Infrastructure

Background

The nation's aging infrastructure makes up an interconnected web of manmade systems that are alarmingly vulnerable to the shocks of climate change (Lehmann, 2014). Disruptions in, and stresses on the power grid can and will have a substantial impact on other systems such as transportation, public health, and water treatment. Underfunded and under-maintained bridges, roadways, and dams will face additional stress from extreme heat, changes in precipitation patterns, and high impact weather events.

Impacts and Solutions

Stress on stormwater systems due to increased rain and snowmelt: Many areas, especially in the Northeastern United States, will see increases in both overall precipitation as well as in the frequency and severity of extreme rainfall and snowmelt events. The result will be that much of the nation's aging and already stressed stormwater systems will face greater pressures in the future (U.S. Global Change Research Program, 2014).

Solutions: Local and state governments can combat the stresses on the stormwater systems by not only using ecological methods to reduce and slow stormwater (*see Inland Flooding*), but also by considering climate impacts when planning building and upgrades to existing systems.

State and Local Examples: One example of how a city considered climate impacts and ecological methodology in developing new stormwater systems can be seen in Fort Collins, CO, where new capital projects to create and/or restore streams, wetlands and riparian habitat to accommodate natural flood processes. These programs also are building new drainage systems that include public parks and trails to increase urban green space (Ashtary). These efforts are part of the City's long-term stormwater management plan, which seeks to make Fort Collins resilient to both current flooding, as build capacity for dealing with future flood risks caused by climate change.

Impacts to power lines in high heat situations: During heat waves, electric transmission cables sag because of the increased electric use. Most of the power lines used in the United States are 1950s-vintage steel-reinforced aluminum conductors. The aluminum is wrapped around a steel bar that maintains its stiffness at temperatures up to about 212◦ F; if the electric current gets too high and the temperature exceeds the cable's thermal rating, the steel loses its tensile strength and the power line sags (Jones, 2006). This becomes a problem when power lines sag into foliage and cause the power lines to short out and potentially cause fires.

Solutions: States can assist in preventing some of the harm caused by power line sagging by making climate-resilient improvements to power grid infrastructure, such as moving towards underground power lines to prevent power outages during extreme weather, and working to ensure that areas where power lines are known to sag are clear of brush and other hazards. Another possible solution is to work with energy utilities to ensure that new, more resilient power lines are utilized wherever possible.

States and Local Examples: A state working to ensure that power grid infrastructure is climate resilient is New York, where the state compelled the utility company Con Edison to incorporate climate impacts into storm hardening improvements (Con Edison of New York, 2013). States can also work with energy utilities to test and adapt new technologies to fit a state's expected climate impacts. One example is Salt Lake City-based Utah Power, a utility that is testing sag- and stretch-resistant composite core power lines.

Another solution that states have been implementing is the rolling out of “microgrids.” A microgrid combines various electric loads with distributed energy resources and advanced control equipment to allow portions of the electric grid to operate independently from the larger grid network, or to "island" in the case of the macrogrid going down (Pyper, 2014). States like Maryland, New Jersey, Connecticut, and Massachusetts have been leading the way with research projects and pilot programs. Connecticut, for example, has a Microgrid Grant and Loan Pilot Program that is being carried out by the Connecticut Department of Energy and Environmental Protection (Connecticut Department of Energy and Environmental Protection, 2012). The use of microgrids could also help mitigate the stress caused by the projected increased in energy draw during extreme heat or cold events because of massive increases in heating and cooling needs.

Transportation routes and climate change impacts: When designing transportation systems, engineers typically rely on historical climate data to determine the stresses that the system will have to endure during its useful lifetime. However, historical data is no longer an adequate predictor of future weather impacts (US Environmental Protection Agency, 2013). Changes such as increases in heat waves, more frequent and severe flooding, sea level rise, and the loss of permafrost need to be taken into account when designing new transportation infrastructure.

Solutions: States can mitigate the severity of damage to transportation systems by considering climate impacts when designing new transportation infrastructure, as well as when repairing and retrofitting old transportation infrastructure. Climate impacts need to be considered through the total expected useful lifetime of the structures, especially those that are in coastal and flood prone areas (National Research Council, 2008).

State and Local Examples: In considering climate impacts on critical transportation infrastructure, California chose to move portions of Highway 1 further inland to mitigate the risks that climate change will cause on this critical roadway. This was done because Caltrans included considerations of current and projected sea level rise and erosion caused by climate change in its strategic planning.

Impacts of extreme weather events on building structures: As with transportation routes, many buildings are engineered to withstand stresses that are determined by past climate and risk data. These structures and existing building codes may not be sufficient to withstand increasingly strong extreme weather events, or the projected increases in sea level. This means that structures will not be sufficiently protected against the new climate extremes and those who live and work in these inadequate structures are at risk of losing life and property.

Solutions: States can assist in adaptive efforts within their jurisdiction by requiring that either new buildings be engineered to withstand greater climate impacts, or requiring that those who develop new structures in at-risk areas submit a plan for dealing with new climate extremes. One example of this can be seen in the International Green Building Code that was adopted by the US Conference of Mayors in 2010 (Plautz & Burnham, 2010).

State and Local Examples: In the City of Boston, climate impacts are of concern to the owners of the city’s housing stock because most of the housing that is occupied was first built during the early 1950’s (Linnean Solutions, 2013). Because of weaknesses that were identified by the city, including several problems with Metro Stations being sited in areas that will be prone to flooding in the future, the city is creating new guidelines for development in areas that are at risk from the impacts of climate change (Rosenthal, 2013).

Impacts on interconnected energy/transportation/health systems: Climate change will have some of the most profound impacts on interconnected points within vulnerable systems (Wilbanks & Fernandez, 2012). These include areas where energy transmission and generation connect to transportation and health and human services. An example of vulnerable interconnection was seen in the loss of transportation and health services after flooding from Hurricanes Katrina and Sandy. Another example is power-generating facilities such as dams that rely on constant supplies of water, that may be at risk in areas experiencing prolonged drought because the lack of water could interfere with the dams ability to produce power (U.S. Global Change Research Program, 2014). The Hoover Dam, for instance, was designed based on a 30-year period that had markedly higher precipitation levels than today. As a result of a decade of drought, the dam is now operating at only 30 percent of its capacity, and new mechanisms have been added to cope with the lower water levels (Pyper, World's Dams Unprepared for Climate Change Conditions, 2010).

> **Solutions:** Solutions to interconnected system vulnerability are highly dependent on the status of existing systems and how they are interwoven. Often the best course of action to address interconnected vulnerabilities starts with a thorough and honest review of what vulnerabilities exist, and an assessment of what parts of the system can be improved in the most efficient way, with special emphasis on power generation and transmission systems.

> **State and Local Examples:** One example of where a state has taken action can be seen in the Washington State Department of Transportation 2011 Climate Impacts Vulnerability Assessment report. The report was written in fulfillment of a grant from the Federal Highway Administration to test its conceptual climate risk assessment model developed for transportation infrastructure. WSDOT applied the model using a scenario-planning device in a series of statewide workshops, using local experts to create a qualitative assessment of climate vulnerability on its assets in each region and mode across Washington. The report found instances where vulnerabilities to energy generation and transmission create weaknesses within transportation planning and infrastructure, and that these vulnerabilities will be increased by climate change (Washington State Department of Transportation , 2011).

Impacts of the Urban Heat Island Effect: As more frequent and severe heat waves become the norm, cities will be affected more than rural areas due to the urban "heat Island" effect. This effect causes densely populated areas to be on average, 5 to 10 °F warmer than the surrounding areas. The effect of this increased heating is especially harmful for those in low-income neighborhoods, which may not have access to air-conditioned areas to use as refuge from the heat (Hoverter, 2012).

> **Solutions:** States can help tackle the problems associated with urban heat by not only working to ensure that effected people have access to cooling shelters *(see the Human Health section)* but also to take action to reduce the disproportionate heating. With programs for cool or green roofs, urban forests, and cool pavement programs, the impact of the new and more extreme heat waves can be mitigated.

> **State and Local Examples:** State and local governments have implemented programs that help mitigate the effects of the urban heat island effect, whether or not they state that climate adaptation is a goal (Hoverter, 2012). Since 2010 Washington, DC has charged a 5-cent fee on all plastic and paper bags used by customers in grocery, convenience, and liquor stores to generate funds to clean up the Anacostia River and support adaptation - a subsidy for green roofs, and community education and outreach. As of 2013, the fee had helped to subsidize green roofs which insulate buildings and increase energy efficiency, while also reducing urban temperatures (Georgetown Climate Center, 2014).

Stress on the Telecommunications systems: The projected increases in the frequency and severity of severe weather events will put strain on telecommunication systems. The telecommunications sector comprises telephone service; internet; cable and satellite TV; wireless phone services; wireless broadcasting (radio, TV); and public wireless communication (e.g., government, first responders, special data transmissions) on reserved radio frequency bands. These systems will be increasingly at-risk due to stronger storms, and their failure can be catastrophic, as seen in the 2009 Northeast ice storm, as well as Hurricane Sandy (Jacob, Maxemchuk, Deodatis, Morla, Schlossberg, & Paung, 2011).

Solutions: Telecommunications systems can be made more resilient to the effects of climate change by increasing the resiliency of exposed sections of the larger systems such as cell phone towers and power lines. Existing telecommunication service delivery systems will be vulnerable to severe wind, icing, snow, hurricanes, lightning, floods, and other extreme weather events, some of which are projected to increase in frequency and intensity (Wong & Schuchard, 2011). By taking measures to harden exposed points, the entire system can be made resilient.

State and Local Examples: New York has taken the initiative to consider the effects of climate change on telecommunications in the states, as part of the states ClimAID program, that was tasked with identifying and providing adaptation options for climate change impacts on telecommunications infrastructure (Jacob, Maxemchuk, Deodatis, Morla, Schlossberg, & Paung, 2011). The ClimAID report suggested taking actions such as introducing redundancy protocols to take over if one part of a system failed, and placing telecommunication cables underground where technically and economically feasible (Jacob, Maxemchuk, Deodatis, Morla, Schlossberg, & Paung, 2011). Other states can use New York's example to evaluate weaknesses within their telecommunications infrastructure, and can use this information to guide future upgrades.

High Heat Damage to Roadways: Higher temperatures can cause pavement to soften and expand. This can create rutting and potholes, particularly in high-traffic areas, and can place stress on bridge joints. Heat waves can also limit construction activities, particularly in areas with high humidity. It could become more costly to build and maintain roads and highways (US Environmental Protection Agency, 2013). The demand for water increases during periods of hot weather, but in extreme heat waves, water is used to cool bridges and other metal structures susceptible to heat failure. This causes a reduced water supply, and may contribute to fire suppression problems for both urban and rural fire departments (City of Denver). Additionally, concrete roads have been known to "explode" lifting 3 to 4 foot pieces of concrete from water underneath the roads boiling (City of Denver).

Solutions: States can take actions to help build resiliency from the effects of high heat on roadways by both using and helping to fund the latest technology and best practices for building climate adaptive road ways. Additionally, states can insert adaptive planning that funds transportation departments and empowers them to respond quickly to high heat situations. Changes in working hours or other strategies to protect laborers from heat waves can be implemented, as well as the deployment of warning systems for where damaged roadways are located to reduce harm to drivers and workers. (Meyer, Flood, Keller, Lennon, McVoy, & Dorney, 2014)

State and Local Examples: The Minnesota Department of Transportation has adopted plans to respond quickly to damaged roadways during extreme heat situations. On the federal level the Center for Disease Control has issued recommendations for construction and other outdoor worker safety in extreme heat (CDC Workplace Safety and Health).

Resources and Tools

Climate Change Community Toolbox: by the South Florida Regional Planning Council, is designed to help decision-makers understand how to carry out adaptation planning, how to conduct analyses of specific sectors and issue areas as the basis for focused response strategies and actions, and presents examples of adaptation planning options. The Toolbox is expected to assist communities to translate concern about global climate change into sound planning, policy and action while this tool is focused on infrastructure with the Southern Florida region, the information presented is valuable when applied nationwide [Link]

Climate Resilience Evaluation and Awareness Tool (CREAT): by the Environmental Protection Agency. This tool is able to assist drinking water and wastewater utility owners and operators in understanding potential climate change threats and in assessing the related risks to their individual utilities. CREAT provides users with access to the most recent national assessment of climate change impacts for use in considering how these changes will impact utility operations and missions. [Link]

Community Vulnerability: Climate Attribution Toolbox: Created by NOAA, the Climate Attribution Toolbox attempts to explain evolving climate conditions and to assess their impacts at the regional and local levels. [Link]

Integrating Extreme Weather Risk into Transportation Asset Management: by American Association of State Highway and Transportation Officials' (AASTHO) Transportation and Climate Change Resource Center. This report provides access to information, services, and resources to support both mitigation and adaptation actions by state transportation departments. [Link]

EPA Stormwater Calculator: The Environmental Protection Agency in 2014 released an updated version of its tool for calculating annual stormwater runoff for different locations across the U.S. The updated National Stormwater Calculator will allow local governments to consider how runoff may vary based on both historical weather and potential future climate. [Link]

Power Failure: How Climate Change Puts Our Electricity at Risk — and What We Can Do: a report by the Union of Concerned Scientists. This report goes into detail on the impacts of climate change on the electricity generation and transmission systems in the United States. [Link]

Regional Climate Change Effects: Useful Information for Transportation Agencies: report by the US Department of Transportation Federal Highway Department. This report provides projections of temperature, sea level rise, and precipitation over three different time periods out to 2100. [Link]

Climate Change and Infrastructure, Urban Systems, and Vulnerabilities: report by U.S. Department of Energy in Support of the National Climate Assessment. This technical report for the US Department of Energy in support of the National Climate Assessment, and addresses these needs by examining how climate change affects urban buildings and communities, and determining which regions are the most vulnerable to environmental disaster. It looks at key elements of urban systems, including transportation, communication, drainage, and energy. The report also highlights critical research gaps in the material. Implications of climate change are examined by assessing historical experience as well as simulating future conditions. [Link]

Adding Green to Urban Design: A City for Us and Future Generations: This report, released in 2008 from the City of Chicago, is a urban planning document that presents a detailed implementation strategy for economically sound and environmentally sustainable urban design. The plan is intended to provide direction to the Chicago City Council in regulating urban design and to the Chicago Plan Commission in reviewing individual development projects. [Link]

Natural Security: How Sustainable Water Strategies Prepare Communities for a Changing Climate: This report from American Rivers reviews the linkage between "green" water management practices and protecting communities from climate change. This publication evaluates green infrastructure strategies implemented in eight communities across the U.S. through the lens of climate changes in these areas and associated impacts. Focus areas include improving public health, reducing flood and storm damage; securing clean water supplies; and resilient communities. [Link]