Indiana and throughout the nation—will shape the climate our children and grandchildren inherit. The time to act is now.

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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