Climate Resilience Strategies for Buildings in New York State

Final Report | Report Number 18-11 | June 2018

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

University at Buffalo School of Architecture and Planning

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Vision Statement:

Serve as a catalyst – advancing energy innovation, technology, and investment; transforming New York's economy; and empowering people to choose clean and efficient energy as part of their everyday lives.

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NOTICE

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List of Abbreviations

AIA	American Institute of Architects
APA	American Planning Association
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BFE	Base Flood Elevation
Btu	British Thermal Unit
DEC	New York State Department of Environmental Conservation
DHSES	New York State Department of Homeland Security and Emergency Services
DOH	New York State Department of Health
DOT	New York State Department of Transporation
FEMA	Federal Emergency Management Agency
FEMP	Federal Emergency Management Program
GIS	Geographic Information System
HVAC	Heating, Ventilation, and Air-Conditioning
IBHS	Insurance Institute for Business & Home Safety
IDEA Center	Center for Inclusive Design and Environmental Access
IECC	International Energy Conservation Code
IPM	Integrated Pest Management
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
NARCCAP	North American Regional Climate Change Assessment Program
NCA	National Climate Assessment
NFIP	National Flood Insurance Program
NFPA	National Fire Protection Agency
NIBS	National Institute of Building Science
NIPP	National Infrastructure Protection Plan
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
NYC	New York City
NYCCSC	New York Climate Change Science Clearinghouse
NYPH	New York Passive House
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
NYU	New York University
PRISM	Partnerships for Regional Invasive Species Management
SUNY	State University of New York
US DHS	United States Department of Homeland Security
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
US GSA	United States General Services Administration
USGBC	United States Green Building Council
USGS	United States Geological Survey

Image Credits

Introduction

Although climate has always been a key consideration for the design, construction, and operation of buildings, many professionals assume that future weather conditions will be similar to what was experienced in the past. Increased exposure to climate-related hazards like Superstorm Sandy[1] and 'Snowvember'[2] will require practitioners in New York State to reevaluate their standard practices. Changing climate conditions,[3] including increases in temperature and precipitation, the likelihood of climate hazard events such as hurricanes and tropical storms, flooding, severe storms, winter storms, wildfire, sea-level rise, heat waves, and pest infestations. Increasing the resilience of buildings in New York State can reduce the negative impacts of these hazards.

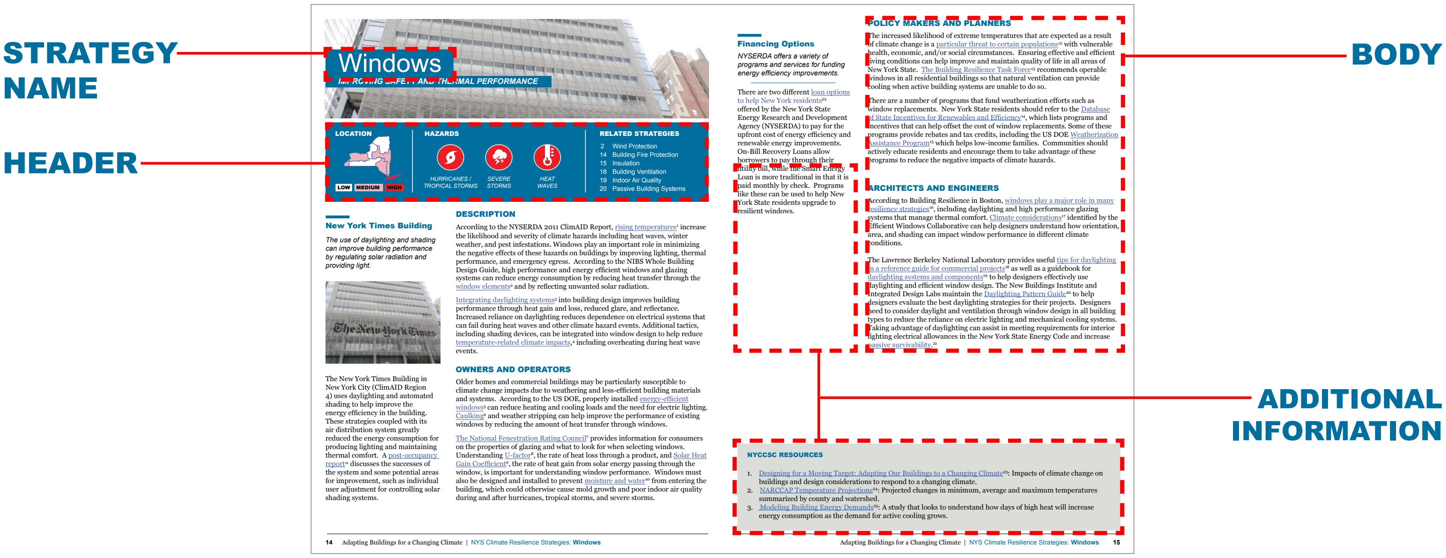
'Climate Resilience Strategies' is an umbrella term used to describe the changes made to a building to improve its performance during climate hazard events. The implementation of strategies, however, includes more than the physical application of a material, technique, or technology. Other actions, including planning, costing, the development of standards, operations, and maintenance all play an equally important role in the application of building resilience. As a result, the resilience process is one that involves contributions from multiple individuals. This document was created to assist in the implementation of these climate resilience strategies in New York State by making useful resilience information accessible.

This Climate Resilience Strategies for Buildings in New York State report builds upon existing documents that assist in the implementation of resilience strategies, including the USGBC Green Buildings and Climate Resilience Document[4] (2011), the USGBC Building Resiliency Task Force Proposals Document[5] (2013), and the Enterprise Green Communities Strategies for Multifamily Building Resilience[6] document (2015). These documents are generally geared towards a particular audience. For example, the 2011 USGBC report is focused on providing information for building professionals, including architects and engineers, while the 2013 USGBC report is focused on broad recommendations useful to policymakers and planners.

This report uses the specific information provided in existing strategy documents and expands the offering to provide general descriptions of climate resilience strategies that are accessible to all audiences. This document aims to give readers an overview of climate resilience strategies, while clickable links within the text allow readers to dig deeper and access more specific information.

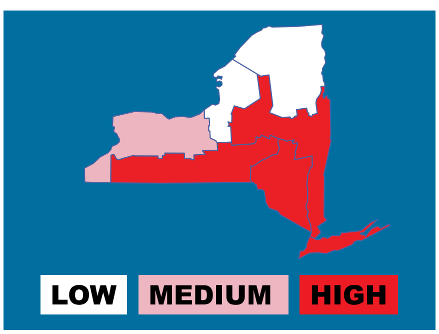
All those involved with the building sector, including building owners and operators, policy makers, planners, architects, and engineers, should play a role in the implementation of climate resilience. However, each will approach resilience in a different way, and as a result, will require different types of information. For example, an architect may need specific design details, while a building owner may want to explore costs and benefits. This guide attempts to bridge this gap by providing links to information that would be most applicable to each of these different groups all within one document. As a result, this document presents an overview of 25 resilience strategies that are effective at improving the resilience of buildings in New York State.

Strategy Layout



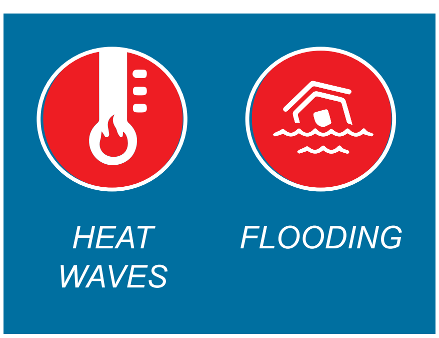
HEADER

This document identifies 25 strategies that can help improve the climate resilience of buildings in New York State. Those involved with the building sector, including building owners and operators, policymakers, planners, architects, and engineers, can use this document as a guide towards understanding how to implement climate resilience strategies. Each strategy is formatted on a two-page spread that is headed by information, including suggested locations, applicable hazards, and related strategies. These three pieces of information help readers understand the relationship between the strategies and the anticipated effects of climate change.



LOCATION

Each ClimAID region[3] of New York State experiences climate change differently, and as a result, should apply different resilience strategies. To provide guidance on where strategies should be applied, the location icon exhibits high, medium, and low values for each region. For example, building flood protection has high values in ClimAID Regions 2, 3, 4, and 5 because these regions have historically experienced the highest frequency of flooding events.



HAZARDS

Each climate resilience strategy is applicable to multiple climate hazards. If readers are using this document to learn how they can improve their building's flood resilience, they can look at this icon to identify which strategies are most effective against flooding. Each strategy lists up to three most applicable hazards: hurricanes/tropical storms, flooding, severe storms, winter storms, wildfire, sea level rise, heat waves, and pest infestation. Many strategies, however, may be applicable to more than three hazards. The information within the strategy write-up can help the reader determine other hazards to which the strategy may be applicable.

Windows
Roof Coverings
Urban Heat Island
Building Ventilation
Passive Building Systems
Active Building Systems

RELATED STRATEGIES

This final section of information helps identify the relationship between the strategies discussed in the document. Climate resilience is most effective when more than one strategy is applied, so readers may use this information to pair strategies with one another. For example, if readers are trying to improve their building's resilience to heat waves, they may begin with the windows strategy and then move on to other related strategies including insulation, building ventilation, and passive building systems.

BODY

The body of each two-page spread is divided into four sections: Description, Owners and Operators, Policy Makers and Planners, and Architects and Engineers. Each section provides links to reports, studies, guides, and other sources of information that may help the reader develop an understanding of the strategy and how it may be applied. The purpose of this document is to offer readers an introduction to each strategy by providing links to sources of information that go into more depth about how the strategy can be facilitated or applied. Each strategy is complex and could be applied in different ways that depend on individual conditions and perspective. As a result, the information is organized within the four sections to help readers locate the information that is most applicable to them. All readers should begin by reading the description to understand the basics of the strategy, and then they may jump to their respective section. Readers may also read through all four sections to develop a complete understanding of each strategy.

DESCRIPTION

This section provides a basic introduction of the strategy and its components by describing anticipated climate and weather conditions that necessitate the strategy and basic definitions with references. All readers, both professional and non-professional, should review this section to understand the basic goals and concepts of the strategy.

OWNERS AND OPERATORS

This section is written for those who manage building space, whether they are owners, renters, or maintenance providers. Information in this section includes additional strategy definitions, implementation suggestions, and potential professional contacts.

POLICYMAKERS AND PLANNERS

The information in this section is aimed at any person who is in charge of writing and enforcing regulations, codes, or plans. Readers can use the information in this section to direct and justify resilience policy, update existing building codes, and initiate cost share programs or any other action that facilitates the implementation of climate resilience.

ARCHITECTS AND ENGINEERS

This section is meant for any person involved with the design process of buildings and/or building systems. Technical information, including performance metrics, key design considerations, specifications, and drawing details, is supplied in this section to provide designers with the information they need to put resilience into practice.

ADDITIONAL INFORMATION

Additional information is provided for each strategy to help readers better understand what the strategies can be applied to, why they are necessary, and where they have been successful in the past. All readers can use this information to expand their strategy research into other projects and studies. The examples and sources provided in this section represent only a small portion of resilience efforts in and around New York State. Readers are encouraged to use these examples as a starting point for discovering additional examples that may help them with their individual projects.

NYCCSC RESOURCES

Much like this document, NYSERDA's recently released New York State Climate Change Science Clearinghouse (NYCCSC)[2] is a source of information that provides reports, articles, plans, and other climate-related resources that help professionals and non-professionals identify problems, investigate solutions, and take action. This document lists for each strategy applicable reports, articles, plans, and other sources that are available through the NYCCSC to help link existing resilience efforts in New York State.

CASE EXAMPLE

Each strategy layout includes two case examples that describe either a past climate hazard event to which the strategy would be applicable, or an example strategy implementation. Historic New York State storms like Superstorm Sandy, Tropical Storm Lee, and Snowvember help justify resilience strategies. Example projects describe how some buildings in New York State are already adapting to climate change.

STRATEGY ORDER

In this document, the strategies are sorted by the primary hazard they address. However, for all strategies, at least one primary and one secondary hazard are listed. In addition to the six hazards listed below, many strategies also increase resilience to rising sea levels and winter storms.

Hurricanes/Tropical Storms

- Windows
- Wind Protection
- Emergency Management
- Redundant Building Systems

Flooding

- Neighborhood Flood Protection
- Building Flood Protection
- Building Systems Flood Protection
- Building Foundations
- Green Infrastructure
- Gray Infrastructure

Severe Storms

- Roof Covering
- Roof Drainage

Wildfire

- Neighborhood Fire Protection
- Building Fire Protection

Heat Waves

- Insulation
- Neighborhood Development
- Urban Heat Island
- Building Ventilation
- Indoor Air Quality
- Passive Building Systems
- Active Building Systems
- Building Operations
- Potable Water Systems
- Reclaimed Water Systems

Pest Infestation

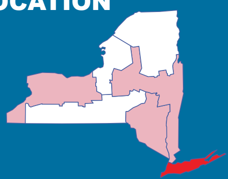
- Integrated Pest Management

Resilience Strategies

Windows

IMPROVING SAFETY AND THERMAL PERFORMANCE

LOCATION



LOW | MEDIUM | HIGH

HAZARDS

HURRICANES / TROPICAL STORMS | *SEVERE STORMS* | *HEAT WAVES*

RELATED STRATEGIES

- Wind Protection
- Building Fire Protection
- Insulation
- Building Ventilation
- Indoor Air Quality
- Passive Building Systems

New York Times Building

The use of daylighting and shading can improve building performance by regulating solar radiation and providing light.

The New York Times Building in NYC (ClimAID Region 4) uses daylighting and automated shading to help improve the energy efficiency in the building. These strategies, coupled with its air distribution system, greatly reduced the energy consumption for lighting and maintaining thermal comfort. A post-occupancy report[11] discusses the successes of the system and some potential areas for improvement, such as individual user adjustment for controlling solar shading systems.

DESCRIPTION

According to Responding to Climate Change in New York State, rising temperatures[1] increase the likelihood and severity of climate hazards including heat waves, winter weather, and pest infestations. Windows play an important role in minimizing the negative effects of these hazards on buildings by improving lighting, thermal performance, emergency egress, and building occupant comfort. According to the NIBS Whole Building Design Guide, high-performance, energy-efficient windows and glazing systems can reduce energy consumption by reducing heat transfer through the window elements[2] and by reflecting unwanted solar radiation.

Integrating daylighting systems[3] into building design improves building performance through heat gain and loss, reduced glare, and reflectance. Increased reliance on daylighting reduces dependence on electrical systems that can fail during heat waves and other climate hazard events. Additional tactics, including shading devices, can be integrated into window design to help reduce temperature-related climate impacts,[4] including overheating during heat waves.

OWNERS AND OPERATORS

Older homes and commercial buildings may be particularly susceptible to climate change impacts due to less efficient building materials and systems. According to the DOE, properly installed energy efficient windows[5] can reduce heating and cooling loads and the need for electric lighting. Caulking[6] and weather stripping can help improve the performance of existing windows by reducing the amount of heat transfer through windows.

The National Fenestration Rating Council[7] provides information for consumers on the properties of glazing and what to look for when selecting windows. Understanding U-factor,[8] the rate of heat loss through a product, and Solar Heat Gain Coefficient,[9] the rate of heat gain from solar energy passing through the window, is important for understanding window performance. Windows must also be designed and installed to prevent moisture and water[10] from entering the building, which could otherwise cause mold growth and poor indoor air quality during and after hurricanes, tropical storms, and severe storms.

Financing Options

NYSERDA offers a variety of programs and services for funding energy efficiency improvements.

There are two different loan options to help New York residents[22] pay the upfront cost of energy efficiency and renewable energy improvements. Offered by NYSERDA, On-Bill Recovery Loans allow borrowers to pay through their utility bill, while the Smart Energy Loan is paid monthly by check. Programs like these can help New York State residents upgrade to higher quality windows.

POLICYMAKERS AND PLANNERS

The increased likelihood of extreme temperatures that are expected as a result of climate change is a particular threat to vulnerable populations[12] with pre-existing health, economic, and/or social concerns. Ensuring effective and efficient living conditions can help improve and maintain quality of life in all areas of New York State. The NYC Building Resilience Task Force[13] recommends operable windows in all residential buildings so that natural ventilation can provide cooling when active building systems are unable to do so.

There are a number of programs that fund weatherization efforts such as window replacements. Refer to the Database of State Incentives for Renewables and Efficiency,[14] which lists programs and incentives that can help offset the cost of window replacements. Some of these programs provide rebates and tax credits, including the DOE Weatherization Assistance Program,[15] which helps low-income families. Communities should actively educate residents and encourage them to take advantage of these programs to reduce the negative impacts of climate hazards.

ARCHITECTS AND ENGINEERS

According to Building Resilience in Boston, windows play a major role in many resilience strategies,[16] including daylighting and high-performance glazing systems that manage thermal comfort. Climate considerations[17] identified by the Efficient Windows Collaborative can help designers understand how orientation, area, and shading can impact window performance in different climate zones.

The Lawrence Berkeley National Laboratory provides useful tips for daylighting in a reference guide for commercial projects[18] as well as a guidebook for daylighting systems and components[19] to help designers effectively use daylighting and efficient window design. The New Buildings Institute and Integrated Design Labs maintain the Daylighting Pattern Guide[20] to help designers evaluate the best daylighting strategies for their projects. Designers need to consider daylight and ventilation through window design in all building types to reduce the reliance on electric lighting and mechanical cooling systems. Taking advantage of daylighting can assist in meeting requirements for interior lighting electrical allowances in the New York State Energy Code and increase passive survivability.[21]

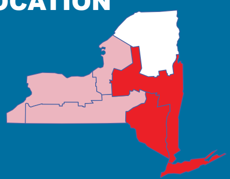
NYCCSC RESOURCES

1. Designing for a Moving Target: Adapting Our Buildings to a Changing Climate:[23] Impacts of climate change on buildings and design considerations to respond to a changing climate.
2. NARCCAP Temperature Projections:[24] Projected changes in minimum, average, and maximum temperatures summarized by county and watershed.
3. A New Modeling Approach to Forecast Building Energy Demands During Extreme Heat Events in Complex Cities:[25] A study describing how heat waves may increase energy consumption as demand for cooling grows.

Wind Protection

SAFETY FROM HIGH WINDS AND AIRBORNE DEBRIS

LOCATION



LOW | MEDIUM | HIGH

HAZARDS

HURRICANES / TROPICAL STORMS

SEVERE STORMS

WINTER STORMS

RELATED STRATEGIES

Windows
Building Foundations

DESCRIPTION

This strategy helps buildings withstand extreme winds common in climate hazards including hurricanes, and severe storms such as tropical and winter storms. The frequency and intensity of hurricanes[1] have increased since 1980, putting buildings in coastal areas at an increased risk of significant structural damage. The third National Climate Assessment states that other extreme wind events, including nor'easters and thunderstorms, may increase in frequency and intensity,[2] affecting those who live in non-coastal areas.

Although extreme wind events such as hurricanes and tropical storms do not occur throughout New York State, gusts of wind as low as 30 miles per hour can cause serious building damage throughout the State.[3] Damage can be caused by the direct force of the wind and by the debris that has been picked up by the wind, including building materials, traffic signs, and equipment. Proactive efforts that improve building resilience can help reduce the amount of damage these events inflict on buildings in all regions of New York State.

OWNERS AND OPERATORS

When addressing wind protection, homeowners should first review FEMA's Avoiding Wind Damage Checklist[4] and assess the existing quality of their home. After understanding what improvements can be made, homeowners should then review the documents in FEMA's Protect Your Property from High Winds[5] collection to learn more about how to make improvements. It is also worthwhile to review FEMA's Wind Retrofit Guide for Residential Buildings[6] before starting a wind protection renovation.

FEMA has multiple resources that help business owners improve wind protection in their buildings. In addition to the sources listed above, the Protecting Your Home or Small Business from Disasters[7] document can help guide improvements, while the Benefit-Cost Analysis Tool[8] can help analyze the benefits and costs of climate resilience strategies. Understanding the areas that need improvement, the strategies that can provide protection, and the potential costs of improvement is an important part of any resilience effort.

The Adirondack Derecho

Extreme wind events can cause significant damage in a short period of time.

In July 1995, a very severe wind storm crossed Upstate New York and caused significant building damage. Wind speeds were estimated to be 100 miles per hour or greater[9] in some areas of Jefferson and St. Lawrence Counties (Region 7). According to NOAA, this derecho, or fast-moving wind storm, caused almost $190 million worth of damage to structures and vehicles in only a four-hour period.

POLICYMAKERS AND PLANNERS

Policy makers and planners within communities that experience severe windstorms in all regions of New York State should reference FEMA's Local Officials Guide for Coastal Construction.[10] Section 2.2 of this document discusses wind hazards such as windborne debris, rainfall penetration, and positive and negative pressure buildup that can lead to roof uplift and building failure in all areas that experience high winds, not just those in coastal areas. Once communities understand the local risks and impacts of extreme wind events, they can incorporate effective wind resilience into local hazard mitigation plans[11] to guide both preparation and response efforts.

FEMA offers a number of grant programs[12] that can assist policy makers and planners in educating and preparing communities for the impacts of high-wind events. Individual homeowners cannot directly apply to FEMA for funding, so local governments and officials must apply[13] on their behalf. Once funding is established, Chapter 15 of FEMA's Coastal Construction Manual[14] describes wind retrofit mitigation packages that can assist resilience improvements in all wind-prone areas of New York State.

ARCHITECTS AND ENGINEERS

Designers can form a better understanding of the wind loads experienced by buildings with the AIA's Buildings at Risk: Wind Design Basics for Practicing Architects[15] guide. The document provides recommended details for both residential and commercial low-, mid-, and high-rise buildings developed from wind impact studies and material reviews. National standards including ASTM E 1886 13a, ASTM E 1996 14a, ASTM E 2112-07 (2016), and ASTM E 330[16] provide performance expectations for building elements exposed to wind impacts such as windows, exterior doors, skylights, and garage doors.

Other technical resources for contractors and designers include the Resilient Design Guide for High-Wind Wood Frame Construction,[17] which provides information on how to make residential buildings more resilient to high winds. Critical facilities such as hospitals, schools, fire and police stations, and emergency operation centers are instrumental in ensuring the safety and security of communities during climate hazard events, and they should be constructed to provide safety during high-wind events.[18] For use in retrofitting both residential buildings and critical facilities, FEMA completed a *Mitigation Assessment Team Report*[19] after Superstorm Sandy that documents building failures due to impacts such as high winds. The lessons learned from Superstorm Sandy can help building professionals understand how to better prepare the building stock for high winds and airborne debris.

NYS Code Amendments

Building codes must be constantly updated to reflect anticipated wind speed projections.

The New York City Special Initiative for Rebuilding and Resilience report titled *A Stronger, More Resilient New York*[20] recommends that local policy makers mandate climate resilience in building design. Initiative 6 calls for amendments to the New York City Building Code and the completion of studies to improve wind resilience in new and substantially improved buildings. The city also recognizes that code minimums can withstand only Category 3 hurricane wind speeds and is looking to improve these requirements as part of the initiative.

NYCCSC RESOURCES

1. Monitoring and Understanding Changes in Extremes: Extratropical Storms, Winds, and Waves:[21] A scientific assessment examining cold season climate extremes in U.S. coastal regions.
2. National Hurricane Center:[22] Source for up-to-date information on hurricanes.

Emergency Management

BUILDING COMMUNITY RESILIENCE BEFORE DISASTER STRIKES

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

HURRICANES / TROPICAL STORMS

WINTER STORMS

FLOODING

RELATED STRATEGIES

Neighborhood Flood Protection
Neighborhood Fire Protection
Building Fire Protection
Neighborhood Development
Urban Heat Island
Potable Water Systems

DESCRIPTION

While emergency management is crucial to all hazards, it applies to hurricanes, winter storms, and floods in particular due to their severity and increased likelihood[1] as a result of climate change. Emergency management[2] can help prepare communities for such events and reduce the amount of damage they cause by preparing the community for the impacts of climate hazard events. The Strategic Foresight Initiative explains that climate change is a necessary concern for emergency managers[3] as they face the critical challenges of climate hazards.

Emergency management is critically important in buildings that contain vulnerable populations.[4] Building occupants including school-aged children and the elderly may require additional assistance during emergencies, such as alternative evacuation routes, areas of refuge, and back-up supplies of food and medical equipment. Proper emergency management for all populations requires up-to-date information, redundant systems, and organization. These tactics are especially useful in dense urban areas[5] when high concentrations of the population may be exposed to a hazard. In these areas, access to supplies can be restricted during these hazard events, emphasizing a need for preparedness.

OWNERS AND OPERATORS

Homeowners and renters can be active participants in the emergency preparedness of their communities. The Citizen Preparedness Corps[6] provides information, training sessions, and preparedness kits to help reduce recovery time after hazard events. The New York State Office of Emergency Management also provides information and links for residents,[7] including the latest news and public alerts. Building owners, operators, and managers should align individual emergency responses with community responses, including response protocols and evacuation routes to ensure effective emergency management.

Since buildings often provide protection during climate hazard events, building owners and operators must ensure their buildings are prepared to respond. Buildings must be prepared to provide and protect critical life elements such as emergency food supplies,[8] which should be able to last for at least three days. FEMA has information on emergency food and water supplies[9] that provides guidance on how to prepare and protect supplies during extreme hazard events. Local planners and policy makers in New York State should develop cohesive emergency management plans that reflect and respond to the specific levels of sensitivity and exposure in their area.

Federal Transit Authority

Affecting one-third of the nation's riders, Superstorm Sandy was the greatest transit disaster in U.S. history.

In 2013, the Federal Transit Authority and FEMA signed a Memorandum of Agreement[10] outlining how to distribute federal assistance for public transportation after a Presidential Disaster Declaration has been made. Stemming from the unprecedented damage to one of the world's most used infrastructure systems caused by Superstorm Sandy, this agreement aims to reduce recovery time in areas where public transportation is a necessity for everyday life.

NYS Thruway Authority

Stranded vehicles on highways during major snow storms create problems for snow removal crews.

Following the 2014 “Snowvember” storm in Western New York (ClimAID Region 1), where hundreds of vehicles and people were stranded on highways after more than six feet of snowfall, the New York State Thruway Authority implemented 16 emergency gates at entrances to Interstate-190 in Erie County. The purpose of the gates is to remove all traffic from highways during violent storms to improve the efficiency of snow removal and significantly reduce community recovery time. The New York State Department of Transportation has installed additional gates along U.S. Route 219 and other local highways throughout Erie County.[22]

POLICYMAKERS AND PLANNERS

FEMA provides a Whole Community Approach Guide[11] that can help planners understand the complex issues associated with emergency management. This document can be paired with FEMA’s Comprehensive Preparedness Guide,[12] which identifies critical processes and actions that should be included in all emergency management plans including plan integration and plan maintenance. When developing these plans, local planners and policy makers should refer to the New York State Comprehensive Emergency Management Plan[13] to ensure their plan aligns with current State-level response protocols.

Planners should also understand the important roles certain building types play in responding to emergencies and their potential, by exceeding the minimum building code requirements, to protect vulnerable populations, including children and the elderly. As a building type present in all urban and rural communities, schools can serve as centers of refuge during emergencies. NOAA developed a guide for developing school weather emergency plans[14] that could be used for reviewing and updating existing emergency plans and building codes. The American Health Care Association and the National Center for Assisted Living provide similar information that guides nursing homes[15] as the elderly prepare to shelter in place during weather emergencies. Public safety officials on local, State, and national levels are able to broadcast emergency alerts[16] and information through Wireless Emergency Alerts, the Emergency Alert System, and NOAA Weather Radio.

ARCHITECTS AND ENGINEERS

One of the critical roles building professionals play in managing responses to emergencies is the organized execution of building assessments[17] after extreme hazard events. After critical hazard events, FEMA develops Mitigation Assessment Team[18] reports in order to gain a better understanding of how buildings and systems were able to respond. Local professionals should consider performing similar assessments after small and medium-sized storms to develop more localized information on how buildings could perform better. The Red Cross has a Detailed Evaluation Safety Assessment Form[19] that can be used to develop a checklist that assesses damage experienced by buildings.

After performing assessments, building professionals should respond to damages that were recorded with applicable resilience strategies that strengthen areas that have failed. The United States Department of Homeland Security developed a National Infrastructure Protection Plan[20] that addresses the damages assessed after extreme hazard events. The AIA also provides additional disaster assistance[21] for responding to and preparing for extreme hazard events.

NYCCSC RESOURCES

1. Philadelphia Office of Emergency Management:[23] Useful information for residents on responding to floods, extreme heat, hurricanes, and droughts.
2. Emergency Managers’ Guide to Communicating Coastal Storm Risks:[24] A resource that explains the importance of communication before, during, and after climate hazard events.
3. Finding a Cooling Center:[25] The New York City Office of Emergency Management’s website for assisting residents during periods of extreme heat.

Redundant Building Systems

PROVIDING BACKUP FOR VITAL BUILDING SYSTEM OPERATIONS

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

HURRICANES / TROPICAL STORMS

HEAT WAVES

WINTER STORMS

RELATED STRATEGIES

Building Systems Flood Protection
Active Building Systems
Building Operations
Potable Water Systems

DESCRIPTION

Climate change has the potential to severely affect building and infrastructural systems through extreme climate hazards including winter weather, heat waves, and hurricanes. Responding to Climate Change in New York State explains there is an urgent need to understand the factors that affect the vulnerability of residents, the economy, and ecosystems.[1] Ensuring resilient building systems through redundancy increases the likelihood that buildings will be able to support these vulnerabilities and function during climate hazard events.

The purpose of redundancy is to ensure that critical building systems such as electrical power, wastewater processing, food and potable water, and heating and cooling remain available in the event that a system is compromised. Redundancy may reduce overall efficiency, but it is necessary to increase resilience[2] and prevent negative impacts from system failures. According to the USGBC Green Building and Climate Resilience[3] report, redundant systems including multiple compressors, boilers, and batteries improve resilience by decreasing the likelihood of complete system failure.

OWNERS AND OPERATORS

Building owners and operators have a responsibility to ensure their buildings are safe and habitable for occupants and tenants. The Building Resiliency Task Force explains that power failures can be detrimental to potable water availability[4] in buildings that rely on pumps to supply higher floors, such as in New York City. Faucets that use city water main pressure located in common spaces can be made available to residents if a power failure disables individual supply pumps. According to Building Resilience in Boston, critical system back-up maintenance[5] should be prioritized in building design and in operation and maintenance plans, completed with backup renewable power generation and battery systems to ensure that systems can respond to local climate issues.

According to the Resilient Design Institute, owners and operators should seek local solutions and expertise to solve problems.[6] Implementing resilient strategies is an incremental process, so owners should implement with professional assistance what is feasible in the short term and then work to systematically improve resilience through a series of planned steps. This is important for redundant systems because of their potentially high upfront costs.

Superstorm Sandy

Redundant systems reduced the recovery time for some offices in New York City.

Offices with protected backup systems and equipment had shorter downtimes after Superstorm Sandy than offices that left their systems and equipment vulnerable to flooding. A PlaNYC report[7] produced after the storm, titled A Stronger, More Resilient New York, identified one office that was equipped with redundant systems including raised generators and standby pumps, and another office that did not have redundant systems. The office with redundant systems restored service within one day of the storm, while the other office remained out of service for nearly two weeks.

The Resilient Power Hub

Back-up electrical systems can reduce or eliminate recovery time following climate hazard events.

The Resilient Power Hub is an on-site energy generation system[15] that provides power through the combined use of solar photovoltaic energy storage and cogeneration for use as an emergency energy supply. The system reduces building energy costs by offsetting electric and gas energy consumption while providing energy to critical building systems during power outages. The power hub received prototype funding from the New York City Economic Development Corporation and is currently being used in three NYC commercial facilities.

POLICYMAKERS AND PLANNERS

Policy makers and planners can improve community-wide resilience by using policy to support redundancy and universal design in critical facilities. FEMA's Superstorm Sandy in New Jersey and New York Building Performance Observations, Recommendations, and Technical Guidance explains how disruptive large storms can be[8] by describing how hospitals were forced to close after losing mechanical equipment to flooding. Enacting policies that encourage redundancy in building systems, including a requirement for providing alternative energy sources,[7] will help critical facilities, such as hospitals and emergency response centers, remain operational during climate hazard events.

Universally designed urban space can also help make communities more resilient by taking the needs of pedestrians, cyclists, automobile drivers, and transit users into account at the same time in order to create redundant evacuation and emergency service routes. To assist in this effort, the IDEA Center at the University at Buffalo released a resource to help communities evaluate complete streets initiatives[9] that can help add redundant means of travel along evacuation routes. Other IDEA resources, including the Universal Design New York[10] document, can help professionals make their cities universally accessible[11] and improve evacuation and emergency service routes within and around buildings.

ARCHITECTS AND ENGINEERS

Redundant building systems reduce the likelihood of a building shutdown and provide the opportunity to repair one system while the other is being maintained. The Resilient Design Institute lists strategies for more resilient building systems,[6] including reducing the dependence on complex building controls and systems and allowing for manual overrides during power outages. To ensure all building occupants have access to building systems, the IDEA Center at the University at Buffalo published resources for designers that provide evidence-based information[12] that may not be covered by accessibility standards, including universal access to building system controls.

FEMA's Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability describes strategies for including redundancy in building systems.[13] FEMA also released a Design Guide for Improving Critical Facility Safety from Flooding and High Winds,[14] which describes redundant building systems strategies, including multiple power feeds that allow for maintenance and repair without disruption even during climate hazard events. These guides can help building professionals include redundant systems in building design and operation.

NYCCSC RESOURCES

1. Rebuild by Design:[16] A pioneering program with new ways to design, fund, and implement resilient strategies and projects.
2. Electrical Blackouts: A Systemic Problem:[17] An article on the causes of electrical blackouts and what can be done to reduce their frequency.

Neighborhood Flood Protection

PROTECTING NEIGHBORHOODS DURING FLOOD EVENTS

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

FLOODING

RISING SEA LEVELS

HURRICANES / TROPICAL STORMS

RELATED STRATEGIES

Emergency Management
Building Flood Protection
Building Systems Flood Protection
Green Infrastructure
Gray Infrastructure
Neighborhood Development

DESCRIPTION

Flooding[1] is the most frequent and most costly natural disaster in the United States, accounting for up to 90% of all natural disasters. With a changing climate, current flood zone delineations are becoming less reliable, as 25% of all flood insurance claims come from low- to moderate-risk areas across New York State. Coastal and riverine flooding[2] seriously threatens environmental, social, and economic systems in New York State neighborhoods and cities.

Neighborhood flood protection helps communities prepare for the collective impacts of flooding hazard events. Extreme precipitation events and sea level rise[3] can overflow drainage systems and waterways with stormwater runoff, which can leave neighborhoods without access to emergency services and critical facilities. Rising sea levels also increase the severity of storm surge in coastal areas. The DEC[4] provides information on preparing for flooding in both coastal and riverine areas.

OWNERS AND OPERATORS

Knowing how to prepare and respond[5] is critical for securing safety during flood hazard events. FEMA provides guides to help business owners[6] and homeowners[7] identify flood preparedness actions such as disaster procedures, emergency communications plans, and insurance policies. Flood insurance can help reduce cost after a flooding hazard event, but using flood insurance maps[8] to develop an understanding of expected flood levels can assist in preemptively avoiding damage. However, with sea levels expected to rise, communities within coastal areas[9] and along the Hudson River[10] should consider using projected flood maps to more accurately represent future flooding conditions.

Neighborhood flood protection is achieved through a collective of individual flood resilience efforts. The reconstruction plan for Red Hook[11] is an example of how to use local community resources for resilience planning. Community members may also look towards the NOAA Sea Grant's Coastal Storm Awareness Program[12] and its funded projects that seek to identify, assess, and forecast flood response behaviors in coastal communities in and around New York State. Neighborhood flood protection begins with an understanding of the community's current flood vulnerability. NYSERDA offers a floodplain projection tool[15] that maps out potential zones and impacts of future sea level rise, storm surge, and flooding to help policy makers respond to these hazards.

Breezy Point Flooding

Flooding during Superstorm Sandy restricted emergency crews' access.

In 2012, more than 130 homes were burned to the ground in the Breezy Point neighborhood of Queens (ClimAID Region 4). Flooding from Superstorm Sandy blocked roads entering the neighborhood, which prevented emergency responders from accessing the fires and limiting the damage. In 2013, the New York Rising Community Reconstruction Program developed a reconstruction plan[13] that emphasizes flood preparedness and response through strategies such as establishing and fortifying safe buildings and evaluating response plans. Many communities in New York, including Breezy Point,[14] have since adopted the plan.

Flood Awareness Program

Awareness and understanding of risk can reduce negative impacts.

To help raise awareness about the issue of flooding in its community, the Town of Amherst, NY (ClimAID Region 1) sends annual letters[27] to residents who are vulnerable to the effects of flooding. These letters contain updated information on flood insurance, flood protection strategies, and warning systems. The letter also includes updated FEMA flood maps to ensure that all citizens are aware of potential flooding locations. These letters are provided by the Town of Amherst's Building Department,[28] which has a page dedicated to Flood Protection on its website. Amherst also takes part in the National Flood Insurance Program Community Rating System.

POLICYMAKERS AND PLANNERS

The EPA offers a Flood Resilience Checklist[16] to assess and improve flood resilience in areas that are at risk. The EPA also developed a guide that addresses smart growth approaches for disaster resilient communities[17] that are exposed to flooding. Communities looking to better prepare for flood hazards and protect their neighborhoods can enroll in the National Flood Insurance Program's Community Rating System,[18] which encourages the use of floodplain management activities that go beyond National Flood Insurance Program minimum requirements.

After major flooding occurred in coastal neighborhoods around New York City and New Jersey during Superstorm Sandy, the NYC Building Resiliency Task Force[19] recommended using precise language to clarify construction requirements and renovation strategies in flood zones. FEMA also published a guide for communities[20] to coordinate responses to both large-scale and small-scale floods. These resources can be used to help direct preparation and response after a community understands its potential for flooding.

ARCHITECTS AND ENGINEERS

FEMA's Home Builder's Guide to Coastal Construction[21] fact sheets provide technical guidance for designing and constructing flood-resilient communities, including information on how building elevation and enhanced freeboard can reduce damage during floods. More in-depth information on hazards, risk management, and maintenance practices for residential buildings in coastal environments is provided in FEMA's Coastal Construction Manual.[22]

Project teams can use the Hazus Multi-Hazard Flood Model[23] to assess coastal and riverine flood risks and estimate potential damage, and use FEMA's Flood Map Service Center[24] to search for flood zone maps by address and understand local community flood risks. After Superstorm Sandy, FEMA released a Mitigation Assessment Team Report[25] that documents observations made during field visits following the storm, a synthesis of the failures in flood preparation, and recommendations for making improvements. The DEC Stormwater Management Design Manual[26] builds on this information and describes ways in which green infrastructure can help control stormwater and decrease flooding issues in communities.

NYCCSC RESOURCES

1. Designing for Flood Risk:[29] A report that identifies key design principles to guide flood resistant construction in urban areas.
2. Extreme Precipitation in New York and New England:[30] A website that allows users to view and download extreme precipitation data.
3. FEMA Flood Hazards:[31] The FEMA National Flood Hazard GIS Layer dataset.

Building Flood Protection

PROTECTING BUILDINGS DURING FLOOD EVENTS

LOCATION

LOW MEDIUM HIGH

HAZARDS

FLOODING

RISING SEA LEVELS

HURRICANES / TROPICAL STORMS

RELATED STRATEGIES

Neighborhood Flood Protection
Building Systems Flood Protection
Building Foundations
Roof Drainage
Building Operations
Potable Water Systems

DESCRIPTION

Responding to Climate Change in New York State states that New York will experience changing patterns of precipitation,[1] increasing the risk of flooding events statewide. To respond to this growing concern, it is critical to break the damage-rebuild-damage cycle[2] and approach building flood resilience with preemptive measures. With the State facing an increased likelihood of inundation, high-velocity flows, erosion, and damage from floating debris, tactics such as flood resistant building materials[3] and flood barriers can help to improve resilience.

The USGS explains the effects urbanization has on flooding,[4] including changes of land use, the removal of vegetation, and increased runoff from man-made drainage networks and how they can increase the chances of flood events in urban areas. According to the Centers for Disease Control and Prevention, flood waters can instigate issues with electrical services and mold,[5] which can be devastating, especially in urban areas. Understanding these impacts will help drive improvements to building flood protection in all regions of New York State.

OWNERS AND OPERATORS

There are multiple FEMA documents that owners and operators can use to improve building flood protection. For example, the Homeowner's Guide to Retrofitting[6] explains how homeowners can implement building flood protection tactics, including elevating the home, installing flood barriers, and wet flood proofing. Additional information can be found in FEMA's guide to Reducing Flood Risk to Residential Buildings That Cannot Be Elevated.[7]

In 2012, Superstorm Sandy proved that flood zone delineations do not always show the true extent of areas exposed to flooding. As a result, the Superstorm Sandy Recovery Advisories from FEMA explain the need to prepare for floods above the base flood elevation[8] to reduce damage during flooding events. Owners and operators can use this document, as well as the Home Builder's Guide to Coastal Construction, for guidance on improving the performance of residential buildings[9] during coastal flooding events. Chapters 14 and 15[10] in Volume II of FEMA's Coastal Construction Manual provide information on maintaining and retrofitting buildings for flood protection based on damage analysis of previous storms. FEMA recommends all owners and occupants should prepare for flooding hazards by purchasing flood insurance.[11]

Tropical Storm Lee

In 2011, New York State was struck by two major storm events within a week.

In the last week of August, Hurricane Irene made landfall in New York State, affecting ClimAID Regions 2, 3, 4, and 5. Then on September 2, the remnants of Tropical Storm Lee dropped nearly a foot of rain in the Southern Tier (ClimAID Region 3). The storms were the second-largest natural disaster in the history of the State,[12] with FEMA awarding more than $1.5 billion in public assistance and over 33,000 residents registering for individual assistance. Since 1955, NYS experienced 42 flood-related Presidential Disaster Declarations.

Hospital Flood Protection

Dry flood mitigation measures keep critical facilities operational during major storm events.

Our Lady of Lourdes Hospital[23] suffered over $20 million in losses when the Susquehanna River flooded in the summer of 2006. With funding from FEMA, the hospital constructed a flood wall around the hospital. In September 2011 following Tropical Storm Lee, the flood wall was tested when the Susquehanna River flooded once again and devastated many parts of Binghamton, NY. The hospital was able to remain fully operational. The flood wall cost approximately $7 million and was built over a period of five years.

POLICYMAKERS AND PLANNERS

Policy makers and planners can learn from previous events what type of damage flood events can cause. After Superstorm Sandy, the NYC Building Resiliency Task Force[13] recommended new legislation and amendments to the New York City Building Codes that can help limit the spread of damage when the next major event occurs. Communities taking part in the National Flood Insurance Program's Community Rating System[14] can assess risks and improve flood hazard preparedness by understanding and making improvements to the things that make their buildings vulnerable.

According to the DEC,[2] flood recovery efforts should include the implementation of resilience strategies that reduce the likelihood of damage caused by future events. The EPA and FEMA released a document entitled Planning for Flood Recovery and Long-Term Resilience in Vermont[15] to discuss policy and planning suggestions for flood disaster resilience. This document could be useful for neighboring areas in New York State, including those in ClimAID Regions 5 and 7. FEMA also completed a Mitigation Assessment Team Report after Superstorm Sandy[16] that documents building failures and suggests how flood-prone areas can adapt and overcome. The failures identified in this document can help policy makers and planners understand what to do and what not do when rebuilding damaged buildings.

ARCHITECTS AND ENGINEERS

After Superstorm Sandy, changes were made to the New York City Building Code, specifically under Appendix G Flood-Resistant Construction.[17] These changes modified standards dealing with backflow prevention, healthcare facilities, survey data and flood maps, cabling and fuel oil storage, and flood barriers in order to ensure safety, resilience, and limited damage during future flooding events. To help guide the design of flood resilient buildings, FEMA released the Floodproofing Non-Residential Buildings[18] document as a comprehensive guide to flood proofing existing buildings. Designers should be aware of the differences between the requirements in the National Flood Insurance Program and the current New York State Building Code, which references the American Society of Civil Engineers' 24-14 Flood Resistant Design and Construction.[19]

FEMA's Technical Bulletin 2[20] for buildings located in special flood hazard areas provides information on flood resistant materials that correspond with NFIP requirements. Other technical bulletins from FEMA provide information on other strategies,[21] including wet flood proofing, below-grade parking, breakaway walls, and metal connector details. The New York City Planning Department Retrofitting Buildings for Flood Risks[22] guide contains a comprehensive analysis of retrofit options based on building type and use for buildings in the New York City flood plain. Strategies from this document can be used in other flood-prone areas within New York State.

NYCCSC RESOURCES

1. Sea Level Rise and Coastal Flooding Impact Viewer:[24] A mapping tool that allows users to visualize potential impacts from sea level rise.
2. Lake Level Viewer: United States Great Lakes:[25] A tool to help visualize water level changes in the Great Lakes.
3. Future Flow Explorer:[26] Application of flood regression and climate change scenarios to explore estimates of future peak flows.

Building Systems Flood Protection

PROTECTING EQUIPMENT DURING FLOOD EVENTS

LOCATION

HAZARDS

FLOODING

RISING SEA LEVELS

HURRICANES / TROPICAL STORMS

RELATED STRATEGIES

Redundant Building Systems
Neighborhood Flood Protection
Building Flood Protection
Roof Drainage
Active Building Systems

DESCRIPTION

This strategy helps building systems, including mechanical equipment and internal infrastructure, more resilient to the impacts of climate change as flooding along coastal areas and near river corridors[1] presents a growing threat to New York State's economic, environmental, and social systems. The Responding to Climate Change in New York State[2] report explains that the increase in frequency of extreme precipitation in New York State will lead to more flooding events. Protecting building systems from such extreme events is critical for ensuring that buildings will remain operational and continue to serve as centers of refuge.

In the days following Superstorm Sandy, many buildings were without essential infrastructure and equipment, including mechanical, electrical, and plumbing systems.[3] Many of these critical building components were placed in basements where they were vulnerable. Due in part to a lack of protection for these expensive building systems and the extended recovery time for reviving essential building systems that are damaged, floods are considered the costliest natural disaster in the United States.[4]

OWNERS AND OPERATORS

Due to the high cost of mechanical system repair and replacement, building flood protection[5] should go beyond structure and material selection to protect systems. Without protection, coastal and river floodwaters[6] can corrode and short-circuit electrical components, fuel storage tanks, and heating and cooling equipment. Resilient building systems can save money in the long term and keep buildings operational[7] during and after major flood events.

To aid in understanding risk and mitigation, FEMA provides information on how buildings were damaged by previous flood events. The Superstorm Sandy Recovery Advisories[8] published by FEMA provide useful information for restoring mechanical, electrical, and plumbing systems[9] in addition to protecting fuel systems from flood damage[10] using tactics including elevating equipment and installing watertight enclosures.

Critical Facility Damage

Damage recovery time can be extended as a result of building system damage.

According to Chapter 5 of FEMA's *Mitigation Assessment Team Report* that followed Hurricane Sandy in 2013, physical damage in healthcare facilities[11] was primarily limited to basements, tunnels, and lower floors. Facilities that were shut down for extended periods of time experienced little structural damage but suffered significant damage to utilities, mechanical equipment, and supplies due to salt water inundation. Proper protection of the building systems in these critical facilities can help reduce post-disaster recovery times.

Building Back Stronger

This NYU building responded to damage from Superstorm Sandy with resilience strategies.

The NYU Langone Medical Center is located 200 feet from New York City's East River and suffered severe flood damage from Superstorm Sandy, which forced an evacuation in the middle of the night. With FEMA's assistance, the center implemented a number of resilience measures to protect its building systems.[20] Critical building equipment was raised 20 feet above base flood elevation, and cogeneration plants were installed to ensure that the hospital can continue to operate during future floods.

POLICYMAKERS AND PLANNERS

Special attention should be given to buildings and populations vulnerable to flooding as climate change increases the likelihood of extreme precipitation events.[2] Proper planning and policy development play an important role in minimizing the damage these events inflict on essential building systems. Additionally, changing sea levels and precipitation patterns[12] require continuous updates to flood zone maps so that municipalities and citizens are aware of areas that are at risk of flooding. Flood zone delineations that are continuously updated can then be used to organize incentives and tax rebates[13] on a local scale in order for homeowners and business owners to improve building systems flood protection.

Municipal infrastructure systems also face increased exposure to flood events. According to the *Third National Climate Assessment*, climate change will put pressure on aging infrastructural systems[14] that influence the economy, security, and culture of cities throughout New York State. People who live in areas vulnerable to flooding that depend on these infrastructural systems will require additional support. Removing barriers including limited funding, policy and legal impediments, and emergency management difficulties, while implementing adaptation strategies[15] such as building system flood protection, will help reduce impact and damage within these vulnerable areas.

ARCHITECTS AND ENGINEERS

Building system flood protection requires reconsidering traditional systems design. FEMA provides guidance for incorporating flood resistant utilities for new construction and substantial renovations in Chapter 3 of the Protecting Building Utilities From Flood Damage[16] document, with tactics including sealing water access to basements and electrical conduits, and backflow preventers. Backflow preventers[17] are simple units that resist sewer backups in flood-prone areas.

Critical facilities such as hospitals, schools, fire and police stations, and emergency operation centers in flood-prone areas must take steps towards improving flood resilience to remain in service during hazard events. FEMA's guide Improving Critical Facility Safety from Flood and High Winds[18] provides guidance for assessing flood vulnerability and implementing proper mitigation strategies to ensure facility functionality during extreme weather events. FEMA also provides a technical bulletin[19] on the National Flood Insurance Program's regulations for elevator installations below the base flood elevations in special flood hazard areas so buildings maintain accessibility during a flood.

NYCCSC RESOURCES

1. Magnitude and Frequency of Floods in New York:[21] Techniques for estimating the magnitude and frequency of flood discharges on rural, unregulated streams.
2. Flood Inundation Mapping (FIM) Program:[22] Tools and information for communities that would like to understand flood risks.

Building Foundations

REDUCING CLIMATE CHANGE IMPACTS FROM THE GROUND UP

LOCATION

LOW MEDIUM HIGH

HAZARDS

FLOODING

RISING SEA LEVELS

WINTER STORMS

RELATED STRATEGIES

Wind Protection
Building Flood Protection
Insulation
Integrated Pest Management

Scour from Storm Surge

Shallow and open foundations are desirable but vulnerable to scour and erosion.

The areas hit hardest by Superstorm Sandy[9] in New York State were the communities of Coney Island, Rockaway Peninsula, and Long Beach Barrier Island. Storm surge in these areas caused an average of 4.5 feet of vertical dune erosion, which led to significant building foundation damage from scour.

DESCRIPTION

Foundations in coastal environments are subject to hazards such as wave action, storm surges, erosion and scour, and floodborne debris. According to the Building Science Corporation,[1] many existing building foundations are not able to withstand required structural loads or keep out groundwater, soil gas, wind, or water vapor. According to FEMA, coastal foundations might need to be stronger, deeper, and higher[2] than what has traditionally been adequate in order to handle the effects of climate change, including sea level rise and flooding.

Properly designed and constructed foundations[3] can reduce homeowner utility bills, prevent potential health effects from soil gas, and prevent moisture penetration. During winter storms, moisture can cause cracks and uplift in building foundations during freeze and thaw cycles. The Whole Building Design Guide[4] from NIBS provides guidance for understanding foundation materials and how they are able to withstand moisture infiltration while resisting vertical and horizontal loads.

OWNERS AND OPERATORS

Buildings located in special flood zones delineated by NFIP have numerous foundation-related risks, including loads from hydrostatic pressure. NFIP allows elevated homes' lower levels to be enclosed[5] in flood zone areas if they use flood resistant materials and provide openings for flood water to flow in and out of the building to reduce water pressure on the foundation. Erosion and scour are also problematic for foundations and are associated with flooding in riverine and coastal areas. FEMA explains the potential impact of scour[6] and provides guidance for building owners and operators seeking to improve the strength of their building foundation.

In New York State, building foundations are exposed to diverse and extreme temperatures over the course of the year. According to the National Association of Home Builders Research Center,[7] a frost-protected shallow foundation may be an alternative to deeper and more costly conventional foundations in cold climates. FEMA also has a guide that presents minimum requirements for crawlspaces that are in accordance with NFIP,[8] which can be used to improve foundation drainage to help reduce cracking and uplift during winter storm events.

The Ocean Club

Foundations that meet current NYS building standards replace those destroyed by Superstorm Sandy.

The Ocean Club on Atlantic Beach, NY was built on wood pilings that were unable to withstand the force of the floods and winds caused by Superstorm Sandy. After the storm, and in accordance with recommendations from FEMA,[18] new pilings were placed to a depth of eight feet to raise the building above the flood levels. The piles are constructed with steel reinforced concrete. For more information regarding the reconstruction plans for Atlantic Beach, the NY Rising Community Reconstruction Plan[19] discusses how the community is reacting to make the village more resilient.

POLICYMAKERS AND PLANNERS

As one of the most common hazards in New York State, flooding can cause significant damage to building foundations. FEMA released Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures[10] to assist local governments, designers, and owners who are seeking to improve their foundations in coastal areas. The Local Officials Guide to Coastal Construction,[11] also published by FEMA, provides design considerations, regulatory guidance, and best practices for coastal communities as well as investigations on elevated buildings and soil to help guide resilient foundation requirements in building codes.

Erosion, another climate change stressor for foundations, is not just a Downstate issue. According to FEMA's Coastal Construction Manual,[12] storm surges along the Great Lakes as high as four to eight feet can cause erosion and permanent damage. Soils can also have varying bearing capacities, and FEMA recommends[12] consulting a geotechnical engineer when unusual or unknown soil conditions are encountered. Currently, Chapter 18 of the New York State Building Code[13] references ASCE 7 for flood resistance in structures, including their foundations. Because New York State is subject to cold winters, the building code also references ASCE 32 to protect foundations from extreme cold and frost.

ARCHITECTS AND ENGINEERS

Moisture control and flood resistance in foundation design should be practiced in New York State to prevent issues with mold growth, poor indoor air quality, and structural failure. The EPA recommends liquid water control strategies,[14] along with vapor and insulation considerations, to prevent condensation from occurring in a variety of foundation types. To supplement this information, the U.S. Army published a Technical Manual for Foundations[15] in expansive soils that discusses hazard assessments, planning, design, and remedial procedures. The Oak Ridge National Laboratory and the University of Minnesota Center for Sustainable Building Research's Foundation Design Handbook[3] provides technical information, details, and recommendations for building foundation design, including proper grading, which can reduce lateral movement and heave.

For projects in coastal areas, FEMA's Home Builder's Guide to Coastal Construction Technical Fact Sheets[16] provide a number of guides for foundations that include construction details and guidelines for the design and installation of piles and reinforced masonry piers. More in-depth information on foundations for residential structures in coastal areas is available in FEMA's Recommended Residential Construction for Coastal Areas[17] document, which provides guidance on hazard identification, design loads, and foundation types that can withstand flooding, erosion, scour, and high winds.

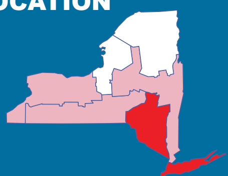
NYCCSC RESOURCES

1. Extreme Weather Map:[20] An interactive map that displays weather-related disasters in the United States between 2010 and 2015.
2. New York State Geographic Information Gateway:[21] A website providing access to data, real-time information, interactive tools, and expert knowledge relevant to planners and development activities in New York State.

Green Infrastructure

SUSTAINABLE MITIGATION AND ADAPTATION IMPROVEMENTS

LOCATION



HAZARDS

FLOODING

RISING SEA LEVELS

HEAT WAVES

RELATED STRATEGIES

Neighborhood Flood Protection
Gray Infrastructure
Roof Covering
Roof Drainage
Urban Heat Island
Reclaimed Water Systems

DESCRIPTION

According to Responding to Climate Change in New York State,[1] temperatures and precipitation amounts in New York State are expected to increase. Extreme precipitation events will likely strain existing and aging infrastructure like combined sewer systems, which may experience more overflow[2] events from large volumes of rainfall.

According to the EPA, green infrastructure can accomplish a variety of climate resiliency goals.[3] For example, managing flooding by using ground infiltration helps prepare for droughts by replenishing groundwater reserves. Creating living shorelines can reduce the impacts of sea level rise, such as erosion and flooding, while restoring wetlands and coastal ecosystems.

Green infrastructure also reduces urban heat island effects, building energy demands, and energy spent managing water. Columbia University's Water Center highlights 11 cities across the country[4] that have demonstrated these economic and environmental benefits through the use of green infrastructure.

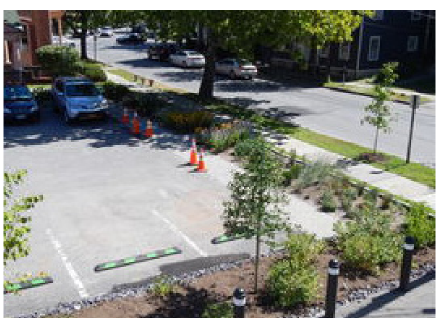
OWNERS AND OPERATORS

Homeowners and businesses can install green infrastructure systems on their property to help manage stormwater runoff, sea level rise, and extreme heat events under the guidance of the Center for Clean Air Policy, which explains how green infrastructure builds resilience.[5] The Stormwater Coalition of Albany released a guidance manual for homeowners[6] providing information on barrels and rain garden construction. For those who are interested in planting larger trees for shade and heat island mitigation, the U.S. Forest Service produced a Tree Owner's Manual[7] that details spacing, soil, species, and other important considerations.

When paired with urban agriculture, green infrastructure can also have positive effects on air quality, human health, and energy demand by reducing the amount of stormwater runoff in an urban areas. The U.S. Department of Agriculture's Urban Agriculture Toolkit[8] discusses the common issues most urban farmers must consider as they start and grow their operations, while the Cornell Institute of Climate Smart Solutions' Climate Smart Farming website[9] can help keep farmers aware of changes in climate throughout the growing season.

Save the Rain Program

This comprehensive program addresses issues with stormwater runoff.



Like many areas of New York State, wet weather events around Onondaga Lake (ClimAID Region 6) can overload existing stormwater infrastructure and wash pollutants into the lake and its tributaries. The Save the Rain[10] program is a comprehensive stormwater management plan that seeks to help reduce this burden through green projects and programs. Some actions performed by the Save the Rain include a rain barrel program, tree planting, and infiltration trenches.

Green Innovation Grant

Green infrastructure provides jobs, increased property values, improved walkability, and improved air quality.

The Green Innovation Grant Program[21] supports projects across New York State that focus on stormwater management. According to the grant program guidelines, successful proposals incorporate unique stormwater management systems and develop green technologies. Projects must address water quality, be innovative, increase community interest in green infrastructure, and help spread technology across the State. In Rochester (ClimAID Region 1), $1.3 million in funding from this program is being used to complete a Regional Green Infrastructure Showcase[22] at the Rochester Museum Science Center.

POLICY MAKERS AND PLANNERS

Planners and policy makers can reduce vulnerability to climate change in communities by expanding green infrastructure systems. The APA released a report for planners that discusses how ecology, economy, and community development can encourage urban forestry[11] and other green infrastructural improvements that contribute to stormwater management and passive cooling. To assist in the implementation of projects, NOAA released a guide to help assess the costs and benefits of green infrastructure[12] by explaining the reduced effects of flooding. The American Society of Landscape Architects highlights the benefits of green infrastructure for handling stormwater in Banking On Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community Wide.[13]

Green infrastructure can provide beautification and a source of pride for neighborhoods, playing a role in both community and climate resiliency. Lack of funding is one of the largest barriers to implementing green infrastructure projects, and as a result, the EPA collected and listed numerous funding opportunities[14] available to communities. The U.S. Department of Housing and Urban Development's Sustainable Communities Initiative[15] offers two grant programs that have funded multiple projects, including those listed in Green Infrastructure and the Sustainable Communities Initiative.[16]

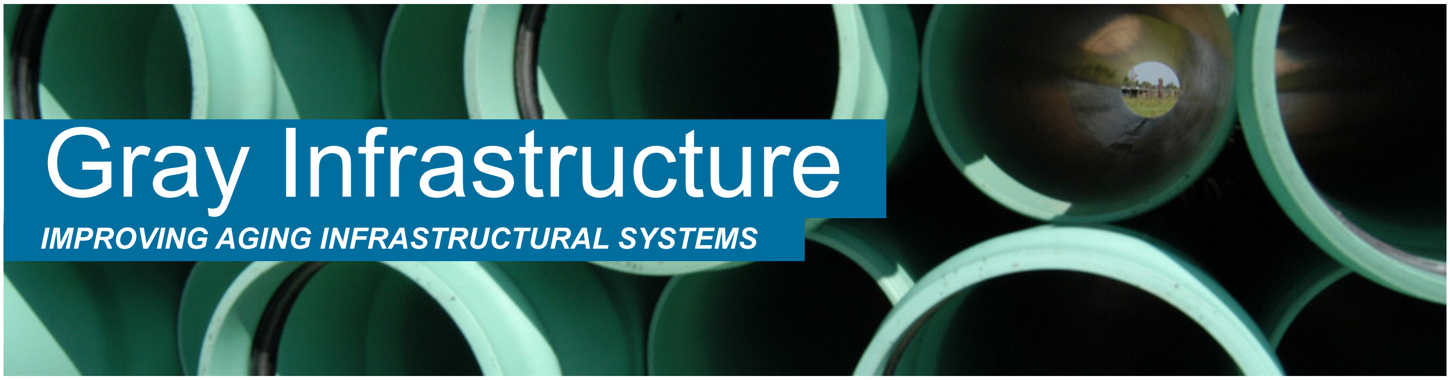
ARCHITECTS AND ENGINEERS

To assist in the design and construction of stormwater systems, the NYS DEC released the New York State Stormwater Management Design Manual,[17] which provides standards, specifications, and design criteria for building professionals. The EPA also provides several resources that discuss hydrological and biological considerations for constructed wetlands,[18] which can be used to filter contaminants out of water in urban settings. Constructed wetlands help reduce the impacts of high volume events by decreasing the amount of stormwater runoff collected by inadequately sized storm sewers.

The New York City Department of Parks and Recreation and the Design Trust for Public Space developed a comprehensive set of guidelines[19] for sustainable and high performing 21st century parks. The guidelines provide a full overview of best practices, including the use of infiltration beds and the use of porous pavement, to tackle many of the critical issues related to green infrastructure. Additionally, the American Society of Landscape Architects describes how green infrastructure[20] can be useful at a city scale as well as at a regional scale through the incorporation of wildlife habitat, wetlands, and infrastructure.

NYCCSC RESOURCES

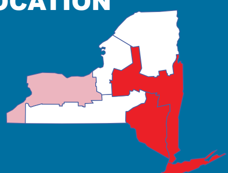
1. Green Infrastructure:[23] Information and resources on green infrastructure, including fact sheets, tools, case studies, and applicable research.
2. Extreme Precipitation:[24] Current and projected data for precipitation in New York State.
3. FEMA Fact Sheet: Green Infrastructure Methods:[25] A sustainable approach to landscape preservation and stormwater management.
4. Getting to Green: Paying for Green Infrastructure:[26] Financing Options and resources for decisionmakers.



Gray Infrastructure

IMPROVING AGING INFRASTRUCTURAL SYSTEMS

LOCATION



LOW MEDIUM HIGH

HAZARDS

FLOODING

RISING SEA LEVELS

HURRICANES / TROPICAL STORMS

RELATED STRATEGIES

Redundant Building Systems
Neighborhood Flood Protection
Green Infrastructure
Roof Drainage
Neighborhood Development
Potable Water Systems

DESCRIPTION

Gray infrastructure includes critical systems[1] that provide sanitation and stormwater control for communities. According to the Third National Climate Assessment, aging infrastructure systems are overburdened[2] by sea level rise, heavy downpours, extreme heat, and other events that they were never designed to handle. As a result, improving resilience through gray infrastructure systems will require extensive renovations that respond to the anticipated impacts of climate change.

The DEC explains the impacts from climate change are already being observed;[3] however, action can still be taken to limit negative impacts. Due to their long-term period of use, it is important the design and implementation of gray infrastructure take these changing climate conditions into account. According the George Mason University Center for Infrastructure Protection and Homeland Security, it is necessary to invest in infrastructure that takes into account potential future changes[4] as climate patterns shift, in order to save money in the long term and reduce damage from future climate events.

OWNERS AND OPERATORS

Responding to Climate Change in New York State[5] explains that climate shifts across the State may result in high volume precipitation events, periods of drought, rising temperatures, and increased stress on existing infrastructure systems. According to the DEC, combined sewer overflows[6] are common throughout New York State, which can lead to serious health concerns when untreated sewage flows into open water during high volume events. However, according to The Homeowner's Guide to Stormwater,[7] homeowners can use simple tactics on private property to reduce strain on gray infrastructure systems, including separating onsite stormwater and sanitary systems and capturing rainwater in barrels for later use in gardens.

For owners and operators of larger buildings and sites, more planning will be necessary during the design process to deal with stormwater management. According to the Federal Resource Guide for Infrastructure Planning and Design, the pre-development phase of design[8] will become more important because there is time to investigate the use of innovative infrastructure design and emerging technologies including resilient materials and aquifer storage to reduce long-term cost and improve environmental performance.

Wastewater Treatment

Improving existing infrastructure systems can reduce energy use and pollution.

The 26th Ward Wastewater Treatment Plant located in Brooklyn (ClimAID Region 4) serves roughly 283,000 residents and processes around 170 million gallons of combined sanitary and stormwater each day. The plant received the Institute of Sustainable Infrastructure Silver Award[9] for using energy efficient sewage pumps, process air blowers, and LED lighting. The plant will also add a green roof, and all equipment will be designed above the BFE to ensure that critical equipment will not fail during flooding events.

Albany 2030

Separating stormwater from sanitary sewers reduces vulnerability to health risks in water supplies.

The Albany 2030 Comprehensive Plan[19] will address reducing solid waste streams, improving communications infrastructure, and supporting energy efficiency and renewable production while maintaining the quality of the city's wastewater management systems to protect drinking water supplies. The City of Albany is planning to retool its utility and infrastructure systems by separating stormwater from the main sewer system through the use of green infrastructure. Part of this storm sewer separation effort will include the integration of graywater reuse, which reduces the volume of water that must be treated at the local sewage treatment plant.

POLICYMAKERS AND PLANNERS

Communities may feel as though they must choose between investing in green infrastructure and investing in gray infrastructure. However, the EPA explains that it is best to invest in both,[10] as the use of green infrastructure can help reduce the amount of investment required to upgrade gray infrastructure. The DOT argues that governments need to clearly articulate comprehensive strategies[11] for sustainable infrastructure to the public and make resilience part of the long-term strategic infrastructure planning agenda. In addition, the University Transportation Research Center released a climate adaptation report that identifies climate change adaptation strategies[12] that incorporate gray infrastructure systems into transportation systems and provides recommendations for incorporating these strategies into legislation, policies, programs, and projects.

The FEMA Hazard Mitigation Grant Program[13] and many other federal grant programs can be used to fund resilient gray infrastructure projects. Other federal resources including the National Infrastructure Protection Plan[14] can be used to help guide the implementation of resilient gray infrastructure projects through a discussion of risks, policies, and partnerships. Federal technical assistance from the Water Infrastructure and Resiliency Finance Center[15] is also available to aid municipalities, communities, and utilities as they make water infrastructure improvements with limited budgets.

ARCHITECTS AND ENGINEERS

The NYS 2100 Commission released its preliminary report Improving the Strength and Resilience of New York State's Infrastructure[16] to help architects and engineers understand the importance of improving gray infrastructure systems. The report recommends addressing vulnerable transportation, energy, and stormwater systems with designs informed by the coordination of data, resources, and mapping. PlaNYC explains that traditional gray infrastructure can be multipurposed[17] by incorporating parking and retail space. In these cases, the creative bringing together of building design and gray infrastructure that is typically used only during extreme hazard events helped attract more sources of funding.

The U.S. Army Corps of Engineers released a Climate Change Adaptation Plan[18] that highlights strategies and identifies priority areas of concern including gray infrastructure. FEMA also provides the Federal Resource Guide for Infrastructure Planning and Design,[8] which includes an overview of infrastructure systems, design principles, and case studies. These documents provide the necessary technical assistance for making improvements to gray infrastructure systems through a discussion of case studies and through linked information that directs readers toward technical bulletins and engineering regulations.

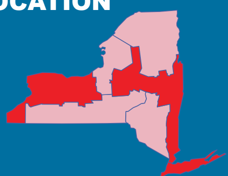
NYCCSC RESOURCES

1. Positioning Infrastructure and Technologies for Low-Carbon Urbanization:[20] An academic article on expected urbanization, aging infrastructure, increasing complexity of man-made systems, and climate change impacts.
2. Water Infrastructure and Resiliency Finance Center:[21] A resource for communities seeking to improve their wastewater, drinking water, and stormwater systems while providing financial guidance.

Roof Covering

UNDERSTANDING THE IMPACT OF BUILDING HEAT ABSORPTION

LOCATION



LOW | MEDIUM | HIGH

HAZARDS

HEAT WAVES

RELATED STRATEGIES

Green Infrastructure
Roof Drainage
Insulation
Urban Heat Island
Reclaimed Water Systems

SUNY ESF Gateway Center

Energy-positive educational facilities provide students a space to experience technology.

Designed by the architectural firm Architerra, this building functions as an interactive teaching space for the SUNY College of Environmental Science and Forestry.[9] One of the main components of the building located in Syracuse (ClimAID Region 3) is the 10,000-square-foot green roof that provides space for teaching, stormwater collection, and insulation. The green roof restricts excessive heat absorption, which reduces the active cooling demand and reduces energy consumption, making the Gateway Center[10] an energy-positive building.

DESCRIPTION

Building roofs absorb excessive amounts of heat, which radiates into buildings and increases the demand for active cooling systems. The absorbed heat can also radiate back into the environment, where it combines with heat from other roofs and non-reflective surfaces to create urban heat island effects[1] in populated areas. The high likelihood of increased temperatures as a result of climate change[2] stresses the importance of roof coverings that can control the amount of heat absorbed from the sun and reduce the energy required to condition interior spaces of buildings.

The EPA states traditional roofing materials have low solar reflectance of 5 to 15%, which means that they absorb 85 to 95% of energy from the sun.[3] Roof coverings with high albedo, also known as cool roofs, reflect energy from the sun back out into the atmosphere rather than absorbing it, decreasing negative impacts during days of high heat. Green roofs[4] are cool roofs that reduce the amount of heat absorbed, as well as reducing the amount of runoff generated during severe storms and after winter storms with melting snow.

OWNERS AND OPERATORS

Increased temperatures increase active cooling demand and cost in buildings as a result of heat absorption. The amount of heat absorbed into buildings, however, can be reduced through the use of cool roofs. The Cool Roof Rating Council[5] assists building owners seeking to understand all types of cool roof systems available, including light colored roof membranes and green roofs. The Lawrence Berkeley National Laboratory[6] also provides information to assist owners and operators in making informed decisions about the best roofing system for their building. The roof coverings described in these documents are increasingly important in all urban areas of New York State because they reduce negative urban heat island effects and reduce the costs of active cooling systems in all building types.

To help owners and operators make economically feasible decisions, the EPA provides cost justification for efficient roof coverings[7] by comparing material costs with the long-term energy savings. In addition, the DOE provides a simulation tool for calculating potential energy savings[8] for multiple building types after roof covering improvements are made.

NYC CoolRoofs

Since 2009, more than 6 million square feet of NYC rooftops have been covered with a light colored cool roof coating.

As an extension of the Mayor's Office of Recovery and Resiliency and the Office of Sustainability,[23] this initiative supports local jobseekers while striving to coat more than one million square feet of rooftop with a white reflective coating each year. Cool roofs with high albedo can reduce interior building temperatures by up to 30%, which decreases active cooling loads, decreases energy consumption, and increases building occupant health. This program[24] also employs and trains local laborers as part of an ongoing effort to make New York City more resilient to the effects of climate change.

POLICYMAKERS AND PLANNERS

According to the Cool Roof Rating Council,[11] efficient/cool roof coverings have direct and indirect effects that can help mitigate climate change and urban heat island effect, providing public health benefits and energy savings. The benefits of cool roofs have prompted mitigation policies such as the New York City Green Roof Tax Abatement,[12] which grants building owners tax relief proportional to their area of green roof. The CRRC also lists additional programs[13] that incentivize the use of efficient roof coverings, such as the USGBC LEED Program, the Collaborative for High-Performance Schools, and the Energy Star® Reflective Roof Program.[14]

The New York City Building Code sets requirements in Section 1504.9[15] for roof reflectance and albedo. It requires roofs with less than a 17% slope to meet minimum solar reflectance thresholds that have been established by ASTM standards. This requirement, however, is not present in the Building Code of New York State.[16] A statewide code requirement could help decrease urban heat island effects in all cities across New York State, in addition to decreasing the summer dependence on active cooling systems.

ARCHITECTS AND ENGINEERS

The DOE is a good source for building professionals to discover different types of cool roofs.[17] Their document discusses multiple existing roof conditions, including flat built-up roofs and steep metal sheet roofs, and explains how these roofing types can be made cool. The New York City Department of Design and Construction's Cool and Green Roofing Manual[18] identifies the importance of high albedo in roof coverings and describes its role in preventing excessive heat absorption. This document presents construction considerations for cool roof and green roof implementation.

For technical assistance in reducing heat absorption, the U.S. General Services Administration provides Best Practices for Green Roof Construction and Maintenance[19], which breaks down the unique construction detailing that is required for green roofs. The National Institute of Building Sciences' Whole Building Design Guide[20] provides additional information including necessary layers of material, design factors, and relevant codes and standards. Green roofs are not limited to new construction, as the National Park Service provides simple guidelines for the installation of green roofs on historic buildings.[21] In both retrofit and new construction projects, green roofs help reduce heat absorption[22] and active cooling loads.

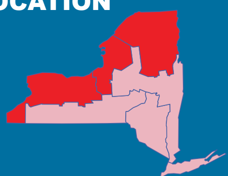
NYCCSC RESOURCES

1. Green Roof vs Bitumen Roof:[25] A comparative analysis based on a five-month measurement campaign to explore the performance differences between green roofs and traditional bitumen roofs.
2. Thermal Effect of Covering the Building Envelope:[26] A paper that discusses the thermal effect that green walls and green roofs have on the built environment.
3. Green Roof Environmental Monitoring:[27] A document that describes the deployment of research stations that monitor the performance of urban environmental conditions at a small scale.

Roof Drainage

ADDRESSING EXTREME AMOUNTS OF PRECIPITATION

LOCATION



LOW **MEDIUM** **HIGH**

HAZARDS

SEVERE STORMS

WINTER STORMS

HURRICANES / TROPICAL STORMS

RELATED STRATEGIES

Building Flood Protection
Building Systems Flood Protection
Green Infrastructure
Gray Infrastructure
Roof Covering
Reclaimed Water Systems

DESCRIPTION

The Responding to Climate Change in New York State states that New York will likely experience increased amounts of precipitation[1] in the coming years as a result of climate change. This increases the demand for effective roof drainage, as excessive amounts of precipitation, both rain and snow, can cause significant damage to a building if the flow of water is allowed to enter through a roof or wall assembly.

According to the Building Science Corporation, insufficient roof drainage after winter weather events can lead to ice dams,[2] which cause interior water leakages and mold growth. Making improvements to roof drainage will help buildings in New York State address the threat of water penetration and structural failures by shedding the increased amounts of rain and snow. Roof and gutter maintenance is critical to protecting buildings of all sizes from the negative effects of poor roof drainage. The IBHS[3] provides guidance for making improvements to poor roof drainage systems in addition to more detailed descriptions of the effects of increased precipitation on buildings.

OWNERS AND OPERATORS

Understanding the present condition of a roof is the first step in addressing issues with poor drainage. The IBHS provides a roof damage checklist[4] for inspecting the quality of existing roofing conditions before and after a severe storm, hurricane, or winter storm. If improvements need to be made, the National Roofing Contractors Association[5] provides additional information on roofing systems, including material choices, construction types, and insulation systems. This information is vital for all building owners and operators for reducing damage due to water infiltration and for mitigating other climate hazards.

Green Seal's[6] Green Building Operations and Maintenance Manual: A Guide for Public Housing Authorities can assist in the implementation of effective roof drainage. The manual provides guidance on snow removal and de-icing,[7] which can help reduce damage to buildings during spring thaws. The manual also discusses the importance of regular roof maintenance[8] during all seasons to ensure water does not collect on building roofs. Gutter maintenance and removal of debris including twigs, leaves, and other flammable materials can also reduce the potential spread of wildfire.[9]

Snowvember 2014

Increased amounts of precipitation can have disastrous effects on roofs that cannot shed rain and snow.

Excessive amounts of lake effect snow crippled the Western New York area (ClimAID Region 1) in November 2014. In its 2014 Annual Report,[10] the NYS Disaster Preparedness Commission stated that several locations in Erie County received more than 50 inches of snow in only a four-day period. The highest total was in Cowlesville (Wyoming County), which recorded 88 inches of snowfall. This climate hazard event caused 13 deaths, more than 370 reports of roof damage, and 30 collapsed roofs.

Rochester Roof Relief

This roof relief program focuses on areas that do not have the financial ability to resist the daunting effects of climate change.

As a way to improve stormwater management in areas vulnerable to the effects of climate change, the City of Rochester in Monroe County (ClimAID Region 1) provides financial assistance for owner-occupied single-family home roof replacements and repairs.[22] The financial assistance covers roof drainage improvements, including gutters, downspouts, flashing, and shingle replacement. The recipients of the roof improvements must maintain ownership of their improved home for three years after the work has been completed, and they must have an income of less than 80% of the area median in order to receive assistance from the program. Participants must also make a financial contribution toward their project based on their annual income.

POLICYMAKERS AND PLANNERS

Due to New York State's exposure to high levels of moisture from the Great Lakes and the Atlantic Ocean, the DHSES warns that the State is highly susceptible to heavy volume hazard events, including severe storms and winter storms.[11] In a similar climate, the City of Toronto includes roof drainage within the on-site stormwater management practices[12] table in its Wet Weather Flow Management Guidelines document. Chapter 4 of the New York City Department of Environmental Protection's Guidelines for the Design and Construction of Stormwater Management Systems is dedicated entirely to rooftop systems[13] and the role they play in mitigating the growing threat of high volume events. Both of these documents present roof drainage as an effective resilience strategy that contributes to mitigating extreme amounts of precipitation on a large scale.

In order to ensure that roof systems in New York State are prepared to handle increased amounts of precipitation, code officials should periodically review Sections 1105 and 1106[14] of Chapter 11 of the Plumbing Code of New York State in order to confirm that the reference figures for sizing gutters reflect the projected amounts of precipitation expected as a result of climate change. Sections 1608 and 1611[15] in Chapter 16 of the Building Code of New York State should also be reviewed to ensure New York State roofs are strong enough to withstand increased snow and rain loads. FEMA provides guidance in its Snow Load Safety Guide[16] for sizing roof structures to withstand snow accumulation and melt.

ARCHITECTS AND ENGINEERS

Resilient roof drainage design provides access for roof maintenance, reduces excessive stormwater runoff and seals interior spaces from increased amounts of precipitation. To help achieve these goals, the EPA provides technical stormwater guidance in its Green Roofs for Stormwater Runoff Control[17] document and the American Society of Plumbing Engineers provides technical assistance in its Storm Drainage Systems[18] continuing education document, which discusses the efficiency of traditional roof drains, scuppers, and gutters.

Roofing guides such as Chapter 9 in the New York State Office of General Services Design Procedures Manual[19] provide design guidelines for roof systems that resist water penetration. Section 7 of the U.S. Department of Defense's Unified Facilities Criteria document presents information on roofing materials and techniques,[20] including material longevity, cost, and UV resistance. The National Roofing Contractors Association also has The NRCA Roofing Manual: Steep Slope Roof Systems,[21] which supplies technical support for constructing roof systems that shed both rainwater and snow.

NYCCSC RESOURCES

1. Design for Exceedance in Urban Drainage:[23] A design guide that seeks to reduce the impacts from runoff through the effective design of both underground and overland flood conveyance systems.
2. Soak Up the Rain:[24] Information on what citizens and municipalities can do with rainwater once it has been removed from the roof.

Neighborhood Fire Protection

LIMITING THE SPREAD OF A DAMAGING HAZARD

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

WILDFIRE

HEAT WAVES

RELATED STRATEGIES

Emergency Management
Building Fire Protection
Neighborhood Development
Building Operations

Adirondack Mountain Fires

Even with improved response technology, wildfire conditions are increasing due to climate change.

Although improvements in communication and technology have strengthened response efforts, wildfires are still a dangerous possibility in the Adirondack Mountains (ClimAID Region 7). In September 2015, approximately 122 acres were consumed by wildfire[10] as a result of an unattended campfire in the Adirondack Mountains. Although the damage was nowhere near that of historical fires, such as the 1903 fires that destroyed more than 460,000 acres, rising temperatures and extended periods of drought increase the likelihood of wildfires in the future.

DESCRIPTION

Severe storms with high winds and heat waves that cause droughts and large amounts of dried vegetation increase the possibility of wildfires.[1] New York State is covered with 18.9 million acres of forested lands. Fires on these lands can cause property loss, air pollution, habitat damage, and loss of life in both rural and urban areas. According to the 2014 NYS DHSES Hazard Mitigation Plan,[2] 6,971 wildfires burned more than 65,000 acres between 1988 and 2012. Neighborhood fire protection is meant to help New York State communities stay aware and be prepared for the growing threat of wildfires.

The DEC provides information on New York State's wildfire history,[3] including links to maps and hazard mitigation strategies. Neighborhood fire awareness and safety are guided by resources like this and organizations like the Fire Adapted Communities Learning Network.[4] This organization helps communities understand their unique sensitivities and the impacts of wildfires. Ready, Set, Go![5] is another organization that helps protect buildings and people from wildfires by creating a dialogue between firefighters and building owners and providing information on how to act before and during wildfires and heatwaves.

OWNERS AND OPERATORS

Protecting neighborhoods from wildfires begins at the individual property level, where fire-safe decisions can be made in landscape design and building maintenance. Firewise Communities[6] is a resilient design organization that provides tips and tools to help owners and operators protect their neighborhoods from fire through the effective use of landscape design and maintenance. The Division of Agricultural and Natural Resources at the University of California also provides information on fire-protected landscapes.[7]

According to the National Interagency Fire Center, cleaning debris and trimming trees are important fire-resistance maintenance[8] tasks that can significantly improve neighborhood fire protection. Firewise Communities also provides a free Homeowner Training Course[9] to help owners and operators understand how fire-safety tactics can be implemented in their buildings to improve neighborhood fire protection.

IBHS Wildfire Research

2015 was the costliest wildfire season in history as wildfire consumed more than 9.4 million acres in the United States.

The IBHS is conducting studies at its research center in South Carolina to develop a better understanding of the spread of wildfires.[21] By testing various wind speeds and the spread of embers through simulated dry field conditions, researchers can develop a better understanding of how the spread of wildfires can be predicted and controlled. The information that comes out of this research is important for those who develop fire response protocols and landscape design professionals. The IBHS also uses its research center to test the resilience of building materials and construction systems, which can be useful to building professionals in New York State.

POLICYMAKERS AND PLANNERS

Preparing a neighborhood for wildfires requires an assessment of what is at risk and what fire mitigation measures are already in place. The Fire Adapted Communities Learning Network created the Self-Assessment Tool,[11] which can help communities assess their capacity to live safely with fire. Efforts that address community risks can be assisted by the National Wildfire Coordinating Group Communicator's Guide for Wildland Fire Management: Fire Education, Prevention, and Mitigation Practices.[12] The strategies identified in this source can be put into action by a local neighborhood fire-protection plan that is similar to the sample fire-safety plans[13] presented in the Fire Adapted Communities Learning Network's Winter 2015 Guide for Community Leaders.

The National Cohesive Wildland Fire Management Strategy[14] prepared by the Wildland Fire Leadership Council outlines a nationwide effort to make meaningful progress towards resilient landscapes, fire-adapted communities, and safe and effective wildfire responses. This document can help guide local fire-safety plans that provide region-specific mitigation strategies. FEMA provides firefighter grants,[15] like the Assistance to Firefighters Grants and the Fire Prevention and Safety Grants, which can aid neighborhood fire-protection implementation. Anyone who participates in fire-protection planning should review Firewise Communities' free community assessment online course[9] to gain a thorough understanding of how to provide effective neighborhood fire protection.

ARCHITECTS AND ENGINEERS

The increased likelihood of high temperatures can potentially increase the frequency of wildfires in New York State. The NFPA defines the wildland-urban interface[16] as the transition zone between developed and non-developed land. According to the Fire Protection Research Foundation's report Pathways for Building Fire Spread at the Wildland Urban Interface,[17] the design of the wildland urban interface plays a critical role in determining to what extent wildfire spreads, and what amount of damage it causes. To assist in reducing potential wildfire spread and damage, NFPA 1144:[18] Standard for Reducing Structure Ignition Hazards from Wildland Fire can help in the assessment of fire hazards, and in the design and construction of neighborhood fire protection.

The International Code Council also addresses the wildland-urban interface in a model code that was founded on data collected from fire incidents and technical reports. The 2015 International Wildland-Urban Interface Code[19] identifies special construction and land use requirements that can be integrated into existing building codes such as defensible space, tree pruning, and firewood storage. These requirements, along with those outlined in Firewise Communities' Safer from the Start: A Guide to Firewise Friendly Developments,[20] can be used to guide the implementation of neighborhood fire protection.

NYCCSC RESOURCES

1. The Role of Fire During Climate Change:[22] A study that explores the effects climate change has had on a forest in Devil's Bathtub, New York (ClimAID Region 1) and how conditions suggest changes in the fire regime.
2. Climate Change Effects on Forests and Grasslands:[23] An education module from the U.S. Department of Agriculture that provides a brief overview of current and projected climate change effects.

Building Fire Protection

REDUCING BUILDING EXPOSURE AND SENSITIVITY TO FIRE

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

WILDFIRE

HEAT WAVES

RELATED STRATEGIES

1 Windows
3 Emergency Management
12 Roof Drainage
13 Neighborhood Fire Protection
22 Building Operations

Post-Sandy Retrofitting

The NYC DCP developed retrofitting strategies after observing damage from Superstorm Sandy.

More than 130 homes burned to the ground before emergency crews could respond in the Breezy Point neighborhood of Queens (ClimAID Region 4) during Superstorm Sandy in 2012. This event prompted the New York City Department of City Planning to develop a retrofitting manual[13] that addresses both fire and flood vulnerability. Although the document is geared mostly toward flood protection, there is a considerable emphasis on fireproofing. Strategies in the document include creating a fire-proof mechanical space and using only fire-rated materials on the exterior of a building.

DESCRIPTION

Due to rising temperatures and drought conditions caused by climate change, buildings can potentially face an increase in exposure to fire. According to the U.S. Fire Administration,[1] New York State was third in the country with 129 civilian home fire fatalities in the year 2015. About 73.4%, of these deaths took place on residential property. Due to the potential for fire in all regions of New York State, building fire protection should be considered in all resilience improvement efforts.

To implement building fire protection, planners and policymakers can improve upon comprehensive fire codes including those for New York City[2] and New York State[3] with guidance from the Whole Building Design Guide[4] from NIBS. This document provides a building fire protection guide that identifies new minimums for egress, fire detection, and material use. This source references progressive codes and standards like the Smithsonian Institute Fire Protection and Life Safety Design Manual,[5] the NIST's evacuation[6] references, and Firewise Communities' guide to fire-friendly development.[7] Architects, engineers, and building owners and operators can use these codes and guides to improve building fire protection in New York State.

OWNERS AND OPERATORS

In response to the overwhelming majority of fires that take place on residential properties, the Cornell Cooperative Extension developed Home Fire Protection Guides[8] to aid homeowner fire sensitivity and mitigation. The U.S. Department of Homeland Security also provides the Owner Performance Requirements Tool,[9] which simulates building performance during climate hazard events to assist in the selection of resilience tactics.

Additional fire protection guides include FEMA's How to Prepare for a Wildfire[10] document, which selects fire-protection strategies based on the successes and failures in previous disasters. The University of California Agriculture and Natural Resources Department also provides a Home Survival in Wildfire-Prone Areas[11] guide that identifies building materials and design considerations. The NFPA identifies home fire sprinklers[12] as an effective strategy and provides a cost assessment for owners and operators to consider when selecting strategies to improve their building's fire protection.

IBHS Building Ignitions

Controlled fire tests provide useful information for selecting fire-protection systems.

In 2011, the IBHS conducted full-scale ignition tests[25] at its research center in South Carolina to learn more about how different building materials and construction systems respond after exposure to burning embers, direct flame contact, and radiant heat. Experiments in controlled environments can help those who work in the building sector make informed decisions about fire protection. Building owners, policymakers, and designers can use this information to assess the sensitivity of their buildings and to help direct decisions on what materials and systems to use in retrofits or new builds.

POLICYMAKERS AND PLANNERS

Wildfires initiated by climate change can inflict heavy damage across entire communities and regions. The American Red Cross provides information that can be used to educate New York State residents on the importance of fire safety and how to respond in the event of a fire.[14] The NFPA also has a guide that can be used as the basis for community-wide fire escape planning.[15] Response education programs can be combined with building fire-protection programs like the Fire Risk Reduction in Buildings Program[16] from NIST. This program generates studies that can help determine material requirements in the Fire Code of New York State.[3]

Funding is available for the implementation of fire preparation and response training. The DHSES has multiple grant programs[17] that support fire safety, including annual Preparedness Grants, Public Safety Answering Points Operations Grants, and Assistance to Firefighters Grants. The U.S. Fire Administration also provides an Assistance to Firefighters Grant Program[18] to enhance fire-safety abilities, protect first responder health, and increase the number of firefighters.

ARCHITECTS AND ENGINEERS

Building fire protection begins with the design and construction of a building that protects those inside. FEMA's Home Builder's Guide to Construction in Wildfire Zones[19] serves as a reliable guide for design considerations of residential homes by breaking down fire-protection tactics that can be applied to roofs, walls, openings, decks, and exterior landscaping.[20] For example, architects can limit the use of gutters, roof vents, and eaves that can collect flammable debris and ignite roof fires. OSHA provides guidance for designers considering building access for firemen[21] in the event of a fire, including strategies such as efficient water supply, key boxes, and rooftop hazard identification.

The NFPA provides a study that assesses the role codes and standards play in fire protection, as well as useful building fire protection standards.[22] The Society of Fire Protection Engineers' Engineering Guide to Performance-Based Fire Protection[23] is one of these standards. It provides a starting point and a comprehensive reference for including fire protection in all phases of the design process. The DOE also provides a Fire Protection Guide[24] that includes fire codes and standards for its own buildings. Although meant for government buildings, this document can be used for many building types in New York State.

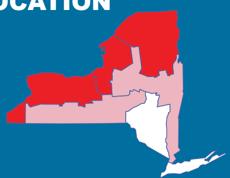
NYCCSC RESOURCES

1. Green Building and Climate Resilience:[26] A document that provides guidance for climate adaptation strategies, including building fire protection.
2. Primary Protection: Enhancing Health Care Resilience for a Changing Climate:[27] A guide that focuses on health care facilities and their resilience to climate change impacts, including wildfires.

Insulation

IMPROVING THERMAL PERFORMANCE IN THE BUILDING ENVELOPE

LOCATION



LOW | MEDIUM | HIGH

HAZARDS

HEAT WAVES

WINTER STORMS

RELATED STRATEGIES

- Windows
- Roof Coverings
- Urban Heat Island
- Building Ventilation
- Passive Building Systems
- Active Building Systems

DESCRIPTION

Proper insulation increases the efficiency of the building envelope by slowing heat transfer through exterior walls and roofs. This can help lower the demand on active building systems by maintaining comfortable interior temperatures, even during extreme hazard events such as heat waves and winter storms. This strategy is intended to help maintain comfortable interior temperatures as climate change increases the likelihood of extreme temperatures.[1] Both high and low exterior temperatures increase demands on active building systems that maintain comfortable temperatures. The U.S. Energy Information Administration reports that homes in New York State already consume 15% more energy[2] than the national average.

Inefficient insulation systems and the uncontrolled transfer of heat, such as through breaks in a home's air barrier, also allow moisture to collect in wall and roof assemblies, which can cause ice dams during the winter and mold growth[3] during the summer. Because insulation improves building performance in both extreme high and low temperatures, insulation improvements both above and below ground are an important climate resilience strategy for all regions of New York State.

OWNERS AND OPERATORS

For a better understanding of insulation systems, the DOE identified insulation types and techniques,[4] in addition to explaining what can happen if improvements are not made. For example, poor insulation can cause ice dams[5] during winter months, which divert water into the interior of the building. Insulation helps prevent ice dams by limiting the escape of warm air through gaps in the roof that would otherwise melt the snow stored on the roof during the winter.

Improving insulation can also be one of the most cost-effective strategies for increasing the energy performance of any type of building. The EPA Energy Star® program concludes that New York State homeowners can save an average of 17.35% on heating and cooling costs[6] after air sealing and insulation improvements. Homeowners can assess their home's insulation after reviewing the DOE's recommendations,[7] which identify where homes should be insulated. Professional energy audits[8] can provide a more thorough analysis of where improvements can be made.

GRoW Home

This zero-energy building uses efficient insulation to decrease the demand on active thermal energy systems.

Students and faculty from the University at Buffalo School of Architecture and Planning designed and built the GRoW Home,[9] a small zero-energy building that uses above code insulation to reduce energy demand. The floor, walls, and roof of the home were constructed using 10-1/4" thick R-40 Structural Insulated Panels (SIPs[10]) that were sealed to create an airtight enclosure. The insulation was combined with thermal zoning and cross ventilation techniques to maintain comfortable interior temperatures and reduce demand on active building systems.

HeatSmart Tompkins

Approximately 75% of the energy consumed by homes in Tompkins County is used to heat and cool interior spaces.

This program was developed in Tompkins County (ClimAID Region 3) as a response to the excessive amount of energy used to heat and cool homes. Providing incentives for home owners to move away from fossil fuels, this program instead encourages more energy efficient air and ground source heat pumps along with better insulation and air-sealing.[22] Multiple local businesses and homeowners have benefited from the program, which was responsible for more than 400 projects that generated $12 million in revenue while adding 70 full-time jobs, all within a one-year period.

POLICYMAKERS AND PLANNERS

Increasing temperatures and precipitation increase the vulnerability of certain populations[11] that live in homes that are not equipped to handle the anticipated changes in climate. One way to initiate change through policy is to constantly review and update insulation and fenestration (window) requirements, such as those included in Table 402.1.3[12] in the Energy Conservation Construction Code of New York State. All changes should be made in accordance with the changing climate conditions in each of the climate zones identified in Chapter 3[13] of the energy code.

In addition to code review and revision, policy makers and planners should provide building owners and operators with resources and incentives to increase the efficiency of their insulation systems in all regions of the state. NYSERDA Home Energy Efficiency Programs[14] can assist local leaders seeking to provide information and incentives for improving insulation systems. Programs like these help professionals and non-professionals understand the importance of insulation and how to make improvements within a budget. New York State also has a Weatherization Assistance Program (WAP)[15] that helps income-eligible families and individuals improve the efficiency of their homes to reduce the impact of heat waves and winter storms.

ARCHITECTS AND ENGINEERS

Exceeding insulation minimums prepares new and retrofitted buildings for a changing climate because restricting the transfer of heat though walls and roofs can decrease loading on active thermal systems and reduce the frequency of ice dams and mold growth. To help guide efficient insulation system design, the IECC's Residential Prescriptive Requirements[16] provides recommended minimums for R-value and U-value thresholds in each of the IECC climate zones in the United States. ASHRAE Standard 90.1[17] is also referenced in this code and sets values for commercial building energy use requirements. Professionals in New York State should consider referring to minimums and standards currently in use for southern states in order to account for the expected increases in temperature over time.

The DOE has an outline of multiple insulation materials[18] that provides typical R-values, installation advice, and information about environmental integrity. A review of these materials can help balance decisions between cost, performance, environmental qualities, and material longevity. The DOE also provides information on where to insulate in existing homes[19] and new construction.[20] Structural insulated panels[21] are building systems that provide wall assemblies with continuous insulation for new building construction. This effective and efficient prefabricated building system eliminates physical gaps in construction that would otherwise serve as entry points for air and moisture in wall and roof assemblies.

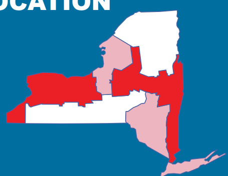
NYCCSC RESOURCES

1. Net Zero Energy Homes:[23] A residential construction program which offers support for homes designed to achieve net zero energy performance.
2. A New Modeling Approach to Forecast Building Energy Demands During Extreme Heat Events in Complex Cities:[24] A study describing how heat waves may increase energy consumption as demand for cooling grows.

Neighborhood Development

STRENGTHENING COMMUNITIES THROUGH CLIMATE ADAPTATION

LOCATION



HAZARDS

HEAT WAVES

FLOODING

WINTER STORMS

RELATED STRATEGIES

Emergency Management
Neighborhood Flood Protection
Gray Infrastructure
Neighborhood Fire Protection
Urban Heat Island
Potable Water Systems

DESCRIPTION

Resilient neighborhoods are prepared to adapt to and recover from climate hazard events[1] by maintaining essential functions, structures, and neighborhood character. Neighborhoods begin the resilience process by assessing how prepared residents are for recovery, and they continue by developing community-driven plans[2] that respond to existing vulnerabilities, use community assets, monitor community conditions, and equip the community with pathways for economic growth.

Resilient neighborhood development builds on neighborhood trust and the activation of strengths to holistically link environment, equity, and economy. Civic buildings, including schools, and critical facilities[3] play a significant role in neighborhoods, serving as a space for discussion and refuge. FEMA considers the whole community[4] a necessary part of resilient neighborhood development. In this view, preparedness is a shared responsibility that must be based on an understanding of the community's complexity and empower local action.

OWNERS AND OPERATORS

FEMA argues that resilience requires a whole community approach,[4] where all members, including individuals, businesses, institutions, schools, media, and government, share responsibility for hazard preparedness. Homeowners can initiate climate change resilience and adaptation efforts through individual management of privately owned green spaces,[5] which can collectively alter climate, pollution, stormwater mitigation, and biodiversity. For example, according to the EPA, compact development[6] strategies that reduce stormwater runoff on individual properties can add up to reduce the impact of climate hazard events including flooding.

Community resilience also includes social and economic factors such as equitable job training. The Baltimore Center for Green Careers[7] is one local organization that trains residents in Brownfield remediation and weatherization and creates opportunities for employment in highly skilled careers. THE POINT[8] is a community development corporation that empowers residents and improves neighborhood resilience by using teens as resources for making improvements to the neighborhood of Hunts Point in New York City.

NY Renews

Sustainable community development working to improve social injustice in New York State.

NY Renews[9] is a campaign comprised of community-based organizations, environmental justice groups, labor unions, business leaders, and many others that is pushing New York State towards sustainable community development. The advocacy group's goals are the creation of clean energy jobs, transition to 100% clean energy by 2050, support of environmental justice, and worker protection. The coalition uses sustainability as a unifying goal to reduce social injustices in New York State through job training, climate hazard response training, and fostering a transition to renewable energy.

Resilience Competition

U.S. Department of Housing and Urban Development awards funds for community resilience interventions.

The U.S. Department of Housing and Urban Development[22] awarded New York State with $35,800,000 and New York City with $176,000,000 in funding. New York State will use the funding for Public Housing Resiliency Pilots that implement site-specific resiliency interventions such as dry flood proofing and backups to critical buildings systems. New York City will use its funding to construct a coastal flood protection system in lower Manhattan while enhancing connections to community facilities, the waterfront, and open space.

POLICYMAKERS AND PLANNERS

Resilient community planning must begin and evolve with input from all populations within the community. FEMA's Whole Community Approach to Emergency Management: Principles, Themes, and Pathways to Action[10] explains traditional reliance on government to manage risks may not be as effective in managing future disasters. Instead, it is necessary for policymakers and planners to facilitate an increase in individual and community preparedness to enhance resiliency. In New York State, the Climate Smart Communities Program[11] guides local governments in taking appropriate climate action and recognizes high-performing communities. The program is comprised of 120 actions, including 13 priority actions for climate change adaptation, vulnerability assessments, and the identification of climate adaptation strategies in existing policies and regulations.

Low-carbon neighborhood planning can help improve resilience by reducing greenhouse gas emissions and the demand on grid utilities that can fail during climate hazard events. The Centre for Sustainable Energy released a guidebook to planning low-carbon neighborhoods[12] that addresses sustainability and resilience in transportation, energy, climate, and ecology. Responding to the impacts of Superstorm Sandy, the New York City Department of Planning's Resilient Neighborhoods[13] plan focuses on place-based neighborhood-specific strategies, including zoning and land use, to protect communities in flood plains. Similarly, changes made to New York City's Zoning Resolution[14] established the Special Coastal Risk District to promote public safety and potential damage reduction in areas with exceptionally high risks of flooding by creating special regulations, such as population limitations and wetland protection, for these areas. New York State also passed the Community Risk and Resiliency Act[15] to ensure that State monies and permits take into consideration the effects of climate risk and extreme weather events.

ARCHITECTS AND ENGINEERS

Resilient neighborhood development is most successful when infrastructure, including infrastructure at the neighborhood scale, is prepared to withstand the impacts of the changing climate. To assist architects and engineers, the EPA released a guide containing tools, strategies, and lessons learned[16] from previous green infrastructure installations. These small-scale infrastructure improvements can be paired with recommendations from FEMA,[17] such as flood modeling, continued education, and construction inspections, to help improve neighborhood resilience in all areas of the State.

NIST and the Technology Engineering Laboratory developed the Community Resilience Planning Guide for Building and Infrastructure Systems.[18] Volume 1[19] of the guide discusses developing a planning process around community resilience, while Volume 2[20] provides information on the issues surrounding the development of resilient neighborhoods including social vulnerability and dependencies. NIST also published The Community Resilience Economic Decision Guide for Buildings and Infrastructure Systems,[21] which details the economic ramifications of potential resilience investments.

NYCCSC RESOURCES

1. Smart Growth in Small Towns and Rural Communities:[23] Information and links to resources on smart growth for rural communities.
2. An Evaluation of the Asthma Intervention of the New York State Healthy Neighborhoods Program:[24] An academic article focusing on the impact of the Health Neighborhoods Program's asthma interventions.

Urban Heat Island

REDUCING THE EFFECTS OF EXTREME HEAT IN AN URBAN SETTING

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

HEAT WAVES

SEVERE STORMS

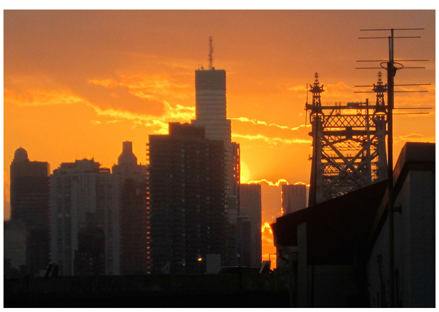
PEST INFESTATION

RELATED STRATEGIES

Emergency Management
Green Infrastructure
Roof Covering
Insulation
Neighborhood Development
Building Ventilation

2003 Northeast Blackout

Due to the urban heat island effect, excessive heat overburdened the energy supply and caused the largest blackout in United States history.



In August of 2003, due to high temperatures excessive cooling loads and energy consumption[11] caused a major power failure throughout the Northeastern U.S. and Canadian Province of Ontario. A study that followed the event[12] concluded that mortality increased for accidental and non-accidental deaths, resulting in approximately 90 excess deaths in New York City alone.

DESCRIPTION

Climate change will lead to longer and more intense heat waves that, according to the EPA,[1] can increase overall energy demand, elevate pollution emissions, compromise human health, and impair water quality. In a phenomenon known as the urban heat island effect,[2] non-reflective surfaces including roads and dark colored roofs absorb heat and make urban areas hotter than neighboring rural areas by as much as 1.8 to 5.4°F during the day and by as much as 22°F during the evening. The EPA describes how the effects of heat waves are exacerbated by urban heat islands and explains the potential impacts to sensitive populations[3] like the elderly, children, low-income populations, and people in poor health.

The EPA developed a Heat Island Compendium[4] to outline key resilience strategies including trees and vegetation, green and cool roofs, cool pavements, and activities to reduce the effects of heat islands. Other organizations like the DEC present useful material for developing an understanding of health risks and the steps that can be taken[5] to reduce the effects of urban heat islands.

OWNERS AND OPERATORS

Rising temperatures as a result of climate change will have devastating impacts on both human and building health.[6] Because heat can exaggerate or accelerate many existing health issues, FEMA's extreme heat fact sheet[7] identifies risks and what can be done before, during, and after extreme heat events.

The EPA's Heat Island Compendium describes urban heat island basics[8] and provides information on resilience tactics that reduce the negative effects of heat islands, including cool roofs and tree canopy growth. The Cool Roof Rating Council provides general information on cool roofs[9] for builders and homeowners, including benefits such as reducing energy bills and reducing the community's urban heat island effect. The EPA provides similar information on using trees and vegetation to reduce heat islands[10] with solar shading. These documents can help owners and operators make informed decisions on how to most effectively reduce the impacts of urban heat islands.

POLICYMAKERS AND PLANNERS

Addressing urban heat island requires community-wide efforts that focus on cooling urban areas with techniques such as high-albedo roofs and streets, and increased tree canopy coverage. The EPA has an excessive heat events guidebook[13] that describes the potential impacts of urban heat island and makes recommendations for mitigating its effects through a discussion of case studies and federal resources. Chapter 6 of the EPA's Heat Island Compendium can supplement this information with heat island reduction activities[14] that can be executed at a neighborhood scale. To facilitate action, the DEC provides access to cost-share grants[15] that provide funding for community groups to get involved in mitigation efforts. In 2017, the New York City Mayor's Office of Recovery and Resiliency launched a $106 million program, Cool Neighborhoods NYC,[16] to provide guidance in mitigation, adaption, and monitoring of rising temperatures and the impacts they have on the city's residents. The project includes plans to increase green space throughout the city and promotes programs like "Be a Buddy NYC," which encourages neighborly attentiveness in cases of emergency.

Mitigating heat islands is a collective effort that requires effective planning. The EPA maintains a Heat Island Community Actions Database[17] of projects that are happening in the United States, which can be used for inspiration to develop collaborations. The U.S. Forest Service and Loyola Marymount University's Prioritizing Preferable Locations for Increasing Urban Tree Canopy in New York City[18] is an example of a study that guides effective urban heat island planning through the use of GIS and other analytical tools.

ARCHITECTS AND ENGINEERS

Material selection and landscape integration play critical roles in mitigating urban heat islands by limiting heat absorption in urban settings. The NYSERDA-funded Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces[19] report can be used as a technical foundation for implementing heat-related mitigation strategies in all of New York State's urban areas. The American Society of Landscape Architects[20] provides links to organizations, government resources, research agendas, and individual projects that can help guide the implementation of strategies that address the effects of the urban heat island.

The EPA's Heat Island Compendium provides guidance for implementing urban heat island resilience strategies, such as tree canopy growth, green roofs, and cool roofs and pavements. The compendium discusses the benefits, costs, and design considerations for using trees and vegetation[21] to reduce exposure to sunlight, and it provides similar information for the construction of green roofs,[22] cool roofs,[23] and cool pavements.[24] Suggested considerations include reviewing the thermal performance of building materials. The Institut National de Santé Publique Québec also has a guide dedicated to heat island mitigation, which describes strategies such as the implementation[25] of selective vegetation, green roofs and walls, and urban infrastructure in a climate similar to that of northern New York State.

Urban Tree Canopy Growth

Tree canopies provide homes with sun shading, improved air quality, and increased comfort levels.

Funded by a grant from the DEC, the Urban Forestry Project[26] is responsible for implementing the Saratoga Urban and Community Forest Master Plan.[27] The main goals of this project are to integrate trees into Saratoga Springs' infrastructure, annually adjust strategies to ensure the use of modern forestry techniques, develop best management practices, commit more resources for trees, and cultivate citizen involvement. The actions within this project reduce urban heat island effects by improving the tree canopy, which shades roads and buildings that would otherwise absorb excessive heat from the sun.

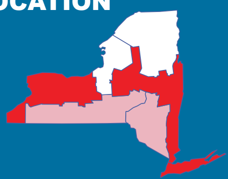
NYCCSC RESOURCES

1. Localizing Global Environmental Science:[28] A paper that assesses the relationship between city planners and climate scientists and explains how addressing local urban heat islands can lead to better decisionmaking.
2. Mitigation Integrating Stakeholder Perspective and Scientific Evaluation:[29] A study that attempts to understand the feasibility of mitigation strategies through stakeholder research questions, focusing on New York City.

Building Ventilation

A PASSIVE STRATEGY FOR ADAPTING TO HIGH-TEMPERATURE EVENTS

LOCATION



LOW **MEDIUM** **HIGH**

HAZARDS

HEAT WAVE

FLOODING

RELATED STRATEGIES

Windows
Insulation
Urban Heat Island
Indoor Air Quality
Passive Building Systems

NIST Planning Guide

Natural ventilation is a passive strategy that can keep buildings cool during brownouts and blackouts.

Electrical power outages are common during disasters and extreme weather events. The NIST Planning Guide[11] focuses on indoor environmental quality issues relating to disaster resilience events. Proper ventilation is an important aspect of providing healthy environments for habitation. Heat waves and storms that cause power failure threaten indoor environmental habitability due to raising temperatures that can cause heat stress and loss of heating/cooling and ventilation.

DESCRIPTION

Responding to Climate Change in New York State[1] explains that human health will be compromised due to higher temperatures and increased precipitation. Building ventilation can help maintain comfortable thermal environments during heat waves, improve indoor air quality[2] to reduce the effects of mold growth after floods, and reduce energy use and greenhouse gas emissions from active building systems.

The National Wildlife Federation and the Asthma and Allergy Foundation of America explain that climate change will worsen respiratory allergies[3] for approximately 25 million Americans, while more airborne allergens could increase the likelihood of asthma attacks for approximately 10 million Americans. The Institute of Medicine also concluded that ventilation is directly related to public health issues[4] such as indoor air quality and heat exposure, and a USGBC report states that New York State schools with good ventilation[5] were 94-184% more likely to have good attendance than schools with poor ventilation.

OWNERS AND OPERATORS

NYSERDA and the EPA teamed up with the National Center for Healthy Housing to create the Homeowner's Guide to Ventilation.[6] This guide describes how properly working ventilation protects humans from harmful pollutants and gases like radon and carbon monoxide, and how it protects homes from moisture damage that could lead to rot, insect infestations, and mold growth. The Building Science Corporation released an advisory containing recommendations for meeting ventilation requirements[7] and discussing how different ventilation system designs function in different climate zones.

Building operators and owners should understand that poor HVAC system maintenance may lead to microbial growth, as the dust, dirt, and moisture that accumulate create an ideal environment for microorganisms that can cause serious illnesses. Because of this, the EPA explains that ducts should be cleaned[8] regularly and maintained to ensure good indoor environmental quality. The National Center for Healthy Housing provides a guide for replacing bathroom exhaust fans[9] and a guide for installing kitchen exhaust fans[10] to help eliminate health hazards in the high activity areas of the home.

Net Zero Energy Homes

Passive systems, like those in net zero energy homes, increase passive survivability.

Passive systems, including building ventilation, are used in efficient buildings to increase passive survivability by reducing dependency on active systems that may fail during a climate hazard event. NYSERDA offers support for builders and developers of single-family and multifamily buildings that are designed to achieve net zero energy. These highly efficient homes incorporate high efficiency systems with passive systems such as air sealing and cross-ventilation to ensure that residential buildings exceed energy performance minimums defined by the New York State Energy Code.[22]

POLICYMAKERS AND PLANNERS

Climate change in New York State is expected to bring more extreme heat events that increase demand on active cooling systems and cause brownouts and blackouts.[12] According to the Building Resiliency Task Force, all housing should contain operable windows that allow and improve natural ventilation[13] to help cool buildings during extreme heat events and improve passive survivability in the event of a loss of power to mechanical ventilation equipment. New York State's Mechanical Code[14] currently states that mechanical ventilation must be provided and supply and exhaust should be equal in volume. Policymakers should consider similar mandates for natural ventilation that is used when mechanical systems are out of power.

Ventilation in buildings can be supplied through mechanical equipment or through natural air currents. The DOE explored different types of ventilation tactics that improve building performance[15] and how they help control moisture, cool spaces, remove indoor air pollutants, and provide fresh air. Building on this information, NYSERDA released a guide for better home construction[16] that explains the advantages and disadvantages of mechanical and natural ventilation in homes, and how to build better ventilation systems. Recommendations from these sources can be integrated into policy to help improve passive survivability in New York State buildings.

ARCHITECTS AND ENGINEERS

Designers should consider using passive ventilation as a supplement to active systems in both new and retrofit construction. To assist in this effort, NIBS discusses natural ventilation[17] in an overview of common issues, techniques, and design considerations. ASHRAE Standard 62.1-2016 and Standard 62.2 -2007[18] specify minimum ventilation rates. Interior air velocities of only 160 feet per minute have the potential to reduce the perceived air temperature by as much as 5 degrees Celsius. The standards also provide guidance on how to meet these ventilation rates with continuous mechanical ventilation that is based on building size and occupancy. Large-diameter, low-speed fans, for instance, tend to be more efficient and effective than smaller, high-speed fans and are typically used in large industrial or commercial spaces.

The DOE provides information regarding ventilation strategies for high-performance homes in its Building America Webinar[19] for building design professionals. The DOE also concludes that whole-house ventilation is a strategy that works well in cold climates,[20] where different system configurations can be used to meet different project and climatic requirements. In addition, the DOE and the Consortium for Advanced Residential Buildings explain how to successfully implement ventilation tactics through smart design, specification, and construction techniques in multifamily residential buildings.[21]

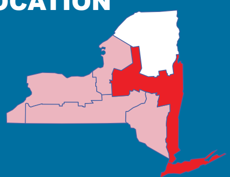
NYCCSC RESOURCES

1. Deaths Associated with Heat Waves in 2006:[23] Summary of investigation into deaths associated with heat waves that occurred in New York City in 2006.
2. Designing for the Next Century's Weather:[24] An article discussing the future effects of climate change on building construction and remodeling.
3. Climate Change and Extreme Heat Events:[25] Information for communities on extreme heat events and their threat to public health.

Indoor Air Quality

REDUCING PUBLIC HEALTH VULNERABILITIES IN BUILDINGS

LOCATION



HAZARDS

HEAT WAVES

FLOODING

PEST INFESTATIONS

RELATED STRATEGIES

Windows
Building Ventilation
Passive Building Systems
Active Building Systems
Integrated Pest Management

Superstorm Sandy

Carbon monoxide poisoning is a leading cause of mortality and morbidity in post-disaster situations.

In the aftermath of Superstorm Sandy, public health agencies observed at poison control centers an increase in exposure to carbon monoxide, which has effects that range from headaches and fatigue to coma and death. The Centers for Disease Control and Prevention[12] note that power outages increase risky behaviors such as improper placement of generators and indoor use of charcoal grills for heat. Ill-advised actions such as these, combined with spilled chemicals and exposed toxic building materials, increase post-storm mortality and morbidity.

DESCRIPTION

Air pollutants including particulates, sulfur oxides, and ground-level ozone can be influenced by meteorological variables[1] such as temperature and humidity. As a result, climate change plays a critical role in determining patterns of indoor air quality[2] in all building types. The EPA takes this information a step further by introducing the immediate and long-term effects[3] of poor indoor air quality including eye, nose, and throat irritation, as well as respiratory diseases and cancer. The severity of these effects depends on the individual sensitivity of the occupant and the level of exposure within the building. A study sponsored by the EPA also found that Americans spend 87% of their life in enclosed buildings,[4] where air pollutant concentrations are often two to five times higher than typical outdoor concentrations.

Climate Change, the Indoor Environment, and Health[1] from the Institute of Medicine provides more detail on the connections between climate change and indoor air quality. According to a study at Northwestern University, ground-level ozone[5] is one of the connections that can trigger multiple health hazards when it enters buildings through unsealed and unfiltered openings in wall and roof constructions.

OWNERS AND OPERATORS

For building managers, the EPA provides a notice that emphasizes the importance of monitoring and addressing indoor air quality[6] in all buildings. It also provides documents that give background information on what affects indoor air quality,[7] as well as information on how to ensure that a building has good indoor air quality.[8] These guides may be used as references for effectively completing the Indoor Air Quality Management Checklist,[9] which outlines a step-by-step procedure for developing a thorough understanding of how to maintain indoor air quality.

To help guide the mitigation of poor air quality, the National Center for Healthy Housing, with support from the EPA and NYSERDA, created the Homeowner's Guide to Ventilation,[10] which can be used as a guide for removing poor-quality air from a building. The EPA also provides additional methods for improving indoor air quality,[11] including source control and air cleaners.

NYS Healthy Neighborhoods

Trained individuals assess air quality and provide residents with the tools they need to improve indoor health.

The New York State Healthy Neighborhoods Program seeks to reduce housing-related illness and injury in New York State by performing in-home assessments that determine indoor air quality.[21] The program focuses on housing in high-risk areas vulnerable to the effects of climate change due to the age of the housing stock, neighborhood income levels, and exposure to potential climate hazards. The home assessments provide residents with condition-specific information, including the identification of existing issues and referrals to products and professionals that can help improve air quality.

POLICYMAKERS AND PLANNERS

Poor indoor air quality can have devastating impacts on populations with existing health conditions. According to the National Center for Environmental Health, warmer temperatures and increased amounts of carbon dioxide can contribute to shifts of pollen initiation in allergenic plant species, causing higher pollen and allergen concentrations.[13] The Lawrence Berkeley National Laboratory reviewed additional effects of climate change on indoor environmental quality and health,[14] including increased hospitalizations for people suffering from asthma, pneumonia, and cardiovascular issues. In response to many of these negative impacts, the Institute of Medicine recommends that public policy address indoor air quality mitigation[1] and prioritize research, regulations, and data to address health impacts of poor indoor air quality.

Building materials in older structures contribute to poor indoor air quality by emitting harmful particulates and microorganisms that become more harmful when exposed to higher temperatures. The EPA developed the Energy Savings Plus Health Guide[15] to protect and improve indoor air quality in schools during building upgrades and renovations. Building materials such as asbestos that were used generations ago during the construction of schools are particularly harmful to youth. Ventilation codes including Section 1203[16] of Chapter 12 of the Building Code of New York State should be considered when establishing ventilation minimums.

ARCHITECTS AND ENGINEERS

Many buildings in New York State are not prepared for projected changes in temperature and precipitation and will need to be renovated; as a result, the EPA sponsored a study that assesses national programs that look into the effects of building materials on air quality.[17] This report can help guide material selection, as there are no current New York State regulations that prevent exposures to product-related emissions in indoor air. ASHRAE's Indoor Air Quality Guide: Best Practices for Design, Construction, and Commissioning[18] is a design manual for ensuring healthy indoor air quality in both retrofit and new construction. The USGBC also provides guidance for improving indoor air quality in its LEED program strategies[19] by incentivizing the use of ventilation, air filtration, exterior contamination prevention, and carbon dioxide monitoring.

Mold growth is a major contributor to poor indoor air quality, yet it can be controlled through moisture control in building construction. The EPA produced Moisture Control Guidance for Building Design, Construction and Maintenance[20] to assist designers in making mold-resistant buildings that maintain healthy indoor air quality.

NYCCSC RESOURCES

1. Air Quality and Climate Change Policy Making:[22] A study that explores the air quality co-benefits of climate change mitigation.
2. U.S. Ozone Air Quality:[23] An examination of the sensitivity of the United States to the effects of ground-level ozone (O3) due to regional emissions increases (and decreases).
3. New York City Air Pollution:[24] A study that focuses on fine particle matter and ozone air pollution in NYC.

Passive Building Systems

REDUCING BUILDING ENERGY CONSUMPTION

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

HEAT WAVES

WINTER STORMS

HURRICANES / TROPICAL STORMS

RELATED STRATEGIES

Windows
Roof Covering
Insulation
Building Ventilation
Indoor Air Quality
Active Building Systems

DESCRIPTION

This strategy is intended to increase building energy performance by using passive rather than active systems. *Responding to Climate Change in New York State*[1] explains how spikes in summertime peak electricity demand due to an increase in the demand for cooling may cause more brownouts and blackouts. Passive building systems can help reduce building energy demand and assist in maintaining thermal comfort during power failures.

According to NIBS,[2] sun shading devices reduce building heat gain and cooling requirements by reducing direct solar heat absorption from the sun, and in some cases, result in a 5-15% reduction in annual cooling energy consumption. Optimizing site potential[3] through ideal building orientation, prevailing wind patterns and daylight availability can greatly impact building energy needs throughout the lifetime of the building. According to the USGBC,[4] using passive building systems has numerous benefits including reductions in heat gain, interior air temperature, peak demand, annual electrical energy usage, and annual energy cost.

OWNERS AND OPERATORS

Understanding thermal comfort can help owners and operators make effective decisions on how to use passive building systems. To facilitate this process, the Lawrence Berkeley National Laboratory provides guidance on setting thermal comfort criteria and minimizing the energy needed to deliver thermal comfort,[5] while the DOE provides information on passive solar design[6] and on the importance of properly sizing south-facing windows. Earth sheltering is another strategy that the DOE discusses as an alternative to conventional construction[7] because thermal mass can mediate temperature swings and reduce the impacts of extreme temperature events.

The incorporation of daylighting[8] is another way building owners and operators can improve the passive performance of their buildings. Daylighting can be improved by adding exterior windows and by reducing the number of interior walls that block the flow of light. According to NIBS, electric lighting accounts for roughly 35-50% of the total electrical energy consumption[9] in commercial buildings. Daylighting can help reduce this consumption and the likelihood of power outages during heat waves. Even if a power outage does occur, daylighting can keep interior spaces operational.

8th St. EnerPHit Project

Exterior envelope upgrades were made to a 100-year-old building to improve passive energy efficiency.

Designed by Redtop Architects and constructed by J's Custom Contracting, a historic Brooklyn Brownstone apartment building[10] was retrofitted more than 100 years after its initial construction with passive design tactics. Extensive improvements were made to the building's insulation with foam and high-performing windows. The airtight renovation and thermal mass improvement increase active system performance by decreasing demand. The high-performing envelope was capped by an extensive green roof that helped reduce the urban heat island.

POLICYMAKERS AND PLANNERS

The New York State Energy Code[11] currently references ASHRAE Standard 90.1 for commercial building energy use. However, the Passive NYC Briefing[12] argues this standard does not account for other comfort factors that increase demand on active systems such as radiant temperature, air velocity, and relative humidity. Developing a better understanding of thermal comfort and increasing exposure to passive building systems through policies and programs can help reduce demand on active building systems and energy consumption.

LEED v4 from the USGBC contained a Resilience Pilot Credit that seeks to ensure passive survivability in buildings for up to seven days in both extremely hot and cold temperatures. Passive survivability describes a building's ability to maintain thermal comfort during power outages, and it is a significant life safety issue for many at-risk populations such as the elderly, low-income, and chronically ill. Adapting building codes to account for passive survivability will help protect these vulnerable populations and reduce energy dependence. To assist in introducing passive survivability to policy and planning, NYSERDA has programs and incentives[13] to help improve the energy performance of New York State buildings.

ARCHITECTS AND ENGINEERS

To help designers incorporate passive building systems, Architecture 2030 developed the 2030 Palette[14] to provide guidance for making resilient and sustainable decisions in urban design, landscape, and building projects. Earth sheltering is one tactic designers can use to reduce heat loss and maintain a steady indoor air temperature[15] by using thermal mass to help regulate thermal comfort during temperature swings in the external environment.

Incorporating daylighting into design can help reduce demands on energy systems. This type of system also helps improve passive survivability if used effectively. A simple way to evaluate daylighting using physical or digital models is to use a heliodon[16] or digital simulation. The New Buildings Institute and the Integrated Design Labs at the University of Washington and the University of Idaho developed the Daylight Pattern Guide[17] as an resource for designers seeking to use daylighting in buildings.

NY Passive House

Organizations focused on resilient design can help bridge the gap between theory and practice.

New York Passive House (NYPH) focuses on making passive building systems information accessible to New York State building professionals. NYPH has multiple publications that include design guides, case study portfolios, and resource snapshots.[18] Organizations like this help establish a community culture focused on improving building performance in New York State. Building professionals can look to such organizations for guidance on multiple building systems, including passive design.

NYCCSC RESOURCES

1. Counting Carbon: Understanding Carbon Footprints of Buildings:[19] An article discussing carbon footprints in buildings as a result of energy use, related transportation, water use, materials, and construction.
2. BuildSmart NY:[20] Governor Andrew Cuomo's statewide initiative to increase energy efficiency in State buildings.

Active Building Systems

CLIMATE CHANGE ADAPTATION THROUGH EFFICIENT ACTIVE SYSTEMS

LOCATION

LOW | MEDIUM | HIGH

HAZARDS

HEAT WAVES

WINTER STORMS

HURRICANES / TROPICAL STORMS

RELATED STRATEGIES

Redundant Building Systems
Building Systems Flood Protection
Insulation
Indoor Air Quality
Passive Building Systems

DESCRIPTION

According to the *Third National Climate Assessment*, intensifying storms and extreme weather events can increase stresses on infrastructure[1] systems that energize buildings. According to Responding to Climate Change in New York State,[2] climate change is likely to increase precipitation and temperatures, which can lead to blackouts during heavy snowfall events and to brownouts during peak periods of active cooling. This strategy is intended to reduce the consumption of electrical and mechanical systems in all building types.

When building systems fail,[3] occupants are exposed to dark interiors, loss of elevators, limited life safety service/equipment, and a lack of proper heating or cooling. Resilient active building systems consume less energy, which lowers grid demand and reduces the likelihood of power outages during climate hazard events. Tactics like thermal energy storage[4] provide access to back-up energy supplies that can be used if power failures occur.

OWNERS AND OPERATORS

Reducing electrical and gas consumption from active building systems can help reduce the strain on energy systems during extreme heat events. Homeowners can reduce their electrical and gas consumption by installing solar water heaters[5] that use direct energy from the sun to provide hot water. According to NIBS, homeowners can realize dramatic reductions in their energy bills through the use of this system, as approximately 18% of energy use[6] in residential buildings is from water heating. In addition, this type of hot water system can remain operational during power outages.

Energy modeling provides building owners and operators with insights into how building performance can be improved. This tool is used to analyze a building's design and energy consumption, allowing decision-makers to evaluate tradeoffs between building components and equipment choices. Commercial building owners should consider having energy modeling performed, especially if they occupy an older building. According to the DOE and the architecture firm HOK,[7] payback for changes made as a result of having energy modeling done can occur in as little as one to two months due to the increased energy savings from understanding how the building can perform more efficiently.

Burrstone Energy Center

Cogeneration can provide back-up energy during grid failures by using waste heat to create steam.

The Faxton St. Luke's Healthcare Center in Utica, New York (ClimAID Region 5) installed a cogeneration plant[8] to supply its thermal output to a central steam plant. The system can provide back-up power in the event of grid failure and sell electricity to the grid, allowing for roughly $800,000 in annual energy savings.

2015 NYS Energy Plan

Updating building codes is critical for improving the energy efficiency of New York State's building stock.

Governor Andrew M. Cuomo launched the energy policy for New York State in 2015 to outline plans for clean, resilient and affordable energy systems.[19] The plan aims at coordinating State agencies and regulatory bodies to push regulatory reform and integrate clean energy as the core of the power grid. The plan helps readers improve the performance of active building systems by providing information on the benefits of exploring alternative energy systems, including cost benefits and incentives.

POLICYMAKERS AND PLANNERS

Severe storms and extreme weather caused by climate change may disrupt power distribution, which makes buildings more vulnerable to brownouts and blackouts. The DHS released the NIPP 2013: Partnering for Critical Infrastructural Security and Resilience[9] as a national plan to guide the management of critical infrastructure that is at risk of damage from climate hazard events. The Applied Technology Council[10] suggests amendments to the building code that require critical active building systems to remain functional during power failures.

Policymakers and planners should prioritize efficient building systems to reduce recovery time after climate hazard events and decrease the demand and cost of electrical grid use. The Institute for Market Transformation and the Pacific Coast Collaborative explain the benefits of benchmarking building performance[11] and how energy efficiency can reduce demand and living costs. To assist in this effort, NIST explains the energy and economic benefits of updated state energy codes[12] and discusses how updates can contribute to saving money, building resilience, and creating jobs. The Environmental and Energy Study Institute discusses the value and impact of building codes[13] while highlighting the benefits of updating energy codes, such as reduced costs and decreased grid dependence. Policymakers and planners can use this information to help support policies and other initiatives that prioritize energy efficiency.

ARCHITECTS AND ENGINEERS

Inefficient active building systems can worsen the impact[3] of climate hazard events by overburdening grid systems and causing power outages. Energy modeling[14] is a technique that can reduce inefficiencies by helping building professionals understand how their buildings can perform better. Architects and engineers can also use energy modeling to test out non-traditional building systems that may improve the efficiency of buildings, such as energy recovery ventilators[15] and solar thermal water heaters.[5]

Reducing energy consumption, however, cannot completely guarantee power outages will not occur during climate hazard events. If power outages do occur, it is important for a building to be able to maintain passive survivability[16] without the assistance of active building systems. Techniques for increasing passive survivability[17] include providing water, backup sanitary services, alternative lighting sources, and non-mechanical ventilation. Architects and engineers should place more emphasis on learning how their building will perform without power and incorporating passive techniques into design. In addition, building professionals should consider using efficient active systems, including energy recovery ventilators, in combination with passive building systems such as daylighting[18] and ventilation in order to extend passive survivability.

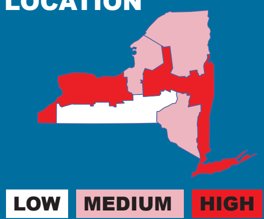
NYCCSC RESOURCES

1. A New Modeling Approach to Building Energy Demands:[20] A research paper from 2013 that demonstrates a new modeling technique to understand energy demands.
2. Model Ordinances:[21] A webpage for the Model Municipal Ordinance project that aims to create best practices for municipal ordinances that guide green buildings, and renewable energy sources.
3. Effects of Climate Change on the Built Environment:[22] An article on new building design that presents resilience strategies with technical details.

Building Operations

IMPROVING EFFICIENCY IN BUILDING MAINTENANCE AND PERFORMANCE

LOCATION



HAZARDS

HEAT WAVES

HURRICANES / TROPICAL STORMS

WINTER STORMS

RELATED STRATEGIES

Redundant Building Systems
Building Systems Flood Protection
Building Fire Protection
Indoor Air Quality
Active Building Systems

DESCRIPTION

As climate change alters temperature and precipitation patterns, buildings will need to operate in extreme conditions that go beyond their initial design capacity. According to *Responding to Climate Change in New York State*,[1] weather-related stresses can disrupt energy systems such as fuel supply chains, reduce power generation output, damage equipment, and increase energy demand. Proper and efficient facility operations and maintenance[2] can help ensure that buildings remain operational during and after climate hazard events.

Efficient building systems that are properly maintained are resilient because they have a reduced demand on energy grid systems that can fail during climate hazard events. Resilient building operations and maintenance can be supported by the adoption of a comprehensive facility operations and maintenance manual[3] and a life-cycle cost analysis[4] that assesses the total cost of owning and operating a facility. Both of these strategies can help identify sustainable and resilient practices that reduce cost and dependency in building systems.

OWNERS AND OPERATORS

Efficient building operations have both economic and environmental benefits. Operators should consult the DOE Operations and Maintenance Best Practices[5] guide, which explains the importance of good operations and maintenance including preventive and predictive maintenance. It defines different operations and maintenance programs, state-of-the-art maintenance technology, and additional resources for building managers. NIBS recommends computerized maintenance management systems[6] as a way for managers to optimize operational resources and ensure that systems run at peak performance without surprise failures.

Retrocommissioning, also known as continual commissioning, is an operations-based process to increase energy performance. Retrocommissioning can also include surveys to improve occupant health and comfort. The EPA released a Retrocommissioning Guide for Building Owners[7] to discuss this cost-effective method for improving the performance of existing buildings. A lack of facilities maintenance can lead to building systems failures, poor occupant health, reduced indoor air quality, and unreliable comfort and productivity. Optimized operational and maintenance practices,[8] including staff training and automated systems, are a critical component of building climate resilience.

Emergency Operations

Resilient building operations include opportunities to safely access alternative energy systems.

In the immediate aftermath of Superstorm Sandy, many residents in ClimAID Regions 4 and 5 were surprised to find out their grid-connected solar photovoltaic (PV) systems were not operational[9] during power outages due to safety shut off features that protect utility workers. As a result, even those who invested in alternative energy sources were left without power. This situation could have been avoided with grid disconnect mechanisms. These devices allow residents to safely activate their PV systems when the grid is shut down.

NYC Energy Audits

Owners of large buildings are required to comply with energy efficiency reporting.

New York City (ClimAID Region 4) requires owners of applicable commercial, mixed use, and residential buildings to submit an Energy Efficiency Report[20] (EER) every 10 years. Energy audits and energy efficiency reports identify areas to reduce energy consumption in the building. This process of retrocommissioning helps ensure that energy systems in an existing building are installed per the design intentions. The purpose of the audit is to identify areas to improve energy consumption and reduce grid demand.

POLICYMAKERS AND PLANNERS

Planners and policymakers can make communities more resilient to climate hazards through evacuation agreements[10] that incorporate evacuation into building operations to allow more buildings to be used as shelters, relocation centers, and transportation support areas. During climate hazard events, community leaders need to more effectively use community assets to better coordinate effective responses. The Building Resiliency Task Force argues for legislation that does not discourage buildings from operating during emergencies,[11] which could open the door towards more buildings being shelter ready in New York State.

FEMA provides information on operations and maintenance plans for community safe rooms in Chapter A4 of Safe Rooms for Tornadoes and Hurricanes,[12] which can be used to develop policy and response emergency response protocols. NYSERDA offers a Commercial Implementation Assistance Program[13] aimed at helping fund comprehensive approaches to energy-efficient improvements at both the State and local levels to help reduce demand on energy grid systems that can fail during climate hazard events. These opportunities can help decrease dependence on energy infrastructure and reduce response time after climate hazard events by ensuring that building systems are properly maintained and protected.

ARCHITECTS AND ENGINEERS

The GSA encourages the use of BIM technologies,[14] which use existing data to inform the design process and improve the efficacy of building operations and maintenance. The BIM Guide for facility management[15] describes how to improve as-built building information and reduce the cost and time required for renovations and repairs by making building information more accessible to maintenance workers and first responders. The GSA also released Facilities Standards for the Public Buildings Service,[16] which establishes design standards for new buildings and renovations.

ASHRAE Guideline 4- 2008[17] covers procedures for documenting operations and maintenance practices for building HVAC systems, which can help building professionals better understand building performance. Resilient building operations strategies, such as retrocommissioning, are recognized by the USGBC LEED Program.[18] According to NIBS, a successfully commissioned building often saves money[19] by running more efficiently, having fewer change orders, and having lower operational costs. Pursuing effective building operations and maintenance of building systems is important because efficient building systems are less dependent on fragile energy infrastructure, and as a result, are less likely to experience failures during power outages caused by climate hazard events.

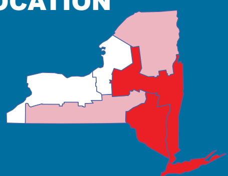
NYCCSC RESOURCES

1. Case Studies: Energy Efficient Municipal Facilities and Operations:[21] Case studies of projects in New York and other states that improve energy efficiency.
2. Mitigating Climate Change through Green Buildings and Smart Growth:[22] An academic article looking at the future role of sustainable buildings in the wake of climate change.

Potable Water Systems

PROTECTING WATER FROM WASTEFUL USE AND CONTAMINATION

LOCATION



LOW MEDIUM HIGH

HAZARDS

HEAT WAVES

HURRICANES / TROPICAL STORMS

FLOODING

RELATED STRATEGIES

Emergency Management
Redundant Building Systems
Building Flood Protection
Gray Infrastructure
Neighborhood Development
Reclaimed Water Systems

DESCRIPTION

Humans require on average 20-50 liters of clean water[1] for drinking, cooking, and sanitation daily. The Center for Disease Control and Prevention explains that drinking water in the United States must undergo an extensive treatment process[2] to remove particulates, parasites, bacteria, and chemicals before consumption.

Contamination of water can occur at the source and within distribution systems. With the increased likelihood of extreme precipitation and temperatures, climate change can alter the quality of surface water and groundwater,[3] which can significantly damage individual water supplies. According to the EPA, which regulates public drinking water systems[4] and provides information for the public, 90% of Americans receive water from these public supplies, while others have individual water supplies that can be affected by new and unfamiliar contaminants. This strategy attempts to ensure water resilience by maintaining clean potable water sources, water conservation, and localized harvesting as the anticipated increases in temperature resulting from of climate change facilitate mold growth in buildings, which could contaminate water supplies.

OWNERS AND OPERATORS

Homeowners and building operators can reduce drought vulnerabilities by protecting and conserving water[5] through the use of efficient fixtures that reduce water consumption. Due to its high cost and energy use, potable water should be used only for necessities. The New York City Department of Environmental Protection encourages conservation actions,[6] such as running a dishwasher only when it is full, and discourages wasteful uses, such as lawn irrigation and washing sidewalks, in order to protect the potable water supply.

The EPA explains nearly 15 million households receive potable water from private water wells that are subject to contamination[7] from seepage through landfills, failed septic tanks, fertilizers, and runoff. Owners of these systems need to take special precautions to test and maintain their systems. If a system is contaminated, the National Sanitation Foundation recommends boiling as well as other emergency water treatments.[8] The Cornell University Cooperative Extension provides water quality information for residents on testing supplies and home water treatment[9] systems.

NYC Water Tanks

NYC's water supply is constantly exposed to bacteria growth and animal feces in rooftop tanks.

In January 2014, the New York Times published its study of 14 New York City rooftop water towers[10] (ClimAID Region 4). Eight of the tanks tested positive for coliform bacteria, and five tested positive for E. coli. Bacterial and microbial growth is the result of exposure to extreme heat and sun during summer months. Tanks that are not properly maintained and open to the air allow animals to enter and potentially contaminate the water. Improved maintenance and microbial management[11] within the tanks can ensure a clean water supply for New York City's residents.

Extreme Precipitation

Heavy rain events contribute to significant water quality issues that can result in contamination.

In August 2011, Hurricane Irene brought 16 inches of rainfall in areas near New York City's[23] upstate water supply reservoirs (ClimAID Regions 2, 4, and 5). Just 10 days later, Tropical Storm Lee dumped more heavy rain on the region, causing flooding. Runoff greatly disrupted the water quality of reservoirs by increasing debris and particulates, which made it challenging to bring high-quality drinking water to the city's residents. Superstorm Sandy also created difficulties with water quality when the storm shut down 10 out of 14 sewage treatment plants in New York City, releasing large amounts of untreated material into local waterways.

POLICYMAKERS AND PLANNERS

The DOH explains nearly 95% of New Yorkers receive drinking water from public water systems.[12] The DEC provides information for public officials and municipal employees regarding the potential contamination of drinking water[13] to reduce the possibility of contamination. The Sewage Pollution Right to Know[14] law enacted in 2013 requires that any sewer discharges not fully treated be reported to the DEC, adjoining municipalities, and the public. The DOE advises using information like this, which outlines overarching policies and goals, assesses current water use and costs, and identifies opportunities for water efficiency, to assist in the development of comprehensive strategic water plans.[15] This information helps policymakers and planners understand where contamination occurs and what sort of protection needs to be facilitated.

The EPA's Community-Based Water Resiliency Tool[16] helps planners and policy makers understand how prepared their community is to handle disasters that affect local water supply. It features the Water Resiliency Action Plan Kit, a step-by-step guide to planning and hosting community meetings on water emergencies. The EPA also provides Incident Action Checklists[17] that help drinking water and wastewater utility operators with emergency preparedness, including response and recovery activities for climate hazards such as drought, heat waves, flooding, hurricanes, and wildfires.

ARCHITECTS AND ENGINEERS

In response to the likely increase in precipitation,[18] the Environmental Finance Center at Syracuse University released the New York State Rainwater Harvesting Guide[19] to help designers understand the potential for rainwater harvesting throughout New York State. The DOE and the Pacific Northwest National Laboratory released Rainwater Harvesting State Regulations and Technical Resources[20] to help designers understand how using rainwater for non-human consumption can help preserve potable water during droughts.

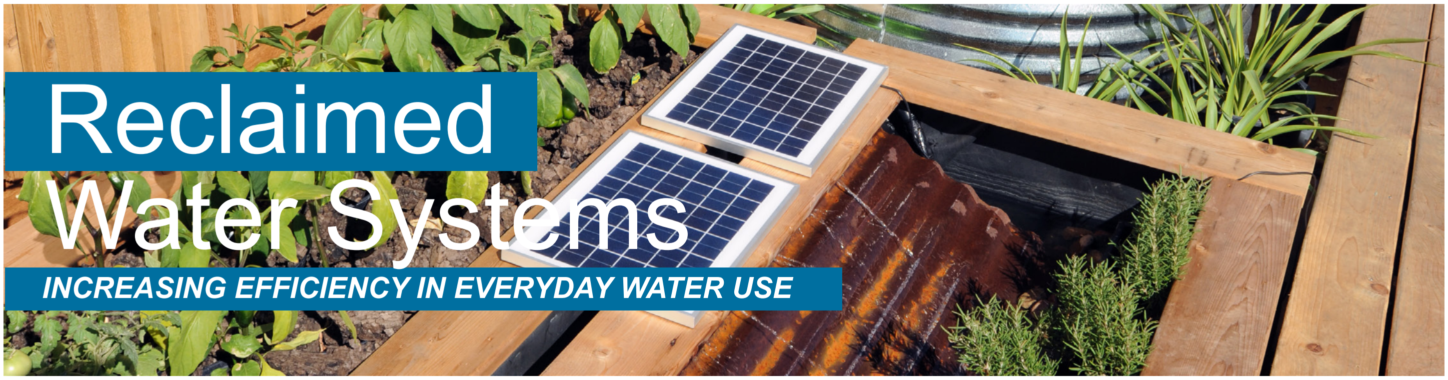
Designers can make buildings' potable water systems more resilient to the effects of climate change by specifying appliances and fixtures that are water efficient. The EPA Water Sense Program provides lists of certified products that are high-performing and water efficient[21] to help protect water resources from being overused during times of drought. The Federal Energy Management Program and the EPA developed 14 best practices for water efficiency[22] that give designers information to consider during the design of mechanical and plumbing systems.

NYCCSC RESOURCES

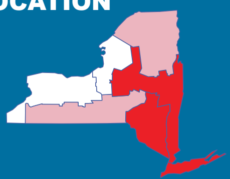
1. NARCCAP Precipitation Projections:[24] Projected precipitation by decade relative to the historic average.
2. U.S. Drought Monitor - Northeast:[25] Current weekly maps and data on northeast U.S. drought conditions; includes a dataset and map viewer.

Reclaimed Water Systems

INCREASING EFFICIENCY IN EVERYDAY WATER USE



LOCATION



HAZARDS

HEAT WAVES

SEVERE STORM

FLOODING

RELATED STRATEGIES

Green Infrastructure
Roof Covering
Roof Drainage
Passive Building Systems
Potable Water Systems

DESCRIPTION

According to *Responding to Climate Change in New York State*, anticipated changes in New York State's climate[1] have the potential to bring extended periods of drought with intermittent periods of intense rainfall. Higher temperatures will simultaneously increase the volume of water required for agriculture and landscaping and lead to increased evapotranspiration. The building sector can help address water shortfalls by using reclaimed water systems like rainwater collection[2] to make water use more efficient.

Shifts in population and associated water demands[3] are further complicated by climate change impacts on a global scale. The growing threats of climate change on existing water systems call for an increased dependence on reclaimed water systems that improve the efficiency of water use. There are multiple methods of reclaiming water,[4] including graywater collection from interior systems and rainwater collection.

OWNERS AND OPERATORS

Owners and operators can help improve their building's water resilience during prolonged periods of low precipitation by using reclaimed water for landscaping. According to the National Research Council, there is a wide range of technologies available for treating wastewater intended for reuse.[5] Treatment techniques depend on what contaminants are in the wastewater, the intended use, the cost, and how waste is disposed. NIBS explains that reclaimed water as a form of conservation can save money[6] by lowering utility and sewer costs while reducing energy use.

The San Francisco Graywater Design Guide for Outdoor Irrigation[7] provides information on using water from laundry to irrigate landscapes in times of drought to protect potable water from being wasted on unnecessary non-human consumption. Graywater from bathroom sinks, bathtub shower drains, and clothes-washing equipment may be reused in reclaimed water systems. The Ecology Center explains the importance graywater-compatible cleaning products[8] and lists specific ingredients to avoid to help keep reclaimed water systems running properly.

Oneida Water Reuse

Reclaimed water is a great source for large irrigation projects.

The EPA 2004 Guidelines for Water Reuse[9] discusses the Oneida Nation Golf Course (ClimAID Region 5), the only major water reuse project in New York State. This joint project between the City of Oneida and the Oneida Indian Nation uses reclaimed water to irrigate the golf course at Turning Stone Casino. The Oneida Nation installed the needed equipment (pumps and treatment) in the city. From there, reclaimed wastewater is delivered to irrigate the golf course so local water supplies are not stressed by large demand.

PUSH Blue

The NYS Environmental Facilities Corporation provides grants for green infrastructure projects.

The Buffalo Neighborhood Stabilization Corporation (ClimAID Region 1), a local nonprofit community development organization, received a green innovation grant from the New York State Environmental Facilities Corporation.[18] The grant funded the project PUSH Blue, which installed bioretention areas, rain gardens, permeable pavement, and green roofs to help address Buffalo's stormwater. The implementation was on a local resident's property.

POLICYMAKERS AND PLANNERS

Increasing demand, depleting resources, and changing precipitation patterns are all ways in which climate change affects New York State water supplies. The International Council for Local Environmental Initiatives released Adapting Urban Water Systems to Climate Change,[10] a handbook to help planners and policymakers develop resilient urban water management. The EPA explains that recycling water on site or nearby[11] reduces the energy used to extract water from aquifers and transport it long distances. The California Energy Commission's 2005 report California's Water-Energy Relationships[12] also discusses the energy intensities of water treatment and distribution, concluding that the energy required for treating wastewater is significantly less when reclaimed water systems are used.

Communities with combined sewer systems can benefit from water reclamation as a means to reduce combined sewer overflows[13] by reducing the amount of graywater that enters the system. Graywater can contain much higher levels of nutrients such as nitrogen, which can be beneficial for irrigation and agricultural uses, but harmful if it is allowed to enter bodies of water. Policymakers and planners can address this issue by establishing policy for the use of green infrastructure[14] projects that incorporate water reclamation to help the built environment adapt to changing patterns of temperature and precipitation.

ARCHITECTS AND ENGINEERS

Incorporating reclaimed water systems into building design improves resilience by increasing the efficiency of use and decreasing the demand for potable water. The National Academy of Sciences released a document that discusses potable water and regulating policies[15] that can help designers understand the necessity of reclaimed water use. Strategies including rainwater collection[16] have been defined by the Centers for Disease Control and Prevention as an effective means of reducing the need to use treated water for landscaping and agricultural purposes. Multiple systems including those for collecting graywater and rainwater, can help extend resilience across all regions of New York State.

New York State provides a Residential Onsite Wastewater Treatment Systems Design Handbook[17] that discusses the design and implementation of septic systems, which can be used to decrease demand on treatment plants that can fail during power outages. The EPA's 2012 Guidelines for Water Reuse[4] provides critical technical information for developing systems for water reuse, as well as case studies that demonstrate best practices in reclaimed water systems throughout the United States using systems such as graywater collection, rainwater collection, and HVAC condensate recapture.

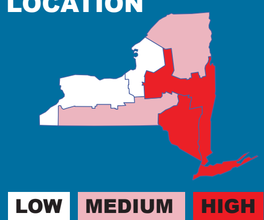
NYCCSC RESOURCES

1. National Drought Mitigation Center:[19] A center established at the University of Nebraska-Lincoln to help people and institutions develop and implement measures to reduce vulnerability to drought.
2. Roadside Ditches: Best Management Practices to Reduce Floods, Droughts, and Water Pollution:[20] A factsheet to improve quantity and quality of water resources.

Integrated Pest Management

PROTECTING BUILDINGS FROM PESTS

LOCATION



HAZARDS

PEST INFESTATION

HEAT WAVES

RELATED STRATEGIES

Windows
Building Foundations
Insulation
Indoor Air Quality

NYC Public Housing

IPM implementation to reduce pest and allergen issues.

In a study conducted in New York City[4] (ClimAID Region 4), a public housing facility used IPM to control cockroach populations. As an alternative to toxic pesticides, which accounted for more than 1,000 cases of accidental poisoning during the year of the study, the IPM strategy involved professional cleaning, sealing of pest entry points, education, and the application of low-toxicity pesticides. The success of the study demonstrates the effectiveness of IPM in reducing pests while providing human health benefits.

DESCRIPTION

This strategy is intended to protect buildings from animals and pests that may damage building structures and materials or pose a threat to human health. As the yearly average temperatures continue to rise, the habitat ranges of some pests, including the wooly adelgid, emerald ash borer, gypsy moth, and termite, will shift and expand northward. These invasive species[1] could spread disease[2] or cause damage in New York State as they enter populated areas.

According to FEMA's HAZUS MH hazard loss simulation software,[3] 42.3% of buildings in New York State are wooden structures, vulnerable to termites. IPM systems require a comprehensive effort[4] of sanitization, building maintenance, and pesticide use to control unwanted pests in New York State. However, according to the EPA, preventive pesticide application[5] should be used with caution because careless application and exposure can outweigh the potential benefits.

OWNERS AND OPERATORS

All buildings in New York State are vulnerable to pest infestation. According to PestWorld, a nonprofit organization, homeowners can protect their home from pest infestations[6] using tactics such as replacing rotted wood, sealing gaps on the home's exterior, and storing food in sealed containers. In addition, the DEC provides resources about residential pest management and pesticide use[7] that highlight potential hazards to children and water quality.

Older schools are a particular place where IPM should be used, as children may contract diseases and suffer asthma attacks from allergens through unnecessary exposure to insects and rodents in these aging buildings. The EPA states that IPM makes economic sense[8] by reducing the number of pests and reducing the number of pesticide applications, which saves schools money in the long term while improving the overall health of the environment. The EPA developed a Strategic Plan for School IPM[9] that outlines how IPM should be integrated in schools and aligned with other EPA programs as the need for IPM increases.

New York PRISM

Making information available on invasive species can help reduce negative impacts.

PRISM is dedicated to proactively identifying, evaluating, and addressing invasive species[19] in eight specific regions of New York State. Coordinating partnerships between local officials, organizations, and private citizens, PRISM aims to improve, restore, and protect local aquatic and terrestrial ecosystems. Fact sheets[20] provided by PRISM describe invasive species and the environments in which they thrive. Those involved with the building sector can use this information to help determine what types of materials and protections to use in building construction.

POLICYMAKERS AND PLANNERS

IPM PRiME is a tool that ranks pesticide products by impact[10] on birds, earthworms, small mammals, aquatic ecosystems, and human health so policymakers and planners can determine which pesticides should or should not be used in their local community. This program also includes GIS data that analyzes site-specific impacts and select effective pest control options.

According to the Institute of Medicine, possible health impacts related to climate change[11] and pests include an increased number of dust mites, disease from the presence of rodents, and the increased prevalence of pesticide use. In New York State, requirements of Chapter 85 of the Laws of 2010 were added to the State Education Law and the Social Services Law limiting the use of pesticides[12] on playgrounds, sport fields, and in schools and daycare centers, providing guidance and supporting the development and use of pesticide alternatives. In support of this legislation, the DEC dedicates a page to information on reducing the hazards of pesticide use in pest management for schools and daycare centers.[13]

ARCHITECTS AND ENGINEERS

According to the USGBC, designers can make buildings more resilient to climate change-related pest control problems[14] by using termite resistant materials and avoiding wood construction in vulnerable locations. Presently, two LEED credits directly incorporate integrated pest control[15] management. LEED v4 Home and LEED v4 Operations and Maintenance each contain one credit for integrated pest management and nontoxic pest control to minimize pest problems and pesticide exposure.

Cornell University's College of Agriculture and Life Sciences provides information on New York State Integrated Pest Management,[16] including fact sheets for different pests such as termites, carpenter ants, paper wasps, bed bugs, and mites. These fact sheets explain the typical behaviors of each pest, as well as techniques for preventing and mitigating problems. The National Pesticide Information Center[17] has information about the various pests that may affect buildings and their occupants. The EPA provides information on structural pests,[18] including information on how to control and prevent them from entering buildings. For example, termite prevention in residential construction can take the form of metal termite shields, treated lumber, proper grading and drainage, ground barriers, and pesticide applications.

NYCCSC RESOURCES

1. Environmental Public Health Tracking Data:[21] New York and national data sources about the environment and human health, including air, water, hazardous waste, radon, pesticides, and more.
2. Projected Change in Climate Thresholds in the Northeastern U.S.:[22] Implications for crops, pests, livestock, and farmers.
3. Invasive Insect Species:[23] Observations of mapped locations of invasive insects by county in New York State.

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Appendix A: Cost Profiles for Climate Resilience Strategies in New York State

INTRODUCTION

Implementing climate resilience strategies requires a consideration of both benefits and costs. This appendix assists with the calculation of a benefit-cost ratio (BCR) for residential and non-residential buildings by providing example first costs for the 25 strategies described in the body of the report. A BCR is a quantitative expression of the "cost-effectiveness" of a project. A project is considered to be cost effective when the BCR is 1.0 or greater, indicating the benefits of a hazard mitigation project are greater than the cost of construction.

The FEMA Hazard Mitigation Grant Program requires a benefit-cost analysis to validate the cost effectiveness of proposed hazard mitigation projects prior to providing funding. The sample first costs provided in this appendix are intended to streamline that process, but must be used with other resources like the FEMA Benefit-Cost Analysis Tool to determine the exact BCR of a strategy or project. Please note that this appendix does not contain the expected benefits of a strategy because they vary significantly by location, occupancy, construction type, the nature of a climate hazard, and other factors.

Finally, the costs in this appendix are intended as examples; exact costs are also variable. The first costs in this appendix are adapted from RS Means Construction Cost Data to establish a point of reference; they should not be used as final numbers for a construction project. RS Means data is commonly used by the construction industry for cost estimation.

TABLE 1

The first step in the implementation of climate resilience strategies is to understand what hazards need to be addressed. Table 1 (pages 108 to 111) lists eight climate-related hazards (in columns) that may increase in frequency and severity across New York State and the strategies that are applicable.

These strategies can be implemented in a number different ways. For example, the implementation of the Building Flood Protection strategy can include flood resistive materials, sewage backflow preventers, and moisture sensors. As a result, each strategy has a cost associated with how a strategy is implemented. Table 1 lists the strategy implementations that are included within this document to more accurately reflect the individual cost of each climate resilience strategy.

STRATEGY IMPLEMENTATION

This document uses the recommendations of organizations including FEMA, The National Institute of Building Sciences, and the United States Green Building Council to develop the cost guidance. Recommendations from these organizations are applied to a benchmark building, a new resilient building, and a retrofitted resilient building to illustrate the cost differences between the different approaches to climate resilience.

Benchmark Building: The costs for the benchmark building reflect the construction costs of a new code compliant building in New York State that would not be considered resilient. If a strategy implementation calls for a specific type of material or technique, the sample cost for this building reflects the cost of the non-resilient and/or most affordable material or technique that would serve the same relative purpose in a building. For example, the implementation of fire resistant materials calls for the use of fiber cement board as siding. The benchmark building, however, would use a less expensive alternative such as vinyl siding.

New Resilient Building: Sample costs for this building reflect the costs of a new building in New York State constructed to resist the anticipated impacts of climate change. The costs for strategy implementation are guided by building resilience and building-related organizations. The sample costs reflect the costs of building construction on a greenfield site in an attempt to form a one-to-one cost comparison with the benchmark building.

Costs that would normally be included in typical building construction, regardless of whether the building is resilient or not, are not included within the sample costs of this intervention type. For example, a contractor would need to excavate a trench to connect the building to a sanitary sewer or septic tank whether the building is resilient or not, and as a result the cost of the excavation is considered equal between the benchmark and new resilient building. However, the cost of a sewage backflow preventer in a new resilient building would be an additional cost.

Retrofitted Resilient Building: The costs for this building reflect the costs of implementing resilience strategies on an existing building in New York State. These costs represent the cost of implementing the resilience tactic in addition to the cost of removing what was already there or the cost of making room for such changes. For example, to execute beyond code wall insulation in an existing building, a contractor may have to remove the exterior wall coverings, add additional insulation, and then replace the exterior wall coverings.

TABLES 2A AND 2B

Tables 2A and 2B (pages 112 to 131) describe each strategy implementation in the Benchmark Building, New Resilient Building, and the Retrofitted Resilient Building. These tables provide a basic outline of how each strategy was implemented related to the costs. Table 2A (pages 112 to 121) describes how each tactic is applied to the sample residential building, while Table 2B (pages 122 to 131) describes how each tactic is applied to the sample non-residential building.

STRATEGY IMPLEMENTATION COSTS

Sample buildings were defined to identify proper quantities for strategy implementation. The development of the sample buildings was guided by general housing data from the United States Census Bureau (residential construction) and the Commercial Buildings Energy Consumption Survey (non-residential construction).

Sample Building Characteristics	Sample Building Types	
	Residential Building	Non-Residential Building
Total Square Footage	2,600 Square Feet (average single family home in Northeastern United States[1])	20,000 Square Feet (Large Office Prototype from 2006 PNNL Report[2])
Accessible Levels	Two (Non-accessible basement)	Two (Non-accessible basement)
Overall Dimensions	30 foot by 43 foot plan dimensions 20 foot from top of foundation to top of exterior wall	100 foot by 100 foot plan dimensions 26 foot from top of foundation to top of exterior wall
Exterior Doors	Two 3 foot by 7 foot exterior doors One on each of the longer dimensioned side of the home	Four 3 foot by 8 foot exterior doors One on each side of the building
Exterior Windows	Six 3 foot by 5 foot windows (1st Floor) Eight 3 foot by 5 foot windows (2nd Floor)	Eight 30 foot by 5 foot ribbon windows (1st Floor) Four 70 foot by 5 foot ribbon windows (2nd Floor)
Exterior Wall Construction Type	Wooden platform frame	Single wythe concrete masonry unit
Roof Construction Type	Wooden rafters with plywood sheathing	Open web steel joists with corrugated metal decking

Notes:

1. United States Census Bureau. Accessed April 20, 2018. https://www.census.gov/topics/housing/data/datasets.html
2. Pacific Northwest National Laboratory. "Technical Support Document: Development of the Advanced Energy Design Guide for Small Office Buildings." Accessed April 20, 2018. http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16250.pdf

TABLES 3A AND 3B

Tables 3A and 3B (pages 132 to 155) provide the sample costs per square foot for each strategy implementation. Quantities were derived from the sample buildings described above using data from the 2016 version of the RS Means Cost Database.

To establish a consistent representation of sample costs across all strategies, the total cost for each strategy implementation was divided by the total square footage of the sample building (2,600 SF for residential, 20,000 SF for non-residential) and is listed as a per square foot cost. In addition, each sample cost is shown as a range in order to account for the different costs for construction across New York State. The range of costs was determined using city cost indexes from RS Means; construction costs in Brooklyn (ClimAID Region 4) are 1.31 times the national average, whereas construction costs in Jamestown (ClimAID Region 1) are indexed at 0.95 times the national average.

Table 1: Strategies and Hazards

Strategy	Strategy Implementation	Severe Storm		Winter Weather	
		Res.	Non-Res.	Res.	Non-Res.
Windows	High Performance Glazing				
Insulation	Beyond Code Insulation: Wall			●	●
	Beyond Code Insulation: Roof			●	●
	Ice Dam Resistant Construction			●	●
	Insulated Water System			●	●
Roof Covering	High Albedo Roofing				
	Green Roofs	●	●		
Neighborhood Fire Protection	Fire-Safe Landscaping				
	Fire Breaks				
Building Fire Protection	Class "A" Roofing System				
	Prevent Flame/Ember Entry				
	Residential Sprinkler System				
	No Eaves/No Gutters				
	Noncombustible Siding				
	Noncombustible Decking				
	Tempered Glazing				
Wind Protection	Design for Increased Wind	●	●		
	Miami-Dade County Opening Protection	●	●		
	Uplift Anchors				
Roof Drainage	Enhanced Roof Access				●
	"Steeper" Low Slope Roofing	●	●		
	Pitched Roof	●		●	
	Oversized Roof Drainage	●	●		
Neighborhood Flood Protection	Enhanced Freeboard				
	Avoidance of Storm Surge/Flood Plains	●	●		
Building Flood Protection	Flood Resistive Materials				
	Sewage Backflow Preventer	●	●		
	Flood Barriers				
	Moisture Sensors				
	Safeguard Toxic Materials				
	Wet Flood Proofing Vents				
	Dry Flood Proofing				

Note: "Res." denotes "Residential" building type, and "Non-Res." denotes "Non-Residential" building type.

Hurricane		Flood		Heat		Sea Level Rise		Wildfire		Pest Infestation	
Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.
				●	●						
				●	●						
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Table 1 (continued): Strategies and Hazards

Strategy	Strategy Implementation	Severe Storm		Winter Weather	
		Res.	Non-Res.	Res.	Non-Res.
Building Systems Flood Protection	Elevated Essential Infrastructure				
	Elevator System Design				
Building Foundations	Hardened Foundations				
	Frost Resistant Foundations			●	●
	Scour Resistant Foundations				
Urban Heat Island	Climate Appropriate Landscaping				
	Woody Trees and Shrubs				
	Covered or Shaded Parking				
	High Albedo Paving				
Gray Infrastructure	Natural or Constructed Wetlands				
	Permeable Paving	●	●		
	Storm/Sanitary Sewer Separations	●	●		
Building Ventilation	Cross Ventilation				
	Stack Ventilation				
Indoor Air Quality	Ceiling Fans				
	Pressure Neutral Rainscreen	●	●		
Passive Building Systems	Shade Exterior HVAC Systems				
	Passive Solar Design/Building Orientation			●	●
	Thermal Zoning			●	●
	Increased Thermal Mass			●	●
Active Building Systems	Thermal Energy Storage				
Building Redundant Systems	Redundant Systems			●	●
	Emergency Bypass Faucet				
	Insulated Refrigeration Equipment	●	●		
Integrated Pest Management	Seal Potential Entry Points				
	Cavity Wall Treatments				
	Mechanical Room Drains				

Note: "Res." denotes "Residential" building type, and "Non-Res." denotes "Non-Residential building type."

Hurricane		Flood		Heat		Sea Level Rise		Wildfire		Pest Infestation	
Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.	Res.	Non-Res.
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Table 2A: Strategy Implementation in Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
High Performance Glazing	Standard casement windows used for exterior glazing.	High-performance casement windows used for exterior glazing.
Beyond Code Insulation: Wall	Code minimum insulation values used on exterior walls.	Code minimum insulation values doubled on exterior walls.
Beyond Code Insulation: Roof	Code minimum insulation values used in roof construction.	Code minimum insulation value exceeded by 50% in roof construction.
Ice Dam Resistant Construction	No ice dam resistance included.	Air gaps are sealed in roof, and areas where heat may escape are enclosed with additional insulation.
Insulated Water System	No water system insulation included.	Water supply insulated below grade.
High Albedo Roofing	Dark colored roof membrane.	Light colored roof membrane.
Green Roofs	Standard built-up roof membrane.	Home constructed with planted roof.
Fire-Safe Landscaping	No fire-safe landscaping included.	All trees pruned 15-foot above ground. All trees located within 10 foot of home removed.
Fire Breaks	No fire breaks included.	Various existing trees removed to create 15-foot wide fire break. 10 foot gravel radius around building.
Class A Roofing System	Class B roofing system.	Class A roofing system.
Prevent Flame/Ember Entry	No flame/ember entry prevention included.	Openings protected with tempered glazing, metal screens, and caulking.
Residential Sprinkler System	No residential sprinkler system included.	Home constructed with wet pipe sprinkler system.
No Eaves/No Gutters	Code minimum gutters and downspouts.	Home not equipped with gutters or downspouts.

Retrofitted Resilient Building	Source
Removal of existing windows from perimeter of home followed by the installation of high performance casement windows.	National Institute of Building Sciences (NIBS) Whole Building Design Guide
Installation of additional insulation with the added cost of removing and replacing existing exterior wall coverings.	USGBC *Green Building and Climate Resilience*; 2009 "International Energy Conservation Code" (IECC)
Existing insulation is removed and replaced in building roof.	USGBC *Green Building and Climate Resilience*; 2009 IECC; DOE Insulation Fact Sheet
Air gaps are sealed in roof, and areas where heat may escape are enclosed with additional insulation.	Insurance Institute for Business and Home Safety (IBHS)
Existing water service exposed and insulated below grade.	USGBC *Green Building and Climate Resilience*
Existing dark colored roof membrane coated with light colored paint.	EPA "Heat Island Compendium", Chapter 4
Removal of existing built-up roof and the installation of a planted roof.	Idea ET-1 in FEMA "Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards"
Various existing trees removed for wider spacing. Remaining trees pruned 15-foot above ground.	University of California Division of Agriculture and Natural Resources "Home Landscaping for Fire"
Various existing trees removed to create 15-foot wide fire break. 10 foot gravel radius around building.	Chapter 4, Oregon State University *Reducing Fire Risk on Your Forest Property* Guide
Removal of existing roofing system and installation of a Class A roofing system.	Chapter 15, NYS Building Code
Existing windows replaced with tempered glazing. Other openings protected with metal screens and caulking.	IBHS *Protect Your Property from Wildfire Guide*, Florida Edition
Installation of wet pipe sprinkler system.	National Fire Protection Association (NFPA) Fire Sprinkler Initiative
Removal of existing gutter and downspout system followed by the installation of additional flashing.	Technical Fact Sheet No. 6 in FEMA P-737

Table 2A (continued): Strategy Implementation in Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Noncombustible Siding	Vinyl siding on all exterior walls.	Fiber cement board on all exterior walls.
Noncombustible Decking	Combustible materials used on exterior deck.	Non-combustible materials and techniques used on exterior deck.
Tempered Glazing	Clear float glass used for exterior glazing.	Tempered glass used for all exterior glazing.
Design for Increased Wind	Standard built-up bitumen roof membrane.	High durability roof membrane with reinforced structural attachment and soffits.
Miami-Dade County Opening Protection	No opening protection included.	Intermediate mitigation package as defined by FEMA installed at building openings.
Uplift Anchors	No uplift anchors included.	Home attached to foundation with cast-in-place anchor bolts.
"Steeper" Low Slope Roofing	Roof tapered with minimum low-slope roof angle.	Roof tapered with increased low-slope roof angle.
Pitched Roof	Gable ended roof with 4 in 12 slope.	Hipped roof with 8 in 12 slope.
Oversized Roof Drainage	Code minimum gutters and downspouts.	Gutters and downspouts designed for beyond code rainfall minimums installed on building.
Enhanced Freeboard	Concrete strip foundation with slab on grade at BFE.	Cast-in-place concrete pile foundation with first floor elevation 2 foot above BFE.
Avoidance of Storm Surge/Flood Plains	Home constructed within storm surge zone/flood plain.	Home constructed outside of storm surge zone/flood plain.
Flood Resistive Materials	Exterior walls clad with vinyl siding and insulated with batt insulation.	Exterior walls clad with fiber cement board and insulated with rigid foam insulation.
Sewage Backflow Preventer	No sewage backflow prevention provided.	Sewage backflow preventer installed between home and public sewer.

Retrofitted Resilient Building	Source
Existing exterior finish material is removed and replaced with fiber cement board on all exterior walls.	Technical Fact Sheet No. 7 in FEMA P-737
Removal of combustible materials and the installation of non-combustible materials and techniques on exterior deck.	Technical Fact Sheet No. 13 in FEMA P-737
Removal of existing glazing and installation of tempered glass on all exterior glazing.	Technical Fact Sheet No. 10 in FEMA P-737
Existing roof replaced with high durability roof membrane and reinforced structural attachment and soffits.	Basic mitigation package as defined in FEMA P-804
Intermediate mitigation package as defined by FEMA installed at building openings.	Intermediate mitigation package as defined in FEMA P-804
Home attached to foundation with new anchor bolts.	Advanced mitigation package as defined in FEMA P-804
Tapered foam added to increase low-slope roof angle.	"Brace Gable End Roof Framing" in FEMA "Protect Your Property from High Winds" Series; USGBC *Green Building and Climate Resilience*
Removal of existing roof and installation of a hipped roof with 8 in 12 slope.	Basic mitigation package as defined in FEMA P-804
Removal of existing gutters and downspouts and installation of gutters and downspouts designed for beyond code rainfall minimums.	USGBC *Green Building and Climate Resilience*
Removal of existing standard strip foundation and placement of home on cast-in-place concrete pile foundation with first floor elevation 2 feet above BFE.	Recommendation 30a in FEMA P-942
Home removed from foundation located in storm surge zone/flood plain and placed on foundation located outside of storm surge zone/flood plain.	Section 2.3.2 in FEMA P-55 Volume I
Existing siding and insulation removed from exterior walls and replaced with fiber cement board and rigid foam insulation.	Technical Fact Sheet No. 1.7 in FEMA P-499
Sewage backflow preventer installed on existing sewer connection between home and public sewer.	Section 5D.10 in FEMA P-259

Table 2A (continued): Strategy Implementation in Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Flood Barriers	No floor barriers included.	Site design includes flood wall that complies with NFIP Free-of-Obstruction requirements.
Moisture Sensors	No moisture sensors included.	Installation of sensors that detect water and/or vapor.
Safeguard Toxic Materials	None.	Toxic materials are protected by flood proofing the home.
Wet Flood Proofing Vents	No wet flood proofing vents included.	Flood vents included on lower level of home to alleviate pressure and excessive lateral loads on exterior walls.
Dry Flood Proofing	No dry flood proofing included.	All openings below BFE are sealed.
Elevated Essential Infrastructure	Essential infrastructure, including water heaters, furnaces, and gas services, located at or below BFE.	Essential infrastructure, including water heaters, furnaces, and gas services, located above BFE.
Hardened Foundations	No hardened foundations included.	Hardening mixture added to foundation concrete mix to decrease water penetration during and after curing process.
Frost Resistant Foundations	No frost resistance provided in foundation.	Horizontal insulation installed to provide frost resistance.
Scour Resistant Foundations	Concrete strip foundation with slab on grade installed at BFE.	Home constructed on concrete pile foundations that are driven to adequate depth. First floor structure secured to pile to resist flotation.
Climate Appropriate Landscaping	Non-resilient plant species on site.	Native trees and plants that are less sensitive to changes in temperature are planted around building.
Woody Trees and Shrubs	No woody trees or shrubs included.	Tree and shrubs planted around building for sun shading and carbon sequestration.
Covered or Shaded Parking	Parking located in area that is exposed to sunlight.	Parking area located in area that is shaded from sunlight by trees.
High Albedo Paving	Black asphalt driveway.	Light colored concrete driveway.

Retrofitted Resilient Building	Source
Installation of permanent flood barrier that complies with NFIP Free-of-Obstruction requirements.	Chapter 5 in FEMA P-259
Installation of sensors that detect water and/or vapor.	Section 3.5.3 in FEMA P-936
Toxic materials are protected by flood proofing the home.	Recommendation 7 in USGBC Building Resiliency Task Force
Openings are cut on lower level of home to allow for the installation of flood vents.	Technical Fact Sheet No. 3.5 in FEMA P-499
All openings below BFE are sealed.	Chapter 7 in FEMA 551
Essential infrastructure, including water heaters, furnaces, and gas services, relocated to above BFE.	Recommendation 34 in FEMA P-942
No hardened foundations provided.	USGBC *Green Building and Climate Resilience*
Excavation around perimeter of building to make room for the installation of horizontal insulation.	U.S. Department of Housing *Revised Builder's Guide to Frost Protected Shallow Foundations*
Removal of existing standard strip foundation, placement of home on concrete pile foundations that are driven to adequate depth. First floor structure secured to pile to resist flotation.	Recommendation 25a in FEMA P-942
Existing non-resilient plants removed. Native trees and plants that are less sensitive to changes in temperature are planted around building.	USGBC *Green Building and Climate Resilience*; *A California-Friendly Guide to Native and Drought Tolerant Gardens* from the Las Virgenes Water District
Tree and shrubs planted around building for sun shading and carbon sequestration.	EPA "Heat Island Compendium", Chapter 2, Section 4.1
Parking area shaded with trees and bushes.	EPA "Heat Island Compendium", Chapter 2, Sections 1 and 2
Asphalt driveway demolished and replaced with concrete.	EPA "Heat Island Compendium", Chapter 5, Section 1.2

Table 2A (continued): Strategy Implementation in Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Natural or Constructed Wetlands	No natural or constructed wetlands included.	Use of stormwater retention pond/ wetland.
Permeable Paving	Impervious asphalt driveway.	Porous asphalt paving.
Storm/Sanitary Sewer Separations	Sump pump and downspouts connected directly to sanitary sewer system.	Sump pump and downspouts splash into yard away from building foundation.
Cross Ventilation	Casement windows on perimeter of home placed without regard to prevailing wind direction.	Operable windows added to walls perpendicular to prevailing wind direction.
Stack Ventilation	No stack ventilation included.	Whole house exhaust fan installed to exhaust air through building roof.
Ceiling Fans	No ceiling fans included.	Electric ceiling fans installed to circulate air.
Pressure Neutral Rainscreen	No pressure neutral rainscreen included.	Pressure neutral rainscreen installed with fiber cement board siding with air gap between siding and wall.
Shade Exterior HVAC Systems	Exterior HVAC systems exposed to sunlight without shading systems.	Exterior HVAC systems placed on north side of building for passive shading.
Passive Solar Design/Building Orientation	Building not oriented to take advantage of passive solar energy.	Building oriented to take advantage of passive solar energy.
Thermal Zoning	Home actively heated and cooled with single zone air handling unit.	Home actively heated and cooled with multi-zoned air handling unit.
Increased Thermal Mass	No thermal mass included.	Thermal mass material used for interior flooring.
Thermal Energy Storage	No thermal energy storage included.	Installation of underground thermal energy storage tank.
Redundant Systems	No redundant systems included.	Installation of a roof mounted photovoltaic (PV) electrical energy system.

Retrofitted Resilient Building	Source
Installation of on-site stormwater retention pond/wetland.	EPA Document 833-B-09-001: *Stormwater Wet Pond and Wetland Management Guidebook*; EPA Technical Guidance on Implementing the Stormwater Runoff Requirements
Impervious asphalt removed and replaced with porous asphalt paving.	EPA "Heat Island Compendium", Chapter 5, Section 1.2
Sump pump and downspouts disconnected from sanitary sewer and allowed to splash into yard away from building foundation.	City of Portland, Oregon Stormwater Management Manual
Additional operable windows installed on walls perpendicular to prevailing wind direction.	Strategy 7 in "Strategies for Multifamily Building Resilience" Guide from Enterprise Green Communities
Installation of whole house exhaust fan to exhaust air through building roof.	NIBS Whole Building Design Guide; ASHRAE Standard 62.2
Electric ceiling fans and necessary electrical updates installed to circulate air.	USGBC *Green Building and Climate Resilience*
Existing siding removed. Pressure neutral rainscreen installed with fiber cement board siding with air gap between siding and wall.	Technical Fact Sheet No. 5.3 in FEMA P-499
Installation of fiberglass solar screen with wooden frame around exterior HVAC systems.	*Building Resilience in Boston*
Building rotated from existing setting into orientation that takes advantage of passive solar energy.	USGBC *Green Building and Climate Resilience*
Existing air handling system removed and replaced with multi-zone air handling unit.	USGBC *Green Building and Climate Resilience*
Existing flooring removed and replaced with thermal mass material.	Passive Solar Design Technical Fact Sheet from the US DOE and the National Renewable Energy Laboratory (NREL)
Installation of underground thermal energy storage tank.	*Thermal Energy Storage Technology* Brief from the International Renewable Energy Agency
Installation of a roof mounted photovoltaic (PV) electrical energy system.	*Applications of Solar Technology for Catastrophe Response, Claims Management, and Loss Prevention*, by Ann Deering and John P. Thornton, P.E., NREL

Table 2A (continued): Strategy Implementation in Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Emergency Bypass Faucet	No emergency bypass faucet included.	Emergency bypass faucet to be used in the event of a loss in electrical power/water pressure.
Insulated Refrigeration Equipment	Standard refrigeration equipment installed in home.	Energy Star® rated refrigeration equipment installed in home.
Seal Potential Entry Points	No entry point sealing included.	Openings sealed to restrict pest access.
Cavity Wall Treatments	No cavity wall treatments included.	Exterior of building coated with pest-resistant treatments.
Mechanical Room Drains	No drains provided.	Floor drains provided near mechanical equipment to prevent the accumulation of standing water.

Retrofitted Resilient Building	Source
Emergency bypass faucet to be used in the event of a loss in electrical power/water pressure.	Strategy 15 in "Strategies for Multifamily Building Resilience" Guide from Enterprise Green Communities
Removal of existing refrigeration equipment and installation of Energy Star rated refrigeration equipment.	USGBC *Green Building and Climate Resilience*
Openings sealed to restrict pest access.	EPA *Energy Savings Plus Health: Indoor Air Quality Guidelines for Multifamily Building Upgrades*
Exterior of building coated with pest-resistant treatments.	Journal of School Business Management "Pest Prevention Construction Guidelines and Practices"
Floor drain installed near mechanical equipment to prevent the accumulation of standing water.	Section 5.3003.10 in NREL Standard Work Specifications

Table 2B: Strategy Implementation in Non-Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
High Performance Glazing	Clear float glass used for exterior glazing.	High-performance insulated glass with heat reflective film used for exterior glazing.
Beyond Code Insulation: Wall	Code minimum insulation values used on exterior walls.	Code minimum insulation values doubled on exterior walls.
Beyond Code Insulation: Roof	Code minimum insulation values used in roof construction.	Code minimum insulation value exceeded by 50% in roof construction.
Ice Dam Resistant Construction	No ice dam resistance included.	Air gaps are sealed in roof, and areas where heat may escape are enclosed with additional insulation.
Insulated Water System	No water system insulation included.	Water supply insulated below grade.
High Albedo Roofing	Dark colored roof membrane.	Light colored roof membrane.
Green Roofs	Standard built-up roof.	Building constructed with a planted roof.
Fire-Safe Landscaping	No fire-safe landscaping included.	All trees pruned 15-foot above ground. All trees within 10 foot of building removed.
Fire Breaks	No fire breaks included.	Various existing trees removed to create 15-foot wide fire break. 10 foot gravel radius around building.
Class A Roofing System	Class B roofing system.	Class A roofing system.
Prevent Flame/Ember Entry	No flame/ember entry prevention included.	Openings protected with tempered glazing, metal screens, and caulking.
No Eaves/No Gutters	Code minimum gutters and downspouts.	Building not equipped with gutters or downspouts.
Noncombustible Siding	Stucco wall finish on all exterior walls.	Fiber cement panels on all exterior walls.

Retrofitted Resilient Building	Source
Clear heat reflective film applied to interior of existing glazing around perimeter of building.	National Institute of Building Sciences (NIBS) Whole Building Design Guide
Installation of additional insulation with the added cost of removing and replacing existing exterior wall coverings.	USGBC *Green Building and Climate Resilience*; 2009 "International Energy Conservation Code" (IECC)
Existing insulation removed and replaced in building roof.	USGBC *Green Building and Climate Resilience*; 2009 IECC; US DOE Insulation Fact Sheet
Air gaps are sealed in roof, and areas where heat may escape are enclosed with additional insulation.	Insurance Institute for Business and Home Safety (IBHS)
Existing water service exposed and insulated below grade.	USGBC *Green Building and Climate Resilience*
Existing dark colored roof membrane coated with white elastomeric coating.	EPA "Heat Island Compendium", Chapter 4
Removal of existing roof covering and the installation of a planted roof.	Idea ET-1 in FEMA "Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards"
Various existing trees removed for wider spacing. Remaining trees pruned 15-foot above ground.	University of California Division of Agriculture and Natural Resources "Home Landscaping for Fire"
Various existing trees removed to create 15-foot wide fire break. 10 foot gravel radius around building.	Chapter 4, Oregon State University *Reducing Fire Risk on Your Forest Property* Guide
Removal of existing roofing system and installation of a Class A roofing system.	Chapter 15, NYS Building Code
Existing windows replaced with tempered glazing. Other openings protected with metal screens and caulking.	IBHS *Protect Your Property from Wildfire Guide*, Florida Edition
Removal of existing gutter and downspout system followed by the installation of additional flashing.	Technical Fact Sheet No. 6 in FEMA P-737
Existing exterior finish material removed and replaced with fiber cement board on all exterior walls.	Technical Fact Sheet No. 7 in FEMA P-737

Table 2B (continued): Strategy Implementation in Non-Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Noncombustible Decking	Combustible materials used on exterior deck.	Non-combustible materials and techniques used on exterior deck.
Tempered Glazing	Clear float glass used for exterior glazing.	Tempered glass used for all exterior glazing.
Design for Increased Wind	Standard built-up roof.	High durability roof membrane with reinforced flashing.
Miami-Dade County Opening Protection	No opening protection included.	Intermediate mitigation package as defined by FEMA installed at building openings.
Uplift Anchors	Welded connections attach roof decking to structure.	Roof decking attached to structure with nut and bolt connection.
Enhanced Roof Access	No roof access provided.	Roof hatch provided for roof access.
“Steeper” Low Slope Roofing	Roof tapered with minimum low-slope roof angle.	Roof tapered with increased low-slope roof angle.
Oversized Roof Drainage	Code minimum gutters and downspouts.	Gutters and downspouts designed for beyond code rainfall minimums installed on building.
Enhanced Freeboard	Slab on grade foundation installed at BFE.	Slab on grade foundation installed 2 feet above BFE.
Avoidance of Storm Surge/ Flood Plains	Building constructed within storm surge zone/flood plain.	Building constructed outside of storm surge zone/flood plain.
Flood Resistive Materials	Stucco wall finish on all exterior walls.	Brick faced cavity wall on all exterior walls.
Sewage Backflow Preventer	No sewage backflow prevention provided.	Sewage backflow preventer installed between building and public sewer.
Flood Barriers	No floor barriers included.	Site design includes flood wall that complies with NFIP Free-of-Obstruction requirements.

Retrofitted Resilient Building	Source
Removal of combustible materials and installation of non-combustible materials and techniques on exterior deck.	Technical Fact Sheet No. 13 in FEMA P-737
Removal of existing glazing and installation of tempered glass on all exterior glazing.	Technical Fact Sheet No. 10 in FEMA P-737
Existing roof replaced with high durability roof membrane with reinforced flashing.	Section 3.4.3.4 in FEMA 543
Intermediate mitigation package as defined by FEMA installed at building openings.	Intermediate mitigation package as defined in FEMA P-804
Roof decking re-attached to structure with nut and bolt connection.	Section 6.3.2 in FEMA 424
Roof hatch installed to provide roof access.	USGBC *Green Building and Climate Resilience*
Existing tapered roofing system removed and replaced with an increased low-slope roof angle.	"Brace Gable End Roof Framing" in FEMA "Protect Your Property from High Winds" Series; USGBC *Green Building and Climate Resilience*
Removal of existing gutters and downspouts and installation of gutters and downspouts designed for beyond code rainfall minimums.	USGBC *Green Building and Climate Resilience* Report
Removal of existing slab, followed by installation of a slab on grade foundation located 2 feet above BFE.	Section 5.3.4 in FEMA 424; Recommendation 30a in FEMA P-942
Building removed from foundation located in storm surge zone/flood plain and placed on foundation located outside of storm surge zone/flood plain.	Section 2.3.2 in FEMA P-55 Volume I
Removal of existing exterior wall finish and installation of a brick faced cavity wall on all exterior walls.	Technical Fact Sheet No. 1.6 in FEMA P-499
Sewage backflow preventer installed on existing sewer connection between building and public sewer.	Section 5D.10 in FEMA P-259
Installation of permanent flood barrier that complies with NFIP Free-of-Obstruction requirements.	Chapter 5 in FEMA P-259

Table 2B (continued): Strategy Implementation in Non-Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Moisture Sensors	No moisture sensors included.	Installation of sensors that detect water and/or vapor.
Safeguard Toxic Materials	No toxic material protection included.	Toxic materials protected in a flood proof enclosure outside of building.
Wet Flood Proofing Vents	No wet flood proofing vents included.	Flood vents included on lower level of building to alleviate pressure and excessive lateral loads on exterior walls.
Dry Flood Proofing	No dry flood proofing included.	All openings below BFE sealed.
Elevated Essential Infrastructure	Essential infrastructure, including water heaters, furnaces, and gas services, located at or below BFE.	Essential infrastructure, including water heaters, furnaces, and gas services, located above BFE
Elevator System Design	Hydraulic elevator system installed in building.	Machine-room less (MRL) traction elevator with sealed shaft installed in building.
Hardened Foundations	No hardened foundations included.	Hardening mixture added to foundation concrete mix to decease water penetration during and after curing process.
Frost Resistant Foundations	No frost resistance provided in foundation.	Horizontal insulation installed to provide frost resistance.
Scour Resistant Foundations	Concrete strip foundation with slab on grade installed at BFE.	Concrete strip foundation with slab on grade with footers at a 6 foot depth and cast-in-place anchor bolts to resist flotation.
Climate Appropriate Landscaping	Non-resilient plant species on site.	Native trees and plants that are less sensitive to changes in temperature are planted around building.
Woody Trees and Shrubs	No woody trees or shrubs included.	Tree and shrubs planted around building for sun shading and carbon sequestration.
Covered or Shaded Parking	Parking located in area that is exposed to sunlight.	Parking area located in area that is shaded from sunlight by trees.
High Albedo Paving	Black asphalt driveway.	Light colored concrete driveway.

Retrofitted Resilient Building	Source
Installation of sensors that detect water and/or vapor.	Section 3.5.3 in FEMA P-936
Toxic materials protected in a flood proof enclosure outside of building.	Recommendation 7 in USGBC Building Resiliency Task Force
Openings cut on lower level of building to allow for the installation of flood vents.	Technical Fact Sheet No. 3.5 in FEMA P-499
All openings below BFE sealed.	Chapter 7 in FEMA P-551
Essential infrastructure, including water heaters, furnaces, and gas services, relocated to above BFE.	Recommendation 34 in FEMA P-942
Existing elevator shaft equipped with inundation protection.	FEMA Technical Bulletin 4
No hardened foundations provided.	USGBC *Green Building and Climate Resilience*
Excavation around perimeter of building to make room for the installation of horizontal insulation.	U.S. Department of Housing *Revised Builder's Guide to Frost Protected Shallow Foundations*
Removal of existing foundation followed by the installation of a concrete strip foundation with footers at a 6 foot depth and cast-in-place anchor bolts to resist flotation.	Recommendation 25a in FEMA P-942
Existing non-resilient plants removed. Native trees and plants that are less sensitive to changes in temperature are planted around building.	USGBC *Green Building and Climate Resilience*; *A California-Friendly Guide to Native and Drought Tolerant Gardens* from the Las Virgenes Water District
Tree and shrubs planted around building for sun shading and carbon sequestration.	EPA "Heat Island Compendium", Chapter 2, Section 4.1
Parking area shaded with trees and bushes.	EPA "Heat Island Compendium", Chapter 2, Sections 1 and 2
Asphalt driveway demolished and replaced with concrete.	EPA "Heat Island Compendium", Chapter 5, Section 1.2

Table 2B (continued): Strategy Implementation in Non-Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Natural or Constructed Wetlands	No natural or constructed wetlands included.	Use of stormwater retention pond/ wetland.
Permeable Paving	Impervious asphalt driveway.	Porous asphalt paving.
Storm/Sanitary Sewer Separations	Sump pump and downspouts connected directly to sanitary sewer system.	Sump pump and downspouts splash into yard away from building foundation.
Cross Ventilation	Fixed glazing around perimeter of building.	Operable windows added to walls perpendicular to prevailing wind direction.
Stack Ventilation	No stack ventilation included.	Whole building exhaust fan installed to exhaust air through building roof.
Ceiling Fans	No ceiling fans included.	Electric ceiling fans installed to circulate air.
Pressure Neutral Rainscreen	No pressure neutral rainscreen included.	Brick faced cavity wall on all exterior walls.
Shade Exterior HVAC systems	Exterior HVAC systems exposed to sunlight without shading systems.	Exterior HVAC systems placed on north side of building for passive shading.
Passive Solar Design/Building Orientation	Building not oriented to take advantage of passive solar energy.	Building oriented to take advantage of passive solar energy.
Thermal Zoning	Building actively heated and cooled with single zone air handling unit.	Building actively heated and cooled with multi-zoned air handling unit.
Increased Thermal Mass	No thermal mass included.	Thermal mass material used for interior flooring.
Thermal Energy Storage	No thermal energy storage included.	Installation of underground thermal energy storage tank.
Redundant Systems	No redundant systems included.	Installation of a diesel generator and a ground mounted photovoltaic (PV) electrical energy system.

Retrofitted Resilient Building	Source
Installation of on-site stormwater retention pond/wetland.	EPA Document 833-B-09-001: *Stormwater Wet Pond and Wetland Management Guidebook*; EPA Technical Guidance on Implementing the Stormwater Runoff Requirements
Impervious asphalt removed and replaced with porous asphalt paving.	EPA "Heat Island Compendium", Chapter 5, Section 1.2
Sump pump and downspouts disconnected from sanitary sewer and allowed to splash into yard away from building foundation.	City of Portland, Oregon Stormwater Management Manual
Additional operable windows installed on walls perpendicular to prevailing wind direction.	Documents DOE/GO-102001-1278: Cooling Your Home with Fans and Ventilation Guide from US DOE and the National Renewable Energy Laboratory (NREL)
Installation of whole building exhaust fan to exhaust air through building roof.	NIBS Whole Building Design Guide; ASHRAE Standard 62.2
Electric ceiling fans and necessary electrical updates installed to circulate air.	USGBC *Green Building and Climate Resilience*
Removal of existing exterior wall finish and installation of a brick faced cavity wall on all exterior walls.	Technical Fact Sheet No. 1.6 in FEMA P-499
Installation of fiberglass solar screen with wooden frame around exterior HVAC systems.	*Building Resilience in Boston*
Building rotated from existing setting into orientation that takes advantage of passive solar energy.	USGBC *Green Building and Climate Resilience*
Existing air handling system removed and replaced with multi-zone air handling unit.	USGBC *Green Building and Climate Resilience*
Existing flooring removed and replaced with thermal mass material.	Passive Solar Design Technical Fact Sheet from the DOE and NREL
Installation of underground thermal energy storage tank.	*Thermal Energy Storage Technology* Brief from the International Renewable Energy Agency
Installation of a diesel generator and a ground mounted photovoltaic (PV) electrical energy system.	*Applications of Solar Technology for Catastrophe Response, Claims Management, and Loss Prevention*, by Ann Deering and John P. Thornton, P.E., NREL

Table 2B (continued): Strategy Implementation in Non-Residential Buildings

Strategy Implementation	Benchmark Building	New Resilient Building
Emergency Bypass Faucet	No emergency bypass faucet included.	Emergency bypass faucet to be used in the event of a loss in electrical power/water pressure.
Insulated Refrigeration Equipment	Standard refrigeration equipment installed in building.	Energy Star® rated refrigeration equipment installed in building.
Seal Potential Entry Points	No entry point sealing included.	Openings sealed to restrict pest access.
Cavity Wall Treatments	No cavity wall treatments included.	Exterior of building coated with pest-resistant treatments.
Mechanical Room Drains	No mechanical room drains included.	Floor drains provided near mechanical equipment to prevent the accumulation of standing water.

Retrofitted Resilient Building	Source
Emergency bypass faucet to be used in the event of a loss in electrical power/water pressure.	Strategy 15 in "Strategies for Multifamily Building Resilience" Guide from Enterprise Green Communities
Removal of existing refrigeration equipment, followed by the installation of Energy Star rated refrigeration equipment.	USGBC *Green Building and Climate Resilience*
Openings sealed to restrict pest access.	EPA *Energy Savings Plus Health: Indoor Air Quality Guidelines for Multifamily Building Upgrades*
Exterior of building coated with pest-resistant treatments.	Journal of School Business Management "Pest Prevention Construction Guidelines and Practices"
Floor drain installed near mechanical equipment to prevent the accumulation of standing water.	Section 5.3003.10 in NREL Standard Work Specifications

Table 3A: Strategy Implementation Costs in Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
High Performance Glazing	Standard casement windows.	$65,700 to $90,400	$3.29 to $4.52 per SF
Beyond Code Insulation: Wall	R-20 batt insulation used on exterior walls.	$2,500 to $3,800	$0.96 to $1.46 per SF
Beyond Code Insulation: Roof	R-49 batt insulation in roof construction.	$2,000 to $3,100	$0.77 to $1.19 per SF
Ice Dam Resistant Construction	N/A		
Insulated Water System	N/A		
High Albedo Roofing	Asphalt built-up roof with gravel roof membrane.	$0	$0 per SF
Green Roofs	Built-up asphalt shingle roof membrane.	$3,700 to $5,800	$1.42 to $2.23 per SF
Fire-Safe Landscaping	N/A		
Fire Breaks	N/A		
Class A Roofing System	Asphalt roof shingles.	$2,600 to $4,000	$1 to $1.54 per SF

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
Double insulated casement window with low-E coating.	$8,600 to $11,800	$3.31 to $4.54 per SF	Removal of existing windows around exterior of home followed by installation of double insulated casement windows with low-e coating.	$9,600 to $13,200	$3.69 to $5.08 per SF
R-40 batt insulation used on exterior walls.	$4,000 to $5,400	$1.54 to $2.08 per SF	Removal of interior wall coverings and insulation followed by installation of additional R-20 insulation and gypsum wall covering.	$8,700 to $12,000	$3.35 to $4.62 per SF
R-60 blown insulation in roof construction.	$4,500 to $6,300	$1.73 to $2.42 per SF	Removal of existing roof insulation and installation of R-60 blown insulation.	$4,700 to $6,500	$1.81 to $2.5 per SF
Ridge vents and seam tape included in roof construction. Additional R-60 blown insulation installed around ceiling openings for fans and light fixtures.	$300 to $400	$0.12 to $0.15 per SF	Cutting of opening for and installation of ridge vents. Installation of joint sealing tape and R-60 blown insulation.	$500 to $700	$0.19 to $0.27 per SF
Installation of polyethylene flexible pipe insulation.	$400 to $600	$0.15 to $0.23 per SF	Excavation and the installation of polyethylene flexible pipe insulation.	$500 to $700	$0.19 to $0.27 per SF
Asphalt built-up roof with gravel roof membrane, coated with light colored elastomeric paint.	$700 to $1,000	$0.27 to $0.38 per SF	Existing roof membrane coated with light colored elastomeric paint.	$700 to $1,000	$0.27 to $0.38 per SF
Green roof system with 4-inch soil depth.	$12,200 to $16,900	$4.69 to $6.50 per SF	Removal of existing roof membrane, lamination of 2-inch by 10-inch roof rafters, and installation of green roof with 4-inch soil depth.	$19,700 to $27,200	$7.58 to $10.46 per SF
Pruning of five trees and removal of two trees.	$900 to $1,300	$0.35 to $0.50 per SF	Pruning of five trees and removal of two trees.	$900 to $1,300	$0.35 to $0.50 per SF
Removal of two trees and installation of a 10-foot wide gravel firebreak around home.	$2,600 to $3,600	$1.00 to $1.38 per SF	Removal of two trees and topsoil and installation of a 10-foot wide gravel firebreak around home.	$2,900 to $3,900	$1.12 to $1.50 per SF
Metal sheet roof covering.	$23,700 to $32,600	$9.12 to $12.54 per SF	Removal of existing asphalt roof shingles and installation of metal sheet roof covering.	$25,700 to $35,400	$9.88 to $13.62 per SF

Table 3A (continued): Strategy Implementation Costs in Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
Prevent Flame/Ember Entry	All exterior windows enclosed with clear float glass.	$5,000 to $7,700	$1.92 to $2.96 per SF
Residential Sprinkler System	N/A		
No Eaves/No Gutters	4 inch diameter aluminum gutter with 2 inch by 3 inch downspouts.	$700 to $1,100	$0.27 to $0.42 per SF
Noncombustible Siding	Exterior walls covered with vinyl siding.	$9,300 to $14,400	$3.58 to $5.54 per SF
Noncombustible Decking	Wood railing on exterior deck.	$100	$0.04 per SF
Tempered Glazing	Plain float glass windows.	$5,000 to $7,700	$1.92 to $2.96 per SF
Design for Increased Wind	Built-up asphalt shingle roof membrane.	$3,700 to $5,800	$1.42 to $2.23 per SF
Miami-Dade County Opening Protection	N/A		
Uplift Anchors	N/A		

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
All exterior windows enclosed with tempered glass. Screens installed over exterior vents, and all seams sealed with caulking.	$6,900 to $9,500	$2.65 to $3.65 per SF	Removal of existing windows and installation of tempered glass windows, screens over exterior vents, and seam caulking.	$7,800 to $10,700	$3 to $4.12 per SF
2 floor wet pipe sprinkler system.	$16,900 to $23,200	$6.50 to $8.92 per SF	2 floor wet pipe sprinkler system.	$16,900 to $23,200	$6.50 to $8.92 per SF
Metal flashing installed along drip edge of the home's roof.	$400 to $500	$0.15 to $0.19 per SF	Removal of existing gutter and downspout system and installation of metal flashing along drip edge of the home's roof.	$500 to $700	$0.19 to $0.27 per SF
Fiber cement board panels with gypsum board underlayment used on all exterior walls.	$20,600 to $28,300	$7.92 to $10.88 per SF	Removal of existing finish material and installation of fiber cement board panels with gypsum board underlayment on all exterior walls.	$23,100 to $31,800	$8.88 to $12.23 per SF
Metal railing, 5-foot wide gravel walkway around perimeter, underside of deck enclosed with fire-resistant material.	$4,800 to $6,600	$1.85 to $2.54 per SF	Removal of wood railing. Installation of metal railing, 5-foot wide gravel walkway around perimeter, and fire resistant material on underside of deck.	$4,900 to $6,700	$1.88 to $2.58 per SF
Tempered glass windows.	$6,700 to $9,200	$2.58 to $3.54 per SF	Removal of plain float glass windows and installation of tempered glass windows.	$7,500 to $10,400	$2.88 to $4.00 per SF
Self-adhering modified bitumen joint tape, ASTM D 4869 type II felt, self-adhering modified bitumen membrane, and asphalt roof shingles roof membrane with aluminum strap ties and soffit panel fasteners below.	$6,600 to $9,000	$2.54 to $3.46 per SF	Removal of existing asphalt roof membrane and installation of self-adhering modified bitumen joint tape, ASTM D 4869 type II felt, self-adhering modified bitumen membrane, and asphalt roof shingles roof membrane with aluminum strap ties and soffit panel fasteners below.	$8,600 to $11,800	$3.31 to $4.54 per SF
Wooden storm shutters over the windows and aluminum storm shutters over the doors.	$4,900 to $6,700	$1.88 to $2.58 per SF	Installation of additional wall studs with wooden storm shutters over the windows and aluminum storm shutters over the doors.	$5,200 to $7,200	$2.00 to $2.77 per SF
Cast-in-place anchor bolts.	$300 to $500	$0.12 to $0.19 per SF	Concrete drilling and installation of anchor bolts on existing foundation.	$1,600 to $2,200	$0.62 to $0.85 per SF

Table 3A (continued): Strategy Implementation Costs in Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
"Steeper" Low Slope Roofing	2 inch by 10 inch, 16 inches on center with .25 in 12 roof slope rafters.	$4,400 to $6,800	$1.69 to $2.62 per SF
Pitched Roof	2 inch by 10 inch, 16 inches on center with 4 in 12 roof slope rafters.	$4,700 to $7,200	$1.81 to $2.77 per SF
Oversized Roof Drainage	4 inch diameter aluminum gutter with 2 inch by 3 inch downspouts.	$700 to $1100	$0.27 to $0.42 per SF
Enhanced Freeboard	Foundation excavation with 16 inch by 8 inch strip footings, 4 inch foundation under drain, 8 inch by 4 foot basement walls, and foundation backfill.	$26,700 to $41,400	$10.27 to $15.92 per SF
Avoidance of Storm Surge/Flood Plains	N/A		
Flood Resistive Materials	Vinyl siding with 3-1/2 inch R11 batt insulation on all exterior walls.	$11,300 to $17,500	$4.35 to $6.73 per SF
Sewage Backflow Preventer	N/A		
Flood Barriers	N/A		
Moisture Sensors	N/A		

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
2 inch by 10 inch, 16 inches on center with 1 in 12 roof slope rafters.	$4,700 to $6,500	$1.81 to $2.50 per SF	Removal of existing asphalt roof membrane and installation of 4-inch R20 foam insulation, foam tapering, and white TPO covering.	$13,500 to $18,500	$5.19 to $7.12 per SF
2 inch by 10 inch, 16 inches on center with 8 in 12 roof slope rafters.	$5,700 to $7,800	$2.19 to $3.00 per SF	Removal of existing roof structure and installation of 2 inch by 10 inch, 16 inches on center, 8 in 12 roof slope rafters.	$17,000 to $23,400	$6.54 to $9.00 per SF
6-inch diameter aluminum gutter with 3-inch diameter downspout and 60-gallon rain barrels..	$2,000 to $2,800	$0.77 to $1.08 per SF	Removal of existing gutter and downspouts and installation of 6-inch diameter aluminum gutter with 3-inch diameter downspout and 60-gallon rain barrels.	$2,100 to $2,900	$0.81 to $1.12 per SF
12-inch hole auger with 12-inch cast-in-place concrete piles.	$12,200 to $16,800	$4.69 to $6.46 per SF	Removal of existing strip footer and existing foundation wall followed by raising of existing house, 12-inch hole auger, 12-inch cast-in-place concrete piles, disconnection and reconnection of utilities, and foundation backfill.	$82,900 to $114,100	$31.88 to $43.88 per SF
N/A			Moving of existing house. Disconnection and reconnection of utilities.	$65,500 to $90,200	$25.19 to $34.69 per SF
Fiber cement board with 3-inch R15 rigid foam insulation on all exterior walls.	$24,500 to $33,700	$9.42 to $12.96 per SF	Removal of existing siding and insulation and installation of fiber cement board with 3-inch R15 rigid foam insulation on all exterior walls.	$27,300 to $37,600	$10.50 to $14.46 per SF
Installation of a sewage backflow preventer.	$2,400 to $3,300	$0.92 to $1.27 per SF	Excavation and removal of pipe section followed by installation of sewage backflow preventer.	$2,400 to $3,300	$0.92 to $1.27 per SF
Excavation and backfill to make room for installation of concrete retaining wall around perimeter of building.	$64,200 to $88,400	$24.69 to $34 per SF	Excavation and backfill to make room for installation of concrete retaining wall around perimeter of building.	$64,200 to $88,400	$24.69 to $34 per SF
Leak detection systems for liquid and vapor.	$200 to $200	$0.08 to $0.08 per SF	Leak detection systems for liquid and vapor.	$200	$0.08 per SF

Table 3A (continued): Strategy Implementation Costs in Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
Safeguard Toxic Materials	N/A		
Wet Flood Proofing Vents	N/A		
Dry Flood Proofing	N/A		
Elevated Essential Infrastructure	N/A		
Hardened Foundations	N/A		
Frost Resistant Foundations	N/A		
Scour Resistant Foundations	Foundation excavation with 16-inch by 8-inch strip footings, 4-inch foundation under drain, 8-inch by 4-foot basement walls, and foundation backfill.	$26,700 to $41,400	$10.27 to $15.92 per SF
Climate Appropriate Landscaping	Four boxwood shrubs, two amur maples, and three pine trees.	$1,400 to $2,200	$0.54 to $0.85 per SF
Woody Trees and Shrubs	N/A		
Covered or Shaded Parking	35-foot by 10-foot asphalt driveway with 6-inch sub-base course.	$700 to $1,000	$0.27 to $0.38 per SF

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
Prefab joint fillers installed to seal all cracks. Storm doors installed.	$800 to $1,100	$0.31 to $0.42 per SF	Removal of existing doors and installation of storm doors with caulking.	$1,200 to $1,700	$0.46 to $0.65 per SF
Installation of flood proofing vents around perimeter of building.	$1,900 to $2,600	$0.73 to $1.00 per SF	Cutting and framing of opening in exterior wall and installation of floodproofing vents around perimeter of building.	$3,400 to $4,700	$1.31 to $1.81 per SF
Prefab joint fillers installed to seal all cracks. Storm doors installed.	$800 to $1,100	$0.31 to $0.42 per SF	Removal of existing doors and installation of storm doors with caulking and additional wall studs.	$1,200 to $1,700	$0.46 to $0.65 per SF
Mechanical equipment elevated on 2-inch thick concrete pad.	$200 to $300	$0.08 to $0.12 per SF	Placement of mechanical equipment on 2-inch thick concrete pad, including disconnection and reconnection of utilities.	$12,700 to $17,500	$4.88 to $6.73 per SF
Concrete hardener added to concrete mixture for foundation.	$200 to $300	$0.08 to $0.12 per SF	N/A		
R10 insulation on 18-inch compacted gravel around perimeter of home.	$1,200 to $1,600	$0.46 to $0.62 per SF	Excavation to make room for installation of R10 insulation on 18-inch compacted gravel around perimeter of home.	$1,500 to $2,000	$0.58 to $0.77 per SF
12-inch hole auger with 12-inch cast-in-place concrete piles and cast-in-place anchor bolts.	$12,500 to $17,300	$4.81 to $6.65 per SF	Removal of existing strip footer and existing foundation wall followed by raising of existing house, 12-inch hole auger, 12-inch cast-in-place concrete piles with anchor bolts, disconnection and reconnection of utilities, and foundation backfill.	$83,200 to $11,4500	$32 to $44.04 per SF
Three lemon bottlebrushes, two hydrangea bushes, and five pin oaks.	$4,300 to $6,000	$1.65 to $2.31 per SF	Removal of existing trees and shrubs, planting of 3 lemon bottlebrushes, 2 hydrangea bushes, and 5 pin oaks.	$6,600 to $9,100	$2.54 to $3.50 per SF
Three lemon bottlebrushes, two hydrangea bushes, and five pin oaks.	$4,300 to $6,000	$1.65 to $2.31 per SF	Three lemon bottlebrushes, two hydrangea bushes, and five pin oaks.	$4,300 to $6,000	$1.65 to $2.31 per SF
15-foot extension of asphalt driveway to shaded area.	$1,000 to $1,400	$0.38 to $0.54 per SF	One lemon bottlebrush, one hydrangea bush, and two pin oaks to shade parking area.	$1,700 to $2,400	$0.65 to $0.92 per SF

Table 3A (continued): Strategy Implementation Costs in Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
High Albedo Paving	35-foot by 10-foot asphalt driveway with 6-inch subbase course.	$700 to $1,000	$0.27 to $0.38 per SF
Natural or Constructed Wetlands	N/A		
Permeable Paving	35-foot by 10-foot asphalt driveway with 6-inch subbase course.	$700 to $1,000	$0.27 to $0.38 per SF
Storm/Sanitary Sewer Separations	Downspouts and sump pump elbow into PVC pipe that leads to public sanitary sewer.	$2,200 to $3,500	$0.85 to $1.35 per SF
Cross Ventilation	N/A		
Stack Ventilation	N/A		
Ceiling Fans	N/A		
Pressure Neutral Rainscreen	Vinyl siding with moisture barrier.	$10,100 to $15,700	$3.88 to $6.04 per SF
Shade Exterior HVAC systems	N/A		
Passive Solar Design/Building Orientation	N/A		
Thermal Zoning	4-ton single-zoned air handing unit.	$12,800 to $19,900	$4.92 to $7.65 per SF

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
35-foot by 10-foot concrete driveway with six inch subbase course.	$2,400 to $3,300	$0.92 to $1.27 per SF	Removal of existing asphalt driveway and installation of 35-foot by 10-foot concrete driveway with six inch subbase course.	$2,400 to $3,300	$0.92 to $1.27 per SF
15-foot by 30 foot by 3 foot retention area with sloped sides and one 8 inch PVC riser.	$4,900 to $6,700	$1.88 to $2.58 per SF	15-foot by 30-foot by 3-foot retention area with sloped sides and one 8-inch PVC riser.	$4,900 to $6,700	$1.88 to $2.58 per SF
35-foot by 10-foot porous asphalt driveway with six inch subbase course.	$1,400 to $2,000	$0.54 to $0.77 per SF	Removal of existing asphalt driveway and installation of 35-foot by 10-foot porous asphalt driveway with six inch subbase course.	$1,500 to $2,000	$0.58 to $0.77 per SF
Downspouts and sump pump discharge onto prefabricated concrete splash pad.	$0 to $100	$0.00 to $0.04 per SF	Downspouts and sump pump separated from PVC pipe that leads to public sanitary sewer. Concrete splash pads installed.	$200 to $300	$0.08 to $0.12 per SF
Four casement windows on opposite exterior walls.	$1,900 to $2,600	$0.73 to $1.00 per SF	Cutting of exterior wall and installation of window framing and Four casement windows on opposite exterior walls.	$2,300 to $3,100	$0.88 to $1.19 per SF
Installation of a whole house exhaust fan.	$1,600 to $2,200	$0.62 to $0.85 per SF	Opening made for installation of a whole house exhaust fan.	$1,600 to $2,300	$0.62 to $0.88 per SF
Installation of two electric ceiling fans.	$800 to $1,100	$0.31 to $0.42 per SF	Installation of two electric ceiling fans and necessary wiring improvements.	$900 to $1,300	$0.35 to $0.50 per SF
1-inch furring strips, fiber cement board, and moisture barrier on exterior of home.	$21,100 to $29,100	$8.12 to $11.19 per SF	Removal of existing siding and installation of 1-inch furring strips, moisture barrier, and fiber cement board on exterior of home.	$24,000 to $33,100	$9.23 to $12.73 per SF
N/A			Fiberglass solar screening with wooden framing.	$800 to $1,100	$0.31 to $0.42 per SF
N/A			Rotation of home and disconnection and reconnection of utilities.	$65,500 to $90,200	$25.19 to $34.69 per SF
4-ton multi-zoned air handing unit.	$10,700 to $14,700	$4.12 to $5.65 per SF	Removal of existing air handler and installation of a 4-ton multi-zoned air handing unit.	$11,300 to $15,600	$4.35 to $6.00 per SF

Table 3A (continued): Strategy Implementation Costs in Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
Increased Thermal Mass	Vinyl flooring on ground floor home.	$900 to $1,400	$0.35 to $0.54 per SF
Thermal Energy Storage	N/A		
Redundant Systems	N/A		
Emergency Bypass Faucet	N/A		
Insulated Refrigeration Equipment	18-cubic foot capacity refrigerator.	$900 to $1,300	$0.35 to $0.50 per SF
Seal Potential Entry Points	N/A		
Cavity Wall Treatments	N/A		
Mechanical Room Drains	N/A		

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
Slate tile flooring on ground floor of home.	$5,500 to $7,600	$2.12 to $2.92 per SF	Removal of existing flooring and installation of slate tile flooring on the ground floor of home.	$5,900 to $8,200	$2.27 to $3.15 per SF
Installation of 66-gallon underground thermal energy storage water tank including excavation and backfill.	$2,200 to $3,100	$0.85 to $1.19 per SF	Installation of 66-gallon underground thermal energy storage water tank including excavation and backfill.	$2,200 to $3,100	$0.85 to $1.19 per SF
Installation of roof mounted 24V, 900W, stand-alone PV system.	$19,700 to $27,200	$7.58 to $10.46 per SF	Installation of roof mounted 24V, 900W, stand-alone PV system.	$19,700 to $27,200	$7.58 to $10.46 per SF
Faucet attached to water supply at low elevation.	$100 to $200	$0.04 to $0.08 per SF	Faucet inserted into water supply at low elevation.	$300	$0.12 per SF
18-cubic foot capacity Energy Star® rated refrigerator.	$1,900 to $2,600	$0.73 to $1.00 per SF	Removal of existing unit and installation of 18-cubic foot capacity Energy Star® rated refrigerator.	$2,600 to $3,600	$1.00 to $1.38 per SF
Caulking and bird netting used to seal large and small openings around perimeter of home.	$400 to $600	$0.15 to $0.23 per SF	Caulking and bird netting used to seal large and small openings around perimeter of home.	$400 to $600	$0.15 to $0.23 per SF
Pest control sprayed and bird netting installed around perimeter of home.	$700 to $900	$0.27 to $0.35 per SF	Pest control sprayed and bird netting installed around perimeter of home.	$700 to $900	$0.27 to $0.35 per SF
Installation of 2-floor drains and 6-inch PVC drainage piping.	$1,000 to $1,400	$0.38 to $0.54 per SF	Saw cutting of ground floor slab followed by the installation of 2-floor drains and 6-inch PVC drainage piping.	$1,100 to $1,400	$0.42 to $0.54 per SF

Table 3B: Strategy Implementation Costs in Non-Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
High Performance Glazing	All exterior windows enclosed with clear float glass.	$65,700 to $90,400	$3.29 to $4.52 per SF
Beyond Code Insulation: Wall	R-20 rigid foam insulation used on exterior walls.	$13,300 to $18,300	$0.67 to $0.92 per SF
Beyond Code Insulation: Roof	R-49 batt insulation in roof construction.	$16,300 to $22,400	$0.82 to $1.12 per SF
Ice Dam Resistant Construction	N/A		
Insulated Water System	N/A		
High Albedo Roofing	Asphalt built-up roof with gravel roof membrane.	$29,100 to $40,000	$1.46 to $2.00 per SF
Green Roofs	Asphalt built-up roof membrane with gravel.	$29,100 to $40,000	$1.46 to $2.00 per SF
Fire-Safe Landscaping	N/A		
Fire Breaks	N/A		
Class A Roofing System	Asphalt built-up roof with gravel.	$29,100 to $40,000	$1.46 to $2.00 per SF
Prevent Flame/Ember Entry	All exterior windows enclosed with clear float glass.	$65,700 to $90,400	$3.29 to $4.52 per SF

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
All exterior windows enclosed with double glazed insulated glass.	$83,000 to $114,300	$4.15 to $5.72 per SF	All exterior windows coated with heat reflective film.	$63,200 to $87,000	$3.16 to $4.35 per SF
R-40 rigid foam insulation used on exterior walls.	$26,600 to $36,600	$1.33 to $1.83 per SF	Removal of exterior stucco finish and rigid foam insulation. Installation of R-40 rigid foam insulation and stucco wall finish.	$58,500 to $80,500	$2.93 to $4.03 per SF
R-60 blown insulation in roof construction.	$35,000 to $48,200	$1.75 to $2.41 per SF	Removal of existing roof insulation and installation of R-60 blown insulation.	$38,100 to $52,500	$1.91 to $2.63 per SF
Ridge vents and seam tape included in roof construction. Additional R-60 blown insulation installed around ceiling openings for fans and light fixtures.	$3,900 to $5,400	$0.20 to $0.27 per SF	Cutting of opening for and installation of ridge vents. Installation of joint sealing tape and R-60 blown insulation.	$4,200 to $5,700	$0.21 to $0.29 per SF
Installation of polyethylene flexible pipe insulation.	$900 to $1,200	$0.05 to $0.06 per SF	Excavation and the installation of polyethylene flexible pipe insulation.	$1,000 to $1,400	$0.05 to $0.07 per SF
White thermoplastic polyolefin (TPO) roof membrane.	$18,500 to $25,500	$0.93 to $1.28 per SF	Existing roof membrane coated with light colored elastomeric paint.	$5,500 to $7,600	$0.28 to $0.38 per SF
Green roof system with 6 inch soil depth.	$106,300 to $146,300	$5.32 to $7.32 per SF	Removal of existing built-up asphalt roof membrane and installation of green roof system with 6 inch soil depth.	$121,800 to $167,700	$6.09 to $8.39 per SF
Pruning of eight trees and removal of three trees.	$1,400 to $1,900	$0.07 to $0.10 per SF	Pruning of eight trees and removal of three trees.	$1,400 to $1,900	$0.07 to $0.10 per SF
Removal of three trees and installation of a 10-foot wide gravel firebreak around building.	$5,300 to $7,300	$0.27 to $0.37 per SF	Removal of three trees and installation of a 10-foot wide gravel firebreak around building.	$5,500 to $7,600	$0.28 to $0.38 per SF
Aluminum roofing.	$42,400 to $58,400	$2.12 to $2.92 per SF	Removal of existing roofing and installation of aluminum roofing.	$57,900 to $79,800	$2.90 to $3.99 per SF
All exterior windows enclosed with tempered glass. Screens installed over exterior vents, and all seams sealed with caulking.	$83,900 to $115,400	$4.20 to $5.77 per SF	Removal of existing windows and installation of tempered glass windows, screens over exterior vents, and seam caulking.	$93,600 to $128,800	$4.68 to $6.44 per SF

Table 3B (continued): Strategy Implementation Costs in Non-Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
No Eaves/No Gutters	4-inch by 6-inch aluminum gutter with 4-inch diameter downspouts.	$4,100 to $5,600	$0.21 to $0.28 per SF
Noncombustible Siding	Exterior walls covered with stucco over metal lathe.	$17,700 to $24,300	$0.89 to $1.22 per SF
Noncombustible Decking	Wood railing on exterior deck.	$200 to $300	$0.01 to $0.02 per SF
Tempered Glazing	Plain float glass windows.	$65,700 to $90,400	$3.29 to $4.52 per SF
Design for Increased Wind	Vapor barrier, 3 inch R15 rigid foam insulation, asphalt built-up roof with gravel, and metal flashing on building roof.	$60,200 to $82,900	$3.01 to $4.15 per SF
Miami-Dade County Opening Protection	N/A		
Uplift Anchors	1/2 inch pins welded to joist for roof connection.	$12,800 to $17,600	$0.64 to $0.88 per SF
Enhanced Roof Access	N/A		
"Steeper" Low Slope Roofing	Sloped underlayment with .25 in 12 slope on building roof.	$31,400 to $43,200	$1.57 to $2.16 per SF

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
Metal flashing installed along drip edge of building roof.	$3,700 to $5,100	$0.19 to $0.26 per SF	Removal of existing gutter and downspout system and installation of metal flashing along drip edge of building roof.	$4,000 to $5,500	$0.20 to $0.28 per SF
Fiber cement board panels with gypsum board underlayment used on all exterior walls.	$40,800 to $56,200	$2.04 to $2.81 per SF	Removal of existing finish material and installation of fiber cement board panels with gypsum board underlayment on all exterior walls.	$50,300 to $69,200	$2.52 to $3.46 per SF
Metal railing, 5-foot wide gravel walkway around perimeter, underside of deck enclosed with fire-resistant material.	$12,100 to $16,600	$0.61 to $0.83 per SF	Removal of wood railing, installation of metal railing, 5-foot wide gravel walkway around perimeter, and fire resistant material on underside of deck.	$100 to $200	<$0.01 per SF
Tempered glass windows.	$83,000 to $114,300	$4.15 to $5.72 per SF	Removal of plain float glass windows and installation of tempered glass windows.	$93,200 to $128,300	$4.66 to $6.42 per SF
Vapor barrier, secondary membrane sealed over concrete deck, 4-inch R20 insulation, 5/8 inch thick glass mat gypsum roof board, self-adhered modified bitumen membrane, metal flashing, and continuous peel-stop on building roof.	$119,300 to $164,300	$5.97 to $8.22 per SF	Removal of existing roof and installation of vapor barrier, secondary membrane sealed over concrete deck, 4-inch R20 insulation, 5/8 inch thick glass mat gypsum roof board, self-adhered modified bitumen membrane, metal flashing, and continuous peel-stop on building roof.	$134,900 to $185,700	$6.75 to $9.29 per SF
Aluminum storm shutters for doors and aluminum battens over windows.	$23,900 to $33,000	$1.20 to $1.65 per SF	Aluminum storm shutters for doors and aluminum battens over windows.	$23,900 to $33,000	$1.20 to $1.65 per SF
1/2 inch bolt with nuts connecting roof decking to joist.	$6,800 to $9,300	$0.34 to $0.47 per SF	1/2 inch metal hole drilling with installation of 1/2 inch bolts with nuts connecting roof decking to joist.	$14,100 to $19,400	$0.71 to $0.97 per SF
Installation of 2 roof hatches.	$1,900 to $2,600	$0.10 to $0.13 per SF	Cutting of roof and installation of 2 roof hatches.	$2,000 to $2,700	$0.10 to $0.14 per SF
Tapered foam with 1 in 12 slope on building roof.	$9,100 to $12,600	$0.46 to $0.63 per SF	Removal of built-up roof and installation of tapered foam with 1 in 12 slope.	$24,700 to $34,000	$1.24 to $1.70 per SF

Table 3B (continued): Strategy Implementation Costs in Non-Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
Oversized Roof Drainage	4-inch by 6-inch aluminum gutter with 4-inch diameter downspouts.	$4,100 to $5,600	$0.21 to $0.28 per SF
Enhanced Freeboard	Foundation excavation and backfill with 12-inch deep by 2-inch wide strip footings, 8 inch foundation under drain, 12-inch wide by 4-foot tall basement walls, and 6-inch slab on grade with reinforcement.	$137,100 to $188,700	$6.86 to $9.44 per SF
Avoidance of Storm Surge/Flood Plains	N/A		
Flood Resistive Materials	3-inch R15 rigid foam insulation, galvanized self-furring lath with plaster cement stucco on all exterior walls.	$36,400 to $50,100	$1.82 to $2.51 per SF
Sewage Backflow Preventer	N/A		
Flood Barriers	N/A		
Moisture Sensors	N/A		
Safeguard Toxic Materials	N/A		
Wet Flood Proofing Vents	N/A		

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
5 inch by 8 inch aluminum gutter with 6-inch diameter downspout and rainwater tanks.	$18,500 to $25,400	$0.93 to $1.27 per SF	Removal of existing gutter and downspouts and installation 5 inch by 8 inch aluminum gutter with 6-inch diameter downspouts and rainwater tanks.	$18,800 to $25,900	$0.94 to $1.30 per SF
Foundation excavation and backfill with 12-inch deep by 23-inch wide strip footings, 8-inch foundation under drain, 12-inch wide by 6-foot tall basement walls, and 6-inch slab on grade with reinforcement.	$153,300 to $211,000	$7.67 to $10.55 per SF	Removal of existing slab on grade, disconnection and reconnection of utilities, raising of existing building, 2-foot of 12-inch CMU foundation, structural backfill, 6-inch slab on grade with reinforcement.	$614,200 to $845,600	$30.71 to $42.28 per SF
N/A			Moving of existing house. Disconnection and reconnection of utilities.	$420,200 to $578,500	$21.01 to $28.93 per SF
3-inch R15 rigid foam insulation, 4-inch thick brick outer wythe with masonry anchors on all exterior walls.	$139,700 to $192,300	$6.99 to $9.62 per SF	Removal of existing wall finish and installation of 3-inch R15 rigid foam insulation, 4-inch thick brick outer wythe with masonry anchors on all exterior walls.	$149,300 to $205,500	$7.47 to $10.28 per SF
Installation of a sewage backflow preventer.	$2,400 to $3,300	$0.12 to $0.17 per SF	Excavation and removal of pipe section followed by installation of sewage backflow preventer.	$2,400 to $3,400	$0.12 to $0.17 per SF
Excavation and backfill to make room for the installation of a concrete retaining wall around perimeter of building.	$170,500 to $234,700	$8.53 to $11.74 per SF	Excavation and backfill to make room for installation of a concrete retaining wall around perimeter of building.	$170,500 to $234,700	$8.53 to $11.74 per SF
Leak detection systems for liquid and vapor.	$400 to $500	$0.02 to $0.03 per SF	Leak detection systems for liquid and vapor.	$400 to $500	$0.02 to $0.03 per SF
Excavation and backfill to make room for installation of concrete retaining wall around 10-foot by 10-foot exterior area.	$11,400 to $15,700	$0.57 to $0.79 per SF	Excavation and backfill to make room for the installation of a concrete retaining wall around 10-foot by 10-foot exterior area.	$11,400 to $15,700	$0.57 to $0.79 per SF
Installation of flood proofing vents around perimeter of building.	$7,900 to $10,900	$0.40 to $0.55 per SF	Cutting of openings in exterior CMU wall and installation of floodproofing vents around perimeter of building.	$23,000 to $31,600	$1.15 to $1.58 per SF

Table 3B (continued): Strategy Implementation Costs in Non-Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
Dry Flood Proofing	N/A		
Elevated Essential Infrastructure	N/A		
Elevator System Design	Hydraulic elevator system.	$61,600 to $84,900	$3.08 to $4.25 per SF
Hardened Foundations	N/A		
Frost Resistant Foundations	N/A		
Scour Resistant Foundations	Foundation excavation with 12-inch by 23 inch strip footings, 4-inch foundation under drain, 12-inch by 6-foot basement walls with cast-in-place anchor bolts, 6-inch slab on grade with reinforcement, and foundation backfill.	$137,100 to $188,700	$6.86 to $9.44 per SF
Climate Appropriate Landscaping	4 boxwood shrubs, 2 amur maples, and 3 pine trees.	$2,800 to $3,800	$0.14 to $0.19 per SF
Woody Trees and Shrubs	N/A		
Covered or Shaded Parking	50-foot by 15-foot concrete driveway with 6-inch subbase course.	$1,500 to $2,100	$0.08 to $0.11 per SF
High Albedo Paving	50-foot by 15-foot concrete driveway with 6-inch subbase course.	$1,500 to $2,100	$0.08 to $0.11 per SF

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
Prefab joint fillers installed to seal all cracks. Storm doors installed.	$1,800 to $2,500	$0.09 to $0.13 per SF	Removal of existing doors and installation of storm doors with caulking.	$2,100 to $2,900	$0.11 to $0.15 per SF
Mechanical equipment elevated on 2 inch thick concrete pad.	$800 to $1,200	$0.04 to $0.06 per SF	Placement of mechanical equipment on 2 inch thick concrete pad, including disconnection and reconnection of utilities.	$13,400 to $18,400	$0.67 to $0.92 per SF
Machine-room-less traction elevator with concrete sealer in pit.	$119,700 to $164,800	$5.99 to $8.24 per SF	Concrete sealer applied in pit with water pump.	$50,800 to $69,900	$2.54 to $3.50 per SF
Concrete hardener added to concrete mixture for foundation.	$600 to $800	$0.03 to $0.04 per SF	N/A		
R10 insulation on 18-inch compacted gravel around perimeter of building.	$3,100 to $4,300	$0.16 to $0.22 per SF	Excavation to make room for installation of R10 insulation on 18-inch compacted gravel around perimeter of building.	$3,800 to $5,300	$0.19 to $0.27 per SF
Foundation excavation with 12-inch by 23 inch strip footings, 4-inch foundation under drain, 12-inch by 6-foot basement walls with cast-in-place anchor bolts, 6-inch slab on grade with reinforcement, and foundation backfill.	$153,500 to $211,300	$7.68 to $10.57 per SF	Removal of existing foundation, installation of 12-inch by 23 inch strip footings, 4-inch foundation under drain, 12-inch by 6-foot basement walls with cast-in-place anchor bolts, 6-inch slab on grade with reinforcement, and foundation backfill..	$657,700 to $905,500	$32.89 to $45.28 per SF
Four lemon bottlebrushes, four hydrangea bushes, and eight pin oaks.	$6,900 to $9,500	$0.35 to $0.48 per SF	Removal of existing trees and shrubs and planting of four lemon bottlebrushes, four hydrangea bushes, and eight pin oaks.	$10,600 to $14,600	$0.53 to $0.73 per SF
Four lemon bottlebrushes, four hydrangea bushes, and eight pin oaks.	$6,900 to $9,500	$0.35 to $0.48 per SF	Four lemon bottlebrushes, four hydrangea bushes, and eight pin oaks.	$6,900 to $9,500	$0.35 to $0.48 per SF
Asphalt driveway extended by 30 feet to reach shaded area.	$2,500 to $3,400	$0.13 to $0.17 per SF	One lemon bottlebrush, one hydrangea bush, and three pin oaks top shade parking area.	$2,500 to $3,500	$0.13 to $0.18 per SF
50-foot by 15-foot concrete driveway with 6-inch subbase course.	$5,100 to $7,000	$0.26 to $0.35 per SF	Removal of existing asphalt driveway and installation of 50-foot by 15-foot concrete driveway with 6-inch subbase course.	$5,200 to $7,200	$0.26 to $0.36 per SF

Table 3B (continued): Strategy Implementation Costs in Non-Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
Natural or Constructed Wetlands	N/A		
Permeable Paving	50-foot by 15-foot porous asphalt driveway with 6-inch subbase course.	$1,500 to $2,100	$0.08 to $0.11 per SF
Storm/Sanitary Sewer Separations	Downspouts and sump pump elbow into PVC pipe that leads to public sanitary sewer.	$5,800 to $8,000	$0.29 to $0.40 per SF
Cross Ventilation	N/A		
Stack Ventilation	N/A		
Ceiling Fans	N/A		
Pressure Neutral Rainscreen	Vapor barrier on all exterior walls.	$2,400 to $3,300	$0.12 to $0.17 per SF
Shade Exterior HVAC systems	N/A		
Passive Solar Design/Building Orientation	N/A		
Thermal Zoning	22-ton single-zoned air handing unit.	$55,800 to $76,800	$2.79 to $3.84 per SF

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
25-foot by 60-foot by 4-foot retention area with sloped sides, two 8-inch PVC risers with grates.	$12,100 to $16,600	$0.61 to $0.83 per SF	25-foot by 60-foot by 4-foot retention area with sloped sides, two 8-inch PVC risers with grates.	$12,100 to $16,600	$0.61 to $0.83 per SF
50-foot by 15-foot porous asphalt driveway with 6-inch subbase course.	$3,100 to $4,200	$0.16 to $0.21 per SF	Removal of existing asphalt driveway and installation of 50-foot by 15-foot porous asphalt driveway with 6-inch subbase course.	$3,200 to $4,400	$0.16 to $0.22 per SF
Downspouts and sump pump discharge onto prefabricated concrete splash pad.	$100	$0.01 per SF	Downspouts and sump pump separated from PVC pipe that leads to public sanitary sewer. Concrete splash pads installed.	$300 to $500	$0.02 to $0.03 per SF
10 operable windows on opposite exterior walls.	$7,300 to $10,000	$0.37 to $0.50 per SF	Cutting of exterior wall and installation of 10 operable windows on opposite exterior walls.	$8,200 to $11,300	$0.41 to $0.57 per SF
Installation of whole building exhaust fan.	$8,800 to $12,100	$0.44 to $0.61 per SF	Opening made for installation of a whole building exhaust fan.	$8,800 to $12,100	$0.44 to $0.61 per SF
Installation of eight electric ceiling fans.	$8,600 to $11,800	$0.43 to $0.59 per SF	Installation of eight electric ceiling fans and necessary wiring improvements.	$9,100 to $12,500	$0.46 to $0.63 per SF
3-inch R15 rigid foam insulation, 4-inch thick brick outer wythe with masonry anchors on all exterior walls.	$142,100 to $195,700	$7.11 to $9.79 per SF	Removal of existing wall finish and installation of 3-inch R15 rigid foam insulation, 4-inch thick brick outer wythe with masonry anchors on all exterior walls.	$151,600 to $208,700	$7.58 to $10.44 per SF
N/A			10-foot by 10-foot by 6-foot fiberglass solar screening with wooden framing.	$5,000 to $6,900	$0.25 to $0.35 per SF
N/A			Rotation of building and disconnection and reconnection of utilities	$420,200 to $578,500	$21.01 to $28.93 per SF
22-ton multi-zoned air handing unit.	$48,100 to $66,300	$2.41 to $3.32 per SF	Removal of existing air handler and installation of a 22-ton multi-zoned air handing unit.	$48,800 to $67,100	$2.44 to $3.36 per SF

Table 3B (continued): Strategy Implementation Costs in Non-Residential Buildings

Strategy Implementation	Benchmark Building		
	Items Included	Cost	Per SF
Increased Thermal Mass	Concrete acrylic sealer adjacent to south facing glass.	$400 to $600	$0.02 to $0.03 per SF
Thermal Energy Storage	N/A		
Redundant Systems	N/A		
Emergency Bypass Faucet	N/A		
Insulated Refrigeration Equipment	22 CF refrigerator.	$1,000 to $1,300	$0.05 to $0.07 per SF
Seal Potential Entry Points	N/A		
Cavity Wall Treatments	N/A		
Mechanical Room Drains	N/A		

New Resilient Building			Retrofitted Resilient Building		
Items Included	Cost	Per SF	Items Included	Cost	Per SF
5-foot wide strip of slate tile flooring adjacent to south facing glass.	$12,900 to $17,800	$0.65 to $0.89 per SF	5-foot wide strip of slate tile flooring adjacent to south facing glass.	$12,900 to $17,800	$0.65 to $0.89 per SF
Installation of 120 gallon underground thermal energy storage water tank including excavation and backfill.	$2,600 to $3,600	$0.13 to $0.18 per SF	Installation of 120 gallon underground thermal energy storage water tank including excavation and backfill.	$2,600 to $3,600	$0.13 to $0.18 per SF
Installation of 30kW diesel generator and ground mounted 20kW PV array.	$186,800 to $257,200	$9.34 to $12.86 per SF	Installation of a 30kW diesel generator and ground mounted 20kW PV array.	$186,800 to $257,200	$9.34 to $12.86 per SF
Faucet attached to water supply at low elevation.	$200	$0.01 per SF	Faucet inserted into water supply at low elevation.	$300 to $400	$0.02 to $0.02 per SF
22 CF Energy Star rated refrigerator.	$2,500 to $3,400	$0.13 to $0.17 per SF	Removal of existing unit and installation of 22 CF Energy Star rated refrigerator.	$3,200 to $4,400	$0.16 to $0.22 per SF
Caulking and bird netting used to seal large and small openings around perimeter of building.	$1,300 to $1,800	$0.07 to $0.09 per SF	Caulking and bird netting used to seal large and small openings around perimeter of building.	$1,300 to $1,800	$0.07 to $0.09 per SF
Pest control sprayed and bird netting installed around perimeter of building.	$4,000 to $5,500	$0.20 to $0.28 per SF	Pest control sprayed and bird netting installed around perimeter of building.	$4,000 to $5,500	$0.20 to $0.28 per SF
Installation of four floor drains and 6-inch PVC drainage piping.	$2,000 to $2,800	$0.10 to $0.14 per SF	Saw cutting of ground floor slab followed by the installation of four floor drains and 6-inch PVC drainage piping.	$2,100 to $2,900	$0.11 to $0.15 per SF

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