Climate Change and National Preparedness

Scientific evidence indicates the climate is changing and significant economic, social, and environmental impacts are expected as a result. Climate change is an increasingly significant factor in assessing and managing risks and vulnerabilities to extreme events. Over the past 50 years, much of the U.S. experienced increases in prolonged periods of excessively high temperatures, heavy precipitation, and, in some regions, severe floods and droughts.[37] The best available scientific data indicates these trends will continue and will likely have further cascading effects on human health, infrastructure, and the economy.[38]

Primary Impacts

The impacts of climate change will vary across the Nation, but the following are examples of critical anticipated shifts in the frequency, intensity, and/or geographic range of natural hazards:

- Increasing heavy precipitation events will contribute to flash floods and urban floods.[39]
- Average global sea level has risen by approximately eight inches since reliable record keeping began in 1880 and is projected to rise another one to four feet by 2100.[40]
- Western forests in the U.S. will be more frequently affected by large and intense fires.[41]
- The frequency and intensity of heat waves will continue to increase.[42]
- Higher temperatures cause faster evaporation rates, which may lead to drought conditions even when there is no decrease in precipitation.[43]
- Over the last three to five decades, the heaviest rainfall events have become heavier and more frequent,[44] and these are projected to continue in most of the U.S.;[45] and
- Although many contributing factors make hurricanes difficult to predict, most models project an overall increase in the frequency of the strongest (Category 4 and 5) hurricanes by the end of the century.[46]

Due to the complexity of climatological forecasting and the myriad anticipated impacts, some uncertainty remains about the magnitude and types of future changes to natural hazards. It is clear, however, that increasing frequency, intensity, and impacts of hazards due to climate

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[37] NCA3 Highlights," *Climate Change Impacts in the United States: The Third National Climate Assessment: Highlights"* http://nca2014.globalchange.gov/Highlights, Pg. 24
[38] NCA3 Highlights, Pgs. 12–14
[39] U.S. Third National Climate Assessment (NCA3), "*Climate Change Impacts in the United States The Third National Climate Assessment*," U.S. Global Change Research Program, May 2014 http://nca2014.globalchange.gov/report, Pg. 75
[40] NCA3, Pg. 66
[41] NCA3, Pg. 192
[42] NCA3, Pg. 64
[43] NCA3 Highlights, Pg. 24
[44] NCA3 Highlights, Pg. 25
[45] NCA3, Pg. 37
[46] NCA3, Pg. 41

change may render historical risk profiles outdated, and, therefore, they may no longer be an adequate measure for identifying and addressing future risks.

Secondary Impacts

As climate change alters the natural hazard risk environment, secondary risk and vulnerability effects are likely. The social and health-related impacts of climate change will likely be more concentrated in communities already facing economic or health-related challenges.[47] Agricultural pressures associated with climate change may lead to rising food prices,[48] which in turn can contribute to food insecurity. More frequent heat waves, worsening air quality, and more favorable growing conditions for common allergens may increase chronic heat-, respiratory-, and allergy-related conditions.[49]

Future climate extremes may strain the reliability of critical infrastructure and availability of key resources, forcing the whole community to reconsider current and future resource needs. Degraded natural barriers such as salt marshes, reefs, mangrove forests, and barrier islands have a reduced capacity to buffer coastal infrastructure from extreme events like floods and storms. Even outside of coastal areas, climate change is expected to have a profound impact on the Nation's infrastructure, including a reduction in the reliability and capacity of transportation infrastructure and systems,[50] which are critical to lifesaving response efforts and disaster recovery.

The economic ramifications of climate change can affect resources and response capabilities at all levels of government. There has been a sizeable upward trend in the number of storm events causing large financial and other losses in the U.S.,[51] though this trend can be attributed to increases in property values at risk in addition to increases in storm activity. In addition to a rising economic toll of disaster response, the underlying drivers of local economies could be significantly altered as climate zones suitable for agricultural production and climate-driven tourism shift.[52] Such economic impacts have the potential to ripple across the Nation. For example, ports are deeply interconnected with inland areas through the goods imported and exported each year.[53] Their exposure to sea level rise is not just a concern for coastal communities, but has far-reaching implications for the Nation's economy as a whole.

Net Impacts

Climate change is expected to act as a hazard multiplier for many current threats and hazards, and in some cases will introduce new hazards to communities. The effects of climate change may cascade into a number of areas that are not directly weather related, affecting population shifts, public health, resources, and local economies. In other words, although a changing climate is not a threat or hazard unto itself, its impacts should be considered throughout risk analyses and

[47] NCA3 Pgs. 228–229
[48] NCA3, Pg. 228
[49] NCA3, Pg. 222
[50] NCA3 Highlights, Pg. 40
[51] NCA3, Pg. 65
[52] NCA3. Pgs. 334–339
[53] NCA3, Pg. 590

future decision making processes in all five mission areas—Prevention, Protection, Mitigation, Response, and Recovery.

Appendix O: Climate Change

Scientific evidence indicates the climate is changing and significant economic, social, and environmental impacts are expected as a result. Climate change is an increasingly significant factor in assessing and managing risks and vulnerabilities to extreme events. Over the past 50 years, much of the U.S. has experienced increases in prolonged periods of excessively high temperatures, heavy precipitation, and, in some regions, severe floods and droughts.[1] The best available scientific data indicates these trends will continue and will likely have further cascading effects on human health, infrastructure, and the economy.[2]

Primary Impacts

The impacts of climate change will vary across the Nation, but the following are examples of critical anticipated shifts in the frequency, intensity, and/or geographic range of natural hazards:

- Increasing heavy precipitation events will contribute to flash floods and urban floods.[3]
- Average global sea level has risen by approximately eight inches since reliable record keeping began in 1880 and is projected to rise another one to four feet by 2100.[4]
- Western forests in the U.S. will be more frequently affected by large and intense fires.[5]
- The frequency and intensity of heat waves will continue to increase.[6]
- Higher temperatures cause faster evaporation rates, which may lead to drought conditions even when there is no decrease in precipitation.[7]
- Over the last three to five decades, the heaviest rainfall events have become heavier and more frequent,[8] and these are projected to continue in most of the U.S.;[9] and
- Although many contributing factors make hurricanes difficult to predict, most models project an overall increase in the frequency of the strongest (Category 4 and 5) hurricanes by the end of the century.[10]

Due to the complexity of climatological forecasting and the myriad anticipated impacts, some uncertainty remains about the magnitude and types of future changes to natural hazards. It is clear, however, that increasing frequency, intensity, and impacts of hazards due to climate change may render historical risk profiles outdated, and, therefore, they may no longer be an adequate measure for identifying and addressing future risks.

[1] NCA3 Highlights, "Climate Change Impacts in the United States: The Third National Climate Assessment: Highlights," http://nca2014.globalchange.gov/Highlights, Pg. 24.
[2] NCA3 Highlights, Pgs. 12–14.
[3] U.S. Third National Climate Assessment (NCA3), "Climate Change Impacts in the United States The Third National Climate Assessment," U.S. Global Change Research Program, May 2014: http://nca2014.globalchange.gov/report. Pg. 75.
[4] NCA3, Pg. 66.
[5] NCA3, Pg. 192.
[6] NCA3, Pg. 64.
[7] NCA3 Highlights, Pg. 24.
[8] NCA3 Highlights, Pg. 25.
[9] NCA3, Pg. 37.
[10] NCA3, Pg. 41.

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Secondary Impacts

As climate change alters the natural hazard risk environment, secondary risk and vulnerability effects are likely. The social and health-related impacts of climate change will likely be more concentrated in communities already facing economic or health-related challenges.[11] Agricultural pressures associated with climate change may lead to rising food prices,[12] which in turn can contribute to food insecurity. More frequent heat waves, worsening air quality, and more favorable growing conditions for common allergens may increase chronic heat-, respiratory-, and allergy-related conditions.[13]

Future climate extremes may strain the reliability of critical infrastructure and availability of key resources, forcing the whole community to reconsider current and future resource needs. Degraded natural barriers such as salt marshes, reefs, mangrove forests, and barrier islands have a reduced capacity to buffer coastal infrastructure from extreme events like floods and storms. Even outside of coastal areas, climate change is expected to have a profound impact on the Nation's infrastructure, including a reduction in the reliability and capacity of transportation infrastructure and systems,[14] which are critical to lifesaving response efforts and disaster recovery.

The economic ramifications of climate change can affect resources and response capabilities at all levels of government. There has been a sizeable upward trend in the number of storm events causing large financial and other losses in the U.S.,[15] though this trend can be attributed to increases in property values at risk in addition to increases in storm activity. In addition to a rising economic toll of disaster response, the underlying drivers of local economies could be significantly altered as climate zones suitable for agricultural production and climate-driven tourism shift.[16] Such economic impacts have the potential to ripple across the Nation. For example, ports are deeply interconnected with inland areas through the goods imported and exported each year.[17] Their exposure to sea level rise is not just a concern for coastal communities, but has far-reaching implications for the Nation's economy as a whole.

[11] NCA3 Pgs. 228–229.
[12] NCA3, Pg. 228.
[13] NCA3, Pg. 222.
[14] NCA3 Highlights, Pg. 40.
[15] NCA3, Pg. 65.
[16] NCA3. Pgs. 334–339.
[17] NCA3, Pg. 590.

Natural Hazard Risk

Long-term, independent records from weather stations, satellites, ocean buoys, tide gauges, and many other data sources all confirm that the Nation, like the rest of the world, is in the midst of a long-term warming trend.[18] Although the warming trend is clear, the exact quantitative risk of climate change is difficult to estimate due to natural climatic variations.[19] The Third National Climate Assessment (NCA3) was produced by a team of more than 300 experts, guided by a 60-member Federal Advisory Committee, and extensively reviewed by the public and experts, including federal agencies and a panel from the National Academy of Sciences. The NCA3 comprises the best available scientific data on the potential impacts of climate change in the U.S. and summarizes the status of the current scientific consensus on various aspects of climate change.

Climate change presents a challenge to individuals throughout the Nation, however, its impacts will vary across the U.S. The NCA3 describes eight regions and their anticipated changes in climate-related hazards:

- In the Northeast, communities will be affected by heat waves, more extreme precipitation events, and coastal flooding due to sea level rise and storm surge.
- In the Southeast and Caribbean, decreased water availability, exacerbated by population growth and land use change, will cause increased competition for water in addition to growing risks associated with extreme events such as hurricanes.
- In the Midwest, an increased occurrence of extreme events such as heat waves, droughts, and floods is anticipated.
- In the Great Plains, rising temperatures will lead to increased demand for water and energy, as well as impacts on agricultural practices.
- In the Southwest, drought and increased warming will increase the risk of wildfires and competition for scarce water resources.
- In the Northwest, changes in the timing of streamflow due to earlier snowmelt will reduce the supply of water in the summer, causing far-reaching ecological and socioeconomic consequences.
- In Alaska, rapidly receding summer sea ice, shrinking glaciers, and thawing permafrost cause damage to infrastructure and major changes to ecosystems.
- In Hawai'i and the Pacific Islands, increasingly constrained fresh water supplies, coupled with increased temperatures, will stress both people and ecosystems and decrease food and water security.[20]

Historical risk profiles for hazards may no longer serve as effective planning tools for identifying and addressing future risks. Climate change has the potential to affect the frequency, intensity, and/or geographic range of many natural hazards. However, due to the complexity of climatological forecasting and the plethora of anticipated impacts, not all projections are backed by equally strong scientific evidence. Some are backed by scientific consensus and a

[18] NCA3.
[19] NCA3, Pg. 28.
[20] NCA3 Highlights, Pg. 8.

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comprehensive body of supporting data; others are supported by limited studies, or are the subject of ongoing scientific debate. Table O1 identifies key natural hazards that will potentially be affected by climate change, and how, as well as the degree of scientific confidence behind each anticipated or observed change in hazard characteristic, according to the NCA3.

Table O1: Climate Change Impacts Table Legend

Hazard	Identifies the hazard for which there is either a projected future or an observed historical shift in frequency, intensity, or range of impact.
"Very High" to "Low"	Indicates the degree of scientific confidence that climate change has/will affect the given hazard characteristic.[21] ▪ Note: Some of the projected hazard increases/shifts have differing degrees of scientific confidence in different regions. This is noted in the qualitative description when applicable.
Qualitative description for each hazard	Provides additional information as to whether the shift is projected (future) vs. observed (current), or regional vs. national in nature. Also provides the source page number from NCA3, or NCA3 Highlights, for each statement.

Table O2: Climate Change Impacts on Natural Hazards in the U.S.

Hazard Characteristic:	Increase in Frequency	Increase in Intensity	Shift in Geographic Range of Impacts
Wildfire	Very High Confidence	Very High Confidence	
▪ Hotter and drier weather and earlier snowmelt may result in wildfires in the west starting earlier in the spring, lasting later into the fall, and burning more acreage. (NCA3 Pg 1) ▪ There is very high confidence that western forests in the United States will be affected increasingly by large and intense fires that occur more frequently. Wildfires will increase substantially in response to warming and also in conjunction with other changes such as an increase in the frequency and/or severity of drought and amplification of pest and pathogen impacts. (192) ▪ Eastern forests are less likely to experience immediate increases in wildfire unless/until a point is reached at which warmer temperatures, concurrent with seasonal dry periods or more protracted drought, trigger wildfires. (192) ▪ Excessive wildfire destroys homes, exposes slopes to erosion and landslides, threatens public health, and causes economic damage. (468)			
Floods	Regional Trends	Regional Trends	
▪ Increasing heavy precipitation events will contribute to flash floods and urban floods, while rising sea levels will contribute to increasing tidal and storm-related flooding. (75) ▪ Confidence is very high that sea level will continue to rise; medium confidence that the rise will be in the range of one to four feet by 2100. (66)			

[21] "**Very High**" - High scientific consensus due to established theory, multiple sources, consistent results, well documented and accepted methods, etc.
"**High**" - Medium scientific consensus due to several sources, some consistency, methods vary and/or documentation limited, etc.
"**Medium**" - Competing schools of thought due to suggestive evidence, few sources, limited consistency, models incomplete, methods emerging, etc.
"**Low**" - Inconclusive evidence due to limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.; disagreement or lack of opinions among experts.

Hazard Characteristic:	Increase in Frequency	Increase in Intensity	Shift in Geographic Range of Impacts
▪ Rates of sea level rise are not uniform along U.S. coasts and can be exacerbated locally by land subsidence or reduced by uplift. (582) ▪ Detailed hydrologic models of rivers that simulate response to projected precipitation and temperature changes from climate models have only recently begun to emerge in peer-reviewed literature. Confidence in current estimates of future changes in flood frequencies and intensities is overall judged to be low [nationally], due to the impact of future development and the need to conduct individual projections for each river basin. (107) ▪ Confidence is high that there have been regional trends in floods and droughts. (65) o **Northeast:** Very High confidence for sea level rise and increasing coastal flooding as well as heat waves; High confidence for more intense precipitation events and riverine flooding. (393) o **Midwest:** There is Medium confidence that, in the absence of substantial adaptation actions, the enhancement in extreme precipitation and other tendencies in land use and land cover result in a projected increase in flooding. (439) o **Southwest:** There is Very High confidence the sea level will continue to rise and that this will entail major damage to coastal regions in the Southwest. There is also very high confidence that flooding and erosion in coastal areas are already occurring even at existing sea levels and damaging some areas of the California coast during storms and extreme high tides. (485) o **Northwest:** There is High confidence in the projections of increased [coastal] erosion and inundation. (509)			
Drought	High Confidence	High Confidence	
▪ The number of extremely hot days is projected to continue to increase over much of the U.S., especially by late century. (39) ▪ Higher temperatures cause increased rates of evaporation, which may result in a decrease of surface water and soil moisture, and lead to drought conditions even when there is no decrease in precipitation. (Highlights 24) ▪ Potential secondary impacts include an increase in wildfire severity and frequency (32), a reduction in energy generation capacity in areas that rely on hydropower (85), and a decrease in water quality due to higher relative concentrations of contaminants in surface water. (78) ▪ Confidence is judged to be medium-high that short-term (seasonal or shorter) droughts are expected to intensify in most U.S. regions. Confidence is high that longer-term droughts are expected to intensify in large areas of the southern U.S. (107) ▪ Confidence is high that the length of dry spells is projected to increase in most areas, especially the southern and northwestern portions of the contiguous U.S. (106) ▪ Confidence is judged to be medium-high that short-term (seasonal or shorter) droughts are expected to intensify in most U.S. regions. Confidence is high that longer-term droughts are expected to intensify in large areas of the Southwest, southern Great Plains, and Southeast. (107)			
Extreme Heat	High Confidence	High Confidence	
▪ Climate change has increased the probability of heat waves. Prolonged (multi-month) extreme heat has been unprecedented since the start of reliable instrumental records in 1895. (NCA 3 Highlights Pg 24) ▪ The national number of heat waves in 2011 and 2012 was almost triple the long-term average. (Highlights 24) ▪ Heat waves sharply increase risks of power outages and fatalities from heat stroke and related			

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Hazard Characteristic:	Increase in Frequency	Increase in Intensity	Shift in Geographic Range of Impacts
conditions, particularly in urban areas. (NCA 3 Pg 224) ▪ High confidence that heat waves everywhere are projected to become more intense in the future. (64) ▪ High confidence that heat waves have become more frequent and intense, especially in the West. (64)			
Heavy Precipitation	High Confidence	High Confidence	
▪ Over the last three to five decades, the heaviest rainfall events have become heavier and more frequent, and the amount of rain falling on the heaviest days has also increased. (Highlights 25) ▪ High confidence that heavy downpours are increasing, and will continue to increase, in most regions of the U.S., with especially large increases in the Midwest and Northeast. (64) ▪ High confidence that further increases in the frequency and intensity of extreme precipitation events are projected for most U.S. areas, including in regions where total precipitation is projected to decrease, such as the Southwest. (37) ▪ Secondary impacts may include increases in flash flooding, erosion and landslides, as well as associated infrastructure stresses.			
Hurricanes	Medium Confidence	Medium Confidence	
▪ Although there are many contributing factors that make hurricanes difficult to predict, most models project an overall increase in the frequency of the strongest (Category 4 and 5) hurricanes by the end of the century. (41) ▪ Rising sea levels along the Atlantic and Gulf coasts will make coastal areas even more vulnerable to storm surge. (401) ▪ Overall, medium confidence that hurricane intensity and rainfall rates are projected to increase as the climate continues to warm. (65)			
Winter Storms	Medium Confidence	Medium Confidence	Medium Confidence
▪ There is evidence of an increase in both winter storm frequency and intensity since 1950 in the northern and eastern parts of the U.S., but they have been less frequent since 2000. (43) ▪ Confidence is high that cold waves have become less frequent and intense across the Nation. (64) ▪ Confidence is medium that winter storms have increased slightly in frequency and intensity, and that their tracks have shifted. (65)			
Tornadoes	Low	Low	
▪ A recent study suggests a projected increased in the conditions favorable for severe thunderstorms, but more studies are required. (43) ▪ Low confidence in increasing trend in intensity and frequency of tornadoes, hail and damaging thunderstorms. (65)			

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Impacts on Society and Systems

Climate change is expected to act as a hazard multiplier for many current threats and hazards, and in some cases will introduce new hazards to communities. The effects of climate change may cascade into a number of areas that are not directly weather related, affecting population shifts, public health, resources, and local economies.

As climate change alters the natural hazard risk environment, cascading risk and vulnerability effects on public health, natural resources, infrastructure, and society are likely. The social and health-related impacts of climate change will likely be more concentrated in communities that already face economic or health-related challenges,[1] but may substantially affect the capacity of communities as a whole to prepare for, respond to, and recover from increasing threats from natural hazards. Below are examples of climate change-related effects that can increase vulnerability to extreme events.

Natural Resources Effects

Climate change, combined with other stressors, is overwhelming the capacity of ecosystems to buffer the impacts from extreme events like droughts, floods, and storms.[2] Salt marshes, reefs, mangrove forests, and barrier islands provide an ecosystem service of defending coastal ecosystems and infrastructure against storm surges. Losses of these natural features to sea level rise and other causes render coastal ecosystems and infrastructure more vulnerable to catastrophic damage during or after extreme events.

Infrastructure Effects

Much of the Nation's infrastructure, including buildings and energy, transportation, water, and sanitation systems, is outdated and/or in need of upgrades. This existing infrastructure is expected to become "more stressed in the next decades—especially when the impacts of climate change are added to the equation."[3] Increased exposure to hazards due to climate change may lead decision makers and planners to consider how climate change will affect their new and existing infrastructure systems, assets, and networks across the lifespan of those structures. Anticipated impacts include a reduction in the reliability and capacity of transportation infrastructure and systems, which are critical to lifesaving response efforts and disaster recovery.[4] Additionally, urban infrastructure systems are highly interdependent, so a failure in one sector may have "cascading effects across affected urban economies."[5]

While it may be obvious that infrastructure faces challenges nationwide, infrastructure exposure to natural hazards is a nationwide concern and requires further analysis and investment in order to mitigate risks of disruption. The Department of Homeland Security (DHS) National Protection and Programs Directorate (NPPD) conducted an in-depth analysis of infrastructure exposure[6] to natural hazards in the contiguous U.S. (see next section). The preliminary analysis reveals where existing infrastructure systems are exposed to natural hazards and where that exposure may shift

[1] NCA 228–229.
[2] NCA3, Pg. 217.
[3] NCA3, Pg. 283.
[4] NCA3 Highlights, Pg. 40.
[5] NCA3, Pg. 283.
[6] DHS NPPD commissioned the RAND Corporation to conduct analysis on infrastructure exposure to natural hazards. As of April 2015, the data, methods, analysis, and findings are being documented and will be reviewed by representatives from across the interagency.

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due to climate change.[7] Even without adjusting for climate change, the Nation's infrastructure is exposed to a range of natural hazards such as landslides, hurricanes, earthquakes, tornadoes, and wildfire. While additional analysis is required to quantify the vulnerability of specific infrastructure systems to climate-related hazards, understanding infrastructure exposure is an important step in planning for adapting to the impacts of climate change.

Climate change impacts on critical infrastructure is examined in greater depth in the following section.

Water Insecurity

Changes in water availability have the potential to drive "critical climate-related conflicts and relief challenges across the globe."[8] Climate change is projected to reduce water availability and increase demand in the American Southwest and Southeast.[9] This will create water management challenges, including potential competition between sectors and/or land owners. The agricultural sector is currently responsible for around 70 percent of freshwater consumption. There is also the potential, as water becomes a scarcer resource, for water infrastructure to become an increasingly attractive target for terrorism.

Sea Level Rise

Global sea level has risen by about eight inches since reliable record keeping began in 1880. It is projected to rise another one to four feet by 2100.[10] This rise will not be constant throughout the U.S., but will be impacted by coastal uplift and subsidence as well as any movement of the Atlantic jet stream. For example, in the same period of 1880 to present, the relative sea level rise was approximately one foot in the Northeast.[11] Since 1992, the rate of global sea level rise measured by satellites has been roughly twice the rate observed over the last century, indicating a potential increase in the rate of sea level rise.

Health Effects

Increasing heat waves, worsening air quality, and more favorable growing conditions for common allergens may increase the strain on health systems due to increasing chronic heat-, respiratory-, and allergy-related conditions.[12] The Department of Health and Human Services (HHS) Climate Change Adaptation Plan[13] identifies several effects that climate change can have on public health. These impacts will likely be most severe among individuals and communities that already face economic or health-related challenges. Individuals with asthma are especially vulnerable to health consequences associated with extreme heat, wildfires, and mold outbreaks from flood events. Asthma prevalence (the percentage of people who have ever been diagnosed with asthma and still have asthma) increased nationwide from 7.3% in 2001 to 8.4% in 2010.[14] Heat waves can also worsen specific health concerns not traditionally associated with heat, such

[7] For the purposes of the infrastructure exposure analysis (pp 481-486), permanent inundation, tidal flooding, coastal surge, extreme temperatures, drought, and wildfires were considered to be impacted by climate change. Earthquakes, landslides, tornadoes, tsunamis, ice storms, riverine flooding, and hurricane winds were not considered related to climate change, as there is not sufficient data to support a nationwide evaluation of how the hazard could be expected to change.
[8] National Research Council "*Climate and Social Stress*," Pg. 98.
[9] NCA3, Pg. 87.
[10] NCA3, Pg. 66.
[11] NCA3, Pg. 370.
[12] NCA3, Pg. 222.
[13] *HHS Climate Change Adaptation Plan*. U.S. Department of Health and Human Services. 2012. http://www.hhs.gov/about/sustainability/adaptation-plan.pdf.
[14] NCA3, Pg. 222.

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as cardiovascular disease and respiratory disease, leading to spikes in hospitalizations during extreme heat events.[15] Finally, the changing climate may impact the geographic range and lengthen the active season of tropical disease-carrying vectors such as mosquitoes.[16]

Food Insecurity

During the next century, the predicted higher incidence of extreme weather will influence agricultural productivity. Near-term climate change effects on agriculture include the potential for increased soil erosion through extreme precipitation events, as well as regional and seasonal changes in the availability of water resources for both rain-fed and irrigated agriculture.[17] According to the U.S. Department of Agriculture (USDA) Climate Change Adaptation plan, pressures associated with climate change, including "weeds, diseases, and insect pests, together with potential changes in timing and coincidence of pollinator lifecycles, will affect growth and yields."[18] In addition to impacting crop agriculture, climate change can "affect animal agriculture in four primary ways: (1) feed-grain production, availability, and price; (2) pastures and forage crop production and quality; (3) animal health, growth, and reproduction; and (4) disease and pest distributions."[19]

In response to the above pressures, food prices are expected to rise.[20] Historically, food insecurity rises with rising food prices, and the NCA3 notes that in such situations, "people cope by turning to nutrient-poor but calorie-rich foods, and/or they endure hunger, with consequences ranging from micronutrient malnutrition to obesity."[21] Additionally, Americans with specific dietary patterns, such as Alaska Natives, will confront shortages of key foods.[22]

Mass Migration/Social Displacement

Climate change could displace many socially vulnerable individuals and lead to significant social disruptions in some coastal areas.[23] There is evidence that tribal communities in Alaska, coastal Louisiana, the Pacific Islands, and other coastal locations are already being forced to relocate due to sea level rise, coastal erosion, melting permafrost, and/or extreme weather events.[24] A recent National Research Council report notes that climate change may contribute to "temporary or permanent displacement of a population following some type of climate event or other disruptive event, such as a tsunami… temporary or permanent relocation of a population from an area threatened by flooding or inundation; and temporary or permanent movement from one region or country to another for economic opportunity."[25] Such events are impossible to predict, but Hurricane Katrina demonstrated the potential of major climate-related disasters to permanently displace large portions of an impacted population.[26] Hurricane Katrina also demonstrated the challenges that may face the migrants, such as establishing themselves in a new community, finding employment, and accessing services. The receiving communities also face challenges, as

[15] NCA3, Pg. 224.
[16] NCA3, Pg. 225.
[17] USDA Climate Change Adaptation Plan, Pg. 9.
[18] USDA Climate Change Adaptation Plan Pg. 10.
[19] USDA Climate Change Adaptation Plan.
[20] NCA3, Pg. 228.
[21] NCA3, Pg. 228.
[22] NCA3, Pg. 228.
[23] NCA3, Pg. 591.
[24] NCA3, Pg. 317.
[25] National Research Council "*Climate and Social Stress,*" Pg. 112.
[26] NCA3, Pg. 401.

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their infrastructure, labor market, commerce, natural resources, and governance structures need to absorb a sudden population growth.[27]

Economic Effects

Climate change has the potential to affect resources and response capabilities at all levels of government. There has been a sizeable upward trend in the number of storm events causing large financial and other losses in the U.S.,[28] though this trend can be attributed to increases in both storm activity and development. In 2012, the warmest year on record for the U.S., the Nation experienced 11 climate-related disasters resulting in over $110 billion in damages.[29]

In addition to the economic toll of disaster response, the underlying drivers of local economies could be significantly altered as climate zones suitable for agricultural production and climate-driven tourism shift.[30] The nation's ports are located in already-vulnerable coastal locations, and increasingly exposed to sea level rise and related hazards.[31] This is not just a concern for coastal communities, but has far-reaching implications for the economy of the Nation as whole as ports are deeply interconnected with inland areas through the goods imported and exported each year.[32] If additional mitigation actions are not taken, the potential economic toll from climate-related disasters could be huge.

Even the necessary mitigation efforts could have significant economic impact, however. There have been no comprehensive, nation-wide estimates of the total necessary mitigation investment, though there have been sector- and region-specific estimates. A water sector-specific study estimated the nationwide climate change adaptation costs for wastewater systems alone would fall between $123 billion and $252 billion by 2050.[33] A Gulf Coast-specific study estimated that investing approximately $50 billion for adaptation over the next 20 years could lead to approximately $135 billion in averted losses over the lifetime of adaptive measures.[34]

Abrupt Climate Change Impacts

An additional climate change consideration is the rate at which the change might occur. Most changes are anticipated to occur gradually, allowing time to implement adaptation measures. However, the National Research Council report *Abrupt Impacts of Climate Change: Anticipating Surprises,* notes that the possibility also exists, however that "some changes will be abrupt, perhaps crossing a threshold or 'tipping point' to change so quickly that there will be little time to react."[35] These 'abrupt' changes could occur over decades or years or could accelerate the rate at which other hazards are affected.[36]

Summary

Climate change will act as a hazard amplifier for many current threats and hazards, or introduce hazards to new communities. The impacts of climate change may strain the reliability of critical

[27] NCA3, Pg. 545.
[28] NCA3, Pg. 65.
[29] *The President's Climate Action Plan*. Executive Office of the President. 2013. http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf.
[30] NCA3. Pgs. 334–339.
[31] NCA3, Pg. 589.
[32] NCA3, Pg. 590.
[33] NCA3, Pg. 588.
[34] NCA3, Pg. 589.
[35] "*Abrupt Impacts of Climate Change: Anticipating Surprises*" by the National Research Council.
[36] "*Abrupt Impacts of Climate Change: Anticipating Surprises*" by the National Research Council.

infrastructure and availability of key resources, forcing the whole community to reconsider current and future resource needs. Its consequences may cascade into a number of areas that are not directly weather related, effecting population shifts, public health problems, and local economies. In other words, although a changing climate is not a threat or hazard unto itself, its impacts can stress capabilities across all five mission areas—prevention, protection, mitigation, response, and recovery—and should be considered throughout risk analyses and future decision making processes.

Added 2015

Infrastructure Exposure to Natural Hazards and Climate Change

The quantitative risk of climate change is difficult to estimate because of the uncertainty that exists. Science does provide insight into the direction in which certain risks are trending. Regions across the U.S. will experience different impacts and need to plan according to their specific challenges. In the National Climate Assessment, the U.S. Global Change Research Program highlighted how regions across the U.S. could face different hazards.

- The National Climate Assessment analyzed data on how the Nation has seen rainfall events become heavier and more frequent in parts of the U.S., primarily in the Northeast, Midwest, and upper Great Plains, and these rainfall events have increased flooding in those regions.[1] As an example, in areas of the country where precipitation is expected to decrease, such as the Southwest, projections suggest there will be increased heavy precipitation.
- In addition to heavier precipitation, the National Climate Assessment analyzed hurricanes and concluded that hurricane-associated storm intensity and rainfall rates are projected to increase as the climate continues to warm.[2]
- The Southwest region of the U.S. is expected to be more prone to drought, wildfires, and heat waves, while the Northeast can expect heat waves, heavy downpours, and sea level rise to challenge their region.

These various hazards will impact the country in different, sometimes unprecedented ways, and may have catastrophic impacts on their populations and infrastructure.

Based on the climate science available today, which underpins the *National Climate Assessment* and is agreed upon by the Intergovernmental Panel on Climate Change (IPCC), DHS conducted a preliminary analysis that reveals where infrastructure systems are exposed to natural hazards and how that exposure is expected to change based on climate change.[3] While additional analysis is required to determine the level of vulnerability that specific infrastructure systems have or will have to climate-related hazards, understanding infrastructure exposure is an important step in planning for adapting to the impacts of climate change.

DHS developed a way to analyze and visualize infrastructure exposure to natural hazards and understand how that exposure may change due to climate change. The DHS National Protection and Programs Directorate (NPPD) conducted an in-depth, nationwide[4] analysis of this exposure.[5] While the preliminary findings are currently being reviewed by the interagency, this analysis reaffirms the work done by the *National Climate Assessment* and reflects the most current climate science. The analysis not only visualizes how infrastructure exposure to climate change and non-climate related hazards may shift, but also allows decision makers to estimate exposure to multiple hazards as well as various intensities. For the purpose of the analysis, DHS used subject matter expertise and expert judgments to identify a set of hazards that could affect critical infrastructure. Recognizing that any hazard event could have a major impact on a specific

[1] U.S. Global Change Research Program, 2015, p. 36.
[2] U.S. Global Change Research Program, 2015, p. 41.
[3] For the purpose of this analysis, permanent inundation, tidal flooding, coastal surge, extreme temperatures, drought, and wildfires were considered to be impacted by climate change. Earthquakes, landslides, tornadoes, tsunamis, ice storms, riverine flooding, and hurricane winds were not considered related to climate change, as there is insufficient data to support a nationwide evaluation of how these hazards could be expected to change.
[4] Due to the scoping for this analysis, DHS focused on the contiguous United States. Additional analysis would be required to incorporate Alaska, Hawaii, and the U.S. Territories.
[5] DHS NPPD commissioned the RAND Corporation to conduct analysis on infrastructure exposure to natural hazards. As of March 2015, the data, methods, analysis, and findings are being documented and will be reviewed by representatives from across the interagency.

Added 2015

community or region, for the purpose of this national level analysis, DHS NPPD classified the hazards into low and high categories based on their relative magnitude.

Table O3: Classification of Hazards Analyzed

Low Magnitude Hazards	High Magnitude Hazards
▪ Landslides ▪ Drought (400-600 Index) ▪ Extreme Heat (120° F daily max) ▪ Hurricane Wind (Category 2) ▪ Ice Storms (Category 4) ▪ Coastal Flooding (1 ft. depth) ▪ Earthquakes (0.34 ground acceleration) ▪ Wildfire (Moderate) ▪ Tornado (EF3)	▪ Drought (600-800 Index) ▪ Extreme Heat (130° F daily max) ▪ Hurricane Wind (Category 4) ▪ Ice Storms (Category 5) ▪ Coastal Flooding (6 ft. depth) ▪ Earthquakes (0.64 ground acceleration) ▪ Wildfire (Very High) ▪ Riverine Flood ▪ Tsunami ▪ Tornado (EF5)

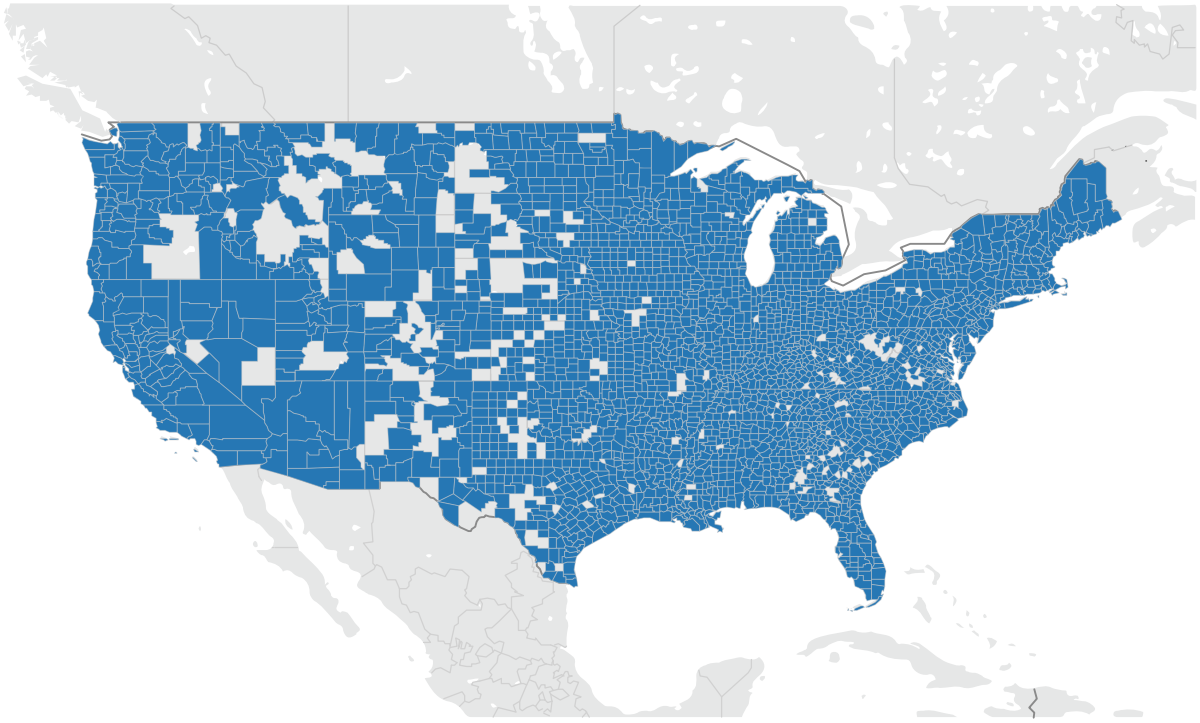
Even without adjusting for climate change, the Nation's infrastructure is exposed to a range of low intensity natural hazards. The map in Figure O1 visually depicts, by county areas across the U.S., where infrastructure[6] is exposed to at least two assessed hazards from the category of low intensity hazards.[7] While it may be obvious that infrastructure faces challenges nationwide, infrastructure exposure to natural hazards is a nationwide concern and requires further analysis and investment in order to mitigate risks of disruption.

[6] The infrastructure data is found in HSIP Gold. The sectors considered in this analysis include chemical, communications, energy, transportation, water, wastewater, and dams.

[7] Subject matter experts determined infrastructure exposure by first identifying which types of infrastructure were vulnerable to which types of hazards (e.g., power transmission lines are vulnerable to high winds), and then identifying where they are co-located. This data does not include mitigation efforts, such as burying electric power transmission lines to mitigate tornado exposure.

Added 2015

Figure O1: Infrastructure Exposure to Relatively Frequent Natural Hazards

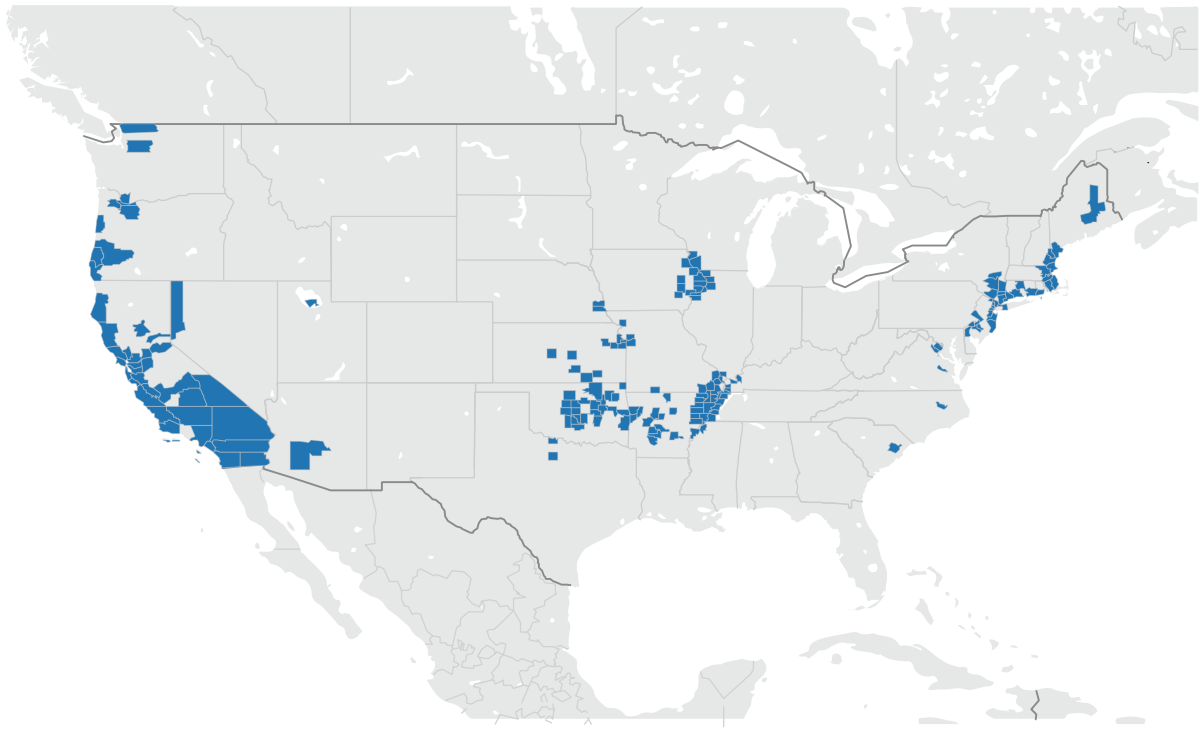


This map illustrates that in 2015, most counties across the U.S. contain infrastructure that is exposed to hazards in the low magnitude category (see Table O3 for additional details) that occur relatively frequently within the U.S. (>1% chance of occurrence per year). These represent relatively common hazards.

Perhaps more significantly than viewing exposure to less severe hazards, DHS can use this analysis to determine where infrastructure is most likely to be exposed to high intensity hazards. This can be used as an indicator for where infrastructure is most likely to be exposed to more significant events that may require a National response. Based on this analysis, infrastructure in the Mid-Atlantic, Midwest, New England, and the West Coast is most likely to be exposed to these severe hazards.

Added 2015

Figure O2: Infrastructure Exposure to High Magnitude, Relatively Infrequent Hazards



This map illustrates that in 2015, a few concentrated regions across the U.S. contain infrastructure that is exposed to multiple[8] hazards in the high magnitude category (see Table O3 for additional details) that occur relatively infrequently (<0.1% chance of occurrence per year), particularly in the Midwest, New England, and the West Coast..

This infrastructure exposure is a challenge today. Much of the Nation's infrastructure is outdated and needs to be upgraded. While the U.S. is trying to find ways to encourage infrastructure investment to address these challenges, experts estimate that the country would need to invest $3.6 trillion in the Nation's infrastructure by 2020 to bring it up to date.[9] Modern, efficient infrastructure is essential to the growth, health, and prosperity of the Nation and the direct cost of a disruption could cost billions of dollars. Hurricane Sandy caused an estimated $1 billion in damage to the power and gas lines in New Jersey alone, and ended up causing an estimated $65 billion in damages and economic loss across the region.[10] Hurricane Sandy demonstrated the widespread catastrophic damage that can occur when a large storm hits a densely populated and highly interconnected region.

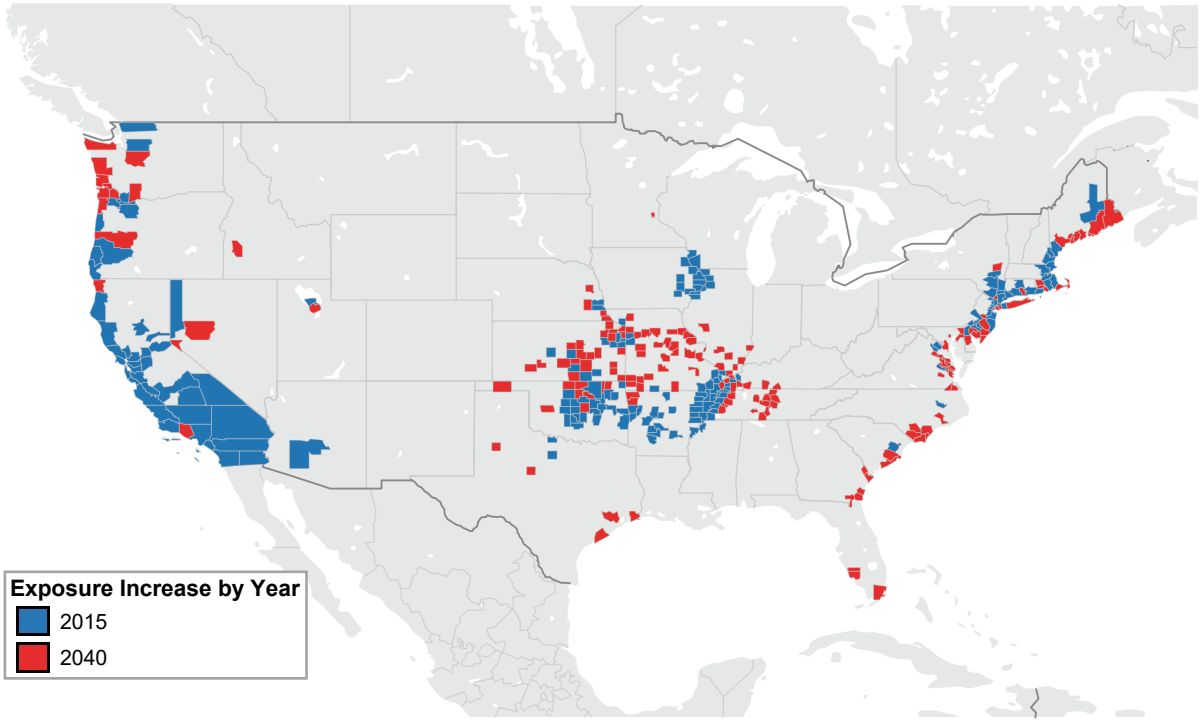
In addition to preparing for today's realities, the Nation must prepare for natural hazards that will be exacerbated by climate change. As regions make choices about their infrastructure and consider how to strategically invest their scarce resources, decision makers should consider how climate change will affect their new and existing infrastructure systems, assets, and networks across the lifespan of those structures. To support this, DHS conducted preliminary analysis on how hazard exposure changes according to a variety of/multiple future climate scenarios. Using representative concentration pathway (RCP) scenarios accepted by the Intergovernmental Panel on Climate Change's Fifth Assessment Report, DHS modeled how different climate futures could alter the frequency and severity of natural hazards, and how these changes, in turn, could

[8] Three or more.
[9] American Society of Civil Engineers, 2013.
[10] Hurricane Sandy Rebuilding Task Force, 2013, p. 21.

Added 2015

expose infrastructure in new and different ways.[11] In addition, DHS leveraged the work done by NOAA to evaluate potential sea level rise scenarios, which inform analysis on permanent inundation, tidal flooding, and coastal surge.

Figure O3: Infrastructure Exposure to High Magnitude, Relatively Infrequent Hazards Using a Pessimistic Climate Scenario



This map illustrates that, under a pessimistic climate scenario, by 2040 there could be an expansion of areas in the U.S. that contain infrastructure exposed to multiple[12] hazards in the high magnitude category (see Table O3 for additional details) that occur relatively infrequently (<0.1% chance of occurrence per year), particularly in the Midwest and along the coasts. .

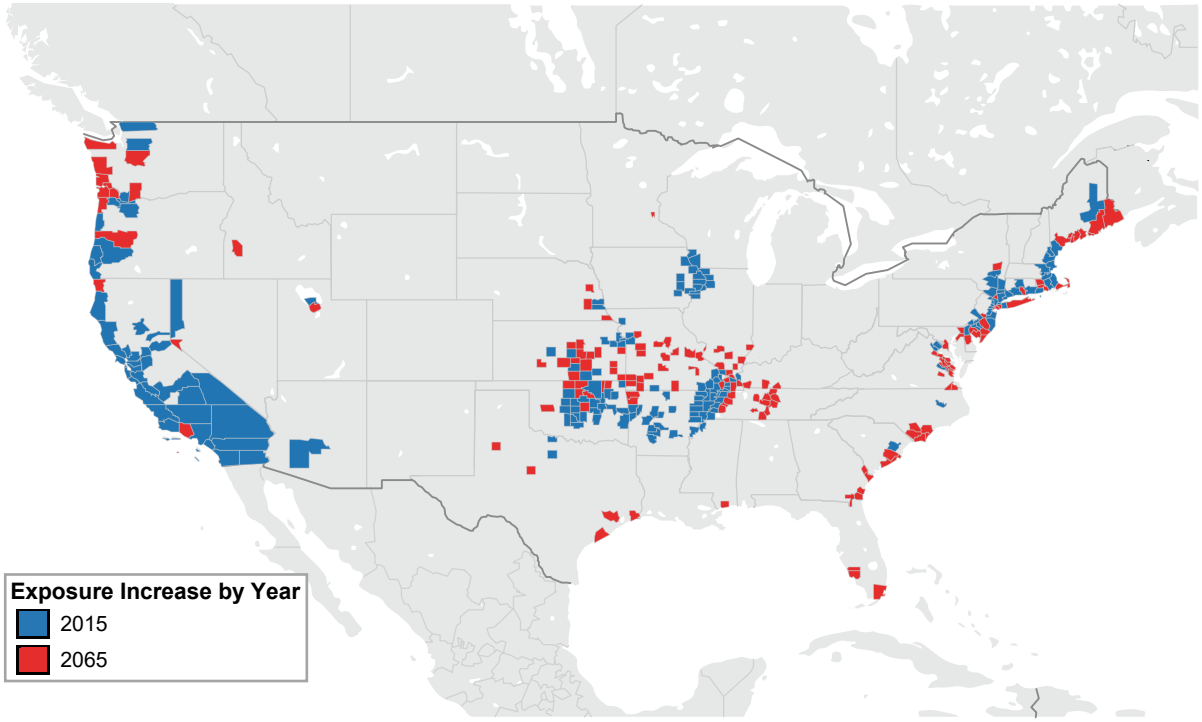
Figure O3 depicts how new concentrations of exposure emerge as a result of climate change scenarios, particularly in the Pacific Northwest, California, the Midwest, the Southeast, and New England. It is important to note that the specific hazards vary across the regions. The Southeast, for instance, is vulnerable to coastal flooding and permanent inundation, whereas the Midwest is more likely to be affected by drought and extreme heat. These different hazards pose their own unique challenges and could require different plans for mitigating the effects. Evaluating the vulnerability and risk to infrastructure in Charleston, South Carolina will involve different variables than the infrastructure in Tulsa, Oklahoma. Likewise, the resources required to respond and recover from disasters in various regions could differ as well. It is important to understand where the hazards are expected to change so the Nation can prepare accordingly.

It is also important to note that the preliminary analysis reflects similar patterns of exposure when selecting a less pessimistic climate scenario, albeit over a longer timeframe. Whereas the model in the High RCP scenario depicted in Figure O3 reflects the changes in exposure in the year 2040, the analysis also reflects similar results for a less aggressive model in the year 2065,

[11] Additional information on the models and the definitions for pessimistic, median, and optimistic climate scenarios used for analysis will be included in the forthcoming technical report. As of March 2015, the report is being finalized by the RAND Corporation on behalf of DHS NPPD. The report will document the data, methods, and analysis and will be reviewed by representatives from across the interagency.
[12] Three or more.

depicted in Figure O4. Considering the lifespan of infrastructure can be 50 to 100 years, the longer timeframe in this analysis still represents a significant finding and suggests the geographic clusters identified under a pessimistic model will be similarly exposed under less pessimistic scenarios.

Figure O4: Infrastructure Exposure to High Magnitude, Relatively Infrequent Hazards Using the Median Climate Scenario



This map illustrates that under the median climate scenario, by 2065 there could be an expansion of areas in the U.S. that contain infrastructure exposed to multiple[13] hazards in the high magnitude category (see Table O3 for additional details) that occur relatively infrequently (<0.1% chance of occurrence per year), particularly in the Midwest and along the coasts.

As cities and regions grow and adapt to changing conditions, the supporting infrastructure will be stressed in new and more extreme ways. This groundbreaking preliminary analysis allows DHS NPPD to visualize infrastructure clusters and estimate how the exposure will change over time. At this point in time, DHS is not able to say precisely where and when a catastrophic hazard will strike. However, by better understanding the exposure of infrastructure to climate change, DHS NPPD and our partners can help decision makers incorporate climate vulnerability considerations into decisions, invest in critical infrastructure security and resilience, and prepare the Nation to adapt to climate change.

[13] Three or more.

Added 2015