CLIMATE CHANGE AND INFRASTRUCTURE, URBAN SYSTEMS, AND VULNERABILITIES

*Technical Report for the US Department of Energy
in Support of the National Climate Assessment*

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Climate Change and Infrastructure, Urban Systems, and Vulnerabilities

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About This Series

This report is published as one of a series of technical inputs to the Third National Climate Assessment (NCA) report. The NCA is being conducted under the auspices of the Global Change Research Act of 1990, which requires a report to the President and Congress every four years on the status of climate change science and impacts. The NCA informs the nation about already observed changes, the current status of the climate, and anticipated trends for the future. The NCA report process integrates scientific information from multiple sources and sectors to highlight key findings and significant gaps in our knowledge. Findings from the NCA provide input to federal science priorities and are used by U.S. citizens, communities and businesses as they create more sustainable and environmentally sound plans for the nation's future.

In fall of 2011, the NCA requested technical input from a broad range of experts in academia, private industry, state and local governments, non-governmental organizations, professional societies, and impacted communities, with the intent of producing a better informed and more useful report. In particular, the eight NCA regions, as well as the Coastal and the Ocean biogeographical regions, were asked to contribute technical input reports highlighting past climate trends, projected climate change, and impacts to specific sectors in their regions. Each region established its own process for developing this technical input. The lead authors for related chapters in the Third NCA report, which will include a much shorter synthesis of climate change for each region, are using these technical input reports as important source material. By publishing this series of regional technical input reports, Island Press hopes to make this rich collection of information more widely available.

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Assessment of Climate Change in the Southwest United States
Climate Change and Infrastructure, Urban Systems, and Vulnerabilities
Climate Change and Energy Supply and Use

Electronic copies of all reports can be accessed on the Climate Adaptation Knowledge Exchange (CAKE) website at www.cakex.org/NCAreports. Printed copies are available for sale on the Island Press website at www.islandpress.org/NCAreports.

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Preface

In connection with the U.S. National Climate Assessment scheduled to be completed in 2014, the U.S. Global Change Research Program (USGCRP) and the National Climate Assessment Development and Advisory Committee (NACDAC) invited technical inputs. Many of the most substantive inputs were sponsored by USGCRP agencies, reflecting the knowledge and experience represented by their programs. The technical inputs were due to be submitted by March 1, 2012.

The U.S. Department of Energy (DOE) produced three technical input reports: Climate Change and Infrastructure, Urban Systems, and Vulnerabilities; Climate Change and Energy Supply and Demand; and Climate and Energy-Water-Land system interactions. All three reports were based in part on a major national workshop of experts from a wide variety of communities of knowledge and experience, and all three reports were peer-reviewed. This book provides the content of the first of these reports to a broader audience.

The author team would like to acknowledge the inspiration, leadership, guidance, and support of Bob Vallario, Director of the Integrated Assessment Research Program of DOE's Climate and Environmental Systems Division, Office of Biological and Environmental Research, Office of Science. Without Bob's knowledge and perspectives on everything from the subject areas to the expert communities, the technical input export could not have been produced and delivered on schedule; and he has continued since the report was delivered to put its scientific content to use; not only in the National Climate Assessment but in a wide variety of other program efforts related to DOE's missions. Although he is not listed as an author of this technical report, he is in every way a full partner of the report's authors and their commitments to advance knowledge about the report's topics.

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Executive Summary

This technical report on “Climate Change and Infrastructure, Urban Systems, and Vulnerabilities” was prepared for the U.S. Department of Energy by the Oak Ridge National Laboratory in support of the U.S. National Climate Assessment (NCA). Prepared on an accelerated schedule to fit time requirements for the NCA, it was a summary of the currently existing knowledge base on its topic, nested within a broader framing of issues and questions that need further attention in the longer run (also see the on-line version of the report, which includes figures in color: <http://www.esd.ornl.gov/eess/NCAInfrastructure.shtml>).

The report arrived at a number of “assessment findings,” each associated with an evaluation of the level of consensus on that issue within the expert community, the volume of evidence available to support that judgment, and the section of the report that provides an explanation for the finding.

Cross-sectoral issues related to infrastructures and urban systems have not received a great deal of attention to date in research literatures in general and climate change assessments in particular. As a result, this technical report breaks new ground as a component of climate change vulnerability and impact assessments in the U.S., which means that some of its assessment findings are rather speculative, more in the nature of propositions for further study than specific conclusions that are offered with a high level of confidence and research support. But it is a start in addressing questions that are of interest to many policymakers and stakeholders.

A central theme of the report is that vulnerabilities and impacts are issues beyond physical infrastructures themselves. The concern is with the value of services provided by infrastructures, where the true consequences of impacts and disruptions involve not only the costs associated with the clean-up, repair, and/or replacement of affected infrastructures but also economic, social, and environmental effects as supply chains are disrupted, economic activities are suspended, and/or social well-being is threatened.

Current knowledge indicates that vulnerability concerns tend to be focused on extreme weather events associated with climate change that can disrupt infrastructure services, often cascading across infrastructures because of extensive interdependencies – threatening health and local economies, especially in areas where human populations and economic activities are concentrated in urban areas. Vulnerabilities are especially large where infrastructures are subject to multiple stresses, beyond climate change alone; when they are located in areas vulnerable to extreme weather events; and if climate change is severe rather than moderate. But the report also notes that there are promising approaches for risk management, based on emerging lessons from a number of innovative initiatives in U.S. cities and other countries, involving both structural and non-structural (e.g., operational) options.

More specifically, the report’s assessment findings are as follows. In each case, the report includes further information to support the finding.

Regarding implications of climate change for infrastructures in the United States, we find that:

- Extreme weather events associated with climate change will increase disruptions of infrastructure services in some locations
- A series of less extreme weather events associated with climate change, occurring in rapid succession, or severe weather events associated with other disruptive events may have similar effects.
- Disruptions of services in one infrastructure will almost always result in disruptions in one or more other infrastructures, especially in urban systems, triggering serious cross-sectoral cascading infrastructure system failures in some locations, at least for short periods of time
- These risks are greater for infrastructures that are:
 - Located in areas exposed to extreme weather events
 - Located at or near particularly climate-sensitive environmental features, such as coastlines, rivers, storm tracks, and vegetation in arid areas
 - Already stressed by age and/or by demand levels that exceed what they were designed to deliver
 - These risks are significantly greater if climate change is substantial rather than moderate

Regarding implications of climate change for urban systems in the United States, we find that:

- Urban systems are vulnerable to extreme weather events that will become more intense, frequent, and/or longer-lasting with climate change
- Urban systems are vulnerable to climate change impacts on regional infrastructures on which they depend
- Urban systems and services will be affected by disruptions in relatively distant locations due to linkages through national infrastructure networks and the national economy
- Cascading system failures related to infrastructure interdependencies will increase threats to health and local economies in urban areas, especially in locations vulnerable to extreme weather events
- Such effects will be especially problematic for parts of the population that are more vulnerable because of limited coping capacities

Regarding implications of climate change for infrastructure and urban system risk management strategies in the United States, we find that:

- Risks of disruptive impacts of climate change for infrastructures and urban systems can be substantially reduced by developing and implementing appropriate adaptation strategies
- Many of the elements of such strategies can be identified based on existing knowledge
- In most cases, climate-resilient pathways for infrastructure and urban systems will require greater flexibility than has been the general practice, along with

selective redundancy where particular interdependencies threaten cascading system failures in the event of disruptions

- Revising engineering standards for buildings and other infrastructures to accommodate projected climate change is a promising strategy
- In some cases, especially if climate change is substantial, climate-resilient pathways will require transformational changes, beyond incremental changes.

Regarding implications of climate change for infrastructure and urban system research needs in the United States, we find that:

- Improving knowledge about interdependencies among infrastructures exposed to climate change risks and vulnerabilities will support strategies and actions to reduce vulnerabilities
- The challenge is to recognize that, although uncertainties about climate change and payoffs from specific response strategies are considerable, many actions make sense now, such as developing monitoring systems to support assessments of emerging threats to infrastructures and urban systems
- A high priority should be given to verifying and validating the report's assessment findings, especially where the current evidence is not strong.

Regarding a continuing assessment process for climate change and infrastructure and urban systems in the United States, we find that:

- A self-sustaining long-term assessment process needs a commitment to improving the science base, working toward a vision of where things should be in the longer term
- Capacities for long-term assessments of vulnerabilities, risks, and impacts of climate change on infrastructures and urban systems will benefit from effective partnerships among a wide range of experts and stakeholders, providing value to all partners