Executive Summary

The Future is in Our Hands

Human-induced climate change is affecting us now. Its impacts on our economy, security, and quality of life will increase in the decades to come. Beyond the next few decades, when warming is "locked in" to the climate system from human activities to date, the future lies largely in our hands. Will we begin reducing heat-trapping emissions now, thereby reducing future climate disruption and its impacts? Will we alter our planning and development in ways that reduce our vulnerability to the changes that are already on the way? The choices are ours.

Beneficial & Detrimental Impacts

While there are likely to be some benefits in some sectors of society in the early stages of warming, most impacts are projected to be detrimental, in part because society and ecosystems have developed and evolved based on historical climate. Impacts are expected to become more detrimental for more people and places with additional warming.

Irreversible Losses

Some of the impacts of climate change will be irreversible, such as species extinctions and civilizations on islands and coasts lost to rising seas. The increase in wind erosion associated with drought and the increase in heavy downpours are also expected to lead to irreversible loss of soil, which will not re-form on human time scales.

Urgency of Action

There is a growing urgency in responding to the climate challenge because choices being made now have long-term implications, and delay will be costly. Aggressive near-term actions would be required to alter the future path of human-induced warming and its impacts. Future generations will inherit the legacy of our decisions.

Tipping Points

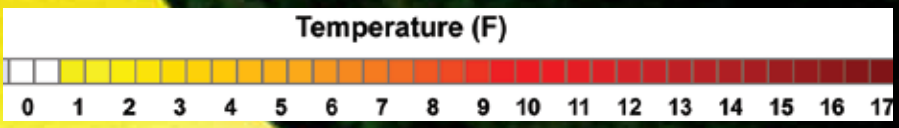
The more climate changes, the more thresholds will be crossed in natural and human systems. Passing such tipping points can have unpredictable consequences due to the complexity of the climate system. Both anticipated and unanticipated impacts become more likely with increased warming. The impacts of abrupt climate changes can exceed our ability to cope.

Rates of Change

For natural systems especially, the rate of climate change is of great concern. Change that occurs very quickly makes successful adaptation much less likely, especially in the context of other human activities that create barriers to adaptation.

Limits to Adaptation

There are limits to what can be achieved by adaptation. We will not be adapting to a new steady state, but rather to a moving target. Climate will be continually changing, sea-level rise will be ongoing, and the precise amount and timing of these changes cannot be predicted with a high level of certainty. While humans have adapted to gradual changes in the past, we are now entering uncharted territory.



Key Findings

Once considered a problem mainly for the future, climate change is now upon us. People are at the heart of this problem: we are causing it, and we are being affected by it. The rapid onset of many aspects of climate change highlights the urgency of confronting this challenge without further delay. The choices that we make now will influence current and future emissions of heat-trapping gases, and can help to reduce future warming. Likewise, our decisions on whether and how to adapt to the degree of warming that is already inevitable can help us reduce the impacts of future warming.

1. Human-induced climate change and its impacts are apparent now throughout the United States.

- Global warming is unequivocal and is due primarily to human-induced emissions of heat-trapping gases and other pollutants[1].
- Observed changes in the United States include temperature increases, sea-level rise, increased heavy downpours, rapidly retreating glaciers, regional droughts, substantial changes in sensitive wildlife, earlier snowmelt, and altered timing and amount of river flows.
- Impacts of these changes are apparent in many facets of society including health, water, food, energy, and quality of life.

2. Many climatic changes are occurring faster than projected even a few years ago. New

- Global emissions of heat-trapping gases are now increasing even more rapidly than the highest emissions scenario scientists have been analyzing.
- Arctic sea ice and the large ice sheets on Greenland and parts of Antarctica are melting faster than expected.

3. The degree to which future climate will change, and the scope and magnitude of the impacts, depend on choices made now.

- Another 1°F of warming in the next few decades (on top of the observed 1.5°F rise) is already locked in due to past emissions.
- The amount of warming we will experience beyond the next few decades depends upon choices about emissions made now and in the near future.
- Lower emissions of heat-trapping gases will result in less climate change and related impacts.

4. Extreme weather and climate are having increasing impacts on society.

- The United States has experienced increases in heat waves, wildfires, heavy downpours, and in some regions, droughts, all of which are disrupting our lives.
- Extreme events affect every aspect of society and nature including human health, energy, transportation, agriculture, ecosystems, and water resources.
- Atlantic hurricane intensity has increased in recent decades and additional future increases are projected.

5. Sea-level rise and storm surges place many U.S. coastal regions at increasing risk.

- The low-lying East Coast and Gulf Coast of the United States are vulnerable to combined effects of sea-level rise, storm surges, and hurricanes.
- Alaska's coast is vulnerable to the effects of sea-ice retreat, thawing of coastal permafrost, and rising sea level, all of which are caused by warming, and combine to increase coastal erosion.
- Sea-level rise threatens the long-term viability of island communities by exacerbating the impacts of coastal storms, flooding infrastructure and ecosystems, and contaminating freshwater supplies with seawater.

6. Assuring an adequate and clean water supply will be an increasing challenge in many parts of the United States.

- Most of the West's surface water comes from snowpack, which is declining as more precipitation falls as rain and snowpack melts earlier, leaving less water available for summer when it is needed most.
- Growing populations and changing precipitation patterns will increase competition among urban, industrial, agricultural, and natural ecosystem water needs in regions where overall water supply declines.

7. Interactions among climate-related and other stresses will present complex challenges to society.

- Simultaneous and back-to-back extreme weather events can amplify impacts, challenging our response capabilities.
- Climate change can combine with other stresses including pollution, invasive species, and the overuse of resources to create impacts larger than any of these alone.
- Trade-offs will be necessary. For example, increasing water scarcity in some regions will force hard choices about the allocation of water for growing food, producing electricity, providing for urban uses, and protecting ecosystems.

8. Our vulnerability to climate change has been increased by some of our decisions.

- Population and development patterns have put more people in places that are vulnerable to climate change impacts.
- U.S. population has grown rapidly in cities on the Atlantic and Gulf coasts, which are vulnerable to extreme heat, sea-level rise, hurricanes, and storm surge.
- There has been very rapid population growth in arid western states where water is projected to become increasingly scarce in a warming world.

9. Historical climate and weather patterns are no longer an adequate guide to the future.

- Planning for providing water, energy, transportation, and other services has assumed the future would be like the past; this is no longer justifiable.
- Long-lived infrastructure, from power plants to roads and buildings, must be designed and built taking climate change into account.
- Long term planning will have to continually incorporate the latest information, as climate will be ever changing, requiring adaptation strategies to constantly evolve.

10. Responses to climate change entail reducing emissions to limit future warming and adapting to the changes that are unavoidable.

- Large cuts in emissions would be required to limit warming to the low end of the range of scenarios, making successful adaptation more likely.
- There are limits to adaptation. For example, the financial and technical challenges of defending coasts against sea-level rise under high emissions scenarios would probably result in the inundation and abandonment of many areas.
- Applying the best scientific information can help avoid unintended consequences of our responses to climate change.

Summary of Impacts on Sectors

SOCIETY

- Population movements and development choices are among the societal changes that are making more Americans vulnerable to climate change impacts.
- Vulnerabilities to climate change impacts are greater for those who have few resources and few choices.
- Climate change will affect the tourism and recreation industries in ways that reduce opportunities for many activities that Americans hold dear.
- Cities, both their residents and their infrastructure, have unique vulnerabilities to climate change.
- The insurance industry is particularly vulnerable to increasing extreme weather events, but can also help society manage the risks.

HUMAN HEALTH

- Significant increases in illness and death related to extreme heat are projected, along with small decreases in cold-related impacts.
- Health impacts due to reduced air quality are projected to be an increasing problem, especially in urban areas.
- Physical and mental health impacts due to extreme weather events are projected to increase.
- Infectious diseases borne by food, water, and insects are projected to increase.
- Allergies and asthma are on the rise, with climate change expected to play an increasing role in the future.
- Certain groups, including children, the elderly, and the poor, are most vulnerable to the range of health effects.

ENERGY

- Warming will be accompanied by significant increases in electricity use and peak demand in most regions, due to increased demand for air conditioning.
- Energy production is dependent upon reliable water supply.
- Rising temperatures decrease power plant efficiency.
- Energy production and delivery systems are vulnerable to sea-level rise and extreme weather events in many regions.
- Climate change is likely to affect some renewable energy sources, especially hydropower.

TRANSPORTATION

- Sea-level rise and storm surges are projected to result in major impacts, including flooding of coastal airports, roads, rail lines, and tunnels.
- Increasingly intense downpours and related flooding will cause disruptions and delays in air, rail, and road transportation.
- The increase in extreme heat will limit some operations and cause pavement and track damage. Decreased extreme cold will confer benefits.
- Increased intensity of strong hurricanes would lead to more evacuations, damages, transportation interruptions, and a greater probability of infrastructure failure.
- Arctic warming reduces sea ice, lengthening the ocean transport season. Permafrost thaw in Alaska damages infrastructure. The ice road season becomes shorter.

WATER RESOURCES

- Climate change will continue to alter the water cycle, affecting where, when, and how much water is available for human and ecosystem uses.
- The quality and quantity of surface water and groundwater are affected by a changing climate.
- Climate change will add yet another burden to already-stressed water systems.
- The past century is no longer a reasonable guide to the future for water management.

AGRICULTURE AND LAND RESOURCES

- Crops show mixed responses to lower levels of warming, but higher levels of warming often negatively affect growth and yields.
- Extreme events such as heavy downpours and droughts reduce crop yields.
- Weeds, diseases, and insect pests benefit from warming, and weeds also benefit from rising carbon dioxide, increasing stress on crop plants and requiring more pesticide and herbicide use.
- Forage quality in pasture and rangeland generally declines, reducing the land's ability to supply adequate livestock feed.
- Increased heat, disease, and weather extremes reduce livestock productivity.
- Warming and rising carbon dioxide increase forest growth, but more insect outbreaks, fire, and drought have negative effects.
- Deserts and dry lands become hotter and drier, feeding a self-reinforcing cycle of invasive plants, fire, and erosion.

NATURAL ENVIRONMENT AND BIODIVERSITY

- Ecosystem processes have been affected by climate change.
- There have been large-scale shifts in species ranges, the timing of the seasons, and animal migration; further such changes are projected.
- There have been increases in fire, insect pests, disease pathogens, and invasive weed species, and more are projected.
- Coastal and near-coastal ecosystems including wetlands and coral reefs are especially vulnerable to the impacts of climate change.
- Mountain species and cold-water fishes like salmon and trout are particularly sensitive to climate change impacts.
- Arctic sea ice ecosystems are extremely vulnerable to warming.

Summary of Impacts on Regions

NORTHWEST

- Declining springtime snowpack leads to reduced summer streamflows, straining water supplies.
- Increased insect outbreaks and wildfires, combined with changing species composition in forests will pose challenges for unique ecosystems.
- Salmon and other cold-water species experience additional stresses due to rising water temperatures and declining summer streamflows.
- Human health threats due to heat waves, reduced air quality, and insect-borne diseases are projected to increase.
- Sea-level rise will result in increased erosion along vulnerable coastlines.

SOUTHEAST

- Projected increases in air and water temperatures will cause heat-related stresses.
- Decreased water availability will impact the economy as well as natural systems.
- Accelerated sea-level rise and increased tropical storm intensity will have serious impacts.
- Ecological thresholds are likely to be crossed, causing the rapid restructuring of ecosystems and the services they provide.
- Quality of life will be adversely affected by increasing heat stress, water scarcity, severe weather events, and reduced availability of insurance for at-risk properties.

ALASKA

- Summers are becoming longer and drier.
- Insect outbreaks and wildfires are increasing with warming.
- Lakes are declining in area.
- Thawing permafrost damages roads, runways, water and sewer systems, and other infrastructure.
- Coastal storms increase risks to villages and fishing fleets.
- Displacement of marine species will impact key fisheries.

Map for islands is still under development

ISLANDS

- Anticipated reductions in the availability of freshwater will have significant implications for island communities, economies, and resources.
- Island communities, infrastructure, and ecosystems are vulnerable to coastal inundation due to sea-level rise and coastal storms.
- Climate changes affecting coastal and marine ecosystems will have major implications for tourism and fisheries.

MIDWEST

- Public health and quality of life, especially in cities, will be negatively affected by increasing heat waves, reduced air quality, and insect- and water-borne diseases.
- Under higher emissions scenarios, significant reductions in Great Lakes water levels will impact shipping, infrastructure, beaches, and ecosystems.
- Increasing precipitation in winter and spring, more heavy downpours, and greater evaporation in summer will mean more periods of both floods and water deficits.
- While a longer growing season provides the potential for increased crop yields, increases in heat waves, floods, droughts, insects, and weeds will present increasing challenges to crops, livestock, and forests.
- Native species will face increasing threats from rapidly changing climate conditions, pests, diseases, and invasive species moving in from warmer regions.

SOUTHWEST

- Water supplies will become increasingly scarce, calling for difficult trade-offs among competing uses.
- Human health concerns include increases in heat waves, reduced air quality, and the spread of diseases from the south.
- Ranching and agriculture decline as climate heats up and water is converted to urban uses for the rapidly growing population.
- Increasing drought and fire are beginning to transform the landscape, threatening biodiversity and protected areas.

NORTHEAST

- Extreme heat and declining air quality are projected to pose increasing problems for human health, especially in urban areas.
- Agricultural production, including dairy, fruit, and maple syrup, will be increasingly affected as favorable climates shift.
- Severe floods due to sea-level rise and heavy downpours are projected to occur more frequently.
- The projected reduction in snow cover will affect winter recreation and the industries that rely upon it.
- The center of lobster fisheries is projected to continue its northward shift and the cod fishery on Georges Bank is likely to be diminished.

GREAT PLAINS

- Projections of increasing temperature, evaporation, and drought frequency exacerbate concerns regarding the availability of water in a region dependent on a declining groundwater source.
- Agriculture, ranching, and natural lands, already under pressure due to an increasingly limited water supply, will also be stressed by rising temperatures.
- Climate change is likely to affect native plant and animal species by altering key habitats such as the wetland ecosystems known as prairie potholes or playa lakes.
- Ongoing shifts in population from rural to urban centers are expected to increase the vulnerability of Great Plains inhabitants to climate change.

COASTS

- Significant sea-level rise and storm surge will affect coastal cities and ecosystems around the nation, with low-lying and subsiding areas most vulnerable.
- Increases in spring runoff and warmer coastal waters will exacerbate the seasonal reduction in dissolved oxygen that results from excess nitrogen from agriculture.
- Warming coastal waters will allow new invasions by non-native species that occur through ship transport and other human activities.
- Rising water temperatures and ocean acidification due to increasing atmospheric carbon dioxide present major additional stresses to coral reefs, resulting in significant die-offs and limited recovery.
- Changing coastal currents will result in shifts in fisheries and cause surprising changes such as oxygen-depleted waters that either kill marine species or cause them to leave the area.

Response Strategies

Most scientific research has focused on understanding the nature, causes, and impacts of climate change, and estimating the human contribution to these changes. Considerably less attention has been paid to the portfolio of approaches that will be needed to respond to the problem of human-induced climate change. Items in this portfolio include reducing emissions of heat-trapping gases, as well as developing measures to adapt to the amount of warming that is not prevented through such reductions. Other potential options, such as intentional manipulation of aspects of the climate system in an attempt to counteract the warming influence of heat-trapping gases, will not be discussed here, though it should be mentioned that such options must be evaluated for unintended consequences.

Throughout this report, the impacts of climate change will be viewed through the lens of our possible responses. Comparing impacts for low and high emission scenarios highlights the choices society faces with regard to levels of heat-trapping emissions. Options for reducing these emissions are often referred to as "mitigation" and include improved energy efficiency, using energy sources that don't produce carbon dioxide or produce less of it, capturing and storing carbon dioxide from fossil fuel use, and so on.

The other major category of response strategies is known as "adaptation," which refers to changes made to better respond to present or future circumstances. This includes deliberately adjusting to actual or anticipated changed conditions to avoid or reduce negative impacts or to take advantage of positive ones. For example, a farmer might switch to growing a different crop variety better suited to warmer or drier conditions. A company might relocate key business centers away from coastal areas vulnerable to sea-level rise and hurricanes. A community might alter its zoning and building codes to place fewer structures in harm's way and make buildings less vulnerable to damage from floods, fires, and other extreme events.

One of the key goals of adaptation is to make a community or system better able to withstand the kinds of perturbations that are expected. Adaptation can be thought of as improved planning, using the best available information about future climatic conditions, and considering climate change in the context of other factors that affect development decisions, particularly the challenge of planning in the face of competing economic and social objectives.

The more we mitigate (reduce emissions), the less climate change we'll experience and the less severe the impacts will be, and thus, the less adaptation will be required. However, no matter how aggressively emissions are reduced, the world will still experience some continued climate change and resulting impacts. This is true for several reasons. First, elevated concentrations of greenhouse gases already in the atmosphere will remain there for many decades, with some fraction of the carbon dioxide produced by fossil fuel burning staying in the atmosphere for many thousands of years. Second, the climate system has significant inertia and can take many centuries to fully respond to such perturbations. And third, the drivers that determine emissions, such as energy supply systems, cannot be changed overnight. Consequently, some degree of adaptation is inevitable.

Unless we explicitly plan for climate change, including reducing emissions and reducing vulnerabilities, we are likely to find that we will reach the limits of our adaptive capacity. Some communities, states, sectors, and the nation as a whole have a generally high capacity to adapt to projected changes in climate, but adaptive capacity is unequal across the nation. Future adaptation and adaptive capacity will be influenced by development decisions implemented in the near and long term in various regions within the United States and other countries.

There are potential synergies between mitigation and adaptation. For example, making buildings more energy efficient makes them more comfortable in extreme heat while also reducing energy use. In addition, some mitigation and adaptation options also produce other benefits to society, such as reducing health risks, and creating jobs or other economic benefits.

Some communities and businesses are developing comprehensive plans to both mitigate climate change by reducing their emissions and to reduce their vulnerability to climate change by pursuing adaptations. Mitigation strategies have been and are being explored extensively by international bodies such as the Intergovernmental Panel on Climate Change and the Global Energy Assessment and will not be a significant focus of this report. Adaptation strategies, however, will be discussed throughout this document.

Despite what is widely assumed to be the considerable adaptive capacity of the United States, we have not always succeeded in avoiding significant losses and disruptions, for example, due to extreme weather events. There are many challenges and limits to adaptation. Some adaptations will be very expensive. We will be adapting to a moving target, as future climate will not be stationary but continually changing. And if emissions and thus warming are at the high end of future scenarios, some changes will be so large that adaptation is unlikely to be successful.

To date, adaptation responses have tended to be decentralized and uncoordinated with uneven results. This may be inevitable, at least at the beginning, for it is at the local level that the impacts of climate change and other stresses are experienced and it is also at the local level that the resources to respond are best understood and mobilized.

Examples of strategies communities can implement to adapt to climate change include:

- Introducing technological changes such as updating levees, water and sewer systems (to avoid increased contamination due to heavy downpours), pollution controls, insect controls, etc.
- Making institutional changes to improve coping capacity such as providing financial mechanisms for implementing adaptation strategies, improving coordination across jurisdictions, and developing targeted assistance programs
- Providing ecological buffers, such as preserving wetlands, that can prevent property damage and loss of life by taking advantage of natural ecosystem services
- Changing the location of people or activities through land-use policies and codes that encourage movement from more vulnerable areas to less vulnerable ones
- Changing the form of communities to encourage green spaces and green buildings through zoning and other measures

Examples of tools available for implementing these strategies include:

- Zoning, building codes, and design codes
- Early warning and disaster response systems
- Insurance pricing, terms, and conditions that send clearer signals to the market
- Incentives to encourage allowing high risk areas to return to a natural state

While adaptation takes place at the local scale, it is influenced by the larger scale context. For example, funding, information, and other support can be provided from higher levels of government, and large-scale regulatory and policy contexts can help resolve jurisdictional issues such as those relating to water supply management, licensing of facilities, forest management, and so on. National policies regarding codes, standards, insurance, and disaster management can support adaptation to climate change at the local level.

Criteria for effective adaptation include taking a long-term, holistic view of the problem and solutions in order to maximize effectiveness, minimize costs, and avoid unintended consequences. Such a holistic view recognizes that the pace and character of future development will influence adaptive capacity, and that improving adaptive capacity can support efforts to achieve economic and environmental objectives, as well as reducing impacts of climate change.