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NJ Climate Adaptation Alliance

The Role of Buildings in Climate Adaptation

Climate Change Preparedness in New Jersey

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Introduction

The Rutgers Center for Green Building (RCGB) has partnered with the New Jersey Climate Adaptation Alliance (NJCAA) to assist in NJCAA's development of a set of recommendations to further the State's climate change preparedness in the buildings sector. RCGB is a research center housed at the Edward J. Bloustein School of Planning & Public Policy at Rutgers, The State University of New Jersey. The Center offers a unique set of skills and expertise in building codes and regulatory mechanisms, design and engineering best practices, building occupant and operator behavior, and industry insights. This report brings together RCGB's expertise with that of industry leaders and stakeholders who offered their comments and contributions. The goal of this document is to provide recommendations for targeted interventions in the buildings sector in New Jersey to assist the State in its resiliency preparations and operations.

Resiliency is a broad term and, as such, definitions are inconsistent and varied depending on the discipline. We employ a definition of resiliency for buildings that is comprehensive and ambitious. Buildings must return to their pre-shock state in order to provide the services they were designed to provide to occupants. They must also be resilient to future shocks, which are uncertain in terms of magnitude and type, thus requiring innovative thinking and design so that buildings can go beyond the provision of initial services to withstand a multitude of disaster types. The National Academy of Sciences offers an appropriately comprehensive definition of resiliency as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events."[1]

Approach

A number of cities – including New York and Boston – have recently produced broadly stakeholdered documents regarding resiliency factors in buildings. Although the New York and Boston reports are city-and context-specific, we believe them to be very well-vetted and highly translatable to New Jersey. RCGB relied on these secondary sources as helpful inputs in the formation of our recommendations and insights, along with those deriving from meetings held between NJ State officials and various organizations including Northeast Energy Efficiency Partnerships, U.S. Green Building Council (USGBC), International Code Council, New Jersey Chapter of USGBC, and New Jersey Chapter of American Institute of Architects (AIA). Additionally, the State's building sector recommendations in its recently released disaster recovery plan refer to an earlier extensive stakeholdered process convened by the Rutgers Center for Green Building in developing the NJ Green Building Manual.[2]

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[1] National Academy of Sciences (2012, p.1)

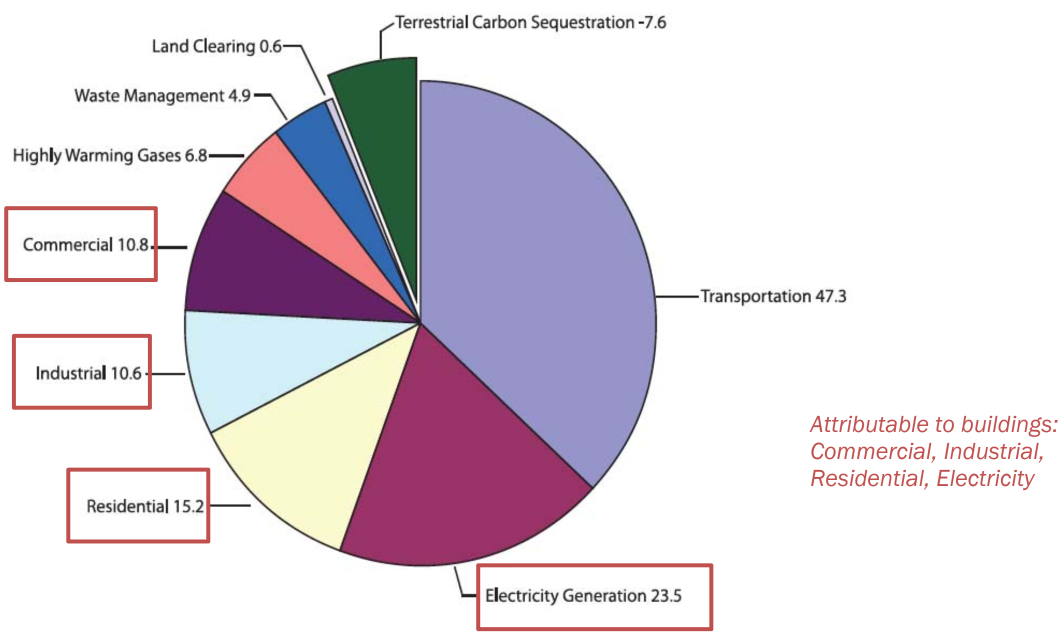
[2] NJDCA (2013 a,b)

Background

Role of Buildings

Buildings play a dual role in climate change in New Jersey. Building operations, still primarily powered by fossil fuels, contribute a significant amount to greenhouse gas emissions in the state. In 2009 (the most recent data available), the residential, commercial and industrial sectors in New Jersey contributed 36.6 million metric tons of Co2 (or roughly 30%) to New Jersey's annual emissions.[3] Additionally, the electricity generation sector (which heavily includes buildings) contributed 23.5 million metric tons of Co2.[4] Combined, these sectors represent approximately 54% of New Jersey's emissions. At the same time, buildings are essential for providing shelter, and adequate built structures can mean the difference between experiencing harm and sheltering safely during a disaster.

Figure 1: New Jersey Greenhouse Gas Inventory by Sector



Source: NJ DEP, 2012 / Units: Million metric tons of CO2 equivalent (MMTCO2e)

Buildings are a central component of New Jersey's built infrastructure. Climate change threats to New Jersey's building stock include intense precipitation events and related flooding, wind, wave and storm surge flooding impacts from coastal storms up to and including structural failure, moisture penetration and associated degradation of building materials, higher incidence of mold and mildew, temperature extremes (both frequent high heat and extreme cold days) leading to material wear and failure, and utility failures from climate events as an indirect cause of material damage or failure. Vulnerability and potential impacts will vary by age of building and location, and also according to how well maintained a structure has been and other factors, such as its level of decentralization in infrastructure dependence.

[3] New Jersey Department of Environmental Protection (NJDEP) (2012)
[4] Ibid

As of 2012, there were approximately 3,555,864 homes existing in New Jersey.[5] Of these structures, approximately 91% were built prior to 2000, when the State adopted the International Building Code (IBC) as its building code standard for all buildings and the International Residential Code (IRC) as its building code standard for one and two family detached residential units.[6] Section 16 of the IBC and Section 3 of the IRC reference the ASCE Flood Resistant Design and Construction Standards 24-05 when guiding the structural design of buildings with regards to flood loads and hazards. The standard also provides requirements for building performance with flood loads, flood-damage resistant materials, location of utilities and service equipment and siting considerations.[7]

Prior to 2000, the State of New Jersey, as well as many other states in the Northeastern United States, adhered to the Building Officials and Code Administrators (BOCA) National Building Code as the official building subcode and the Council of American Building Officials (CABO) One and Two Family Dwelling Code as the official residential subcode. The BOCA National Building Code and CABO One and Two Family Dwelling Code did require structural design in accordance with flood loads but both codes only referred to section 5 of ASCE Standard 7, not the additional flood proofing requirements found in ASCE 24-05. Therefore, all buildings built before 2000 are more likely to prove vulnerable to flooding related hazards. Figure 2 shows the age distribution of homes in New Jersey by year, and Figure 3 shows the age distribution of commercial space (industrial and office) in New Jersey by year. Roughly 90% of homes and 92% of commercial buildings (office and industrial, with year built known) were built prior to 2000, when the IBC with its greater flood protections was adopted.

Figure 2: Age Distribution of Housing Units in New Jersey

	Housing Units	
	Estimate	Percentage of Total
Total:	3,555,864	
Built 2010 or later	6,515	0.18%
Built 2000 to 2009	330,415	9.29%
Built 1990 to 1999	315,099	8.86%
Built 1980 to 1989	411,195	11.56%
Built 1970 to 1979	461,365	12.97%
Built 1960 to 1969	502,883	14.14%
Built 1950 to 1959	568,181	15.98%
Built 1940 to 1949	308,961	8.69%
Built 1939 or earlier	651,250	18.31%

Source: U.S. Census Bureau, 2008-2012 American Community Survey

[5] US Census Bureau (2008-2014 American Community Survey). According to Census, a housing unit may be a house, an apartment, a mobile home, a group of rooms or a single room that is occupied (or, if vacant, intended for occupancy) as separate living quarters. Both occupied and vacant housing units are included in the housing unit inventory.
[6] New Jersey Department of Consumer Affairs (NJDCA) (2012)
[7] Federal Emergency Management Agency (FEMA) (2010)

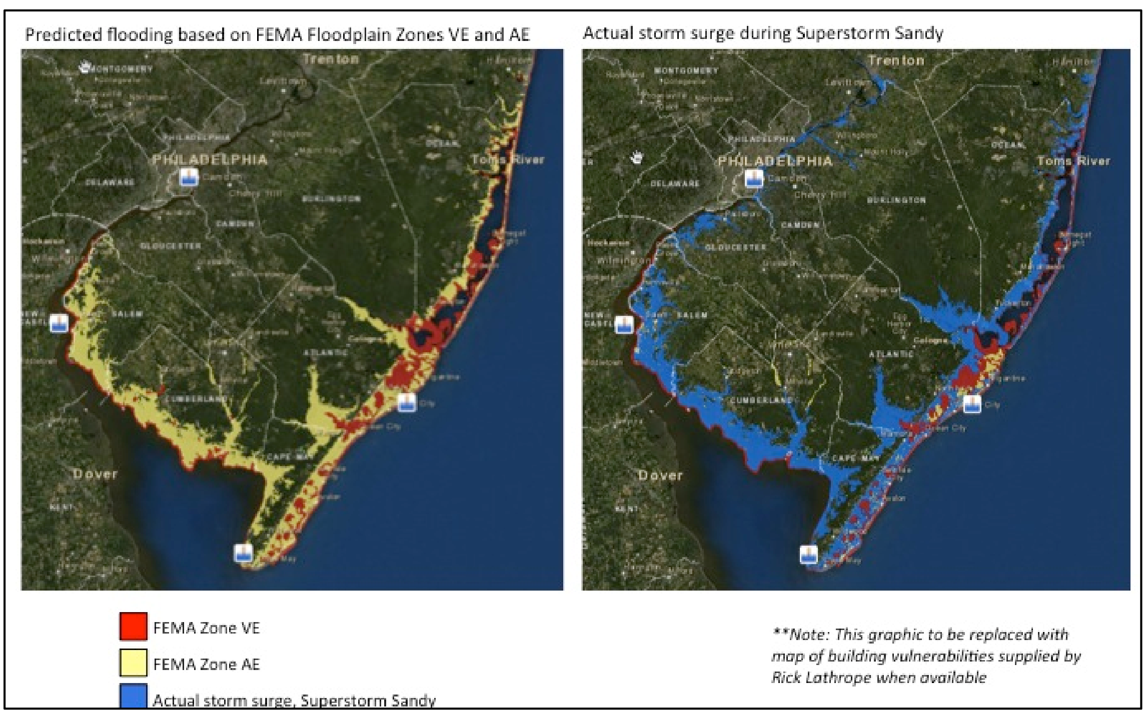
Figure 3: Age Distribution of Commercial Buildings in New Jersey

	Commercial Buildings (Industrial and Office)	
	Number of Buildings	Percentage of Total
Total:	20,035	14438
Built 2010 or later	152	1.05%
Built 2000 to 2009	1,017	7.04%
Built 1990 to 1999	734	5.08%
Built 1980 to 1989	3,242	22.45%
Built 1970 to 1979	2,869	19.87%
Built 1960 to 1969	2,492	17.26%
Built 1950 to 1959	1,505	10.42%
Built 1940 to 1949	762	5.28%
Built 1939 or earlier	1,665	11.53%
Year Built data unavailable	5,597	N/A

Source: Co-Star and CBRE Industrial and Office Building Data

Of these buildings, a great many are located in vulnerable coastal or floodplain areas. Further, Superstorm Sandy illustrated that vulnerabilities to flooding may be worse than expected, as depicted in Figure 4 below. Actual storm surge waters reached further inland in some areas than FEMA flood zones predicted, and in locations not in flood zones at all, such as areas along the state's western border.

Figure 4: Predicted Versus Actual Vulnerabilities



Source: njfloodmapper.org

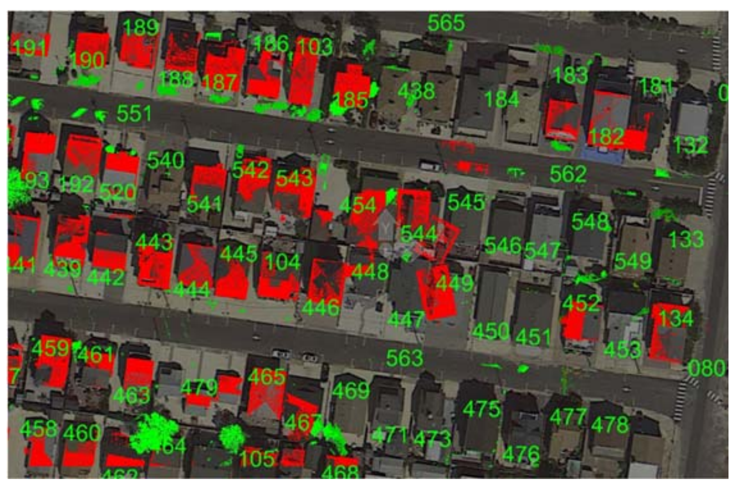
Vulnerabilities in the Buildings Sector

Vulnerabilities relating to buildings and their occupants can broadly be categorized into three types. Social vulnerability pertains primarily to sociological and psychological impacts on individuals and communities due to loss of home or personal injury during a disaster. Economic vulnerabilities relate to the services buildings provide and the financial loss this creates when these services are interrupted during a shock. Environmental vulnerabilities include impacts on water supply, natural ecosystems and habitats, soils, etc. due to damage to built structures and the release of toxic materials into the environment. Each of these will be discussed in more detail below.

Social Vulnerabilities

It is estimated that over 80,000 residential units were damaged in New Jersey as a result of Superstorm Sandy.[8] Of this, reports on the storm estimate that over 40,000 owner-occupied homes and over 15,000 rental units in New Jersey experienced major or severe damage during the storm.[9] In addition, homeowners that faced damages in excess of 50% of the value of the home now face the daunting and expensive task of elevating the structure to meet Federal Emergency Management Agency (FEMA) floodplain requirements.[10] The financial need to fully repair and rebuild all of New Jersey's housing stock damaged during the storm is estimated at over $4 billion.[11] These losses illustrate the far-reaching social vulnerability that results when the housing stock is at risk of damage or destruction.

Mantoloking Post-Sandy
Photo courtesy of Jie Gong



Ortley Beach
Photo courtesy of Jie Gong

Further, twelve deaths in New Jersey were associated directly with the storm.[12] Additional lives were lost indirectly, through hypothermia, vehicle accidents, fires, and other incidents during the storm event.[13] Often, home damage or loss disproportionately impacts already disadvantaged or more vulnerable populations and communities, and the disaster event only serves to highlight the weak social and structural support these communities have for coping with a

[8] NJDCA (2013a)
[9] Ibid
[10] Ibid
[11] NJDCA (2013b)
[12] Blake et al. (2013)
[13] Botts et al. (2013)

shock.[14] For example, it is estimated that nearly all of New Jersey's public housing stock suffered roof damage and at least minor flooding during Superstorm Sandy, and of those applicants who applied for FEMA Individual Assistance for home repairs, nearly 30,000 households (49%) were low or moderate income.[15] In addition, multiple structures that could be used to accommodate homeless individuals (such as motels) were damaged or destroyed during Sandy, significantly reducing shelter availability for the homeless population.[16]

Economic Vulnerabilities

Economic vulnerability during a disaster event can be equally impactful to towns and communities, and is particularly challenging to businesses because they face the one-time shock of property damage during the disruptive event itself, and then face an uncertain period of business interruption and loss of revenue, depending on the type and severity of the shock.[17] According to a report by the New Jersey Department of Consumer Affairs (NJDCA), businesses in 113 of New Jersey's municipalities suffered total losses from Superstorm Sandy of nearly $450 million in combined property damage and interrupted business operations. NJDCA estimates approximately $1.8 billion in total financial need for businesses in the State as a result of the storm.[18] Although millions of dollars in grants and loans have been disbursed by the Small Business Administration (SBA) and state-administered Community Development Block Grant (CDBG) funds, as of late 2013 there were still millions of dollars in unmet need for businesses in the state.[19]

Photo Credit: shutterstock_117665929

[14] Vogel et al. (2007)
[15] NJDCA (2013a; 2013b)
[16] NJDCA (2013a)
[17] Rose and Krausmann (2013)
[18] NJDCA (2013a)
[19] NJDCA (2013b)

While these losses are impactful to the individual business owner, it is important to also recognize the far-reaching community impacts business losses cause; businesses provide necessary goods and services to towns and communities and, during times of disruption or shock, are often relied upon even more by residents. Businesses provide an important point of community stability and resiliency, and their ability to operate – or resume operations quickly – becomes crucial.[20] In addition, if a business is unable to operate, its employees are also impacted. It is estimated that over 1 million individuals in New Jersey's labor force were impacted by the storm.[21] Over twice as many unemployment claims were filed in New Jersey in November 2012 as in November 2011, and it is expected that higher-than-average unemployment rates will continue for 3 years post-Sandy, due to business closures, downsizing and revenue struggles caused by damages from the storm.[22]

Environmental Vulnerabilities

There is a high likelihood that a hurricane or other disaster will cause disruptions to the built environment. These disruptions can unsettle and release toxic materials into the environment, creating a host of water, soil, air quality, and public health issues. New Jersey faced a number of environmental impacts from Superstorm Sandy. A ruptured storage tank at a Woodbridge facility caused the release of nearly 350,000 gallons of diesel and fuel into Arthur Kill, the waterway between New Jersey and Staten Island.[23] Sewer overflows and wastewater treatment plant failures during Sandy caused the release of raw sewage and industrial chemicals into waterways in many areas.[24] There were similar concerns in New Orleans in 2005 after Hurricane Katrina. A number of superfund sites, industrial facilities, and chemical-containing commercial businesses (such as dry cleaners and pest control facilities) were heavily flooded, causing the release of toxic chemicals into waterways and soils.[25]

Buildings pose particular issues. A number of toxic materials are commonly used in construction materials, such as Polyvinyl Chloride (PVC), asbestos, mercury and flame-retardants.[26] These materials are typically well contained and pose minimal threat to human health in occupied buildings, but if the building is damaged or destroyed during a disruptive event, these materials are released into the environment. PVC, for example, is a known carcinogen, and found in materials like piping, waterproofing, siding, conduits, and some flooring and carpeting.[27] Asbestos poses particular problems during a hurricane because of the high likelihood it will become wet, increasing the chance it will crumble into a fine powder and become a particulate in the air.[28] Industrial facilities such as petroleum refineries typically have emergency plans in place to secure hazardous materials on site in the case of a disaster event.[29] Buildings, especially single-family residential structures, usually have no such plan in place, nor are they required to do so. Most homeowners are unaware of the toxicity of many building materials used to construct their home, and are not trained in handling the materials if they are released into the environment in a hurricane or other event. This creates a high level of environmental vulnerability from the release of hazardous building materials after a disaster.

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[20] Beermann (2011)
[21] NJDCA (2013a)
[22] NJDCA (2013a)
[23] United States Geological Survey (USGS) (2013); Kirkham (2012)
[24] USGS (2013)
[25] Reible et al. (2006)
[26] Healthy Building Science (2012)
[27] Bernstein (2012)
[28] Peeples (2012)
[29] Cruz, Steinberg and Luna (2001)

Current State of Preparedness: Insights and Opportunities

In this section, we offer a number of insights and opportunities based on the current state of preparedness of New Jersey's building stock and technical and policy best practices. To the extent possible, we formulate strategies for turning vulnerabilities into opportunities. In cases where there are efforts underway in New Jersey to adopt changes consistent with our recommendations we note that as well.

Design and Engineering Recommendations

Develop a taxonomy of building types

Buildings are not one-size-fits-all and, as such, strategies to strengthen the resilience of the building stock should not be either. New York City makes a distinction between construction type (combustible or non-combustible), the structure's proximity to other buildings (detached, semi-detached or attached), and height (low-rise, mid-rise, or high-rise).[30] Alternatively, Boston offers eleven categories of existing building type.[31] An additionally important distinction is between new construction and retrofitted buildings, in addition to standard building characteristics such as age. In New Jersey, similar to both New York and Boston, a multi-pronged approach to building categorization would be useful for optimizing the effectiveness of statewide strategies as categories of built structure require different targeted interventions to increase resiliency. Unfortunately, very little data about how climate change will impact buildings is available; additional downscaling of climate models is needed.

Concurrently, it is important to consider the locations of vulnerable populations as earlier discussed. The most robust taxonomy for the creation of a forward-looking strategy for rebuilding would jointly consider building location, building characteristics, and demographic data. In New York City, for instance, "most of the buildings in the city's 100-year floodplain are older, constructed to codes and standards that did not incorporate flood resistance."[32] A significant number of these house vulnerable populations.

Choose strategies that are synergistic

Hazards from future climate change impacts come along with a high degree of uncertainty in terms of type of disruptive event, cost of damage, duration of the event, etc. For instance, we do not know with certainty that the next mid-Atlantic disaster will again be storm-surge related, as was the case with Superstorm Sandy, and buildings must be able to withstand a multitude of potential climate change related impacts. Thus, the best strategies for increasing resilience in buildings will be those that offer synergies with other strategies to make buildings better protected against more than one type of risk. Synergistic strategies will be more cost-effective, and will offer protection from multiple shock types.[33] The City of Boston suggests a number of resiliency strategies for its buildings that overlap with green building principles such as those outlined in the United States Green Building Council's LEED rating system.[34] New Jersey is poised to pursue a similar approach.

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30 New York City Office of Long Term Planning & Sustainability (2013)

31 Linnean Solutions, The Built Environment Coalition, and The Resilient Design Institute (2013)

32 NYC Office of Long Term Planning & Sustainability (2013, p. 78)

33 Linnean Solutions et al. (2013)

34 Ibid

Address toxicity issues in buildings

There are opportunities to decrease toxicity in both new and existing buildings, with implications for the surrounding environment. In existing buildings, on-site toxins should be secured in advance of the next disruptive event. More importantly, developers of newly built structures should be more wary of toxins used in building materials in the knowledge that they may end up in the water supply and soils if the building is not disposed of in the intended way, but rather littered across the landscape in the case of a natural disaster. This again highlights potential synergies between increased resiliency in buildings and green building practices which call for the use of non-toxic construction materials and interior finishes. Beyond voluntary measures regarding building material toxicity, future building code changes can take this trajectory of environmental and human health impact into account by specifying low- and non-toxic construction materials.

Incorporate more resilient wall assemblies

Lessons learned from Superstorm Sandy revealed that the most vulnerable buildings were single-family, low-rise combustible structures; high-rise structures of non-combustible construction (e.g. reinforced concrete frame buildings) fared much better during the storm, losing services such as electricity and telecommunications in some cases, but avoiding the structural damage faced by more vulnerable structures.[35] New Jersey is home to an overwhelming number of detached, single-family homes. As mentioned above, these structures face a high level of vulnerability.

Although wood frame construction continues to be the predominant wall assembly system used in the U.S. residential housing market, there are several alternative wall assembly systems including precast concrete panels, insulated concrete forms (ICFs), structural insulated panels (SIPs) and autoclaved aerated concrete (AAC) that perform equally or better in terms of energy performance, resistance to hazards such as fire, winds and earthquakes, and improved indoor environmental quality, although not always in terms of their cost.[36] Concrete variants in particular provide much better protection against wind hazards than wood-frame construction and are resistant to mold. These options highlight alternative pathways to building construction that can make single-family combustible structures more resilient.

For protection against extreme storm surge, as was experienced in some areas of New Jersey during Superstorm Sandy, the State could potentially pursue a large-scale program of both dry and wet flood proofing for some structures. Wet flood proofing, which allows floodwaters to flow freely through the structure (typically the ground floor), helps the property avoid the catastrophic structural damage that results from water pressure when floodwaters flow around – and not through – a structure. This measure has, in fact, been promoted in New Jersey for commercial building reconstruction although it is not always easily implemented. This approach requires rethinking of the ground floor end-uses in vulnerable buildings.

[35] NYC Office of Long Term Planning & Sustainability (2013)
[36] Rutgers Center for Green Building (2014)

Figure 5: Wall Assembly Comparison

	WOOD FRAME WALL	PRECAST CONCRETE SANDWICH PANEL	INSULATED CONCRETE FORMS (ICFS)	STRUCTURAL INSULATED PANELS (SIPS)	AUTOCLAVED AERATED CONCRETE (AAC)
MATERIAL COST	Very Good	Fair	Fair	Good	Good
LABOR COST	Very Good	Good	Fair	Good	Good
EQUIPMENT COST	Excellent	Good	Good	Good	Good
TIME ON SITE	Fair	Very Good	Good	Excellent	Very Good
ENERGY EFFICIENCY	Poor	Very Good	Very Good	Excellent	Very Good
WIND RESISTANCE	Fair	Very Good	Excellent	Very Good	Good
FIRE RESISTANCE	Fair	Excellent	Very Good	Good	Excellent
SEISMIC RESISTANCE	Good	Very Good	Very Good	Excellent	Good
INSECT/MOLD	Fair	Very Good	Good	Good	Excellent
INDOOR AIR QUALITY	Fair	Very Good	Very Good	Very Good	Very Good
ACOUSTIC PERFORMANCE	Fair	Very Good	Excellent	Fair	Excellent
MAINTENANCE COST	Fair	Very Good	Very Good	Very Good	Very Good

Excellent	Very Good	Good	Fair	Poor

Source; Rutgers Center for Green Building (2012)

In addition to flood proofing, another preemptive strategy is to re-think the location of critical infrastructure in the building. In New York City, some of the best-case scenarios of buildings that did not lose power or critical services during Superstorm Sandy resulted from the building either having elevated mechanical systems in protected areas in basements, or mechanical systems located on ground floor level or higher. Although permanent location decisions are made at the time of building design and construction, even existing buildings with poorly located mechanical systems can benefit from new technologies that offer encasements and enclosures for mechanical equipment to protect from flooding.

Adaptations to Existing Buildings

A number of existing agencies and organizations, including FEMA, recognize the need to make adaptations to existing structures as a crucial strategy in increasing overall resiliency of the building stock. Given the differences in characteristics between residential and commercial structures, high and low-rise buildings, and combustible and non-combustible structures, existing buildings should be adapted or retrofitted in ways that are most appropriate to their characteristics.

In this section, we distinguish between residential and commercial structures, but acknowledge that within these two broad categories a number of finer grained distinctions exist. For instance, high-rise multi-family residential will require a very different approach than single-family low-rise residential. The following recommendations represent, at minimum, a starting point for organizing and thinking about technical adaptations to existing structures.

For a fuller listing of strategies broken down by regional considerations please see Green Building and Climate Resistance: Understanding Impacts and Preparing for Changing Conditions, University of Michigan and USGBC[37] and also the NJ-specific NJ Green Building Manual and NJ Green Home Remodeling Guidelines.[38]

While these are similar to the Best Management Practices issued by several Federal and State agencies, they provide additional useful information in terms of in what manner a strategy may be synergistic with other considerations and, in the case of the NJ documents, local case studies and available costs.

Residential Buildings

Residential buildings play a particularly important role in decreasing individual vulnerability by providing shelter, but they are often freestanding, combustible frame single- or two-family structures, particularly in suburban New Jersey, which creates additional vulnerabilities. However, there are some advantages to low-rise residential structures, including the ability to supply water without pumps to higher floors. There are a number of strategic investments homeowners can make to increase the resiliency of their home.

BASIC/LOW COST

- Weatherization: Upgrading insulation and window seals in homes can help keep warmth in during winter if the ability to heat the home is lost during an event, and can keep heat out during summer if a blackout occurs.[39]

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[37] Larsen et al. (2011)
[38] Rutgers Center for Green Building (2011)
[39] Urban Green Council (2013)

- Appropriate landscaping: Installing absorptive flexible form vegetation and landscaping at the home can help vegetation weather the storm while storing water, and prevent other less appropriate landscaping from breaking or becoming detached, potentially causing damage to the property.

INTERMEDIATE/MEDIUM COST

- Roof security: Installing roof tie-downs or retrofitting roof material to heavy pavers instead of gravel will help eliminate the risk of material becoming detached and causing harm during a storm event with high winds.[40]
- Dry flood proofing: Dry flood proofing, which can range from fairly inexpensive sandbags to more elaborate and technical sealing methods, prevents water from entering the home.[41] If the home cannot be elevated, dry flood proofing may be an alternative option.
- Sprinklers: Installing residential sprinklers could prove an important factor in saving lives if the disruptive event causes a fire in the home.

LONGER-TERM/HIGH COST

- On-site energy supply: Installing photovoltaic systems on-site may provide additional security and energy supply during a disruptive event; this benefit however is dependent on ability to function independently of the grid.
- Home elevation and foundation support: Homes in vulnerable, flood-prone areas may consider elevating the home. If this is not possible or desirable for other reasons (such as decreased accessibility), the homeowner could anchor the frame to the foundation, which prevents it from becoming detached during a major surge event.[42]

<u>Commercial Buildings</u>

Commercial buildings range from low-rise 1, 2 or 3 story structures, often found in commercial corridors and some office parks in suburban New Jersey to high-rise buildings associated with more dense urban areas. Although commercial buildings may seem less important than residential buildings as a place of shelter for individuals, people spend so much time at work that there is a high likelihood that a disruptive event may occur while many are at their offices; thus commercial buildings need to be able to provide basic services and withstand disasters. Additionally, making decisions to retrofit commercial buildings to a higher level of resiliency often makes economic sense for owners who wish to avoid business disruption of building tenants and to avoid catastrophic losses.

BASIC/LOW COST

- Weatherization: As in residential buildings, upgrading insulation and window seals in commercial buildings can help keep warmth in during winter if the ability to heat the building is lost during an event, and can keep heat out during summer if a blackout occurs.[43]
- Critical equipment location: Commercial owners should consider locating critical operating equipment to ground level or higher, instead of in basements or sub-basements.[44]

[40] Urban Green Council (2013)
[41] FEMA (2009)
[42] FEMA (2009); Urban Green Council (2013)
[43] Urban Green Council (2013)
[44] NYC Office of Long Term Planning & Sustainability (2013); Urban Green Council (2013)

INTERMEDIATE/MEDIUM COST

- Vegetated roofs: Although appropriate vegetation can be helpful in low-rise residential buildings, commercial buildings with flat, expansive roofs can benefit even more from this strategy, as it becomes a means of collecting rainwater, cooling the overall building temperature, and reducing heat absorption.
- Roof security: Installing roof tie-downs or retrofitting roof material to heavy pavers instead of gravel will help eliminate the risk of material becoming detached and causing harm during a storm event with high winds.[45] This recommendation is particularly important for high-rise commercial buildings where detached materials become even more dangerous when falling from greater heights.

LONGER-TERM/HIGH COST

- On-site cogeneration or off-grid energy sources: Cogeneration systems or on-site photovoltaic panels can provide additional sources of electricity during a disruptive event.
- Smart building connectivity and features: The use of “smart” building features, such as advanced metering infrastructure (AMI) or smart grid connectivity, can reduce building dependence on grid infrastructure and provide an added layer of resiliency and independence during a storm event. This strategy is discussed in more detail in a later section.

Policy Recommendations

Reconsider shelter policies

In New Jersey, the State’s Office of Emergency Management (OEM) offers broad guidelines for evacuation and sheltering-in-place, but responsibility for disaster planning and sheltering ultimately falls to individual cities and counties; municipalities may defer to their county’s OEM (and county-by-county policies vary widely), or they may develop their own disaster plan. For example, Mercer County recommends that individuals “Go In, Stay In, Tune In” during a disaster event or, more specifically, move to the indoors, shelter in place, and listen to local television and radio broadcasts for more information.[46] Mercer County stresses sheltering at home and personal preparedness to reduce burden on municipal shelters, noting that due to variability in levels of vulnerability in different towns in the county, not all towns can adequately provide shelter for its residents.[47] Hudson County, consisting of towns and cities adjacent to New York City across the Hudson River, identifies 57 shelter structures in its 10 municipalities in the county’s 2008 All-Hazards Mitigation Plan in both a chart and map; the majority of these structures are schools and churches.[48] Hoboken, a city within Hudson County that was heavily impacted during Hurricane Sandy, has developed its own Community Resilience Plan, and worked with FEMA to develop a document for residents to help in disaster preparedness.[49] There is a good amount of variability across municipalities in terms of availability of information, shelter provisions, and recommendations; however, common to most plans is a tendency to designate municipal and other public buildings as shelters.

[45] Urban Green Council (2013)
[46] Hughes (2013)
[47] Ibid
[48] Hudson County Office of Emergency Management (2008)
[49] City of Hoboken (2014)

Even where an adequate amount of space may exist, municipally-designated shelter structures are often not the best choices for shelter-in-place functions. In Hoboken, NJ, for example, Hurricane Sandy caused flooding to the city's community center, public works garage, and multiple fire stations.[50] Across the State, damage to public and community buildings as a result of Superstorm Sandy has been estimated to be $231,408,083.[51] Of this amount, there is an unmet need of $136,010,719 for reconstruction of public and community buildings.

Many more resilient and less vulnerable structures are likely to exist beyond the publicly-owned building stock. Thus, jurisdictions should re-think disaster plans to better account for vulnerabilities in the shelter-in-place buildings they provide to residents; this may require new partnerships with private sector real estate developers and owners.

Develop resilient building guidelines

Cities like New York have relied on independent organizations and expert stakeholders such as the Urban Green Council, New York City's arm of the United States Green Building Council (USGBC) to craft resilient building guidelines and suggest modifications to the existing building code. A similar approach has been initiated in New Jersey, with input sought from organizations including the USGBC, NJ-GBC, the New Jersey Chapters of the AIA and NEEPS, and sources cited including two developed by the Rutgers Center for Green Building, namely the NJ Green Building Manual and the NJ Green Home Remodeling Guidelines. However, there does not exist in New Jersey a standing Building Resiliency Task Force (BRTF) as there is in New York City, wherein large groups of stakeholders would continue to meet and influence building code and related policies, nor has the state formally convened a climate adaptation group to focus on building measures.

To date, the State has adopted the following provisions for buildings:[52]

- Height and construction requirements in FEMA's ABFE maps as a standard for reconstruction. For those residences that were substantially damaged in excess of 50% of the value of the home, the homeowner is required to elevate the structure to meet new FEMA ABFE maps.
- Permits by rule, allowing property owners who rebuild to the ABFEs (plus one additional foot as required by the NJ Flood Area Control Act) to save on time and money of applying for permits to do so.
- Wet flood proofing for non-residential buildings.
- Foundation requirements prohibiting certain buildings from having only three walls (a safety issue).

According to the Disaster Recovery Action Plan, the State additionally will require both replacement and new construction to meet green building standards by requiring compliance with ENERGY STAR™ (residential) and will encourage green building practices such as found in LEED and the NJ Green Building Manual.[53]

A number of other recovery programs and policies have been put in place by the state to disburse CDBG funds to aid in housing, infrastructure and economic development recovery. Expenses for elevating a residence can be partially offset by funds up to $150,000 per home under the

50 Blake et. al. (2013)
51 Method: FEMA project worksheets, CDBG Report, Amendment 7, 2-28 op.cit.
52 CDBG Report, Section 6.2, Op Cit.
53 NJDCA, Ibid

Homeowner Reconstruction, Rehabilitation, Elevation and Mitigation (RREM) Program. It is estimated that 5,124 homeowners will be assisted through the RREM Program's first disbursement of $710 million. The second phase of the program proposes an additional $390 million in funds. For an overview of all programs, see NJDCA, 2013b, Section 3.

Revise New Jersey's building codes

The NJ Division of Codes and Standards, a division of the NJDCA, has made available on its website a number of important clarifications and in some cases exemptions to the existing building code as concerns rebuilding Sandy damaged structures. These include requirements and guidance on building elevations and corresponding impacts on building height in terms of fire safety and wind exposure, proper asbestos and mold removal, breakaway walls, and foundation design. Unfortunately, there exist some disconnects between building code and insurance requirements, which also are identified by the NJDCA.[54]

A number of amendments to the NJ rehabilitation code on flood resistant construction have been proposed and are awaiting adoption (the comments period closed on March 22, 2014). Beyond these measures, an opportunity exists to improve the State's rehabilitation code to incorporate the synergistic resilient design structures noted above, particularly in the areas of energy efficiency, non- or low-toxicity building materials, and mold resistant materials.

The most recent energy codes for new construction also should be adopted. These include ICC 2015 (for residential construction) and ASHRAE 2013 (for commercial buildings). Other options would include the International Green Construction Code (IgCC) and ASHRAE 189.1. Not moving forward to adopt updated building codes (i.e., ICC 2015), which in any case is required by HUD for the provision of reconstruction funding, represents a missed opportunity to intervene efficiently in the construction of buildings, leveraging synergistic building level strategies and political processes.

Infrastructural Recommendations

Consider appropriate levels of decentralization and "smart-building" features

Although non-combustible concrete-frame structures tend to fare better during a natural disaster event, they are still vulnerable to loss of utilities such as electricity (and the many interconnected building services that depend on electricity) due to the building's reliance on citywide grid and infrastructure. An important resiliency consideration for buildings becomes an analysis of the tradeoffs between centralization and decentralization of building systems.[55] Less centralized systems mean the building can be more self-sufficient during a disruptive event. More flexible systems – such as those that can have grid connectivity when needed as well as grid independence – can offer building managers choices about how to operate a building during a disaster.

Buildings have a number of options available to them to reduce dependency on the electric grid. They can rely on local, distributed generation, and smart grid technologies.[56] Emergency backup generators, if wired into the building appropriately, can reduce the burden on the electric power network. Local photovoltaic (PV) systems that convert sunlight to electricity coincident with times of high building demand may also clip the peak demand. Fuel cells and other emerging distributed

[54] NJDCA (2014)
[55] Dieleman (2013)
[56] Romer, Reichhart, Kranz & Picot (2012); Tekiner, Coit and Felder (2012)

generation or energy storage technologies can also play this role. The use of these technologies is growing rapidly.

In particular, “smart” buildings or responsive buildings – those that incorporate technologies such as advanced metering infrastructure (AMI) or smart-grid connectivity – can increase building independence and, thus, resiliency. A recent Department of Energy (DOE) report highlights case studies in Pennsylvania of electricity customers who were able to regain power more quickly than traditional buildings after Hurricanes Irene and Sandy due to the installation of smart meters or AMI.[57]

Another infrastructural recommendation is to decrease our use of potable drinking water for non-human consumption. Employing more grey water and reclaimed water systems in buildings to serve irrigation and other purposes will decrease the burden on drinking water facilities. Similarly, increased use of vegetated roofs (as described earlier in this paper), and also, rain gardens and bio swales will relieve already overtaxed stormwater systems, which are particularly vulnerable during flooding events.

Re-think models of residential development

New Jersey is home to large number of detached, single-family homes. Lessons learned from Superstorm Sandy in New York City illustrated that the most vulnerable buildings were single-family, low-rise combustible structures. High-rise structures of non-combustible construction (e.g. reinforced concrete frame buildings) fared much better during the storm, losing services such as electricity and telecommunications in some cases, but avoiding the structural damage faced by more vulnerable structures.[58] Two parallel trends are important in this regard. First is the high cost of investing in low-rise residential properties for purposes of increasing their resiliency against climate-related events. As extreme weather events increase in frequency, it will become more and more cost prohibitive to add resiliency features to small properties that do not gain from economies of scale. Second, there is a preference among younger generations towards living in larger format (high rise) residential structures. This lifestyle preference is likely to drive patterns of development in the future, shifting investment away from suburbs and subdivisions and into denser urban cores. Together, these trends give good reason to rethink the traditional and ubiquitous model of suburban single-family residential development.

Additionally, trends in household dynamics are shifting, leading to more examples of accessory zoning options for multi-generational living. Lack of affordable housing, longer life spans, the influence of immigrant cultures and a long-standing aversion towards institutional solutions are leading some developers to construct explicitly multi-generational living options in new or retrofitted multifamily buildings. Beyond the day-to-day benefits such arrangements can convey, co-habitation of populations that are vulnerable to weather-related events with younger, more able-bodied relatives suggests a beneficial ‘private’ solution to sheltering and providing basic needs to vulnerable populations. Although there is resistance in some circles to accessory zoning, the strategy creates an opportunity for the planning community to tackle little-explored synergies between accessibility and hazard protection. Urban coastal areas provide both an evidence base for exploring these potential synergies and conflicts and also a laboratory for experimenting with better options.

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[57] Department of Energy (2013)
[58] NYC Office of Long Term Planning & Sustainability (2013)

Conclusion

New Jersey was heavily impacted by Superstorm Sandy in nearly every sector, and suffered major damage to its homes, businesses, beaches, and infrastructure. In particular, the event served to highlight the nested and intertwined nature of the impacts. Business impacts cannot be mitigated, for instance, without tackling the built structures in which they are housed. Thus, resiliency in the built environment becomes a key measure of the State's ability to withstand future disasters. We have begun to tackle issues of resiliency in the building sector here, and have outlined and organized some of the more important vulnerabilities as well as opportunities. Going forward, we recommend ongoing stakeholder and expert input to continue to refine and shape plans, and capitalize on vulnerabilities to make New Jersey's building stock stronger and more resilient against future disruptive events.

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