Climate Adaptation by Design: Overview for New York State Building Professionals

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CONTACTS

Amanda Stevens
NYSERDA
17 Columbia Circle
Albany, New York 12203-6399
amanda.stevens@nyserda.ny.gov

Nicholas B. Rajkovich
University at Buffalo School of Architecture and Planning
Hayes Hall, University at Buffalo
Buffalo, New York 14214
rajkovic@buffalo.edu

PROJECT ADVISORY COMMITTEE

Claire Barnett, Healthy Schools Network
Joe Borowiec, NYSERDA
Robert Carver, NYSERDA
Tom Eisele, New York City Mayor's Office of Recovery and Resiliency
Jeff Jones, Healthy Schools Network
Kim Knowlton, Natural Resources Defense Council and Columbia University's Mailman School of Public Health
Dana Kochnower, New York City Mayor's Office of Recovery and Resiliency
Ann Kosmal, U.S. General Services Administration
Alison Kwok, University of Oregon
Chris Pyke, U.S. Green Building Council
Jodi Smits Anderson, Dormitory Authority of the State of New York (DASNY)
Robert Shibley, University at Buffalo School of Architecture and Planning
Kevin Stack, Northeast Green Building Consulting, LLC
Ernest Sternberg, University at Buffalo Department of Urban and Regional Planning
Alex Wilson, Resilient Design Institute

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Table of Contents

List of Abbreviations

AIA	American Institute of Architects
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
DEC	New York State Department of Environmental Conservation
DHSES	New York State Department of Homeland Security and Emergency Services
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HVAC	Heating, Ventilation, and Air-Conditioning
LEED	Leadership in Energy and Environmental Design
NFIP	National Flood Insurance Program
NIST	National Institute of Standards and Technology
NYC	New York City
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
USGBC	United States Green Building Council

Executive Summary

Building professionals in New York State are now being asked to design and construct buildings that respond to the coming changes in climate, but they need information and professional structures to do so. This document provides an overview for New York State building professionals about the state of resilience research for the building sector. It also suggests mechanisms to act on this information to create more resilient buildings in the State of New York.

While buildings represent 44.6% of US carbon dioxide emissions (Architecture 2030, 2013) and are a major driver of climate change, this report focuses on the impact of climate change on the buildings themselves. These impacts will become increasingly extreme as the climate itself becomes more severe, but they will vary significantly by region. Building professionals will need to adjust their practices to conditions that will continue to shift; there is no “new normal.” Professionals will need to begin to take probabilistic future occurrences into account during design. Because current codes and standards are based on historic climate data, they do not reflect conditions that buildings will experience during their operating years and are not yet structured to reduce risks for buildings and occupants in the future.

Projected Climate Hazards in New York State discusses the past, present, and future climate hazards in New York State. Hurricanes and tropical storms, flooding, severe storms, winter storms, sea level rise, and heat waves are expected to increase in frequency and intensity in the coming decades, with significant regional variation across the State in the degree and rate of change.

How a Changing Climate Impacts Buildings highlights how changing climate conditions are expected to impact buildings and occupants. New York State’s building stock is at risk of impact from climate change. The vulnerability of buildings and occupants to this risk is highly diverse given the regional variations in climate hazards and the range of building types and ages across the State.

Adapting Buildings to a Changing Climate explains how buildings can adjust to reduce impacts and how adaptation strategies might be prioritized. Building professionals must develop mechanisms to prioritize adaptations to climate hazards in a specific geographic region based on the needs of a particular building and client. While technical guidance for adaptation abounds, it will be critical for the design professional to set priorities for investment in adaptation strategies and overcome various barriers to climate adaptive design.

Building Professionals’ Roles discusses professional considerations, including barriers to adoption, in climate adaptive building work.

Future work should address the currently uneven adaptation efforts evidenced throughout the State. It should also examine the emergent bias toward technological solutions over social, informational, organization and behavioral adaptation strategies. Finally, building professionals need better definitions of their standard of care under changing climate conditions to appropriately address the risks climate change poses to the built environment.

Appendix A summarizes additional technical resources for building adaptation.

Introduction

Building professionals in New York State are now being asked to design and construct buildings that respond to the coming changes in climate, but they need information and professional structures to do so. This document provides an overview for New York State building professionals about the state of resilience research for the building sector. It also suggests mechanisms to act upon this information to create more resilient buildings in the State of New York.

The principal driver of climate change is the increase in levels of greenhouse gases, concentrations of which are now one-third higher than in pre-industrial times (Rosenzweig et al. 2011). During their construction, operation, and demolition, buildings contribute to greenhouse gas emissions, representing somewhere between 25 and 40% of average global emissions (Huovila et al. 2009), 44.6% of total US carbon dioxide emissions (Architecture 2030 2013) and 32% of total New York State greenhouse gas emissions (NYSDEC 2018). (These figures are significantly higher if carbon from transportation to and from buildings is included.) US buildings represent 7.4% of total global carbon dioxide emissions (USDOE 2012). Further, between 1971 and 2004, carbon dioxide emissions grew by about 2.5% per year for commercial buildings and 1.7% per year for residential buildings (Levine et al. 2007). While mitigation efforts are underway through known vehicles such as energy codes, green building rating systems, and so on, climate change will continue even if these programs are effective and mitigation manages to bring building-related emissions to zero (Karl, Melillo, and Peterson 2009).

While the context described above is important, this report discusses the impact of climate changes on buildings, not the impact of buildings on climate change. This report focuses on the changes that have occurred and are occurring, and on preparation for future changes that will result from the impacts of climate-related hazards on buildings, occupants, and operations. Because buildings are typically designed for long lifetimes (50 to 100 years or more is not uncommon), they will experience increased risks and impacts as the climate changes over the decades, affecting both the longevity and performance of buildings. Buildings that perform well in a volatile climate will not need to be torn down and rebuilt.

Buildings need to work successfully in both the current and future climate, and there is a pressing need to address environmental concerns other than climate change as well. However, significant forces resist changes in the way buildings are designed and constructed. Decisions are often driven by short-term return on investment calculations, rather than long-term considerations of costs. Many areas, such as coastal New York City and the Hudson and Mohawk River floodplains, will continue to see development pressure regardless of their vulnerabilities to shifting climate conditions.

A CHANGING CLIMATE IMPACTS BUILDINGS

Climate impacts on buildings will become increasingly severe as the climate itself becomes more severe. Because climate risks to buildings are not the same in all locations, they must be addressed regionally. While it is true that cities and buildings, especially historic ones, have always withstood change, they have never experienced change as fast as what is currently happening. Their capacity to absorb such change is unknown. While some changing climate conditions are subtle, even small climate changes can increase hazards dramatically. For example, small temperature increases will likely intensify storms dramatically, resulting in greater winds, precipitation, and flooding.

Climate change creates challenging impacts on building stocks, through higher temperatures, increased storm severity and frequency, and greater rainfall (Steenbergen, Koster, and Geurts 2012). Some effects, such as temperature shifts, may be small, gradual changes, and some, such as flooding, may be extreme events. Buildings exist at the threshold between the dynamic outdoor environment and the indoor environment, which must maintain appropriate conditions for the occupants' safety and comfort and for any processes taking place in the building. Buildings have complex interactions between 1) local weather conditions; 2) internal loads from people, lights, and equipment; and 3) active and passive heating and cooling systems (Crawley 2007). These interactions will change with time and be unique to location and building type.

Buildings and Climate Change: Key Terms

Adaptation: The process of preparing for an intensifying climate by making adjustments for actual or expected effects. Adaptation seeks to moderate harm, exploit beneficial opportunities, and cope with consequences. For example, designing HVAC systems for higher design temperatures and providing passive survivability in case of power outages are adaptations to heat waves.

Hazard: Climate events that cause damage to buildings. For example, hazards discussed in this report include hurricanes/tropical storms, flooding, severe storms, winter storms, sea level rise, and heat waves. Other secondary hazards can include wildfire and pest infestation.

Impacts: The potential effects climate change has or could have on buildings or occupants. For example, cladding damage, water damage to building contents, and increased occurrence of asthma are all potential impacts of climate changes on buildings.

Mitigation: Reducing the magnitude of climate change by reducing demand for resources. For example, designing beyond-code energy-efficient HVAC systems should reduce the magnitude of climate change in the future.

Resilience: The capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation. For example, a community's ability to undergo a heat wave without heat-related injury or death is one measure of that community's resilience.

Risk: A product of the probability of a climate hazard occurring, the likelihood of impacts from that hazard, and the magnitude of consequences if that impact occurs. An example of a high-risk scenario is expensive electrical equipment located on the ground floor of a building in a flood plain.

Vulnerability: The degree to which buildings, occupants, and related social systems are susceptible to and unable to cope with the adverse impacts of climate change. An example of increased vulnerability is elderly occupants' susceptibility to injury and death from heat waves relative to that of healthy younger occupants.

Sources: (Rosenzweig et al. 2011; Anderson 2017)

BUILDINGS AND CHANGE

The climate is not currently projected to stabilize at a new normal within the next century, but rather is expected to continue to shift over the coming decades. There is no "new normal." This suggests that an iterative process to climate adaptation is helpful; making communities resilient is a long-term endeavor as buildings are incrementally renovated or built to new standards. Further, the prediction of ongoing climate changes suggests that 100% resilience is an impossible goal for buildings. Prioritizing adaptation strategies is important to meet the most pressing needs of a particular building in a particular place at a particular time; there are no universal prescriptions to make buildings resilient to climate change.

Building professionals, especially engineers and energy consultants, frequently deal with climate-related data when designing and ensuring code compliance for buildings and mechanical systems. However, there is a key difference between the use of climate data for projections of building energy use though modeling and the projections of future climate data. Building energy modeling is a precise (though sometimes inaccurate) form of prediction. On the other hand, climate modeling is inherently probabilistic. By definition, it cannot give precise predictions, only likelihoods of occurrences of presumed scenarios. It is, therefore, impossible to predict the precise future climate or resultant hazards for a specific building, and nearly impossible to make precise predictions for a city. However, models can give an indication of trending hazards, and building professionals can plan for the likely impacts.

Building professionals have long grappled with probabilistic future situations as a matter of course. All built projects need to accommodate change over their lengthy lifespans. For example, buildings are designed for flexibility in tenant fit outs, designed to be disassembled and designed for the ability to upgrade assemblies or equipment. Neighborhoods are also designed for growth, decline, or change. Design for climate change is similar, albeit more urgent, because of the risks it poses to people and buildings.

MITIGATION AND ADAPTATION

Mitigation has been described as avoiding the unmanageable and adaptation as managing the unavoidable (Kropp and Scholze 2009). Climate mitigation is reducing greenhouse gas emissions, such as through sustainable building design. Mitigation strategies are familiar to anyone who has worked on energy-efficient, high-performing, or green buildings. Adaptation is preparing buildings for intensifying climate conditions to improve their performance and reduce risk relative to hazards. A common definition of adaptation comes from the IPCC report: Adaptation is “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities” (Revi et al. 2014). While mitigation is necessary to reduce the most extreme consequences, the climate has already begun to change, so adaptation is prudent.

In some cases, mitigation without adaptation may be maladaptive. For example, a newly constructed building designed with a fixed-glass curtain wall enclosure and a super-high-performing HVAC system may exceed code requirements and accrue good energy scores on green building rating systems. Yet it may still overheat during a summer power outage, causing risk to human occupants. One adaptation to the risk would be to include operable façade elements.

Adaptation strategies help close the gap between a currently vulnerable design and improved conditions (NIST 2015). However, adaptation measures do not prevent climate change impacts, they only lessen risk. Despite action, much of the building stock simply will not perform as desired in future climate scenarios. Building professionals must recognize this reality because it is not technologically possible, nor is it financially feasible, to eliminate every future climate threat that a building will experience. Therefore, it is critical to prioritize adaptation strategies, taking into consideration a particular a project’s location, use, and construction, so that limited resources achieve the greatest possible protection against the predicted risks.

REGULATIONS: CODES AND STANDARDS

Many energy and climate-related design and operational decisions for buildings are governed by building and energy codes, which set prescriptive or performance-based requirements grounded in a location’s historical climate data (de Wilde and Coley 2012). Regulations guide professionals to change their practices, but code- and standard-setting bodies are largely reactive entities; for example, major changes to fire codes tend to occur following disasters. The requirements for design, construction, and operation of buildings need to be examined in light of anticipated changes in climate. Because the construction industry is so strongly influenced by codes and standards, it is slow to change in response to new information. New and future climate conditions are not reflected in current building codes and standards, but during the multi-year lag time before they are, precautionary design is one approach to responding to new climate conditions. Code changes, while necessary to address the altered climate hazards coming in future decades, will not be sufficient to address the challenges. The large number of variables involved in designing buildings to be climate adaptive (occupancy, building age, construction type, location) make broad prescriptive measures unlikely to be sufficient. Holistic, forward-looking, precautionary and multidisciplinary design with teams from outside the building sector will be required to address the challenges of future climates.

REPORT ORGANIZATION

This report is organized as follows to help building professionals find the information they need to adapt buildings to climate change.

- Projected Climate Hazards in New York State discusses the past, present, and future climate hazards in the State.
- How a Changing Climate Impacts Buildings highlights how changing climate conditions are expected to impact buildings and occupants.
- Adapting Buildings to a Changing Climate explains how buildings can adapt to prevent impacts and how adaptation strategies might be prioritized.
- Building Professionals' Roles discusses professional considerations, including barriers, in climate adaptive building work.
- Appendix A summarizes additional technical resources for building adaptation.

Projected Climate Hazards in New York State

New York State has a humid continental climate with a wide range of climate conditions, influenced variously by Atlantic maritime exposure, the proximity of the Great Lakes, and mountainous regions. Historic average annual temperatures vary from around 40˚F in the Adirondacks to about 55˚F in New York City. Precipitation varies from about 30 inches per year in Western New York to over 50 inches/year in the Adirondacks. More than 40 inches of snow per year is the statewide average, but maximum snowfall varies regionally, from more than 175 inches in some northern and western areas to less than 36 inches in the New York City metro region. The state experiences extremes of heat and cold, intense precipitation and the resultant flooding, and coastal storms with flooding, all with high variability across the state (Rosenzweig et al. 2011).

UNCERTAINTY AND PRECAUTION

Climate scientists can say with a high level of confidence that the future climate will differ from historic trends. However, building professionals should not expect forecasts of the precise level of climate change in a particular location. While global, national, and even regional or state-specific climate forecasts are available, the higher resolution needed to create local predictions comes at the price of greater uncertainty (Schiermeier 2010). What will be critical is appropriate design for a plausible range of conditions, bearing in mind that historically based standards and codes do not yet reflect this range of conditions, and may not for several years. For example, wind speeds are likely to increase in many regions as temperatures warm, but it is difficult to quantify how much. In addition, location-based design wind speeds are based on historic data, so they do not reflect the projected climate change-related increases. Given that new scientific knowledge is outpacing the regulatory response, precautionary design with regard to massing/form, assembly selection, and attachment details is helpful.

THE NATURE OF CHANGE

New York State faces a range of climate hazards due to its size and diverse geophysical characteristics of the state, and these hazards will shift in frequency and intensity as underlying climate conditions change. However, the climate will not simply reset to a new, static normal; change is projected to unfold for decades. The new "normal" is dynamic. Changes will affect averages and extremes: Building designers will need to consider new routine hazards, new design hazards, and new extreme hazards. New normal/routine climate hazards (e.g., elevated levels of annual precipitation) are those with at least a 50% chance of occurring over a 50-year period. New design hazards (e.g., more severe summer storms) are those with a 10% chance of occurring over a 50-year period. New extreme hazards (e.g., major, news-making storm events) are those with a 2-3% chance of occurring over a 50-year period (NIST 2015). Adaptation is not as straightforward as increasing load factors for new extreme conditions; adaptation considerations will also affect routine material selection and system design.

THE HISTORY, CURRENT TRENDS, AND FUTURE PROJECTIONS OF NEW YORK STATE CLIMATE HAZARDS

The 2014 New York State ClimAID report gives quantitative projections for how temperature, precipitation, sea level, and extreme events will change, as well as qualitative projections for snowfall, intense precipitation, and storms. These are summarized below. More details are available in the companion document *New York State Climate Hazards Profile*.

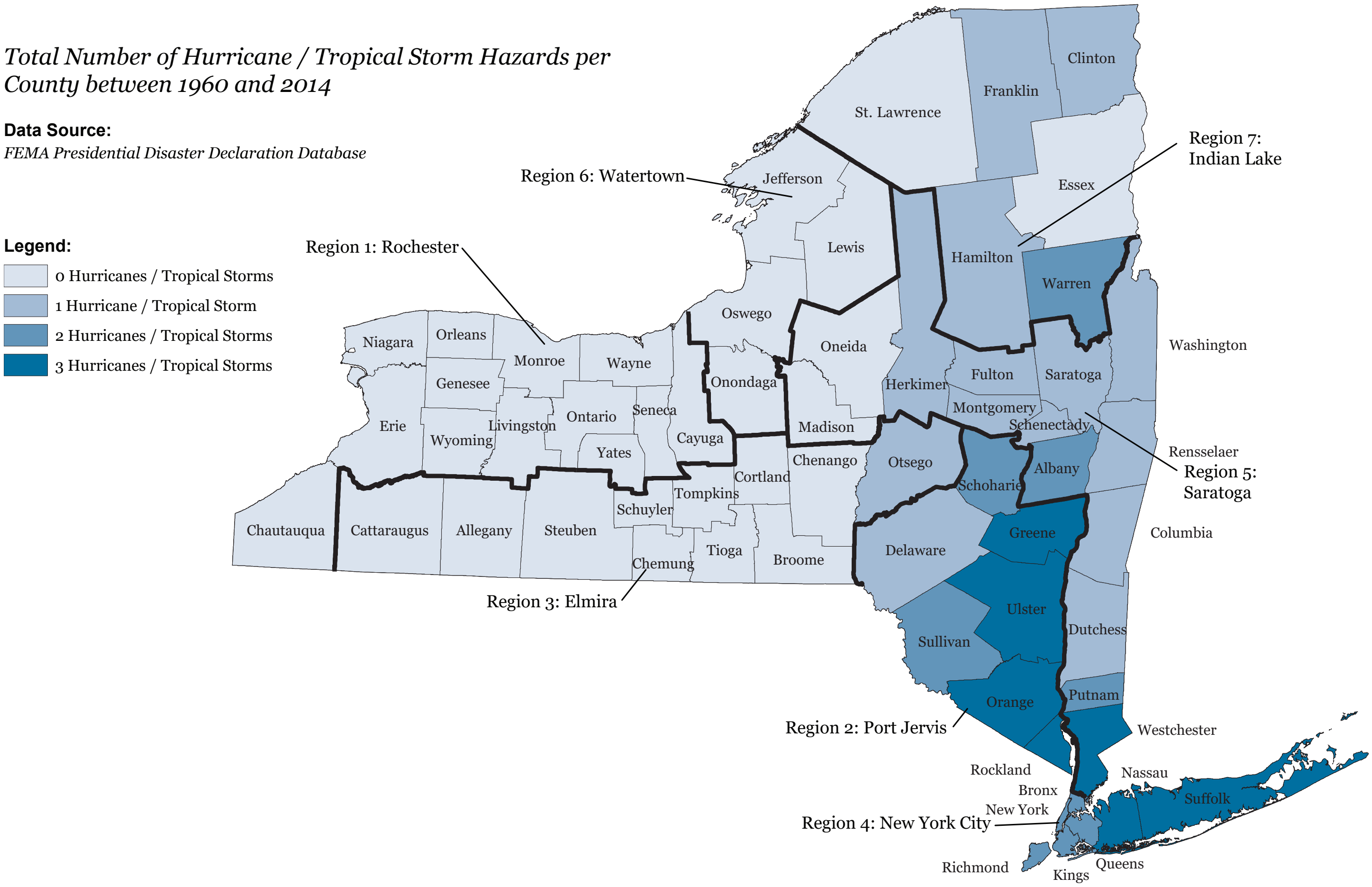
HURRICANES/TROPICAL STORMS

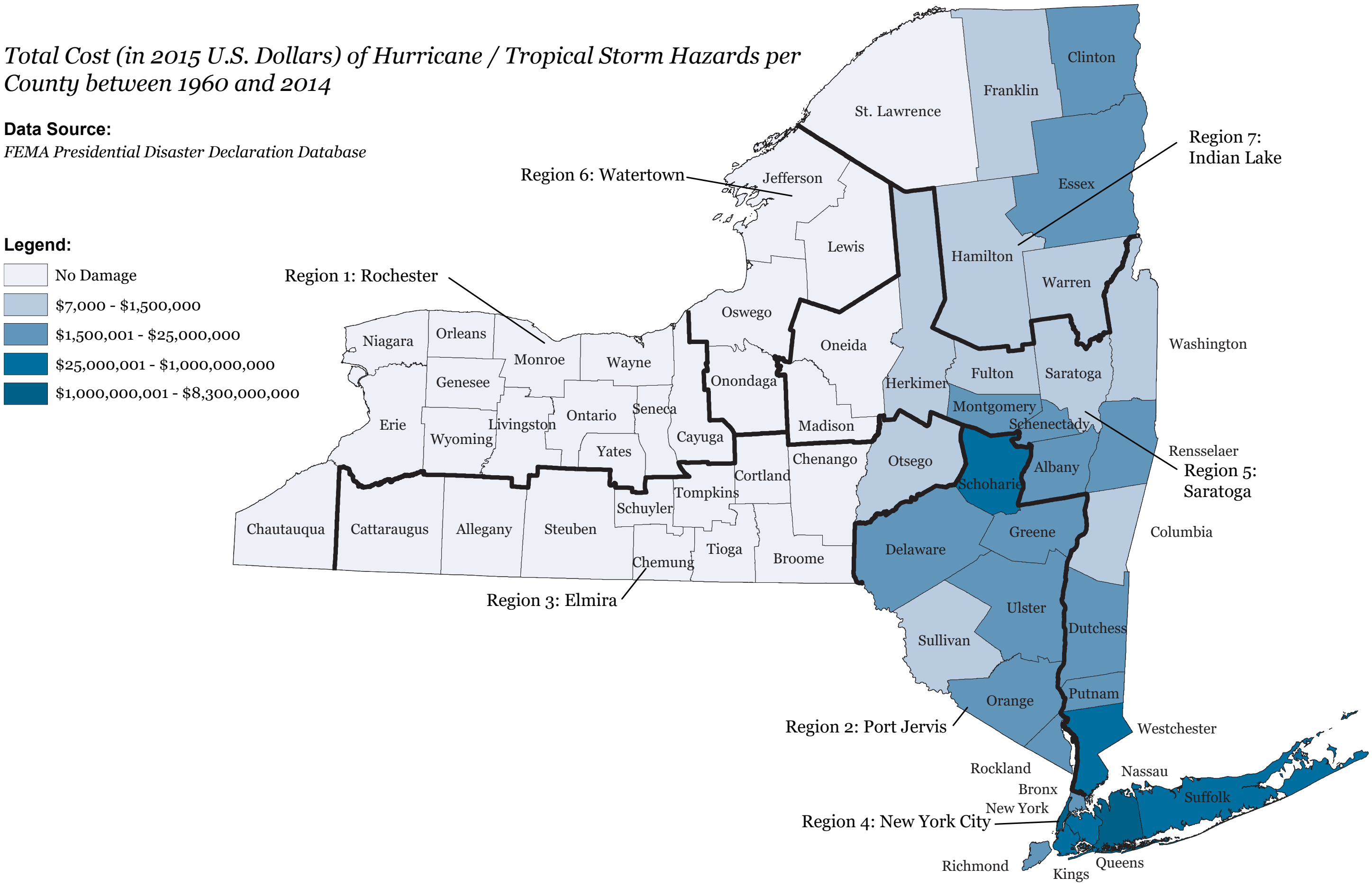
While impacts are most concentrated in New York City and Long Island, hurricanes and tropical storms have historically caused severe damage throughout New York State. Along with the rest of the eastern seaboard, New York has been experiencing a period of heightened hurricane activity since 1995 that is anticipated to last until at least 2025 (NYSDHSES 2014). Additionally, it is more likely than not that the number of the most intense hurricanes will increase in the North Atlantic, and intense precipitation from hurricanes will likely increase as well. We cannot anticipate precisely how these will impact New York State because paths of tropical storms are highly variable and unpredictable (Horton et al. 2014).

Storm surge is a type of flooding caused by wind-driven water during tropical storms, hurricanes, and nor'easters, particularly if they occur at high tide. Storm surge is expected to increase in frequency and magnitude as a result of rising sea level (see below) and increasing storm frequency and intensity.

Images source: *New York State Climate Hazards Profile*. Data source: FEMA Presidential Disaster Declaration Database.

Total Number of Hurricane / Tropical Storm Hazards per County between 1960 and 2014




Total Cost (in 2015 U.S. Dollars) of Hurricane / Tropical Storm Hazards per County between 1960 and 2014

Data Source:
FEMA Presidential Disaster Declaration Database

Images source: *New York State Climate Hazards Profile*. Data source: FEMA Presidential Disaster Declaration Database.

FLOODING

Total precipitation in New York State ranges from an average of 30 inches per year in parts of western New York to around 50 inches per year in parts of the Adirondacks, Catskills, Tug Hill Plateau, and New York City metro area (Rosenzweig et al. 2011). Although historic precipitation variation did not trend uniformly upward (Rosenzweig et al. 2011), precipitation is projected to increase in the coming decades, with the greatest increases in the northern parts of the state by the end of the century (Horton et al. 2014). Annual precipitation is projected to increase, with much of the additional precipitation occurring in the winter. This wetter climate will intensify flooding and storm hazards.

Inland floods occur regularly in every New York county and are most commonly caused by rain or snow melt beyond the capacities of soils to absorb the water and stream/rivers to remove it. Heavy-precipitation events (days with more than 1 or 2 inches of rainfall) are projected to increase across the state. This greater precipitation will increase flood events, the severity of which will vary depending on local factors such as elevation, proximity to water, and land cover characteristics (NYSDHSES 2014).

FUTURE DAYS WITH MORE THAN 1" OF RAINFALL IN A DAY

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 5 days/year)	4	5 to 5	6	4	5 to 5	6	4	5 to 6	7
Region 2: Port Jervis (Average of 12 days/year)	11	12 to 13	14	12	13 to 14	15	12	13 to 15	16
Region 3: Elmira (Average of 6 days/year)	6	6 to 7	7	6	6 to 7	8	6	7 to 8	8
Region 4: New York City (Average of 13 days/year)	13	14 to 15	16	13	14 to 16	17	14	15 to 17	18
Region 5: Saratoga (Average of 10 days/year)	10	10 to 11	12	10	11 to 12	13	10	11 to 13	14
Region 6: Watertown (Average of 6 days/year)	6	7 to 8	8	7	7 to 8	9	7	7 to 9	10
Region 7: Indian Lake (Average of 7 days/year)	7	7 to 8	9	7	8 to 9	10	8	8 to 10	11

FUTURE DAYS WITH MORE THAN 2" OF RAINFALL IN A DAY

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 0.6 days/year)	0.6	0.6 to 0.7	0.8	0.5	0.6 to 0.8	0.9	0.5	0.6 to 0.9	1
Region 2: Port Jervis (Average of 2 days/year)	2	2 to 2	3	2	2 to 3	3	2	2 to 3	3
Region 3: Elmira (Average of 0.6 days/year)	0.6	0.7 to 0.9	1	0.7	0.8 to 1	1	0.7	0.8 to 1	1
Region 4: New York City (Average of 3 days/year)	3	3 to 4	5	3	4 to 4	5	3	4 to 5	5
Region 5: Saratoga (Average of 1 day/year)	1	1 to 2	2	1	1 to 2	2	1	1 to 2	2
Region 6: Watertown (Average of 0.8 days/year)	0.6	0.7 to 1	1	0.7	0.7 to 1	1	0.7	0.8 to 1	1
Region 7: Indian Lake (Average of 0.8 days/year)	0.7	0.8 to 1	1	0.8	0.9 to 1	1	0.8	0.9 to 1	1

Images source: New York State Climate Hazards Profile. Data source: (Horton et al. 2014)

SEVERE STORMS

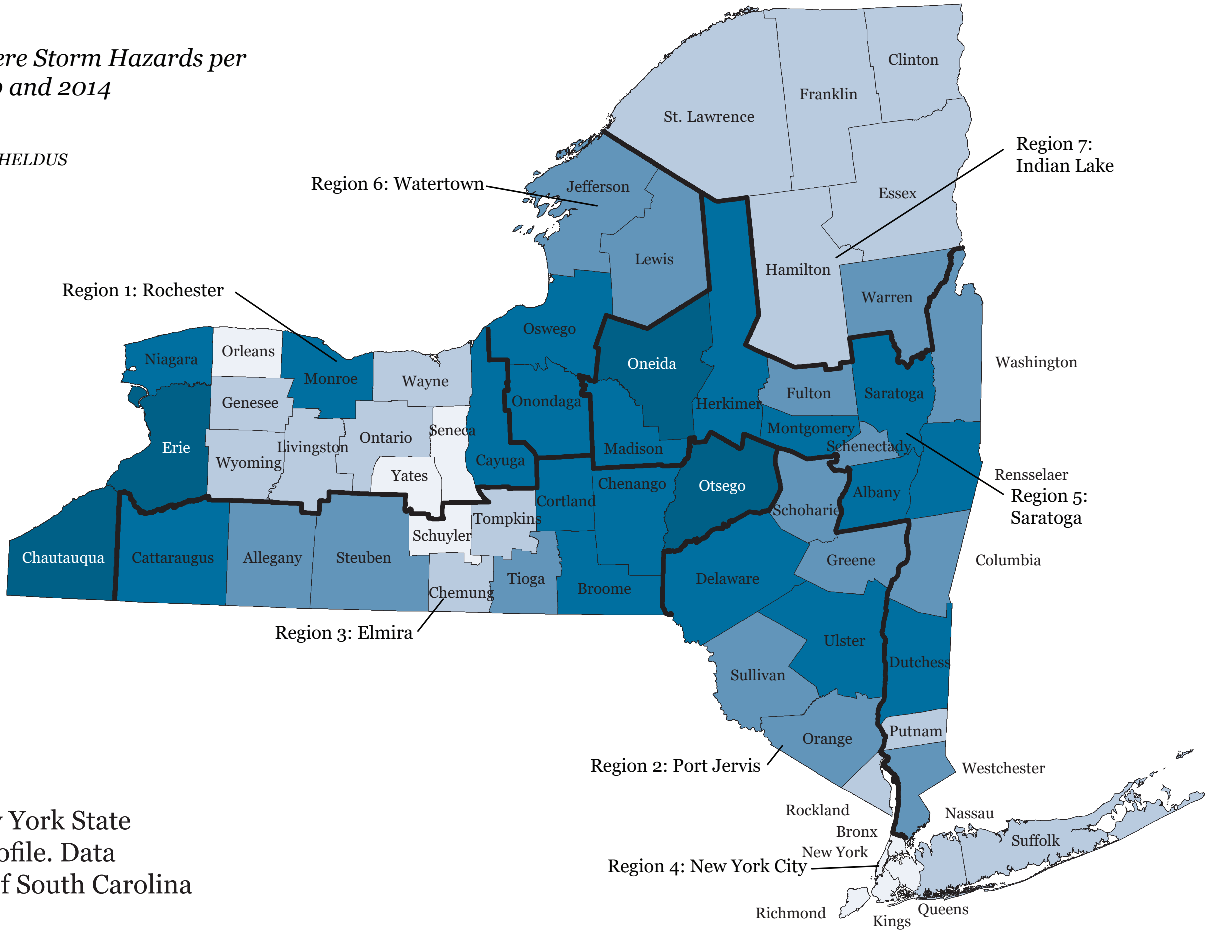
Severe storms, such as thunderstorms, continue to be common throughout the State, with greatest frequency in Western and Central New York (University of South Carolina 2016). Severe storms are likely to increase due to warming temperatures and increased precipitation (Horton et al. 2014). Although the projected total annual precipitation increases are relatively small, larger increases are expected in the frequency, intensity, and duration of extreme precipitation events (defined as events with more than 1, 2, or 4 inches of rainfall).

Total Number of Severe Storm Hazards per County between 1960 and 2014

Data Source:
University of South Carolina SHELDUS

Legend:

- ▭ 90 - 102 Severe Storms
- ▭ 103 - 120 Severe Storms
- ▭ 121 - 139 Severe Storms
- ▭ 140 - 164 Severe Storms
- ▭ 165 - 194 Severe Storms



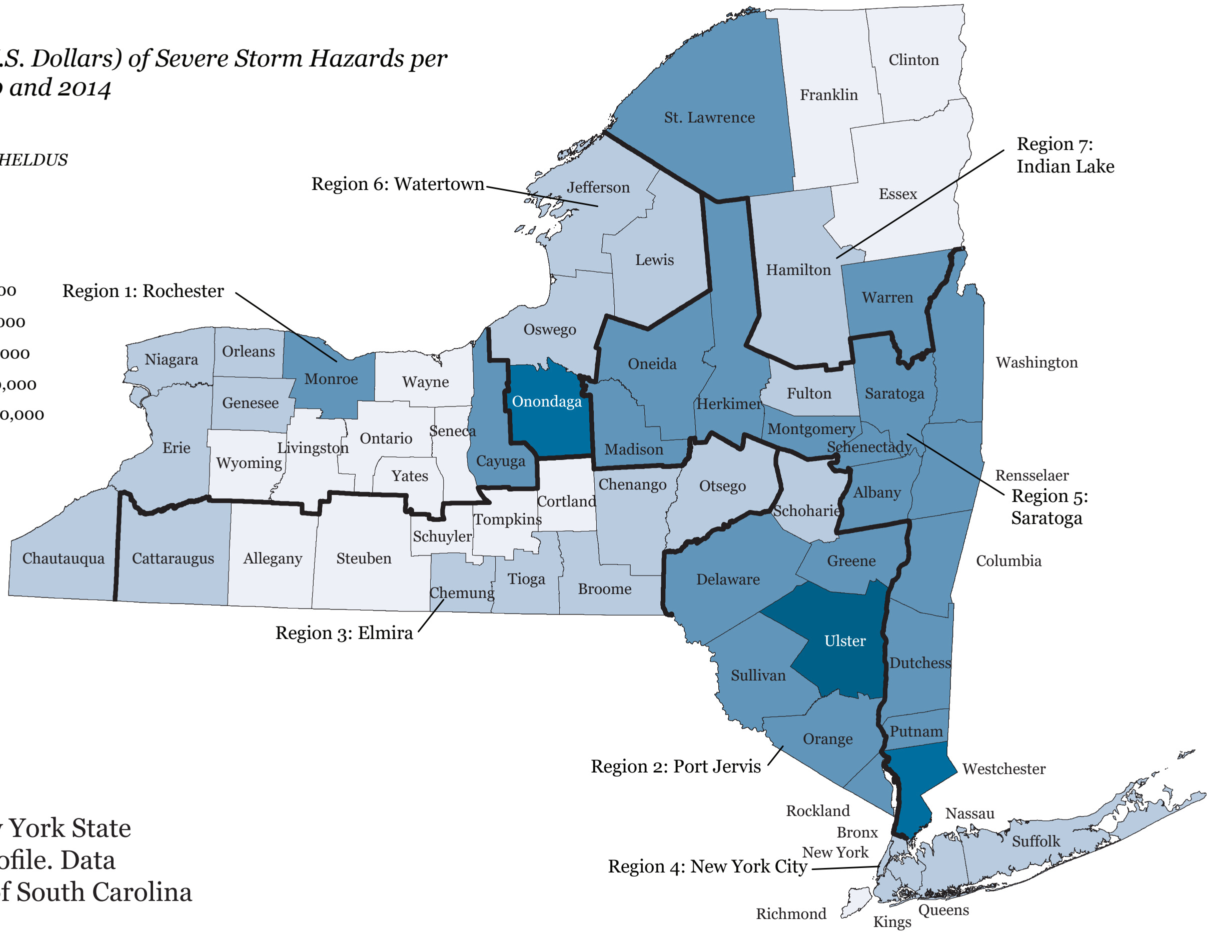
Images source: New York State Climate Hazards Profile. Data source: University of South Carolina SHELDUS

Total Cost (in 2015 U.S. Dollars) of Severe Storm Hazards per County between 1960 and 2014

Data Source:
University of South Carolina SHELDUS

Legend:

- ▭ $4,350,000 - $16,700,000
- ▭ $16,700,001 - $38,000,000
- ▭ $38,000,001 - $82,000,000
- ▭ $82,000,001 - $136,000,000
- ▭ $136,000,001 - $667,800,000



Images source: New York State Climate Hazards Profile. Data source: University of South Carolina SHELDUS

WINTER STORMS

Historic winter precipitation has been highly variable, obscuring historic trends in annual snowfall (Rosenzweig et al. 2011). Seasonal ice cover has decreased about 8% per year over the past three decades, which suggests that lake effect snow will increase in coming decades. These lake-influenced winter storms can drop 80 inches or more (Horton et al. 2014). Winter storms are possible in all areas of New York State but are most prevalent along the Great Lakes and in the Adirondacks. With passing decades, snowfall is likely to become less frequent in New York State, in line with a shortening snow season throughout North America (Rosenzweig et al. 2011), but it is plausible that the colder northern and western parts of the State could see higher snowfall totals during individual snow events.

Images source: New York State Climate Hazards Profile. Data source: (Horton et al. 2014)

FUTURE DAYS UNDER 32° F

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 133 days/year)	99	103 to 111	116	78	84 to 96	102	59	68 to 88	97
Region 2: Port Jervis (Average of 138 days/year)	106	108 to 116	120	79	86 to 100	108	59	65 to 89	101
Region 3: Elmira (Average of 152 days/year)	119	122 to 130	134	94	100 to 114	120	72	79 to 103	116
Region 4: New York City (Average of 71 days/year)	50	52 to 58	60	37	42 to 48	52	25	30 to 42	49
Region 5: Saratoga (Average of 155 days/year)	123	127 to 136	139	98	104 to 119	125	77	84 to 109	120
Region 6: Watertown (Average of 147 days/year)	116	119 to 126	130	96	102 to 113	119	78	85 to 104	114
Region 7: Indian Lake (Average of 193 days/year)	159	162 to 172	177	131	138 to 154	161	107	118 to 143	156

SEA LEVEL RISE

While pre-industrial sea level rise was 0.34 to 0.43 inches/decade, sea level rise in New York's coastal areas and the tidal Hudson has been about 1.2 inches/decade over the last 100 years (Rosenzweig et al. 2011). The high-end estimate for sea level rise by the 2080s is 58 inches, given a worst-case scenario of global ice melting.

As sea levels rise, coastal flooding during storms will also increase in frequency, intensity, and duration. By the end of this century, flooding at the level currently associated with a 100-year flood may occur about 19 times as often due to sea level rise alone (Horton et al. 2014).

Images source: New York State Climate Hazards Profile. Data source: (Horton et al. 2014)

FUTURE SEA LEVEL RISE HAZARDS (INCHES)

ClimAID Region (Analyzed City)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 4 (at New York City)	2	4 to 8	10	8	11 to 21	30	13	18 to 39	58
Regions 2 and 5 (at Troy Dam)	1	3 to 7	9	5	9 to 19	27	10	14 to 36	54

HEAT WAVES

Temperatures have been rising each decade for the past century. They are projected to rise more quickly in the coming decades, with the greatest warming projected to occur in the northern part of the State (Horton et al. 2014). Summers are expected to be more intense, and winters milder; hot summer conditions are expected to arrive three weeks earlier and last three weeks longer (NYSDHSES 2014).

The frequency and duration of heat waves (three or more consecutive days with maximum temperatures at or above 90° F) are expected to increase throughout the state. New York City, for example, currently experiences two heat waves per year. It is projected to have three to four annual heat waves by the 2020s, four to seven annual heat waves by the 2050s, and five to nine annual heat waves by the 2080s (Horton et al. 2014).

Images source: New York State Climate Hazards Profile. Data source: (Horton et al. 2014)

FUTURE DAYS OVER 90° F

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 8 days/year)	12	14 to 17	19	18	22 to 34	42	22	27 to 57	73
Region 2: Port Jervis (Average of 12 days/year)	16	19 to 25	27	24	31 to 47	56	31	38 to 77	85
Region 3: Elmira (Average of 10 days/year)	15	17 to 21	23	22	26 to 41	47	28	33 to 67	79
Region 4: New York City (Average of 18 days/year)	24	26 to 31	33	32	39 to 52	57	38	44 to 76	87
Region 5: Saratoga (Average of 10 days/year)	14	17 to 22	23	22	27 to 41	50	27	35 to 70	82
Region 6: Watertown (Average of 3 days/year)	5	6 to 8	10	9	12 to 21	26	12	17 to 44	57
Region 7: Indian Lake (Average of 0.3 days/year)	0.5	0.8 to 2	2	2	3 to 6	10	3	5 to 19	27

FUTURE NUMBER OF HEAT WAVES

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Currently 0.7 per year)	2	2 to 2	2	2	3 to 4	5	3	3 to 8	8
Region 2: Port Jervis (Currently 1 per year)	2	3 to 3	4	3	4 to 6	8	4	5 to 9	9
Region 3: Elmira (Currently 1 per year)	2	2 to 3	3	3	3 to 6	6	3	4 to 9	9
Region 4: New York City (Currently 2 per year)	3	3 to 4	4	4	5 to 7	7	5	6 to 9	9
Region 5: Saratoga (Currently 1 per year)	2	2 to 3	4	3	4 to 6	7	4	5 to 8	9
Region 6: Watertown (Currently 0.2 per year)	0.6	0.8 to 0.9	1	1	1 to 3	3	1	2 to 6	7
Region 7: Indian Lake (Currently 0 per year)	0	0.1 to 0.2	0.2	0.2	0.3 to 0.7	1	0.2	0.5 to 2	3

FUTURE DURATION OF HEAT WAVES

ClimAID Region: City (Current Baseline)	2020s			2050s			2080s		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Region 1: Rochester (Average of 4 days)	4	4 to 4	4	4	4 to 5	5	4	5 to 6	6
Region 2: Port Jervis (Average of 4 days)	4	5 to 5	5	5	5 to 6	6	5	5 to 7	8
Region 3: Elmira (Average of 4 days)	4	4 to 5	5	5	5 to 5	5	5	5 to 6	7
Region 4: New York City (Average of 4 days)	5	5 to 5	5	5	5 to 6	6	5	5 to 7	8
Region 5: Saratoga (Average of 4 days)	4	5 to 5	5	5	5 to 6	6	5	5 to 7	9
Region 6: Watertown (Average of 4 days)	3	4 to 4	4	4	4 to 4	5	4	4 to 6	6
Region 7: Indian Lake (Average of 3 days)	3	3 to 4	4	3	3 to 4	4	4	4 to 5	5

Images source: New York State Climate Hazards Profile. Data source: (Horton et al. 2014)

HISTORIC ECONOMIC IMPACT OF CLIMATE HAZARDS

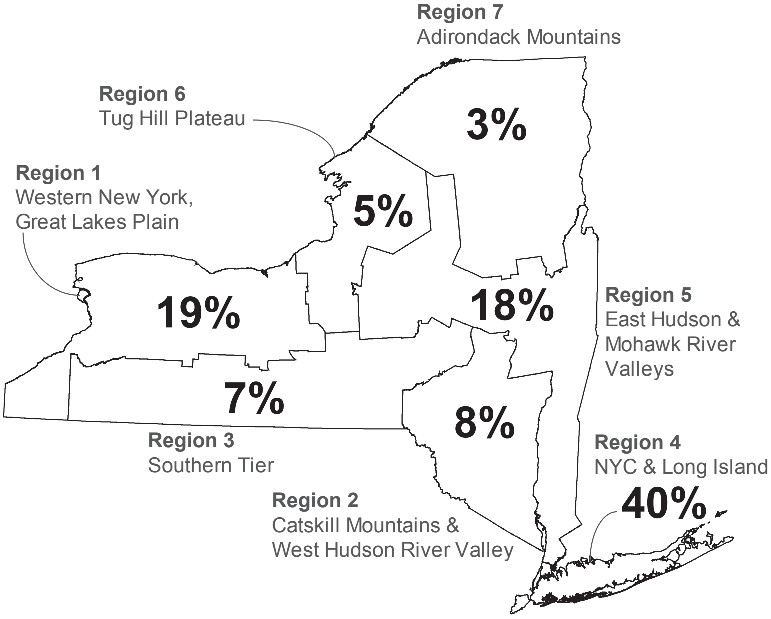
Detailed information on the historic building-related economic losses from winter storms, hurricanes, severe storms, and flooding can be found in the companion document *Regional Costs of Climate-Related Hazards for the New York State Building Sector*. The most economically significant hazards in the state were hurricanes and flooding. Hurricanes happened infrequently but caused extraordinary amounts of damage; widespread and regular flooding incurred a massive cost over time. While the New York City area saw the most total damage, it was a lower percentage of that region's building stock's assessed value than in less populated regions. The capacity of the building sector to recover from future climate hazards may be lower in regions without a sizable central city.

How a Changing Climate Impacts Buildings

Buildings provide the spaces in which nearly all functions of modern life and society take place. To plan effectively, it is important to understand the types, numbers, and values of buildings that are at risk and where they are located across the State. This section includes an overview of New York State's building sector.

NEW YORK STATE BUILDING STOCK

New York State buildings represent a wide variety of ages, sizes, uses, and construction types, and acknowledging this diversity is important. Adaptations for increased rooftop snow loading on a house in the Adirondacks seem unrelated to adaptations for storm surge in a Brooklyn apartment building, yet both are valid design responses in New York State. General, statewide recommendations about impacts and adaptations are not possible, and experience in one region or building type may not apply directly to another. However, an approach that seeks to understand localized climate hazards, assess the risk of impact to a particular building, and develop appropriate adaptation strategies is a transferable process that transcends regional, construction, and usage variability.



Regional distribution of buildings across ClimAID Regions (2015 data). Image from the companion report Regional Costs of Climate-Related Hazards for the New York State Building Sector.

Data source: FEMA HAZUS MH.

The State has 13.78 billion square feet of space in 5.28 million buildings collectively worth over $2 trillion (2014 dollars), of which 90.1% (4,754,100) are residential. While cities are spread statewide, the State's building inventory is dominated by the New York City and Long Island regions. While it accounts for only 3% of the land area in New York State, this region has almost 40% of the buildings, over 50% of built space square footage, and almost 58% of total building value. Densities in the New York City and Long Island regions can reach up to 16,000 buildings per square mile (Ray et al. 2018).

Outside of the New York City and Long Island regions, buildings occur largely in cities along the New York State Thruway (US I-90) and the Hudson River Valley. The regions encompassing these corridors account for another 42% of the State's buildings, 36% of its built space square footage, and 31% of its total building value. The rest of the building stock is found in the remaining rural areas. These regions account for 18% of the State's buildings, 13% of its built square footage, and 11% of its total building value (Ray et al. 2018).

BUILDING EXPOSURE AND OCCUPANT VULNERABILITY TO CLIMATE HAZARDS

Some buildings and occupants are more susceptible to harm from any kind of hazard due to preexisting vulnerabilities. Buildings that are old, improperly or inadequately constructed, or in riskier locations will be disproportionately impacted by increasing hazards from a changing climate. For example, geographic location is the main factor determining buildings' exposure to risks of coastal flooding and sea level rise. Flood plain maps that are based exclusively on historic data do not take into account projected sea level rise, so land use planning that relies on these maps may increase building vulnerability. Similarly, occupants who are already vulnerable to the effects of climate change due to age, poor health, poverty, language barriers, or social isolation will be disproportionately affected by the hazards of a changing climate.

RISKS TO OCCUPANTS' HEALTH, BUILDINGS, AND OPERATIONS FROM CLIMATE HAZARDS

Climate change increases risk to human health and productivity, increases risk of disruptions to building or community operations, and increases risk of physical damage to buildings and contents.

The indoor environment already exerts considerable influence on human health, learning, and productivity, and research indicates that climate change will make existing indoor environmental problems worse and introduce new problems in three ways. First, it will alter the frequency or severity of outdoor conditions that adversely affect the indoor environment. Second, it will create outdoor conditions that are more hospitable to pests, infectious agents, or disease vectors that can enter the indoor environment. Third, it will lead to mitigation or adaptation measures or behaviors that cause or exacerbate harmful indoor environmental conditions. The potential increased risks to occupants include thermal stress from heat waves, decreasing indoor air quality due to reduced ventilation from weatherization of buildings, increased use of combustion for electricity generation in the event of power failure, increased mold growth due to dampness from increasing heat and humidity, and increased building material breakdown due to the presence of flood water (IOM 2011). Detailed information on the human health impacts of climate change in the U.S. appears in the 2016 report from the U.S. Global Change Research program.[1]

Buildings present various levels of risk associated with their structural failure, depending on the seriousness of the consequences of their failure. These levels are designated "risk categories" and are defined by ASCE/SEI Standard 7. Risk category I buildings present low risk to human life; an example of this is an agricultural storage facility. Risk category II buildings pose "normal" risk; houses fall into this category. Risk category III buildings pose substantial risk to human life in the event of failure; examples are buildings like daycares and schools. Risk category IV buildings are essential facilities such as hospitals, fire, and police stations (NIST 2015). These risk categories, along with specific information on the building's role in the community, help building professionals decide the extent to which they must take adaptation measures to provide protection from changing climate hazards.

However, these ASCE/SEI 7 risk categories do not address the issue of disruption to building or community operations when a building is temporarily inoperative after damage from an extreme event. Some buildings provide essential or important functions in a community and need to function with no or little interruption. The following table summarizes risks from structural failure and discontinuity of operations for different types of facilities.

	Example Facilities	Considerations	Risk Category	Post-Hazard Performance Level
Government	Emergency operations centers, first responder facilities, airports, prisons, water and waste treatment facilities	Provide essential services, shelter occupants, shelter equipment needed for essential services.	IV	A
	City halls, county administrative buildings, public schools, mass transit stations/garages, judicial courts, community centers	May not be needed during immediately following hazard, but may be needed in intermediate recovery phase.	II and III	A or B
Health Care	Hospitals, essential health care facilities and supporting infrastructure	Critical to response and recovery efforts.	IV	A
	Nursing homes, residential treatment centers for non-ambulatory patients	Need to be functional immediately after a hazard event.	III	A
	Doctors' offices, pharmacies, outpatient clinics	Some subset may need to be remain functional in an event.	II	A or B
Schools/ Daycare Centers	K-12 schools	May be used as emergency shelters; return to typical use influences perception of community return to normalcy.	III	B; A if emergency shelter
	Higher education facilities	Universities may want to protect research facilities, long-term experiment materials and data, but facilities may not have been designed for protection during hazard events or timely recovery of function.	II if regulated as business, III if regulated as assembly	A or B
	Daycare centers	House children who may require mobility assistance and are unable to make decisions.	II or III	A or B
Religious/ Spiritual Centers	Churches, temples, mosques, halls	Often offer a safe haven for people with emotional distress after a hazard event. May operate non-profits that provide supplies or services. May provide temporary emergency housing. May be older structures that perform poorly in hazard events.	II or III	B
Residential/ Hospitality	One- and two-unit housing	Code-compliant buildings often perform well in earthquakes, but are more variable in high-wind events.	II	A, B, or C
	Multi-unit housing		II; III for very large occupancies (e.g., > 5000)	A, B, or C
	Nursing homes, senior living centers		II or III	A or B
	Hotels and motels	If homes are not functional after event, providing lodging for visiting emergency personnel may compete with providing temporary shelter for residents.	II	A or B
Business/ Service	Services essential for recovery	Grocery stores, pharmacies, banks/financial institutions, hardware/home improvement stores, gas stations, refineries provide essential services during recovery.	II or higher	A or B
	Other services essential for long-term resilience	Other facilities deemed critical for recovery and long-term economic stability.	II	C
Conference/ Event Venues/		May be important for long-term recovery because of revenue generation. May need improvements before being considered for temporary shelter or staging area.	III	A, B, or C
Detention/ Correctional Facilities	Detention centers, prisons	Codes typically require higher performance and risk categories because people cannot evacuate without supervision.	II or III	A or B

Buildings in New York State have a collective value of about $2.34 trillion in 2014 dollars (Ray et al. 2018). A single disaster, such as 2012's Superstorm Sandy, can wipe out many years' worth of investment and development in a matter of days. It can also divert resources from other priorities during recovery. Physical damage to buildings reduces a community's ability to attract and retain investment. Resilient buildings not only protect occupants and contents, but also can provide a platform for quicker recovery (Anderson 2017).

See chart on previous page.

Summary of risks to human life from structural failure and risks to community function from operational discontinuity. Post-hazard performance-level category definitions:

A. "Safe and operational." These may incur minor damage but should continue to function without interruption.

B. "Safe and useable during repair." These may experience moderate damage to interior finishes, contents, and support systems.

C. "Safe and not usable." These should meet minimum safety goals but are not functional and remain closed until repaired.

D. "Unsafe – partial or complete collapse." These may be dangerous because of the extent of damage.

(NIST 2015).

RISK OF CASCADING EFFECTS

Buildings have fundamentally linked interactions with infrastructure, occupants, and climate that can yield cascading effects with impacts on people in buildings. These occur when failure in one system triggers a failure in another. For example, the 1906 earthquake and fire in San Francisco destroyed more than 28,000 buildings. Damage was so extensive in part because the city's gas and water pipes were not seismically designed. When the gas pipes broke during the earthquake, they drove up the risk of fire, but at the same time, the broken water pipes made fire control difficult, which led to a large conflagration. Better planning and design could have decoupled the additional fire risk to buildings from earthquakes by designing gas and water infrastructure for earthquake resistance (Snow and Prasad 2011). Hurricane Katrina saw multiple, linked failures in infrastructure, evacuation systems, and critical response systems (Melillo, Richmond, and Yohe 2014). Following Superstorm Sandy, the loss of electricity led to the cascading consequence of communication system disruptions; many cell towers did not work, and individuals could not charge cell phones. People lost access to social networks as well as public information. Transportation systems were also disrupted when gas station fuel lines had no power (USDOI Strategic Sciences Group 2013).

Buildings can help decouple community-scale risks. For example, green roofs can lower urban heat island effect, reduce cooling energy demand, and capture rainwater to reduce urban flooding. Some buildings with high-risk categories or demand for high-performance post hazard will need better design to shield them from cascading risks. For example, a hospital will need to be passively survivable even when the power is out.

IMPACTS OF A CHANGING CLIMATE ON BUILDINGS

Buildings will better meet the challenges of a changing climate if their designers consider the hazards the building will likely face. The following sections summarize the impacts on buildings of each of the New York State's shifting climate hazards: hurricanes and tropical storms, flooding, severe storms, winter storms, sea level rise, and heat waves. Adapting Buildings to a Changing Climate includes a summary of adaptations to these hazards.

Impacts of Hurricanes/Tropical Storms

Hurricanes and tropical storms bring high winds, intense rainfall, and, in coastal areas, storm surge. High winds cause damage to buildings in three main ways. The first type of damage is direct, for example when the building slides off its foundation, the building overturns off its foundation, the structural frame racks, or roof uplift occurs (Anderson 2017). The second type is impact damage from wind-borne debris, usually to brittle materials like glass. The third type of damage is collateral, in which another structure or a tree falls on a building. Impact from intense rainfall is discussed below with severe storms. Storm surge is discussed with flooding.

Impacts of Flooding

Flooding is one of the most significant climate-change threats to buildings (Alzahrani and Boussabaine 2013). Approximately 700,000 people live in areas designated as "flood-prone" in New York State, and millions more work, travel through, or recreate in flood-prone areas (NYSDHSES 2014). Sea level rise coupled with storm surge and flooding can inundate roads, isolate communities, and damage buildings and infrastructure.

Impacts are greatest in urban areas with high percentages of impermeable surfaces because there is little capacity for absorption of excess water (Anderson 2017). FEMA has reported that about a third of the claims filed under the NFIP are from damages outside the 100-year floodplain; this includes urban flooding from undersized and poorly functioning drainage systems (NYSDHSES 2014).

Basement and ground-level buildings are the most exposed to flooding risks. Damage can occur to the building itself, to services and fittings, and to personal possessions (Snow and Prasad 2011). Flood water may also contain sewage and pollutants that cause health concerns, including the spread of disease.

Flooding can also have also multiple economic impacts on the buildings sector. Delays and disruption of building operations can lead to financial losses to business. Investments in construction repairs and general financial losses after major flooding events place a burden on communities and the local government. A study of 136 global cities found that New York City has the third-highest financial vulnerability to annual flood losses due to its relatively high value and relatively low levels of coastal protection (Hallegatte et al. 2013).

Impacts of Severe Storms

Severe land-based storms bring high winds and intense rainfall. As precipitation levels increase, building failures, and flooding will increase. Wind-driven rain is more likely to penetrate roofs, walls, apertures, and foundations. Roofs have the greatest exposure to precipitation, and low-slope or geometrically complex roof shapes will be most prone to water penetration. Cladding materials will experience more moisture migration, and windows and doors will experience more water intrusion. Damage to the building exterior may create cascading risk, whereby an envelope breach increases the possibility of cladding system failure, as well as damage to the structure, building systems, and building contents. Envelope breach increases risk of mold. Foundations will experience more water vulnerability from saturated soils. Pests may be more prevalent in wetter exterior conditions. Overall, buildings will have higher maintenance requirements.

Impacts of Winter Storms

In the areas of the state that may see increased winter precipitation, buildings may see increased roof loading due to larger snowfall during storm events. Roofs may experience structural damage or collapse due to this additional loading. Ice dam formation during cold weather may damage eaves and allow water to penetrate roofing. Like increased warm-weather precipitation, increased snowfall will incur more wear on building cladding materials and require more maintenance. Snow buildup at a building perimeter can drive moisture into wall assemblies. Snow and ice accumulation may threaten electrical distribution infrastructure at the community level, leading to power outages.

Impacts of Sea Level Rise

In coastal and tidal areas of the State, levees and seawalls may be overtopped or undermined, and other water control infrastructure may become overwhelmed, which will increase the threat of flooding and water damage to buildings. Increased erosion due to sea level rise may shift shoreline position sufficiently to destabilize foundations or affect infrastructure. See the “Impacts of flooding” section.

Impacts of Heat Waves

Increasing outdoor temperatures will primarily affect the indoor environment. Warmer and more humid conditions induce buildings to use slightly less energy, often non-electric fuels, for heating in winter. However, they increase energy demand (particularly for electricity) for mechanical cooling in summer, further exacerbating the warming trends of global climate change by increasing fossil fuel consumption overall (Anderson 2017).

Required ventilation air for non-residential buildings is increasingly provided by mechanical ventilation systems alone, usually with little or no provision for natural ventilation. Consequently, many buildings have no means of ventilation, let alone space cooling, during power outages. These buildings can become uncomfortable or unsafe, particularly for occupants who are vulnerable due to age, illness, or other factors. A higher reliance on mechanical systems with lower air exchanges for energy conservation suggests that indoor air pollution may increase. Reductions in indoor air quality increase risks of asthma, heart disease, and heart attacks. Increases in humidity increase the chances of mold growth, which is also strongly associated with health problems such as asthma (IOM 2011).

In heat waves, energy consumption for cooling is particularly high and may overwhelm electrical grids, leading to brownouts and outages. Extreme heat events may cause temperatures to exceed intended setpoints in buildings with insufficient (or nonexistent) mechanical cooling equipment, as well as in mechanically sufficient buildings during summertime power outages. Such overheating can lead to discomfort, loss of productivity, illness, and, in some cases, death.

On the exteriors of buildings, rising temperatures may reduce the service life of building cladding materials due to cracking, and higher humidity levels may increase corrosion or rotting of structural members. An intensified urban heat island on the outside of buildings will further increase demand for mechanical conditioning inside.

CODES, STANDARDS, AND CERTIFICATIONS

With the exception of New York City, New York State requires buildings adhere to the State Uniform Fire Prevention and Building Code (Uniform Code) and the State Energy Conservation Construction Code (Energy Code). New York City's Construction codes (NYCCC) are independently adopted and enforced. Both State and city codes are based upon the International Code Council's family of national model codes (I-codes), with amendments.

Local governments are responsible for enforcing codes through plan review, permitting, licensing, and inspections. They may also have their own additional provisions beyond the minimum standards provided.

Building codes are articulated chiefly through a set of technical standards, which are developed and issued by independent organizations and become enforceable only when referenced by codes. The Uniform Code alone contains more than 500 referenced standards generated by 50 unique standard-setting bodies, and the Energy Code refers to more than 60 additional standards.

Code Update Process

Codes and standards are dynamic, regularly evolving due to the commercial availability of new materials or technologies, in response to performance in disasters, or based on new research findings. Adoption typically occurs on a three-year cycle and follows a consensus-based process. Codes have historically responded to changing demands for safety based on an iterative process using comments and observations of failures in previous codes, especially following disasters (Anderson 2017). The types of provisions directly related to climate include fire protection, energy efficiency, wind resistance, and flood resistance. While codes were developed to protect against the dangers of fire and inadequate construction, they were not intended to provide comprehensive resilience to changing climate conditions.

Historic or Projected Climate Information

Codes and standards are generally based on historic performance data, with built-in statistical analyses of failure rates within an acceptable level of risk. Standard-setting bodies face many institutional and technical challenges to using forward-looking climate information that might better describe the climatic context a building will experience during its useful lifetime (USGAO 2016). Code requirements currently lag behind the professional community's awareness of and concern about the impact of climate change on buildings. Hence building professionals lack tools to determine the appropriate standard of professional care to provide under changing basic climate conditions.

Going Beyond Code Compliance

Given that relying on code or standard updates will likely be too slow or otherwise insufficient to address local concerns about climate change, local governments may choose to enact new additional code provisions addressing the specific climate-related risks facing buildings in their jurisdictions. Fifty-four municipalities in New York have already adopted more restrictive local standards than state codes require to address the unique characteristics, building practices, or demands of their locality.

This process could also be used to address localized climate risks. Third-party building certifications such as LEED provide a different structured mechanism for buildings to set performance targets beyond code-minimum requirements regarding climate adaptation. These systems already incorporate goals and strategies related to energy efficiency, sustainability, and resilience.

To be eligible for participation in the National Flood Insurance Program (NFIP), communities must meet the requirements of their own jurisdictions and adopt specific zoning and code provisions that meet or exceed NFIP requirements. Such provisions include requirements for building elevation, flood proofing, anchoring, material selection, equipment locations, drainage, water and sewage infrastructure, and other permitting requirements.

FEMA provides technical assistance and review to ensure compliance, and in recent years it has tried to align its provisions with the I-codes and the referenced standards within them. To be clear, the NFIP is not sufficient to protect communities from increased flooding risks as the climate changes. However, the structure of the NFIP could provide a model for accounting for the new and varied risks to buildings under climate change.

New Code Provisions Slow to Show Results Across the Building Stock

A building's performance under a changing climate will in part depend upon the version of the codes and standards in place at its construction and the extent to which code provisions are enforced and maintained at the local level. The capacity of the current building stock to resist hazards already varies considerably across the state. The ability to better protect buildings via future climate-oriented code provisions and datasets is limited temporally by the cycles of code updates and adoptions, and it is limited in scope because new codes apply only to new and renovated buildings. While adoption of modern codes and standards with forward-looking climate data is necessary, it is likely insufficient to protect most the State's buildings against future climate hazards. The positive effects of code improvements are slow to accumulate; much of the buildings in the state will remain untouched for several decades (NIST 2016). As buildings are replaced, code compliance is mandatory, but historically, the annual replacement rate is only about 2% per year. The enforcement of these codes will impact the extent to which buildings are adaptive to a changing climate.

Adapting Buildings to a Changing Climate

A crucial part of the adaptation process is identifying and developing appropriate adaptation strategies or measures. Strategies that limit exposure to risk and take advantage of the potential opportunities of climate change must respond to the specifics of place. As a result, adaptation strategies that emerge from different projects vary widely. Some adaptation strategies are project specific, while others are generalizable.

PRIORITIZATION OF INVESTMENT OVER TIME

Whether and when to adapt is a complex decision that must consider a building's lifetime, its program, its importance, and its constituent materials and systems. While it may be more costly and difficult to retrofit a building the older it gets, it is even less cost effective when a building is close to the end of its useful life. Thus, if it is worth doing, it is worth doing sooner rather than later. Being reactive simply incurs expenses rather than deferring them (Snow and Prasad 2011). At the same time, adaptation is needed only for buildings that will still be standing and usable when the climate change impacts occur (Camilleri 2001). Determining the feasible useful life of a building given changing climate parameters will become increasingly important.

Adaptation does not always have a clear and certain short-term return on investment. (One exception is passive survivability measures that reduce operating energy use.) In fact, the value of adaptation measures may not be seen until retroactive avoided-loss calculations are done after a disaster. While this logic is compelling to some, it may not provide sufficient justification for others. For this reason, adaptation strategies with collateral public benefits can influence public perception and increase financial viability (Anderson 2017). For example, open vegetated areas designed to absorb increasing stormwater can add a site amenity for occupants and an adaptive response to potential flooding.

PARSING FUTUREPROOFING FROM CURRENT BENEFITS

Adaptation strategies might be divided into strategies that only prepare a building for new or increased hazards in the future, and "no-regret" strategies that not only anticipate future needs but also provide auxiliary benefits under current climate conditions. Strategies that provide current benefits generally dovetail considerably with sustainable and energy-efficient design practices.

TECHNICAL GUIDES AND TOOLS FOR ADDRESSING CLIMATE HAZARDS

Appendix A provides synopses of existing adaptation guides that building professionals can use to incorporate climate change adaptation into their work across varying scales and contexts. Also see the companion report *Climate Resilience Strategies for Buildings in New York State* for more detailed information.

ADAPTATION OF BUILDINGS TO A CHANGING CLIMATE

This document provides a broad overview of adaptation to the climate hazards of hurricanes and tropical storms, flooding, severe storms, winter storms, sea level rise, and heat waves in New York State. Many more details and additional references for individual strategies are provided in the companion report *Climate Resilience Strategies for Buildings in New York State.*

Adaptations for Hurricanes/Tropical Storms

The most critical design response to intense storms is to establish a continuous load path between walls, floors, roof, and foundation. A holistic design is important; otherwise, increasing strength in just one area may only change the mode of failure (Snow and Prasad 2011). Aerodynamically efficient building massing and form can help to deflect high winds and protect roof, walls, and apertures. Hurricane shutters can protect building openings. Impact-resistant glazing resists breakage and prevents the life safety hazard of flying broken glass. A backup power supply ensures electricity continuity during hurricanes and tropical storms.

Adaptations for Flooding

There are three overarching approaches to adapting to sea level rise, coastal flooding, and storm surge: retreating, accommodating, and protecting (Anderson 2017; Snow and Prasad 2011).

Retreating involves leaving high-risk coastal areas and maintaining protective setbacks from potentially hazardous areas. Land use planning plays an important role in minimizing exposure to climate variability and hazards. As population centers and urban areas grow, decision-makers must consider the need to mitigate risks by incorporating structural and behavioral adaptation within the planning process, or when appropriate by preventing growth and construction in highly exposed areas (Noble et al. 2014).

Accommodating allows water to collect and move without causing damage, displacement, or interruption. This includes elevating structures on piles or plinths, or allowing water to move through the lowest level without damaging the structure or building contents. (This is known as "wet floodproofing," which uses water-resistant materials, allows water in during a flood event, keeps sewage out with backflow preventers, and cleans materials afterward.) Site planning for greater capture, absorption, and storage of water helps the building and community accommodate flood waters.

Protecting buildings from storm surge involves constructing hard structures like seawalls or soft structures like berms. The building itself can be designed with foundations to withstand uplift forces due to buoyancy when submerged in water. It can also be designed to withstand wave shear, waterborne impact, and scour. Mechanical and electrical equipment can be located high in the building, above flood elevations. Walls may be designed to equalize floodwater pressure with flood vents or breakaway framing. Walls may be "dry floodproofed," where watertight materials protect all openings, and backflow preventer valves stop sewage intrusion.

Adaptations for Severe Storms

In addition to implementing the adaptations for flooding, building designs should anticipate higher precipitation. Roofs should be designed with proper drainage for higher expected precipitation levels and have sufficient slope or structural stiffness to prevent ponding. Complex roof forms may need higher-quality waterproofing membranes. Drainage systems should shed water away from openings and building foundations. Additional protection against vapor penetration and water migration may be needed at the foundation, including below-slab membranes, vapor barriers at the interior of sub-grade walls, gravel backfill around foundation walls, and damp-proof courses of masonry (Anderson 2017). A backup power supply may be needed to ensure electricity continuity in severe storms.

Adaptations for Winter Storms

Strengthening roof structures to meet higher design snow loads will be important, as will appropriate roof and eave detailing to protect against ice dams. Cladding material durability and maintainability should also be considered. Permeable paving or landscape approaches to help with snow thaw and drainage can help minimize moisture accumulation. A backup power supply may be needed to provide electricity continuity in winter storms. Renewable sources such as solar photovoltaic, wind, and solar hot water will do so without creating further climate-change-inducing emissions.

Adaptations for Sea Level Rise

As with adaptation to flooding, above, the overarching approaches to adaptation to sea level rise include retreating, accommodating, and protecting.

Adaptations for Heat Waves

Adaptive techniques for increased temperatures are important for two reasons: They allow the building to maintain better thermal safety and comfort for its occupants when it cannot be mechanically conditioned (a characteristic known as "passive survivability"), and they enable the building's mechanical equipment to use less energy when deployed, which helps to mitigate further warming. Winter heating loads may be reduced as well. However, some of these strategies can be maladaptive from a human health perspective, so building professionals must consider them holistically, accounting for risks to occupant health. For example, reducing air leaks without source control or increased mechanical ventilation may increase indoor pollutants and spur mold/bacteria growth (IOM 2011).

Passive Design. Basic passive design strategies can help buildings make the most of climatic resources so that mechanical equipment runs as little as possible when creating comfort conditions. Appropriate east-west orientation helps to optimize solar exposure. Shading and glazing vulnerable building surfaces reduces heat gain. Tailoring building form and massing to program and use allows some spaces to act as thermal buffers for other spaces that have precise thermal requirements. Operable windows may reduce demand for cooling and ventilation air and provide some relief when mechanical equipment is not functioning. Thermal mass may help moderate temperature swings.

High-Performing Envelope. A high-performance building envelope will reduce environmentally driven cooling loads. About 50% of the heating load in residential buildings and 60% in commercial buildings, as well as virtually all of the cooling load in residential buildings, is due to energy flows through the envelope (U.S. DOE 2014). Reduced air infiltration with air barriers, sealants, caulks, and mastics can reduce energy consumption by 25% or more in residential projects (Anderson 2017). Higher insulation levels, radiant barriers, and low-Solar Heat Gain Coefficient/low-U factor windows further reduce cooling loads.

Efficient HVAC Equipment. Higher overall temperatures and more frequent extreme heat events will increase the frequency and amount of mechanical cooling needed. This suggests the value of higher-performing HVAC equipment such as variable speed drives on fans, heat recovery, ground-source heating and cooling, radiant systems, displacement ventilation, and other innovative systems that help reduce energy consumption. Load shifting techniques such as ice-storage and "smart" demand-response equipment can help the electrical grid as a whole avoid brownouts and blackouts on heavy-use summer days. Providing space to add or increase cooling ducts may be appropriate if no or limited cooling is initially provided.

Backup Power Supply. Battery backups and onsite energy production can ensure a continuous energy supply to provide space conditioning when needed. Renewable sources such as solar photovoltaic, wind, or solar hot water will do so without creating additional climate-change-inducing emissions.

Building Professionals' Roles

Building owners and designers can take a climate change adaptation cue from the insurance industry. A survey of insurance claims by Munich RE found that weather-related natural catastrophes occurred three times as often from 1994 to 2004 as they did in the 1960s. During the same time period, economic losses increased by a factor of 5.3, and insured losses by a factor of 9.6; this was mainly due to floods and windstorms (Snow and Prasad 2011). Previously, natural disaster risk was distributed over a large pool of clients, but more recently insurance companies are taking care to assess assets at a local level and better match premiums to more localized risk (Snow and Prasad 2011). In the UK, some mortgage lenders have started to require third-party certification of newly built properties (Sanders and Phillipson 2003). In this way, insurance companies increasingly influence where and how buildings are constructed. The U.S. National Flood Insurance Program already does so overtly; it not only provides insurance to individual property owners, but also requires participating communities to establish regulations to reduce future flood damages. As the insurance industry and regulators begin to think more precisely about the risks climate hazards pose to buildings, building professionals will need to develop the technical skills to design or retrofit buildings to reduce liabilities from extreme weather impacts.

A resilient community is arguably the high-level goal of most adaptation work. Indeed, an individual building cannot in itself be resilient unless the surrounding context and infrastructure are as well. However, community resilience can emerge only in relation to individual property rights and many individual decisions and actions. Therefore, public and community engagement by building professionals will be critical (Anderson 2017).

RATING SYSTEMS AND RESILIENCE

Green building ratings and certifications are voluntary systems that suggest various mitigation strategies related to climate change. They aim to reduce energy consumption, mitigating high temperature hazards; they aim to conserve water, mitigating drought conditions; they aim to expand stormwater capacity, mitigating flood hazards. Some green building standards are beginning to address adaptation overtly as well, but this is not typically the primary focus of these systems.

There is also an emerging body of certifications, benchmarking systems, planning frameworks, and design principles for resilience. None has yet consolidated the market in the way that the LEED rating system has done for sustainable design. Each offers a slightly different focus, addressing different hazards, analysis scales, and performance outcomes. Analysis of these systems suggests that a lack of industry outreach and diffuse return on investment have made adoption of resilience rating systems slow, but the insurance and reinsurance industries will be the drivers of resilience certification. Specialized financing for resilience is currently limited, and thus far lenders are not responsive to resilience standards.

Owners and operators report that those in the real estate market lack awareness of resilience tools and standards. Regulators and State/local officials can influence the practice of climate adaptive design through building code adoptions or zoning/permit incentives (Meister Consultants Group 2017).

CLIMATE MODELING VS. BUILDING ENERGY MODELING

Projections of future climate conditions differ from the historically averaged weather data conventionally used for building energy simulation and mechanical system sizing. This presents a problem, given that buildings may now be designed to just meet criteria for overheating. In other words, they are designed to eliminate any cooling loads not met under the typical worst-case scenario given by the design temperature conditions. When exterior temperatures go up in future decades, the number of hours with unmet loads will increase over the lifetime of the building, yielding ever-worsening comfort attainment. Data from both historical and future climate datasets will be more instructive in predicting how a building will perform in the short and long term.

Please see a companion report for a comparison of building energy simulations using current typical weather data and future climate projection data. This report presents an energy analysis of five model buildings types (low-rise residential, multifamily, commercial, industrial, and education) in the seven ClimAID zones of New York State. This analysis looks at energy use, demand, and temperature using both typical meteorological year (TMY) climate data and extreme meteorological year (XMY) climate data.

Mechanisms Of Resilient And Adaptive Design

The mechanisms by which the various building and building-related professions can adapt to climate change differ markedly.

Governments/planning entities: Can enact policy changes regarding code adoption, land use planning, or zoning.

Code officials/standard-setting-bodies: Can deploy changes to standards and codes to reflect projections of future probability, not just historic frequency. These will determine design criteria for climate-related elements in codes/standards governing fire protection, energy efficiency, wind resistance, and flood resistance.

Insurers: Can take actions to constrain losses by spatially influencing development through location- or construction-based premium prices and varying availability of insurance.

Builders: Can leverage familiarity with changing hazards in relevant market to educate clients about what quality construction for long-term viability looks like.

Owners/operators: Can demand resilience of professionals and participate in climate action planning exercises that prioritize adaptation approaches.

Architects/engineers/landscape architects: Can provide expertise and leadership in holistically integrating adaptation techniques into buildings; can leverage familiarity with changing hazards in relevant markets to educate clients about what quality construction for long-term viability looks like.

Professional organizations (AIA, AHSRAE, BOMA, NAHB): Can provide support and resources to educate professionals on new professional expectations in a paradigm of a changing climate, and can help establish clearly what these norms are or should be.

BARRIERS

There are many barriers to the practice of resilient design, and they combine in various ways to form impediments to the work of building professionals.

Fuzzy Problem Definitions. A coherent problem definition is required by all parties in any collaboration, and diverse definitions or perceptions impact the ability to communicate and ensure an effective decision-making process (NRC 2009). In the building industry, this may occur between architects, engineers, and policymakers who each have distinct problem-defining priorities and attitudes towards adaptation.

Complexity of Existing Processes. Given the intricate landscape of requirements, team members, deadlines, and budgets required to bring a building from conception to construction, it can be quite difficult to intervene with additional performance requirements.

Lack of Awareness. To understand the need for adaptation, one must perceive signals that climate change is occurring. Superstorm Sandy was one such signal, but not all signals are as dramatic as hurricanes or disasters, and not all are publicly available through the media.

Lack of Direct Experience. If clients or team members have not personally experienced climate-related impacts, they may be less prepared to work on adaptation projects. For example, those who directly experienced Superstorm Sandy's consequences have driven policy development and increased community engagement in climate change adaptation and mitigation (Schmeltz et al. 2013; Dubois and E. Krasny 2016; PlaNYC 2013). The abstract and statistical nature of climate change risk does not evoke visceral reactions (Weber 2006). In some cases, there is enough uncertainty about location, extent, and timing of hazards to discourage investment in adaptation. Not all cities have yet had dramatic first-hand experiences with climate change, so in many cases, perceptions of climate change are based on descriptions unlikely to prompt action.

Perceived Consensus Gap. Within the larger culture, a disconnect exists between the public's perception of scientific consensus about climate change and actual scientific consensus about climate change (McCright, Dunlap, and Xiao 2013; Ding et al. 2011). Cognitive and affective biases, such as climate change denial, impact how climate change signals are perceived and understood (Weber 2006). A similar disconnect may exist between the public and building professionals, whereby the public may infer from a uneven policy context that building professionals do not agree about whether and how to respond to changing climate conditions.

Power/Responsibility Gaps. Even among concerned professionals, a lack of a leadership or decision-making responsibility may impede adaptation (Ekstrom, Moser, and Tom 2011; NRC 2009). For example, a climate-conscientious builder with an unconcerned client will not be able to produce an adaptive building.

Information Gaps. While climate projections are freely available, they are not as accessible to building professionals as other relevant information such as building codes and standards. There is a perceived lack of information on which to base adaptative designs. The industry lacks awareness of the professional standard of care required under the conditions presented by a changing climate. These gaps are impacted by education and training, as well as the values, preexisting beliefs, and problem perception of an individual or organization (Lorenzoni, Nicholson-Cole, and Whitmarsh 2007; NRC 2009). To respond to these challenges, the industry may need new leaders to emerge within organizations to help drive the process.

Cost/Perceived Cost. Costs to deploy appropriate adaptive strategies on a project might be modest or in fact save money when amortized over a long building lifetime, particularly when one considers total building ownership costs, including replacement costs. At the same time, there may be significant perceived costs of adaptation for some buildings, particularly given the uncertainty intrinsic to future climate hazards. Even when understood as a phased cost, the investment may be significant and overwhelming to some clients and building owners.

Development Pressure. There is often political pressure to maintain urban development in certain locations; this can inhibit adaptation strategies like retreating from floodplains.

Inertia. The status quo has historically worked well in many cases, and it may be difficult for some to acknowledge the need to change behaviors.

Conclusion

This report examined the climate hazards likely to be experienced by New York State in the next century, as well as the impacts of these hazards on the buildings in the State. It has offered some suggestions for how building professionals may need to respond to these changing conditions. Some additional areas of concern are as follows:

UNEVEN ADAPTATION EFFORTS

Within the building sector, knowledge about climate change impacts and the benefits of implementing adaptation is improving. Still, adaptation efforts have been uneven and driven mainly by climate disasters such as Superstorm Sandy. Even in New York City, some climate change impacts (e.g., flooding) have been widely captured in governmental programs and initiatives, while other impacts of climate change (e.g., decreasing indoor air quality) have not. This indicates the importance of addressing the many impacts of climate change to manage the building sector's exposure to climate change risks.

TECHNOLOGICAL BIAS OF ADAPTATION EFFORTS

The development of adaptation options has also mainly focused on technological and engineered strategies, as seen in Adapting Buildings to a Changing Climate. Little attention has been given to other types, such as social, informational, organizational, and behavioral adaptation strategies. This technological bias makes it more difficult for building professionals to perform a comprehensive assessment of adaptation strategies to implement in a specific project to address a specific climate risk.

UNCERTAIN PROFESSIONAL RESPONSIBILITY

Many of the vehicles defining building professionals' standards of care, such as codes and standards, are not currently structured to anticipate future hazards and risks. This leaves professionals uncertain about how to deliver services that match their own level of understanding of climate issues. Still, the AIA Code of Ethics and Professional Conduct calls for its members to "advocate the design, construction, and operation of sustainable buildings and communities."[2] The ASHRAE Code of Ethics states that members should shall "enhance public health, safety and welfare" and "be good stewards of the world's resources."[3] While members of the building community have an implicit obligation to their clients to think about the long-term future of projects, they must further address the need to define the responsibilities required of professionals as the climate continues to change.

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Appendix A: Adaptation Guides

This section provides an overview of existing adaptation guides that building professionals can use to incorporate climate change adaptation into their work across varying scales and contexts. While most guidebooks contain general climate change adaptation strategies for the built environment and urban centers, few offer a comprehensive examination of adaptation in the building sector.

CLIMATE RESILIENCE STRATEGIES FOR BUILDINGS IN NEW YORK STATE

A companion to the current document, this report lays out 25 strategies specific to the climate hazards in New York State. It provides information and external resources geared toward owners/operators, policymakers/planners, and architects/engineers.

http://ap.buffalo.edu/content/dam/ap/PDFs/NYSERDA/Climate-Resilience-Strategies-for-Buildings.pdf

FEMA GUIDELINES AND MANUALS

FEMA produces a set of guidelines for design, construction and maintenance to increase durability of buildings. These collections of best practices typically exceed minimum requirements of model building codes, standards, and local regulations. The best practices recommended in earlier FEMA guides have since been implemented into building codes via standards, so these guidelines portend the future of regulatory changes to encourage more climate resilient buildings. See especially the following:

- FEMA P-55 (Volumes I and II, 2011) Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Construction, and Maintaining Residential Buildings in Coastal Areas
- FEMA P-259 (2012) Engineering Principles and Practices for Retrofitting Floodprone Buildings
- FEMA P-312 (2014) Homeowners' Guide to Retrofitting: Six Ways to Protect Your Home From Flooding
- FEMA P-424 (2010) Design Guide to Improve School Safety in Earthquakes, Floods, and High Winds
- FEMA P-499 (2010) Home Builder's Guide to Coastal Construction: Technical Fact Sheet Series
- FEMA P-550 (2009) Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations
- FEMA P-804 (2010) Wind Retrofit Guide for Residential Buildings
- FEMA P-936 (2013) Floodproofing Non-residential Buildings

ICC 600 (2014) STANDARD FOR RESIDENTIAL CONSTRUCTION IN HIGH-WIND REGIONS

This standard specifies methods to provide wind resistant designs and construction details for residential buildings in regions where design wind speeds are 120 to 180 mph.

http://shop.iccsafe.org/icc-600-2014-standard-for-residential-construction-in-high-wind-regions-1.html

ATC (2009) DESIGN GUIDE 2: BASIC WIND ENGINEERING FOR LOW-RISE BUILDINGS

This is a step-by-step guide illustrating proper application of wind load provisions for low-rise buildings.

http://shop.iccsafe.org/atc-design-guide-2-basic-wind-engineering-for-low-rise-buildings.html

IPCC (2014) CLIMATE CHANGE 2014: MITIGATION OF CLIMATE CHANGE

This report covers the energy consumption and emissions of the buildings sector, including both new and existing buildings. Discussions include Passive House standards, commissioning, net zero energy buildings (NZEB), envelope upgrades, equipment and control systems upgrades, lighting retrofits, alternative energy sources, building material, behavioral adjustments, and policy instruments.

http://www.ipcc.ch/report/ar5/wg3/

IPCC (2014) CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY

This report examines issues related to urban areas, including a section dedicated to adapting housing and urban settlements. A general discussion covers adapting to extreme heat (e.g., passive cooling and natural ventilation) and disaster-preparedness measures (e.g., cooling centers).

http://www.ipcc.ch/report/ar5/wg2/

EPA ENERGY SAVINGS PLUS HEALTH: INDOOR AIR QUALITY GUIDELINES FOR SCHOOL BUILDING UPGRADES

This was written to help manage the relationships between energy efficiency upgrade activities and indoor air quality. It is primarily for school administrative personnel, and secondarily for design professionals.

https://www.epa.gov/sites/production/files/2014-10/documents/energy_savings_plus_health_guideline.pdf

EPA (2016) ENERGY SAVINGS PLUS HEALTH: INDOOR AIR QUALITY GUIDELINES FOR MULTIFAMILY BUILDING UPGRADES

This was written for construction professionals working on energy-focused residential upgrades.

https://www.epa.gov/sites/production/files/2016-02/documents/esh_multifamily_building_upgrades_508c_02_09_2016.pdf

USGBC/U MICHIGAN (2011) GREEN BUILDING AND CLIMATE RESILIENCE: UNDERSTANDING IMPACTS AND PREPARING FOR CHANGING CONDITIONS

This report summarizes the impacts of climate change at various scales and suggests 81 adaptation strategies.

https://www.usgbc.org/resources/green-building-and-climate-resilience-understanding-impacts-and-preparing-changing-conditi

NIST (2016) COMMUNITY RESILIENCE PLANNING GUIDE FOR BUILDINGS AND INFRASTRUCTURE SYSTEMS

This provides guidance at the community scale for long-term planning and disaster-recovery planning.

https://www.nist.gov/topics/community-resilience/community-resilience-planning-guide

IOM (2011) INSTITUTE OF MEDICINE REPORT ON CLIMATE CHANGE, THE INDOOR ENVIRONMENT, AND HEALTH

This report provides a comprehensive analysis of the impact of climate change on public health and the quality of indoor environments. It includes general guidelines to address the health-related impacts of climate change.

BSA (2013) BUILDING RESILIENCE IN BOSTON

This guide contains a set of strategies for property owners to reduce their vulnerability to climate change, and policies and programs that policy makers can use to spur such efforts.

https://www.architects.org/sites/default/files/Building_Resilience_in_Boston_SML_0.pdf

FEMA (2013) HURRICANE SANDY MITIGATION ASSESSMENT TEAM REPORT

This report evaluates the damage from Superstorm Sandy. It offers conclusions and recommendations for more resilient performance of low-, mid-, and high-rise buildings, critical facilities, and historic properties in the greater New York City area.

https://www.fema.gov/media-library/assets/documents/85922

ENTERPRISE COMMUNITY PARTNERS (2015) READY TO RESPOND: STRATEGIES FOR MULTIFAMILY BUILDING RESILIENCE

This is a collection of 19 strategies for building owners to make their properties more resilient to extreme weather events.

https://www.enterprisecommunity.org/resources/ready-respond-strategies-multifamily-building-resilience-13356

HHS (2014) PRIMARY PROTECTION: ENHANCING HEALTH CARE RESILIENCY FOR A CHANGING CLIMATE

This framework addresses the resilience of the health care infrastructure to extreme weather risks. One of the framework's five elements is "land use planning, building design, and regulations." Strategies relate to land use, siting, and landscape; transportation and site access; building regulations; building envelope and vertical transportation systems; and passive survivability.

https://toolkit.climate.gov/sites/default/files/SCRHCFI%20Best%20Practices%20Report%20final2%202014%20Web.pdf

NYC PLANNING (2013) COASTAL CLIMATE RESILIENCE: URBAN WATERFRONT ADAPTIVE STRATEGIES

This document provides specific guidance for resilient development in New York City coastal areas.

https://www1.nyc.gov/assets/planning/download/pdf/plans-studies/sustainable-communities/climate-resilience/urban_waterfront.pdf

NYC PLANNING (2013) A STRONGER, MORE RESILIENT NEW YORK

This is a comprehensive plan for New York City, including climate change adaptations and mitigation activities, some of which involve buildings. It discusses initiatives for new construction, retrofits of existing construction, and community economic recovery.

https://www.nycedc.com/resource/stronger-more-resilient-new-york

GLOBAL COOL CITIES ALLIANCE (2012) A PRACTICAL GUIDE TO COOL ROOFS AND COOL PAVEMENTS

This is a technical guide on cool roofs and pavements for facilities managers and building professionals.

https://www.coolrooftoolkit.org/wp-content/pdfs/CoolRoofToolkit_Full.pdf

AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY (2014) COOL POLICIES FOR COOL CITIES: BEST PRACTICES FOR MITIGATING URBAN HEAT ISLANDS IN NORTH AMERICAN CITIES

This report gathers the experiences of several North American cities into a set of policies, programs, and practices useful for mitigating urban heat islands.

https://aceee.org/research-report/u1405

GEORGETOWN CLIMATE CENTER (2012), ADAPTING TO URBAN HEAT: A TOOLKIT FOR LOCAL GOVERNMENTS

This report discusses the benefits, challenges, outcome criteria, governance criteria, and policy tools related to cool roofs, green roofs, cool pavements, and urban forestry.

https://kresge.org/sites/default/files/climate-adaptation-urban-heat.pdf

C3 LIVING DESIGN PROJECT (2015) RELI RESILIENCY ACTION LIST + CREDIT CATALOG

This is a detailed and robust checklist of actions to make design projects more resilient.

http://online.anyflip.com/zyqc/ojoi/mobile/index.html

FEMA HAZUS-MH

This is a GIS-based methodology developed by the Federal Emergency Management Agency (FEMA) to estimate and spatially map potential losses of life and property from earthquakes, hurricane winds, and floods.[4]

https://www.fema.gov/hazus

NY-CHPS VERSION 1.1: HIGH PERFORMANCE SCHOOLS GUIDELINES

This document provides a framework for sustainable school planning, design, construction and operation. Based on a national precedent framework, it is tailored to the New York State context, including climate and code requirements.

http://www.p12.nysed.gov/facplan/NYSERDA/NY-CHPS_Ver_1-1_Feb_07.pdf

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1. https://health2016.globalchange.gov/downloads
2. http://www.aiacc.org/2016/10/26/aia-code-ethics-professional-conduct/
3. https://www.ashrae.org/about/governance/code-of-ethics
4. https://www.fema.gov/hazus-mh-overview

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University of Buffalo
School of Architecture and Planning

121 Hayes Hall
Buffalo, NY 14214-8030

local: 716-829-5900
fax: 716-829-2297

ap-info@buffalo.edu
ap.buffalo.edu

New York State
Energy Research and
Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

State of New York
Andrew M. Cuomo, Governor

New York State Energy Research and Development Authority
Richard L. Kauffman, Chair | Alicia Barton, President and CEO

University at Buffalo School of Architecture and Planning
Robert G. Shibley, Professor and Dean